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MINIMUM FLOW DETERMINATION FOR ALEXANDER SPRINGS LAKE COUNTY, FLORIDA

by

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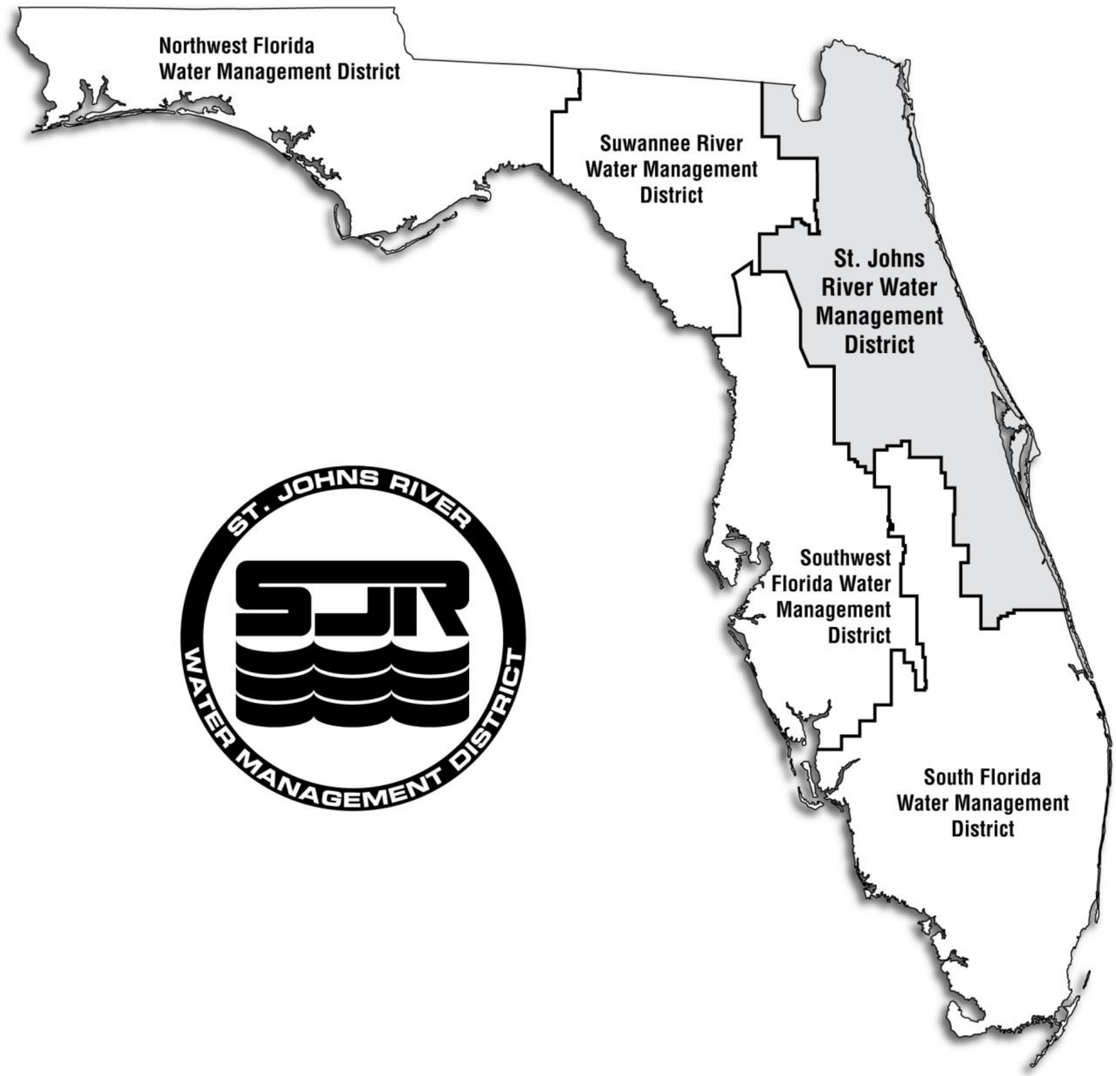
Palatka, Florida

2017



The St. Johns River Water Management District was created in 1972 by passage of the Florida Water Resources Act, which created five regional water management districts. The St. Johns District includes all or part of 18 counties in northeast and east-central Florida. Its mission is to preserve and manage the region's water resources, focusing on core missions of water supply, flood protection, water quality and natural systems protection and improvement. In its daily operations, the district conducts research, collects data, manages land, restores and protects water above and below the ground, and preserves natural areas.

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EXECUTIVE SUMMARY

The St. Johns River Water Management District (SJRWMD) establishes minimum flows and levels (MFLs) for priority water bodies within its boundaries. MFLs define the limits at which further consumptive use withdrawals would be significantly harmful to the water resources or ecology of the area. MFLs are one of many effective tools used by SJRWMD to assist in making sound water management decisions and preventing significant adverse impacts due to water withdrawals.

Alexander Springs is one of only 27 first-magnitude springs in Florida. The spring and spring run are bordered by national forest lands, including the Alexander Springs Wilderness, and comprise one of the most scenic and biologically diverse ecosystems in the state. Several state and federally listed species have been documented within the Alexander Springs Creek basin. Because of Alexander Springs' relatively unimpacted conditions, and many natural attributes, the spring boil and the spring run are both regionally important destinations for swimming, canoeing, kayaking and other recreation. Alexander Springs has been designated by the state as both an Outstanding Florida Water and Outstanding Florida Spring. Florida Statute requires the adoption of minimum flows and levels for Outstanding Florida Springs by July 1, 2017.

The Alexander Springs MFLs originally identified a frequent high flow (FH) and a frequent low flow (FL) based on multiple criteria developed from vegetation, soils and topography data. Frequency analysis results indicated that the hydrologic requirements for the most sensitive flow criterion, FL, are met under current pumping defined by 2010 conditions. However, the results from these conventional metrics also suggested an allowable reduction of 21% in the mean flow, prior to the system experiencing significant harm. This allowable flow reduction is outside the range of flow reduction (0 to 10%) allowed by other springs' MFLs established within the state of Florida. The hydrology of Alexander Springs and Creek is complex and there is currently a paucity of data with which to determine the hydrological requirements of ecological criteria identified for this system.

Given Alexander Springs' high recreational and ecological value, near-pristine condition, and uncertainty regarding system hydrology, SJRWMD recommends a minimum flow for Alexander Springs based on the statewide mean of allowable reduction in springs' flows of 6.8%. The recommended minimum flow for Alexander Springs is a mean flow of 95.7 cfs. This is the mean flow for the observed period of record (1983–2014) measured at the headspring (USGS gauge 00291896), adjusted by a 7 cfs reduction in spring flow (6.8%).

Groundwater modeling (Northern District Model version 5) was used to estimate flow reduction due to current and projected groundwater withdrawals. Current pumping defined by 2010 conditions resulted in a flow reduction of approximately 0.7 cfs (< 1%) from a pre-groundwater development condition. Because a 7 cfs reduction is allowable, and 0.7 cfs reduction has occurred, the allowable flow reduction from current conditions is 6.3 cfs.

Alexander Springs is surrounded by National Forest and wilderness lands. Current water withdrawals have had minimal effect on flow at Alexander Springs and water use demands are not expected to increase significantly during the planning horizon. Estimated flow reduction (0.4 cfs) resulting from projected water use for the 20-year planning horizon is less than the flow reduction allowed by the recommended MFL. Therefore, the proposed minimum flow for Alexander Springs is achieved now and over the 20-year planning horizon, and no recovery or prevention strategy is required.

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ACRONYMS AND ABBREVIATIONS

ATM	Applied Technology and Management Inc.
F.A.C.	Florida Administrative Code
FDEP	Florida Department of Environmental Protection
F.S.	Florida Statutes
GIS	Geographic Information System
FH	minimum frequent high
FL	minimum frequent low
MA	minimum average
MFLs	minimum flows and levels
IH	minimum infrequent high
IL	minimum infrequent low
LOESS	Locally Weighted Scatterplot Smoothing
NDMv5	Northern District groundwater model (version 5)
NGVD	1929 National Geodetic Vertical Datum
NAVD	1988 North American Vertical Datum
NRCS	Natural Resources Conservation Service
OFS	Outstanding Florida Spring
OFW	Outstanding Florida Water
POR	period of record
SAV	submerged aquatic vegetation
SJRWMD	St. Johns River Water Management District
SRWMD	Suwannee River Water Management District
SMI	Soil Moisture Index
SSURGO	Soil Survey Geographic database
SWIDS	Surface Water Inundation/Dewatering Signatures
UFA	Upper Floridan aquifer
USGS	U.S. Geological Survey

ACKNOWLEDGEMENTS

We acknowledge the assistance of the numerous people at SJRWMD who contributed to this report. G.B. “Sonny” Hall initiated this investigation of the natural communities and hydrologic processes of the Alexander Springs system. Jane Mace and Travis Richardson conducted initial reconnaissance surveys of the Alexander Springs watershed for MFLs development. Jodi Slater led field investigations, provided preliminary ecological data analysis and provided preliminary review of this manuscript. Awes Karama developed the surface water hydrologic model. David Clapp developed and updated the hydraulic model. Fatih Gordu managed and reviewed the hydrological data analysis. Mike DeLoach, Mark Willick, and Kermit Hilliard conducted the elevation surveys of the transects under the direction of Tommy Walters, and later Stephen Speaks. Richard Guilfoyle processed the elevation data and provided quality assurance review. Tara Rodgers, John Fitzgerald, Warren Zwanka, Casey Harris, and numerous interns assisted with field data collection.

Clay Coates from USFS provided valuable insight into management issues. Ken Watson and Scott Emery provided independent scientific review of the manuscript and associated data. Intera, Inc. reviewed the hydrologic model.

INTRODUCTION

The St. Johns River Water Management District (SJRWMD) completed a minimum flows determination for Alexander Springs in Lake County, Florida. Alexander Springs and the associated Alexander Springs Creek are designated Outstanding Florida Waters (OFWs) for their natural attributes. They are popular outdoor recreation destinations enjoyed by numerous visitors each year. SJRWMD is charged with protecting these unique natural resources by developing minimum flows and levels (MFLs) pursuant to Florida Statutes. Alexander Springs has been designated an Outstanding Florida Spring (OFS), and as such, Section 373.042(2), *Florida Statutes* (F.S.), requires the adoption of MFLs for this priority water body by July 1, 2017.

LEGISLATIVE OVERVIEW

SJRWMD establishes minimum flows and levels for priority water bodies within its boundaries (section 373.042, F.S.). Minimum flows and levels for a given water body are the limits "at which further withdrawals would be significantly harmful to the water resources or ecology of the area" (section 373.042, F.S.). Minimum flows and levels are established using the best information available (section 373.042(1), F.S.), with consideration also given to “changes and structural alterations to watersheds, surface waters, and aquifers and the effects such changes or alterations have had, and the constraints such changes or alterations have placed, on the hydrology of the affected watershed, surface water, or aquifer...,” provided that none of those changes or alterations shall allow significant harm caused by withdrawals (section 373.0421(1)(a), F.S.).

The minimum flows and levels section of the State Water Resources Implementation Rule (rule 62-40.473, *Florida Administrative Code* [F.A.C.]) also requires that “consideration shall be given to natural seasonal fluctuations in water flows or levels, nonconsumptive uses, and environmental values associated with coastal, estuarine, riverine, spring, aquatic, and wetlands ecology.” The environmental values described by the rule include:

1. Recreation in and on the water
2. Fish and wildlife habitats and the passage of fish
3. Estuarine resources
4. Transfer of detrital material
5. Maintenance of freshwater storage and supply
6. Aesthetic and scenic attributes
7. Filtration and absorption of nutrients and other pollutants
8. Sediment loads
9. Water quality
10. Navigation

MFLs provide technical support to SJRWMD's regional water supply planning process (Section 373.0361, F.S.), the consumptive use permitting program (Chapter 40C-2, F.A.C.), and the environmental resource permitting program (Chapter 62-330, F.A.C.).

SJRWMD MFLs Program Overview

SJRWMD is engaged in a districtwide effort to develop MFLs for protecting priority surface water bodies, watercourses, associated wetlands, and springs from significant harm caused by water withdrawals. MFLs provide an effective tool for decision-making regarding planning and permitting of surface water or groundwater withdrawals. If a requested withdrawal would cause significant harm to a water body, a permit cannot be issued. If a water body is not in compliance with an MFLs, or expected not to be in compliance during the 20-year planning horizon due to withdrawals, a recovery or prevention plan must be developed and implemented.

The SJRWMD MFLs program includes environmental assessments, hydrologic modeling, independent scientific peer review, and rule making. A fundamental assumption of SJRWMD's approach is that alternative hydrologic regimes exist that are lower than historical but will protect the ecological structure and function of priority water bodies, watercourses, associated wetlands, and springs from significant harm caused by water withdrawals. Significant harm is a function of changes in frequencies of water level and/or flow events of defined magnitude and duration caused by water withdrawals. These changes cause impairment or loss of ecological structure (e.g., permanent downhill shift in plant communities caused by water withdrawals) or function (e.g., insufficient fish reproductive or nursery habitat caused by water withdrawals).

MFLs typically define the frequency of high, intermediate, and low water events necessary to protect relevant water resource values. Three MFLs are usually defined for each system—minimum frequent high (FH), minimum average (MA), and minimum frequent low (FL) flows and/or water levels. In some cases, minimum infrequent high (IH) and/or minimum infrequent low (IL) MFLs may also be set (Neubauer et al. 2008; see *Technical Approach* below for more detail). No matter how many MFLs are adopted, the most constraining (i.e., most sensitive to water withdrawal) MFL is used for water supply planning and permitting.

ALEXANDER SPRINGS SETTING AND DESCRIPTION

SITE LOCATION AND DESCRIPTION

Alexander Springs ("Spring") and Alexander Springs Creek ("Creek") are located in northern Lake County, Florida, within the boundaries of the U.S. Forest Service (USFS) Ocala National Forest. The spring has a mean discharge of 103 cubic feet per second (cfs), making it a first-magnitude spring (Walsh et al, 2009). The headspring pool measures more than 300 feet from north to south and 250 feet from east to west. The spring is approximately 57 miles north of Orlando, 47 miles west of Daytona Beach, 51 miles south of Palatka, and 52 miles east of Ocala. The location of the creek watershed and springshed are shown in Figure 1.

The approximately 9.3-mile long creek is a tributary of the St. Johns River and joins it approximately four miles south (upstream) of Astor, Florida. The creek receives considerable surface water inflows from Billie's Bay and Nine Mile Branch, which join the creek within half a mile of the headspring and contribute tannin-stained water from the swamps of Billie's Bay Wilderness Area. Smaller tributaries to the creek include Glenn Branch and Tracy Canal, as well as several unnamed drainage ways. The land adjoining most of the creek is national forest.

Alexander Springs and Alexander Springs Creek were designated Outstanding Florida Waters (OFW) on Sept. 1, 1982 (Rule 62-302.700(9)(n), F.A.C. The Florida Department of Environmental Protection (FDEP) uses this designation to provide special protection to certain water bodies because of their natural attributes. It requires that any projects regulated by FDEP or water management districts (WMDs) must not lower existing ambient water quality. In addition to OFW designation, in 2016 Alexander Springs was designated as an Outstanding Florida Spring (OFS). Pursuant to SB552 all first-magnitude springs in Florida received OFS status, and must have MFLs adopted by July 1, 2017.

SPRINGSHED CHARACTERISTICS

The prevailing direction of flow in the Upper Floridan aquifer (UFA) system near Alexander Springs is from southwest to northeast (Shoemaker et al., 2004). Therefore, the area to the southwest of Alexander Springs is the principal area contributing recharge to the spring. Investigators have used different models to delineate the springshed area. Knowles et al. (2002) used a particle tracking analysis in conjunction with groundwater model to delineate a 76 mi^2 contributing area with 18 inches per year average recharge flux. Shoemaker et al.

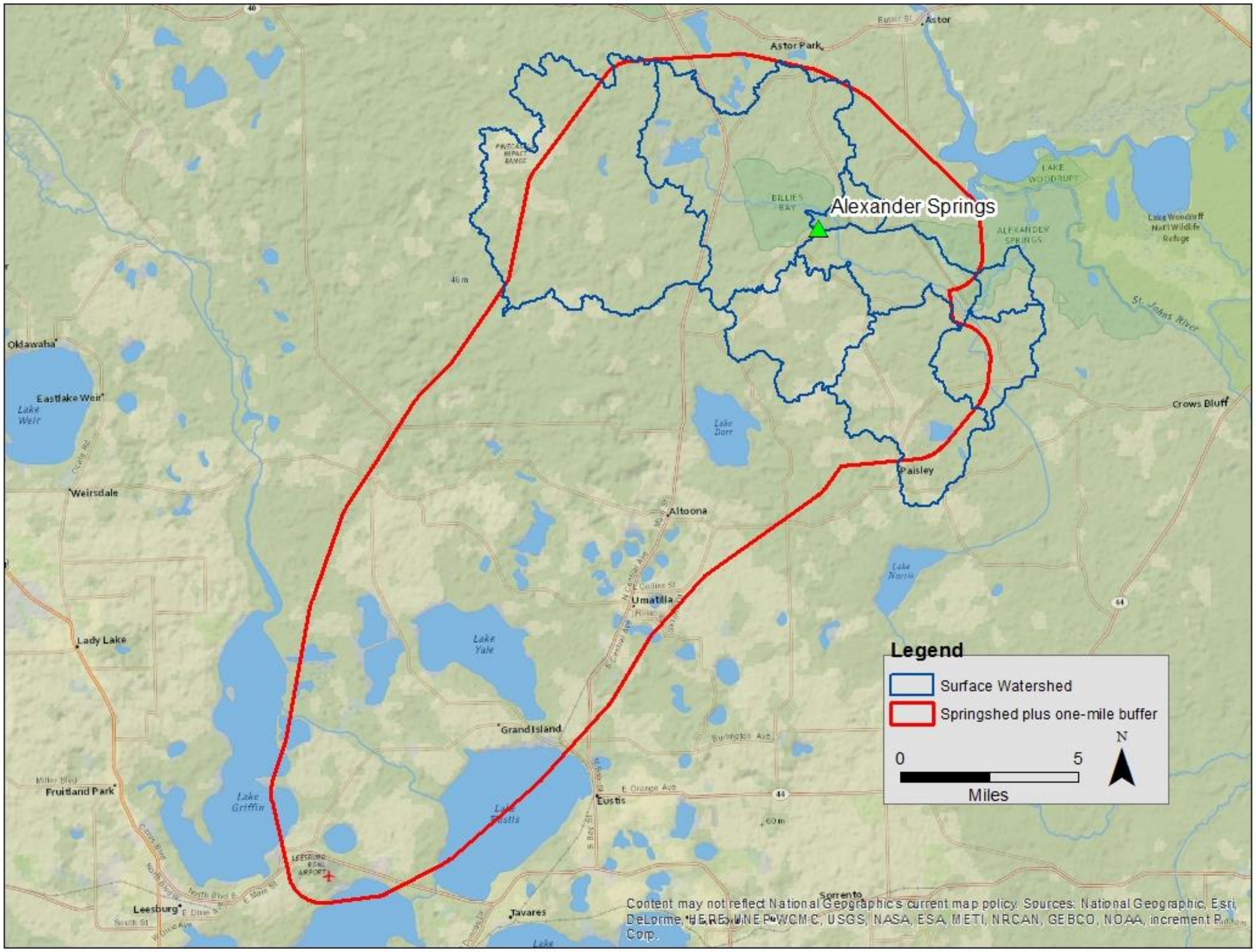

Figure 1. Alexander Springs springshed and surface watershed locations

(2004) used the composite areas produced by three different groundwater models to estimate the recharge area at approximately 110 mi^2. Walsh et al. (2009) estimated the springshed at 58.5 mi^2. For comparison, the watershed of the creek occupies 99 mi^2 (63,419 acres). The springshed shown in Figure 1 was delineated by modifying the springshed developed by the USGS (Shoemaker, 2004) using the most recent UFA potentiometric surface maps. The one-mile buffer was added to account for potential variations in springshed boundaries under different hydrologic conditions (i.e., springshed may expand during wet season).

WATERSHED CHARACTERISTICS

Walsh et al. (2009) describes Alexander springshed land use in 2004 as primarily urban (58.2%) with lesser amounts of water and wetlands (25.3%), forestland (9.0%), and agriculture (7.5%). This estimate would appear to reflect a larger springshed that extends into central Lake County. However, this southern area accounts for less than 6% of the total springflow (Knowles et al, 2002) and the majority of the spring flow appears to originate from forested land. Figure 2 shows the dominant land uses within the Alexander Springs Creek watershed.

Water Quality

The U.S. Geological Survey (USGS) has sampled water quality at Alexander Springs sporadically since 1956 and more regularly since 1982. SJRWMD currently samples water quality at the headspring four times per year. A summary of water quality data and trend analysis results are shown in Table 1. Many chemical parameters in the water exhibited a trend over the period of record (POR). The parameters associated with the rock matrix of the UFA, such as calcium, magnesium, and potassium, all showed increasing trends, while nitrate + nitrite, typically associated with changing land use, showed a declining trend (Table 1 and Figures 3–7). The increase in rock matrix-associated constituents is likely due to a higher proportion of the spring discharge consisting of "older" water which had a longer contact time with the rock matrix in the UFA. This results in more material dissolved from the rock matrix, therefore, higher concentration over time. The declining trend of nitrate-nitrite also suggests that less young water is contributing to the flow in the spring (Table 1 and Figure 6), since the NOx is contributed from recharge from land uses on the land surface. Sulfate is another water chemical constituent that has higher concentration in the deeper portions of the UFA suggesting that more of the spring discharge consists of "older" water. The smoothing parameter value used for fitting the Locally Weighted Scatterplot Smoothing (LOESS) regression lines was achieved through an iterate process of fitting the line through the data points by minimizing the corrected Akaike information criterion.

Physiography

Alexander Springs and Alexander Springs Creek lie in the Ocala Scrub sub-district of the Central Lake District (Brooks 1982). It is primarily a paleo sand dune field that supports extensive sand pine. The relatively flat areas northeast of Alexander Springs, which borders the St. Johns River Off-set sub-district, have elevations generally below 70 feet. This

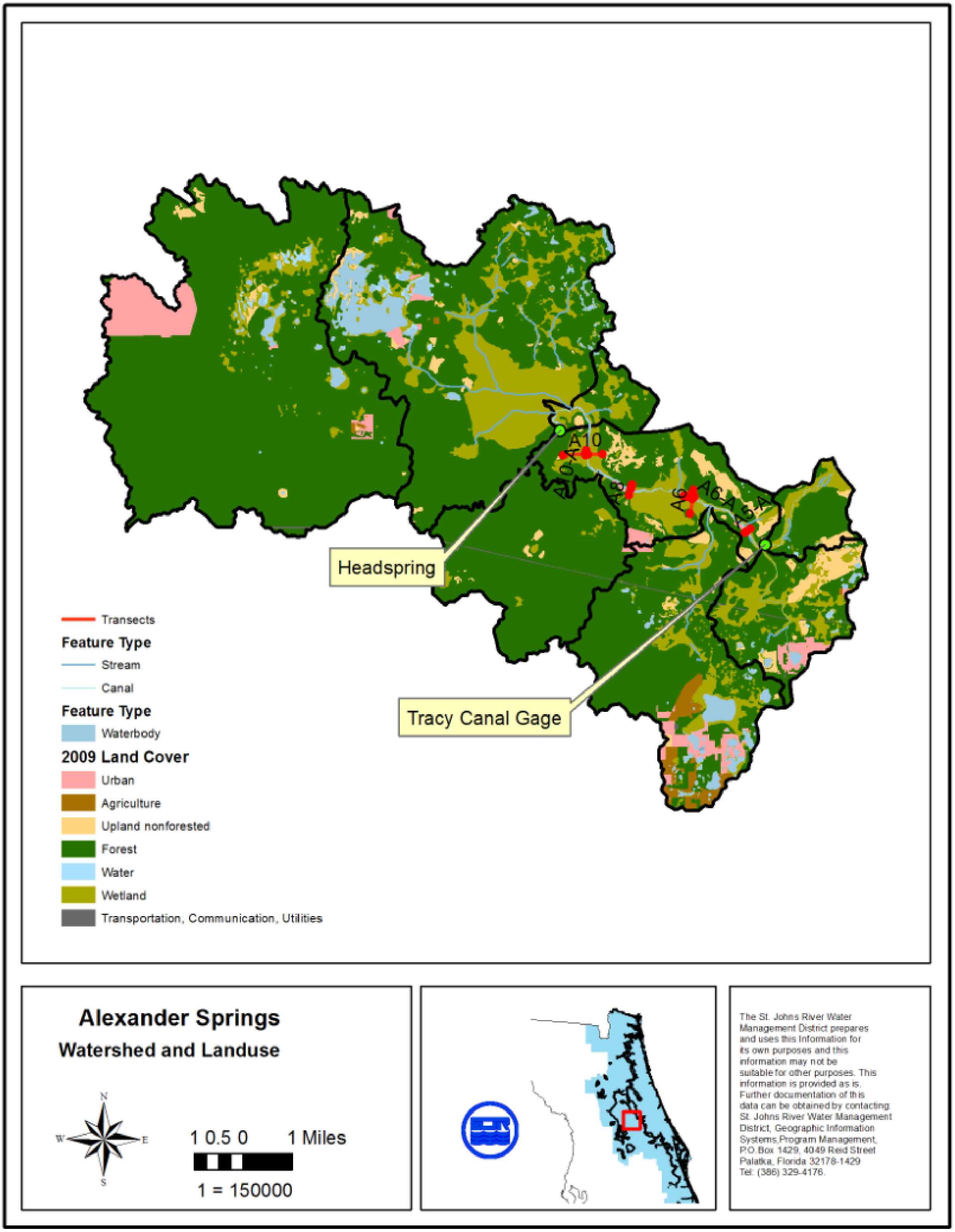

Figure 2. Watershed Land Use (Source: SJRWMD; 2009)

contrasts with the rolling, xeric sand hills southwest of Alexander Springs, which have higher elevations between 110 and 130 feet. Internal drainage in the latter area makes this an important recharge area for the UFA (Figure 8).

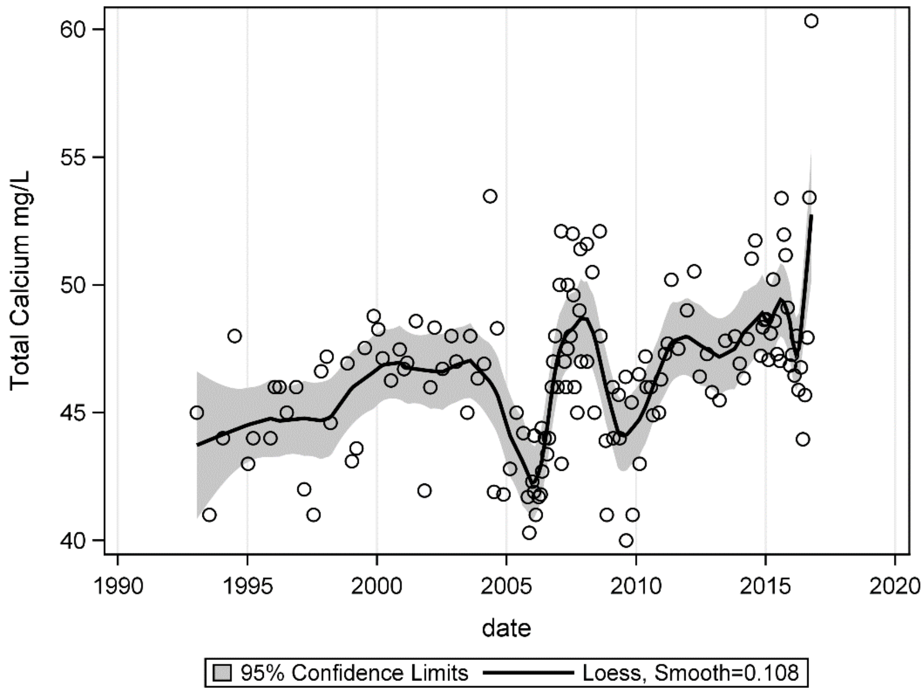

Figure 3. Calcium time series with LOESS regression line 1993 – 2016.

Table 1. Alexander spring water quality and discharge statistics (Source: SJRWMD)

Parameter	Mean	Med	Min	Max	Count	Beginning date	Recent date	Tau*	P**
Discharge, cfs***	102	100	60	202	273	02/21/31	11/03/16	-0.082	0.083
Alkalinity, total, mg/L as CaCO3	84	82	73	174	162	04/23/56	11/15/16	0.334	0.000
Calcium, total, mg/L as Ca	46	47	40	53	142	01/18/93	09/07/16	0.276	0.000
Chloride, total, mg/L as Cl	251	252	7	333	165	04/23/56	10/05/16	0.140	0.010
Conductivity, field, µmhos/cm	1088	1116	459	2571	152	06/11/84	08/10/16	0.099	0.086
Dissolved Oxygen, mg/L	1.899	1.910	0.670	4.760	59	03/01/01	08/10/16	0.446	0.000
Fluoride, total, mg/L as F	0.111	0.119	0.000	0.161	18	11/15/02	11/15/16	0.309	0.075
Magnesium, total, mg/L as Mg	21	21	18	37	143	07/06/92	09/07/16	0.229	0.000
Nitrate + nitrite, dissolved, mg/L	0.046	0.041	0.003	0.326	154	04/14/72	10/05/16	-0.152	0.007
Othophosphate, dissolved, mg/L as P	0.047	0.046	0.000	0.292	136	04/14/72	10/05/16	-0.039	0.514
pH, field, S.U.	7.808	7.800	6.900	8.730	169	04/23/56	08/10/16	0.141	0.010
Phosphorus, total, mg/L as P	0.053	0.049	0.030	0.440	109	04/14/72	10/05/16	0.176	0.010
Potassium, total, mg/L as K	4.057	4.100	2.970	5.200	143	07/06/92	09/07/16	0.207	0.000
Sodium, total, mg/L as Na	141	140	115	246	143	07/06/92	09/07/16	0.289	0.000
Sulfate, total, mg/L as SO_4	66	66	7	85	163	04/23/56	10/05/16	0.211	0.000
Total dissolved solids, mg/L	592	591	371	756	129	06/22/67	06/11/13	0.109	0.081
Water temperature, ^{o}C	23.51	23.50	19.10	26.50	195	11/16/60	08/10/16	0.036	0.486

* : Kendall's Tau correlation coefficient

** :P-value from Mann-Kendall trend test

*** :The discharge trend analysis is based on the data from 1980 to 2016

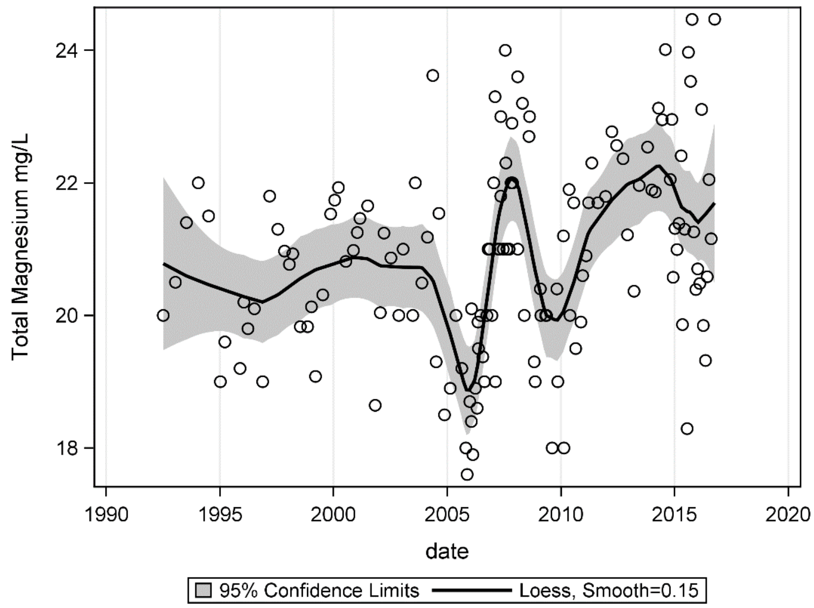

Figure 4. Magnesium time series with LOESS regression line 1992 – 2016.

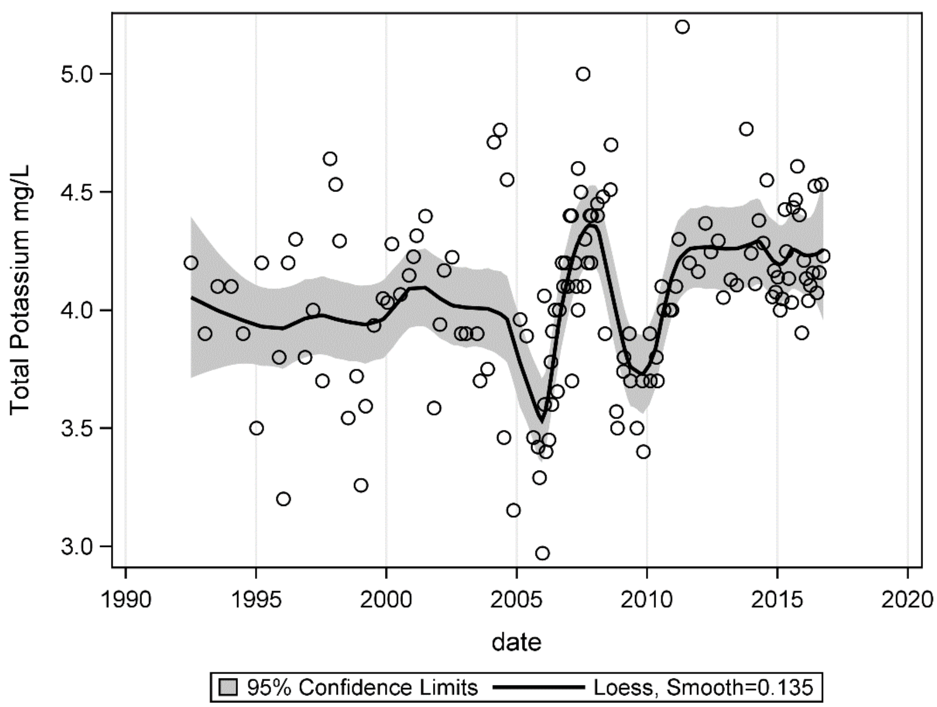

Figure 5. Potassium time series with LOESS regression line 1992–2016.

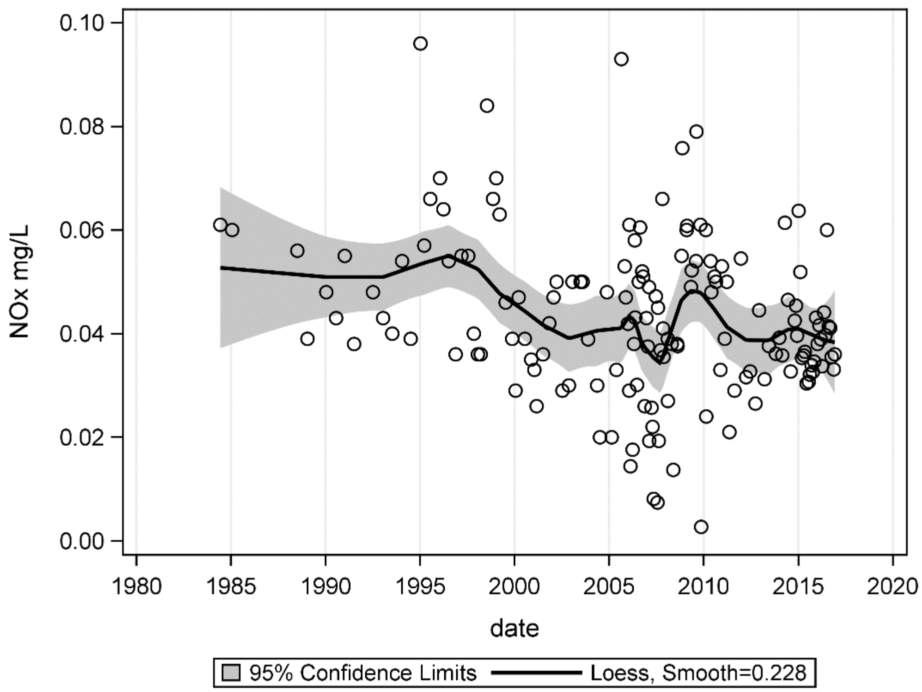

Figure 6. Nitrate + Nitrite time series with LOESS regression line 1985–2016.

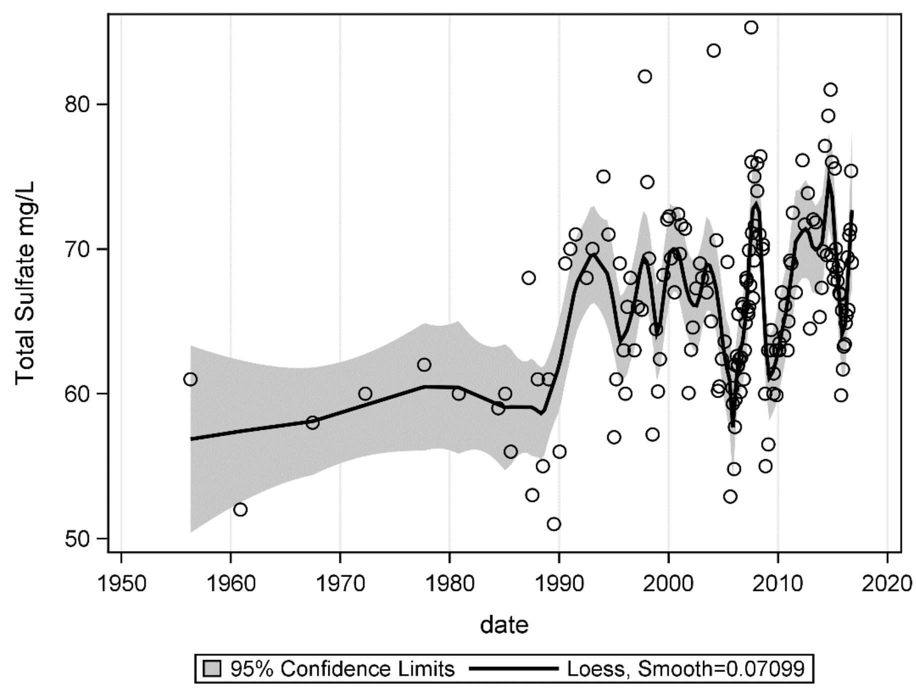

Figure 7. Sulfate time series with LOESS regression line 1956–2016.

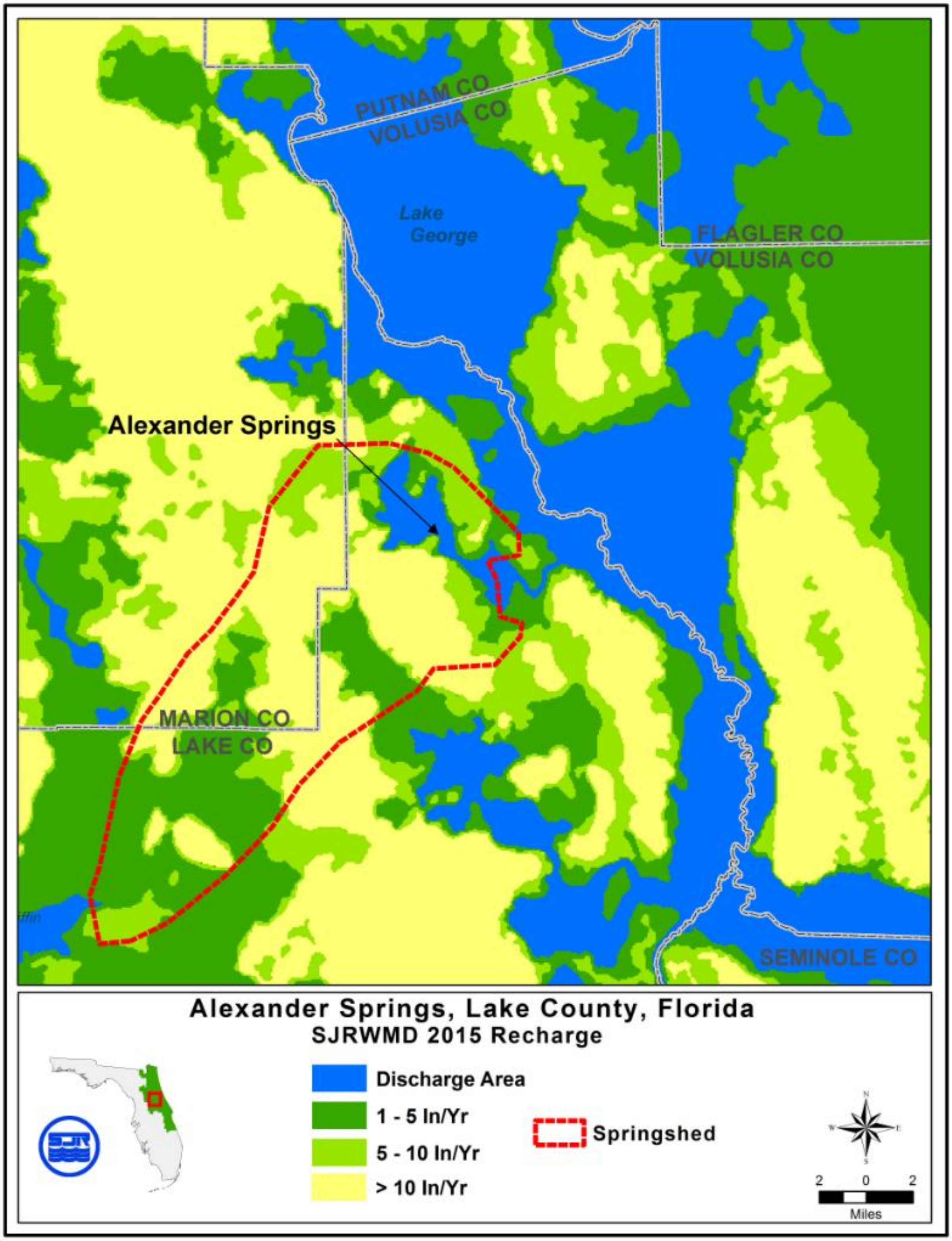

Figure 8. Upper Floridan Aquifer Recharge Areas (Source: SJRWMD; 2015)

HYDROLOGIC DATA

Gauging Stations

Hydrologic data from gauging stations are used in conjunction with biological data (e.g., vegetation communities and soils) to develop MFLs. Figure 9 shows the locations of gauges used to collect continuous surface water data along the Creek. Random manual water level readings were collected at a headspring gauge from 1990 to 2012. The gauge was relocated in 2014 and now collects water levels continuously. SJRWMD has operated continuous gauges at County Road (CR) 445 bridge and Tracy Canal since October 2003. Additional gauging stations were established at cross-sections A8, A6, and A5 in March 2010. A water level reference pipe was installed at cross-section A10 in 2010 and is read manually on a quarterly basis.

The CR 445 gauge has undergone shifts in the stage-discharge relationship due to scour and fill of sand deposits, debris, and aquatic growth associated with the bridge. It has also been subject to vandalism on at least two occasions. These factors have compromised the quality of some data from that site. Therefore, the Tracy Canal gauge was selected as the site where MFLs will be set for the Alexander Springs Creek system.

Hydrologic Data

Hydrologic data for Alexander Springs and Alexander Springs Creek have been collected at various stations for different time periods (Table 2). Alexander Springs discharge data at SJRWMD station 00291896 are not continuous daily data but are random samples. In the early part of the POR the samples are sporadic and monthly. From 2002, the data are regular monthly samples. Except for sporadic extreme values, spring discharge is very consistent with a mean value of 102 cfs. Observed Alexander Springs discharge data are presented in Figure 10. Observed Alexander Springs stage data are shown in Figure 11. Summary statistics of discharge and stage are presented in Table 3 and Table 4, respectively.

SJRWMD station 18523784 is on upstream Alexander Creek at CR 445. The station has both daily discharge and stage data from October 2003. However, discharge data were discontinued from April 3, 2012. Data quality at this station is not consistent, mainly due to vandalism. For this reason, these data at this station were not used in the development of this MFL. The gauge used in the development of this MFL is SJRWMD station 18553786 located on Alexander Creek (spring run) just upstream of the Tracy Canal confluence. This station represents the best long-term data, and consists of daily discharge and stage data from October 2003 to current. As with other stations, there are missing data, with the most important missing values related to tropical storm Fay in late August 2008. Table 5 summarizes both discharge and stage data, and shows the discharge and stage data for the entire period of record, respectively.

Figure 9. Locations of gauges and HEC-RAS cross-sections

Table 2. SJRWMD hydrological data collection stations within the Alexander Springs watershed

Station Number	Station Name	Discharge Period of Record	Stage Period of Record
00291896	Alexander Springs at Astor (spring pool)	2/12/1931 – Current	10/30/1980 – Current
18523784	Alexander Springs Run at CR445	10/1/2003 – 4/3/2012	10/9/2003 – Current
18553786	Alexander Springs Run at Tracy Canal	10/1/2003 – Current	10/10/2003 – Current
34365072	Alexander Springs Creek A1 at Shell Landing	-	5/14/2014 – Current
31033149	Alexander Springs Creek Transect A5 North Bank	-	3/23/2010 – Current
31023387	Alexander Springs Creek Transect A6 North Bank	-	3/23/2010 – Current
31273459	Alexander Springs Creek Transect A8 North Bank	-	3/23/2010 – Current

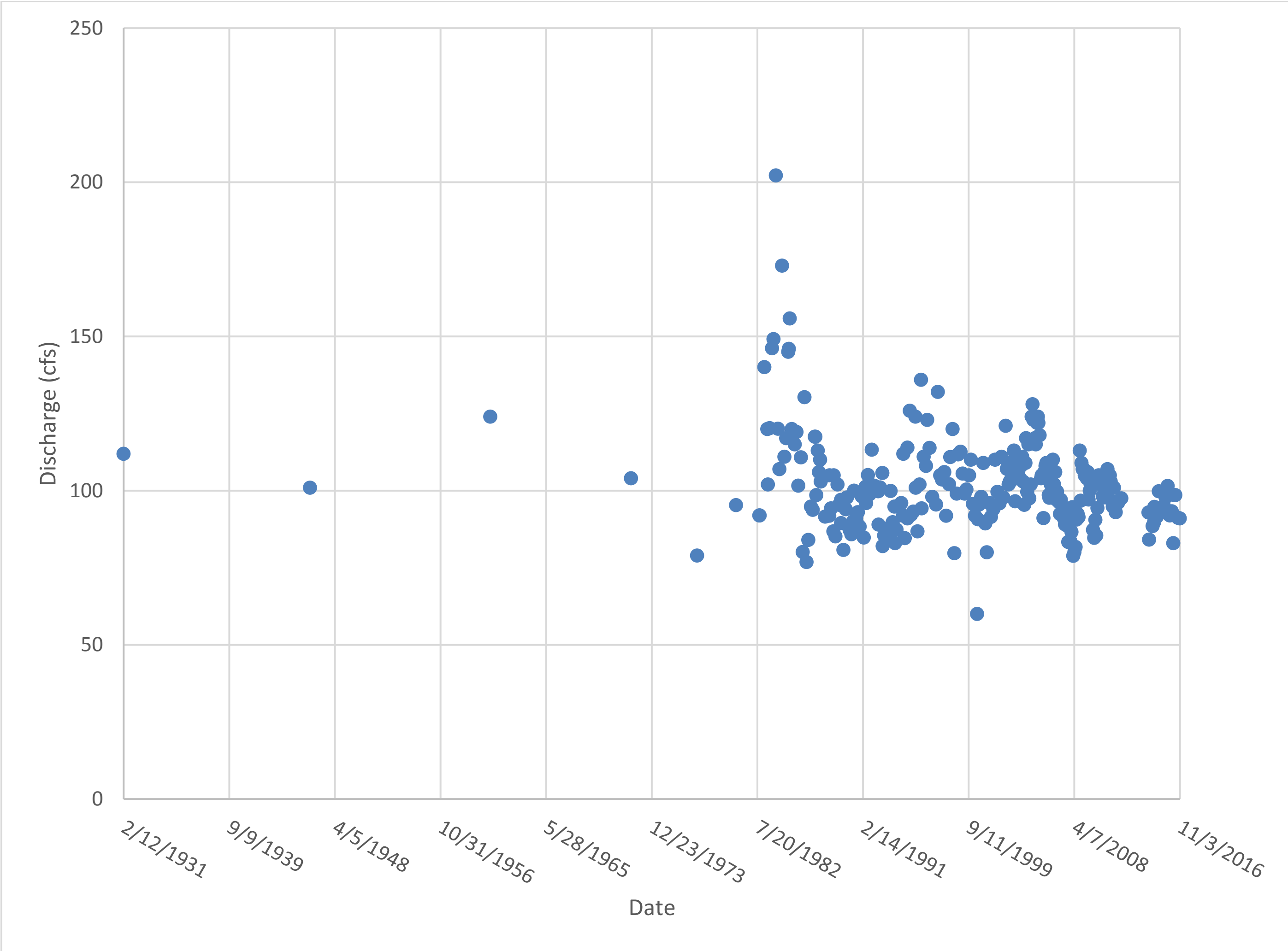

Figure 10. Alexander Springs (STA 00291896) Discharge POR (2/12/1931–11/3/2016)

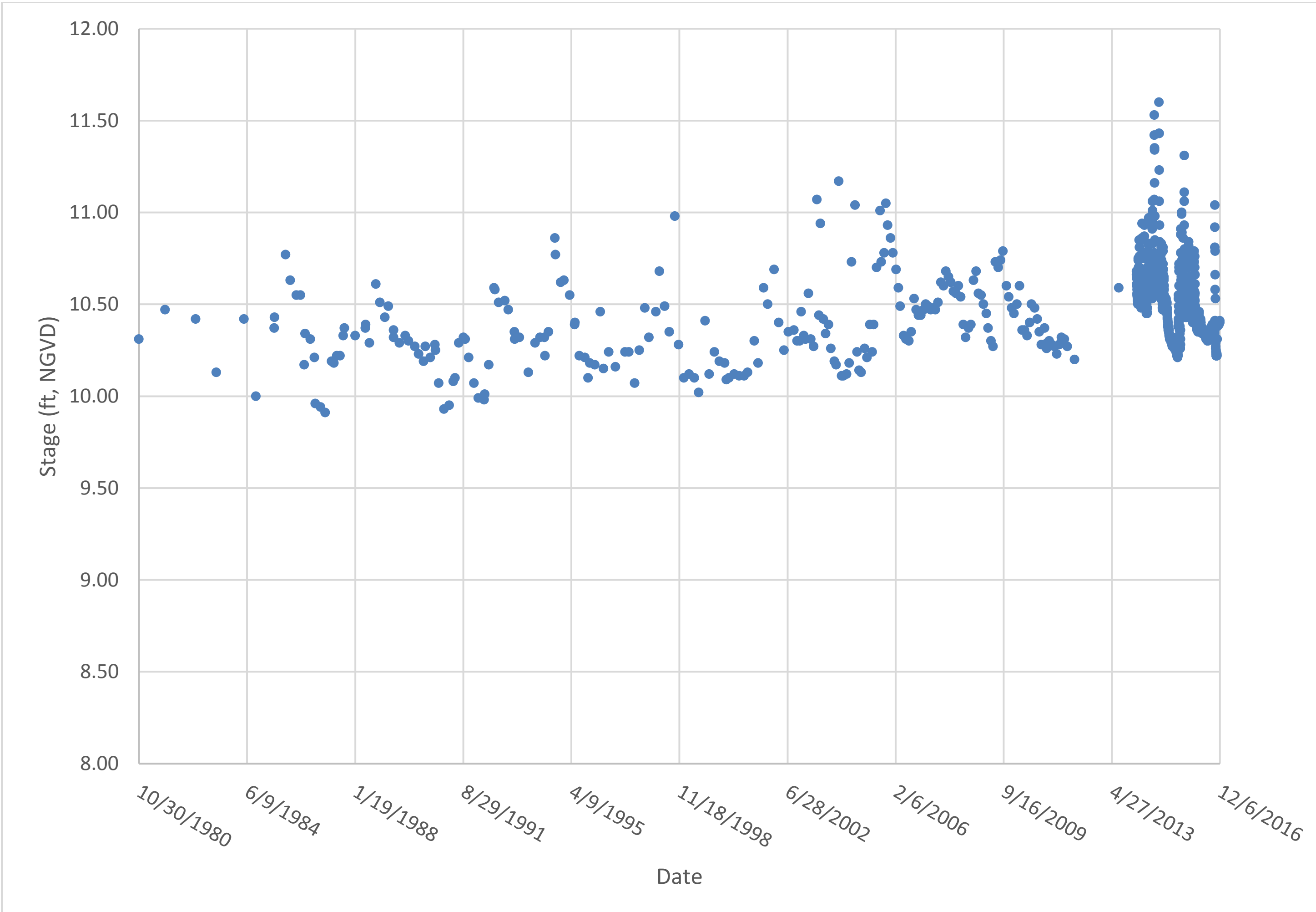

Figure 11. Alexander Springs (STA 00291896) Stage POR (10/30/1980–12/6/2016)

Table 3. Alexander Springs (STA 00291896) Discharge Summary Statistics POR (2/12/1931–11/3/2016)

Descriptive Statistics	Discharge (cfs)
Mean	101.88
Standard Error	0.91
Median	99.95
Mode	102.00
Standard Deviation	15.09
Minimum	60.00
Maximum	202.19

Table 4. Alexander Springs (STA 00291896) Stage Summary Statistics POR (10/30/1980–12/6/2016)

Descriptive Statistics	Stage (ft NGVD29)
Mean	10.46
Standard Error	0.01
Median	10.44
Mode	10.36
Standard Deviation	0.20
Minimum	9.91
Maximum	11.60

Table 5. Discharge and Stage Summary Statistics at Station 18553786

Descriptive Statistics	Discharge (cfs) (10/1/2003–11/14/2016)	Stage (ft, NGVD) (10/10/2003–11/14/2016)
Mean	129.09	4.22
Standard Error	0.63	0.01
Median	115.00	4.06
Mode	104.00	3.94
Standard Deviation	42.92	0.54
Minimum	79.82	3.42
Maximum	680.00	8.26

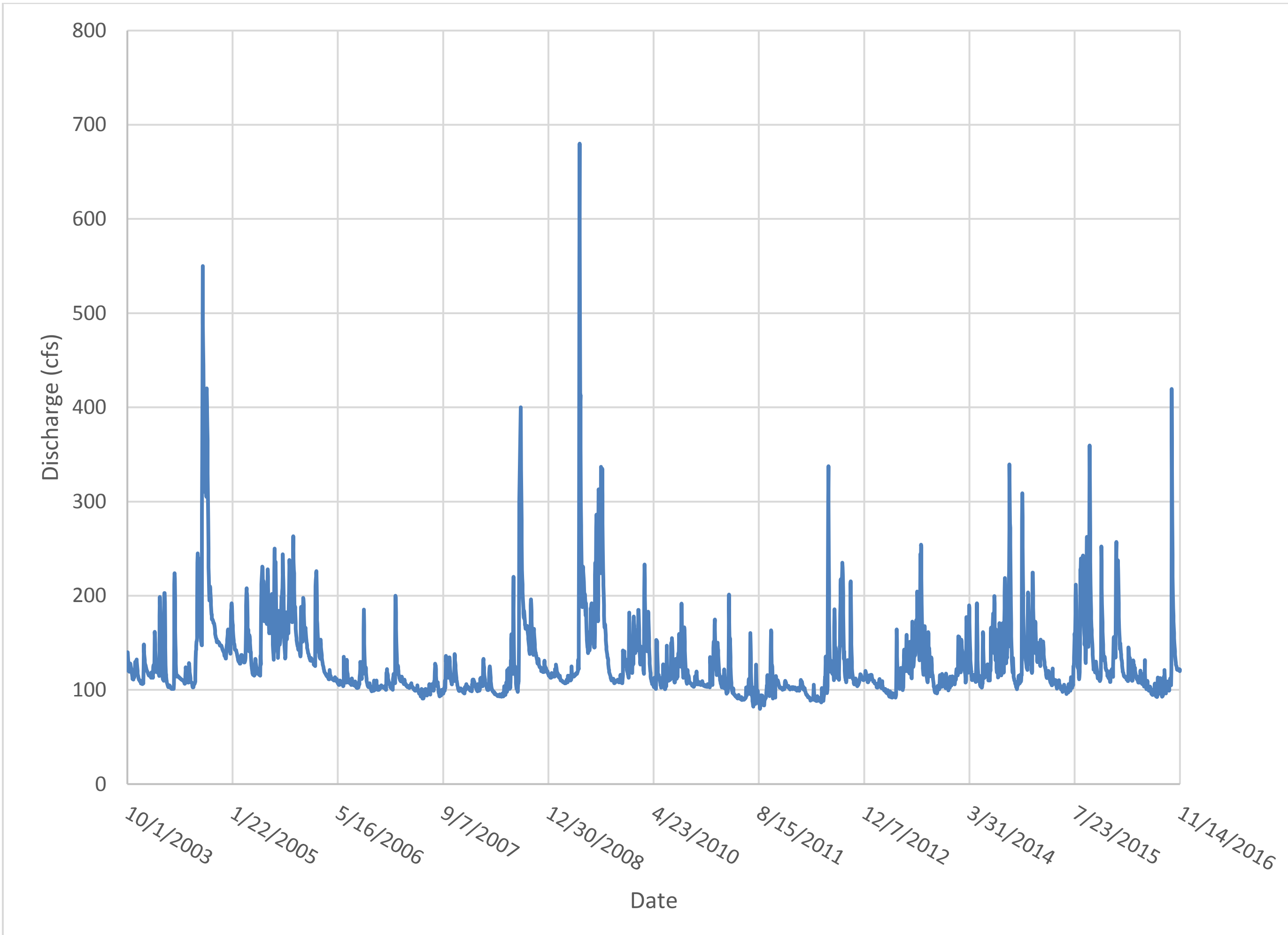

Figure 12. Discharge Hydrograph at Station 18553786 POR (10/1/2003–11/14/2016)

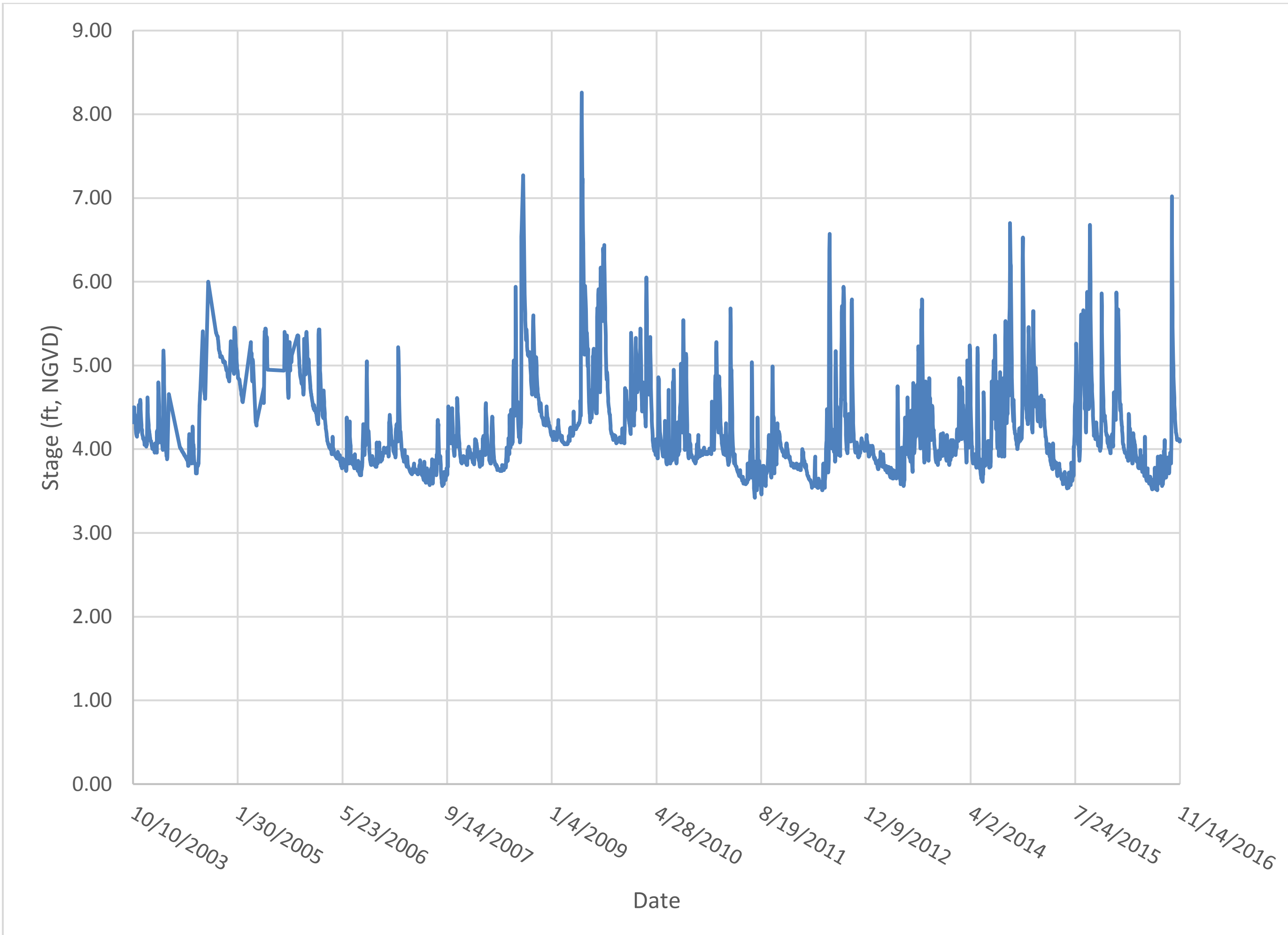

Figure 13. Stage Hydrograph at Station 18553786 POR (10/10/2003–11/14/2016)

Spring Discharge Trend Analysis

Discharge measurements have been conducted on a sporadic basis at the headspring since 1931 and values have ranged from 60 to 202 cubic feet per second (cfs) (Figure 14). The discharge data collection frequency varied over the period of record. There were fewer observations prior to 1983. Since 1983, discharge measurements were conducted on about a bi-monthly schedule. Between February 2012 and March 2014 no discharge data were collected. Figure 14 shows the Alexander spring discharge time series with a LOESS regression line fitted through the data points from the early 1980s to current. The PROC LOESS procedure with corrected Akaike information criteria option in Statistical Analysis System (SAS®) was used to determine the optimum smoothing parameter value for smoothing the LOESS regression line. Trend analysis was conducted on these data using Seasonal Mann-Kendall method in the R statistical analysis package. The trend was statistically insignificant at alpha 0.05 level, but it had a slightly negative trend for the period of 1980 to 2016. It would be inappropriate to do the trend analysis for the entire period since there are only five data points over the 1930–1979 period. Sporadic discharge measurements were made at CR 445 and Tracy Canal in 2003.

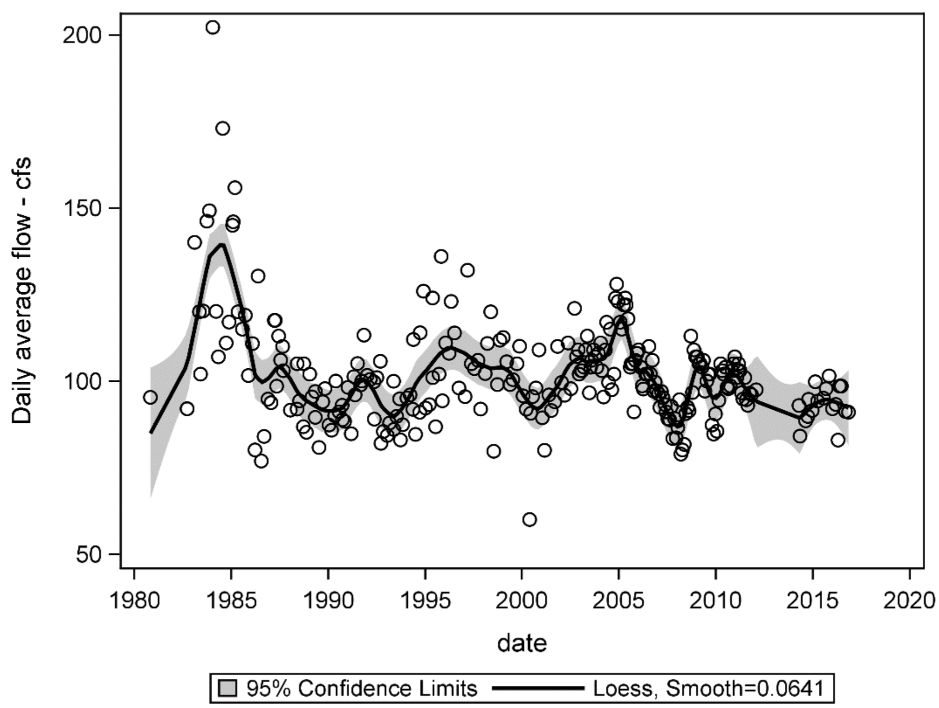

Figure 14. Alexander Spring discharge time series with LOESS regression line (1980–2016)

SOIL AND VEGETATION BACKGROUND INFORMATION

Soil Types

The distribution of soil types in the Alexander Springs Creek watershed are shown in Figure 15. Although highly detailed soil maps are available from Soil Survey Geographic database (SSURGO), soil groupings in this figure are more general and display only the dominant soil orders.

In general, the high elevation, rolling sandhills to the southwest of the creek are Entisols while the low elevation, flatwoods to the northeast of the creek are Spodosols. Significant areas of Histosols occur in depressions along and near the creek. A comparison of Figures 8 and 15 shows that recharge rates are high in Entisol areas and medium in Spodosol areas. Histosols and some other wetland soils occur in discharge zones. The following is a summary of pertinent characteristics of these soil orders (SSS, 1999, NRCS Official Series Descriptions, 2016).

- Entisols have little or no horizon development aside from a thin surface layer stained by organic matter. Most of the Entisols near Alexander Springs Creek classify as Quartzipsamments, which are very deep, excessively drained, sandy soils with seasonal high water tables below 2 meters. Typical soil series include Astatula and Paola as well as the moderately well drained Tavares series.

- Spodosols are poorly drained, sandy soils with a subsoil layer known as a “spodic” horizon. Spodic horizons form by an accumulation of translocated organic acids that coat, stain, and sometimes cement sand grains. This can impede drainage and perch water tables at certain times of the year. An alternative explanation is that the spodic horizon forms near the approximate depth of the seasonal high water table. Typical soil series include Myakka, St. Johns, and Immokalee.

- Histosols are wetland soils derived largely from organic deposits at least 16 inches deep. Water tables are near the surface much of the year. Permeability is often rapid due to large, interconnected macropores. Typical soil series include Terra Ceia, Samsula, and Gator.

Vegetation Types

The distribution of mapped wetland vegetation in the Alexander Springs Creek watershed is depicted in Figure 16. This map is based on remote sensing techniques and uses a classification system developed at SJRWMD (Kinser, 2012).

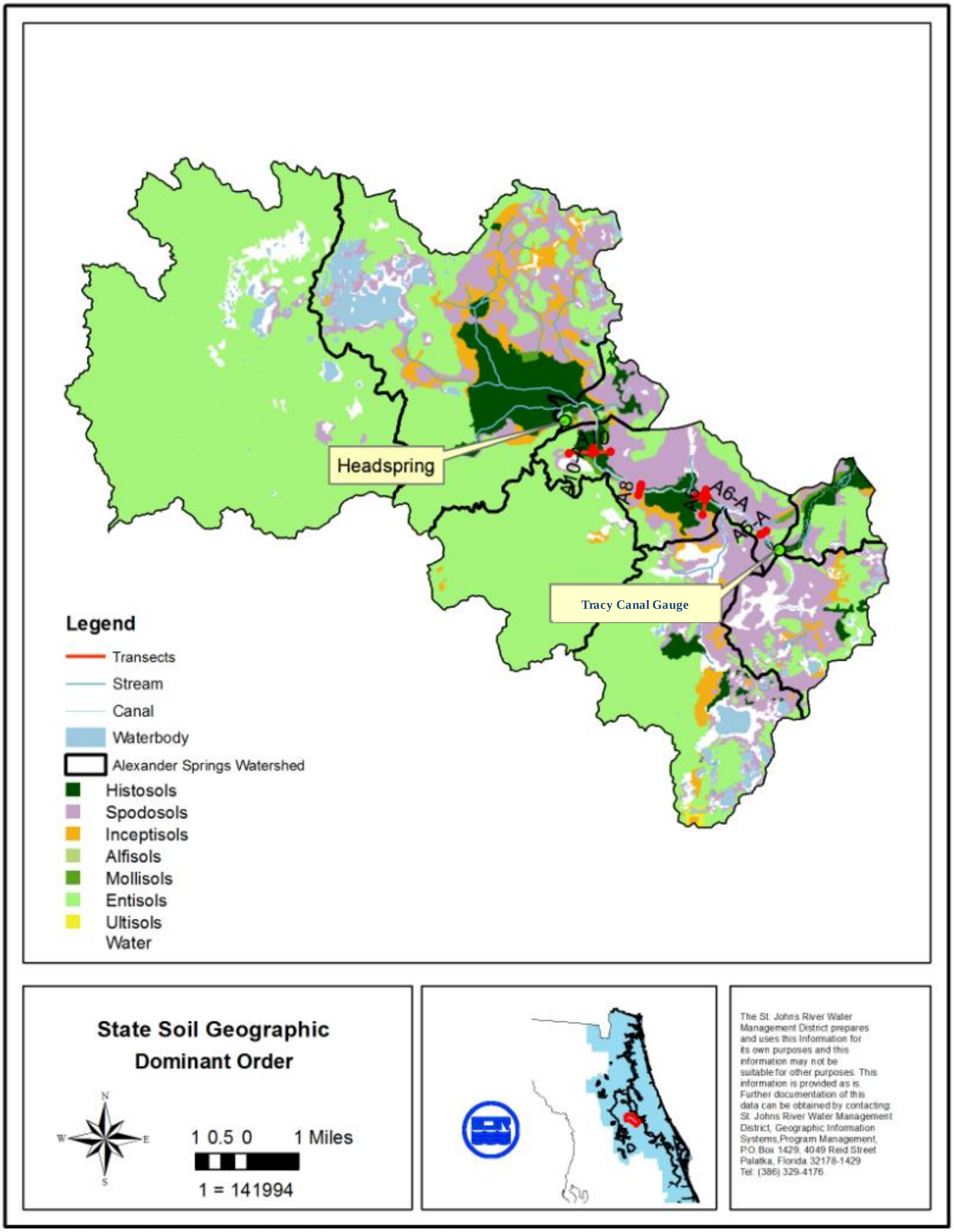

Figure 15. Soil Types (Source: SSURGO data; 2016)

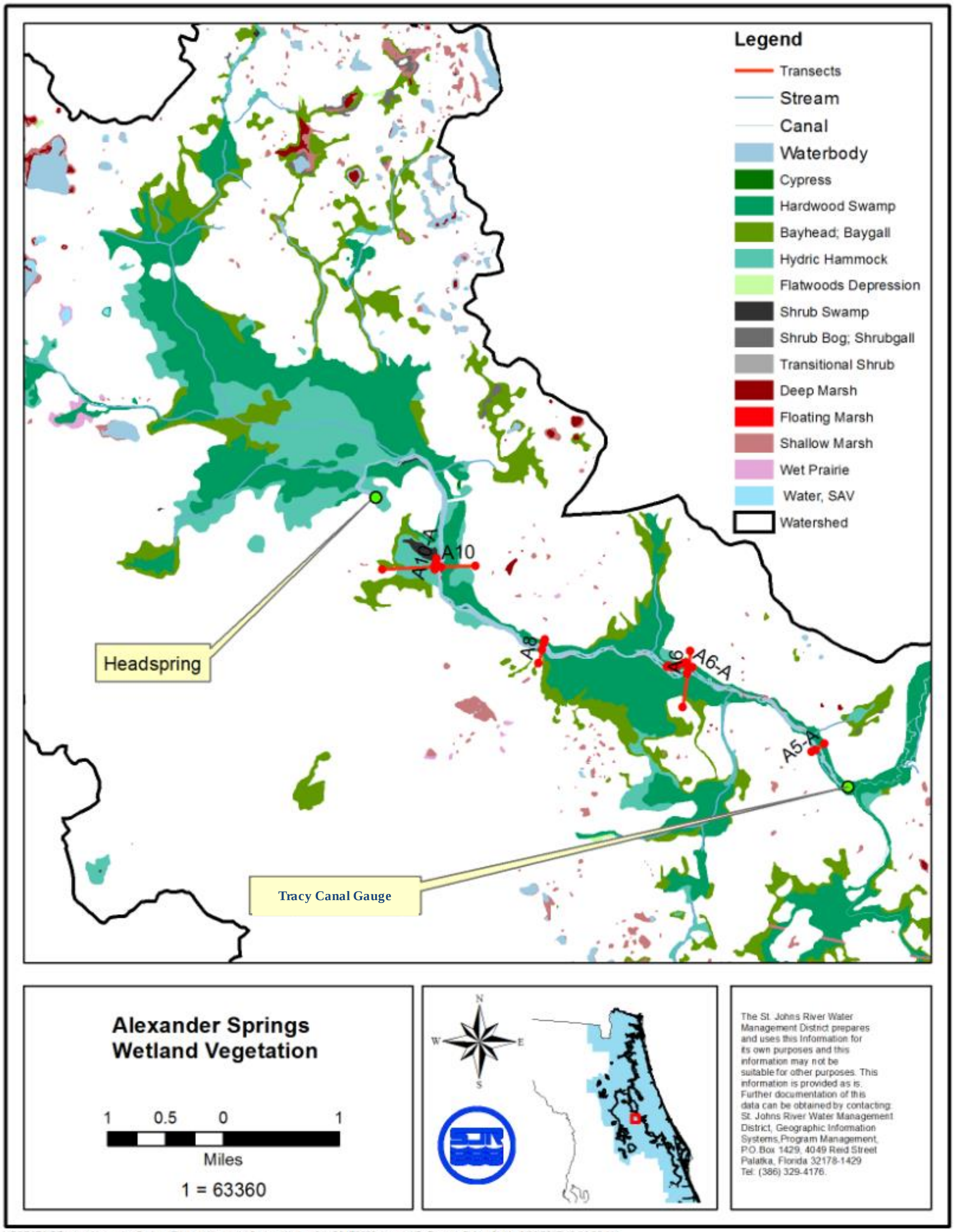

Figure 16. Wetland Vegetation (Source: SJRWMD; 2012)

In general, the floodplain of Alexander Springs Creek is hydric hammock with hardwood swamp in a few backswamp and island locations. The creek channel is typically aquatic bed with some areas of deep marsh along channel edges. The following discussion compares plant community descriptions from Kinser (2012) with more detailed descriptions developed by the Florida Natural Areas Inventory (FNAI, 2010). Information from other sources is included as pertinent.

- Hydric hammocks are forested systems dominated by broadleaved evergreen and deciduous species. They are seldom inundated but soils are saturated much of the year (Kinser, 2012). FNAI (2010) describes them as laurel oak and/or cabbage palm dominated forests. However, there is much variation between and within sites. Other common canopy species include sweetgum (*Liquidambar styraciflua*), red maple (*Acer rubrum*), red cedar (*Juniperus virginiana*), and American elm (*Ulmus americana*). Bald cypress (*Taxodium distichum*) can occur but is never abundant. The understory is similarly variable and includes American hornbeam (*Carpinus caroliniana*), swamp bay (*Persea palustris*), wax myrtle (*Myrica cerifera*), and needle palm (*Rhapidophyllum hystrix*). Groundcovers include graminoids such as sedges (*Carex* spp.) and woodoats (*Chasmanthium* spp.) and various ferns. Vines and epiphytes are common. The hydrology of hydric hammocks is complex and is influenced by rainfall, river inundation, overland flow, and seepage from adjacent uplands (Vince et al, 1989). Hydric hammocks adjacent to spring runs may have high water tables due to discharges from deep aquifers. Subsurface clay layers may perch water at the surface. The complex flora and hydrology creates diverse habitats that support a variety of wildlife. For example, a study of inland hydric hammocks of Florida noted a high diversity of herpetofauna (Florida Game and Freshwater Fish Commission, 1976).

- Hardwood swamps flood more frequently, for a longer duration, and to a greater depth than hydric hammocks. Kinser (2012) defines hardwood swamps as forested wetlands dominated by deciduous hardwoods such as swamp gum, Carolina ash, red maple, and bald cypress. FNAI (2010) describes floodplain swamps as closed canopy forests of hydrophytic trees occurring on frequently or permanently flooded hydric soils adjacent to stream channels and in depressions and oxbows of floodplains. Bald cypress commonly shares dominance with swamp tupelo (*Nyssa sylvatica* var. *biflora*). Other canopy trees include red maple and laurel oak. Smaller trees or shrubs such as Carolina ash, buttonbush, cabbage palm, and dahoon holly may be present. Typical groundcovers include lizard’s tail (*Saururus cernuus*), false nettle (*Boehmeria cylindrical*), savannah panicum (*Phanopyrum gymnocarpon*), and various flood tolerant ferns.

- Aquatic beds are communities of aquatic plants rooted in the sediments of shallow water bodies. They are generally permanently flooded (Kinser, 2012). Spring-run streams, which derive most water from artesian openings (FNAI, 2010) have a channel often dominated by submerged macrophytes. Clear spring discharge allows deep penetration of light while relatively constant discharge minimizes environmental fluctuations that sometimes limit production on other stream types. Submerged aquatic vegetation (SAV) includes tapegrass (*Vallisneria americana*), pondweed (*Potamogeton* spp.), southern naiads (*Najas quadalupensis*). Emergent species may include arrowheads (*Sagittaria* spp.) and wild rice (*Zizania aquatic*a). Spring-run streams are among the most productive of aquatic habitats. They support a variety of mollusks, stoneflies, mayflies, caddisflies, and many fishes. Reptiles include alligators, various watersnakes, and turtles. Where water sources are influenced by nearby swamps or flatwoods, the spring run may be temporarily stained with tannins and other dissolved organics during or following heavy rains.

- Floodplain marshes are herbaceous wetland communities along river floodplains (FNAI, 2010). Species occur along a hydrologic gradient from shallow to deep marsh. Sand cordgrass, sawgrass, and maidencane dominate higher portions subject to seasonal inundation while such species as bulltongue arrowhead (*Sagittaria lancifolia*), pickerelweed (*Pontederia cordata*), and spatterdock (*Nuphar advena*) occur in the deeper, more frequently flooded zones. Patches of shallow and deep marsh and shrub thickets occur throughout the floodplain, providing diversity of habitats to wildlife. Kinser (2012) describes deep marshes as semi-permanently to permanently flooded wetlands dominated by a mix of water lilies and deep water emergent species while shallow marshes are herbaceous or graminoid communities subject to lengthy seasonal inundation and occasional fire.

MANAGEMENT CONSIDERATIONS

Issues of Concern

USFS staff members in charge of managing the Alexander Springs Recreation Area have noted the following concerns:

- Influx of a large volume of "beach sand" has buried or obscured rock formations near the headspring, possibly altering flow patterns. This material was reportedly brought into the site at least 40 years ago. Despite the bulkhead around the headspring pool area, big storms still occasionally cause "blowouts" as subsurface piping and undercutting deliver additional doses of sand to the headspring. A sand plume of an estimated 12- to 18-inch thickness now extends about 150 feet downstream from the vent. A management plan is being developed that will propose mitigation measures while also addressing issues of endemic snails and disposal of large volumes of sand. This MFLs determination does not specifically address this localized disturbance. However, soil and vegetation data collected near the headspring (cross-section A16) were not used in this determination in part due to uncertainty regarding pre-disturbance elevations.

- Patches of the invasive blue-green algae (genus *Lyngbya)* appear to be expanding into portions of the channel formerly occupied by SAV beds. Peer reviewers from HSW, Inc.

noted a particularly large patch of *Lyngbya* in July 2016 between Transects A9 and A10 at a sharp bend in the creek channel. The expansion of this species degrades in-channel habitat quality. The causes of the expansion are not well understood but suggest some localized water quality problems.

- Based on anecdotal information, there is a perceived broadening and slowing of the spring run. Field observations suggest that this is caused by proliferation of emergent vegetation, which restricts boat passage in places. Lake County manages this by frequent spraying. Development of an Infrequent High (IH) level might help protect channel maintenance processes since these events typically flush the channel. However, IH events are driven by influx of surface water during large storm events and by a backwater effect of the St. Johns River. Therefore, they have little relationship to spring base flow, are not easily modeled, and are thus not addressed by this MFLs determination.

Recreational Use

A recreation area at the headspring attracts numerous swimmers, bathers, and divers as well as offering camping and hiking opportunities. It is especially popular with visitors during the summer. The recreation area also rents canoes for use on the creek. The creek section from the headspring to Highway 445 bridge receives heavy canoe and kayak traffic. The two-mile section below Highway 445 to the established take-out on the south side of the creek receives moderate canoe and kayak traffic. The section below this point has diminished canoe traffic (*personal communication*, Clay Coates, USFS). The creek below Highway 445 bridge is also open to airboats and small motorboats. Photographs of some important recreational features are shown in Figure 17.

Threatened and Endangered Species

The FNAI biodiversity matrix is an online screening tool that provides access to information on rare species occurrences throughout the state. For each mile-square grid cell, the matrix produces lists of rare species, their rank, protection status, and likelihood of occurrence (documented, likely, or potential). Table 6 summarizes these lists for hydrologically sensitive species in grid cells along Alexander Springs Creek. This includes nine invertebrates, two plant, two bird, and two herpetofauna species.

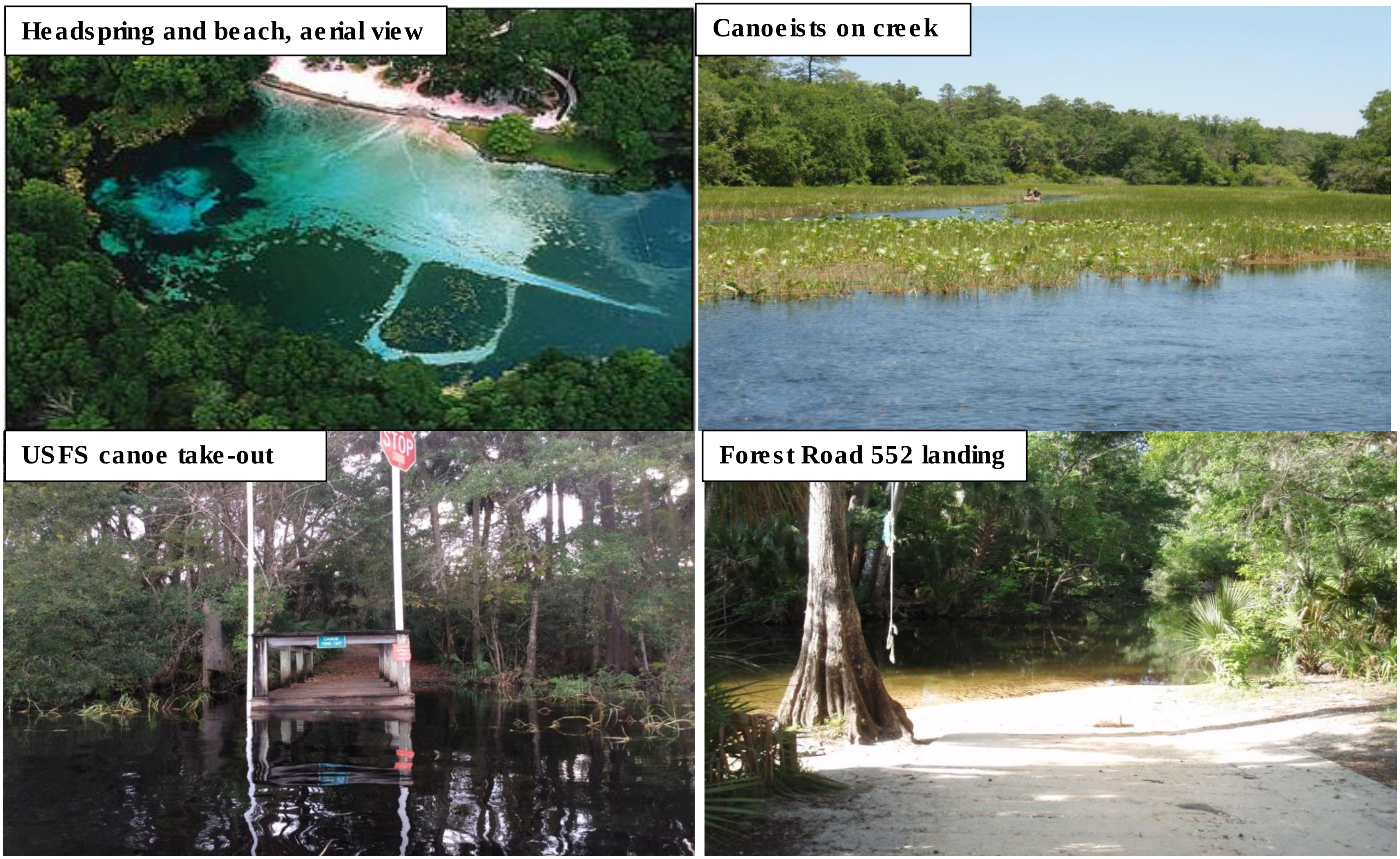

Figure 17. Photographs of Recreational Use Areas

Table 6. Hydrologically sensitive rare species near Alexander Springs Creek (Source: FNAI biodiversity matrix, accessed June 2016).

Species Common name	Global status[1]	State rank[2]	Federal status[3]	State Status[4]	Notes
Invertebrates					
Hydroptila berneri Berner's Microcaddisfly	G4G5	S3	N	N	Documented found unit 42593
Hydroptila wakulla Wakulla Springs Vari-colored Microcaddisfly	G2	S2	N	N	Documented found unit 42593
Neotrichia rasmusseni Rasmussen's Neotrichia Caddisfly	G1G2	S1S2	N	N	Documented found unit 42593
Oxyethira janella Little-entrance Oxyethiran Microcaddisfly	G5	S4S5	N	N	Documented found unit 42593, 42594
Oxyethira pescadori Pescador's Bottle-Cased Caddisfly	G3G4	S3	N	N	Documented found unit 42593
Nectopsyche tavara Tavares White Miller Caddisfly	G3	S3	N	N	Documented found unit 42964
Aphaostracon pycnus Dense Hydrobe Snail	G1	S1	N	N	Documented historic
Floridobia alexander Alexander Siltsnail	G1	S1	N	N	Likely unit 42593, 42964
Procambarus delicatus Big-cheeked Cave Crayfish	G1	S1	N	N	Likely unit 42965
Plants					
Carex chapmanii Chapman's Sedge	G3	S3	N	T	Documented historic, in calcareous hydric hammocks
Vicea ocalensis Ocala Vetch	G1	S1	N	E	Documented unit 42594, along margins of spring runs
Birds					
Aramus guarauna Limpkin	G5	S3	N	SSC	Documented by SJRWMD staff, numerous occasions
Mycteria americana Wood Stork	G4	S2	T	FT	Likely
Reptiles and Amphibians					

Drymarchon couperi Eastern Indigo Snake	G3	S3	T	FT	Likely, forages at edges of wetland for amphibians, snakes
Notophthalmus perstriatus Striped Newt	G2G3	S2	C	N	Documented found unit 42964

[1]**FNAI global element rank**

G1 = Critically imperiled globally because of extreme rarity (5 or fewer occurrences or less than 1,000 individuals) or because of extreme vulnerability to extinction due to some natural or man-made factor.
G2 = Imperiled globally because of rarity (6 to 20 occurrences or less than 3,000 individuals) or because of vulnerability to extinction due to some natural or man-made factor.
G3 = Either very rare and local throughout its range (21–100 occurrences or less than 10,000 individuals) or found locally in a restricted range or vulnerable to extinction from other factors.
G4 = Apparently secure globally (may be rare in parts of range).
G5 = Demonstrably secure globally.

[2]**FNAI state element rank**

S1 = Critically imperiled in Florida because of extreme rarity (5 or fewer occurrences or less than 1000 individuals) or because of extreme vulnerability to extinction due to some natural or man-made factor.
S2 = Imperiled in Florida because of rarity (6 to 20 occurrences or less than 3,000 individuals) or because of vulnerability to extinction due to some natural or man-made factor.
S3 = Either very rare and local in Florida (21–100 occurrences or less than 10,000 individuals) or found locally in a restricted range or vulnerable to extinction from other factors.
S4 = Apparently secure in Florida (may be rare in parts of range).
S5 = Demonstrably secure in Florida.

[3]**Federal Legal Status**

C = Candidate species for which federal listing agencies have sufficient information on biological vulnerability and threats to support proposing to list the species as Endangered or Threatened.
E = Endangered: species in danger of extinction throughout all or a significant portion of its range.
E, T = Species currently listed endangered in a portion of its range but only listed as threatened in other areas
T = Threatened: species likely to become Endangered within the foreseeable future throughout all or a significant portion of its range.

[4]**State Legal Status**

Animals: Definitions derived from "Florida's Endangered Species and Species of Special Concern, Official Lists" published by Florida Fish and Wildlife Conservation Commission, 1 August 1997, and subsequent updates.

C = Candidate for listing at the Federal level by the U. S. Fish and Wildlife Service
FE = Listed as Endangered Species at the Federal level by the U. S. Fish and Wildlife Service
FT = Listed as Threatened Species at the Federal level by the U. S. Fish and Wildlife Service
SSC = Listed as Species of Special Concern by the FWC. Defined as a population which warrants special protection, recognition, or consideration because it has an inherent significant vulnerability to habitat modification, environmental alteration, human disturbance, or substantial human exploitation which, in the foreseeable future, may result in its becoming a threatened species.)

N = Not currently listed, nor currently being considered for listing.

Plants: Definitions derived from Sections 581.011 and 581.185(2), Florida Statutes, and the Preservation of Native Flora of Florida Act,5B-40.001.
E = Endangered: species of plants native to Florida that are in imminent danger of extinction within the state, the survival of which is unlikely if the causes of a decline in the number of plants continue; includes all species determined to be endangered or threatened pursuant to the U.S. Endangered Species Act.
T = Threatened: species native to the state that are in rapid decline in the number of plants within the state, but which have not so decreased in number as to cause them to be Endangered.
N = Not currently listed, nor currently being considered for listing.

TECHNICAL APPROACH

The SJRWMD MFLs approach involves three separate but interrelated analyses of a given priority water body: environmental characterization; hydrological data analyses; and status assessment. The purpose of these analyses is to answer an overarching question: Is the current hydrologic regime (baseline condition) sufficient to protect critical environmental functions and values of a priority water body from significant harm?

Environmental analyses are conducted to characterize ecological attributes and other sensitive beneficial uses of a water body. This typically includes consideration of site-specific field-based ecological and topographical information, empirical data collected at other MFLs sites and supportive information from the scientific literature. Using this information, a determination is made of the most critical environmental features to protect, and of the minimum hydrologic regime (MFL condition) required for their protection.

Hydrological analyses are also conducted to characterize the hydrological (flow and/or stage) regime that exists under a current pumping condition, called the “baseline” condition. Two key types of information are required to generate the baseline condition. The first is a long-term flow or stage time series data set that is used to estimate the long-term variability in the system, described as the distribution of high, low and average conditions for a given water body. Various types of data analyses, groundwater models, and surface water modes are used to generate long-term time series (stages, flows, groundwater levels, climate) such as the second requirement for establishing the baseline condition is a best estimate of current impact due to water withdrawal. This is typically determined using best available groundwater models and water use data.

MFL status is then assessed by comparing the MFL condition with the baseline condition. Using frequency analysis, or other methods, the MFL and baseline conditions are compared to determine if there is currently water available for withdrawal (freeboard). An MFL is achieved if the freeboard is greater than or equal to zero. If freeboard is less than zero, a water body is in recovery, and requires the development of a recovery strategy. If the MFL is currently being achieved but is projected to not be achieved within the 20-year planning horizon, then a water body is in “prevention,” and a prevention strategy must be developed.

This section describes the methods used in the MFLs determination process for Alexander Springs, including field procedures such as site selection and field data collection, data analyses, hydrologic data analyses and consideration of relevant environmental criteria. Neubauer et al. (2008) provides further description of the SJRWMD MFLs methods.

AN EVENT-BASED APPROACH

Wetland and aquatic species, and hydric soils require a minimum frequency of critical hydrologic (drying and/or flooding) events for long-term persistence. Wetland communities require a range of flooding and drying events to fulfill many different aspects of their life-history requirements (Euliss et al. 2004, Murray-Hudson et al. 2014). Because of the role of hydroperiod in structuring and maintaining wetland and aquatic communities, the SJRWMD MFLs approach is centered around the concept of protecting a minimum number of flooding events or preventing more than a maximum number of drying events for a given ecological system.

Hydroperiod is a primary driver of wetland plant distribution and diversity, hydric soils type and location, and to a lesser degree freshwater fauna (Foti et al. 2012, Murray-Hudson et al. 2014). Hydroperiod is often described as the inter-annual and seasonal pattern of water level resulting from the combination of water fluxes and storage capacity (Welsch et al. 1995). Wetland hydroperiods vary spatially and temporally and consist of multiple components including return frequency, duration and magnitude. Native wetland and aquatic communities have adapted to and are structured by this natural variability (Poff et al. 1997, Richter et al. 1997, Murray-Hudson et al. 2014).

Five critical components of hydrological events are typically recognized; return interval, duration, magnitude, rate of change and timing (Poff et al., 1997). However, because the latter two are thought to be a function of climate, only the first three are a focus of the SJRWMD MFLs approach. Magnitude and duration components define the critical ecological events that effect species at an individual level (i.e., individual organisms). The return interval (frequency) of an event is what changes due to climate and/or water withdrawal. Therefore, it is by assessing the effects of water withdrawal on the return interval of MFLs events that a determination is made regarding whether additional water is available. By comparing the frequency of ecologically critical events, to the allowable frequency of these same events, the SJRWMD MFLs method is able to determine the amount of water that is available (or needed for recovery) within a given ecosystem under different withdrawal conditions.

Variable flooding and/or drying events are necessary to maintain the extent, composition, and function of wetland and aquatic communities. For example, the long-term maintenance of the maximum extent of a wetland may require an infrequent flooding event, of sufficient duration and frequency, to ensure that upland species do not permanently shift downslope into that wetland. In addition to flooding events, some aspects of wetland ecology (e.g., plant recruitment, soil compaction, nutrient mineralization) are also dependent upon drying events, as long as they do not occur too often. Because hydroperiods vary spatially and temporally (Mitsch and Gosselink 2015), multiple MFLs are typically used to address and protect different portions of a system’s natural hydrologic regime (Neubauer et al. 2008). For many systems SJRWMD sets three MFLs: a minimum frequent high (FH), minimum average (MA), and minimum frequent low (FL) flow and/or water level. In some cases, (e.g., for sandhill-type lakes) a minimum infrequent high (IH) and/or minimum infrequent low (IL) may also be set.

ENVIRONMENTAL ANALYSIS

The following sections describe the methods used to characterize the ecological attributes and other sensitive beneficial uses at Alexander Springs. Additional information is provided in Appendix A. Using this information, a determination is made of the most critical environmental features to protect, and of the minimum hydrologic regime (MFLs Condition) required for their protection.

Field Transect Site Selection

Ecological, soils and topography data for the Alexander Springs MFLs were collected along transects that extended from uplands to open water (Figure 18). A literature and data search was conducted prior to establishing field transects. This included a review of SJRWMD library documents, project record files, the hydrologic database, and SJRWMD surveying files. The FNAI biodiversity matrix tool (http://www.fnai.org/) was queried for the presence of threatened or endangered species. The goal of the search was to familiarize investigators with site characteristics, locate important basin features, and assess prospective sampling locations. Proposed transects were inspected prior to intensive data collection to confirm the presence of desired features, including: representative examples of common wetland communities; unique or high quality wetlands; edge of uplands or open water; hydric soils and organic soils.

SJRWMD staff collected field data at a number of existing cross sections also used for hydrologic analysis. Topographic, wetland, and soil maps were used to evaluate potential transects for the presence of hydrologically sensitive features. Field reconnaissance allowed staff to verify the presence of desired features. Three transects (A6, A8, A10) were selected in 2009 for field investigations. A6 had good quality hardwood swamp, organic soils, and the presence of an island, which eliminated seepage as an influence. A8 had good quality SAV beds, presence of bald cypress trees, and organic soils. A10 had good quality SAV beds, a variety of wetland habitats, and organic soils. A new transect (A5-A) was established in 2016 to collect additional data to characterize hardwood swamps and organic soils. Transects A6 and A10 were expanded in 2016 to sample features in detail that were only marginally captured by the alignment of the main transects. Transect A6-A sampled a series of vernal pools located in backswamp depressions. It was aligned perpendicular to A6, crossing it at station 600. A10-A sampled a slough feature and was aligned perpendicular to A10, crossing it at station 1890.

District staff sampled vegetation and soil at A6, A8, and A10 from 2010 to 2014, and from A5-A, A6-A and A10-A in 2016. SJRWMD Surveying staff collected elevation data during these same periods. Survey data were collected to the nearest hundredth foot and calculations based on field data are discussed in this report with two decimal places. All elevations in this report are relative to the 1988 North American Vertical Datum (NAVD88).

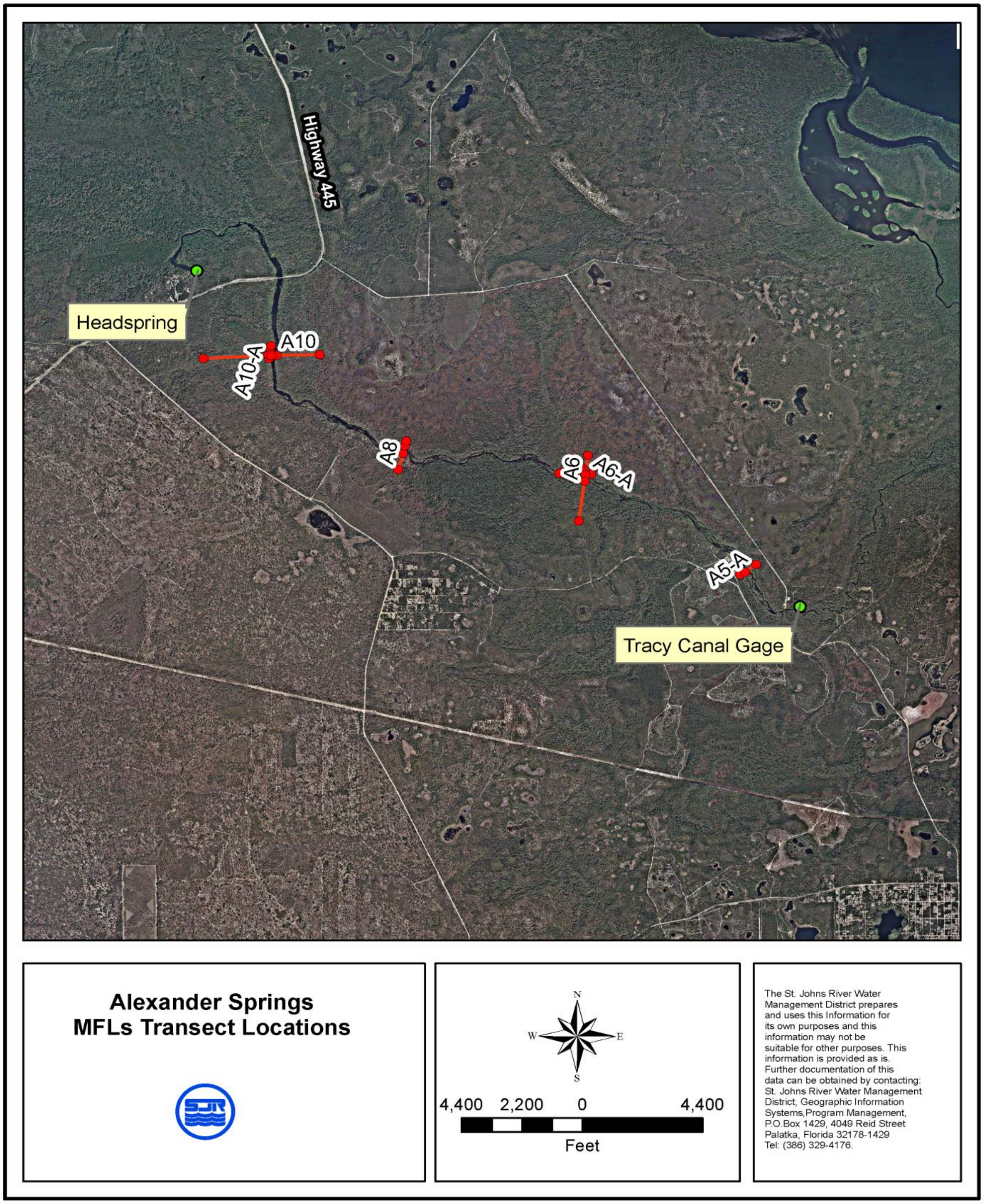

Figure 18. Field transect locations

Field Data Collection

Sampling of soil and vegetation followed standard field procedures in soil science and vegetation ecology. Detailed information on these methods and transect selection procedures are provided in Appendix A.

Surface Water Inundation/ Dewatering Signatures (SWIDS)

Frequency analysis of annual maximum and minimum stage data series generated from long-term modeled stage time series provides probabilities of flooding/drying events for wetland plant communities and organic soil indicators. Because ground elevations are transformed to inundation durations and probabilities, comparisons of like plant communities or soils indicators from different systems at different landscape elevations results in quantitative hydrologic signatures. The mean, minimum, and maximum elevations of vegetation (species and communities), and soil indicators are often used for SWIDS analysis (Neubauer et al. 2004; Neubauer et al. 2007, draft).

SWIDS of vegetation communities provide a hydrologic range for each community, with a transition to a drier community on one side of the range and a transition to a wetter community on the other side. These hydrologic signatures provide a target for MFLs determinations that are focused on vegetation community protection criteria, and provide an estimate of how much the return interval or probability of a flooding or dewatering can be shifted at a specified duration and still maintain a vegetation community within its observed hydrologic range.

Hydrologic Data Analyses

MFLs provide a method with which to compare the hydrologic regime of a system to the regime necessary to protect critical water resources. Hydrologic models are used to quantify the relative effects of natural variability (e.g., climate) and man-made alterations (e.g., groundwater withdrawal) on a given water body. The majority of SJRWMD MFLs determinations are based on a concept of maintaining a critical frequency of an ecologically important event (i.e., combination of magnitude and duration). The effects of different groundwater withdrawal or recovery scenarios on these critical events can be evaluated by comparing hydrological statistics derived from surface water model output. Statistical analysis provides a framework to summarize hydrologic characteristics of a given water body. For this type of analysis, the SJRWMD MFLs program uses a statistical method known as frequency analysis.

An HSPF surface water budget model for Alexander Springs and Alexander Springs Creek was developed by SJRWMD in 2016 (Karama 2017; Appendix B). The HSPF model was calibrated for a period of record from 10/9/2003 to 12/31/2014 based on available observed data. Alexander Springs discharge data are not continuous daily data. In general discharge data consist of random measurements and, for some years, monthly data is available. Up until 1983, very few records are available (eight records from 1931 to 1982). Pool elevation records are not available until 1980. Similar to discharge data, pool elevation data are random measurements and sporadic until 2014. Daily pool elevation data is available since 2014. The review of available data indicates that there is insufficient data available before 1983 to be used for an MFL analysis. Therefore, only the data collected after 1983 were used for Alexander Springs MFL analyses.

Critical elevations for MFLs were calculated from field data at transects along Alexander Springs Creek. However, the recommended MFLs are set at Tracy Canal gauge. MFLs transect elevations are transferred to the Tracy Canal gauge using regression analysis. Stage data were converted to flow at Tracy Canal using a rating curve developed by MFLs staff.

For springs and rivers, surface water models are typically used to create simulated flow time series with which to evaluate the recommended MFLs under different conditions. Typically, a “no-pumping” and “baseline condition” hydrograph are developed with which to compare the MFL to relatively unimpacted and current conditions. The no-pumping condition represents the flow time series as if there had been minimal consumptive use of water during the period of record. The baseline condition is usually created from the no-pumping condition and represents a best estimate of current impacted condition. Due to the very small magnitude of impact (0.7 cfs) from groundwater withdrawal at Alexander Springs, there was no need to generate a no-pumping or baseline condition. The observed flow time series has been influenced by very little impact, and therefore the HSPF long-term simulation which extends this POR back to 1983 is a good estimate of the current condition. See Appendix C for more detail on hydrological data analyses.

MFLs Status Assessment

Current Status

MFLs status was assessed using frequency analysis to compare the frequency of critical ecological events under baseline conditions to the frequency of those same events based on the recommended MFLs. Frequency analysis was used to determine the amount of water available for withdrawal (freeboard), defined as the flow reduction (cfs) that is allowable before the most constraining MFL is no longer achieved.

Frequency analysis is used to estimate how often, on average over the long term, a given environmentally important event will occur, and to compare that frequency with the recommended MFL frequency. Using annual series data generated from a flow time series (e.g., baseline condition), frequency analysis is used to estimate the probability of a given hydrologic (exceedance or non-exceedance) event happening in any given year. Annual series data are ranked using the Weibull plotting position formula:

$$P(S \geq \hat{S}_m) = \frac{m}{n+1}$$

Ranked data are then graphed on a frequency plot, thus summarizing the flow characteristics of the water body. The annual flow frequency under baseline conditions plotted and compared graphically to the recommended flow for each MFL. The difference between baseline condition flow and minimum flow constitutes the allowable flow reduction (freeboard) or necessary recovery before the MFLs is achieved (deficit). An MFL is achieved if the freeboard is greater than or equal to zero. If freeboard is less than zero, a water body is in recovery, and requires the development of a recovery strategy.

Future / Projected Status

If the MFLs is currently being achieved but is projected to not be achieved within the 20-year planning horizon, then a water body is in "prevention," and a prevention strategy must be developed. Whether an MFL is being achieved within the planning horizon is determined by comparing the freeboard under baseline conditions to the amount of projected flow reduction at the planning horizon. For Alexander Springs, the projected drawdown at 2035 was estimated using version 5 of the Northern District Model groundwater model (NDMv5; SJRWMD 2017).

Ongoing Status / Adaptive Management

A screening level analysis, which incorporates change in rainfall trend and uncertainty in MFLs, will be performed approximately every five years to monitor the status of an adopted MFL, as well as when permit applications are considered that may impact an MFL. If the screening level analysis shows that the MFL is being met based on the rainfall-adjusted flows or levels, then no further actions are required beyond continued monitoring. If the analysis shows that the MFL is not being met, or is trending toward not being met based on the rainfall-adjusted flows and levels, SJRWMD will conduct a cause and effect analysis to independently evaluate the potential impacts of various stressors on the MFL water body being assessed. Factors other than consumptive uses of water (e.g., long-term drought) can cause the flow or level of a surface watercourse, aquifer, surface water, or spring to drop below an adopted minimum flow or level. Factors to be considered in the determination of causation include, but are not limited to:

- rainfall or other climatic variables;
- consumptive use;
- land use changes or development;

- surface water drainage;
- geology/hydromorphology (e.g., sinkhole formation);
- water levels/flows in other appropriate water resources (e.g., nearby wells, lakes, streams, wetlands); and
- ecological assessment information.

The types of tools used in the causation analysis include, but are not limited to:

- double-mass analyses;
- rainfall/flow statistical analysis or flow regression;
- stage/duration/frequency analysis;
- modeling (regional, groundwater, ecological or water budget models); and
- ecological tools.

SJRWMD will assess existing MFL criteria and any associated recovery and prevention strategies to determine the effectiveness of the strategies in recovering from or preventing significant harm to the water body.

CONSIDERATION OF ENVIRONMENTAL VALUES PURSUANT TO 62-40.473, *F.A.C.*

Pursuant to sections 373.042 and 373.0421, F.S., SJRWMD considered the following 10 environmental values identified for consideration in rule 62-40.473, F.A.C.

1. Recreation in and on the water—The active use of water resources and associated natural systems for personal activity and enjoyment. These legal water sports and activities may include, but are not limited to swimming, scuba diving, water skiing, boating, fishing, and hunting.
2. Fish and wildlife habitat and the passage of fish—Aquatic and wetland environments required by fish and wildlife, including endangered, endemic, listed, regionally rare, recreationally or commercially important, or keystone species; to live, grow, and migrate. These environments include hydrologic magnitudes, frequencies, and durations sufficient to support the life cycles of wetland and wetland-dependent species.
3. Estuarine resources—Coastal systems and their associated natural resources that depend on the habitat where oceanic salt water meets freshwater. These highly productive aquatic systems have properties that usually fluctuate between those of marine and freshwater habitats.
4. Transfer of detrital material—The movement by surface water of loose organic material and associated biota.

5. Maintenance of freshwater storage and supply—The protection of an adequate amount of freshwater for nonconsumptive uses and environmental values associated with coastal, estuarine, riverine, spring, aquatic, and wetlands ecology.
6. Aesthetic and scenic attributes—Those features of a natural or modified waterscape usually associated with passive uses, such as bird-watching, sightseeing, hiking, photography, contemplation, painting and other forms of relaxation.
7. Filtration and absorption of nutrients and other pollutants—The reduction in concentration of nutrients and other pollutants through the process of filtration and absorption (i.e., removal of suspended and dissolved materials) as these substances move through the water column, soil or substrate, and associated organisms.
8. Sediment loads—The transport of inorganic material, suspended in water, which may settle or rise. These processes are often dependent upon the volume and velocity of surface water moving through the system.
9. Water quality—The chemical and physical properties of the aqueous phase (i.e., water) of a water body (lentic) or a watercourse (lotic) not included in definition number 7 (i.e., nutrients and other pollutants).
10. Navigation—The safe passage of watercraft (e.g., boats and ships), which is dependent upon adequate water depth and channel width.

SJRWMD examined the 10 environmental values identified in Rule 62-40.473, F.A.C., through a matrix screening tool to determine the most restrictive/sensitive environmental value (Table 7). The screening process used field data collected at Alexander Springs Creek, the scientific literature, and expert opinion to evaluate and score each environmental value. Scores are assigned based on: 1) level of risk of harm from water withdrawals or structural changes; 2) importance of the criterion to the water body; and 3) legal constraints on the resource/water body (e.g., presence of endangered species, Outstanding Florida Springs designation, state-owned lands, etc.). The environmental screening scores indicate which environmental values should receive primary consideration and are likely to afford protection to all other relevant environmental values. The screening process serves to focus the evaluation and to shape the types of analyses needed to complete the MFLs development process.

SJRWMD contracted with environmental and engineering consulting firm Applied Technology and Management, Inc. (ATM), to evaluate protection of the 10 environmental values identified in Rule 62-40.473, F.A.C., (ATM 2016).

Table 7. Environmental values/Water Resource Values (WRV) decision matrix for Alexander Springs and Alexander Springs Creek (Lake County, Florida) based on Rule 62-40.473, F.A.C.

Environmental Value (WRV)	Component	Score	Rationale
Recreation in and on the water	**Level of resource risk[1]**	**3**	**Water depths in several parts of the river channel are shallow and frequent encroachment of aquatic vegetation threatens to close off the open channel in places. Decreased spring flow could aggravate this condition.**
	Importance of resource value[2]	**2**	**Recreational visitation during the summer months is high but economic importance is low since there are few local outfitters that rely on recreation-based business at the spring and creek.**
	Resource legal constraint[3]	**3**	**None**
	Screening value[4]	**8**	
	Criterion limiting[5]?	**N**	
Fish and wildlife habitats and passage of fish	**Level of resource risk[1]**	**3**	**Reduced spring flows could have negative ramifications for the Alexander Springs Creek ecosystem. Reduced flows could mean less frequent flooding and reduced regeneration for some species in the floodplain. It could mean reduced interactions between creek and floodplain. Reduced spring flow would lower base flow in the creek and could lead to a general drying of the floodplain and associated communities. Reduced flows could affect integrity of SAV beds. If a greater proportion of creek flows were derived from tannin-stained surface water rather than spring discharge, then the extent and productivity of SAV might diminish. Reduced flow velocities could also mean increased algae growth on SAV.**
	Importance of resource value[2]	**3**	**The wildlife habitat along the creek is of very high quality and supports numerous species, both common and rare. The creek serves as a unique reference site for other springs in that it is relatively little impacted by anthropogenic alterations.**
	Resource legal constraint[3]	**3**	**Many hydrologically sensitive threatened and endangered species occur in and along Alexander Springs Creek.**
	Screening value[4]	**9**	
	Criterion limiting[5]?	Y	

Estuarine resources	**Level of resource risk[1]**	**0**	**Probably no potential for negative impacts to salinity regime of middle St. Johns River.**
	Importance of resource value[2]	**1**	**Alexander Springs Creek provides a very minor portion of the water budget to the middle St. Johns River, even during dry periods.**
	Resource legal constraint[3]	**3**	**No legal constraints.**
	Screening value[4]	**4**	
	Criterion limiting[5]?	**N**	
Transfer of detrital material	**Level of resource risk[1]**	**1**	**Accumulated detrital materials on the floodplain are detached from the land surface during frequent high events. This process is largely driven by storm events and inflows from the watershed. Since the creek watershed is mostly public land, the level of risk to watershed hydrologic processes is probably low.**
	Importance of resource value[2]	**3**	**Detrital material transported into the Alexander Springs Creek and St. Johns River supports food webs.**
	Resource legal constraint[3]	**3**	**No legal constraints**
	Screening value[4]	**7**	
	Criterion limiting[5]?	**N**	
Maintenance of freshwater storage and supply	**Level of resource risk[1]**	**1**	**Excessive removal of groundwater would affect capacity of the system to store and supply water for nonconsumptive uses. Because of the location of Alexander Springs in the Ocala National Forest, and the very low projected use within the planning horizon, this risk is low.**
	Importance of resource value[2]	**3**	**The storage of water in the wetland and aquatic systems of the creek are essential to all WRV functions.**
	Resource legal constraint[3]	**3**	**No legal constraints.**
	Screening value[4]	**7**	
	Criterion limiting[5]?	**N**	

Aesthetics and scenic attributes	**Level of resource risk[1]**	**1**	**Aesthetics is somewhat subjective and difficult to quantify. Therefore, risk is low.**
	Importance of resource value[2]	**3**	**The aesthetic appeal of the Alexander Spring and Creek attract numerous visitors drawn to the clear spring water, abundant fish and wildlife, and beauty of the various in-channel and floodplain habitats.**
	Resource legal constraint[3]	**3**	**No legal constraints.**
	Screening value[4]	**7**	
	Criterion limiting[5]?	**N**	
Filtration and adsorption of nutrients and other pollutants	**Level of resource risk[1]**	**1**	**Most of the watershed and springshed are protected under national forest ownership. Inputs of nutrients should remain low. Therefore, risk is low.**
	Importance of resource value[2]	**3**	**Filtration is an important process for maintaining water quality. Therefore, importance is high.**
	Resource legal constraint[3]	**3**	**No degradation of water quality is allowed since Alexander Springs Creek and Alexander Springs are designated as Outstanding Florida Waters (OFWs) — Rule 62-302.700(9) (n),** F.A.C.
	Screening value[4]	**7**	
	Criterion limiting[5]?	**N**	
Sediment loads	**Level of resource risk[1]**	**1**	**Changes in stream channel velocities can affect sediment mobilization and transport. Flooding events typically move sediment and in this case are driven by surface water inputs. Since the watershed is mostly protected under national forest, risk is minimal.**
	Importance of resource value[2]	**1**	**Spring fed creeks do not typically transport large volumes of sediment and there is more biologic rather than alluvial control of geomorphology (Kiefer, 2010).**
	Resource legal constraint[3]	**3**	**No legal constraints.**
	Screening value[4]	**5**	
	Criterion limiting[5]?	**N**	

Water quality	**Level of resource risk[1]**	**1**	**There is no evidence that flow reductions have significant effects on nitrate concentrations (Upchurch** et al**. 2007). Maintenance of adequate discharge and floodplain inundation events to provide filtration and adsorption of nutrients and other pollutants will protect instream water quality affected by existing and future water withdrawals.**
	Importance of resource value[2]	**3**	**High water quality is essential for maintaining other WRVs such as recreation, fish and wildlife habitats, and aesthetics.**
	Resource legal constraint[3]	**3**	**No degradation of water quality is allowed since Alexander Springs Creek and Alexander Springs are designated as Outstanding Florida Waters (OFWs) — Rule 62-302.700(9) (n),** F.A.C.
	Screening value[4]	**7**	
	Criterion limiting[5]?	**N**	
Navigation	**Level of resource risk[1]**	**3**	**Water depth in several parts of the creek is shallow and frequent encroachment of aquatic vegetation threatens to close off the open channel in places.**
	Importance of resource value[2]	**1**	**Boat traffic on the creek is minimal**
	Resource legal constraint[3]	**3**	**No legal constraints.**
	Screening value[4]	**7**	
	Criterion limiting[5]?	**N**	

Notes: **1. Evaluation of the level to which the resource is at risk. Score: 0 = none, 1 = low, 2 = medium, 3 = high**

2. Evaluation of importance of the criterion with respect to resource. Score: 0 = none, 1 = low, 2 = medium, 3 = high

3. Legal constraints on resource, such as endangered species, Outstanding Florida Water, etc. Score: 0 = none, 1 = low, 2 = medium, 3 = high

4. Screening value = sum of Resource Risk, Resource Importance, and Resource Legal Constraint scores. Indicates overall importance of criterion to MFLs development.

5. Evaluation as to whether criterion is potentially limiting for MFLs development. (Y = Yes or N = No)

RESULTS AND DISCUSSION

This section summarizes elevation, soil, and vegetation data in narrative, tabular, and graphical format. The rationale for criteria and recommended minimum flows are also presented, along with a discussion of the effect of these flows on maintaining ecological structure and function of wetland and aquatic communities.

MFL TRANSECT SITES

Considerable variation exists between transects in terms of soil and plant species distributions and associated elevations. This is because flooding and dewatering probabilities (as indicated by elevation) are only one determinant of vegetation composition. Other determinants include seepage from uplands, localized ponding within depressions, fire history, human disturbance, substrate or geological features, topographic relief, and proximity to seed and other propagule sources. Given this variability, it is important to have multiple transects to estimate the central tendency for vegetation and soil features.

The following describes the delineated plant communities, hydric soils, and soil series at each of the four transects. Listed elevations represent start and stop points of delineated features, not necessarily maximum or minimum elevations. More detailed vegetation and soils data are provided in Appendix D.

Transect A5-A

Physical Description

A5-A begins in uplands north of the spring run and extends southwest for 714 feet. It descends a short 8.8% slope to the footslope and floodplain of Alexander Springs Run near station 35. Five channels divide the floodplain into four islands with steep (1.2 to 2.6 feet high) channel banks. The wide, shallow central channel from 252 to 410 feet has a highly irregular profile. The edge of the floodplain beyond 590 feet is not readily discernible due to placement of approximately 1.5 feet of fill associated with a nearby residence. A 4.5% sideslope extends to 714 feet. Figure 19 shows representative photographs and Figures 20 and 21 show topographic cross-sections overlaid with vegetation and soils data, respectively. Detailed plant community data are shown in Table D1 (Appendix D).

Figure 19. Transect A5-A photographs, plant communities

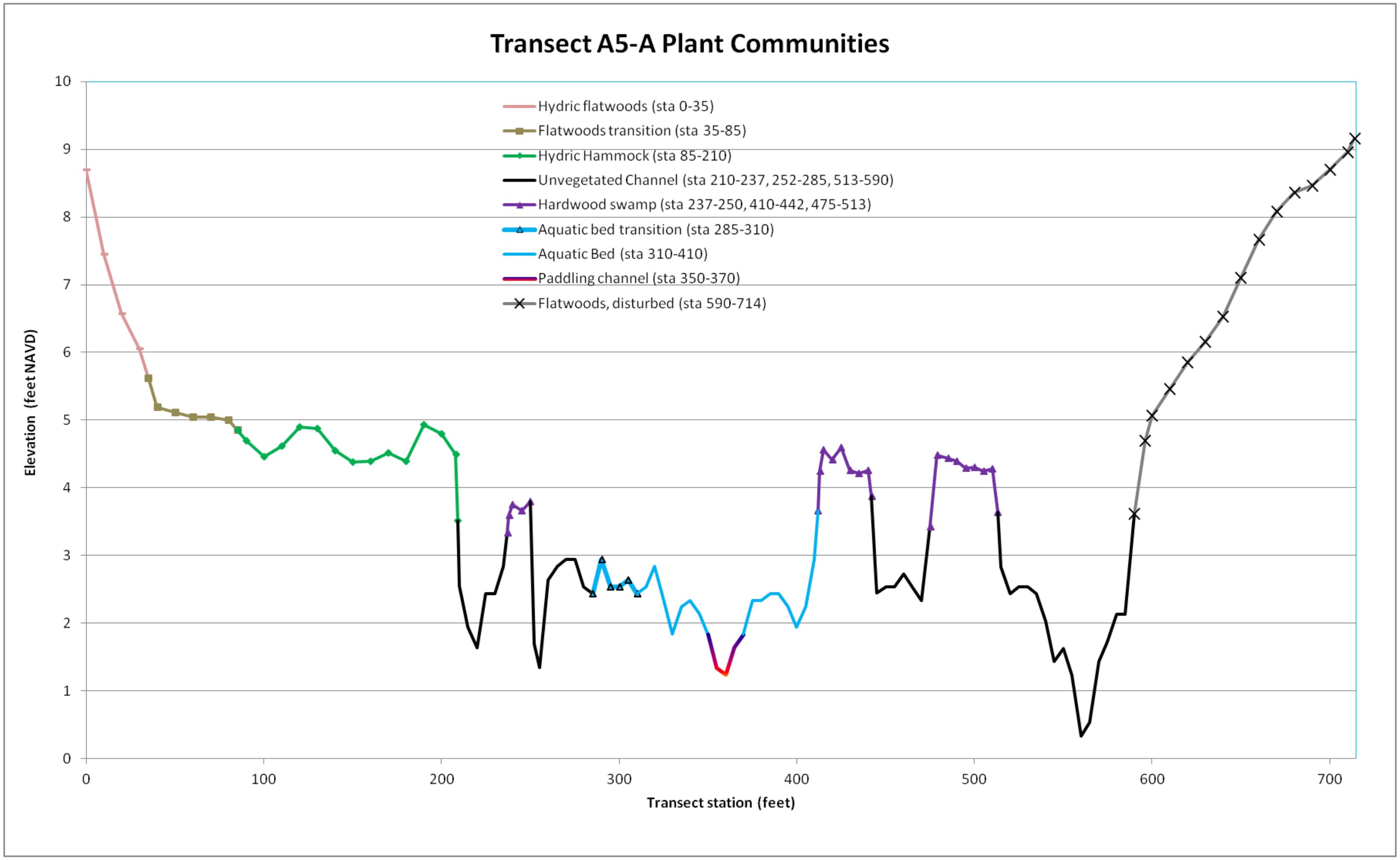

Figure 20. Transect A5-A Plant Communities

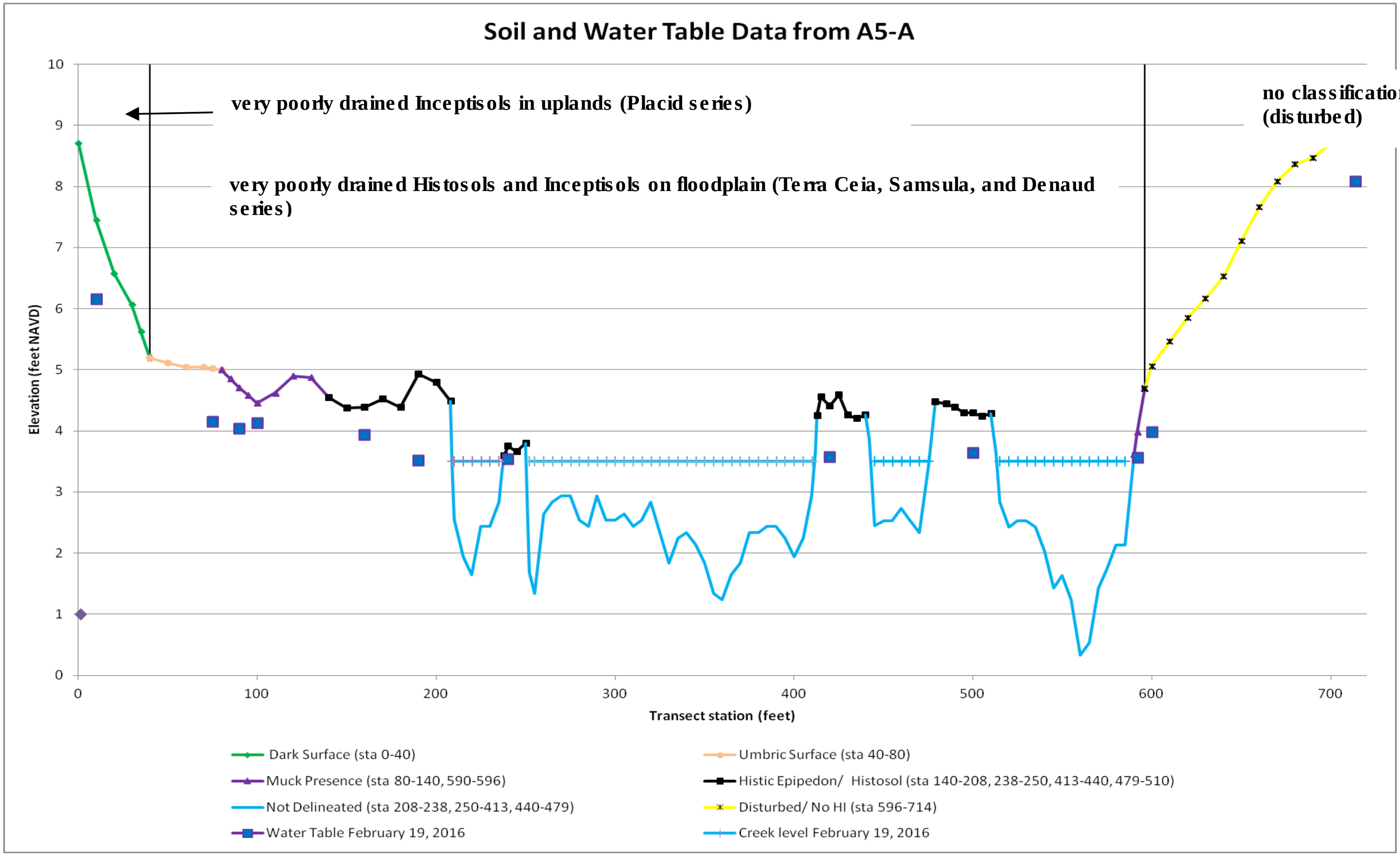

Figure 21. Soil and water table data from A5-A

Vegetation and Soils

Hydric flatwoods (0 to 35 feet) has an open canopy of scattered loblolly bay, pond pine, and laurel oak. Saw palmetto dominates the understory along with scattered anise and maleberry (*Lyonia ligustrina*) shrubs. The hydric soil indicator at station 10 is S7 Dark Surface and the soil series is Placid. This sandy, very poorly drained, rapidly permeable soil had a water table 15.5 inches deep in February 2016.

Flatwoods transition (35 to 85 feet) has a mix of flatwoods and hydric hammock species. The canopy has abundant sweet gum and scattered cabbage palm, swamp gum, and laurel oak. Saw palmetto dominates the understory. Hydric soils at station 75 on the footslope are F13 Umbric Surface and the water table was 10.5 inches deep in February 2016.

Hydric hammock (85 to 210 feet) has a canopy dominated by cabbage palm with numerous laurel oak and red maple. The understory has numerous small cabbage palms and scattered wax myrtle shrubs. Several widely scattered grass and sedge species comprise the groundcover. The first part of the floodplain has A8 Muck Presence at stations 90 and 100 while deep organic soils (A2 Histic Epipedon and A1 Histosol) extend across the floodplain starting near station 150. The soils at stations 90 and 160 are Denaud (or similar) series, a very poorly drained, moderately permeable, loamy soil. Terra Ceia, a very deep, highly decomposed, rapidly permeable Histosol, occurs on the berm bordering the creek channel at station 190. The water table in this community ranged from 4 to 17 inches deep in February 2016.

Water (210 to 237, 252 to 284, 442 to 475, 513 to 590 feet) delineations are occurrences of heavily shaded, narrow, streambed channels with mineral sediments. Although generally unvegetated, a few patches of submerged and emergent species occur in the relatively wide channel from 513 to 590 feet.

Hardwood swamps (237 to 252, 410 to 442, 475 to 513 feet) occur on three islands in the channel. The canopy has abundant pop-ash and scattered to numerous dahoon holly and red maple. Cover of bald cypress is none to scattered but cypress knees are frequent, often associated with cypress trees outside the belt quadrats. Numerous, small cabbage palms occur in the understory. Scattered swamp dogwood line channel edges. Groundcover is sparse, mostly consisting of a few clumps of royal fern. Hydric soils are A1 Histosol as typified by the Samsula series, a moderately deep, rapidly permeable organic soil with sand substrate at stations 240, 420, and 500. Water tables ranged from 2.5 to 10 inches deep in February 2016.

Aquatic bed transition (284 to 310 feet) is a stand of mostly shrubby vegetation on the upstream edge of an island. Swamp dogwood (*Cornus foemina*) is abundant, dahoon holly is numerous, and groundsel tree (*Baccharis halimifolia*) is scattered. There are rare patches of herbaceous vegetation including water celery (*Cicuta maculata*) and primrosewillow (*Ludwigia repens*). This area was flooded several inches deep in February 2016.

Aquatic bed (310 to 410 feet) occurs in the widest channel. Direct sunlight allows development of dense stands of submerged and emergent species in the shallow waters. Tapegrass (*Vallisneria americana*) dominates the submerged strata while numerous Egyptian paspalidium (*Paspalidium geminatum*) and scattered pickerelweed comprise the emergent layer.

Flatwoods, disturbed (590 to 714 feet) is an area of mostly disturbed (e.g. mowed) vegetation associated with a nearby residence. A sparse canopy of a few sweet gum, cabbage palm and pond pine are present. There is no understory but the groundcover consists of numerous patches of bahia grass (*Paspalum notatum*), scattered spadeleaf (Centella asiatica) and assorted other grasses, sedges, and forbs. Soils are generally disturbed and did not have hydric indicators. However, A2 Histic Epipedon was observed buried at a depth of 18 to 30 inches at station 600. Water tables ranged from 5 to 13 inches deep in February 2016.

Transect A6

Physical Description

A6 begins on a gently sloping ridge north of the spring run and extends 2565 feet south. From 400 to 500 feet, it descends a sideslope at a 2.4% grade and enters the floodplain of Alexander Springs Run. The floodplain has numerous microtopographic hummocks and swales. The channel bank drops 4.5 feet drop to the channel bottom from 777 to 790 feet. The channel extends to 850 feet and a similarly abrupt 5.4 feet elevation increase occurs from 850 to 863 feet. The transect traverses an island from 863 to 928 feet, crosses a second channel from 928 to 1010 feet and reaches the floodplain on the south side of the channel at 1,010 feet. There is a barely perceptible elevation increase across the floodplain toward the uplands. From 1,720 to 2,280 feet, elevations increase on a 0.8% grade sideslope. A nearly level ridgetop extends to station 2565. Representative photographs are shown in Figure 22 and topographic cross-sections with vegetation and soils data are shown in Figures 23 and 24. Detailed plant community data are shown in Table D2 (Appendix D).

Vegetation and Soils

Hydric flatwoods (0 to 290 feet) has a canopy of numerous slash (*Pinus ellliottii*) and pond (*Pinus serotina*) pines. Saw palmetto (*Serenoa repens*) dominates the understory but hydrophytic species such as cinnamon fern (*Osmunda cinnamomea*) and swamp bay (*Persea palustris*) are also common. Hydric soils occur throughout this community with indicators A7 Mucky Mineral, A8 Muck Presence, and S7 Dark Surface. The Floridana series, a very poorly drained, slowly permeable soil at station 10 has 20 inches of sand over a fine-textured (sandy clay loam) subsoil. Water tables ranged from 2 to 5 inches deep in March 2014.

