Black Creek Water Resources Development Preliminary Assessment

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Summary

The St. Johns River Water Management District (District) recognized the potential for harm to water resources in north Florida associated with continued reliance on groundwater to meet the growing need of human water consumption. In the North Florida Regional Water Supply Plan (NFRWSP), the District identified many alternative water supply projects to meet the region's future water needs while protecting the natural resources of Florida. One alternative water supply project currently under consideration is the Black Creek Water Resource Development (WRD) Project. This project is conceptually located in Clay County near SR 16 at Penny Farms and SR 21 near Camp Blanding. It will capture flow in the creek above a predetermined threshold. The water will then be piped along SR 16/SR 21 towards the Keystone Heights area and discharged on Camp Blanding property, where it will be dispersed onto a spreader field and make its way to Alligator Creek. Water will flow down Alligator Creek and be stored in lakes Brooklyn and Geneva, where it will also provide recharge to the Upper Floridan aquifer.

This technical memorandum describes a preliminary assessment of the Black Creek WRD Project to estimate the potential yield of Black Creek at SR16 and evaluate potential downstream environmental impacts. The potential water yield of Black Creek is estimated by applying a withdrawal schedule to the flows at the Black Creek near Penny Farms. The withdrawal schedule is developed based on the assumptions of a minimum withdrawal threshold of 21 cfs, the 85th percentile of flows over the last 30 years, and the pump capacities of 5 and 10 million gallons per day (mgd). The results show that the surface water withdrawals from Black Creek can produce the average yields of 4.0 and 7.5 mgd for the 5 and 10 mgd capacity scenarios with the average reliabilities of 77% and 70%. The potential constraints from the downstream environmental impacts are also considered when developing the withdrawal scenarios. The preliminary environmental assessment shows the effects of proposed withdrawals are negligible. Therefore, these additional restrictions are considered unnecessary and are not implemented.

To evaluate the salinity impacts of proposed withdrawals, the Environmental Fluid Dynamics Model (EFDC) is applied to the downstream reach of Black Creek. The EFDC model is calibrated to a set of observed salinity intrusion events with the salinity concentrations exceeding 1.0 part per thousand (ppt). The calibrated model is run for the two withdrawal scenarios over

the simulation period between 1995 and 2012. Salinity differences between the no-withdrawal base scenario and withdrawal scenarios are small. The maximum daily salinity difference at the Black Creek near Henley Road (roughly 9 miles above the mouth of Black Creek) between the base scenario and 10 mgd capacity scenario is 0.2 ppt and differences are less than 0.05 ppt for 99% of the days. These results indicate that salinity intrusions into Black Creek are insensitive to flow withdrawal at the level tested, and are, instead, driven by St. Johns River salinity. The salinity effects caused by the tested withdrawal scenarios are negligible. Consequently, the withdrawals will likely not result in any changes to tidal or submerged plant communities at the downstream reach of Black Creek.

The assessment of environmental effects focuses on the possible changes to riverine wetland plant community types and submerged aquatic vegetation (SAV) arising from the reduction in the delivery of freshwater to the Lower St. Johns River estuary by the Black Creek WRD Project. In addition, the impacts on water quality and rare endemic species are analyzed. The key conclusions of environmental assessment are listed below:

- Tidal Wetlands – Applying two metrics of tidal wetland salinity tolerance, the 10 mgd capacity scenario is estimated to lead to an upstream migration in the Lower St. Johns River of the lower tidal swamp community of 217 – 249 feet, while the 5 mgd capacity scenario would lead to an upstream migration of the community of 120 – 138 feet. This analysis did not examine the areas of tidal swamp potentially affected.
- Submerged Aquatic Vegetation – Based on a scaling of effect relative to the SAV model developed for the St. Johns River Water Supply Impact Study (WSIS), the 10 mgd capacity scenario is estimated to result in an 8.3 acre increase in the area of SAV exposed to moderate salinity stress 20 percent of the time, and a 4.4 acre increase in the area exposed to extreme stress. The reduced withdrawal scenario would lead to 4.6 and 2.4 acres increase of exposure to moderate and extreme salinity stress.
- Salinity changes in the mouth of Black Creek are negligible even under the maximum tested withdrawal and would not result in shifts in riparian tidal wetland communities. However, this analysis did not consider the future expanded Jacksonville Port and upstream water withdrawal effect on St. Johns River salinity at the mouth of Black Creek, and how this would in turn affect the water imported to the tidal portions of the creek during low and reverse flow events.
- Because the estimated effects on tidal wetlands and SAV are within the range deemed tolerable by the WSIS, we conclude that the effects of the Black Creek WRD Project on St. Johns River wetland plant communities under current conditions are negligible.
- Water Quality – Available water chemistry data collected in the South Fork of Black Creek near the proposed withdrawal location indicate generally good water quality. Nitrogen and phosphorus are similar to, or greater than, downstream concentrations, suggesting that changes in the proportion of this upstream contribution would not increase downstream nutrient concentrations. A pesticide and organic contaminants scan performed in 1994 indicated no constituents above detection limit.
- Rare Endemic Species – The upstream reaches of Black Creek support an endemic species of crayfish, *Procambarus pictus*, the Black Creek crayfish. Historic surveys indicate the crayfish inhabits the reach in the area of SR 16, at or near the proposed withdrawal. Crayfish females hold their egg masses until the larvae mature and the

juvenile crayfish hatch as fully-formed "mini adults", hence there is no planktonic stage that is susceptible to entrainment in intake flow. Nonetheless, design of any intake structure should take into consideration the potential for impingement and/or entrainment of this rare endemic species.

In conclusion, this preliminary assessment shows that the proposed quantity of surface water may be safely withdrawn from Black Creek with negligible environmental effects. However, it should be noted that this assessment is based primarily on existing and readily available information, supplemented by professional judgment. The findings should be considered preliminary in nature and should be used to assist refinement of the project concept and provide guidance for the future phases of project design.

1 Introduction

The Black Creek watershed is a sub-basin of the Lower St. Johns River Basin and has a drainage area of approximately 508 square miles. Major tributaries are the North and South Forks of Black Creek and Little Black Creek. The confluence of the North and South Forks is near Middleburg. From this point, Black Creek runs approximately 13 miles to the St. Johns River. Tidal effects are evident in the lower 8 miles of the North Fork and South Fork, as well as in the lower 13 miles of Black Creek. Black Creek is a "blackwater" stream, fed largely by surface water runoff and seepage from the water table surficial aquifer. Water quality in the upstream reaches of the creek is generally good because large areas of the drainage are in the Camp Blanding military base, are in conservation lands, or are on land used for commercial silviculture.

The St. Johns River Water Management District (District) has identified Black Creek as a possible alternative water supply source in north Florida. One alternative water supply project currently under consideration is the Black Creek Water Resource Development (WRD) Project (Figure 1). This project is conceptually located in Clay County near SR 16 at Penny Farms and SR 21 near Camp Blanding. It will capture flow in the creek above a predetermined threshold. The water will then be piped along SR 16/SR 21 towards the Keystone Heights area and discharged on Camp Blanding property, where it will be dispersed onto a spreader field and make its way to Alligator Creek. Water will flow down Alligator Creek and be stored in lakes Brooklyn and Geneva, where it will also provide recharge to the Upper Floridan aquifer.

The objective of this preliminary assessment is to estimate the potential yield of Black Creek at SR16 and evaluate potential downstream environmental impacts. The description of this assessment is organized as follows. Section 2 describes the yield analysis. Two withdrawal scenarios with the withdrawal capacities of 5 and 10 mgd are analyzed. Section 3 discusses the development of the Environmental Fluid Dynamics Model (EFDC) for the simulation of salinity intrusions into Black Creek and presents the results of salinity effects under the two withdrawal scenarios. The assessment of environmental impacts on tidal wetlands and submerged aquatic vegetation (SAV) is based mainly on the methods and results from the St. Johns River Water Supply Impact Study (WSIS) and is presented in Sections 4 and 5. Sections 6 and 7 summarize the impacts on water quality and the Black Creek crayfish.

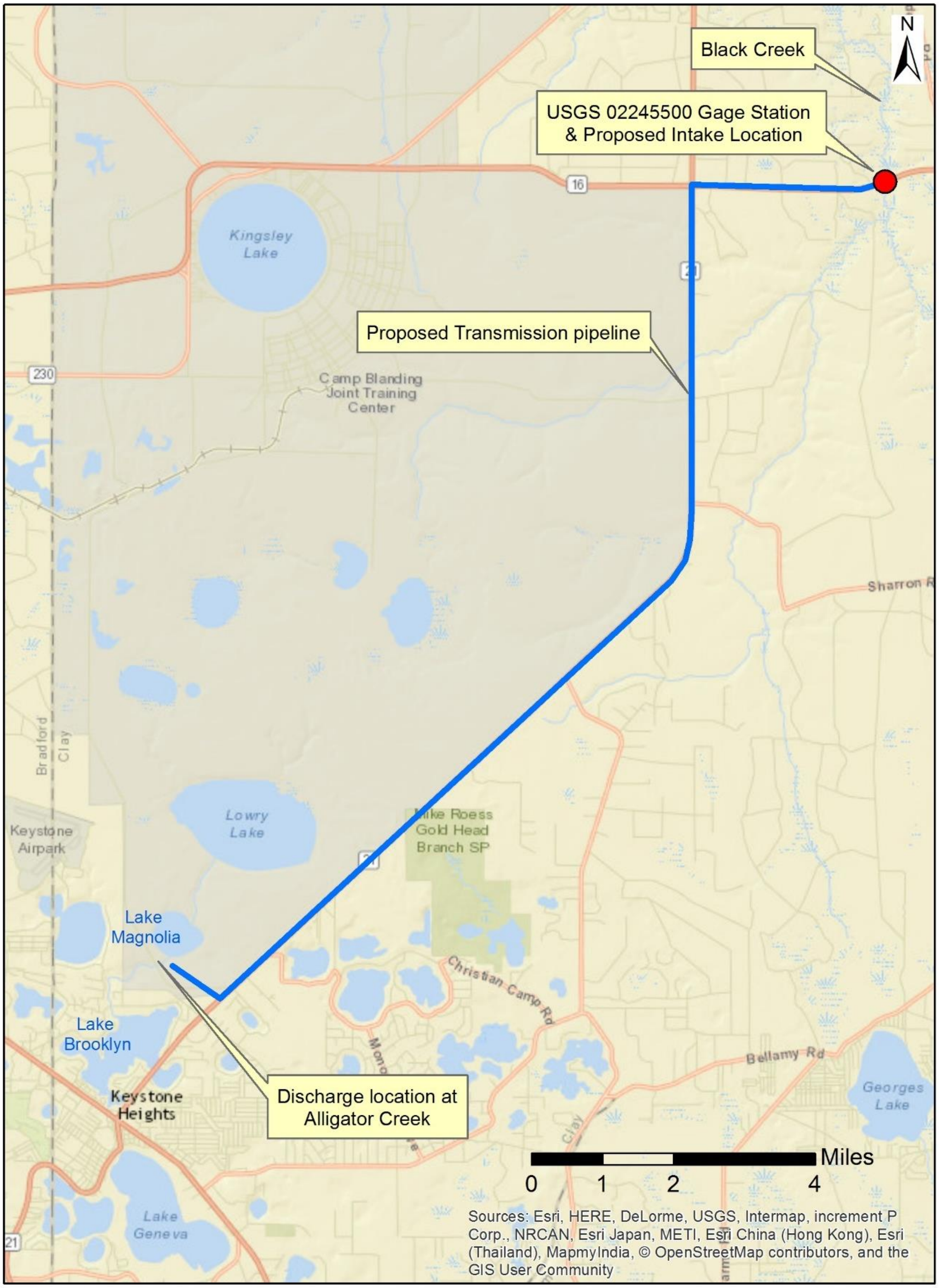

Figure 1. Black Creek Water Resource Development Project concept locator map.

2 Yield Analysis

The potential water yield of Black Creek is estimated by applying a withdrawal schedule to the flows at the intake location. The intake location is at the South Fork Black Creek near Penny Farms, where continuous daily flows are available from USGS site 02245500 since 1939. There appears to be a downward trend in flows at this site as indicated by the downward trendline for the annual average flow in Figure 2. This downward trend likely results from the decreasing rainfall in recent decades at this region. However, the flows, particularly low flows, have been stabilized in the last 30 years. As shown in Table 1, the 85^{th}, 90^{th}, and 95^{th} percentiles of flows over the last 10, 20 and 30 years are very close, although they are about 30% lower than those over the entire period of record. We recommend using the last 30 years of record for the yield analysis because the flow regime seems to be stationary during this period. Using the entire period of record could over-estimate the reliability of water yield.