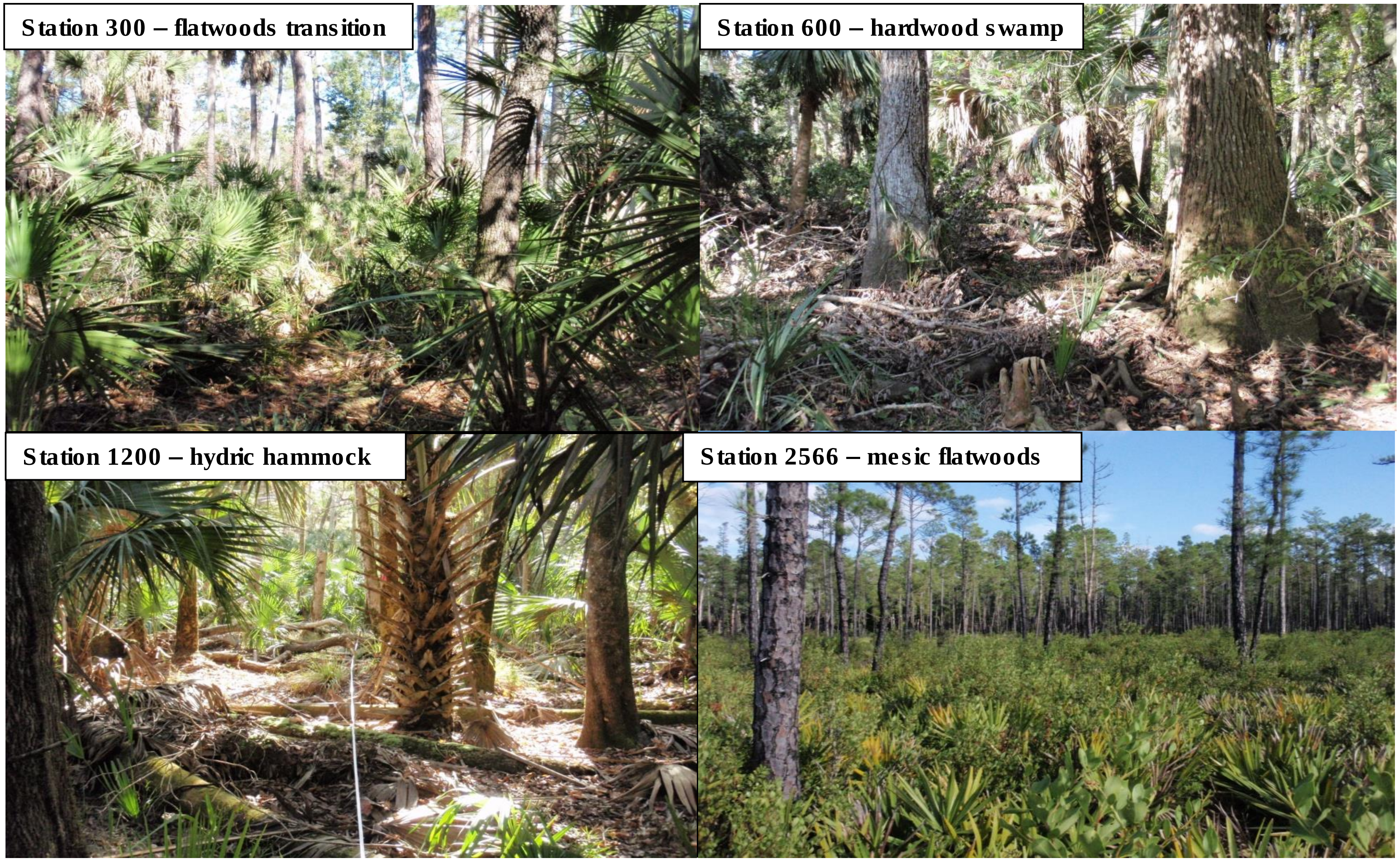

Figure 22. Photographs, Transect A6 plant communities

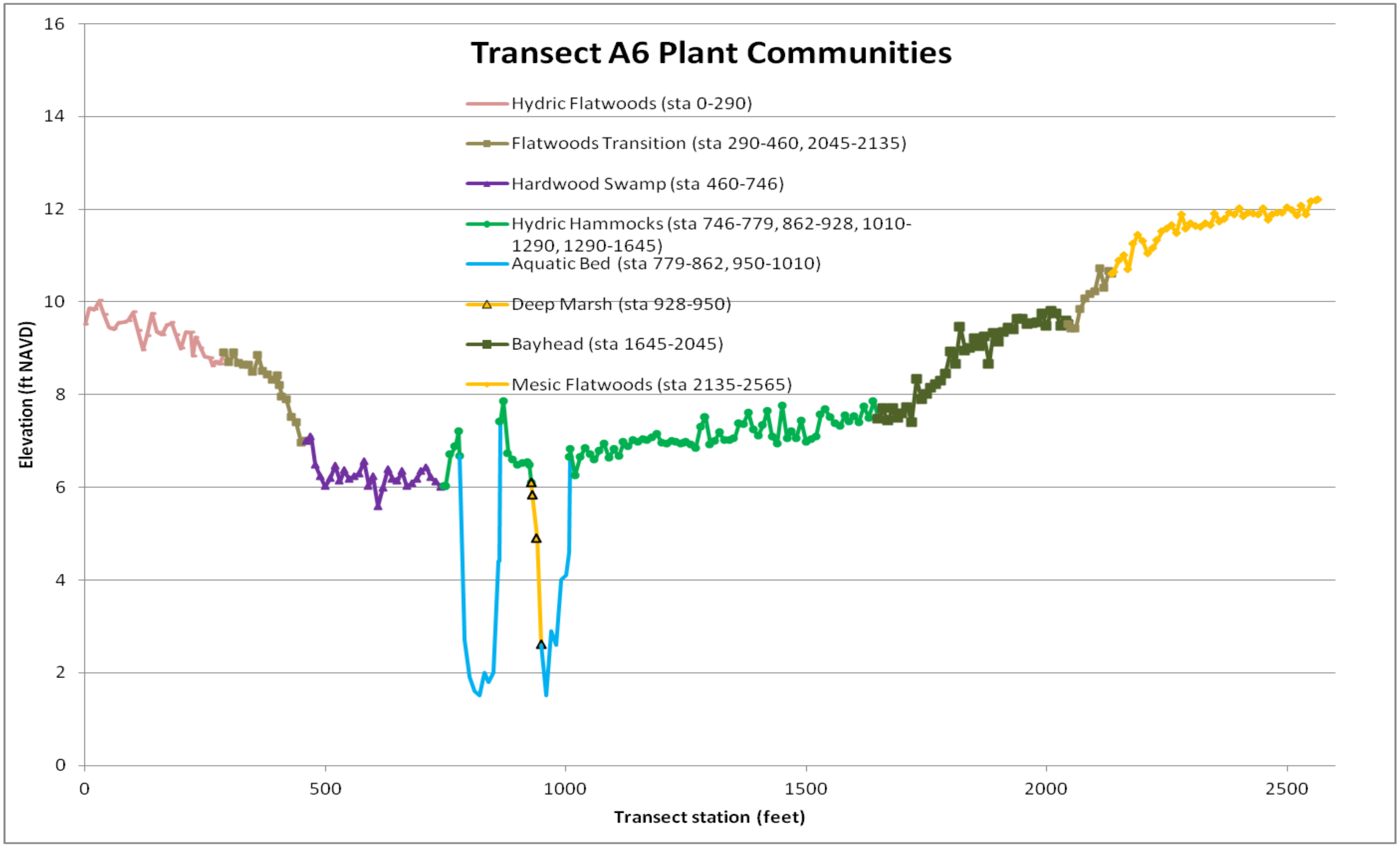

Figure 23. Transect A6 plant communities

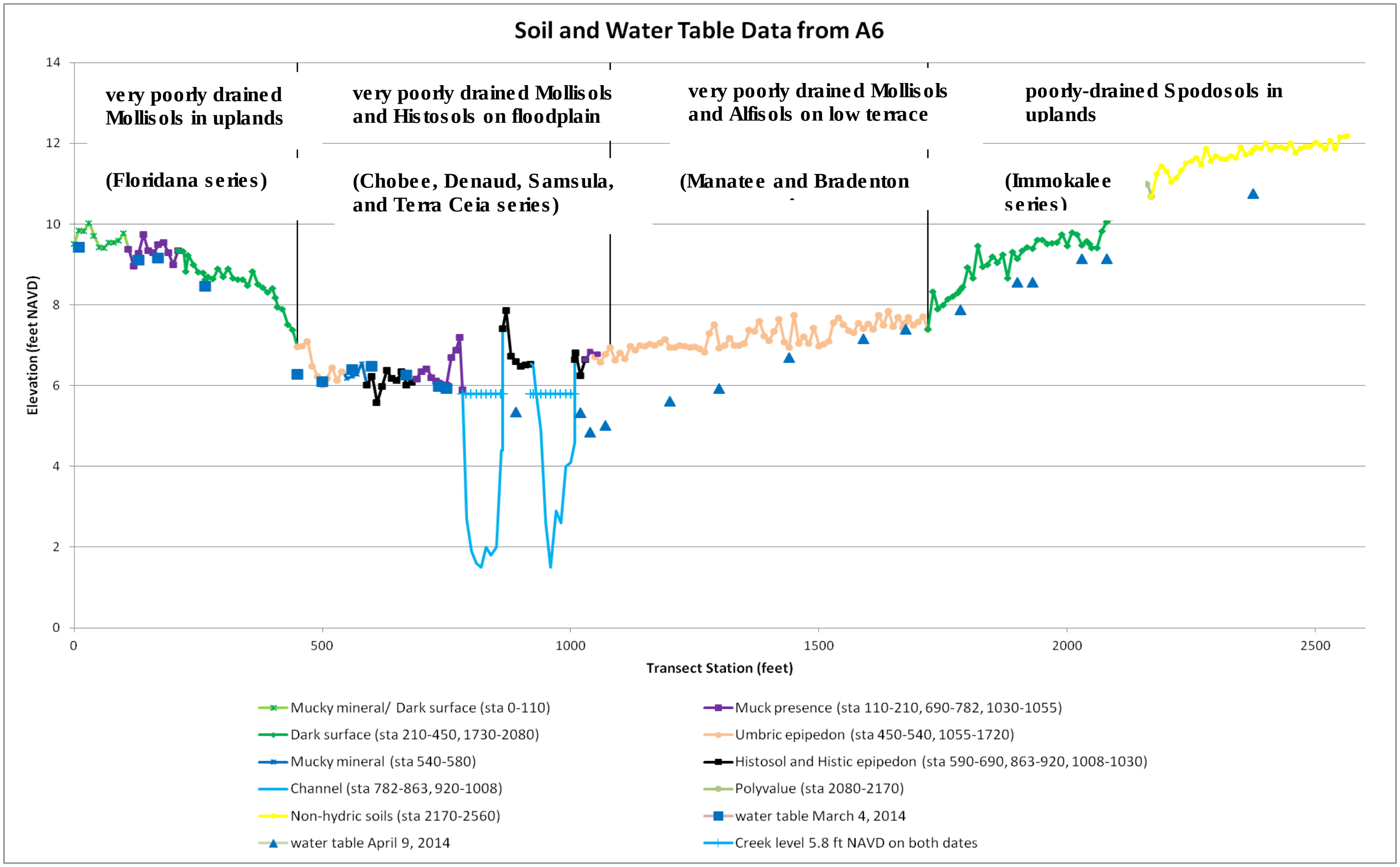

Figure 24. Transect A6 soil and water table data

Flatwoods transition (290 to 460 feet) has a canopy of numerous hydrophytic, hardwood species such as red maple (*Acer rubrum*) and swamp bay while saw palmetto dominates the understory. Soils on this sideslope transition from the sandy surfaces of the uplands to the finer-textured surfaces of the floodplain. Station 450 had F13 Umbric Surface and a water table 8 inches deep in March 2014.

Hardwood swamp (460 to 746 feet) occurs on the footslope and floodplain. The canopy has abundant swamp tupelo (*Nyssa biflora*), and numerous bald cypress (*Taxodium distichum*), sweet gum (*Liquidambar styraciflua*), and red maple. Cabbage palm is also numerous, mostly in the understory. Herbaceous groundcovers include abundant interrupted fern (*Thelypteris interrupta*), numerous lizard tail (*Saururus cernuus*), and scattered patches of beaksedges (*Rhynchospora* spp.). Pickerelweed, although common in some depressions, is generally rare. Hydric indicators are F13 Umbric Surface, A7 Mucky Mineral, A2 Histic Epipedon, and A8 Muck Presence. Subsoil textures are moderately fine in places and include sandy clay loams of the slowly permeable Chobee series (station 500). In other places, the loams of the moderately permeable Denaud series occur (station 670 feet). Deep organic soils of the Denaud series extend throughout the lowest portion of the floodplain from 590 to 690 feet. Water tables were at or slightly above the soil surface in most of this community in March 2014.

Transect A6-A sampled the backswamp landforms of this hardwood swamp. The backswamp has numerous isolated depressions aligned linearly along the base of the uplands, parallel to the creek. Vegetation consists of abundant lizard tail, with numerous pickerelweed in depressions and scattered interrupted fern at higher elevations. Although trees often overhang these backswamp depressions, they are seldom rooted there. In several instances, toppling of shallowly rooted trees in saturated soil appears to form new depressions. Photographs of typical depressions are shown in Figure 25. An elevation cross-section of A6-A shows the distribution of these depressions (Figure 26).

Hydric hammock (746 to 779 feet) occurs on a narrow berm at the edge of the creek. Cabbage palm dominates the canopy and numerous slender woodoats (*Chasmanthium laxum*) occur in the groundcover. The hydric soil indicator is A8 Muck Presence.

Aquatic bed (779 to 862 feet) occurs in the main channel of the creek. There are a few clumps of emergent vegetation near the banks and rare patches of submerged species (e.g. tapegrass and spatterdock) near the center.

Hydric hammock (862 to 928 feet) occurs on an island in the creek. The canopy has abundant cabbage palm, and various hardwood species such as numerous American elm, pop ash (*Fraxinus caroliniana*), swamp gum, sweet gum, and laurel oak. Although bald cypress is present on the island, it is a minor component and did not occur within the belt transect. Small cabbage palms dominate the understory. A1 Histosol occurs throughout the island as typified by the Terra Ceia

Figure 25. Transect A6-A, pickerelweed pools

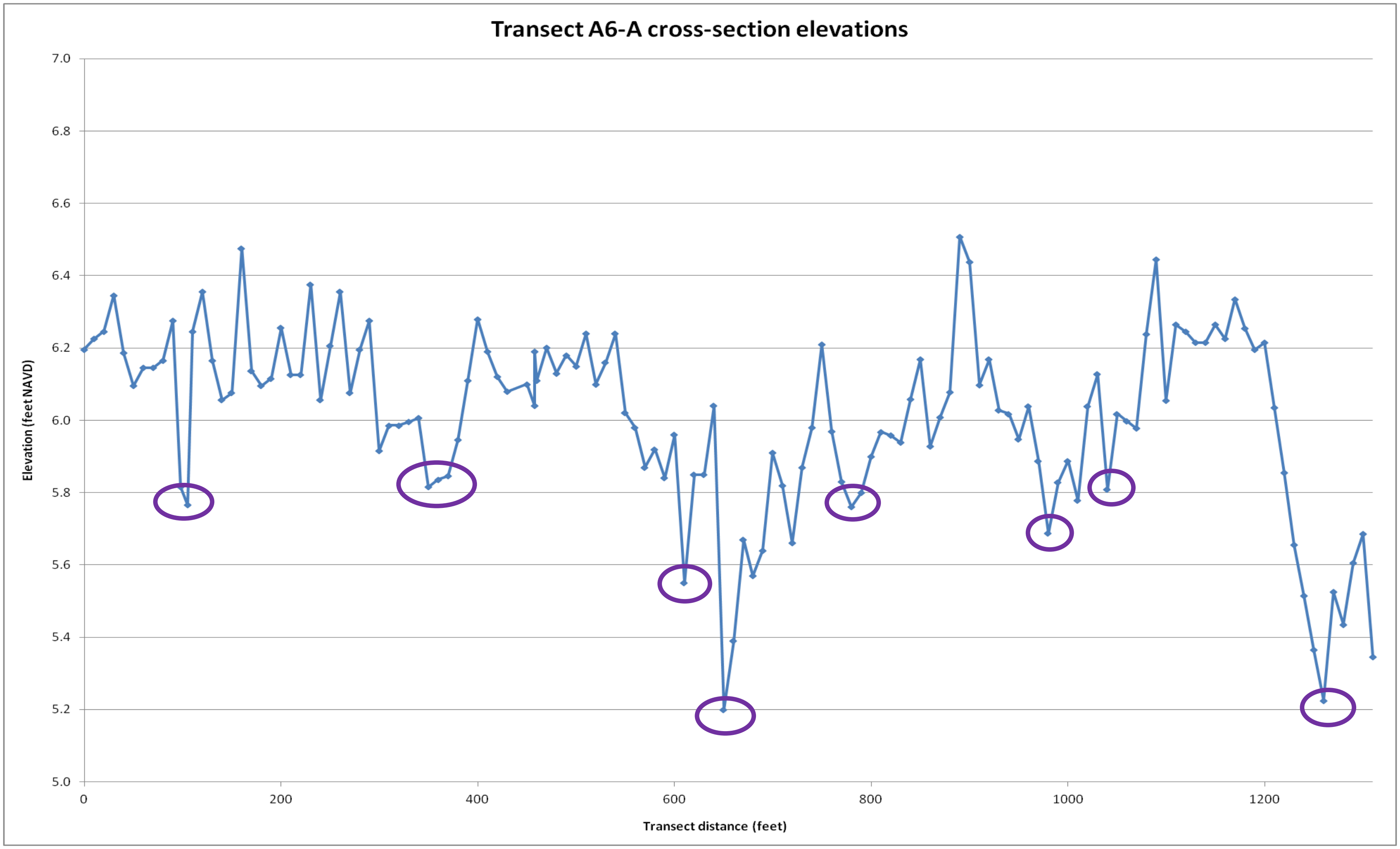

Figure 26. Transect A6-A cross-section with pickerelweed pools; circles indicate the depressions used in the analysis.

series at station 888. This very deep, highly decomposed, rapidly permeable soil had a water table 15 inches deep in April 2014.

Deep marsh (928 to 950 feet) on the south side of the island occurs on a steep topographic gradient. The upper edge is frequently dewatered while the lower edge is permanently flooded. Dense herbaceous vegetation includes dominant pickerelweed, and scattered bulltongue arrowhead (*Sagittaria lancifolia*) and spatterdock, some of it probably floating.

Aquatic bed (950 to 1,010 feet) with scattered spatterdock occurs in a secondary creek channel.

Hydric hammock (1,010 to 1,645 feet) occurs on the floodplain south of the channel. There are abundant cabbage palm in both canopy and understory layers. Various hardwood species include swamp gum, laurel oak, pop-ash, sweet gum, American elm, and hornbeam (*Carpinus caroliniana*), which are rare to scattered. Needlepalm (*Rhapidophyllum hystrix*) becomes increasingly abundant with elevation. This shrub is absent at low elevations from 1,010 to 1,290 feet but becomes numerous beyond 1,290 feet.

A1 Histosol occurs in the first approximately 20 feet near the channel as typified by the Samsula series at station 1020. This moderately deep, highly decomposed, organic soil with a sandy substrate is rapidly permeable. As elevations increase, fine-textured hydric indicators such as F13 Umbric Surface and F7 Depleted Dark Surface occur. Soils are moderately permeable and include the poorly drained Bradenton series (station 1200) and the very poorly drained Manatee series (station 1590). Water table depths in this community ranged from 3 to 24 inches in April 2014.

Bayhead (1,645 to 2,045 feet) was delineated based on a shift in understory species. Needlepalm diminishes in abundance, replaced by anise (*Illicium parviflorum*) and fetterbush (*Lyonia lucida*). Canopy composition is similar to that of the hydric hammock although cabbage palm abundance decreases and sweet bay (*Magnolia virginiana*), loblolly bay (*Gordonia lasianthus*), and swamp bay are present. Fine-textured indicators (F13 Umbric Surface) occur at 1,675 feet near the upland edge of the floodplain but sandy hydric indicators such as S7 Dark Surface, S8 Polyvalue, and S9 Thin Dark Surface occur on the adjacent sideslope. Water tables in this community ranged from 2 to 10 inches deep in April 2014.

Flatwoods transition (2,045 to 2,135 feet) occurs on the upper sideslope. It includes a mix of bayhead species such as loblolly bay and fetterbush alongside flatwoods species such as saw palmetto. Laurel oak and blueberry (*Vaccinium corymbosum*) are also numerous. Sandy hydric indicators are S7 Dark Surface and S8 Polyvalue. The water table at station 2,080 was 11 inches deep in April 2014.

Mesic flatwoods (2,135 to 2,565 feet) starts near the shoulder of a ridgetop and extends to the end of the transect. It is dominated by saw palmetto and other understory shrubs but has a sparse canopy of pond pine and small loblolly bays. Hydric soils (S8 Polyvalue) end near station 2150. Soils are typified by the Immokalee series at station 2375, which is a sandy, poorly drained

Spodosol. Most soil layers are rapidly permeable but the spodic layer restricts downward movement of water. The water table at this station was 13 inches deep in April 2014.

Transect A8

Physical Description

A8 begins on the shoulder of a ridgetop north of the spring run, and extends 1,133 feet south. It descends a sideslope at 3.3% grade and reaches the creek channel at 208 feet. There is an abrupt 3.4 feet drop into the channel bottom. The channel extends to approximately 490 feet and elevations increase abruptly into the floodplain on the south side of the channel. The floodplain has microtopographic hummocks and swales but is otherwise nearly level to 715 feet. The transect then ascends an irregular sideslope at a 2.4% grade to a nearly level ridgetop. Representative photographs are shown in Figure 27 and topographic cross-sections with vegetation and soils data are shown in Figures 28 and 29. Detailed plant community data are shown in Table D3 (Appendix D).

Vegetation and Soils

Hydric flatwoods (0 to 185 feet) are dominated by saw palmetto but hydrophytic species such as anise and cinnamon fern are present throughout this zone. Pond pine dominates the canopy of the first 40 feet, while laurel and water oak (*Quercus nigra*) dominate the latter 145 feet. These oaks may be present due to less frequent fires on this sideslope above the creek. Soils are initially non-hydric as typified by the Wauchula series at station 0. This poorly drained Spodosol has sandy surface and subsoil layers underlain by a fine textured (sandy clay loam and sandy loam) substrate which causes an overall slow permeability. The water table was 23 inches deep in November 2013. Hydric soils start at 40 feet with the S7 Dark Surface indicator. The water table on the footslope at station 150 was 12 inches deep in November 2013.

Flatwoods transition (185 to 205 feet) occurs on the toeslope at the edge of the creek. Flatwoods species co-occur with herbaceous, hydrophytic species such as bushy bluestem (*Andropogon glomeratus*), slender woodoats, and assorted fern species. Buttonbush (*Cephalanthus occidentalis*), an obligate (OBL) wetland species, occurs at the edge of the channel. A7 Mucky Mineral occurs at station 200 with a water table 5 inches deep in November 2013.

Aquatic bed (205 to 430 feet) occurs in the creek channel and has a dense stand of submerged tapegrass, scattered to numerous spatterdock, and scattered bulrush (*Scirpus validus*).

Deep marsh (430 to 490 feet) on the south side of the channel occurs on a steep topographic gradient. The upper edge is frequently dewatered and vegetation is rooted in organic soil. The lower edge is permanently flooded and some vegetation appears floating. Dense, emergent,

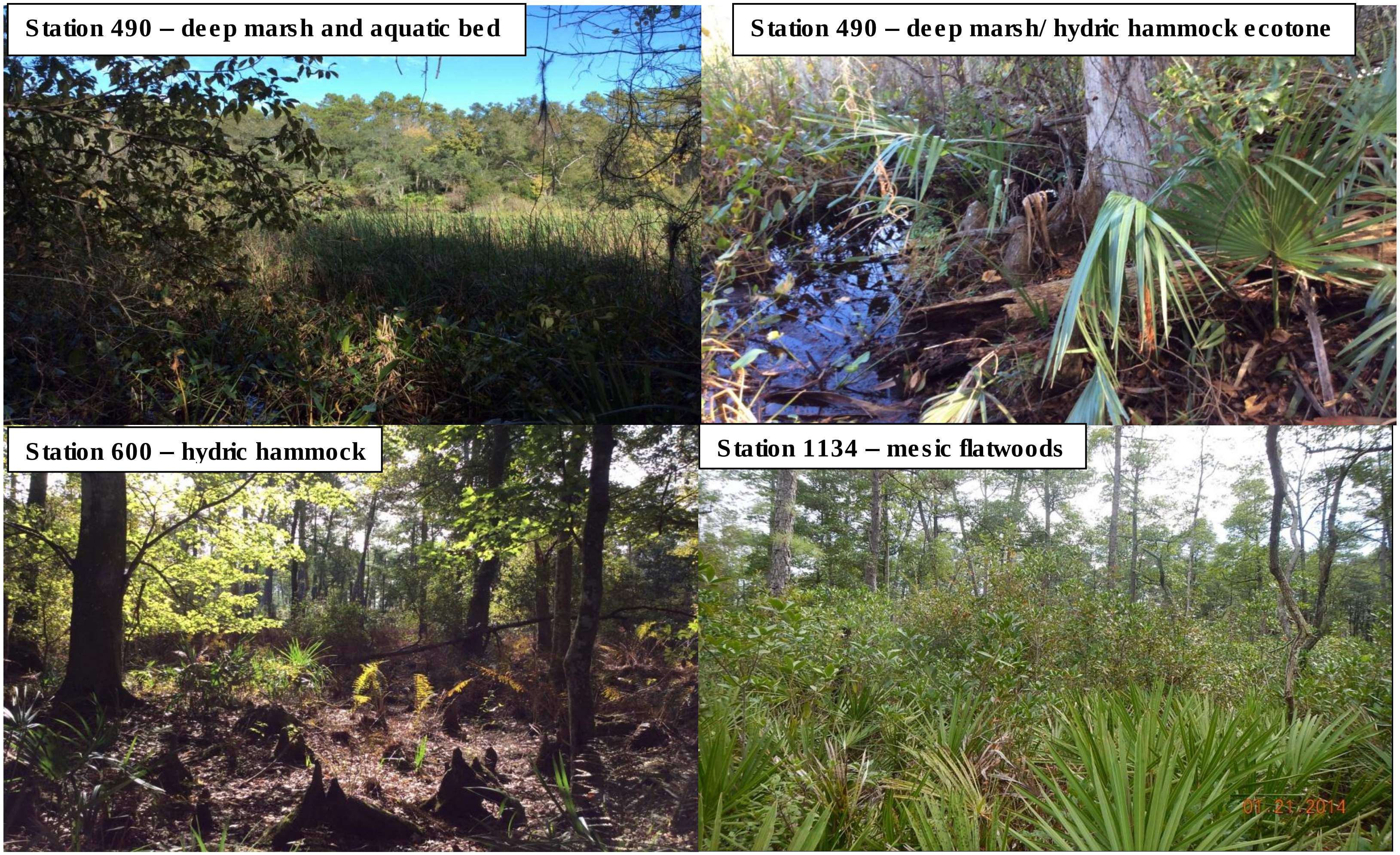

Figure 27. Photographs, Transect A8 plant communities

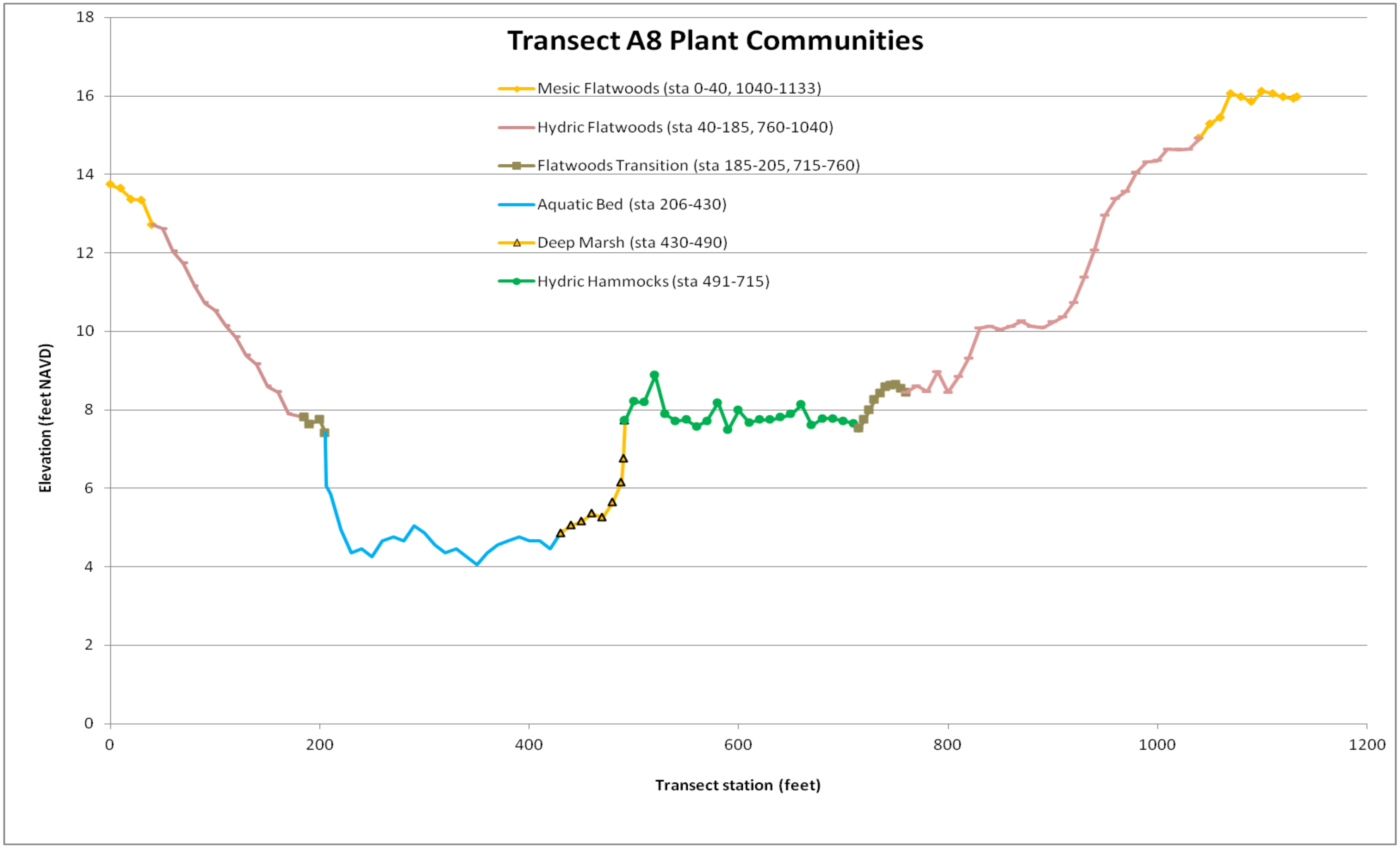

Figure 28. Transect A8 plant communities

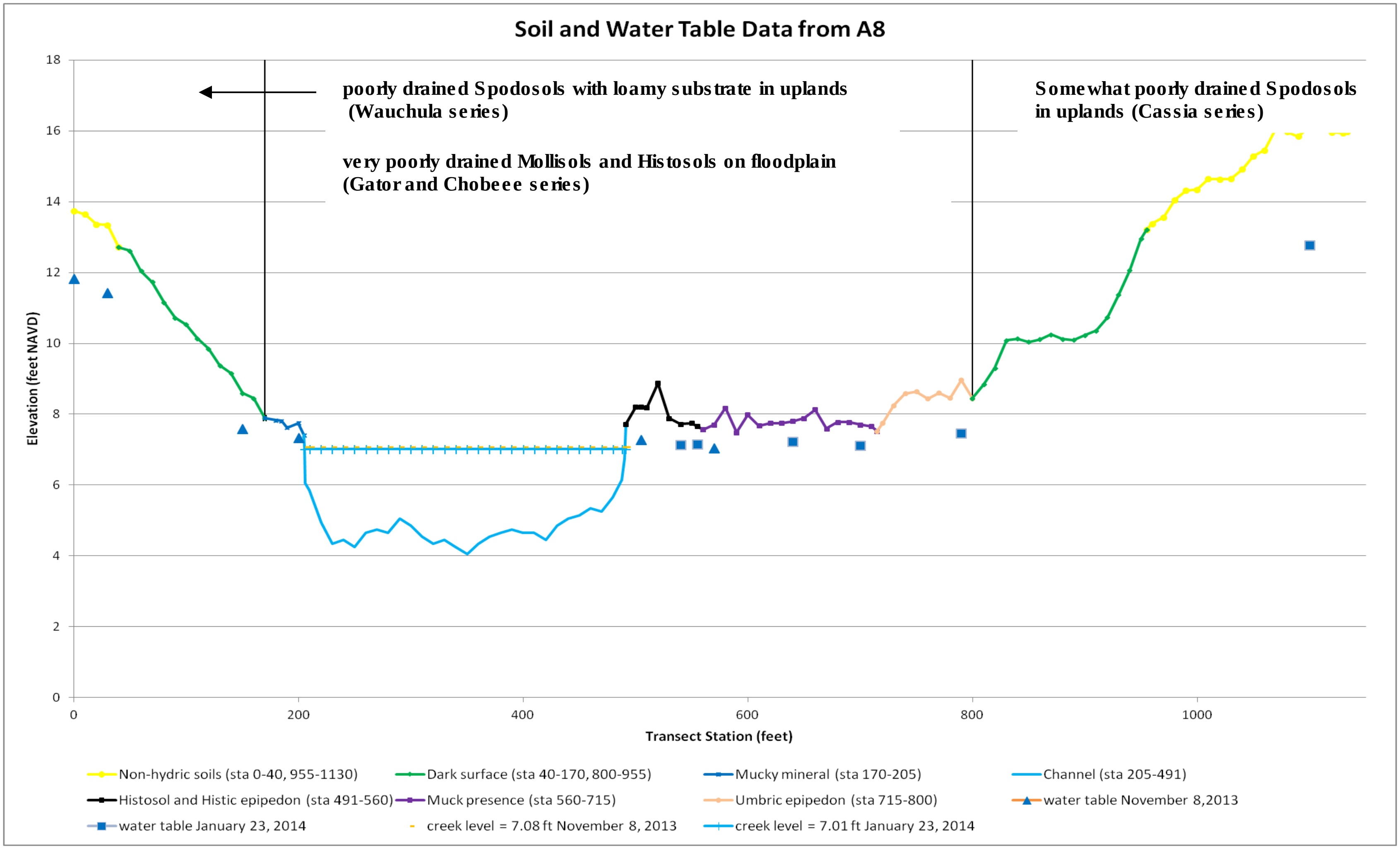

Figure 29. Soil and water table data from A8

herbaceous vegetation includes dominant cattails (*Typha domingensis*), abundant pickerelweed and bulrush, and numerous arrowhead and willow (*Salix caroliniana*).

Hydric hammock (491 to 715 feet) occupies all the floodplain south of the channel. The portion from 491 to 639 feet was originally delineated as hardwood swamp due to the presence of bald cypress. It was later reclassified as hydric hammock since cabbage palm and laurel oak are the dominant species, while cypress and swamp gum each contribute less than 10% cover. Other canopy species include red maple and sweet gum, species characteristic of either hardwood swamp or hydric hammock communities. The zone from 639 to 715 feet has sparse canopy cover probably due to frequent fire incursions from the adjacent flatwoods but species are still typical of hydric hammocks. The sparse canopy allows for a dense groundcover of mostly cinnamon fern. Deep organic soils (A2 Histic Epipedon) extend from 491 to 560 feet as typified by the Denaud series at station 540. The surface organic layer is underlain by a sandy loam substrate, which causes an overall moderate permeability. Hydic indicators beyond 560 feet are A8 Muck Presence and A7 Mucky Mineral as typified the Chobee series at station 700. The fine textured substrate (sandy clays and sandy clay loams) make this soil slowly to very slowly permeable. The water table in this community ranged from 6 to 11 inches deep in November 2013 and January 2014.

Flatwoods transition (715 to 760 feet) has numerous pond pine and abundant saw palmetto. However, cinnamon fern provides the greatest total cover. Based on soil borings at stations 700 and 790, hydric soils are F13 Umbric Surface.

Hydric flatwoods (760 to 1040 feet) has a canopy of abundant pond pine and an understory dominated by saw palmetto. However, hydrophytic species such as loblolly bay, anise, and cinnamon fern are also numerous. The F13 Umbric Surface indicator occurs at station 790 on the footslope while sandy indicators such as S7 Dark Surface, and S6 Stripped Matrix occur on the sideslope. Non-hydric soils occur on the upper sideslope above station 955. Water tables in this community were everywhere deeper than 12 inches in January 2014.

Mesic flatwoods (1040 to 1133 feet) have numerous pond pines in the canopy and dominant saw palmetto in the understory. Soils are non-hydric as typified by the Cassia series at station 1100. This sandy, somewhat poorly drained Spodosol has moderately rapid permeability. The water table was 40 inches deep in January 2014.

Transect A10

Physical Description

A10 begins on a sideslope east of the spring run, and extends 4255 feet west. The sideslope descends at a 2.7% grade and reaches the floodplain at 250 feet. The floodplain has a lot of micro-topography/relief due to numerous hummocks and swales but overall elevations decrease slightly toward the channel. The creek bank drops 3.5 feet to the channel bottom from 1,586 to 1,590 feet.

The channel extends to 1,775 feet and elevations increase 4.7 feet to the west creek bank at 1,777 feet. Elevations then decrease at a 2.9% grade to an abandoned creek channel or slough from 1,880 to 1,895 feet. The west side of the floodplain has much microrelief and overall elevations increase slightly to station 2450. An elevated terrace is evident from 2,450 to 3,660 feet, probably the remnant of an older floodplain surface. A 1.2% grade sideslope occurs from 3,660 to 4,020 feet. A gently ascending shoulder extends to 4,255 feet. Representative photographs are shown in Figure 30 and topographic cross-sections with vegetation and soils data are shown in Figures 31 and 32. Detailed plant community data are shown in Table D4 (Appendix D).

Vegetation and Soils

<u>Mesic flatwoods (0 to 210 feet)</u> has a canopy of numerous pond and loblolly pines. Saw palmetto dominates the understory and inkberry (*Ilex glabra*) is numerous. Hydric soil indicator S6 Stripped Matrix occurs at 10 feet as typified by the Myakka series. This sandy, poorly drained Spodosol has a subsoil layer (spodic horizon) with moderate to moderately slow permeability that can perch water. This may account for the presence of S6 Stripped Matrix on this upland landform at 10 feet and the absence of hydric indicators further downslope at 50, 190, and 210 feet. At station 10, the water table was 13 inches deep while at station 190 it was greater than 20 inches deep in October 2013.

<u>Hydric flatwoods (210 to 255 feet)</u> are similar to the upslope mesic flatwoods except for the groundcover dominated by cinnamon fern. Soils are consistently hydric starting near station 220 as indicated by S9 Thin Dark Surface at 230 feet, A7 Mucky Mineral at 240 feet, and A8 Muck Presence at 245 feet.

<u>Bayhead (255 feet to 532 feet)</u> occurs at the base of the slope and its vegetation contrasts sharply with the flatwoods on the sideslope. Pine and saw palmetto are nearly absent and hydrophytic, hardwood trees such as red maple, swamp tupelo, dahoon holly, swamp bay, and loblolly bay dominate. Cabbage palm is scattered to numerous. The understory includes scattered to dominant anise, rare to numerous sawgrass (*Cladium jamaicense*) and frequent patches of sphagnum moss. A2 Histic Epipedon extends from 250 to 380 feet as typified by the very poorly drained, moderately permeable Denaud series at 310 feet. Water tables in this community ranged from 2 inches deep to 2 inches ponded in October 2013. The source of this water may be seepage from adjacent uplands and collection of local runoff in depressions.

<u>Transition zone (532 to 1,030 feet)</u> includes a diverse mix of species characteristic of several communities: flatwoods (pine, saw palmetto), bayhead (swamp bay, blueberry), hydric hammock (cabbage palm, laurel oak, sweet gum), and hardwood swamp (swamp gum, dahoon, red maple, lizard tail, buttonbush). This may reflect a complex hydrology with numerous sources of water that structure the habitat. Frequent fire, evidenced by abundant soil charcoal fragments, is also important. Soils are hydric throughout with indicator A8 Muck Presence at stations 560, 710, 770, and 900. A2 Histic Epipedon occurs in a depression from 610 to 680 feet as typified by the sandy,

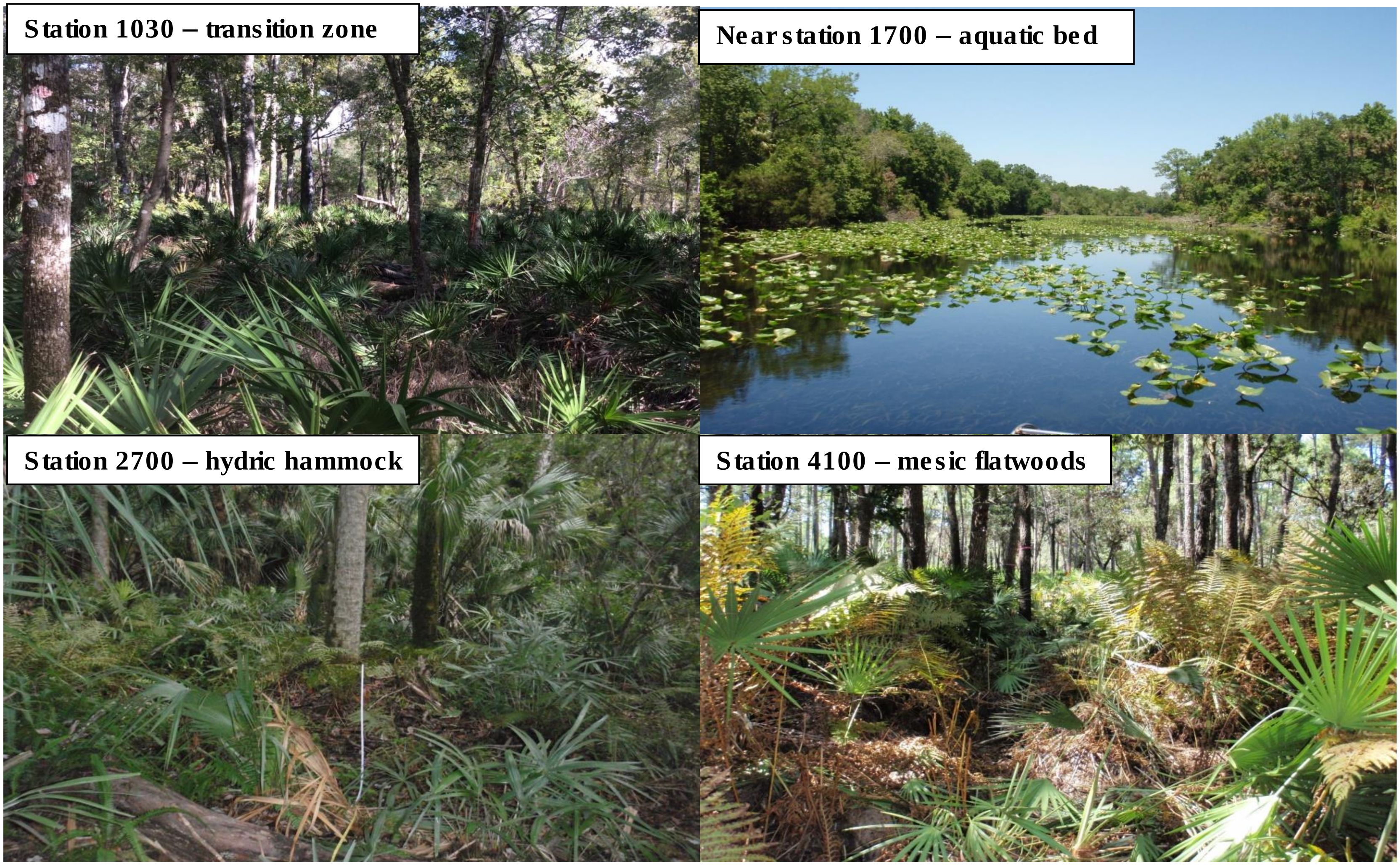

Figure 30. Transect A10 photographs, plant communities

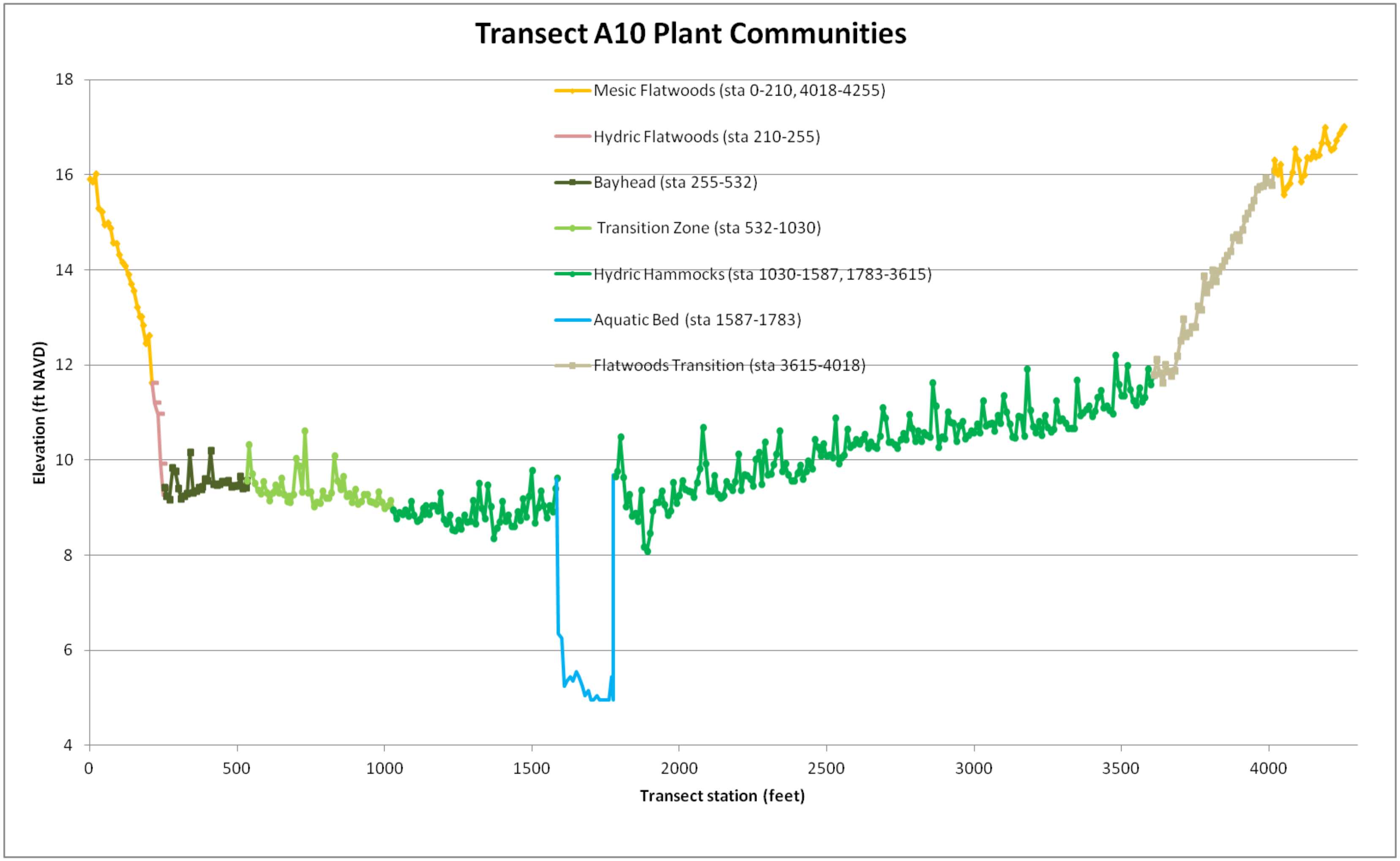

Figure 31. Transect A10 plant communities

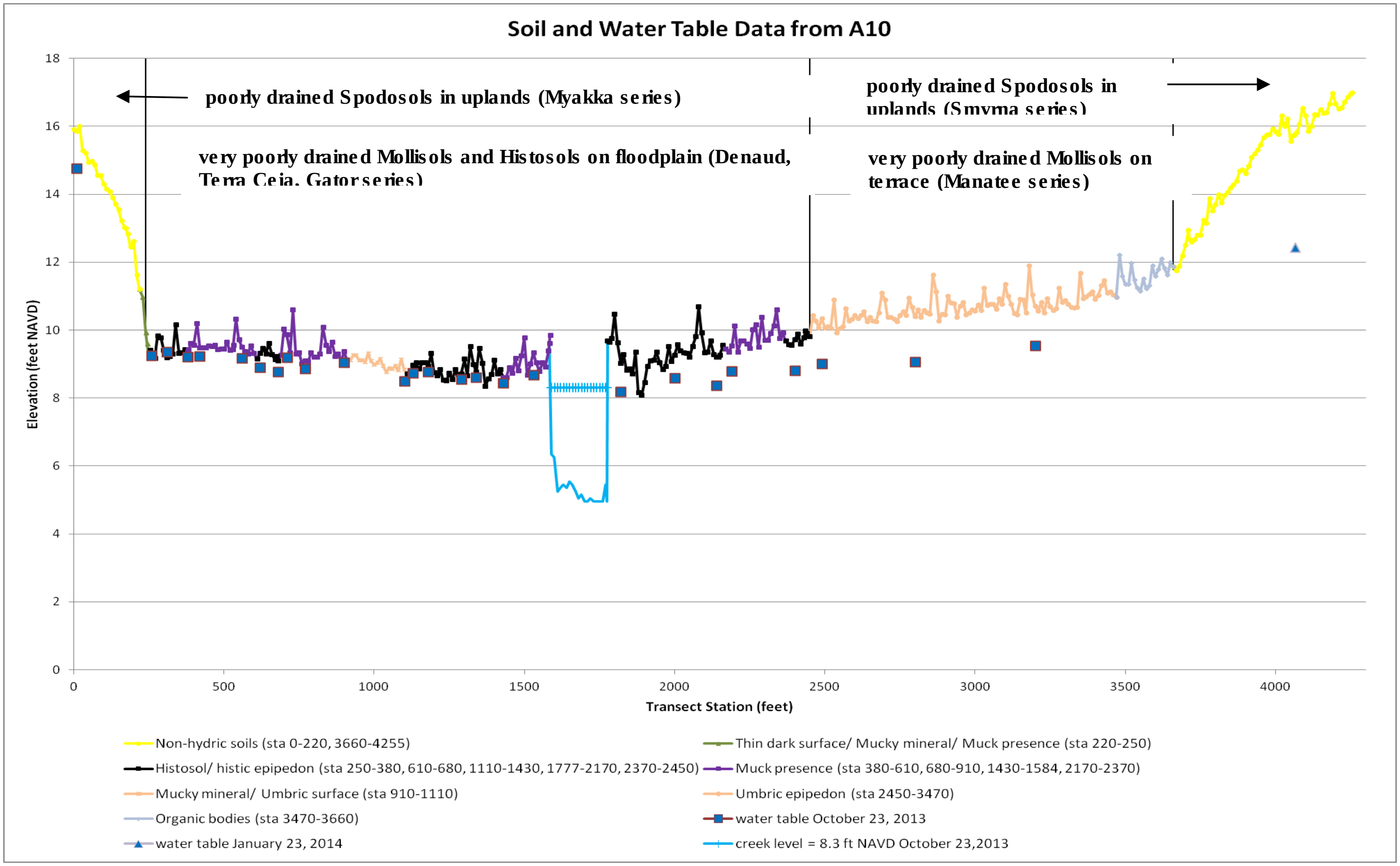

Figure 32. Soil and Water Table Data from A10

very poorly drained, rapidly permeable Sanibel series at station 620. Water tables ranged from 3 to 8 inches deep in October 2013.

Hydric hammock (1,030 to 1,587 feet) extends across the floodplain to the creek channel. Laurel oak is numerous to abundant, cabbage palm and red maple are scattered to abundant, and sweet gum is rare to numerous. Saw palmetto, numerous in patches, is an unusual component of this community. Its recumbent rhizomes are consistently elevated, possibly an adaptation to extremely wet conditions. Beaksedges are often numerous in the groundcover. Hydric soil indicators are A7 Mucky Mineral near the start of the community at station 1100 but shift to A2 Histic Epipedon in the lowest areas of the floodplain from 1,110 to 1,430 feet. These deep organic soils are typified by the Denaud series at station 1180. The depth of organic material diminishes toward the creek with indicator A8 Muck Presence at station 1530, typified by a Denaud taxadjunct. The water table ranged from 2 to 8 inches deep in October 2013.

Aquatic bed (1,587 to 1,783 feet) has mostly submerged species such as rare to dominant tapegrass and numerous water nymph (*Najas guadeloupensis*).

Hydric hammock (1,783 to 3,615 feet) resumes at the west creek bank and extends the entire width of the floodplain spanning a relatively large elevation range of approximately 3.8 feet. Cabbage palm dominates both canopy and understory while laurel oak and red maple are numerous. Cinnamon fern and other ferns are important groundcover components. Needlepalm is absent from 1,783 to 2,000 feet but becomes increasingly abundant with elevation.

The slough feature (1,880 to 1,895 feet) is included within the hydric hammock due to its narrow width. Its sparse vegetation contrasts sharply with dense vegetation of the adjoining hydric hammock. The sparse vegetation cover may be due to anoxic conditions resulting from long duration saturation and ponding. Heavy shade and unconsolidated organic soils may also be factors. Transect A10-A was established in 2016 to sample elevations in the slough more intensively. Slough photographs are shown in Figure 33 and the A10-A cross-section is shown in Figure 34. A10-A starts near the downstream end where the slough re-joins the creek and extends 520 feet north, parallel to the creek and ending where the slough channel becomes poorly defined from the surrounding hydric hammock. The sparse vegetation is scattered brookweed (*Samolus valerandi*), with occasional patches of buttonbush, sawgrass, and beaksedges.

A1 Histosol/ A2 Histic Epipedon indicators occur in the lowest elevations of the hydric hammock from approximately 1,777 to 2,170 feet. Typical soil series are Terra Ceia, Denaud, and Gator at stations 1820, 2000, and 2140, respectively. Elevated hummocks are common in this zone and have as much as 20 inches of peat over highly decomposed muck layers. Peat material consists largely of living and dead root material that may have originated as overturned root balls from tree throws. Organic materials diminish in thickness at higher elevations and A8 Muck Presence occurs from 2,170 to 2,370 feet. Another zone of A1 Histosol/ A2 Histic Epipedon occurs from 2,370 to 2,450 feet in a depression at the base of the elevated terrace. Runoff and seepage may help sustain these soils.

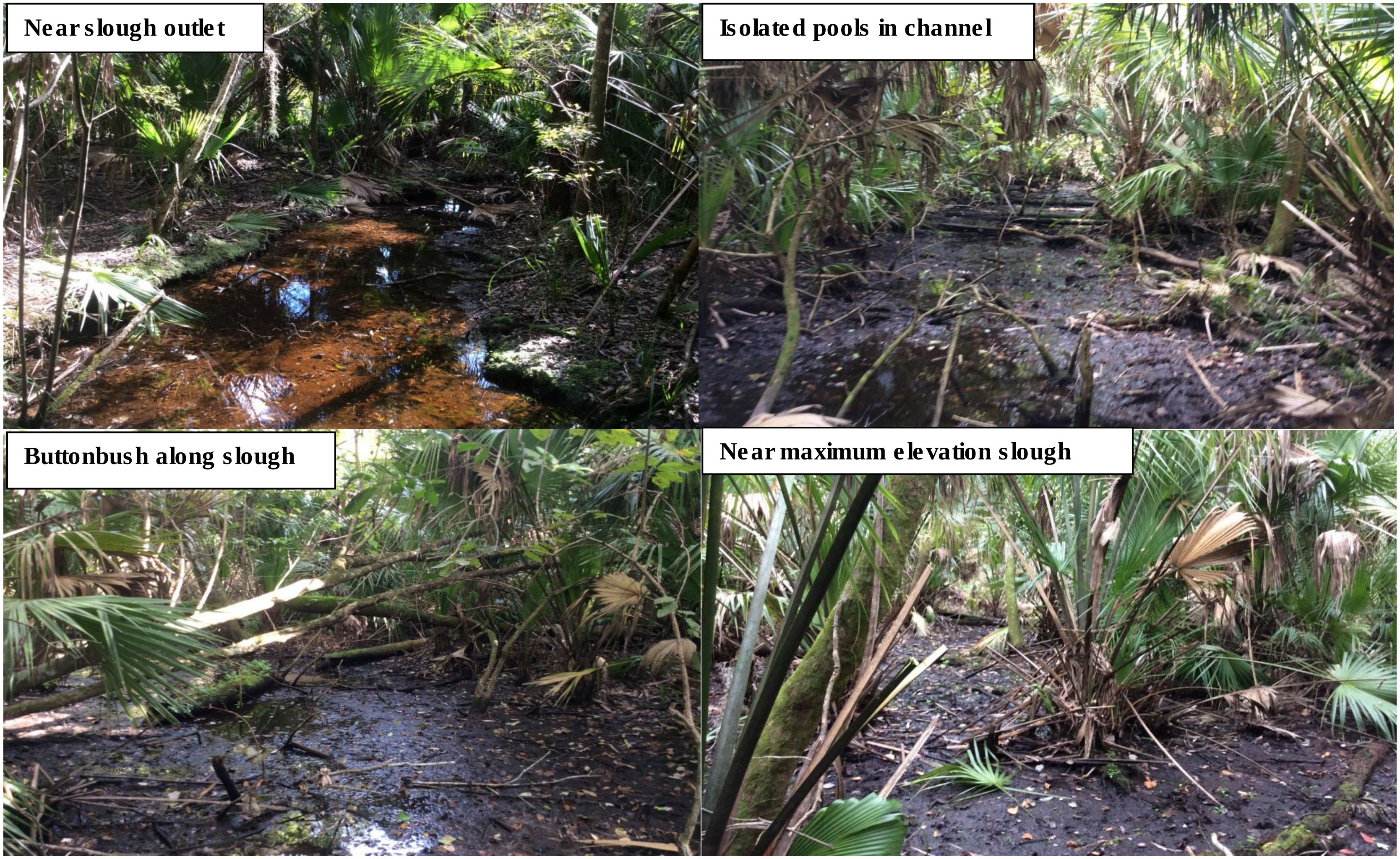

Figure 33. Transect A10-A photographs, slough

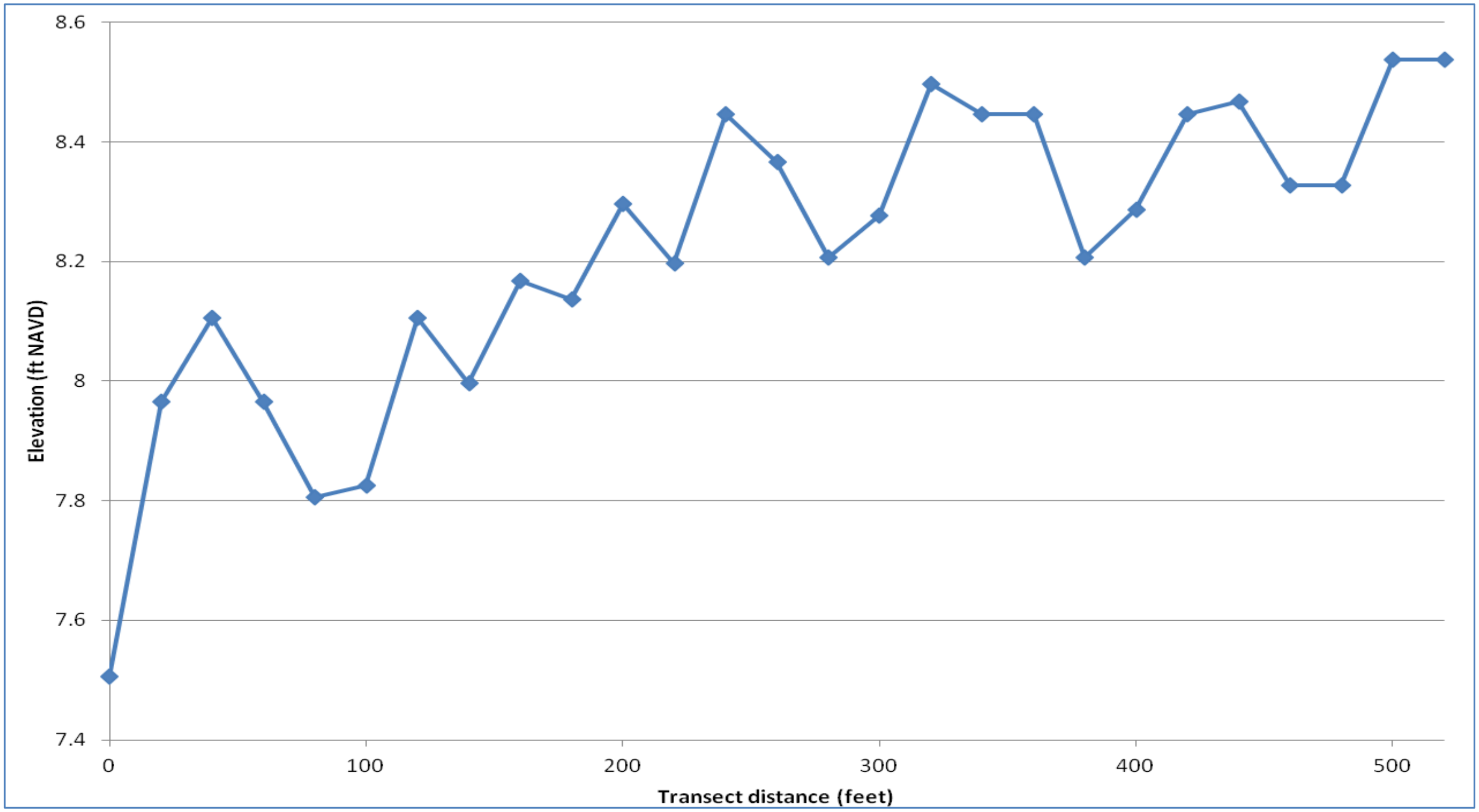

Figure 34. Transect A10-A slough channel elevations

Hydric indicators from 2,450 to 3,660 feet are mostly F13 Umbric Surface as typified by the very poorly drained, moderately permeable Manatee series at station 2800. Hydric soils near the upper edge of the hydric hammock have indicator A6 Organic Bodies. Water tables in this community ranged widely from a few inches of ponding in the slough to greater than 22 inches deep at station 3610 in October 2013.

Flatwoods transition (3,615 to 4,018 feet) has characteristics of both hydric hammock and flatwoods. Abundant species include laurel oak and cabbage palm in the canopy, saw palmetto in the understory, and cinnamon fern in the groundcover. Soils on this sideslope are generally non-hydric starting near station 3660. Water tables in October 2013 were deeper than 20 inches.

Mesic flatwoods (4,018 to 4,255 feet) are dominated by saw palmetto with some scattered laurel oak and either swamp or red bay in the canopy. Soils are non-hydric as typified by the Smyrna series at station 4065. This sandy, poorly drained Spodosol has moderate to moderately rapid permeability and the water table was 40 inches deep in January 2014.

INTERPRETATION OF SOIL AND WATER TABLE DATA

Distribution of Soil Characteristics Affecting Water Movement

Soils in the uplands near Alexander Springs Creek typically have thick, sandy, rapidly permeable surface layers underlain by spodic and/ or fine-textured, argillic (e.g. sandy loam to sandy clay loam) horizons. These subsoil features may perch water tables allowing conduction of water toward the floodplain. In contrast, floodplain soils are relatively uniform loams and sandy loams either with organic surface layers (Denaud series) or without organic surface layers (Bradenton and Manatee series). Deeper organic soils (Histosols) occur in the lowest elevations of the floodplain as typified by the Terra Ceia, Gator, and Samsula series. The Chobee series, occasionally encountered at Transects A6 and A8, is a relatively fine-textured soil that is highly likely to pond water after storms or flood events.

Water Tables

In lieu of monitoring well data, water table depths observed during soil investigations were converted to elevations and displayed graphically (Figures 21, 24, 29, 32). This has the advantage of providing detailed spatial data but the disadvantage of not showing temporal variation. The data has several sources of error that include: 1) slight differences between where the elevation reading was made and where the soil borehole was dug (as much as one to two lateral feet), 2) error in observer reading, which was recorded to the nearest half-inch, and 3) time allowed for equilibration of borehole water with soil water. Equilibration time was the duration required to describe the soil before moving to the next borehole station and varied from approximately five to 20 minutes. However, in the case of investigations at A5-A, a full day was allowed for equilibration.

Despite these problems, the data provides water table profile information from all transects and captures a seasonal range from November to April, mostly from the 2013 to 2014 period. Creek level data from the same sampling days are shown in the figures for comparison and were collected from staff gauges (A6, A8), a water level reference pipe (A10), and channel soundings (A5-A).

The figures show that water tables in the floodplain closely match creek levels most of the time, particularly for locations near the creek channel. Water tables gradually increase in elevation further away from the creek and tend to follow the land surface contour. Water tables rise steeply into the flatwoods indicating a large hydraulic gradient from flatwoods to floodplain, which supports that seepage is an important hydrologic process maintaining hydric hammocks of the floodplain.

Soil and water table investigations at A6 were conducted on two different dates in spring 2014 (Figure 24). Levels north of the creek were measured on March 4, when trees began to put out leaves. Levels south of the creek were measured on April 9, when trees were fully leafed. Creek levels were the same on both days though there were probably differences in antecedent conditions. Water table levels on the earlier date matched creek levels, as was the case at all other transects. However, on the latter date, creek and water table levels appear to decouple, probably due to high evapotranspiration rates in mid-spring, which draw down water tables. A comparison of water table levels at stations 1020 (creek edge) and 1040 suggests that some lateral recharge from the creek may occur.

The water table is a continuum from flatwoods to floodplain to creek. Factors such as evapotranspiration, rainfall, and flooding prevent there from being a perfect relationship between creek levels and floodplain water tables. Nonetheless, during periods of low water, low precipitation, and low evapotranspiration, the relationship should approach equilibrium particularly given the stable base flow supplied by the spring. Darcy's Law ($q = K^*\Delta H/L$) describes discharge rate or flux (q) through a saturated, porous media as a function of the following elements (Hillel, 1998):

K: hydraulic conductivity of soil
$\Delta H/L$: hydraulic head per unit distance in the direction of flow

The ΔH component is the difference in head between inflow and outflow boundaries. In this case, creek elevation represents the outflow boundary of the system and thereby controls groundwater discharge through the floodplain system.

MINIMUM FLOWS DETERMINATION FOR ALEXANDER SPRINGS

Minimum frequent high (FH), and minimum frequent low (FL) levels, and associated flows were determined for Alexander Springs to protect ecological functions of the Alexander Springs Creek system. The rationale and criteria for these two levels are described below.

Typically, a minimum average (MA) level would be set at water bodies bordered by significant areas of deep organic soils. The MA protects this feature by preventing excessive drying due to water withdrawals, which could lead to oxidation and subsidence. Although deep organic soils are present at each Alexander Springs MFLs transect, typical MA criteria (i.e. mean elevation deep organic soils — 0.3 feet, 180-day mean dewatering duration, 1.7-year return interval) cannot be met at Alexander Springs Creek under current conditions. Although these organic soil areas have very high dewatering probabilities, the stable base flow of the creek may prevent large, seasonal declines in soil water tables. This factor in conjunction with strong capillarity of organic soil material may ensure near saturated conditions and thereby protect these soils under hydrologic conditions that would expose organic soils at more highly fluctuating systems to oxidation and subsidence.

Minimum infrequent high (IH), and minimum infrequent low (IL) levels were not determined due to lack of suitable criteria. Spring baseflow ensures stable water levels in the creek, which suggests that IL conditions do not occur here. While IH levels do occur along Alexander Springs Creek, they are largely due to backwater effects from the St. Johns River.

Minimum Frequent High (FH) Flow: 183.6 cfs, 7-day duration, 2.6-year return interval

A general goal of the FH is to ensure sufficient flooding to maintain functions of floodplain wetlands. Surface or groundwater withdrawals should not reduce the long-term number of FH events beyond a defined return interval threshold. FH events are usually associated with wet season rainfall during or following periods of normal or above normal precipitation. Spring discharge provides a base flow level in the creek, which enables storm-driven water to inundate floodplain wetlands. The more sensitive of the two FH criteria, described below, defines the Frequent High MFL for Alexander Springs.

Criterion #1: Maintenance of Surface Water Connections

The first specific goal of the FH is to maintain surface water connections between creek and floodplain, which allows exchange of water, organisms, and nutrients. Exchanges take place at breaks in the channel banks where rising water levels enter the floodplain and flow through narrow channels or rivulets into depressions, sloughs, or back to the creek. Frequent inundation does not directly affect most parts of the floodplain but this process enhances the structure, and function of the entire system.

Elevation to maintain surface water connections

The slough that crosses A10 at stations 1880 to 1895 is a water conveyance feature that frequently brings surface water into the hydric hammock (Figure 34). High flows may also back flood the slough from the downstream end. The slough enhances habitat diversity of the hydric hammock by supporting isolated, ephemeral pools in channel depressions, scattered clumps of marsh (e.g. sawgrass, beaksedge) and shrub swamp (e.g. buttonbush) vegetation. High flows may also maintain the distinctive unvegetated condition and poorly consolidated organic soils of the slough. Although SJRWMD staff did not observe tadpoles in March 2016, the isolated pools might provide breeding habitat for amphibians. Numerous families of aquatic insects were present and other wildlife may use the pools. High levels of soil carbon and alternating aerobic/ anaerobic zones create conditions for denitrification, an important process that maintains water quality. Collectively, these functions make this and other similar sloughs ecologically important.

By maintaining frequent flooding at the maximum elevation of the slough, the ecological functions of the slough are maintained. The maximum elevation occurs at stations 500 to 520, the point at which the slough is no longer readily discernible from surrounding hydric hammock. When the maximum elevation of 8.54 feet NAVD is transferred to the Tracy Canal gauge, the resulting proposed FH elevation is 3.84 feet NAVD. The regression analysis used to transfer the proposed FH elevation to the Tracy Canal gauge is described in Appendix C. Based on a rating curve developed from data at the Tracy Canal gauge, the equivalent flow used for this FH is 162.2 cfs.

Duration to maintain surface water connections

Seven-day flood duration is based on POR data, which show that floods on Alexander Springs Creek typically frequently occur for approximately seven days or less (Figure 13). Shallow ponding in irregular depressions of the slough means that there is a longer than seven day “effective” duration. These short-duration, frequently occurring floods maintain an open slough channel more effectively than would longer duration but less frequent floods.

Return interval to maintain surface water connections

The proposed two-year return interval of 2.0 years is based on the minimum long-term frequency threshold recommended by NRC (1995) to define wetland hydrology. This frequency is deemed sufficient to maintain an open channel. Less frequent floods might allow encroachment of hammock vegetation into the slough and infilling of this feature.

This MFLs criterion is the least sensitive criterion for the FH (and overall; Table 8). Frequency analysis results indicate that this criterion would allow a decrease in flow at Tracy Canal of

Table 8. Comparison of MFLs criteria for Alexander Springs at Tracy Canal.

	Criterion	Level (ft NAVD)	Baseline Flow (cfs)	MFLs Flow (cfs)	Duration	RI (yrs)	Freeboard (cfs)	Reduction of mean flow at head springs (%)
FH	Creek – floodplain connections	3.84	239.99	162.17	7-day flood	2.0	77.8	**76**
FH	Cypress regeneration	4.13[1]	242.86	183.63	7-day flood	2.6	59.2	**58**
FL	Deep marsh	2.37	120.56	87.41	120-day dewater	2.7	33.2	**33**
FL	Slough inundation	2.32	115.96	84.80	120-day dewater	3.6	31.2	**31**
FL	Vernal pools / amphibian habitat	2.62	120.56	99.36	120-day dewater	2.7	21.2	**21**

[1] This elevation is the mean of three FH elevations (A5, A6 and A8; see Appendix C, Table 10)

approximately 78 cfs. This is a 76% reduction of mean flow at the head springs; the mean flow at the head spring equals ~102 cfs for the POR 1983 to 2014.

Criterion #2: Maintenance of Bald Cypress

The second specific goal of the FH is to maintain wetland vegetation features that are sensitive to flooding. Although seepage from adjacent flatwoods strongly influences wetlands along Alexander Springs Creek, the presence of bald cypress trees suggests that flooding also plays an important role in creating and maintaining the vegetation. Flooding should occur sufficiently often to maintain this species as a component of floodplain communities. This will help protect structure and diversity of habitats and maintain an aesthetically appealing feature for visitors.

Elevation to maintain bald cypress

A commonly used FH elevation criterion is mean elevation of the highest, seasonally flooded wetland community on the landscape. However, this criterion is not appropriate here because most of the floodplain is hydric hammock, a wetland community with multiple hydrologic sources that include short duration overbank floods, seepage, and localized runoff and ponding of rainfall in depressions.

Individual plant species have specific physiological requirements that limit where they can compete successfully and hydrologic tolerances are one of the primary determinants (Barbour el al, 1999). Therefore, vegetation features at a finer scale than the community level can provide valuable information regarding extent and elevation of frequent flooding. Bald cypress is a slow-growing, long-lived species classified as obligate (OBL) by FDEP and therefore is a good indicator of long-term wetland hydrology.

Bald cypress has very specific flooding and dewatering requirements. Flowing water disperses seed, removes plant debris, exposes bare soil, and saturates the soil, all requisites for seed germination (Ware, 2003). However, extended dewatering periods are also necessary since seed cannot germinate under water and floods that over-top the slow-growing seedlings may kill them. Bald cypress produces good seed crops only once every 3 to 5 years and seed viability is low. A field study showed that less than 1% of germinated seedlings were alive after 3 years (Gunderson, 1986). Collectively, these characteristics mean that recruitment occurs infrequently.

Once established, this species tolerates a variety of hydrologic regimes. Bald cypress growth rates were not significantly different between seedlings in periodically flooded vs. continuously flooded treatments (Megonigal, 1992). However, one study shows that prolonged anoxia can slow bald cypress growth rates (Young and Keeland, 1995). Periodic floods may be important in suppressing competitors to bald cypress.

Line intercept data from Alexander Springs transects indicate that bald cypress occurs in the lowest elevations of the floodplain. In such environments, it produces abundant knees, which are the characteristic aerial root projections unique to this species. Recent research suggests that knees function as pneumatophores, which convey oxygen to roots growing in saturated, anaerobic soil (Martin and Francke, 2015). Presence of knees was the metric used to delineate the extent of bald cypress in this study. Extent of knees is superior to measurements of canopy cover since knees are 1) evenly distributed, 2) easier to measure than the aerial canopy, and 3) as extensions of the root system, they are directly subject to system hydrology as opposed to canopy cover, which can overhang areas with different hydrologic conditions.

Bald cypress extent is scattered (canopy cover class 1) in hardwood swamps at A5-A, abundant (canopy cover class 3) in hardwood swamps at A6. In the hydric hammock at A8, it is scattered (canopy cover class 1), mostly consisting of a few large individuals. Table 9 shows the extent and ground elevations of bald cypress knees at these transects. Bald cypress was not present at A10. When mean elevations from these three transects are transferred to the Tracy Canal gauge using regression analysis (Appendix C), the resulting proposed FH elevation is 4.13 feet NAVD. The equivalent FH flow obtained from the Tracy Canal gauge rating curve is 183.63 cfs.

Flood duration to maintain bald cypress

The recommended duration of seven days continuous flooding is based on POR data that shows most floods along Alexander Springs Creek at the elevation of the proposed FH occur for approximately seven days or less. Seven-day floods are sufficient to remove plant debris, expose bare soil, transport seed, and saturate the soil thereby creating conditions conducive to bald cypress germination.

Table 9 Ground elevations and extents of cypress knees at three transects

Transect	Extent of knees (station)	Mean	Maximum	Minimum	N
A5-A	410-440, 475-513, 622	4.22	4.96	2.94	17
A6	460-746	6.25	7.10	5.59	30
A8	491-515, 584-639	7.84	8.21	7.49	9

Thirty-day flood durations are often recommended for the FH at other MFLs systems. This period is sufficient to kill upland species that invade wetlands during drought (Topa and McLeod, 1986) and thereby maintain wetland vegetation. However, wetlands along Alexander Springs Creek receive sufficient seepage from adjacent flatwoods to exclude upland plant invasions. POR data show that longer duration floods (20 to 40 days) occasionally occur at Alexander Springs Creek, approximately every five to 10 years. However, the short duration, more frequent flood events provide greater opportunities for bald cypress recruitment than longer duration, less frequent events. Therefore, 30-day flood duration for the FH was rejected in favor of 7-day duration.

One-day floods also occur frequently at Alexander Springs Creek but this duration may too brief to fully mobilize and transport plant debris and deliver seeds to suitable germination sites. To maintain the existing hydrologic conditions that are of crucial ecologic importance, 1-day flood duration for the FH was rejected in favor of 7-day duration.

The FH event will saturate the mean elevation of bald cypress for the defined 7-day period. It will flood areas below that elevation for longer than seven days. Areas above that elevation will flood for shorter durations. Due to the numerous closed depressions on the floodplain, these short duration floods will produce longer duration ponding, which helps suppress competition from other species.

Important spatial and temporal features influence extent and duration of ponding. Evapotranspiration rates are low from late fall to early spring and ponding will be particularly prolonged at these times. Fine-textured soil layers (e.g. sandy clay loams) occur intermittently in the floodplain, often associated with the Chobee soil series. Where present, these soil layers can restrict percolation and lateral discharge from ponded depressions.

Return interval to maintain bald cypress

The proposed return interval of 2.6 years is based on 7-day flood probabilities for mean elevations of bald cypress from six reference sites (Figure 35). The reference set includes four transects along the spring-fed Silver River and two transects of hydric hammocks along the St. Johns River. Bald cypress distribution data from wetland lakes and from hardwood swamps along the St. Johns River were not included in the reference set because they have very high 7-day flood probabilities that do not occur at Alexander Springs Creek under current conditions. The mean probability of 7-day floods from the reference systems is 50.92 and the driest signature, which comes from the floodplain of the Silver River at Transect 3, is 38.75% or a 2.6-year return interval.

This MFLs criterion is the most sensitive of the two FH criteria, and is therefore the basis of the recommended FH (Table 8). However, this metric is also relatively insensitive. Frequency analysis results indicate that this criterion would allow a decrease in flow at Tracy Canal of approximately 59 cfs. This is equivalent to a 58% reduction of mean flow at the head springs.

In summary, the purpose of the two proposed FH criteria is to maintain the following functions:

- Habitat quality: Levels of flooding are appropriate to maintain characteristic vegetation and habitat diversity in the floodplain of Alexander Springs Run.
- Productivity: Frequent, brief flooding stimulates primary productivity, creates surface water connections between creek and floodplain thereby expanding habitat and food resources for aquatic fauna. Short-term flooding redistributes plant seeds and detritus within aquatic and wetland habitats.
- Biogeochemistry: frequent, brief flooding creates alternating anaerobic and aerobic conditions, which maintains hydric soil functions such as denitrification. Other water quality improvements occur by filtration and uptake of dissolved and particulate materials during these events.

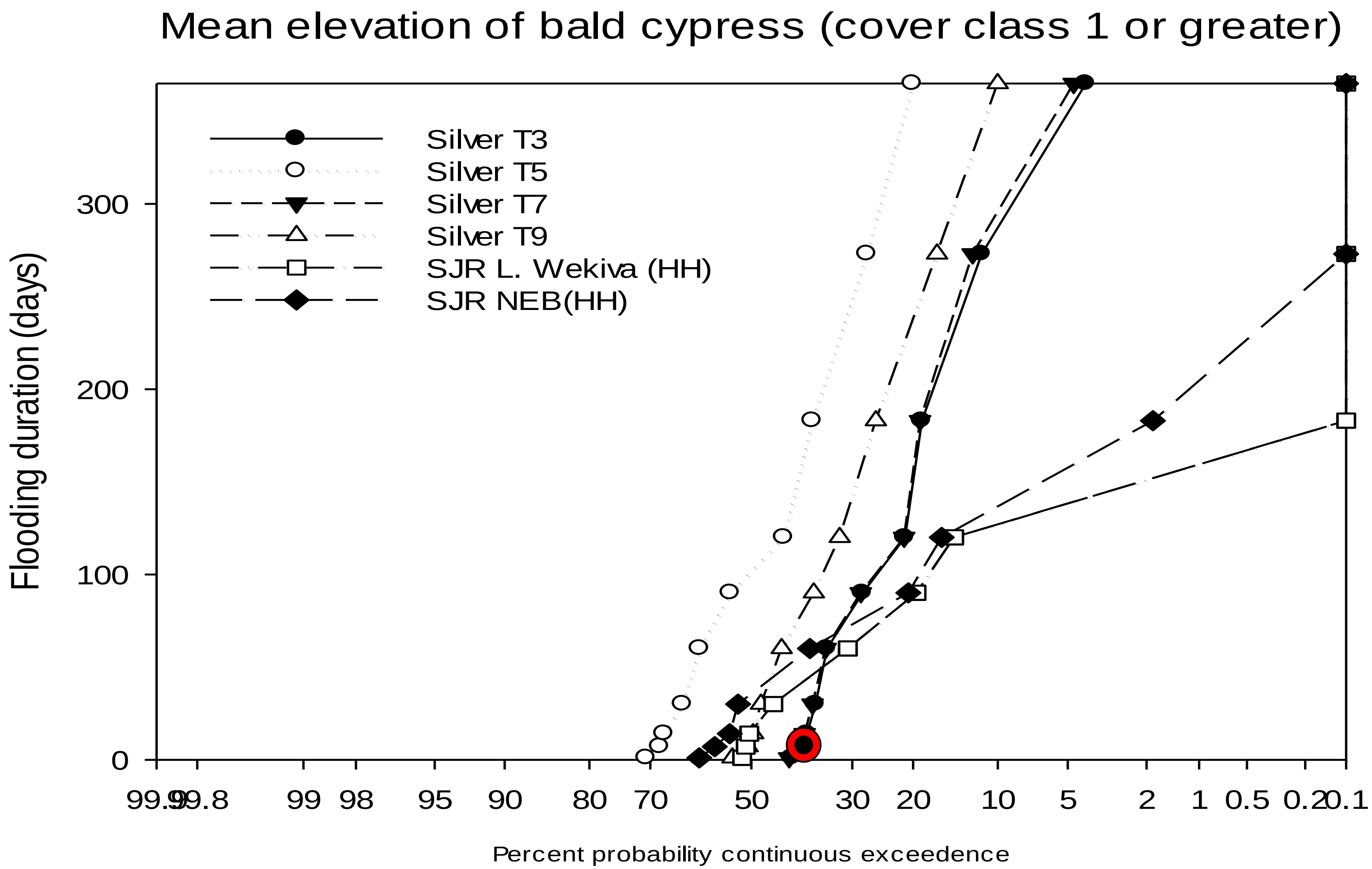

Figure 35. Hydrologic signatures for mean elevation of bald cypress (7-day driest signature marked with red circle)

Minimum Frequent Low (FL) Level – 99.4 cfs, 120-day duration, 2.7-year return interval

The general goal of the FL is to prevent excessive drying due to ground or surface water withdrawals, which increase the frequency of dewatering. Excessive drying refers to events that occur too often to maintain ecological functions identified as critical for this system. Multiple specific goals are proposed based on presence of significant ecological features at different transects. The most sensitive criterion is used as the basis for the FL.

Criterion #1: Protection of Deep Marshes

Elevation to protect deep marshes

Deep marshes are subject to long duration flooding and infrequent dewatering events. Infrequent dewatering selects for flora that either can germinate under water (Gerritsen and Greening, 1989) or are well adapted to prolonged flooding and can expand clonally. Vegetation is generally a mix of emergent plants such as bulrush, bulltongue arrowhead, pickerelweed and floating-leaved plants such as water lilies. The dense vegetation and extended inundation periods provide important refugia for fish.

Zones above the deep marsh are frequently dewatered and may include communities such as hardwood swamp, shallow marsh, or hydric hammock. Frequent dewatering benefits these communities by allowing flood-sensitive seeds and propagules to sprout and grow to sufficient heights to survive subsequent flooding.

Maximum elevation of deep marsh is a typical FL criterion since it indicates the extent of frequent dewatering. This feature occurs at Transect A8, station 490 (6.75 feet NAVD). This FL criterion maintains the long-term ecotone between deep marsh and hydric hammock, thereby preventing downhill shift in species, possible channel encroachment, and loss of open water.

The 6.75 feet NAVD elevation equates to a 2.37 feet NAVD elevation at Tracy Canal. The equivalent flow based on the Tracy Canal gauge rating curve is 87.4 cfs (Appendix C).

Duration to protect deep marshes

The recommended duration component of the FL is 120 days of continuous dewatering, the approximate duration of the spring and early summer dry season in central Florida (i.e., mid-February to mid-June). This duration is sufficient to allow seed germination, seedling establishment and plant growth to occur before seasonally dewatered wetlands re-flood (Kushlan, 1990).

Return interval to protect deep marshes

The proposed return interval of 2.7 years is based on 120-day dewatering probabilities for the maximum elevation of pickerelweed from wetlands at 10 reference sites (Figure 36). Cattail, bulrush, and pickerelweed are the most common species in the A8 deep marsh. Cattail occurs in large patches as is typical of this opportunistic species, which spreads clonally. Bulrush occurs near the lower elevation of the deep marsh. In contrast, line intercept data shows that pickerelweed occurs evenly in the deep marsh (stations 430-451, 459-462, and 474-488). A field visit in April 2016 indicated pickerelweed was present to station 490, slightly off the transect line, where it was firmly rooted in organic soil. Since pickerelweed occurs throughout the deep marsh up to the maximum elevation of the community, the set of hydrologic signatures for maximum elevation of pickerelweed may be used to estimate an appropriate MFLs return interval for this deep marsh community. The driest signature in this dataset has a probability of 36.9%, which equates to a return interval of 2.7 years.

This MFLs criterion is more sensitive than either FH criteria (Table 8). However, frequency analysis indicates that this criterion would allow a decrease in flow at Tracy Canal of approximately 33 cfs. This is equivalent to a 33% reduction of mean flow at the head springs.

Criterion #2: Maintenance of Slough Inundation

Elevation to maintain slough inundation

FNAI (2010) defines sloughs as broad channels inundated with slow moving or stagnant water, except during extreme droughts. Although water levels fluctuate, this definition implies that some water should remain in the typical slough except during infrequent low conditions.

The A10-A slough has numerous shallow depressions that become isolated pools at different creek levels. The lowest depression occurs at stations 80 to 100 feet near the slough outlet. The minimum elevation of this feature (7.80 feet NAVD) is the basis for the proposed FL at A10. By maintaining long-term creek levels equal to the lowest point of the slough, water tables in the entire slough will stay near saturation. This is because capillary action in the interconnected pores of soil organic matter can cause soil saturation at elevations above the water table. As described in FL Criterion #2, the relationship between creek levels and slough levels may decouple during periods of high evapotranspiration.

Soil saturation in the slough promotes biogeochemical processes such as denitrification and maintains high water table levels in the nearby hydric hammock. Soil saturation and prolonged anoxia may also be important processes keeping organic soils unconsolidated, thereby excluding most vegetation and allowing the slough to function as a water conduit.

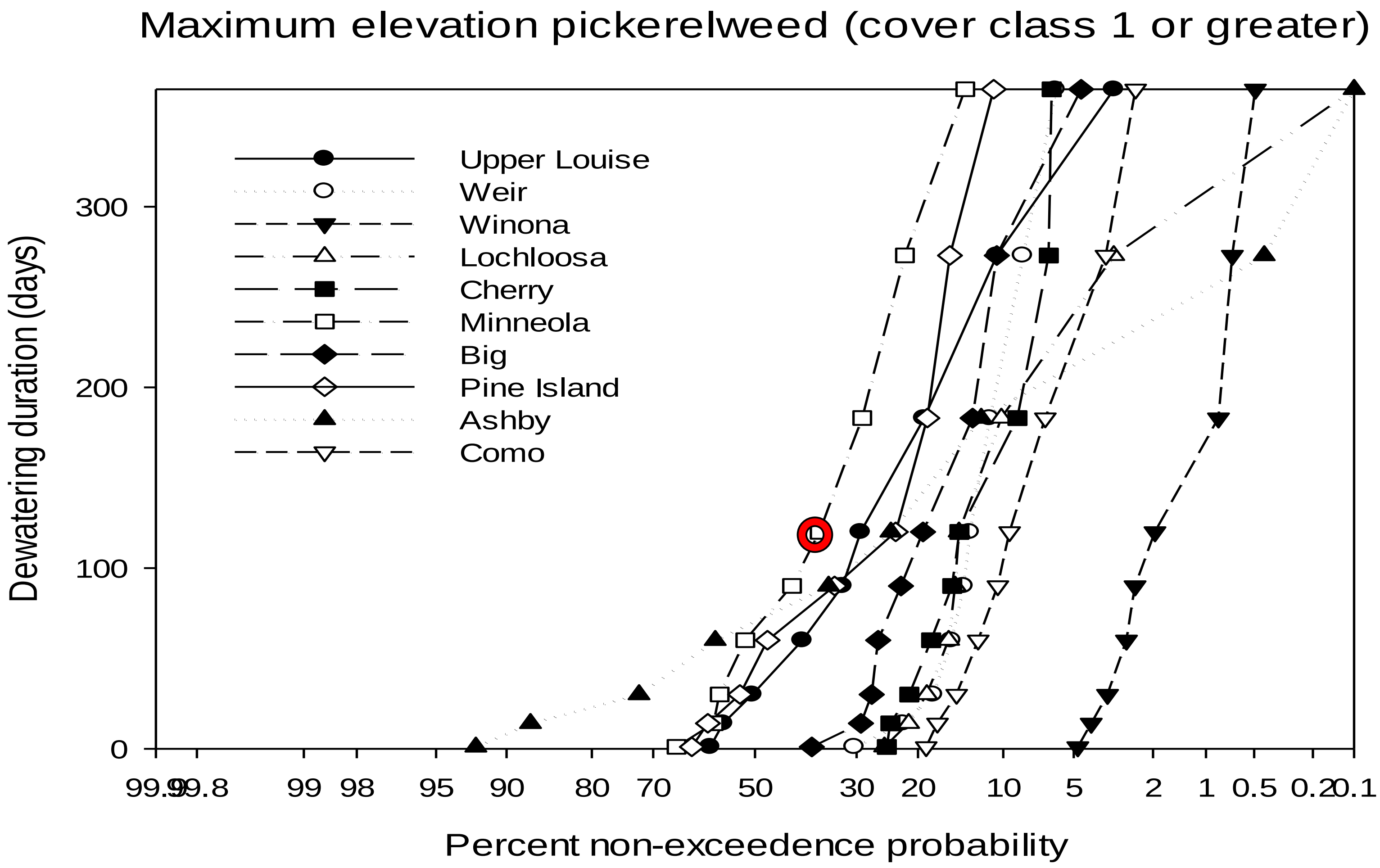

Figure 36. Hydrologic signatures for maximum elevation of pickerelweed at 10 sites (120-day UCL marked with red circle)

High water tables also mean that rainfall events will cause frequent pooling in slough channel depressions, possibly benefiting amphibians and other wildlife. However, the shallowness of the pools (typically < 0.3 feet deep) may mean that they will readily reconnect with the creek during many rainfall events thus rendering them generally poor amphibian habitat. No tadpoles were observed in March 2016 but several families of aquatic insects were using the pools.

The 7.80 feet NAVD elevation equates to a 2.32 feet NAVD elevation at Tracy Canal. The equivalent flow based on the Tracy Canal gauge rating curve is 84.8 cfs (Appendix C).

<u>Duration to maintain slough inundation</u>

The proposed dewatering duration is 120 days of continuous dewatering, the approximate duration of the spring and early summer dry season in central Florida (i.e., mid-February to mid-June).

<u>Return interval to maintain slough inundation</u>

The proposed return interval of 3.6 years is based on 120-day dewatering probabilities for the minimum elevation of buttonbush from wetlands at 13 reference sites (Figure 37). Buttonbush is scattered (cover class 1) in the hydric hammocks at A10 and reaches its minimum elevation along the A10-A slough. The assumption is that by maintaining hydrologic conditions necessary for buttonbush, we protect the ecological functions of the associated slough. The mean probability of 120-day, dewatering events for the minimum elevation of buttonbush is 19.3% and the driest signature in the dataset is 27.4%, which comes from Halfmoon Lake. This driest signature probability equates to a return interval of 3.6 years.

This FL criterion is also relatively insensitive (Table 8). Frequency analysis results indicate that this criterion would allow a decrease in flow at Tracy Canal of 31 cfs. This is equivalent to a 31% reduction of mean flow at the head springs.

Criterion #3: Protection of Amphibian Habitat

<u>Elevation to protect amphibian habitat</u>

The hardwood swamp community at A6 has a distinct backswamp zone at the north edge of the floodplain, near the base of the uplands. Numerous isolated depressions or vernal pools occur in a linear pattern suggesting an abandoned creek channel, largely infilled with organic matter. These depressions are typically vegetated with lizard tail and pickerelweed and have a relatively open tree canopy. While lizard tail occurs widely in the floodplain, pickerelweed is generally restricted to these depressions. Pickerelweed is an obligate wetland species generally found in areas with significant ponding. However, dense canopy shade may suppress it.

Investigations in February 2016 revealed that some depressions were supporting tadpoles. Potential species that breed in early spring include spring peeper, southern leopard frog, southern cricket frog, ornate chorus frog, little grass frog, and spadefoot toads (Gregoire, 2005). Transect A6-A was established perpendicular to A6 in 2016 to sample several backswamp depressions. Probable amphibian breeding pools were defined for this study as depressions that are at least 0.3 feet deep in cross-section that also support pickerelweed. The 0.3-foot depth is a topographic criterion that ensures the depression can hold a significant depth of water.

Several characteristics of these pools suggest valuable amphibian breeding habitat:

- Amphibians have high fidelity to breeding sites and even our one-time observations may indicate regular utilization.
- Sphagnum moss beds, located upslope of the pools on A6, may harbor amphibians (Carmichael, 1991).
- The location of the pools near the interface of upland and riparian habitats allows utilization by various terrestrial and aquatic amphibians during portions of their life cycles (deMaynadier and Hunter, 1995).
- Inland hydric hammocks in Florida have a diverse herpetofauna and high abundance of selected species (Vince et al, 1989).
- Water bodies with emergent vegetation are likely to support a higher number of frog species than poorly vegetated sites (Hazell et al, 2004).

Amphibians are adapted to exploit resource rich but ephemeral aquatic habitats (Wassersug, 1975). Pond breeding amphibians play three important ecosystem roles (Semlitsch, 2003). They are important nutrient vectors that connect aquatic and terrestrial environments through their migrations. They consume zooplankton and aquatic insects that are too small to be prey for larger vertebrates. They are fast growing, and provide abundant, high-quality protein to groups up the food chain such as birds, mammals, and snakes.

The endangered indigo snake, which FNAI ranks as “likely” near Alexander Springs Creek, forages at the edge of wetlands for frogs, toads, and fish (Kochman, 1978). Amphibian species are in steep decline worldwide for a variety of reasons (Beebee and Griffiths, 2005) that include hydrologic alterations and habitat fragmentation. Thus, efforts to protect their breeding pools deserve special consideration.

Water table information at the four transects (Figures 21, 24, 29, and 32) shows a distinct hydraulic gradient from flatwoods to floodplain suggesting that the source of soil water in the floodplain is generally from seepage rather than from creek inundation. These figures also show that floodplain water tables generally track creek levels and that the two form a continuum. Although floodplain inundation occurs only briefly, the creek exerts a long-term, pervasive influence on floodplain hydrology. If creek levels were to decline significantly then there would be a corresponding drying

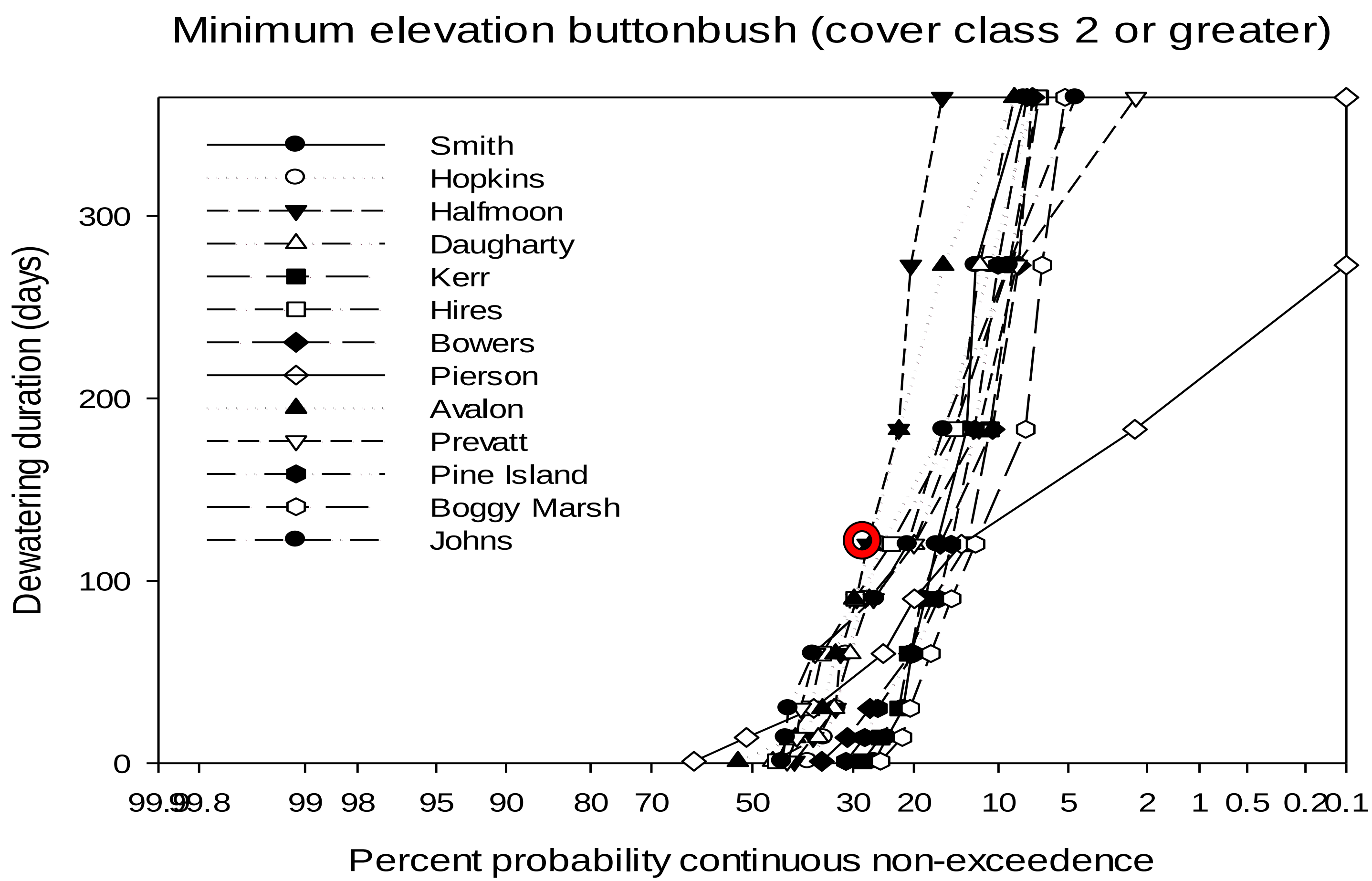

Figure 37. Hydrologic signature for minimum elevation of buttonbush at 13 sites (120-day LCL marked with red circle)

of the floodplain. This relationship has important implications for ecological functions of the floodplain.

As discussed in section 4.5, the relationship of creek level to floodplain water table level may decouple during periods of high evapotranspiration. Therefore, it is uncertain whether these pools would also support tadpoles during the summer rainy season. Although rainfall is frequent, high evapotranspiration rates may prevent ponding of sufficient duration to support summer-breeding amphibians such as various treefrogs, pig frog, carpenter frog, and river frog. The spring drying period means that these pools probably could not support bullfrogs, which have a very long metamorphosis period of 1 to 2 years (Semlitsch, 2003).

By maintaining a long-term FL creek level equal to the average base elevation of these pools, high water tables in the floodplain will be maintained during the late fall to early spring period and possibly at other times as well. Rainfall can frequently refill the pools and provide habitat to amphibians, aquatic insects, and other wildlife. The proposed FL is based on the mean elevation (5.60 feet NAVD) of nine pickerelweed-dominated pools at A6 and A6-A (Table 10). The 5.60 feet NAVD elevation equates to a 2.62 feet NAVD elevation at Tracy Canal. The equivalent flow based on the Tracy Canal rating curve is 99.4 cfs (Appendix C).

<u>Duration to protect amphibian habitat</u>

The proposed FL dewatering duration is 120-days, the approximate duration of the dry season in central Florida (mid-February to mid-June). These moderately long duration drawdowns will cause water tables to drop below the average bottom elevation of the pools. Rainfall is unlikely to cause pooling during these periods thus any fish colonizers as well as amphibian larvae will die during that time.

Table 10. Elevation of nine pickerelweed-dominated pools

Transect	Station (feet)	Elevation (feet NAVD)
A6-A	105	5.77
A6-A	350	5.82
A6-A	610	5.55
A6-A	650	5.2
A6-A	780	5.76
A6-A	980	5.69
A6-A	1040	5.81
A6-A	1260	5.23
A6	610	5.59
	mean	**5.60**

Work by Heyer et al. (1975) and Wilbur (1980, 1984) indicate that temporary pools with hydroperiods less than 30 days are too brief to support metamorphosis of many amphibian species. Ponds with hydroperiods longer than one year may allow fish to colonize and consume larvae, rendering the habitat unsuitable for many amphibian species. Pools with intermediate hydroperiods have the greatest species diversity.

Two processes make it likely that the A6-A pools will have intermediate hydroperiods: 1) the annual spring dry-down period when evapotranspiration causes water tables to fall below the level of the creek, and 2) periodic drought (as described by the proposed FL) when the creek level will fall below the mean elevation of the pools. However, a diversity of pool hydroperiods is important on a landscape level to maximize overall species diversity. Different species will be successful during different years in different pools depending on whether it is a wet or dry year (Semlitsch, 2003).

<u>Return interval to protect amphibian habitat</u>

As described in the discussion of FL #1 (protect deep marsh), the proposed return interval of 2.7 years is based on 120-day dewatering probabilities for the maximum elevation of pickerelweed from wetlands at 10 reference sites (Figure 36). Line intercept data from A6 shows that pickerelweed has its minimum elevation at stations 936–946 in the deep marsh (elevation range 3.52–5.28 feet NAVD) and its maximum elevations in these backswamp depressions. The assumption is that by maintaining the hydrologic conditions necessary for pickerelweed, we also maintain habitat requirements for frogs that use these pickerelweed-dominated pools. The mean probability of 120-day, dewatering events is 18.7% and the driest system has a dewatering probability of 36.9%. This driest signature equates to a return interval of 2.7 years.

This FL criterion is the most sensitive metric, although it still allows a relatively high flow reduction (Table 8). Frequency analysis indicates that this criterion would allow a reduction of 21 cfs (Figure 38). This is equivalent to a 21% reduction of mean flow at the head springs.

In summary, the proposed FL criteria maintain the following set of functions:

- Habitat Quality: Water table levels are appropriate to maintain pickerelweed-dominated depressions and deep marshes, and buttonbush-lined sloughs in the floodplain of Alexander Springs Creek.
- Productivity: Amphibian breeding habitats are maintained, upper portions of deep marsh are accessible to wading birds while maintaining lower parts of deep marshes as fish refugia
- Biogeochemistry: Conditions conducive to denitrification are maintained in off-creek sloughs
- Physical processes: High water tables are maintained in the floodplain, which benefits both hydric hammock and hardwood swamp communities

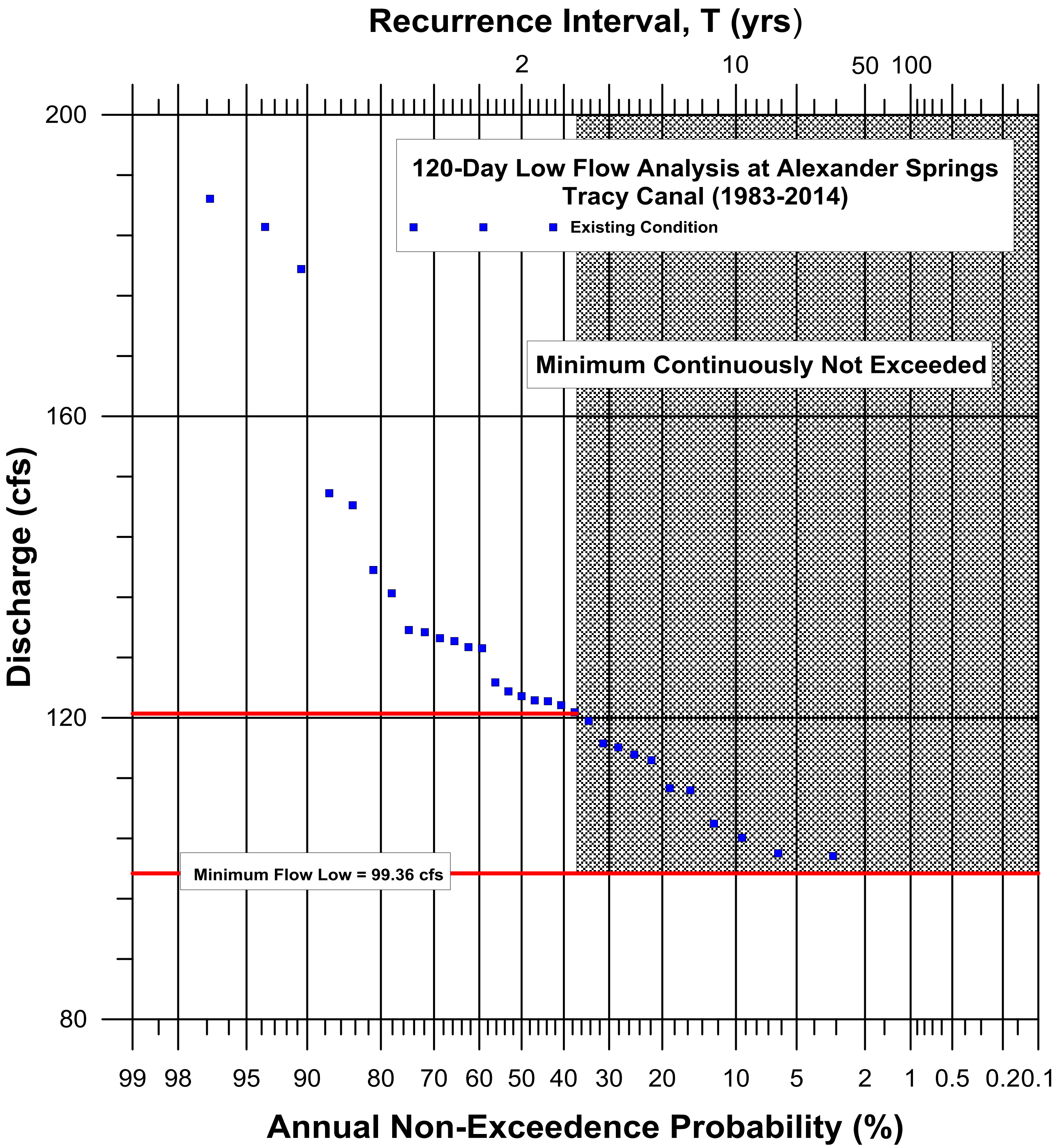

Figure 38. Frequency analysis plot for Frequent Low, the most constraining MFL for Alexander Springs

REVIEW OF ENVIRONMENTAL VALUES (62-40.473, *F.A.C.*)

Based on a screening analysis (Table 7), the following environmental values (Rule 62-40.473, F.A.C.) were deemed relevant considerations for MFLs development at Alexander Springs and Alexander Springs Creek:

- Recreation in and on the water
- Fish and wildlife habitats and the passage of fish
- Estuarine resources
- Transfer of detrital material
- Aesthetic and scenic attributes
- Filtration and absorption of nutrients and other pollutants
- Sediment loads
- Water quality
- Navigation

The environmental value “Fish and wildlife habitats and the passage of fish” had the highest score, an “8” out of a maximum possible score of “9.” Therefore, the criteria developed for this MFLs determination reflect an emphasis on protecting fish and wildlife habitats, particularly wetlands.

Applied Technology and Management, Inc. (ATM) were contracted to evaluate the protection of other relevant environmental criteria based on the MFL recommended herein (ATM 2017). ATM found the recommended MFL for Alexander Springs to be protective of all relevant WRVs, because it prevents unacceptable reductions in inundation of the floodplain and results in very small changes in instream critical velocities (ATM 2017; Appendix E).

CONCLUSIONS AND RECOMMENDATIONS

Alexander Springs is one of only 27 first-magnitude springs in Florida and has been designated by the state as both an Outstanding Florida Water and Outstanding Florida Spring. Several state and federally listed species have been documented within the Alexander Springs Creek basin. The spring and spring run are bordered by national forest lands including the Alexander Springs Wilderness, and comprise one of the most scenic and biologically diverse ecosystems in the state. Because of Alexander Springs' relatively unimpacted conditions, and many natural attributes, the spring boil, and the spring run are both regionally important destinations, for swimming, canoeing, kayaking and other recreation.

Historically, impact to the Alexander spring system, due to groundwater withdrawal, has been minimal. Alexander Springs is surrounded by National Forest and wilderness lands. Current water withdrawals have had minimal effect on flow at Alexander Springs. Impact to the UFA due to groundwater pumping, near Alexander Springs, was estimated using the best available tool, the NDMv5 regional groundwater model. Based on the NDMv5, a flow reduction estimate of 0.7 cfs (< 1%) represents the change in Alexander Springs flow from a no-pumping condition to 2010. Estimated flow reduction (0.4 cfs) resulting from projected water use for the 20-year planning horizon is also very low (SJRWMD 2017).

The Alexander Springs MFLs determination described above identified two MFLs, a Frequent High event and Frequent Low event, based on multiple criteria developed from vegetation, soils and topographical data. Frequency analysis results indicate that the hydrologic requirements for the most sensitive MFL criterion are met under baseline conditions (Figure 38). However, all five ecological criteria investigated (two FH criteria and three FL criteria) were relatively insensitive, allowing for a 21% to 76% reduction in the mean flow of Alexander Springs. This allowable flow reduction is far outside the statewide range (0 to 10%) and many times higher than the mean of recommended flow reduction (6.8%) based on spring MFLs that have been adopted or recommended across the state (Table 11).

One potential reason for the disparity in the estimated allowable flow reduction between the most constraining MFL criterion and the statewide average (6.8%), is due to the lack of data to determine the hydrological requirements of ecological criteria identified for this system. Long-term water level and flow time series at both Tracy Canal and the CR445 bridge are limited and contain numerous gaps. In addition, the hydrologic data at MFLs transects is relative short (less than four years), resulting in increased uncertainty about the variability of the system and the relative contribution of factors other than spring flow to the long-term maintenance of important environmental resources. In particular, the lack of data limits the understanding of the relative importance of spring flow, seepage and ponding for maintaining the specific environmental criteria investigated. Evidence suggests that floodplain swamps and hydric hammock communities at Alexander Springs are supported by seepage and ponding of rain.

Table 11. Allowable flow reduction for spring MFLs in Florida, as of January 26, 2017.

NOTE: Some MFLs reports are still in draft form, but are used because they represent the recommendation of spring flow reduction from respective water management districts.

#	Springs / MFL	District	MFL criteria and Number of Springs Identified	Recommended Flow Reduction
1	Blue Spring — Volusia County	SJRWMD	Thermal refugia for manatee	0%
2	Wekiwa Springs	SJRWMD	Based on flow necessary to meet MFLs for the Wekiva River at SR46	9%
	Rock Springs			
	Messant Spring			
	Miami Springs			
	Palm Springs			
	Sanlando Springs			
	Seminole Springs			
	Starbuck Springs			
3	DeLeon Springs	SJRWMD	Thermal refugia for manatee	9.3%
4	Rainbow	SWFWMD	A minimum flow was recommended for Rainbow Springs based on the recommended Rainbow River MFLs. which were to protect seasonally flooded wetlands, hydric soils, and the associated ecological structure and functions.	5%
5	Blue Spring - Levy County	SRWMD	Maximum flow reduction to prevent significant reductions in the associated water resources	10%
6	Manatee Springs	SRWMD	Thermal refugia for manatee	10%

#	Springs / MFL	District	MFL criteria and Number of Springs Identified	Recommended Flow Reduction
7	Fanning Spring	SRWMD	Maintenance of depth for manatee passage	10%
8	ALA112971 (Treehouse) Santa Fe Rise Hornsby Columbia Poe COL101974 Rum Island July Devil's Ear (Ginnie Group)	SRWMD	Based on the median percent MFL reduction in the streamflows for the Lower Santa Fe River	8%
9	Ichetucknee Head Blue Hole Mission Devil's Eye Grassy Hole Mill Pond	SRWMD	Based on the median percent MFL reduction in the streamflows for the Ichetucknee River	3%
10	Aucilla River and Nutall Rise	SRWMD	Nutall Rise is a resurgence primarily of the Aucilla River	6.5%

#	Springs / MFL	District	MFL criteria and Number of Springs Identified	Recommended Flow Reduction
11	Wacissa River and 12+ Springs	SRWMD	Flow reductions developed for Wacissa River gauge is considered an index for the combined flows of the Wacissa Springs Group	5.1%
12	Homosassa Springs	SWFWMD	Protection of low-salinity benthic habitats	3%
13	Gum Slough Spring Run	SWFWMD	Aquatic habitat availability	6%
14	Peace River at Zolfo Spring	SWFWMD	Officially this is a River MFL but since nearly all the baseflow at low flows is groundwater we included it	8%
15	Chassahowitzka Spring (12 springs)	SWFWMD	Aquatic habitat availability	9%
16	Weeki Wachee Spring	SWFWMD	A 15% reduction of resource/habitat was adopted as representing significant harm	10%

RECOMMENDED MINIMUM FLOW FOR ALEXANDER SPRINGS

Alexander Springs and Springs Creek are relatively unimpacted and of high regional ecological and recreational importance. Given Alexander Springs' OFW and OFS designations, and the uncertainty regarding system hydrology and hydrological requirements of sensitive ecological criteria due to a lack of data, SJRWMD recommends basing the MFL for Alexander Springs on the statewide mean. If future data collection or the identification of more sensitive environmental criteria suggest that a different minimum flow is more appropriate, the Alexander Springs MFL will be reevaluated to incorporate this additional information.

The recommended minimum flow for Alexander Springs is a mean flow of 95.7 cfs. This is the mean flow for the observed period of record (1983–2014) measured at the headspring (USGS gauge 00291896), adjusted by a 7 cfs reduction in spring flow (6.8%), which is equal to the mean flow reduction allowed for springs-based MFLs within Florida. Because a 7 cfs reduction is allowable, and 0.7 cfs reduction has occurred, the allowable flow reduction from current conditions is 6.3 cfs.

Based on the best available information, including the NDMv5 groundwater model, the predicted flow reduction (0.4 cfs) resulting from projected water use for the 20-year planning horizon is less than the flow reduction allowed by the recommended MFL. Therefore, the proposed MFLs for Alexander Springs are achieved for the 20-year planning horizon, and a prevention strategy is not required (SJRWMD 2017).

ONGOING STATUS ASSESSMENT

Future monitoring will be conducted to ensure that the recommended 6.8% flow reduction continues to maintain critical physical characteristics, and protect critical environmental functions and values of Alexander Springs and Alexander Springs Creek. As previously described, a critical part of future monitoring will be the assessment of MFLs compliance. A screening level analysis that incorporates climatic factors and uncertainty will be used to determine whether minimum flows are being achieved. If this screening level analysis suggests that they are not being achieved, further analyses will be undertaken to determine the cause. See the *MFLs Status Assessment* section for more details.

LITERATURE CITED

Barbour, M.G., J.H. Burk, W.D. Pitts, F.S. Gilliam, M.W. Schwartz. 1999. Terrestrial Plant Ecology, Third Edition. Addison, Wesley Longman, Inc. Menlo Park, CA.

Beebee, T.J.C. and R.A. Griffiths. 2005. The amphibian decline crisis: A watershed for conservation biology? Biological Conservation 125: 271–285.

Boniol, D., M. Williams, and D. Munch. 1993. Mapping Recharge to the Floridan Aquifer Using a Geographic Information System. Technical Publication. SJ93-5. St. Johns River Water Management District, Palatka, FL.

Bonn, M. A. 2004. Visitor profiles, economic impacts and recreational aesthetic values associated with eight priority Florida springs located in the St. Johns River Water Management District. Tallahassee, FL: Bonn Marketing Research Group, Inc.

Brooks, H.K. 1982. *Guide to the Physiographic Divisions of Florida*. Compendium to the map Physiographic Divisions of Florida, 8-5M-82. Univ. of Florida, Institute of Food and Agricultural Sciences, Cooperative Extension Service, Gainesville, FL.

Bunn, S. E. and A. H. Arthington. 2002. Basic Principles and Ecological Consequences of Altered Flow Regimes for Aquatic Biodiversity. Environmental Management 30(4): 492–507.

Burns, J.W., A.D. Chapman, E. Messer, and J. Konwinski. 1997. Submerged Aquatic Vegetation of the Lower St. Johns River. Draft Final Report. Prepared for FDEP.

Capers, R.S. 2003. Six years of submerged plant community dynamics in a freshwater tidal wetland. Freshwater Biology 48, 1640–1651.

Carmichael, P. 1991. Florida’s fabulous reptiles and amphibians: their stories. World Publications. Tampa, FL.

Carr, G. M, H. C. Duthie, and W. D. Taylor. 1997. Models of aquatic plant productivity: a review of the factors that influence growth. Aquatic Botany 59 (1997) 195–215.

Catling, P.M., Spicer, K.W., Biernacki, M., Lovett Doust, J., 1994. The biology of Canadian weeds. 103. Vallisneria americana Michx. Can. J. Plant Sci. 74,883–897.

Clapp, D. 2016. Summary of Alexander Creek HEC-RAS Calibration. SJRWMD internal memo.

Cohen, M. J., J. B. Heffernan, A. Albertin, R. Hensley, M. Fork, C. Foster, and L. Korhnak. 2011. Mechanisms of nitrogen removal in spring-fed rivers. University of Florida, School of Forest Resources and Conservation, Gainesville, FL. Final Report to the St. Johns River Water Management District. March 2011.

deMaynadier, P.G. and M.L. Hunter. 1995. The relationship between forest management and amphibian ecology: a review of the North American literature. Environ Rev 3:230–261.

Environmental Laboratory. 1987. Corps of Engineers wetland delineation manual, Technical Report Y-87-1 US Army Engineers Waterways Experiment Station. Vicksburg, MS.

Fagan, W.F., Fortin, M.J., and Soykan, C. 2003. Integrating edge detection and dynamic modeling in quantitative analyses of ecological boundaries. Bioscience 53: 730–738.

Florida Game and Freshwater Fish Commission. 1976. Cross Florida Barge Canal restudy report. Wildlife study. Vols. 1–5. Wildlife Research Laboratory, Gainesville, FL.

Florida Natural Areas Inventory biodiversity matrix. Accessed on line October 2015 (*http://www.fnai.org/biointro.cfm*)

Florida Natural Areas Inventory (FNAI). 2010. Guide to the natural communities of Florida: 2010 edition. Florida Natural Areas Inventory, Tallahassee, FL.

Gerritsen, J. and H.S. Greening. 1989. Marsh seed banks of the Okefenokee swamp: effects of hydrologic regime and nutrients. Ecology 70 (3) pp. 750–763.

Godfrey, R.K. and J.W. Wooten, 1979. Aquatic and wetland plants of southeastern United States. University of Georgia Press, Athens.

Gregoire, D.R. 2005. Tadpoles of the Southeastern United States Coastal Plain. United States Geological Survey Report. Florida Integrated Science Center. 60 pp.

Gunderson, L. 1986. Regeneration of cypress in logged and burned strands at Corkscrew Swamp Sanctuary, Florida. In *Cypress Swamps*, K.C. Ewel and H.T. Odum, eds.Gainesville: University of Florida Press.

Hauxwell, J., T.K. Frazer, C.W. Osenberg. 2007. An annual cycle of biomass and productivity of Vallisneria American in a subtropical spring-fed estuary. Aquatic Botany 87(2007) 61–68.

Hazell, D., J. Hero, D. Lindenmayer, R. Cunningham 2004. A comparison of constructed and natural habitat for frog conservation in an Australian agricultural landscape. Biological Conservation 119, pp.61–71.

Heffernan, J. B., M. J. Cohen, T. K. Frazer, R. G. Thomas, T. J. Rayfield, J. Gulley, J. B. Martin, J. J. Delfino, and W. D. Graham. 2010. Hydrologic and biotic influences on nitrate removal in a subtropical spring-fed river. Limnol. Oceanogr. 55(1): 249–263.

Heyer, W.R., McDiarmid, R.W., Weigmann, D.L., 1975. Tadpoles,predation and pond habitats in the tropics. Biotropica 7, 100–111.

Hillel, D. 1998. Environmental Soil Physics. Academic Press. Amsterdam

Hupalo, R.B., C.P. Neubauer, L.W. Keenan, D.A. Clapp, and E.F. Lowe. 1994. Establishment of minimum flows and levels for the Wekiva River System. Technical Publication SJ94-1. St. Johns River Water Management District Governing Board, Palatka, FL.

Karama, A. 2017. HSPF model report for Alexander Springs and Alexander Springs Creek. SJRWMD.

Kinser, Palmer 2012. Wetland and Soil Types in the Floodplain of the St. Johns River, Florida. Appendix 10-B, Chapter10, Wetlands Vegetation. *In* E.F. Lowe, L.F. Battoe, H. Wilkening, M. Cullum and T. Bartol (Eds). St. Johns River Water Supply Impact Study. Technical Publication SJ2012-1. St. Johns River Water Management District, Palatka, Florida. Accessed July 22, 2014. *www.sjrwmd.com/technicalreports/pdfs/TP/SJ2012-1_Appendix10-B.pdf*.

Knowles, L., A.M. O'Reilly, and J.C. Adamski. 2002. Hydrogeology and simulated effects of groundwater withdrawals from the Floridan aquifer system in Lake County and in the Ocala National Forest and vicinity, North-central Florida. US Geological Survey, Water Resources Investigations Report 02-4207.

Kochman, H.I. 1978. Eastern indigo snake. *Drymarchon corais couperi*. Pages 68–69 *in* R.W. McDiarmid, ed. Rare and endangered biota of Florida. University Pressesof Florida; Gainesville, Florida.

Martin, C.E. and S.K. Francke. 2015. Root aeration function of baldcypress knees (*Taxodium distichum*) Int J. Plant Sci. 176(2):170-173

McFarland, D., 2006. Reproductive ecology of *Vallisneria americana* Michaux. SAV Technical Notes Collection (ERDC/TN SAV-06-4) U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Megonigal, J.P. and F.P. Day. 1992. Effects of flooding on root and shoot production of bald cypress in large experimental enclosures. Ecology 74(4), pp. 1182–1193.

Mitsch, W.J. and J.G. Gosselink. 1993. Wetlands. 2nd ed. Van Nostrand Reinhold. New York.

National Research Council, 1995. Wetlands: Characteristics and Boundaries. National Academy Press. Washington, DC.

[NRCS] United States Dept. of Agriculture, Natural Resources Conservation Service. 2010. *Field indicators of hydric soils in the United States, vers. 7.0*. G.W. Hurt and L.M. Vasilas, eds. Lincoln, Nebr.: USDA, NRCS, in cooperation with the National Technical Committee for Hydric Soils, Fort Worth, Texas.

[NRCS] United States Dept. of Agriculture, Natural Resources Conservation Service. 1999. *Soil Taxonomy,* Second Edition. Soil Survey Staff. Agriculture Handbook No. 436. U.S. Government Printing Office. Washington, D.C.

[NRCS] United States Department of Agriculture, Natural Resources Conservation Service. 2016. Official Soil Series Descriptions. Available online at *http://soils.usda.gov/technical/classification/osd/index.html*.

Neubauer, C.P., C.P. Robison, T.C. Richardson, and P. Valentine-Darby. 2007 (draft). A method for defining surface water inundation/dewatering signatures for plant communities. St. Johns River Water Management District, Palatka, FL.

Neubauer, C.P., G.B. Hall, E.F. Lowe, C.P. Robison, R.B. Hupalo, and L.W. Keenan. 2008. Minimum Flows and Levels Method of the St. Johns River Water Management District, Florida. Environmental Management 42:1101-1114.

Schoeneberger, P.J., D.A. Wysocki, E.C. Benham, and W.D Broderson (eds). 2002. Field book for describing and sampling soils, Version 2.0. Natural Resources Conservation Service, National Soil Survey Center, Lincoln, NE.

Scott, T. M., G. H. Means, R. C. Means, and R. P. Meegan. 2002. First magnitude springs of Florida. Florida Geological Survey Open File Report No. 85. Florida Geological Survey, Tallahassee, FL.

Semlitsch, RD. 2003. Conservation of pond-breeding amphibians. *In* Semlitsch, RD (ed.), Amphibian Conservation (pp. 8–23). Washington: Smithsonian Books.

Shoemaker, W.B., A.M. O'Reilly, N. Depulveda, S.A. Williams, L.H. Motz, and Q. Sun. 2004. Comparison of estimated areas contributing recharge to selected springs in north-central Florida by using multiple ground-water flow models. US Geological Survey. Open File Report 03-448.

[SCS] Soil Conservation Service, United States Department of Agriculture. 1968. Soil Survey of Ocala National Forest Area, Florida. National Cooperative Soil Survey, United States Department of Agriculture.

[SJRWMD] St. Johns River Water Management District. 2006 (draft). Minimum Flows and Levels Methods Manual. G.B. Hall, C.P. Neubauer, and C.P. Robison, eds. St. Johns River Water Management District, Palatka, FL.

SJRWMD. 2012. St. Johns River Water Supply Impact Study. SJR2012-1.

Smart, R.M., R.D. Doyle, J.D. Madsen, and G.O. Dick. 1996. Establishing native submersed aquatic plants communities in southern reservoirs. Technical Report A-96-2. U.S. Army Corps of Engineers Waterways Experiment Statio. Vicksburg, MS

Topa, M. A. and K. W. McLeod. 1986. Responses of *Pinus clausa*, *Pinus serotina*, and *Pinus taeda* seedlings to anaerobic solution culture. I. Changes in growth and root morphology. Physiol. Plantarum, 68: 523-531.

Upchurch, S.B., J. Chen, and C.R. Cain. 2007. Relationships of Nitrate to Discharge in Springs of the Suwannee River Water Management District, Florida. Report prepared by SDII Global Corporation, Tampa, FL, for the Suwannee River Water Management District, Live Oak, FL.

Vince, S.W., S.R. Humphrey, and R.W. Simons. 1989. The ecology of hydric hammocks: a community profile. U.S. Fish Wildl. Serv. Biol. Rep. 85(7.26). 81 pp.

Walsh, SJ, L. Knowles, BG Katz, and DG Strom. 2009. Hydrology, water quality, and aquatic communities of selected springs in the St. Johns River Water Management District, Florida. US Geological Survey Scientific Investigations Report 2009–5046, 116 p.

Ware, C. 2003. Minimum Flows and Levels Plant Ecology Series: Ecological Summaries of Plants Commonly Encountered During Minimum Flow and Level Determinations. No.10. *Taxodium distichum* (L.) Rich (Bald Cypress) and *Taxodium ascendens* Brogn. (Pond Cypress). St. Johns River Water Management District. Palatka, Florida. 45 pp.

Wassersug, R.J. 1975. The adaptive significance of the tadpole stage with comments on the maintenance of complex life cycles in anurans. American Zoologist 15:405–417.

Wilbur, H.M.1980. Complex life cycles. Annual Review of Ecology and Systematics 11:67–93.

Wilbur, H.M. 1984. Complex life cycles and community organization in amphibians. Pp. 195–224 *in* P.W. Price, C.N. Slobodchikoff, and W.E. Gaud, editors. A New Ecology: Novel Approaches to Interactive Systems. John Wiley and Sons, New York, NY.

Young, P.J., B.D. Keeland, and R.R. Sharitz. 1995. Growth response of bald cypress [Taxodium distichum (L.) to an altered hydrologic regime. The American Midland Naturalist, Apr95, Vol 133 Issue 2, p.206, 7p.

APPENDIX A – FIELD DATA COLLECTION METHODS

Elevation Surveys

Vegetation along the transect line is trimmed to allow clear line-of-sight. A measuring tape is used to mark the transect stations. Ground elevations are read using a rod and transit, recorded to the nearest hundredth of a foot. Inundated areas are read as soundings below the top of water, recorded to the nearest tenth of a foot. Measurement intervals may range from 1 foot to 20 feet or more, depending on topographic complexity and distribution of features of interest to the investigator. Such features may include obvious topographic breaks, changes in vegetation or soil features, and high water marks. Spot elevations may also be recorded at discrete points not part of a larger transect.

Elevations are calculated relative to a datum associated with established benchmarks near the transect. All elevation data from this project are relative to NAVD 88. Latitude and longitude data are collected with a global positioning system (GPS) receiver at selected points along the length of the transects.

Soil Sampling Procedures

MFLs field investigations typically involve delineating the extent and types of hydrologically sensitive soil features such as deep organic soils (Histosols and histic epipedons) and hydric indicators (NRCS, 2010). Hydric indicators with alphanumeric “S” abbreviation are restricted to soils with sandy surface textures (loamy fine sand or coarser). Hydric indicators with alphanumeric “F” abbreviation are restricted to soils with finer, mineral, surface textures. Hydric indicators with “A” abbreviations can occur in all soils without regard to surface texture. The extent of hydric indicators along transect lines is estimated by close inspection of topographic breaks in conjunction with frequent soil borings.

Soil borings along transects should sample all significant geomorphic features, landscape positions, and plant communities. Permanently flooded areas such as deep marshes are generally not sampled due to difficulty in obtaining samples and frequent lack of hydric indicators in such environments. Soil profile descriptions follow NRCS guidelines (Schoeneberger et al. 2002). Soil descriptions include the horizon depth, texture, colors, redoximorphic features, presence of roots, and consistence of soil materials.

Taxonomic keys are used to determine classification of selected soil pedons (Soil Survey Division Staff 1999). A soil pedon is the smallest body of one kind of soil sufficient to represent the nature and arrangement of horizons and other features. Soil classification of a pedon allows investigators to query the NRCS website of official series descriptions, select an appropriate soil series, and access associated hydrologic data. The following website provides additional information:

(http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nrcs142p2_053587)

A variant of a soil series is assigned if the pedon fits the taxonomic classification but has some feature that is out of range for the series criteria. A taxadjunct of a soil series may be assigned if the pedon does not fit some part of the taxonomic classification of a soil series but is otherwise similar in morphology and can be expected to have the same properties as the named series.

Vegetation Sampling Procedures

Plant associations are well-documented groupings of vegetation with relatively consistent floristic composition, uniform physiognomy, and a distribution characteristic of a particular habitat (Barbour et al., 1999). For purposes of the MFLs program, plant associations are termed “communities.” Ecotones are intermediate habitats that have characteristics of more than one adjoining community. Community boundaries are spatial localities where the magnitude of change in species composition is greatest (Fagan et al., 2003).

MFLs investigations involve sampling vegetation along a belt transect: a long, narrow, rectangular area sub-divided into smaller sampling areas or plots, which traverses the area of interest (SJRWMD 2006). Each plot represents a separate community or ecotone. Belt width is 10 feet for herbaceous areas and 50 feet for forested areas (Figure A1). Biologists may delineate plots based on presence of dominant or common species, indicator species, vegetation physiognomy, soil characteristics, and topography. A biologist may also deem additional criteria important based on his or her experience in the region. Community types are based on a SJRWMD classification system (Kinser 2012).

Once the sampling plots are defined, a detailed assessment is conducted of vegetation cover, which is the percentage of the plot area beneath the canopy of species rooted within the plot (Barbour, 1999). Cover has greater ecological significance than stem density since it is a better measure of biomass. Since the canopies of plant species often overlap, total cover may sum to more than 100 percent. Cover of each species within a plot is recorded based on an ocular estimate, a technique known as relevé. Annuals, vines, and floating species, which are not reliable indicators of site hydrology, are often excluded from the assessment. Broad cover class estimates are preferable because results are more likely to be consistent between observers. The following cover class scale (with descriptors) is based on a Braun-Blanquet cover abundance scale (Barbour et al, 1999):

- 5: >75% cover (dominant)
- 4: 50-75% cover (co-dominant)
- 3: 25-50% cover (abundant)
- 2: 10-25 % cover (numerous)
- 1: 1-10% cover (scattered)
- 0: <1 % cover (rare)

Line-intercept is a technique used in the MFLs program to sample distribution of plant species. This semi-quantitative method involves measuring the lengths of vegetation by plant species that either overlap the transect line or that occur within a defined distance of the line. This data can confirm or modify plant community boundaries based on professional judgment. It can also provide information on finer-scale vegetation features that are hydrologically sensitive but not detected by the belt method. While the belt method involves delineating community boundaries prior to collecting cover data, the line intercept method collects vegetation data prior to delineating community boundaries. The two techniques used in conjunction improve accuracy and consistency of vegetation surveys.

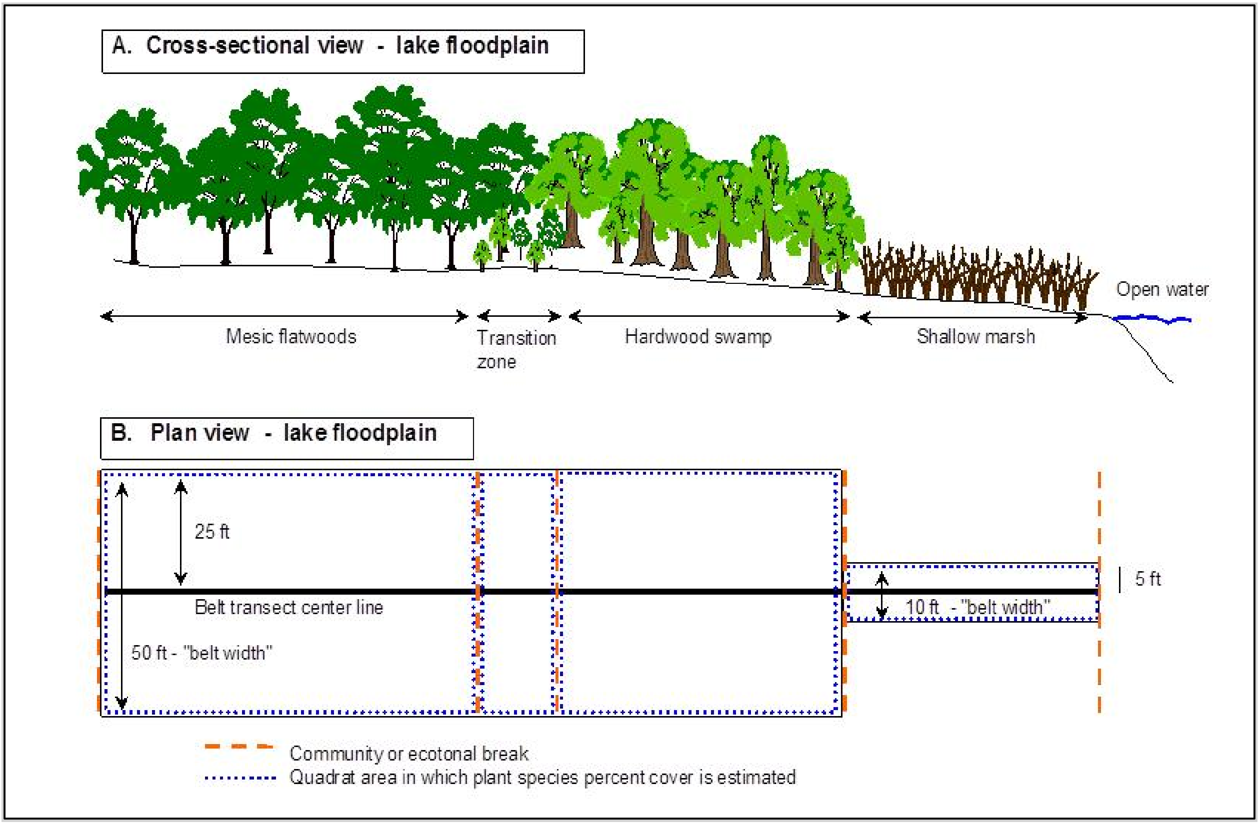

Figure A1 Generalized belt transect through forested and herbaceous plant communities

HYDROLOGIC MODEL DEVELOPMENT OF ALEXANDER SPRINGS CREEK FOR MFLs EVALUATION

by

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Draft

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Bureau of Resource Evaluation and Modeling

St. Johns River Water Management District

Palatka, Florida

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EXECUTIVE SUMMARY

Alexander Springs watershed is located mainly in the northeastern corner of Lake County, Florida. Most of the watershed areas are in the Ocala National Forest. Ocala National Forest is the second largest nationally protected forests in the United States. The climate is subtropical and characterized by warm, humid, rainy summers and temperate dry winters.

The major feature in the watershed is the Alexander Springs. It is a first-magnitude spring in Florida (Scott et al., 2004). The water flows westward for a few hundred yards and then flows eastward to Alexander Springs Creek until it reaches the St. Johns River south of Lake Dexter (Astor). The creek is about 8 miles. The contributing recharge areas of Alexander Springs range from 60 to 110 sq. mile (Shoemaker et al. 2004). Riparian areas surrounding Alexander Springs Creek are mixed hardwood, pine, and palm forest and wetlands.

The watershed consists of eight sub-watersheds. They are Farles Lake, Nine Mile Creek, Upper Alexander Springs, Mud Pond, Glen Branch, Middle Alexander Creek, Tracy Canal, and Lower Alexander Creek. The sub-watershed Farles Lake is considered as a non-contributing area.

This study reports a hydrologic modeling of Alexander Springs watershed.

The Alexander Springs watershed hydrologic modeling uses the Hydrological Simulation Program – FORTRAN (HSPF) model. HSPF is a continuous watershed model that simulates the hydrologic processes of land surfaces and water quantity and quality of natural and man-made water systems.

Rainfall and evapotranspiration are the primary driving forces of HSPF simulation. The model uses two long-term NOAA rainfall gauges which are near study area. The NOAA stations are DeLand and Lisbon gauges. The mean annual rainfall for the period of 1/1/1948 to 21/31/2014 at DeLand and Lisbon are about 56 and 48 inches, respectively. The lowest annual rainfall at Lisbon was about 29.28 in. in year 2000, which is a know dry year. At DeLand, the driest year was 2006 at about 38.48 in. of rainfall. The highest annual rainfall at DeLand and Lisbon are 76.69 in. for year 2001 and 67.58 in. for year 1959, respectively. The NOAA rainfall data for both stations are daily data. The daily data were disaggregated to hourly data that are used in the HSPF model.

Potential evapotranspiration (PET) is one of the essential time series in the HSPF model. Temperature data at both DeLand and Lisbon were used to compute PET based on Hargraves-Samani (1985) method. The mean annual PET for the period of 1/1/1948 to 21/31/2014 at DeLand and Lisbon are about 59.41 and 58.42 inches, respectively.

Land use and land cover 1995 data obtained from District’s GIS database were used in the modeling. The land use and land cover data were combined and grouped into 14 major classifications for modeling purposes. The dominant land use category, more then 70% area, in the watershed is forest. Most the Alexander Springs watershed is within the Ocala National Forest. Wetlands land use category is a distance second with about 18% of the land area. Not much has changed from 1995 land use and land cover. For modeling purposes, wetland land use in the watershed is subdivided into riparian wetland if it is within 35 feet of the nearest model reach and non-riparian wetland if it is further away. Riparian wetlands are assumed to flow directly to the reach while non-riparian wetlands flow into other land use units before it reaches the stream. Furthermore, the residential and industrial/commercial land uses are subdivided into pervious and impervious segments.

The HSPF model was calibrated for a period of record from 10/10/2003 to 12/31/2014 based on the available observed data. The period of calibration covers both dry and wet years in the watershed. Both discharge and stage were considered in the calibration.

A parameter estimation optimization tool PEST was utilized in model calibration. PEST is a non-linear parameter estimator that adjusts and evaluates model parameters based on the improvements of objective functions. Major objective function includes matching daily, monthly, and annual discharges as well as flow duration curves between observed and simulated data.

Various analysis of the calibration results was performed to ascertain the robustness of the model. The overall performance of the model was determined through conservation of mass within each land segment of the watershed. All the components of the water balance appear to be very reasonable. Comparisons of observed and simulated discharge and stage hydrographs as well as their duration curves indicate very reasonable model calibration. The overall daily mean simulated discharge and stage are 132.31 cfs and 4.31 ft, NGVD while the corresponding observed values are 129.07 cfs and 4.23 ft, NGVD. The mean simulated discharge and stage are within 2% of the observed discharge and stage.

INTRODUCTION

PROJECT AREA

The study area is located mainly in the northeastern corner of Lake County, Florida (Figure 1). The total watershed area is about 63,419 acres. Most of the watershed areas are in the Ocala National Forest. Ocala National Forest is one of the (second) largest nationally protected forests in the United States. The climate is subtropical and characterized by warm, humid, rainy summers and temperate dry winters.

The major feature in the watershed is the Alexander Springs. It is a first-magnitude spring in Florida (Scott et al., 2004). It discharges water from a large cavernous opening in the bottom central part of the pool. The spring pool measures about 300 ft. from north to south and about 258 ft. from east to west. The pool has a maximum depth of about 28 ft. U.S. Forest Service maintains an open to the public multiple use recreational area at the spring pool.

The water flows westward for a few hundred yards and then flows eastward to Alexander Springs Creek until it reaches the St. Johns River south of Lake Dexter (Astor). The creek is about 8 miles. The contributing recharge areas of Alexander Springs range from 60 to 110 sq. miles (Shoemaker et al. 2004). Riparian areas surrounding Alexander Springs Creek are mixed hardwood, pine, and palm forest and wetlands.

The watershed consists of eight sub-watersheds (Figure 2). The sub-watershed Farles Lake is considered as a non-contributing area. Table 1 presents the sub-watersheds and their corresponding areas.

Table 1. Alexander Springs Creek Watershed

SUB-WATERSHED NAME	SUB-WATERSHED ID	AREA (acres)
FARLES LAKE	0	20662.81
NINEMILE CREEK	1	15874.89
UPPER ALEXANDER SPRING CREEK	2	1248.49
MUD POND	3	6476.74
GLENN BRANCH	4	8771.37
MIDDLE ALEXANDER SPRING CREEK	5	4915.37
TRACY CANAL CONNECTION	6	3959.77
LOWER ALEXANDER SPRING CREEK	7	1509.84
TOTAL		63419.28

PURPOSE AND SCOPE

The SJRWMD is charged with protecting priority water bodies by developing minimum flows and levels (MFLs) pursuant to section 373.042, Florida Statutes (F.S.). Minimum flows for Alexander Springs are scheduled for establishment in 2017. Alexander Springs has been designated an Outstanding Florida Spring (OFS), and as such, Florida Statute requires the adoption of MFLs for this priority water body by July 1, 2017.

The purposes of this report are to:

- Present the hydrologic modeling of the Alexander Springs Creek watershed.

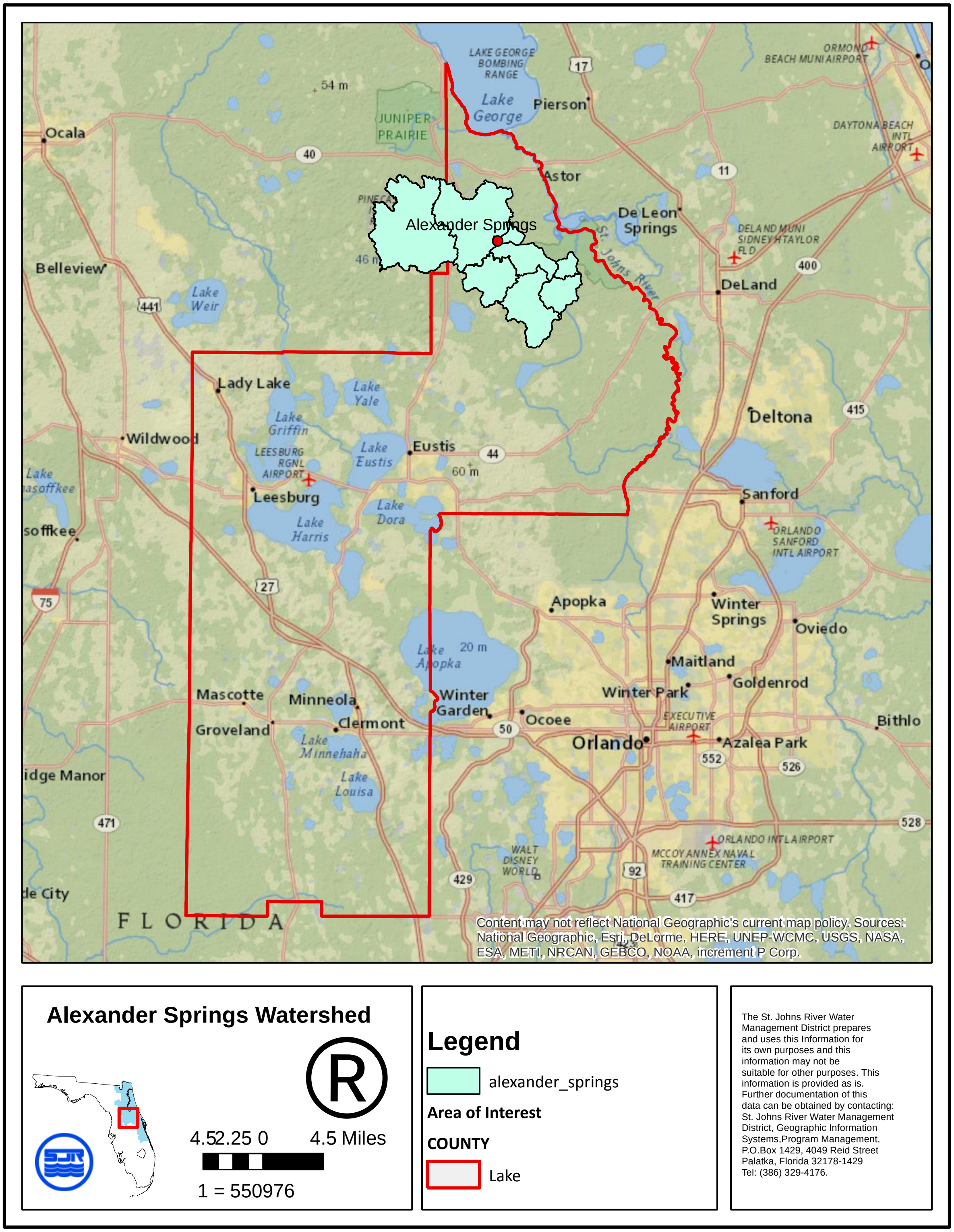

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Figure 1. Alexander Springs Watershed

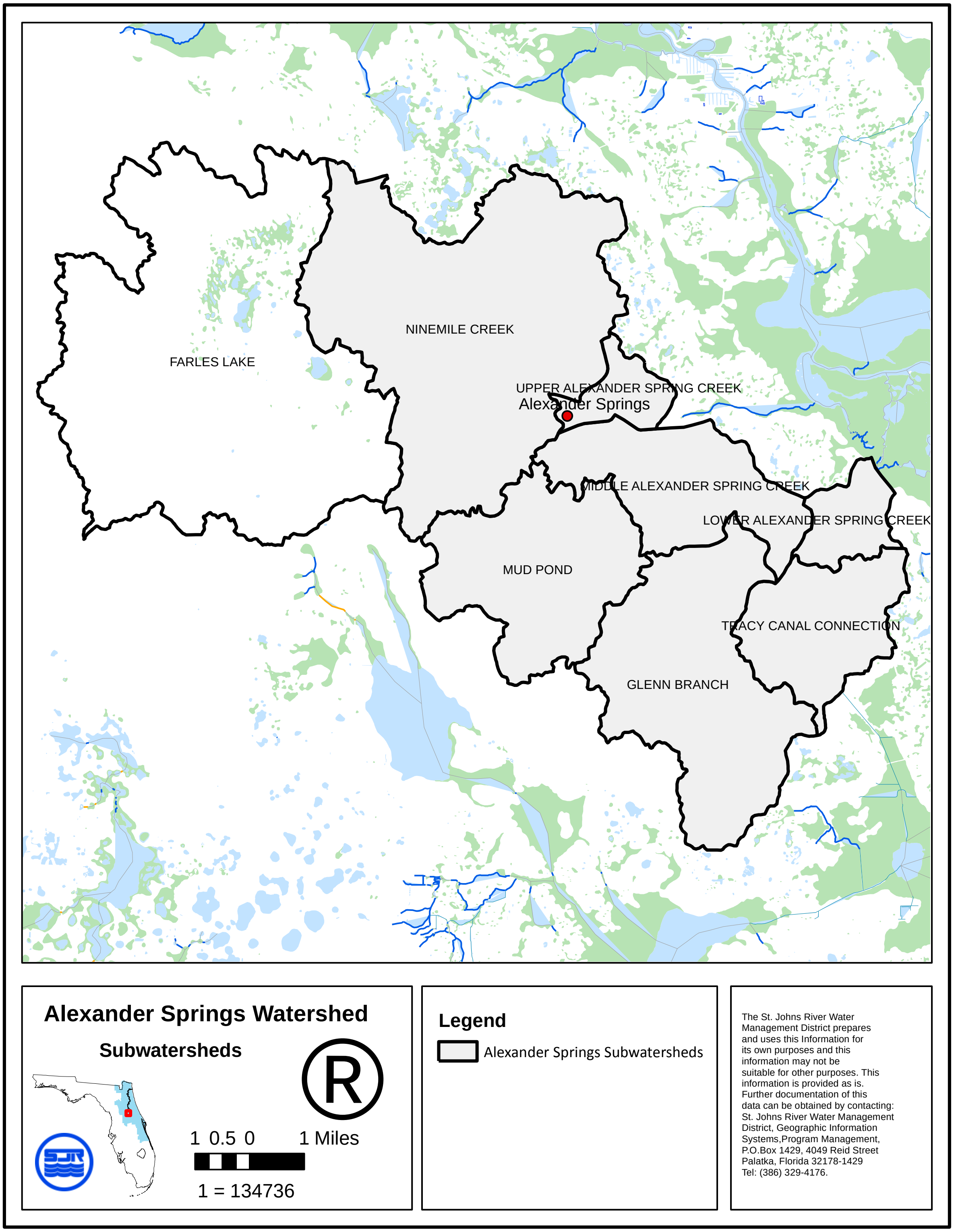

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Figure 2. Alexander Springs Sub-Watersheds

HSPF MODEL DEVELOPMENT

The Alexander Springs Creek watershed hydrologic modeling uses the Hydrological Simulation Program – FORTRAN (HSPF) model. HSPF is a continuous watershed model that simulates the hydrologic processes of land surfaces and water quantity and quality of natural and man-made water systems (Bicknell et al. 2005). HSPF model conceptualizes the watershed into two processes:

- Land Surface Processes
- Instream Processes

LAND SURFACE PROCESSES

HSPF conceptualizes the watershed into land segments. A land segment is an area with similar hydrologic characteristics. A land segment that has the capacity to allow enough water infiltration is defined as a pervious land segment. Impervious land segment has a little or no infiltration capacity. In HSPF, PERLND module simulates the water quantity and quality processes on a pervious land segment, while IMPLND module simulates the water quantity and quality processes on an impervious land segment. Specialized sub-modules in PERLND and IMPLND handle the details of land surface processes.

INSTREAM PROCESSES

RCHRES module in HSPF simulates the processes that occur in streams and lakes. Flow in RCHRES is normally unidirectional. Specialized sub-modules in RCHRES simulate the details of physical and biochemical processes in water systems.

DATA REQUIREMENTS

HSPF model uses extensive meteorological, spatial, and hydrological data. However, data requirements vary depending on the objectives of the modeling.

METEOROLOGICAL DATA

Rainfall and evapotranspiration are the primary driving forces of HSPF simulation. Other meteorological data may include air temperature, dew point temperature, solar radiation, wind speed, and cloud cover. The compilation and manipulation of basic meteorological data were part of the District's Water Supply Impact Study (WSIS) study (WSIS, 2012).

Rainfall

The model uses two long-term NOAA rainfall gauges which are in the vicinity of study area. The NOAA stations are DeLand and Lisbon gauges. Figure 3 shows locations of the NOAA rainfall gauges. Table 2 presents summary description of the gauges. The location of both these gauges have slightly varied over the period of record. The Lisbon gauge is a conglomeration of two different NOAA rain gauges located near lake Eustis. These gauges are the NOAA Eustis (08-2827) from Jan-1948 through Nov-1958 and Lisbon (08-5076) from Dec-1958 through Dec-2014. The Eustis gauge was located at latitude $28^{o}\ 50^{'}\ 00^{''}$ and longitude $81^{o}\ 40^{'}\ 00^{''}$.

The annual rainfall time series of DeLand and Lisbon gauges are shown in Figure 4 and Figure 5, respectively. Rainfall gauges commonly have periods of missing and accumulated record. To develop a period of record which can be used for modeling purposes, the missing data are estimated and filled.

The district has used two different methods to do these estimates. Up to 2008, estimates were made from nearby rain gauges. Accumulated daily rainfall was disaggregated using the surrounding rain gauge data distribution from the gauge with the closest cumulative total to the data being estimated. NOAA in their annual summaries estimated data for many missing periods in early records. If these data were available, these estimates were used, otherwise, missing data were estimated using the average total rainfall data for the period of missing record at three closest rainfall stations. When data were missing for periods of over a month, rainfall was estimated on a monthly period. These rainfall totals were then disaggregated using the same method as disaggregation of accumulated data. From 2009 through 2014 the estimation method uses radar rainfall data for accumulated distributions and missing rainfall periods.

A summary of descriptive statistics is presented in Table 3. A comparison of annual rainfall data is shown in Figure 6. Overall, the DeLand mean annual rainfall and the standard deviation are higher than Lisbon. The mean annual rainfall for the period of 1/1/1948 to 21/31/2014 at DeLand is about 56 in. compare to about 48 in. at Lisbon. The lowest annual rainfall at Lisbon was about 29.28 in. in year 2000, which is a know dry year. At DeLand, the driest year was 2006 at about 38.48 in. of rainfall. The highest annual rainfall at DeLand and Lisbon are 76.69 in. for year 2001 and 67.58 in. for year 1959, respectively.

The NOAA rainfall data for both stations are daily data. However, the HSPF model for Alexander Creek uses hourly data. The daily data were disaggregated to hourly data using WDMUtil software (Hummel et at., 2001). The daily data were disaggregated by using the hourly data rainfall stations with the closest daily total rainfall. The hourly stations primarily used for this area were Orlando, Daytona Beach, Lisbon, and Lynne. The Lisbon hourly although located at a nearby location is a different gauge from the daily gauge used to develop the daily data. The hourly gauge is a tenth of an inch recorder and had many periods of missing record which is why it was not used to develop the daily data. From 2009 through 2014, the disaggregation method uses the hourly radar rainfall data instead of nearby stations data.

Table 2. NOAA Rainfall Stations

Station Name	Site ID	Latitude (dd mm ss.ss)	Longitude (dd mm ss.ss)
DeLand	08-2229	29° 01′ 00″	81° 19′ 00″
Lisbon	08-5076	28° 52′ 00″	81° 47′ 00″

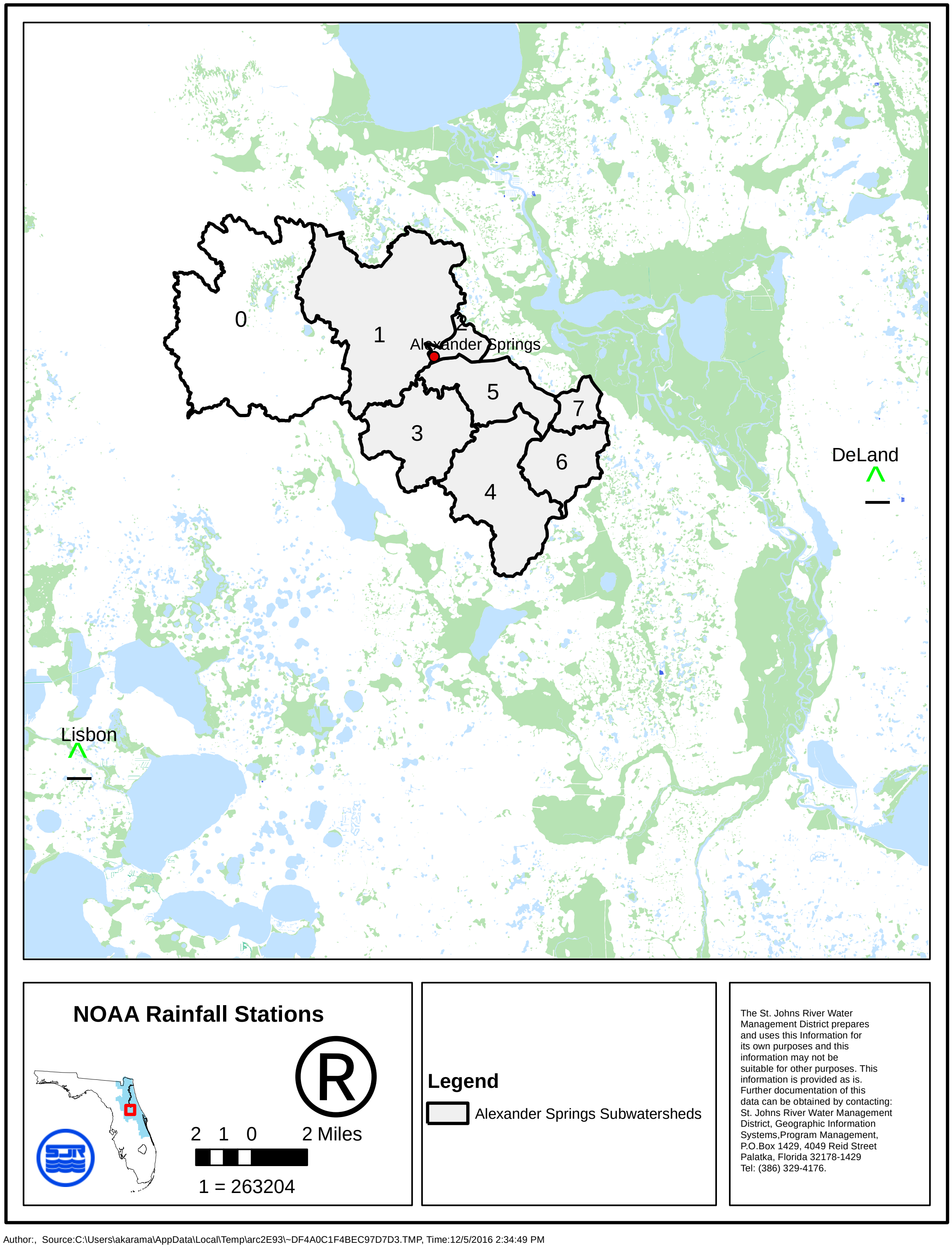

Figure 3. Location of NOAA Rainfall Stations

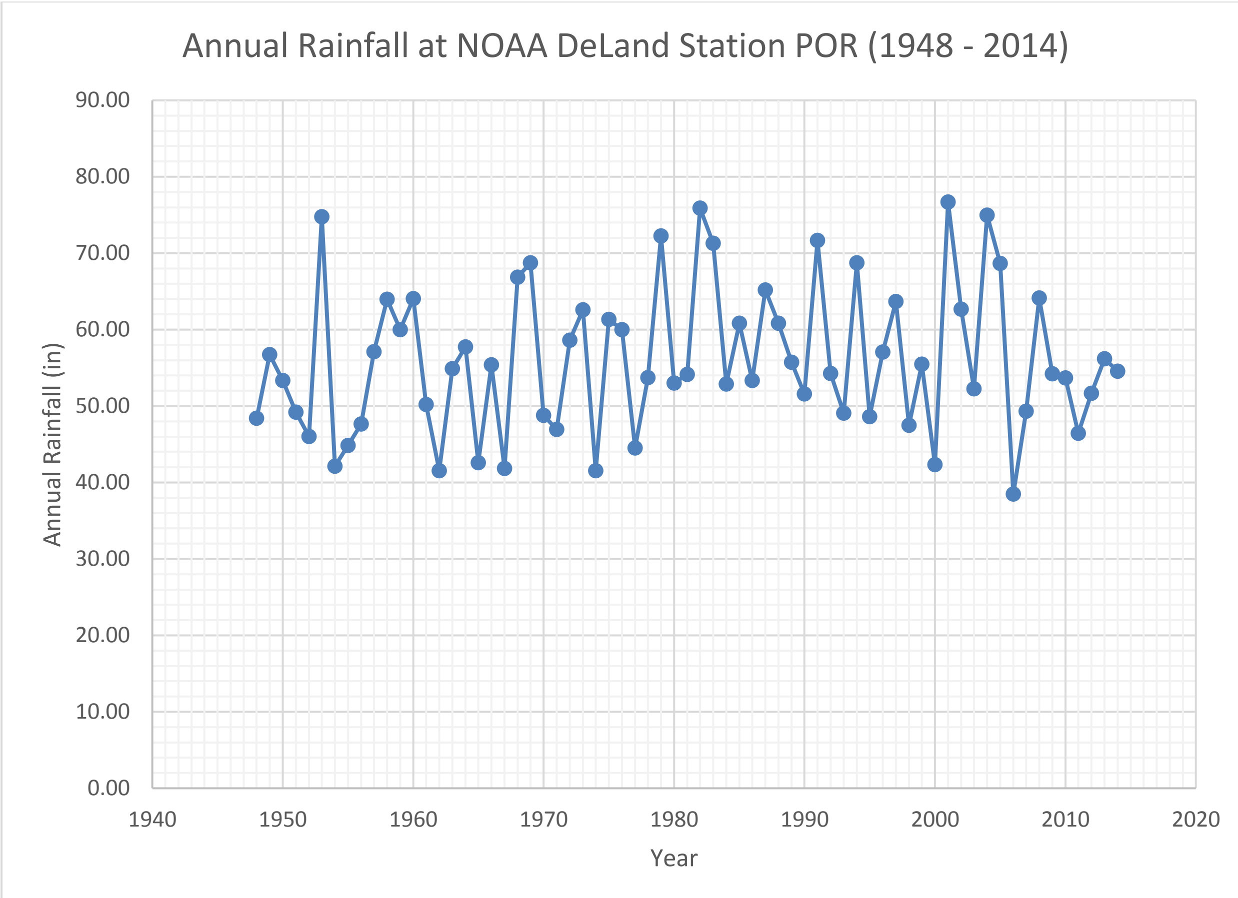

Figure 4. Annual Rainfall (in) at DeLand Station (1948 - 2014)

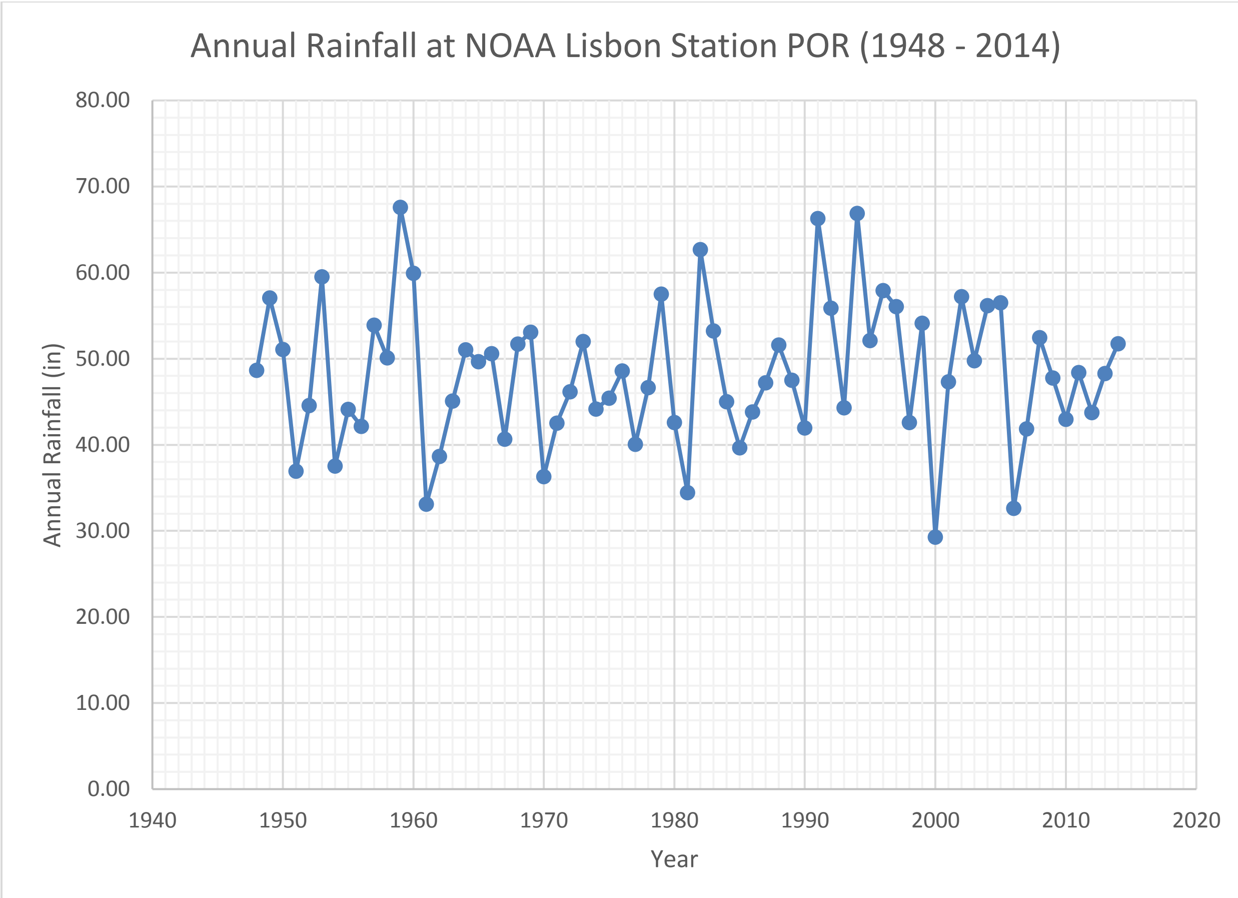

Figure 5. Annual Rainfall (in) at Lisbon Station

Table 3. Summary Statistics of Rainfall (in) at the NOAA Stations (1948 - 2014)

Statistical Parameter	DeLand	Lisbon
Mean	56.06	48.32
Standard Error	1.17	1.00
Median	54.55	48.26
Standard Deviation	9.56	8.18
Sample Variance	91.38	66.88
Minimum	38.48	29.28
Maximum	76.69	67.58

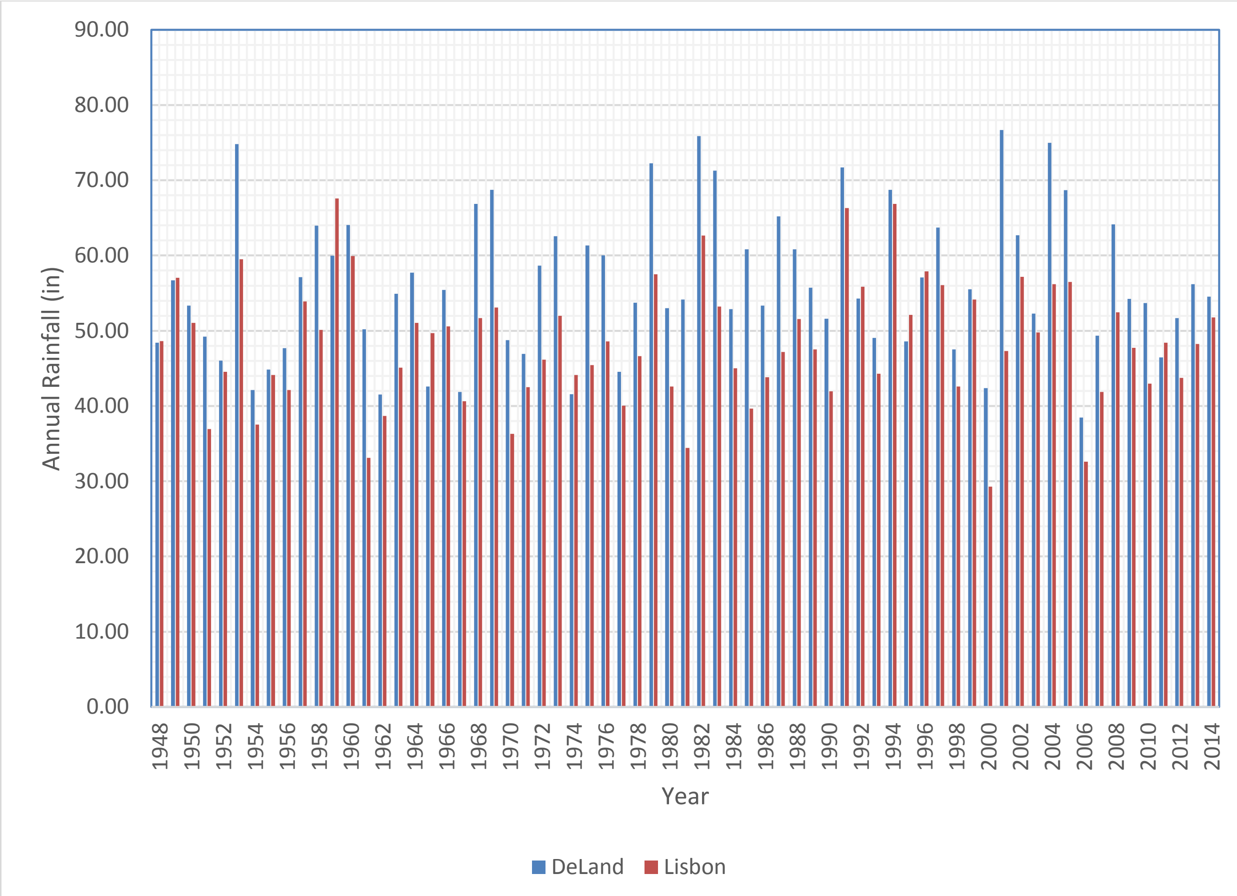

Figure 6. Comparison of Annual Rainfall at the NOAA Stations

Evapotranspiration

Potential evapotranspiration (PET) is one of the essential time series in the HSPF model. PET was computed using Hargraves-Samani (1985) method. The method is a simple temperature equation requiring daily minimum and maximum air temperature and extraterrestrial radiation, which is computed from the latitude of the station and the time of the year.

The Hargreaves-Samani PET equation is written as (Hargreaves and Samani, 1985; Hargreaves and Allen, 2003):

$$PET = (0.408\ ) (0.0023)\ R_a\ (T_{mean} + 17.8)\ (\Delta T)^{0.5}$$

Where

PET: daily potential evapotranspiration in mm/d

R_a: extraterrestrial radiation in MJ/ m^2/d

T_{mean}: mean air temperature in degrees Celsius estimated as the average of minimum (T_{min}) and maximum (T_{max}) daily air temperature

ΔT: difference between T_{max} and T_{min} in degrees Celsius.

The coefficient 0.408 is a conversion factor, which converts MJ/ m^2/d to mm/d, and 0.0023 is an empirical constant of the Hargreaves -Samani equation.

Daily extraterrestrial radiation (R_a) estimation is based on the Sun-Earth geometry for a given day of the year and latitude (Allen et al., 2005).

$$R_a = \frac{118}{\pi} d \begin{Bmatrix} \sin(\theta)\sin(\delta)\,[cos^{-1}(-\tan(\delta)\tan(\theta))] \\ + \cos(\theta)\cos(\delta)\,sin[cos^{-1}(-\tan(\delta)\tan(\theta))] \end{Bmatrix}$$

Where

d: the inverse relative distance between earth and sun, which is approximately equal to 1.0

θ: latitude in radians (negative in the southern hemisphere and positive in the northern hemisphere)

Δ: declination angle of the sun in radians for each day of the year (J), approximated using the the following equation (Allen et al., 2005)

$$\delta = 0.409 \sin\left(\frac{2\pi}{365}(J - 80)\right)$$

In Florida, statewide PET/RET data are available for 1995 – 2015 from USGS Florida Water Science Center database (USGS, 2015). The data rely on Geostationary Operational Environmental Satellites (GOES) providing near continuous infrared incoming solar radiation data. The GOES uses Priestly-Taylor method to compute PET.

The Hargraves-Samani method was scaled with a coefficient to GOES Priestly-Taylor evaporation estimate (WSIS, 2012). The coefficient is obtained by regressing Hargraves-Samani PET against Priestly-Taylor PET.

Data at NOAA weather stations of DeLand and Lisbon were used to develop PET data at the two locations using Hargraves-Samani method. The daily PET data from the two stations were disaggregated into hourly values using the WDMUtil software. The PET coefficients of DeLand and Lisbon stations are 0.8726 and 0.9114, respectively. Figure 7 shows the computed annual PET data for POR from 1948 to 2014 at both DeLand and Lisbon stations. Table 4 presents summary descriptive statistics of PET at both stations for POR (1948 – 2014).

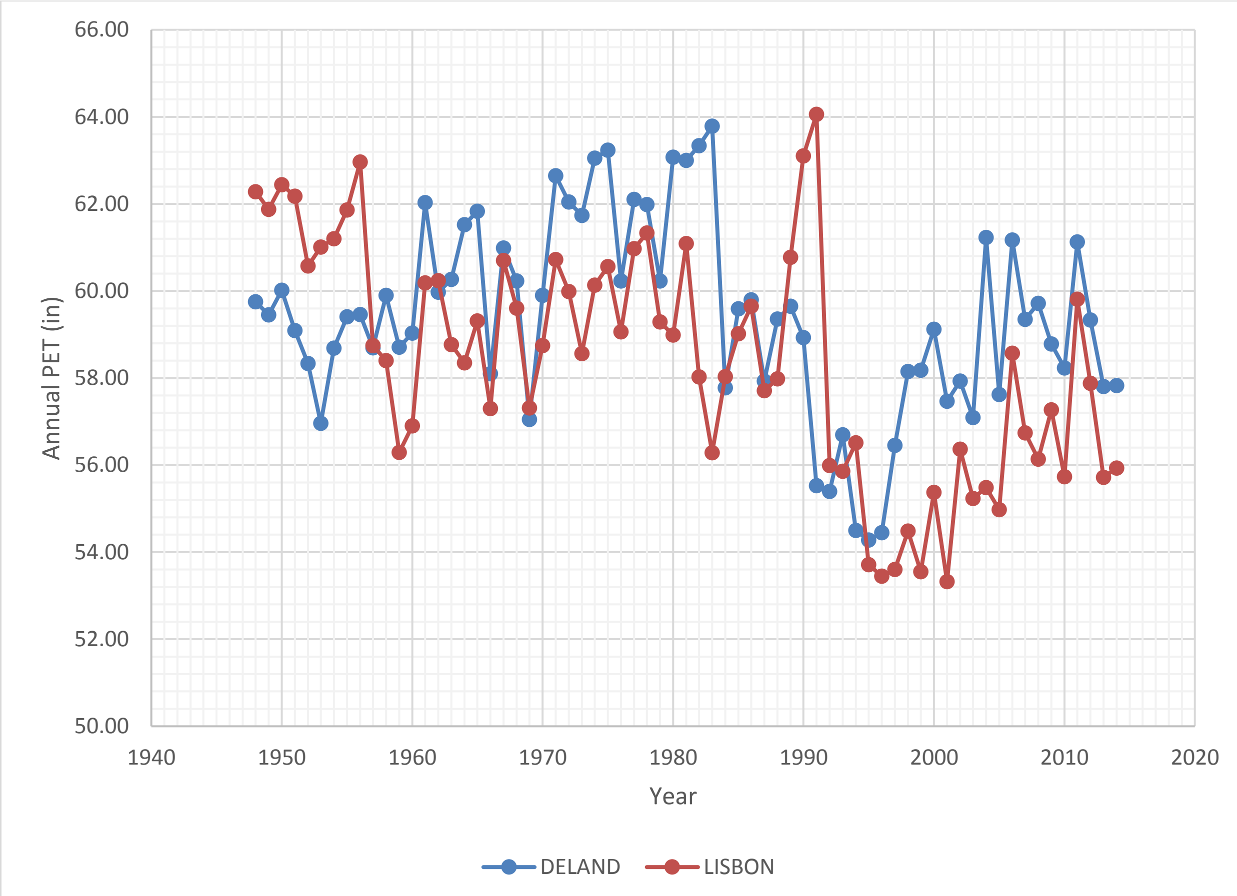

Figure 7. Annual Computed PET at DeLand and Lisbon Stations POR (1948 - 2014)

Table 4. Computed PET (in) Summary Statistics at Deland and Lisbon for POR (1948 - 2014)

Statistical Parameter	DeLand	Lisbon
Mean	59.41	58.42
Standard Error	0.27	0.32
Median	59.41	58.57
Mode	59.90	58.75
Standard Deviation	2.23	2.66
Minimum	54.28	53.32
Maximum	63.79	64.06

SPATIAL DATA

Land use and land cover distributions within the basin as well as soil characteristics are of a great important to the watershed hydrology in general and model parameters in particular. Land use and land cover 1995 data were obtained from District's GIS database. Ocala National Forest is the dominant feature in land use of the watershed. Not much has changed from 1995 land use and land cover.

The detailed land use and land cover data were combined and grouped into 14 major classifications for modeling purposes as presented in Table 5. Figure 8 shows a generalized 1995 land use. Land use and land cover classifications follow WSIS study classification and descriptions (WSIS, 2012).

Table 5. Entire Watershed 1995 Land Use

Land Use Description	1995 Land Use Area (ac.)	Percent Area (%)
Low-density residential	649.00	1.02
Medium-density residential	743.00	1.17
High-density residential	28.00	0.04
Industrial and commercial	117.00	0.18
Mining	0.00	0.00
Open and barren land	528.00	0.83
Pasture	189.00	0.30
Agriculture general	373.00	0.59
Agriculture tree crops	75.00	0.12
Rangeland	483.00	0.76
Forest	49614.00	78.23
Water	2305.00	3.63
Wetlands combined	8315.00	13.11
Total	63419.00	100.00

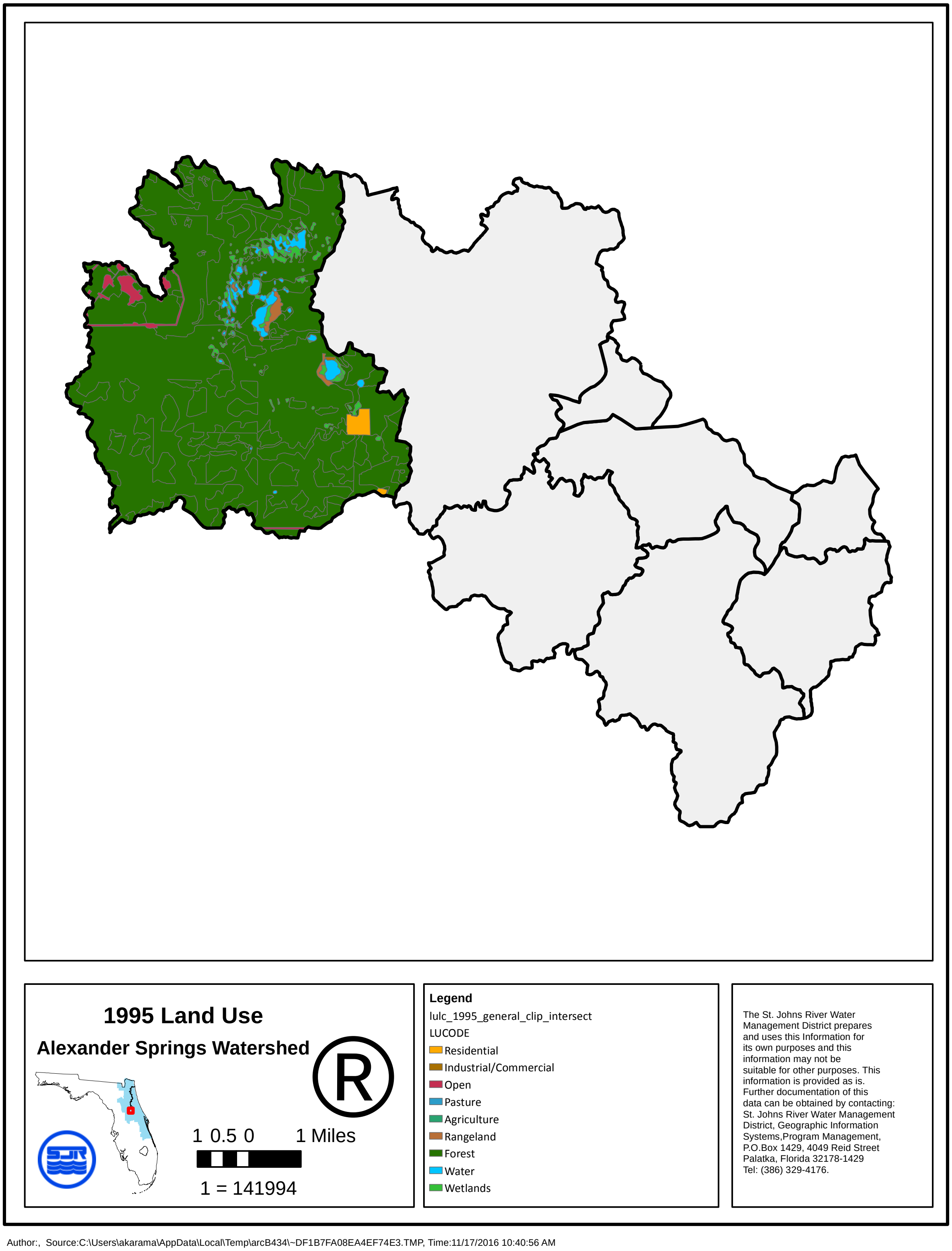

Figure 8. Alexander Springs Watershed 1995 Land Use

As Table 6 shows, the dominant land use category, more then 70% area, in the watershed is forest. The majority of the Alexander Springs watershed is within the Ocala National Forest. Wetlands land use category is a distance second with about 18% of the land area. Table 6 presents the contributing Alexander Springs sub-watershed 1995 land use.

For modeling purposes, wetland land use in the watershed is subdivided into riparian wetland if it is within 35 ft. of the nearest model reach and non-riparian wetland if it is further away. Riparian wetlands are assumed to flow directly to the reach while non-riparian wetlands flow into other land use units before it reaches the stream. Figure 9 shows riparian and non-riparian wetlands in the Alexander Springs watershed. Furthermore, the residential and industrial/commercial land uses are subdivided into pervious and impervious segments. The impervious segments are basically the directly connected impervious areas (DCIA) which produce high runoff directly to the stream. Table 7 shows the conversion rate used to develop the impervious areas.

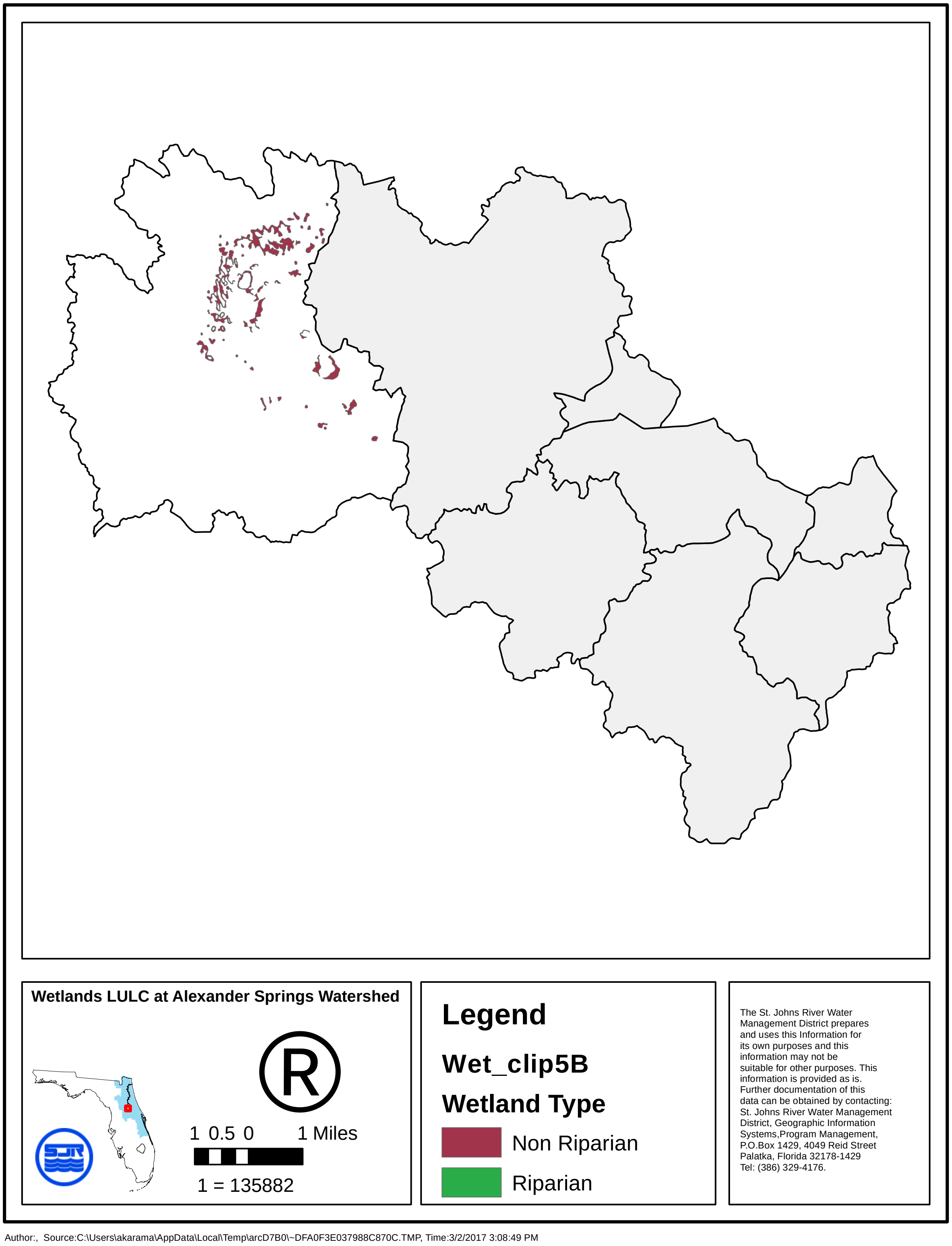

Figure 9. Riparian and Non-Riparian Wetlands in Alexander Springs

Table 6. Alexander Springs Sub-watershed land uses in acres

Land Use Description	Glenn Branch	Lower Alexander Creek	Middle Alexander Creek	Mud Pond	Nine Mile Creek	Tracy Canal	Upper Alexander Creek	Total Area (ac)	Percentage Area
Low Density Residential	247.80	15.90	114.50	23.00	89.90	16.00	0.00	507.10	1.19
Medium Density Residential	390.80	0.00	0.00	53.70	0.00	298.40	0.00	742.90	1.74
High Density Residential	28.10	0.00	0.00	0.00	0.00	0.00	0.00	28.10	0.07
Industrial and Commercial	25.80	0.00	0.00	0.00	81.60	0.00	0.00	107.40	0.25
Mining	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Open Land	69.60	0.00	3.70	46.70	95.20	26.10	13.70	255.00	0.60
Pasture	128.20	0.00	0.00	46.10	0.00	14.20	0.00	188.50	0.44
Agriculture	372.90	0.00	0.00	0.00	0.00	0.00	0.00	372.90	0.87
Agriculture Trees	74.70	0.00	0.00	0.00	0.00	0.00	0.00	74.70	0.17
Rangeland	183.20	0.00	0.00	7.70	179.40	10.00	4.00	384.30	0.90
Forest	5503.20	1112.20	3547.90	6067.90	10639.70	2652.10	786.70	30309.70	70.89
Water	503.60	12.80	0.00	20.20	1118.90	145.80	23.30	1824.60	4.27
Riparian Wetlands	1009.60	363.50	1152.00	16.50	2886.50	515.30	411.50	6354.90	14.86
Non-Riparian Wetlands	233.60	5.70	97.00	194.50	783.10	281.80	9.10	1604.80	3.75
Total	8771.10	1510.10	4915.10	6476.30	15874.30	3959.70	1248.30	42754.90	100.00

Table 7. Percentage Impervious Area

Land Use Description	Percentage Impervious Area
Low Density Residential	5
Medium Density Residential	15
High Density Residential	35
Industrial and Commercial	50

HYDROLOGIC DATA

The hydrologic data at Alexander Springs watershed are retrieved from SJRWMD database. Table 8 summarizes the available SJRWMD stations in the watershed. Figure 10 shows the gage stations in the watershed.

Alexander Springs discharge data at SJRWMD station 00291896 are not continuous daily data but rather they are random samples. In the early period, the samples are sporadic monthly data. From 2002, the data are regular monthly samples. Except some early high values, the spring discharge is very consistent with a mean value of 102 cfs. The daily discharge data were estimated by linearly interpolating the irregular samples. Figure 11 shows the observed Alexander Springs discharge hydrograph. The observed Alexander Springs stage data from 1980 to 2001 are irregular monthly samples. Regular monthly data are collected from 2002 to 2013. From 2014 to current, the observed stage data daily. Figure 12 presents the observed stage data at Alexander Springs. Table 9 and Table 10 present the summary descriptive statistical data of discharge and stage, respectively.

Table 8. SJRWMD Stations at Alexander Springs Watershed

Station Number	Station Name	Discharge Period of Record	Stage Period of Record
00291896	Alexander Springs at Astor	2/12/1931 - Current	10/30/1980 - Current
18523784	Alexander Springs Run at CR445	10/1/2003 – 4/3/2012	10/9/2003 - Current
18553786	Alexander Springs Run at Tracy Canal	10/1/2003 - Current	10/10/2003 - Current
34365072	Alexander Springs Creek A1 at Shell Landing	-	5/14/2014 - Current
31033149	Alexander Springs Creek Transect A5 North Bank	-	3/23/2010 - Current
31023387	Alexander Springs Creek Transect A6 North Bank	-	3/23/2010 - Current
31273459	Alexander Springs Creek Transect A8 North Bank	-	3/23/2010 - Current

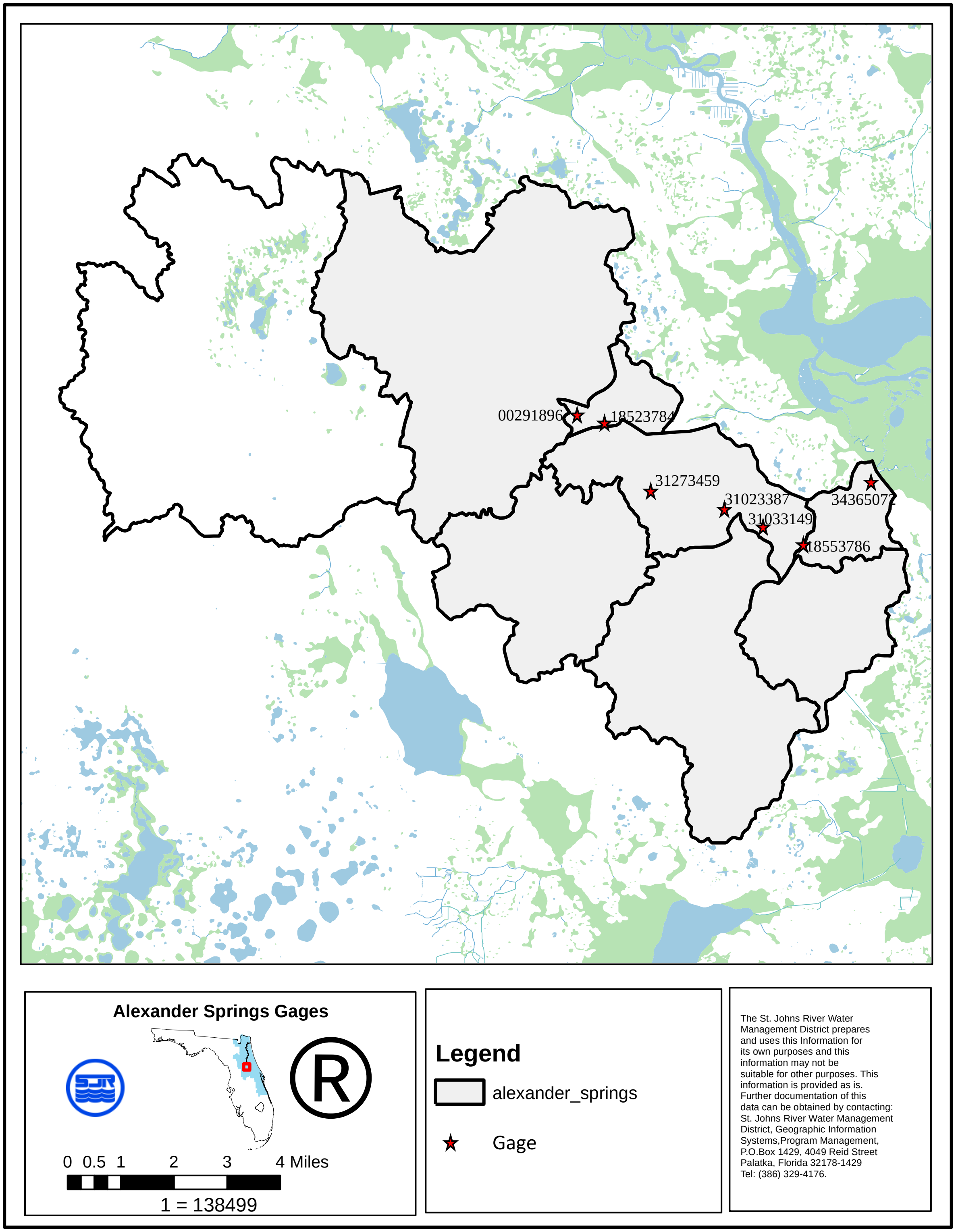

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Figure 10. Gage Stations at Alexander Springs Watershed

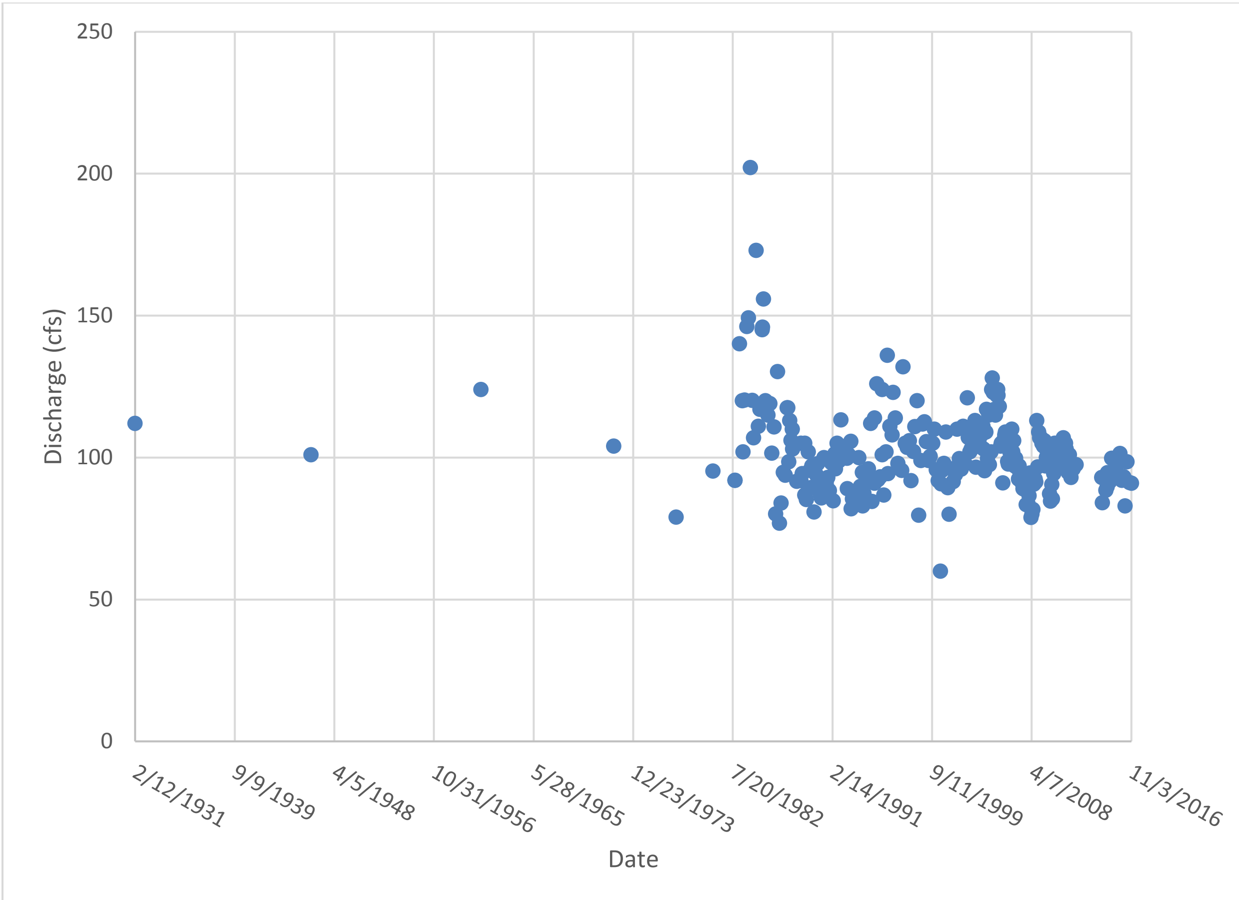

Figure 11. Alexander Springs Discharge POR (2/12/1931 - 11/3/2016)

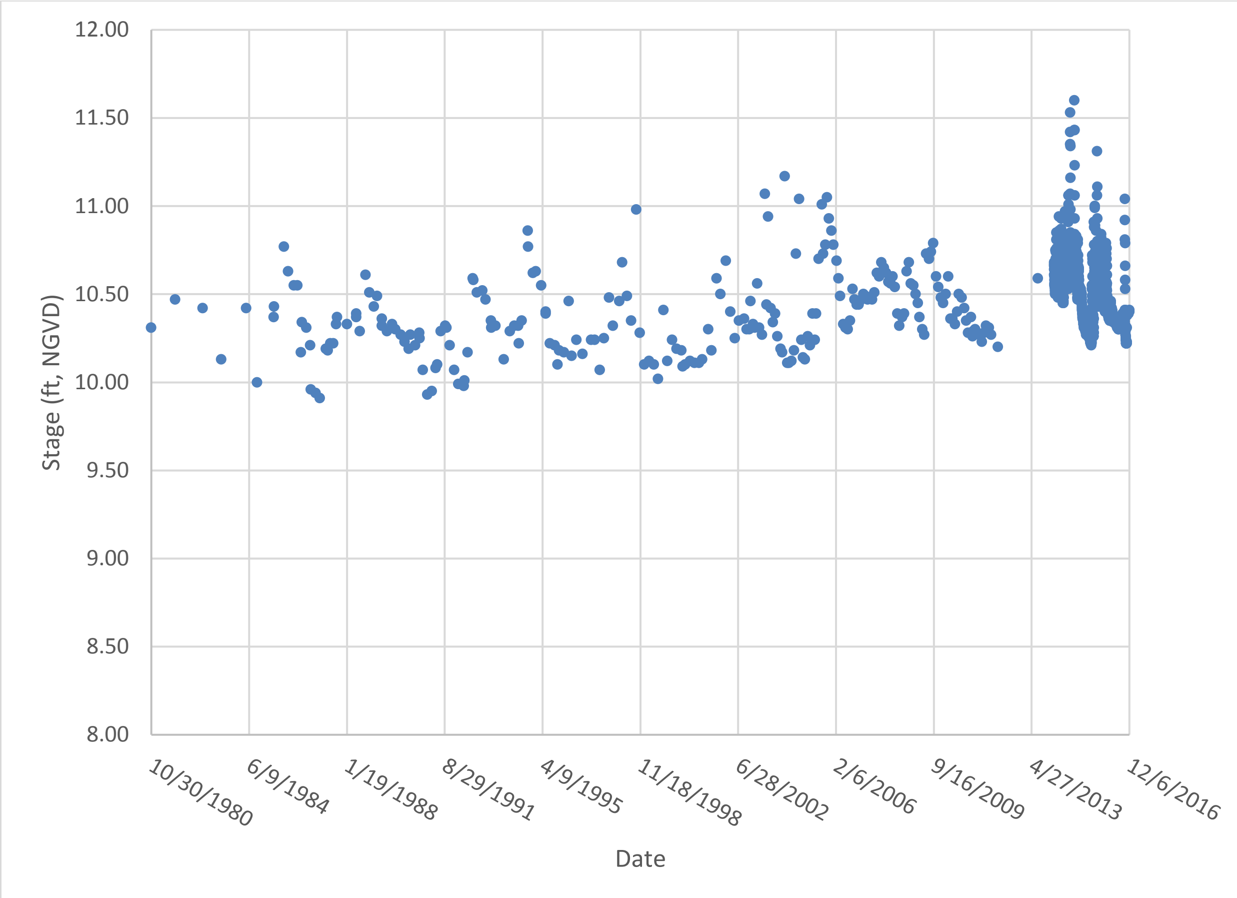

Figure 12. Alexander Springs Stage POR (10/30/1980 - 12/6/2016)

Table 9. Alexander Springs Discharge Summary Statistics POR (2/12/1931 - 11/3/2016)

Descriptive Statistics	Discharge (cfs)
Mean	101.88
Standard Error	0.91
Median	99.95
Mode	102.00
Standard Deviation	15.09
Minimum	60.00
Maximum	202.19

Table 10. Alexander Springs Stage Summary Statistics POR (10/30/1980 - 12/6/2016)

Descriptive Statistics	*Stage (ft NGVD29)*
Mean	10.46
Standard Error	0.01
Median	10.44
Mode	10.36
Standard Deviation	0.20
Minimum	9.91
Maximum	11.60

The SJRWMD station 18523784 is on upstream Alexander Creek at County Road (CR 445). The station has both daily discharge and stage data from October 2003. However, discharge data were discontinued from 4/3/2012. It is unfortunate that the quality of data at this station are not consistent, mainly due to vandalism. Figure 13 and Figure 14 show the period of record of discharge and stage, respectively. The discharge and stage data are summarized in Table 11.

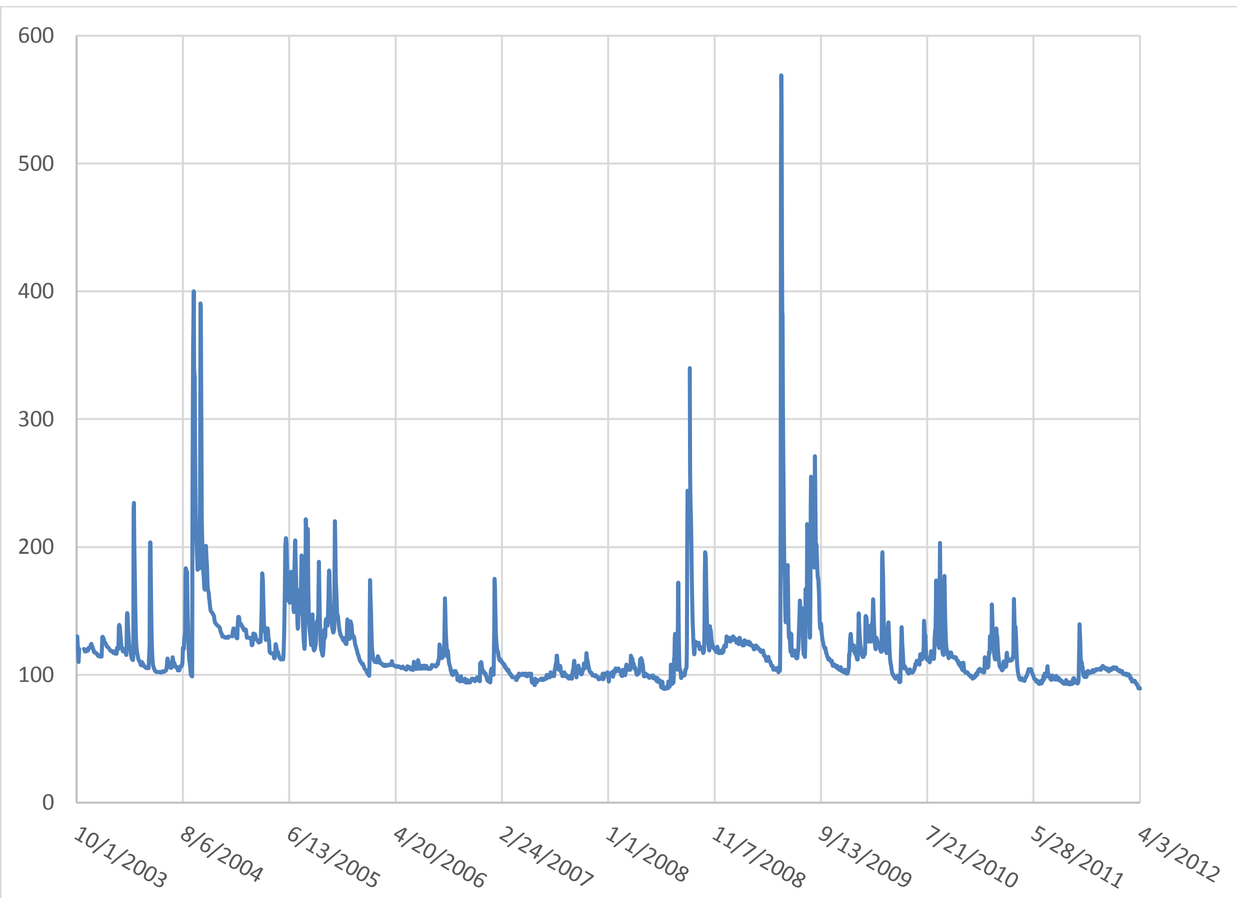

Figure 13. Discharge Hydrograph at Station 18523784 POR (10/1/2003 - 4/3/2012)

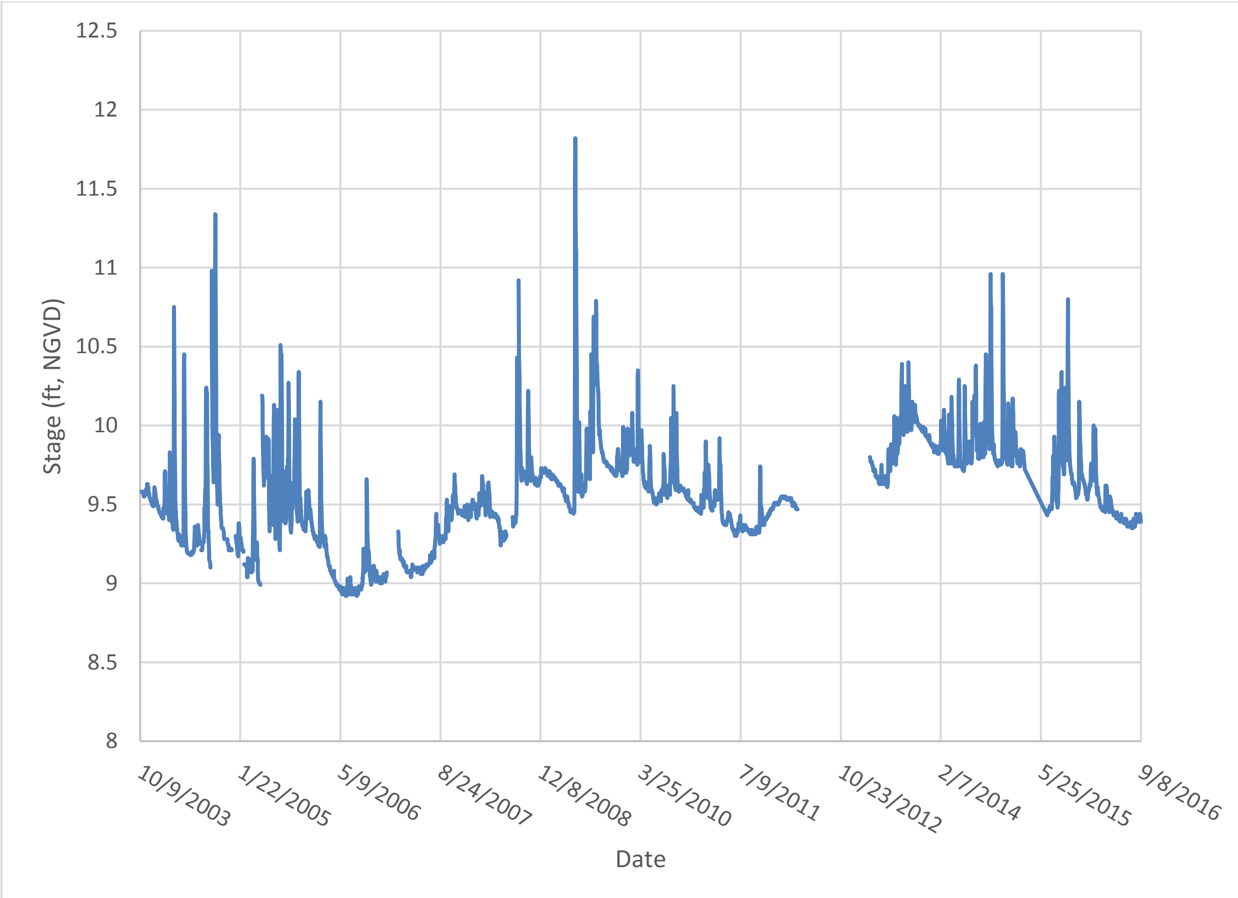

Figure 14. Stage Hydrograph at Station 18523784 POR (10/9/2003 - 9/8/2016)

Table 11. Station 18523784 Discharge and Stage Data Summary Statistics

Descriptive Statistics	Discharge (cfs) (10/1/2003-4/3/2012)	Stage (ft, NGVD) (10/9/2003-9/8/2016)
Mean	119.36	9.56
Standard Error	0.61	0.00
Median	110.39	9.54
Mode	101.00	9.48
Standard Deviation	32.81	0.32
Minimum	89.00	8.92
Maximum	569.00	11.82

The main gauging point is the SJRWMD station 18553786 on downstream Alexander Creek Run just prior at Tracy Canal confluence. The station has both daily discharge and stage data from October 2003 to current. As usual, there are missing data but the most important missing values related to tropical storm

Fay in late August 2008. Figure 15 and Figure 16 show the discharge and stage data for the entire period of record, respectively. Table 12 summarizes both discharge and stage data.

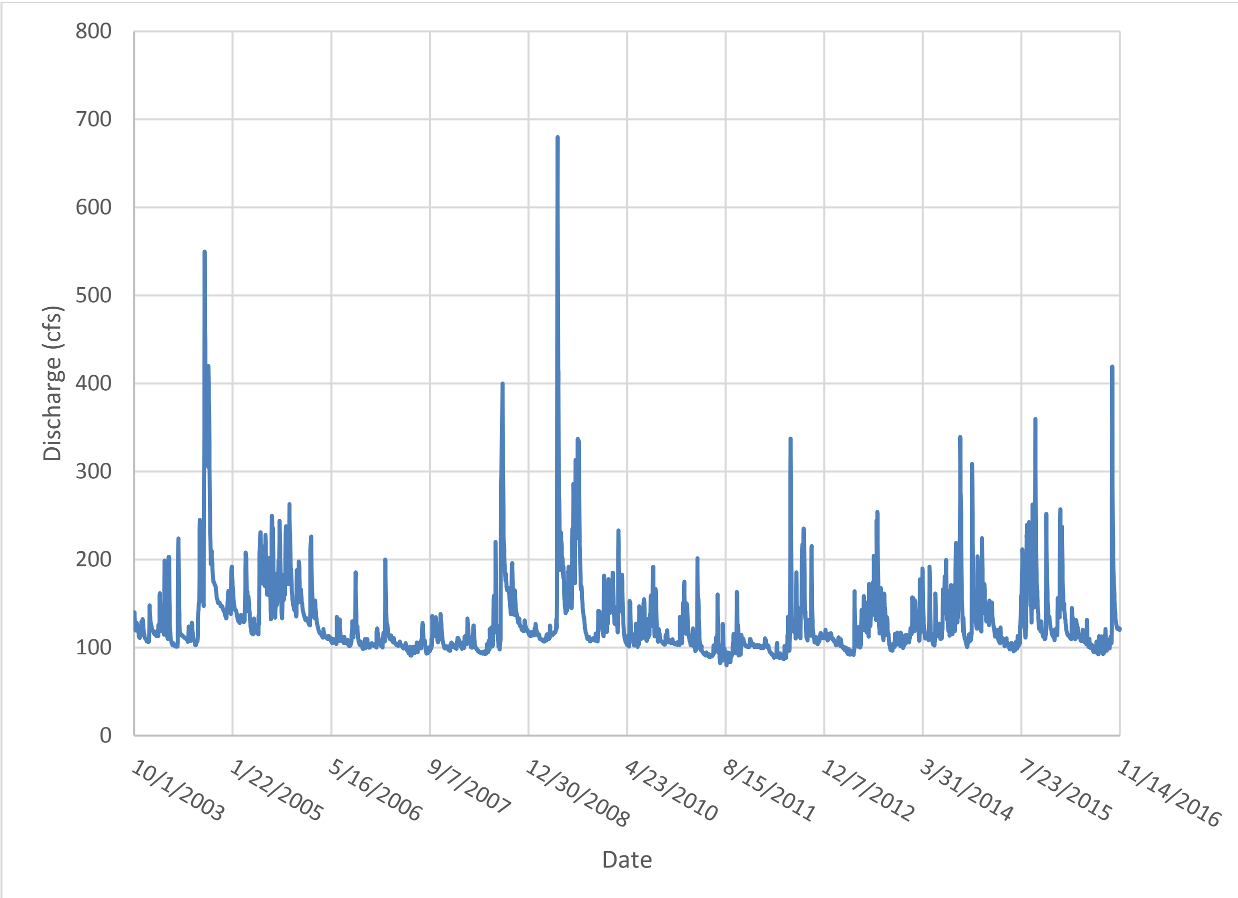

Figure 15. Discharge Hydrograph at Station 18553786 POR (10/1/2003 - 11/14/2016)

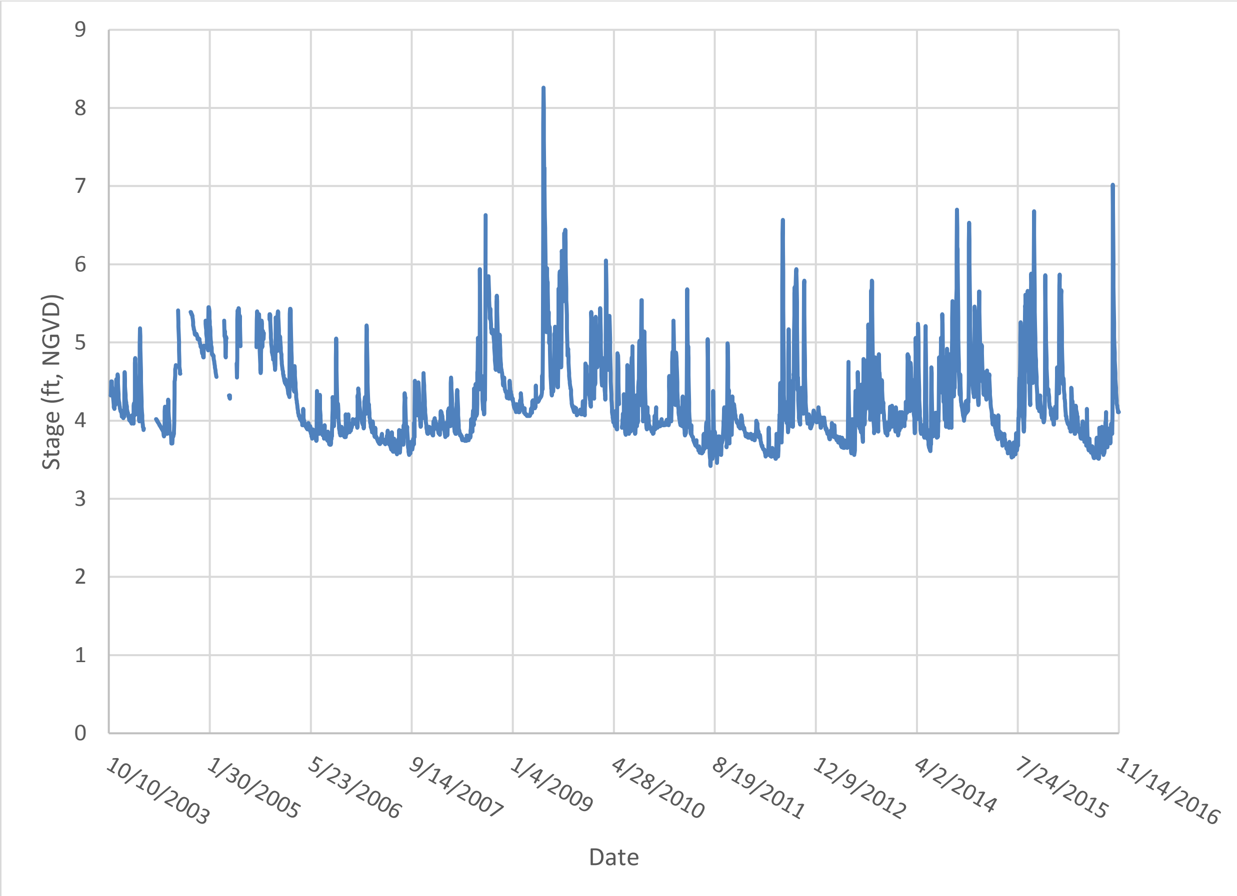

Figure 16. Stage Hydrograph at Station 18553786 POR (10/10/2003 - 11/14/2016)

Table 12. Discharge and Stage Summary Statistics at Station 18553786

Descriptive Statistics	Discharge (cfs) (10/1/2003-11/14/2016)	Stage (ft, NGVD) (10/10/2003-11/14/2016)
Mean	129.09	4.22
Standard Error	0.63	0.01
Median	115.00	4.06
Mode	104.00	3.94
Standard Deviation	42.92	0.54
Minimum	79.82	3.42
Maximum	680.00	8.26

MODEL CALIBRATION

Model calibration processes consist of iteratively adjusting model parameters to reasonable predict the observed data of interest. Most commonly in hydrology, the typical data of interest include stages, discharges and water quality. The end result of the calibration should be a robust reliable model that is fit to predict hydrologic responses under different scenarios.

MODELING APPROACH

The HSPF model was calibrated for a period of record from 10/1/2003 to 12/31/2014 for discharges and from 10/10/2003 to 12/31/2014 for stages based on the available observed data. The period of calibration covers both dry and wet years in the watershed. Both discharge and stage are considered in the calibration.

The model uses rainfall and evapotranspiration data of the NOAA stations DeLand and Lisbon. A single rain gage station is assigned to each sub-watershed based on Theissen polygon area that covers majority of the watershed (WSIS, 2012). Table 13 presents the sub-watersheds and their assigned rainfall and ET station.

Table 13. Sub-Watersheds and Assigned Rainfall and ET Stations

Sub-Watershed No.	Sub-Watershed Name	Station
1	Nine Mile Creek	Lisbon
2	Upper Alexander Creek	DeLand
3	Mud Pond	Lisbon
4	Glenn Branch	DeLand
5	Middle Alexander Creek	DeLand
6	Tracy Canal	DeLand
7	Lower Alexander Creek	DeLand

The model uses Alexander Springs discharge data at SJRWMD station 00291896 as an input hydrograph in the Upper Alexander Creek sub-watershed reach.

Observed discharge and stage data are available at SJRWMD stations 18523784 at CR 445 and 18553786 at Tracy Canal. However, the data at CR 445 station 18523784 are not reliable due to quality issues. Therefore, the model is calibrated using the observed discharge and stage data at Tracy Canal station 18553786.

The watershed is conceptualized into pervious land segments (PERLND), Impervious land segments (IMPLND), and reach segments (RCHRES). The land uses of the watershed are grouped into 14 land use categories. Only the urban land uses have been subdivided into pervious and impervious land segments, as detailed in above section of land use. The reach segments are represented in FTABLEs. Each FTABLE describes the hydraulic rating curves of the RCHRES. The rating curves constitute the relationships between stage or depth, surface area, storage volume, and discharge. U.S. Corps of Engineers' Hydraulic Engineering Center HEC-RAS model was used to develop the FTABLEs.

ESTIMATION OF PARAMETERS

HSPF model uses both spatial and hydrologic data as well as parameters related to watershed characteristics. Model calibration is the process in which parameters are adjusted iteratively to get representative watershed parameters. The end result is a calibrated model that accurately reproduces the observed discharge and stage data.

A parameter estimation optimization tool PEST was utilized in model calibration (Doherty, 2004). PEST is a non-linear parameter estimator that adjusts and evaluates model parameters based on the improvements of objective functions. Major objective function includes matching daily, monthly, and annual discharges as well as flow duration curves between observed and simulated data. A PEST parameter file is shown in Appendix A

CALIBRATION RESULTS

Table 14 shows the final PEST results of the HSPF hydrology parameters. All values of the parameters are within acceptable ranges.

Various analysis of the calibration results was performed to ascertain the robustness of the model. The overall performance of the model was determined through conservation of mass within each land segment of the watershed. Forest land segment covers about three-quarter of the watershed. The annual water balance of forest land use provides a good account of model mass conservation. Table 15 to Table 16 illustrate detailed forest annual water balance of the sub-watersheds Nine Mile Creek and Glenn Branch, respectively. The two sub-watersheds represent samples of the two meteorological stations in the watershed. The annual water budget of the forest land use is generally summarized in Figure 17 and Figure 18 for the same sub-watersheds. All the components of the water balance appear to be very reasonable. It should be noted that the model shows that the Alexander Springs watershed also is a recharge area into the Floridan Aquifer. Figure 19 shows the Upper Floridan Aquifer (UFA) recharge rates in Alexander Springs watershed (SJRWMD, 2016) which supports the model results presented in Tables 15 and 16.

Table 14. PEST Estimated HSPF Model Hydrologic Parameters

NAME	DEFINITION	UNITS	MODEL VALUES	
			MIN	MAX
PWAT-PARM2				
FOREST	Fraction Forest Cover	none	0.000	0.500
LZSN	Lower Zone Nominal Soil Moisture Storage	inches	3.430	6.000
INFILT	Index to Infiltration Capacity	in/hr	0.050	1.000
LSUR	Length of Overland Flow	feet	400.000	400.000
SLSUR	Slope of Overland Flow Plane	ft/ft	0.001	0.001
KVARY	Variable Groundwater Recession	1/inches	0.001	0.001
AGWRC	Base Groundwater Recession	none	0.900	0.900
PWAT-PARM3				
PETMAX	Temp Below which ET is Reduced	deg. F	40.000	40.000
PETMIN	Temp Below which ET is set to Zero	deg. F	35.000	35.000
INFEXP	Exponent in Infiltration Equation	none	2.000	2.000
INFILD	Ratio of MAX/Mean Infiltration Capacity	none	2.000	2.000
DEEPFR	Fraction of GW Inflow to Deep Recharge	none	0.000	0.442
BASETP	Fraction of Remaining ET from Baseflow	none	0.010	0.010
AGWETP	Fraction of Remaining ET from Active GW	none	0.000	0.000
PWAT-PARM4				
CEPSC	Interception Storage Capacity	inches	0.030	0.100
UZSN	Upper Zone Nominal Soil Moisture Storage	inches	0.010	0.200
NSUR	Manning's n Roughness for Overland Flow	none	0.150	0.350
INTFW	Interflow Inflow Parameter	none	0.000	0.100
IRC	Interflow Recession Parameter	none	0.334	0.334
LZETP	Lower Zone ET parameter	none	0.390	0.920

Table 15. Forest Land Use Water Budget (inches) at Nine Mile Creek

Parameter		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Water Supply	Precipitation (SUPY)	56.180	56.480	32.670	41.800	52.440	49.540	41.180	48.420	43.720	48.382	51.660
Runoff	Surface (SURO)	0.640	0.028	0.005	0.004	3.464	0.010	0.389	0.027	0.010	0.007	0.009
	Interflow (IFWO)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Baseflow (AGWO)	7.285	7.120	1.132	2.913	6.474	5.130	4.504	4.372	4.065	5.357	3.580
	Total (PERO)	7.925	7.148	1.137	2.917	9.938	5.140	4.893	4.399	4.074	5.364	3.589
Evaporation	Potential (PET)	50.567	50.110	53.380	51.715	51.166	52.197	50.795	54.512	52.753	50.781	50.977
	Intercept (CEPE)	11.116	13.279	7.908	9.916	9.088	10.606	10.195	9.612	10.648	12.011	11.628
	Upper Zone (UZET)	1.853	2.863	0.500	1.670	1.888	1.691	1.498	2.199	1.472	2.470	1.865
	Lower Zone (LZET)	25.197	26.754	23.300	23.589	28.263	23.365	25.878	26.232	24.773	22.445	27.045
	Baseflow (BASET)	0.389	0.487	0.268	0.322	0.419	0.344	0.371	0.368	0.319	0.338	0.448
	Total (TAET)	38.555	43.382	31.976	35.498	39.658	36.006	37.942	38.411	37.211	37.263	40.987
Deep Recharge/Loss	Inactive Groundwater (IGWI)	6.158	5.980	1.113	2.571	5.418	4.517	3.680	3.759	3.472	4.517	3.335

Table 16. Forest Land Use Water Budget (inches) at Glenn Branch

Parameter		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Water Supply	Precipitation (SUPY)	74.980	68.680	38.480	49.350	64.130	56.700	51.230	46.440	51.690	56.363	54.389
Runoff	Surface (SURO)	2.074	0.281	0.004	0.009	4.225	0.357	0.072	0.005	0.022	0.348	0.009
	Interflow (IFWO)	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
	Baseflow (AGWO)	15.215	12.677	2.344	4.616	11.695	8.892	7.666	3.573	6.050	8.579	4.986
	Total (PERO)	17.290	12.958	2.348	4.625	15.920	9.250	7.738	3.578	6.072	8.926	4.995
Evaporation	Potential (PET)	53.430	50.281	53.381	51.785	52.108	51.295	50.816	53.342	51.772	50.444	50.460
	Intercept (CEPE)	14.503	16.340	9.430	13.147	12.332	12.738	10.998	9.465	12.200	13.148	12.949
	Upper Zone (UZET)	3.124	4.523	1.229	1.898	2.501	2.745	3.142	1.554	2.657	3.364	2.102
	Lower Zone (LZET)	24.750	23.287	25.474	23.657	26.113	22.015	27.790	26.424	24.159	23.093	27.643
	Baseflow (BASET)	0.434	0.481	0.353	0.385	0.418	0.319	0.450	0.383	0.360	0.374	0.495
	Total (TAET)	42.811	44.631	36.485	39.087	41.364	37.817	42.379	37.826	39.376	39.979	43.189
Deep Recharge/Loss	Inactive Groundwater (IGWI)	12.538	10.321	2.144	4.001	9.506	7.486	6.234	3.138	5.092	7.107	4.434

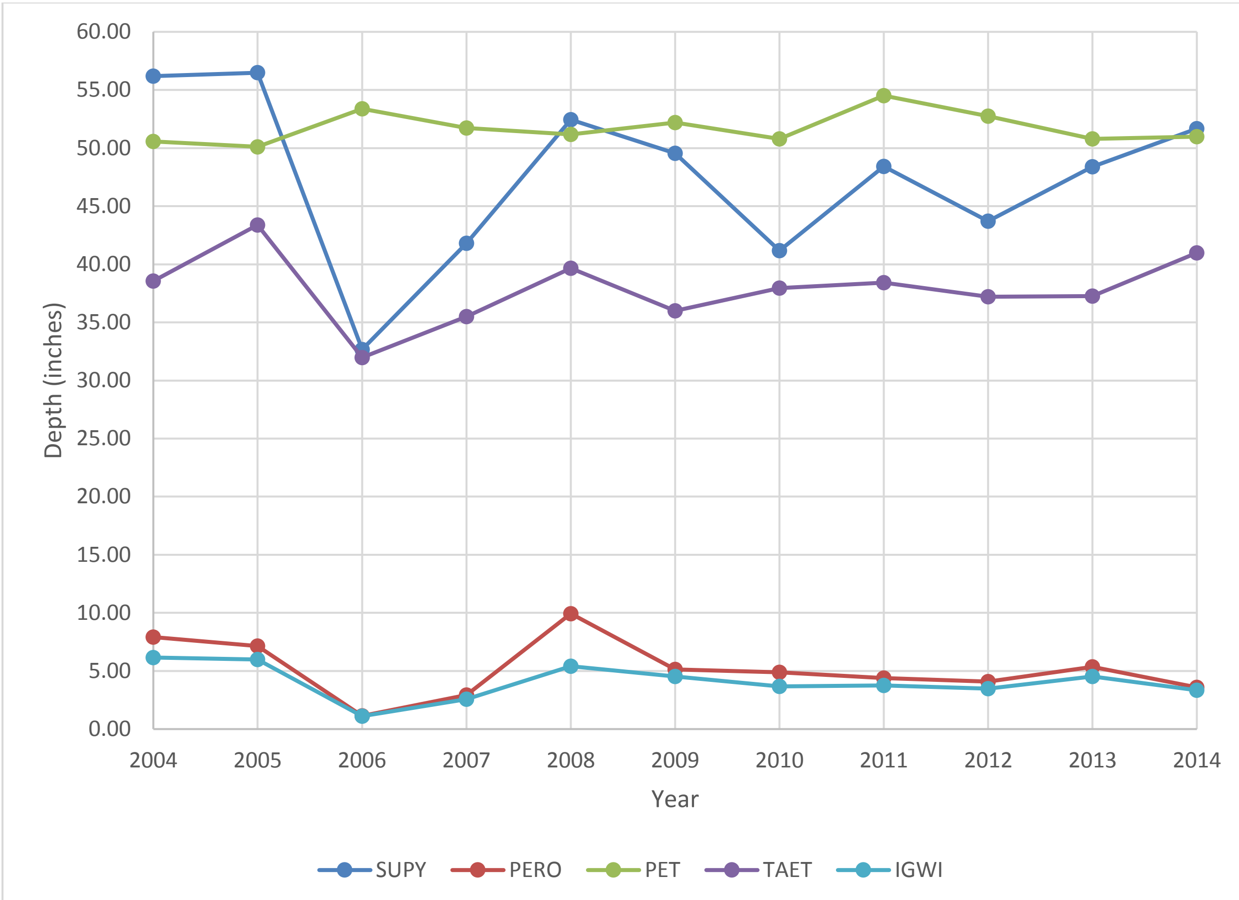

Figure 17. Generalized Forest Land Use Annual Water Budget for Nine Mile Creek

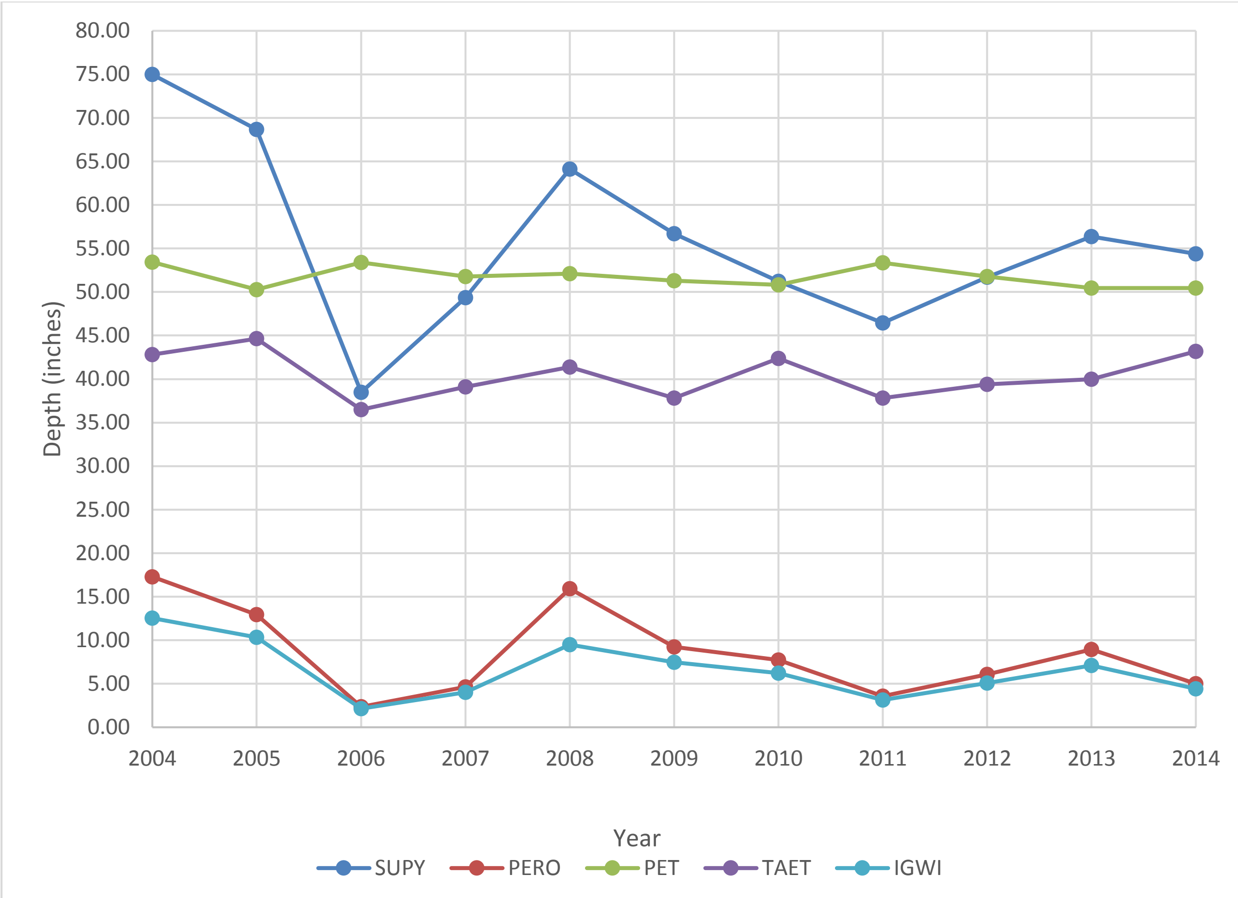

Figure 18. Generalized Forest Land Use Annual Water Budget for Glenn Branch

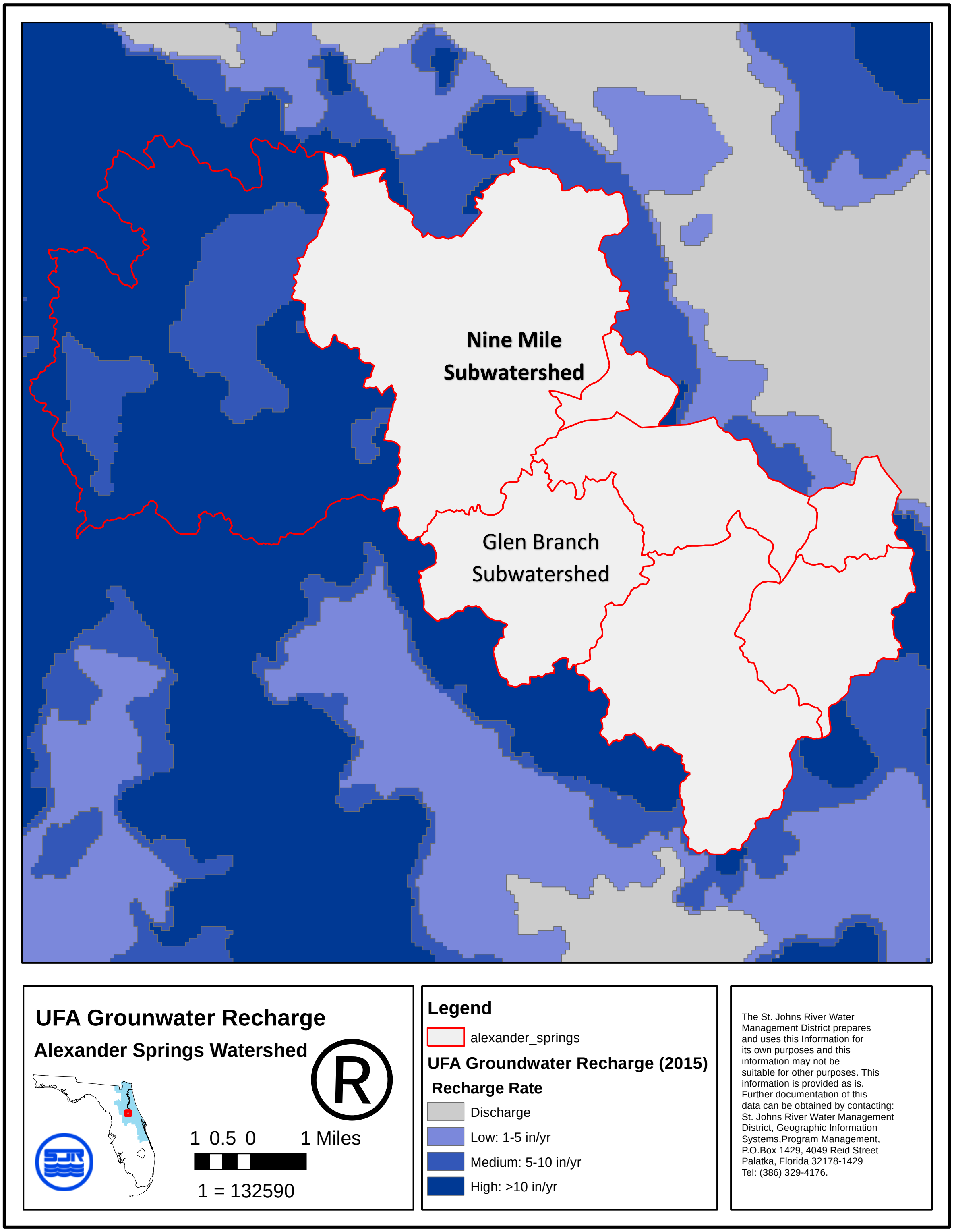

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Figure 19. UFA Groundwater Recharges at Alexander Springs Watershed

A major performance evaluation of model calibration is discharge and stage hydrograph comparisons of observed and simulated values. Figure 20 shows the observed and simulated discharge hydrographs for the period of calibration. The discharge duration curves are presented in Figure 21. The figures indicate a very reasonable model results. Figure 22 and Figure 23 show simulated and observed stage hydrographs and stage duration curves, respectively. Both discharge and stage plots comparisons indicate a very decent model calibration.

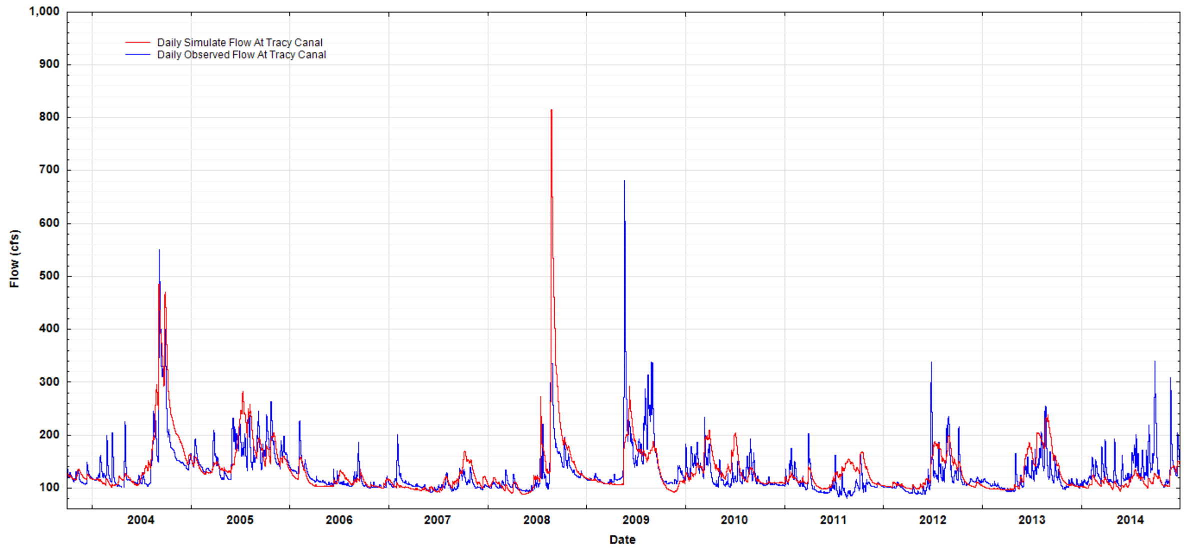

Figure 20. Observed and Simulated Discharge Hydrograph at Tracy Canal POR (10/1/2003 - 12/31/2014)

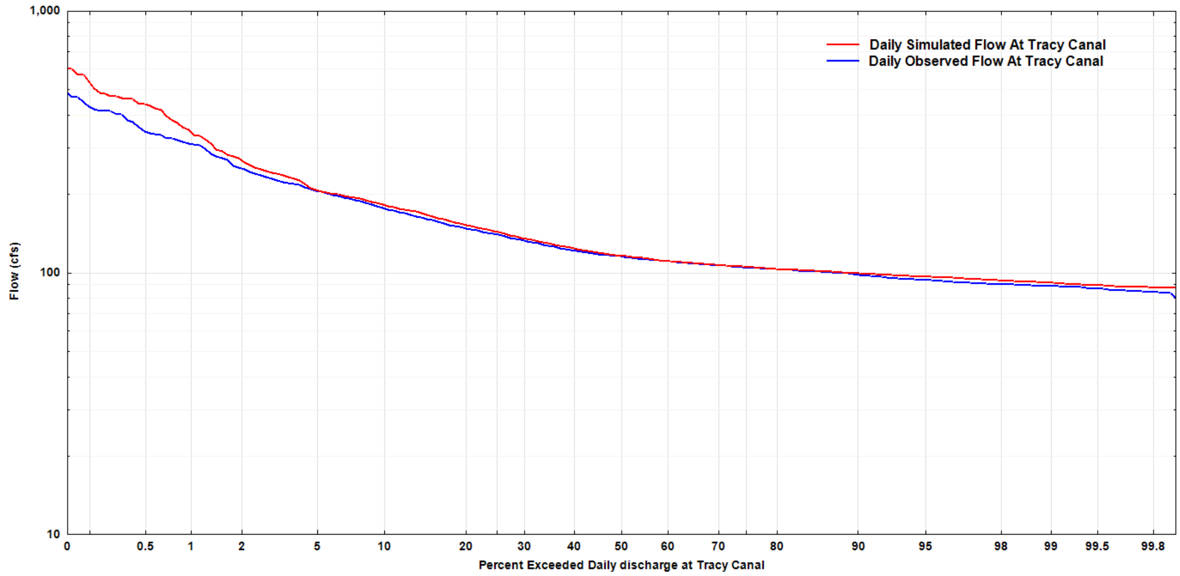

Figure 21. Observed and Simulated Discharge Duration Curves at Tracy Canal

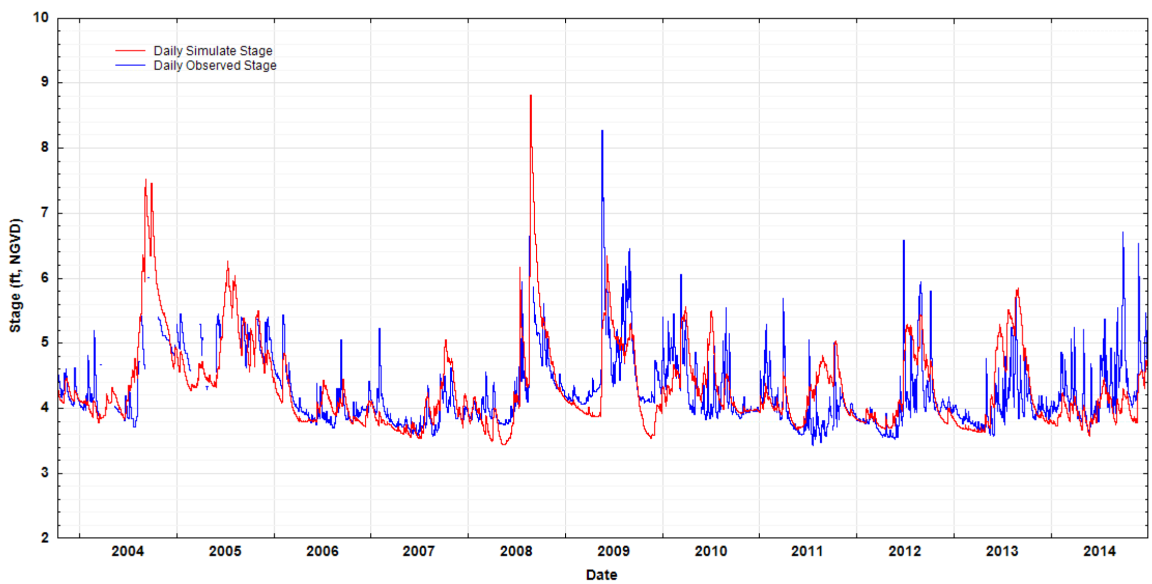

Figure 22. Observed and Simulated Stage Hydrograph at Tracy Canal POR (10/10/2003 - 12/31/2014)

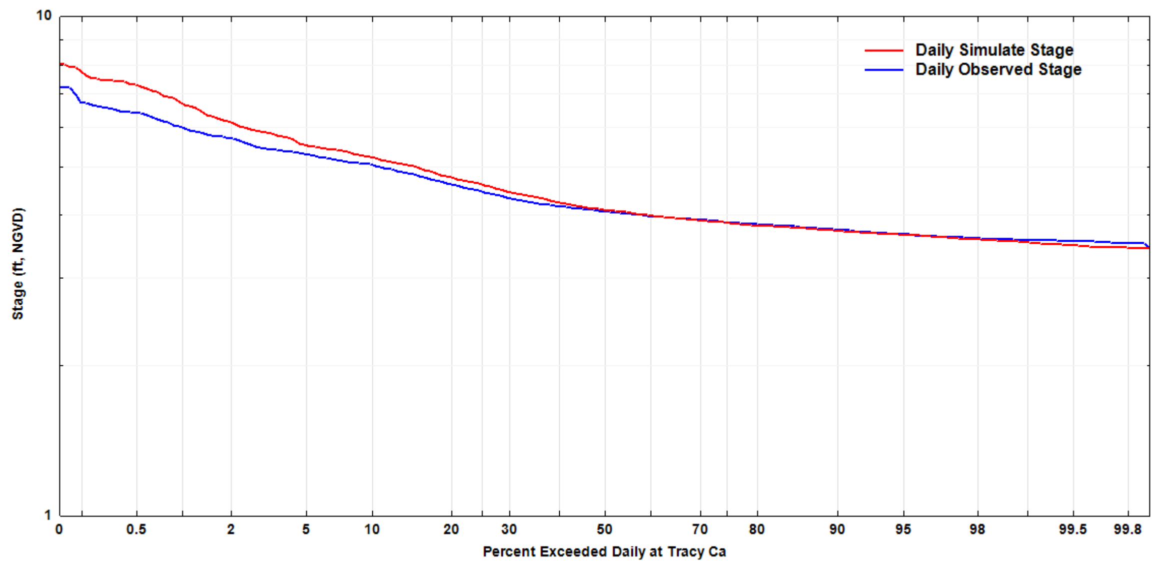

Figure 23. Observed and Simulated Stage Duration Curves at Tracy Canal

Furthermore, the observed and simulated discharge and stage time series are summarized in Tables 17 to 21. Table 17 presents the overall descriptive statistics parameters for discharge and stage. The overall daily mean simulated discharge and stage are 132.31 cfs and 4.31 ft, NGVD while the corresponding observed values are 129.07 cfs and 4.23 ft, NGVD. The mean simulated discharge and stage are within 2% of the observed discharge and stage.

Table 18 and Table 19 show the mean monthly observed and simulated discharges for period of calibration. Table 20 and Table 21 present the observed and simulated mean monthly stages. The model performs very reasonable throughout the seasons.

Table 17. Summary Statistics of Mean Daily Observed and Simulated Discharge and Stage at Tracy Canal

Parameter	Discharge (cfs)		Stage (ft, NGVD)	
	Observed	Simulated	Observed	Simulated
Mean	129.07	132.31	4.23	4.31
Standard Error	0.69	0.81	0.01	0.01
Median	115.00	115.81	4.06	4.10
Mode	104.00	102.14	3.94	4.00
Standard Deviation	43.70	51.68	0.54	0.66

The sensitivity of the model to the change in discharge was analyzed by changing plus or minus 10% the discharge at the calibration point, which is Tracy Canal, FTABLE ratings. The mean discharges of the calibration period of record for the original discharge, 10% discharge decrease, and 10% discharge increase are 132.31, 132.29, and 132.33 cfs, respectively. The 10% discharge decrease resulted a decrease of 0.03 cfs, which is about 0.02% mean discharge decrease, while 10% discharge increase caused an increase of 0.02 cfs, which is about 0.01% mean discharge increase. The mean stages are 4.31, 4.57, 4.08 ft for the original, 10% decrease, and 10% increase discharges, respectively. The mean stage value of the 10% discharge decrease resulted an increase of 0.26 ft, which is about 5.92% mean stage increase. The 10% discharge increase lead to a decrease of 0.23 ft of mean stage, which is about 5.35% decrease of the mean stage. These results indicate a very stable model.

Table 18. Mean Monthly Observed Discharges at Tracy Canal

Month	Year											
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Average
January		116.70	159.76	131.96	107.29	103.97	115.63	143.90	126.40	101.54	110.60	110.10	121.08
February		137.92	135.41	161.99	130.74	103.61	116.28	151.50	120.40	102.26	104.81	134.54	127.27
March		132.63	148.81	123.11	107.36	109.29	109.14	156.55	106.37	97.34	98.60	133.66	120.80
April		103.29	136.31	112.64	103.19	105.40	114.40	116.27	116.53	91.68	93.72	119.69	110.63
May		131.77	122.61	108.53	98.76	94.23	234.35	116.58	91.67	90.48	112.02	121.32	120.84
June		112.00	197.61	111.98	95.43	99.60	185.23	111.68	94.19	135.66	126.74	122.58	126.80
July		110.78	175.77	107.72	100.84	131.39	166.00	122.26	100.63	133.22	136.18	151.76	130.89
August		172.25	170.17	108.55	105.00	165.52	248.26	137.64	92.87	157.65	178.67	132.59	151.50
September		340.23	177.45	124.34	110.71	177.89	178.50	123.62	95.44	131.57	130.32	167.75	159.99
October	122.63	200.70	200.25	102.37	118.13	155.16	112.50	106.47	110.76	126.32	111.79	146.79	135.29
November	118.38	152.74	154.79	102.22	106.91	129.76	110.05	107.73	105.26	109.95	104.85	136.41	120.09
December	119.07	142.86	164.73	108.17	100.20	121.10	125.23	104.74	103.85	112.65	105.87	152.21	122.22
Average	120.04	156.34	162.58	117.25	107.30	123.89	156.56	124.80	105.27	115.92	118.00	135.78	129.07

Table 19. Mean Monthly Simulated Discharge at Tracy Canal

Month	Year												
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Average
January		115.26	149.91	122.94	107.02	109.67	115.16	122.55	116.99	102.50	100.09	101.10	114.83
February		110.29	130.03	142.29	103.01	105.91	111.78	136.41	114.71	106.14	97.80	113.38	115.54
March		105.79	132.65	111.66	99.55	96.48	107.84	174.13	111.69	102.29	96.41	109.31	113.44
April		113.71	139.97	102.57	96.37	101.88	106.01	156.93	120.02	99.34	96.65	106.21	112.70
May		119.17	131.27	102.56	95.63	88.76	143.37	125.11	99.46	101.26	106.39	102.19	110.47
June		108.43	167.76	108.20	96.44	103.08	223.36	147.47	101.85	120.17	161.70	105.62	131.28
July		132.79	238.36	124.05	101.73	153.10	170.40	157.96	122.13	178.27	168.37	123.72	151.90
August		201.47	207.61	109.81	109.39	308.70	162.37	120.44	142.93	160.88	200.28	112.99	166.99
September		371.52	172.76	117.94	118.52	310.38	161.48	122.79	139.60	157.18	182.66	111.58	178.76
October	120.80	277.85	169.69	105.38	153.31	183.09	106.86	108.58	150.19	129.42	128.69	116.20	145.84
November	125.83	196.29	169.63	102.56	124.23	145.66	93.56	109.30	118.86	104.88	106.83	108.83	125.54
December	119.54	159.10	149.27	106.27	111.48	123.24	108.56	109.31	106.15	105.60	102.66	139.73	120.08
Average	122.01	167.63	163.52	112.84	109.79	152.61	134.28	132.53	120.43	122.44	129.21	112.61	132.31

Table 20. Mean Monthly Observed Stage at Tracy Canal

Month	Year												
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Average
January		4.03	5.13	4.48	4.08	3.95	4.15	4.75	4.40	3.80	3.92	4.02	4.25
February		4.39	4.73	4.75	4.26	3.92	4.16	4.88	4.29	3.82	3.83	4.43	4.30
March		4.14	5.28	4.17	3.82	4.05	4.09	4.91	4.02	3.73	3.75	4.32	4.10
April			4.75	3.96	3.74	3.97	4.24	4.18	4.21	3.61	3.69	4.01	4.00
May		3.98	4.69	3.85	3.73	3.76	5.47	4.26	3.68	3.59	3.82	3.98	4.01
June		3.93	5.27	3.92	3.65	3.95	5.12	4.00	3.66	4.29	4.06	4.00	4.12
July		3.89		3.83	3.74	4.61	4.77	4.13	3.79	4.27	4.16	4.57	4.18
August		4.54	4.95	3.84	3.84	4.66	5.66	4.48	3.73	4.73	4.80	4.24	4.45
September		4.90	5.05	4.18	3.95	5.26	4.97	4.23	3.79	4.37	4.22	4.82	4.47
October	4.32	5.37	5.13	3.84	4.19	4.94	4.14	3.90	4.12	4.33	4.12	4.67	4.30
November	4.30	5.12	4.94	3.91	4.01	4.47	4.12	3.96	4.08	4.00	3.97	4.49	4.28
December	4.17	4.94	5.04	4.07	3.91	4.32	4.42	3.96	3.94	4.01	3.95	4.76	4.28
Average	4.26	4.38	5.00	4.06	3.91	4.31	4.61	4.30	3.97	4.05	4.03	4.36	4.23

Table 21. Mean Monthly Simulated Stage at Tracy Canal

Month	Year												
	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Average
January		4.09	4.72	4.23	3.90	3.96	4.08	4.22	4.12	3.80	3.74	3.76	4.06
February		3.98	4.36	4.58	3.81	3.88	4.02	4.48	4.07	3.89	3.68	4.04	4.07
March		3.88	4.41	4.00	3.73	3.65	3.93	5.07	4.01	3.79	3.65	3.96	4.01
April		4.05	4.54	3.80	3.65	3.78	3.88	4.82	4.17	3.72	3.66	3.88	4.00
May		4.16	4.39	3.80	3.63	3.46	4.53	4.27	3.72	3.77	3.88	3.79	3.95
June		3.94	4.98	3.93	3.65	3.80	5.69	4.67	3.78	4.17	4.90	3.87	4.31
July		4.41	5.84	4.25	3.77	4.71	5.06	4.82	4.22	5.17	4.99	4.25	4.68
August		5.37	5.50	3.97	3.95	5.72	4.93	4.18	4.60	4.89	5.44	4.03	4.78
September		6.84	5.08	4.14	4.14	6.39	4.90	4.23	4.54	4.83	5.20	4.00	4.93
October	4.15	6.16	5.03	3.87	4.78	5.24	3.89	3.95	4.72	4.35	4.33	4.10	4.56
November	4.29	5.41	5.02	3.80	4.25	4.64	3.58	3.96	4.15	3.86	3.90	3.93	4.23
December	4.17	4.87	4.71	3.88	4.00	4.24	3.94	3.96	3.89	3.87	3.80	4.54	4.16
Average	4.21	4.76	4.89	4.02	3.94	4.46	4.37	4.38	4.17	4.18	4.27	4.01	4.31

REFERENCES

Allen, R. G., Walter, I. A., Elliott, R. L., Howell, T. A., Itenfisu, D., Jensen, M. E., and Snyder, R. L. (2005). The ASCE standardized reference evapotranspiration equation. American Society of Civil Engineers, Reston, Virginia.

Bicknell, Brian R., Imhoff, J. C., Kittle, J. L., Jobes, T. H., and Donigian, A. S., Jr. (2005). *HYDROLOGICAL SIMULATION PROGRAM - FORTRAN, HSPF, Version 12.2, User's Manual.* Athens, GA: U.S. Environmental Protection Agency - National Exposure Research Laboratory.

Doherty, J. (2004). *PEST, Model-Independent Parameter Estimation, User Manual: 5th Edition.* Watermark Numerical Computing.

Hargreaves, G.H., and Samani, Z.A. (1985). *Reference crop evapotranspiration from temperature*. Transactions of the American Society of Agricultural Engineers*,* 1(2), 96-99.

Hargreaves, H. George, and Allen, R.G. 2003. History of Evaluation of Hargreaves Evaporation Equation. Journal of Irrigation and Drainage Engineering, Vol. 129, No. 1, pp 53-63, January/February 2003.

(Hummel, P., Kittle, J., and Gray, M. (2001). *WDMUtil, Version 2.0, A Tool for Managing Watershed Modeling Time-Series Data, User's Manual.*

Scott, T. M., Means, G. H., Meegan, R. P., Means, R. C., Upchurch, S. B., Copeland, R. E., Jones, J., Roberts, T., and Willet, A. (2004). *Springs of Florida*. Florida Geological Survey Bulletin 66.

Shoemaker, W. B., O'Reilly, A. W., Sepulveda, N., Williams, S. A., Motz, L. H., and Sun, Q. (2004). *Comparison of Estimated Areas Contributing Recharge to Selected Springs in North-Central Florida by Using Multiple Ground-Water Flow Models.* U.S. Geological Survey, Open-File Report 03-448.

SJRWMD (2016). Recharge to the Upper Floridan Aquifer in the SJRWMD, Florida. Technical Fact Sheet SJ2016-FS1.

U. S. Geological Survey (2015). Florida Water Science Center, Evapotranspiration Information and Data [cited May 2015] *http://fl.water.usgs.gov/et/*

Water Supply Impact Study, WSIS. (2012). *St. Johns River Water Supply Impact Study: Chapter 3. Watershed Hydrology.* St. Johns River Water Management District.

APPENDIX A

deepfr	log	factor	0.4700	0.0100	0.5000	deepfrgroup	1	0	1
kvary	fixed	factor	0.0100	0.0100	3.0000	kvarygroup	1	0	1
basetp	log	factor	0.0100	0.0100	0.1000	basetpgroup	1	0	1
ircx	log	factor	0.5000	0.4300	2.3000	ircxgroup	1	0	1
intfw	log	factor	0.1000	0.0100	3.0000	intfwgroup	1	0	1
lzsn01	tied_lzsn11	factor	4.2858	4.0000	10.0000	lzsngroup	1	0	1
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lzsn03	tied_lzsn11	factor	4.2858	4.0000	10.0000	lzsngroup	1	0	1
lzsn04	tied_lzsn11	factor	4.2858	4.0000	10.0000	lzsngroup	1	0	1
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lzsn06	tied_lzsn11	factor	4.7143	4.7143	10.0000	lzsngroup	1	0	1
lzsn07	tied_lzsn11	factor	4.7143	4.7143	10.0000	lzsngroup	1	0	1
lzsn08	tied_lzsn11	factor	5.1429	5.1429	10.0000	lzsngroup	1	0	1
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agwrcx04	tied_agwrcx11	factor	9.0000	9.0000	999.0000	agwrcxgroup	1	0	1
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agwrcx10	tied_agwrcx11	factor	9.0000	9.0000	999.0000	agwrcxgroup	1	0	1
agwrcx11	log	factor	9.0000	9.0000	999.0000	agwrcxgroup	1	0	1
agwrcx12	tied_agwrcx11	factor	9.0000	9.0000	999.0000	agwrcxgroup	1	0	1
agwrcx13	tied_agwrcx11	factor	9.0000	9.0000	999.0000	agwrcxgroup	1	0	1
uzsn01	tied_uzsn11	factor	0.0778	0.0778	1.0000	uzsngroup	1	0	1
uzsn02	tied_uzsn11	factor	0.0778	0.0778	1.0000	uzsngroup	1	0	1
uzsn03	tied_uzsn11	factor	0.0778	0.0778	1.0000	uzsngroup	1	0	1
uzsn04	tied_uzsn11	factor	0.0778	0.0778	1.0000	uzsngroup	1	0	1
uzsn05	tied_uzsn11	factor	0.0778	0.0778	1.0000	uzsngroup	1	0	1
uzsn06	tied_uzsn11	factor	0.0778	0.0778	1.0000	uzsngroup	1	0	1
uzsn07	tied_uzsn11	factor	0.0778	0.0778	1.0000	uzsngroup	1	0	1
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uzsn09	tied_uzsn11	factor	0.0889	0.0889	1.0000	uzsngroup	1	0	1
uzsn10	tied_uzsn11	factor	0.0889	0.0889	1.0000	uzsngroup	1	0	1
uzsn11	log	factor	0.1000	0.1000	1.0000	uzsngroup	1	0	1
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uzsn13	log	factor	0.0100	0.0100	4.0000	uzsngroup	1	0	1
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lzetp03	tied_lzetp11	factor	0.5000	0.4000	0.5500	lzetpgroup	1	0	1
lzetp04	tied_lzetp11	factor	0.5000	0.4000	0.5500	lzetpgroup	1	0	1
lzetp05	tied_lzetp11	factor	0.4000	0.3300	0.4500	lzetpgroup	1	0	1
lzetp06	tied_lzetp11	factor	0.4000	0.3300	0.4500	lzetpgroup	1	0	1
lzetp07	tied_lzetp11	factor	0.5500	0.4500	0.6000	lzetpgroup	1	0	1
lzetp08	tied_lzetp11	factor	0.7000	0.5500	0.7500	lzetpgroup	1	0	1
lzetp09	tied_lzetp11	factor	0.7000	0.5500	0.7500	lzetpgroup	1	0	1
lzetp10	tied_lzetp11	factor	0.6000	0.5000	0.6500	lzetpgroup	1	0	1
lzetp11	log	factor	0.8000	0.6500	0.8500	lzetpgroup	1	0	1
lzetp12	tied_lzetp11	factor	0.9500	0.7500	1.0000	lzetpgroup	1	0	1
lzetp13	tied_lzetp11	factor	0.9500	0.7500	1.0000	lzetpgroup	1	0	1

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TECHNICAL MEMORANDUM

Date: April, 2017

By: Awes Karama, PhD and Fatih Gordu. P.E

Subject: Alexander Springs MFL Hydrologic Data Analysis

Introduction

In addition to extensive work conducted to understand the ecological structure and function of priority water bodies, determining minimum flows and levels (MFLs) and evaluating the current status of water bodies require substantial hydrologic analysis of available data. Several steps were involved in performing the hydrologic data analysis for the Alexander Springs MFLs determination and current status assessment.

1. Review of available data
2. Determination of period-of record (POR) for data analysis
3. Transferring MFL field transect data to the gage location where long-term measured flow data are available
4. Development of a stage-flow relationship to converting MFL stages to MFL flows
5. Groundwater pumping impact assessment
6. Development of synthetic flow time series representing no-pumping and current-pumping (baseline) conditions
7. Estimating available water (freeboard or deficit)

This document describes each of the above steps and associated results.

Hydrologic Analysis

1 Data review

Data that are used in Alexander Springs MFLs determination can be categorized into meteorological and hydrological data. Meteorological data consist of rainfall and evapotranspiration time series data. Hydrological data encompass discharge and stage time series data for both surface and groundwater components.

1.1 METEOROLOGICAL DATA

1.1.1 Rainfall

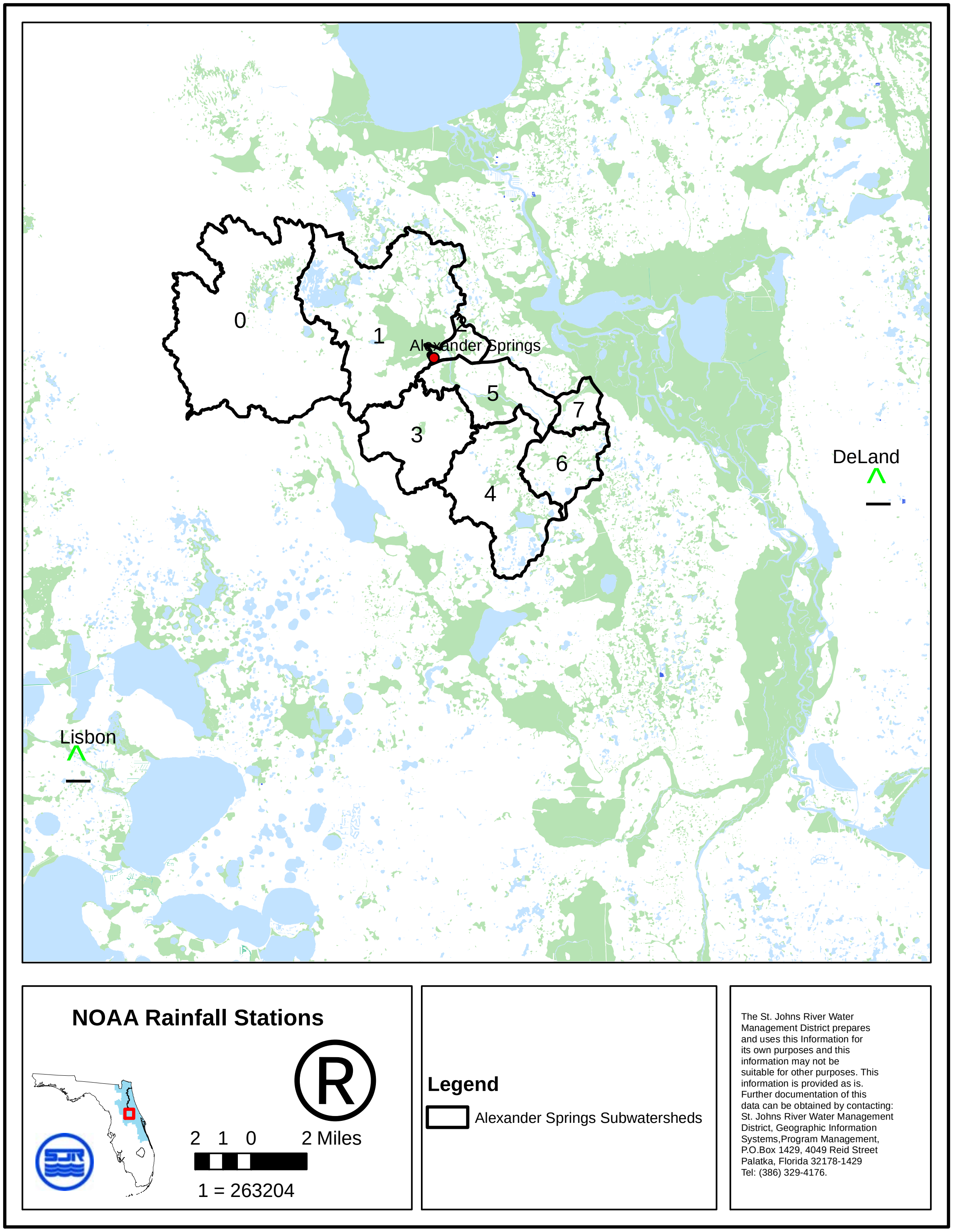
Two long-term NOAA rainfall gauges are in the vicinity of study area. The NOAA stations are DeLand and Lisbon gauges. Figure 1 shows locations of the NOAA rainfall gauges. Table 1 presents summary description of the gauges.

The long-term period of record for both stations are from 1/1/1914 to 12/31/2014. The annual rainfall time series of DeLand and Lisbon gauges are shown in Figure 2 and Figure 3, respectively. A summary of descriptive statistics is presented in Table 2.

A comparison of annual rainfall data is shown in Figure 4. Overall, the DeLand mean annual rainfall and the standard deviation are higher than Lisbon. The mean annual rainfall for the period of 1/1/1914 to 21/31/2014 at DeLand is about 56 inches compare to about 48 inches at Lisbon. The lowest annual rainfall at Lisbon was about 29.28 inches in year 2000, which is a know dry year. At DeLand, the driest year was 2006 at about 38.48 inches of rainfall. The highest annual rainfall at DeLand and Lisbon are 76.69 inches for year 2001 and 67.58 inches for year 1959, respectively.

TABLE 1. NOAA RAINFALL STATIONS

Station Name	Site ID	Latitude (dd mm ss.ss)	Longitude (dd mm ss.ss)
DeLand	08-2229	$29^{o}\ 01'\ 00''$	$81^{o}\ 19'\ 00''$
Lisbon	08-5076	$28^{o}\ 52'\ 00''$	$81^{o}\ 47'\ 00''$



Author:, Source:C:\Users\akarama\AppData\Local\Temp\arc2E93\~DF4A0C1F4BEC97D7D3.TMP, Time:12/5/2016 2:34:49 PM

Figure 1. Location of NOAA Rainfall Stations

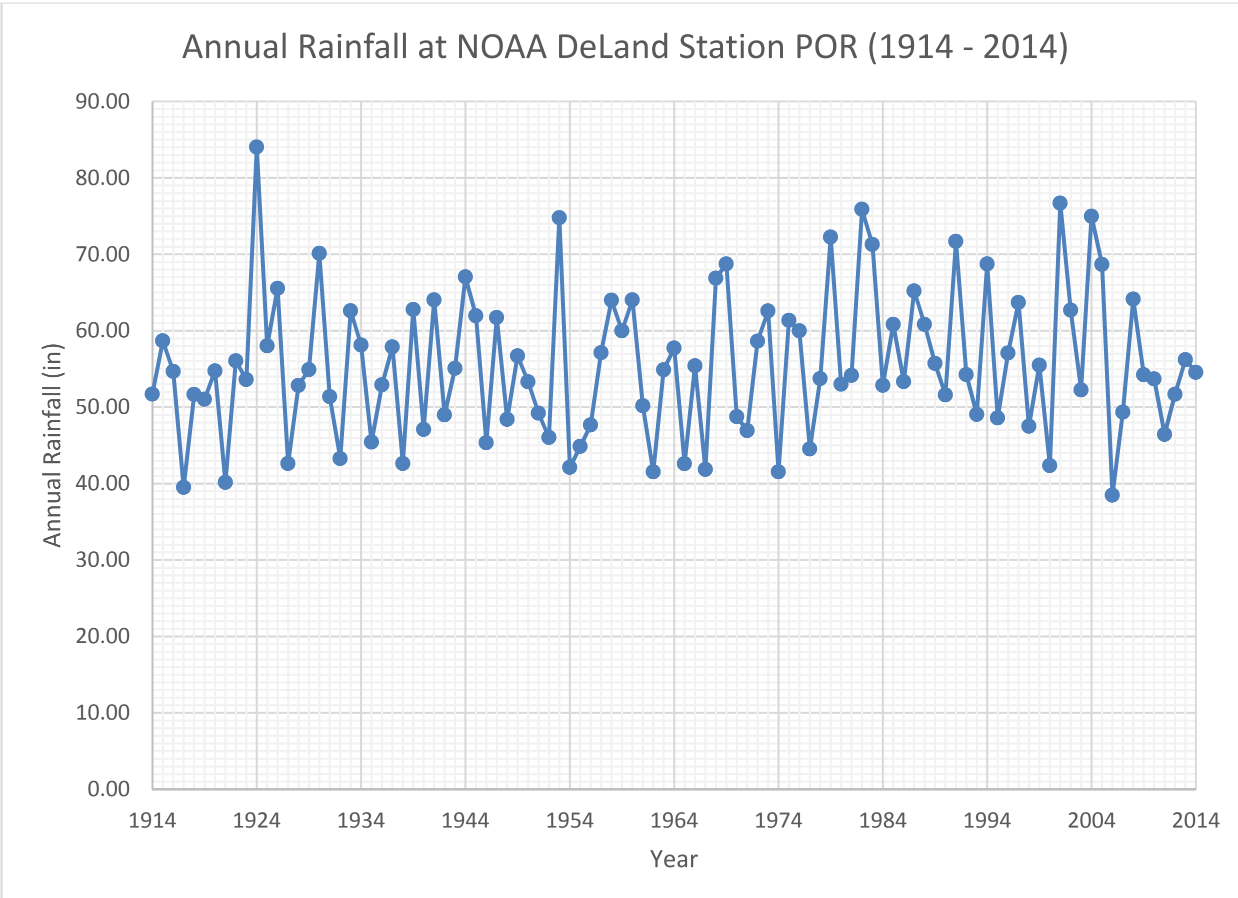


FIGURE 2. ANNUAL RAINFALL (INCHES) AT DELAND STATION (1914 - 2014)

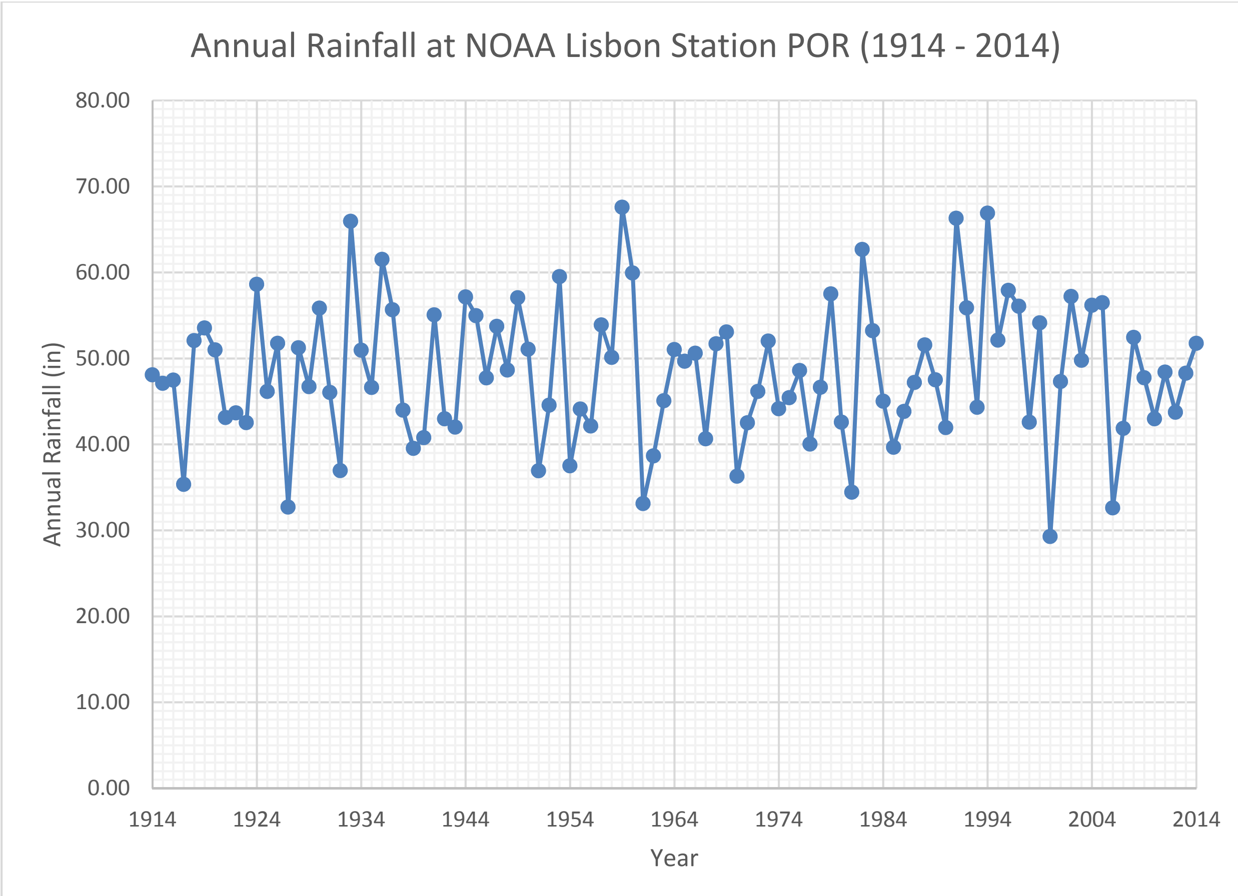


FIGURE 3. ANNUAL RAINFALL (INCHES) AT LISBON STATION

TABLE 2. SUMMARY STATISTICS OF RAINFALL (INCHES) AT THE NOAA STATIONS (1914 - 2014)

Statistical Parameter	DeLand	Lisbon
Mean	55.68	48.37
Standard Error	0.94	0.79
Median	54.68	47.75
Mode	64.04	51.75
Standard Deviation	9.47	7.91
Sample Variance	89.70	62.51
Minimum	38.48	29.28
Maximum	84.03	67.58

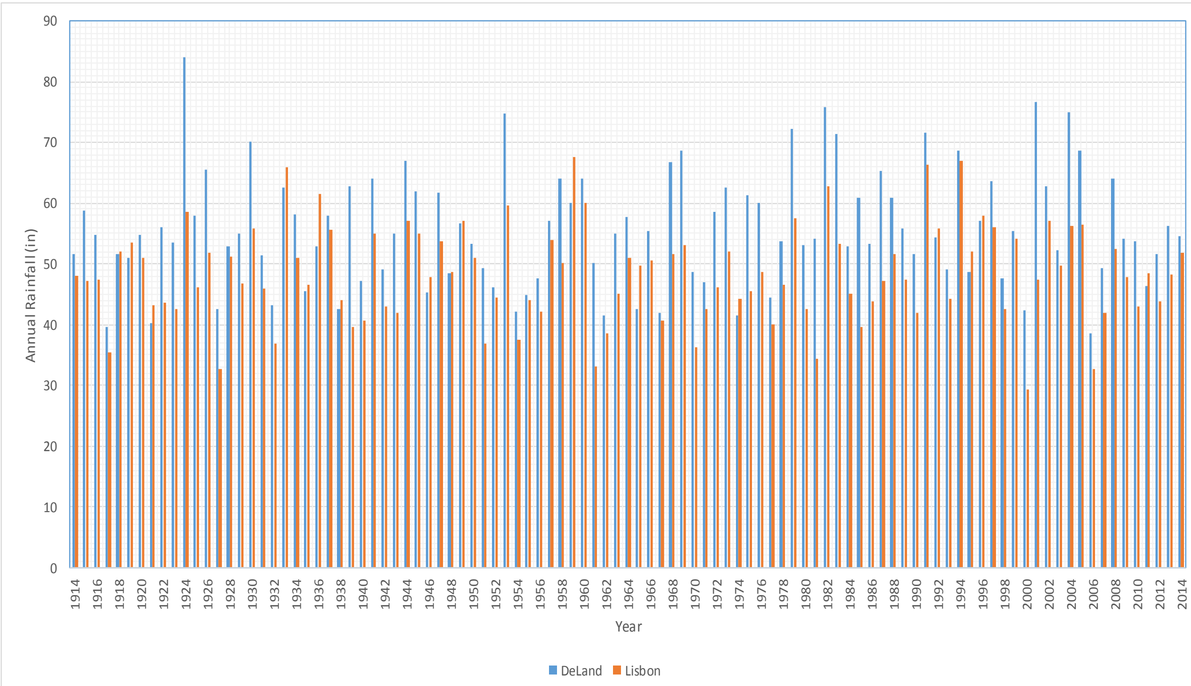


FIGURE 4. COMPARISON OF ANNUAL RAINFALL AT THE NOAA STATIONS

1.1.2 Evapotranspiration

Potential Evapotranspiration (PET) data used in the Alexander Springs study were computed using Hargraves-Samani (1985) method. The method is a simple temperature equation requiring daily minimum and maximum air temperature and extraterrestrial radiation, which is computed from the latitude of the station and the time of the year.