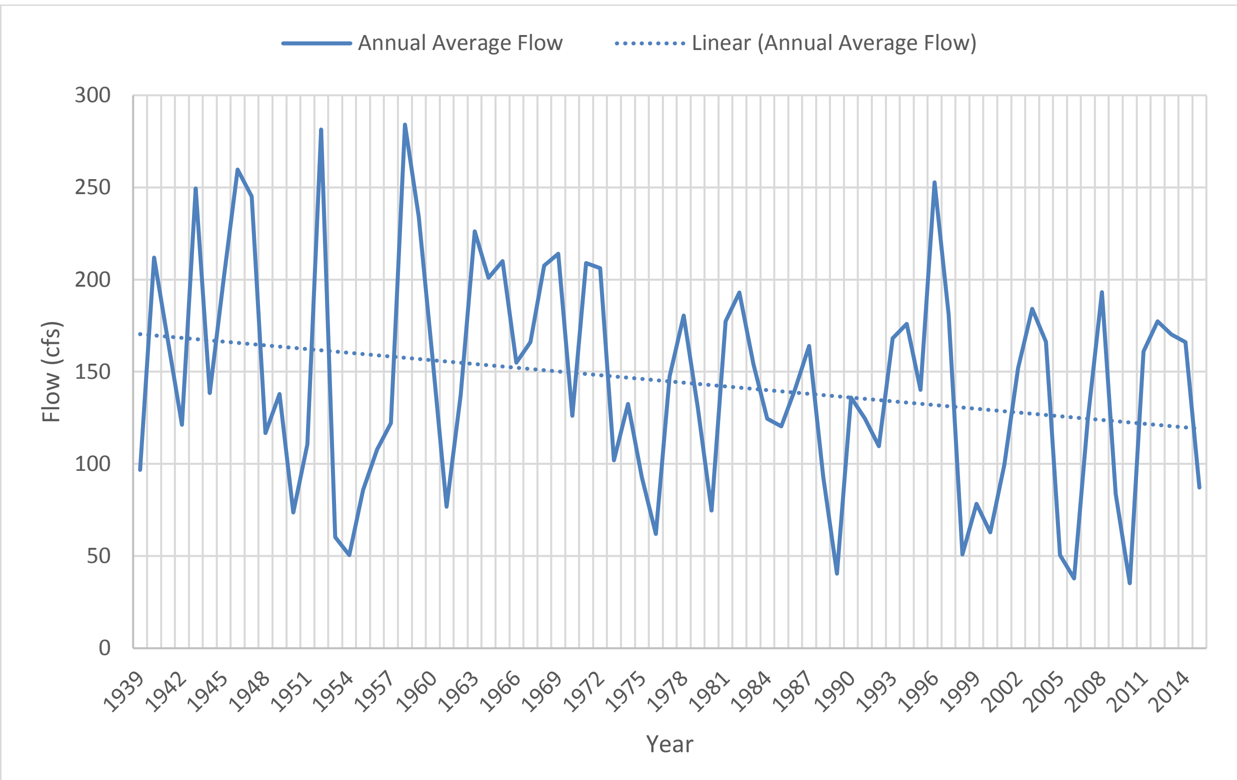

Figure 2. Observed annual average daily flows at USGS 02245500 showing a downward trend line for annual average flow.

Table 1. 85th, 90th, and 95th percentiles of observed flows at USGS 02245500 over the last 10, 20, 30, and 77.5 years.

Data		# of Years	Flow Percentile (cfs)		
from	**to**		**85th**	**90th**	**95th**
1/1/2007	12/31/2016	10	19.5	16.7	12.4
1/1/1997	12/31/2016	20	19.0	15.0	11.5
1/1/1987	12/31/2016	30	21.0	17.0	12.5
10/1/1939	3/26/2017	77.5	29.0	24.0	18.0

The withdrawal schedule is developed based on the following assumptions:

1. The minimum withdrawal threshold is 21 cfs, the 85th percentile of flows over the period between 1987 and 2016.
2. The water above the minimum threshold will be withdrawn up to the pump capacity.

We also considered the potential constraints from the downstream environmental impacts when developing the withdrawal schedule. The preliminary environmental assessment, which will be discussed in detail below, shows the effects of water withdrawals are negligible. Therefore, the restrictions based on the downstream effects are considered unnecessary and are not implemented.

Two withdrawal scenarios, with pump capacities of 5 and 10 mgd, are evaluated (Table 2). The results show that the surface water withdrawals from Black Creek can produce the average yields of 4.0 and 7.5 mgd for the two scenarios with the average reliabilities of 77% and 70%. The yield and reliability can be improved by varying the withdrawal with flow or stage and by incorporating water demand, recharge capacity, seasonality, and storage. This refinement is outside the scope of this work and should be explored in the future conceptual design phase of this project.

Table 2. Average yields and reliabilities of the two withdrawal scenarios.

Pump Capacity (mgd)	Average Yield (mgd)	Average Reliability (%)
5.0	4.0	77
10.0	7.5	70

Note: this yield analysis is based on the 30-year period of record between 1987 and 2016. The salinity analysis is based on a 10-year period between 1995 and 2005. The average yield for the 10-year record is 4.1 and 7.4 mgd for the two scenarios.

3 Salinity Effects

Observed Salinity

Ocean salinity intermittently extends up the main-stem of the St. Johns River and can then intrude into Black Creek. The District monitors salinity at station SJRHB, near the mouth of Black Creek, and at three locations within Black Creek: BLC at Henley Road, NBC where the

North Fork passes under Blanding Boulevard, and BSF where the South Fork passes under C.R. 238 in Middleburg (Figure 3).

Salinity exceeded 1 ppt at station SJRHBP 35% of the time over the period 1992 – 2016, whereas this salinity level was observed for 5% of the time at station SRB. Salinity never exceeded 1 ppt at either station NBC or BSF. Maximum observed salinity was 0.3 ppt at NBC and 0.07 at BSF.