In Florida, statewide PET data are available for 1995 – 2015 from USGS Florida Water Science Center database (USGS, 2015). The data rely on Geostationary Operational Environmental Satellites (GOES) providing near continuous infrared incoming solar radiation data. The GOES uses Priestly-Taylor method to compute PET. The Hargraves-Samani method was scaled with a factor to GOES Priestly-Taylor evaporation estimate (WSIS, 2012).

Data at NOAA weather stations of DeLand and Lisbon were used to develop PET data at the two locations using Hargraves-Samani method. The PET coefficients of DeLand and Lisbon stations are 0.8726 and 0.9114, respectively. Figure 5 shows the computed annual ET data for POR from 1948 to 2014 at both DeLand and Lisbon stations. Table 3 presents summary descriptive statistics of PET at both stations for POR (1948 – 2014).

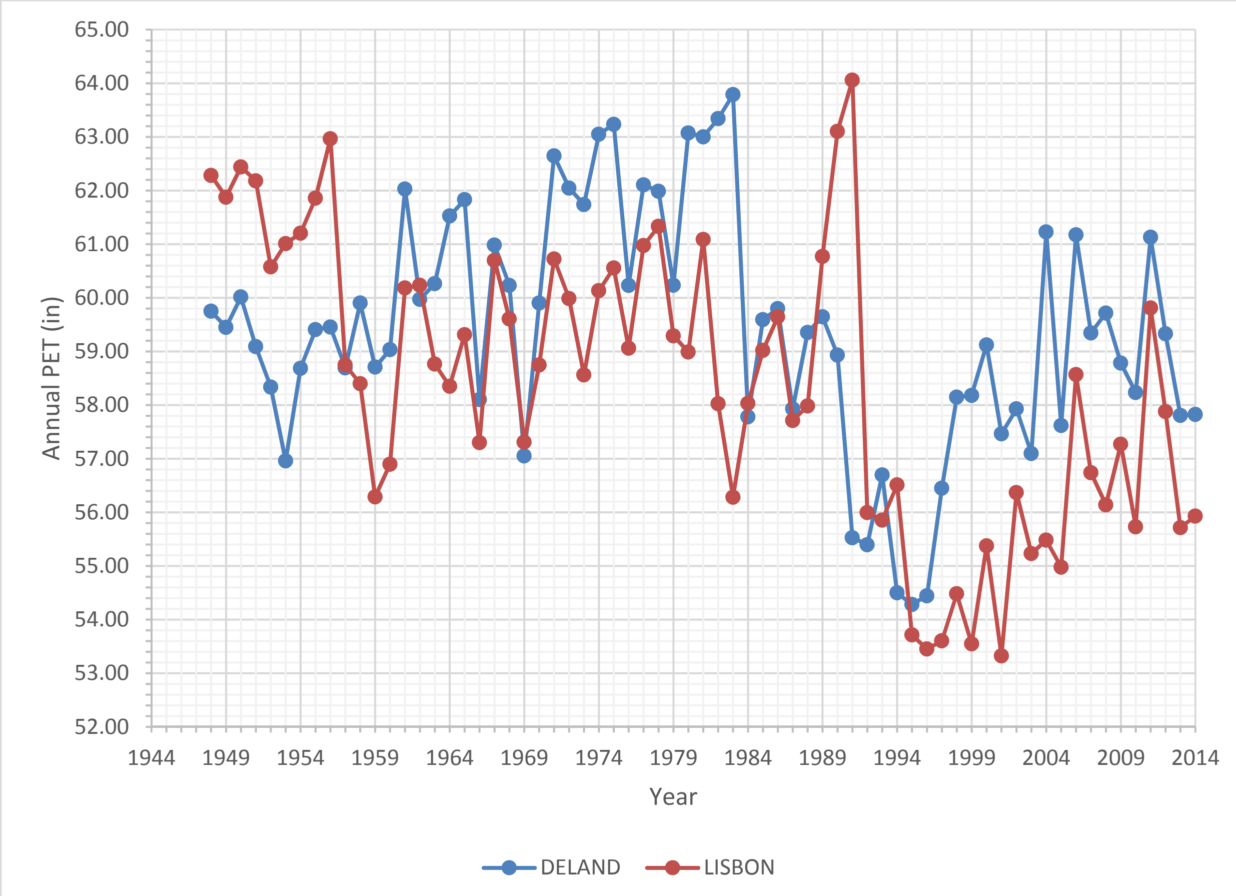


FIGURE 5. ANNUAL COMPUTED PET (INCHES) AT DELAND AND LISBON STATIONS POR (1948 - 2014)

TABLE 3. COMPUTED PET (INCHES) SUMMARY STATISTICS AT DELAND AND LISBON FOR POR (1948 - 2014)

Statistical Parameter	DeLand	Lisbon
Mean	59.41	58.42
Standard Error	0.27	0.32
Median	59.41	58.57
Mode	59.90	58.75
Standard Deviation	2.23	2.66
Minimum	54.28	53.32
Maximum	63.79	64.06

1.2 HYDROLOGIC DATA

The hydrologic data at Alexander Springs watershed are retrieved from SJRWMD database. Table 4 summarizes the available SJRWMD stations in the watershed.

Alexander Springs discharge data at SJRWMD station 00291896 are not continuous daily data but rather they are random samples. In the early period, the samples are sporadic monthly data. From 2002, the data are regular monthly samples. Except sporadic extreme values, the spring discharge is very consistent with a mean value of 102 cfs. The daily discharge data were estimated by linearly interpolating the irregular samples. Figure 6 shows the observed Alexander Springs discharge hydrograph. The observed Alexander Springs stage data are shown in Figure 7. Table 5 and Table 6 present the summary descriptive statistical data of discharge and stage, respectively.

TABLE 4. SJRWMD STATIONS AT ALEXANDER SPRINGS WATERSHED

Station Number	Station Name	Discharge Period of Record	Stage Period of Record
00291896	Alexander Springs at Astor	2/12/1931 - Current	10/30/1980 - Current
18523784	Alexander Springs Run at CR445	10/1/2003 – 4/3/2012	10/9/2003 - Current
18553786	Alexander Springs Run at Tracy Canal	10/1/2003 - Current	10/10/2003 - Current
34365072	Alexander Springs Creek A1 at Shell Landing	-	5/14/2014 - Current
31033149	Alexander Springs Creek Transect A5 North Bank	-	3/23/2010 - Current
31023387	Alexander Springs Creek Transect A6 North Bank	-	3/23/2010 - Current
31273459	Alexander Springs Creek Transect A8 North Bank	-	3/23/2010 - Current

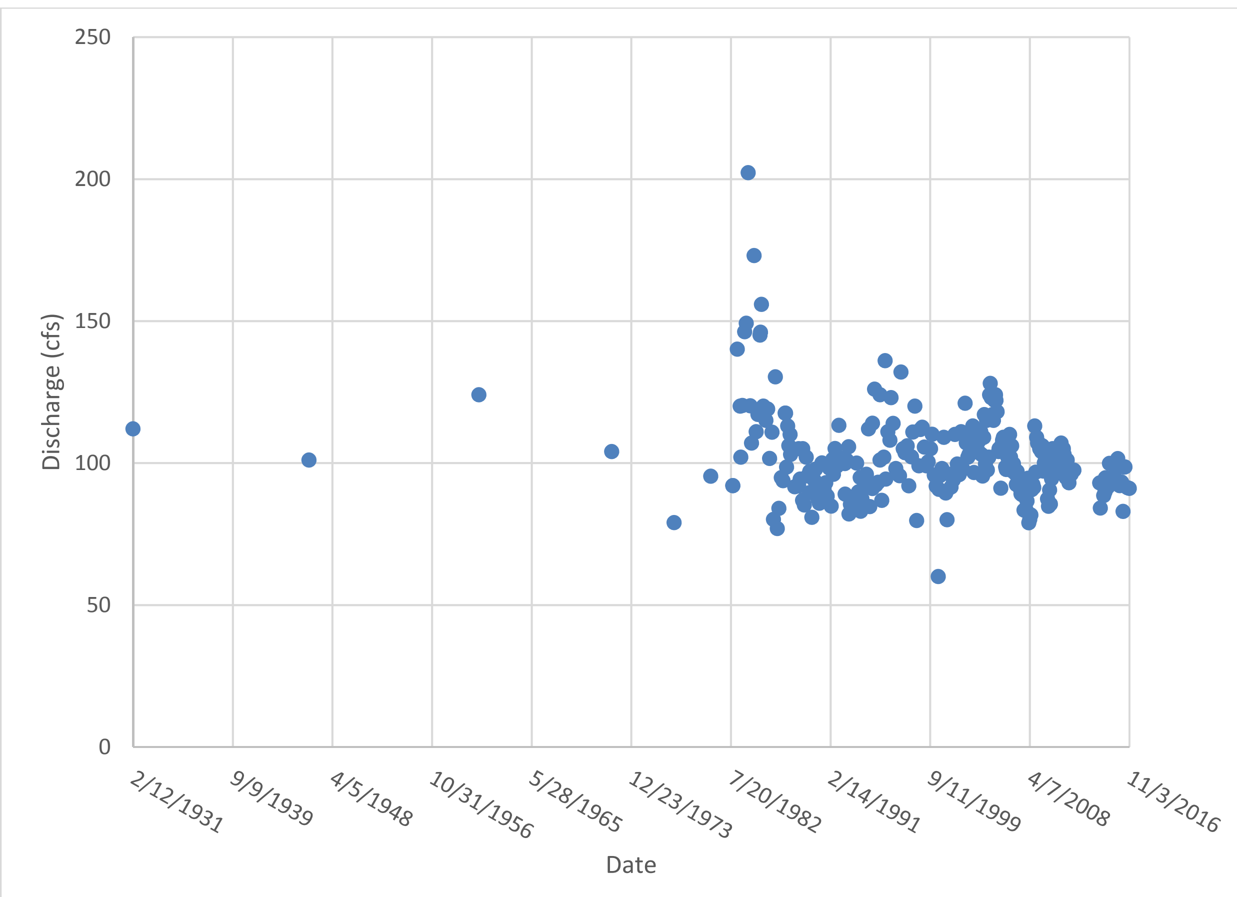


FIGURE 6. ALEXANDER SPRINGS DISCHARGE POR (2/12/1931 - 11/3/2016)

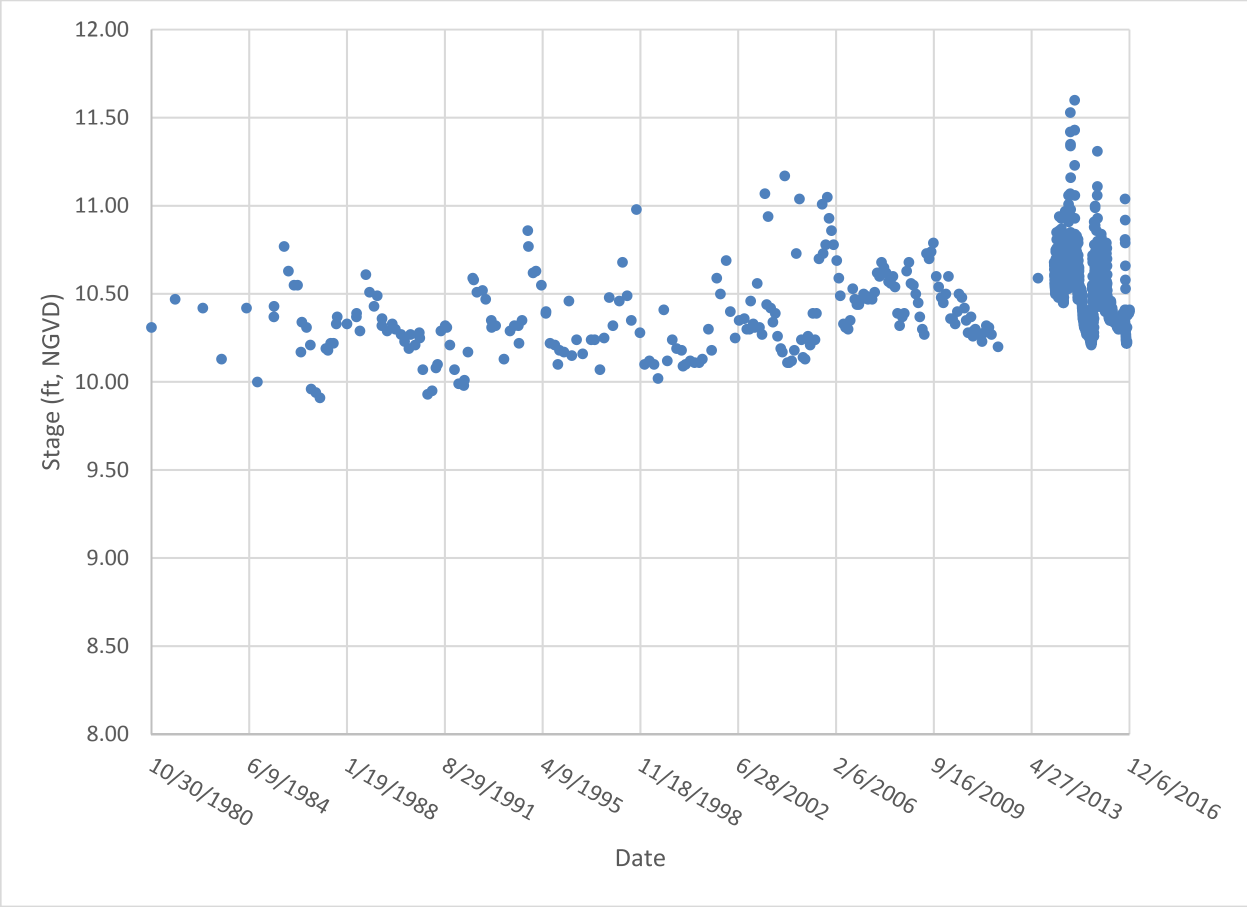


FIGURE 7. ALEXANDER SPRINGS STAGE POR (10/30/1980 - 12/6/2016)

TABLE 5. ALEXANDER SPRINGS DISCHARGE SUMMARY STATISTICS POR (2/12/1931 - 11/3/2016)

Descriptive Statistics	Discharge (cfs)
Mean	101.88
Standard Error	0.91
Median	99.95
Mode	102.00
Standard Deviation	15.09
Minimum	60.00
Maximum	202.19

Table 6. Alexander Springs Stage Summary Statistics POR (10/30/1980 - 12/6/2016)

Descriptive Statistics	Stage (ft NGVD29)
Mean	10.46
Standard Error	0.01
Median	10.44
Mode	10.36
Standard Deviation	0.20
Minimum	9.91
Maximum	11.60

The SJRWMD station 18523784 is on upstream Alexander Creek at County Road (CR 445). The station has both daily discharge and stage data from October 2003. However, discharge data were discontinued from 4/3/2012. It is unfortunate that the quality of data at this station are not consistent, mainly due to vandalism. Figure 8 and Figure 9 show the period of record of discharge and stage, respectively. The discharge and stage data are summarized in Table 7.

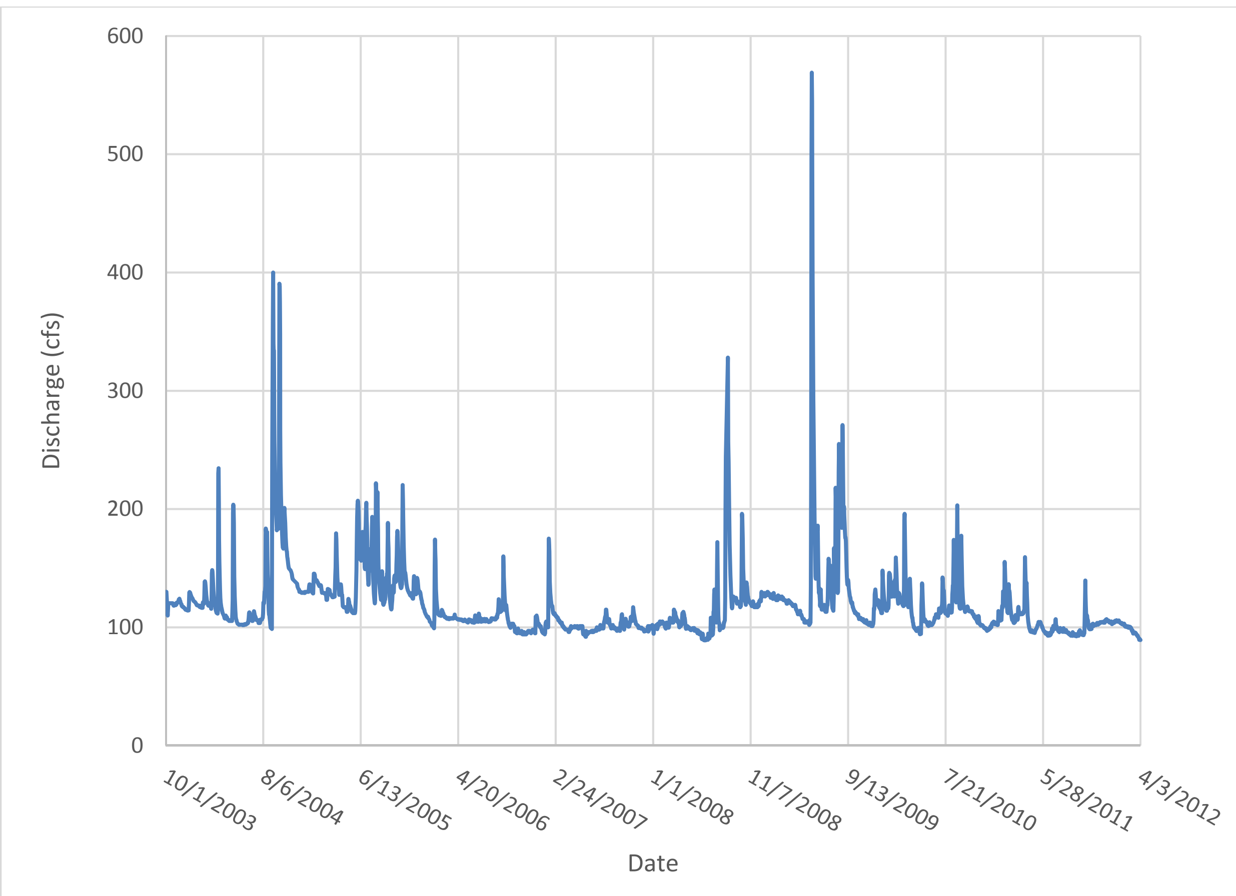


Figure 8. Discharge Hydrograph at Station 18523784 POR (10/1/2003 - 4/3/2012)

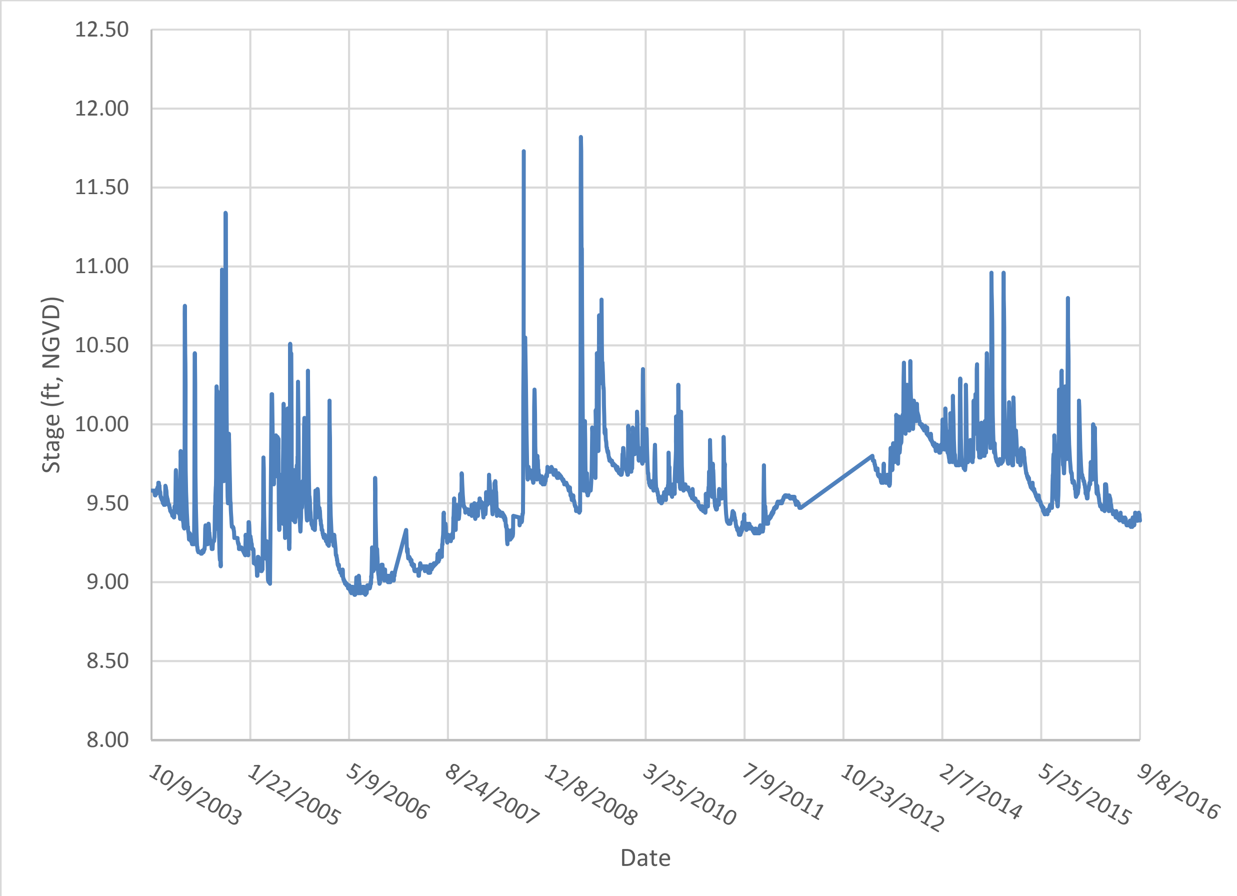


Figure 9. Stage Hydrograph at Station 18523784 POR (10/9/2003 - 9/8/2016)

Table 7. Station 18523784 Discharge and Stage Data Summary Statistics

Descriptive Statistics	Discharge (cfs) (10/1/2003-4/3/2012)	Stage (ft, NGVD) (10/9/2003-9/8/2016)
Mean	119.36	9.56
Standard Error	0.61	0.00
Median	110.39	9.54
Mode	101.00	9.48
Standard Deviation	32.81	0.32
Minimum	89.00	8.92
Maximum	569.00	11.82

The main gauging point is the SJRWMD station 18553786 on downstream Alexander Creek Run just prior at Tracy Canal confluence. The station has both daily discharge and stage data from October 2003 to current. As usual, there are missing data but the most important missing values related to tropical storm Fay in late August 2008. Figure 10 and Figure 11 show the discharge and stage data for the entire period of record, respectively. Table 8 summarizes both discharge and stage data.

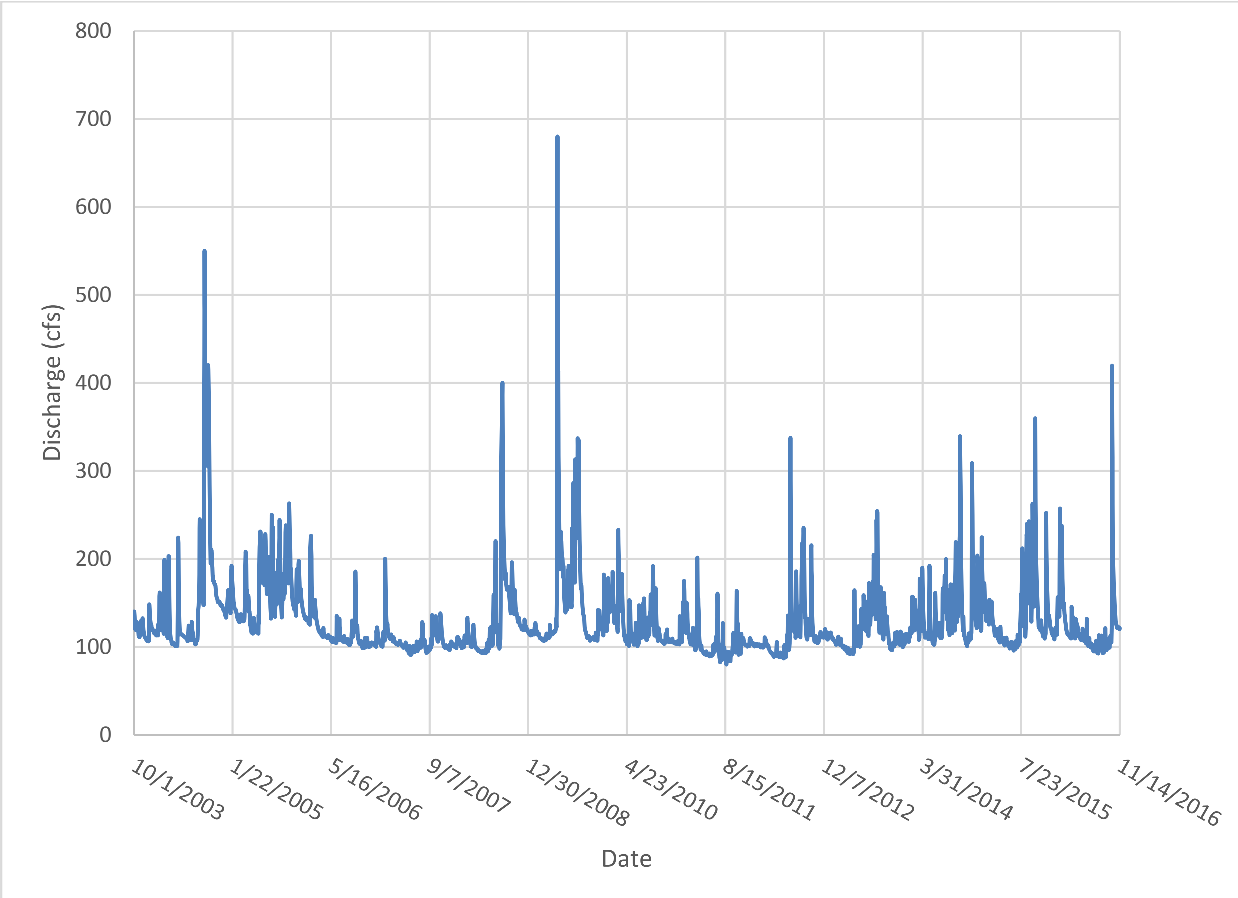


FIGURE 10. DISCHARGE HYDROGRAPH AT STATION 18553786 POR (10/1/2003 - 11/14/2016)

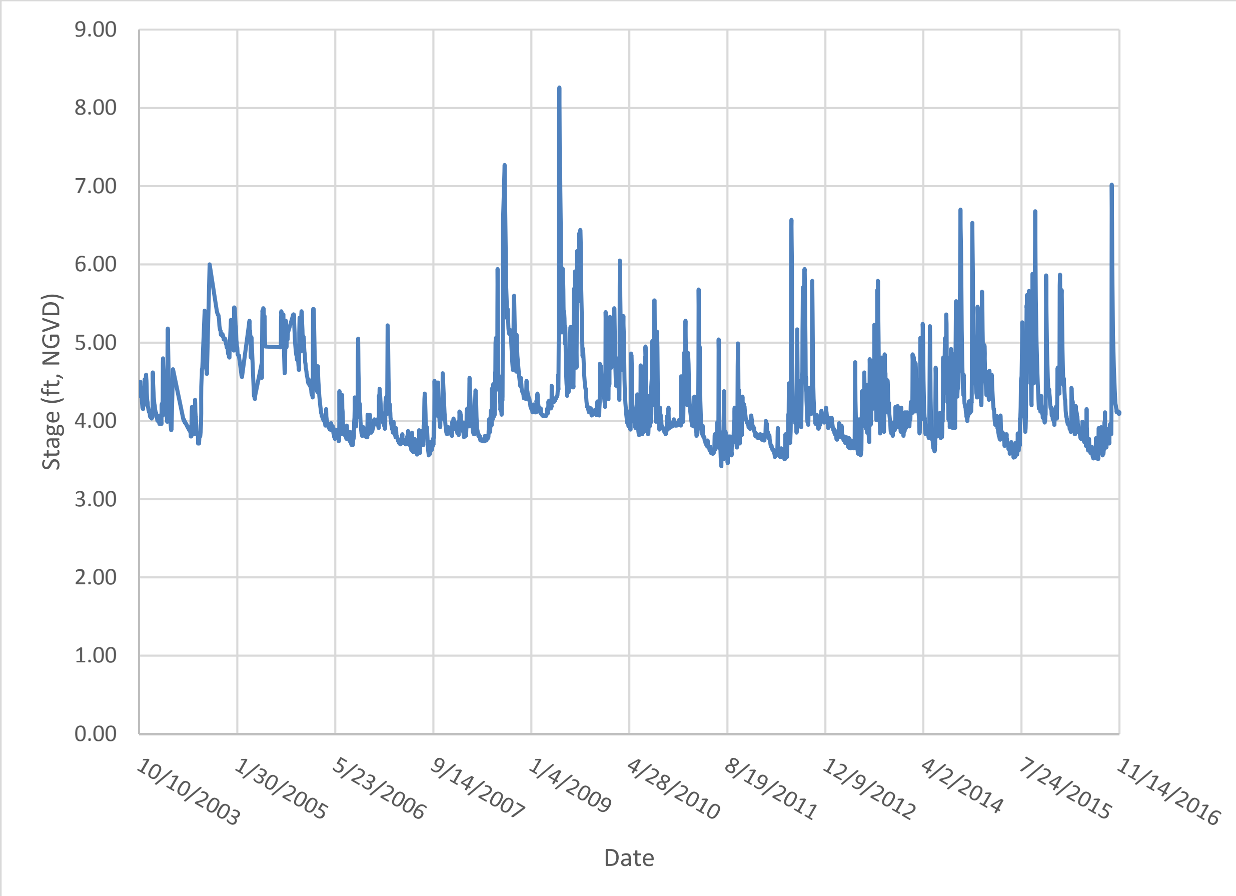


Figure 11. Stage Hydrograph at Station 18553786 POR (10/10/2003 - 11/14/2016)

Table 8. Discharge and Stage Summary Statistics at Station 18553786

Descriptive Statistics	Discharge (cfs) (10/1/2003-11/14/2016)	Stage (ft, NGVD) (10/10/2003-11/14/2016)
Mean	129.09	4.22
Standard Error	0.63	0.01
Median	115.00	4.06
Mode	104.00	3.94
Standard Deviation	42.92	0.54
Minimum	79.82	3.42
Maximum	680.00	8.26

2 Period of Record

As discussed in Section 1.2, Alexander Springs discharge data are not continuous daily data. They were generally random measurements and for some years, monthly data was available. In the early period until 1983, very few records were available (8 records from 1931 to 1982). The pool elevation records were not available till 1980. Similar to discharge data, they were also random measurements and sporadic until 2014. Daily pool elevation data seems to be available since 2014. Table 9 shows the number of records available for spring discharge and pool elevations (SJRWMD station 00291896) per year. The review of available data indicated that there was not sufficient data available before 1983 to be used for the MFL analysis. Therefore, only the data collected after 1983 were used in the MFL analysis.

TABLE 9. NUMBER OF RECORDS AT STATION 00291896

Year	Number of Records	
	Spring Flow	Pool Elevation
1931	1	0
1946	1	0
1960	1	0
1972	1	0
1977	1	0
1980	1	1
1982	2	1
1983	6	1
1984	6	2
1985	7	4
1986	6	8
1987	8	7
1988	7	6
1989	7	7
1990	8	8
1991	8	8
1992	8	8
1993	8	6
1994	8	8
1995	8	8
1996	5	5
1997	6	6
1998	6	6
1999	6	6
2000	7	7
2001	6	6
2002	8	8
2003	12	12
2004	12	12
2005	12	12
2006	12	12
2007	12	12

2008	12	12
2009	12	12
2010	12	12
2011	11	11
2012	1	1
2014	6	310
2015	5	365
2016	6	361

3 Transferring MFL field transect data to SJRWMD gage 18553786

MFLs field data are collected at four transects along the Alexander Springs Creek. Figure 12 shows the locations of the MFLs transects. SJRWMD collects stage data at three of the transects, A8, A6, and A5. The period of record of the transects data are short as shown in Table 4. The recommended MFLs at Alexander Springs is set at Tracy Canal gage where a relatively longer period of record exists. Furthermore, the HSPF model of the Alexander Springs is calibrated at Tracy Canal gage and the model results are outputted. Hence, the MFLs transects data are transferred to the Tracy Canal gage.

Elevation data of the MFLs transects were transferred sequentially from upstream to downstream along Alexander Creek using regression equations. Observed data from 1/1/2013 to 9/8/2016 were used to develop the regression equations. Figures 13 to 15 show the graphs and associated regression equations. Table 10 presents the computation of elevation data transfer.

TABLE 10. ELEVATION DATA TRANSFER COMPUTATIONS

MFLs	Transect	Stage at A8 (ft, NAVD88)	Stage at A6 (ft, NAVD88)	Stage at A5 (ft, NAVD88)	Stage at Tracy Canal (ft, NAVD88)
FH	A5			5.44	4.06
FH	A6		6.3	5.38	3.96
FH	A8	7.8	6.52	5.62	4.36
FL	A5			5.07	3.43
FL	A6		5.6	4.62	2.62
FL	A8	6.7	5.47	4.49	2.37

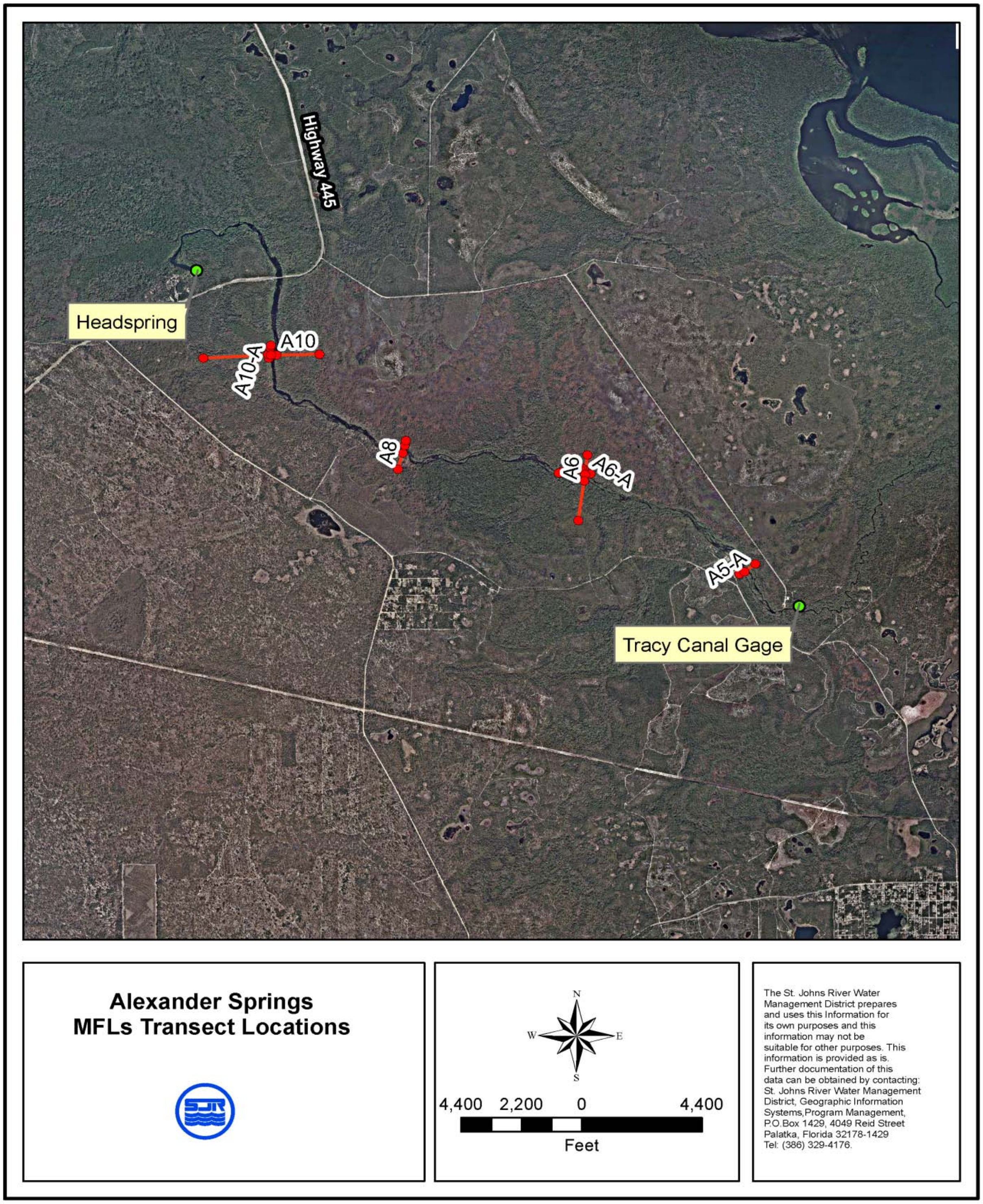


FIGURE 12. MFLS TRANSECTS AT ALEXANDER SPRINGS

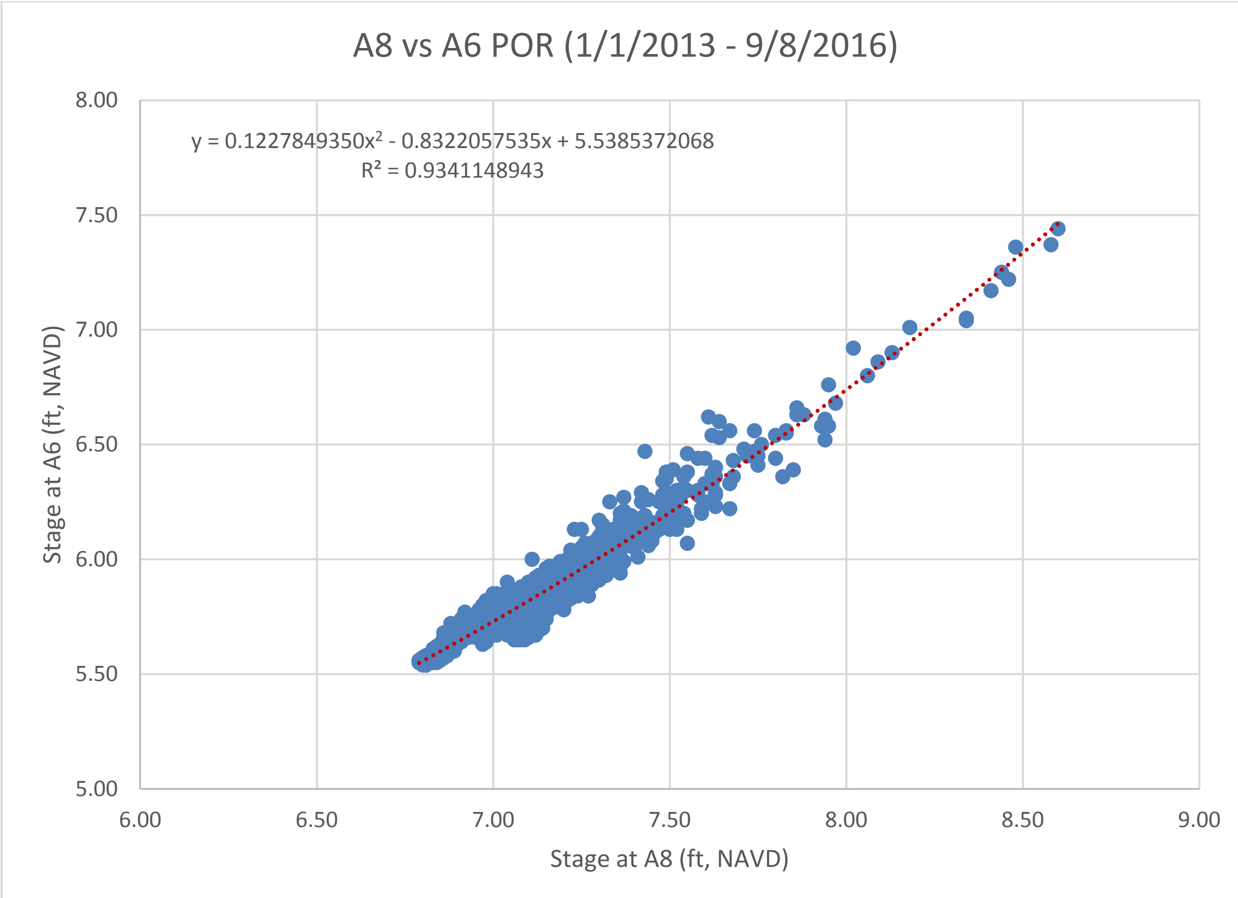


FIGURE 13. RELATIONSHIP BETWEEN TRANSECTS A8 AND A6

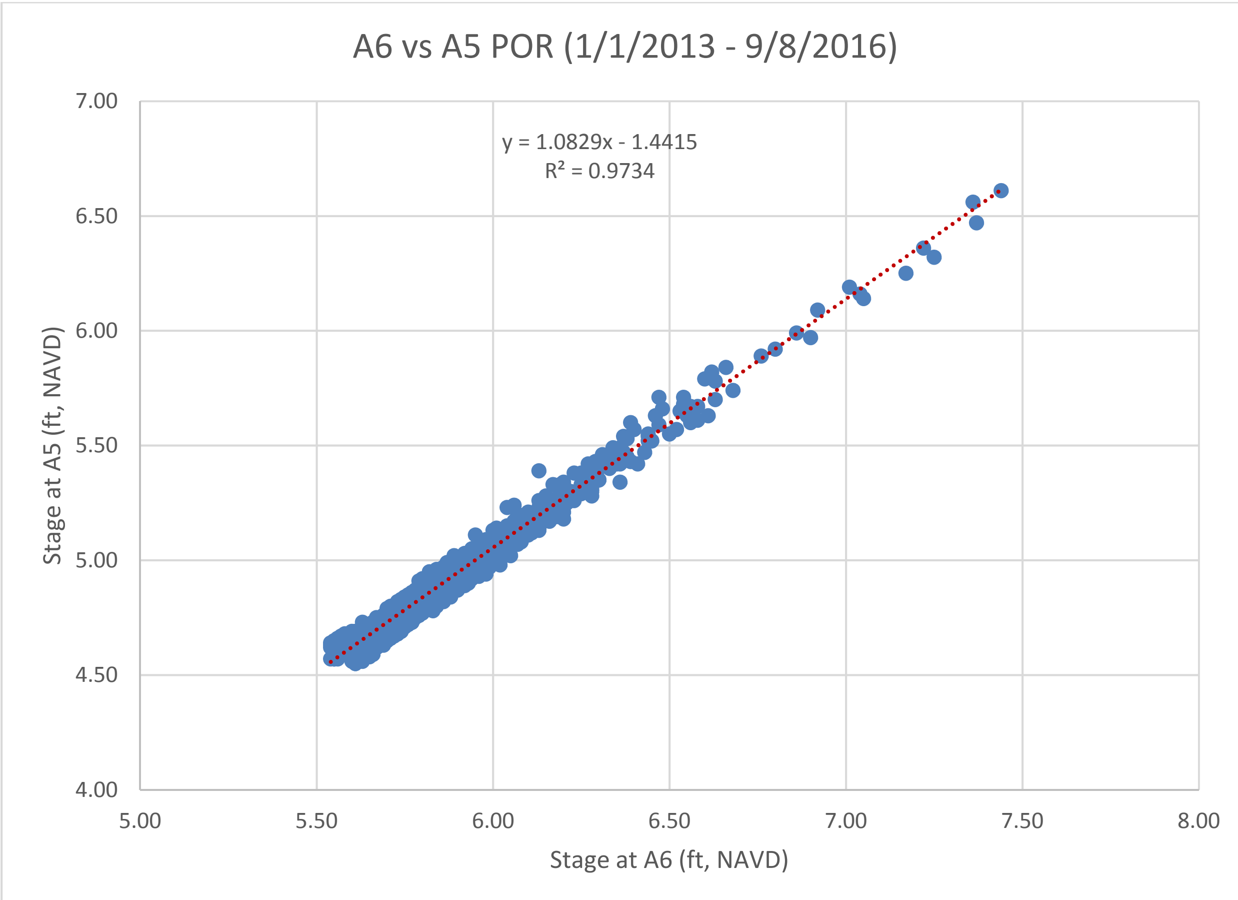


FIGURE 14. RELATIONSHIP BETWEEN TRANSECTS A6 AND A5

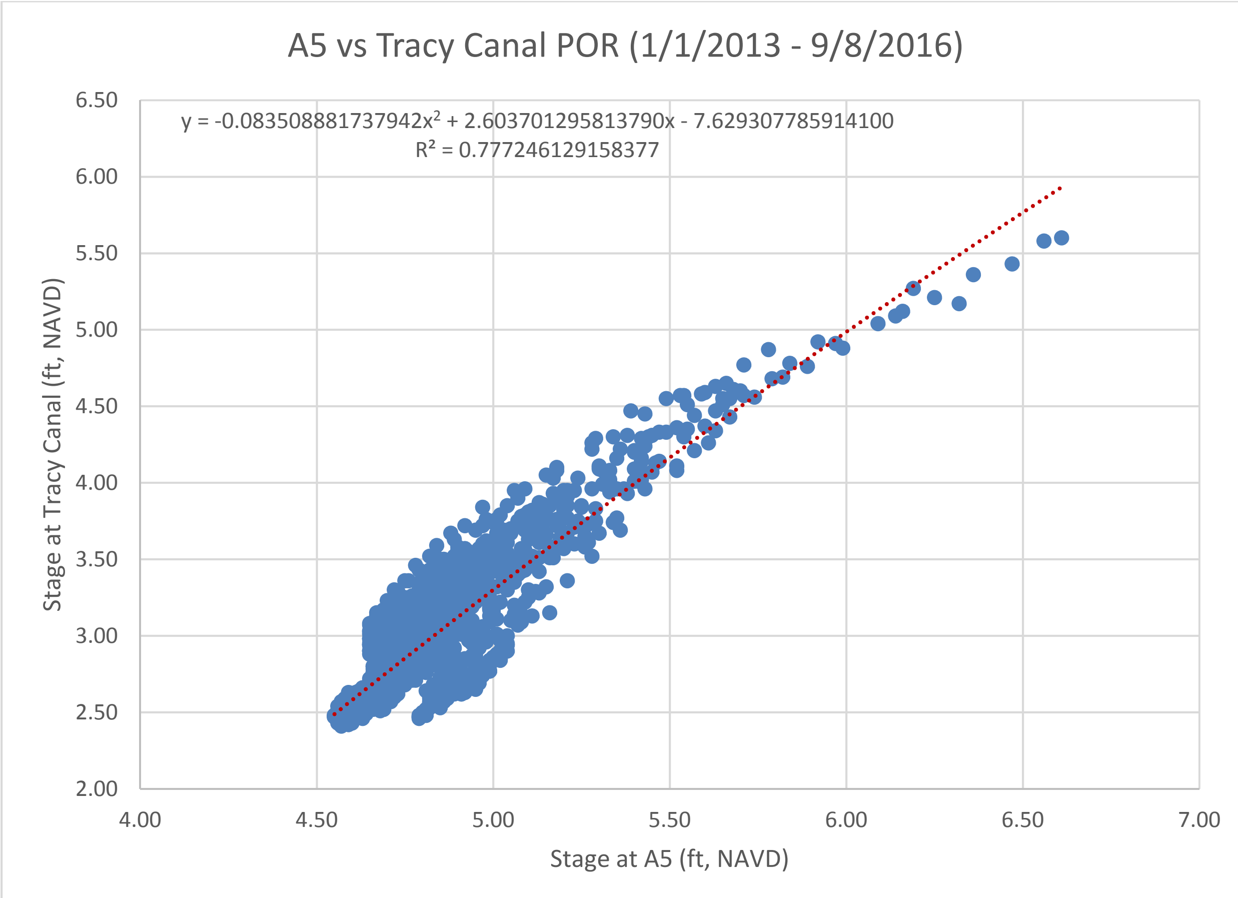


FIGURE 15. RELATIONSHIP BETWEEN TRANSECT A5 AND TRACY CANAL GAGE

4 Stage-flow relationships

At Alexander Springs the recommended MFLs are expressed in flows. MFLs stages at Tracy Canal gage are translated to MFLs flows using a stage-flow relationship at the gage. Observed stage and flow data for the period of record between 10/10/2003 and 11/14/2016 were used to develop polynomial regression equation. Figure 16 shows the stage-flow relationship and associated regression equation at Tracy Canal gage.

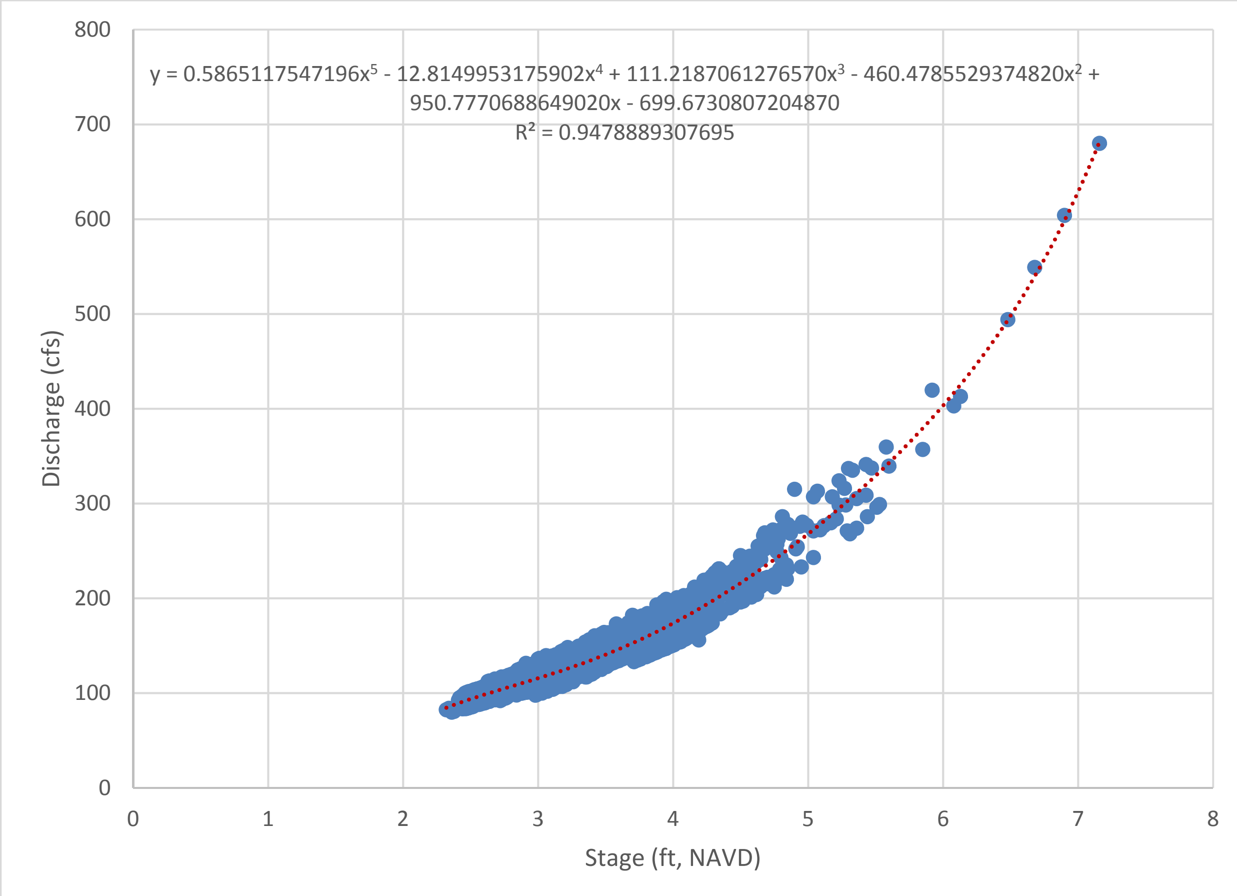


FIGURE 16. STAGE-FLOW RELATIONSHIP AT TRACY CANAL GAGE POR (10/10/2003 - 11/14/2016)

5 Groundwater pumping impact assessment

5.1 Groundwater Use

To estimate the potential impact on spring flows from groundwater pumping, annual groundwater use from 1950 to present was estimated within the estimated Alexander Springs springshed plus a one-mile buffer (Figure 17). The springshed was delineated by modifying the springshed developed by the USGS (Shoemaker, 2004) using the most recent UFA potentiometric surface maps. The one-mile buffer was added to account for potential variations in springshed boundaries under different hydrologic conditions (i.e, springshed may expand during wet season).

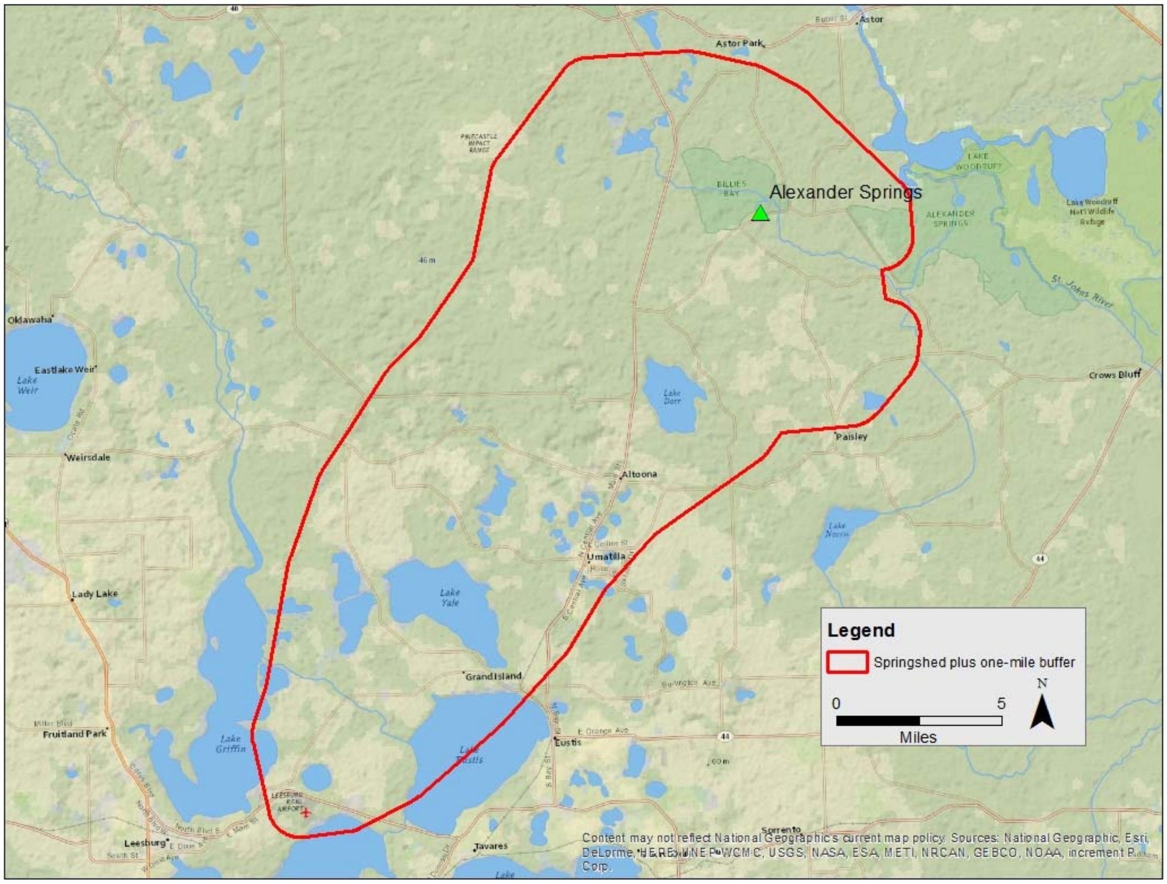


FIGURE 17. ALEXANDER SPRINGSHED PLUS ONE-MILE BUFFER

Groundwater pumping from 1950 – 2015 was estimated using annual groundwater use data from two sources. SJRWMD data from 1995 to 2015 was available within the springshed. Annual data within Marion and Lake Counties estimated by USGS was used for 1950 to 1994. To estimate springshed groundwater use from the county data, each available year was multiplied by the average proportion of groundwater use within the adjusted springshed. Figure 18 shows the estimated groundwater use within the springshed.

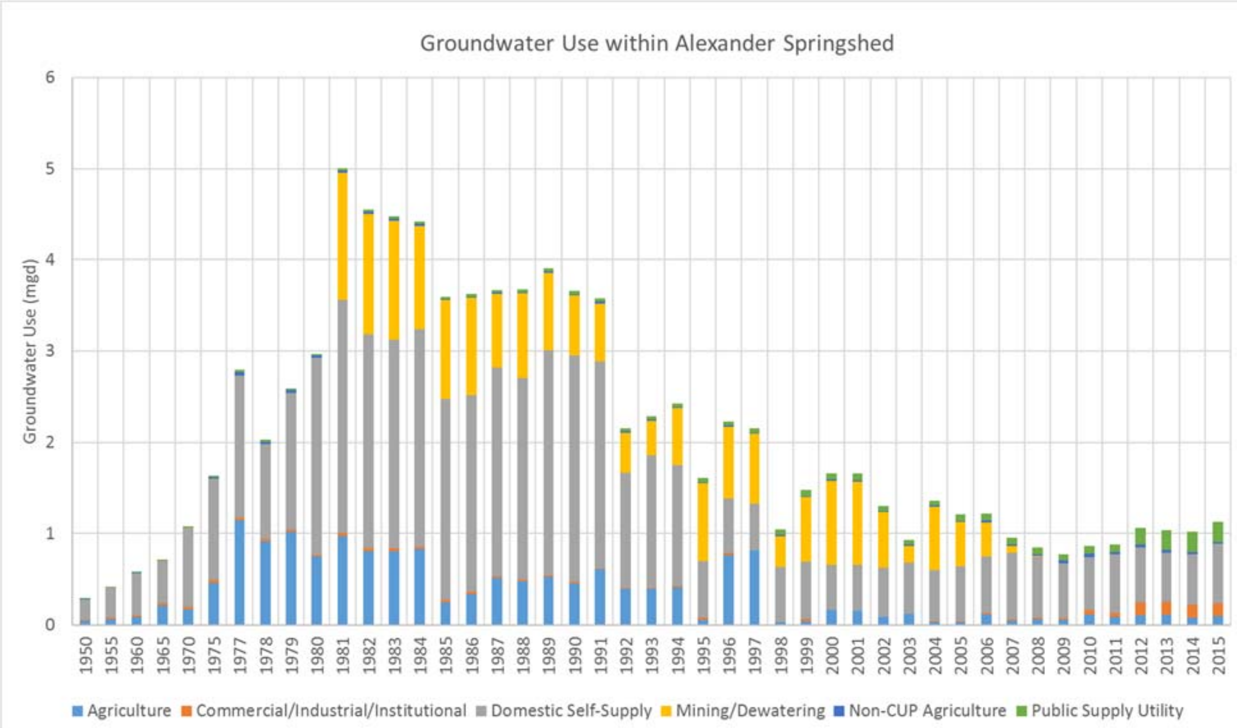


FIGURE 18. ESTIMATED GROUNDWATER USE WITHING ALEXANDER SPRINGSHED PLUS ONE-MILE BUFFER

As shown in Figure 18, groundwater use within the estimated springshed area reached at its highest level in 1981 (about 5 mgd) and has declined about 80% thereafter. The total groundwater use in 2015 was 1.1 mgd.

5.2 Groundwater Pumping Impact Assessment

It should be noted that the estimated springshed shown in Figure 17 represents the possible maximum extent of the groundwater contribution area for Alexander springs. Any groundwater pumping outside the springshed can still have an impact on the spring flows which, however, could be limited. In addition, because of presence of other springs in the area, springs can interact each other, which means springsheds could overlap. Therefore, the impact of any pumping within the springshed could also extend beyond the springshed boundary. Because of the complicated nature of groundwater flow dynamics, the groundwater models, which take into account the interaction of springs with other water bodies and complex aquifer system, are the best available tools to evaluate the impact of groundwater pumping on spring flows.

The reduction in Alexander spring flow due to pumping was estimated using version 5.0 of the SWFWMD Northern District Groundwater Flow Model (NDMv5 model) (HGL and Dynamic Solutions, 2016). The NDMv5 groundwater model estimated a reduction of Alexander Springs flow of 0.7 cfs in 2010 due to pumping. The 2010-condition is the latest pumping and hydrologic condition NDMv5 was calibrated to. Therefore, it represents the best available information regarding the impact of current withdrawal on spring flow at Alexander Springs.

6 Development of Flow Time Series

HSPF model was used to develop a long term flow time series at Tracy Canal. A period of record from 1/1/1983 to 12/31/2014 was used for MFLs computations. Figure 19 shows the simulated daily discharge time series at Tracy Canal. Table 11 presents a summary statistics of simulated discharge time series at Tracy Canal.

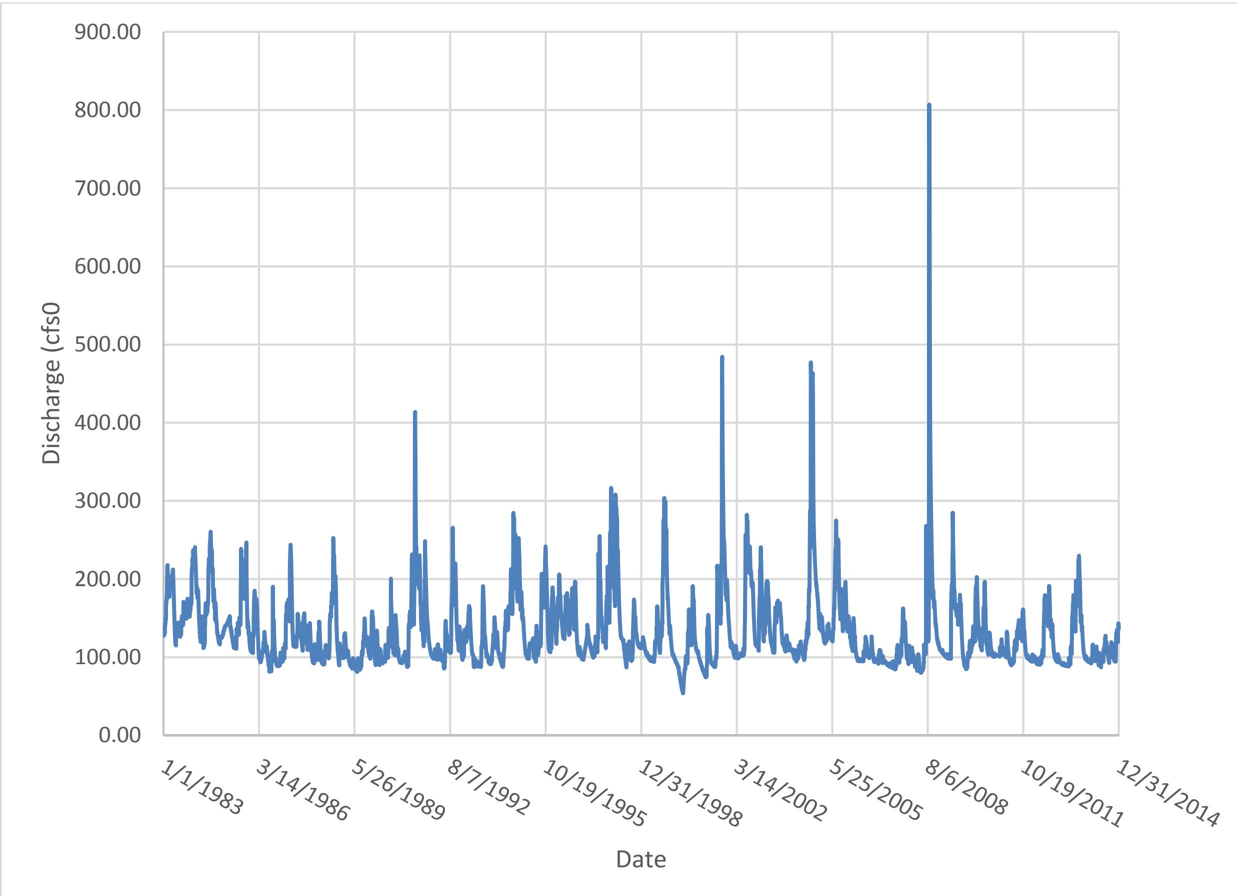


FIGURE 19. SIMULATED DISCHARGE TIME SERIES AT TRACY CANAL POR (1/1/1983 - 12/31/2014)

TABLE 11. SUMMARY STATISTICS OF SIMULATED DISCHARGE TIME SERIES AT TRACY CANAL POR (1/1/1983 - 12/31/2014)

Parameter	Simulated Discharge (cfs)
Mean	132.59
Standard Error	0.44
Median	117.58
Standard Deviation	47.87
Minimum	53.95

Maximum	806.99
Confidence Level (95.0%)	0.87

Since the impact from pumping on the spring flows is insignificant (about 0.5% of mean flow at Tracy canal), the observed flow time series was assumed to be the baseline flow time series which was used to perform the frequency analysis.

7 Estimating freeboard/deficit

7.1 Determination of MFLs

Minimum frequent high (FH), and minimum frequent low (FL) levels and flows were determined for Alexander Springs to protect ecological functions of the Alexander Springs Creek system. The stage-flow relationship at Tracy Canal gage, which was described in Section 4, was used to compute the MFLs flows. Table 12 presents the computed MFLs flow at Tracy Canal.

7.2 Frequency Analysis

SJRWMD's MFLs method is an event based method (Neubauer *et al*. 2008). An event is characterized by a defined magnitude, duration, and return interval. Statistical frequencies of stage and flow time series are analyzed. Two MFLs were recommended at Alexander Springs. They are based on the most constraining criteria among two for the minimum frequent high (FH) and among three for the minimum frequent low (FL) (Table 12). The annual frequencies of the simulated flows at Tracy Canal are computed for period of record from 1983 to 2014. Baseline flow for each MFLs are obtained from the annual frequency analysis for each specific duration and return interval (RI). Table 12 shows the computed baseline flow at Tracy Canal.

The difference between baseline and MFLs flows at each MFLs constitutes the freeboard. Frequency analysis results indicate that the hydrologic requirements for the most sensitive MFL criterion are met under baseline conditions (i.e., there is positive freeboard).

TABLE 12. MFLS COMPUTATIONS AT TRACY CANAL

MFL	Criterion	Level (ft NAVD88)	Baseline Flow (cfs)	MFLs Flow (cfs)	Duration	RI (yrs)	Freeboard (cfs)
FH	Cypress regeneration	4.13	242.86	183.63	7-day flood	2.6	59.23
FH	Creek – floodplain connections	3.84	239.99	162.17	7-day flood	2.0	77.82

FL	Deep marsh	2.37	120.56	87.41	120-day dewater	2.7	33.15
FL	Vernal pools	2.62	120.56	99.36	120-day dewater	2.7	21.20
FL	Slough inundation	2.32	115.96	84.80	120-day dewater	3.6	31.16

However, this most constraining MFL (the FL) allows a reduction of 21% in the mean flow for Alexander Springs. When compared to other springs MFLs across the state (i.e., at multiple water management districts) this allowable flow reduction is outside the range of flow reduction (0 to 10%) allowed by other springs' MFLs established within the state of Florida and is many times higher than the statewide mean of 6.8%. A potential reason for the disparity between the results for Alexander Springs and other springs' MFLs in the state, is due to the paucity of data that exists for this system. The hydrology of Alexander Springs and Creek is complex and there is a lack of hydrological data with which to determine the hydrological requirements of ecological criteria identified for this system.

Given Alexander Springs' high recreational and ecological value, unimpacted condition and high uncertainty regarding system hydrology due to a lack of data, the SJRWMD recommends a minimum flow for Alexander Springs based on the more protective statewide mean (6.8% reduction in mean flow), rather than the less protective Frequent Low that was determined based on available data.

The recommended minimum flow for Alexander Springs is a mean flow of 95.7 cfs. This is the mean flow for the no-pumping condition for the period of record (1983 – 2014) at the headspring (USGS gage 00291896), adjusted by a 7 cfs reduction in spring flow (6.8%). The no-pumping condition flow time series was generated by adding 0.7 cfs of impact from groundwater pumping to the observed flows at the headsprings. The average annual rainfall (average of Deland and Lisbon stations) for the same time is 53.2 inches whereas the long-term (1914-2015) average annual rainfall is 52 inches. Therefore, the time period used to determine the MFL represents a slightly higher than long-term average rainfall condition.

References

HGL and Dynamic Solutions, 2016. Northern district groundwater flow model version 5.0. Report prepared for the St Johns River Water Management District and Southwest Florida Water Management District.

APPENDIX D – PLANT COMMUNITY DATA AND SUMMARY STATISTICS

Table D1. Transect A5-A vegetation data

		Community names* and ranges (feet)												
		FW	**TZ**	**HH**	**W**	**HS**	**W**	**TZ**	**AB**	**HS**	**W**	**HS**	**W**	**FW**
		0	35	85	210	237	252	284	310	410	442	475	513	590
		35	85	210	237	252	284	310	410	442	475	513	590	714
Species	**Common Name**	**Species abundance (cover class)**												
Serenoa repens	saw palmetto	5	4											
Gordonia lasianthus	loblolly bay	1												
Osmunda cinnamomea	cinnamon fern	0	0											
Pinus serotina	pond pine	0												1
Quercus laurifolia	laurel oak	0	1	2		0								
Diospyros virginiana	persimmon	0												
Illicium parviflorum	yellow anise	1												
Sabal palmetto	cabbage palm		1	4		2				1		2		1
Liquidambar styraciflua	sweetgum		3											1
Fraxinus caroliniana	pop-ash			1		2				3		3		
Vaccinum corymbosum	blueberry		0	0										
Chasmanthium laxum	woodoats			0										
Acer rubrum	red maple			2		2				1		1		
Ilex cassine	dahoon holly			1		1		2		2		2		
Persea palustris	swamp bay	0		0								0		0
Cornus foemina	swamp dogwood			0				3		1		1		
Dichanthelium sp.	witchgrass			0										
Myrica cerifera	wax myrtle		0	1						0		0		
Lyonia ligustrina	maleberry	1	0											

Osmunda regalis	royal fern		0							0		0		
Habenaria sp.	false reinorchid	0												
Baccharis halimifolia	groundsel tree					1		1		0		0		
Cephalanthus occidentalis	buttonbush					0								
Smilax bona-nox	greenbrier					0								
Taxodium distichum	bald cypress									1		0		
Vallisneria americana	tapegrass								4				0	
Paspalidium geminatum	Egyptian paspalidium								2				0	
Magnolia virginiana	sweetbay		0											
Nyssa biflora	swampgum		1											
unknow Cyperaceae	sedge			0				0						1
Cicuta maculata	water hemlock							0	0				0	
Blechnum serrulatum	swamp fern							0						
Ludwigia repens	primrosewillow							0						
Pontederia cordata	pickerelweed								1				1	
Hydrocotyle umbellata	pennywort								0				0	
Nuphar advena	spatterdock												0	
Hymenocallis rotata	spiderlily												0	
Rhynchospora sp.	beaksedge											0		
Iris sp.	Iris											0		
Paspalum notatum	bahia grass													2
Centella asiatica	spadeleaf													1
Cirsium sp.	thistle													0

* FW = flatwoods, TZ = transition zone, HH = hydric hammock, W = water, HS = hardwood swamp, AB = aquatic bed

Table D 2. Transect A6 vegetation data

		Community names* and ranges (feet)												
		FW	**TZ**	**HS**	**HH**	**AB**	**HH**	**TZ**	**AB**	**HH**	**HH**	**BH**	**TZ**	**FW**
		0	290	460	746	779	862	928	950	1010	1290	1645	2045	2135
		290	460	746	779	862	928	950	1010	1290	1645	2045	2135	2566
Species	**Common name**	**Species abundance (cover class)**												
Acer rubrum	red maple	1	2	1			1			1	1	1		
Ageratina jucunda	hammock snakeroot	1												
Andropogon virginicus	broomsedge bluestem												0	0
Baccharis halimifolia	eastern baccharis										0			
Boehmeria cylindrica	smallspike false nettle								0					
Callicarpa americana	American beautyberry	1	0											
Carex alata	broadwing sedge					0								
Carpinus caroliniana	American hornbeam									1	1	1		
Centella asiatica	spadeleaf	0												
Cephalanthus occidentalis	buttonbush						1							
Chasmanthium laxum	slender woodoats	0		1	1					0	1	1		
Cladium jamaicense	swamp sawgrass	0		0										
Cornus foemina	swamp dogwood						1							
Crinum americanum	string lily						0	1						
Dichanthelium commutatum	variable panicgrass									1	1	1		
Dichanthelium dichotomum	cypress panicgrass	2	1	1	0									1
Dichanthelium oligosanthes	Heller's rosette grass			1										

Dichanthelium sabulorum	hemlock rosette grass		0							0	1	1		
Dichanthelium sp.	witchgrass												1	1
Diospyros virginiana	common persimmon	0												
Erigeron sp.				0										
Fraxinus sp.	ash						2			0				
Galium sp.		0												
Gordonia lasianthus	loblolly bay											1	3	1
Habenaria sp.	false reinorchid	0	0											
Hydrocotyle sp.	pennywort			1										
Hypericum brachyphyllum	coastal plain St. Johnswort	1												
Hypericum cistifolium	roundpod St. Johnswort	1												
Hypericum hypericoides	St. Andrew's cross	1	0											
Hypoxis curtissii	Curtis' star-grass			0										
Hyptis alata	clustered bushmint	0												
Ilex cassine	Dahoon holly		1	0	0		1							
Ilex glabra	inkberry	0	0											1
Illicium parviflorum	yellow anisetree											3	1	
Juniperus virginiana	eastern redcedar		2											
Liquidambar styraciflua	sweetgum	0	1	2	0		1			1	1	1	1	
Lyonia fruticosa	coastal plain staggerbush	1												
Lyonia ligustrina	maleberry													1
Lyonia lucida	fetterbush lyonia				0								2	2
Magnolia virginiana	sweetbay		1							0	1	2		0
Mitchella repens	partridgeberry									0	0	0	0	
Myrica cerifera	wax myrtle	1	0		0		1							
Nuphar advena	yellow pond-lily					0		1	2					

Nyssa biflora	swamp tupelo		1	3			1			1	0	1		
Oplismenus hirtellus	basketgrass				0					1	1	1		
Osmunda cinnamomea	cinnamon fern	1	1									0	1	
Osmunda regalis	royal fern						1							
Oxalis sp.		0												
Panicum rigidulum	redtop panicgrass			0						0	1			
Persea palustris	swamp bay	1	2		0		1			0	1	1	1	0
Pinus elliottii	slash pine	2	1											
Pinus serotina	pond pine													1
Pontederia cordata	pickerelweed			0		0		5						
Psychotria nervosa	wild coffee										0			
Pteridium aquilinum	western brackenfern	1											0	1
Quercus laurifolia	laurel oak	1	1	1			1			1	1	2	2	
Quercus virginiana	live oak	1												
Rhapidophyllum hystrix	needle palm										2	1		
Rhus copallinum	winged sumac	0												
Rhynchospora caduca	anglestem beaksedge													
Rhynchospora colorata	starrush whitetop													
Rhynchospora corniculata	shortbristle horned beaksedge					0	1	0	0					
Rhynchospora inundata	narrowfruit horned beaksedge			1										
Rhynchospora microcarpa	southern beaksedge	1	1	1										
Rhynchospora miliacea	millet beaksedge		1	1						1	1	1		
Rosa palustris	swamp rose						0							
Rubus pensilvanicus	blackberry	0		0	0		0							

Ruellia caroliniensis	Carolina wild petunia	0												
Sabal palmetto	cabbage palmetto	1	1	2	4		3			4	3	2	1	
Sagittaria lancifolia	bulltongue arrowhead					0								
Sagittaria latifolia	broadleaf arrowhead			0										
Saururus cernuus	lizard's tail			2	0									
Scleria sp.		0								0	1	0		
Selaginella sp.		0												
Serenoa repens	saw palmetto	5	5										3	5
Solidago sempervirens	seaside goldenrod	0												
Sphagnum sp.			0	0										
Symphyotrichum carolinianum	climbing aster				0									
Symphyotrichum dumosum	rice button aster	0												
Taxodium distichum	bald cypress			2						0				
Thelypteris interrupta	hottentot fern	0	1	3	0				0	0	1	1	0	
Toxicodendron vernix	poison sumac		0											
Ulmus americana	American elm			0	0		1			1	0			
Vaccinium corymbosum	highbush blueberry	1	1									1	2	0
Vaccinium myrsinites	shiny blueberry													1
Vallisneria americana	American eelgrass					0								
Woodwardia areolata	netted chainfern											1	0	
Woodwardia virginica	Virginia chainfern	0	0											

* FW = flatwoods, TZ = transition zone, HH = hydric hammock, HS = hardwood swamp, AB = aquatic bed, BH = bayhead

Table D3. Transect A8 vegetation data

		Community names* and ranges (feet)									
		FW	FW	TZ	AB	DM	HH	HH	TZ	FW	FW
		0	40	185	205	430	491	639	715	760	1040
		40	185	205	430	490	639	715	760	1040	1134
Species	**Common name**	**Species abundance (cover class)**									
Acer rubrum	red maple		1				2	0			
Andropogon glomeratus	bushy bluestem		0	3							
Aristida beyrichiana	Beyrich threeawn										1
Baccharis halimifolia	eastern baccharis						0				
Blechnum serrulatum	swamp fern		0								
Cephalanthus occidentalis	common buttonbush			1		0	1				
Chasmanthium laxum	slender woodoats		0	1							
Cicuta maculata	spotted water hemlock				0						
Cornus foemina	stiff dogwood			1			0				
Dichanthelium commutatum	variable panicgrass						1				
Dichanthelium sp.	witchgrass			1							
Diospyros virginiana	common persimmon		1								
Gaylussacia sp.	huckleberry										1
Gordonia lasianthus	loblolly bay								0		1
Hibiscus coccineus	scarlet rosemallow					1					
Hydrocotyle sp.	pennywort			1	1	1					
Hypericum tenuifolium	St. Johns wort										0
Ilex cassine	dahoon						1				
Ilex glabra	inkberry										1
Illicium parviflorum	yellow anisetree	1	0							2	1
Liquidambar styraciflua	sweetgum			1			0	1	1		
Ludwigia repens	creeping primrose-willow			1							
Lyonia ferruginea	rusty staggerbush									1	1
Lyonia ligustrina	maleberry									0	
Lyonia lucida	fetterbush lyonia										1

Magnolia virginiana	sweetbay		0					0			
Myrica cerifera	wax myrtle			1			0				
Nuphar advena	yellow pond-lily				2						
Nyssa biflora	swamp tupelo						2	0			
Oplismenus hirtellus	basketgrass						1				
Osmunda cinnamomea	cinnamon fern	4	2	1			2	4	3	2	
Osmunda regalis	royal fern			0			0				
Pinus elliottii	slash pine								1		
Pinus serotina	pond pine	4	0	3					2	2	2
Pinus taeda	loblolly pine		0								
Polygonum setaceum	bog smartweed					1					
Pontederia cordata	pickerelweed				0	3					
Quercus geminata	sand live oak										1
Quercus laurifolia	laurel oak		3	3			3	1			
Quercus nigra	water oak		2								
Rhynchospora miliacea	millet beaksedge						1				
Rhynchospora sp.	beaksedge			1							
Rubus pensilvanicus	blackberry			0							
Sabal palmetto	cabbage palmetto						3	1			
Sagittaria lancifolia	bulltongue arrowhead					2					
Salix caroliniana	coastal plain willow					2					
Samolus valerandi	seaside brookweed			1			0				
Schoenoplectus tabernaemontani	softstem bulrush				1	3					
Serenoa repens	saw palmetto	5	5	3					2	5	5
Taxodium distichum	bald cypress						1				
Thelypteris sp.				1			1				
Toxicodendron vernix	poison sumac									1	
Typha domingensis	southern cattail					4					
Vaccinium corymbosum	highbush blueberry		1				0			0	
Vaccinium myrsinites	shiny blueberry										0
Vallisneria americana	American eelgrass				5						
Woodwardia areolata	netted chainfern						1				

Woodwardia virginica	Virginia chainfern		0	1			2	2			

* FW = flatwoods, TZ = transition zone, HH = hydric hammock, AB = aquatic bed, DM = deep marsh

Table D4. Transect A10 vegetation data

		Community names* and ranges (feet)									
		FW	FW	BH	TZ	HH	AB	HH	HH	TZ	FW
		0	210	255	532	1030	1587	1783	2190	3615	4018
		210	255	532	1030	1587	1783	2190	3615	4018	4255
Species	**Common name**	**Species abundance (cover class)**									
Acer rubrum	red maple		2	2	2	2		2	2	1	
Andropogon virginicus	broomsedge bluestem				0	0					
Asimina angustifolia	slimleaf pawpaw	0									
Blechnum sp.	swamp fern								0		
Boehmeria cylindrica	smallspike false nettle							0			
Cephalanthus occidentalis	common buttonbush				1	1					
Chasmanthium laxum	slender woodoats			0	0	2		1	0		
Cladium jamaicense	swamp sawgrass			1	1	1					
Cornus foemina	stiff dogwood					1		0	0		
Dichanthelium commutatum	variable panicgrass					1		1	1		
Dichanthelium dichotomum	cypress panicgrass		1								
Dichanthelium dichotomum	cypress panicgrass			2	2	1					
Diospyros virginiana	common persimmon					0			1		0
Dryopteris ludoviciana	southern woodfern								1		
Erechtites hieraciifolius	American burnweed				0	1		0			
Gaylussacia tomentosa	hairytwig huckleberry	1									
Gordonia lasianthus	loblolly bay			0					0	1	3
Hypericum cistifolium	roundpod St. Johnswort					0					
Hypericum hypericoides	St. Andrew's cross			0	0						
Ilex cassine	dahoon			1							
Ilex cassine	dahoon				2	1		1		1	
Ilex glabra	inkberry	2		0							
Illicium parviflorum	yellow anisetree	1	1	1							
Juniperus virginiana	eastern redcedar					1		0			
Liquidambar styraciflua	sweetgum			1	0	2		1	1		
Lyonia lucida	fetterbush lyonia					0					
Lyonia mariana	piedmont staggerbush	0									

Magnolia virginiana	sweetbay			0		0		1	1		
Morus rubra	red mulberry					0		0	1		
Myrica cerifera	wax myrtle			0	0	1		0			
Najas guadalupensis	southern waternymph						1				
Nephrolepis exaltata	Boston swordfern					0			1		
Nuphar advena	yellow pond-lily						0				
Nyssa biflora	swamp tupelo			1	1						
Oplismenus hirtellus	basketgrass					0		1	1		
Osmunda cinnamomea	cinnamon fern	0	4	2	1	1		3	3	3	
Osmunda regalis	royal fern			0	0	0		1	1		
Panicum anceps	beaked panicgrass							1			
Panicum rigidulum	redtop panicgrass							0			
Persea palustris	swamp bay			1	1	1		1		1	1
Pinus palustris	longleaf pine	1									
Pinus serotina	pond pine	2		0	0					2	3
Pinus taeda	loblolly pine	2	1	1	1						
Pteridium aquilinum	western brackenfern	2	0								
Quercus laurifolia	laurel oak		2	1	2	2		2	2	3	1
Quercus virginiana	live oak		2								
Rhapidophyllum hystrix	needle palm							0	2		
Rhynchospora colorata	starrush whitetop				0	0					
Rhynchospora fascicularis	fascicled beaksedge			0	0						
Rhynchospora miliacea	millet beaksedge					1		1	1		
Rubus pennsilvanicus	blackberry				1	0		0			
Sabal palmetto	cabbage palmetto			2	2	3		4	4	2	
Saccharum giganteum	sugarcane plumegrass				0						
Samolus valerandi	brookweed							0			
Saururus cernuus	lizard's tail				0	0		0	0		
Serenoa repens	saw palmetto	5	5	1	4	2				3	5
Sphagnum sp.	sphagnum moss		0	1							
Thelypteris palustris	eastern marsh fern					1		1	1		
Typha sp.	cattail						0				
Ulmus americana	American elm				0	1		1	1		

Vaccinium corymbosum	highbush blueberry			1	1	1		1	1	1	
Vaccinium myrsinites	shiny blueberry	0									
Vallisneria americana	American eelgrass						3				
Vitis sp.	grape	1	1								
Woodwardia areolata	netted chainfern					0		0	1		
Woodwardia virginica	Virginia chainfern		1	1	0			1	1		

* FW = flatwoods, BH = bayhead, TZ = transition zone, HH = hydric hammock, AB = aquatic bed

Table D5. Vegetative community elevations at each MFL transect

Transect A5A

Community	Elevation (ft NAVD) Mean	Max	Min	N
Hydric Hammock	4.63	4.93	4.38	14
Unvegetated Channel	2.17	3.64	0.33	30
Hardwood Swamp	4.24	4.59	3.66	16
Aquatic Bed Transition	2.59	2.94	2.44	6
Aquatic Bed	2.17	2.94	1.24	21
Canoe Passage Channel	1.58	2.40	1.24	5

Transect A6

Community	Elevation (ft NAVD) Mean	Min	Max	N
Hardwood Swamp	6.25	5.59	7.10	30
Hydric Hammock	7.07	6.03	7.86	75
Aquatic Bed	2.79	1.50	4.60	16
Deep Marsh	4.45	2.60	5.84	3
Bayhead	8.80	7.40	9.80	41

Transect A8

Community	Elevation (ft NAVD) Mean	Min	Max	N
Hydric Flatwoods	10.86	7.81	14.91	45
Flatwoods Transition	8.10	7.41	8.64	14
Aquatic Bed	4.63	4.05	5.85	23
Deep Marsh	5.44	4.85	6.75	7
Hydric Hammock	7.85	7.49	8.88	24

Transect A10

Community	Elevation (ft NAVD) Mean	Min	Max	N
Hydric Flatwoods	10.39	9.26	11.62	6
Bayhead	9.49	9.16	10.19	29
Transition Zone	9.35	8.95	10.60	52
Hydric Hammock	8.88	8.05	9.77	57
Aquatic Bed	5.40	4.95	7.32	20
Flatwoods Transition	13.86	11.62	16.06	41

WATER RESOURCES AND HUMAN USE VALUE ASSESSMENT OF ALEXANDER SPRINGS AND ALEXANDER SPRINGS CREEK, LAKE COUNTY

APRIL 2017

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EXECUTIVE SUMMARY

An evaluation was conducted to determine if the recommended minimum flows for Alexander Springs and Alexander Springs Creek, in Lake County, Florida, protect the 10 water resource values (WRVs) defined in Rule 62-40.473, Florida Administrative Code (*F.A.C.).* The determination of the recommended minimum flows and levels (MFLs) for Alexander Springs is presented in Freese and Sutherland (2017). The recommended minimum flow for Alexander Springs is a mean flow of 95.7 cubic feet per second (cfs). This is the mean flow for the observed period of record (1983 – 2014) measured at the headspring [U.S. Geological Survey (USGS)] gage 00291896), adjusted by a 7 cfs reduction in spring flow (6.8 percent), which is equal to the mean flow reduction allowed for springs-based MFLs within Florida.

The WRV evaluations for Alexander Springs and Alexander Springs Creek were conducted using an event-based analysis of changes in return intervals for critical flow events between no-pumping conditions and the recommended MFLs hydrologic regimes, where possible. Not all WRVs were evaluated using this approach. WRV-10 (Navigation) does not exist in Alexander Springs Creek. WRV-3 (Estuarine Resources), WRV-5 (Water Supply), WRV-8 (Sediment Loads) and WRV-9 (Water Quality) did not reveal critical events that could be evaluated using the event-based approach. WRV-1 (Recreation in and on the Water), WRV-2 (Fish, Wildlife and the Passage of Fish), WRV-4 (Transfer of Detrital material), WRV-6 Aesthetics) and WRV-7 (Filtration and Absorption of Nutrients and Other Pollutants) were evaluated using this approach.

The development of the two hydrologic regimes is discussed in detail in Karama and Gordu (2017). More specifically, the return intervals (frequency of occurrence) of hydrologic conditions from which one may infer protection of the WRVs were evaluated under no-pumping conditions and MFLs hydrologic regimes. The resource value was determined to be protected if the frequency of occurrence of these key events under the MFLs hydrologic regime did not differ unacceptably from the no-pumping condition based available data, literature research and professional judgment where necessary (Table ES-1). Table ES-1 provides a summary of the WRV assessment.

WRV 1 (Recreation In and On Water) is considered protected. Given that the relative frequency of the low-water events remains on average once every 10 years or more, this WRV is considered protected under the proposed MFLs hydrologic regime.

WRV-2 (Fish and Wildlife Habitats and the Passage of Fish) was considered to be one of the more sensitive WRVs. The analysis concluded that it is protected with respect to fish and velocities to protect fish and shellfish habitats. The analysis with respect to floodplain inundation to protect hydric soils concluded that hydric soils would be protected under the proposed Alexander Springs MFLs. Wetland communities and associated fauna within the floodplain were also determined to be protected.

WRV-3 (Estuarine Resources) and WRV-5 (Maintenance of Freshwater Storage and Supply) were found to be protected. For WRV-3, the contribution of Alexander Springs to downstream estuarine resources is contained within the cumulative contributions of other flow reductions evaluated in the St. Johns River Water Supply Impact Study (WSIS) for which estuarine resource protection is one of the major considerations. The WSIS concluded that the proposed and assessed flow reductions do not cause harm to estuarine resources. Therefore, flow reductions associated with Alexander Springs MFL will be protective of WRV-3 since Alexander Springs future contribution to flow reductions to the lower St. Johns River will have been accounted for. Under any circumstances flows from Alexander Springs are small relative to flows of the entire St. Johns River system. Protection of WRV-5 under the preliminary Alexander Springs MFLs is related to non-consumptive uses and environmental values. This WRV is encompassed in the other eight (8) WRVs. Given that those evaluations concluded that all nine WRVs are protected, it is concluded that WRV-5 is also protected by the draft MFLs.

WRV-4 (Transfer of Detrital Material) and WRV-7 (Filtration and Absorption of Nutrients and Other Pollutants) were also considered to be two of the more sensitive WRVs evaluated. The sensitivities are primarily related to a lowering in floodplain inundation frequency. The major factor that would be affected by flow reductions allowed under the recommended MFLs would be the reduction in the frequency of physical contact of water with riparian, or floodplain vegetation. The preliminary MFL was considered to be protective as it prevents unacceptable reductions in contact time with the floodplain, which is important for maintaining these characteristics.

Changes in velocities associated with flow reductions allowed under the preliminary MFLs were also evaluated. WRV-8 (Sediment Loads), Algal Scour and aspects of WRV-4 (Transfer of Detrital Material) and WRV-7 (Filtration and Absorption of Nutrients and Other Pollutants) have a velocity dependence associated with their function. They were considered protected under all scenarios with respect to velocity. Given the small decrease, generally 0.05 ft/sec or less, in average in-channel velocities anticipated, these WRVs should be protected under the preliminary Alexander Springs MFLs.

The assessment of WRV-9, (Water Quality), found no important relationships between flow rates or water levels and water quality trends in Alexander Springs and Alexander Springs Creek. Given the general lack of significant changes in water quality with changes in flows, there will be some improvement in such water quality constituents as inorganic nitrogen (NOx) concentrations and no apparent degradation in other constituents.

Table ES-1. Summary results for WRV evaluation of the recommended MFLs Hydrologic Regime

Water Resource Value (WRV)	**MFLs Hydrologic Regime Protective?**
WRV-1: Recreation In and On the Water	Yes
WRV-2: Fish and Wildlife Habitats and the Passage of Fish	
Fish Passage	Yes
Fish/Shellfish Habitat (flow velocity related issues)	Yes
Floodplain Inundation (wetland communities)	Yes
Floodplain Inundation (hydric soils)	Yes
WRV-3: Estuarine Resources	Yes
WRV-4: Transfer of Detrital Material	Yes
WRV-5: Maintenance of Freshwater Storage and Supply	Yes
WRV-6: Aesthetic and Scenic Attributes	Yes
WRV-7: Filtration and Absorption of Nutrients and Other Pollutants	Yes
WRV-8: Sediment Loads	Yes
WRV-9: Water Quality	Yes
WRV-10: Navigation	Not Applicable

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1.0 INTRODUCTION

Alexander Springs and Alexander Springs Creek in Lake County, Florida, are listed as priority waterbodies on the State of Florida's Minimum Flows and Levels (MFLs) Priority Water Body List. Pursuant to Section 373.042(2) of the Florida Statutes (F.S.), the St. Johns River Water Management District (SJRWMD) must therefore establish MFLs for these systems.

The methodology for determining these recommended MFLs is detailed in two SJRWMD draft reports: Minimum Flows Determination for Alexander Springs and Alexander Springs Creek, Lake County, Florida (Freese and Sutherland (2017), and Development of Flow and Stage Time Series at MFL Transects of Alexander Springs and Alexander Springs Creek (Karama and Gordu, 2017). The recommended MFLs will remain preliminary until the SJRWMD Governing Board formally adopts them by rule [Rule 40C-8, Florida Administrative Code (*F.A.C.*)]. Prior to its consideration by the Governing Board, an assessment may be conducted to determine whether the recommended MFLs hydrologic regime will protect designated natural resource and environmental values. This document provides such an assessment.

Alexander Springs is located in the Ocala National Forest and, therefore, lacks large water users nearby. Existing or observed flow is essentially unimpacted by groundwater pumping and serves as the baseline hydrologic regime. The MFLs hydrologic scenario was developed in relation to the baseline hydrologic scenario.

Neubauer et al. (2008) provides an overview of the SJRWMD's MFLs program, which establishes MFLs for lakes, streams and rivers, wetlands, springs, and groundwater aquifers, as mandated by state water policy (section 373.042, F.S.). The establishment of MFLs gives priority to waters that are located within: (a) an Outstanding Florida Water, (b) an aquatic preserve, (c) an area of critical state concern, or (d) an area subject to Chapter 380 Resource Management Plans (rule 62-40.473(3), *F.A.C.*).

According to Rule 62-40.473(1), *F.A.C.*, in establishing MFLs pursuant to Section 373.042 and Section 373.0421, F.S., consideration shall be given to natural seasonal fluctuations in water flows or levels; nonconsumptive uses; and environmental values associated with coastal, estuarine, riverine, spring, aquatic, and wetlands ecology, including:

a. Recreation in and on the water (62.40.473 (1) (a), *F.A.C.*)
b. Fish and wildlife habitats and the passage of fish (62.40.473 (1) (b), *F.A.C.*)
c. Estuarine resources (62.40.473 (1) (c), *F.A.C.*)
d. Transfer of detrital material (62.40.473 (1) (d), *F.A.C.*)
e. Maintenance of freshwater storage and supply (62.40.473 (1) (e), *F.A.C.*)
f. Aesthetic and scenic attributes (62.40.473 (1) (f), *F.A.C.*)
g. Filtration and absorption of nutrients and other pollutants (62.40.473 (1) (g), *F.A.C.*)
h. Sediment loads (62.40.473 (1) (h), *F.A.C.*)
i. Water quality (62.40.473 (1) (i), *F.A.C.*)
j. Navigation (62.40.473 (1) (j), *F.A.C.*)

It is these 10 natural resource and environmental values that are the focus of this assessment. The assessment will determine how these values may be affected under the proposed MFLs hydrologic regime.

2.0 ALEXANDER SPRINGS AND ALEXANDER SPRINGS CREEK BACKGROUND INFORMATION

Alexander Springs and Alexander Springs Creek are located in Lake County in the of Ocala National Forest (Figure 2-1). Alexander Springs Creek is the spring run for Alexander Springs, which is one of Florida’s first magnitude springs, (Scott et al., 2004; Osburn et al., 2006; Rosenau et al., 1977; as cited in Munch et al., 2006) The spring and creek make up Alexander Springs State Park.

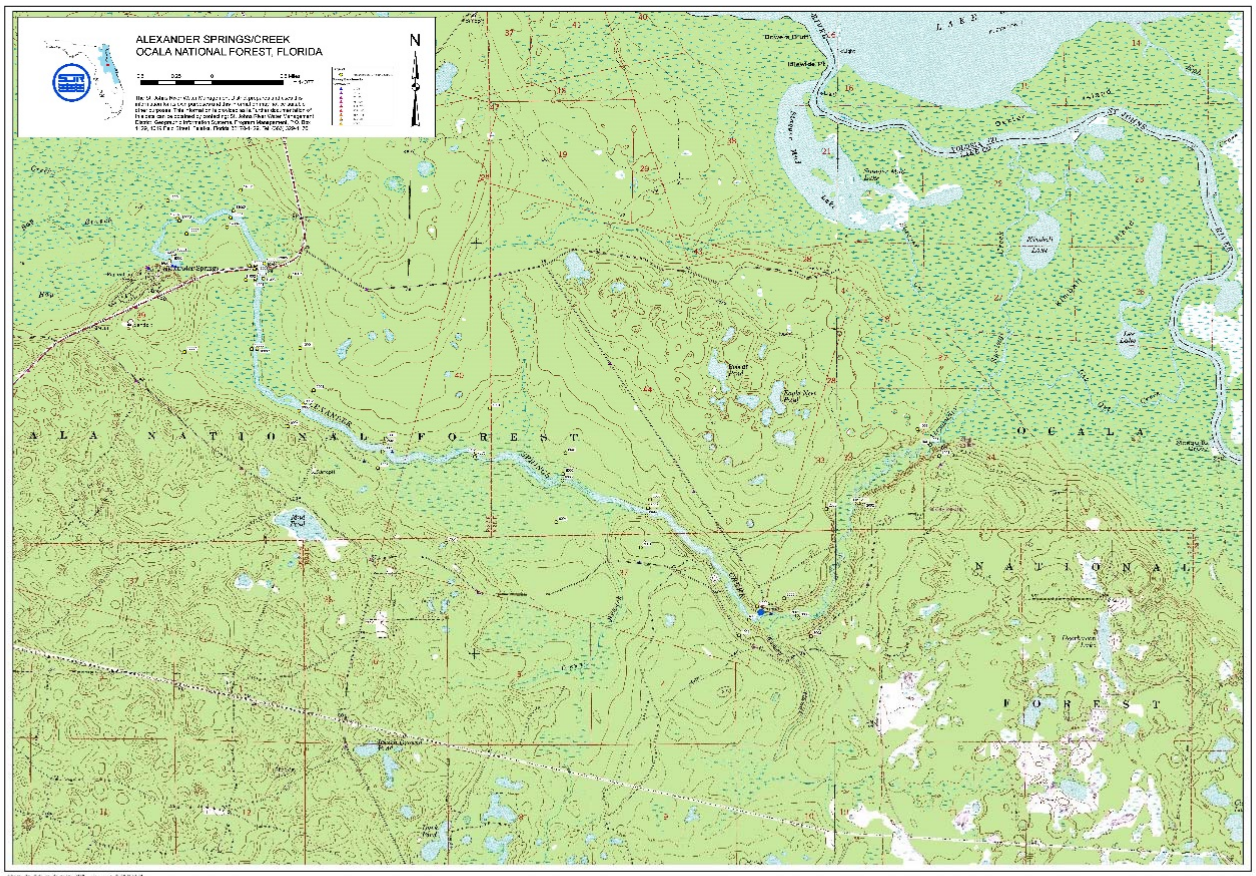

Figure 2-1. Location map for the Alexander Springs study site in Lake County, Florida. Source: SJRWMD, 2016.

Karama and Gordu (2017) details the development of flow and stage time series at transects on Alexander Springs and Alexander Springs Creek.

Figure 2-2 provides a map of the Alexander Springs Creek watershed. Figure 2-3 presents the land use/land cover within the watershed.

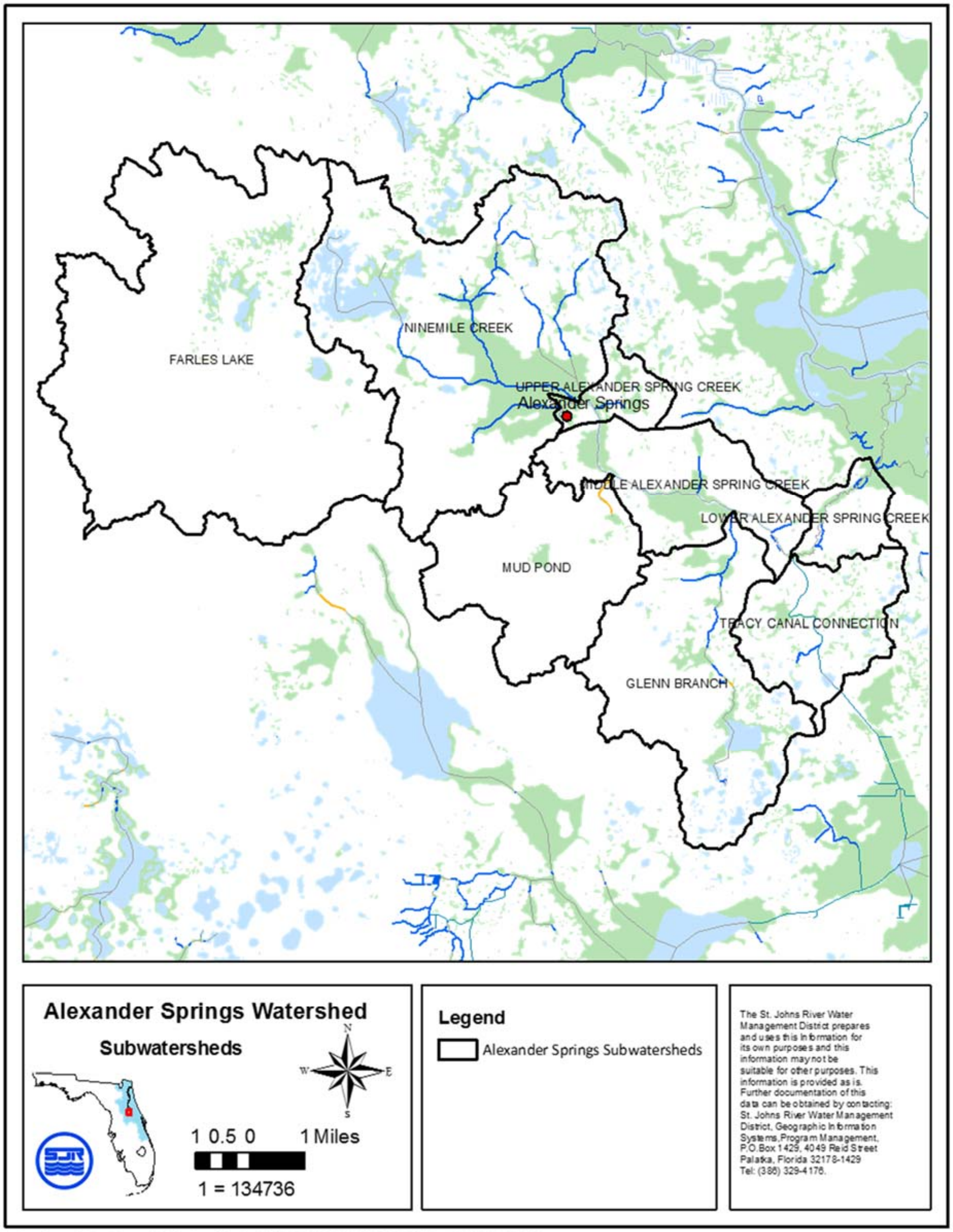

Figure 2-2. Watershed map for the Alexander Springs study site in Lake County, Florida. Source: Karama and Gordu, 2017.

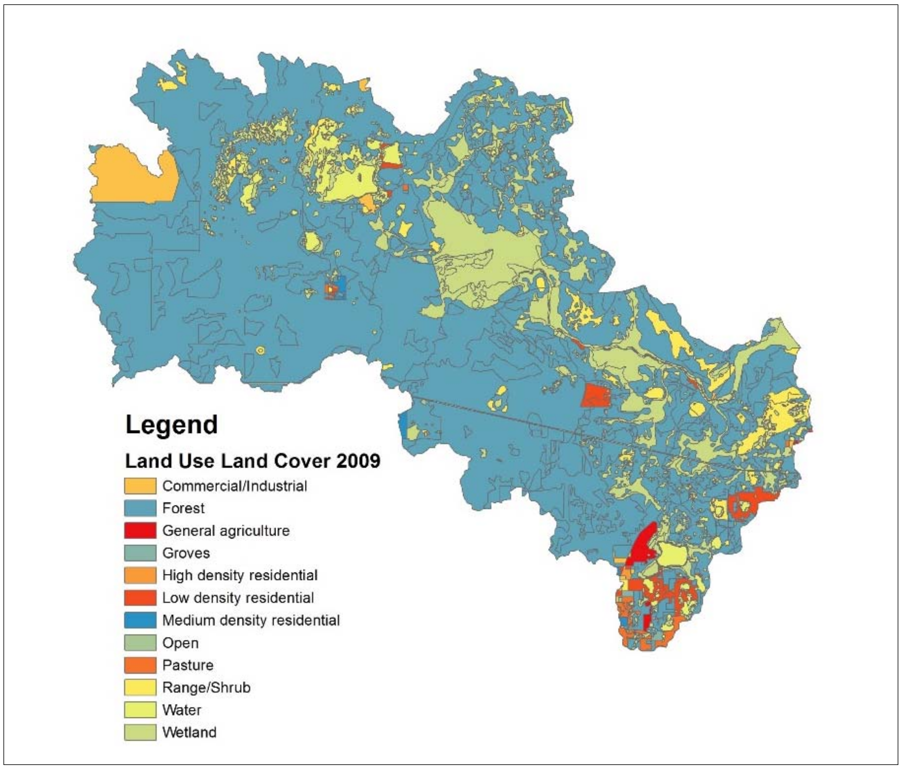

Figure 2-3. 2009 Land use/land cover map for the Alexander Springs study area in Lake County, Florida. Source: SJRWMD.

The spring head is a semicircular pool about 250 feet in diameter bounded by semitropical forest at the base of low, pine-wooded sand hills to the north and east. A broad sand swimming beach forms the southwest edge of the pool and extends 200 to 300 feet down the southwest bank of the spring run. The pool discharges directly to a run about 150 feet wide that flows northwest a short distance, then curves north and then east to the St. Johns River. Most of the spring flow issues from one large cavern opening in the bottom of the central part of the pool.

Flows emanate from the large, cavernous opening in the bottom part of the central pool. The large pool measures approximately 300 feet in diameter. The pool bottom is sandy near the beach. Aquatic vegetation surrounds the area of the main vent where the pool bottom falls away to reveal a large, open area of exposed limestone rock and boulders to a depth of 25 to 28 feet. The force of the discharging water causes a conspicuous, large-diameter boil at the water's surface over the spring orifice that is visible from the shore. A broad sandy beach forms the southwest edge of the pool, with mixed hardwood and palm forest around the spring. Forests and wetlands surround the spring area. Figure 2-4 presents the area around the headspring.

Author: Source:G:\FILES\MFL Projects\AlexanderSpgs_20140130.mxd, Time:2/3/2014 11:40:06 AM

Figure 2-4. Alexander Springs recreation area.
Source: SJRWMD, 2016

The U.S. Forest Service has developed the spring area into a multiple-use recreational facility that is open to the public. It offers clean beaches and clear water; provides picnic and camping facilities, nature trails, and boat rentals; and allows swimming, scuba diving, and snorkeling in a designated area at the headspring. Alexander Springs Creek is also popular for kayaking and canoeing.

Alexander Springs Creek has its headwaters at Alexander Springs and then flows approximately 10.4 miles eastward to its confluence with the northward flowing St. Johns River near Lake Dexter within the Lake Woodruff National Wildlife Refuge. Figure 2-5 provides a more detailed overview of the Alexander Springs and Alexander Springs Creek water resource value (WRV) assessment project area. Descriptions for the U.S. Geological Survey (USGS) gaging station and SJRWMD stations located along Alexander Springs and Alexander Springs Creek (Figure 2-5) are included in Appendix A.

The spring discharge has been measured since 1931, however, measurements were sporadic from 1931 to 1981. Since 1982, USGS has measured the spring discharge twice per year. Since 1983, SJRWMD has measured the discharge four times per year. Except for sporadic extreme values, the spring discharge is very consistent, with a mean value of 102 cubic feet per second (cfs) (Karama and Gordu, 2017) The difference between the minimum and maximum discharges is 146 cfs over the period. The maximum measured discharge of 202 cfs occurred in January 1984; the minimum discharge of 56 cfs occurred in May 1986. Figure 2-6 presents the discharge hydrograph for Alexander Springs, and Table 2-1 presents basic statistics of the discharge record.

Figure 2-7 presents the discharge hydrograph for Alexander Springs, and Table 2-2 presents basic statistics of the discharge record.

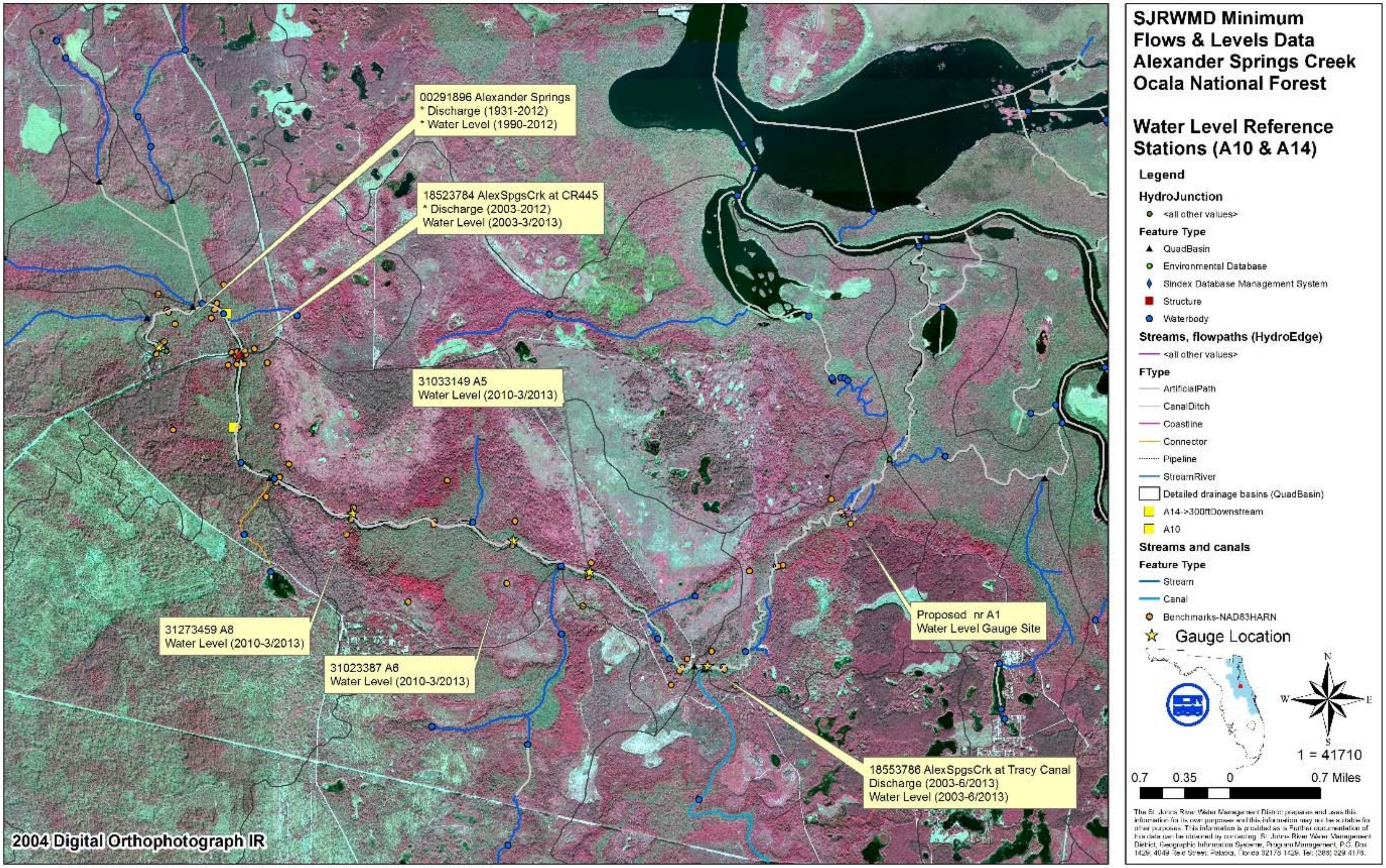

Figure 2-5. *Alexander Springs Creek study area and gaging locations in Lake County, Florida.*
Data Source: SJRWMD, FDEP HUC-8 Drainage Basins, 2002
Source: SJRWMD, 2016.

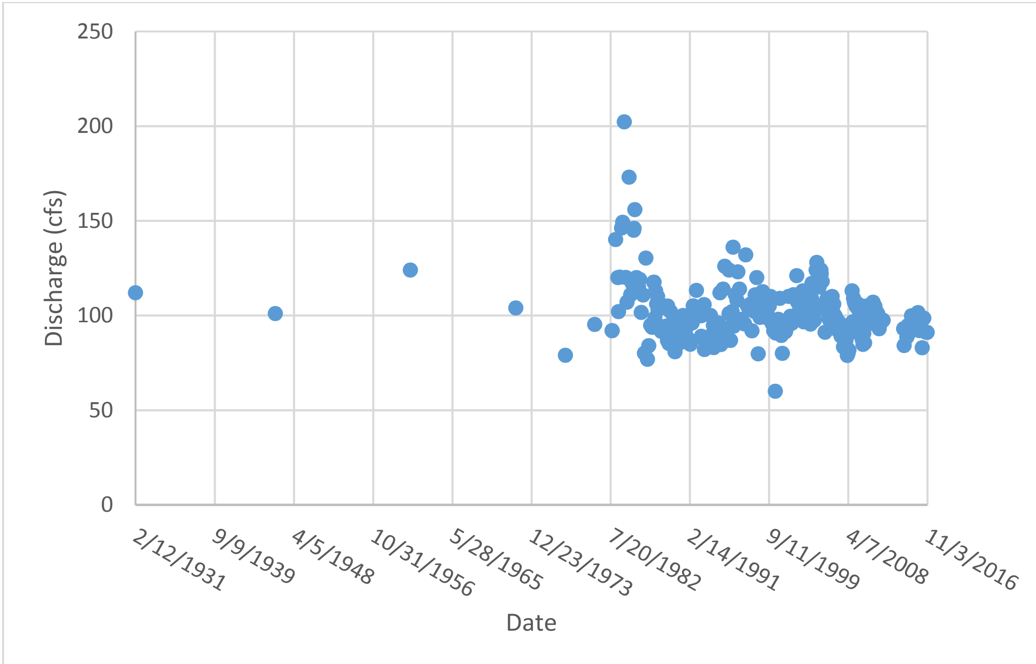

Figure 2-6. Alexander Springs discharge POR (2/12/1931 - 11/3/2016). Source: Karama and Gordu, 2017.

Table 2-1. Alexander Springs discharge summary statistics POR (2/12/1931 - 11/3/2016).

Descriptive Statistics	Discharge (cfs)
Mean	101.88
Standard Error	0.91
Median	99.95
Mode	102.00
Standard Deviation	15.09
Minimum	60.00
Maximum	202.19

Source: Karama and Gordu, 2017.

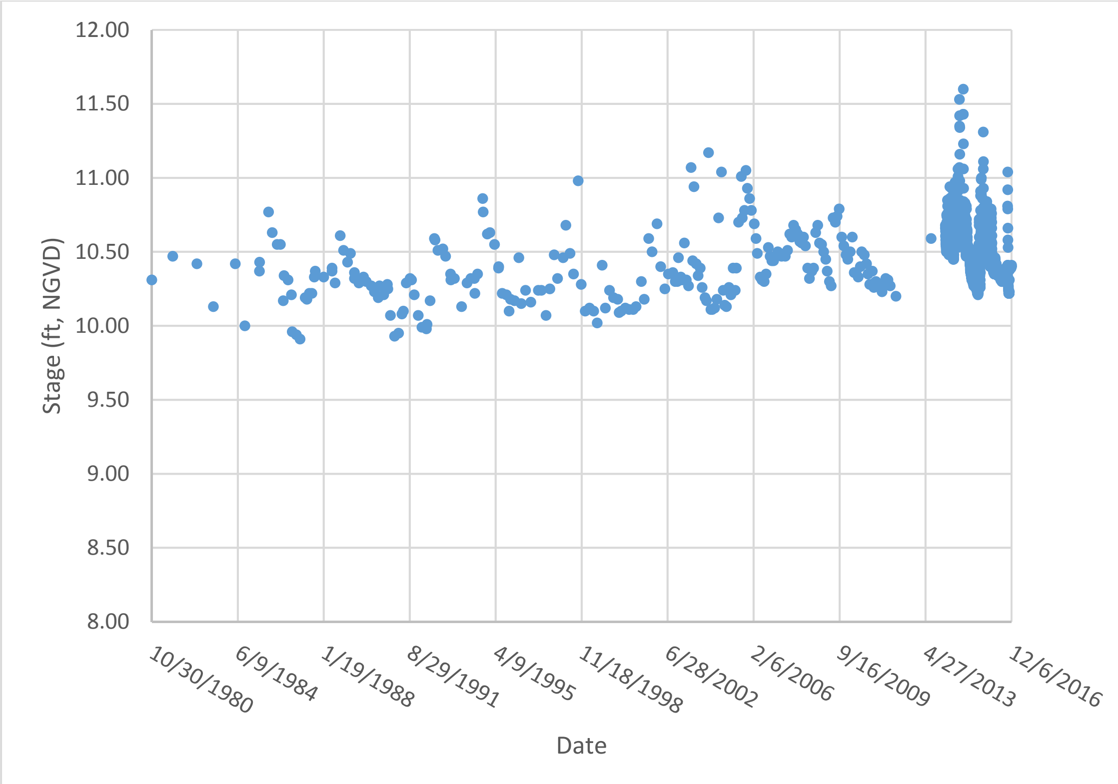

Figure 2-7. Alexander Springs stage POR (10/30/1980 - 12/6/2016). Source: Karama and Gordu, 2017.

Table 2-2. Alexander Springs stage summary statistics POR (10/30/1980 - 12/6/2016).

Descriptive Statistics	Stage (ft NGVD29)
Mean	10.46
Standard Error	0.01
Median	10.44
Mode	10.36
Standard Deviation	0.20
Minimum	9.91
Maximum	11.60

Source: Karama and Gordu, 2017.

Shoemaker et al. (2004) discusses the determination of areas contributing to spring discharge. The report presents and compares the delineation of areas contributing recharge to four springs in north-central Florida (including Alexander Springs by using particle-tracking results from four regional ground-water flow models. The three ground-water flow models that contain Alexander Spring are referred to as the Peninsular Florida (PF) model (Sepúlveda, 2002); the Lake County/Ocala National Forest (LCONF) model (Knowles and others, 2002); and the North-

Central Florida (NCF) model (Motz and Dogan, 2002). The areas contributing recharge to Alexander Springs range in area from about 60 to 70 square miles (mi^2). Combining the areas from each model resulted in a composite area contributing recharge to Alexander Springs. The composite area encompasses about 110 mi^2. The composite area indicates that some of the ground water discharging at Alexander Springs originates from areas north and northwest of the spring. However, most of the area contributing recharge lies southwest of the spring because the prevailing direction of groundwater flow in the Upper Floridan aquifer (UFA) in this area is from southwest to northeast.

Particle travel times derived from a backward-tracking analysis were used to estimate the percentage of spring discharge that has traveled to Alexander Springs in a given amount of time from the water source. About 45 percent of the total discharge of Alexander Springs simulated by the PF model reaches the spring within 100 years. For the NCF and LCONF models, about 75 and 85 percent, respectively, of the total discharge of Alexander Springs reaches the spring within 100 years. It is likely that differences in areas contributing recharge and in travel time are caused by the different hydraulic properties, boundary conditions, and hydrologic conditions of the calibration period used by each model.

The 10 WRVs are assessed at eight locations along Alexander Springs Creek, indicated on Figure 2-8 as Transects A16, A14, A10 A8, A6, A5, A4.3 and Tracy Canal. As will be discussed in more detail in the following sections, the WRV assessments will consider how changes in the frequency of high or low water events may affect WRVs in both the river channel and the adjacent floodplain at each of the transects.

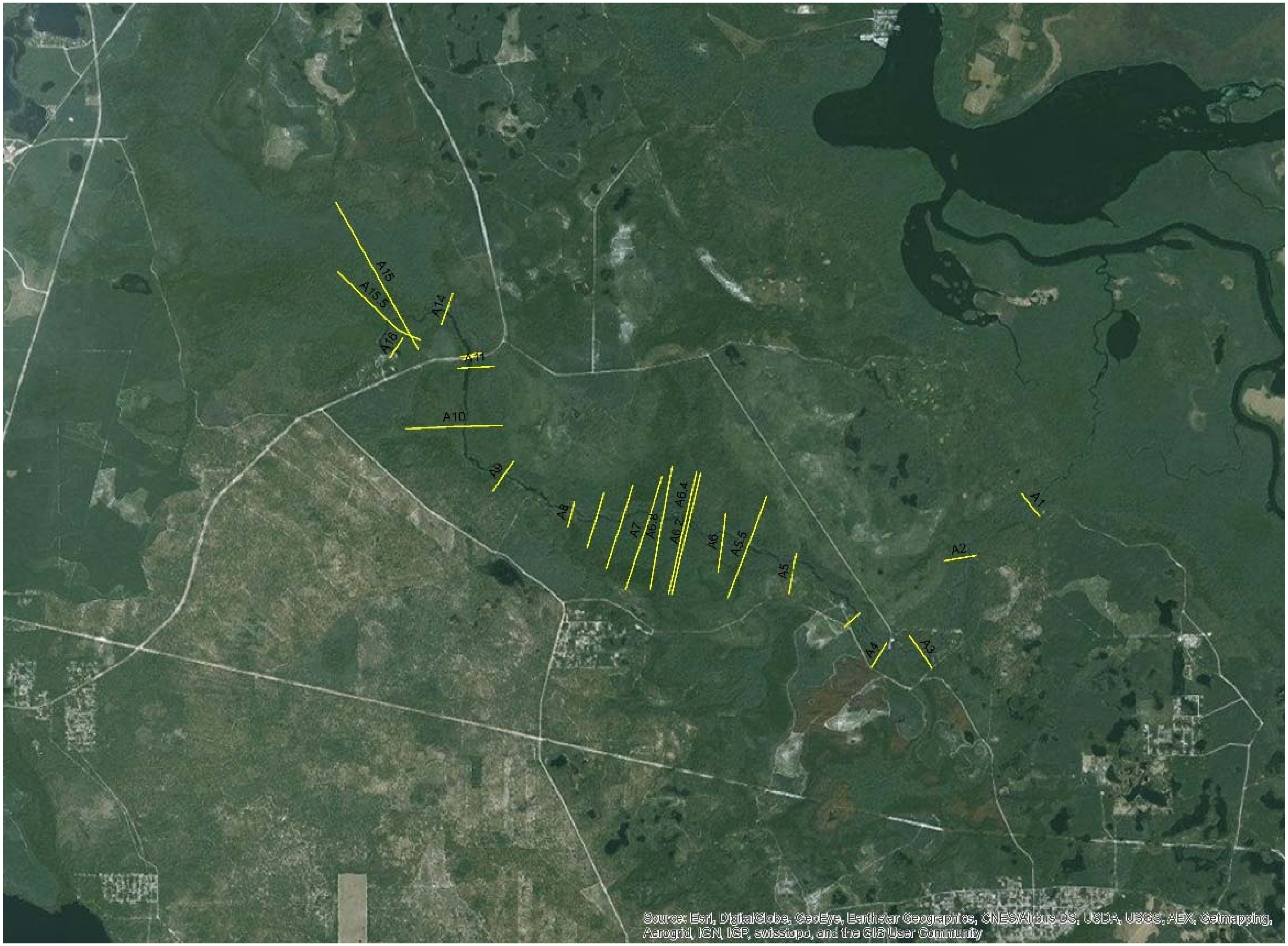

Figure 2-8. Transect map for the Alexander Springs study site in Lake County, Florida.

3.0 BACKGROUND ON MFLS DEVELOPMENT

Freese and Sutherland (2017) provides a detailed description of the methodology for determining the recommended MFLs for Alexander Springs and Alexander Springs Creek. This section provides background on the MFLs determination process for Alexander Springs and Alexander Springs Creek.

SJRWMD establishes minimum flows and levels for priority waterbodies within its boundaries. MFLs provide an effective tool to assist in making sound water management decisions that prevent significant adverse impacts to the water resources or ecology of the area due to water withdrawals.

Alexander Springs is one of only 27 first magnitude springs in Florida. The spring and spring run are bordered by national forest lands, including the Alexander Springs Wilderness, and comprise one of the most scenic and biologically diverse ecosystems in the state. Several state and federally listed species have been documented within the Alexander Springs Creek basin. Because of Alexander Springs' relatively unimpacted conditions and many natural attributes, the spring boil and the spring run are both regionally important destinations for swimming, canoeing, kayaking and other recreation. The state has designated Alexander Springs as both an Outstanding Florida Water and Outstanding Florida Spring. Florida Statute requires the adoption of MFLs for Outstanding Florida Springs by July 1, 2017.

MFLs at SJRWMD are typically established as multiple hydrologic events to protect an ecosystem's natural hydrologic variability and the resources that depend on these inter-annual fluctuations. Minimum flows, which are set for springs and riverine systems, are either set as minimum mean flows or as events with three components: magnitude (flow, in cfs), duration (in days), and frequency (in years). MFLs set the limit of available water, beyond which further water withdrawals would be significantly harmful to the ecological structure and/or function, or other beneficial uses of a given water body.

SJRWMD is charged with determining the threshold of significant harm caused by water withdrawals and to separate the effects of groundwater withdrawals from those of climate (i.e., drought) on the hydrology of priority water bodies. Impact on the UFA, estimated as flow reduction due to groundwater withdrawals, was estimated using the best available tool, Version 5 of the Northern District Model (NDMv5) regional groundwater model. A flow reduction of approximately 0.7 cfs was estimated, based on the NDMv5, which represents the change from a no-pumping condition to the current impacted (baseline) condition. This estimated flow reduction is less than 1 percent of mean flow for Alexander Springs. Typically, the baseline condition is determined by adjusting the observed flow record by historical impact. Because of the relatively low impact at Alexander Springs, un-adjusted observed flow data were used to calibrate a surface water model. The simulated flow time series was used for initial evaluation of the MFLs. As described in the report, the observed flows were used to calculate the MFL for Alexander Springs.

The Alexander Springs MFLs determination identified two MFLs (Frequent High (FH) and Frequent Low (FL)) based on multiple criteria developed from vegetation, soils and topography data. Frequency analysis results indicate that the hydrologic requirements for the most sensitive MFL criterion are met under baseline conditions. However, this most constraining MFL (the FL) allows a reduction of 21 percent in the mean flow for Alexander Springs. When compared to other springs' MFLs across the state (i.e., at multiple water management districts), this allowable flow reduction is outside the range of flow reduction (0 to 10 percent) allowed by other springs' MFLs established within the state of Florida and is many times higher than the statewide mean of 6.8 percent.

A potential reason for the disparity between the results for Alexander Springs and other springs' MFLs in the state is due to the paucity of data that exists for this system. The hydrology of Alexander Springs and Creek is complex and there is a lack of hydrological data to determine the hydrological requirements of ecological criteria identified for this system.

Given Alexander Springs' high recreational and ecological value, unimpacted condition, uncertainty regarding system hydrology due to a lack of data, and July 1, 2017 deadline for setting an MFL, SJRWMD recommends a minimum flow for Alexander Springs based on the more protective statewide mean (6.8 percent reduction in mean flow), rather than the less protective MFL (FL) that was determined based on available data.

The recommended minimum flow for Alexander Springs is a mean flow of 95.7 cfs. This is the mean flow for the observed period of record (1983 – 2014) measured at the headspring (USGS gage 00291896), adjusted by a 7 cfs reduction in spring flow (6.8 percent), which is equal to the mean flow reduction allowed for springs-based MFLs within Florida.

Based on the best available information, including the NDMv5 groundwater model, the predicted flow reduction resulting from projected water use for the 20-year planning horizon is less than the flow reduction allowed by the recommended MFL. Therefore, the proposed MFLs for Alexander Springs are achieved for the 20-year planning horizon, and a prevention strategy is not required.

4.0 PROCEDURE FOR EVALUATING WATER RESOURCE VALUES

SJRWMD contracted Applied Technology and Management, Inc. (ATM) to evaluate whether the minimum flows for Alexander Springs that Freese and Sutherland (2017) recommended will protect the 10 WRVs for Alexander Springs and Alexander Springs Creek. This section describes the method for evaluating the WRVs in the context of the draft MFLs. The WRV evaluation was conducted using no-pumping conditions and MFLs hydrologic regimes.

The 10 WRVs were assessed at numerous locations along Alexander Springs Creek (Figure 2-8). As discussed in more detail in subsequent sections, the WRV assessments consider how changes in the frequency of high or low water events (stage and/or flow) may affect both the river channel and the adjacent floodplain at each of the transects and at other locations surveyed along the river's reach.

The MFLs' transects correspond to cross-sections surveyed across the river channel and the width of the adjacent floodplain. Three of the transects (A10, A8 and A6) were surveyed in detail to characterize soils (Appendix B) and vegetation (Appendix C) along the transect. Seventeen cross-sections were surveyed for use in the Alexander Springs Creek Hydrologic Engineering Center's River Analysis System (HEC-RAS) model. The HEC-RAS transects resulting from this effort are presented in Appendix D.

The analytical approach for this work effort is frequency analysis and parallels SJRWMD methods to develop the MFLs (i.e., by identifying ecologically meaningful thresholds defined by magnitude, duration, and return interval components). Working definitions of protection of WRVs proposed for this project are as follows.

> High flow (flooding): related WRVs are considered protected if, under an MFLs hydrologic regime, a critical high-flow event of a specified magnitude and duration does not occur too infrequently when compared to the high-flow event frequency under long-term no-pumping conditions.
>
> Low flow (dewatering) - related WRVs are considered protected if, under an MFLs hydrologic regime, the low-flow event of a specified magnitude and duration does not occur too frequently compared to the low-flow event frequency under long-term no-pumping conditions.

Each WRV represents a broad class of functions, processes and/or activities that require consideration of protection. A four-level hierarchical approach was utilized to assess whether the MFLs hydrologic regime was protective of each WRV. This approach, described below, moves from broad, general definitions to more specific criteria of protection, then to general indicators of protection and, finally, to specific indicators of protection that can be measured and assessed. The indicators should reflect characteristics that are most sensitive to changes in hydrology and should be applied to the most sensitive portion of the system being evaluated.

- Level 1 – Restate the WRV in terms of criteria that are specific to the water body being evaluated. Include the definition of the WRV as provided by SJRWMD.
- Level 2 – Identify a representative function, process, or activity that should be very sensitive or possibly the most sensitive to changes in the return interval of high or low flow or stage events. This function, process, or activity should be one for which data resources are available.
- Level 3 – Identify a general indicator for the protection of that function, process, or activity.
- Level 4 – Identify a specific indicator of protection in terms of magnitude. Include an assessment of the change in the number of events per century under the no-pumping condition and the MFLs hydrologic regimes.

An example with WRV 1 for Alexander Springs Creek follows:

- Level 1 – Recreation in and on the water is defined as the active use of water resources and associated natural systems for personal activity and enjoyment. The criteria for protection of this WRV are “legal water sports and activities.”
- Level 2– Recreational boat passage for canoes and kayaks is the representative function used to assess protection of this WRV.
- Level 3 – Sufficient water depth in the main channel and shallow-water areas to allow safe recreational boat passage is the general indicator to protect this WRV.
- Level 4 – The specific indicator is a low water level event, of the specific magnitude and specific duration, resulting in insufficient depth and cross-sectional areas at hydraulic controls in the main channel and shallow-water areas. The WRV is considered protected if the return interval of this event does not increase significantly beyond the return interval under the no-pumping scenario.

The 10 WRVs are present at varying levels in each waterbody, taking on different levels of importance. In a no-pumping condition, they will naturally occur at some level, although it is possible for a water body to not exhibit all 10 WRVs (i.e., navigation in a very shallow spring run). The WRV is considered protected if there is not an unacceptable change in the frequency of exceedances and non-exceedances (i.e., Level 4) between the no-pumping condition hydrologic regime and the MFLs hydrologic regime that would indicate loss of that WRV at whatever level of importance from what existed in the no-pumping or natural condition. Evaluations of the WRV are performed at several locations along Alexander Springs Creek that provides a more holistic WRV assessment under the MFL hydrologic regime. Some locations may experience relative large changes in exceedances or non-exceedances, while other locations experience relatively small changes. A determination would then be made as to whether the location with the large relative change is of such importance that it must experience only small changes or that much of the system experiences small changes and the particular WRV is protected for the majority of the system. It is desired to apply this hierarchical approach to all WRVs.

Frequency analysis, as it is applied to evaluating WRV protection, involved the following five steps. The details for Steps 1 through 3 are discussed in Karama and Gordu (2017).