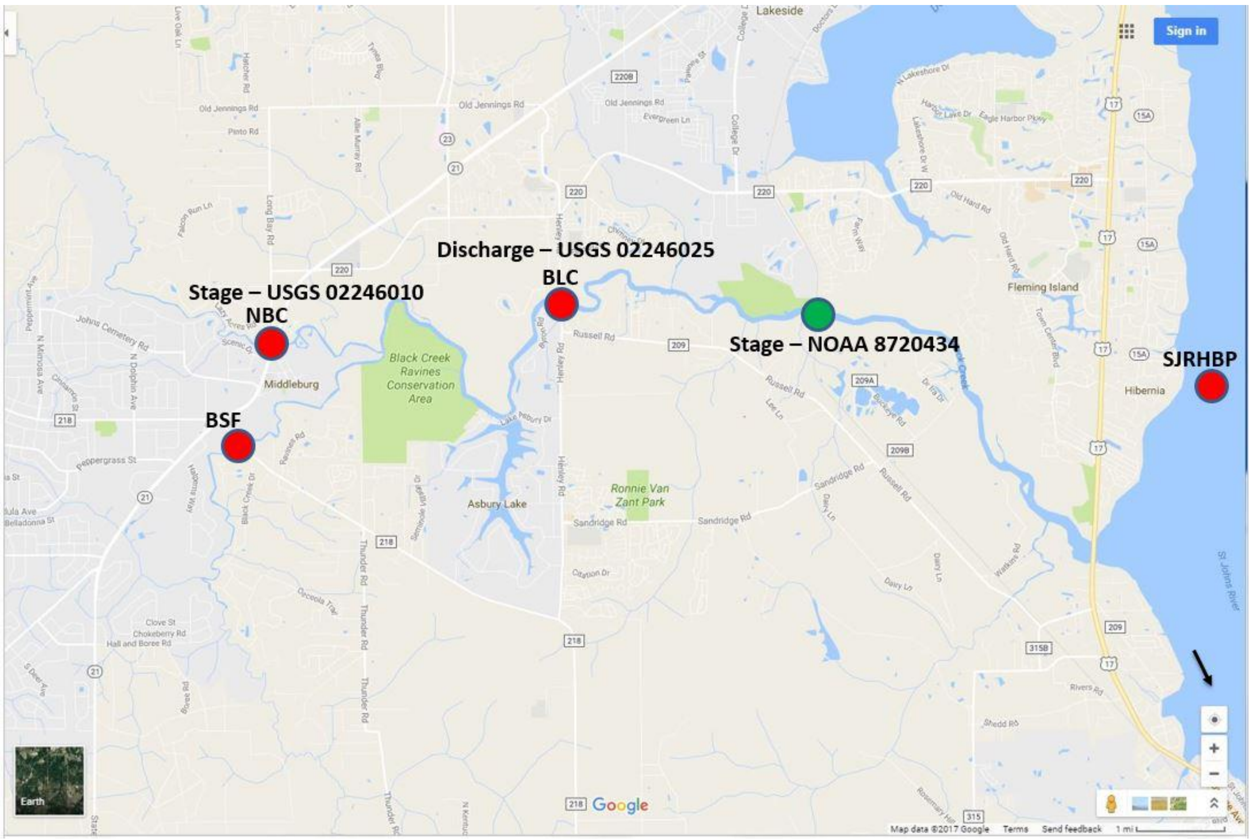

Figure 3. Locations of observed salinity (red circles). Tidal range was measured at NOAA tide station (8720434) located at a railroad bridge. USGS also measured discharge at BLC and stage at NBC. USGS also measures discharge (stations not shown on this figure) farther upstream on both the North and South Forks.

EFDC Salinity Model Set-Up

The Environmental Fluid Dynamics Model (EFDC) was applied to the portions of Black Creek from the confluence of the St. Johns River to stations NBC and BSF on the North and South Forks, respectively. The model was developed as simple, one-cell wide grid with branches at the upper end to represent the North and South Forks. Bathymetry data are available for the lower portion of Black Creek to the railroad bridge (NOAA station 8720434 in Figure 3). Depth of upstream areas was the principle tuning parameter for salinity.

The model was forced with river stage and salinity at the mouth. These time-series were obtained from an existing EFDC model of the Lower St. Johns River for the period 1995 – 2005.

Discharge was applied to the model at six locations: North Fork, South Fork, a location above station BLC, Little Black Creek, Bradley Creek, and Peters Creek.

Both the North and South Forks have been gauged continuously since October 1939. Over the period 1939 – 2016, the average discharge at the North and South Fork gauges was 188.6 cfs and 144.1 cfs, respectively.

From 2002 to 2010, USGS observed discharge at Henley Road (location of station BLC). Over that period, the combined discharge from the North and South Fork gauges averaged 284.5 cfs, while the discharge at Henley Road was 456.7 cfs. Interestingly, a large portion of the flow increase between the North and South Fork gauges and Henley Road is the increased base flow. A time-series of flow for Henley Road (Q_{henley}) was estimated from the combined discharge (Q_{total}) observed at the North and South Fork gauges using the following rules:

(a) If $Q_{total} < 100$ cfs, then $Q_{henley} = Q_{total} *3.0$
(b) If 100 cfs $\leq Q_{total} <$ 200 cfs, then $Q_{henley} = Q_{total} *2.1$
(c) If 200 cfs $\leq Q_{total} <$ 300 cfs, then $Q_{henley} = Q_{total} *1.8$
(d) If 300 cfs $\leq Q_{total} <$ 400 cfs, then $Q_{henley} = Q_{total} *1.6$
(e) If 400 cfs $\leq Q_{total} <$ 500 cfs, then $Q_{henley} = Q_{total} *1.6$
(f) If 500 cfs $\leq Q_{total} <$ 1000 cfs, then $Q_{henley} = Q_{total} *1.5$
(g) If 1000 cfs $\leq Q_{total} <$ 2000 cfs, then $Q_{henley} = Q_{total} *1.3$
(h) If 2000 cfs $\leq Q_{total}$, then $Q_{henley} = Q_{total} *1.1$

The time-series of discharge for the portion of the watershed between the North and South Fork gauges and Henley Road was then obtained by subtraction ($Q_{diff} = Q_{henley} - Q_{total}$).

Additional discharge was then added at three locations below Henley Road based on the average proportion of flow simulated by an existing HSPF hydrologic model. The HSPF hydrologic model showed that the ungauged areas downstream of Henley Road ($Q_{ungauged}$) would add an additional 90% of Q_{diff}. The ungauged discharge was apportioned by watershed area as 45% to Little Black Creek, 26% to Bradley Creek, and 29% to Peters Creek.

For the simulation period of 1995 – 2015, the average discharge entering Black Creek from the six sub-basins was summarized in Table 3.

Table 3. Minimum, maximum, and mean flows for the Black Creek tributary locations

Tributary Location	**Mean Discharge (cfs)**	**Minimum Daily Discharge (cfs)**	**Maximum Daily Discharge (cfs)**
South Fork	129	5.7	6,797
North Fork	157	2.4	15,793
Above Henley Road	171	19.5	2,022
Little Black Creek	69	7.9	819
Bradley Creek	40	4.5	473
Peters Creek	45	5.1	528
TOTAL	611	46.7	24,063

Salinity Calibration Events

The salinity model of Black Creek is intended to predict salinity intrusions from the St. Johns River into Black Creek. A set of calibration events was assembled, then, of days when salinity at BLC exceeded 1.0 ppt. There were seventeen days meeting this criterion. An additional four events were added for days when additional salinity observations were made downstream of BLC. The assembled calibration events are listed in Table 4.

Table 4. Salinity calibration events. Last four columns are observed salinity at SJRHBP, BLC, NBC, and BSF. Second column is combined observed discharge entering the North and South Forks. Third column is estimated discharge at Henley Road.

DATE	Q_{total} (cfs)	Q_{henley} (cfs)	SJRHBP	BLC	NBC	BSF
5/13/1999	28.0	84.0	7.4	1.76	0.06	0.03
6/13/2000	16.9	50.7	9.8	3.84	0.12	0.03
7/11/2000	18.7	56.1	8.9	2.64	0.1	0.04
6/12/2001	83.2	249.6	4.8	1.89	0.05	0.04
5/20/2002	41.2	114.0	2.5	0.05	0.06	0.04
6/11/2002	47.3	243.0	10.2	4.35	0.3	0.03
5/23/2005	120.8	327.0	0.3	0.03	0.04	0.05
10/10/2006	55.4	108.0	5.1	2.48	0.08	0.03
11/8/2006	39.3	201.0	3.4	1.22	0.05	0.04
5/16/2007	25.2	120.0	13.0	3	0.13	0.03
6/7/2007	29.4	273.0	9.1	3.25	0.05	0.04
7/12/2007	22.1	96.2	9.2	3.26	0.15	0.04
10/28/2010	25.0	211.0	4.6	1.16	0.06	0.03
12/1/2010	26.3	128.0	5.2	1.83	0.06	0.03
12/15/2010	27.7	30.7	3.9	1.31	0.06	0.03
4/12/2011	51.9	155.7	2.3	0.1	0.08	0.04
6/20/2011	12.8	38.4	8.4	2.66	0.07	ND
7/27/2011	64.1	192.3	6.8	1.25	0.07	0.04
10/26/2011	50.8	152.4	2.4	0.56	ND	ND
5/3/2012	14.2	42.6	6.0	2.89	ND	ND
5/23/2012	16.7	50.1	9.0	1.5	ND	ND

Figure 4 is a plot comparing discharge (Q) at Henley Road and salinity at SJRHBP (SJRSAL) with salinity at BLC (SAL).

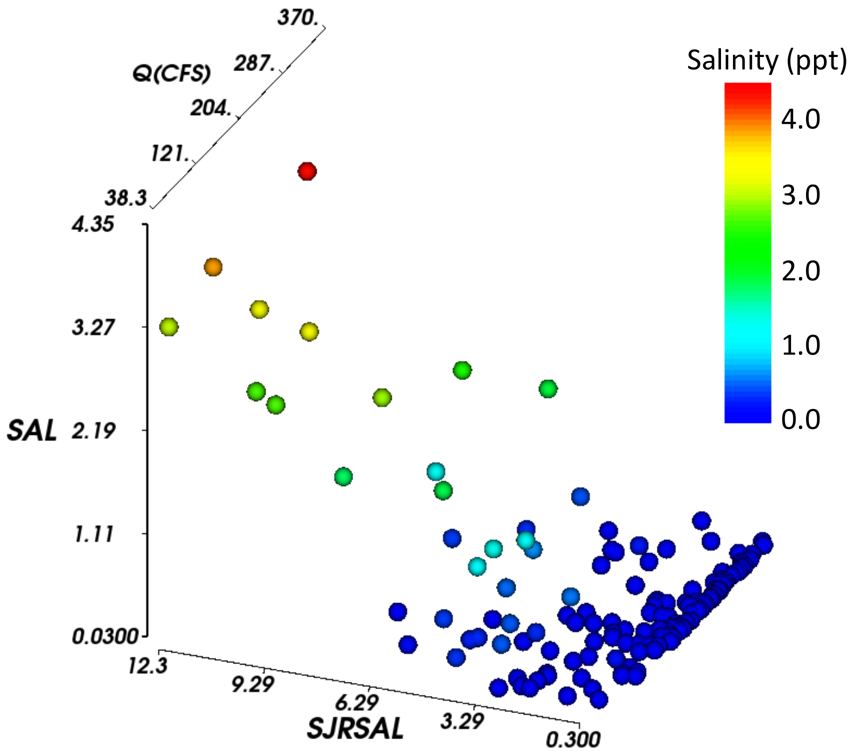

Figure 4. Three-dimensional plot comparing salinity at SJRHBP (SJRSAL) and discharge at Henley Road (Q(cfs)) with salinity at BLC (SAL). Each point is colored by salinity at BLC. The plot shows a strong relationship between salinity at SJRHBP and BLC.

EFDC Salinity Model Calibration

The EFDC model was run continuously for the period 1995 – 2012. Bathymetry was adjusted to match observed salinity at BLC, NBC, and BSF. Results for BLC are shown in Figure 5. The linear correlation between observed and predicted salinity was 0.83 and root mean square error between predicted and observed salinity was 0.26 ppt.

Model Scenarios

The EFDC salinity model was run for two withdrawal scenarios from the South Fork. Maximum withdrawals were 5 and 10 mgd for the two scenarios and withdrawals were ceased if the daily discharge at the South Fork location dropped below 21 cfs. Because of the low flow constraint, the average net withdrawal for the two scenarios was 4.1 and 7.4 mgd.