1. Generate hydrographs for the river flows and stages based on the existing flow and stage record.
2. Generate synthetic hydrographs for the river flow and stages for the no-pumping hydrologic condition.
3. Generate synthetic hydrographs for river flow and stage for the MFLs scenario.
4. For each WRV, select a key water resource criterion (e.g., boat passage, fish passage, sediment transport) that is most sensitive to changes in hydrology.
5. Develop relevant high- and low-flow/stage frequency statistics curves from hydrographs developed in Steps 1 and 2 and evaluate the return intervals of a specific critical event under the no-pumping condition and MFLs hydrologic regimes to determine if the WRV is protected.

Not all WRVs were evaluated using this approach. WRV-10 (Navigation) does not exist in Alexander Springs Creek. WRV-3 (Estuarine Resources), WRV-5 (Water Supply), WRV-8

(Sediment Loads) and WRV-9 (Water Quality) did not reveal critical events that could be evaluated using the event-based approach. WRV-1 (Recreation In and On the Water), WRV-2 (Fish, Wildlife and the Passage of Fish), WRV-4 (Transfer of Detrital material), WRV-6 Aesthetics) and WRV-7 (Filtration and Absorption of Nutrients and Other Pollutants) were evaluated using this approach.

Karama and Gordu (2017) developed daily stage and flow time series for Alexander Springs and Alexander Springs Creek for the no-pumping and MFLs hydrologic regimes covering the time period from 1983 through 2014, from which the high- and low-flow/level frequency statistics were developed. SJRWMD provided the frequency analysis, which encompasses three types of events: (1) minimum average stages or flows, (2) maximum stages or flows continuously exceeded, and (3) minimum stages or flows continuously not exceeded. Frequency statistics were developed at selected cross-sections for each of these event-types for the no-pumping condition and MFLs hydrologic regimes for 1-, 7-, 14-, 30-, 60-, 90-, 120-, 183-, 273-, and 365-day durations (Appendix E).

Where possible, the difference in the frequencies of the selected WRV event between the no-pumping condition and the MFLs hydrologic regimes was evaluated. Each of the WRVs was evaluated by identifying key hydrologic conditions that were relevant to that WRV. Through analyses of all the WRVs, using a common quantitative approach, including WRVs that involved more complex processes (e.g., fish and wildlife and the passage of fish), along with supporting literature and discussion, a professional judgment was made for whether the WRV is protected under the MFLs hydrologic regime.

Available information was researched to support the selection of the specific indicator parameter(s) and duration(s) for each WRV assessment. This consideration dictated that the selection of general and specific indicators of WRV protection (Level 3 and 4) be conducted by a team of senior professionals with in-depth knowledge of biology, ecology, hydrology, and cultural practices. Table 4-1 summarizes the WRV hierarchy for evaluating the MFLs hydrologic scenarios for the Alexander Springs Creek.

Table 4-1. WRV hierarchy for hydrologic scenarios evaluation for Alexander Springs Creek.

WRV		Criteria	Representative Functions	General Indicator	Specific Indicator	Event
1.	Recreation in and on the Water	Legal water sports and activities	Recreational boat passage for canoes, kayak, and motor boats	Water depth in river channel and shallow-water areas	Sufficient water level in river channel and shallow-water areas to accommodate canoes, kayaks, and motor boats	1- and 7-day low stage continuously not exceeded
2.	Fish and Wildlife Habitat and the Passage of Fish	Aquatic and wetland environments required by fish and wildlife	Fish Passage	Water depth in river channel	0.8 ft water depth across 25% of channel cross-section	7-day low flow continuously not exceeded
			Fish/Shellfish Habitat	Water flow in river channel	Minimal (< 0.1 ft/sec) reduction in water flow velocity	1-day low flow continuously not exceeded
			Floodplain inundation for fish, birds, and wetland vegetation	Floodplain inundation duration	Inundation to hardwood swamp mean elevation	30-day critical water level continuously exceeded
			Floodplain inundation to protect hydric soils	Floodplain inundation duration	Inundation to 0.3 ft below organic soil mean elevation	180-day critical water level not exceeded
3.	Estuarine Resources	Coastal systems and associated natural resources	Salinity fluctuations in the estuary	Large salinity zone shifts that are associated with changes in the hydrologic regime.	Flow variations in the subject section of the river that may influence the occurrence of extreme salinity events.	Not applicable. Utilized findings of the St. Johns River Water Supply Impact Study (2012)
4.	Transfer of Detrital Material	The movement of loose organic material and debris and associated decomposing biota	Water depth and floodplain inundation in the spring run	Water stage to maintain detrital transfer to the Alexander Springs Creek	Stage associated with depth and area of inundation for transfer of detrital material into suspension in Alexander Springs Creek	7- and 30-day high stage continuously exceeded

Table 4-1. WRV hierarchy for hydrologic scenarios evaluation for Alexander Springs Creek.

WRV		Criteria	Representative Functions	General Indicator	Specific Indicator	Event
5.	Maintenance of Freshwater Storage and Supply	The amount(s) of surface water and groundwater needed for non-consumptive uses	The maintenance of adequate surface water levels, flows, and aquifer levels in the area adjacent to the water body.	Aquifer levels, surface water levels and flows that do not result in adverse impacts to the water body.	Evaluation as to whether the groundwater-surface water interactions will change because of flow reductions in Alexander Springs Creek to the extent that WRVs are not protected	Protection of this WRV is dependent on the other WRV assessments. No event specific to this WRV is used.
6.	Aesthetics and Scenic Attributes	Passive recreation	Visual setting at selected points	Water level and clarity	Water level associated with optimal scenic and wildlife viewing	30- and 90-day low stage continuously not exceeded
7.	Filtration and Absorption of Nutrients and Other Pollutants	The process of absorption and filtration	Ability of water to promote nutrient removal in the river and adjacent wetlands	Depth and duration of floodplain inundation and residence time	Return intervals of stages associated with selected duration sufficient to maintain contact with riparian vegetation and residence time similar to no-pumping conditions	14-day and 30-day high stage continuously exceeded
8.	Sediment Loads	The process of sediment movement and deposition	Water velocities and flow	Changes in velocity and bed shear stress	Flows associated with velocity and bed shear stress necessary for sediment mobilization and transport	No event specific to this WRV is used. Used anticipated in-channel velocity changes
9.	Water Quality	Chemical and physical properties of the water	The concentration of key chemicals/ indicators in the springs.	Maintenance of discharge events for maintenance of acceptable water quality to support a healthy aquatic community	Differences in frequency, duration and return interval of events within the water column necessary to maintain adequate protection of water resource	1-day low flow continuously not exceeded

Table 4-1. WRV hierarchy for hydrologic scenarios evaluation for Alexander Springs Creek.						
WRV		**Criteria**	**Representative Functions**	**General Indicator**	**Specific Indicator**	**Event**
10.	Navigation	Legal operation of eco-tourism and commercial fishing vessels				WRV not present

5.0 EVALUATION OF WATER RESOURCE VALUES

5.1 WRV-1: RECREATION IN AND ON THE WATER

Recreation in and on the Water is defined as the active use of water resources and associated natural systems for personal activity and enjoyment. The criterion for protection for *Recreation in and on the Water* is all legal water sports and activities (Table 4-1). Alexander Springs Creek is largely contained within the boundaries of the Alexander Springs Recreation and Wilderness Areas. Accordingly, the representative function used to assess the effect of the MFLs hydrologic regime is recreational boat passage, specifically canoes/kayaks. The water depth at the MFLs transects (Figure 2-3) provides both the general and specific indicators regarding protection of the boating function.

Alexander Springs Recreation Area and Alexander Springs Wilderness Area contains both Alexander Springs and Alexander Springs Creek. The spring is a major recreation area in the Ocala National Forest. The U.S. Forest Service developed the spring area into a multiple-use recreational facility that is open to the public. In addition to the headspring and surrounding beach, it provides picnic and camping facilities, nature trails, and boat rentals. Swimming, scuba diving, and snorkeling are allowed in the headspring area. The area offers camping (67 sites for tents and RVs), hiking, fishing, swimming, canoeing (with drop-off and pick-up for a fee), canoe rentals, rest rooms, bicycling (a 22-mile trail), concessions, picnic facilities, and showers. There is an established and popular 7-mile canoe trail that begins just below the spring. Pick-up can be arranged for a fee.

The Alexander Springs Timucuan Natural Trail, which begins by the spring, is a 1-mile loop through the dense, semi-tropical forest near the spring and its run. It also offers viewing platforms along Alexander Springs Creek.

Fishing and canoeing are popular outside of the swimming area. Fishing access in Alexander Springs Creek is available from one of the platforms along the Timucuan Trail. Visitors can rent canoes or bring their own canoes or kayaks for trips down the creek and into the Alexander Springs Wilderness Area.

Access to Alexander Springs Creek is provided at three locations (Figure 5-1): CR 445, 52 Landing (at Forest Road 18/552), and the Alexander Springs Recreation Area. The park provides boat ramps and a canoe/kayak launch. Recreational use of the headspring is high, particularly in the summer, but attendance figures (number of persons per day) were not available. Much of Alexander Spring Creek below the CR 445 bridge is open to motorized boat traffic, but it is not heavily used due to shallow depths. Use of the creek by canoes and kayaks is moderate.

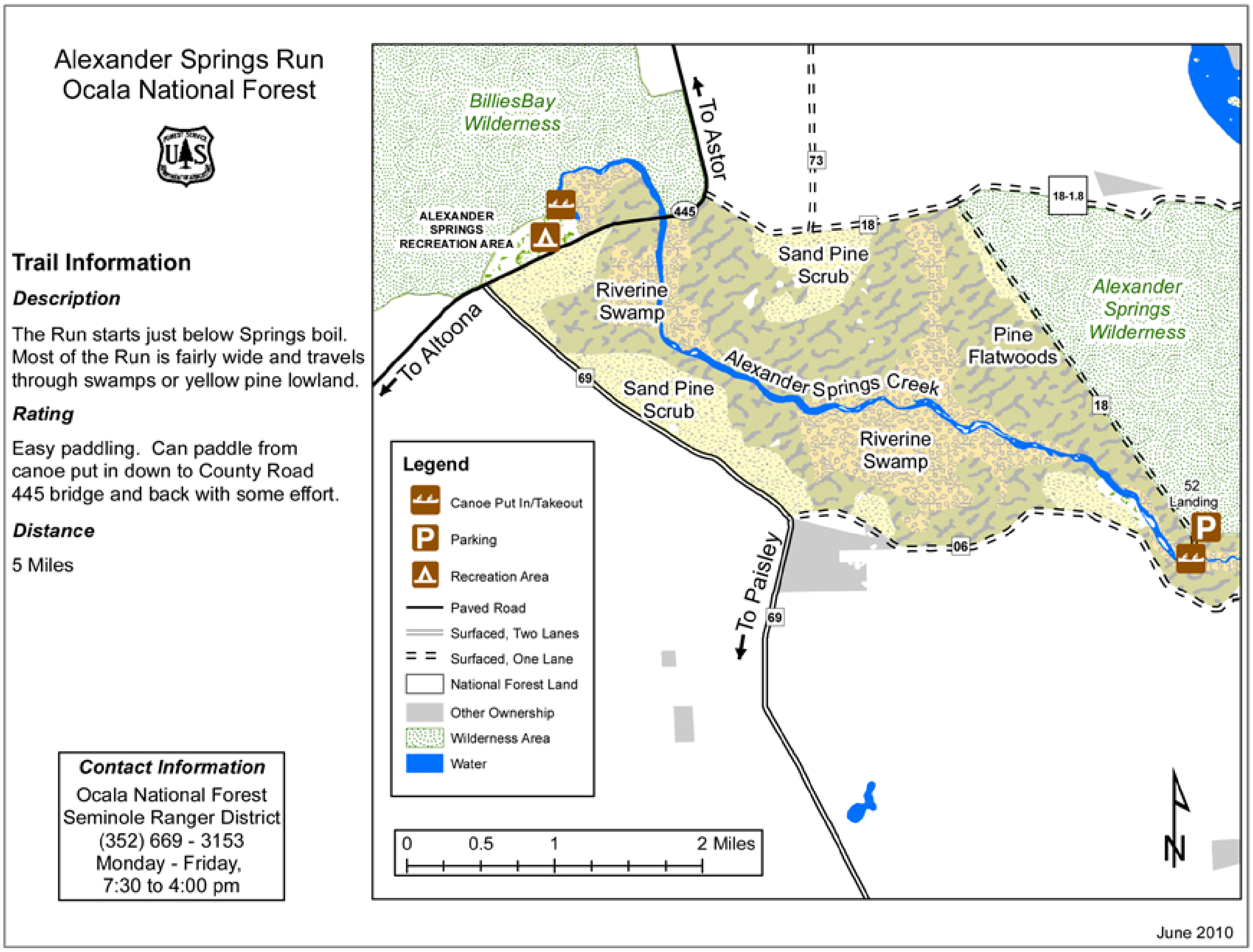

Figure 5-1. *Alexander Springs Creek canoe run and launch points.*
Source: U.S. Forest Service, 2010

Protection of the recreational boating function is dependent on maintaining sufficient water level in river channel and shallow water areas to accommodate canoes and kayaks. Two areas where these events would be most critical would be 1) in the shallow areas in the river and 2) canoe/kayak launch points.

FDEP and the Florida Greenways Coordinating Council (1998) provide guidelines for minimum depth of paddling trails. Paddling trails are publicly owned waterways that possess scenic and recreational qualities and are accessible by the public. These include rivers, creeks, lakes, estuaries and coastlines, including all waters of the state. Except for periods of extreme drought, paddling trails should be a minimum depth of 6 inches.

Another scenario in which boat passage would be limited would be in areas where downed trees force boats into shallow areas of the river. This type of restriction is ephemeral and dependent upon management actions (clearing channel) and flow conditions. Particularly high flows shift downed trees into the channel and dislodge floating mats. Therefore, this scenario was not investigated further.

Review of the transects (Appendix E) indicates that the most critical areas are located near cross-section A4.3, located near the 52 Landing Canoe Put In/Takeout (Figure 5-2). Figures 5-3 and 5-4 show the character of the area at A4.3. Another critical location is the canoe launch in the recreation area. Figures 5-5 through 5-7 show the canoe/kayak launch location. Table 5-1 summarizes the critical elevations for this evaluation.

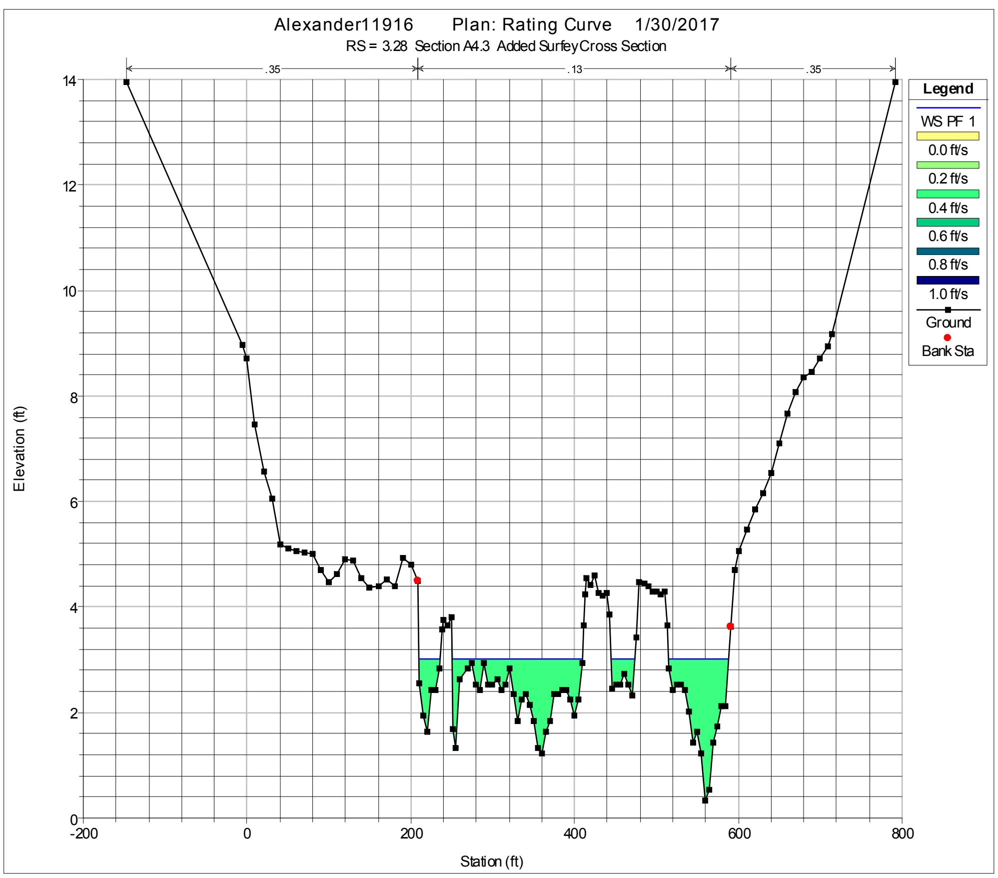

Figure 5-2. Cross-section geometry at Transect A4.3.

Figure 5-3. Transect A4.3 looking downstream.

Figure 5-4. Transect A4.3 looking upstream.

Figure 5-5. *Alexander Springs recreation area canoe/kayak launch.*

Figure 5-6. *Alexander Springs recreation area canoe/kayak launch looking downstream.*

Figure 5-7. Alexander Springs recreation area canoe/kayak launch looking upstream.

Table 5-1. Critical stage values at shallow-water transects in Alexander Springs Creek.

Location	Shallow-Water Transect ID	Critical Stage (ft-NAVD)
52 Landing	Transect A4.3	2.73*
Canoe/Kayak Launch	Transect A16	9.85

*Reflects control elevation of middle passage in the cross-section (minimum elevation plus 6 inches).

Comparison of the no-pumping condition stage levels to the MFLs hydrologic regime was conducted using the frequency analyses representing the 1-day minimum continuously not exceeded stage because the 1-day analyses have lower minimum stages than the longer duration analyses and, consequently, offer a worst-case scenario regarding water depths. Additionally, a 7-day minimum continuously not exceeded stage duration was evaluated since this duration of low water would have a greater economic impact on recreation in and on the water.

Tables 5-2a and 5-2b present the results of the frequency analysis of critical threshold stage for protection of recreational boating with respect to motor clearance depth. Currently, the critical events at transect A4.3 occur on average once every 16.7 years. Under the MFLs hydrologic regime, these critical low water events will be occurring on average every 6.7 and 10 years, respectively. While this represents a large percentage increase in the number of critical low stage events, the relative frequency of the low water events remains infrequent and is not considered critical to WRV protection. Therefore, it is the professional opinion that this WRV is considered protected under the proposed MFLs hydrologic regime.

Table 5-2a. Frequency analysis of critical threshold stage for protection of recreational boating 1-day duration low stage continuously not exceeded.

Transect	Critical Threshold Stage ft, NAVD	Statistic[1]	Hydrologic Scenario	
			No-Pumping Condition	MFL
A4.3	2.73	Events/100 yr	6	15
		Increase in Events	-	9
A16	9.85	Events/100 yr	0	0
		Increase in Events	-	

1 Events /100 years= number of events per 100 years in which the critical stage event occurs. Difference = difference between the number of events occurring under no-pumping conditions and the MFLs hydrologic regimes.

Table 5-2b. Frequency analysis of critical threshold stage for protection of recreational boating – 7-day duration low stage continuously not exceeded.

Transect	Critical Threshold Stage ft, NAVD	Statistic[1]	Hydrologic Scenario	
			No-Pumping Condition	MFL
A4.3	2.73	Events/100 yr	6	10
		Increase in Events	-	4
A16	9.85	Events/100 yr	0	0
		Increase in Events	-	

1 Events /100 years= number of events per 100 years in which the critical stage event occurs. Difference = difference between the number of events occurring under no-pumping conditions and the MFLs hydrologic regimes.

5.2 WRV-2: FISH AND WILDLIFE HABITATS AND THE PASSAGE OF FISH

For this evaluation, *fish and wildlife habitat and the passage of fish* is defined as *aquatic and wetland environments required by fish and wildlife, including endangered, endemic, listed, regionally rare, recreationally or commercially important, or keystone species, to live, grow, and migrate. These environments include hydrologic magnitudes, durations, and frequencies sufficient to support the life cycles of aquatic, wetland and wetland-dependent species*

(SJRWMD 2006). Although water quality including dissolved oxygen is an important element of fish and wildlife habitat, that component is discussed under WRV-9, Water Quality.

Thus, the criteria for the assessment of the protection of this WRV are *aquatic and wetland environments required by fish and wildlife*.

The representative functions used to assess protection are:

1. Fish passage, and breeding and growth habitats for dominant species; and
2. Habitat for other significant taxa including birds and turtles.

The general indicators of protection are:

1. The relationships between dominant fish species and spring hydrology (flow and stage), and
2. The relationships between significant taxa other than fish and spring hydrology.

The specific indicators of protection are water levels and flows adequate to:

1. Allow the passage of larger dominant fish species such as the bowfin, largemouth bass, and Florida gar;
2. Provide for floodplain inundation of sufficient duration and frequency to maintain wetland habitats and organic soils; and
3. Provide for floodplain inundation of sufficient duration and frequency to facilitate bird feeding and small fish breeding and growth.

The multiple WRV criteria that are defined represent long-term minimum hydrologic requirements necessary for the protection of fish and wildlife habitat and passage of fish. The best available information was used for these analyses. Some of the criteria have been developed to protect key umbrella species, under the assumption that protection of these representative species will also provide sufficient protection of other members of the ecological community.

Specific Criteria for Channel Water Depth to Protect Fish Passage

One of the specific habitat criteria is to maintain a minimum water depth in stream channels required for passage of fish. An example of the SJRWMD indicator is a low water level and associated flow that corresponds to a water depth less than 0.8 foot (ft) [0.2 meter (m)] over 25 percent of the channel width, at a hydraulic control elevation of the river channel with a duration of 7 continuous days and 20-year return interval [i.e., five such dewatering events per 100 years, on average (SJRWMD 2006)]. This criterion is based on work by Everest et al. (1985) and others who recommended a minimum depth of 0.5 to 0.8 ft for salmon and trout. The relative size of these fishes is comparable to larger fish in Alexander Springs Creek (e.g., largemouth bass and gar).

For this work, the critical return interval is the number of occurrences of the critical depth during the no-pumping condition period. The number of occurrences of the critical depth should not greatly exceed the no-pumping condition under the MFLs hydrologic regime. Thus, the specific criteria for fish passage used here is to maintain a water depth of 0.8 ft or more over at least 25 percent of the channel width for not less than 7 continuous days. An example is illustrated in Figure 5-8.

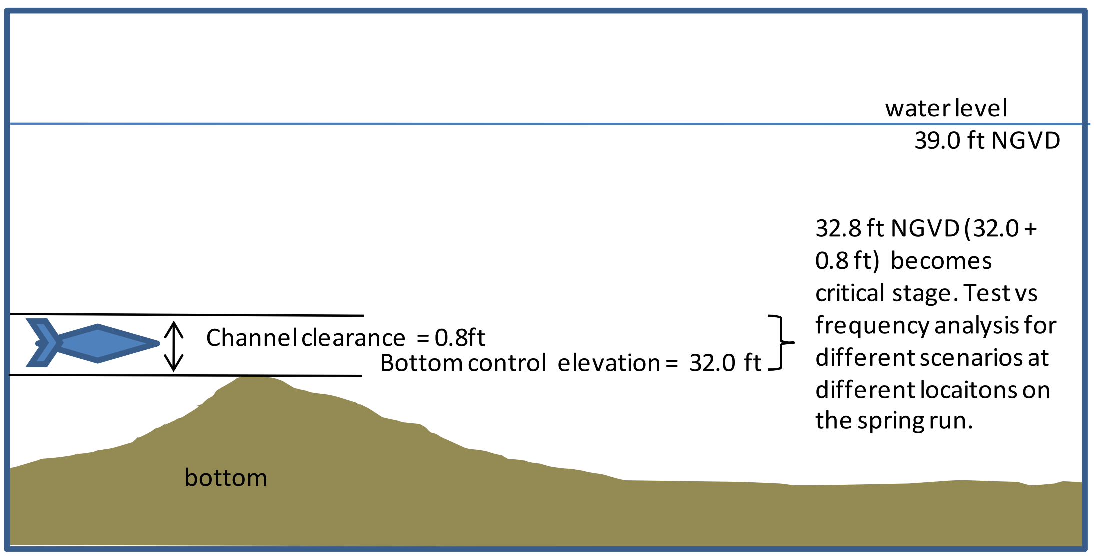

Figure 5-8. Illustration of channel clearance critical stage for fish passage (Figure from SJRWMD)

The hydrologic analyses conducted by Karama and Gordu (2017) were used to assess the ability of the proposed MFL to support fish passage and provide suitable habitat for fishes and other significant taxa including birds and turtles. Figure 5-9 presents the locations of the transects included in the HEC-RAS model used by Karama and Gordu.

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Figure 5-9. HEC-RAS cross sections and gages at Alexander Springs and Alexander Springs Creek.

To assess the likelihood of fish passage at each of the transects, the water depth at the deepest point in each transect (i.e., thalweg) was estimated by the difference between the stage at the minimum frequent low flow and the thalweg elevation. Table 5-3 presents the results of this calculation.

Table 5-3. Estimates of the water depths at the deepest point in each transect as the difference between the stage at the minimum frequent low flow and the thalweg elevation

Parameter	Transect							
	A4_3	A5	A6	A8	A10	A14	A16	Tracy Canal
Stage (ft)	2.14	3.78	3.76	5.68	6.66	7.29	7.99	1.60
Thalweg Elevation (ft)	0.33	1.41	0.30	4.04	4.60	4.92	5.76	-1.37
Depth at Thalweg (ft)	1.81	2.37	3.46	1.64	2.06	2.37	2.23	2.97

The results indicate that the depth at the thalweg under the minimum frequent low flow exceeds 0.8 ft at each transect. Therefore, the proposed MFL will support the fish passage along the entire length of the Alexander Springs run represented by the hydrologic model.

In addition to fish passage, the proposed MFL should provide for floodplain inundation of sufficient duration and frequency to maintain wetland habitats and organic soils and provide for floodplain inundation of sufficient duration and frequency to facilitate bird feeding and small fish breeding and growth.

Freese and Sutherland (2017) identified a frequent high flow (FH) and a frequent low flow (FL) based on multiple criteria developed from vegetation, soils and topography data. Frequency analysis results indicate that the hydrologic requirements for the most sensitive flow criterion i.e., the criterion with the highest minimum flow requirement, are met under baseline conditions. Their results also suggest an allowable reduction of 21 percent in the mean flow for Alexander Springs. This result, when compared to other springs MFLs across the state, is significantly outside the range of flow reduction (0 to 10 percent) allowed by other springs' MFLs established within the state of Florida and is many times higher than the statewide mean of 6.8 percent.

Therefore, the recommended minimum flow for Alexander Springs of a mean flow of 95.7 cfs. i.e., the mean flow for the observed period of record (1983 – 2014) measured at the headspring

(USGS gage 00291896), adjusted by a 7 cfs reduction in spring flow (6.8 percent) will provide the hydrologic requirements of the floodplain vegetation and organic soils. Given this result, it is also reasonable to conclude that the recommended MFL will provide for floodplain inundation of sufficient duration and frequency to maintain wetland habitats and organic soils, and provide for floodplain inundation of sufficient duration and frequency to facilitate bird feeding and small fish breeding and growth.

5.3 WRV-3: ESTUARINE RESOURCES

Estuarine Resources are defined as coastal systems and their associated natural resources that depend on the habitat where oceanic salt water meets fresh water. These highly productive aquatic systems have properties, particularly salinity, that usually fluctuates between those of marine and freshwater habitats. There are no estuarine habitats in the Alexander Springs Creek, so this WRV analysis focused on downstream riverine systems including the St. Johns River as discussed below.

The criterion for protection is "coastal systems and their associated natural resources." The representative function used to assess protection is "salinity fluctuations in the estuary." General indicators of protection include changes in the number of extreme high or low salinity events occurring that are associated with changes in the flow and hydrologic regime. The specific indicators of protection are flow variations in the subject section of the river that may influence the occurrence of extreme salinity events.

An estuary is a dynamic environment where freshwater inflows from the watershed mix with saline estuarine water. Mixing and circulation are driven by tides, freshwater flows, coastal geomorphometry, and meteorological forces. Estuarine resources including fish and wildlife, benthos, aquatic vegetation, and water quality are significantly influenced by this mix of fresh and salt water. Salinity conditions in an estuary can affect the biological community on either short term or long-term time scales. Changing the frequency of extreme salinity events can adversely impact the following resources:

- Vegetation communities (through osmotic and molecular stress)
- Water chemistry processes (denitrification, nitrogen fixation, metals and organic chemical fate, carbon dioxide (CO_2) uptake in water, etc.)
- Sediment processes

- Benthos
- Algae
- Fish and other vertebrates
- Pelagic invertebrates
- Bacteria community

Therefore, for this work it is important to examine whether or not the recommended MFLs hydrologic regime will result in unacceptable impacts to downstream estuarine resources resulting from changes in the salinity regime. This includes providing oligohaline (low salinity) habitat within the river system and providing for seasonality effects.

The flow of Alexander Springs under the MFLs hydrologic regime is 7 cfs less than under the no-pumping hydrologic regime.

Daily discharge data for the USGS gauge #02236125 (St. Johns River at Astor, FL) were obtained to examine the potential relative impact to stream flow that the MFLs flow regime could have, as shown in Table 5-4. The decrease in mean daily discharge under the MFLs hydrologic regime for Alexander Springs would result in approximately 0.2 percent decrease in mean daily discharge the St. Johns River at Astor.

Table 5-4. Estimated reduction in mean daily discharge at the St. Johns River USGS gauge downstream of Alexander Springs Creek under the recommended MFLs hydrologic regime

USGS Gauge	Mean Daily Discharge (cfs)	Predicted Percent Reduction
02236125 St. Johns River at Astor, FL	3,770	0.2%

Hydrodynamic modeling conducted for the St. Johns River Water Supply Impact Study (SJRWMD 2012) was also reviewed to identify any potential impacts to estuarine resources resulting from river flow reductions. The Environmental Fluids Dynamic Code (EFDC) hydrodynamic model was used to simulate water level and salinity differences in the St. Johns River between baseline conditions (scenario “Base1995NN” – 1995 conditions with no additional withdrawals) and a simulated 155 million gallons per day (mgd) withdrawal scenario. Model results suggest that the 155 mgd withdrawal would result in a drop in mean water level of less than 0.5 cm and a mean increase in salinity of less than 0.01 part per thousand (ppt) in the

St. Johns River at Buffalo Bluff, about 10 river miles downstream of the mouth of the Ocklawaha River (SJRWMD 2012).

It should be noted that mean salinity in the river remains at approximately 0.5 ppt (effectively freshwater) from upstream reaches to Shands Bridge, about 40 river miles downstream of Buffalo Bluff. It can therefore be assumed that any effects at Astor due to changes in Alexander Springs discharges would be less in the estuarine downstream reaches.

Also, estuarine biota are adapted to widely and rapidly changing environmental conditions including salinity, temperature, and water level. Table 5-5 shows the wide range of salinity preferences for a variety of common estuarine species.

Table 5-5. Salinity preferences for selected species (ppt)

Species	Lower Limit	Upper Limit
Adult oyster	11	33
Oyster Larval	11	31
Blue Crab, Megalopae	16	38
Blue Crab, Spawning Female	21	38
Sea Trout	15	34
Turtle grass	7	48
Bay Anchovy	10	20
Pinfish	20	25
Pink Shrimp	10	15

The St. Johns River Water Supply Impact Study Fisheries Working Group came to similar conclusions regarding the potential for impacts to fisheries due to the above potential withdrawals. The Fisheries Working Group's Final Report (SJRWMD 2012) states:

> *"Salinity—The EFDC hydrodynamic model output indicates that water withdrawals would have little effect on the overall spatial coverage of various salinity habitats in the Lower Basin estuary. This is consistent with the conclusions reached by other working groups."*
>
> And:
>
> *"Based on these analyses we conclude that water withdrawals under the potential near-term and long-term withdrawal scenarios will have a negligible effect on the spatial coverage of the various salinity habitats as defined here."*

The St. Johns River Water Supply Impact Study Wetlands Working Group also came to similar conclusions regarding the potential for impacts to wetlands due to the above potential withdrawals. The Wetlands Working Group's Final Report (SJRWMD 2012) states:

> *Under Scenario Full1995NN* [or any others]*, no or only very small effects are projected to occur at the upper and lower wetland boundaries.*

The wetlands report states that in estuarine fringe habitats in downstream modeled reaches of the St. Johns River, salt marshes and hardwood swamps would have "very low" likelihood of effects based on changes in water level resulting from the "Full1995NN" scenario withdrawals. Also, salt marshes have a "low" likelihood of salinity effects from the "Full1995NN" scenario withdrawals, however hardwood swamps in downstream-most reach 1 have a "high" likelihood of salinity effects under the same scenario. Based on the modeling results and the assessment of fishery resources and wetlands, it appears likely that the scenario water withdrawals examined in the Water Supply Impact Study (SJRWMD 2012) will have a negligible effect on estuarine resources.

The flow reduction allowed under the recommended MFLs hydrologic regime for Alexander Springs that is examined in this WRV assessment is less than the withdrawals examined in the Water Supply Impact Study and would be expected to have considerably milder effects on downstream river stage and salinity, and by inference, estuarine resources. Thus, estuarine resources as defined in WRV-3 would be protected under the recommended MFLs hydrologic regime.

5.4 WRV-4: TRANSFER OF DETRITAL MATERIAL

Transfer of Detrital Material is defined as the movement by water of loose organic material and debris and associated decomposing biota. The criterion for protection is "the movement of loose organic materials." In addition, a distinction is made in the literature (Mehta et al., 2004) regarding the "transfer" of detrital material from the banks to the water column versus the "transport" of material (e.g., sediment, under WRV-8) within the run. The representative functions used to assess protection are water depth and floodplain inundation in the spring run. The general indicators of protection will be water stage events to maintain detrital transfer to Alexander Springs Creek. Specific indicators of protection will be the number of events per 100 years associated with water depth and area of inundation necessary for adequate detrital transfer to the water column that does not differ unacceptably from baseline conditions.

Detrital material is an important component of the food web in aquatic ecosystems (Mitsch and Gosselink, 2007). Detrital material transport is an important ecological function in many riverine systems (Wetzel, 2001) including spring runs (Odum, 1957). This detrital material forms the basis for a detritus food web, in which microbes and aquatic insects utilize the reduced carbon in the dead plant material from an upstream ecosystem to promote their own growth and metabolism. These organisms, in turn, are food for fish and wildlife in downstream segments.

Detrital transfer in the present context refers to the movement of organic-rich sedimentary material from the banks into the water column when high water levels occur (Mehta et al., 2004). Unlike systems dominated by stormwater runoff in which storm flows can be two orders of magnitude or greater than base flows, the spring-fed Alexander Springs Creek typically receives 50 percent or more of its discharge from Alexander Springs. Because of its relatively large watershed (99 mi^2), it can experience large stormwater runoff inputs (overland flow and seepage) to the creek during large storms when all catchment areas are contributing, particularly in the lower reaches of the creek. It should be noted that Alexander Springs Creek water levels are affected by St. Johns River backwater in the lower portion of the creek.

Observations are that much of the spring run has a bank along the channel that would seem to allow direct flooding from the river at fairly high stages. However, further observations indicate that there is significant seepage from adjacent uplands into the floodplain. It is this seepage that dominates the hydrology of the floodplain more so than overbank flows from the channel (Robert Freese, Personal Communication, 2016). In-channel water levels still affect floodplain hydrology acting as a boundary for the seepage slope from upland areas. SJRWMD's HEC-RAS model construction for Alexander Springs Creek allows the water level in the floodplain to fluctuate in concert with that in the main channel, giving an approximation of the seepage contribution to the floodplain. Conveyance in the floodplain areas was limited through the specification of a high roughness coefficient (Manning n of 0.35) when water levels exceeded the overbank elevations.

A summary of vegetation transect information can be found in Appendix C, including the mean elevations of the hardwood swamps and the hydric hammocks.

Two processes important to the transfer of detrital material are inundation of the floodplain, as that is the primary source of detritus that is mobilized by the inundation, and transfer of the material from the floodplain to the main channel, where it is transported to other locations. The important consideration is not necessarily the flow condition, but rather that the proposed MFLs would not cause a substantial shift in the occurrence of those critical flow events.

SJRWMD developed the Alexander Springs Creek HEC-RAS model to evaluate hydraulic characteristics at 26 cross-sections along Alexander Springs Creek for a range of flow conditions.

Table 5-6 presents in-channel average velocities at 25 cross-sections along Alexander Springs Creek for a range of flow conditions. Given the small decrease, typically 0.02 foot per second (ft/sec) or less (maximum of 0.07 ft/sec at terminus of the HEC-RAS model), in average in-channel velocities anticipated under the MFLs hydrologic regime from the period-of-record (POR) 1983-2014 hydrologic conditions, transport of detrital material from the banks of Alexander Springs Creek should not change significantly under the MFLs hydrologic regime.

The Alexander Springs Creek HEC-RAS model was also used to assess mean flow velocities in the floodplains. Mean flow velocities in the floodplain are generally less than 0.2 ft/sec, with a few exceptions during larger storm events. Given that velocity reductions under the MFLs hydrologic regime are expected to be minimal, transport capacity within the floodplain areas is also expected to not change significantly.

Current velocity affects the composition of biological communities in streams, as well as being significant for channel erosion and downstream transport of materials. Studies of Florida springs have noted a possible relationship between reduced velocity and the proliferation of algae that may interact with algal response to nutrient increases (Stevenson et al., 2007). A recent study of three southwest Florida rivers identified a velocity threshold of 0.82 ft/sec, below which river substrates were suitable for colonization of submerged aquatic vegetation (SAV) (Hoyer et al., 2004). Recent studies at the Gum Slough spring system in Sumter County, Florida, identified a flow velocity threshold of 1.1 ft/sec above which algal abundance was minimal (King, 2012).

Table 5-6. In-channel average velocities (in ft/sec) as simulated by the Alexander Springs HEC-RAS model at cross-sections along Alexander Springs Creek for a range of flow conditions.

Profile	Q Total	9.27	9	8.82	8.38	7.96	7.95	7.94	7.86	7.37	6.74	6.07	5.83*	5.59*	5.35	5.23	5.02	4.99	4.65	4.41	3.98	3.28	2.91	2.52	1.05	0
Baseline																										
PF 1	78	0.21	0.19	0.21	0.22	0.16	0.21	0.37	0.15	0.19	0.19	0.2	0.29	0.26	0.22	0.12	0.17	0.17	0.2	0.21	0.27	0.38	0.3	0.86	0.56	0.91
PF 2	86.6	0.22	0.2	0.22	0.23	0.17	0.22	0.37	0.16	0.2	0.2	0.2	0.3	0.27	0.23	0.12	0.18	0.18	0.21	0.22	0.28	0.37	0.3	0.83	0.56	0.73
PF 3	91.1	0.22	0.21	0.23	0.23	0.17	0.22	0.37	0.16	0.2	0.2	0.2	0.31	0.28	0.24	0.13	0.18	0.18	0.21	0.22	0.29	0.37	0.3	0.82	0.56	0.71
PF 4	94.6	0.23	0.22	0.24	0.24	0.17	0.23	0.37	0.16	0.21	0.2	0.2	0.31	0.28	0.24	0.13	0.19	0.19	0.22	0.23	0.29	0.36	0.3	0.82	0.56	0.68
PF 5	97.1	0.23	0.22	0.24	0.24	0.17	0.23	0.37	0.16	0.21	0.2	0.2	0.31	0.28	0.25	0.13	0.19	0.19	0.22	0.23	0.3	0.36	0.31	0.81	0.57	0.67
PF 6	99.7	0.23	0.22	0.25	0.24	0.17	0.23	0.37	0.17	0.21	0.2	0.2	0.31	0.29	0.25	0.13	0.19	0.19	0.23	0.24	0.31	0.35	0.31	0.81	0.59	0.68
PF 7	104	0.23	0.23	0.25	0.25	0.18	0.23	0.37	0.17	0.22	0.21	0.21	0.32	0.3	0.26	0.14	0.2	0.2	0.23	0.25	0.33	0.34	0.31	0.79	0.61	0.69
PF 8	107	0.22	0.23	0.26	0.25	0.18	0.24	0.37	0.17	0.22	0.21	0.21	0.33	0.31	0.27	0.14	0.21	0.21	0.24	0.26	0.35	0.32	0.31	0.79	0.64	0.71
PF 9	111	0.22	0.23	0.27	0.26	0.18	0.24	0.36	0.18	0.23	0.22	0.21	0.34	0.32	0.28	0.15	0.21	0.21	0.26	0.27	0.38	0.29	0.31	0.8	0.67	0.72
PF 10	115	0.22	0.24	0.28	0.26	0.18	0.25	0.36	0.18	0.23	0.22	0.21	0.34	0.32	0.29	0.15	0.22	0.22	0.26	0.28	0.39	0.28	0.31	0.81	0.7	0.75
PF 11	118	0.21	0.24	0.29	0.26	0.19	0.25	0.36	0.19	0.24	0.23	0.21	0.34	0.33	0.3	0.16	0.22	0.22	0.27	0.29	0.4	0.27	0.32	0.82	0.73	0.75
PF 12	123	0.2	0.23	0.3	0.27	0.2	0.27	0.37	0.2	0.25	0.24	0.22	0.36	0.36	0.33	0.18	0.25	0.25	0.29	0.32	0.43	0.26	0.33	0.82	0.73	0.67
PF 13	124	0.19	0.23	0.31	0.28	0.2	0.27	0.37	0.2	0.26	0.24	0.22	0.37	0.37	0.34	0.18	0.25	0.25	0.29	0.32	0.44	0.26	0.34	0.82	0.75	0.68
PF 14	125	0.19	0.23	0.31	0.28	0.2	0.27	0.37	0.2	0.26	0.24	0.22	0.39	0.37	0.35	0.19	0.25	0.25	0.31	0.33	0.45	0.26	0.35	0.81	0.76	0.66
PF 15	126	0.18	0.22	0.31	0.27	0.2	0.27	0.36	0.2	0.26	0.24	0.22	0.37	0.36	0.36	0.18	0.23	0.23	0.29	0.33	0.5	0.26	0.37	0.82	0.89	0.8
PF 16	127	0.16	0.19	0.32	0.28	0.22	0.3	0.38	0.22	0.29	0.27	0.24	0.4	0.38	0.43	0.2	0.24	0.25	0.29	0.36	0.54	0.27	0.4	0.84	0.99	0.91
PF 17	127.2	0.14	0.16	0.32	0.29	0.24	0.32	0.41	0.25	0.3	0.29	0.25	0.4	0.39	0.47	0.21	0.25	0.26	0.29	0.39	0.57	0.28	0.43	0.85	1.06	1.03
PF 18	127.4	0.14	0.15	0.31	0.29	0.25	0.34	0.43	0.26	0.31	0.31	0.27	0.41	0.4	0.49	0.23	0.26	0.27	0.3	0.42	0.58	0.29	0.44	0.86	1.07	1.04
PF 19	127.6	0.13	0.13	0.31	0.3	0.27	0.37	0.45	0.28	0.32	0.33	0.28	0.41	0.41	0.51	0.24	0.28	0.28	0.31	0.44	0.6	0.3	0.46	0.87	1.13	1.12
PF 20	127.8	0.1	0.08	0.29	0.31	0.33	0.45	0.54	0.34	0.3	0.4	0.34	0.42	0.34	0.4	0.27	0.29	0.29	0.31	0.49	0.71	0.35	0.58	1	1.42	1.93
PF 21	128	0.06	0.03	0.2	0.35	0.5	0.72	0.81	0.42	0.26	0.55	0.46	0.41	0.26	0.24	0.3	0.3	0.3	0.32	0.58	0.99	0.5	0.85	1.33	1.92	4.48
PF 22	133	0.05	0.02	0.16	0.38	0.6	0.87	0.97	0.46	0.27	0.61	0.54	0.42	0.27	0.23	0.32	0.32	0.32	0.32	0.6	1.11	0.57	0.98	1.47	2.14	4.29
MFL																										
PF 1	71	0.21	0.17	0.19	0.21	0.16	0.21	0.37	0.15	0.18	0.18	0.19	0.28	0.25	0.21	0.11	0.16	0.16	0.19	0.19	0.26	0.39	0.29	0.87	0.53	0.84
PF 2	79.6	0.21	0.19	0.21	0.22	0.16	0.21	0.37	0.15	0.19	0.19	0.2	0.29	0.26	0.22	0.12	0.17	0.17	0.2	0.21	0.27	0.38	0.3	0.83	0.53	0.68
PF 3	84.1	0.22	0.2	0.22	0.23	0.16	0.22	0.37	0.16	0.2	0.19	0.2	0.3	0.27	0.23	0.12	0.18	0.18	0.2	0.21	0.28	0.37	0.3	0.82	0.53	0.66
PF 4	87.6	0.22	0.2	0.22	0.23	0.17	0.22	0.37	0.16	0.2	0.2	0.2	0.3	0.27	0.23	0.12	0.18	0.18	0.21	0.22	0.28	0.37	0.3	0.81	0.54	0.64
PF 5	90.1	0.22	0.21	0.23	0.23	0.17	0.22	0.37	0.16	0.2	0.2	0.2	0.3	0.27	0.24	0.13	0.18	0.18	0.21	0.22	0.29	0.37	0.3	0.81	0.54	0.63
PF 6	92.7	0.22	0.21	0.23	0.23	0.17	0.22	0.37	0.16	0.2	0.2	0.2	0.31	0.28	0.24	0.13	0.19	0.19	0.22	0.23	0.3	0.36	0.3	0.8	0.56	0.64
PF 7	97	0.22	0.22	0.24	0.24	0.17	0.23	0.37	0.17	0.21	0.2	0.2	0.31	0.29	0.25	0.13	0.19	0.19	0.23	0.24	0.31	0.34	0.3	0.78	0.58	0.65
PF 8	100	0.22	0.22	0.25	0.24	0.18	0.23	0.37	0.17	0.22	0.21	0.2	0.32	0.3	0.26	0.14	0.2	0.2	0.24	0.25	0.34	0.32	0.31	0.78	0.62	0.68
PF 9	104	0.22	0.22	0.26	0.25	0.18	0.24	0.36	0.17	0.22	0.21	0.21	0.33	0.31	0.27	0.15	0.21	0.21	0.25	0.26	0.36	0.3	0.31	0.79	0.65	0.69
PF 10	108	0.22	0.23	0.27	0.25	0.18	0.24	0.36	0.18	0.23	0.22	0.21	0.33	0.31	0.28	0.15	0.21	0.21	0.26	0.27	0.38	0.28	0.31	0.81	0.69	0.72
PF 11	111	0.21	0.23	0.28	0.26	0.19	0.25	0.36	0.18	0.23	0.22	0.21	0.34	0.33	0.3	0.16	0.22	0.22	0.27	0.28	0.4	0.27	0.31	0.82	0.71	0.73
PF 12	116	0.19	0.23	0.29	0.27	0.2	0.26	0.37	0.19	0.25	0.23	0.22	0.35	0.36	0.33	0.18	0.23	0.24	0.29	0.31	0.42	0.26	0.33	0.81	0.71	0.65
PF 13	117	0.19	0.22	0.3	0.27	0.2	0.26	0.37	0.2	0.25	0.23	0.22	0.36	0.36	0.33	0.18	0.25	0.25	0.29	0.32	0.44	0.26	0.34	0.82	0.73	0.66
PF 14	118	0.18	0.22	0.3	0.28	0.2	0.27	0.37	0.2	0.26	0.24	0.22	0.37	0.37	0.35	0.18	0.25	0.25	0.3	0.33	0.45	0.26	0.34	0.81	0.74	0.64

Table 5-6. In-channel average velocities (in ft/sec) as simulated by the Alexander Springs HEC-RAS model at cross-sections along Alexander Springs Creek for a range of flow conditions.

Profile	Q Total	9.27	9	8.82	8.38	7.96	7.95	7.94	7.86	7.37	6.74	6.07	5.83*	5.59*	5.35	5.23	5.02	4.99	4.65	4.41	3.98	3.28	2.91	2.52	1.05	0
PF 15	119	0.17	0.21	0.3	0.27	0.2	0.27	0.36	0.2	0.26	0.24	0.22	0.38	0.37	0.35	0.18	0.23	0.23	0.29	0.32	0.5	0.26	0.36	0.82	0.88	0.78
PF 16	120	0.15	0.18	0.31	0.28	0.22	0.29	0.38	0.22	0.28	0.26	0.23	0.4	0.38	0.42	0.2	0.24	0.24	0.29	0.36	0.53	0.27	0.4	0.83	0.97	0.89
PF 17	120.2	0.14	0.16	0.31	0.28	0.24	0.32	0.4	0.24	0.3	0.29	0.25	0.4	0.39	0.47	0.21	0.25	0.25	0.29	0.39	0.56	0.28	0.42	0.85	1.05	1.01
PF 18	120.4	0.13	0.14	0.31	0.29	0.25	0.34	0.42	0.26	0.31	0.31	0.26	0.41	0.4	0.49	0.22	0.26	0.27	0.3	0.41	0.57	0.29	0.44	0.86	1.06	1.02
PF 19	120.6	0.12	0.12	0.31	0.29	0.27	0.36	0.45	0.28	0.32	0.33	0.28	0.41	0.41	0.51	0.24	0.28	0.28	0.31	0.44	0.6	0.3	0.46	0.87	1.12	1.1
PF 20	120.8	0.1	0.08	0.28	0.31	0.33	0.45	0.53	0.33	0.3	0.39	0.33	0.42	0.34	0.4	0.26	0.29	0.29	0.31	0.48	0.71	0.35	0.57	1	1.42	1.91
PF 21	121	0.06	0.03	0.2	0.35	0.5	0.72	0.81	0.42	0.26	0.54	0.46	0.41	0.26	0.24	0.3	0.3	0.3	0.32	0.58	0.99	0.5	0.85	1.33	1.92	4.46
PF 22	126	0.05	0.02	0.16	0.38	0.6	0.87	0.97	0.46	0.27	0.61	0.54	0.42	0.27	0.23	0.32	0.32	0.32	0.32	0.6	1.11	0.57	0.98	1.47	2.13	4.28

*Interpolated cross-sections

Walsh et al. (2009) indicate that mats of algae accumulate during the winter and spring months in the pool and run areas when recreational activity in the spring is at a minimum. During the spring and summer months when swimming activity is high, much of the algae that has accumulated during the previous season becomes dislodged and drifts down the run. Cohen et al. (2011) found that despite having the lowest nitrate concentration of any first magnitude spring in Florida (mean of 0.07 mg/L), a continuous benthic mat dominated by the filamentous green alga, *Hydrodictyon* sp., covers 24,000 square meters (m^2) of the bottom of the spring run.

Seston is a collective term for all particulate material present in free water. Seston includes both bioseston (plankton and nekton) and abioseston or tripton (nonliving particulate material). (Wetzel, 2001). Cohen et al. (2011) found that a large amount of seston (comprised largely of masses of *Hydrodictyon* sp. with pieces of other macrophytes and terrestrial organic carbon interspersed) flows down Alexander Springs Creek each day. They calculated that a total dry mass of 368 kg/day, or 1 percent of the standing benthic mat, is exported daily. A Wetland Solutions, Inc.(WSI) study (2007) also measured community export (seston), both as dry mass and as organic carbon (ash –free dry weight), along Alexander Springs Creek. Unlike the conclusions of Cohen et al (2011), WSI (2007) reported a net loss of export between the upper and lower transects used for measurement. It is difficult to compare both studies, however, since they were conducted in completely different reaches of the river run. The upper and lower sites WSI used were much further downstream [the upstream site was approximately 1,500 meters (m) from the spring vent, and the downstream site was at the CR-445 bridge]. The reach studied was dominated by SAV. The site Cohen et al. (2011) used was much further upstream (550 m from the spring vent), in an area dominated by a continuous benthic mat, with relatively little SAV present. The amount of seston dry mass that was captured (550 m from the vent) ranged from 0.29 to 33.52 grams per square meter per day ($g/m^2/day$), depending on the time in which the seston net was sampled. In comparison, the amount of dry mass WSI captured in the upstream site (1500 m from the spring vent) ranged from 0.428 to 0.646 $g/m^2/day$. Additionally, floating seston can be trapped by SAV in the river run. Part of the reduction in seston seen further downstream may be because it gets caught in SAV as it floats down river. Peak export times were in the afternoon, when photosynthesis was highest. A possible explanation is oxygen bubbles formed within the algal mat, helping to slough off overlying masses of algae (Cohen et al., 2011).

In-channel, average velocities were calculated by the Alexander Springs Creek HEC-RAS model for the POR 1983-2014 baseline condition and the MFLs hydrologic regime. The simulated average in-channel velocity profiles (Table 5-7) indicate that Alexander Springs Creek has an average channel velocity greater than 1.15 ft/sec in the lower quarter of the reach beginning at the Tracy Canal inflow and for flow events expected to occur once every 30 years.

Given the limited algal scour capacity that currently exists and that velocity reductions under the MFL hydrologic regime is 0.07 ft/sec or less, algal scour capacity will not change significantly.

Overbank elevations were examined at a number of cross-sections to evaluate changes in critical events related to both floodplain inundation and detritus transport processes. For this evaluation, inundation of the typical top-of-bank elevation at the stream channel edge, or overbank elevation, allowing sweeping of detritus by flow from the aquatic bed areas immediately adjacent to the river channel, were explored. It is at these elevations that large increases in wetted perimeter begin to occur. The elevation targets are summarized in Table 5-8. Figures 5-10 through 5-16 present the cross-sections of interest.

Table 5-8. Critical stage values for detrital transfer.

Transect ID	Overbank Elevation (ft-NGVD)
A4.3	4.19
A5	5.43
A6	6.13
A8	7.51
A10	9.33
A14	8.95
A16	10.1

Table 5-7. Algal Scour: Simulated in-channel average velocities (in ft/sec) at cross-sections along Alexander Springs Creek for a range of flow conditions for the POR 1983-2014 baseline condition and the MFLs hydrologic regime. Highlighted cells indicate locations where critical velocity of 1.1 fps was equaled or exceeded.

Profile	Q Total	9.27	9	8.82	8.38	7.96	7.95	7.94	7.86	7.37	6.74	6.07	5.83*	5.59*	5.35	5.23	5.02	4.99	4.65	4.41	3.98	3.28	2.91	2.52	1.05	0
Baseline																										
PF 1	78	0.21	0.19	0.21	0.22	0.16	0.21	0.37	0.15	0.19	0.19	0.2	0.29	0.26	0.22	0.12	0.17	0.17	0.2	0.21	0.27	0.38	0.3	0.86	0.56	0.91
PF 2	86.6	0.22	0.2	0.22	0.23	0.17	0.22	0.37	0.16	0.2	0.2	0.2	0.3	0.27	0.23	0.12	0.18	0.18	0.21	0.22	0.28	0.37	0.3	0.83	0.56	0.73
PF 3	91.1	0.22	0.21	0.23	0.23	0.17	0.22	0.37	0.16	0.2	0.2	0.2	0.31	0.28	0.24	0.13	0.18	0.18	0.21	0.22	0.29	0.37	0.3	0.82	0.56	0.71
PF 4	94.6	0.23	0.22	0.24	0.24	0.17	0.23	0.37	0.16	0.21	0.2	0.2	0.31	0.28	0.24	0.13	0.19	0.19	0.22	0.23	0.29	0.36	0.3	0.82	0.56	0.68
PF 5	97.1	0.23	0.22	0.24	0.24	0.17	0.23	0.37	0.16	0.21	0.2	0.2	0.31	0.28	0.25	0.13	0.19	0.19	0.22	0.23	0.3	0.36	0.31	0.81	0.57	0.67
PF 6	99.7	0.23	0.22	0.25	0.24	0.17	0.23	0.37	0.17	0.21	0.2	0.2	0.31	0.29	0.25	0.13	0.19	0.19	0.23	0.24	0.31	0.35	0.31	0.81	0.59	0.68
PF 7	104	0.23	0.23	0.25	0.25	0.18	0.23	0.37	0.17	0.22	0.21	0.21	0.32	0.3	0.26	0.14	0.2	0.2	0.23	0.25	0.33	0.34	0.31	0.79	0.61	0.69
PF 8	107	0.22	0.23	0.26	0.25	0.18	0.24	0.37	0.17	0.22	0.21	0.21	0.33	0.31	0.27	0.14	0.21	0.21	0.24	0.26	0.35	0.32	0.31	0.79	0.64	0.71
PF 9	111	0.22	0.23	0.27	0.26	0.18	0.24	0.36	0.18	0.23	0.22	0.21	0.34	0.32	0.28	0.15	0.21	0.21	0.26	0.27	0.38	0.29	0.31	0.8	0.67	0.72
PF 10	115	0.22	0.24	0.28	0.26	0.18	0.25	0.36	0.18	0.23	0.22	0.21	0.34	0.32	0.29	0.15	0.22	0.22	0.26	0.28	0.39	0.28	0.31	0.81	0.7	0.75
PF 11	118	0.21	0.24	0.29	0.26	0.19	0.25	0.36	0.19	0.24	0.23	0.21	0.34	0.33	0.3	0.16	0.22	0.22	0.27	0.29	0.4	0.27	0.32	0.82	0.73	0.75
PF 12	123	0.2	0.23	0.3	0.27	0.2	0.27	0.37	0.2	0.25	0.24	0.22	0.36	0.36	0.33	0.18	0.25	0.25	0.29	0.32	0.43	0.26	0.33	0.82	0.73	0.67
PF 13	124	0.19	0.23	0.31	0.28	0.2	0.27	0.37	0.2	0.26	0.24	0.22	0.37	0.37	0.34	0.18	0.25	0.25	0.29	0.32	0.44	0.26	0.34	0.82	0.75	0.68
PF 14	125	0.19	0.23	0.31	0.28	0.2	0.27	0.37	0.2	0.26	0.24	0.22	0.39	0.37	0.35	0.19	0.25	0.25	0.31	0.33	0.45	0.26	0.35	0.81	0.76	0.66
PF 15	126	0.18	0.22	0.31	0.27	0.2	0.27	0.36	0.2	0.26	0.24	0.22	0.37	0.36	0.36	0.18	0.23	0.23	0.29	0.33	0.5	0.26	0.37	0.82	0.89	0.8
PF 16	127	0.16	0.19	0.32	0.28	0.22	0.3	0.38	0.22	0.29	0.27	0.24	0.4	0.38	0.43	0.2	0.24	0.25	0.29	0.36	0.54	0.27	0.4	0.84	0.99	0.91
PF 17	127.2	0.14	0.16	0.32	0.29	0.24	0.32	0.41	0.25	0.3	0.29	0.25	0.4	0.39	0.47	0.21	0.25	0.26	0.29	0.39	0.57	0.28	0.43	0.85	1.06	1.03
PF 18	127.4	0.14	0.15	0.31	0.29	0.25	0.34	0.43	0.26	0.31	0.31	0.27	0.41	0.4	0.49	0.23	0.26	0.27	0.3	0.42	0.58	0.29	0.44	0.86	1.07	1.04
PF 19	127.6	0.13	0.13	0.31	0.3	0.27	0.37	0.45	0.28	0.32	0.33	0.28	0.41	0.41	0.51	0.24	0.28	0.28	0.31	0.44	0.6	0.3	0.46	0.87	1.13	1.12
PF 20	127.8	0.1	0.08	0.29	0.31	0.33	0.45	0.54	0.34	0.3	0.4	0.34	0.42	0.34	0.4	0.27	0.29	0.29	0.31	0.49	0.71	0.35	0.58	1	1.42	1.93
PF 21	128	0.06	0.03	0.2	0.35	0.5	0.72	0.81	0.42	0.26	0.55	0.46	0.41	0.26	0.24	0.3	0.3	0.3	0.32	0.58	0.99	0.5	0.85	1.33	1.92	4.48
PF 22	133	0.05	0.02	0.16	0.38	0.6	0.87	0.97	0.46	0.27	0.61	0.54	0.42	0.27	0.23	0.32	0.32	0.32	0.32	0.6	1.11	0.57	0.98	1.47	2.14	4.29
MFL																										
PF 1	71	0.21	0.17	0.19	0.21	0.16	0.21	0.37	0.15	0.18	0.18	0.19	0.28	0.25	0.21	0.11	0.16	0.16	0.19	0.19	0.26	0.39	0.29	0.87	0.53	0.84
PF 2	79.6	0.21	0.19	0.21	0.22	0.16	0.21	0.37	0.15	0.19	0.19	0.2	0.29	0.26	0.22	0.12	0.17	0.17	0.2	0.21	0.27	0.38	0.3	0.83	0.53	0.68
PF 3	84.1	0.22	0.2	0.22	0.23	0.16	0.22	0.37	0.16	0.2	0.19	0.2	0.3	0.27	0.23	0.12	0.18	0.18	0.2	0.21	0.28	0.37	0.3	0.82	0.53	0.66
PF 4	87.6	0.22	0.2	0.22	0.23	0.17	0.22	0.37	0.16	0.2	0.2	0.2	0.3	0.27	0.23	0.12	0.18	0.18	0.21	0.22	0.28	0.37	0.3	0.81	0.54	0.64
PF 5	90.1	0.22	0.21	0.23	0.23	0.17	0.22	0.37	0.16	0.2	0.2	0.2	0.3	0.27	0.24	0.13	0.18	0.18	0.21	0.22	0.29	0.37	0.3	0.81	0.54	0.63
PF 6	92.7	0.22	0.21	0.23	0.23	0.17	0.22	0.37	0.16	0.2	0.2	0.2	0.31	0.28	0.24	0.13	0.19	0.19	0.22	0.23	0.3	0.36	0.3	0.8	0.56	0.64
PF 7	97	0.22	0.22	0.24	0.24	0.17	0.23	0.37	0.17	0.21	0.2	0.2	0.31	0.29	0.25	0.13	0.19	0.19	0.23	0.24	0.31	0.34	0.3	0.78	0.58	0.65
PF 8	100	0.22	0.22	0.25	0.24	0.18	0.23	0.37	0.17	0.22	0.21	0.2	0.32	0.3	0.26	0.14	0.2	0.2	0.24	0.25	0.34	0.32	0.31	0.78	0.62	0.68
PF 9	104	0.22	0.22	0.26	0.25	0.18	0.24	0.36	0.17	0.22	0.21	0.21	0.33	0.31	0.27	0.15	0.21	0.21	0.25	0.26	0.36	0.3	0.31	0.79	0.65	0.69
PF 10	108	0.22	0.23	0.27	0.25	0.18	0.24	0.36	0.18	0.23	0.22	0.21	0.33	0.31	0.28	0.15	0.21	0.21	0.26	0.27	0.38	0.28	0.31	0.81	0.69	0.72
PF 11	111	0.21	0.23	0.28	0.26	0.19	0.25	0.36	0.18	0.23	0.22	0.21	0.34	0.33	0.3	0.16	0.22	0.22	0.27	0.28	0.4	0.27	0.31	0.82	0.71	0.73
PF 12	116	0.19	0.23	0.29	0.27	0.2	0.26	0.37	0.19	0.25	0.23	0.22	0.35	0.36	0.33	0.18	0.23	0.24	0.29	0.31	0.42	0.26	0.33	0.81	0.71	0.65
PF 13	117	0.19	0.22	0.3	0.27	0.2	0.26	0.37	0.2	0.25	0.23	0.22	0.36	0.36	0.33	0.18	0.25	0.25	0.29	0.32	0.44	0.26	0.34	0.82	0.73	0.66
PF 14	118	0.18	0.22	0.3	0.28	0.2	0.27	0.37	0.2	0.26	0.24	0.22	0.37	0.37	0.35	0.18	0.25	0.25	0.3	0.33	0.45	0.26	0.34	0.81	0.74	0.64

Table 5-7. Algal Scour: Simulated in-channel average velocities (in ft/sec) at cross-sections along Alexander Springs Creek for a range of flow conditions for the POR 1983-2014 baseline condition and the MFLs hydrologic regime. Highlighted cells indicate locations where critical velocity of 1.1 fps was equaled or exceeded.

Profile	Q Total	9.27	9	8.82	8.38	7.96	7.95	7.94	7.86	7.37	6.74	6.07	5.83*	5.59*	5.35	5.23	5.02	4.99	4.65	4.41	3.98	3.28	2.91	2.52	1.05	0
PF 15	119	0.17	0.21	0.3	0.27	0.2	0.27	0.36	0.2	0.26	0.24	0.22	0.38	0.37	0.35	0.18	0.23	0.23	0.29	0.32	0.5	0.26	0.36	0.82	0.88	0.78
PF 16	120	0.15	0.18	0.31	0.28	0.22	0.29	0.38	0.22	0.28	0.26	0.23	0.4	0.38	0.42	0.2	0.24	0.24	0.29	0.36	0.53	0.27	0.4	0.83	0.97	0.89
PF 17	120.2	0.14	0.16	0.31	0.28	0.24	0.32	0.4	0.24	0.3	0.29	0.25	0.4	0.39	0.47	0.21	0.25	0.25	0.29	0.39	0.56	0.28	0.42	0.85	1.05	1.01
PF 18	120.4	0.13	0.14	0.31	0.29	0.25	0.34	0.42	0.26	0.31	0.31	0.26	0.41	0.4	0.49	0.22	0.26	0.27	0.3	0.41	0.57	0.29	0.44	0.86	1.06	1.02
PF 19	120.6	0.12	0.12	0.31	0.29	0.27	0.36	0.45	0.28	0.32	0.33	0.28	0.41	0.41	0.51	0.24	0.28	0.28	0.31	0.44	0.6	0.3	0.46	0.87	1.12	1.1
PF 20	120.8	0.1	0.08	0.28	0.31	0.33	0.45	0.53	0.33	0.3	0.39	0.33	0.42	0.34	0.4	0.26	0.29	0.29	0.31	0.48	0.71	0.35	0.57	1	1.42	1.91
PF 21	121	0.06	0.03	0.2	0.35	0.5	0.72	0.81	0.42	0.26	0.54	0.46	0.41	0.26	0.24	0.3	0.3	0.3	0.32	0.58	0.99	0.5	0.85	1.33	1.92	4.46
PF 22	126	0.05	0.02	0.16	0.38	0.6	0.87	0.97	0.46	0.27	0.61	0.54	0.42	0.27	0.23	0.32	0.32	0.32	0.32	0.6	1.11	0.57	0.98	1.47	2.13	4.28

*Interpolated cross-sections

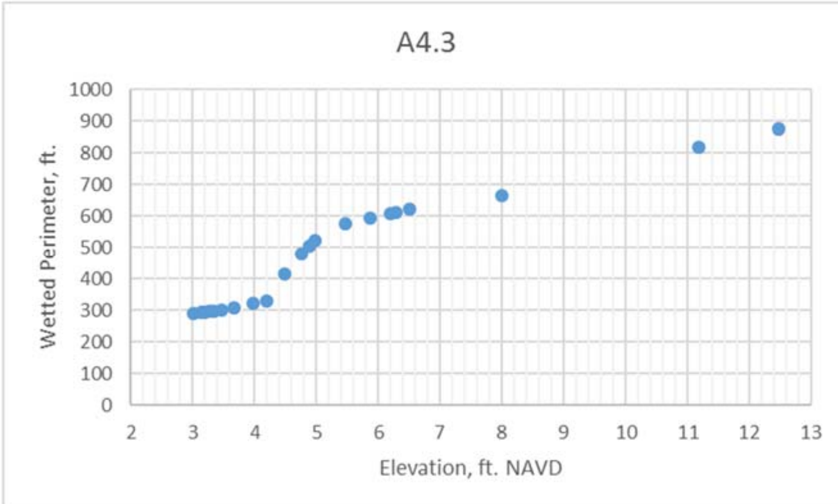


Figure 5-10. Wetted perimeter versus elevation for Cross-Section A4.3.

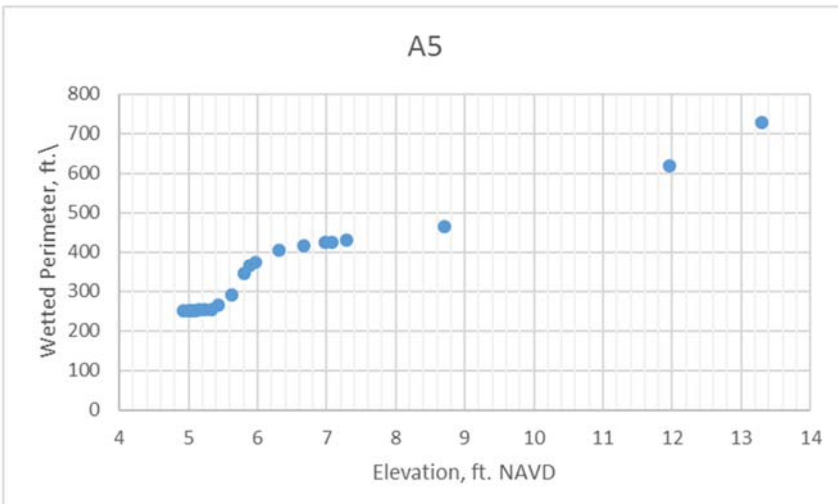


Figure 5-11. Wetted perimeter versus elevation for Cross-Section A5.

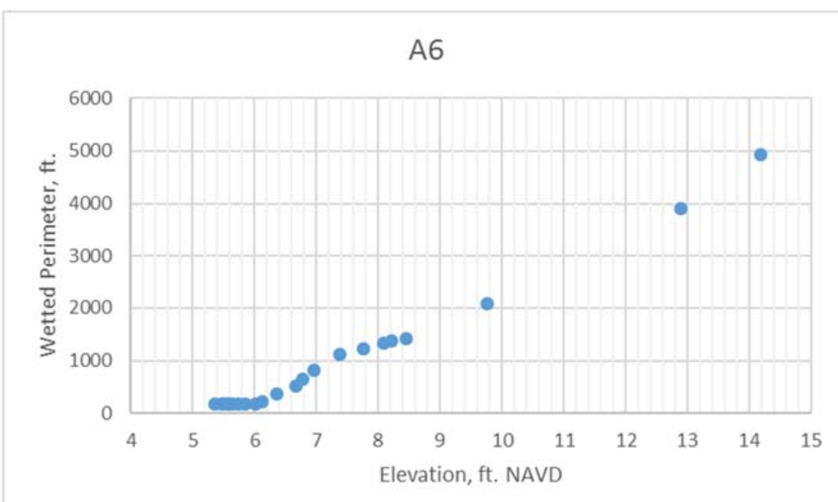


Figure 5-12. Wetted perimeter versus elevation for Cross-Section A6.

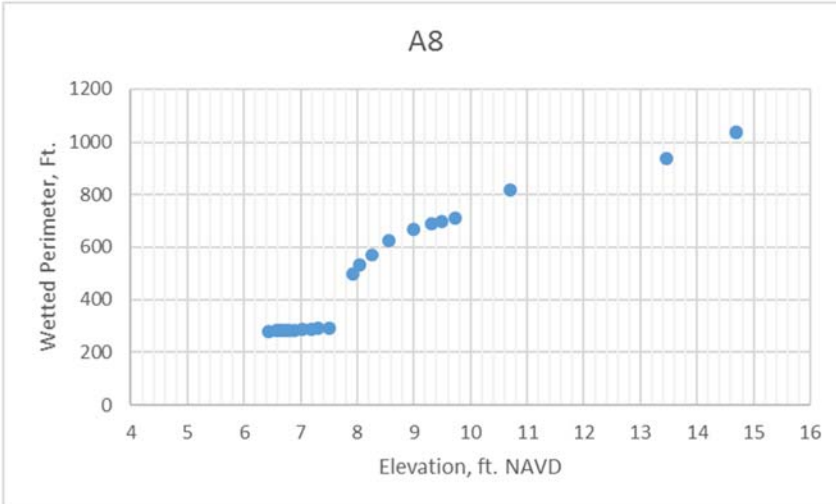


Figure 5-13. *Wetted perimeter versus elevation for Cross-Section A8.*

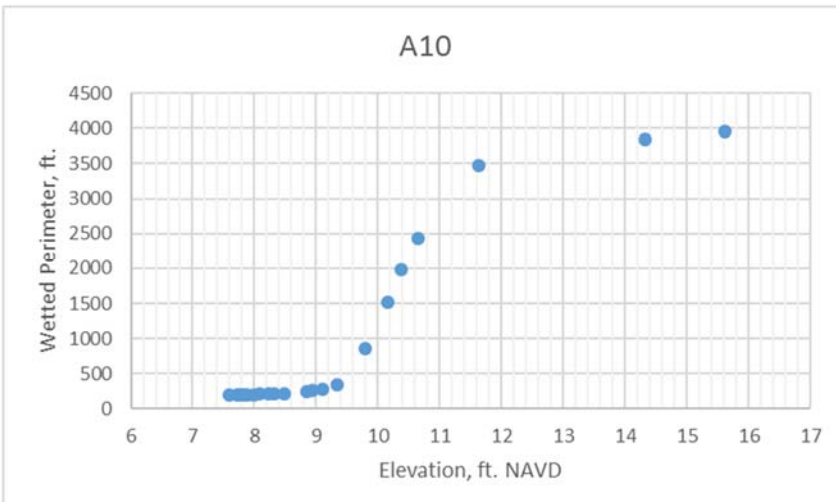


Figure 5-14. *Wetted perimeter versus elevation for Cross-Section A10.*

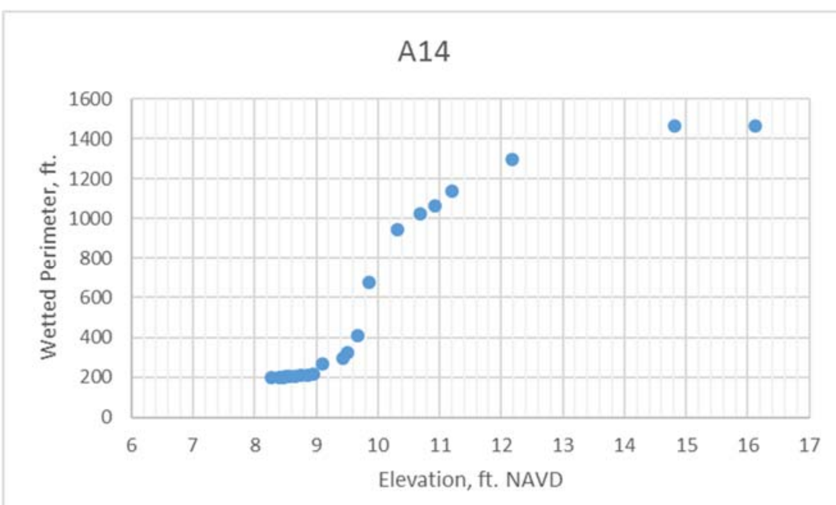


Figure 5-15. *Wetted perimeter versus elevation for Cross-Section A14.*

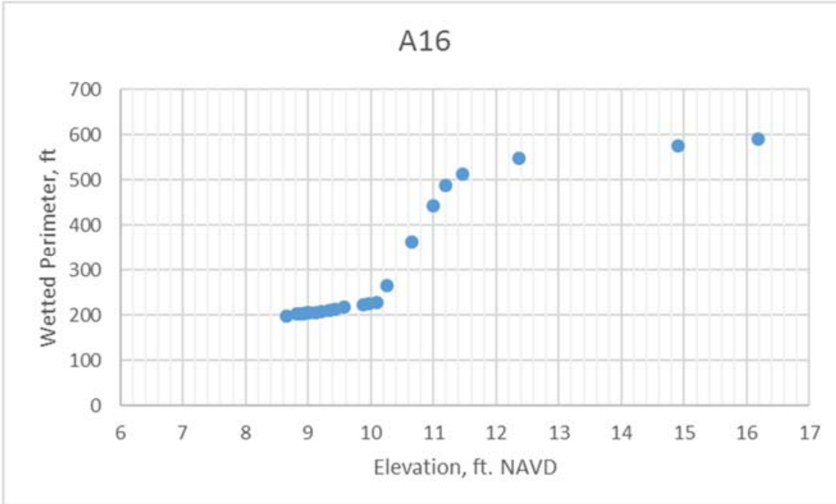


Figure 5-16. Wetted perimeter versus elevation for Cross-Section A16.

Durations of 7 days and 30 days were examined because these durations will provide a range of sufficient contact times between the river and the adjacent floodplain to maintain connectivity and facilitate the transfer of detritus. Tables 5-9a and 5-9b present the frequency and duration parameter results for the evaluation of detrital transfer. SJRWMD provided the stage frequency analysis.

Five of the transects (A4.3, A5, A6, A8 and A14) experience the critical event at a frequency important for detrital transfer and the food web (once every 3 years on average). Transect A10 under the 7-day duration experiences the greatest percent reduction in the critical stage event of 23 percent with a corresponding reduction in the frequency of occurrence from once every 4 years to once every 5 years. Transect A16 currently experiences the critical event relatively infrequently (once every 5 years or less) and is not considered critical to the detrital transfer processes in Alexander Springs Creek. For the critical stage event under the 30-day duration, Transects A6 and A14 experience a percent reduction of approximately 30 percent, with a corresponding reduction in occurrence frequency from once every 1.9 years to once every 2.7 years.

Based on the available data and professional judgment, WRV 4, Transfer of Detrital Material, is protected under the recommended MFLs hydrologic regime.

Table 5-9a. Frequency analysis results for the protection of detrital transfer—7-day duration high stage continuously exceeded.				
			Hydrologic Scenario	
Transect	Critical Stages (ft-NAVD)	Statistic[1]	No-Pumping Condition	MFL
A4.3	4.19	Events/100 yr	67.4	63.9
		Difference		3.5
A5	5.43	Events/100 yr	68.0	64.3
		Difference	-	3.7
A6	6.13	Events/100 yr	65.6	60.4
		Difference	-	5.2
A8	7.51	Events/100 yr	59.7	52.7
		Difference	-	7.0
A10	9.33	Events/100 yr	26.5	20.4
		Difference	-	6.1
A14	8.95	Events/100 yr	65.6	62.5
		Difference	-	3.1
A16	10.1	Events/100 yr	21.9	9.9
		Difference	-	12.0

1 Events /100 years= number of events per 100 years in which the critical stage event occurs. Difference = difference between the number of events occurring under no-pumping conditions and MFLs hydrologic regimes.

Table 5-9b. Frequency analysis results for the protection of detrital transfer—30-day duration high stage continuously exceeded.				
			Hydrologic Scenario	
Transect	Critical Stages (ft-NAVD)	Statistic[1]	No-Pumping Condition	MFL
A4.3	4.19	Events/100 yr	46.9	41.1
		Difference		5.8
A5	5.43	Events/100 yr	46.9	41.7
		Difference	-	5.2
A6	6.13	Events/100 yr	53.1	37.2
		Difference	-	15.9
A8	7.51	Events/100 yr	37.2	33.3
		Difference	-	2.9
A10	9.33	Events/100 yr	0	0
		Difference	-	0
A14	8.95	Events/100 yr	53.1	37.5
		Difference	-	15.6
A16	10.1	Events/100 yr	10.4	9.1
		Difference	-	1.3

1 Events /100 years= number of events per 100 years in which the critical stage event occurs. Difference = difference between the number of events occurring under no-pumping conditions and MFLs hydrologic regimes.

5.5 WRV-5: MAINTENANCE OF FRESHWATER STORAGE AND SUPPLY

For this analysis, *Maintenance of Freshwater Storage and Supply* is defined as the protection of an adequate amount of freshwater for non-consumptive uses and environmental values associated with coastal, estuarine, riverine, spring, aquatic, and wetlands ecology. The analysis focuses on whether the proposed minimum levels or flows protect the capacity of wetlands, surface waters, or the aquifer to store and supply water for non-consumptive uses and environmental values. The criterion for protection is the amount(s) of surface water and groundwater that is needed for non-consumptive uses. The representative function used to assess protection is the maintenance of adequate surface water levels and aquifer levels in the area(s) adjacent to the water body. The general indicator of protection is aquifer levels, surface water levels and flows that do not result in adverse impacts to the water body. The specific indicator of protection includes an evaluation of whether the groundwater-surface water interactions will change because of flow reductions in Alexander Springs and Alexander Springs Creek to the extent that WRVs are not protected.

The evaluation of this WRV is related to non-consumptive uses and environmental values. This WRV is encompassed in the other nine WRVs. As a spring MFL, the groundwater-surface water interactions are present in all WRVs since spring flow is solely groundwater.

Their evaluation is presented in other sections of Chapter 5. If the results of those evaluations conclude that the draft MFLs protect those WRVs, then WRV-5 is considered protected. Given that those evaluations concluded that all WRVs present in Alexander Springs and Alexander Springs Creek are protected, it is concluded that WRV-5 is also protected by the draft MFL.

5.6 WRV-6: AESTHETIC AND SCENIC ATTRIBUTES

Aesthetic and Scenic Attributes, is defined as those features of a waterscape usually associated with passive uses such as bird watching, sightseeing, hiking, photography, contemplation, and painting, plus other forms of relaxation that usually result in human emotional responses of well-being and contentment. As access to Alexander Springs Creek is primarily by boat, several of these passive uses, e.g., bird watching, photography, or contemplation, would be integrated with the recreational boating criteria in WRV-1.

The criterion for protection is *passive recreation*. The representative function used to assess protection is the visual setting at representative points, which, in this case, are the MFLs transects, as observed by a person on a boat. The general indicators of protection are changes in the visual setting at low flows under the no-pumping, or baseline, condition hydrologic regime versus low flows under the draft MFLs hydrologic regime. The specific indicators of protection are whether an obvious visual difference exists between the no-pumping low-flow hydrologic condition and the draft MFLs hydrologic regime and, if so, the extent to which these visual conditions may be changed (i.e., the extent of shifts in return interval at selected threshold water levels and duration).

As indicated in Table 4-1, the specific indicator for the aesthetics WRV is water level and clarity associated with desirable scenic and fish/wildlife viewing, including riparian and floodplain habitats. The evaluation focused on the top-of-bank elevation, which optimizes wildlife viewing access. The top-of-bank elevation at each of the MFLs transects was used and is presented in Table 5-10. The chosen event was the 30-day and 90-day high-stage continuously exceeded. These durations were chosen to reflect the durations of seasonal periods that currently exist and because longer durations of a particular condition will have a greater economic impact on ecotourism. Changes in the frequency of the 30-day and 90-day continuously exceeded stage are summarized in Tables 5-11a and 5-11b. SJRWMD provided the stage frequency analysis.

Table 5-10. Critical stage values for aesthetics and scenic attributes.

Transect ID	Overbank Elevation (ft-NGVD)
A4.3	4.19
A5	5.43
A6	6.13
A8	7.51
A10	9.33
A14	8.95
A16	10.1

For the critical stage event under the 30-day duration, Transects A6 and A14 experience a percent reduction of approximately 30 percent, with a corresponding reduction in occurrence frequency from once every 1.9 years to once every 2.7 years. This frequency is consistent with that of other transects, even with the relatively large percent reduction in critical events. Critical events of a 90-day duration are relatively infrequent and reflect the influence of storm flows on flows and water levels in Alexander Springs Creek

Given that the critical stage events are still occurring at a frequency sufficient to maintain existing scenic and fish/wildlife viewing patterns, based on the available data and professional judgment, WRV 6, Aesthetics and Scenic Attributes, is protected under the recommended MFLs hydrologic regime.

Table 5-11a. Frequency analysis results for the protection of aesthetics and scenic attributes—30-day duration high stage continuously exceeded.

Transect	Critical Stages (ft-NAVD)	Statistic[1]	Hydrologic Scenario: No-Pumping Condition	Hydrologic Scenario: MFL
A4.3	4.19	Events/100 yr	46.9	41.1
		Difference		5.8
A5	5.43	Events/100 yr	46.9	41.7
		Difference	-	5.2
A6	6.13	Events/100 yr	53.1	37.2
		Difference	-	15.9
A8	7.51	Events/100 yr	37.2	33.3
		Difference	-	2.9
A10	9.33	Events/100 yr	0	0
		Difference	-	0
A14	8.95	Events/100 yr	53.1	37.5
		Difference	-	15.6
A16	10.1	Events/100 yr	10.4	9.1
		Difference	-	1.3

1 Events /100 years= number of events per 100 years in which the critical stage event occurs. Difference = difference between the number of events occurring under no-pumping conditions and MFLs hydrologic regimes.

Table 5-11b. Frequency analysis results for the protection of aesthetics and scenic attributes — 90-day duration high stage continuously exceeded.

Transect	Critical Stages (ft-NAVD)	Statistic[1]	Hydrologic Scenario: No-Pumping Condition	Hydrologic Scenario: MFL
A4.3	4.19	Events/100 yr	15.6	9.1
		Difference		6.5
A5	5.43	Events/100 yr	15.6	9.4
		Difference	-	6.2
A6	6.13	Events/100 yr	20.4	14.1
		Difference	-	6.3
A8	7.51	Events/100 yr	11.5	7.7
		Difference	-	3.8
A10	9.33	Events/100 yr	0	0
		Difference	-	0
A14	8.95	Events/100 yr	20.1	13
		Difference	-	7.1
A16	10.1	Events/100 yr	9.1	9.0
		Difference	-	0.1

1 Events /100 years= number of events per 100 years in which the critical stage event occurs. Difference = difference between the number of events occurring under no-pumping conditions and MFLs hydrologic regimes.

5.7 WRV-7: FILTRATION AND ABSORPTION OF NUTRIENTS AND OTHER POLLUTANTS

Filtration and Absorption of Nutrients and Other Pollutants is defined as the reduction in concentration of nutrients and other pollutants through the processes of filtration and absorption (i.e., the removal of suspended and dissolved materials) as these substances move through the water column, soil, or substrate and associated organisms. The criteria for protection are the processes of filtration and absorption. The representative function used to assess protection is the ability of water to promote nutrient removal in the river and adjacent wetlands. The general indicators of protection are the depth and duration of floodplain inundation. The specific indicators of protection are the return intervals of stages associated with selected duration sufficient to maintain contact with riparian vegetation similar to no-pumping conditions.

Filtration and absorption of nutrients and other pollutants are natural system processes associated with aquatic and wetland ecology and are protected under *F.A.C*. 62-40.470 (Natural Systems Protection and Management) and *F.A.C.* 60-40.473 (Minimum Flows and Levels). Filtration consists of physical, chemical and biological processes that occur as water flows through media such as soil, sediment, and vegetation. Absorption is a chemical process that occurs during filtration. In natural environments, filtration and absorption can take place at many points throughout the hydrologic cycle. Therefore, understanding where these processes occur is important in evaluating the protection of this WRV in terms of MFLs.

Battelle (2004) investigated the sensitivity of this WRV to alterations in hydrologic regimes. The report concluded that filtration and absorption of nutrients and other pollutants related to springs occur in the flow path through the aquifer from the recharge area to the point of discharge. Filtration is primarily a function of the soil porosity. Adsorption is also primarily a function of the soil properties. Geochemical reactions are driven by the water quality of the source water and the chemical constituents of the aquifer soils. Alteration of groundwater level by pumping or diversions from surface water bodies could have an indirect effect on filtration and absorption. Lowering of the groundwater level by pumping or river level declines may affect retention time of water in the aquifer, which is a factor in geochemical reactions involving absorption (Battelle, 2004). Once the spring emerges, filtration and absorption can also occur on other biologically active surfaces on the floodplain.

The biogeochemical processing of dissolved constituents is controlled by complex interactions between the rate at which water flows through surface and subsurface flow paths and the rate at which dissolved constituents are processed by such processes as adsorption to sediments or uptake by microorganisms and vegetation (Hamilton and Helsel, 1995). This processing of dissolved constituents typically occurs in the floodplains of streams and water bodies. Floodplain soils and sediments that comprise the boundaries of streams support abundant microorganisms and vegetation as well as low redox environments and/or steep redox gradients that are essential for numerous biogeochemical processes (Ponnamperuma, 1972). Consequently, floodplain soils and sediments that comprise the boundaries of streams are areas in which a large proportion of the biogeochemical processing of dissolved constituents typically occurs (Hill et al., 1998; Hill and Lymburner, 1998).

Filtration and absorption processes occur within the water column through contact with SAV and in riparian zones where major medium such as vegetation, sediments, and soils exist. The rates of these processes are functions of residence time, or contact time, with these media. The longer nutrient and pollutant particles exist within a water body, the more likely they will be filtered, absorbed, or assimilated. As corroborated by the HEC-RAS results, spring flow reductions will very slightly reduce the average in-channel flow velocity, which would allow more contact time for nutrients and pollutants within the water column. The increased residence time would allow more time for the nutrients and pollutants to be filtrated, absorbed, or otherwise assimilated by SAV, bottom sediments and organisms in water columns. Therefore, it may be reasonable to conclude that changes to hydraulic residence times associated with the MFLs' hydrologic regime would benefit the filtration and absorption functional capacities of the SAV, which is abundant throughout Alexander Springs Creek.

The residence time of Alexander Springs Creek was estimated using in-channel travel time calculations modeled in HEC-RAS. The in-channel residence times are on the order of 1.5 to 2 days for the entire reach.

Cohen et al. (2011) investigated nitrogen removal mechanisms on a number of spring-fed rivers, including Alexander Springs and Alexander Springs Creek. One conclusion was that significant nitrogen removal occurs in spring run streams and that denitrification was the dominant process across almost all the systems. They found that denitrification is strongly coupled to gross primary productivity (GPP), as is presented in Figure 5-17. GPP is one measure of ecosystem metabolism that provides insights into the overall function of an aquatic ecosystem.

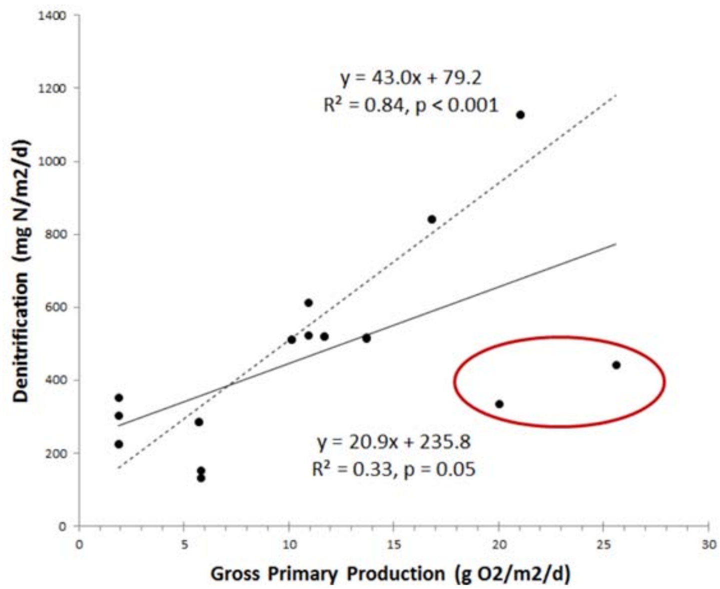


Figure 5-17. Relationship between denitrification (Uden) and gross primary production across rivers. The two outliers removed to yield the dashed line fit are both for upper river sites (Silver and Rainbow), which may not achieve the same level of denitrification as the rest of the river because of stronger hydraulic gradients (precluding water entering the sediments from the river) or because of reduced labile C availability. Source: Cohen et al., 2011.

WSI (2010) examined ecosystem metabolism parameters, including GPP, in 12 Florida springs. The consumption and production of oxygen by all spring flora and fauna are included in these measurements (WSI, 2010). As part of this assessment, WSI examined the relationship between GPP and spring velocity and discharge. At current velocities of up to about 0.82 ft/sec, GPP increased, whereas at velocities greater than this, GPP declined (WSI, 2010). The decline in GPP above this velocity is likely related to physical conditions that reduce habitat suitability for SAV, which is a key component in primary production in spring ecosystems (WSI, 2010).

Cohen et al. (2011) found Alexander Springs Creek to behave differently than other spring-fed systems as it pertains to nitrogen cycling. Alexander Springs Creek is an important study site for all springs research because it is one of the few springs in Florida that continues to exhibit background nitrate concentrations of ca. 0.05 milligrams per liter (mg/L) [50 micrograms per liter (µg/L)]. It is among the only “reference” springs that also has a well-lit and well-protected run (Juniper Creek is also low nitrogen but is highly shaded along much of its length, and Silver Glen Spring run is heavily impacted by recreational activities). Some of the most extensive algal mat development is observed in the upper 600 m of Alexander Springs Creek, which has been interpreted as one line of evidence countering nitrogen enrichment as the fundamental cause of algal accumulation in spring run streams (Heffernan et al., 2010).

Cohen et al. (2011) found that in all rivers studied, except Alexander Springs Creek, the profile of nitrate is declining with distance downstream, consistent with nitrogen removal via both denitrification and assimilation. Diel variations in nitrate concentrations in Alexander Springs Creek are inverted as compared to other spring-fed rivers in Florida, with peak nitrate concentrations occurring during the day, while concentrations are lowest at night. Despite having the lowest nitrate concentration of any first magnitude spring in Florida (mean of 0.07 mg/L), a continuous benthic mat dominated by the filamentous green alga, *Hydrodictyon* sp., covers 24,000 m^2 of the bottom of the spring run. The system is highly productive, with a mean GPP of 15 grams of oxygen per square meter per day (g $O_2/m^2/d$). Reaeration in Alexander Springs was highly stable over the deployment period, at a mean value of 0.39 (hr^{-1}) and a standard deviation of 0.05 hr^{-1}. While the nominal velocity in Alexander Springs Creek was relatively slow (0.23 ft/sec) compared to other spring fed rivers, it was somewhat surprising to see such a low reaeration rate given the broad shallow channel morphology that characterizes the upper reach (500 m long).

Cohen et al (2011) postulate that the majority of nitrogen uptake at night is due to denitrification, although some assimilation by *Hydrodictyon* sp. can occur as well. During the day, denitrification is inhibited due to high dissolved oxygen conditions within the benthic mat and in the sediment. The majority of nitrogen assimilation takes place during the day. Relatively high levels of nitrate in the water column can be explained by the assimilation of large amounts of internally recycled nitrogen, as high as 61 percent, rather than relying on water column nitrate.

Table 5-12 presents in-channel average velocities at cross-sections along Alexander Springs Creek for a range of flow conditions. Except at the lower portion of the reach, in-channel average velocities are generally far below the 0.82 ft/sec threshold where GPP is at a maximum. Unlike most spring-fed rivers in Florida, nitrogen cycling in Alexander Springs Creek does not appear to be strongly a function of flow. Given the small decrease in average in-channel velocities (0.05 ft/sec) anticipated under the MFL hydrologic regime from the POR 1983- 2014 condition as illustrated in Table 5-12, nitrogen removal, due to denitrification in Alexander Springs Creek, is not anticipated to change.

Table 5-12. Gross primary productivity - In-channel, average velocities (feet per second, ft/s) at cross-sections along Alexander Springs Creek for a range of flow conditions for the POR 1983-2014 baseline condition and the MFLs hydrologic regime Highlighted cells indicate locations where critical velocity of 0.82 fps was equaled or exceeded.

Profile	Q Total	9.27	9	8.82	8.38	7.96	7.95	7.94	7.86	7.37	6.74	6.07	5.83	5.59	5.35	5.23	5.02	4.99	4.65	4.41	3.98	3.28	2.91	2.52	1.05	0
Baseline																										
PF 1	78	0.21	0.19	0.21	0.22	0.16	0.21	0.37	0.15	0.19	0.19	0.2	0.29	0.26	0.22	0.12	0.17	0.17	0.2	0.21	0.27	0.38	0.3	0.86	0.56	0.91
PF 2	86.6	0.22	0.2	0.22	0.23	0.17	0.22	0.37	0.16	0.2	0.2	0.2	0.3	0.27	0.23	0.12	0.18	0.18	0.21	0.22	0.28	0.37	0.3	0.83	0.56	0.73
PF 3	91.1	0.22	0.21	0.23	0.23	0.17	0.22	0.37	0.16	0.2	0.2	0.2	0.31	0.28	0.24	0.13	0.18	0.18	0.21	0.22	0.29	0.37	0.3	0.82	0.56	0.71
PF 4	94.6	0.23	0.22	0.24	0.24	0.17	0.23	0.37	0.16	0.21	0.2	0.2	0.31	0.28	0.24	0.13	0.19	0.19	0.22	0.23	0.29	0.36	0.3	0.82	0.56	0.68
PF 5	97.1	0.23	0.22	0.24	0.24	0.17	0.23	0.37	0.16	0.21	0.2	0.2	0.31	0.28	0.25	0.13	0.19	0.19	0.22	0.23	0.3	0.36	0.31	0.81	0.57	0.67
PF 6	99.7	0.23	0.22	0.25	0.24	0.17	0.23	0.37	0.17	0.21	0.2	0.2	0.31	0.29	0.25	0.13	0.19	0.19	0.23	0.24	0.31	0.35	0.31	0.81	0.59	0.68
PF 7	104	0.23	0.23	0.25	0.25	0.18	0.23	0.37	0.17	0.22	0.21	0.21	0.32	0.3	0.26	0.14	0.2	0.2	0.23	0.25	0.33	0.34	0.31	0.79	0.61	0.69
PF 8	107	0.22	0.23	0.26	0.25	0.18	0.24	0.37	0.17	0.22	0.21	0.21	0.33	0.31	0.27	0.14	0.21	0.21	0.24	0.26	0.35	0.32	0.31	0.79	0.64	0.71
PF 9	111	0.22	0.23	0.27	0.26	0.18	0.24	0.36	0.18	0.23	0.22	0.21	0.34	0.32	0.28	0.15	0.21	0.21	0.26	0.27	0.38	0.29	0.31	0.8	0.67	0.72
PF 10	115	0.22	0.24	0.28	0.26	0.18	0.25	0.36	0.18	0.23	0.22	0.21	0.34	0.32	0.29	0.15	0.22	0.22	0.26	0.28	0.39	0.28	0.31	0.81	0.7	0.75
PF 11	118	0.21	0.24	0.29	0.26	0.19	0.25	0.36	0.19	0.24	0.23	0.21	0.34	0.33	0.3	0.16	0.22	0.22	0.27	0.29	0.4	0.27	0.32	0.82	0.73	0.75
PF 12	123	0.2	0.23	0.3	0.27	0.2	0.27	0.37	0.2	0.25	0.24	0.22	0.36	0.36	0.33	0.18	0.25	0.25	0.29	0.32	0.43	0.26	0.33	0.82	0.73	0.67
PF 13	124	0.19	0.23	0.31	0.28	0.2	0.27	0.37	0.2	0.26	0.24	0.22	0.37	0.37	0.34	0.18	0.25	0.25	0.29	0.32	0.44	0.26	0.34	0.82	0.75	0.68
PF 14	125	0.19	0.23	0.31	0.28	0.2	0.27	0.37	0.2	0.26	0.24	0.22	0.39	0.37	0.35	0.19	0.25	0.25	0.31	0.33	0.45	0.26	0.35	0.81	0.76	0.66
PF 15	126	0.18	0.22	0.31	0.27	0.2	0.27	0.36	0.2	0.26	0.24	0.22	0.37	0.36	0.36	0.18	0.23	0.23	0.29	0.33	0.5	0.26	0.37	0.82	0.89	0.8
PF 16	127	0.16	0.19	0.32	0.28	0.22	0.3	0.38	0.22	0.29	0.27	0.24	0.4	0.38	0.43	0.2	0.24	0.25	0.29	0.36	0.54	0.27	0.4	0.84	0.99	0.91
PF 17	127.2	0.14	0.16	0.32	0.29	0.24	0.32	0.41	0.25	0.3	0.29	0.25	0.4	0.39	0.47	0.21	0.25	0.26	0.29	0.39	0.57	0.28	0.43	0.85	1.06	1.03
PF 18	127.4	0.14	0.15	0.31	0.29	0.25	0.34	0.43	0.26	0.31	0.31	0.27	0.41	0.4	0.49	0.23	0.26	0.27	0.3	0.42	0.58	0.29	0.44	0.86	1.07	1.04
PF 19	127.6	0.13	0.13	0.31	0.3	0.27	0.37	0.45	0.28	0.32	0.33	0.28	0.41	0.41	0.51	0.24	0.28	0.28	0.31	0.44	0.6	0.3	0.46	0.87	1.13	1.12
PF 20	127.8	0.1	0.08	0.29	0.31	0.33	0.45	0.54	0.34	0.3	0.4	0.34	0.42	0.34	0.4	0.27	0.29	0.29	0.31	0.49	0.71	0.35	0.58	1	1.42	1.93
PF 21	128	0.06	0.03	0.2	0.35	0.5	0.72	0.81	0.42	0.26	0.55	0.46	0.41	0.26	0.24	0.3	0.3	0.3	0.32	0.58	0.99	0.5	0.85	1.33	1.92	4.48
PF 22	133	0.05	0.02	0.16	0.38	0.6	0.87	0.97	0.46	0.27	0.61	0.54	0.42	0.27	0.23	0.32	0.32	0.32	0.32	0.6	1.11	0.57	0.98	1.47	2.14	4.29
MFL																										
PF 1	71	0.21	0.17	0.19	0.21	0.16	0.21	0.37	0.15	0.18	0.18	0.19	0.28	0.25	0.21	0.11	0.16	0.16	0.19	0.19	0.26	0.39	0.29	0.87	0.53	0.84
PF 2	79.6	0.21	0.19	0.21	0.22	0.16	0.21	0.37	0.15	0.19	0.19	0.2	0.29	0.26	0.22	0.12	0.17	0.17	0.2	0.21	0.27	0.38	0.3	0.83	0.53	0.68
PF 3	84.1	0.22	0.2	0.22	0.23	0.16	0.22	0.37	0.16	0.2	0.19	0.2	0.3	0.27	0.23	0.12	0.18	0.18	0.2	0.21	0.28	0.37	0.3	0.82	0.53	0.66
PF 4	87.6	0.22	0.2	0.22	0.23	0.17	0.22	0.37	0.16	0.2	0.2	0.2	0.3	0.27	0.23	0.12	0.18	0.18	0.21	0.22	0.28	0.37	0.3	0.81	0.54	0.64
PF 5	90.1	0.22	0.21	0.23	0.23	0.17	0.22	0.37	0.16	0.2	0.2	0.2	0.3	0.27	0.24	0.13	0.18	0.18	0.21	0.22	0.29	0.37	0.3	0.81	0.54	0.63
PF 6	92.7	0.22	0.21	0.23	0.23	0.17	0.22	0.37	0.16	0.2	0.2	0.2	0.31	0.28	0.24	0.13	0.19	0.19	0.22	0.23	0.3	0.36	0.3	0.8	0.56	0.64
PF 7	97	0.22	0.22	0.24	0.24	0.17	0.23	0.37	0.17	0.21	0.2	0.2	0.31	0.29	0.25	0.13	0.19	0.19	0.23	0.24	0.31	0.34	0.3	0.78	0.58	0.65
PF 8	100	0.22	0.22	0.25	0.24	0.18	0.23	0.37	0.17	0.22	0.21	0.2	0.32	0.3	0.26	0.14	0.2	0.2	0.24	0.25	0.34	0.32	0.31	0.78	0.62	0.68
PF 9	104	0.22	0.22	0.26	0.25	0.18	0.24	0.36	0.17	0.22	0.21	0.21	0.33	0.31	0.27	0.15	0.21	0.21	0.25	0.26	0.36	0.3	0.31	0.79	0.65	0.69
PF 10	108	0.22	0.23	0.27	0.25	0.18	0.24	0.36	0.18	0.23	0.22	0.21	0.33	0.31	0.28	0.15	0.21	0.21	0.26	0.27	0.38	0.28	0.31	0.81	0.69	0.72
PF 11	111	0.21	0.23	0.28	0.26	0.19	0.25	0.36	0.18	0.23	0.22	0.21	0.34	0.33	0.3	0.16	0.22	0.22	0.27	0.28	0.4	0.27	0.31	0.82	0.71	0.73
PF 12	116	0.19	0.23	0.29	0.27	0.2	0.26	0.37	0.19	0.25	0.23	0.22	0.35	0.36	0.33	0.18	0.23	0.24	0.29	0.31	0.42	0.26	0.33	0.81	0.71	0.65
PF 13	117	0.19	0.22	0.3	0.27	0.2	0.26	0.37	0.2	0.25	0.23	0.22	0.36	0.36	0.33	0.18	0.25	0.25	0.29	0.32	0.44	0.26	0.34	0.82	0.73	0.66
PF 14	118	0.18	0.22	0.3	0.28	0.2	0.27	0.37	0.2	0.26	0.24	0.22	0.37	0.37	0.35	0.18	0.25	0.25	0.3	0.33	0.45	0.26	0.34	0.81	0.74	0.64
PF 15	119	0.17	0.21	0.3	0.27	0.2	0.27	0.36	0.2	0.26	0.24	0.22	0.38	0.37	0.35	0.18	0.23	0.23	0.29	0.32	0.5	0.26	0.36	0.82	0.88	0.78

Table 5-12. Gross primary productivity - In-channel, average velocities (feet per second, ft/s) at cross-sections along Alexander Springs Creek for a range of flow conditions for the POR 1983-2014 baseline condition and the MFLs hydrologic regime Highlighted cells indicate locations where critical velocity of 0.82 fps was equaled or exceeded.

Profile	Q Total	9.27	9	8.82	8.38	7.96	7.95	7.94	7.86	7.37	6.74	6.07	5.83	5.59	5.35	5.23	5.02	4.99	4.65	4.41	3.98	3.28	2.91	2.52	1.05	0
PF 16	120	0.15	0.18	0.31	0.28	0.22	0.29	0.38	0.22	0.28	0.26	0.23	0.4	0.38	0.42	0.2	0.24	0.24	0.29	0.36	0.53	0.27	0.4	0.83	0.97	0.89
PF 17	120.2	0.14	0.16	0.31	0.28	0.24	0.32	0.4	0.24	0.3	0.29	0.25	0.4	0.39	0.47	0.21	0.25	0.25	0.29	0.39	0.56	0.28	0.42	0.85	1.05	1.01
PF 18	120.4	0.13	0.14	0.31	0.29	0.25	0.34	0.42	0.26	0.31	0.31	0.26	0.41	0.4	0.49	0.22	0.26	0.27	0.3	0.41	0.57	0.29	0.44	0.86	1.06	1.02
PF 19	120.6	0.12	0.12	0.31	0.29	0.27	0.36	0.45	0.28	0.32	0.33	0.28	0.41	0.41	0.51	0.24	0.28	0.28	0.31	0.44	0.6	0.3	0.46	0.87	1.12	1.1
PF 20	120.8	0.1	0.08	0.28	0.31	0.33	0.45	0.53	0.33	0.3	0.39	0.33	0.42	0.34	0.4	0.26	0.29	0.29	0.31	0.48	0.71	0.35	0.57	1	1.42	1.91
PF 21	121	0.06	0.03	0.2	0.35	0.5	0.72	0.81	0.42	0.26	0.54	0.46	0.41	0.26	0.24	0.3	0.3	0.3	0.32	0.58	0.99	0.5	0.85	1.33	1.92	4.46
PF 22	126	0.05	0.02	0.16	0.38	0.6	0.87	0.97	0.46	0.27	0.61	0.54	0.42	0.27	0.23	0.32	0.32	0.32	0.32	0.6	1.11	0.57	0.98	1.47	2.13	4.28

The major factor that would be affected by flow reductions allowed under the recommended MFLs would be the reduction in the frequency of physical contact of water with riparian, or floodplain vegetation. The degree of nutrient release and assimilation in the wetlands, as well as the decomposition of the vegetation communities, depends to a large extent on the frequency and duration of inundation, because the process of filtration and absorption requires both wet and dry periods. If the selected critical stages will not occur substantially less frequently under the MFLs scenario than under no-pumping conditions, it can be inferred that the process of filtration and absorption/adsorption in wetland soils, sediments, and vegetative communities, littoral vegetation, bottom sediments, and water column organisms would be protected. As such, this WRV is also protected by maintaining contact with the floodplain.

The process of selecting the critical elevations for analysis is presented in Section 5-4. These targets, which are summarized in Table 5-13 represent a range of flow conditions to compare across the two hydrologic regimes.

Table 5-13. Critical stage values for filtration and the absorption of nutrients and other pollutants.

Transect ID	Overbank Elevation (ft-NGVD)
A4.3	4.88
A5	6.01
A6	5.7
A8	7.7
A10	10.2
A14	8.86
A16	11.47

Durations of 14 days and 30 days were evaluated to determine changes in frequency of contact between the river and the adjacent hardwood swamps. These durations were chosen as they approximate design residence time requirements for wet-detention systems as presented in Chapter 40C-42, *F.A.C.* (SJRWMD, 2010). Tables 5-14a and 5-14b present the frequency and duration parameter results for the evaluation of WRV-7, Filtration and Absorption of Nutrients and Other Pollutants. SJRWMD provided the frequency analysis statistics.

Table 5-14a. Frequency analysis results for the protection of filtration and absorption of nutrients and other pollutants —14-day duration high stage continuously exceeded.				
			Hydrologic Scenario	
Transect	**Critical Stages (ft-NAVD)**	**Statistic[1]**	**No-Pumping Condition**	**MFL**
A4.3	4.19	Events/100 yr	62.5	60.8
		Difference		1.7
A5	5.43	Events/100 yr	62.5	61.3
		Difference	-	1.2
A6	6.13	Events/100 yr	62.5	52.7
		Difference	-	9.8
A8	7.51	Events/100 yr	52.0	48.0
		Difference	-	4.0
A10	9.33	Events/100 yr	9.5	5.2
		Difference	-	4.3
A14	8.95	Events/100 yr	64.2	56.3
		Difference	-	7.9
A16	10.1	Events/100 yr	18.2	9.2
		Difference	-	9

1 Events /100 years= number of events per 100 years in which the critical stage event occurs. Difference = difference between the number of events occurring under no-pumping conditions and MFLs hydrologic regimes.

Table 5-14b. Frequency analysis results for the protection of filtration and absorption of nutrients and other pollutants —30-day duration high stage continuously exceeded.				
			Hydrologic Scenario	
Transect	**Critical Stages (ft-NAVD)**	**Statistic[1]**	**No-Pumping Condition**	**MFL**
A4.3	4.19	Events/100 yr	46.9	41.1
		Difference		5.8
A5	5.43	Events/100 yr	46.9	41.7
		Difference	-	5.2
A6	6.13	Events/100 yr	53.1	37.2
		Difference	-	15.9
A8	7.51	Events/100 yr	37.2	33.3
		Difference	-	2.9
A10	9.33	Events/100 yr	0	0
		Difference	-	0
A14	8.95	Events/100 yr	53.1	37.5
		Difference	-	15.6
A16	10.1	Events/100 yr	10.4	9.1
		Difference	-	1.3

1 Events /100 years= number of events per 100 years in which the critical stage event occurs. Difference = difference between the number of events occurring under no-pumping conditions and MFLs hydrologic regimes.

Five of the transects (A4.3, A5, A6, A8 and A14) experience the critical event at a frequency important for filtration and the absorption of nutrients and other pollutants. For the critical stage event under the 14-day duration, Transects A6 and A14 experience a percent reduction of 16 percent and 12 percent, respectively, with a corresponding reduction in occurrence frequency from once every 1.6 years to once every 1.9 years. For the critical stage event under the 30-day duration, Transects A6 and A14 experience a reduction of approximately 30 percent, with a corresponding reduction in occurrence frequency from once every 1.9 years to once every 2.7 years. This frequency is consistent with that of the other transects, even with the relatively large percent reduction in critical events.

Based on the available data and professional judgment, WRV 7, Filtration and the Absorption of Nutrients and Other Pollutants, is protected under the recommended MFLs hydrologic regime.

5.8 WRV-8: SEDIMENT LOADS

Sediment Loads is defined as the transport of inorganic materials, suspended in water, that may settle or rise, often depending on the volume and velocity of the water. The criterion for protection is the "transport of inorganic materials." The assessment focused on the effect of changing the return interval of events on the transport, erosion, and deposition of sediment. The representative function used to assess protection of sediment loads is to maintain transport of sediment in Alexander Springs Creek. The general indicators of protection for high-water and low-water conditions are variations in stage, velocity, and bed shear stress between the no-pumping conditions and the MFLs hydrologic regimes. The specific indicators of protection are the minimum current velocities and bed shear stress, derived from the literature, required for adequate sediment transport, and the extent to which the number of events per 100 years for which intervals of these critical velocities will change under the MFLs hydrologic regime.

The movement or transport of sediment is a function of flow events, sediment material composition, and supply (i.e., source of particulate matter). Figure 5-18 depicts the classification categories (Mehta et al., 2004). Sediment transport amount, or "sediment load," is conveyed as a mass or weight per unit time [e.g., tons/day or kilograms per second (kg/sec)].

Total sediment load	Classification System: Based on Mechanism of Transport	Classification System: Based on Particle Size
Wash load	Suspended load	Wash load
Suspended bed-material load		Bed-material load
Bed load	Bed load	

Table 2.4 – Sediment load terms.
In Stream Corridor Restoration: Principles, Processes, and Practices (10/98)
by the Federal Interagency Stream Restoration Working Group (FISRWG) (15 Federal agencies of the U.S.)

Figure 5-18. Sediment load classification categories.
Source: FISRWG, 1998.

To protect this WRV, the effect of flow reductions allowed under the draft MFLs hydrologic regime on suspended load and bed material load (as defined in Figure 5-18), must be considered. The key variable is flow velocity, which transports the suspended particles (both organic and inorganic). If the number of critical flow velocity events per 100 years is not substantially changed under the recommended MFLs hydrologic regime, it can be inferred that this WRV will be protected.

Conversations with the U.S. Forest Service manager of Alexander Springs recreation area revealed that the headspring pool has filled in considerably over the years with white "beach sand" that was transported to the site at least 40 years ago. The manager estimates there is at least a 12- to 18-inch depth of this foreign sand across the spring pool, which has obscured or buried rock formations and possibly altered flow patterns. This sand tends to be loose and of consistent grain size whereas the native substrate is more compact. The sand plume extends about 150 feet downstream from the vent. Even though the beach area now has a bulkhead around it, big storms still occasionally cause "blowouts," as subsurface piping and undercutting deliver additional doses of sand to the headspring. Maintenance to remove this sand was last performed in 2005-2006 but should be repeated every 3 to 5 years. No other sediment-related issues were noted.

5.8.1 SEDIMENT-LOAD-SPECIFIC CRITERIA AND METRICS

Grain size analysis was not available for sediments within the Alexander Springs Creek main channel. Based on the Natural Resources Conservation Service (NRCS) Soil Survey for Lake County, the soils surrounding Alexander Springs Creek are dominated by well- to moderately well-sorted medium to fine sand over a majority of its length. Based on the Unified Soil Classification System (USCS), fine to medium sand would have a median grain size diameter (D50) of approximately 0.5 millimeter (mm), with most particles being less than 2.0 mm in size.

As such, for sediment transport purposes, the bed material can be analyzed as non-cohesive inorganic fine sediment with a D50 of 0.50 mm. The initiation of motion of these particles is primarily a function of bed shear stress and particle size (Yang, 2006). Bed shear stress (τ) is computed as:

$$\tau = \gamma \, RS$$

where

- γ = specific weight of water
- R = hydraulic radius (cross-sectional flow area over wetted perimeter)
- S = the slope of the energy grade line (which can be approximated by the bottom slope of the channel for uniform or gradually varied flow conditions)

A commonly accepted measure of the initiation of motion for uniform non-cohesive sediments can be determined using the Shields diagram (Shields, 1936) presented in Figure 5-19. The Shields curve divides a region of motion from a region of no motion. By determining the dimensionless Shields parameter and dimensionless grain Reynolds number, a prediction of sediment motion may be obtained. For D50 sediment grain sizes of approximately 0.50 mm, the critical bed shear for motion is about 0.006 pound per square foot (lb/ft^2).

SJRWMD's HEC-RAS results can be utilized to evaluate bed shear across the range of flows and along the river reach. Based on the HEC-RAS results SJRWMD provided, Shields parameters were calculated for a range of flows to determine if the bed is mobilized and sediment transported across the entire range of flows and cross-sections per the Shields incipient motion diagram. For all flows and cross-sections evaluated under the 1983-2014 conditions, sediment motion occurs. A summary of modeled average in-channel velocities under two hydrologic regimes is presented in Table 5-15.

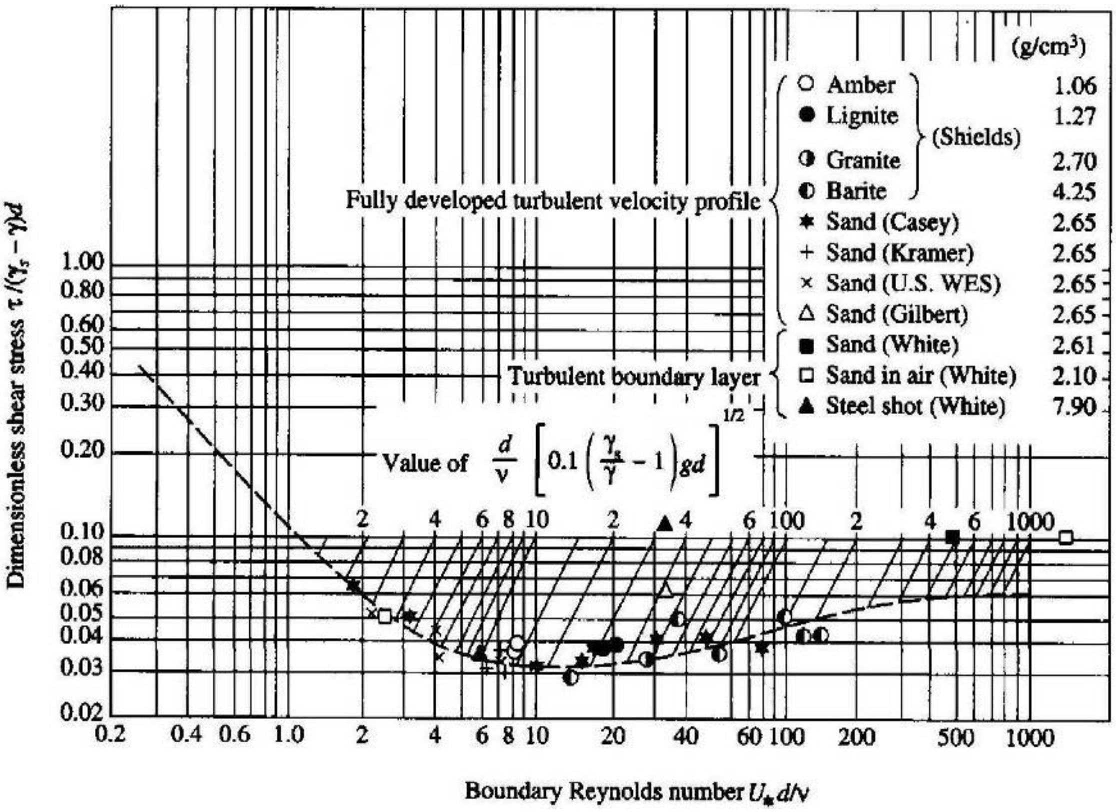


Figure 5-19. Incipient motion diagram.
Source: Shields, 1936.

A key protection metric is whether the long-term transport of sediment will be influenced by withdrawals. Major changes in the sediment transport regime could cause net erosion or deposition of sediment in the channel, thereby changing the natural sediment regime. A simplified approach for this analysis is based on the work of Hjulstrom. Hjulstrom (1935) considered a wide range of uniform sediment size and flow conditions and developed a chart that indicates the regions of erosion, transport, and deposition (or sedimentation) (Figure 5-20). Therefore, sediment of a diameter of 0.5 mm would remain transported at a rate of between 3.7 centimeters per second (cm/sec) and 19 cm/sec (0.1 ft/sec and 0.6 ft/sec, respectively). Specifically, 0.1 ft/sec is the threshold velocity below which 0.5 mm sized particles begin to settle out and accrete on the bottom, and 0.6 ft/sec is the threshold above which bottom material of that size erodes and becomes suspended.

Table 5-15. Sediment -In-channel, average velocities (feet per second, ft/s)) at cross-sections along Alexander Springs Creek for a range of flow conditions for the POR 1983-2014 baseline condition and the MFLs hydrologic regime. Highlighted cells indicate locations where critical velocity of 0.60 fps was equaled or exceeded.

Profile	Q Total	9.27	9	8.82	8.38	7.96	7.95	7.94	7.86	7.37	6.74	6.07	5.83	5.59	5.35	5.23	5.02	4.99	4.65	4.41	3.98	3.28	2.91	2.52	1.05	0
Baseline																										
PF 1	78	0.21	0.19	0.21	0.22	0.16	0.21	0.37	0.15	0.19	0.19	0.2	0.29	0.26	0.22	0.12	0.17	0.17	0.2	0.21	0.27	0.38	0.3	0.86	0.56	0.91
PF 2	86.6	0.22	0.2	0.22	0.23	0.17	0.22	0.37	0.16	0.2	0.2	0.2	0.3	0.27	0.23	0.12	0.18	0.18	0.21	0.22	0.28	0.37	0.3	0.83	0.56	0.73
PF 3	91.1	0.22	0.21	0.23	0.23	0.17	0.22	0.37	0.16	0.2	0.2	0.2	0.31	0.28	0.24	0.13	0.18	0.18	0.21	0.22	0.29	0.37	0.3	0.82	0.56	0.71
PF 4	94.6	0.23	0.22	0.24	0.24	0.17	0.23	0.37	0.16	0.21	0.2	0.2	0.31	0.28	0.24	0.13	0.19	0.19	0.22	0.23	0.29	0.36	0.3	0.82	0.56	0.68
PF 5	97.1	0.23	0.22	0.24	0.24	0.17	0.23	0.37	0.16	0.21	0.2	0.2	0.31	0.28	0.25	0.13	0.19	0.19	0.22	0.23	0.3	0.36	0.31	0.81	0.57	0.67
PF 6	99.7	0.23	0.22	0.25	0.24	0.17	0.23	0.37	0.17	0.21	0.2	0.2	0.31	0.29	0.25	0.13	0.19	0.19	0.23	0.24	0.31	0.35	0.31	0.81	0.59	0.68
PF 7	104	0.23	0.23	0.25	0.25	0.18	0.23	0.37	0.17	0.22	0.21	0.21	0.32	0.3	0.26	0.14	0.2	0.2	0.23	0.25	0.33	0.34	0.31	0.79	0.61	0.69
PF 8	107	0.22	0.23	0.26	0.25	0.18	0.24	0.37	0.17	0.22	0.21	0.21	0.33	0.31	0.27	0.14	0.21	0.21	0.24	0.26	0.35	0.32	0.31	0.79	0.64	0.71
PF 9	111	0.22	0.23	0.27	0.26	0.18	0.24	0.36	0.18	0.23	0.22	0.21	0.34	0.32	0.28	0.15	0.21	0.21	0.26	0.27	0.38	0.29	0.31	0.8	0.67	0.72
PF 10	115	0.22	0.24	0.28	0.26	0.18	0.25	0.36	0.18	0.23	0.22	0.21	0.34	0.32	0.29	0.15	0.22	0.22	0.26	0.28	0.39	0.28	0.31	0.81	0.7	0.75
PF 11	118	0.21	0.24	0.29	0.26	0.19	0.25	0.36	0.19	0.24	0.23	0.21	0.34	0.33	0.3	0.16	0.22	0.22	0.27	0.29	0.4	0.27	0.32	0.82	0.73	0.75
PF 12	123	0.2	0.23	0.3	0.27	0.2	0.27	0.37	0.2	0.25	0.24	0.22	0.36	0.36	0.33	0.18	0.25	0.25	0.29	0.32	0.43	0.26	0.33	0.82	0.73	0.67
PF 13	124	0.19	0.23	0.31	0.28	0.2	0.27	0.37	0.2	0.26	0.24	0.22	0.37	0.37	0.34	0.18	0.25	0.25	0.29	0.32	0.44	0.26	0.34	0.82	0.75	0.68
PF 14	125	0.19	0.23	0.31	0.28	0.2	0.27	0.37	0.2	0.26	0.24	0.22	0.39	0.37	0.35	0.19	0.25	0.25	0.31	0.33	0.45	0.26	0.35	0.81	0.76	0.66
PF 15	126	0.18	0.22	0.31	0.27	0.2	0.27	0.36	0.2	0.26	0.24	0.22	0.37	0.36	0.36	0.18	0.23	0.23	0.29	0.33	0.5	0.26	0.37	0.82	0.89	0.8
PF 16	127	0.16	0.19	0.32	0.28	0.22	0.3	0.38	0.22	0.29	0.27	0.24	0.4	0.38	0.43	0.2	0.24	0.25	0.29	0.36	0.54	0.27	0.4	0.84	0.99	0.91
PF 17	127.2	0.14	0.16	0.32	0.29	0.24	0.32	0.41	0.25	0.3	0.29	0.25	0.4	0.39	0.47	0.21	0.25	0.26	0.29	0.39	0.57	0.28	0.43	0.85	1.06	1.03
PF 18	127.4	0.14	0.15	0.31	0.29	0.25	0.34	0.43	0.26	0.31	0.31	0.27	0.41	0.4	0.49	0.23	0.26	0.27	0.3	0.42	0.58	0.29	0.44	0.86	1.07	1.04
PF 19	127.6	0.13	0.13	0.31	0.3	0.27	0.37	0.45	0.28	0.32	0.33	0.28	0.41	0.41	0.51	0.24	0.28	0.28	0.31	0.44	0.6	0.3	0.46	0.87	1.13	1.12
PF 20	127.8	0.1	0.08	0.29	0.31	0.33	0.45	0.54	0.34	0.3	0.4	0.34	0.42	0.34	0.4	0.27	0.29	0.29	0.31	0.49	0.71	0.35	0.58	1	1.42	1.93
PF 21	128	0.06	0.03	0.2	0.35	0.5	0.72	0.81	0.42	0.26	0.55	0.46	0.41	0.26	0.24	0.3	0.3	0.3	0.32	0.58	0.99	0.5	0.85	1.33	1.92	4.48
PF 22	133	0.05	0.02	0.16	0.38	0.6	0.87	0.97	0.46	0.27	0.61	0.54	0.42	0.27	0.23	0.32	0.32	0.32	0.32	0.6	1.11	0.57	0.98	1.47	2.14	4.29
MFL																										
PF 1	71	0.21	0.17	0.19	0.21	0.16	0.21	0.37	0.15	0.18	0.18	0.19	0.28	0.25	0.21	0.11	0.16	0.16	0.19	0.19	0.26	0.39	0.29	0.87	0.53	0.84
PF 2	79.6	0.21	0.19	0.21	0.22	0.16	0.21	0.37	0.15	0.19	0.19	0.2	0.29	0.26	0.22	0.12	0.17	0.17	0.2	0.21	0.27	0.38	0.3	0.83	0.53	0.68
PF 3	84.1	0.22	0.2	0.22	0.23	0.16	0.22	0.37	0.16	0.2	0.19	0.2	0.3	0.27	0.23	0.12	0.18	0.18	0.2	0.21	0.28	0.37	0.3	0.82	0.53	0.66
PF 4	87.6	0.22	0.2	0.22	0.23	0.17	0.22	0.37	0.16	0.2	0.2	0.2	0.3	0.27	0.23	0.12	0.18	0.18	0.21	0.22	0.28	0.37	0.3	0.81	0.54	0.64
PF 5	90.1	0.22	0.21	0.23	0.23	0.17	0.22	0.37	0.16	0.2	0.2	0.2	0.3	0.27	0.24	0.13	0.18	0.18	0.21	0.22	0.29	0.37	0.3	0.81	0.54	0.63
PF 6	92.7	0.22	0.21	0.23	0.23	0.17	0.22	0.37	0.16	0.2	0.2	0.2	0.31	0.28	0.24	0.13	0.19	0.19	0.22	0.23	0.3	0.36	0.3	0.8	0.56	0.64
PF 7	97	0.22	0.22	0.24	0.24	0.17	0.23	0.37	0.17	0.21	0.2	0.2	0.31	0.29	0.25	0.13	0.19	0.19	0.23	0.24	0.31	0.34	0.3	0.78	0.58	0.65
PF 8	100	0.22	0.22	0.25	0.24	0.18	0.23	0.37	0.17	0.22	0.21	0.2	0.32	0.3	0.26	0.14	0.2	0.2	0.24	0.25	0.34	0.32	0.31	0.78	0.62	0.68
PF 9	104	0.22	0.22	0.26	0.25	0.18	0.24	0.36	0.17	0.22	0.21	0.21	0.33	0.31	0.27	0.15	0.21	0.21	0.25	0.26	0.36	0.3	0.31	0.79	0.65	0.69
PF 10	108	0.22	0.23	0.27	0.25	0.18	0.24	0.36	0.18	0.23	0.22	0.21	0.33	0.31	0.28	0.15	0.21	0.21	0.26	0.27	0.38	0.28	0.31	0.81	0.69	0.72
PF 11	111	0.21	0.23	0.28	0.26	0.19	0.25	0.36	0.18	0.23	0.22	0.21	0.34	0.33	0.3	0.16	0.22	0.22	0.27	0.28	0.4	0.27	0.31	0.82	0.71	0.73
PF 12	116	0.19	0.23	0.29	0.27	0.2	0.26	0.37	0.19	0.25	0.23	0.22	0.35	0.36	0.33	0.18	0.23	0.24	0.29	0.31	0.42	0.26	0.33	0.81	0.71	0.65
PF 13	117	0.19	0.22	0.3	0.27	0.2	0.26	0.37	0.2	0.25	0.23	0.22	0.36	0.36	0.33	0.18	0.25	0.25	0.29	0.32	0.44	0.26	0.34	0.82	0.73	0.66
PF 14	118	0.18	0.22	0.3	0.28	0.2	0.27	0.37	0.2	0.26	0.24	0.22	0.37	0.37	0.35	0.18	0.25	0.25	0.3	0.33	0.45	0.26	0.34	0.81	0.74	0.64

Table 5-15. Sediment -In-channel, average velocities (feet per second, ft/s)) at cross-sections along Alexander Springs Creek for a range of flow conditions for the POR 1983-2014 baseline condition and the MFLs hydrologic regime. Highlighted cells indicate locations where critical velocity of 0.60 fps was equaled or exceeded.

Profile	Q Total	9.27	9	8.82	8.38	7.96	7.95	7.94	7.86	7.37	6.74	6.07	5.83	5.59	5.35	5.23	5.02	4.99	4.65	4.41	3.98	3.28	2.91	2.52	1.05	0
PF 15	119	0.17	0.21	0.3	0.27	0.2	0.27	0.36	0.2	0.26	0.24	0.22	0.38	0.37	0.35	0.18	0.23	0.23	0.29	0.32	0.5	0.26	0.36	0.82	0.88	0.78
PF 16	120	0.15	0.18	0.31	0.28	0.22	0.29	0.38	0.22	0.28	0.26	0.23	0.4	0.38	0.42	0.2	0.24	0.24	0.29	0.36	0.53	0.27	0.4	0.83	0.97	0.89
PF 17	120.2	0.14	0.16	0.31	0.28	0.24	0.32	0.4	0.24	0.3	0.29	0.25	0.4	0.39	0.47	0.21	0.25	0.25	0.29	0.39	0.56	0.28	0.42	0.85	1.05	1.01
PF 18	120.4	0.13	0.14	0.31	0.29	0.25	0.34	0.42	0.26	0.31	0.31	0.26	0.41	0.4	0.49	0.22	0.26	0.27	0.3	0.41	0.57	0.29	0.44	0.86	1.06	1.02
PF 19	120.6	0.12	0.12	0.31	0.29	0.27	0.36	0.45	0.28	0.32	0.33	0.28	0.41	0.41	0.51	0.24	0.28	0.28	0.31	0.44	0.6	0.3	0.46	0.87	1.12	1.1
PF 20	120.8	0.1	0.08	0.28	0.31	0.33	0.45	0.53	0.33	0.3	0.39	0.33	0.42	0.34	0.4	0.26	0.29	0.29	0.31	0.48	0.71	0.35	0.57	1	1.42	1.91
PF 21	121	0.06	0.03	0.2	0.35	0.5	0.72	0.81	0.42	0.26	0.54	0.46	0.41	0.26	0.24	0.3	0.3	0.3	0.32	0.58	0.99	0.5	0.85	1.33	1.92	4.46
PF 22	126	0.05	0.02	0.16	0.38	0.6	0.87	0.97	0.46	0.27	0.61	0.54	0.42	0.27	0.23	0.32	0.32	0.32	0.32	0.6	1.11	0.57	0.98	1.47	2.13	4.28

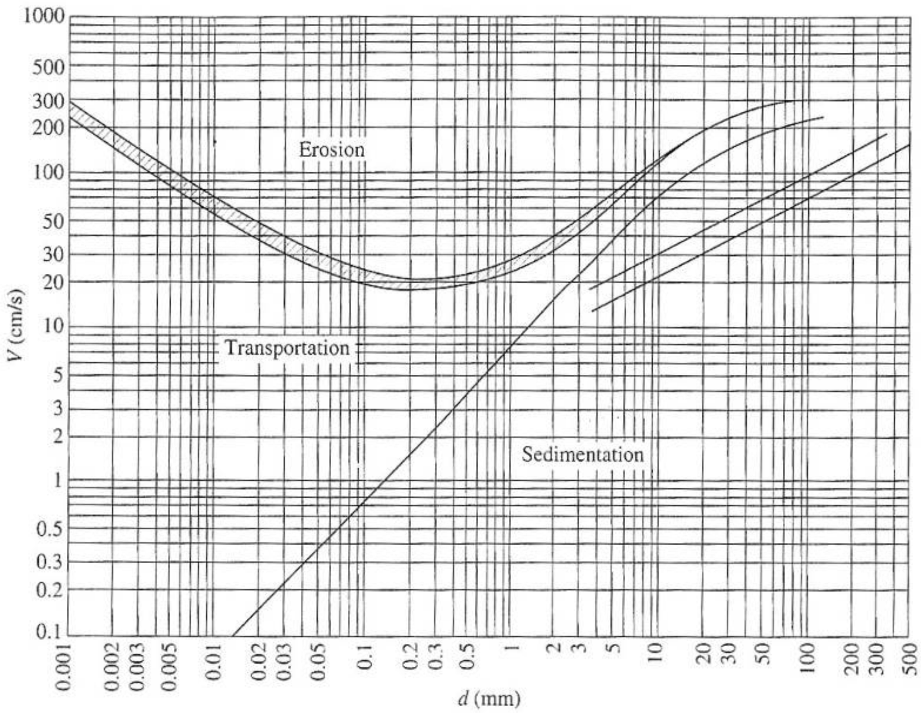


Figure 5-20. Erosion-deposition criteria for uniform particles.
Source: after Hjulstrom, 1935; USBR, 2006.

The important consideration is not necessarily the flow condition (erosion versus transport), but rather that flow reductions allowed under the draft MFLs hydrologic regime would not cause a substantial shift in the occurrence of those critical flow events. If, for example, the flow condition at a particular location is erosive under the no-pumping condition hydrologic regime, then it should remain erosive under the recommended MFLs hydrologic regime to maintain the natural morphology of the river. Therefore, for the ranges of bed material sediment size present in this river, mean channel velocities between 0.1 and 0.6 ft/sec are critical for transport. A major shift in the frequency of occurrence of these velocities could cause morphological changes in the river.

Using HEC-RAS results from Table 5-15, velocities are expected to change very little under the MFLs hydrologic regime (typically 0.02 ft/sec or less). Flow events of a magnitude and duration identified as critical for maintaining sediment transport occur throughout Alexander Springs Creek. Given the small decrease, typically 0.02 ft/sec or less, in average in-channel velocities anticipated, sediment transport capacity should not change significantly.

5.9 WRV-9: WATER QUALITY

5.9.1 INTRODUCTION AND REGULATORY ACTIONS

Water Quality is defined as the chemical and physical properties of the aqueous phase (i.e., water) of a water body (lentic) or a flowing water course (lotic). The analyses presented for this WRV include water quality issues not addressed in WRV-7 (nutrients and other pollutants).

The criterion for protection was defined as the *chemical and physical properties of the water* that affect the aquatic community. The representative function used to assess protection of water resource values in Alexander Springs and Alexander Springs Creek is defined as the concentration event of key chemicals/indicators in the water column. The general indicators of protection of WRVs in Alexander Springs and the Alexander Springs Creek are maintenance of adequate discharge events to provide mixing/dilution and the maintenance of acceptable temperatures, nutrients, water clarity, bacteria, and dissolved oxygen levels. The specific indicators were defined as the differences in frequency of events within the water column necessary to maintain adequate protection of WRVs under baseline hydrologic conditions and the MFLs hydrologic regime.