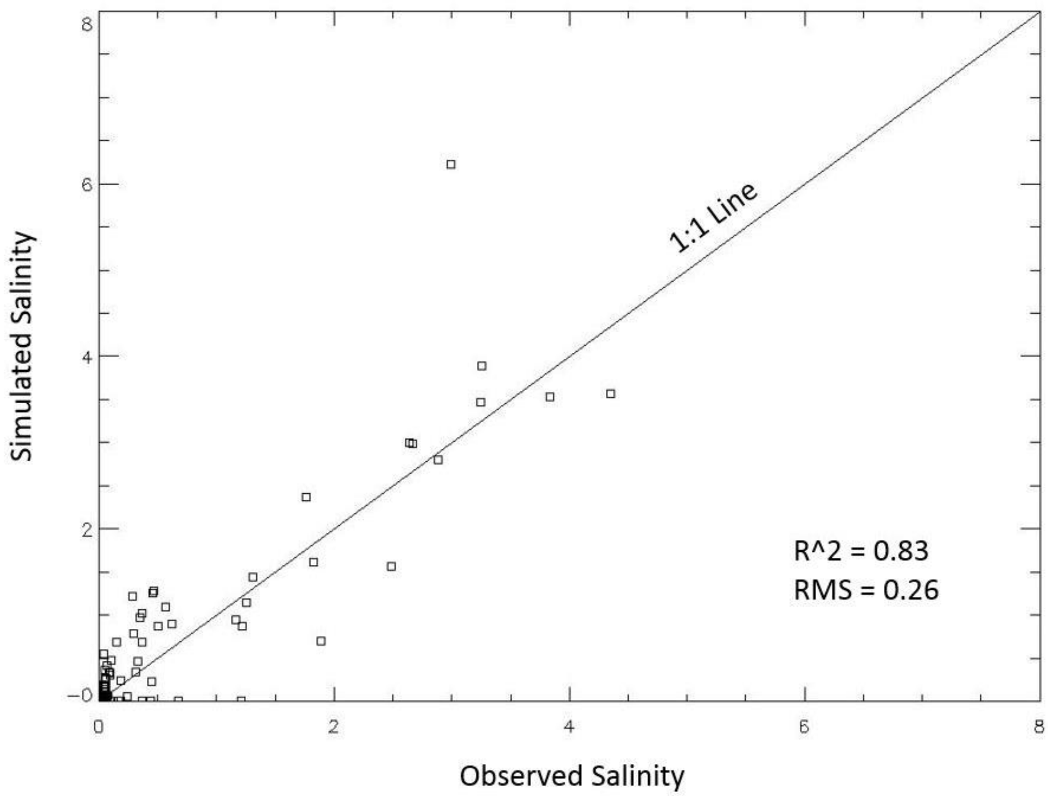

Figure 5. Simulated vs. observed salinity at BLC, 1995 – 2015.

Model Results

Salinity differences between the no-withdrawal base conditions and withdrawal scenarios were small. The maximum daily salinity difference at BLC between the base scenario and 10 mgd capacity scenario was 0.2 ppt and differences were less than 0.05 ppt for 99% of the days. These results indicate that salinity intrusions into Black Creek are insensitive to flow withdrawal at the level tested, and are, instead, driven by St. Johns River salinity. St. Johns River salinity would, of course, be affected by the withdrawals, but this effect was not considered for this modeling, since the salinity boundary condition was held constant for the scenario tests. The effect of flow withdrawal of St. Johns River salinity was a principle result of the WSIS and those results are combined with the present results to analyze the total impact of salinity alteration due to Black Creek withdrawals on wetland vegetation and SAV below.

4 Tidal Wetland

As indicated in the modeling analysis, salinity changes in the mouth of Black Creek will be negligible and will likely not result in any changes to tidal or submerged plant communities. This portion of the analysis focuses on the possible changes to riverine wetland plant community types arising from the reduction in the delivery of freshwater to the Lower St. Johns River estuary by the Black Creek WRD Project.

Freshwater riparian swamps and/or wetlands provide a sink for terrestrial pollutants, habitat, and shoreline protection. The Florida Natural Areas Inventory (2010) defines freshwater tidal swamps as floodplains below the head of tide dominated by hydrophytic trees, with common species including swamp tupelo (*Nyssa sylvatica*), water tupelo (*Nyssa aquatic*) sweetbay (*Magnolia virginiana*), bald cypress (*Taxodium distichum*), American elm (*Ulmus americana*) and red maple (*Acer rubrum*). In freshwater tidal swamps (upper tidal swamp), trees exhibit healthy growth and do not demonstrate stress from salinities. Groundcover is extensive and dominated by arrowhead (*Sagittaria spp*.), pickerelweed (*Pontederia cordata*), and royal fern (*Osmunda regalis*), and soils will have a high organic matter content (USACE, 2015). Salt-intolerant species such as lizard's tail, swamp leather-flower (*Clematis crispa*), swamp doghobble (*Eubotrys racemose*), highbush blueberry (*Vaccinium corymbosum*), Walter’s viburnum (*Viburnum obovatum*), and bluebeech may be present (WSIS, 2012). Lower tidal swamps, which are subjected to occasional inundation with saline water, will exhibit a thinning canopy, facilitating the growth of a salt-tolerant understory (WSIS 2012).

If obligate freshwater tidal wetlands are exposed to pulses of salinity, this can lead to changes in the composition of the vegetation, the soil chemistry, and ultimately the habitat function. With repeated exposure to salinity, obligate freshwater hydrophytes will decline, and be replaced by more salt-tolerant species. Because there are relatively fewer salt tolerant species, this transition generally leads to a reduction in plant diversity. Exposure of tidal swamp soils to salinity can supply sulfate, which can increase the rate of anaerobic soil decomposition, leading soil subsidence, release of nitrogen and phosphorus, and tree-throw (Noe 2013). Though the changes in salinity in the tidal reach of Black Creek will be negligible, changes could potentially result from the reduction in fresh water delivery to the estuary. The effect of upstream migrating salinity on tidal riparian wetlands and submersed aquatic vegetation (SAV) was examined in the WSIS, Chapters 9 and 10, and in the Supplemental Environmental Impact Statement for the Jacksonville Port Deepening Project. These studies are relied on in this analysis to quantify the potential effect of the Black Creek WRD Project.

For the WSIS tidal wetland analysis, Kinser et al. (2012) developed a model, based on data for the Ortega River in southwest Jacksonville, that related the location of tidal wetland community break points to the 95th percentile of the daily mean salinity. Break points for the wetland categories are listed in the Table 5. The authors applied this model to predict the upstream migration of riparian swamp/wetland community types in the Ortega and St. Johns Rivers for various upstream water withdrawal scenarios. The full 155 mgd withdrawal scenario resulted in the upstream migration of the freshwater and lower tidal marsh communities 1.11 and 1.12 kilometers (km) in the Ortega River, and 1.42 and 1.59 km in the Lower St. Johns River.

Table 5. Breakpoints for riparian wetland community types in the Ortega and St. Johns Rivers for the WSIS current condition 155 mgd upstream withdrawal and without sea level rise and the Upper St. Johns River Basin Project.

Wetland Community Type	Wetland Community Boundary, 95th Percentile Salinity (psu)	Ortega River Wetland Community Upstream Migration (km)	St. Johns River Wetland Community Upstream Migration (km)
Freshwater Tidal Swamp	3.22	1.11	1.42
Lower Tidal Swamp	4.13	1.12	1.59
Intermediate Marsh	4.93	1.13	1.68
Sand Cordgrass Marsh	5.77	1.13	1.69

Based on the conditions for withdrawal, the 10-year mean reduction in discharge from Black Creek under the 10 mgd capacity scenario would be 7.4 mgd, while the 5 mgd capacity scenario would be 4.1 mgd. By applying a simple linear interpolation, assuming that the 10 mgd scenario would be equivalent to 7.4/155 or 4.8 percent of the WSIS effect, the Black Creek WRD Project would move the lower tidal swamp boundary in the Ortega River upstream by 175 feet. By a similar calculation, the 5 mgd capacity withdrawal would elicit a response of 4.1/155 or 2.6 percent of 1.12 km, or a 97-foot upstream encroachment of the lower tidal swamp boundary. Applying this same proportional effect calculation to the St. Johns River, the 10 mgd capacity withdrawal would migrate the lower tidal swamp boundary upstream by 249 feet, while the 5 mgd capacity withdrawal would migrate the boundary by 138 feet.