A spring's water quality is determined by several factors. These include the chemical composition of the water entering the aquifer, the composition and solubility of the rocks with which the water comes into contact along flow paths, the length of time the water is in contact with the rocks as it moves from recharge to discharge areas, and the mixing of fresh groundwater with residual formation water or seawater. Land use activities in a spring's recharge basin and the upconing of poorer quality water from deeper zones due to groundwater withdrawals may also impact water quality.

5.9.2 TOTAL MAXIMUM DAILY LOAD FOR ALEXANDER SPRINGS

No total maximum daily loads (TMDLs) are drafted or adopted for either water body segment (WBID) directly connected to Alexander Springs, WBID 2918Z, Alexander Springs or WBID 2918A, Alexander Springs Run (Creek) (Figure 5-21). However, WBID 2918A was identified as impaired for nutrients, causing excessive algal growth in samples collected in 2012. The listing was adopted by Secretarial Order on April 27, 2016, with a high priority for TMDL development, but it is not yet included in the current draft schedule of TMDLs to be completed by 2022.

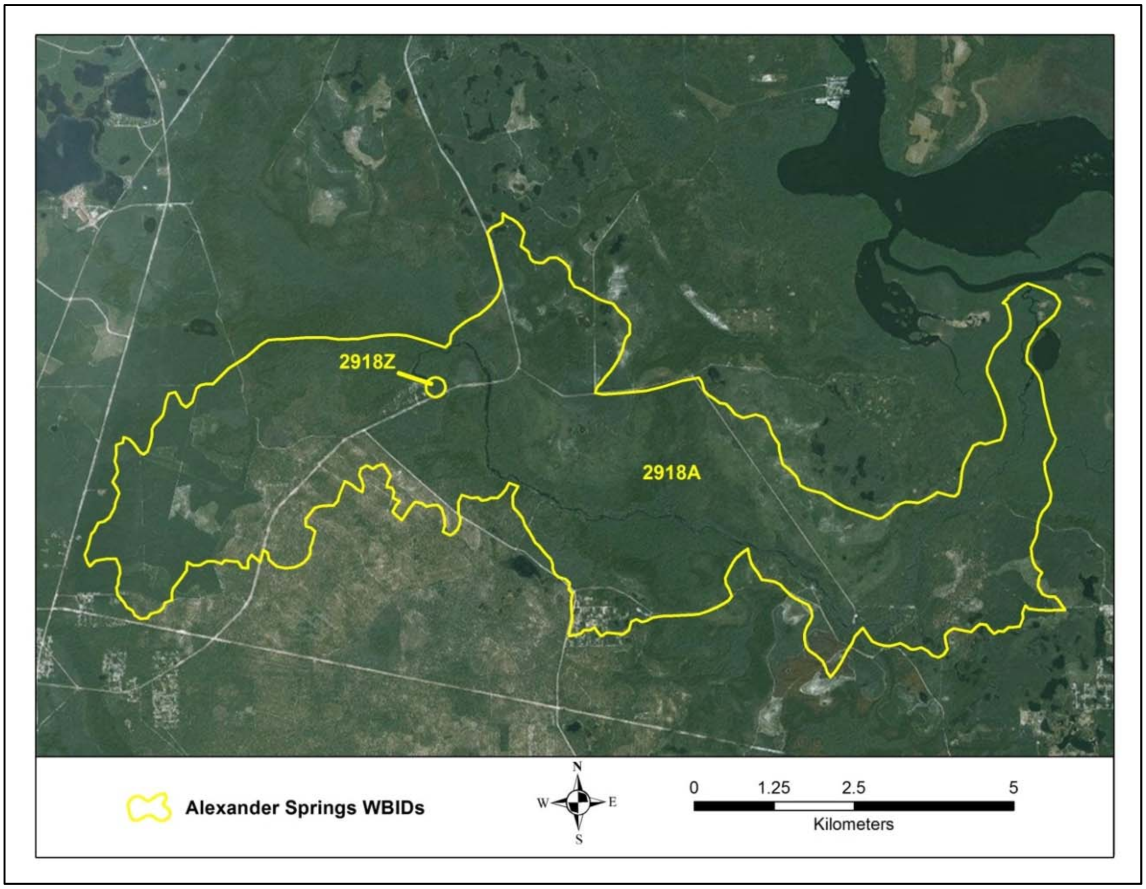


Figure 5-21. WBIDs associated with Alexander Springs.

5.9.3 DESCRIPTION OF ALEXANDER SPRINGS WATER QUALITY

The measured water quality data were investigated for relationships with the existing conditions spring discharge rates as provided by SJRWMD and reviewed above in Chapter 2. Threshold values for these key water quality characteristics have been identified as events to protect the aquatic habitat and ecological communities of the Alexander Springs and Alexander Springs Creek. It is the return interval of these events, given any statistically significant relationships, that is the subject of this evaluation.

Two datasets were combined to evaluate WRV-9. The first was the St Johns River Water Management Environmental Data Retrieval Tool available at http://webapub.sjrwmd.com/agws10/edqt/. The second was the Florida Department of Environmental Protection (FDEP) Impaired Waters Rule (IWR) Run 53 SAS dataset which was queried for the WBIDs associated with Alexander Springs. The IWR dataset is a compilation of the data from Florida STORET that meets stringent criteria used to assess waterbodies as directed by the Clean Water Act. An earlier version of this dataset was used by the Department to determine that Alexander Springs Creek was impaired.

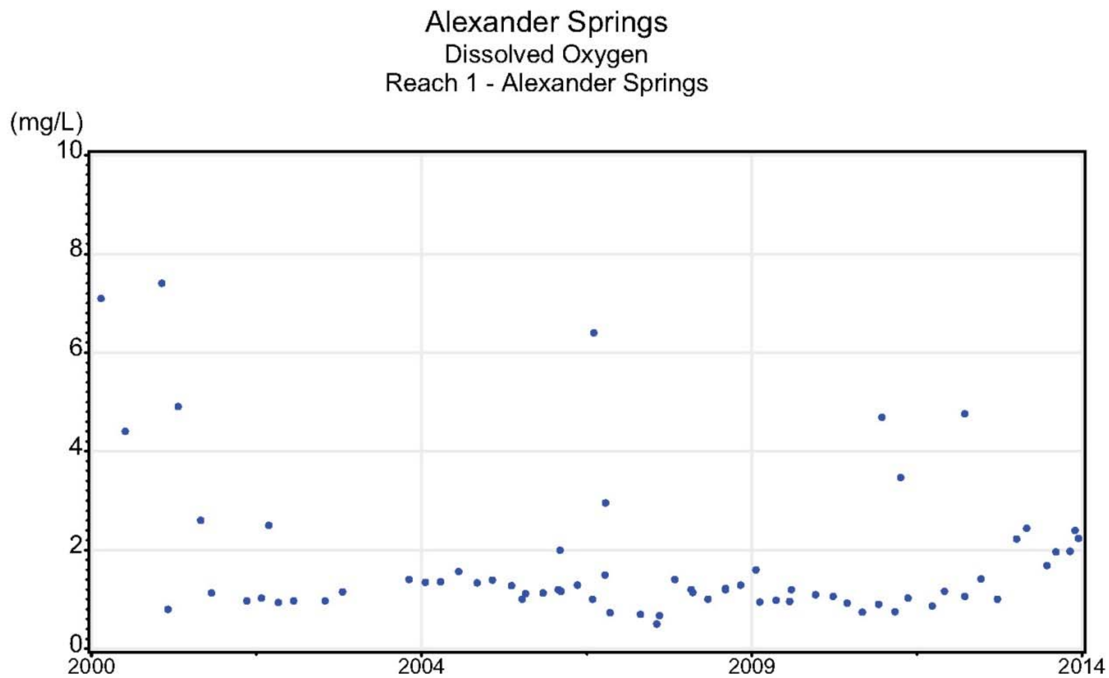
The study area was limited to the WBIDs FDEP used for assessment but was grouped into two reaches (Figure 5-21). The first reach, Reach 1, consists of Alexander Springs, WBIDs 2918Z. Reach 2 consists of the Alexander Springs Creek, WBID 2918A.

The relationships between existing discharge and the key measured water quality parameters were investigated. The key water quality parameters included dissolved oxygen, acidity measured as pH, color, nitrate plus nitrite (NOx), total nitrogen (TN), total phosphorus (TP), and turbidity. Daily means were calculated by reach for all water quality parameters were plotted versus the discharge (in cfs) corresponding to the water quality sample collection dates.

5.9.3.1 Dissolved Oxygen

The time series plots of the daily mean dissolved oxygen concentrations for each reach are presented in Figure 5-22. Dissolved oxygen measurements from the spring reach were generally low and steady as expected, whereas there is a lack of any obvious trend in the creek.

Cumulative distribution plots of dissolved oxygen collected in each reach are shown in Figure 5-23, providing a direct comparison of the distributions observed. The distributions for each reach are quite different, demonstrating a lack of association between them. This is reasonable considering there is additional hydrologic input to the system above the spring head. Since anaerobic groundwater is the primary source of water to the system, lower dissolved oxygen values that fail to meet that or the current percent saturation standard are not unexpected. Plots of the relationship of dissolved oxygen with flow in Figure 5-24 show that, for Reaches 1 (top), there is a slight decrease in dissolved oxygen concentration with increased flow, while Reach 2 shows little to no change.



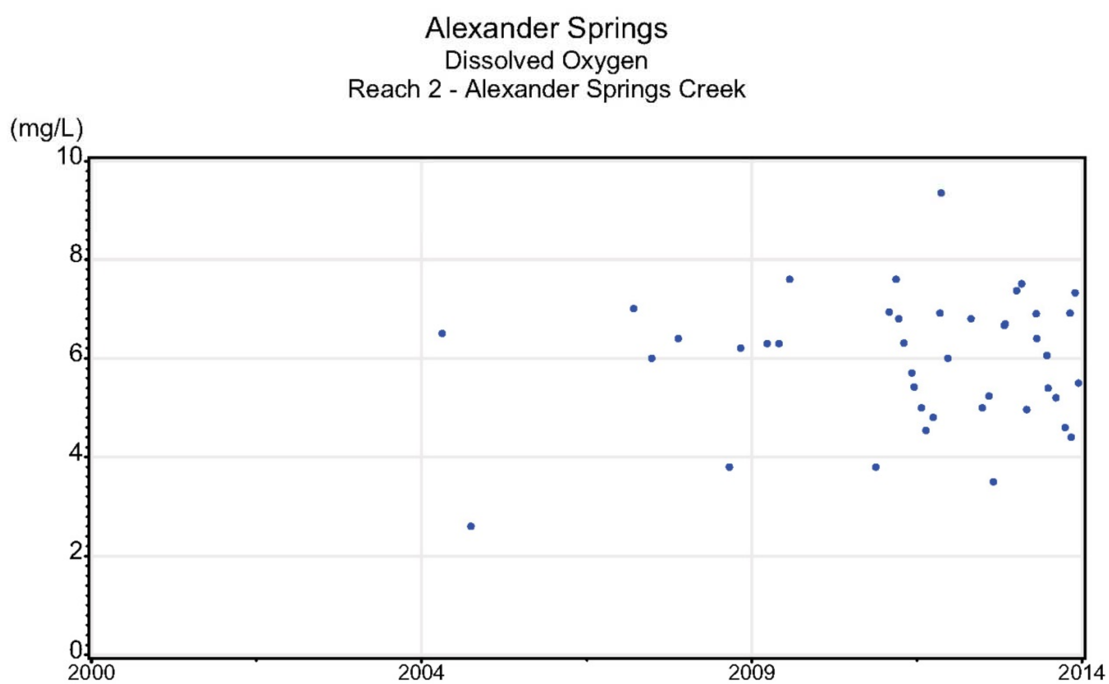


Figure 5-22. Time series plots of daily mean dissolved oxygen values for Reach 1 (top) and Reach 2 (bottom).

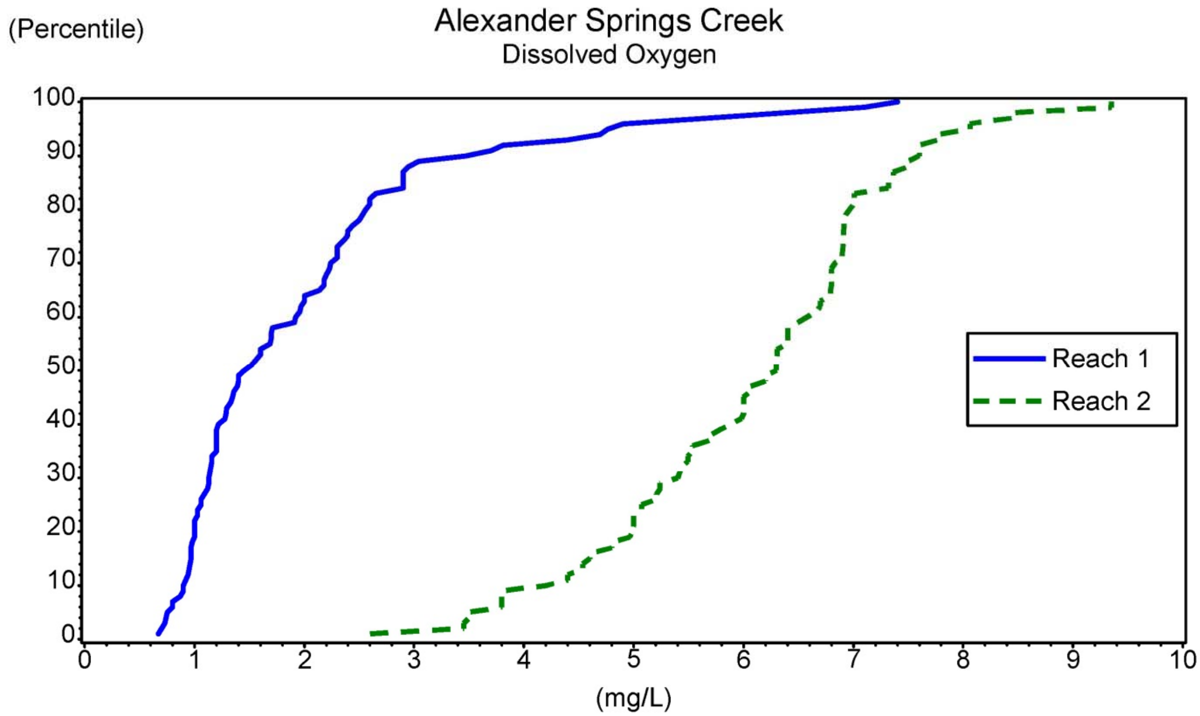


Figure 5-23. Distributions of the dissolved oxygen data collected in each of the reaches.

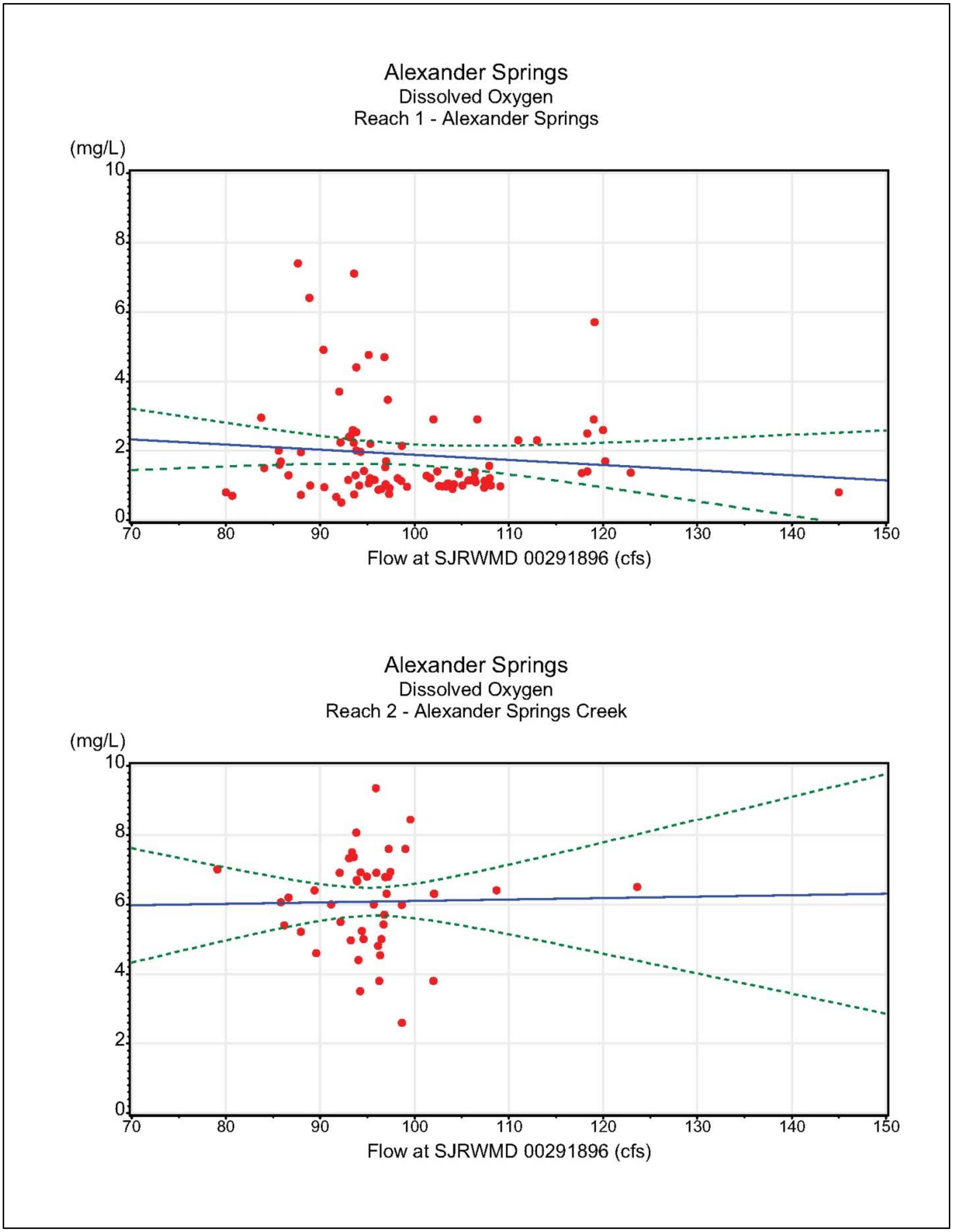


Figure 5-24. Plots of dissolved oxygen concentration versus flow for Reach 1 (top) and Reach 2 (bottom).

5.9.3.2 pH

pH is a measure of the acidity or alkalinity of water and is reported on a logarithmic scale that represents the negative of the log of the concentration of hydrogen ions (H^+). The units of pH are expressed as laboratory standard units (SU). Values of pH less than 7.0 are considered acidic. Values of pH greater than 7.0 are considered alkaline (basic), and a pH of 7.0 is considered neutral. Acidity in water comes from two main natural sources: rainwater that contains carbonic acid that results from reactions with atmospheric carbon dioxide (CO_2), and organic acids from soil, especially humic and tannic acids (Scott et al., 2004). Site geology also influences groundwater and spring discharge pH. Local groundwater is high in carbonates and bicarbonates, which should buffer the system to significant pH changes.

The pH of water is important to biochemical reactions such as the extraction of calcium from water for mollusks and crustaceans to produce shells. Experiments on freshwater bivalves such as *Corbicula* have shown dissolution of shells and mortality in acidic water (Kat, 1972).

Florida Class III surface water criteria for pH requires freshwater to be within the range of 6.0 to 8.5 (FDEP, 2006). For this analysis, a minimum pH of 6.0 is used as the criterion to comply with the Florida state standard to maintain an acidity-alkalinity balance favorable to the natural fish and benthic fauna. In the absence of highly acidic or basic contaminants within the springshed, the pH in Florida spring discharges can be expected to remain within these limits.

Time series of mean daily pH values for the two reaches are shown in Figure 5-25. The majority of the data falls between 7 and 8 SU. Cumulative distribution plots comparing the two reaches are presented in Figure 5-26. While the shapes of the curves are similar, Reach 2 is appreciably lower. This is likely due to the relative contribution of flows from other freshwater inputs. The lower pH can be attributed to the organic acid inputs typical of waters with wetland origins.

Plots of the relationship between pH with flow in each reach are presented in Figure 5-27. There is a slight decrease in pH associated with increases in flows in both reaches.

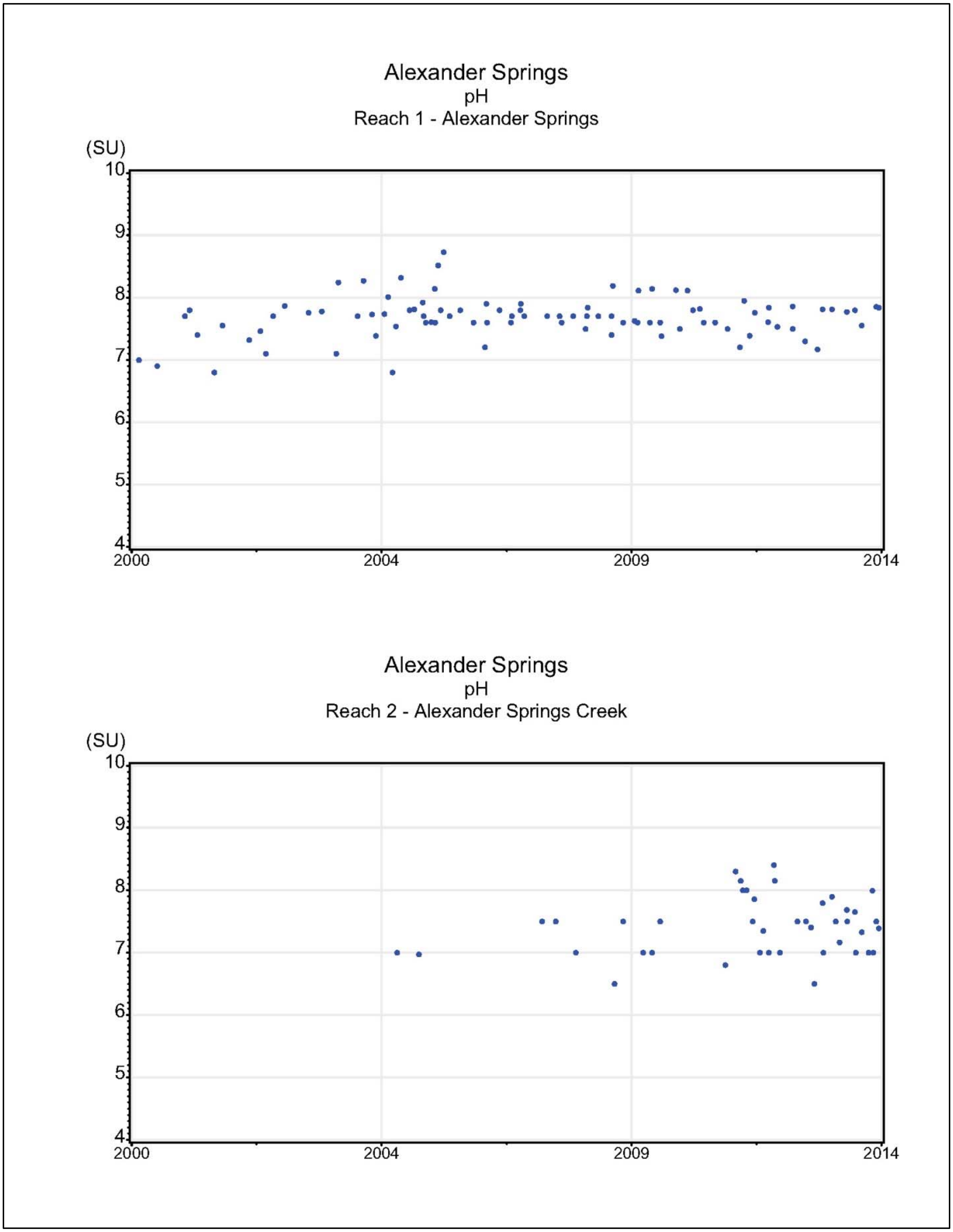


Figure 5-25. Time series plots of daily mean pH values for Reach 1 (top) and Reach 2 (bottom).

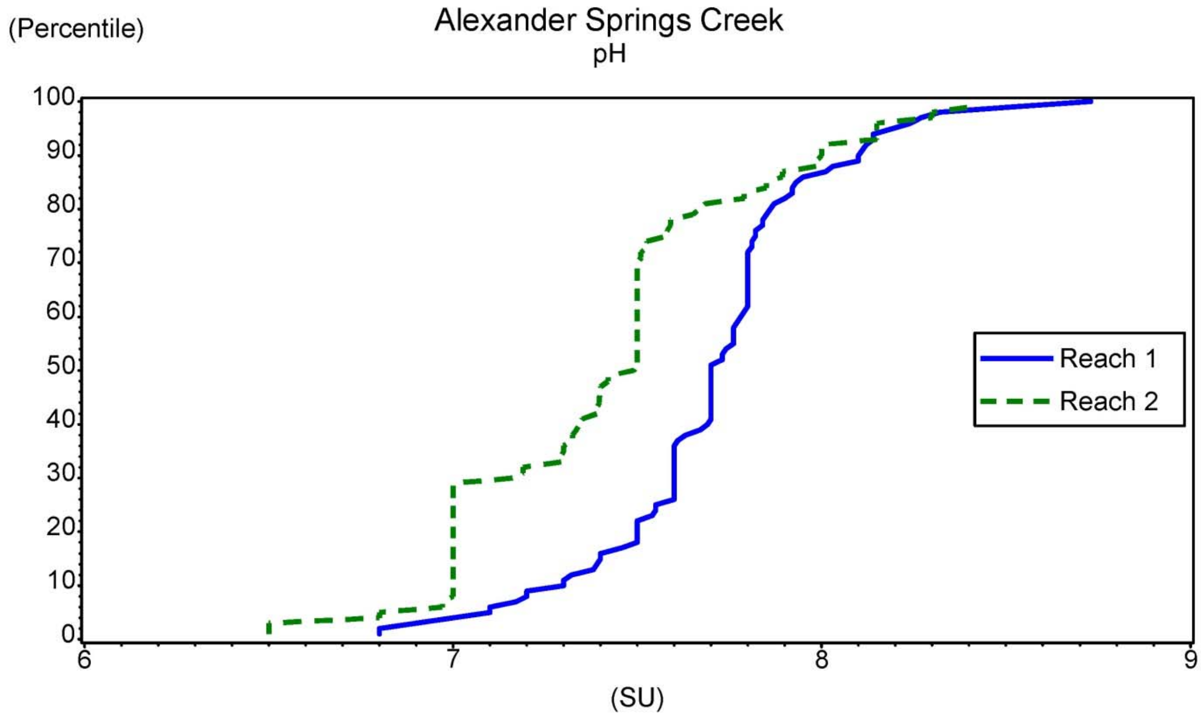


Figure 5-26. *Distributions of the pH data collected in each of the reaches.*

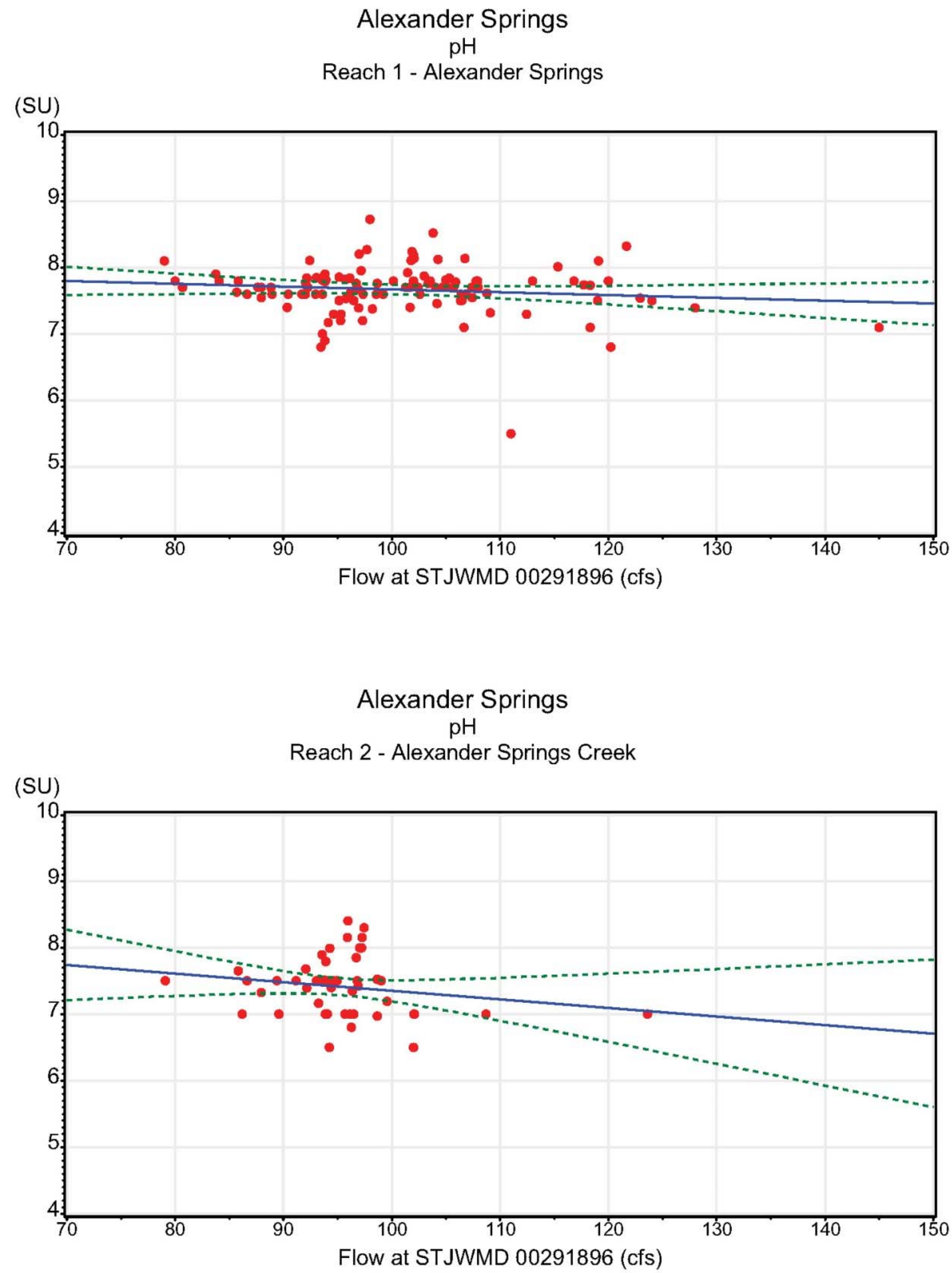


Figure 5-27. Plots of pH versus flow for Reach 1 (top) and Reach 2 (bottom).

5.9.3.3 Nutrients

The nutrients nitrogen and phosphorus are two major constituents of aquatic plant tissues. As such, the amount of nitrogen and phosphorus in the water can control the rate of growth of aquatic macrophytes and algae (Odum, 1971). In the aquatic environment, the forms of nitrogen and phosphorus that are the most soluble and easily absorbed by green plants are nitrate (NO_3) and orthophosphate (PO_4) (Wetzel, 1975). In surface waters, the total amounts of TN and TP in the water column are often used as an indicator of the amount of nutrients available to fuel algae growth, since these also include particulate organic and inorganic forms. Most of the nitrogen and phosphorus is incorporated in benthic macroalgae and microalgae including diatoms (Stevenson et al., 2007), epiphytes (periphyton), and macrophytes such as *Sagittaria* (Munch et al., 2006) rather than the phytoplankton community.

Studies of Florida springs by Stevenson et al. (2007) included bioassays to correlate nutrient additions and growth of macroalgae. Strong evidence was developed indicating that the growth of both *Vaucheria* and *Lyngbya* could be controlled by reducing nitrogen or phosphorus loads to the springsheds and springs. The researchers performed bioassay experiments on nutrient limitation of the growth rates of the benthic macroalgae *Vaucheria*, a filamentous green algae, and Lyngbya, a colonial filamentous cyanobacteria.

Stevenson et al. (2007) took the work one step further by calculating the approximate amount of reduction in loads of nitrogen or phosphorus that may control the growth of the nuisance macroalgae in Florida springs. Field samples and laboratory experiments on *Lyngbya wollei* and subsequent mathematical models showed that the extent of cover of spring bottoms by algal mats of *Lyngbya* could be reduced if TN concentrations could be reduced below 0.25 mg/L or if TP concentration could be reduced below 0.035 mg/L. They also studied the possibility of reducing the cover of spring bottoms by *Vaucheria* mats, with similar results.

Suwannee River Water Management District (SRWMD) sponsored field research that showed a relationship between nitrate and algae that reached a critical point at 0.44 mg/L NOx, as presented by the FDEP (2008a), above which algae cell density would increase in a logistic growth curve pattern. FDEP (2008a, 2008b) used these and other studies to propose a standard for NOx concentration in spring waters equal to 0.35 mg/L. Nutrient cycling in the aquatic environment is discussed in WRV-7. The following discussion focuses on chemical concentration in the water column in relation to flow rate.

Time series plots are presented by reach depicting the mean daily NOx concentrations (Figure 5-28). Data from both reaches show relatively stable concentrations of NOx with all values except one well below the state standard 0.35 mg/L NOx for springs. This is in stark contrast to many other springs within the state struggling to meet the standard. Distributions of NOx data from both reaches are very comparable (Figure 5-29).

Plots of the relationship between NOx with flows by reach are shown in Figure 5-30. There is no apparent trend in Reach 1 and only a slightest increase in Reach 2.

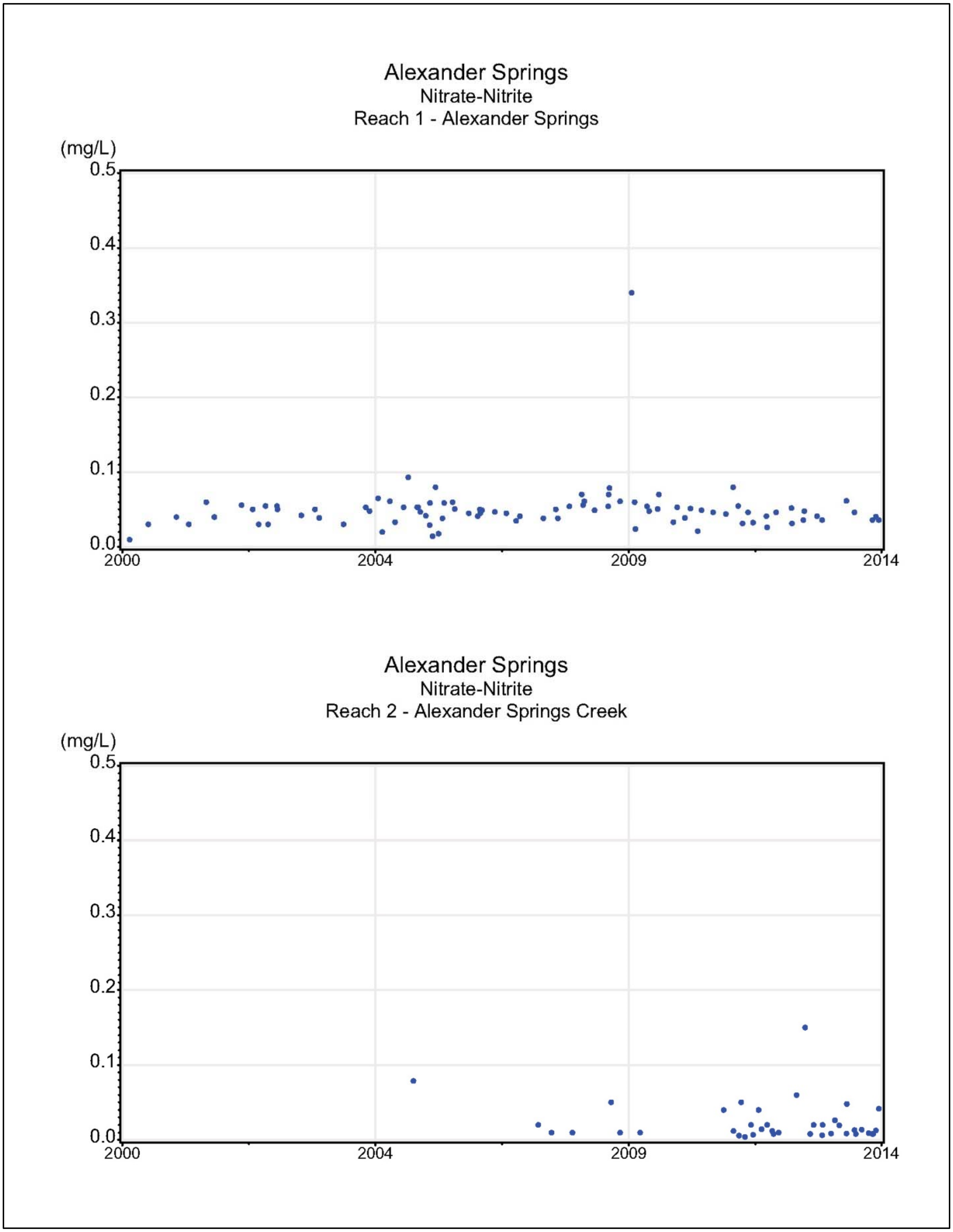


Figure 5-28. Time series plots of daily mean NOx values for Reach 1 (top) and Reach 2 (bottom).

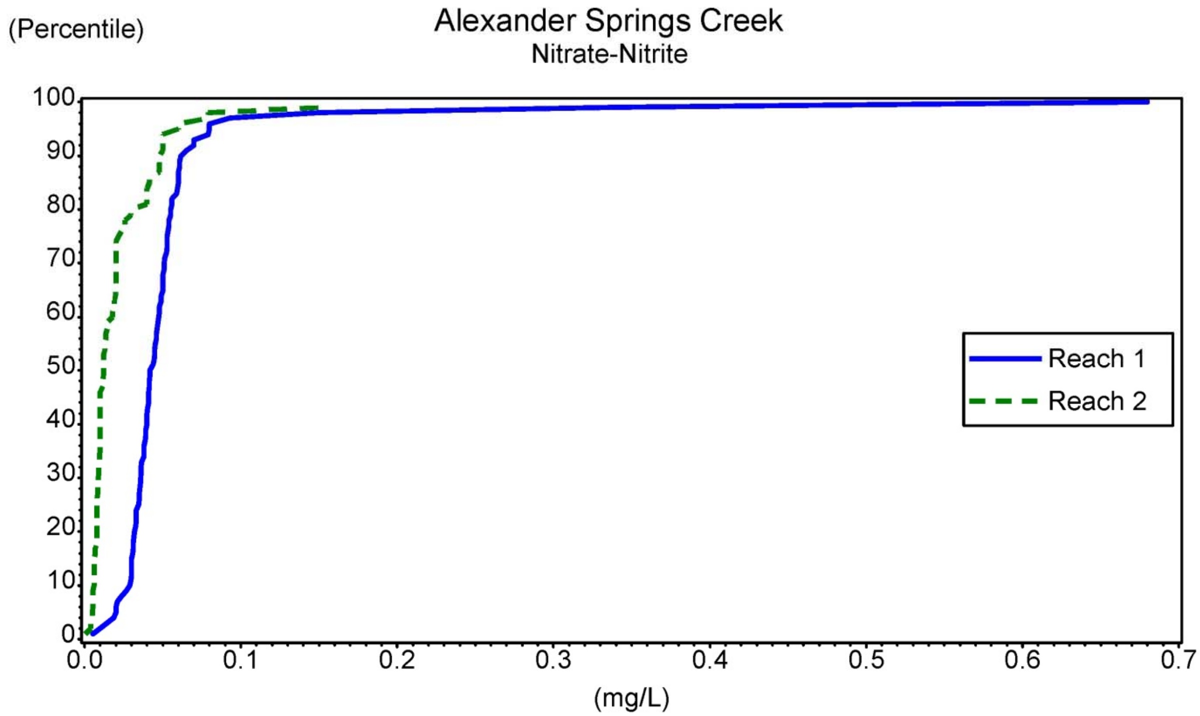


Figure 5-29. Distributions of the NOx data collected in each of the reaches.

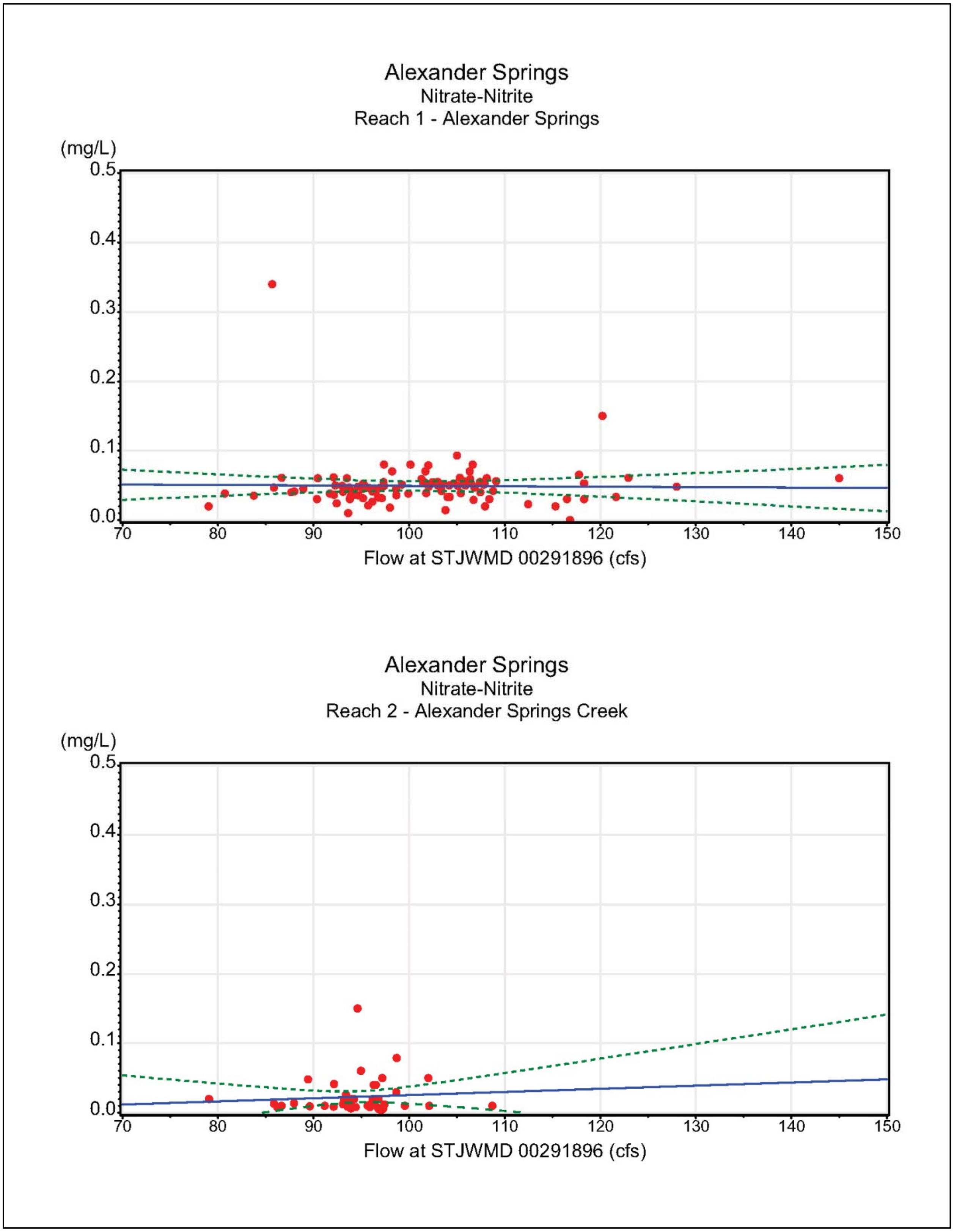
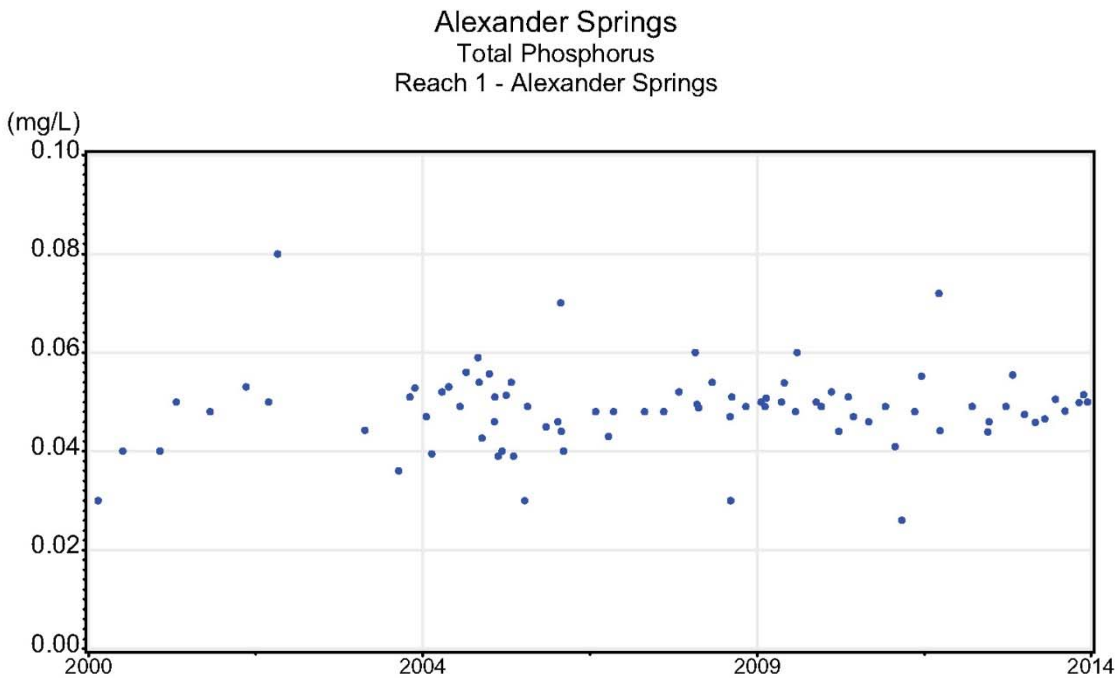


Figure 5-30. Time series plots of daily mean NOx values for Reach 1 (top) and Reach 2 (bottom) versus daily flows.

5.9.4 PHOSPHORUS

The natural source of phosphorus in Florida springs comes from the large deposits of ancient marine sediments that contain a high concentration of phosphate compounds such as carbonate-fluorapetite, $Ca_5(PO_4\,CO_3)_3F$ (Upchurch, 1992). Phosphate can also come from agricultural fertilizers that infiltrate the aquifer or enter the river in surface runoff. Although a large amount of land area has been converted from forest to urban land uses, agriculture, and pasture in most of the springsheds of Florida, there has not been an increasing trend reported in the concentration of phosphate in Florida springs since the beginning of data collection in the 1950s (FDEP, 2008a). This suggests that concentrations of phosphorus have always been high and may always be high because of the ancient and extensive marine deposits that contain large amounts of phosphorus.

Time series plots of TP for each of the reaches are shown in Figure 5-31. Very little change is shown over time. Cumulative plots by reach of the same data (Figure 5-32) again show the similarities between the two reaches. Plots of the relationship of TP with flow for each reach only show the slightest increase in concentration, with increased flow in Reach 1 and a decrease in Reach 2 (Figure 5-33). Considering the range of values and the number of data points, these changes are not very large.



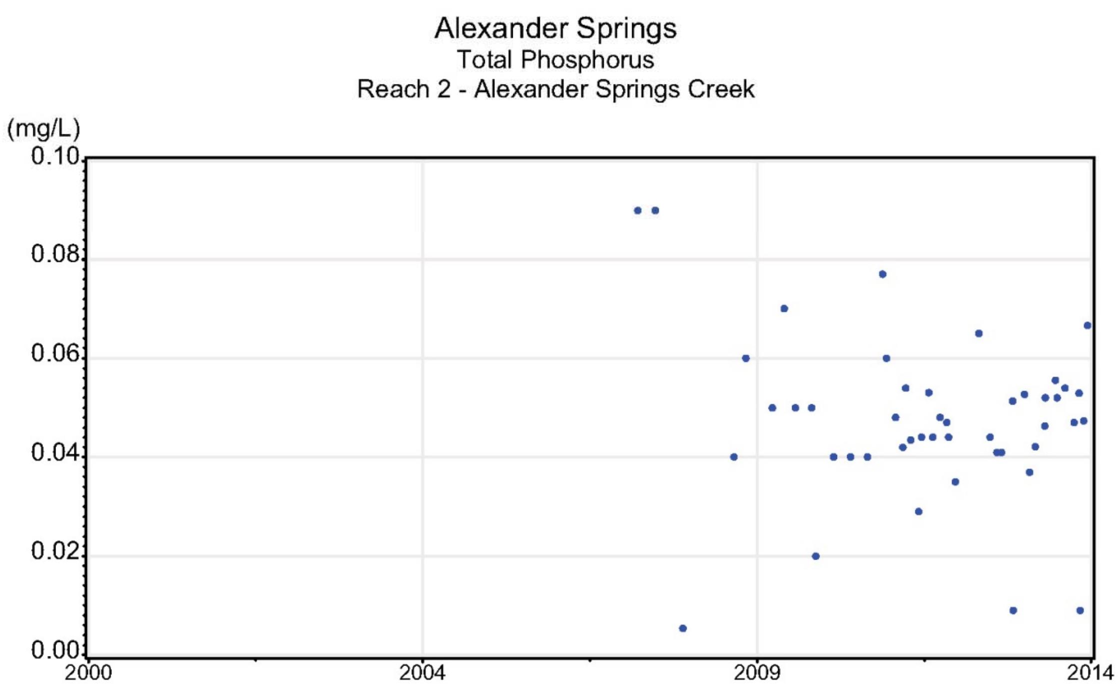


Figure 5-31. Time series plots of daily mean TP values for Reach 1 (top) and Reach 2 (bottom).

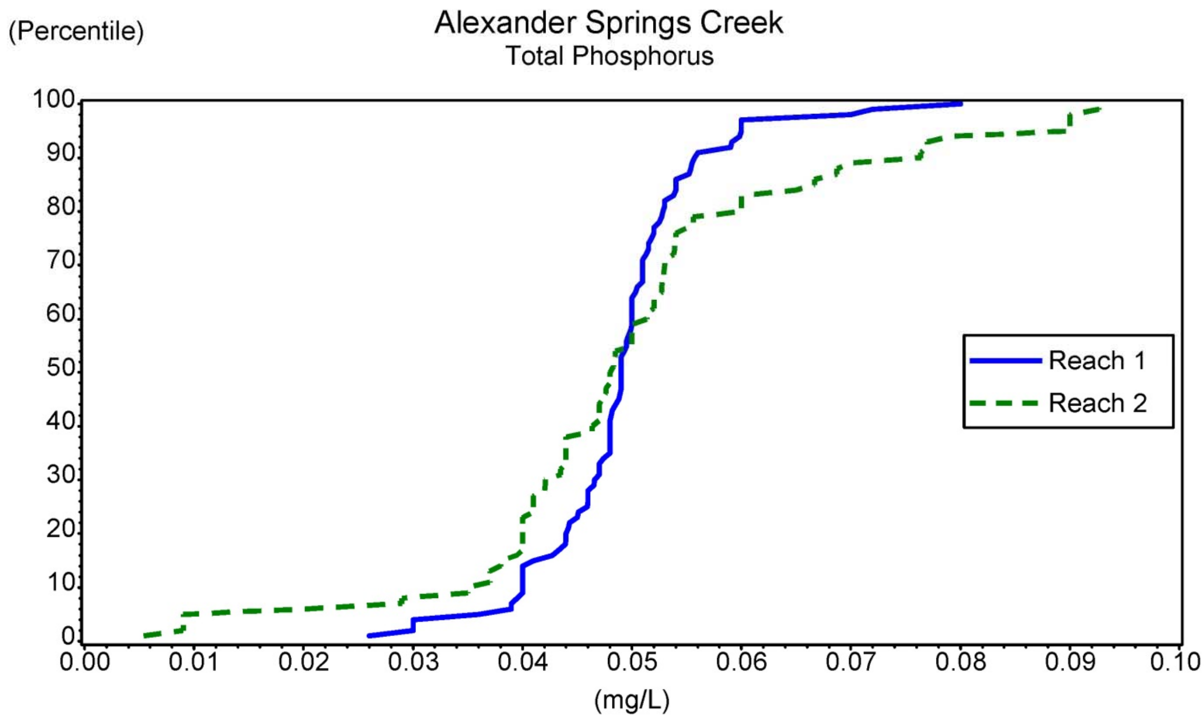


Figure 5-32. Distributions of the TP data collected in each of the reaches.

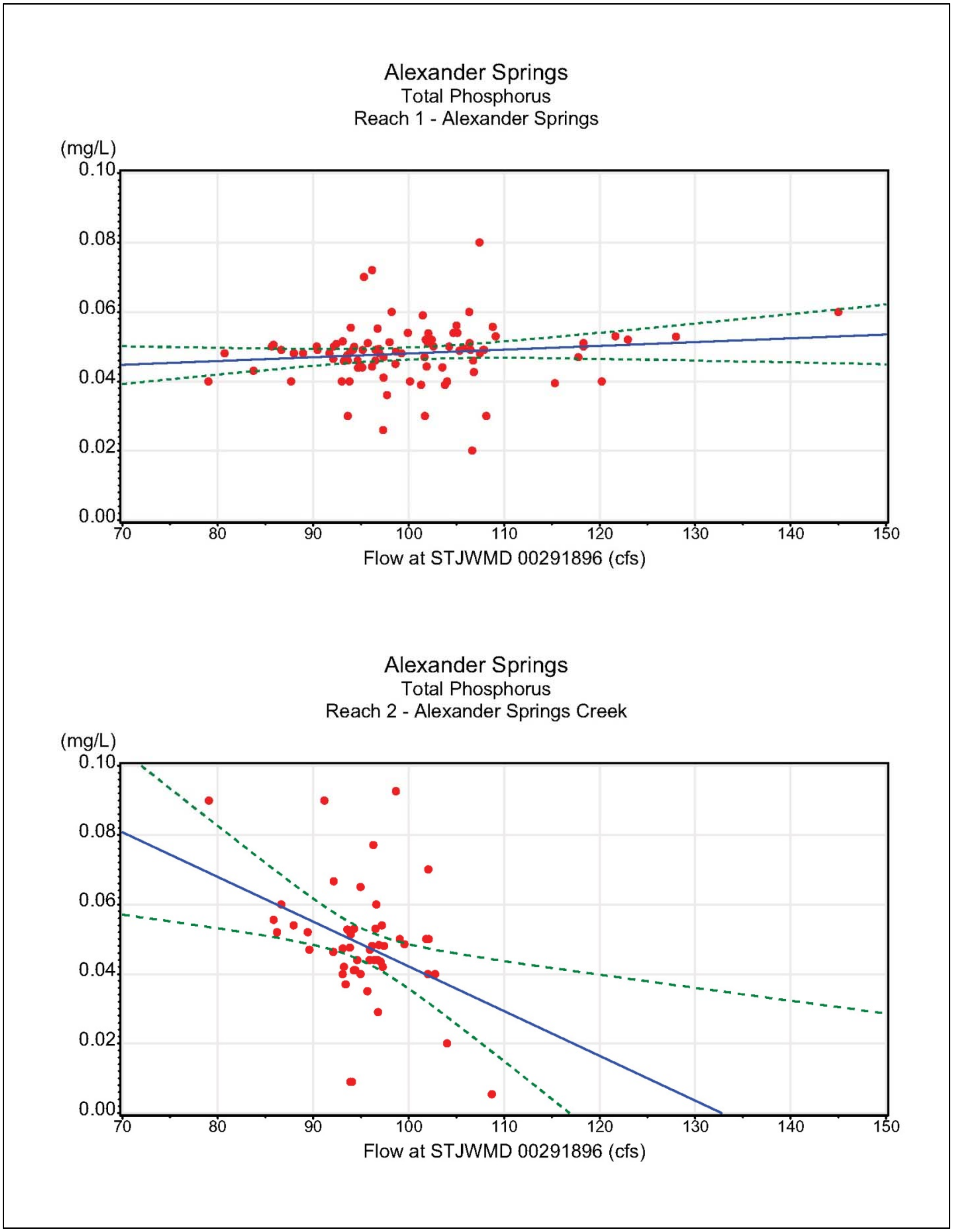


Figure 5-33. Plots of TP versus flow for Reach 1 (top) and Reach 2 (bottom).

5.9.5 WATER CLARITY

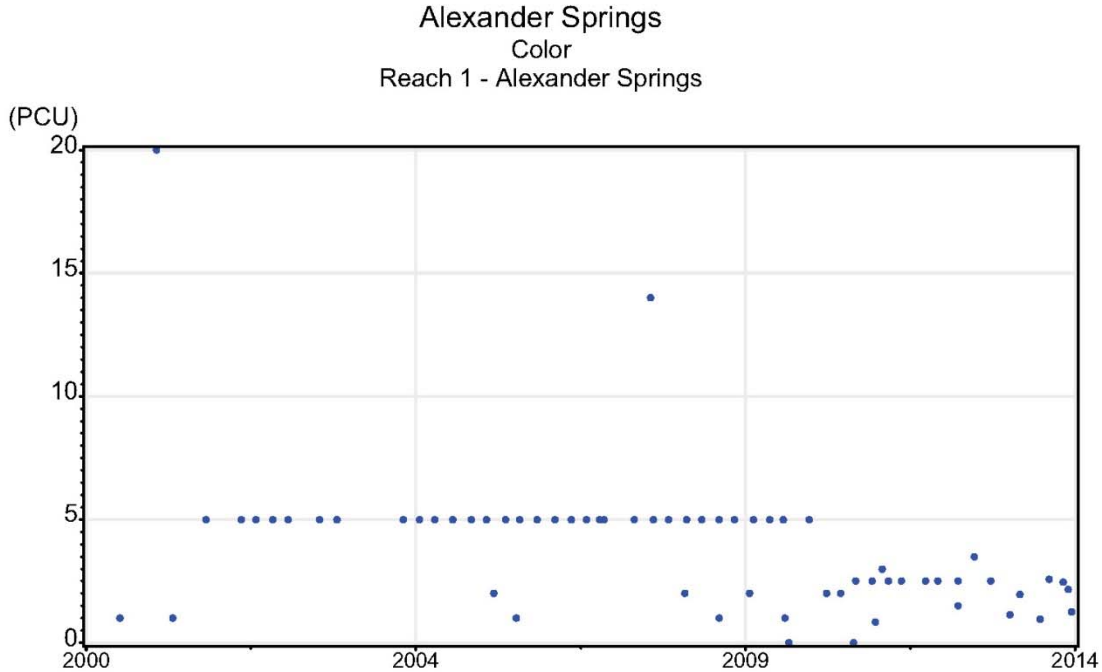
The clarity of the Alexander Springs system is a key issue of concern. Water clarity is essential to allow the passage of light to aquatic vascular plants and algae for photosynthesis, as well as for aesthetic and recreational purposes. Color, turbidity, dissolved and suspended solids, and chlorophyll concentrations are the primary determinants of a decline in water clarity when present in high concentration. The amount of light transmitted through water can be measured using a Secchi disc, or an electronic instrumentation that measures the attenuation and absorption of light in water. Such sensors measure photosynthetically active radiation (PAR) and solar insolation, that is, incoming solar radiation (Wetzel, 1975) and are used to calculate light extinction coefficients that define the rate of attenuation of light through the water column at increasing depth.

5.9.5.1 <u>Color</u>

Color is probably the largest contributor to freshwater light attenuation. Time series plots of the available color data are shown in Figure 5-34. There little variation in the spring reach, with only several values greater than 5 nephelometric turbidity units (NTUs), while the creek reach has much greater temporal variability. There is no apparent temporal trend in the data from either reach.

Cumulative distribution plots of the color are shown in Figure 5-35. In Reach 1, 90 percent of the color values are less than 5 platinum-cobalt unit (PCU). In Reach 2, on the other hand, more than 50 percent of the color values are greater the 50 NTU. These differences are likely dependent on the relative contribution of surface runoff from upstream regions that contribute colored, relatively acidic water typical of waters draining wetland areas.

There is a slight increase in the color with an increase in flow in Reach 2, as shown in the bottom panel of Figure 5-36. Again, this is likely due to an increase in stormwater runoff associated with higher flows. No discernable relationships are exhibited in the spring reach.



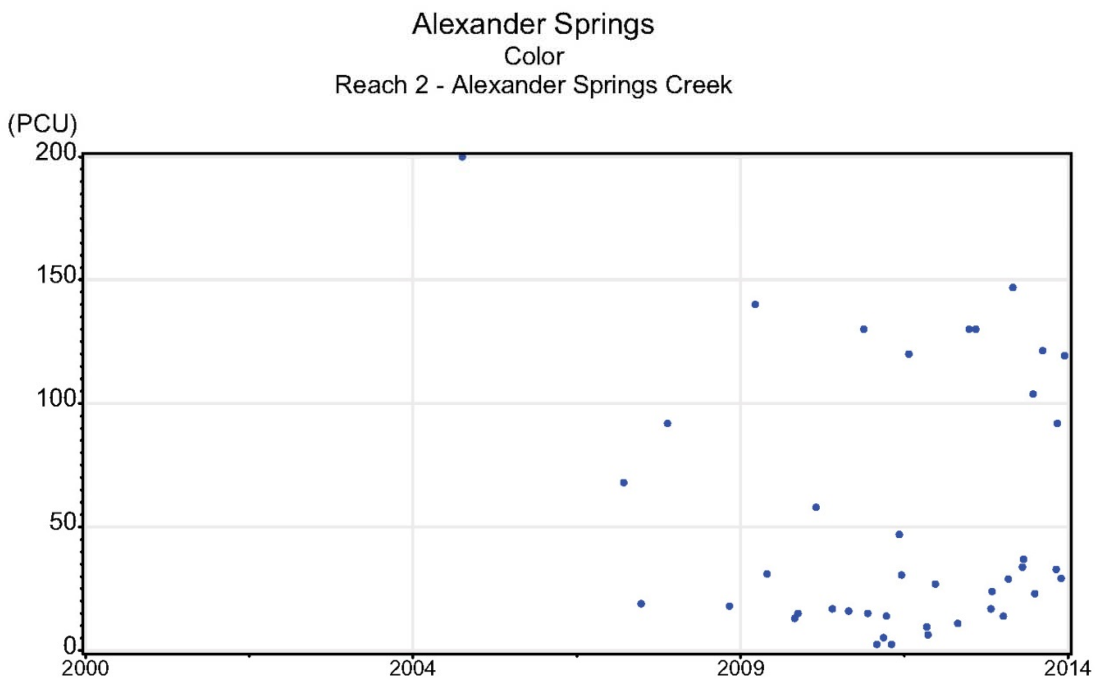


Figure 5-34. Time series plots of daily mean color values for Reach 1 (top) and Reach 2 (bottom).

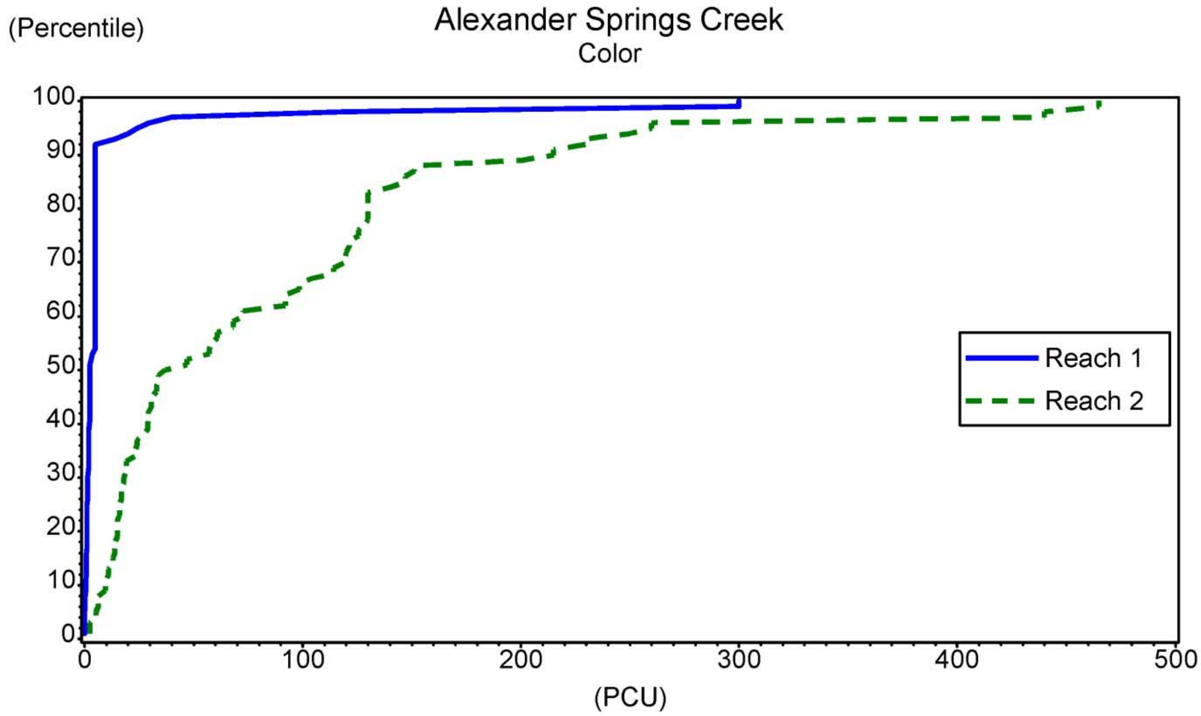


Figure 5-35. Distributions of the color data collected in each of the reaches.

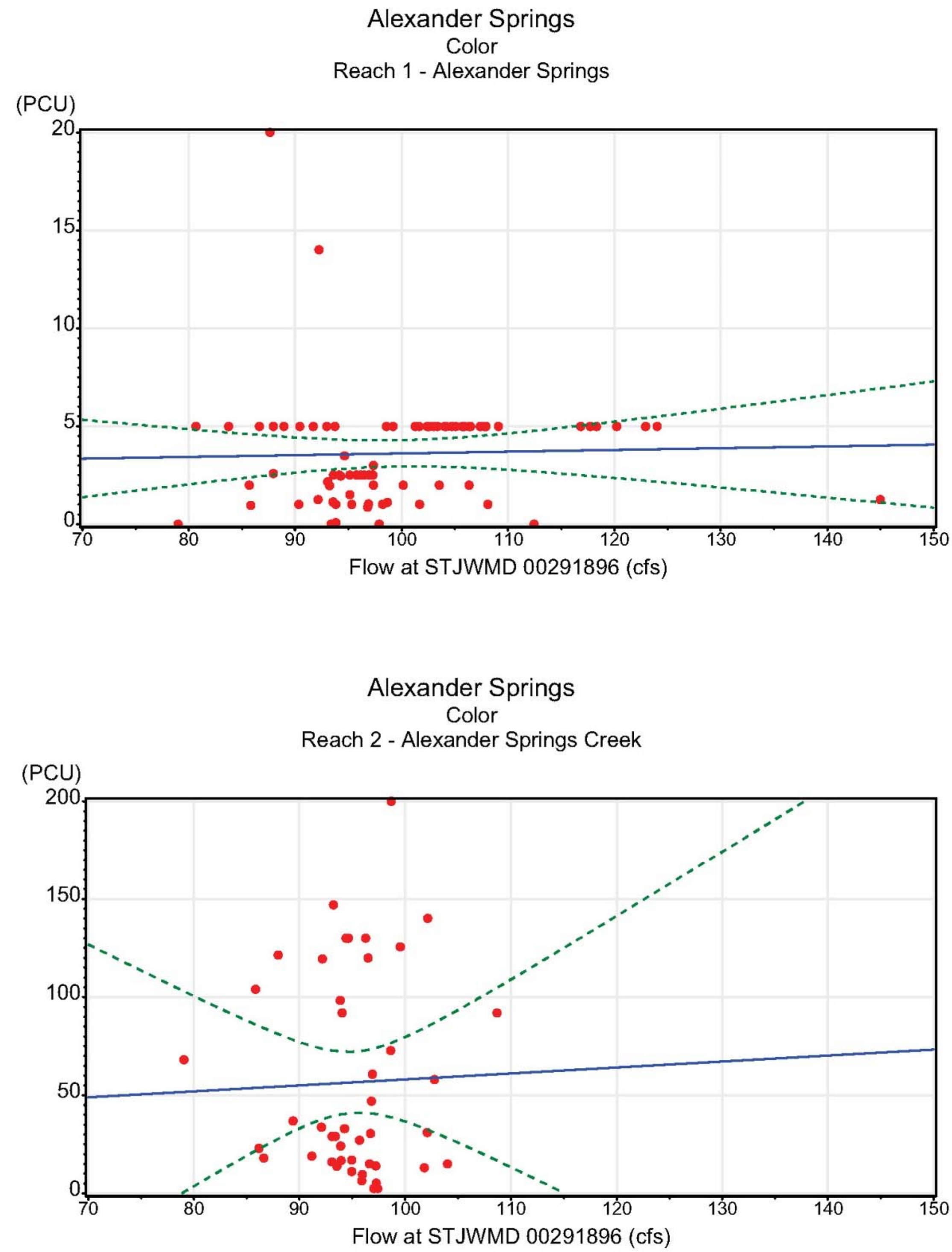


Figure 5-36. Plots of color versus flow for Reach 1 (top) and Reach 2 (bottom).

5.9.5.2 Turbidity

Turbidity is a measure of the amount of very fine suspended particles in the water column in terms of the interference of light transmission by the particles. It is generally used to measure the amount of particulate material that interferes with light available to aquatic plants. Time series plots (Figure 5-37) indicate that turbidity values never exceeded 5 NTU in either reach. Similar to the results found for color, no trend in turbidity values was apparent.

Cumulative distribution plots of the turbidity data from the two reaches are shown in Figure 5-38. As has been shown in many of the previous parameters, the values in both reaches are similar, with the creek being typically higher.

Reach 1 has a slight increase in turbidity associated with increased flows (Figure 5-39). This result is not unexpected, as turbidity increase at higher flows often results from the displacement of smaller particles entrained by the increased velocities associated with the higher flows. Reach 2 indicates a decrease with higher flows. While both plots indicate changes in turbidity associated with flows, the scale of the change is within a few detection limits of the measurements.

5.9.6 EFFECT OF THE PROPOSED MINIMUM FLOWS ON WATER QUALITY

Given the general lack of significant changes in water quality with changes in flows, there will be some improvement in such water quality constituents as inorganic nitrogen (NOx) concentrations and no apparent degradation in other constituents.

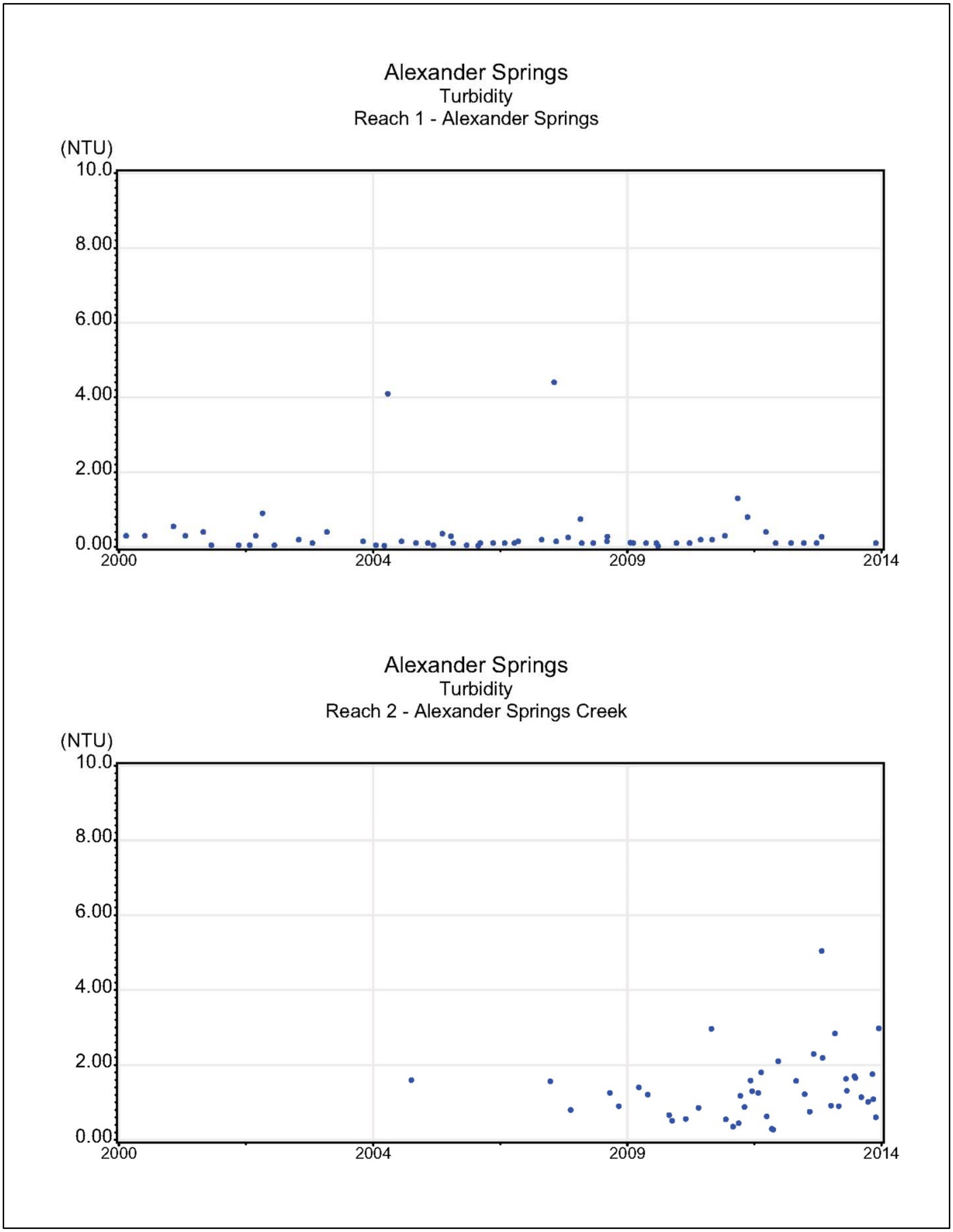


Figure 5-37. Time series plots of daily mean turbidity values for Reach 1 (top) and Reach 2 (bottom).

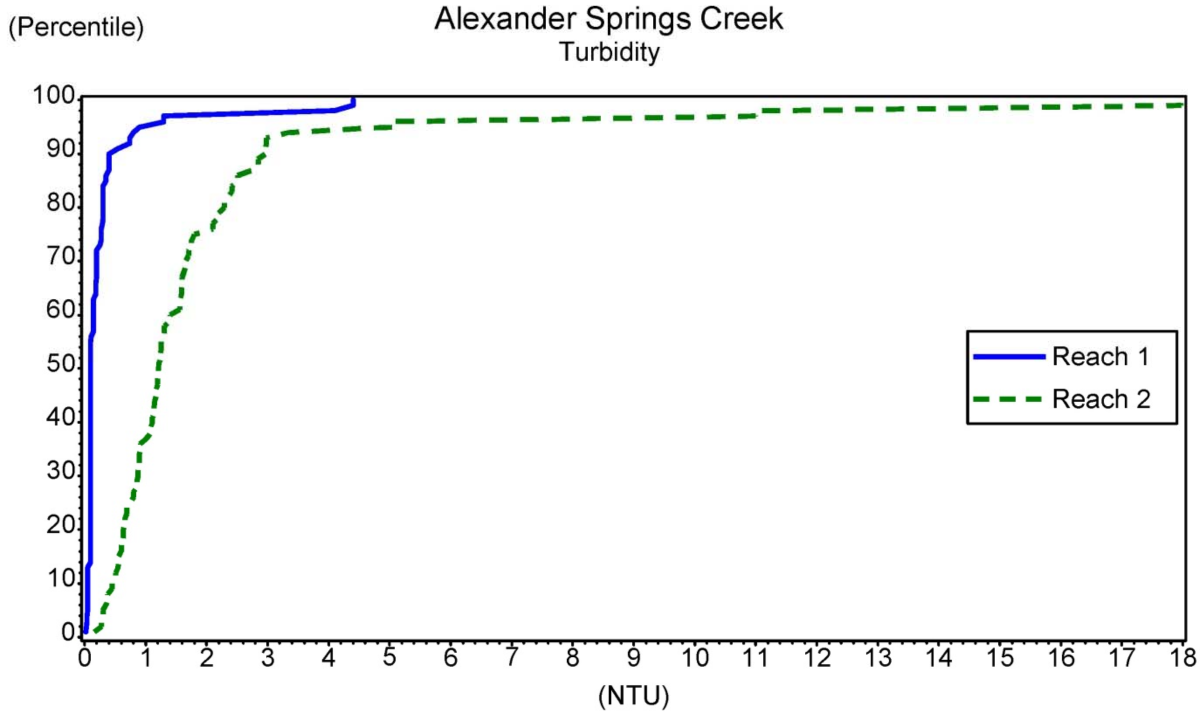


Figure 5-38. *Distributions of the turbidity data collected in each of the reaches.*

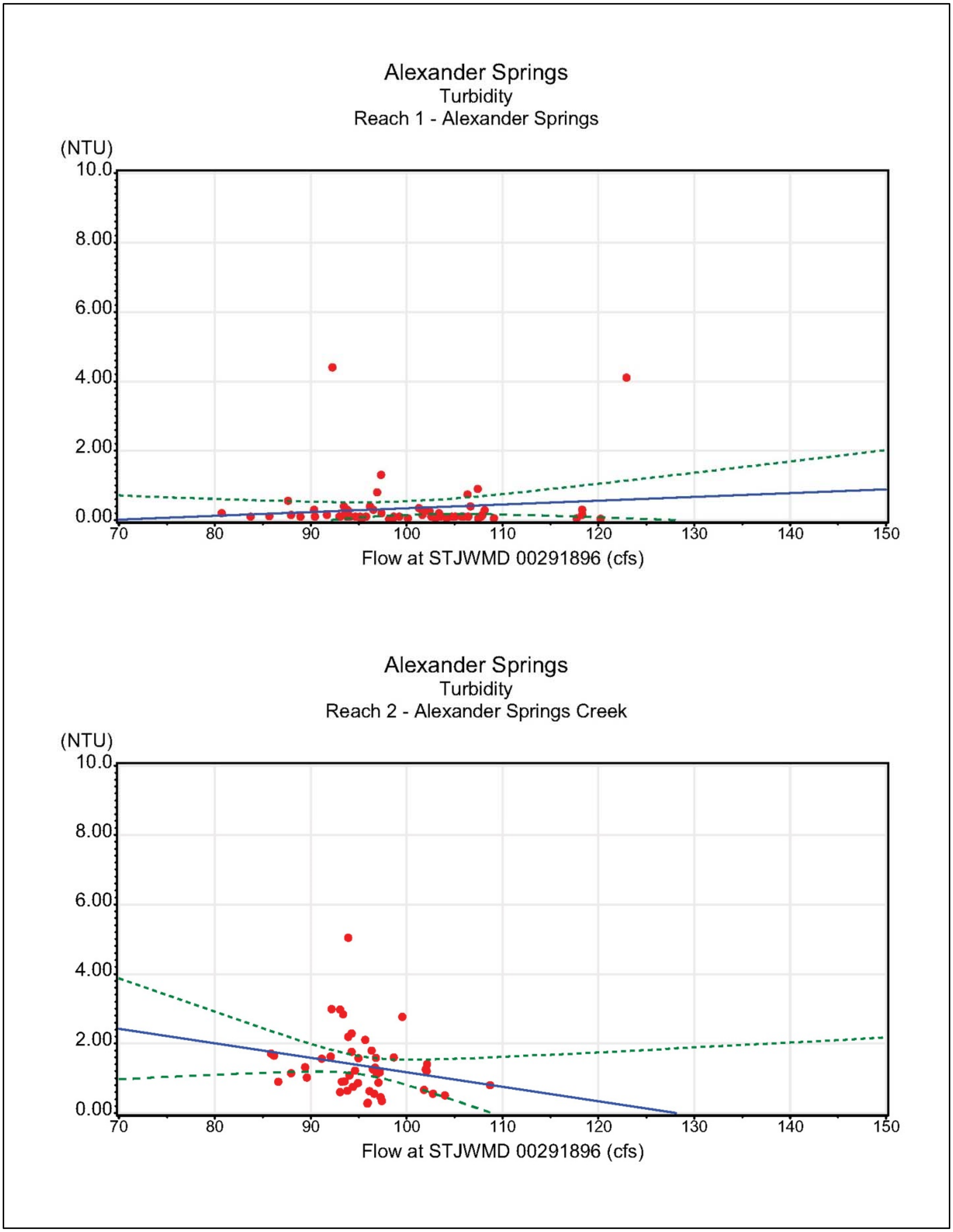


Figure 5-39. Plots of turbidity versus flow for Reach 1 (top) and Reach 2 (bottom).

5.10 WRV-10: NAVIGATION

Navigation is defined as the safe passage for legal operation of ecotourism and commercial fishing vessels that are dependent on sufficient water depth, sufficient channel width, and appropriate water velocities. These types of vessels do not operate in Alexander Creek due to shallow depths in the channel. Aquatic vessels using Alexander Springs Creek are limited to canoes, kayaks and smaller private motor vessels that may occasionally access the lower reaches of the creek from the St. Johns River. As such, this WRV is currently not present at Alexander Springs Creek and will not be evaluated as part of this WRV assessment.

6.0 CONCLUSIONS

An evaluation was conducted to determine if the recommended MFLs for Alexander Springs as presented in Freese and Sutherland (2017) protects the 10 WRVs defined in Rule 62-40.473, *F.A.C.*

The WRV evaluations for Alexander Springs and Alexander Springs Creek were conducted using an event-based analysis of changes in return intervals for critical flow events between no-pumping conditions and the recommended MFLs hydrologic regimes, where possible. Not all WRVs were evaluated using this approach. WRV-10 (Navigation) does not exist in Alexander Springs Creek. WRV-3 (Estuarine Resources), WRV-5 (Water Supply), WRV-8 (Sediment Loads) and WRV-9 (Water Quality) did not reveal critical events that could be evaluated using the event-based approach. WRV-1 (Recreation In and On the Water), WRV-2 (Fish, Wildlife and the Passage of Fish), WRV-4 (Transfer of Detrital material), WRV-6 Aesthetics) and WRV-7 (Filtration and Absorption of Nutrients and Other Pollutants) were evaluated using this approach.

The development of the two hydrologic regimes is discussed in detail in Karama and Gordu (2017). More specifically, the return intervals (frequency of occurrence) of hydrologic conditions from which one may infer protection of the WRVs were evaluated under no-pumping conditions and MFLs hydrologic regimes. The resource value was determined to be protected if the frequency of occurrence of these key events under the MFLs hydrologic regime did not differ unacceptably from the no-pumping condition based available data, literature research and professional judgment where necessary (Table 6-1). Table 6-1 provides a summary of the WRV assessment.

WRV 1 (Recreation In and On Water) is considered protected. Given that the relative frequency of the low-water events remains on average once every 1 to 2 years, this WRV is considered protected under the proposed MFLs hydrologic regime.

WRV-2 (Fish and Wildlife Habitats and the Passage of Fish) was considered to be one of the more sensitive WRVs. The analysis concluded that it is protected with respect to fish and velocities to protect fish and shellfish habitats. The analysis with respect to floodplain inundation to protect hydric soils concluded that hydric soils would be protected under the proposed

Alexander Springs MFLs. Wetland communities and associated fauna within the floodplain were also determined to be protected.

WRV-3 (Estuarine Resources) and WRV-5 (Maintenance of Freshwater Storage and Supply) were found to be protected. For WRV-3, the contribution of Alexander Springs to downstream estuarine resources is contained within the cumulative contributions of other flow reductions evaluated in the St. Johns River Water Supply Impact Study (WSIS) for which estuarine resource protection is one of the major considerations. The WSIS concluded that the proposed and assessed flow reductions do not cause harm to estuarine resources. Therefore, flow reductions associated with Alexander Springs MFL will be protective of WRV-3 since Alexander Springs future contribution to flow reductions to the lower St. Johns River will have been accounted for. Under any circumstances flows from Alexander Springs are small relative to flows of the entire St. Johns River system. Protection of WRV-5 under the preliminary Alexander Springs MFLs is related to non-consumptive uses and environmental values. This WRV is encompassed in the other nine (9) WRVs. Given that those evaluations concluded that all nine WRVs are protected, it is concluded that WRV-5 is also protected by the draft MFLs.

WRV-4 (Transfer of Detrital Material) and WRV-7 (Filtration and Absorption of Nutrients and Other Pollutants) were also considered to be two of the more sensitive WRVs evaluated. The sensitivities are primarily related to a lowering in floodplain inundation frequency. The major factor that would be affected by flow reductions allowed under the recommended MFLs would be the reduction in the frequency of physical contact of water with riparian, or floodplain vegetation. The preliminary MFL was considered to be protective as it prevents unacceptable reductions in contact time with the floodplain, which is important for maintaining these characteristics.

Changes in velocities associated with flow reductions allowed under the preliminary MFLs were also evaluated. WRV-8 (Sediment Loads), Algal Scour and aspects of WRV-4 (Transfer of Detrital Material) and WRV-7 (Filtration and Absorption of Nutrients and Other Pollutants) have a velocity dependence associated with their function. were considered protected under all scenarios with respect to velocity. Given the small decrease, 0.05 ft/sec or less, in average in-channel velocities anticipated, these WRVs should be protected under the preliminary Alexander Springs MFLs.

The assessment of WRV-9, (Water Quality), found no important relationships between flow rates or water levels and water quality trends in Alexander Springs and Alexander Springs Creek. Given the general lack of significant changes in water quality with changes in flows, there will be some improvement in such water quality constituents as inorganic nitrogen (NOx) concentrations and no apparent degradation in other constituents.

Table 6-1. Summary results for WRV evaluation of the recommended MFLs Hydrologic Regime

Water Resource Value (WRV)	MFLs Hydrologic Regime Protective?
WRV-1: Recreation In and On the Water	Yes
WRV-2: Fish and Wildlife Habitats and the Passage of Fish	
Fish Passage	Yes
Fish/Shellfish Habitat (flow velocity related issues)	Yes
Floodplain Inundation (wetland communities)	Yes
Floodplain Inundation (hydric soils)	Yes
WRV-3: Estuarine Resources	Yes
WRV-4: Transfer of Detrital Material	Yes
WRV-5: Maintenance of Freshwater Storage and Supply	Yes
WRV-6: Aesthetic and Scenic Attributes	Yes
WRV-7: Filtration and Absorption of Nutrients and Other Pollutants	Yes
WRV-8: Sediment Loads	Yes
WRV-9: Water Quality	Yes
WRV-10: Navigation	Not Applicable

REFERENCES

Applied Technology and Management, Inc. (ATM) 2012. Evaluation of the Effects of Hypothetical Flow Reductions on Water Resource Values of Silver Springs and the Silver River, Marion County. Final Report. Prepared for St. Johns River Water Management District (SJRWMD). Gainesville, FL.

Battelle. 2004. Final Report: Sensitivities of Filtration and Absorption of Nutrients and Other Pollutants and Water Quality to Alterations in Hydrologic Regimes. Special Publication SJ2004-SP37, http://www.floridaswater.com/technicalreports/pdfs/SP/SJ2004-SP37.pdf. St. Johns River Water Management District, Palatka, FL.

Cohen, M.J., J.B. Heffernan, A. Albertin, R. Hensley, M. Fork, Foster, and L. Korhnak. 2011. Mechanisms of Nitrogen Removal in Spring-Fed Rivers. Final Report to the St. Johns River Water Management District (SJRWMD).

Everest E R., Armantrout, N.B., Nickerson, T.E., Keller, S.M., Johnson, J.M., Parante, W. D., and Haugen, G. N. 1985. Salmonids. Management of Wildlife and Fish Habitats in Forests of Western Oregon and Washington - Part 1. Brown E.R., ed. USDA Forest Service. pp 199-230.

Federal Interagency Stream Restoration Working Group (FISRWG). 1998. Stream Corridor Restoration. Principles, Processes, and Practices. Federal Interagency Stream Restoration Working Group. Washington DC.

Florida Department of Environmental Protection (FDEP). 2006. 62-302.530, Criteria for Surface Water Quality Classifications. www.dep.state.fl.us/water/wqssp/classes.htm#criteria/302-Table.doc. Sept. 7, 2010.

Florida Department of Environmental Protection (FDEP). 2008a. Basis for the Proposed Nitrate-Nitrite Criterion for Spring Vents. Triennial Review of State Surface Water Quality Standards, Nitrate Criterion Workshop, July 2008. www.dep.state.fl.us/water/wqssp/tr_review.htm/nitrate-criterion.pdf. Dec. 8, 2008.

Florida Department of Environmental Protection (FDEP). 2008b. Chapter 62-302, Surface Water Quality Standards, Draft 7-1-08. www.dep.state.fl.us/water/wqssp/docs/tr_review/62-302-full-draft_7-1-08.pdf. Sept. 12, 2010.

Florida Department of Environmental Protection (FDEP) and Florida Greenways Coordinating Council. 1998. Connecting Florida's Communities with Greenways and Trails – Five Year Implementation Plan

Freese, R. and A. Sutherland. 2017. Minimum Flow Determination for Alexander Springs Lake County, Florida. Technical Publication SJ2017-XX. St. Johns River Water Management District. Palatka, FL.

Hamilton, P., and D. Helsel. 1995. Effects of Agriculture on Groundwater Quality in Five Regions of the United States. Ground Water 33:217-226.

Heffernan, J.B., D.M. Liebowitz, T.K. Frazer, J.M. Evans, and M.J. Cohen. 2010. Algal Blooms and the Nitrogen-Enrichment Hypothesis in Florida Springs: Evidence, Alternatives, and Adaptive Management. Ecological Applications, 20: 816-829.

Hill, A.R. and D.J. Lymburner. 1998. Hyporheic Zone Chemistry and Stream-Subsurface Exchange in Two Groundwater-Fed Streams. Canadian Journal of Fisheries and Aquatic Sciences 55: 495-506.

Hill, A.R., C.F. Labadia, and K. Sanmugadas. 1998. Hyporheic Zone Hydrology and Nitrogen Dynamics in Relation to the Streambed Topography of an N-Rich Stream. Biogeochemistry 42: 285-310.

Hjulstrom, F. 1935. The Morphological Activity of River as Illustrated by River Fyris. Bulletin of the Geological Institute, Uppsala, 25(3).

Hoyer, M.V, T.K. Fraser, S.K. Notestein and D.E. Canfield. 2004. Vegetative Characteristics of Three Low-Lying Florida Coastal Rivers in Relation to Flow, Light, Salinity, And Nutrients. Hydrobiologia 528: 31-43.

Karama, A., and F. Gordu. 2017. Development of Flow and Stage Time Series at MFL Transects of Alexander Springs and Alexander Springs Creek. Technical Memorandum. St. Johns River Water Management District, Palatka, FL.

Kat, P.W. 1972. Shell Dissolution as a Significant Cause of Mortality for *Corbicula fluminea* (*Bivalvia:Corbiculidae*) Inhabiting Acidic Waters. Malacol Rev 15:129–134.

King, S.A. 2012. Effects of Flow on Filamentous Algae and Nutrient Limitation in Lotic Systems. Ph. D. dissertation, University of Florida, Gainesville, FL.

Knowles, L., Jr., A.M. O'Reilly, and J.C. Adamski. 2002. Hydrology and Simulated Effects of Ground-Water Withdrawals from the Floridan Aquifer System in Lake County and in the Ocala National Forest and Vicinity, North-Central Florida. U.S. Geological Survey Water-Resources Investigation Report 02-4207, 140 p.

Mehta, A.J., E.J. Hayter, and R. Kirby. 2004. Sediment Transport and Detritial Transfer Related to Minimum Flows and Levels. Special Publication SJ2004-SP31 http://www.floridaswater.com/technicalreports/pdfs/SP/SJ2004-SP31.pdf. St. Johns River Water Management District. Palatka, Florida.

Mitsch, W.J. and J.G. Gosselink. 2007. Wetlands. Van Nostrand Reinhold. New York, New York.

Motz, L.H., and A. Dogan. 2002. Revised North Central Florida Regional Groundwater Flow Model. Prepared for St. Johns River Water Management District. 107 p.

Munch D.A., D.J. Toth, C. Huang, J.B. Davis, C.M. Fortich, W.L. Osburn, E.J. Phlips, E.L. Quinlan, M.S. Allen, M.J. Woods, P. Cooney, R.L. Knight, R.A. Clarke, S.L. Knight. 2006. Fifty-Year Retrospective Study of the Ecology of Silver Springs, Florida. Prepared by St. Johns River Water Management District, University of Florida Department of Fisheries and Aquatic Sciences, Wetland Solutions Inc. Special Publication SJ2007-SP4. http://www.sjrwmd.com/technicalreports/pdfs/SP/SJ2007-SP4.pdf. St. Johns River Water Management District. Palatka, FL.

Neubauer, C.P., G.B. Hall, E.F. Lowe, C. Robinson, R. Hupalo, and L.W. Keenan. 2008. Minimum Flows and Levels Method of the St. Johns River Water Management District, Florida, USA. Environmental Management 42:1101-1114.

Odum, E.P. 1971. Fundamentals of Ecology, Third Edition. W.B. Saunders Company. Philadelphia, PA. 574 p.

Odum, H.T. 1957. Trophic Structure and Productivity of Silver Springs, Florida. Ecological Monographs 27:55-112.

Osburn, W., D. Toth, and D. Boniol. 2006. *Springs of the St. Johns River Water Management District. Technical Publication SJ2006-3,* http://floridaswater.com/springs/index.html*. St. Johns River Water Management District, Palatka, FL.*

Ponnamperuma, F.N. 1972. The Chemistry of Submerged Soils. Adv. Agron. 24, 29-96.

Rosenau, J.C., G.L. Faulkner, C.W. Hendry Jr., and R.W. Hull. 1977. Springs of Florida. Geological Bulletin No. 31, Revised http://ufdc.ufl.edu/UF00000232/00002/3j. Florida Geological Survey. Tallahassee, FL.

Scott, T.M., G.H. Means, R.P. Meegan, R.C. Means, S.B. Upchurch, R.E. Copeland, J. Jones, T. Roberts, and A. Willet. 2004. Springs of Florida. Bulletin No. 66. Tallahassee, FL: Florida Geological Survey. 677 p.

Sepúlvedan, N. 2002. Simulation of Ground-Water Flow in the Intermediate and Floridan Aquifer System in Peninsular Florida. U.S. Geological Survey Water-Resources Investigation Report 02-4009, 130 p.

Shields, A. 1936. "Anwendung der Aehnlichkeitsmechanik und der Turbulenzforschung auf die Geschiebebewegung", Mitteilungen der Preussischen Versuchsanstalt für Wasserbau und Schiffbau, Berlin, 26.

Shoemaker, W.B., A.M. O'Reilly, N. Sepúlvedan, S.A. Williams, L.H. Motz, and Q. Sun. 2004. Comparison of Estimated Areas Contributing Recharge to Selected Springs in North-Central Florida by Using Multiple Ground-Water Flow Models. Prepared in Cooperation with St. Johns River Water Management District and the Florida Department of Environmental Protection. U.S. Geological Survey Open-File Report 03-448. Tallahassee, FL.

St. Johns River Water Management District (SJRWMD). 2006. Minimum Flows and Levels Methods Manual Version 2.0. Prepared by Environmental Assessment Section Division of Water Supply Planning Department of Resource Management. Palatka, FL.

St. Johns River Water Management District (SJRWMD). 2010. Applicant's Handbook: Regulation of Stormwater Management Systems Chapter 40C-42, *F.A.C.* http://www.sjrwmd.com/handbooks/stormwaterhandbook.html

St. Johns River Water Management District (SJRWMD). 2012. St. Johns River Water Supply Impact Study. Technical Publication SJ2012-1. Palatka, FL.

Stevenson, R.J., A. Pinowska, A. Albertin and J.O. Sickman. 2007. Ecological Condition of Algae and Nutrients in Florida Springs: The Synthesis Report. http://publicfiles.dep.state.fl.us/dear/sas/library/docs/springs/synthesisreport.pdf DEP Contract WM858, submitted to the Florida Department of Environmental Protection, Tallahassee, FL, by the Department of Zoology, Michigan State University, East Lansing, MI.

U.S. Bureau of Reclamation (USBR). 2006. Erosion and Sedimentation Manual. Washington, D.C.

Upchurch, S.B., 1992. Quality of Waters in Florida's Aquifers. In G.L. Maddox, J.M. Lloyd, T.M. Scott, S.B. Upchurch, and R. Copeland (eds.), Florida Ground Water Quality Monitoring Program – Volume 2, Background Hydrogeochemistry, Florida Geological Survey, Special Publication No. 34, Ch. IV, pp. 12-52, 64-84, 90-347.

Walsh, S.J., L. Knowles, Jr., B.G. Katz, D.G. Strom. 2009. Hydrology, Water Quality, and Aquatic Communities of Selected Springs in the St. Johns River Water Management District, Florida. Prepared by U.S. Department of the Interior and U.S. Geological Survey, in cooperation with St. Johns River Water Management District (SJRWMD). Scientific Investigations Report 2009-5046.

Wetland Solutions, Inc. (WSI) 2007. Pollutant Load Reduction Goal (PLRG) Analysis for the Wekiva River and Rock Springs Run, Florida 2006-2007. Final Phase 3 Report. Prepared for St. Johns River Water Management District

Wetland Solutions, Inc. (WSI). 2010. An Ecosystem-Level Study of Florida's Springs. Final Report. Prepared for Florida Fish and Wildlife Conservation Commission, St. Johns River Water Management District, Southwest Florida Water Management District, Florida Park Service, Florida Springs Initiative, and Three Rivers Trust, Inc. FWC Project Agreement No. 08010

Wetzel, R.G. 1975. Limnology. W.B. Saunders Co., Philadelphia. 743 p.

Wetzel, R.G. 2001. Limnology, 3rd Ed. Elsevier Academic Press, San Diego, California

Yang, C.T. 2006. Noncohesive Sediment Transport. In: Erosion and Sedimentation Manual. United States Bureau of Reclamation, Washington, D.C.

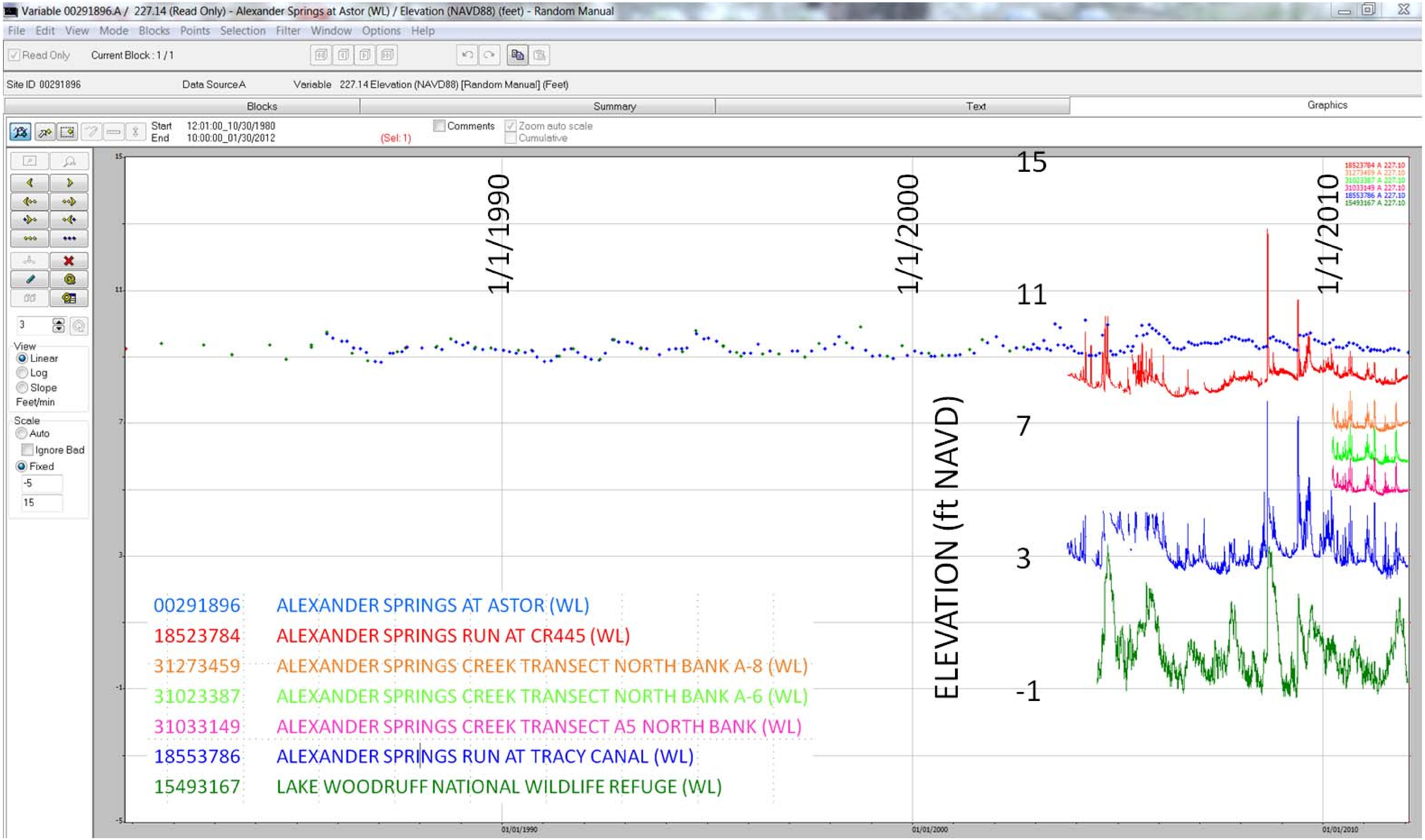
Appendix A

Gaging Station Descriptions and Transects

HYDSTRA (DATA AVAILABLE TO *PRESENT* (7/15/2013)]

HYDSTRA	FEATURE NAME	START	STOP	STATS
00291896	ALEXANDER SPRINGS AT ASTOR (WL)			
	RANDOM MANUAL WL	10/30/1990	1/30/2012	[MAX 10.10 ft NAVD, MIN 8.84 ft NAVD]
	*DISCHARGE (RANDOM)	2/12/1931	1/30/2012	[MAX 202.19 cfs, MIN 60 cfs (5/24/2000), N=255]
18523784	ALEXANDER SPRINGS RUN AT CR445 (WL)			
	CONTINUOUS WL	10/8/2003	4/3/2012	[MAX 12.87 ft NAVD, MIN 7.81 ft NAVD]
	RANDOM MANUAL WL	11/19/2003	3/11/2013	[MAX 9.97 ft NAVD, MIN 7.83 ft NAVD]
	*DISCHARGE (RANDOM)	11/19/2003	4/3/2012	[MAX 328 cfs, MIN 84 cfs]
	*DISCHARGE (EST DAILY MEAN)	10/1/2003	4/3/2012	[MAX 1340 cfs, MIN 89 cfs]
31273459	ALEXANDER SPRINGS CREEK TRANSECT NORTH BANK A-8 (WL)			
	CONTINUOUS WL	3/24/2010	3/11/2013	[MAX 8.79 ft NAVD, MIN 6.79 ft NAVD]
	RANDOM MANUAL WL	3/23/2010	3/11/2013	[MAX 8.33 ft NAVD, MIN 6.79 ft NAVD]
31023387	ALEXANDER SPRINGS CREEK TRANSECT NORTH BANK A-6 (WL)			
	CONTINUOUS WL	3/24/2010	3/11/2013	[MAX 7.88 ft NAVD, MIN 5.76 ft NAVD]
	RANDOM MANUAL WL	3/23/2010	3/11/2013	[MAX 7.15 ft NAVD, MIN 5.8 ft NAVD]
31033149	ALEXANDER SPRINGS CREEK TRANSECT A5 NORTH BANK (WL)			
	CONTINUOUS WL	3/24/2010	3/11/2013	[MAX 6.95 ft NAVD, MIN 4.83 ft NAVD]
	RANDOM MANUAL WL	3/23/2010	3/11/2013	[MAX 6.23 ft NAVD, MIN 4.90 ft NAVD]
18553786	ALEXANDER SPRINGS RUN AT TRACY CANAL (WL)			
	CONTINUOUS (WL)	10/9/2003	6/5/2013	[MAX 7.70 ft NAVD, MIN 2.31 ft NAVD]
	RANDOM MANUAL WL	11/19/2003	6/5/2013	[MAX 6.17 ft NAVD, MIN 2.5 ft NAVD]
	DISCHARGE (RANDOM)	11/19/2003	6/5/2013	[MAX 388 cfs, MIN 86.1 cfs]
	DISCHARGE (EST DAILY MEAN)	10/1/2003	6/5/2013	[MAX 1870 cfs, MIN 79.82 cfs]
15493167	LAKE WOODRUFF NATIONAL WILDLIFE REFUGE (WL)			
	CONTINUOUS WL	6/30/2004	3/7/2013	[MAX 3.34 ft NAVD, MIN -1.27 ft NAVD]
	RANDOM MANUAL WL	6/5/2001	3/7/2013	[MAX 2.20 ft NAVD, MIN -1.23 ft NAVD]

* DISCONTINUED



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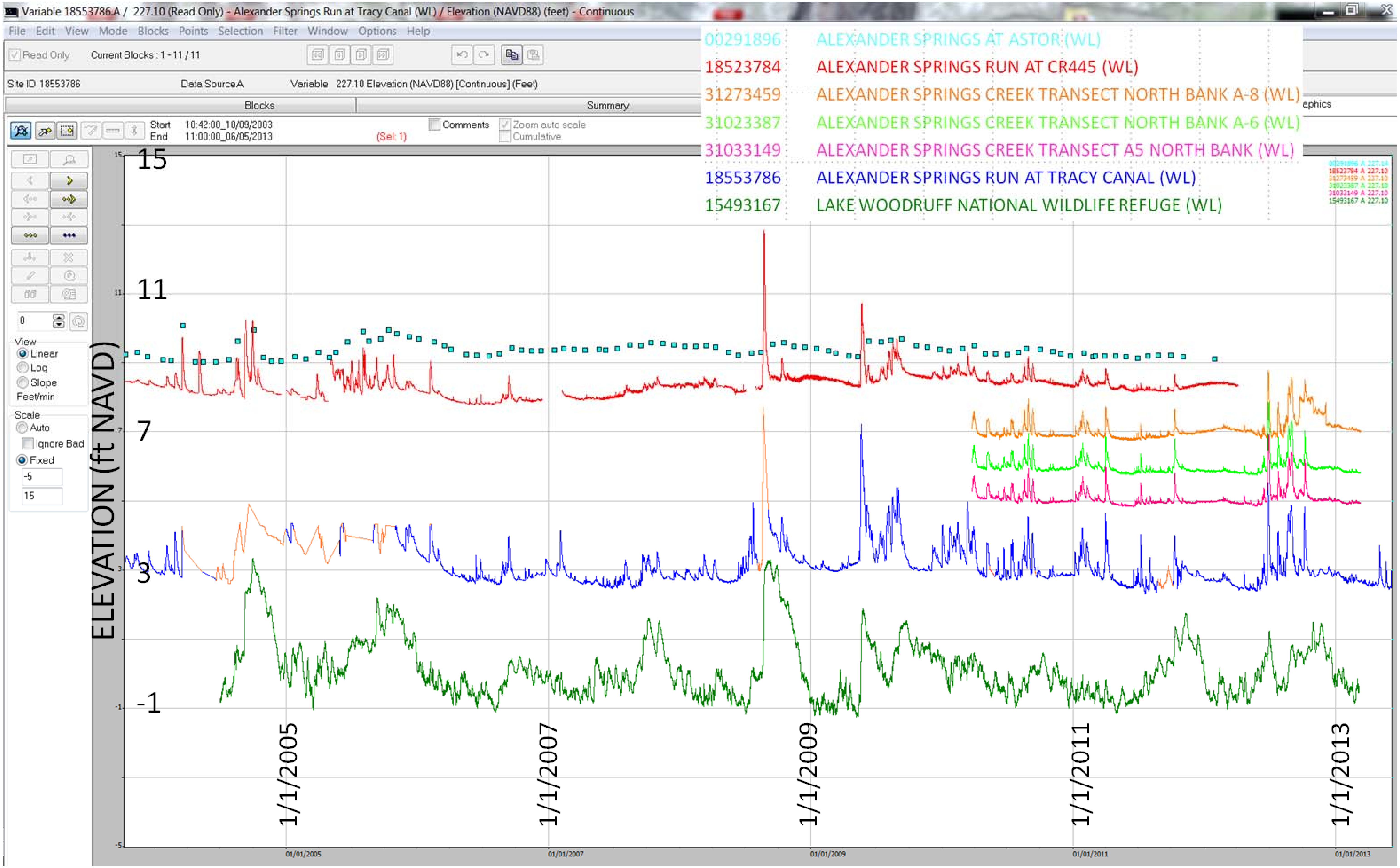
Blocks Summary Text Graphics
Start 12:01:00_10/30/1980
End 10:00:00_01/30/2012
(Sel: 1)
Comments
Zoom auto scale
Cumulative
View
Linear
Log
Slope
Feet/min
Scale
Auto
Ignore Bad
Fixed
-5
15
1/1/1990
1/1/2000
1/1/2010
15
11
7
3
-1
ELEVATION (ft NAVD)
00291896 ALEXANDER SPRINGS AT ASTOR (WL)
18523784 ALEXANDER SPRINGS RUN AT CR445 (WL)
31273459 ALEXANDER SPRINGS CREEK TRANSECT NORTH BANK A-8 (WL)
31023387 ALEXANDER SPRINGS CREEK TRANSECT NORTH BANK A-6 (WL)
31033149 ALEXANDER SPRINGS CREEK TRANSECT A5 NORTH BANK (WL)
18553786 ALEXANDER SPRINGS RUN AT TRACY CANAL (WL)
15493167 LAKE WOODRUFF NATIONAL WILDLIFE REFUGE (WL)
01/01/1990
01/01/2000
01/01/2010

PRELIMINARY DATA – SUBJECT TO CHANGE: Alexander Spring Creek



Appendix E

Frequency Analysis Tables

Discharge – Baseline
Stage – Baseline
Discharge – MFL
Stage – MFL

Frequency Analysis Tables

Discharge – Baseline

31 yrs HIs: Simulated Discharges at Alexander Creek (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
3.13	813.69	597.31	425.77	292.39	236.96	196.52	168.03	156.13	133.08	118.70
6.25	490.65	416.78	348.00	262.72	215.18	194.85	164.51	154.12	124.48	118.66
9.38	484.72	406.12	323.82	262.18	195.69	178.02	162.58	139.79	123.36	109.97
12.50	420.08	362.56	284.98	241.05	194.75	177.02	158.74	137.20	118.55	108.52
15.63	323.39	300.15	277.47	234.70	194.42	172.83	154.81	134.18	115.08	104.99
18.75	310.47	284.83	272.63	233.76	191.36	170.27	149.98	123.36	114.65	103.64
21.88	291.92	267.43	259.41	231.58	186.56	162.40	141.77	120.92	113.40	103.32
25.00	291.85	258.60	255.45	222.62	185.93	155.32	139.89	119.56	112.31	101.83
28.13	288.90	257.40	250.64	210.08	182.37	148.54	138.02	117.79	109.54	101.44
31.25	281.95	255.93	239.80	210.07	181.55	148.14	137.22	115.62	107.43	101.15
34.38	272.21	246.84	237.93	203.00	180.23	145.97	135.47	115.08	107.23	100.65
37.50	267.37	245.22	229.85	201.57	178.50	142.06	133.53	114.97	105.51	97.64
40.63	259.69	241.82	228.29	190.10	173.62	141.77	132.96	114.21	105.02	97.46
43.75	254.30	241.79	225.95	186.41	170.73	141.58	127.13	113.40	104.30	96.68
46.88	250.57	240.92	223.19	180.43	168.89	139.89	123.96	112.43	103.65	95.23
50.00	248.63	239.99	217.76	174.13	163.80	137.39	120.92	112.40	103.64	94.16
53.13	247.86	232.61	215.53	173.13	159.22	135.00	120.59	110.42	102.24	94.03
56.25	238.75	226.69	204.65	169.01	152.60	131.47	119.87	109.35	101.13	93.98
59.38	237.06	225.47	192.40	168.51	152.49	131.31	118.36	107.43	100.99	93.65
62.50	203.58	200.64	190.26	165.26	146.51	129.47	118.10	105.14	99.11	93.04
65.63	203.39	195.04	177.43	162.06	145.65	127.57	116.12	104.26	99.03	92.39
68.75	198.17	190.09	177.37	157.75	142.32	122.69	114.99	102.05	98.73	92.15
71.88	197.84	187.73	174.39	149.17	130.69	122.31	114.97	101.33	96.87	92.13
75.00	197.50	185.41	170.72	147.62	128.07	119.13	113.84	101.31	96.74	91.85
78.13	180.51	176.63	170.17	146.88	124.23	117.14	109.86	100.65	96.57	91.67
81.25	179.53	173.79	163.17	143.02	122.31	110.35	107.96	98.94	96.35	90.17
84.38	169.03	165.31	154.43	142.71	121.86	109.86	106.11	98.29	95.66	88.41
87.50	167.84	162.34	150.06	137.57	120.36	109.34	105.34	98.09	94.23	88.20
90.63	165.46	161.07	149.32	129.13	118.77	108.78	105.06	97.13	91.67	87.49
93.75	163.09	159.60	146.34	128.27	117.61	106.16	101.18	96.87	91.39	70.15
96.88	134.43	128.25	125.34	115.90	106.92	106.11	99.84	96.57	81.22	60.62

31 yrs LOs: Simulated Discharges at Alexander Creek (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	124.48	125.23	126.53	127.34	135.03	145.70	149.40	169.35	175.36	185.13
93.75	118.66	119.49	120.58	125.02	131.97	142.21	144.38	155.15	162.05	175.73
90.63	117.79	118.15	118.91	120.40	131.46	134.61	143.87	148.10	159.99	168.15
87.50	113.40	113.74	115.21	116.93	123.59	134.10	133.97	138.83	154.94	163.62
84.38	112.57	113.70	114.05	116.37	123.17	129.32	133.46	138.51	152.47	163.48
81.25	105.51	105.96	106.37	106.97	110.74	114.40	114.27	123.80	146.60	154.67
78.13	104.98	105.24	105.36	106.65	109.34	110.48	113.81	122.71	138.83	153.71
75.00	103.64	104.38	105.32	105.91	108.82	109.56	112.47	121.34	138.25	152.92
71.88	101.83	103.29	104.46	105.54	108.17	109.42	111.21	117.46	137.20	151.36
68.75	101.44	103.01	104.34	104.87	107.12	109.01	110.99	116.86	134.40	147.34
65.63	101.15	102.02	102.05	103.26	106.28	107.23	110.80	115.54	131.13	146.29
62.50	100.99	101.16	101.52	102.52	104.20	107.21	110.20	114.44	129.61	145.20
59.38	97.64	98.72	100.70	102.22	104.16	106.36	109.13	113.76	123.15	136.45
56.25	97.46	98.37	100.04	101.86	103.08	106.20	108.82	113.43	119.27	135.82
53.13	96.87	97.85	98.05	100.81	102.94	105.27	108.06	112.17	118.74	135.41
50.00	96.68	97.32	97.68	100.05	102.47	105.15	107.61	112.09	118.04	133.71
46.88	95.66	96.03	97.66	98.90	102.03	105.00	107.10	111.77	117.79	133.30
43.75	95.23	95.77	97.05	98.47	101.86	104.50	106.49	111.56	115.93	131.81
40.63	94.16	95.64	96.44	98.23	101.75	103.46	106.39	110.63	115.84	131.20
37.50	94.03	94.87	96.13	98.16	100.02	103.09	105.84	110.36	115.36	131.03
34.38	93.65	94.69	95.91	97.40	99.33	102.62	105.52	109.42	115.18	129.97
31.25	93.04	94.56	95.20	96.31	99.25	102.55	104.49	109.39	112.96	129.83
28.13	92.13	94.39	94.87	96.09	98.05	100.93	102.64	107.63	111.26	129.36
25.00	91.85	92.92	93.91	95.59	97.59	100.77	101.90	105.65	110.33	127.74
21.88	91.67	92.15	92.69	93.75	96.99	97.59	100.56	102.84	110.10	127.46
18.75	91.39	91.86	92.32	93.48	96.32	96.83	97.70	102.23	107.84	125.39
15.63	88.41	90.29	91.79	93.45	95.32	95.62	96.06	100.51	106.98	120.98
12.50	88.20	89.55	90.73	91.86	94.74	95.03	96.00	99.68	105.48	116.38
9.38	87.49	87.54	87.65	88.62	91.86	94.35	95.76	98.51	104.57	111.91
6.25	81.22	81.95	82.10	83.46	86.84	90.70	95.30	97.98	103.95	110.36
3.13	60.62	61.45	62.86	66.07	72.74	78.67	83.54	90.79	100.49	103.49

31 yrs LOs: Simulated Discharges at Alexander Creek (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	124.48	126.06	129.03	140.74	172.78	188.86	188.86	239.76	420.08	813.69
93.75	118.66	120.90	122.58	131.91	159.24	175.76	185.12	210.82	314.79	490.65
90.63	117.79	118.63	121.20	129.85	144.44	170.26	179.53	203.39	291.85	484.72
87.50	113.40	114.76	119.21	123.70	141.43	149.79	149.79	194.67	265.91	439.75
84.38	112.57	113.82	115.25	119.58	135.13	142.79	148.20	184.49	261.19	420.08
81.25	105.51	106.55	107.40	109.80	124.02	127.40	139.61	179.66	250.57	323.39
78.13	104.98	105.45	107.11	109.78	123.74	125.13	136.52	172.11	247.86	310.47
75.00	103.64	105.39	106.63	109.39	116.65	124.89	131.64	162.52	245.37	299.13
71.88	101.83	105.15	106.08	108.58	116.57	124.22	131.36	161.91	213.41	291.92
68.75	101.44	104.76	105.45	107.65	116.39	123.09	130.56	161.13	212.76	291.85
65.63	101.15	102.20	103.65	107.25	116.24	121.25	130.18	159.64	209.14	281.57
62.50	100.99	101.36	103.64	107.12	115.40	120.75	129.38	158.11	191.79	272.21
59.38	97.64	100.12	102.28	106.40	114.56	118.51	129.23	152.71	186.30	267.37
56.25	97.46	99.66	102.26	104.97	112.07	118.19	124.70	148.68	172.11	267.31
53.13	96.87	98.67	101.89	104.90	111.18	117.91	123.51	147.05	167.98	261.13
50.00	96.68	97.99	101.31	102.85	110.45	117.64	122.87	142.81	167.84	259.69
46.88	95.66	97.96	98.99	102.82	110.09	114.37	122.32	141.18	166.65	254.30
43.75	95.23	97.39	98.45	102.32	108.97	113.10	122.20	139.61	165.46	250.57
40.63	94.16	96.73	98.35	101.82	106.85	111.90	121.68	133.25	161.13	248.63
37.50	94.03	96.22	97.47	101.00	106.44	111.89	120.73	132.92	159.64	247.03
34.38	93.65	95.98	96.73	100.86	105.81	110.68	119.59	130.18	158.88	245.83
31.25	93.04	95.23	96.51	99.32	105.43	110.67	116.60	129.18	157.09	237.06
28.13	92.13	94.77	96.38	99.14	105.29	109.82	116.07	127.23	153.42	226.87
25.00	91.85	94.00	96.27	98.37	105.15	108.25	115.12	123.51	152.71	211.48
21.88	91.67	92.74	96.05	97.87	103.98	107.82	114.37	123.14	152.45	209.14
18.75	91.39	92.53	94.44	97.37	102.68	106.16	110.67	119.87	152.23	206.16
15.63	88.41	92.19	94.10	95.77	102.47	105.81	110.39	115.29	140.16	203.38
12.50	88.20	91.32	93.91	95.50	99.98	102.57	105.96	110.78	137.97	198.17
9.38	87.49	87.60	87.95	90.70	98.66	100.54	104.08	110.62	134.77	154.50
6.25	81.22	82.64	82.66	87.54	93.77	99.66	102.02	110.39	123.59	150.88
3.13	60.62	62.35	65.42	71.83	86.95	98.27	101.66	108.75	116.39	132.37

31 yrs HIs: Computed Discharge (cfs) at Alexander Creek A5 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
3.13	768.20	491.27	373.69	253.71	202.59	182.97	161.75	156.04	133.51	119.88
6.25	469.47	360.94	304.65	239.65	198.71	181.56	158.09	145.70	124.86	119.04
9.38	468.60	355.42	279.28	231.29	192.57	173.63	154.41	134.84	123.69	109.50
12.50	395.37	351.80	257.15	224.19	184.78	173.58	154.31	134.24	117.53	108.54
15.63	308.65	281.45	253.13	220.31	181.03	167.30	146.76	134.21	114.70	104.99
18.75	295.87	253.43	242.79	217.28	176.85	164.16	137.65	123.69	114.55	103.90
21.88	277.00	245.57	238.94	210.70	176.56	153.41	134.98	120.21	113.66	103.78
25.00	270.84	242.96	234.09	210.36	175.44	149.14	134.89	118.75	112.61	103.06
28.13	265.66	238.18	232.17	202.40	172.58	139.76	134.81	117.36	108.58	101.61
31.25	255.14	237.33	225.98	190.60	169.72	139.30	134.14	115.77	107.92	101.52
34.38	250.21	233.90	218.82	185.16	166.02	138.31	133.59	114.55	107.50	100.37
37.50	238.24	229.87	209.74	181.50	165.63	137.86	131.66	114.26	106.21	98.62
40.63	237.18	223.13	205.09	175.70	162.69	136.83	131.20	114.06	105.11	98.37
43.75	231.42	220.66	199.13	167.84	158.67	136.35	123.85	113.66	104.54	97.75
46.88	225.33	215.31	194.53	167.48	153.67	135.88	122.51	112.98	103.78	96.30
50.00	224.96	209.61	194.45	166.05	150.58	134.93	120.23	112.44	102.66	94.87
53.13	217.40	208.37	191.20	162.14	150.41	132.01	120.21	109.95	102.64	94.85
56.25	205.81	199.93	185.14	161.74	148.70	130.88	118.60	109.74	102.04	94.62
59.38	205.30	193.93	180.24	159.45	145.67	127.18	117.83	108.08	101.63	94.09
62.50	179.77	178.10	167.63	154.33	142.66	125.55	115.46	105.00	99.04	93.68
65.63	173.27	170.13	166.10	154.28	138.84	122.98	114.98	103.78	98.96	93.22
68.75	171.20	165.52	163.10	150.93	134.93	121.23	113.62	102.38	98.55	93.04
71.88	170.53	164.14	155.30	139.71	127.24	119.27	112.44	101.79	97.42	93.02
75.00	166.58	163.32	155.02	139.41	124.84	117.65	111.51	100.94	96.89	92.28
78.13	165.41	160.97	149.25	134.62	123.80	116.95	109.42	100.76	96.81	92.04
81.25	165.19	160.15	149.14	133.81	118.29	109.42	106.66	99.62	96.17	91.46
84.38	153.84	151.81	146.41	133.04	117.65	106.90	106.58	98.44	96.00	88.09
87.50	149.70	145.63	142.43	129.24	117.15	106.66	105.53	96.89	95.19	87.97
90.63	143.99	140.43	138.08	124.17	116.04	106.59	103.98	96.88	92.04	87.37
93.75	142.10	140.06	133.71	121.79	112.77	106.54	101.03	96.81	91.91	72.88
96.88	123.66	122.58	121.57	114.53	107.86	103.76	99.85	95.97	81.68	61.18

31 yrs LOs: Computed Discharge (cfs) at Alexander Creek A5 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	124.86	125.33	126.09	126.91	132.46	140.61	145.89	164.41	169.80	177.76
93.75	119.04	120.11	121.32	125.31	130.01	138.66	139.83	149.11	154.23	165.71
90.63	118.83	119.21	119.57	120.41	128.04	132.69	139.64	143.92	153.37	159.72
87.50	113.66	113.73	114.08	115.51	123.07	131.67	132.19	137.21	149.21	156.72
84.38	112.66	113.26	113.90	115.40	122.08	126.66	130.06	136.07	145.99	153.06
81.25	106.21	106.46	106.67	107.22	109.49	113.45	113.56	118.52	138.67	148.52
78.13	105.60	106.21	106.25	106.40	108.53	109.58	113.14	118.39	136.02	146.61
75.00	103.78	104.30	104.85	106.00	108.17	109.02	110.32	117.55	131.68	144.29
71.88	103.06	103.10	104.05	105.47	106.81	108.52	109.63	117.06	131.22	144.25
68.75	102.04	102.96	103.53	104.61	106.11	107.72	109.49	114.47	128.41	138.35
65.63	101.61	102.83	103.12	103.18	103.42	105.84	109.11	113.51	126.75	136.83
62.50	101.52	102.11	102.36	102.86	103.41	104.68	107.81	112.59	124.45	136.52
59.38	98.62	99.11	99.67	101.49	103.40	104.61	106.81	111.96	118.91	129.23
56.25	98.37	98.77	99.44	100.15	103.17	104.26	106.47	111.28	117.46	129.18
53.13	97.75	98.24	98.89	100.04	102.25	104.19	106.45	111.17	115.42	126.95
50.00	96.89	98.06	98.54	99.38	101.56	104.09	106.41	111.07	115.08	126.86
46.88	96.30	96.43	96.51	99.13	101.42	103.46	105.86	109.03	113.87	126.15
43.75	96.00	96.27	96.34	98.05	100.72	102.88	105.04	108.77	113.77	125.73
40.63	94.85	95.28	96.16	97.92	100.69	101.58	104.89	108.56	113.35	125.16
37.50	94.62	95.19	96.05	97.33	99.62	101.53	104.25	108.31	111.97	124.22
34.38	94.09	94.91	95.95	96.77	99.45	101.22	102.77	107.81	110.59	123.71
31.25	93.68	94.70	95.45	96.55	97.71	100.91	101.99	105.99	110.32	123.47
28.13	93.02	94.66	95.05	96.45	97.29	100.57	101.42	105.87	109.48	123.40
25.00	92.28	93.10	93.83	95.77	96.81	99.62	101.11	103.15	108.92	123.17
21.88	92.04	92.50	92.92	93.69	96.53	97.19	99.37	102.33	107.15	123.09
18.75	91.91	92.30	92.37	93.27	95.16	96.75	97.73	99.38	104.71	120.67
15.63	88.09	89.09	89.84	91.33	94.39	94.94	95.62	98.77	104.49	114.69
12.50	87.97	88.21	89.17	90.45	92.24	94.54	95.05	98.76	102.54	113.92
9.38	87.37	87.70	88.48	89.41	92.17	93.05	94.66	97.41	101.52	107.96
6.25	81.68	82.11	82.45	83.64	86.59	90.23	94.28	96.68	101.49	106.88
3.13	61.18	62.43	63.78	66.99	73.36	79.16	83.87	90.56	99.49	101.36

31 yrs LOs: Computed Discharge (cfs) at Alexander Creek A5 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	124.86	126.05	127.34	138.52	166.70	176.07	176.84	230.39	395.37	768.20
93.75	119.04	121.30	123.58	128.20	150.60	167.83	176.07	195.15	295.13	469.47
90.63	118.83	119.82	120.46	123.33	138.88	160.24	171.20	179.45	249.89	468.60
87.50	113.66	114.13	115.58	121.62	137.95	144.62	144.62	178.31	238.24	395.37
84.38	112.66	113.77	114.47	117.69	131.64	136.22	143.33	176.20	237.18	377.23
81.25	106.21	106.78	107.11	108.60	119.37	124.57	136.38	174.31	224.96	308.65
78.13	105.60	106.33	106.37	107.99	114.36	123.66	132.41	165.08	222.58	295.87
75.00	103.78	104.88	106.36	107.33	111.40	117.36	130.34	157.04	221.22	277.00
71.88	103.06	103.83	105.65	107.03	111.36	116.78	129.00	152.22	199.10	275.86
68.75	102.04	103.73	104.25	106.70	111.33	116.61	127.13	148.09	195.62	270.84
65.63	101.61	103.14	103.18	105.80	109.53	115.50	125.73	143.38	193.57	270.18
62.50	101.52	102.26	102.86	104.55	108.35	115.03	117.85	140.74	176.35	267.95
59.38	98.62	99.79	101.88	103.45	108.18	113.95	117.76	139.52	165.08	250.21
56.25	98.37	99.37	100.91	102.99	107.74	112.84	117.01	136.45	163.17	237.18
53.13	97.75	98.91	99.24	102.91	107.70	111.36	116.74	136.38	157.04	231.42
50.00	96.89	98.57	99.10	101.73	107.66	111.36	116.10	134.73	153.84	224.96
46.88	96.30	96.87	98.81	101.33	105.21	110.62	115.26	132.41	149.09	223.46
43.75	96.00	96.55	98.68	101.08	105.08	110.05	115.25	125.08	147.56	217.40
40.63	94.85	96.42	97.30	100.79	104.20	109.34	114.37	124.31	146.60	205.81
37.50	94.62	95.79	96.82	100.30	104.17	109.02	114.15	123.89	145.19	205.30
34.38	94.09	95.69	96.53	99.74	104.05	108.11	112.72	123.66	143.99	202.64
31.25	93.68	95.63	96.10	97.09	102.70	107.18	112.32	122.59	143.15	199.10
28.13	93.02	95.38	95.71	97.08	102.41	106.02	112.11	117.76	140.74	198.30
25.00	92.28	93.32	94.92	96.83	102.25	105.60	112.10	114.37	138.01	198.15
21.88	92.04	92.88	93.56	95.57	101.62	104.13	110.62	113.78	134.73	184.98
18.75	91.91	92.84	92.91	94.98	99.10	102.58	107.18	113.10	129.87	183.12
15.63	88.09	90.14	92.55	93.76	97.81	100.57	105.60	109.43	124.90	173.27
12.50	87.97	88.46	91.57	93.17	97.20	98.53	103.85	108.76	124.54	150.97
9.38	87.37	87.98	89.04	91.30	96.68	98.09	100.78	107.34	123.86	148.88
6.25	81.68	82.54	83.10	86.66	91.93	97.20	100.50	105.87	119.91	143.14
3.13	61.18	63.72	66.39	72.88	85.13	93.63	99.19	103.88	109.62	116.48

31 yrs HIs: Computed Discharge (cfs) at Alexander Creek A8 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
3.13	528.30	322.48	254.74	202.41	182.62	165.87	151.93	146.03	125.23	118.94
6.25	371.44	294.50	222.07	200.24	174.57	165.61	151.52	131.68	123.20	113.84
9.38	348.69	273.22	218.66	193.81	169.43	157.35	136.92	125.34	121.50	106.68
12.50	339.48	244.99	217.65	192.34	168.03	153.53	135.49	123.20	113.03	105.51
15.63	271.94	242.27	213.06	192.16	165.99	153.43	133.30	121.52	111.98	103.37
18.75	264.41	225.86	208.31	186.37	163.27	152.64	129.04	114.72	110.84	103.10
21.88	248.44	225.46	204.40	179.98	160.74	140.21	126.98	113.12	110.56	102.73
25.00	248.37	225.26	202.82	172.08	147.89	132.40	124.42	113.03	108.75	102.72
28.13	228.03	217.17	190.85	171.39	146.52	130.57	122.59	111.98	106.01	99.39
31.25	222.56	210.79	188.23	165.55	143.60	129.89	121.52	110.60	105.66	98.14
34.38	219.42	195.99	181.71	159.66	143.13	129.04	118.23	110.56	103.96	97.63
37.50	210.60	195.76	179.52	153.16	140.81	125.18	118.21	108.75	103.56	97.33
40.63	203.40	184.16	175.05	150.04	139.15	122.73	117.80	108.34	103.49	96.17
43.75	202.94	183.87	173.84	149.15	136.72	119.95	117.09	107.09	102.74	95.86
46.88	181.60	180.40	164.20	148.86	130.65	119.39	114.72	106.78	102.73	94.58
50.00	180.73	166.70	157.63	147.09	129.96	118.39	114.71	106.44	101.85	94.36
53.13	162.41	160.84	152.94	146.34	129.04	115.21	112.33	106.32	99.59	93.45
56.25	158.12	156.49	151.84	140.10	127.89	114.95	110.62	106.15	98.90	93.44
59.38	155.92	155.18	149.60	139.02	126.22	114.73	109.99	102.50	98.20	92.70
62.50	150.30	149.13	146.32	136.95	125.42	114.71	107.34	102.11	97.29	92.61
65.63	149.80	146.41	140.79	136.64	122.11	113.83	107.25	101.75	96.96	91.95
68.75	146.87	143.51	140.52	132.37	120.43	112.96	107.20	101.42	96.73	91.64
71.88	144.49	143.33	138.18	127.00	114.73	112.24	105.67	99.07	95.86	91.52
75.00	140.15	139.22	134.04	125.63	113.83	112.06	105.39	98.00	94.71	91.45
78.13	128.82	125.96	124.70	120.28	112.38	107.26	103.12	97.43	93.74	90.57
81.25	128.21	125.06	121.56	116.70	109.84	106.04	101.62	96.16	93.18	87.39
84.38	125.52	124.60	121.07	110.76	108.33	104.42	101.14	95.65	92.18	85.62
87.50	122.63	120.01	118.01	110.54	107.69	102.50	99.60	93.74	92.17	83.52
90.63	121.01	118.37	116.22	110.36	105.79	101.03	98.75	93.24	91.95	83.33
93.75	117.22	114.00	113.72	110.08	105.41	100.77	95.90	93.23	90.77	72.87
96.88	114.66	113.62	113.52	109.35	98.09	95.74	94.31	91.69	81.62	61.18

31 yrs LOs:	Computed Discharge (cfs) at Alexander Creek A8 (1983 - 2014).									
weib	1	7	14	30	60	90	120	180	270	1 year
96.88	120.69	123.52	124.06	124.79	126.63	132.00	138.73	155.36	159.66	165.02
93.75	118.23	118.66	118.81	121.59	126.55	131.34	131.51	138.01	140.41	148.86
90.63	114.97	116.25	117.90	119.61	121.99	128.93	131.31	134.31	139.87	144.75
87.50	110.56	110.77	111.46	113.52	120.24	125.44	129.08	131.00	138.85	144.53
84.38	109.20	110.37	111.10	112.19	118.93	120.48	122.33	125.71	134.31	136.96
81.25	105.56	105.99	106.06	106.24	106.66	107.54	111.29	112.60	133.15	135.20
78.13	102.74	103.01	103.41	104.01	105.42	107.43	109.56	111.86	124.58	134.57
75.00	102.73	102.92	103.23	103.87	104.76	106.54	108.83	111.09	118.92	131.61
71.88	102.72	102.89	102.93	102.99	103.96	106.28	108.31	111.04	118.73	127.14
68.75	101.87	101.92	102.04	102.44	103.92	105.77	106.90	109.96	118.18	124.14
65.63	99.39	100.30	100.66	102.39	103.29	104.12	105.31	109.41	117.44	119.68
62.50	98.14	98.47	99.25	101.89	103.03	103.63	104.57	108.66	115.85	117.34
59.38	97.63	98.23	98.53	98.93	100.07	101.04	102.81	108.27	113.44	117.09
56.25	97.33	98.06	98.36	98.79	99.27	100.92	101.62	106.83	111.16	116.76
53.13	96.17	96.35	96.75	97.46	98.97	100.32	101.38	106.07	110.42	116.65
50.00	95.86	96.34	96.34	96.75	98.75	99.62	101.25	105.05	109.42	116.36
46.88	94.52	94.93	95.44	96.45	98.65	99.52	100.57	104.55	109.27	115.32
43.75	93.45	93.91	93.97	95.19	96.69	99.38	99.93	103.97	108.38	115.23
40.63	92.21	92.58	92.83	94.26	96.41	97.07	99.01	103.22	106.29	114.83
37.50	92.18	92.39	92.79	93.50	95.89	96.93	97.54	103.21	106.29	114.41
34.38	91.95	92.30	92.72	93.39	94.79	96.10	97.37	102.73	105.52	113.00
31.25	91.64	92.01	92.49	93.36	94.40	95.58	97.23	100.88	105.18	112.29
28.13	91.52	91.85	92.09	93.27	94.39	94.87	97.21	99.68	104.09	111.76
25.00	90.77	90.91	91.83	93.26	94.34	94.71	96.82	98.27	101.73	110.94
21.88	90.57	90.91	91.03	91.33	92.26	94.31	95.65	98.26	100.75	109.68
18.75	87.39	87.86	88.35	90.08	91.90	93.25	95.59	97.44	98.53	109.06
15.63	85.62	85.84	86.10	87.58	91.77	92.31	93.78	94.91	96.75	107.83
12.50	83.52	84.07	84.77	85.87	88.62	90.52	92.80	94.74	96.71	103.28
9.38	83.33	83.90	84.50	84.90	87.25	89.03	90.75	92.88	96.46	100.57
6.25	81.62	82.04	82.36	83.48	86.14	88.96	90.68	92.54	96.21	100.24
3.13	61.18	62.43	63.77	66.95	73.11	78.89	83.20	89.32	95.35	97.42

31 yrs LOs: Computed Discharge (cfs) at Alexander Creek A8 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	120.69	123.87	125.26	129.34	146.58	156.43	165.87	214.82	339.48	528.30
93.75	118.23	118.88	120.62	126.11	138.69	156.34	157.90	166.61	271.94	371.44
90.63	114.97	117.80	119.62	121.98	132.70	145.67	155.92	161.73	222.56	348.69
87.50	110.56	111.68	113.29	120.31	129.56	138.12	138.12	161.14	209.26	339.48
84.38	109.20	111.00	111.72	114.39	123.94	123.94	135.28	160.09	181.60	296.80
81.25	105.56	106.18	106.33	106.73	111.57	120.25	130.79	156.11	180.73	271.94
78.13	102.74	103.36	104.11	105.84	108.68	112.87	124.81	147.80	179.23	264.41
75.00	102.73	103.12	103.80	105.61	108.29	112.47	123.32	142.16	173.17	248.44
71.88	102.72	102.93	103.16	104.95	108.04	110.86	122.54	142.06	167.67	248.37
68.75	101.87	101.97	102.34	104.68	107.44	109.30	115.05	138.49	166.61	240.88
65.63	99.39	101.08	101.81	103.87	105.07	108.97	114.84	138.27	157.04	228.03
62.50	98.14	99.81	101.30	103.25	104.91	108.42	113.62	135.28	156.97	223.74
59.38	97.63	98.59	99.00	101.50	104.50	106.74	111.59	132.11	149.80	219.42
56.25	97.33	98.34	98.75	99.93	104.15	106.52	111.55	128.82	149.15	202.94
53.13	96.17	96.93	97.70	99.92	103.80	106.45	110.44	125.52	140.15	181.60
50.00	95.86	96.50	96.60	98.98	102.86	105.36	109.96	121.73	138.58	180.73
46.88	94.52	95.31	96.35	98.96	102.64	104.73	109.30	117.08	128.82	180.54
43.75	93.45	94.18	94.38	97.03	100.86	104.48	108.11	117.03	128.21	164.37
40.63	92.21	92.96	94.29	96.03	100.42	103.53	106.84	114.66	127.94	162.41
37.50	92.18	92.84	93.44	95.51	100.16	103.14	106.74	114.43	127.21	162.02
34.38	91.95	92.78	93.44	95.26	99.27	102.67	105.11	110.65	124.98	157.04
31.25	91.64	92.48	93.41	95.22	98.17	101.68	103.74	108.31	120.27	150.96
28.13	91.52	92.42	93.33	95.13	97.65	101.17	103.58	107.60	119.82	150.30
25.00	90.77	91.43	92.88	94.60	97.41	100.82	103.14	107.45	117.26	149.80
21.88	90.57	91.09	91.55	94.05	97.10	100.73	102.87	106.21	117.22	146.87
18.75	87.39	88.28	89.28	92.86	95.87	98.27	101.31	105.14	114.54	146.58
15.63	85.62	86.07	86.61	91.28	95.84	97.69	99.81	104.16	113.67	142.32
12.50	83.52	84.96	86.20	88.23	94.96	97.42	98.83	102.93	112.79	138.32
9.38	83.33	84.24	85.66	87.83	91.82	96.25	97.98	101.68	112.77	129.87
6.25	81.62	82.44	83.02	86.23	90.54	96.16	97.31	98.86	108.55	124.72
3.13	61.18	63.72	66.37	72.87	85.06	93.25	97.13	98.03	101.48	105.04

31 yrs HIs: Computed Discharge (cfs) at Alexander Creek A10 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
3.13	495.72	284.10	223.13	197.47	181.63	163.69	151.64	144.60	121.28	118.10
6.25	347.88	261.38	209.43	196.17	164.88	151.32	137.34	120.97	119.27	107.42
9.38	334.74	249.45	208.52	176.92	161.82	150.05	132.72	120.00	118.10	106.68
12.50	309.20	230.68	192.24	171.61	153.26	147.60	127.13	119.27	108.00	105.51
15.63	251.72	216.86	189.18	165.25	152.64	142.39	125.75	114.74	107.20	102.78
18.75	243.19	214.10	188.98	162.54	150.03	138.42	120.04	109.18	106.29	101.25
21.88	234.70	213.81	181.46	160.47	143.37	130.74	118.23	108.42	105.56	99.99
25.00	224.80	210.60	177.34	158.31	138.24	126.74	118.10	108.00	105.19	98.91
28.13	219.29	200.83	175.77	155.71	136.92	124.73	115.86	107.98	103.46	98.14
31.25	219.00	196.11	173.80	155.10	132.86	122.26	115.67	106.29	103.17	97.60
34.38	207.09	184.38	168.35	146.57	130.55	119.98	115.25	106.02	102.75	97.55
37.50	201.42	183.59	167.17	141.70	130.52	119.39	114.00	105.59	101.81	96.17
40.63	192.59	174.45	165.43	140.82	130.43	118.44	112.36	105.19	100.35	95.03
43.75	190.60	172.22	165.26	139.63	124.84	116.56	111.71	104.95	99.99	94.36
46.88	172.39	171.29	154.03	139.54	124.07	116.25	109.65	104.14	98.82	94.18
50.00	169.81	157.13	147.70	136.04	123.62	114.05	108.31	102.75	98.01	92.70
53.13	150.76	149.09	143.41	134.40	123.53	110.74	106.85	101.91	97.34	90.73
56.25	149.05	147.66	143.11	133.73	123.26	109.65	106.51	101.44	97.29	90.57
59.38	146.78	145.83	140.52	131.01	120.83	109.06	105.59	100.49	96.74	90.43
62.50	146.31	142.96	140.42	129.71	117.67	108.87	105.14	99.47	95.87	90.05
65.63	141.89	137.05	132.75	127.74	116.60	107.53	104.95	99.19	95.62	89.98
68.75	138.46	136.52	131.43	126.28	115.83	107.28	103.86	99.07	95.11	89.97
71.88	137.64	135.66	131.34	121.55	110.74	106.68	103.12	97.95	94.54	89.63
75.00	131.44	130.67	126.90	119.45	108.47	106.27	102.63	97.17	92.07	89.53
78.13	123.70	120.81	118.00	116.12	107.85	106.15	101.01	96.16	91.77	88.78
81.25	121.43	119.91	117.30	111.31	107.39	105.50	100.60	94.54	91.06	85.94
84.38	121.24	119.33	116.64	109.22	107.28	104.40	98.61	92.61	90.54	84.01
87.50	118.36	114.77	113.08	109.10	105.41	99.98	97.49	92.51	89.63	83.52
90.63	117.21	114.65	112.71	108.49	104.12	99.79	97.42	92.21	88.78	81.66
93.75	114.51	113.15	112.28	107.02	102.39	98.36	93.60	91.14	88.35	72.87
96.88	114.22	111.28	110.86	106.00	95.20	94.75	92.65	90.77	81.62	61.18

31 yrs LOs: Computed Discharge (cfs) at Alexander Creek A10 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	118.10	118.39	119.80	120.53	123.55	128.91	135.54	151.90	157.30	161.43
93.75	112.22	115.78	118.54	118.75	122.25	124.35	125.58	129.99	133.95	140.41
90.63	111.89	113.16	114.84	118.65	119.86	123.33	124.56	126.60	132.62	136.21
87.50	105.56	105.96	107.04	109.19	114.06	120.48	123.52	126.55	131.27	133.49
84.38	104.68	105.82	106.03	106.18	113.36	119.20	122.29	125.36	128.73	130.84
81.25	102.75	103.07	103.50	104.64	106.49	106.95	107.67	112.19	126.26	128.69
78.13	101.87	101.89	101.94	102.24	103.22	105.68	107.61	109.25	118.60	127.37
75.00	101.25	101.35	101.57	101.85	102.87	103.94	107.00	108.81	114.17	126.09
71.88	100.35	100.66	101.00	101.84	102.39	103.49	105.18	106.99	114.12	119.77
68.75	99.99	100.14	100.38	101.11	102.19	103.05	104.90	106.35	114.09	118.41
65.63	98.91	99.64	99.90	100.58	101.45	102.80	104.03	106.25	112.20	117.35
62.50	98.14	98.47	98.53	98.79	99.95	102.16	103.65	106.16	111.54	115.03
59.38	97.55	97.84	98.07	98.59	99.60	100.82	101.21	106.00	110.37	113.83
56.25	96.17	96.34	96.34	97.91	98.96	100.24	101.05	105.49	109.78	113.54
53.13	95.03	95.52	96.06	96.45	98.75	99.29	99.68	105.18	109.33	112.87
50.00	94.42	95.08	95.93	96.25	97.22	98.00	99.62	103.24	107.85	112.17
46.88	94.18	94.66	94.80	95.19	96.69	97.44	99.31	102.38	106.66	111.82
43.75	91.06	91.43	91.83	95.19	96.33	96.93	97.16	102.32	104.83	111.08
40.63	90.90	91.15	91.72	92.55	95.07	96.06	96.82	101.60	104.24	109.78
37.50	90.77	90.91	91.16	91.99	94.37	95.71	96.79	100.81	103.66	109.61
34.38	90.57	90.91	91.09	91.83	92.70	95.28	96.61	100.71	103.43	108.43
31.25	90.05	90.43	91.03	91.33	92.26	93.29	96.59	100.10	102.78	108.33
28.13	89.97	90.27	90.79	91.32	92.11	93.17	94.90	98.25	101.89	108.22
25.00	89.53	89.68	90.59	91.22	92.10	92.87	94.59	97.89	100.17	107.40
21.88	88.78	89.07	89.37	89.91	91.93	92.73	94.15	96.73	98.75	106.49
18.75	85.94	86.45	86.75	88.45	90.31	92.62	93.94	95.25	96.37	106.01
15.63	84.01	84.11	84.77	85.86	90.00	89.76	93.40	94.45	96.15	105.93
12.50	83.52	84.07	84.22	85.51	87.23	88.89	90.68	92.50	95.87	100.73
9.38	81.66	82.23	83.14	83.48	87.00	88.82	90.58	92.25	95.69	98.51
6.25	81.62	82.04	82.36	83.45	86.11	88.82	90.27	92.08	94.05	97.29
3.13	61.18	62.43	63.77	66.91	72.79	78.40	82.63	87.75	93.19	97.02

31 yrs LOs: Computed Discharge (cfs) at Alexander Creek A10 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	118.10	119.69	120.36	125.94	139.15	152.49	162.49	211.21	309.20	495.72
93.75	112.22	118.76	118.91	121.66	134.96	148.93	148.93	156.95	238.96	347.88
90.63	111.89	114.51	117.90	119.34	128.00	138.41	146.78	155.48	219.00	334.74
87.50	105.56	107.14	108.97	115.34	123.94	131.65	135.28	150.16	184.28	309.20
84.38	104.68	106.18	106.33	107.73	121.23	123.94	134.28	146.78	172.39	267.35
81.25	102.75	103.40	104.51	106.63	107.79	114.42	122.01	144.74	169.81	251.72
78.13	101.87	101.91	102.22	103.76	107.65	112.56	120.96	142.16	168.69	243.19
75.00	101.25	101.55	102.11	103.76	107.24	108.81	120.65	137.75	163.33	234.70
71.88	100.35	100.97	101.66	103.73	104.89	108.12	117.55	137.18	157.04	229.90
68.75	99.99	100.32	100.93	102.51	104.49	107.42	114.13	134.28	156.97	224.80
65.63	98.91	100.29	100.55	101.50	104.30	106.74	111.10	134.02	153.41	219.29
62.50	98.14	98.59	98.75	101.13	103.93	106.19	110.58	131.19	148.84	207.09
59.38	97.55	98.09	98.54	99.61	103.76	105.36	109.75	128.64	143.46	204.41
56.25	96.17	96.58	98.00	99.46	101.91	105.27	109.29	123.70	138.59	190.60
53.13	95.03	96.50	96.60	98.80	101.46	104.15	107.92	121.24	137.75	172.39
50.00	94.42	96.08	96.53	97.36	100.42	102.99	106.74	118.67	131.44	170.12
46.88	94.18	94.72	95.09	97.03	99.46	102.70	106.34	115.12	123.70	169.81
43.75	91.06	92.18	93.44	95.98	99.34	101.82	105.77	114.31	123.30	157.04
40.63	90.90	91.43	92.53	95.02	99.14	101.72	105.62	114.22	123.14	150.76
37.50	90.77	91.24	92.41	94.22	98.55	101.46	104.07	112.79	121.43	148.84
34.38	90.57	91.18	92.18	93.84	97.45	101.08	103.31	110.26	119.53	146.73
31.25	90.05	91.09	91.76	93.06	97.41	100.38	102.68	107.47	119.50	146.31
28.13	89.97	91.02	91.55	92.96	96.98	100.04	102.12	105.52	118.70	141.93
25.00	89.53	90.30	91.34	92.86	95.85	98.79	101.08	103.49	114.51	141.89
21.88	88.78	89.35	90.11	92.75	94.96	98.76	100.04	103.46	114.12	138.46
18.75	85.94	86.89	87.42	90.88	94.96	98.27	100.00	102.76	113.36	138.42
15.63	84.01	84.96	85.66	89.65	94.12	96.65	99.32	101.18	111.96	138.13
12.50	83.52	84.22	84.66	88.23	93.31	95.97	98.27	100.67	111.92	130.60
9.38	81.66	82.83	84.63	86.57	91.68	94.86	96.82	100.40	109.58	124.65
6.25	81.62	82.44	83.02	86.21	90.54	94.85	96.65	98.24	103.46	115.02
3.13	61.18	63.72	66.37	72.67	83.97	92.64	96.16	98.03	100.95	104.89

31 yrs HIs: Computed Discharge (cfs) at Alexander Creek A14 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
3.13	503.63	264.64	211.13	195.07	176.08	161.43	151.34	143.49	120.97	115.83
6.25	349.81	257.04	208.04	192.13	162.09	150.04	135.71	121.16	115.83	106.74
9.38	333.13	232.73	205.45	166.72	157.12	148.92	132.85	120.21	107.84	105.95
12.50	305.68	217.88	186.00	165.78	152.61	140.99	126.86	119.35	107.04	105.36
15.63	253.92	212.66	181.34	160.77	148.32	137.26	123.82	111.97	105.78	101.43
18.75	244.57	212.54	180.19	159.45	147.56	135.81	119.29	108.45	105.43	100.66
21.88	236.06	212.49	173.88	157.71	140.93	129.67	116.78	108.45	103.50	99.99
25.00	226.93	203.45	170.85	153.25	137.67	124.25	116.15	107.84	103.45	98.79
28.13	216.15	197.69	168.21	153.04	132.90	123.42	115.02	107.73	103.17	97.78
31.25	215.92	186.75	168.06	148.62	130.14	122.30	114.56	105.78	102.65	97.60
34.38	203.12	180.08	166.68	140.41	128.32	118.43	114.53	105.13	102.17	97.20
37.50	196.51	178.92	162.44	139.85	125.17	117.12	112.32	104.84	101.44	96.33
40.63	190.42	168.78	159.48	138.06	124.00	116.78	111.73	104.45	100.23	95.04
43.75	186.16	165.89	157.73	137.48	123.32	116.30	111.66	102.65	99.99	94.42
46.88	168.51	164.53	152.08	137.09	121.69	112.88	106.88	102.17	98.58	93.78
50.00	165.90	154.17	145.61	133.68	120.57	110.24	106.78	102.09	97.90	92.89
53.13	146.30	145.17	142.75	133.46	118.29	109.82	106.07	101.40	97.46	90.79
56.25	144.84	144.06	139.88	132.71	118.14	108.94	104.68	100.50	97.44	90.71
59.38	143.24	140.70	137.49	127.20	117.89	107.81	104.59	100.39	96.80	90.28
62.50	141.01	139.91	136.30	125.50	117.26	107.40	104.45	99.40	95.63	90.18
65.63	134.30	133.23	129.78	122.33	116.63	106.07	103.40	99.08	95.56	89.69
68.75	134.21	131.41	128.84	121.81	111.29	105.51	102.88	98.76	95.04	89.63
71.88	134.19	128.52	127.05	119.87	109.82	105.17	101.68	97.92	94.19	89.47
75.00	129.87	128.27	124.53	118.77	107.29	104.53	101.11	97.12	91.94	89.37
78.13	120.15	118.17	116.22	114.02	105.65	104.09	100.92	95.71	91.08	88.86
81.25	119.19	117.53	115.88	108.82	104.53	101.95	99.40	94.55	90.62	83.84
84.38	118.50	117.40	114.88	108.82	104.09	100.42	98.57	92.27	89.63	83.14
87.50	114.71	113.12	111.20	108.63	103.13	99.32	97.01	91.94	88.86	82.06
90.63	112.89	112.10	111.00	108.61	101.14	98.03	95.84	91.51	88.16	80.92
93.75	112.43	111.40	110.58	106.04	100.42	97.66	93.11	91.15	87.49	73.42
96.88	112.06	111.37	110.55	104.97	92.11	91.25	91.25	90.82	81.70	61.30

31 yrs LOs: Computed Discharge (cfs) at Alexander Creek A14 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	116.37	116.61	117.59	120.42	122.81	127.86	134.49	150.51	155.72	159.36
93.75	112.00	113.51	116.87	118.77	121.97	123.61	125.17	128.26	131.53	137.61
90.63	110.75	113.31	114.99	117.13	117.53	121.87	123.37	125.77	130.68	134.27
87.50	105.42	105.70	106.16	108.66	113.04	118.33	122.16	125.00	129.63	131.12
84.38	104.58	105.32	105.97	106.35	112.86	118.00	118.56	121.52	126.60	128.82
81.25	102.65	102.96	103.35	104.41	106.41	106.79	107.32	109.59	124.43	126.98
78.13	102.07	102.10	102.13	102.23	102.88	105.27	107.31	108.67	116.32	124.44
75.00	101.43	101.55	101.69	101.98	102.70	103.30	106.38	108.32	112.42	124.35
71.88	100.23	100.46	100.69	100.99	102.54	102.97	104.84	105.57	112.10	117.16
68.75	99.99	100.14	100.28	100.81	101.73	102.62	103.78	105.37	111.93	116.18
65.63	98.79	99.12	99.61	100.49	101.10	102.53	103.62	105.25	110.89	115.05
62.50	98.30	98.39	98.50	98.62	99.77	101.90	103.61	105.21	110.86	113.98
59.38	97.20	97.26	97.40	98.13	99.12	99.62	99.93	105.13	108.96	111.90
56.25	96.33	96.37	96.44	97.47	98.79	99.06	99.92	104.96	108.85	111.77
53.13	95.04	95.14	95.43	96.51	97.26	98.92	99.33	104.46	108.49	111.10
50.00	94.19	94.71	95.38	95.75	96.68	97.30	98.47	102.15	107.25	110.61
46.88	93.78	94.60	94.78	95.20	96.35	97.06	98.16	101.44	105.06	110.25
43.75	90.86	91.17	91.76	93.75	96.25	96.76	96.95	101.22	103.86	108.28
40.63	90.82	90.97	91.56	92.47	94.30	95.32	96.02	100.42	103.47	107.95
37.50	90.62	90.86	90.96	91.54	93.01	94.84	95.87	99.98	103.09	107.87
34.38	90.28	90.70	90.77	91.07	91.99	94.38	95.64	99.78	102.25	107.07
31.25	90.18	90.23	90.47	90.87	91.57	92.32	95.27	99.27	101.63	106.63
28.13	89.69	89.75	90.17	90.75	91.46	92.31	93.77	97.46	100.75	106.55
25.00	89.37	89.73	89.83	90.24	91.10	91.96	93.70	96.99	99.21	106.46
21.88	88.86	89.14	89.41	89.97	91.10	91.61	92.73	95.06	97.25	104.30
18.75	83.84	83.91	83.97	84.94	89.82	91.06	92.48	93.96	95.22	104.28
15.63	83.14	83.48	83.87	84.78	87.91	89.54	92.30	93.47	95.14	103.32
12.50	82.06	82.78	83.45	84.72	86.38	88.16	90.36	91.95	94.96	98.96
9.38	81.70	82.06	82.43	83.27	85.08	86.95	90.04	91.47	94.32	97.40
6.25	80.92	81.23	81.60	82.40	84.42	86.56	88.70	91.15	92.61	96.35
3.13	61.30	62.63	63.99	67.10	72.91	78.49	82.51	87.47	91.88	96.33

31 yrs LOs: Computed Discharge (cfs) at Alexander Creek A14 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	116.37	117.23	120.30	125.72	135.87	150.25	161.09	208.87	305.68	503.63
93.75	112.00	116.84	118.24	121.65	132.33	146.30	146.30	153.21	244.57	349.81
90.63	110.75	114.72	117.18	117.42	125.88	135.58	144.28	148.58	215.92	333.13
87.50	105.42	106.09	107.60	113.50	121.12	129.13	132.82	146.84	178.75	305.68
84.38	104.58	105.97	106.30	107.08	118.40	119.58	121.92	144.84	168.51	253.92
81.25	102.65	103.30	104.00	106.68	107.18	114.06	120.88	144.32	165.90	248.15
78.13	102.07	102.13	102.17	102.93	107.18	112.65	119.05	142.35	161.31	244.57
75.00	101.43	101.71	101.94	102.66	103.81	108.13	116.88	134.99	157.33	236.06
71.88	100.23	100.65	101.06	102.50	103.76	107.56	114.12	133.82	156.63	236.02
68.75	99.99	100.28	100.59	101.45	103.39	105.36	109.94	132.82	153.21	226.93
65.63	98.79	99.55	100.50	101.01	103.28	104.87	108.88	129.60	146.18	216.15
62.50	98.30	98.49	98.68	99.70	102.84	104.24	108.45	128.85	141.01	203.12
59.38	97.20	97.40	97.74	98.81	101.91	103.16	107.81	125.94	137.22	199.41
56.25	96.33	96.45	97.63	98.54	101.81	102.66	107.41	120.15	135.28	186.16
53.13	95.04	96.21	96.53	97.58	99.45	102.04	105.53	118.50	134.12	168.51
50.00	94.19	95.27	95.64	96.73	99.24	101.00	104.36	114.12	126.97	165.90
46.88	93.78	94.74	95.12	96.30	98.83	100.82	103.72	113.04	120.15	162.86
43.75	90.86	91.65	93.24	95.98	98.03	100.62	103.08	112.96	119.69	157.33
40.63	90.82	91.49	92.28	94.25	97.46	100.00	102.04	112.89	119.38	143.46
37.50	90.62	90.92	91.09	92.95	97.10	99.05	101.80	111.40	118.50	143.24
34.38	90.28	90.75	90.89	91.52	95.10	97.93	101.49	108.33	116.58	141.01
31.25	90.18	90.28	90.84	91.33	94.64	97.54	101.30	104.58	115.23	139.40
28.13	89.69	90.10	90.82	91.20	94.25	97.19	100.25	104.27	113.86	136.76
25.00	89.37	89.78	90.01	91.07	93.74	96.60	99.79	103.51	110.24	135.28
21.88	88.86	89.44	89.90	90.99	93.06	96.31	98.88	101.16	109.85	134.30
18.75	83.84	83.98	84.66	88.03	92.48	94.88	98.12	101.01	105.76	134.19
15.63	83.14	83.78	84.59	87.79	91.73	93.70	98.09	99.71	105.56	130.07
12.50	82.06	83.42	84.04	86.33	89.83	93.42	97.75	99.16	104.29	129.87
9.38	81.70	82.42	83.13	84.82	88.68	93.32	95.80	98.65	103.51	122.10
6.25	80.92	81.55	82.21	84.26	88.51	92.75	95.53	98.19	102.00	113.28
3.13	61.30	63.90	66.51	72.76	84.06	92.37	94.82	97.68	99.70	104.76

31 yrs HIs: Computed Discharge (cfs) at Alexander Creek A16 (AS)(1983 - 2014)

weib	1	7	14	30	60	90	120	180	270	1 year
3.13	202.19	198.83	195.46	187.05	171.91	156.59	148.26	138.78	115.84	111.00
6.25	173.00	170.14	167.28	160.12	147.24	138.22	130.60	119.10	111.00	102.00
9.38	136.00	132.21	128.58	125.27	121.80	118.05	115.67	115.00	102.00	97.80
12.50	132.00	130.45	128.35	124.39	116.79	115.00	115.00	104.00	99.28	97.50
15.63	130.33	127.70	126.73	121.39	116.68	110.21	108.00	104.00	98.88	95.50
18.75	128.00	127.44	124.27	119.92	115.51	109.18	107.96	103.39	97.80	95.40
21.88	125.96	125.01	123.86	117.25	112.75	108.00	106.21	102.00	97.03	94.80
25.00	121.00	119.84	118.71	116.40	111.90	107.34	105.00	101.60	96.70	94.74
28.13	120.69	119.53	118.65	115.62	110.24	107.05	104.00	100.28	96.60	93.00
31.25	120.24	119.28	118.41	114.74	109.92	106.06	103.60	100.28	95.50	92.03
34.38	120.00	117.53	117.53	114.46	107.17	105.85	102.79	100.17	95.28	91.91
37.50	117.00	115.55	114.10	112.25	107.10	105.79	102.49	97.70	94.30	91.60
40.63	113.26	112.51	112.43	110.82	107.00	105.70	102.11	97.58	94.10	91.50
43.75	113.00	112.50	111.68	109.79	106.97	105.30	102.00	97.10	93.71	91.10
46.88	113.00	112.22	111.36	109.35	106.31	104.16	101.43	96.74	93.41	89.00
50.00	112.81	111.04	109.35	108.00	106.06	102.76	101.25	96.58	93.40	87.10
53.13	112.00	110.27	109.13	107.46	105.87	102.08	101.00	96.21	93.22	86.80
56.25	111.00	109.62	109.07	107.38	104.25	102.00	99.02	95.90	92.40	85.20
59.38	110.06	109.17	108.35	106.24	103.92	101.38	98.35	95.78	91.91	84.78
62.50	110.00	108.66	107.42	105.52	102.47	99.50	97.06	94.41	91.60	84.70
65.63	109.00	108.24	106.31	105.46	102.25	98.38	96.99	94.09	91.10	84.60
68.75	107.00	106.69	104.78	103.64	101.98	98.26	96.12	93.75	89.54	84.10
71.88	105.71	105.28	104.27	103.39	101.58	97.11	95.39	93.73	87.85	83.00
75.00	105.00	104.67	100.64	99.09	97.23	96.29	94.07	92.20	85.80	82.00
78.13	105.00	102.73	99.63	98.03	96.46	96.15	93.01	90.22	85.20	80.82
81.25	101.28	100.32	99.36	97.20	96.18	94.27	92.51	89.52	84.70	80.10
84.38	101.00	100.31	97.15	96.63	95.24	94.24	91.71	88.35	83.40	79.72
87.50	100.00	99.29	96.72	96.16	94.50	93.87	89.93	86.60	83.04	78.90
90.63	96.79	96.75	96.31	95.62	94.41	92.33	88.82	85.50	83.00	76.90
93.75	94.74	94.70	94.66	94.57	92.80	91.12	88.05	84.28	82.00	72.28
96.88	94.60	93.48	92.20	89.97	88.94	88.80	85.45	83.40	80.00	60.00

31 yrs LOs: Computed Discharge (cfs) at Alexander Creek A16 (AS)(1983 - 2014)

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	111.45	111.78	112.17	113.07	114.98	118.40	124.51	135.49	143.66	147.74
93.75	107.00	107.77	108.54	110.31	113.63	116.48	116.92	119.88	128.93	126.60
90.63	99.00	99.94	102.02	103.61	104.17	105.80	108.79	113.36	114.86	116.56
87.50	98.05	99.07	99.15	99.31	101.66	104.42	105.65	108.32	110.87	111.21
84.38	96.60	97.22	97.84	99.27	101.47	102.95	103.83	105.07	106.51	106.02
81.25	96.07	96.10	97.04	98.08	99.76	102.24	103.53	104.79	105.11	105.99
78.13	95.90	96.07	96.41	97.88	99.62	99.98	100.45	104.45	104.95	105.53
75.00	95.50	95.90	96.26	97.57	99.05	99.92	100.40	102.19	103.87	105.36
71.88	95.40	95.75	96.12	96.66	98.91	99.78	99.91	101.62	102.79	104.79
68.75	94.65	95.57	95.96	96.36	97.43	98.25	99.29	101.48	102.68	103.48
65.63	94.30	95.12	95.64	96.18	96.27	96.86	97.72	101.25	102.51	103.31
62.50	94.06	94.07	94.09	95.82	96.13	96.45	96.78	100.21	101.80	102.88
59.38	93.00	93.12	93.34	94.14	95.28	96.36	96.44	98.37	101.59	102.66
56.25	91.10	92.20	93.25	93.53	94.22	95.19	96.02	98.22	99.19	101.40
53.13	87.39	88.38	88.86	92.22	94.13	94.31	94.39	97.98	98.65	100.43
50.00	86.92	87.36	87.87	89.04	91.18	92.32	94.17	96.61	97.39	99.96
46.88	86.81	87.22	87.65	88.92	90.48	92.26	92.79	96.44	97.31	99.79
43.75	86.80	87.13	87.50	88.64	89.83	91.49	92.29	96.39	96.84	96.74
40.63	85.80	85.87	85.95	88.31	89.18	90.66	92.08	94.56	94.81	95.81
37.50	84.78	85.23	85.69	86.74	88.70	89.68	91.74	92.37	94.59	95.56
34.38	84.70	84.89	85.09	86.12	86.77	88.78	89.97	91.74	93.44	95.08
31.25	84.10	84.22	84.48	85.54	86.48	87.85	89.81	91.31	93.39	94.11
28.13	83.77	84.10	84.36	85.36	86.45	87.15	88.41	91.14	92.86	94.10
25.00	82.76	82.99	83.78	84.67	85.76	86.83	87.40	90.29	92.62	93.67
21.88	82.00	82.23	83.26	83.87	85.24	85.81	87.37	89.09	91.70	93.61
18.75	80.82	81.18	81.54	82.74	84.55	85.48	87.04	88.87	90.87	92.43
15.63	80.00	80.42	81.13	82.37	83.93	84.64	86.38	88.79	90.30	92.07
12.50	79.72	80.35	80.72	81.55	83.09	84.64	86.25	87.65	89.52	91.85
9.38	78.90	79.03	79.18	79.50	80.44	82.46	84.61	85.79	89.17	90.63
6.25	76.90	77.31	77.72	78.67	80.11	81.17	83.14	85.17	87.96	88.77
3.13	60.00	61.27	62.58	65.57	71.14	76.64	80.57	84.47	85.48	88.65

31 yrs LOs:	Computed Discharge (cfs) at Alexander Creek A16 (AS)(1983 - 2014)									
weib	1	7	14	30	60	90	120	180	270	1 year
96.88	111.45	112.12	112.90	114.69	120.11	135.17	150.08	173.00	202.19	202.19
93.75	107.00	108.52	110.05	113.44	116.96	117.95	120.00	141.02	155.85	155.85
90.63	99.00	101.84	104.73	105.00	108.54	113.77	118.93	124.00	132.00	136.00
87.50	98.05	99.13	99.29	101.84	105.00	111.00	111.00	124.00	130.33	132.00
84.38	96.60	97.83	99.07	101.42	104.34	109.33	111.00	122.87	124.00	130.33
81.25	96.07	96.86	98.01	99.67	103.06	103.86	110.82	122.61	124.00	128.00
78.13	95.90	96.32	97.58	99.62	100.89	102.00	106.94	117.53	123.00	125.96
75.00	95.50	96.22	97.34	99.01	100.60	102.00	103.69	112.17	120.00	121.00
71.88	95.40	96.12	96.61	98.60	100.24	101.24	103.18	111.00	117.53	120.00
68.75	94.65	95.94	96.17	97.39	99.88	101.09	102.37	110.82	117.00	117.53
65.63	94.30	95.63	95.78	96.27	98.95	100.17	102.00	109.46	113.00	117.00
62.50	94.06	94.09	95.52	96.13	96.76	100.09	101.91	108.88	112.58	115.57
59.38	93.00	93.22	94.13	95.39	96.44	97.79	101.77	108.12	112.00	114.14
56.25	91.10	93.04	93.50	94.22	95.60	97.70	101.00	106.00	111.00	113.26
53.13	87.39	88.85	90.62	94.05	94.80	97.39	100.45	104.65	109.00	113.00
50.00	86.92	87.79	88.91	91.15	94.39	96.61	99.38	104.36	107.00	112.58
46.88	86.81	87.57	88.82	90.42	93.02	96.43	98.17	101.72	105.71	110.06
43.75	86.80	87.44	88.44	89.76	91.88	94.80	96.82	101.47	105.15	110.00
40.63	85.80	85.94	88.18	89.04	91.74	94.56	96.78	98.17	105.00	109.00
37.50	84.78	85.66	86.54	88.66	91.74	92.67	95.16	97.11	105.00	109.00
34.38	84.70	85.04	86.09	86.71	90.01	91.81	94.73	97.00	102.90	107.00
31.25	84.10	84.43	85.46	86.44	88.89	91.41	93.25	96.13	102.00	105.07
28.13	83.77	84.35	85.20	86.38	88.79	91.33	93.01	96.00	100.00	105.00
25.00	82.76	83.22	84.60	85.59	87.09	91.28	92.88	96.00	99.95	105.00
21.88	82.00	82.46	83.75	85.22	86.95	90.50	92.70	95.72	99.70	103.81
18.75	80.82	81.52	82.51	84.67	86.34	90.10	91.87	95.62	97.48	102.37
15.63	80.00	81.12	82.23	83.87	86.12	89.18	90.50	95.60	97.00	100.00
12.50	79.72	80.66	81.37	83.06	85.06	88.27	90.07	95.06	96.67	99.95
9.38	78.90	79.16	79.46	80.40	83.91	87.50	89.65	93.01	95.57	97.48
6.25	76.90	77.72	78.54	80.06	82.05	86.15	88.59	92.40	94.60	96.10
3.13	60.00	62.45	64.90	70.78	81.33	85.43	85.43	92.17	93.52	94.05

Frequency Analysis Tables

Stage – Baseline

31 yrs HIs: Simulated Stage (ft, NAVD) at Alexander Creek Tracy Canal (1983 - 2014)

weib	1	7	14	30	60	90	120	180	270	1 year
3.13	7.70	6.92	6.07	5.23	4.74	4.31	3.92	3.73	3.32	3.05
6.25	6.45	6.05	5.63	4.98	4.52	4.29	3.87	3.69	3.16	3.05
9.38	6.42	5.99	5.47	4.92	4.30	4.07	3.83	3.44	3.14	2.88
12.50	6.07	5.73	5.17	4.78	4.29	4.06	3.77	3.39	3.05	2.84
15.63	5.47	5.30	5.11	4.72	4.29	4.00	3.70	3.34	2.98	2.76
18.75	5.37	5.17	5.07	4.71	4.25	3.96	3.62	3.14	2.97	2.73
21.88	5.23	5.02	4.95	4.69	4.19	3.83	3.48	3.09	2.95	2.72
25.00	5.23	4.94	4.91	4.60	4.18	3.71	3.44	3.07	2.93	2.68
28.13	5.21	4.93	4.86	4.47	4.13	3.60	3.41	3.04	2.87	2.67
31.25	5.15	4.91	4.77	4.47	4.12	3.59	3.39	2.99	2.82	2.67
34.38	5.06	4.83	4.75	4.39	4.10	3.55	3.36	2.98	2.81	2.65
37.50	5.02	4.82	4.67	4.37	4.08	3.48	3.33	2.98	2.77	2.58
40.63	4.95	4.78	4.66	4.23	4.01	3.48	3.32	2.97	2.76	2.58
43.75	4.90	4.78	4.63	4.19	3.97	3.47	3.21	2.95	2.74	2.56
46.88	4.86	4.77	4.61	4.11	3.94	3.44	3.15	2.93	2.73	2.52
50.00	4.85	4.77	4.55	4.02	3.86	3.40	3.09	2.93	2.73	2.49
53.13	4.84	4.70	4.53	4.00	3.78	3.36	3.09	2.89	2.69	2.49
56.25	4.76	4.64	4.41	3.94	3.66	3.29	3.07	2.86	2.66	2.49
59.38	4.74	4.63	4.26	3.93	3.66	3.29	3.05	2.82	2.66	2.48
62.50	4.39	4.36	4.24	3.88	3.56	3.25	3.04	2.76	2.62	2.47
65.63	4.39	4.30	4.07	3.83	3.55	3.22	3.00	2.74	2.61	2.45
68.75	4.33	4.23	4.06	3.75	3.49	3.13	2.98	2.69	2.61	2.44
71.88	4.33	4.20	4.01	3.61	3.28	3.12	2.98	2.67	2.56	2.44
75.00	4.32	4.17	3.97	3.58	3.23	3.06	2.96	2.67	2.56	2.44
78.13	4.11	4.05	3.96	3.57	3.16	3.02	2.88	2.65	2.55	2.43
81.25	4.09	4.01	3.85	3.50	3.12	2.89	2.83	2.61	2.55	2.40
84.38	3.94	3.88	3.70	3.49	3.11	2.88	2.79	2.60	2.53	2.35
87.50	3.92	3.83	3.62	3.40	3.08	2.86	2.77	2.59	2.50	2.35
90.63	3.88	3.81	3.61	3.25	3.05	2.85	2.76	2.57	2.43	2.33
93.75	3.84	3.79	3.56	3.23	3.03	2.79	2.67	2.56	2.43	1.86
96.88	3.35	3.23	3.18	3.00	2.81	2.79	2.63	2.55	2.16	1.60

31 yrs LOs: Simulated Stage (ft, NAVD) at Alexander Creek Tracy Canal (1983 - 2014)

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	3.16	3.19	3.25	3.46	4.00	4.22	4.22	4.77	6.07	7.70
93.75	3.05	3.09	3.13	3.30	3.78	4.04	4.17	4.47	5.41	6.45
90.63	3.04	3.05	3.10	3.26	3.52	3.96	4.09	4.39	5.23	6.42
87.50	2.95	2.98	3.06	3.15	3.47	3.62	3.62	4.29	5.01	6.18
84.38	2.93	2.96	2.99	3.07	3.36	3.49	3.59	4.16	4.96	6.07
81.25	2.77	2.80	2.82	2.88	3.15	3.22	3.44	4.10	4.86	5.47
78.13	2.76	2.77	2.81	2.88	3.15	3.17	3.38	3.99	4.84	5.37
75.00	2.73	2.77	2.80	2.87	3.01	3.17	3.29	3.83	4.82	5.29
71.88	2.68	2.76	2.79	2.85	3.01	3.16	3.29	3.82	4.50	5.23
68.75	2.67	2.75	2.77	2.82	3.01	3.13	3.27	3.81	4.50	5.23
65.63	2.67	2.69	2.73	2.81	3.01	3.10	3.27	3.79	4.46	5.14
62.50	2.66	2.67	2.73	2.81	2.99	3.09	3.25	3.76	4.26	5.06
59.38	2.58	2.64	2.69	2.79	2.97	3.05	3.25	3.67	4.18	5.02
56.25	2.58	2.63	2.69	2.76	2.92	3.04	3.16	3.60	3.99	5.02
53.13	2.56	2.61	2.68	2.76	2.91	3.04	3.14	3.57	3.92	4.96
50.00	2.56	2.59	2.67	2.71	2.89	3.03	3.13	3.49	3.92	4.95
46.88	2.53	2.59	2.61	2.71	2.88	2.97	3.12	3.47	3.90	4.90
43.75	2.52	2.57	2.60	2.69	2.86	2.94	3.12	3.44	3.88	4.86
40.63	2.49	2.56	2.60	2.68	2.80	2.92	3.11	3.32	3.81	4.85
37.50	2.49	2.55	2.58	2.66	2.79	2.92	3.09	3.32	3.79	4.83
34.38	2.48	2.54	2.56	2.66	2.78	2.90	3.07	3.27	3.77	4.82
31.25	2.47	2.52	2.55	2.62	2.77	2.90	3.01	3.25	3.74	4.74
28.13	2.44	2.51	2.55	2.62	2.77	2.88	3.00	3.21	3.68	4.64
25.00	2.44	2.49	2.55	2.60	2.76	2.84	2.98	3.14	3.67	4.48
21.88	2.43	2.46	2.54	2.59	2.73	2.83	2.97	3.14	3.66	4.46
18.75	2.43	2.45	2.50	2.57	2.70	2.79	2.90	3.07	3.66	4.42
15.63	2.35	2.45	2.49	2.53	2.70	2.78	2.89	2.99	3.45	4.39
12.50	2.35	2.42	2.49	2.53	2.64	2.70	2.78	2.90	3.41	4.33
9.38	2.33	2.33	2.34	2.41	2.61	2.65	2.74	2.89	3.35	3.70
6.25	2.16	2.20	2.20	2.33	2.48	2.63	2.69	2.89	3.14	3.64
3.13	1.60	1.65	1.73	1.91	2.32	2.60	2.68	2.85	3.01	3.31

31 yrs LOs:	Simulated Stage (ft, NAVD) at Alexander Creek Tracy Canal (1983 -									
weib	1	7	14	30	60	90	120	180	270	1 year
96.88	3.16	3.18	3.20	3.21	3.35	3.52	3.60	3.88	3.97	4.10
93.75	3.05	3.07	3.09	3.17	3.29	3.48	3.50	3.68	3.73	3.93
90.63	3.04	3.04	3.06	3.08	3.29	3.34	3.50	3.57	3.68	3.81
87.50	2.95	2.96	2.99	3.02	3.14	3.34	3.33	3.42	3.65	3.75
84.38	2.93	2.96	2.96	3.01	3.13	3.25	3.33	3.41	3.61	3.70
81.25	2.77	2.78	2.79	2.81	2.89	2.96	2.96	3.10	3.40	3.66
78.13	2.76	2.76	2.77	2.80	2.85	2.88	2.95	3.08	3.39	3.60
75.00	2.73	2.74	2.77	2.78	2.85	2.87	2.91	3.08	3.35	3.58
71.88	2.68	2.72	2.75	2.77	2.84	2.86	2.90	3.02	3.35	3.54
68.75	2.67	2.71	2.74	2.76	2.81	2.84	2.89	3.01	3.27	3.50
65.63	2.67	2.69	2.69	2.72	2.79	2.81	2.88	2.95	3.26	3.35
62.50	2.66	2.66	2.67	2.70	2.74	2.81	2.87	2.94	3.22	3.33
59.38	2.58	2.61	2.65	2.69	2.74	2.78	2.85	2.94	3.10	3.30
56.25	2.58	2.60	2.64	2.68	2.71	2.78	2.85	2.94	3.06	3.29
53.13	2.56	2.59	2.59	2.66	2.71	2.76	2.82	2.91	3.02	3.26
50.00	2.56	2.57	2.58	2.64	2.70	2.75	2.80	2.90	3.02	3.25
46.88	2.53	2.54	2.58	2.61	2.69	2.75	2.80	2.89	3.01	3.23
43.75	2.52	2.53	2.57	2.60	2.68	2.75	2.79	2.89	2.98	3.23
40.63	2.49	2.53	2.55	2.59	2.68	2.72	2.79	2.88	2.98	3.22
37.50	2.49	2.51	2.54	2.59	2.64	2.71	2.78	2.86	2.98	3.21
34.38	2.48	2.51	2.54	2.57	2.62	2.70	2.77	2.85	2.97	3.19
31.25	2.47	2.51	2.52	2.55	2.62	2.70	2.74	2.85	2.93	3.19
28.13	2.44	2.50	2.51	2.54	2.59	2.66	2.70	2.82	2.88	3.18
25.00	2.44	2.46	2.49	2.53	2.58	2.66	2.68	2.77	2.87	3.17
21.88	2.43	2.44	2.46	2.48	2.56	2.58	2.65	2.71	2.84	3.15
18.75	2.43	2.44	2.45	2.48	2.55	2.56	2.58	2.66	2.80	3.13
15.63	2.35	2.40	2.44	2.48	2.52	2.53	2.54	2.65	2.80	3.07
12.50	2.35	2.38	2.41	2.44	2.51	2.52	2.54	2.63	2.74	2.99
9.38	2.33	2.33	2.33	2.36	2.44	2.50	2.53	2.60	2.72	2.87
6.25	2.16	2.18	2.18	2.22	2.31	2.41	2.52	2.59	2.70	2.87
3.13	1.60	1.63	1.66	1.75	1.93	2.09	2.22	2.40	2.65	2.72

31 yrs HIs: Computed Stage (ft, NAVD) at Alexander Creek A4.3 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
3.13	7.93	6.63	6.04	5.16	4.66	4.43	4.10	4.01	3.63	3.41
6.25	6.53	5.97	5.60	5.02	4.62	4.41	4.04	3.83	3.48	3.39
9.38	6.53	5.93	5.41	4.95	4.55	4.29	3.98	3.65	3.46	3.25
12.50	6.17	5.91	5.19	4.89	4.46	4.29	3.98	3.64	3.37	3.24
15.63	5.62	5.43	5.15	4.85	4.40	4.19	3.85	3.64	3.33	3.19
18.75	5.54	5.16	5.05	4.82	4.34	4.14	3.69	3.46	3.33	3.17
21.88	5.38	5.08	5.02	4.75	4.33	3.96	3.65	3.41	3.31	3.17
25.00	5.32	5.06	4.97	4.74	4.32	3.89	3.65	3.39	3.30	3.16
28.13	5.27	5.01	4.95	4.66	4.27	3.73	3.65	3.37	3.24	3.15
31.25	5.17	5.00	4.90	4.53	4.23	3.72	3.63	3.34	3.23	3.14
34.38	5.13	4.97	4.83	4.47	4.17	3.70	3.63	3.33	3.22	3.13
37.50	5.01	4.93	4.74	4.41	4.16	3.70	3.60	3.32	3.20	3.11
40.63	5.00	4.88	4.69	4.32	4.11	3.68	3.59	3.32	3.19	3.11
43.75	4.95	4.85	4.62	4.20	4.05	3.67	3.47	3.31	3.18	3.10
46.88	4.89	4.79	4.57	4.19	3.97	3.66	3.45	3.30	3.17	3.09
50.00	4.89	4.73	4.57	4.17	3.91	3.65	3.41	3.30	3.16	3.07
53.13	4.82	4.72	4.54	4.10	3.91	3.60	3.41	3.26	3.16	3.07
56.25	4.69	4.63	4.47	4.10	3.88	3.58	3.39	3.26	3.15	3.06
59.38	4.69	4.57	4.39	4.06	3.83	3.52	3.38	3.23	3.15	3.06
62.50	4.38	4.36	4.19	3.98	3.78	3.49	3.34	3.19	3.12	3.05
65.63	4.28	4.23	4.17	3.98	3.71	3.45	3.33	3.17	3.12	3.05
68.75	4.25	4.16	4.12	3.92	3.65	3.43	3.31	3.15	3.11	3.05
71.88	4.24	4.14	3.99	3.73	3.52	3.40	3.30	3.15	3.10	3.05
75.00	4.18	4.12	3.99	3.72	3.48	3.37	3.28	3.14	3.09	3.04
78.13	4.16	4.09	3.89	3.64	3.47	3.36	3.25	3.14	3.09	3.03
81.25	4.15	4.07	3.89	3.63	3.38	3.25	3.21	3.13	3.08	3.03
84.38	3.97	3.93	3.84	3.62	3.37	3.21	3.21	3.11	3.08	2.93
87.50	3.90	3.83	3.78	3.56	3.36	3.21	3.19	3.09	3.07	2.93
90.63	3.80	3.74	3.70	3.47	3.35	3.21	3.17	3.09	3.03	2.91
93.75	3.77	3.73	3.63	3.44	3.30	3.21	3.14	3.09	3.03	2.48
96.88	3.46	3.45	3.43	3.33	3.23	3.17	3.13	3.08	2.74	2.14

31 yrs LOs: Computed Stage (ft, NAVD) at Alexander Creek A4.3 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	3.48	3.50	3.52	3.71	4.18	4.32	4.34	4.94	6.17	7.93
93.75	3.39	3.43	3.46	3.54	3.91	4.20	4.32	4.58	5.53	6.53
90.63	3.39	3.40	3.41	3.46	3.71	4.07	4.25	4.38	5.12	6.53
87.50	3.31	3.32	3.34	3.43	3.70	3.81	3.81	4.36	5.01	6.17
84.38	3.30	3.31	3.32	3.37	3.59	3.67	3.79	4.33	5.00	6.06
81.25	3.20	3.21	3.22	3.24	3.40	3.48	3.67	4.30	4.89	5.62
78.13	3.19	3.20	3.21	3.23	3.32	3.46	3.61	4.15	4.87	5.54
75.00	3.17	3.18	3.20	3.22	3.28	3.37	3.57	4.02	4.86	5.38
71.88	3.16	3.17	3.19	3.21	3.28	3.36	3.55	3.94	4.62	5.37
68.75	3.15	3.17	3.18	3.21	3.28	3.36	3.52	3.87	4.58	5.32
65.63	3.15	3.16	3.16	3.20	3.25	3.34	3.50	3.79	4.56	5.32
62.50	3.14	3.15	3.16	3.18	3.23	3.33	3.38	3.75	4.33	5.30
59.38	3.11	3.13	3.15	3.17	3.23	3.32	3.37	3.72	4.15	5.13
56.25	3.11	3.12	3.14	3.16	3.23	3.30	3.36	3.67	4.12	5.00
53.13	3.10	3.12	3.12	3.16	3.22	3.28	3.36	3.67	4.02	4.95
50.00	3.09	3.11	3.12	3.15	3.22	3.28	3.35	3.64	3.97	4.89
46.88	3.09	3.09	3.12	3.14	3.19	3.27	3.34	3.61	3.89	4.88
43.75	3.08	3.09	3.11	3.14	3.19	3.26	3.34	3.49	3.86	4.82
40.63	3.07	3.09	3.10	3.14	3.18	3.25	3.32	3.47	3.85	4.69
37.50	3.06	3.08	3.09	3.13	3.18	3.24	3.32	3.47	3.82	4.69
34.38	3.06	3.08	3.09	3.13	3.17	3.23	3.30	3.46	3.80	4.66
31.25	3.05	3.08	3.08	3.09	3.16	3.22	3.29	3.45	3.79	4.62
28.13	3.05	3.07	3.08	3.09	3.15	3.20	3.29	3.37	3.75	4.61
25.00	3.04	3.05	3.07	3.09	3.15	3.19	3.29	3.32	3.70	4.61
21.88	3.03	3.04	3.05	3.08	3.15	3.17	3.27	3.31	3.64	4.46
18.75	3.03	3.04	3.04	3.07	3.12	3.16	3.22	3.30	3.57	4.43
15.63	2.93	2.99	3.04	3.05	3.10	3.14	3.19	3.25	3.48	4.28
12.50	2.93	2.94	3.03	3.05	3.10	3.11	3.17	3.24	3.48	3.92
9.38	2.91	2.93	2.96	3.02	3.09	3.11	3.14	3.22	3.47	3.88
6.25	2.74	2.77	2.79	2.89	3.03	3.10	3.13	3.20	3.41	3.79
3.13	2.14	2.21	2.29	2.48	2.85	3.05	3.12	3.17	3.25	3.35

31 yrs LOs: Computed Stage (ft, NAVD) at Alexander Creek A4.3 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	3.48	3.49	3.50	3.52	3.61	3.75	3.83	4.10	4.18	4.28
93.75	3.39	3.41	3.43	3.49	3.57	3.71	3.74	3.88	3.93	4.09
90.63	3.39	3.39	3.40	3.41	3.54	3.61	3.73	3.80	3.89	4.00
87.50	3.31	3.31	3.32	3.34	3.46	3.60	3.60	3.69	3.89	3.97
84.38	3.30	3.31	3.32	3.34	3.44	3.51	3.57	3.67	3.83	3.90
81.25	3.20	3.21	3.21	3.22	3.25	3.31	3.31	3.41	3.67	3.87
78.13	3.19	3.20	3.20	3.21	3.24	3.25	3.31	3.40	3.66	3.81
75.00	3.17	3.18	3.18	3.20	3.23	3.25	3.26	3.39	3.59	3.80
71.88	3.16	3.16	3.17	3.19	3.21	3.24	3.26	3.37	3.59	3.76
68.75	3.15	3.16	3.17	3.18	3.20	3.23	3.25	3.33	3.55	3.71
65.63	3.15	3.16	3.16	3.16	3.17	3.20	3.25	3.32	3.52	3.60
62.50	3.14	3.15	3.15	3.16	3.17	3.19	3.23	3.31	3.49	3.56
59.38	3.11	3.12	3.13	3.14	3.17	3.18	3.22	3.29	3.41	3.56
56.25	3.11	3.12	3.12	3.13	3.16	3.18	3.22	3.29	3.37	3.55
53.13	3.10	3.11	3.12	3.13	3.15	3.18	3.21	3.28	3.35	3.52
50.00	3.09	3.11	3.11	3.12	3.15	3.17	3.21	3.28	3.34	3.51
46.88	3.09	3.09	3.09	3.12	3.15	3.17	3.20	3.25	3.33	3.50
43.75	3.08	3.09	3.09	3.11	3.14	3.16	3.20	3.25	3.32	3.49
40.63	3.07	3.07	3.08	3.10	3.14	3.15	3.19	3.24	3.31	3.48
37.50	3.06	3.07	3.08	3.10	3.13	3.15	3.18	3.24	3.30	3.48
34.38	3.06	3.07	3.08	3.09	3.12	3.14	3.16	3.24	3.27	3.48
31.25	3.05	3.07	3.07	3.09	3.10	3.14	3.15	3.20	3.27	3.47
28.13	3.05	3.06	3.07	3.09	3.10	3.13	3.14	3.20	3.26	3.47
25.00	3.04	3.05	3.06	3.08	3.09	3.12	3.14	3.17	3.25	3.47
21.88	3.03	3.04	3.04	3.05	3.09	3.10	3.12	3.15	3.23	3.46
18.75	3.03	3.04	3.04	3.05	3.06	3.09	3.10	3.12	3.20	3.44
15.63	2.93	2.96	2.99	3.01	3.06	3.07	3.08	3.11	3.19	3.34
12.50	2.93	2.94	2.96	2.99	3.03	3.05	3.06	3.10	3.15	3.32
9.38	2.91	2.92	2.94	2.97	3.02	3.04	3.06	3.10	3.15	3.25
6.25	2.74	2.76	2.77	2.80	2.89	2.96	3.03	3.09	3.12	3.22
3.13	2.14	2.17	2.21	2.31	2.50	2.66	2.78	2.91	3.09	3.15

31 yrs HIs: Computed Stage (ft, NAVD) at Alexander Creek A5 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
3.13	8.64	7.41	6.83	6.09	5.74	5.60	5.39	5.35	5.22	5.14
6.25	7.31	6.76	6.42	6.00	5.72	5.58	5.37	5.29	5.17	5.13
9.38	7.31	6.73	6.26	5.94	5.68	5.50	5.34	5.23	5.16	5.07
12.50	6.95	6.71	6.12	5.89	5.62	5.50	5.34	5.23	5.12	5.07
15.63	6.45	6.28	6.09	5.87	5.58	5.43	5.30	5.23	5.11	5.03
18.75	6.37	6.09	6.02	5.85	5.53	5.41	5.25	5.16	5.10	5.03
21.88	6.25	6.04	5.99	5.80	5.53	5.34	5.23	5.14	5.10	5.03
25.00	6.21	6.02	5.96	5.80	5.52	5.31	5.23	5.13	5.09	5.02
28.13	6.17	5.99	5.95	5.74	5.49	5.26	5.23	5.12	5.07	5.01
31.25	6.10	5.98	5.91	5.66	5.45	5.26	5.23	5.11	5.06	5.01
34.38	6.07	5.96	5.86	5.62	5.42	5.25	5.22	5.10	5.05	5.00
37.50	5.99	5.93	5.79	5.58	5.42	5.25	5.21	5.10	5.04	4.99
40.63	5.98	5.89	5.76	5.52	5.40	5.24	5.21	5.10	5.03	4.99
43.75	5.94	5.87	5.72	5.43	5.37	5.24	5.16	5.10	5.03	4.98
46.88	5.90	5.83	5.69	5.43	5.34	5.24	5.15	5.10	5.03	4.97
50.00	5.90	5.79	5.69	5.42	5.32	5.23	5.14	5.09	5.02	4.96
53.13	5.85	5.78	5.67	5.39	5.32	5.21	5.14	5.08	5.02	4.96
56.25	5.77	5.73	5.62	5.39	5.31	5.20	5.13	5.08	5.01	4.96
59.38	5.76	5.68	5.57	5.38	5.29	5.18	5.12	5.06	5.01	4.95
62.50	5.56	5.55	5.43	5.34	5.28	5.17	5.11	5.03	4.99	4.95
65.63	5.49	5.46	5.42	5.34	5.25	5.15	5.11	5.03	4.99	4.95
68.75	5.47	5.42	5.40	5.32	5.23	5.14	5.10	5.02	4.99	4.95
71.88	5.46	5.41	5.35	5.26	5.18	5.13	5.09	5.01	4.98	4.95
75.00	5.43	5.40	5.35	5.26	5.16	5.12	5.09	5.01	4.98	4.94
78.13	5.42	5.39	5.31	5.23	5.16	5.12	5.07	5.01	4.97	4.94
81.25	5.41	5.38	5.31	5.22	5.13	5.07	5.05	5.00	4.97	4.93
84.38	5.34	5.33	5.30	5.22	5.12	5.05	5.05	4.99	4.97	4.82
87.50	5.32	5.29	5.28	5.19	5.12	5.05	5.04	4.98	4.96	4.81
90.63	5.28	5.26	5.25	5.16	5.11	5.05	5.03	4.98	4.94	4.79
93.75	5.27	5.26	5.22	5.15	5.09	5.05	5.01	4.97	4.94	4.23
96.88	5.16	5.15	5.15	5.10	5.06	5.03	5.00	4.97	4.57	3.78

31 yrs LOs: Computed Stage (ft, NAVD) at Alexander Creek A5 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	5.17	5.17	5.18	5.25	5.43	5.52	5.53	5.94	6.95	8.64
93.75	5.13	5.14	5.16	5.19	5.32	5.43	5.52	5.69	6.37	7.31
90.63	5.13	5.14	5.14	5.16	5.26	5.38	5.47	5.56	6.07	7.31
87.50	5.10	5.10	5.11	5.15	5.25	5.29	5.29	5.55	5.99	6.95
84.38	5.09	5.10	5.10	5.12	5.21	5.24	5.28	5.53	5.98	6.85
81.25	5.04	5.05	5.05	5.07	5.13	5.16	5.24	5.50	5.90	6.45
78.13	5.04	5.04	5.04	5.06	5.10	5.16	5.22	5.41	5.88	6.37
75.00	5.03	5.03	5.04	5.05	5.09	5.12	5.20	5.36	5.87	6.25
71.88	5.02	5.03	5.04	5.05	5.09	5.12	5.19	5.33	5.72	6.24
68.75	5.01	5.03	5.03	5.05	5.09	5.12	5.18	5.31	5.70	6.21
65.63	5.01	5.02	5.02	5.04	5.07	5.11	5.17	5.28	5.68	6.20
62.50	5.01	5.01	5.02	5.03	5.06	5.11	5.12	5.26	5.53	6.19
59.38	4.99	5.00	5.01	5.02	5.06	5.10	5.12	5.26	5.41	6.07
56.25	4.99	4.99	5.01	5.02	5.06	5.09	5.12	5.24	5.40	5.98
53.13	4.98	4.99	4.99	5.02	5.06	5.09	5.12	5.24	5.36	5.94
50.00	4.98	4.99	4.99	5.01	5.06	5.09	5.11	5.23	5.34	5.90
46.88	4.97	4.98	4.99	5.01	5.03	5.08	5.11	5.22	5.31	5.89
43.75	4.97	4.97	4.99	5.01	5.03	5.08	5.11	5.17	5.30	5.85
40.63	4.96	4.97	4.98	5.01	5.03	5.07	5.10	5.16	5.30	5.77
37.50	4.96	4.97	4.97	5.00	5.03	5.07	5.10	5.16	5.29	5.76
34.38	4.95	4.97	4.97	5.00	5.03	5.06	5.09	5.16	5.28	5.74
31.25	4.95	4.97	4.97	4.98	5.02	5.05	5.09	5.15	5.28	5.72
28.13	4.95	4.96	4.97	4.98	5.02	5.04	5.09	5.12	5.26	5.72
25.00	4.94	4.95	4.96	4.97	5.01	5.04	5.09	5.10	5.25	5.71
21.88	4.94	4.95	4.95	4.97	5.01	5.03	5.08	5.10	5.23	5.62
18.75	4.94	4.94	4.95	4.96	4.99	5.02	5.05	5.10	5.20	5.60
15.63	4.82	4.90	4.94	4.95	4.98	5.00	5.04	5.07	5.17	5.49
12.50	4.81	4.83	4.93	4.95	4.98	4.99	5.03	5.07	5.16	5.32
9.38	4.79	4.81	4.85	4.93	4.97	4.99	5.01	5.05	5.16	5.31
6.25	4.57	4.60	4.62	4.76	4.94	4.98	5.00	5.04	5.14	5.28
3.13	3.78	3.88	3.98	4.23	4.70	4.95	4.99	5.03	5.08	5.11

31 yrs LOs: Computed Stage (ft, NAVD) at Alexander Creek A5 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	5.17	5.17	5.17	5.18	5.21	5.27	5.30	5.44	5.48	5.54
93.75	5.13	5.14	5.14	5.17	5.20	5.25	5.26	5.33	5.38	5.45
90.63	5.13	5.13	5.13	5.14	5.19	5.22	5.26	5.29	5.36	5.42
87.50	5.10	5.10	5.10	5.11	5.16	5.21	5.21	5.24	5.33	5.38
84.38	5.09	5.10	5.10	5.11	5.15	5.18	5.20	5.24	5.31	5.38
81.25	5.04	5.04	5.05	5.05	5.07	5.09	5.09	5.13	5.26	5.33
78.13	5.04	5.04	5.04	5.04	5.06	5.07	5.09	5.12	5.23	5.33
75.00	5.03	5.03	5.03	5.04	5.06	5.07	5.07	5.12	5.22	5.30
71.88	5.02	5.02	5.03	5.04	5.05	5.06	5.07	5.12	5.21	5.30
68.75	5.01	5.02	5.03	5.03	5.04	5.06	5.07	5.10	5.19	5.26
65.63	5.01	5.02	5.02	5.02	5.03	5.04	5.07	5.10	5.18	5.25
62.50	5.01	5.01	5.02	5.02	5.02	5.03	5.06	5.09	5.17	5.23
59.38	4.99	4.99	5.00	5.01	5.02	5.03	5.05	5.08	5.12	5.20
56.25	4.99	4.99	4.99	5.00	5.02	5.03	5.05	5.08	5.12	5.20
53.13	4.98	4.99	4.99	5.00	5.01	5.03	5.05	5.08	5.11	5.18
50.00	4.98	4.98	4.99	4.99	5.01	5.03	5.04	5.07	5.10	5.18
46.88	4.97	4.97	4.97	4.99	5.01	5.02	5.04	5.06	5.10	5.17
43.75	4.97	4.97	4.97	4.98	5.00	5.02	5.04	5.06	5.09	5.16
40.63	4.96	4.96	4.97	4.98	5.00	5.01	5.03	5.06	5.09	5.16
37.50	4.96	4.96	4.97	4.98	5.00	5.01	5.03	5.05	5.08	5.16
34.38	4.95	4.96	4.97	4.97	4.99	5.01	5.02	5.05	5.07	5.16
31.25	4.95	4.96	4.96	4.97	4.98	5.00	5.01	5.04	5.07	5.16
28.13	4.95	4.96	4.96	4.97	4.98	5.00	5.01	5.04	5.07	5.15
25.00	4.94	4.95	4.95	4.97	4.97	4.99	5.01	5.02	5.06	5.15
21.88	4.94	4.94	4.95	4.95	4.97	4.98	4.99	5.02	5.05	5.14
18.75	4.94	4.94	4.94	4.95	4.96	4.97	4.98	4.99	5.03	5.10
15.63	4.82	4.86	4.88	4.91	4.94	4.96	4.97	4.98	5.02	5.10
12.50	4.81	4.82	4.85	4.89	4.93	4.94	4.95	4.98	5.01	5.09
9.38	4.79	4.80	4.83	4.87	4.92	4.94	4.95	4.97	5.00	5.05
6.25	4.57	4.59	4.60	4.65	4.76	4.83	4.89	4.94	4.98	5.05
3.13	3.78	3.83	3.88	4.00	4.25	4.46	4.59	4.74	4.88	5.01

31 yrs HIs: Computed Stage (ft, NAVD) at Alexander Creek A6 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
3.13	9.14	8.01	7.55	6.87	6.61	6.42	6.22	6.12	5.83	5.75
6.25	8.26	7.83	7.21	6.84	6.51	6.41	6.21	5.92	5.80	5.68
9.38	8.15	7.68	7.14	6.76	6.46	6.30	5.99	5.83	5.78	5.58
12.50	8.11	7.48	7.13	6.73	6.44	6.24	5.97	5.80	5.68	5.57
15.63	7.68	7.46	7.04	6.73	6.42	6.24	5.94	5.78	5.66	5.54
18.75	7.62	7.28	6.95	6.65	6.39	6.23	5.88	5.70	5.65	5.54
21.88	7.50	7.27	6.90	6.58	6.36	6.04	5.85	5.68	5.64	5.53
25.00	7.50	7.27	6.88	6.49	6.15	5.93	5.82	5.68	5.61	5.53
28.13	7.32	7.12	6.71	6.48	6.13	5.90	5.80	5.66	5.58	5.49
31.25	7.22	7.00	6.67	6.41	6.09	5.89	5.78	5.64	5.57	5.47
34.38	7.16	6.79	6.59	6.34	6.08	5.88	5.74	5.64	5.55	5.47
37.50	6.99	6.78	6.57	6.24	6.05	5.83	5.74	5.61	5.55	5.46
40.63	6.89	6.62	6.52	6.18	6.03	5.80	5.73	5.61	5.55	5.45
43.75	6.88	6.62	6.51	6.17	5.99	5.76	5.72	5.59	5.53	5.44
46.88	6.59	6.58	6.40	6.17	5.91	5.75	5.70	5.59	5.53	5.43
50.00	6.58	6.43	6.31	6.14	5.89	5.74	5.70	5.58	5.52	5.42
53.13	6.38	6.36	6.23	6.13	5.88	5.70	5.67	5.58	5.49	5.41
56.25	6.32	6.29	6.21	6.04	5.87	5.70	5.65	5.58	5.48	5.41
59.38	6.28	6.27	6.18	6.02	5.84	5.70	5.64	5.53	5.47	5.40
62.50	6.19	6.17	6.13	5.99	5.83	5.70	5.59	5.53	5.46	5.40
65.63	6.18	6.13	6.05	5.99	5.79	5.68	5.59	5.52	5.46	5.39
68.75	6.13	6.09	6.04	5.93	5.77	5.68	5.59	5.52	5.45	5.39
71.88	6.10	6.08	6.01	5.85	5.70	5.67	5.57	5.49	5.44	5.39
75.00	6.04	6.03	5.95	5.84	5.68	5.66	5.57	5.47	5.43	5.38
78.13	5.88	5.84	5.82	5.76	5.67	5.59	5.54	5.46	5.41	5.37
81.25	5.87	5.83	5.78	5.72	5.63	5.58	5.52	5.45	5.41	5.24
84.38	5.83	5.82	5.78	5.65	5.61	5.56	5.51	5.44	5.39	5.14
87.50	5.80	5.76	5.74	5.64	5.60	5.53	5.49	5.41	5.39	5.02
90.63	5.77	5.74	5.71	5.64	5.57	5.51	5.48	5.41	5.39	5.01
93.75	5.73	5.69	5.68	5.64	5.57	5.51	5.44	5.41	5.38	4.41
96.88	5.70	5.68	5.68	5.63	5.47	5.44	5.42	5.39	4.91	3.76

31 yrs LOs: Computed Stage (ft, NAVD) at Alexander Creek A6 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	5.77	5.81	5.83	5.89	6.13	6.29	6.42	7.07	8.11	9.14
93.75	5.74	5.75	5.77	5.84	6.02	6.29	6.31	6.42	7.68	8.26
90.63	5.70	5.73	5.76	5.79	5.93	6.12	6.28	6.37	7.22	8.15
87.50	5.64	5.66	5.68	5.76	5.89	6.01	6.01	6.36	6.97	8.11
84.38	5.62	5.65	5.66	5.69	5.81	5.81	5.97	6.35	6.59	7.85
81.25	5.57	5.58	5.58	5.58	5.66	5.76	5.91	6.28	6.58	7.68
78.13	5.53	5.54	5.55	5.57	5.61	5.67	5.82	6.15	6.57	7.62
75.00	5.53	5.54	5.55	5.57	5.61	5.67	5.80	6.07	6.50	7.50
71.88	5.53	5.54	5.54	5.56	5.60	5.65	5.79	6.07	6.44	7.50
68.75	5.52	5.52	5.53	5.56	5.59	5.62	5.70	6.01	6.42	7.45
65.63	5.49	5.51	5.52	5.55	5.56	5.62	5.70	6.01	6.30	7.32
62.50	5.47	5.49	5.51	5.54	5.56	5.61	5.68	5.97	6.30	7.24
59.38	5.47	5.48	5.48	5.52	5.56	5.58	5.66	5.93	6.18	7.16
56.25	5.46	5.47	5.48	5.50	5.55	5.58	5.66	5.88	6.17	6.88
53.13	5.45	5.46	5.47	5.50	5.55	5.58	5.64	5.83	6.04	6.59
50.00	5.44	5.45	5.45	5.48	5.54	5.57	5.64	5.78	6.02	6.58
46.88	5.42	5.43	5.45	5.48	5.53	5.56	5.62	5.72	5.88	6.58
43.75	5.41	5.42	5.42	5.46	5.51	5.56	5.61	5.72	5.87	6.40
40.63	5.39	5.40	5.42	5.44	5.50	5.55	5.59	5.70	5.87	6.38
37.50	5.39	5.40	5.41	5.44	5.50	5.54	5.58	5.69	5.86	6.37
34.38	5.39	5.40	5.41	5.43	5.49	5.53	5.57	5.65	5.83	6.30
31.25	5.39	5.40	5.41	5.43	5.47	5.52	5.55	5.61	5.76	6.20
28.13	5.39	5.40	5.41	5.43	5.47	5.51	5.55	5.60	5.76	6.19
25.00	5.38	5.38	5.40	5.43	5.46	5.51	5.54	5.59	5.73	6.18
21.88	5.37	5.38	5.39	5.42	5.46	5.51	5.54	5.58	5.73	6.13
18.75	5.24	5.28	5.34	5.40	5.44	5.47	5.51	5.57	5.69	6.13
15.63	5.14	5.16	5.19	5.38	5.44	5.47	5.49	5.55	5.68	6.07
12.50	5.02	5.10	5.17	5.28	5.43	5.46	5.48	5.54	5.67	6.01
9.38	5.01	5.06	5.14	5.26	5.39	5.45	5.47	5.52	5.67	5.89
6.25	4.91	4.95	4.99	5.17	5.37	5.45	5.46	5.48	5.61	5.82
3.13	3.76	3.90	4.05	4.41	5.10	5.41	5.46	5.47	5.52	5.56

31 yrs LOs: Computed Stage (ft, NAVD) at Alexander Creek A6 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	5.77	5.80	5.81	5.82	5.85	5.93	6.03	6.25	6.31	6.39
93.75	5.74	5.74	5.74	5.78	5.85	5.93	5.92	6.02	6.04	6.16
90.63	5.70	5.71	5.74	5.76	5.80	5.88	5.92	5.96	6.04	6.11
87.50	5.64	5.65	5.65	5.68	5.76	5.84	5.88	5.91	6.03	6.10
84.38	5.62	5.64	5.65	5.66	5.75	5.77	5.79	5.84	5.96	6.00
81.25	5.57	5.57	5.58	5.58	5.58	5.60	5.65	5.67	5.94	5.98
78.13	5.53	5.54	5.54	5.55	5.57	5.60	5.62	5.66	5.82	5.97
75.00	5.53	5.54	5.54	5.55	5.56	5.58	5.62	5.65	5.76	5.92
71.88	5.53	5.54	5.54	5.54	5.55	5.58	5.61	5.64	5.75	5.86
68.75	5.52	5.52	5.53	5.53	5.55	5.57	5.59	5.63	5.74	5.82
65.63	5.49	5.50	5.51	5.53	5.54	5.55	5.57	5.62	5.73	5.75
62.50	5.47	5.48	5.49	5.52	5.54	5.55	5.56	5.61	5.71	5.73
59.38	5.47	5.47	5.48	5.48	5.50	5.51	5.54	5.61	5.68	5.72
56.25	5.46	5.47	5.48	5.48	5.49	5.51	5.52	5.59	5.65	5.72
53.13	5.45	5.45	5.45	5.46	5.48	5.50	5.52	5.58	5.64	5.72
50.00	5.44	5.45	5.45	5.45	5.48	5.49	5.51	5.56	5.62	5.70
46.88	5.42	5.43	5.44	5.45	5.48	5.49	5.50	5.56	5.61	5.70
43.75	5.41	5.42	5.42	5.43	5.45	5.49	5.50	5.55	5.60	5.69
40.63	5.39	5.40	5.40	5.42	5.45	5.46	5.48	5.54	5.58	5.69
37.50	5.39	5.40	5.40	5.41	5.44	5.46	5.46	5.53	5.58	5.67
34.38	5.39	5.39	5.40	5.41	5.43	5.45	5.46	5.51	5.57	5.66
31.25	5.39	5.39	5.40	5.41	5.42	5.44	5.46	5.50	5.57	5.66
28.13	5.39	5.39	5.39	5.41	5.42	5.43	5.46	5.49	5.55	5.63
25.00	5.38	5.38	5.39	5.41	5.42	5.43	5.46	5.47	5.52	5.63
21.88	5.37	5.38	5.38	5.38	5.40	5.41	5.44	5.47	5.51	5.62
18.75	5.24	5.26	5.29	5.34	5.37	5.41	5.41	5.46	5.48	5.59
15.63	5.14	5.15	5.16	5.23	5.35	5.35	5.39	5.43	5.45	5.57
12.50	5.02	5.05	5.09	5.15	5.24	5.30	5.37	5.41	5.44	5.54
9.38	5.01	5.04	5.07	5.10	5.23	5.28	5.32	5.37	5.43	5.50
6.25	4.91	4.93	4.95	5.01	5.16	5.25	5.30	5.35	5.42	5.49
3.13	3.76	3.82	3.90	4.08	4.43	4.73	4.91	5.11	5.27	5.46

31 yrs HIs: Computed Stage (ft, NAVD) at Alexander Creek A8 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
3.13	10.35	9.34	8.86	8.25	7.94	7.68	7.47	7.36	7.03	6.92
6.25	9.59	9.15	8.59	8.21	7.81	7.68	7.46	7.13	6.99	6.84
9.38	9.47	9.01	8.56	8.11	7.74	7.55	7.22	7.03	6.96	6.72
12.50	9.43	8.78	8.54	8.09	7.71	7.49	7.19	6.99	6.83	6.70
15.63	9.00	8.76	8.45	8.09	7.68	7.49	7.16	6.96	6.81	6.67
18.75	8.94	8.62	8.36	8.00	7.64	7.48	7.09	6.85	6.79	6.66
21.88	8.81	8.61	8.28	7.90	7.60	7.27	7.05	6.83	6.79	6.66
25.00	8.81	8.61	8.25	7.78	7.40	7.14	7.01	6.83	6.76	6.66
28.13	8.64	8.53	8.07	7.77	7.37	7.11	6.98	6.81	6.71	6.60
31.25	8.59	8.40	8.03	7.68	7.32	7.10	6.96	6.79	6.70	6.58
34.38	8.56	8.15	7.92	7.59	7.32	7.09	6.91	6.79	6.68	6.57
37.50	8.40	8.15	7.89	7.49	7.28	7.03	6.91	6.76	6.67	6.57
40.63	8.26	7.96	7.82	7.43	7.25	6.99	6.90	6.75	6.67	6.55
43.75	8.26	7.96	7.80	7.42	7.21	6.94	6.89	6.73	6.66	6.54
46.88	7.92	7.90	7.66	7.41	7.11	6.93	6.85	6.72	6.66	6.52
50.00	7.91	7.69	7.56	7.38	7.10	6.91	6.85	6.72	6.64	6.52
53.13	7.63	7.61	7.48	7.37	7.09	6.86	6.82	6.72	6.61	6.50
56.25	7.56	7.54	7.46	7.27	7.07	6.86	6.79	6.71	6.59	6.50
59.38	7.53	7.52	7.43	7.25	7.04	6.85	6.78	6.65	6.58	6.49
62.50	7.44	7.42	7.37	7.22	7.03	6.85	6.73	6.65	6.57	6.49
65.63	7.43	7.37	7.28	7.21	6.97	6.84	6.73	6.64	6.56	6.47
68.75	7.38	7.32	7.27	7.14	6.95	6.82	6.73	6.64	6.56	6.47
71.88	7.34	7.32	7.24	7.06	6.85	6.81	6.70	6.60	6.54	6.47
75.00	7.27	7.25	7.17	7.03	6.84	6.81	6.70	6.58	6.52	6.47
78.13	7.09	7.04	7.02	6.94	6.82	6.73	6.66	6.57	6.51	6.45
81.25	7.07	7.02	6.97	6.88	6.78	6.71	6.64	6.55	6.50	6.38
84.38	7.03	7.02	6.96	6.79	6.75	6.68	6.63	6.54	6.48	6.33
87.50	6.98	6.94	6.90	6.79	6.74	6.65	6.61	6.51	6.48	6.28
90.63	6.95	6.91	6.88	6.79	6.71	6.63	6.59	6.50	6.47	6.27
93.75	6.89	6.84	6.84	6.78	6.70	6.63	6.54	6.50	6.45	5.99
96.88	6.85	6.84	6.83	6.77	6.58	6.54	6.51	6.47	6.22	5.68

31 yrs LOs: Computed Stage (ft, NAVD) at Alexander Creek A8 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	6.95	7.00	7.03	7.09	7.37	7.54	7.68	8.48	9.43	10.35
93.75	6.91	6.92	6.95	7.04	7.24	7.54	7.56	7.69	9.00	9.59
90.63	6.86	6.90	6.93	6.97	7.15	7.36	7.53	7.62	8.59	9.47
87.50	6.79	6.81	6.83	6.94	7.10	7.24	7.24	7.61	8.38	9.43
84.38	6.77	6.80	6.81	6.85	7.01	7.01	7.19	7.59	7.92	9.17
81.25	6.70	6.71	6.72	6.72	6.80	6.94	7.12	7.53	7.91	9.00
78.13	6.66	6.67	6.68	6.71	6.76	6.82	7.02	7.39	7.89	8.94
75.00	6.66	6.66	6.68	6.70	6.75	6.82	6.99	7.30	7.79	8.81
71.88	6.66	6.66	6.66	6.69	6.75	6.79	6.98	7.30	7.71	8.81
68.75	6.64	6.64	6.65	6.69	6.74	6.77	6.86	7.24	7.69	8.74
65.63	6.60	6.63	6.64	6.68	6.70	6.76	6.85	7.24	7.55	8.64
62.50	6.58	6.61	6.63	6.67	6.69	6.75	6.84	7.19	7.55	8.60
59.38	6.57	6.59	6.59	6.64	6.69	6.72	6.80	7.14	7.43	8.56
56.25	6.57	6.58	6.59	6.61	6.68	6.72	6.80	7.09	7.42	8.26
53.13	6.55	6.56	6.57	6.61	6.68	6.72	6.79	7.03	7.27	7.92
50.00	6.54	6.55	6.55	6.59	6.66	6.70	6.78	6.97	7.24	7.91
46.88	6.52	6.53	6.55	6.59	6.66	6.69	6.77	6.89	7.09	7.91
43.75	6.50	6.51	6.52	6.56	6.63	6.69	6.75	6.89	7.07	7.66
40.63	6.48	6.49	6.51	6.55	6.62	6.67	6.72	6.85	7.07	7.63
37.50	6.48	6.49	6.50	6.54	6.61	6.66	6.72	6.85	7.06	7.62
34.38	6.47	6.49	6.50	6.53	6.60	6.66	6.70	6.79	7.02	7.55
31.25	6.47	6.48	6.50	6.53	6.58	6.64	6.67	6.75	6.94	7.45
28.13	6.47	6.48	6.50	6.53	6.57	6.63	6.67	6.74	6.93	7.44
25.00	6.45	6.47	6.49	6.52	6.57	6.63	6.66	6.74	6.89	7.43
21.88	6.45	6.46	6.47	6.51	6.56	6.62	6.66	6.71	6.89	7.38
18.75	6.38	6.40	6.43	6.49	6.54	6.58	6.63	6.70	6.85	7.37
15.63	6.33	6.34	6.36	6.46	6.54	6.57	6.61	6.68	6.84	7.30
12.50	6.28	6.31	6.35	6.40	6.53	6.57	6.59	6.66	6.82	7.24
9.38	6.27	6.30	6.33	6.39	6.47	6.55	6.58	6.64	6.82	7.10
6.25	6.22	6.25	6.26	6.35	6.45	6.55	6.57	6.59	6.76	7.02
3.13	5.68	5.74	5.82	5.99	6.32	6.50	6.56	6.58	6.64	6.70

31 yrs LOs: Computed Stage (ft, NAVD) at Alexander Creek A8 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	6.95	7.00	7.01	7.02	7.05	7.14	7.25	7.51	7.58	7.67
93.75	6.91	6.91	6.92	6.97	7.05	7.13	7.13	7.23	7.26	7.40
90.63	6.86	6.87	6.90	6.93	6.97	7.09	7.12	7.17	7.25	7.34
87.50	6.79	6.79	6.80	6.84	6.94	7.03	7.09	7.12	7.25	7.32
84.38	6.77	6.79	6.80	6.81	6.92	6.95	6.98	7.03	7.17	7.22
81.25	6.70	6.71	6.71	6.71	6.72	6.74	6.80	6.82	7.15	7.18
78.13	6.66	6.66	6.67	6.68	6.70	6.73	6.77	6.81	6.98	7.17
75.00	6.66	6.66	6.67	6.68	6.69	6.72	6.76	6.79	6.92	7.13
71.88	6.66	6.66	6.66	6.66	6.68	6.72	6.75	6.79	6.92	7.03
68.75	6.64	6.64	6.64	6.65	6.68	6.71	6.73	6.78	6.91	7.01
65.63	6.60	6.62	6.62	6.65	6.67	6.68	6.70	6.77	6.90	6.92
62.50	6.58	6.59	6.60	6.64	6.66	6.67	6.69	6.75	6.87	6.89
59.38	6.57	6.58	6.59	6.59	6.61	6.63	6.66	6.75	6.83	6.88
56.25	6.57	6.58	6.58	6.59	6.60	6.63	6.64	6.72	6.80	6.88
53.13	6.55	6.55	6.56	6.57	6.60	6.62	6.63	6.71	6.78	6.88
50.00	6.54	6.55	6.55	6.56	6.59	6.61	6.63	6.69	6.76	6.86
46.88	6.52	6.53	6.53	6.55	6.59	6.60	6.62	6.69	6.76	6.86
43.75	6.50	6.51	6.51	6.53	6.56	6.60	6.61	6.68	6.75	6.85
40.63	6.48	6.49	6.49	6.52	6.55	6.56	6.59	6.66	6.72	6.83
37.50	6.48	6.48	6.49	6.50	6.54	6.56	6.57	6.66	6.72	6.83
34.38	6.47	6.48	6.49	6.50	6.52	6.55	6.57	6.65	6.70	6.82
31.25	6.47	6.48	6.49	6.50	6.52	6.54	6.57	6.63	6.70	6.81
28.13	6.47	6.47	6.48	6.50	6.52	6.53	6.56	6.61	6.68	6.80
25.00	6.45	6.46	6.47	6.50	6.52	6.52	6.56	6.58	6.64	6.79
21.88	6.45	6.46	6.46	6.46	6.48	6.51	6.54	6.58	6.62	6.77
18.75	6.38	6.39	6.40	6.44	6.47	6.50	6.53	6.57	6.59	6.76
15.63	6.33	6.34	6.34	6.38	6.47	6.47	6.51	6.53	6.55	6.72
12.50	6.28	6.29	6.31	6.34	6.40	6.44	6.48	6.52	6.55	6.67
9.38	6.27	6.28	6.30	6.31	6.37	6.41	6.44	6.48	6.55	6.62
6.25	6.22	6.24	6.24	6.28	6.34	6.40	6.44	6.47	6.55	6.61
3.13	5.68	5.71	5.75	5.83	6.00	6.15	6.25	6.38	6.50	6.57

31 yrs HIs: Computed Stage (ft, NAVD) at Alexander Creek A10 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
3.13	11.23	10.00	9.48	9.11	8.90	8.67	8.51	8.42	8.07	8.02
6.25	10.42	9.83	9.35	9.09	8.69	8.51	8.31	8.06	8.04	7.87
9.38	10.34	9.73	9.34	8.84	8.65	8.49	8.24	8.05	8.02	7.86
12.50	10.19	9.55	9.04	8.77	8.53	8.46	8.16	8.04	7.88	7.84
15.63	9.75	9.42	9.00	8.69	8.53	8.39	8.14	7.97	7.87	7.80
18.75	9.67	9.40	9.00	8.65	8.49	8.33	8.05	7.89	7.85	7.78
21.88	9.59	9.39	8.90	8.63	8.40	8.21	8.02	7.88	7.84	7.76
25.00	9.50	9.36	8.85	8.60	8.33	8.15	8.02	7.88	7.84	7.74
28.13	9.45	9.19	8.82	8.57	8.31	8.12	7.99	7.88	7.81	7.73
31.25	9.44	9.09	8.80	8.56	8.24	8.08	7.99	7.85	7.80	7.73
34.38	9.33	8.94	8.73	8.44	8.21	8.05	7.98	7.85	7.80	7.73
37.50	9.20	8.93	8.71	8.38	8.21	8.04	7.96	7.84	7.78	7.71
40.63	9.04	8.81	8.69	8.36	8.21	8.03	7.94	7.84	7.76	7.69
43.75	9.02	8.78	8.69	8.35	8.12	8.00	7.93	7.83	7.76	7.68
46.88	8.78	8.77	8.55	8.35	8.11	7.99	7.90	7.82	7.74	7.68
50.00	8.75	8.59	8.46	8.29	8.10	7.96	7.88	7.80	7.73	7.66
53.13	8.50	8.48	8.40	8.27	8.10	7.91	7.86	7.78	7.72	7.63
56.25	8.48	8.46	8.40	8.26	8.10	7.90	7.86	7.78	7.72	7.62
59.38	8.45	8.44	8.36	8.22	8.06	7.89	7.84	7.77	7.72	7.62
62.50	8.44	8.39	8.36	8.20	8.02	7.89	7.84	7.75	7.70	7.62
65.63	8.38	8.31	8.24	8.17	8.00	7.87	7.83	7.75	7.70	7.61
68.75	8.33	8.30	8.22	8.14	7.99	7.87	7.81	7.75	7.69	7.61
71.88	8.32	8.29	8.22	8.07	7.91	7.86	7.80	7.73	7.68	7.61
75.00	8.22	8.21	8.15	8.04	7.88	7.85	7.80	7.72	7.64	7.61
78.13	8.10	8.06	8.02	7.99	7.88	7.85	7.77	7.71	7.64	7.59
81.25	8.07	8.05	8.01	7.92	7.87	7.84	7.77	7.68	7.63	7.50
84.38	8.07	8.04	8.00	7.89	7.87	7.82	7.74	7.65	7.62	7.43
87.50	8.02	7.97	7.95	7.89	7.84	7.76	7.72	7.65	7.61	7.41
90.63	8.01	7.97	7.94	7.88	7.82	7.76	7.72	7.65	7.59	7.35
93.75	7.97	7.95	7.94	7.86	7.79	7.74	7.67	7.63	7.58	7.06
96.88	7.97	7.92	7.92	7.85	7.69	7.68	7.65	7.63	7.35	6.66

31 yrs LOs: Computed Stage (ft, NAVD) at Alexander Creek A10 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	8.02	8.04	8.05	8.14	8.34	8.52	8.65	9.37	10.19	11.23
93.75	7.94	8.03	8.03	8.07	8.28	8.48	8.48	8.58	9.63	10.42
90.63	7.93	7.97	8.02	8.04	8.17	8.33	8.45	8.56	9.44	10.34
87.50	7.84	7.86	7.89	7.98	8.11	8.23	8.28	8.49	8.94	10.19
84.38	7.83	7.85	7.85	7.87	8.07	8.11	8.27	8.45	8.78	9.88
81.25	7.80	7.81	7.82	7.86	7.87	7.97	8.08	8.42	8.75	9.75
78.13	7.78	7.78	7.79	7.81	7.87	7.94	8.06	8.38	8.73	9.67
75.00	7.78	7.78	7.79	7.81	7.87	7.89	8.06	8.32	8.66	9.59
71.88	7.76	7.77	7.78	7.81	7.83	7.88	8.01	8.31	8.58	9.55
68.75	7.76	7.76	7.77	7.79	7.82	7.87	7.96	8.27	8.58	9.50
65.63	7.74	7.76	7.77	7.78	7.82	7.86	7.92	8.26	8.54	9.45
62.50	7.73	7.74	7.74	7.78	7.82	7.85	7.91	8.22	8.48	9.33
59.38	7.73	7.73	7.74	7.76	7.81	7.84	7.90	8.18	8.40	9.27
56.25	7.71	7.71	7.73	7.75	7.78	7.84	7.89	8.10	8.33	9.02
53.13	7.69	7.71	7.71	7.74	7.78	7.82	7.88	8.07	8.32	8.78
50.00	7.68	7.70	7.71	7.72	7.77	7.80	7.86	8.03	8.22	8.75
46.88	7.68	7.68	7.69	7.72	7.75	7.80	7.86	7.98	8.10	8.75
43.75	7.63	7.65	7.67	7.70	7.75	7.78	7.85	7.97	8.10	8.58
40.63	7.63	7.64	7.65	7.69	7.75	7.78	7.84	7.97	8.10	8.50
37.50	7.63	7.63	7.65	7.68	7.74	7.78	7.82	7.94	8.07	8.48
34.38	7.62	7.63	7.65	7.67	7.72	7.77	7.80	7.91	8.04	8.45
31.25	7.62	7.63	7.64	7.66	7.72	7.76	7.80	7.87	8.04	8.44
28.13	7.61	7.63	7.64	7.66	7.72	7.76	7.79	7.84	8.03	8.38
25.00	7.61	7.62	7.64	7.66	7.70	7.74	7.77	7.81	7.97	8.38
21.88	7.59	7.61	7.62	7.66	7.69	7.74	7.76	7.81	7.96	8.33
18.75	7.50	7.53	7.55	7.63	7.69	7.74	7.76	7.80	7.95	8.33
15.63	7.43	7.46	7.49	7.61	7.68	7.71	7.75	7.78	7.93	8.32
12.50	7.41	7.44	7.45	7.57	7.66	7.70	7.74	7.77	7.93	8.21
9.38	7.35	7.39	7.45	7.52	7.64	7.69	7.72	7.76	7.90	8.12
6.25	7.35	7.38	7.40	7.51	7.62	7.69	7.71	7.74	7.81	7.98
3.13	6.66	6.75	6.84	7.05	7.43	7.65	7.71	7.73	7.77	7.83

31 yrs LOs: Computed Stage (ft, NAVD) at Alexander Creek A10 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	8.02	8.02	8.05	8.06	8.10	8.18	8.28	8.50	8.58	8.64
93.75	7.94	7.99	8.03	8.03	8.08	8.11	8.13	8.20	8.25	8.34
90.63	7.93	7.95	7.97	8.03	8.05	8.10	8.12	8.15	8.24	8.29
87.50	7.84	7.85	7.86	7.89	7.97	8.06	8.10	8.15	8.22	8.24
84.38	7.83	7.85	7.85	7.85	7.95	8.04	8.08	8.13	8.17	8.21
81.25	7.80	7.80	7.81	7.83	7.86	7.86	7.87	7.94	8.14	8.18
78.13	7.78	7.78	7.78	7.79	7.81	7.84	7.87	7.89	8.02	8.15
75.00	7.78	7.78	7.78	7.79	7.80	7.82	7.86	7.89	7.97	8.14
71.88	7.76	7.77	7.77	7.78	7.79	7.81	7.83	7.86	7.97	8.04
68.75	7.76	7.76	7.76	7.77	7.79	7.80	7.83	7.85	7.96	8.03
65.63	7.74	7.75	7.76	7.77	7.78	7.80	7.82	7.85	7.94	8.00
62.50	7.73	7.74	7.74	7.74	7.76	7.79	7.81	7.85	7.93	7.98
59.38	7.73	7.73	7.73	7.74	7.75	7.77	7.78	7.85	7.91	7.96
56.25	7.71	7.71	7.71	7.73	7.75	7.76	7.77	7.84	7.90	7.95
53.13	7.69	7.70	7.71	7.71	7.74	7.75	7.76	7.84	7.89	7.95
50.00	7.68	7.69	7.70	7.71	7.72	7.73	7.76	7.81	7.87	7.94
46.88	7.68	7.68	7.68	7.69	7.71	7.72	7.75	7.79	7.84	7.93
43.75	7.63	7.64	7.64	7.69	7.71	7.72	7.72	7.79	7.83	7.90
40.63	7.63	7.63	7.64	7.65	7.69	7.70	7.71	7.77	7.82	7.88
37.50	7.63	7.63	7.63	7.64	7.68	7.70	7.71	7.77	7.81	7.88
34.38	7.62	7.63	7.63	7.64	7.65	7.69	7.71	7.76	7.81	7.88
31.25	7.62	7.62	7.63	7.64	7.65	7.66	7.71	7.76	7.80	7.87
28.13	7.61	7.62	7.63	7.63	7.65	7.66	7.69	7.74	7.79	7.87
25.00	7.61	7.61	7.63	7.63	7.65	7.66	7.68	7.73	7.76	7.85
21.88	7.59	7.60	7.61	7.61	7.64	7.65	7.67	7.71	7.74	7.85
18.75	7.50	7.52	7.53	7.57	7.61	7.65	7.67	7.69	7.71	7.85
15.63	7.43	7.43	7.46	7.49	7.58	7.58	7.65	7.68	7.70	7.83
12.50	7.41	7.43	7.44	7.48	7.54	7.57	7.61	7.64	7.69	7.77
9.38	7.35	7.37	7.40	7.41	7.51	7.56	7.60	7.63	7.69	7.73
6.25	7.35	7.37	7.38	7.41	7.50	7.56	7.59	7.63	7.66	7.72
3.13	6.66	6.71	6.75	6.86	7.05	7.23	7.35	7.48	7.59	7.72

31 yrs HIs: Computed Stage (ft, NAVD) at Alexander Creek A14 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
3.13	12.26	10.64	10.09	9.90	9.57	9.36	9.22	9.11	8.77	8.69
6.25	11.30	10.57	10.05	9.87	9.37	9.20	8.99	8.77	8.69	8.56
9.38	11.19	10.34	10.02	9.44	9.30	9.19	8.94	8.76	8.57	8.54
12.50	10.98	10.17	9.74	9.43	9.24	9.07	8.85	8.75	8.56	8.54
15.63	10.54	10.11	9.65	9.35	9.18	9.01	8.81	8.64	8.54	8.48
18.75	10.45	10.10	9.63	9.34	9.17	8.99	8.74	8.58	8.54	8.47
21.88	10.37	10.10	9.54	9.31	9.07	8.90	8.71	8.58	8.51	8.46
25.00	10.27	10.00	9.50	9.25	9.02	8.82	8.70	8.57	8.51	8.45
28.13	10.15	9.93	9.46	9.24	8.95	8.81	8.68	8.57	8.51	8.44
31.25	10.14	9.76	9.46	9.18	8.90	8.79	8.67	8.54	8.50	8.43
34.38	9.99	9.63	9.44	9.06	8.88	8.73	8.67	8.53	8.49	8.43
37.50	9.92	9.61	9.38	9.05	8.83	8.71	8.64	8.53	8.48	8.42
40.63	9.84	9.47	9.34	9.03	8.81	8.71	8.63	8.52	8.47	8.40
43.75	9.75	9.43	9.31	9.02	8.80	8.70	8.63	8.50	8.46	8.39
46.88	9.47	9.41	9.23	9.01	8.78	8.65	8.56	8.49	8.44	8.38
50.00	9.43	9.26	9.14	8.96	8.76	8.61	8.56	8.49	8.44	8.37
53.13	9.15	9.13	9.10	8.95	8.73	8.60	8.55	8.48	8.43	8.34
56.25	9.13	9.12	9.05	8.94	8.73	8.59	8.53	8.47	8.43	8.34
59.38	9.11	9.07	9.02	8.86	8.72	8.57	8.52	8.47	8.42	8.33
62.50	9.07	9.06	9.00	8.84	8.72	8.56	8.52	8.46	8.41	8.33
65.63	8.97	8.95	8.90	8.79	8.70	8.55	8.51	8.45	8.41	8.32
68.75	8.97	8.92	8.89	8.78	8.63	8.54	8.50	8.45	8.40	8.32
71.88	8.97	8.88	8.86	8.75	8.60	8.53	8.48	8.44	8.39	8.32
75.00	8.90	8.88	8.82	8.74	8.56	8.52	8.48	8.43	8.35	8.32
78.13	8.76	8.73	8.70	8.67	8.54	8.52	8.48	8.41	8.34	8.31
81.25	8.74	8.72	8.69	8.59	8.52	8.49	8.46	8.39	8.34	8.17
84.38	8.73	8.72	8.68	8.59	8.52	8.47	8.44	8.36	8.32	8.14
87.50	8.68	8.65	8.62	8.58	8.51	8.45	8.43	8.35	8.31	8.10
90.63	8.65	8.64	8.62	8.58	8.48	8.44	8.41	8.35	8.30	8.05
93.75	8.64	8.63	8.61	8.55	8.47	8.43	8.37	8.34	8.29	7.76
96.88	8.64	8.63	8.61	8.53	8.36	8.35	8.35	8.34	8.08	7.29

31 yrs LOs: Computed Stage (ft, NAVD) at Alexander Creek A14 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	8.70	8.72	8.76	8.84	8.99	9.21	9.36	10.06	10.98	12.26
93.75	8.64	8.71	8.73	8.78	8.94	9.15	9.15	9.25	10.45	11.30
90.63	8.62	8.68	8.71	8.72	8.84	8.99	9.12	9.18	10.14	11.19
87.50	8.54	8.55	8.57	8.66	8.77	8.89	8.94	9.16	9.61	10.98
84.38	8.52	8.55	8.55	8.56	8.73	8.75	8.78	9.13	9.47	10.54
81.25	8.50	8.51	8.52	8.55	8.56	8.67	8.77	9.12	9.43	10.48
78.13	8.49	8.49	8.49	8.50	8.56	8.65	8.74	9.09	9.36	10.45
75.00	8.48	8.49	8.49	8.50	8.52	8.58	8.71	8.98	9.31	10.37
71.88	8.47	8.47	8.48	8.50	8.51	8.57	8.67	8.96	9.30	10.37
68.75	8.46	8.47	8.47	8.48	8.51	8.54	8.60	8.94	9.25	10.27
65.63	8.45	8.46	8.47	8.48	8.51	8.53	8.59	8.90	9.15	10.15
62.50	8.44	8.44	8.45	8.46	8.50	8.52	8.58	8.89	9.07	9.99
59.38	8.43	8.43	8.43	8.45	8.49	8.51	8.57	8.84	9.01	9.95
56.25	8.42	8.42	8.43	8.44	8.49	8.50	8.56	8.76	8.98	9.75
53.13	8.40	8.41	8.42	8.43	8.46	8.49	8.54	8.73	8.96	9.47
50.00	8.39	8.40	8.41	8.42	8.45	8.48	8.52	8.67	8.86	9.43
46.88	8.38	8.40	8.40	8.42	8.45	8.47	8.51	8.65	8.76	9.38
43.75	8.34	8.35	8.37	8.41	8.44	8.47	8.51	8.65	8.75	9.31
40.63	8.34	8.35	8.36	8.39	8.43	8.46	8.49	8.65	8.75	9.11
37.50	8.34	8.34	8.34	8.37	8.43	8.45	8.49	8.63	8.73	9.11
34.38	8.33	8.34	8.34	8.35	8.40	8.44	8.48	8.58	8.70	9.07
31.25	8.33	8.33	8.34	8.35	8.40	8.43	8.48	8.52	8.68	9.05
28.13	8.32	8.33	8.34	8.34	8.39	8.43	8.47	8.52	8.66	9.01
25.00	8.32	8.32	8.33	8.34	8.38	8.42	8.46	8.51	8.61	8.98
21.88	8.31	8.32	8.32	8.34	8.37	8.42	8.45	8.48	8.60	8.97
18.75	8.17	8.17	8.20	8.30	8.36	8.40	8.44	8.48	8.54	8.97
15.63	8.14	8.16	8.19	8.30	8.35	8.38	8.44	8.46	8.54	8.90
12.50	8.10	8.15	8.17	8.26	8.32	8.38	8.43	8.45	8.52	8.90
9.38	8.08	8.11	8.14	8.20	8.31	8.38	8.41	8.45	8.51	8.79
6.25	8.05	8.08	8.10	8.18	8.31	8.37	8.41	8.44	8.49	8.65
3.13	7.29	7.39	7.49	7.74	8.17	8.36	8.40	8.43	8.46	8.53

31 yrs LOs: Computed Stage (ft, NAVD) at Alexander Creek A14 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	8.70	8.70	8.72	8.76	8.80	8.87	8.97	9.21	9.28	9.34
93.75	8.64	8.66	8.71	8.74	8.78	8.81	8.83	8.88	8.93	9.01
90.63	8.62	8.66	8.68	8.71	8.72	8.78	8.81	8.84	8.91	8.97
87.50	8.54	8.54	8.55	8.58	8.65	8.73	8.79	8.83	8.90	8.92
84.38	8.52	8.53	8.55	8.55	8.65	8.73	8.73	8.78	8.85	8.89
81.25	8.50	8.50	8.51	8.52	8.55	8.56	8.57	8.60	8.82	8.86
78.13	8.49	8.49	8.49	8.49	8.50	8.54	8.56	8.59	8.70	8.82
75.00	8.48	8.48	8.49	8.49	8.50	8.51	8.56	8.58	8.65	8.82
71.88	8.47	8.47	8.47	8.48	8.50	8.50	8.53	8.55	8.64	8.71
68.75	8.46	8.47	8.47	8.47	8.49	8.50	8.51	8.54	8.63	8.70
65.63	8.45	8.45	8.46	8.47	8.48	8.50	8.51	8.54	8.62	8.67
62.50	8.44	8.44	8.44	8.45	8.46	8.49	8.51	8.54	8.62	8.66
59.38	8.43	8.43	8.43	8.44	8.45	8.46	8.46	8.54	8.59	8.64
56.25	8.42	8.42	8.42	8.43	8.45	8.45	8.46	8.53	8.59	8.63
53.13	8.40	8.40	8.40	8.42	8.43	8.45	8.46	8.53	8.58	8.62
50.00	8.39	8.40	8.40	8.41	8.42	8.43	8.44	8.49	8.56	8.61
46.88	8.38	8.39	8.40	8.40	8.42	8.43	8.44	8.49	8.53	8.61
43.75	8.34	8.34	8.35	8.38	8.42	8.42	8.42	8.48	8.52	8.58
40.63	8.34	8.34	8.35	8.36	8.39	8.40	8.41	8.47	8.51	8.57
37.50	8.34	8.34	8.34	8.35	8.37	8.39	8.41	8.46	8.51	8.57
34.38	8.33	8.34	8.34	8.34	8.35	8.39	8.40	8.46	8.50	8.56
31.25	8.33	8.33	8.33	8.34	8.35	8.36	8.39	8.45	8.49	8.56
28.13	8.32	8.32	8.33	8.34	8.35	8.36	8.38	8.43	8.48	8.55
25.00	8.32	8.32	8.32	8.33	8.34	8.35	8.38	8.43	8.45	8.53
21.88	8.31	8.31	8.32	8.33	8.34	8.35	8.37	8.40	8.43	8.53
18.75	8.17	8.17	8.17	8.21	8.30	8.32	8.36	8.38	8.40	8.53
15.63	8.14	8.15	8.17	8.20	8.27	8.30	8.33	8.38	8.40	8.50
12.50	8.10	8.12	8.15	8.20	8.25	8.28	8.32	8.35	8.39	8.45
9.38	8.08	8.10	8.11	8.14	8.21	8.25	8.31	8.34	8.38	8.43
6.25	8.05	8.06	8.08	8.11	8.18	8.24	8.28	8.33	8.36	8.42
3.13	7.29	7.34	7.39	7.52	7.74	7.93	8.05	8.18	8.27	8.42

31 yrs HIs: Computed Stage (ft, NAVD) at Alexander Creek A16 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
3.13	16.94	16.90	16.86	16.77	16.61	16.44	16.35	16.24	9.47	9.33
6.25	16.62	16.59	16.56	16.48	16.34	16.24	15.57	9.64	9.33	9.07
9.38	16.21	15.98	15.05	10.14	9.81	9.57	9.46	9.43	9.07	8.98
12.50	15.92	15.53	14.99	10.02	9.51	9.43	9.43	9.12	9.01	8.98
15.63	15.50	11.92	10.55	9.78	9.51	9.31	9.24	9.12	9.00	8.94
18.75	14.90	11.25	10.00	9.69	9.45	9.27	9.24	9.11	8.98	8.94
21.88	10.24	10.10	9.95	9.53	9.37	9.24	9.19	9.07	8.97	8.92
25.00	9.76	9.68	9.61	9.49	9.35	9.22	9.15	9.06	8.96	8.92
28.13	9.74	9.66	9.61	9.46	9.31	9.21	9.12	9.03	8.96	8.90
31.25	9.71	9.65	9.60	9.42	9.30	9.18	9.11	9.03	8.94	8.88
34.38	9.69	9.55	9.55	9.42	9.22	9.18	9.09	9.03	8.93	8.88
37.50	9.52	9.46	9.41	9.36	9.21	9.17	9.09	8.98	8.92	8.88
40.63	9.39	9.37	9.37	9.32	9.21	9.17	9.08	8.98	8.91	8.88
43.75	9.38	9.37	9.35	9.29	9.21	9.16	9.07	8.97	8.91	8.87
46.88	9.38	9.36	9.34	9.28	9.19	9.13	9.06	8.96	8.90	8.84
50.00	9.38	9.33	9.28	9.24	9.18	9.09	9.06	8.96	8.90	8.82
53.13	9.35	9.31	9.27	9.22	9.18	9.07	9.05	8.95	8.90	8.81
56.25	9.33	9.29	9.27	9.22	9.13	9.07	9.01	8.95	8.89	8.79
59.38	9.30	9.27	9.25	9.19	9.12	9.06	8.99	8.94	8.88	8.78
62.50	9.30	9.26	9.22	9.17	9.08	9.02	8.97	8.92	8.88	8.78
65.63	9.27	9.25	9.19	9.16	9.08	8.99	8.97	8.91	8.87	8.77
68.75	9.21	9.20	9.14	9.11	9.07	8.99	8.95	8.91	8.85	8.77
71.88	9.17	9.16	9.13	9.11	9.06	8.97	8.94	8.91	8.83	8.75
75.00	9.15	9.14	9.04	9.01	8.97	8.95	8.91	8.89	8.80	8.73
78.13	9.15	9.09	9.02	8.99	8.96	8.95	8.90	8.86	8.79	8.71
81.25	9.06	9.03	9.01	8.97	8.95	8.91	8.89	8.85	8.78	8.70
84.38	9.05	9.03	8.97	8.96	8.93	8.91	8.88	8.83	8.75	8.69
87.50	9.03	9.01	8.96	8.95	8.92	8.91	8.85	8.81	8.75	8.68
90.63	8.96	8.96	8.95	8.94	8.92	8.89	8.84	8.79	8.75	8.62
93.75	8.92	8.92	8.92	8.92	8.89	8.87	8.83	8.77	8.73	8.45
96.88	8.92	8.90	8.89	8.85	8.84	8.84	8.79	8.75	8.69	7.99

31 yrs LOs: Computed Stage (ft, NAVD) at Alexander Creek A16 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	9.34	9.36	9.38	9.42	9.70	16.20	16.37	16.62	16.94	16.94
93.75	9.21	9.26	9.30	9.39	9.52	9.57	9.69	16.27	16.43	16.43
90.63	9.01	9.07	9.14	9.15	9.26	9.40	9.63	9.96	15.92	16.21
87.50	8.99	9.01	9.01	9.07	9.15	9.33	9.33	9.96	15.50	15.92
84.38	8.96	8.98	9.01	9.06	9.13	9.28	9.33	9.87	9.96	15.50
81.25	8.95	8.97	8.99	9.02	9.10	9.12	9.32	9.86	9.96	14.90
78.13	8.95	8.95	8.98	9.02	9.05	9.07	9.21	9.55	9.88	10.24
75.00	8.94	8.95	8.98	9.01	9.04	9.07	9.11	9.36	9.69	9.76
71.88	8.94	8.95	8.96	9.00	9.03	9.06	9.10	9.33	9.55	9.69
68.75	8.92	8.95	8.95	8.98	9.02	9.05	9.08	9.32	9.52	9.55
65.63	8.92	8.94	8.94	8.95	9.01	9.03	9.07	9.28	9.38	9.52
62.50	8.91	8.91	8.94	8.95	8.96	9.03	9.07	9.27	9.37	9.46
59.38	8.90	8.90	8.91	8.94	8.96	8.98	9.07	9.24	9.35	9.41
56.25	8.87	8.90	8.90	8.91	8.94	8.98	9.05	9.18	9.33	9.39
53.13	8.82	8.84	8.86	8.91	8.92	8.98	9.04	9.14	9.27	9.38
50.00	8.81	8.83	8.84	8.87	8.92	8.96	9.01	9.13	9.21	9.37
46.88	8.81	8.82	8.84	8.86	8.90	8.96	8.99	9.07	9.17	9.30
43.75	8.81	8.82	8.83	8.85	8.88	8.92	8.96	9.06	9.15	9.30
40.63	8.80	8.80	8.83	8.84	8.88	8.92	8.96	8.99	9.15	9.27
37.50	8.78	8.79	8.81	8.84	8.88	8.89	8.93	8.97	9.15	9.27
34.38	8.78	8.78	8.80	8.81	8.85	8.88	8.92	8.97	9.09	9.21
31.25	8.77	8.77	8.79	8.81	8.84	8.87	8.90	8.95	9.07	9.15
28.13	8.76	8.77	8.79	8.81	8.84	8.87	8.90	8.95	9.03	9.15
25.00	8.74	8.75	8.77	8.79	8.82	8.87	8.90	8.95	9.03	9.15
21.88	8.73	8.74	8.76	8.79	8.81	8.86	8.89	8.94	9.02	9.12
18.75	8.71	8.72	8.74	8.78	8.81	8.86	8.88	8.94	8.98	9.08
15.63	8.69	8.71	8.73	8.76	8.80	8.84	8.86	8.94	8.97	9.03
12.50	8.69	8.71	8.72	8.75	8.78	8.83	8.86	8.93	8.96	9.03
9.38	8.68	8.68	8.69	8.70	8.76	8.82	8.85	8.90	8.94	8.98
6.25	8.62	8.65	8.67	8.70	8.73	8.80	8.84	8.89	8.92	8.95
3.13	7.99	8.08	8.17	8.39	8.72	8.79	8.79	8.89	8.90	8.91

31 yrs LOs: Computed Stage (ft, NAVD) at Alexander Creek A16 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	9.34	9.35	9.36	9.38	9.45	10.61	12.03	13.44	13.99	14.64
93.75	9.21	9.23	9.26	9.31	9.42	9.50	9.52	10.36	12.35	11.96
90.63	9.01	9.03	9.08	9.12	9.13	9.18	9.27	9.47	9.60	9.65
87.50	8.99	9.01	9.01	9.01	9.07	9.15	9.18	9.27	9.50	9.59
84.38	8.96	8.97	8.98	9.01	9.07	9.10	9.13	9.22	9.35	9.48
81.25	8.95	8.95	8.97	8.99	9.03	9.09	9.11	9.16	9.18	9.18
78.13	8.95	8.95	8.96	8.99	9.02	9.03	9.04	9.15	9.17	9.18
75.00	8.94	8.94	8.95	8.98	9.01	9.03	9.04	9.08	9.15	9.18
71.88	8.94	8.94	8.95	8.96	9.00	9.02	9.03	9.08	9.13	9.17
68.75	8.92	8.94	8.95	8.96	8.98	8.99	9.01	9.07	9.12	9.17
65.63	8.92	8.93	8.94	8.95	8.95	8.97	8.99	9.06	9.10	9.16
62.50	8.91	8.91	8.91	8.94	8.95	8.96	8.96	9.06	9.10	9.13
59.38	8.90	8.90	8.90	8.91	8.94	8.95	8.96	9.05	9.10	9.12
56.25	8.87	8.89	8.90	8.90	8.91	8.93	8.95	9.04	9.09	9.11
53.13	8.82	8.83	8.84	8.89	8.91	8.92	8.92	9.02	9.02	9.08
50.00	8.81	8.82	8.83	8.84	8.87	8.89	8.92	9.01	9.01	9.07
46.88	8.81	8.82	8.82	8.84	8.86	8.89	8.90	8.96	9.01	9.03
43.75	8.81	8.82	8.82	8.84	8.85	8.88	8.89	8.96	8.96	8.96
40.63	8.80	8.80	8.80	8.83	8.84	8.87	8.89	8.92	8.94	8.96
37.50	8.78	8.79	8.80	8.81	8.84	8.85	8.88	8.89	8.93	8.95
34.38	8.78	8.78	8.78	8.80	8.81	8.84	8.85	8.88	8.91	8.93
31.25	8.77	8.77	8.77	8.79	8.81	8.83	8.85	8.87	8.91	8.92
28.13	8.76	8.77	8.77	8.79	8.81	8.82	8.85	8.87	8.90	8.92
25.00	8.74	8.75	8.76	8.78	8.79	8.81	8.82	8.87	8.89	8.92
21.88	8.73	8.73	8.75	8.76	8.79	8.80	8.82	8.84	8.88	8.91
18.75	8.71	8.72	8.72	8.74	8.77	8.79	8.81	8.84	8.87	8.90
15.63	8.69	8.70	8.71	8.74	8.76	8.78	8.80	8.84	8.86	8.89
12.50	8.69	8.70	8.71	8.72	8.75	8.77	8.80	8.82	8.85	8.89
9.38	8.68	8.68	8.68	8.69	8.70	8.74	8.78	8.79	8.83	8.86
6.25	8.62	8.63	8.65	8.67	8.70	8.72	8.75	8.77	8.81	8.85
3.13	7.99	8.04	8.09	8.20	8.40	8.54	8.63	8.72	8.79	8.84

Frequency Analysis Tables

Discharge – MFL

31 yrs HIs: Simulated MFLs Discharges at Tracy Canal(1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
3.13	806.99	591.28	418.01	285.70	230.26	189.64	159.89	149.22	126.20	111.81
6.25	484.45	409.95	341.31	256.24	208.01	188.02	156.90	147.22	117.57	111.76
9.38	477.11	399.28	316.99	256.00	188.83	171.11	155.22	132.86	116.45	103.15
12.50	413.74	355.07	278.19	233.61	187.52	170.02	151.82	130.28	111.64	101.60
15.63	316.54	293.42	270.79	227.86	187.51	165.51	147.89	127.28	108.35	98.08
18.75	303.70	278.00	265.91	226.92	184.48	162.26	143.11	116.45	107.84	96.72
21.88	284.99	260.77	252.44	224.12	179.69	155.28	134.77	114.02	106.52	96.41
25.00	284.76	251.74	249.78	215.84	179.12	148.41	132.98	112.64	105.41	94.92
28.13	282.22	250.59	243.73	203.20	176.11	141.65	131.11	110.93	102.64	94.52
31.25	274.88	248.84	233.16	203.13	174.73	141.24	130.31	108.75	100.52	94.24
34.38	265.76	239.92	231.05	196.17	173.29	139.06	128.56	108.35	100.32	93.71
37.50	260.52	238.59	223.17	194.83	171.75	135.15	126.62	108.29	98.60	90.73
40.63	252.67	235.03	220.88	182.31	166.44	134.78	126.05	107.40	98.10	90.56
43.75	246.79	234.71	219.15	179.47	163.52	134.68	120.24	106.52	97.39	89.78
46.88	243.90	233.63	216.54	173.33	160.87	132.98	117.05	105.56	96.72	88.32
50.00	241.74	233.15	211.00	166.70	155.77	130.49	114.02	105.52	96.72	87.76
53.13	240.82	225.78	208.73	166.09	152.46	128.07	113.69	103.54	95.31	87.72
56.25	231.68	219.76	198.59	162.35	145.69	124.57	112.97	102.44	94.21	87.63
59.38	229.89	218.68	185.56	160.71	145.51	124.41	111.44	100.52	94.08	87.35
62.50	196.80	193.87	184.38	158.27	139.56	122.59	111.20	98.22	92.18	87.33
65.63	196.53	188.30	170.71	154.63	138.76	120.67	109.40	97.33	92.12	87.08
68.75	191.27	183.37	170.57	150.81	135.38	115.79	108.29	95.13	91.81	86.23
71.88	191.04	181.00	167.85	142.28	123.75	115.38	108.26	94.41	89.95	85.57
75.00	190.94	178.67	164.08	140.71	121.17	112.21	107.03	94.39	89.83	85.51
78.13	174.05	169.72	162.75	139.96	117.32	110.36	102.98	93.73	89.64	84.78
81.25	172.65	167.06	155.92	136.10	115.38	103.50	101.06	92.03	89.44	83.24
84.38	162.43	158.23	147.53	135.72	114.97	102.98	99.20	91.37	88.73	81.52
87.50	161.20	155.35	143.18	130.68	113.43	102.60	98.43	91.17	87.72	81.23
90.63	158.58	154.12	142.43	122.19	111.83	101.87	98.14	89.95	84.78	80.02
93.75	156.14	152.69	139.45	121.39	110.77	99.26	94.27	89.64	84.57	62.81
96.88	126.58	121.37	118.41	109.22	100.00	99.20	92.92	87.88	74.38	53.95

31 yrs LOs: Simulated MFLs Discharges at Tracy Canal(1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	117.57	118.31	119.60	120.42	128.12	138.79	142.51	162.44	168.46	178.21
93.75	111.76	112.59	113.69	118.12	125.01	135.30	137.45	148.25	155.12	168.82
90.63	110.93	111.27	112.01	113.50	124.54	127.70	136.95	141.16	153.10	161.25
87.50	106.52	106.83	108.32	110.02	116.68	127.17	127.05	131.91	148.03	156.70
84.38	105.87	106.79	107.17	109.44	116.25	122.41	126.54	131.60	145.55	156.56
81.25	98.60	99.04	99.45	100.05	103.81	107.48	107.35	116.88	139.69	147.75
78.13	98.06	98.33	98.43	99.72	102.43	103.55	106.89	115.81	131.92	146.78
75.00	96.72	97.46	98.41	98.98	101.90	102.64	105.54	114.40	131.33	146.00
71.88	94.92	96.37	97.53	98.62	101.26	102.51	104.29	110.54	130.29	144.44
68.75	94.52	96.09	97.40	97.95	100.20	102.09	104.07	109.94	127.48	140.43
65.63	94.24	95.11	95.14	96.36	99.36	100.32	103.89	108.61	124.21	139.37
62.50	94.08	94.25	94.61	95.60	97.29	100.29	103.29	107.52	122.69	138.28
59.38	90.73	91.81	93.78	95.31	97.25	99.43	102.21	106.84	116.23	129.53
56.25	90.56	91.44	93.12	94.93	96.16	99.28	101.91	106.51	112.34	128.92
53.13	89.95	90.94	91.13	93.89	96.02	98.35	101.14	105.24	111.82	128.49
50.00	89.78	90.41	90.98	93.13	95.55	98.24	100.69	105.16	111.11	126.78
46.88	88.73	89.10	90.77	91.98	95.10	98.08	100.18	104.86	110.87	126.38
43.75	88.32	88.97	90.15	91.62	94.93	97.58	99.57	104.64	109.01	124.89
40.63	87.76	88.76	89.54	91.30	94.82	96.54	99.48	103.71	108.92	124.29
37.50	87.72	88.73	89.20	91.25	93.10	96.16	98.93	103.45	108.44	124.12
34.38	87.55	87.96	89.00	90.48	92.42	95.70	98.60	102.50	108.26	123.05
31.25	87.35	87.83	88.30	89.38	92.34	95.63	97.54	102.48	106.04	122.90
28.13	87.08	87.82	88.03	89.17	91.12	94.01	95.71	100.70	104.33	122.44
25.00	85.57	86.79	87.27	88.67	90.67	93.85	94.98	98.73	103.42	120.84
21.88	84.78	85.27	85.87	86.83	90.08	90.67	93.65	95.91	103.18	120.55
18.75	84.57	85.12	85.49	86.73	89.40	89.91	90.77	95.31	100.92	118.47
15.63	81.52	83.47	85.08	86.71	88.40	88.70	89.14	93.59	100.05	114.06
12.50	81.23	82.71	83.82	85.18	87.90	88.10	89.10	92.75	98.56	109.46
9.38	80.02	80.31	80.59	81.71	84.95	87.49	88.84	91.59	97.65	104.97
6.25	74.38	75.04	75.17	76.36	79.94	83.78	88.38	91.05	97.02	103.44
3.13	53.95	54.78	56.13	59.18	65.82	71.81	76.64	83.87	93.57	96.57

31 yrs LOs: Simulated MFLs Discharges at Tracy Canal(1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	117.57	119.13	122.09	133.84	166.31	182.05	182.05	232.91	413.74	806.99
93.75	111.76	113.99	115.69	125.01	152.29	169.14	178.21	204.03	307.99	484.45
90.63	110.93	111.74	114.19	122.88	137.56	163.81	172.65	196.53	284.99	477.11
87.50	106.52	107.72	112.31	116.70	134.54	142.82	142.82	187.64	259.21	433.04
84.38	105.87	106.91	108.47	112.41	128.21	135.87	141.28	177.66	253.88	413.74
81.25	98.60	99.63	100.46	102.84	116.94	120.44	132.53	172.82	243.90	316.54
78.13	98.06	98.49	100.16	102.83	116.22	118.21	129.62	165.82	240.82	303.70
75.00	96.72	98.48	99.70	102.43	109.58	117.98	124.60	155.62	238.84	292.37
71.88	94.92	98.23	99.15	101.62	109.57	117.29	124.45	154.19	206.94	284.99
68.75	94.52	97.84	98.54	100.71	109.44	115.71	123.65	153.99	205.94	284.76
65.63	94.24	95.29	96.74	100.25	109.15	114.35	123.12	152.59	202.62	275.36
62.50	94.08	94.45	96.71	100.18	108.11	113.21	122.40	151.21	185.02	265.76
59.38	90.73	93.20	95.36	99.44	107.88	111.06	122.28	145.79	179.55	260.56
56.25	90.56	92.74	95.35	97.99	105.22	110.61	117.76	141.50	165.82	260.52
53.13	89.95	91.75	94.98	97.91	104.25	110.54	116.59	140.16	161.39	255.12
50.00	89.78	91.06	94.35	95.92	103.58	110.18	115.95	135.89	161.20	252.67
46.88	88.73	91.04	91.67	95.91	103.20	107.39	115.02	134.04	159.58	246.79
43.75	88.32	90.48	91.53	95.40	101.99	106.05	114.60	132.53	158.58	243.90
40.63	87.76	89.30	91.43	94.62	99.88	104.81	114.60	126.31	154.19	241.74
37.50	87.72	89.07	89.81	94.08	99.42	104.73	113.82	125.79	152.59	240.63
34.38	87.55	88.83	89.56	93.91	98.89	103.87	112.69	123.12	151.87	238.61
31.25	87.35	87.99	89.43	92.41	98.49	103.74	109.46	122.27	150.20	229.89
28.13	87.08	87.94	89.11	92.17	98.37	102.88	109.26	120.21	146.50	220.02
25.00	85.57	87.45	88.90	90.91	98.15	101.28	107.98	116.59	145.79	203.93
21.88	84.78	86.06	88.77	90.43	97.05	100.84	107.39	116.22	145.48	202.62
18.75	84.57	85.75	87.25	89.08	95.77	99.23	103.74	112.97	145.31	200.43
15.63	81.52	85.59	86.98	88.15	95.51	98.89	103.46	108.12	132.66	196.48
12.50	81.23	84.58	86.73	87.84	92.98	95.64	99.00	103.86	131.10	191.27
9.38	80.02	80.63	81.10	83.79	91.70	93.62	97.16	103.66	127.89	147.56
6.25	74.38	75.65	75.67	79.60	87.68	92.71	95.07	103.46	116.66	143.98
3.13	53.95	55.84	58.49	64.92	79.93	87.80	94.50	101.78	109.35	125.45

31 yrs HIs: Computed MFLs Discharge (cfs) at A5 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
3.13	761.62	484.41	366.83	246.92	195.68	176.05	154.83	149.11	126.59	112.96
6.25	463.37	354.52	297.84	232.86	191.77	174.63	151.17	138.78	117.93	112.12
9.38	461.62	348.46	272.46	224.23	185.67	166.66	147.49	127.92	116.77	102.57
12.50	388.28	344.93	250.21	217.29	177.40	166.61	147.39	127.29	110.61	101.61
15.63	301.96	274.45	246.35	213.44	174.10	160.37	139.84	127.29	107.77	98.07
18.75	289.01	246.07	235.77	210.36	169.85	157.24	130.74	116.77	107.63	96.98
21.88	270.48	238.73	232.07	203.69	169.63	146.48	128.04	113.29	106.73	96.85
25.00	264.00	236.07	227.24	203.43	168.52	142.22	127.95	111.82	105.69	96.14
28.13	258.78	231.36	225.22	195.09	165.67	132.83	127.88	110.44	101.66	94.69
31.25	248.01	230.51	219.16	183.69	162.80	132.37	127.22	108.84	100.99	94.60
34.38	243.21	226.99	211.38	178.25	159.11	131.39	126.67	107.63	100.58	93.41
37.50	231.18	223.06	202.89	174.58	158.71	130.94	124.74	107.34	99.30	91.70
40.63	229.31	216.29	199.17	168.79	155.77	129.90	124.28	107.12	98.19	91.45
43.75	224.54	213.89	192.18	160.92	151.73	129.43	116.93	106.73	97.62	90.83
46.88	218.53	208.40	187.59	160.51	146.70	128.96	115.58	106.06	96.85	89.38
50.00	218.19	202.74	186.89	159.13	143.65	128.02	113.31	105.51	95.77	87.97
53.13	210.50	201.36	184.29	155.22	143.49	125.09	113.29	103.03	95.72	87.95
56.25	198.98	193.01	178.20	154.77	141.78	123.96	111.68	102.82	95.13	87.69
59.38	198.37	187.00	173.32	152.53	138.73	120.25	110.91	101.15	94.71	87.18
62.50	172.83	171.19	160.71	147.42	135.74	118.62	108.54	98.08	92.12	86.75
65.63	166.31	163.21	159.18	147.36	131.89	116.03	108.07	96.86	92.04	86.30
68.75	164.27	158.61	156.19	143.99	128.02	114.22	106.69	95.46	91.63	86.11
71.88	163.62	157.23	148.37	132.80	120.32	112.34	105.52	94.87	90.50	86.09
75.00	159.67	156.40	148.08	132.49	117.90	110.72	104.58	94.02	89.97	85.38
78.13	158.50	154.06	142.34	127.70	116.87	110.03	102.49	93.84	89.87	85.11
81.25	158.28	153.24	142.09	126.87	111.37	102.49	99.75	92.71	89.25	84.53
84.38	146.92	144.89	139.49	126.12	110.72	99.98	99.67	91.51	89.07	81.16
87.50	142.79	138.72	135.49	122.30	110.21	99.75	98.61	89.97	88.27	81.04
90.63	137.08	133.51	131.17	117.25	109.11	99.68	97.06	89.95	85.11	80.43
93.75	135.17	133.14	126.79	114.88	105.86	99.62	94.09	89.87	84.98	65.95
96.88	116.70	115.67	114.62	107.61	100.94	96.89	92.91	88.90	74.77	54.38

31 yrs LOs: Computed MFLs Discharge (cfs) at A5 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	117.93	118.40	119.17	119.98	125.53	133.68	138.97	157.48	162.87	170.83
93.75	112.12	113.19	114.40	118.39	123.08	131.73	132.91	142.19	147.30	158.79
90.63	111.91	112.29	112.64	113.48	121.11	125.77	132.71	136.99	146.44	152.80
87.50	106.73	106.80	107.15	108.58	116.14	124.74	125.26	130.29	142.29	149.80
84.38	105.74	106.32	106.97	108.47	115.16	119.73	123.13	129.14	139.06	146.13
81.25	99.30	99.55	99.75	100.30	102.57	106.52	106.64	111.60	131.74	141.59
78.13	98.68	99.29	99.34	99.48	101.60	102.66	106.22	111.46	129.10	139.68
75.00	96.85	97.38	97.93	99.08	101.24	102.09	103.39	110.63	124.75	137.36
71.88	96.14	96.19	97.12	98.55	99.89	101.60	102.70	110.13	124.29	137.33
68.75	95.13	96.03	96.60	97.69	99.19	100.80	102.56	107.54	121.49	131.42
65.63	94.69	95.89	96.20	96.27	96.50	98.91	102.19	106.58	119.82	129.90
62.50	94.60	95.20	95.45	95.94	96.49	97.75	100.88	105.66	117.52	129.60
59.38	91.70	92.18	92.75	94.57	96.48	97.69	99.89	105.04	111.98	122.31
56.25	91.45	91.86	92.51	93.22	96.25	97.33	99.54	104.35	110.53	122.25
53.13	90.83	91.32	91.97	93.12	95.32	97.26	99.52	104.25	108.50	120.02
50.00	89.97	91.11	91.63	92.45	94.64	97.17	99.49	104.14	108.15	119.93
46.88	89.38	89.51	89.59	92.22	94.49	96.53	98.94	102.11	106.94	119.23
43.75	89.07	89.33	89.41	91.13	93.80	95.96	98.11	101.84	106.84	118.81
40.63	87.97	88.36	89.24	91.00	93.76	94.65	97.96	101.63	106.42	118.23
37.50	87.69	88.27	89.12	90.40	92.70	94.60	97.33	101.38	105.04	117.30
34.38	87.18	87.98	89.03	89.84	92.53	94.30	95.84	100.88	103.67	116.78
31.25	86.75	87.75	88.52	89.62	90.77	93.98	95.06	99.06	103.40	116.54
28.13	86.09	87.71	88.12	89.52	90.36	93.65	94.50	98.94	102.56	116.48
25.00	85.38	86.18	86.90	88.84	89.89	92.69	94.18	96.22	101.99	116.24
21.88	85.11	85.57	85.99	86.75	89.60	90.27	92.44	95.41	100.22	116.16
18.75	84.98	85.37	85.44	86.34	88.23	89.82	90.81	92.45	97.79	113.74
15.63	81.16	82.16	82.91	84.40	87.46	88.01	88.69	91.84	97.57	107.76
12.50	81.04	81.28	82.24	83.52	85.31	87.61	88.12	91.83	95.61	106.99
9.38	80.43	80.78	81.55	82.48	85.24	86.12	87.73	90.48	94.59	101.03
6.25	74.77	75.18	75.52	76.71	79.66	83.29	87.35	89.76	94.56	99.96
3.13	54.38	55.52	56.89	60.07	66.43	72.23	76.95	83.63	92.57	94.43

31 yrs LOs: Computed MFLs Discharge (cfs) at A5 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	117.93	119.13	120.41	131.59	159.77	169.16	169.35	223.50	388.28	761.62
93.75	112.12	114.38	116.66	121.28	143.67	160.91	169.16	188.24	288.63	463.37
90.63	111.91	112.90	113.55	116.34	131.96	153.31	164.27	172.62	243.06	461.62
87.50	106.73	107.16	108.66	114.64	131.03	137.65	137.65	171.39	231.18	388.28
84.38	105.74	106.84	107.55	110.75	124.72	129.30	136.40	169.28	229.31	370.37
81.25	99.30	99.86	100.16	101.65	112.46	117.65	129.46	167.39	218.19	301.96
78.13	98.68	99.42	99.46	101.02	107.44	116.74	125.48	158.16	215.66	289.01
75.00	96.85	97.96	99.40	100.40	104.48	110.44	123.42	150.12	214.47	270.48
71.88	96.14	96.88	98.72	100.07	104.44	109.85	122.08	145.31	192.44	269.19
68.75	95.13	96.70	97.33	99.78	104.42	109.69	120.20	141.14	188.71	264.00
65.63	94.69	96.23	96.26	98.88	102.50	108.58	118.81	136.46	186.40	263.35
62.50	94.60	95.35	95.93	97.57	101.39	108.09	110.93	133.82	169.43	261.12
59.38	91.70	92.88	94.96	96.53	101.21	107.02	110.82	132.52	158.16	243.21
56.25	91.45	92.43	93.99	95.99	100.82	105.92	110.09	129.53	156.26	229.31
53.13	90.83	91.99	92.32	95.99	100.77	104.44	109.81	129.46	150.12	224.54
50.00	89.97	91.65	92.17	94.82	100.64	104.41	109.18	127.83	146.92	218.19
46.88	89.38	89.87	91.89	94.39	98.27	103.71	108.34	125.48	142.18	216.73
43.75	89.07	89.63	91.79	94.14	98.16	103.12	108.30	118.16	140.65	210.50
40.63	87.97	89.50	90.39	93.87	97.22	102.43	107.45	117.31	139.68	198.98
37.50	87.69	88.87	89.89	93.39	97.21	102.10	107.16	116.97	138.27	198.37
34.38	87.18	88.68	89.58	92.82	97.14	101.19	105.80	116.70	137.08	195.73
31.25	86.75	88.58	89.11	90.12	95.78	100.26	105.40	115.68	136.24	192.44
28.13	86.09	88.46	88.68	90.06	95.50	99.10	105.19	110.82	133.82	191.29
25.00	85.38	86.47	88.08	89.90	95.29	98.68	105.18	107.45	131.11	191.24
21.88	85.11	85.96	86.63	88.65	94.70	97.21	103.71	106.87	127.83	178.07
18.75	84.98	85.90	85.99	88.04	92.11	95.29	100.26	106.17	122.96	176.20
15.63	81.16	83.21	85.62	86.85	90.89	93.67	98.67	102.50	117.98	166.31
12.50	81.04	81.53	84.53	86.21	90.28	91.57	96.94	101.82	117.63	144.03
9.38	80.43	81.09	82.11	84.36	89.75	91.03	93.86	100.37	116.95	141.96
6.25	74.77	75.57	76.16	79.73	85.01	90.28	93.59	98.96	112.99	136.22
3.13	54.38	56.47	59.59	65.95	78.15	86.78	92.27	96.86	102.70	109.56