A second metric developed by Hackney (2013) was also examined for the effect of salinity changes in the Lower St. Johns. Hackney described a transition zone from tidal swamp to tidal marsh defined by the frequency of occurrence of high tide salinity exceeding 1.0 practical salinity unit (psu). For the Cape Fear River, tidal swamps occurred where high tide salinities of greater than 1 psu occurred less than 12% of the time, while tidal marsh occurred where more than 25% of high tides exceeded 1 psu salinity. The zone between the 12% and 25% frequency of 1 psu high tide salinity defined a transition area in which freshwater vegetation exhibited salt-stress and salt intolerant vegetation disappeared from the wetlands.

To apply this metric in a screening assessment, the EFDC hydrodynamic model simulations developed for the WSIS base and 155 mgd upstream withdrawal scenarios were used to develop a simple regression models relating the Lower St. Johns River mile location to the 12 percent occurrence frequency salinities. These models were then used to predict the locations of the current and 155 mgd withdrawal locations corresponding to the 1 psu high tide salinity. Hourly model output for the surface at 5 river locations, bracketing the reach of upstream marine water intrusion, were reduced to the daily maximum salinity (assumed roughly equivalent to the high tide salinity), which were them rendered as probability density functions to identify the salinity for the 12 percent occurrence frequency. The graph in Figure 6 depicts the relationship between daily maximum salinity which is exceeded 12 percent of the time, and river mile, for the base (current condition) and the 155 mgd upstream water withdrawal scenarios. The difference between the locations predicted by these models for the position of the 1 psu salinity which is exceeded 12 percent of the time, equaling 0.86 mi (1.38 km), was proportioned to the expected withdrawal for the Black Creek WRD Project, to estimate the possible distance change for tidal swamp and tidal marsh community boundaries. The resulting upstream movement in the 12 percent occurrence line was similar to that predicted by Kinser et al. (2012), with the 7.4 mgd withdrawal producing a 217 ft (66 m) upstream change in the freshwater tidal wetland boundary, and the 4.1 mgd withdrawal producing a 120 ft. (37 m) upstream change.

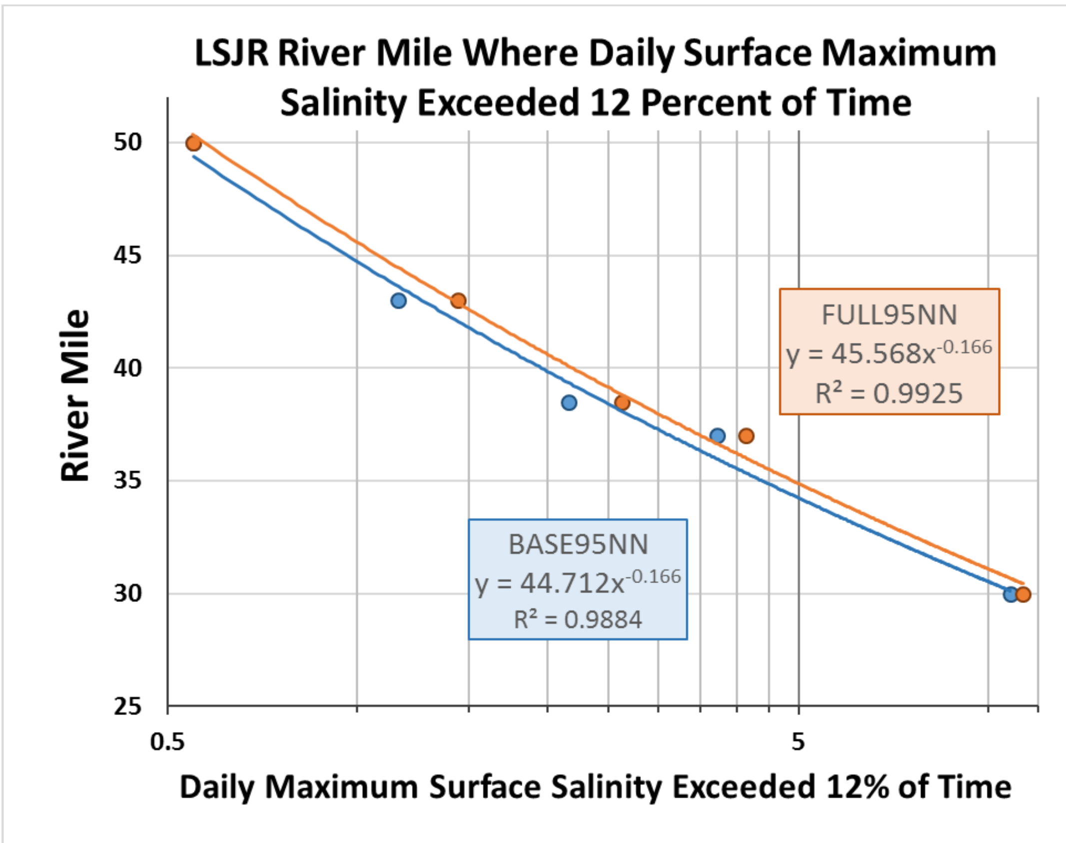

Figure 6. Relationship between Lower St. Johns River Mile (mouth = 0) and the salinity values that are exceeded 12 percent of the time. Salinity data provided by simulations of the Lower St. Johns River application of the EFDC hydrodynamic model for the Water Supply Impact Study.

5 Submerged Aquatic Vegetation

Though relatively small in terms of aerial coverage, the littoral zone of the Lower St. Johns River represents an important and vital habitat, and typically contains far greater abundance and diversity of fish and aquatic invertebrates than the open, pelagic environment. Due to the narrower channel, steeper shoreline and bulkheading, and large tide range, the downstream, Jacksonville portion of the LSJR does not support underwater rooted vascular plant communities, hence the SAV of the LSJR is almost exclusively a freshwater community, present only upstream of the Ortega River. Plant genera in this community include *Vallisneria*, *Ruppia*, *Najas*, *Hydrilla*, and *Ceratophyllum*, with *Vallisneria americana* the dominant species. The two main stressors that limit SAV distribution and abundance in the St Johns River are underwater light, controlled largely by natural colored dissolved organic matter and turbidity (of which algal turbidity is the major component) and salinity.