31 yrs HIs: Computed MFLs Discharge (cfs) at A8 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
3.13	521.72	315.62	247.87	195.39	175.79	158.69	145.01	139.11	118.31	112.02
6.25	364.46	287.63	215.13	193.38	167.34	158.63	144.60	124.76	116.28	106.93
9.38	342.59	266.04	211.76	187.03	162.71	150.44	130.00	118.43	114.58	99.75
12.50	332.39	237.99	210.78	185.37	161.11	146.61	128.56	116.28	106.11	98.59
15.63	265.44	237.54	206.17	185.28	159.08	146.50	126.38	114.60	105.06	96.45
18.75	257.89	218.96	201.53	179.09	156.33	143.94	122.11	107.80	103.91	96.18
21.88	241.58	218.57	197.38	172.67	153.74	133.30	120.06	106.19	103.63	95.81
25.00	241.54	218.42	196.00	165.15	140.97	125.48	117.50	106.11	101.82	95.80
28.13	221.03	210.26	184.07	164.32	139.61	123.65	115.67	105.06	99.09	92.47
31.25	215.50	203.63	181.38	158.63	136.68	122.96	114.60	103.68	98.74	91.22
34.38	212.54	188.97	174.15	152.75	136.16	122.11	111.31	103.63	97.04	90.71
37.50	203.47	188.80	172.70	146.25	133.90	118.26	111.28	101.82	96.64	90.44
40.63	196.60	177.35	167.81	143.08	132.22	115.82	110.80	101.36	96.58	89.25
43.75	196.08	177.00	167.61	142.23	129.78	113.00	110.17	100.16	95.82	88.94
46.88	174.85	173.60	157.33	141.89	123.74	112.46	107.80	99.86	95.80	87.65
50.00	174.17	159.49	150.71	140.15	123.01	111.46	107.79	99.53	94.93	87.45
53.13	155.48	153.82	146.02	139.42	122.12	108.28	105.42	99.39	92.69	86.53
56.25	151.19	149.57	144.93	133.19	120.97	108.00	103.69	99.24	91.97	86.49
59.38	148.99	148.26	142.68	132.11	119.30	107.81	103.06	95.57	91.28	85.78
62.50	143.29	142.21	139.41	129.99	118.50	107.79	100.41	95.19	90.36	85.67
65.63	142.88	139.50	133.86	129.70	115.17	106.92	100.33	94.84	90.03	85.02
68.75	139.95	136.60	133.61	125.45	113.50	106.03	100.28	94.50	89.80	84.71
71.88	137.58	136.42	131.25	120.09	107.81	105.32	98.75	92.15	88.94	84.60
75.00	133.23	132.27	127.12	118.70	106.92	105.14	98.47	91.07	87.79	84.51
78.13	121.90	119.03	117.78	113.37	105.46	100.34	96.21	90.50	86.83	83.65
81.25	121.26	118.14	114.64	109.78	102.92	99.12	94.70	89.24	86.27	80.47
84.38	118.60	117.62	114.15	103.84	101.41	97.51	94.22	88.58	85.25	78.68
87.50	115.68	113.07	111.10	103.62	100.77	95.56	92.68	86.83	85.25	76.59
90.63	114.07	111.46	109.30	103.42	98.88	94.11	91.83	86.31	85.02	76.41
93.75	110.15	107.09	106.81	103.15	98.49	93.86	88.98	86.31	83.84	65.95
96.88	107.70	106.71	106.61	102.43	91.21	88.83	87.39	84.76	74.71	54.38

31 yrs LOs: Computed MFLs Discharge (cfs) at A8 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	113.76	116.59	117.13	117.86	119.70	125.08	131.80	148.43	152.73	158.09
93.75	111.31	111.74	111.89	114.67	119.63	124.41	124.58	131.08	133.48	141.94
90.63	108.05	109.33	110.98	112.69	115.05	122.00	124.38	127.39	132.94	137.83
87.50	103.63	103.84	104.53	106.59	113.32	118.51	122.16	124.07	131.92	137.60
84.38	102.28	103.44	104.17	105.26	112.00	113.56	115.40	118.78	127.39	130.04
81.25	98.63	99.07	99.14	99.32	99.74	100.62	104.36	105.67	126.22	128.27
78.13	95.82	96.09	96.49	97.09	98.49	100.51	102.63	104.93	117.66	127.64
75.00	95.81	96.01	96.31	96.95	97.84	99.61	101.91	104.16	112.00	124.68
71.88	95.80	95.98	96.01	96.07	97.03	99.36	101.38	104.13	111.80	120.21
68.75	94.96	95.00	95.13	95.52	97.00	98.85	99.98	103.04	111.26	117.22
65.63	92.47	93.37	93.74	95.47	96.37	97.20	98.39	102.49	110.52	112.76
62.50	91.22	91.55	92.33	94.97	96.11	96.71	97.65	101.73	108.92	110.42
59.38	90.71	91.30	91.61	92.01	93.15	94.12	95.88	101.35	106.51	110.16
56.25	90.44	91.13	91.44	91.87	92.34	93.99	94.70	99.91	104.23	109.84
53.13	89.25	89.43	89.82	90.53	92.04	93.39	94.46	99.14	103.50	109.72
50.00	88.94	89.41	89.42	89.83	91.82	92.69	94.33	98.12	102.49	109.43
46.88	87.64	88.01	88.52	89.52	91.72	92.59	93.64	97.62	102.34	108.39
43.75	86.53	86.97	87.04	88.26	89.77	92.46	93.01	97.05	101.46	108.30
40.63	85.28	85.64	85.89	87.33	89.48	90.14	92.08	96.30	99.37	107.90
37.50	85.25	85.46	85.86	86.57	88.96	90.00	90.62	96.28	99.37	107.49
34.38	85.02	85.37	85.79	86.46	87.86	89.17	90.44	95.80	98.59	106.07
31.25	84.71	85.09	85.56	86.43	87.48	88.65	90.30	93.95	98.25	105.36
28.13	84.60	84.92	85.16	86.34	87.46	87.94	90.29	92.75	97.17	104.83
25.00	83.84	83.99	84.90	86.33	87.41	87.78	89.89	91.34	94.80	104.02
21.88	83.65	83.99	84.10	84.40	85.33	87.38	88.73	91.33	93.83	102.76
18.75	80.47	80.93	81.42	83.15	84.97	86.32	88.66	90.51	91.60	102.13
15.63	78.68	78.91	79.18	80.65	84.84	85.38	86.85	87.98	89.82	100.91
12.50	76.59	77.14	77.84	78.94	81.69	83.60	85.87	87.81	89.78	96.36
9.38	76.41	76.97	77.58	77.97	80.31	82.10	83.82	85.95	89.53	93.64
6.25	74.71	75.10	75.43	76.56	79.21	82.03	83.75	85.62	89.28	93.31
3.13	54.38	55.52	56.88	60.03	66.18	71.96	76.27	82.39	88.43	90.49

31 yrs LOs: Computed MFLs Discharge (cfs) at A8 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.880	113.760	116.930	118.320	122.410	139.670	149.520	158.850	207.930	332.390	521.720
93.750	111.310	111.960	113.700	119.170	131.780	149.430	150.960	159.700	265.440	364.460
90.630	108.050	110.880	112.660	115.050	125.760	138.740	148.990	154.900	215.500	342.590
87.500	103.630	104.750	106.330	113.330	122.640	131.150	131.150	154.220	202.430	332.390
84.380	102.280	104.070	104.790	107.470	116.900	116.900	127.840	153.170	174.850	289.940
81.250	98.630	99.250	99.420	99.780	104.610	113.340	123.860	149.190	174.170	265.440
78.130	95.820	96.440	97.160	98.900	101.760	105.960	117.890	140.850	172.480	257.890
75.000	95.810	96.210	96.890	98.680	101.310	105.550	116.400	135.240	166.570	241.580
71.880	95.800	96.010	96.250	98.030	101.070	103.910	115.610	135.150	160.760	241.540
68.750	94.960	95.060	95.420	97.750	100.460	102.390	108.110	131.580	159.700	234.210
65.630	92.470	94.110	94.890	96.910	98.150	102.050	107.890	131.320	150.120	221.030
62.500	91.220	92.880	94.380	96.330	97.950	101.500	106.700	128.360	149.100	216.900
59.380	90.710	91.670	92.070	94.500	97.580	99.720	104.660	125.180	142.880	212.540
56.250	90.440	91.420	91.820	93.000	97.200	99.600	104.620	121.900	142.220	196.080
53.130	89.250	90.010	90.780	92.990	96.860	99.530	103.470	118.600	133.230	174.850
50.000	88.940	89.580	89.670	92.030	95.810	98.450	103.040	114.810	131.580	174.170
46.880	87.640	88.390	89.430	92.030	95.730	97.550	102.390	110.070	121.900	173.810
43.750	86.530	87.220	87.410	90.070	93.780	97.520	101.170	109.940	121.260	157.460
40.630	85.280	86.030	87.290	89.120	93.410	96.620	99.920	107.700	121.020	155.480
37.500	85.250	85.950	86.490	88.610	93.250	96.220	99.720	107.510	120.220	155.110
34.380	85.020	85.850	86.480	88.280	92.300	95.750	98.190	103.670	118.070	150.120
31.250	84.710	85.550	86.470	88.260	91.250	94.730	96.750	101.270	113.270	144.050
28.130	84.600	85.460	86.290	88.210	90.760	94.210	96.660	100.680	112.900	143.290
25.000	83.840	84.490	85.920	87.670	90.490	93.810	96.220	100.530	110.340	142.880
21.880	83.650	84.160	84.610	86.970	90.090	93.770	95.950	99.290	110.150	139.950
18.750	80.470	81.330	82.350	85.750	88.810	91.300	94.390	98.220	107.630	139.520
15.630	78.680	79.140	79.670	84.330	88.530	90.780	92.890	97.240	106.570	135.400
12.500	76.590	78.010	79.270	81.280	87.880	90.490	91.910	96.010	105.860	131.370
9.380	76.410	77.300	78.730	80.890	84.910	89.200	91.070	94.760	105.850	122.930
6.250	74.710	75.470	76.080	79.300	83.500	89.190	90.360	91.820	101.610	117.800
3.130	54.380	56.470	59.570	65.950	78.070	86.350	90.220	91.100	94.560	98.120

31 yrs HIs: Computed MFLs Discharge (cfs) at A10 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
3.13	489.14	277.24	216.85	190.61	174.80	156.65	144.71	137.68	114.35	111.17
6.25	340.90	254.51	202.54	189.32	158.28	144.40	130.42	114.05	112.35	100.51
9.38	328.64	242.49	201.65	170.13	154.50	143.13	125.80	113.08	111.17	99.75
12.50	302.11	225.95	185.22	164.82	146.34	140.67	120.20	112.35	101.08	98.59
15.63	245.20	210.02	182.28	158.19	145.73	135.47	118.83	107.82	100.28	95.86
18.75	236.50	207.28	182.04	155.23	143.11	131.49	113.11	102.26	99.36	94.33
21.88	227.84	206.90	174.64	153.75	136.45	123.81	111.31	101.50	98.63	93.07
25.00	217.97	203.60	170.56	151.24	131.32	119.81	111.17	101.08	98.27	91.99
28.13	212.36	193.93	168.92	148.78	130.01	117.81	108.88	101.06	96.54	91.22
31.25	211.94	189.13	167.02	148.18	125.95	115.33	108.75	99.36	96.24	90.68
34.38	200.21	177.36	161.53	139.65	123.63	113.05	108.33	99.10	95.82	90.63
37.50	194.29	176.63	161.27	134.79	123.60	112.46	107.08	98.68	94.89	89.25
40.63	185.80	167.64	158.41	133.89	123.51	111.51	105.44	98.27	93.43	88.11
43.75	183.74	165.35	158.26	132.70	117.92	110.00	104.78	98.03	93.07	87.45
46.88	165.64	164.55	147.16	132.62	117.15	109.32	102.73	97.23	91.90	87.30
50.00	163.37	149.92	141.18	129.12	116.70	107.10	101.40	95.82	91.09	85.78
53.13	143.83	142.18	136.49	127.43	116.62	103.82	99.93	94.98	90.42	83.80
56.25	142.13	140.74	136.17	126.80	116.32	102.73	99.59	94.51	90.36	83.65
59.38	139.85	138.91	133.60	124.05	113.88	102.13	98.67	93.57	89.81	83.49
62.50	139.48	136.03	133.51	122.80	110.75	101.94	98.22	92.55	88.94	83.14
65.63	134.88	130.14	125.82	120.80	109.67	100.61	98.03	92.26	88.71	83.11
68.75	131.53	129.60	124.52	119.36	108.89	100.37	96.94	92.15	88.19	83.04
71.88	130.73	128.75	124.43	114.62	103.82	99.76	96.21	91.03	87.62	82.72
75.00	124.52	123.75	119.98	112.53	101.55	99.34	95.71	90.24	85.16	82.60
78.13	116.78	113.89	111.08	109.20	100.93	99.23	94.09	89.24	84.87	81.85
81.25	114.48	112.93	110.39	104.39	100.46	98.57	93.68	87.62	84.14	79.01
84.38	114.32	112.40	109.72	102.30	100.37	97.48	91.69	85.67	83.61	77.09
87.50	111.42	107.83	106.17	102.18	98.49	93.04	90.57	85.43	82.72	76.59
90.63	110.26	107.74	105.80	101.56	97.20	92.87	90.50	85.29	81.85	74.74
93.75	107.44	106.24	105.37	100.10	95.47	91.44	86.68	84.22	81.42	65.95
96.88	107.26	104.35	103.95	99.06	88.28	87.84	85.73	83.84	74.71	54.38

31 yrs LOs: Computed MFLs Discharge (cfs) at A10 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	111.17	111.46	112.88	113.60	116.62	121.98	128.61	144.97	150.37	154.50
93.75	105.29	108.86	111.61	111.83	115.33	117.42	118.65	123.06	127.03	133.49
90.63	104.97	106.24	107.92	111.73	112.93	116.40	117.63	119.67	125.69	129.29
87.50	98.63	99.04	100.11	102.26	107.13	113.56	116.59	119.62	124.34	126.57
84.38	97.76	98.89	99.11	99.26	106.43	112.27	115.36	118.43	121.80	123.91
81.25	95.82	96.14	96.58	97.71	99.57	100.03	100.74	105.26	119.33	121.76
78.13	94.95	94.97	95.02	95.32	96.29	98.76	100.68	102.32	111.67	120.44
75.00	94.33	94.43	94.64	94.93	95.94	97.02	100.08	101.89	107.25	119.16
71.88	93.43	93.74	94.08	94.92	95.47	96.56	98.25	100.06	107.20	112.85
68.75	93.07	93.21	93.46	94.18	95.27	96.13	97.97	99.42	107.16	111.48
65.63	91.99	92.71	92.97	93.65	94.52	95.88	97.10	99.33	105.27	110.43
62.50	91.22	91.55	91.61	91.87	93.02	95.23	96.72	99.23	104.61	108.11
59.38	90.63	90.92	91.15	91.67	92.68	93.90	94.28	99.07	103.44	106.91
56.25	89.25	89.41	89.42	90.99	92.04	93.31	94.13	98.57	102.86	106.61
53.13	88.11	88.61	89.14	89.52	91.81	92.36	92.75	98.25	102.40	105.94
50.00	87.54	88.14	89.00	89.32	90.30	91.07	92.69	96.31	100.92	105.25
46.88	87.30	87.73	87.87	88.26	89.77	90.51	92.39	95.45	99.73	104.89
43.75	84.14	84.49	84.90	88.26	89.41	90.00	90.23	95.39	97.91	104.16
40.63	83.97	84.23	84.79	85.61	88.14	89.13	89.88	94.67	97.31	102.85
37.50	83.84	83.99	84.23	85.05	87.44	88.78	89.86	93.88	96.73	102.68
34.38	83.65	83.99	84.16	84.90	85.77	88.36	89.68	93.79	96.50	101.50
31.25	83.14	83.50	84.10	84.40	85.33	86.36	89.67	93.17	95.85	101.40
28.13	83.04	83.35	83.86	84.40	85.18	86.23	87.97	91.32	94.96	101.30
25.00	82.60	82.76	83.65	84.29	85.17	85.94	87.66	90.96	93.25	100.47
21.88	81.85	82.14	82.43	82.98	85.00	85.80	87.22	89.80	91.82	99.56
18.75	79.01	79.53	79.82	81.51	83.38	85.69	87.01	88.32	89.44	99.08
15.63	77.09	77.18	77.84	78.93	83.07	82.83	86.47	87.52	89.22	99.01
12.50	76.59	77.14	77.29	78.58	80.29	81.96	83.75	85.57	88.94	93.80
9.38	74.74	75.31	76.22	76.55	80.07	81.90	83.65	85.32	88.76	91.58
6.25	74.71	75.10	75.43	76.52	79.18	81.89	83.34	85.15	87.12	90.37
3.13	54.38	55.52	56.88	59.99	65.86	71.47	75.70	80.82	86.26	90.09

31 yrs LOs: Computed MFLs Discharge (cfs) at A10 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	111.17	112.77	113.44	119.00	132.24	145.58	155.35	204.32	302.11	489.14
93.75	105.29	111.84	111.96	114.73	128.05	141.97	141.97	150.04	232.46	340.90
90.63	104.97	107.59	110.98	112.39	121.08	131.49	139.85	148.65	211.94	328.64
87.50	98.63	100.21	102.01	108.36	116.90	124.73	127.84	143.24	177.41	302.11
84.38	97.76	99.25	99.42	100.80	114.31	116.90	127.31	139.85	165.64	260.49
81.25	95.82	96.48	97.58	99.68	100.87	107.50	115.08	137.82	163.37	245.20
78.13	94.95	95.00	95.29	96.83	100.68	105.64	114.03	135.24	161.94	236.50
75.00	94.33	94.63	95.18	96.79	100.27	101.86	113.73	130.75	156.90	227.84
71.88	93.43	94.04	94.74	96.72	97.93	101.20	110.63	130.23	150.12	223.23
68.75	93.07	93.40	94.01	95.59	97.50	100.50	107.19	127.31	150.06	217.97
65.63	91.99	93.31	93.63	94.50	97.34	99.72	104.15	127.10	146.96	212.36
62.50	91.22	91.67	91.82	94.20	97.01	99.22	103.66	124.24	140.97	200.21
59.38	90.63	91.14	91.62	92.69	96.82	98.45	102.73	121.71	136.54	197.57
56.25	89.25	89.65	91.06	92.55	94.94	98.35	102.36	116.78	131.66	183.74
53.13	88.11	89.58	89.67	91.82	94.40	97.20	101.00	114.32	130.75	165.64
50.00	87.54	89.15	89.62	90.40	93.41	95.78	99.72	111.74	124.52	163.39
46.88	87.30	87.80	88.15	90.07	92.54	95.78	99.42	108.03	116.78	163.37
43.75	84.14	85.25	86.49	89.04	92.42	94.89	98.85	107.30	116.31	150.12
40.63	83.97	84.49	85.61	88.11	92.17	94.78	98.71	107.26	116.22	143.83
37.50	83.84	84.29	85.38	87.29	91.64	94.40	97.15	105.87	114.48	140.97
34.38	83.65	84.25	85.18	86.93	90.52	94.13	96.39	103.29	112.62	139.80
31.25	83.14	84.16	84.79	86.13	90.49	93.46	95.68	100.51	112.58	139.48
28.13	83.04	84.05	84.61	85.98	90.07	93.11	95.19	98.56	111.70	135.02
25.00	82.60	83.41	84.38	85.75	88.84	91.79	94.16	96.57	107.44	134.88
21.88	81.85	82.42	83.14	85.69	88.04	91.73	93.11	96.54	107.20	131.88
18.75	79.01	79.95	80.49	83.96	87.88	91.30	93.09	95.73	106.25	131.53
15.63	77.09	78.01	78.73	82.71	87.24	89.70	92.40	94.25	105.03	131.07
12.50	76.59	77.29	77.71	81.27	86.34	89.03	91.30	93.60	104.82	123.65
9.38	74.74	75.94	77.71	79.62	84.77	87.93	89.90	93.49	102.66	117.71
6.25	74.71	75.47	76.08	79.28	83.50	87.87	89.70	91.21	96.54	108.10
3.13	54.38	56.47	59.57	65.74	77.07	85.70	89.20	91.10	94.03	97.96

31 yrs HIs: Computed MFLs Discharge (cfs) at A14 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
3.13	496.70	257.71	204.20	188.14	169.15	154.50	144.41	136.56	114.04	108.90
6.25	342.87	250.11	201.11	185.20	155.16	143.10	128.78	114.23	108.90	99.82
9.38	326.20	225.80	198.52	159.79	150.19	141.99	125.92	113.28	100.92	99.02
12.50	298.75	210.95	179.07	158.85	145.68	134.06	119.93	112.42	100.11	98.44
15.63	246.98	205.73	174.41	153.84	141.39	130.33	116.89	105.04	98.86	94.50
18.75	237.63	205.61	173.26	152.52	140.63	128.88	112.36	101.52	98.51	93.74
21.88	229.13	205.56	166.95	150.78	134.00	122.74	109.85	101.52	96.58	93.06
25.00	220.00	196.53	163.92	146.32	130.74	117.32	109.22	100.92	96.52	91.86
28.13	209.22	190.76	161.28	146.11	125.97	116.49	108.09	100.81	96.24	90.85
31.25	208.99	179.82	161.13	141.69	123.21	115.37	107.63	98.86	95.72	90.67
34.38	196.19	173.15	159.74	133.49	121.39	111.49	107.60	98.20	95.25	90.27
37.50	189.58	171.99	155.51	132.92	118.24	110.19	105.39	97.92	94.52	89.40
40.63	183.49	161.85	152.55	131.13	117.07	109.85	104.80	97.53	93.31	88.11
43.75	179.23	158.96	150.80	130.56	116.39	109.37	104.73	95.72	93.06	87.49
46.88	161.57	157.60	145.16	130.16	114.76	105.95	99.95	95.25	91.65	86.85
50.00	158.97	147.24	138.68	126.75	113.64	103.32	99.85	95.17	90.97	85.96
53.13	139.37	138.24	135.82	126.53	111.36	102.89	99.14	94.48	90.53	83.86
56.25	137.92	137.13	132.95	125.78	111.21	102.00	97.75	93.58	90.51	83.78
59.38	136.31	133.77	130.56	120.27	110.96	100.88	97.67	93.47	89.87	83.35
62.50	134.08	132.98	129.37	118.57	110.33	100.47	97.53	92.47	88.70	83.25
65.63	127.37	126.30	122.85	115.40	109.70	99.15	96.48	92.15	88.63	82.76
68.75	127.28	124.48	121.91	114.88	104.37	98.58	95.95	91.83	88.11	82.69
71.88	127.26	121.59	120.12	112.94	102.89	98.25	94.75	90.99	87.26	82.54
75.00	122.94	121.34	117.60	111.84	100.36	97.61	94.19	90.19	85.01	82.44
78.13	113.22	111.24	109.29	107.09	98.73	97.16	94.00	88.78	84.15	81.93
81.25	112.26	110.60	108.95	101.89	97.61	95.02	92.47	87.62	83.69	76.91
84.38	111.57	110.47	107.95	101.89	97.16	93.50	91.64	85.34	82.69	76.21
87.50	107.78	106.19	104.27	101.70	96.20	92.39	90.08	85.01	81.93	75.13
90.63	105.96	105.17	104.07	101.67	94.22	91.10	88.91	84.58	81.23	73.99
93.75	105.50	104.47	103.65	99.12	93.50	90.73	86.18	84.22	80.56	66.49
96.88	105.13	104.44	103.62	98.05	85.18	84.32	84.32	83.89	74.77	54.37

31 yrs LOs: Computed MFLs Discharge (cfs) at A14 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	109.44	109.68	110.66	113.49	115.88	120.93	127.56	143.58	148.79	152.43
93.75	105.07	106.58	109.94	111.84	115.04	116.68	118.24	121.33	124.60	130.68
90.63	103.82	106.38	108.06	110.20	110.60	114.95	116.44	118.84	123.75	127.34
87.50	98.50	98.77	99.24	101.73	106.11	111.40	115.23	118.07	122.70	124.19
84.38	97.65	98.39	99.05	99.42	105.93	111.07	111.63	114.59	119.67	121.89
81.25	95.72	96.03	96.42	97.49	99.48	99.86	100.40	102.66	117.51	120.05
78.13	95.14	95.18	95.20	95.31	95.95	98.34	100.38	101.74	109.39	117.51
75.00	94.50	94.63	94.77	95.06	95.78	96.37	99.45	101.39	105.49	117.42
71.88	93.31	93.54	93.76	94.07	95.62	96.05	97.92	98.64	105.18	110.23
68.75	93.06	93.22	93.35	93.88	94.81	95.69	96.85	98.44	105.00	109.25
65.63	91.86	92.19	92.68	93.56	94.18	95.60	96.69	98.32	103.96	108.12
62.50	91.37	91.46	91.57	91.69	92.84	94.97	96.68	98.28	103.93	107.06
59.38	90.27	90.33	90.47	91.20	92.19	92.70	93.01	98.20	102.03	104.98
56.25	89.40	89.44	89.51	90.54	91.86	92.13	92.99	98.03	101.92	104.84
53.13	88.11	88.21	88.50	89.58	90.33	91.99	92.40	97.54	101.57	104.17
50.00	87.26	87.78	88.45	88.82	89.75	90.37	91.54	95.22	100.32	103.68
46.88	86.85	87.67	87.85	88.27	89.42	90.13	91.23	94.51	98.13	103.32
43.75	83.93	84.24	84.83	86.82	89.32	89.83	90.02	94.29	96.93	101.35
40.63	83.89	84.04	84.63	85.54	87.37	88.39	89.09	93.49	96.54	101.02
37.50	83.69	83.93	84.03	84.61	86.08	87.91	88.94	93.05	96.16	100.94
34.38	83.35	83.77	83.84	84.14	85.06	87.45	88.71	92.85	95.32	100.14
31.25	83.25	83.30	83.54	83.94	84.64	85.39	88.34	92.34	94.70	99.70
28.13	82.76	82.82	83.24	83.82	84.53	85.38	86.84	90.53	93.83	99.62
25.00	82.44	82.80	82.90	83.31	84.17	85.03	86.77	90.06	92.28	99.53
21.88	81.93	82.21	82.48	83.04	84.17	84.68	85.80	88.13	90.32	97.38
18.75	76.91	76.98	77.04	78.01	82.89	84.13	85.55	87.03	88.29	97.35
15.63	76.21	76.55	76.94	77.85	80.98	82.61	85.37	86.54	88.21	96.39
12.50	75.13	75.85	76.52	77.79	79.45	81.23	83.43	85.02	88.03	92.03
9.38	74.77	75.13	75.50	76.34	78.15	80.02	83.11	84.54	87.39	90.47
6.25	73.99	74.30	74.67	75.47	77.49	79.63	81.77	84.22	85.68	89.42
3.13	54.37	55.70	57.06	60.17	65.98	71.56	75.58	80.54	84.96	89.40

31 yrs LOs: Computed MFLs Discharge (cfs) at A14 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	109.44	110.30	113.37	118.79	128.94	143.32	154.16	201.94	298.75	496.70
93.75	105.07	109.91	111.31	114.72	125.40	139.37	139.37	146.28	237.63	342.87
90.63	103.82	107.79	110.25	110.49	118.95	128.65	137.35	141.65	208.99	326.20
87.50	98.50	99.17	100.67	106.57	114.19	122.20	125.89	139.91	171.82	298.75
84.38	97.65	99.05	99.38	100.15	111.47	112.65	114.99	137.92	161.57	246.98
81.25	95.72	96.37	97.07	99.75	100.25	107.13	113.95	137.39	158.97	241.21
78.13	95.14	95.21	95.25	96.01	100.25	105.72	112.12	135.42	154.38	237.63
75.00	94.50	94.78	95.01	95.73	96.88	101.20	109.95	128.06	150.40	229.13
71.88	93.31	93.73	94.13	95.57	96.83	100.63	107.19	126.89	149.70	229.09
68.75	93.06	93.36	93.66	94.53	96.47	98.43	103.01	125.89	146.28	220.00
65.63	91.86	92.62	93.58	94.09	96.35	97.95	101.94	122.67	139.25	209.22
62.50	91.37	91.56	91.75	92.77	95.92	97.32	101.53	121.92	134.08	196.19
59.38	90.27	90.47	90.81	91.88	94.99	96.23	100.88	119.01	130.29	192.48
56.25	89.40	89.52	90.69	91.61	94.88	95.74	100.48	113.22	128.35	179.23
53.13	88.11	89.28	89.60	90.65	92.52	95.12	98.61	111.57	127.19	161.57
50.00	87.26	88.34	88.71	89.80	92.31	94.08	97.43	107.19	120.04	158.97
46.88	86.85	87.81	88.19	89.37	91.90	93.89	96.80	106.11	113.22	155.93
43.75	83.93	84.72	86.31	89.05	91.10	93.69	96.15	106.02	112.76	150.40
40.63	83.89	84.56	85.35	87.32	90.53	93.07	95.12	105.96	112.45	136.53
37.50	83.69	83.99	84.16	86.02	90.17	92.12	94.88	104.47	111.57	136.31
34.38	83.35	83.82	83.96	84.59	88.17	91.00	94.57	101.40	109.65	134.08
31.25	83.25	83.35	83.91	84.40	87.71	90.61	94.38	97.65	108.30	132.47
28.13	82.76	83.17	83.89	84.27	87.32	90.26	93.32	97.35	106.93	129.83
25.00	82.44	82.85	83.08	84.14	86.81	89.67	92.86	96.58	103.31	128.35
21.88	81.93	82.51	82.97	84.06	86.13	89.38	91.95	94.23	102.92	127.37
18.75	76.91	77.05	77.73	81.10	85.55	87.95	91.19	94.08	98.84	127.26
15.63	76.21	76.85	77.66	80.86	84.80	86.77	91.16	92.78	98.64	123.14
12.50	75.13	76.49	77.11	79.40	82.90	86.49	90.82	92.23	97.37	122.94
9.38	74.77	75.49	76.20	77.89	81.75	86.39	88.87	91.72	96.58	115.17
6.25	73.99	74.62	75.28	77.33	81.58	85.82	88.60	91.26	95.08	106.35
3.13	54.37	56.97	59.58	65.83	77.13	85.44	87.89	90.75	92.77	97.84

31 yrs HIs: Computed MFLs Discharge (cfs) at A16 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
3.13	195.26	191.90	188.53	180.12	164.98	149.66	141.33	131.85	108.91	104.07
6.25	166.07	163.21	160.35	153.19	140.31	131.29	123.67	112.17	104.07	95.07
9.38	129.07	125.28	121.65	118.34	114.87	111.12	108.74	108.07	95.07	90.87
12.50	125.07	123.52	121.42	117.46	109.86	108.07	108.07	97.07	92.35	90.57
15.63	123.40	120.77	119.80	114.46	109.75	103.28	101.07	97.07	91.95	88.57
18.75	121.07	120.51	117.34	112.99	108.58	102.25	101.03	96.46	90.87	88.47
21.88	119.03	118.08	116.93	110.32	105.82	101.07	99.28	95.07	90.10	87.87
25.00	114.07	112.91	111.78	109.47	104.97	100.41	98.07	94.67	89.77	87.81
28.13	113.76	112.60	111.72	108.69	103.31	100.12	97.07	93.35	89.67	86.07
31.25	113.31	112.35	111.48	107.81	102.99	99.13	96.67	93.35	88.57	85.10
34.38	113.07	110.60	110.60	107.53	100.24	98.92	95.86	93.24	88.35	84.98
37.50	110.07	108.62	107.17	105.32	100.17	98.86	95.56	90.77	87.37	84.67
40.63	106.33	105.58	105.50	103.89	100.07	98.77	95.18	90.65	87.17	84.57
43.75	106.07	105.57	104.75	102.86	100.04	98.37	95.07	90.17	86.78	84.17
46.88	106.07	105.29	104.43	102.42	99.38	97.23	94.50	89.81	86.48	82.07
50.00	105.88	104.11	102.42	101.07	99.13	95.83	94.32	89.65	86.47	80.17
53.13	105.07	103.34	102.20	100.53	98.94	95.15	94.07	89.28	86.29	79.87
56.25	104.07	102.69	102.14	100.44	97.32	95.07	92.09	88.97	85.47	78.27
59.38	103.13	102.24	101.42	99.31	96.99	94.45	91.42	88.85	84.98	77.85
62.50	103.07	101.73	100.49	98.59	95.54	92.57	90.13	87.48	84.67	77.77
65.63	102.07	101.31	99.38	98.53	95.32	91.45	90.06	87.16	84.17	77.67
68.75	100.07	99.76	97.85	96.71	95.05	91.33	89.19	86.82	82.61	77.17
71.88	98.78	98.35	97.34	96.46	94.65	90.18	88.46	86.80	80.92	76.07
75.00	98.07	97.74	93.71	92.16	90.30	89.36	87.14	85.27	78.87	75.07
78.13	98.07	95.80	92.70	91.10	89.53	89.22	86.08	83.29	78.27	73.89
81.25	94.35	93.39	92.43	90.27	89.25	87.34	85.58	82.59	77.77	73.17
84.38	94.07	93.38	90.22	89.70	88.31	87.31	84.78	81.42	76.47	72.79
87.50	93.07	92.36	89.79	89.23	87.57	86.94	83.00	79.67	76.11	71.97
90.63	89.86	89.82	89.38	88.69	87.48	85.40	81.89	78.57	76.07	69.97
93.75	87.81	87.77	87.73	87.64	85.87	84.19	81.12	77.35	75.07	65.35
96.88	87.67	86.55	85.27	83.04	82.01	81.87	78.52	76.47	73.07	53.07

31 yrs LOs: Computed MFLs Discharge (cfs) at A16 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	104.52	104.85	105.24	106.14	108.05	111.47	117.58	128.56	136.73	140.81
93.75	100.07	100.84	101.61	103.38	106.70	109.55	109.99	112.95	122.00	119.67
90.63	92.07	93.01	95.09	96.68	97.24	98.87	101.86	106.43	107.93	109.63
87.50	91.12	92.14	92.22	92.38	94.73	97.49	98.72	101.39	103.94	104.28
84.38	89.67	90.29	90.91	92.34	94.54	96.02	96.90	98.14	99.58	99.09
81.25	89.14	89.17	90.11	91.15	92.83	95.31	96.60	97.86	98.18	99.06
78.13	88.97	89.14	89.48	90.95	92.69	93.05	93.52	97.52	98.02	98.60
75.00	88.57	88.97	89.33	90.64	92.12	92.99	93.47	95.26	96.94	98.43
71.88	88.47	88.82	89.19	89.73	91.98	92.85	92.98	94.69	95.86	97.86
68.75	87.72	88.64	89.03	89.43	90.50	91.32	92.36	94.55	95.75	96.55
65.63	87.37	88.19	88.71	89.25	89.34	89.93	90.79	94.32	95.58	96.38
62.50	87.13	87.14	87.16	88.89	89.20	89.52	89.85	93.28	94.87	95.95
59.38	86.07	86.19	86.41	87.21	88.35	89.43	89.51	91.44	94.66	95.73
56.25	84.17	85.27	86.32	86.60	87.29	88.26	89.09	91.29	92.26	94.47
53.13	80.46	81.45	81.93	85.29	87.20	87.38	87.46	91.05	91.72	93.50
50.00	79.99	80.43	80.94	82.10	84.25	85.39	87.24	89.68	90.46	93.03
46.88	79.88	80.29	80.72	81.99	83.55	85.33	85.86	89.51	90.38	92.86
43.75	79.87	80.20	80.57	81.71	82.90	84.57	85.36	89.46	89.91	89.81
40.63	78.87	78.94	79.02	81.38	82.25	83.73	85.15	87.63	87.88	88.88
37.50	77.85	78.30	78.76	79.81	81.77	82.75	84.81	85.44	87.66	88.63
34.38	77.77	77.96	78.16	79.19	79.84	81.85	83.04	84.81	86.51	88.15
31.25	77.17	77.29	77.56	78.61	79.55	80.92	82.88	84.38	86.46	87.18
28.13	76.84	77.17	77.43	78.44	79.52	80.22	81.48	84.21	85.92	87.17
25.00	75.83	76.06	76.85	77.74	78.83	79.90	80.47	83.36	85.69	86.74
21.88	75.07	75.30	76.33	76.94	78.31	78.88	80.44	82.16	84.77	86.68
18.75	73.89	74.25	74.61	75.81	77.62	78.55	80.11	81.94	83.94	85.50
15.63	73.07	73.49	74.20	75.44	77.00	77.71	79.45	81.86	83.37	85.14
12.50	72.79	73.42	73.79	74.62	76.16	77.71	79.32	80.72	82.59	84.92
9.38	71.97	72.10	72.25	72.57	73.51	75.53	77.68	78.86	82.24	83.70
6.25	69.97	70.38	70.79	71.74	73.18	74.24	76.21	78.24	81.03	81.84
3.13	53.07	54.34	55.65	58.63	64.21	69.71	73.64	77.54	78.55	81.72

31 yrs LOs: Computed MFLs Discharge (cfs) at A16 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	104.52	105.19	105.97	107.76	113.18	128.24	143.15	166.07	195.26	195.26
93.75	100.07	101.59	103.12	106.51	110.03	111.02	113.07	134.09	148.92	148.92
90.63	92.07	94.91	97.80	98.07	101.61	106.84	112.00	117.07	125.07	129.07
87.50	91.12	92.20	92.36	94.91	98.07	104.07	104.07	117.07	123.40	125.07
84.38	89.67	90.90	92.14	94.49	97.41	102.40	104.07	115.94	117.07	123.40
81.25	89.14	89.93	91.08	92.74	96.13	96.93	103.89	115.68	117.07	121.07
78.13	88.97	89.39	90.65	92.69	93.96	95.07	100.01	110.60	116.07	119.03
75.00	88.57	89.29	90.41	92.08	93.67	95.07	96.76	105.24	113.07	114.07
71.88	88.47	89.19	89.68	91.67	93.31	94.31	96.25	104.07	110.60	113.07
68.75	87.72	89.01	89.24	90.46	92.95	94.16	95.44	103.89	110.07	110.60
65.63	87.37	88.70	88.85	89.34	92.02	93.24	95.07	102.53	106.07	110.07
62.50	87.13	87.16	88.59	89.20	89.83	93.16	94.98	101.95	105.65	108.64
59.38	86.07	86.29	87.20	88.46	89.51	90.86	94.84	101.19	105.07	107.21
56.25	84.17	86.11	86.57	87.29	88.67	90.77	94.07	99.07	104.07	106.33
53.13	80.46	81.92	83.69	87.12	87.87	90.46	93.52	97.72	102.07	106.07
50.00	79.99	80.86	81.98	84.22	87.46	89.68	92.45	97.43	100.07	105.65
46.88	79.88	80.64	81.89	83.49	86.09	89.50	91.24	94.79	98.78	103.13
43.75	79.87	80.51	81.51	82.83	84.95	87.87	89.89	94.54	98.22	103.07
40.63	78.87	79.01	81.25	82.11	84.81	87.63	89.85	91.24	98.07	102.07
37.50	77.85	78.73	79.61	81.73	84.81	85.74	88.23	90.18	98.07	102.07
34.38	77.77	78.11	79.16	79.78	83.08	84.88	87.80	90.07	95.97	100.07
31.25	77.17	77.50	78.53	79.51	81.96	84.48	86.32	89.19	95.07	98.14
28.13	76.84	77.42	78.27	79.45	81.86	84.40	86.08	89.07	93.07	98.07
25.00	75.83	76.29	77.67	78.66	80.16	84.35	85.95	89.07	93.02	98.07
21.88	75.07	75.53	76.82	78.29	80.02	83.57	85.77	88.79	92.77	96.88
18.75	73.89	74.59	75.58	77.74	79.41	83.17	84.94	88.69	90.55	95.44
15.63	73.07	74.19	75.30	76.94	79.19	82.25	83.57	88.67	90.07	93.07
12.50	72.79	73.73	74.44	76.13	78.13	81.34	83.14	88.13	89.74	93.02
9.38	71.97	72.23	72.53	73.47	76.98	80.57	82.72	86.08	88.64	90.55
6.25	69.97	70.79	71.61	73.13	75.12	79.22	81.66	85.47	87.67	89.17
3.13	53.07	55.52	57.97	63.85	74.40	78.50	78.50	85.24	86.59	87.12

Frequency Analysis Tables

Stage – MFL

31 yrs HIs: Simulated MFLs Stage (ft, NAVD) at Tracy Canal (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
3.13	7.68	6.89	6.03	5.18	4.68	4.23	3.79	3.61	3.19	2.92
6.25	6.42	6.01	5.59	4.91	4.44	4.21	3.74	3.57	3.03	2.92
9.38	6.38	5.95	5.42	4.87	4.22	3.97	3.71	3.32	3.01	2.71
12.50	6.04	5.68	5.12	4.71	4.20	3.96	3.65	3.27	2.92	2.68
15.63	5.42	5.24	5.05	4.65	4.20	3.88	3.58	3.21	2.84	2.59
18.75	5.32	5.11	5.01	4.64	4.16	3.83	3.50	3.01	2.83	2.56
21.88	5.17	4.96	4.88	4.61	4.10	3.71	3.35	2.96	2.80	2.55
25.00	5.17	4.88	4.86	4.53	4.09	3.59	3.32	2.94	2.77	2.51
28.13	5.15	4.86	4.80	4.39	4.05	3.47	3.28	2.90	2.70	2.50
31.25	5.09	4.85	4.70	4.39	4.03	3.47	3.27	2.85	2.65	2.50
34.38	5.01	4.77	4.68	4.31	4.01	3.43	3.24	2.84	2.65	2.48
37.50	4.96	4.75	4.60	4.29	3.98	3.36	3.20	2.84	2.60	2.41
40.63	4.88	4.72	4.58	4.13	3.90	3.35	3.19	2.82	2.59	2.41
43.75	4.83	4.72	4.56	4.09	3.85	3.35	3.08	2.80	2.57	2.39
46.88	4.80	4.71	4.54	4.00	3.81	3.32	3.02	2.77	2.56	2.35
50.00	4.78	4.70	4.48	3.90	3.72	3.27	2.96	2.77	2.56	2.34
53.13	4.78	4.63	4.45	3.89	3.66	3.23	2.96	2.72	2.52	2.34
56.25	4.69	4.57	4.34	3.83	3.55	3.16	2.94	2.70	2.50	2.33
59.38	4.67	4.56	4.18	3.80	3.54	3.16	2.91	2.65	2.49	2.33
62.50	4.32	4.28	4.16	3.76	3.44	3.13	2.91	2.59	2.45	2.33
65.63	4.31	4.21	3.97	3.70	3.42	3.09	2.87	2.57	2.44	2.32
68.75	4.25	4.15	3.96	3.63	3.36	3.00	2.84	2.52	2.44	2.30
71.88	4.25	4.11	3.92	3.49	3.15	2.99	2.84	2.50	2.39	2.28
75.00	4.24	4.08	3.86	3.46	3.10	2.93	2.81	2.50	2.39	2.28
78.13	4.02	3.95	3.84	3.44	3.03	2.89	2.71	2.48	2.38	2.26
81.25	4.00	3.91	3.72	3.37	2.99	2.72	2.66	2.44	2.38	2.22
84.38	3.83	3.76	3.58	3.37	2.98	2.71	2.62	2.43	2.36	2.17
87.50	3.81	3.71	3.50	3.28	2.95	2.70	2.60	2.42	2.34	2.16
90.63	3.77	3.69	3.49	3.12	2.92	2.68	2.59	2.39	2.26	2.13
93.75	3.73	3.67	3.43	3.10	2.90	2.62	2.50	2.38	2.25	1.66
96.88	3.20	3.10	3.05	2.86	2.64	2.62	2.46	2.34	1.98	1.45

31 yrs LOs: Simulated MFLs Stage (ft, NAVD) at Tracy Canal (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	3.03	3.05	3.07	3.08	3.22	3.39	3.48	3.78	3.86	4.00
93.75	2.92	2.93	2.96	3.04	3.16	3.35	3.38	3.56	3.62	3.82
90.63	2.90	2.91	2.92	2.95	3.15	3.21	3.37	3.45	3.56	3.70
87.50	2.80	2.80	2.84	2.88	3.01	3.21	3.21	3.30	3.53	3.64
84.38	2.78	2.80	2.81	2.86	3.00	3.12	3.20	3.29	3.50	3.58
81.25	2.60	2.61	2.62	2.64	2.73	2.81	2.80	2.95	3.27	3.55
78.13	2.59	2.60	2.60	2.63	2.69	2.72	2.80	2.94	3.26	3.48
75.00	2.56	2.57	2.60	2.61	2.68	2.70	2.75	2.94	3.22	3.46
71.88	2.51	2.55	2.58	2.60	2.67	2.70	2.74	2.87	3.21	3.41
68.75	2.50	2.54	2.57	2.59	2.64	2.68	2.73	2.86	3.14	3.37
65.63	2.50	2.52	2.52	2.55	2.62	2.64	2.72	2.79	3.12	3.21
62.50	2.49	2.50	2.50	2.53	2.57	2.64	2.72	2.79	3.08	3.19
59.38	2.41	2.44	2.48	2.52	2.57	2.62	2.69	2.79	2.96	3.16
56.25	2.41	2.43	2.47	2.51	2.54	2.62	2.68	2.79	2.91	3.15
53.13	2.39	2.42	2.42	2.49	2.54	2.59	2.65	2.76	2.88	3.12
50.00	2.39	2.40	2.42	2.47	2.53	2.59	2.65	2.75	2.87	3.11
46.88	2.36	2.37	2.41	2.44	2.52	2.59	2.64	2.74	2.86	3.09
43.75	2.35	2.37	2.40	2.43	2.51	2.58	2.63	2.73	2.83	3.09
40.63	2.34	2.36	2.38	2.42	2.51	2.55	2.62	2.72	2.83	3.08
37.50	2.34	2.36	2.37	2.42	2.47	2.54	2.61	2.71	2.82	3.07
34.38	2.33	2.34	2.37	2.40	2.45	2.53	2.60	2.69	2.82	3.05
31.25	2.33	2.34	2.35	2.38	2.45	2.53	2.57	2.69	2.77	3.05
28.13	2.32	2.34	2.34	2.37	2.42	2.49	2.53	2.65	2.72	3.04
25.00	2.28	2.31	2.33	2.36	2.41	2.49	2.52	2.60	2.71	3.03
21.88	2.26	2.27	2.29	2.31	2.39	2.41	2.48	2.54	2.68	3.01
18.75	2.25	2.27	2.28	2.31	2.38	2.39	2.41	2.49	2.64	2.99
15.63	2.17	2.22	2.27	2.31	2.35	2.36	2.37	2.48	2.64	2.93
12.50	2.16	2.20	2.23	2.27	2.34	2.34	2.37	2.46	2.58	2.84
9.38	2.13	2.14	2.14	2.18	2.26	2.32	2.36	2.43	2.56	2.72
6.25	1.98	2.00	2.00	2.03	2.13	2.23	2.34	2.42	2.54	2.71
3.13	1.45	1.47	1.50	1.57	1.75	1.91	2.04	2.22	2.48	2.55

31 yrs LOs: Simulated MFLs Stage (ft, NAVD) at Tracy Canal (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	3.03	3.06	3.12	3.33	3.90	4.13	4.13	4.70	6.04	7.68
93.75	2.92	2.96	2.99	3.17	3.66	3.94	4.08	4.40	5.35	6.42
90.63	2.90	2.92	2.97	3.13	3.40	3.86	4.00	4.31	5.17	6.38
87.50	2.80	2.82	2.93	3.01	3.35	3.49	3.49	4.20	4.94	6.15
84.38	2.78	2.81	2.84	2.93	3.23	3.37	3.47	4.07	4.90	6.04
81.25	2.60	2.63	2.65	2.71	3.02	3.09	3.31	4.00	4.80	5.42
78.13	2.59	2.60	2.64	2.71	3.00	3.04	3.26	3.89	4.78	5.32
75.00	2.56	2.60	2.63	2.70	2.87	3.04	3.16	3.72	4.76	5.23
71.88	2.51	2.59	2.62	2.68	2.87	3.03	3.16	3.69	4.43	5.17
68.75	2.50	2.58	2.60	2.65	2.87	2.99	3.15	3.69	4.42	5.17
65.63	2.50	2.52	2.56	2.64	2.86	2.97	3.14	3.67	4.38	5.09
62.50	2.49	2.50	2.56	2.64	2.83	2.95	3.12	3.64	4.17	5.01
59.38	2.41	2.47	2.52	2.62	2.83	2.90	3.12	3.55	4.09	4.96
56.25	2.41	2.46	2.52	2.59	2.76	2.89	3.03	3.47	3.89	4.96
53.13	2.39	2.44	2.51	2.59	2.74	2.89	3.01	3.45	3.81	4.91
50.00	2.39	2.42	2.50	2.54	2.72	2.88	3.00	3.37	3.81	4.88
46.88	2.36	2.42	2.43	2.54	2.72	2.82	2.98	3.34	3.78	4.83
43.75	2.35	2.40	2.43	2.53	2.69	2.78	2.97	3.31	3.77	4.80
40.63	2.34	2.38	2.43	2.51	2.63	2.75	2.97	3.20	3.69	4.78
37.50	2.34	2.37	2.39	2.49	2.62	2.75	2.96	3.19	3.67	4.77
34.38	2.33	2.36	2.38	2.49	2.61	2.73	2.94	3.14	3.65	4.75
31.25	2.33	2.34	2.38	2.45	2.60	2.73	2.87	3.12	3.62	4.67
28.13	2.32	2.34	2.37	2.45	2.60	2.71	2.86	3.08	3.56	4.57
25.00	2.28	2.33	2.37	2.41	2.59	2.67	2.83	3.01	3.55	4.40
21.88	2.26	2.29	2.36	2.40	2.57	2.66	2.82	3.00	3.54	4.38
18.75	2.25	2.28	2.32	2.37	2.53	2.62	2.73	2.94	3.54	4.36
15.63	2.17	2.28	2.32	2.35	2.53	2.61	2.72	2.83	3.31	4.31
12.50	2.16	2.25	2.31	2.34	2.47	2.53	2.61	2.73	3.28	4.25
9.38	2.13	2.15	2.16	2.23	2.43	2.48	2.57	2.73	3.22	3.58
6.25	1.98	2.01	2.01	2.12	2.34	2.46	2.52	2.72	3.01	3.52
3.13	1.45	1.49	1.55	1.72	2.13	2.34	2.50	2.68	2.86	3.18

31 yrs HIs: Computed MFLs Stage (ft, NAVD) at A4.3 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
3.13	7.90	6.60	6.00	5.09	4.58	4.32	3.99	3.89	3.51	3.30
6.25	6.50	5.93	5.55	4.96	4.54	4.30	3.92	3.71	3.38	3.29
9.38	6.49	5.89	5.34	4.89	4.47	4.18	3.86	3.53	3.36	3.16
12.50	6.13	5.87	5.13	4.81	4.35	4.18	3.86	3.52	3.27	3.15
15.63	5.58	5.36	5.09	4.77	4.29	4.08	3.73	3.52	3.23	3.11
18.75	5.49	5.09	4.99	4.74	4.23	4.02	3.58	3.36	3.22	3.09
21.88	5.32	5.02	4.95	4.67	4.22	3.84	3.54	3.31	3.21	3.09
25.00	5.26	4.99	4.91	4.67	4.21	3.77	3.53	3.29	3.20	3.08
28.13	5.21	4.95	4.89	4.58	4.16	3.61	3.53	3.27	3.15	3.07
31.25	5.10	4.94	4.83	4.44	4.12	3.61	3.52	3.24	3.14	3.06
34.38	5.06	4.91	4.75	4.36	4.05	3.59	3.51	3.22	3.14	3.05
37.50	4.95	4.87	4.66	4.30	4.05	3.58	3.48	3.22	3.12	3.03
40.63	4.93	4.80	4.62	4.21	4.00	3.57	3.47	3.22	3.11	3.03
43.75	4.89	4.78	4.55	4.08	3.93	3.56	3.36	3.21	3.10	3.02
46.88	4.83	4.72	4.50	4.08	3.85	3.55	3.34	3.20	3.09	2.97
50.00	4.82	4.66	4.49	4.06	3.80	3.54	3.31	3.19	3.08	2.93
53.13	4.74	4.65	4.45	3.99	3.79	3.49	3.31	3.16	3.08	2.93
56.25	4.62	4.56	4.36	3.98	3.76	3.47	3.28	3.16	3.07	2.92
59.38	4.61	4.49	4.28	3.95	3.71	3.41	3.27	3.14	3.07	2.91
62.50	4.27	4.25	4.08	3.86	3.66	3.39	3.24	3.11	3.03	2.89
65.63	4.17	4.12	4.06	3.86	3.60	3.35	3.23	3.09	3.03	2.88
68.75	4.14	4.05	4.01	3.80	3.54	3.32	3.21	3.07	3.03	2.88
71.88	4.13	4.02	3.88	3.61	3.41	3.29	3.19	3.07	3.01	2.87
75.00	4.06	4.01	3.87	3.61	3.38	3.27	3.18	3.06	2.99	2.85
78.13	4.05	3.97	3.77	3.53	3.36	3.26	3.15	3.05	2.99	2.85
81.25	4.04	3.96	3.77	3.52	3.28	3.15	3.13	3.04	2.97	2.83
84.38	3.85	3.82	3.72	3.50	3.27	3.13	3.13	3.03	2.96	2.73
87.50	3.78	3.71	3.66	3.44	3.26	3.13	3.11	2.99	2.94	2.73
90.63	3.68	3.62	3.59	3.37	3.25	3.13	3.09	2.99	2.85	2.71
93.75	3.65	3.62	3.52	3.33	3.20	3.13	3.06	2.99	2.84	2.28
96.88	3.36	3.34	3.33	3.22	3.14	3.09	3.04	2.96	2.54	1.94

31 yrs LOs: Computed MFLs Stage (ft, NAVD) at A4.3 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	3.38	3.38	3.40	3.41	3.50	3.64	3.72	4.00	4.08	4.19
93.75	3.29	3.30	3.32	3.38	3.46	3.60	3.63	3.77	3.82	3.99
90.63	3.29	3.29	3.30	3.31	3.44	3.50	3.62	3.69	3.80	3.89
87.50	3.21	3.21	3.22	3.24	3.35	3.49	3.49	3.58	3.78	3.88
84.38	3.20	3.21	3.21	3.24	3.34	3.41	3.46	3.56	3.72	3.81
81.25	3.12	3.12	3.13	3.13	3.16	3.21	3.22	3.31	3.57	3.76
78.13	3.11	3.12	3.12	3.12	3.15	3.16	3.21	3.30	3.56	3.72
75.00	3.09	3.10	3.10	3.12	3.14	3.15	3.17	3.29	3.50	3.69
71.88	3.08	3.08	3.09	3.11	3.13	3.15	3.17	3.27	3.49	3.67
68.75	3.07	3.08	3.09	3.10	3.12	3.14	3.16	3.23	3.45	3.60
65.63	3.07	3.08	3.08	3.08	3.09	3.11	3.15	3.22	3.42	3.50
62.50	3.06	3.07	3.07	3.08	3.09	3.10	3.14	3.21	3.38	3.46
59.38	3.03	3.03	3.04	3.06	3.09	3.10	3.13	3.19	3.30	3.46
56.25	3.03	3.03	3.04	3.05	3.08	3.10	3.12	3.19	3.27	3.44
53.13	3.02	3.03	3.03	3.04	3.07	3.09	3.12	3.19	3.25	3.42
50.00	2.99	3.02	3.03	3.04	3.06	3.08	3.12	3.18	3.25	3.41
46.88	2.97	2.98	2.98	3.03	3.05	3.08	3.10	3.16	3.23	3.39
43.75	2.96	2.97	2.97	3.00	3.05	3.08	3.10	3.15	3.22	3.39
40.63	2.93	2.94	2.97	3.00	3.04	3.05	3.10	3.15	3.22	3.38
37.50	2.92	2.94	2.96	2.98	3.04	3.05	3.08	3.14	3.20	3.38
34.38	2.91	2.93	2.96	2.98	3.03	3.05	3.07	3.13	3.18	3.38
31.25	2.89	2.92	2.94	2.98	3.00	3.04	3.06	3.12	3.17	3.37
28.13	2.87	2.92	2.94	2.97	2.99	3.03	3.06	3.11	3.17	3.37
25.00	2.85	2.88	2.90	2.96	2.98	3.02	3.05	3.08	3.15	3.35
21.88	2.85	2.86	2.87	2.89	2.97	3.00	3.02	3.07	3.14	3.35
18.75	2.84	2.85	2.86	2.88	2.92	2.98	3.01	3.03	3.10	3.34
15.63	2.73	2.76	2.78	2.82	2.92	2.93	2.95	2.99	3.08	3.24
12.50	2.73	2.73	2.76	2.80	2.85	2.89	2.91	2.98	3.03	3.23
9.38	2.71	2.72	2.74	2.77	2.85	2.88	2.90	2.96	3.03	3.13
6.25	2.54	2.55	2.56	2.60	2.69	2.79	2.87	2.95	3.02	3.13
3.13	1.94	1.97	2.01	2.11	2.29	2.47	2.60	2.77	2.96	3.05

31 yrs LOs: Computed MFLs Stage (ft, NAVD) at A4.3 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	3.38	3.39	3.41	3.59	4.07	4.22	4.22	4.88	6.13	7.90
93.75	3.29	3.32	3.36	3.43	3.80	4.08	4.22	4.50	5.49	6.50
90.63	3.29	3.30	3.31	3.35	3.60	3.96	4.14	4.27	5.06	6.49
87.50	3.21	3.22	3.24	3.33	3.58	3.69	3.69	4.25	4.95	6.13
84.38	3.20	3.21	3.22	3.27	3.48	3.56	3.67	4.22	4.93	6.02
81.25	3.12	3.13	3.13	3.15	3.30	3.37	3.56	4.19	4.82	5.58
78.13	3.11	3.12	3.12	3.14	3.22	3.36	3.49	4.04	4.80	5.49
75.00	3.09	3.11	3.12	3.13	3.18	3.27	3.46	3.91	4.79	5.32
71.88	3.08	3.09	3.11	3.13	3.18	3.26	3.44	3.82	4.55	5.31
68.75	3.07	3.09	3.10	3.13	3.18	3.26	3.41	3.75	4.51	5.26
65.63	3.07	3.08	3.08	3.12	3.16	3.24	3.39	3.67	4.48	5.25
62.50	3.06	3.07	3.08	3.10	3.14	3.23	3.27	3.63	4.22	5.23
59.38	3.03	3.04	3.07	3.09	3.14	3.22	3.27	3.61	4.04	5.06
56.25	3.03	3.04	3.06	3.08	3.14	3.20	3.26	3.56	4.01	4.93
53.13	3.02	3.03	3.04	3.08	3.14	3.18	3.26	3.56	3.91	4.89
50.00	2.99	3.03	3.03	3.07	3.14	3.18	3.25	3.53	3.85	4.82
46.88	2.97	2.99	3.03	3.06	3.11	3.17	3.24	3.49	3.77	4.81
43.75	2.96	2.98	3.03	3.06	3.11	3.16	3.23	3.38	3.74	4.74
40.63	2.93	2.98	3.00	3.06	3.10	3.15	3.22	3.37	3.73	4.62
37.50	2.92	2.96	2.99	3.05	3.10	3.15	3.22	3.36	3.70	4.61
34.38	2.91	2.95	2.98	3.04	3.10	3.14	3.20	3.36	3.68	4.58
31.25	2.89	2.95	2.96	2.99	3.08	3.13	3.19	3.34	3.67	4.55
28.13	2.87	2.94	2.95	2.99	3.07	3.12	3.19	3.27	3.63	4.54
25.00	2.85	2.89	2.93	2.99	3.07	3.11	3.19	3.22	3.59	4.54
21.88	2.85	2.87	2.89	2.95	3.07	3.10	3.17	3.21	3.53	4.36
18.75	2.84	2.87	2.87	2.93	3.03	3.07	3.13	3.20	3.45	4.33
15.63	2.73	2.79	2.86	2.90	3.02	3.05	3.11	3.16	3.38	4.17
12.50	2.73	2.74	2.83	2.88	3.00	3.03	3.09	3.15	3.37	3.80
9.38	2.71	2.73	2.76	2.82	2.98	3.02	3.06	3.13	3.36	3.77
6.25	2.54	2.56	2.58	2.69	2.84	3.00	3.05	3.12	3.30	3.67
3.13	1.94	2.00	2.09	2.28	2.64	2.90	3.04	3.09	3.16	3.25

31 yrs HIs: Computed MFLs Stage (ft, NAVD) at A5 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
3.13	8.61	7.38	6.79	6.05	5.70	5.52	5.35	5.31	5.18	5.10
6.25	7.28	6.72	6.38	5.95	5.67	5.51	5.32	5.25	5.12	5.09
9.38	7.27	6.69	6.22	5.89	5.63	5.43	5.30	5.19	5.12	5.02
12.50	6.91	6.67	6.07	5.85	5.54	5.42	5.30	5.18	5.08	5.01
15.63	6.41	6.23	6.04	5.82	5.50	5.38	5.26	5.18	5.06	4.99
18.75	6.33	6.04	5.97	5.80	5.46	5.36	5.20	5.12	5.06	4.98
21.88	6.21	5.99	5.95	5.75	5.45	5.30	5.19	5.10	5.05	4.98
25.00	6.16	5.97	5.91	5.75	5.44	5.27	5.19	5.09	5.04	4.97
28.13	6.13	5.94	5.90	5.69	5.42	5.22	5.19	5.08	5.01	4.96
31.25	6.05	5.94	5.86	5.61	5.40	5.21	5.18	5.07	5.01	4.96
34.38	6.02	5.91	5.81	5.55	5.37	5.21	5.18	5.06	5.00	4.95
37.50	5.94	5.89	5.75	5.51	5.37	5.21	5.16	5.05	4.99	4.94
40.63	5.93	5.84	5.72	5.45	5.35	5.20	5.16	5.05	4.99	4.93
43.75	5.90	5.82	5.67	5.39	5.33	5.20	5.12	5.05	4.98	4.92
46.88	5.86	5.79	5.64	5.38	5.30	5.19	5.11	5.04	4.98	4.87
50.00	5.85	5.75	5.64	5.37	5.28	5.19	5.10	5.04	4.97	4.81
53.13	5.80	5.74	5.61	5.35	5.28	5.17	5.10	5.02	4.97	4.81
56.25	5.72	5.68	5.55	5.35	5.27	5.16	5.09	5.02	4.96	4.80
59.38	5.72	5.64	5.49	5.33	5.25	5.14	5.08	5.01	4.96	4.78
62.50	5.49	5.47	5.39	5.30	5.24	5.13	5.07	4.99	4.94	4.77
65.63	5.42	5.40	5.38	5.30	5.21	5.11	5.06	4.98	4.94	4.75
68.75	5.41	5.37	5.36	5.28	5.19	5.10	5.05	4.96	4.93	4.74
71.88	5.40	5.36	5.31	5.22	5.14	5.09	5.04	4.96	4.91	4.74
75.00	5.38	5.36	5.31	5.22	5.12	5.08	5.03	4.95	4.89	4.71
78.13	5.37	5.34	5.27	5.18	5.12	5.08	5.02	4.95	4.89	4.70
81.25	5.37	5.34	5.27	5.18	5.09	5.02	5.00	4.94	4.86	4.68
84.38	5.30	5.29	5.26	5.17	5.08	5.00	5.00	4.93	4.86	4.55
87.50	5.28	5.25	5.23	5.15	5.08	5.00	4.99	4.89	4.82	4.54
90.63	5.24	5.22	5.21	5.12	5.07	5.00	4.98	4.89	4.70	4.52
93.75	5.23	5.22	5.18	5.11	5.04	5.00	4.95	4.89	4.70	3.96
96.88	5.12	5.11	5.10	5.06	5.01	4.98	4.94	4.85	4.30	3.51

31 yrs LOs: Computed MFLs Stage (ft, NAVD) at A5 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	5.12	5.13	5.13	5.14	5.17	5.22	5.25	5.39	5.43	5.49
93.75	5.09	5.10	5.10	5.13	5.16	5.21	5.22	5.28	5.33	5.40
90.63	5.09	5.09	5.09	5.10	5.14	5.17	5.21	5.24	5.32	5.37
87.50	5.05	5.05	5.05	5.06	5.11	5.16	5.17	5.20	5.28	5.33
84.38	5.04	5.04	5.05	5.06	5.11	5.14	5.16	5.19	5.27	5.33
81.25	4.99	5.00	5.00	5.00	5.02	5.05	5.05	5.07	5.21	5.28
78.13	4.99	4.99	4.99	5.00	5.01	5.02	5.04	5.06	5.19	5.28
75.00	4.98	4.98	4.98	4.99	5.01	5.01	5.03	5.06	5.17	5.25
71.88	4.97	4.97	4.98	4.99	5.00	5.01	5.02	5.05	5.16	5.25
68.75	4.96	4.97	4.97	4.98	4.99	5.01	5.02	5.05	5.14	5.21
65.63	4.96	4.97	4.97	4.97	4.97	4.99	5.02	5.05	5.13	5.21
62.50	4.96	4.96	4.96	4.97	4.97	4.98	5.00	5.04	5.10	5.15
59.38	4.94	4.94	4.94	4.96	4.97	4.98	5.00	5.03	5.07	5.14
56.25	4.93	4.94	4.94	4.95	4.96	4.98	5.00	5.03	5.06	5.14
53.13	4.92	4.93	4.94	4.94	4.96	4.98	4.99	5.02	5.05	5.13
50.00	4.89	4.92	4.93	4.94	4.95	4.97	4.99	5.01	5.05	5.13
46.88	4.87	4.87	4.88	4.92	4.95	4.96	4.98	5.01	5.04	5.12
43.75	4.86	4.87	4.87	4.90	4.94	4.96	4.97	5.01	5.04	5.11
40.63	4.81	4.83	4.86	4.90	4.93	4.95	4.96	5.01	5.03	5.11
37.50	4.80	4.82	4.86	4.88	4.92	4.94	4.96	4.99	5.03	5.11
34.38	4.78	4.81	4.85	4.87	4.92	4.94	4.95	4.99	5.02	5.10
31.25	4.77	4.81	4.83	4.86	4.90	4.93	4.95	4.98	5.02	5.10
28.13	4.74	4.80	4.82	4.86	4.89	4.91	4.94	4.96	5.01	5.09
25.00	4.71	4.74	4.77	4.85	4.87	4.90	4.93	4.96	5.01	5.09
21.88	4.70	4.72	4.74	4.77	4.85	4.88	4.91	4.96	4.99	5.05
18.75	4.70	4.71	4.72	4.75	4.79	4.87	4.91	4.93	4.98	5.05
15.63	4.55	4.59	4.62	4.68	4.78	4.82	4.84	4.88	4.92	5.05
12.50	4.54	4.55	4.59	4.64	4.71	4.74	4.78	4.85	4.91	4.99
9.38	4.52	4.53	4.56	4.60	4.70	4.74	4.77	4.83	4.90	4.99
6.25	4.30	4.32	4.33	4.38	4.49	4.62	4.72	4.80	4.87	4.96
3.13	3.51	3.55	3.61	3.73	3.98	4.20	4.38	4.58	4.76	4.93

31 yrs LOs: Computed MFLs Stage (ft, NAVD) at A5 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	5.12	5.13	5.14	5.21	5.38	5.45	5.45	5.89	6.91	8.61
93.75	5.09	5.10	5.12	5.14	5.28	5.39	5.45	5.65	6.33	7.28
90.63	5.09	5.10	5.10	5.11	5.21	5.34	5.41	5.49	6.02	7.27
87.50	5.05	5.05	5.07	5.10	5.21	5.25	5.25	5.47	5.94	6.91
84.38	5.04	5.05	5.06	5.08	5.16	5.19	5.24	5.45	5.93	6.81
81.25	4.99	5.00	5.00	5.01	5.09	5.12	5.20	5.43	5.85	6.41
78.13	4.99	5.00	5.00	5.01	5.05	5.12	5.17	5.37	5.84	6.33
75.00	4.98	4.98	5.00	5.00	5.03	5.08	5.16	5.32	5.83	6.21
71.88	4.97	4.98	4.99	5.00	5.03	5.08	5.15	5.29	5.67	6.20
68.75	4.96	4.97	4.98	5.00	5.03	5.08	5.14	5.27	5.65	6.16
65.63	4.96	4.97	4.97	4.99	5.02	5.07	5.13	5.24	5.63	6.16
62.50	4.96	4.96	4.97	4.98	5.01	5.06	5.09	5.22	5.45	6.14
59.38	4.94	4.94	4.96	4.97	5.01	5.05	5.08	5.22	5.37	6.02
56.25	4.93	4.94	4.95	4.97	5.01	5.04	5.08	5.20	5.36	5.93
53.13	4.92	4.94	4.94	4.97	5.01	5.03	5.08	5.20	5.32	5.90
50.00	4.89	4.94	4.94	4.96	5.00	5.03	5.07	5.18	5.30	5.85
46.88	4.87	4.89	4.94	4.96	4.99	5.02	5.06	5.17	5.27	5.84
43.75	4.86	4.88	4.94	4.95	4.99	5.02	5.06	5.13	5.26	5.80
40.63	4.81	4.87	4.91	4.95	4.98	5.02	5.05	5.12	5.26	5.72
37.50	4.80	4.85	4.89	4.95	4.98	5.01	5.05	5.12	5.25	5.72
34.38	4.78	4.84	4.88	4.94	4.98	5.01	5.04	5.12	5.24	5.70
31.25	4.77	4.84	4.86	4.90	4.97	5.00	5.04	5.11	5.24	5.67
28.13	4.74	4.83	4.84	4.89	4.96	4.99	5.03	5.08	5.22	5.67
25.00	4.71	4.75	4.82	4.89	4.96	4.99	5.03	5.05	5.21	5.67
21.88	4.70	4.73	4.76	4.84	4.96	4.98	5.02	5.05	5.18	5.54
18.75	4.70	4.73	4.74	4.82	4.94	4.96	5.00	5.04	5.15	5.52
15.63	4.55	4.63	4.72	4.77	4.93	4.95	4.99	5.02	5.12	5.42
12.50	4.54	4.56	4.68	4.74	4.90	4.93	4.98	5.01	5.12	5.28
9.38	4.52	4.55	4.59	4.67	4.88	4.93	4.95	5.00	5.12	5.27
6.25	4.30	4.33	4.36	4.49	4.70	4.90	4.95	4.99	5.10	5.24
3.13	3.51	3.59	3.71	3.96	4.43	4.77	4.94	4.98	5.02	5.08

31 yrs HIs: Computed MFLs Stage (ft, NAVD) at A6 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
3.13	9.10	7.97	7.50	6.78	6.53	6.33	6.11	6.02	5.74	5.66
6.25	8.22	7.79	7.08	6.75	6.43	6.33	6.10	5.82	5.71	5.59
9.38	8.12	7.63	7.02	6.66	6.38	6.19	5.90	5.74	5.69	5.49
12.50	8.07	7.42	7.00	6.64	6.36	6.13	5.87	5.71	5.58	5.48
15.63	7.63	7.42	6.92	6.64	6.33	6.13	5.84	5.69	5.56	5.45
18.75	7.57	7.15	6.86	6.57	6.29	6.09	5.79	5.60	5.55	5.45
21.88	7.45	7.14	6.81	6.49	6.25	5.94	5.76	5.58	5.55	5.44
25.00	7.45	7.14	6.79	6.41	6.05	5.83	5.73	5.58	5.52	5.44
28.13	7.19	6.99	6.62	6.40	6.03	5.81	5.71	5.56	5.49	5.40
31.25	7.09	6.89	6.59	6.33	5.99	5.80	5.69	5.55	5.48	5.38
34.38	7.03	6.68	6.51	6.23	5.98	5.79	5.65	5.55	5.46	5.37
37.50	6.89	6.68	6.49	6.12	5.95	5.74	5.65	5.52	5.45	5.37
40.63	6.79	6.55	6.44	6.08	5.93	5.71	5.65	5.52	5.45	5.34
43.75	6.79	6.54	6.44	6.07	5.89	5.68	5.64	5.50	5.44	5.32
46.88	6.52	6.50	6.30	6.06	5.81	5.67	5.60	5.50	5.44	5.25
50.00	6.51	6.34	6.20	6.04	5.80	5.66	5.60	5.49	5.43	5.24
53.13	6.27	6.25	6.12	6.03	5.79	5.61	5.57	5.49	5.40	5.19
56.25	6.20	6.18	6.11	5.94	5.77	5.60	5.55	5.49	5.39	5.18
59.38	6.17	6.16	6.07	5.93	5.75	5.60	5.54	5.44	5.38	5.14
62.50	6.08	6.07	6.03	5.90	5.74	5.60	5.50	5.43	5.37	5.14
65.63	6.08	6.03	5.95	5.89	5.70	5.59	5.50	5.43	5.37	5.10
68.75	6.04	5.99	5.95	5.83	5.68	5.58	5.50	5.42	5.36	5.08
71.88	6.00	5.99	5.91	5.76	5.60	5.57	5.48	5.39	5.32	5.08
75.00	5.94	5.93	5.85	5.74	5.59	5.57	5.48	5.38	5.26	5.07
78.13	5.79	5.75	5.73	5.68	5.57	5.50	5.45	5.37	5.20	5.02
81.25	5.78	5.74	5.69	5.63	5.54	5.49	5.43	5.34	5.17	4.84
84.38	5.74	5.73	5.69	5.55	5.52	5.46	5.42	5.30	5.11	4.74
87.50	5.71	5.68	5.65	5.55	5.51	5.44	5.40	5.20	5.11	4.63
90.63	5.69	5.66	5.62	5.54	5.48	5.42	5.39	5.17	5.10	4.62
93.75	5.64	5.59	5.59	5.54	5.48	5.42	5.32	5.17	5.03	4.02
96.88	5.60	5.58	5.58	5.53	5.38	5.32	5.24	5.09	4.52	3.37

31 yrs LOs: Computed MFLs Stage (ft, NAVD) at A6 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	5.68	5.72	5.72	5.73	5.76	5.83	5.93	6.15	6.21	6.29
93.75	5.65	5.66	5.66	5.69	5.76	5.83	5.83	5.92	5.94	6.06
90.63	5.60	5.62	5.65	5.67	5.70	5.79	5.83	5.87	5.93	6.01
87.50	5.55	5.55	5.56	5.59	5.68	5.74	5.79	5.82	5.91	5.98
84.38	5.53	5.54	5.55	5.57	5.66	5.68	5.71	5.75	5.87	5.90
81.25	5.48	5.48	5.49	5.49	5.49	5.51	5.56	5.57	5.85	5.88
78.13	5.44	5.44	5.45	5.46	5.48	5.50	5.53	5.56	5.70	5.88
75.00	5.44	5.44	5.45	5.46	5.47	5.49	5.52	5.54	5.66	5.83
71.88	5.44	5.44	5.44	5.44	5.46	5.49	5.52	5.53	5.66	5.74
68.75	5.43	5.43	5.43	5.44	5.46	5.48	5.50	5.53	5.65	5.73
65.63	5.40	5.41	5.41	5.44	5.45	5.46	5.48	5.52	5.62	5.66
62.50	5.38	5.39	5.40	5.43	5.44	5.45	5.47	5.50	5.61	5.64
59.38	5.37	5.38	5.39	5.39	5.41	5.42	5.44	5.49	5.58	5.63
56.25	5.37	5.38	5.38	5.39	5.39	5.42	5.43	5.49	5.55	5.62
53.13	5.34	5.35	5.36	5.37	5.39	5.40	5.42	5.48	5.55	5.62
50.00	5.32	5.35	5.35	5.35	5.38	5.40	5.40	5.47	5.53	5.61
46.88	5.25	5.27	5.30	5.34	5.36	5.37	5.40	5.46	5.49	5.60
43.75	5.19	5.21	5.22	5.24	5.34	5.36	5.38	5.45	5.49	5.59
40.63	5.12	5.14	5.15	5.23	5.29	5.35	5.37	5.43	5.49	5.57
37.50	5.11	5.12	5.15	5.19	5.29	5.33	5.33	5.42	5.48	5.56
34.38	5.10	5.12	5.15	5.18	5.25	5.30	5.33	5.42	5.46	5.56
31.25	5.08	5.10	5.13	5.18	5.24	5.28	5.31	5.38	5.46	5.53
28.13	5.08	5.10	5.11	5.18	5.24	5.26	5.30	5.36	5.44	5.53
25.00	5.03	5.04	5.10	5.17	5.23	5.26	5.29	5.34	5.43	5.53
21.88	5.02	5.04	5.05	5.07	5.12	5.19	5.28	5.32	5.39	5.48
18.75	4.84	4.87	4.90	5.00	5.09	5.18	5.20	5.31	5.35	5.43
15.63	4.74	4.76	4.77	4.85	5.09	5.05	5.15	5.26	5.30	5.43
12.50	4.63	4.66	4.70	4.76	4.90	5.01	5.10	5.19	5.25	5.42
9.38	4.62	4.65	4.68	4.70	4.84	4.94	5.02	5.13	5.24	5.39
6.25	4.52	4.54	4.56	4.62	4.77	4.93	5.02	5.13	5.24	5.33
3.13	3.37	3.44	3.51	3.69	4.04	4.36	4.61	4.88	5.09	5.32

31 yrs LOs: Computed MFLs Stage (ft, NAVD) at A6 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	5.68	5.72	5.74	5.79	6.03	6.18	6.33	6.95	8.07	9.10
93.75	5.65	5.66	5.68	5.75	5.92	6.17	6.20	6.34	7.63	8.22
90.63	5.60	5.65	5.67	5.70	5.84	6.02	6.17	6.26	7.09	8.12
87.50	5.55	5.56	5.58	5.68	5.80	5.91	5.91	6.25	6.87	8.07
84.38	5.53	5.55	5.56	5.59	5.72	5.72	5.86	6.24	6.52	7.80
81.25	5.48	5.49	5.49	5.49	5.56	5.68	5.81	6.17	6.51	7.63
78.13	5.44	5.45	5.46	5.48	5.52	5.57	5.73	6.05	6.49	7.57
75.00	5.44	5.45	5.46	5.48	5.52	5.57	5.72	5.97	6.42	7.45
71.88	5.44	5.44	5.45	5.47	5.51	5.55	5.71	5.97	6.36	7.45
68.75	5.43	5.43	5.44	5.47	5.50	5.53	5.60	5.92	6.34	7.40
65.63	5.40	5.42	5.43	5.46	5.47	5.53	5.60	5.91	6.19	7.19
62.50	5.38	5.40	5.42	5.45	5.47	5.52	5.58	5.87	6.17	7.11
59.38	5.37	5.39	5.39	5.42	5.46	5.49	5.56	5.83	6.08	7.03
56.25	5.37	5.38	5.39	5.40	5.46	5.49	5.56	5.79	6.07	6.79
53.13	5.34	5.37	5.38	5.40	5.46	5.49	5.54	5.74	5.94	6.52
50.00	5.32	5.36	5.36	5.39	5.44	5.48	5.54	5.70	5.92	6.51
46.88	5.25	5.29	5.35	5.39	5.44	5.46	5.53	5.64	5.79	6.51
43.75	5.19	5.23	5.24	5.37	5.41	5.46	5.51	5.63	5.78	6.31
40.63	5.12	5.16	5.23	5.33	5.41	5.45	5.50	5.60	5.77	6.27
37.50	5.11	5.15	5.18	5.30	5.41	5.45	5.49	5.60	5.76	6.27
34.38	5.10	5.15	5.18	5.29	5.40	5.44	5.47	5.55	5.74	6.19
31.25	5.08	5.13	5.18	5.28	5.38	5.43	5.45	5.52	5.68	6.09
28.13	5.08	5.13	5.17	5.28	5.38	5.42	5.45	5.51	5.67	6.08
25.00	5.03	5.07	5.15	5.25	5.37	5.42	5.45	5.50	5.64	6.08
21.88	5.02	5.05	5.08	5.21	5.37	5.41	5.44	5.49	5.64	6.04
18.75	4.84	4.89	4.95	5.14	5.32	5.38	5.42	5.47	5.60	6.03
15.63	4.74	4.77	4.80	5.06	5.30	5.38	5.40	5.46	5.58	5.97
12.50	4.63	4.71	4.78	4.89	5.26	5.37	5.39	5.44	5.57	5.91
9.38	4.62	4.67	4.75	4.87	5.10	5.34	5.38	5.43	5.57	5.80
6.25	4.52	4.56	4.60	4.78	5.02	5.34	5.37	5.39	5.52	5.73
3.13	3.37	3.49	3.66	4.02	4.71	5.18	5.37	5.38	5.42	5.47

31 yrs HIs: Computed MFLs Stage (ft, NAVD) at A8 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
3.13	10.31	9.30	8.80	8.14	7.83	7.57	7.35	7.25	6.91	6.81
6.25	9.55	9.11	8.49	8.11	7.70	7.57	7.34	7.02	6.88	6.73
9.38	9.44	8.96	8.42	8.01	7.63	7.44	7.10	6.91	6.85	6.61
12.50	9.39	8.72	8.40	7.98	7.61	7.37	7.08	6.88	6.71	6.59
15.63	8.95	8.72	8.32	7.98	7.58	7.37	7.05	6.85	6.70	6.55
18.75	8.89	8.56	8.23	7.88	7.54	7.33	6.97	6.74	6.68	6.55
21.88	8.75	8.55	8.17	7.79	7.50	7.16	6.94	6.71	6.67	6.54
25.00	8.75	8.55	8.15	7.67	7.28	7.03	6.90	6.71	6.64	6.54
28.13	8.58	8.39	7.96	7.66	7.26	7.00	6.87	6.70	6.60	6.48
31.25	8.49	8.27	7.92	7.57	7.21	6.99	6.85	6.67	6.59	6.46
34.38	8.44	8.04	7.81	7.48	7.20	6.97	6.80	6.67	6.56	6.45
37.50	8.26	8.04	7.79	7.37	7.17	6.91	6.80	6.64	6.56	6.45
40.63	8.16	7.86	7.71	7.32	7.14	6.87	6.79	6.63	6.55	6.43
43.75	8.15	7.85	7.71	7.30	7.10	6.83	6.78	6.61	6.54	6.42
46.88	7.82	7.80	7.55	7.30	7.00	6.82	6.74	6.61	6.54	6.39
50.00	7.81	7.58	7.44	7.27	6.99	6.80	6.74	6.60	6.53	6.38
53.13	7.52	7.50	7.36	7.26	6.97	6.75	6.70	6.60	6.49	6.36
56.25	7.45	7.42	7.35	7.16	6.95	6.74	6.67	6.60	6.48	6.35
59.38	7.42	7.40	7.31	7.14	6.93	6.74	6.66	6.54	6.46	6.34
62.50	7.32	7.30	7.26	7.10	6.91	6.74	6.62	6.53	6.45	6.33
65.63	7.31	7.26	7.17	7.10	6.86	6.73	6.62	6.52	6.44	6.32
68.75	7.26	7.21	7.16	7.03	6.83	6.71	6.62	6.52	6.44	6.31
71.88	7.23	7.21	7.12	6.94	6.74	6.70	6.59	6.48	6.42	6.30
75.00	7.16	7.14	7.06	6.92	6.73	6.70	6.59	6.46	6.39	6.30
78.13	6.97	6.92	6.90	6.83	6.70	6.62	6.55	6.45	6.36	6.28
81.25	6.96	6.91	6.85	6.78	6.66	6.60	6.52	6.43	6.35	6.19
84.38	6.91	6.90	6.84	6.68	6.64	6.57	6.51	6.41	6.32	6.15
87.50	6.87	6.83	6.80	6.67	6.62	6.54	6.49	6.36	6.32	6.09
90.63	6.84	6.80	6.77	6.67	6.59	6.51	6.47	6.35	6.32	6.09
93.75	6.78	6.73	6.72	6.66	6.59	6.51	6.42	6.35	6.28	5.80
96.88	6.74	6.72	6.72	6.65	6.46	6.42	6.38	6.31	6.04	5.50

31 yrs LOs: Computed MFLs Stage (ft, NAVD) at A8 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	6.84	6.88	6.89	6.90	6.93	7.02	7.13	7.40	7.47	7.55
93.75	6.80	6.81	6.81	6.85	6.93	7.01	7.01	7.12	7.15	7.29
90.63	6.75	6.77	6.80	6.82	6.86	6.97	7.01	7.06	7.14	7.23
87.50	6.67	6.68	6.69	6.72	6.83	6.91	6.97	7.01	7.13	7.21
84.38	6.65	6.67	6.68	6.70	6.81	6.83	6.86	6.92	7.06	7.10
81.25	6.59	6.60	6.60	6.60	6.61	6.62	6.68	6.70	7.04	7.07
78.13	6.54	6.55	6.55	6.56	6.59	6.62	6.66	6.69	6.87	7.06
75.00	6.54	6.54	6.55	6.56	6.58	6.61	6.64	6.67	6.81	7.02
71.88	6.54	6.54	6.54	6.55	6.56	6.60	6.63	6.66	6.80	6.92
68.75	6.53	6.53	6.53	6.54	6.56	6.59	6.61	6.66	6.80	6.89
65.63	6.48	6.50	6.51	6.54	6.55	6.57	6.59	6.65	6.78	6.81
62.50	6.46	6.47	6.48	6.53	6.55	6.56	6.57	6.63	6.75	6.78
59.38	6.45	6.46	6.47	6.48	6.50	6.51	6.54	6.63	6.72	6.77
56.25	6.45	6.46	6.47	6.47	6.48	6.51	6.52	6.61	6.68	6.77
53.13	6.43	6.43	6.44	6.45	6.48	6.49	6.52	6.60	6.67	6.76
50.00	6.42	6.43	6.43	6.43	6.47	6.49	6.51	6.58	6.65	6.75
46.88	6.39	6.40	6.41	6.43	6.46	6.48	6.50	6.56	6.63	6.74
43.75	6.36	6.37	6.37	6.39	6.44	6.48	6.49	6.56	6.63	6.73
40.63	6.32	6.33	6.34	6.38	6.42	6.44	6.45	6.55	6.60	6.71
37.50	6.32	6.33	6.34	6.36	6.42	6.44	6.45	6.54	6.60	6.71
34.38	6.32	6.32	6.33	6.35	6.39	6.42	6.44	6.52	6.59	6.70
31.25	6.31	6.32	6.33	6.35	6.38	6.41	6.44	6.51	6.58	6.70
28.13	6.30	6.31	6.32	6.35	6.38	6.39	6.44	6.48	6.56	6.69
25.00	6.28	6.29	6.31	6.35	6.38	6.39	6.43	6.46	6.52	6.66
21.88	6.28	6.29	6.29	6.30	6.32	6.37	6.41	6.46	6.50	6.66
18.75	6.19	6.21	6.22	6.27	6.31	6.35	6.38	6.44	6.46	6.65
15.63	6.15	6.15	6.16	6.20	6.31	6.31	6.36	6.39	6.42	6.59
12.50	6.09	6.10	6.12	6.15	6.22	6.27	6.33	6.37	6.41	6.55
9.38	6.09	6.10	6.12	6.13	6.19	6.24	6.28	6.33	6.41	6.49
6.25	6.04	6.05	6.06	6.09	6.16	6.24	6.28	6.33	6.41	6.48
3.13	5.50	5.53	5.56	5.65	5.81	5.97	6.08	6.23	6.36	6.44

31 yrs LOs: Computed MFLs Stage (ft, NAVD) at A8 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	6.84	6.89	6.91	6.98	7.26	7.42	7.57	8.35	9.39	10.31
93.75	6.80	6.81	6.84	6.92	7.13	7.42	7.45	7.59	8.95	9.55
90.63	6.75	6.79	6.82	6.86	7.04	7.24	7.42	7.51	8.49	9.44
87.50	6.67	6.69	6.72	6.83	6.98	7.12	7.12	7.50	8.25	9.39
84.38	6.65	6.68	6.69	6.74	6.89	6.89	7.07	7.49	7.82	9.12
81.25	6.59	6.60	6.60	6.61	6.69	6.83	7.00	7.42	7.81	8.95
78.13	6.54	6.55	6.56	6.59	6.64	6.71	6.90	7.28	7.78	8.89
75.00	6.54	6.55	6.56	6.59	6.63	6.70	6.88	7.19	7.69	8.75
71.88	6.54	6.54	6.55	6.58	6.63	6.68	6.87	7.19	7.60	8.75
68.75	6.53	6.53	6.53	6.57	6.62	6.65	6.75	7.13	7.59	8.69
65.63	6.48	6.51	6.53	6.56	6.58	6.65	6.74	7.13	7.43	8.58
62.50	6.46	6.49	6.52	6.55	6.58	6.64	6.72	7.08	7.42	8.52
59.38	6.45	6.47	6.48	6.52	6.57	6.61	6.69	7.03	7.31	8.44
56.25	6.45	6.47	6.47	6.49	6.56	6.60	6.69	6.97	7.30	8.15
53.13	6.43	6.44	6.46	6.49	6.56	6.60	6.67	6.91	7.16	7.82
50.00	6.42	6.43	6.44	6.48	6.54	6.59	6.66	6.85	7.13	7.81
46.88	6.39	6.41	6.43	6.48	6.54	6.57	6.65	6.78	6.97	7.80
43.75	6.36	6.37	6.38	6.44	6.51	6.57	6.63	6.78	6.96	7.55
40.63	6.32	6.34	6.38	6.43	6.50	6.55	6.61	6.74	6.96	7.52
37.50	6.32	6.34	6.35	6.41	6.50	6.55	6.61	6.74	6.94	7.52
34.38	6.32	6.34	6.35	6.40	6.48	6.54	6.58	6.67	6.90	7.43
31.25	6.31	6.33	6.35	6.40	6.46	6.52	6.56	6.63	6.83	7.33
28.13	6.30	6.33	6.35	6.40	6.45	6.51	6.56	6.62	6.82	7.32
25.00	6.28	6.30	6.34	6.39	6.45	6.51	6.55	6.62	6.79	7.31
21.88	6.28	6.29	6.30	6.37	6.44	6.51	6.54	6.60	6.78	7.26
18.75	6.19	6.22	6.24	6.34	6.42	6.46	6.52	6.58	6.74	7.26
15.63	6.15	6.16	6.17	6.30	6.41	6.46	6.49	6.57	6.72	7.19
12.50	6.09	6.13	6.16	6.22	6.39	6.45	6.47	6.54	6.71	7.13
9.38	6.09	6.11	6.15	6.20	6.31	6.43	6.46	6.52	6.71	6.99
6.25	6.04	6.06	6.08	6.16	6.27	6.43	6.45	6.47	6.64	6.90
3.13	5.50	5.55	5.63	5.80	6.13	6.35	6.45	6.46	6.52	6.58

31 yrs HIs: Computed MFLs Stage (ft, NAVD) at A10 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
3.13	11.19	9.95	9.42	9.02	8.81	8.58	8.42	8.32	7.97	7.92
6.25	10.38	9.78	9.23	9.00	8.60	8.41	8.21	7.96	7.94	7.77
9.38	10.30	9.66	9.20	8.75	8.55	8.40	8.14	7.95	7.92	7.76
12.50	10.14	9.51	8.95	8.68	8.44	8.36	8.05	7.94	7.77	7.74
15.63	9.69	9.36	8.91	8.60	8.43	8.28	8.03	7.87	7.76	7.70
18.75	9.61	9.33	8.91	8.56	8.40	8.22	7.95	7.79	7.75	7.68
21.88	9.53	9.33	8.81	8.54	8.30	8.11	7.92	7.78	7.74	7.66
25.00	9.43	9.25	8.76	8.51	8.22	8.05	7.92	7.77	7.74	7.64
28.13	9.38	9.06	8.74	8.48	8.20	8.02	7.89	7.77	7.71	7.63
31.25	9.38	9.00	8.71	8.47	8.14	7.98	7.89	7.75	7.71	7.62
34.38	9.17	8.85	8.64	8.35	8.10	7.95	7.88	7.75	7.70	7.62
37.50	9.06	8.84	8.64	8.27	8.10	7.94	7.86	7.74	7.69	7.60
40.63	8.96	8.72	8.60	8.26	8.10	7.93	7.84	7.74	7.67	7.57
43.75	8.93	8.69	8.60	8.24	8.02	7.90	7.83	7.73	7.66	7.55
46.88	8.69	8.68	8.45	8.24	8.01	7.89	7.80	7.72	7.64	7.54
50.00	8.67	8.49	8.37	8.19	8.00	7.86	7.78	7.70	7.63	7.49
53.13	8.41	8.38	8.30	8.16	8.00	7.81	7.76	7.69	7.62	7.42
56.25	8.38	8.36	8.29	8.15	7.99	7.80	7.75	7.68	7.62	7.42
59.38	8.35	8.34	8.26	8.11	7.96	7.79	7.74	7.67	7.61	7.41
62.50	8.34	8.29	8.25	8.09	7.92	7.79	7.74	7.65	7.60	7.40
65.63	8.28	8.20	8.14	8.06	7.90	7.77	7.73	7.65	7.59	7.40
68.75	8.22	8.19	8.12	8.04	7.89	7.76	7.72	7.65	7.57	7.40
71.88	8.21	8.18	8.11	7.97	7.81	7.76	7.71	7.63	7.55	7.39
75.00	8.12	8.10	8.05	7.94	7.78	7.75	7.70	7.62	7.47	7.38
78.13	8.00	7.96	7.92	7.89	7.77	7.75	7.68	7.60	7.46	7.36
81.25	7.97	7.95	7.91	7.82	7.77	7.74	7.67	7.55	7.44	7.26
84.38	7.97	7.94	7.90	7.79	7.76	7.73	7.64	7.49	7.42	7.20
87.50	7.92	7.87	7.85	7.79	7.74	7.66	7.62	7.48	7.39	7.18
90.63	7.91	7.87	7.85	7.78	7.72	7.66	7.62	7.47	7.36	7.12
93.75	7.87	7.85	7.84	7.76	7.70	7.64	7.52	7.44	7.34	6.82
96.88	7.87	7.82	7.82	7.75	7.58	7.56	7.49	7.43	7.12	6.43

31 yrs LOs: Computed MFLs Stage (ft, NAVD) at A10 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	7.92	7.92	7.94	7.96	8.00	8.08	8.18	8.40	8.48	8.54
93.75	7.84	7.89	7.93	7.93	7.98	8.01	8.03	8.10	8.15	8.24
90.63	7.83	7.85	7.88	7.93	7.95	8.00	8.02	8.05	8.14	8.19
87.50	7.74	7.75	7.76	7.79	7.86	7.96	8.00	8.04	8.12	8.12
84.38	7.73	7.74	7.75	7.75	7.85	7.94	7.98	8.03	8.05	8.11
81.25	7.70	7.71	7.71	7.73	7.75	7.76	7.77	7.84	8.04	8.08
78.13	7.69	7.69	7.69	7.69	7.71	7.74	7.77	7.79	7.90	8.06
75.00	7.68	7.68	7.68	7.69	7.70	7.72	7.76	7.79	7.87	8.04
71.88	7.67	7.67	7.67	7.69	7.70	7.71	7.74	7.75	7.86	7.93
68.75	7.66	7.66	7.67	7.68	7.69	7.71	7.73	7.75	7.86	7.93
65.63	7.64	7.65	7.66	7.67	7.68	7.70	7.72	7.75	7.84	7.90
62.50	7.63	7.64	7.64	7.64	7.66	7.69	7.71	7.74	7.83	7.88
59.38	7.62	7.63	7.63	7.64	7.65	7.67	7.68	7.73	7.80	7.85
56.25	7.60	7.61	7.61	7.63	7.65	7.65	7.67	7.72	7.80	7.85
53.13	7.57	7.59	7.60	7.61	7.62	7.65	7.66	7.71	7.79	7.85
50.00	7.55	7.57	7.59	7.60	7.62	7.63	7.65	7.71	7.77	7.83
46.88	7.54	7.56	7.56	7.58	7.61	7.62	7.65	7.69	7.73	7.83
43.75	7.44	7.45	7.46	7.55	7.60	7.61	7.62	7.69	7.72	7.79
40.63	7.43	7.44	7.46	7.49	7.56	7.59	7.60	7.67	7.71	7.78
37.50	7.43	7.43	7.44	7.47	7.54	7.57	7.59	7.66	7.71	7.78
34.38	7.42	7.43	7.44	7.46	7.49	7.54	7.57	7.64	7.70	7.77
31.25	7.40	7.41	7.44	7.45	7.48	7.51	7.56	7.63	7.69	7.75
28.13	7.40	7.41	7.43	7.44	7.47	7.50	7.54	7.61	7.68	7.74
25.00	7.38	7.39	7.42	7.44	7.47	7.50	7.53	7.61	7.66	7.74
21.88	7.36	7.37	7.38	7.40	7.47	7.49	7.53	7.58	7.62	7.73
18.75	7.26	7.28	7.29	7.35	7.41	7.48	7.52	7.55	7.58	7.71
15.63	7.20	7.20	7.22	7.26	7.40	7.37	7.47	7.55	7.57	7.70
12.50	7.18	7.20	7.20	7.25	7.31	7.36	7.42	7.48	7.55	7.66
9.38	7.12	7.14	7.17	7.18	7.30	7.36	7.41	7.47	7.55	7.60
6.25	7.12	7.13	7.14	7.18	7.27	7.36	7.41	7.45	7.51	7.60
3.13	6.43	6.47	6.52	6.62	6.82	7.01	7.15	7.31	7.45	7.60

31 yrs LOs: Computed MFLs Stage (ft, NAVD) at A10 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	7.92	7.94	7.95	8.03	8.23	8.43	8.56	9.27	10.14	11.19
93.75	7.84	7.93	7.93	7.97	8.17	8.38	8.38	8.49	9.57	10.38
90.63	7.83	7.87	7.92	7.94	8.06	8.22	8.35	8.48	9.38	10.30
87.50	7.74	7.76	7.79	7.88	8.00	8.12	8.17	8.40	8.85	10.14
84.38	7.73	7.75	7.75	7.77	7.97	8.00	8.16	8.35	8.69	9.83
81.25	7.70	7.71	7.73	7.76	7.77	7.87	7.98	8.32	8.67	9.69
78.13	7.69	7.69	7.69	7.72	7.77	7.84	7.96	8.28	8.65	9.61
75.00	7.68	7.68	7.69	7.72	7.76	7.78	7.96	8.21	8.58	9.53
71.88	7.67	7.67	7.68	7.71	7.73	7.78	7.91	8.20	8.49	9.48
68.75	7.66	7.67	7.67	7.70	7.73	7.77	7.87	8.16	8.49	9.43
65.63	7.64	7.66	7.67	7.68	7.72	7.76	7.82	8.16	8.45	9.38
62.50	7.63	7.64	7.64	7.68	7.72	7.75	7.81	8.11	8.37	9.17
59.38	7.62	7.63	7.64	7.65	7.72	7.74	7.80	8.07	8.30	9.11
56.25	7.60	7.61	7.63	7.65	7.69	7.74	7.79	8.00	8.23	8.93
53.13	7.57	7.61	7.61	7.64	7.68	7.72	7.77	7.97	8.21	8.69
50.00	7.55	7.60	7.61	7.62	7.67	7.70	7.76	7.93	8.12	8.67
46.88	7.54	7.56	7.57	7.62	7.65	7.70	7.75	7.88	8.00	8.67
43.75	7.44	7.47	7.52	7.60	7.65	7.69	7.74	7.87	7.99	8.49
40.63	7.43	7.45	7.49	7.57	7.65	7.69	7.74	7.87	7.99	8.41
37.50	7.43	7.44	7.48	7.54	7.64	7.68	7.72	7.85	7.97	8.37
34.38	7.42	7.44	7.47	7.53	7.62	7.68	7.71	7.80	7.94	8.35
31.25	7.40	7.44	7.46	7.50	7.62	7.67	7.70	7.77	7.94	8.34
28.13	7.40	7.43	7.45	7.50	7.62	7.66	7.69	7.74	7.93	8.28
25.00	7.38	7.41	7.44	7.49	7.59	7.64	7.68	7.71	7.87	8.28
21.88	7.36	7.38	7.40	7.49	7.57	7.64	7.66	7.71	7.87	8.23
18.75	7.26	7.30	7.31	7.43	7.56	7.63	7.66	7.70	7.85	8.22
15.63	7.20	7.23	7.25	7.39	7.54	7.61	7.65	7.68	7.83	8.22
12.50	7.18	7.21	7.22	7.34	7.51	7.60	7.63	7.67	7.83	8.10
9.38	7.12	7.16	7.22	7.28	7.46	7.56	7.61	7.67	7.80	8.02
6.25	7.12	7.14	7.16	7.27	7.41	7.56	7.61	7.63	7.71	7.88
3.13	6.43	6.50	6.61	6.82	7.20	7.49	7.60	7.63	7.67	7.73

31 yrs HIs: Computed MFLs Stage (ft, NAVD) at A14 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
3.13	12.23	10.58	10.01	9.79	9.47	9.27	9.12	9.00	8.67	8.59
6.25	11.25	10.50	9.97	9.72	9.28	9.10	8.88	8.67	8.59	8.46
9.38	11.14	10.26	9.94	9.34	9.20	9.09	8.84	8.66	8.48	8.45
12.50	10.93	10.09	9.62	9.33	9.14	8.96	8.75	8.64	8.46	8.44
15.63	10.47	10.02	9.55	9.26	9.08	8.91	8.71	8.53	8.45	8.39
18.75	10.38	10.02	9.53	9.24	9.07	8.89	8.64	8.48	8.44	8.38
21.88	10.30	10.02	9.44	9.21	8.96	8.80	8.60	8.48	8.42	8.37
25.00	10.19	9.92	9.40	9.15	8.91	8.72	8.59	8.48	8.42	8.35
28.13	10.07	9.85	9.36	9.15	8.84	8.70	8.58	8.47	8.42	8.34
31.25	10.06	9.63	9.36	9.08	8.80	8.69	8.57	8.45	8.41	8.34
34.38	9.91	9.53	9.34	8.95	8.78	8.63	8.57	8.44	8.40	8.33
37.50	9.82	9.52	9.28	8.95	8.73	8.61	8.54	8.44	8.39	8.32
40.63	9.69	9.37	9.24	8.92	8.71	8.60	8.53	8.43	8.38	8.30
43.75	9.62	9.33	9.21	8.91	8.70	8.59	8.53	8.41	8.37	8.29
46.88	9.37	9.31	9.13	8.90	8.68	8.54	8.46	8.40	8.35	8.28
50.00	9.33	9.16	9.04	8.85	8.66	8.51	8.46	8.40	8.34	8.25
53.13	9.05	9.03	8.99	8.85	8.63	8.50	8.45	8.39	8.33	8.17
56.25	9.02	9.01	8.95	8.84	8.62	8.49	8.43	8.38	8.33	8.16
59.38	9.00	8.96	8.91	8.76	8.62	8.47	8.43	8.38	8.32	8.15
62.50	8.96	8.95	8.89	8.73	8.61	8.47	8.43	8.36	8.31	8.14
65.63	8.86	8.85	8.80	8.69	8.60	8.45	8.42	8.36	8.31	8.12
68.75	8.86	8.82	8.78	8.68	8.52	8.44	8.41	8.35	8.30	8.12
71.88	8.86	8.78	8.76	8.65	8.50	8.44	8.40	8.34	8.29	8.12
75.00	8.80	8.78	8.72	8.63	8.47	8.43	8.39	8.33	8.21	8.11
78.13	8.65	8.62	8.59	8.56	8.45	8.43	8.39	8.31	8.18	8.09
81.25	8.64	8.61	8.59	8.49	8.43	8.40	8.36	8.29	8.16	7.90
84.38	8.63	8.61	8.57	8.49	8.43	8.38	8.35	8.22	8.12	7.87
87.50	8.57	8.55	8.52	8.49	8.42	8.36	8.33	8.21	8.09	7.83
90.63	8.54	8.53	8.52	8.49	8.39	8.34	8.31	8.19	8.06	7.78
93.75	8.54	8.52	8.51	8.45	8.38	8.34	8.26	8.18	8.04	7.49
96.88	8.53	8.52	8.51	8.44	8.22	8.18	8.18	8.17	7.81	7.02

31 yrs LOs: Computed MFLs Stage (ft, NAVD) at A14 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	8.60	8.60	8.61	8.66	8.69	8.77	8.87	9.11	9.18	9.24
93.75	8.53	8.55	8.60	8.63	8.68	8.71	8.73	8.78	8.82	8.91
90.63	8.51	8.55	8.57	8.61	8.61	8.68	8.70	8.74	8.81	8.86
87.50	8.44	8.45	8.45	8.49	8.55	8.63	8.69	8.73	8.80	8.80
84.38	8.43	8.44	8.45	8.46	8.55	8.62	8.63	8.67	8.73	8.78
81.25	8.41	8.41	8.42	8.43	8.46	8.46	8.47	8.50	8.72	8.76
78.13	8.40	8.40	8.40	8.40	8.41	8.44	8.47	8.49	8.59	8.72
75.00	8.39	8.39	8.40	8.40	8.41	8.42	8.46	8.48	8.54	8.72
71.88	8.38	8.38	8.38	8.39	8.41	8.41	8.44	8.45	8.54	8.60
68.75	8.37	8.37	8.38	8.38	8.40	8.41	8.42	8.44	8.53	8.60
65.63	8.35	8.36	8.37	8.38	8.39	8.40	8.42	8.44	8.52	8.58
62.50	8.35	8.35	8.35	8.35	8.37	8.40	8.42	8.44	8.52	8.57
59.38	8.33	8.33	8.33	8.34	8.36	8.37	8.37	8.43	8.49	8.54
56.25	8.32	8.32	8.32	8.33	8.35	8.36	8.36	8.42	8.49	8.53
53.13	8.30	8.30	8.31	8.32	8.32	8.35	8.36	8.40	8.48	8.53
50.00	8.29	8.29	8.30	8.31	8.32	8.33	8.35	8.40	8.47	8.52
46.88	8.28	8.29	8.30	8.30	8.32	8.33	8.34	8.39	8.42	8.52
43.75	8.17	8.18	8.20	8.26	8.32	8.32	8.33	8.38	8.42	8.47
40.63	8.17	8.17	8.20	8.23	8.27	8.29	8.31	8.37	8.41	8.47
37.50	8.16	8.17	8.17	8.19	8.25	8.28	8.30	8.37	8.40	8.46
34.38	8.15	8.16	8.16	8.18	8.20	8.26	8.28	8.34	8.38	8.46
31.25	8.14	8.14	8.15	8.17	8.20	8.22	8.25	8.33	8.38	8.43
28.13	8.12	8.13	8.14	8.16	8.19	8.21	8.24	8.31	8.38	8.43
25.00	8.11	8.12	8.13	8.15	8.18	8.21	8.23	8.29	8.36	8.42
21.88	8.09	8.10	8.11	8.13	8.18	8.20	8.23	8.27	8.31	8.41
18.75	7.90	7.90	7.90	7.94	8.10	8.15	8.23	8.25	8.28	8.39
15.63	7.87	7.88	7.90	7.93	8.05	8.08	8.13	8.25	8.28	8.37
12.50	7.83	7.85	7.88	7.93	8.00	8.06	8.12	8.19	8.25	8.34
9.38	7.81	7.83	7.84	7.88	7.94	8.02	8.12	8.16	8.23	8.31
6.25	7.78	7.80	7.81	7.84	7.92	8.00	8.08	8.16	8.20	8.30
3.13	7.02	7.08	7.13	7.25	7.48	7.69	7.84	8.00	8.13	8.29

31 yrs LOs: Computed MFLs Stage (ft, NAVD) at A14 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	8.60	8.61	8.66	8.74	8.89	9.11	9.26	9.98	10.93	12.23
93.75	8.53	8.60	8.62	8.68	8.83	9.05	9.05	9.15	10.38	11.25
90.63	8.51	8.57	8.61	8.61	8.74	8.88	9.01	9.08	10.06	11.14
87.50	8.44	8.45	8.47	8.55	8.67	8.79	8.84	9.05	9.51	10.93
84.38	8.43	8.45	8.46	8.47	8.63	8.65	8.68	9.02	9.37	10.47
81.25	8.41	8.42	8.43	8.46	8.47	8.56	8.67	9.02	9.33	10.42
78.13	8.40	8.40	8.40	8.41	8.47	8.54	8.64	8.98	9.26	10.38
75.00	8.39	8.40	8.40	8.41	8.42	8.48	8.60	8.87	9.21	10.30
71.88	8.38	8.38	8.39	8.41	8.42	8.47	8.56	8.86	9.20	10.30
68.75	8.37	8.38	8.38	8.39	8.42	8.44	8.50	8.84	9.15	10.19
65.63	8.35	8.37	8.38	8.39	8.42	8.44	8.49	8.79	9.04	10.07
62.50	8.35	8.35	8.35	8.37	8.41	8.43	8.48	8.78	8.96	9.91
59.38	8.33	8.33	8.34	8.35	8.40	8.42	8.47	8.74	8.91	9.87
56.25	8.32	8.32	8.34	8.35	8.40	8.41	8.47	8.65	8.88	9.62
53.13	8.30	8.32	8.32	8.34	8.36	8.40	8.45	8.63	8.86	9.37
50.00	8.29	8.30	8.31	8.32	8.36	8.39	8.43	8.56	8.76	9.33
46.88	8.28	8.29	8.30	8.32	8.35	8.38	8.42	8.55	8.65	9.29
43.75	8.17	8.20	8.26	8.31	8.34	8.38	8.41	8.55	8.65	9.21
40.63	8.17	8.19	8.22	8.29	8.33	8.37	8.40	8.54	8.64	9.00
37.50	8.16	8.17	8.18	8.25	8.33	8.36	8.40	8.52	8.63	9.00
34.38	8.15	8.16	8.17	8.19	8.30	8.34	8.39	8.48	8.60	8.96
31.25	8.14	8.15	8.17	8.19	8.29	8.34	8.39	8.43	8.58	8.94
28.13	8.12	8.14	8.17	8.18	8.29	8.33	8.38	8.43	8.56	8.90
25.00	8.11	8.13	8.14	8.18	8.28	8.32	8.37	8.42	8.51	8.88
21.88	8.09	8.11	8.13	8.17	8.25	8.32	8.36	8.39	8.50	8.86
18.75	7.90	7.90	7.93	8.06	8.23	8.30	8.34	8.39	8.45	8.86
15.63	7.87	7.89	7.93	8.05	8.20	8.28	8.34	8.37	8.45	8.80
12.50	7.83	7.88	7.90	7.99	8.13	8.27	8.34	8.36	8.43	8.80
9.38	7.81	7.84	7.87	7.94	8.08	8.26	8.31	8.35	8.42	8.68
6.25	7.78	7.81	7.83	7.91	8.08	8.24	8.31	8.35	8.40	8.55
3.13	7.02	7.13	7.23	7.47	7.91	8.23	8.30	8.34	8.37	8.44

31 yrs HIs: Computed MFLs Stage (ft, NAVD) at A16 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
3.13	16.86	16.82	16.79	16.70	16.53	16.36	16.27	15.89	9.27	9.12
6.25	16.54	16.51	16.48	16.40	16.26	15.74	9.93	9.36	9.12	8.93
9.38	15.17	10.14	9.80	9.59	9.43	9.33	9.26	9.24	8.93	8.87
12.50	10.11	9.92	9.78	9.54	9.30	9.24	9.24	8.97	8.89	8.86
15.63	9.91	9.74	9.68	9.42	9.29	9.10	9.05	8.97	8.88	8.84
18.75	9.76	9.73	9.54	9.38	9.26	9.08	9.05	8.96	8.87	8.83
21.88	9.63	9.57	9.52	9.31	9.17	9.05	9.01	8.93	8.86	8.83
25.00	9.41	9.38	9.35	9.28	9.15	9.04	8.99	8.92	8.85	8.83
28.13	9.40	9.37	9.35	9.26	9.10	9.03	8.97	8.90	8.85	8.80
31.25	9.39	9.36	9.34	9.23	9.10	9.01	8.96	8.90	8.84	8.78
34.38	9.38	9.32	9.32	9.23	9.03	9.00	8.95	8.90	8.83	8.78
37.50	9.30	9.26	9.22	9.16	9.03	9.00	8.94	8.87	8.82	8.78
40.63	9.19	9.17	9.17	9.12	9.03	9.00	8.93	8.86	8.82	8.77
43.75	9.18	9.17	9.14	9.09	9.03	8.99	8.93	8.86	8.81	8.77
46.88	9.18	9.16	9.13	9.08	9.01	8.97	8.92	8.85	8.81	8.73
50.00	9.18	9.12	9.08	9.05	9.01	8.94	8.92	8.85	8.81	8.70
53.13	9.15	9.10	9.08	9.04	9.01	8.93	8.91	8.85	8.80	8.69
56.25	9.12	9.09	9.08	9.04	8.97	8.93	8.88	8.84	8.79	8.66
59.38	9.10	9.08	9.06	9.01	8.97	8.92	8.87	8.84	8.78	8.65
62.50	9.10	9.07	9.04	9.00	8.94	8.89	8.86	8.82	8.78	8.65
65.63	9.08	9.06	9.01	9.00	8.93	8.87	8.86	8.82	8.77	8.65
68.75	9.03	9.02	8.98	8.96	8.93	8.87	8.84	8.81	8.74	8.63
71.88	9.00	8.99	8.97	8.96	8.92	8.86	8.83	8.81	8.71	8.59
75.00	8.99	8.98	8.91	8.89	8.86	8.85	8.82	8.79	8.68	8.55
78.13	8.99	8.94	8.89	8.87	8.85	8.85	8.80	8.75	8.66	8.51
81.25	8.92	8.90	8.89	8.86	8.85	8.82	8.79	8.74	8.65	8.48
84.38	8.91	8.90	8.86	8.85	8.83	8.82	8.78	8.72	8.60	8.47
87.50	8.90	8.89	8.85	8.85	8.82	8.81	8.75	8.69	8.59	8.44
90.63	8.85	8.85	8.85	8.84	8.82	8.79	8.73	8.67	8.59	8.36
93.75	8.83	8.83	8.83	8.82	8.80	8.77	8.71	8.64	8.55	8.19
96.88	8.82	8.81	8.79	8.75	8.73	8.73	8.67	8.60	8.48	7.73

31 yrs LOs: Computed MFLs Stage (ft, NAVD) at A16 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	9.14	9.15	9.16	9.19	9.24	9.48	11.12	12.74	13.36	14.16
93.75	9.03	9.05	9.07	9.11	9.20	9.29	9.30	9.75	11.91	11.31
90.63	8.88	8.90	8.94	8.96	8.97	9.01	9.09	9.21	9.25	9.31
87.50	8.87	8.88	8.89	8.89	8.93	8.99	9.01	9.08	9.14	9.20
84.38	8.85	8.86	8.87	8.89	8.93	8.95	8.98	9.04	9.08	9.06
81.25	8.84	8.84	8.85	8.87	8.90	8.94	8.96	8.99	9.00	9.01
78.13	8.84	8.84	8.85	8.87	8.89	8.90	8.91	8.99	8.99	9.01
75.00	8.84	8.84	8.85	8.86	8.88	8.90	8.90	8.94	8.97	9.00
71.88	8.83	8.84	8.84	8.85	8.88	8.90	8.90	8.93	8.96	9.00
68.75	8.82	8.84	8.84	8.85	8.86	8.87	8.89	8.92	8.96	9.00
65.63	8.82	8.83	8.84	8.85	8.85	8.85	8.87	8.92	8.95	8.97
62.50	8.82	8.82	8.82	8.84	8.84	8.85	8.85	8.91	8.95	8.96
59.38	8.80	8.80	8.81	8.82	8.83	8.85	8.85	8.90	8.95	8.96
56.25	8.77	8.79	8.80	8.81	8.82	8.83	8.84	8.89	8.89	8.93
53.13	8.70	8.72	8.73	8.79	8.82	8.82	8.82	8.87	8.88	8.93
50.00	8.69	8.70	8.71	8.73	8.77	8.79	8.81	8.86	8.88	8.92
46.88	8.69	8.70	8.71	8.73	8.76	8.79	8.79	8.85	8.88	8.90
43.75	8.69	8.70	8.70	8.73	8.75	8.77	8.78	8.85	8.85	8.85
40.63	8.68	8.68	8.68	8.72	8.73	8.76	8.78	8.82	8.83	8.84
37.50	8.65	8.66	8.67	8.69	8.73	8.74	8.77	8.79	8.82	8.83
34.38	8.65	8.66	8.66	8.68	8.69	8.71	8.75	8.77	8.80	8.83
31.25	8.63	8.63	8.64	8.67	8.69	8.71	8.74	8.77	8.80	8.81
28.13	8.62	8.63	8.64	8.66	8.69	8.70	8.70	8.77	8.80	8.81
25.00	8.58	8.59	8.60	8.65	8.66	8.69	8.70	8.75	8.79	8.80
21.88	8.55	8.56	8.60	8.62	8.65	8.67	8.68	8.73	8.77	8.79
18.75	8.51	8.52	8.53	8.58	8.64	8.65	8.68	8.72	8.76	8.78
15.63	8.48	8.49	8.52	8.56	8.62	8.65	8.68	8.71	8.74	8.77
12.50	8.47	8.49	8.50	8.53	8.59	8.63	8.66	8.71	8.74	8.76
9.38	8.44	8.44	8.45	8.46	8.49	8.56	8.65	8.67	8.71	8.76
6.25	8.36	8.38	8.39	8.43	8.48	8.52	8.57	8.61	8.67	8.72
3.13	7.73	7.78	7.83	7.94	8.15	8.33	8.45	8.57	8.64	8.71

31 yrs LOs: Computed MFLs Stage (ft, NAVD) at A16 (1983 - 2014).

weib	1	7	14	30	60	90	120	180	270	1 year
96.88	9.14	9.16	9.18	9.23	9.38	14.96	16.29	16.54	16.86	16.86
93.75	9.03	9.06	9.10	9.20	9.30	9.33	9.38	16.19	16.35	16.35
90.63	8.88	8.93	8.98	8.99	9.06	9.21	9.36	9.53	10.11	15.17
87.50	8.87	8.89	8.89	8.93	8.99	9.12	9.12	9.53	9.91	10.11
84.38	8.85	8.87	8.88	8.92	8.98	9.08	9.12	9.47	9.53	9.91
81.25	8.84	8.85	8.87	8.89	8.95	8.97	9.12	9.46	9.53	9.76
78.13	8.84	8.85	8.86	8.89	8.91	8.93	9.03	9.32	9.48	9.63
75.00	8.84	8.85	8.86	8.88	8.91	8.93	8.96	9.16	9.38	9.41
71.88	8.83	8.84	8.85	8.88	8.90	8.92	8.95	9.12	9.32	9.38
68.75	8.82	8.84	8.85	8.86	8.90	8.91	8.94	9.12	9.30	9.32
65.63	8.82	8.84	8.84	8.85	8.88	8.90	8.93	9.09	9.18	9.30
62.50	8.82	8.82	8.84	8.84	8.85	8.90	8.93	9.07	9.17	9.26
59.38	8.80	8.80	8.82	8.83	8.85	8.87	8.92	9.05	9.15	9.22
56.25	8.77	8.80	8.81	8.82	8.84	8.87	8.91	9.01	9.12	9.19
53.13	8.70	8.73	8.76	8.82	8.83	8.86	8.90	8.98	9.08	9.18
50.00	8.69	8.71	8.73	8.77	8.82	8.85	8.89	8.98	9.03	9.17
46.88	8.69	8.71	8.73	8.76	8.80	8.85	8.87	8.92	9.00	9.10
43.75	8.69	8.70	8.72	8.74	8.78	8.83	8.85	8.92	8.99	9.10
40.63	8.68	8.68	8.72	8.73	8.78	8.82	8.85	8.87	8.99	9.08
37.50	8.65	8.67	8.69	8.73	8.78	8.79	8.83	8.86	8.99	9.08
34.38	8.65	8.66	8.68	8.69	8.75	8.78	8.83	8.86	8.95	9.03
31.25	8.63	8.64	8.67	8.69	8.73	8.77	8.81	8.84	8.93	8.99
28.13	8.62	8.64	8.66	8.69	8.73	8.77	8.80	8.84	8.90	8.99
25.00	8.58	8.60	8.65	8.67	8.70	8.77	8.80	8.84	8.90	8.99
21.88	8.55	8.57	8.62	8.67	8.70	8.76	8.80	8.84	8.89	8.97
18.75	8.51	8.53	8.57	8.65	8.68	8.75	8.78	8.84	8.86	8.94
15.63	8.48	8.52	8.56	8.62	8.68	8.73	8.76	8.84	8.86	8.90
12.50	8.47	8.50	8.53	8.59	8.66	8.72	8.75	8.83	8.85	8.90
9.38	8.44	8.45	8.46	8.49	8.62	8.70	8.74	8.80	8.84	8.86
6.25	8.36	8.39	8.42	8.48	8.55	8.68	8.72	8.79	8.82	8.84
3.13	7.73	7.82	7.92	8.13	8.53	8.67	8.67	8.79	8.81	8.82

Appendix F

Peer Review Comments

Comment Resolution Document Water Resource and Human Use Value Assessment of Alexander Springs and Alexander Springs Creek, Lake County Peer Review Panel Comments					
No.	**Reviewer**	**Page**	**Para-graph**	**Comment**	**Response**
1	Emery	4 - 3	2	only certain WRVs were analyzed using frequency analysis…..perhaps ID these	Text has been added identifying these WRVs.
2	Emery	5 - 2	2	speaks to protection of canoes/kayaks, but then on 5-3, has a motor boat	The figure has been removed and replaced with appropriate text for canoes and kayaks.
3	Emery	5 - 3	Fig. 5-2	motor boat, not canoe/kayak	The figure has been removed and replaced with appropriate text for canoes and kayaks.
4	Emery	5 - 7	1	speaks to motor clearance depths….perhaps add verbiage on 5-2 to explain how protection of motor boats protects canoes/kayaks	The figure has been removed and replaced with appropriate text for canoes and kayaks.
5	Emery	5 - 7	Table 5-2a	event per 100 yrs increases by a factor of 2.5……still occurs infrequently, but may want to acknowledge the large % increase	Text has been added to clarify.
6	Emery	5 - 10	3	is the thalweg at each location at least 25% of the width?	Unknown.
7	Emery	5 - 11	3	if there is no assessment of changes in wetland inundation, and there is great reliance on Freese and Sutherland's report, perhaps added verbiage about how Freese and Sutherland's work clearly demonstrates this protection would be valuable	Freese and Sutherland (2017) identified a frequent high flow (FH) and a frequent low flow (FL) based on multiple criteria developed from vegetation, soils and topography data. Frequency analysis results indicate that the hydrologic requirements for the most sensitive flow criterion are met under baseline conditions. Their results also suggest an allowable reduction of 21 percent in the mean flow for Alexander Springs. This result, when compared to other springs MFLs across the state, is significantly outside the range of flow reduction (0 to 10 percent) allowed by other springs' MFLs established within the state of Florida and is many times higher than the statewide mean of 6.8 percent.
8	Emery	5 - 20	2	would it be informative to examine the higher velocities within the channel in addition to the average velocities?	Estimated variability is not significant.
9	Emery	5 -26	2	what is the "frequency important for detrital transfer"? Is it the same for both Tables 5-9a and 5-9b? Transect A16 has the Hydrologic Scenario reduced by more than 50%. Perhaps explain why this is not important for detrital transfer.	A specific frequency threshold was not found. The analysis focused on the relative change in events and whether that change was significant to system detrital transfer capacity. The change in the frequency of events was small percentage-wise, except for a few transects. Therefore, the professional opinion was that the WRV was protected.
10	Emery	5 - 27	Table 5-9b	Transect A6 has its events/100 yrs reduced from above 50 (53.1) to well below 50 (37.2). Does this change render it no longer at a frequency important to detrital transfer?	Text has been added to clarify. Frequency of occurrence is reduced but is consistent with most of the creek reach.
11	Emery	5 - 28	1	Aquifer level protection is mentioned here, and the specific indicator of protection is whether groundwater-surface water interactions will change. Then there is a sentence that generally refers the reader to the 9 other WRVs (note there are really only 8 other WRVs examined - Navigation is not). Would be helpful to be more specific as to which WRV analyses speak to the groundwater-surface water interactions.	Since this is a spring (i.e., groundwater source) MFL, all present WRVs interact with the groundwater. The text has been edited to clarify the number of WRVs evaluated.
12	Emery	5 - 29	Table 5-11a	what is the "frequency sufficient to maintain desirable scenic and wildlife viewing?"….see also page 5-30, paragraph 2.	A specific frequency threshold was not found. The analysis focused on the change in events and whether that change was significant to system aesthetics and scenic attributes.
13	Emery	5 - 30	1	is the reduction of 30% still within the "frequency sufficient to maintain desirable scenic and wildlife viewing"?	A specific frequency threshold was not found. The analysis focused on the relative change in events and whether that change was significant. The change in the frequency of events was small percentage-wise, except for a few transects. Therefore, the professional opinion was that the WRV was protected.
14	Emery	5 - 34	4	Refers the reader back to "Detrital Transfer"….so is it concluding that a reduction at A16 of more than 50% is protective?....and at A6 from 53.1 to 37.2 (30%) is protective?	This was meant to refer to the process of establishing critical elevations, and that contact with the floodplain was important for the both WRVs. The analysis focused on the relative change in events and whether that change was significant to system filtration capacity. The change in the frequency of events was small percentage-wise, except for a few transects. Therefore, the professional opinion was that the WRV was protected.
15	Emery			Or, is it concluding that 7 day durations are too short a time period and it is required to examine longer durations?	The longer duration was used to reflect residence time and treatment performance of wet detention and wetland-based treatment systems.

Comment Resolution Document Water Resource and Human Use Value Assessment of Alexander Springs and Alexander Springs Creek, Lake County Peer Review Panel Comments					
No.	**Reviewer**	**Page**	**Para-graph**	**Comment**	**Response**
16	Emery	5 -37	4	What is the "critical stage event frequency required to maintain filtration and absorption"? Why is a 30% reduction still at sufficient frequency?	A specific frequency threshold was not found. The analysis focused on the change in events and whether that change was significant to system filtration attributes.
17	Emery	5 - 45	Section	It probably is not worth the effort to undertake a frequency analysis for select components that have a numeric standard (pH at 6; Nox at 0.35mg/l, etc.)	Agreed.
18	Emery	6 - 1	2	it might be more accurate to state which of the 9 WRVs analyzed employed event-based analysis and which did not	Text has been added to clarify.
19	Emery	6 - 1	5	WRV-5 had been stated to be encompassed within the other WRV analyses…..but is unclear which analyses address the groundwater aquifer and groundwater-surface water interactions	Since this is a spring (i.e., groundwater source) MFL, all present WRVs interact with the groundwater. The text has been edited to clarify the number of WRVs evaluated.
20	Emery	6 - 2	1	only 8 other WRVs were examined (Navigation was not)	Text has been added to correct this.
21	Watson	2-4	Figure 2-4	general comment that font is difficult to read.	This and other similar figures have been changed to full page to improve readability.
22	Watson	2-5	1	discharge variation does not seem great. Is statement based on other springs in the area and associated flow statistics in Table 2-1?	Text has been modified for consistency with Karama and Gordu (2017).
23	Mades			Agree. Also, cite reference for assertion that low spring discharge corresponds to below-average rainfall.	Text has been modified for consistency with Karama and Gordu (2017).
24	Watson	2-8	1	how does the springshed area compare to spring flow. I come up with about 1 inch per year over 110 mi2.	Comment noted.
25	Mades	2-8	Figure 2-8	Transect labels impossible to read. Also consider adding a map illustrating the HEC-RAS cross-sections and a table that cross-references the HEC-RAS sections to the transects. (This cross-reference information is buried in the cross-section titles in Appendix D.) A table in this section of the report would facilitate reader's orientation when reading tables and figures in Section 5.	The figure has been changed to full page to improve readability.
26	Watson	4-1 and 4-2		there is a subtle difference between the working definitions on the bottom of page 4-1 and the level 4 (example at bottom of page 4-2). in 4-1 the difference in the frequency of events is mentioned with respect to MFL and non-pumping scenarios, which implies a relative change criterion. On page 4-2 a threshold value is mentioned, which is more similar to the MFL approach where a threshold value is known. is one or the other or both approaches used.	Text has been modified to reflect relative change criterion.
27	Mades			Suggest a different word than "violations"; such as exceedance and nonexceedances. This is also the first use of "unacceptable change" (after the Executive Summary) that should be explained in this introductory section. The relative (i.e., percentage) change in event frequencies of baseline and MFL conditions for some WRVs is not insignificant.	The text has been modified as suggested.
28	Mades	4-5	Table 4-1	WRV-4: Is the reference to Silver River correct?	This has been corrected.
WRV-1					
29	Mades	5-3	2	What "critical clearance" was considered for this analysis? Figure 5-2 indicates 2.5 feet for motorized recreational boats that have a deeper draft than kayaks and canoes. Also, Table 5-3 (page 5-11) indicates Transect A8 may be shallower than A4_3.	Text has been added to reflect canoeing and kayaking. References to motorized boating have been removed. Also, Table 5-3 refers to the thalweg depths.

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30	Watson	5-3	3	the statement that a 1 day duration event has a lower stage than a longer duration event (of the same frequency) is true for all low flow related metrics. Should this be the basis for selecting an analysis or should it be associated with the appropriate duration of the important event - i.e., the level 4 selection of magnitude and duration. Put another way, is the concern not canoeing for 1 day or 7 days in a row. Should the magnitude and duration of an important event be viewed somewhat independently?	The "important event" was not defined, nor was guidance found. The reasoning behind the duration choice was to find low water events that would preclude access where it has not been an issue previously. The 1-day duration provides this. The 7-day duration was chosen to evaluate potential economic harm from increased low-water events. Given the year-round access to the park, and particularly in the summer, this was deemed appropriate since access was not an issue at longer durations.
31	Mades			How does duration (either 1 or 7 day) impact "boating accessibility"? A 7-day minimum stage is usually higher than a 1-day minimum, hence less limiting.	Accessibility is not affected but the economic impact is greater. The text has been modified to reflect this.
32	Watson	5-7	1	why was the motorized vessel depth/stage rather that canoe or kayak depth/stage considered? No events?	Text has been added to reflect canoeing and kayaking. References to motorized boating have been removed.
33	Watson	5-7	table-2b	interesting that the number of 1 and 7 day baseline events are the same	Comment noted.
34	Watson	general		agree that 6 versus 15 1-day events and 6 versus 10 7-day events per 100 years, while a substantial relative change, does not create significant harm with regards to boating/recreation	Comment noted.
				WRV-2	
35	Watson	5-10	Figure 5-10	difficult to make out marks and to read, particularly whatever is written in lower left hand corner of legend. Suggest enlarging font or dropping text that is not readable.	The figure has been enlarged to improve readability.
36	Watson	5-9 to 10		the specific criteria is 0.8 ft of 25% of the channel width but then at the bottom of 5-10 it appears that 0.8 ft at the thalweg is used and related to the minimum frequent low flow.	True - we have no data to estimate across 25% of the bottom.
37	Mades			Agree	True - we have no data to estimate across 25% of the bottom.
38	Watson	5-11	2 and 3	The WRV analysis is or can be different than the MFL analysis. The SJRWMD uses a bottom up approach where important protective events are known (hopefully). The WRV analyses takes the MFL and compares to a baseline and answers the question - do events as defined for each WRV change appreciably from baseline to MFL (withdrawal scenario). As mentioned in an earlier comment, the authors do imply that threshold event criteria may be used (bottom of page 4-2).	Agreed. In most cases, a comparison to baseline was used as threshold events were not able to be identified due to insufficient information.
39	Mades			Explain "most sensitive flow criterion".	Text added.
40	Watson	5-1	2 and 3	Also, in the Freeze and Sutherland report, a 7 % allowable reduction was recommended based on concerns about the paucity of data, understanding of hydrology, and general uncertainty, so it seems inappropriate to reference a 21 % allowable withdrawal that ultimately was not used.	Comment noted.
41	Mades			Agree	Comment noted.
				WRV-3	
42	Watson	general		has an MFL been set on the SJs River that is associated with WRV-3? Perhaps this could be referenced and then by apportionment it could be said that similar withdrawals at the Spring is protective.	No MFL has been established but a District study of SJR flows provided a range of flows and their potential effects.
43	Mades	5-12	1	Is the reference to Silver River correct?	Fixed.

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44	Mades	5-13	3	Perhaps another way to look at it is that the spring-flow reduction compared to the SJR withdrawal scenario is comparable to (even less than) the spring-flow contribution to SJR@Astor. A flow reduction of 7 cfs (4.52 MGD) is 2.9% of the 155 MGD withdrawal considered for the SJR. This is similar to the average spring-flow contribution of 129 cfs that is 3.4% of the 3,770 cfs average discharge of SJR@Astor gage.	Comment noted.
45	Watson	5-15	1	is SJRWMD 2012 being used as a regulatory basis for setting an estuarine MFL?	No.
WRV-4					
46	Watson	5-16	3	seepage is discussed as a mechanism for floodplain hydrologic response. What is the river gain from the headwaters to the mouth, can it be apportioned between runoff and baseflow, and does it (or maybe can it) support the assertion that seepage is an important mechanism for floodplain wetness?	River gain is unknown. The observation of floodplain seepage was made by Robert Freese as the result of many hours of field study. This seemed to be confirmed based on infrequent out-of-channel flows, coupled with ecology requiring more frequent hydration.
47	Mades			Agree. Also, it is unclear what "overbank, levee-type flow from the main channel into the floodplain" means. Please clarify.	Text has been added to clarify.
48	Mades	5-18	Table 5-6	The sharp increase in velocities downstream from HEC-RAS station 2.91, particularly the those exceeding 4 ft/sec, is unusual. Suggest checking the downstream boundary condition prescribed in the HEC-RAS model.	The model received from the District incorporated a fixed boundary. This, in combination with the high inflows from Tracy Canal during storm events, results in the high simulated velocities. Given the location of the apparent high velocities and that they occurred at relatively high flow rates, they did not impact the analysis performed.
49	Mades	5-21	Table 5-7	Same comment as for Table 5-6.	See above response.
50	Watson	5-26	3	the concluding sentence phrase "a frequency sufficient to maintain detrital transfer processes" needs clarification. Has this frequency sufficiency been defined? Again this seems more like the MFL approach than the stated approach for evaluating WRVs.	A specific frequency threshold was not found. The analysis focused on the relative change in events and whether that change was significant. The change in the frequency of events was small percentage-wise, except for a few transects. Therefore, the professional opinion was that the WRV was protected.
51	Mades			Agree	See above response.
WRV-5					
WRV-6					
52	Mades	5-28	4	desirable viewing of what ... riparian and floodplain habitat?	Text has been added to better explain viewing goals
53	Watson	5-30	2	same as above regarding "a frequency sufficient to maintain ….."	The analysis focused on the relative change in events and whether that change was significant to system detrital transfer capacity. The change in the frequency of events was small percentage wise except for a few transects. Therefore, professional opinion was that the WRV was protected. Text was modified to better reflect this.
WRV-7					
54	Mades	5-35	Table 5-12	Same comment as for Table 5-6.	See above response to Comment 48.
55	Mades	5-37	3	How is it known that "all areas of the floodplain experience periodic inundation"? Were spatial GIS coverages of HEC-RAS result evaluated?	Text has been modified to be more accurate.
56	Watson	5-37	4	same. "a frequency sufficient to maintain ….." . This argument may be appropriate but perhaps rephrased. If the authors are comfortable with the frequency that is sufficient, what is a critical frequency that would not be sufficient?	The analysis focused on the relative change in events and whether that change was significant to system detrital transfer capacity. The change in the frequency of events was small percentage-wise, except for a few transects. Therefore, the professional opinion was that the WRV was protected. Text was modified to better reflect this.
57	Mades			Agree. What literature supports the statement?	See above response.

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WRV-8					
58	Mades	5-40	2	It is not clear how sediment accumulation within the spring relate to this particular WRV assessment? Has some "beach sand" somehow escaped the spring pool ands accumulated within upper reaches of the spring run?	The spring pool is part of the WRV assessment. Downstream transport is limited. This was the only sedimentation issue identified by the park ranger.
59	Mades	5-42	2	It would beneficial to the lay audience to further explain the relevance of the 0.1 and 0.6 ft/sec thresholds. The 0.1 ft/sec as the threshold velocity below which 0.5 mm sized particles begin to settle out and accrete on the bottom, and 0.6 ft/sec the threshold above which bottom material of that size erodes and becomes suspended.	Text has been added to better explain the velocity thresholds.
60	Watson	5-42	4	what does "quite frequently" mean	Text has been modified to clarify conclusion.
61	Mades	5-43	Table 5-15	Same comment as for Table 5-6.	See above response in Comment 48.
WRV-9					
62	Watson			the observations are what the reviewers have typically found.	Noted.
63	Mades	5-69	4	Suggest re-phrasing the assertion that a flow reduction "will" improve water quality.	Given the lack of a relationship with flow and a decreasing trend in nitrates, it is fair to conclude that changes in flow are not likely to result in a degradation of water quality.
CONCLUSIONS					
64	Mades	6-1	4	Correct the reference to Silver River.	This has been corrected.
APPENDIX E					
65	Mades	Appendix E		Suggest adding an explanation to the Appendix E title page that explains that three tables are presented for each location. One table (HIs)is for high-flow events and another table (LOs) is for low-low events. It is not clear what the second "LOs" table represents. Are these Minimum Averages"?	The suggestions have been incorporated.