In the WSIS Chapter 9, *Submerged Aquatic Vegetation*, Dobberfuhl et al. (2012) proposed a model that established a scale of severity of harm to *V. americana* based on the concentration and duration of salinity exposure. The graphical depiction of this scale is shown below.

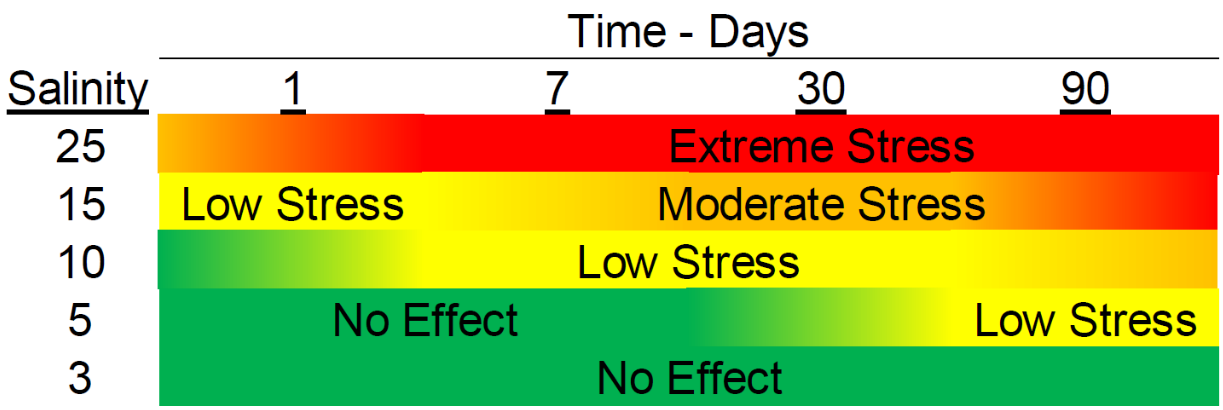

Figure 7. Salinity exposure model for *Vallisneria americana*.

Utilizing this model, Dobberfuhl et al. (2012) estimated the potential reduction in SAV acreage in the river for the most extreme withdrawal scenario, one that withdrew water from not only the upper and middle SJR, but also from the Lower Ocklawaha, for a total withdrawal amount of 262 mgd. Under this large withdrawal scenario, Dobberfuhl et al. (2012) predicted the area of LSJR SAV exposed to moderate salinity stress 10 percent of the time would increase by 151 acres, while the area exposed 20 percent of the time would increase by 146 acres; and the area exposed to extreme salinity stress 10 percent of the time would increase by 215 acres, while the area exposed 20 percent of the time would increase by 156 acres (Table 6). Dobberfuhl et al. (2012) point out that these increases in affected areas represent about 1 – 1.5 percent of the total LSJR littoral area.

Again, based on the simple assumption that the effect of the Black Creek WRD Project would be proportional to the WSIS scenarios, the 7.4 mgd project would translate to an increase of 4.3 acres of area exposed to moderate salinity stress 10 percent of the time, and an increase by 4.1 acres in area exposed 20 percent of the time. The 7.4 mgd project would similarly increase the area exposed to extreme stress 10 percent of the time by 6.1 acres, and the area exposed 20 percent of the time by 4.4 acres (Table 6). The 4.1 mgd project would increase these areas affected by about half as much (Table 6).

Table 6. Lower St. Johns River SAV increase in area affected by salinity stress from the freshwater supply reduction of the Black Creek WRD Project. Areas are in acres.

	WSIS **262 mgd**		**Black Creek WRD** **4.1 mgd**		**Black Creek WRD** **7.4 mgd**	
	10% of Time	20% of Time	10% of Time	20% of Time	10% of Time	20% of Time
Moderate Stress	151	146	2.4	2.3	4.3	4.1
Extreme Stress	215	156	3.4	2.4	6.1	4.4

6 Water Quality

Surface water quality data for the upstream reach of the South Fork of Black Creek were obtained from the USEPA STORET data base for the Souh Fork of Black Creek. Eighteen individual samples for standard wet chemistry, collected at Highway 16 near Penny Farms, were available from 1994 – 2013. These data are summarized in Table 7. In general, this reach of Black Creek exhibits water quality typical of blackwater streams of the northcentral Florida Pleistocene Ridge province, exhibiting low concentrations of inorganic ions, low to moderate alkalinity, and moderately high colored dissolved organic matter. While nitrate + nitrite and total nitrogen (TN) concentrations are very low, total phosphorus (TP) concentrations are consistently and unusually high for this physiographic region, suggesting anthropogenic enrichment. The overall geometric mean concentration of TN, at 0.52 mg/L, is not substantially different than the annual geometric mean observed at the long-term sampling station near the mouth of Black Creek, which is 0.65 mg/L. The geometric mean TP concentration at SR 16, at 0.128 mg/L, is noticeably higher than the mean at the Black Creek mouth station, which is 0.085 mg/L. Thus it does not appear that the reduction of this upstream contribution would adversely affect the concentration of TN and TP at the mouth of Black Creek, and may even reduce the TP concentration.

In 1994, the US Geological Survey, as part of the National Water Quality Assessment Program (NAWQA), collected and analyzed two samples for pesticides and synthetic organic contaminants. All analytes in this scan were below detection limit.

Table 7. Summary of Water Quality Data Colelcted from the South Fork of Black Creek at State Road 16 Near Penny Farms.

AGENCY	DATE	Project	Ammonia and ammonium	Apparent color	True color	Biochemical oxygen demand	Chloride	Nitrate + Nitrite)	Tot. Kjeldahl Nitrogen	Tot. Nitrogen*	Tot. Organic Carbon	Ortho-phosphate	Phosphorus, Total*	pH	Turbidity
			mg/l as N	PCU	PCU	mg/l	mg/l	mg/l as N	mg/l as N	mg/l as N	mg/l	mg/l as P	mg/l as P	SU	NTU
USGS	4/27/1994	NAWQA	0.02					0.025				0.08	0.11		
USGS	6/16/1994	NAWQA						0.025	0.7	0.725		0.08	0.11		
FDEP	1/8/2004	TMDL				0.5								7.08	
FDEP	7/6/2004	TMDL			120									7.47	
FDEP	8/5/2004	TMDL			250	2								5.36	
FDEP	9/1/2004	TMDL			400	2								5.02	
FDEP	10/6/2004	TMDL			500									4.55	
FDEP	4/11/2005	DO STUDY	0.01		300			0.004	0.71	0.714	31.6		0.07	4.49	3.38
FDEP	6/20/2005	DO STUDY	0.01		250			0.01	0.56	0.57	26.1		0.12	5.08	1.59
FDEP	8/23/2005	DO STUDY	0.01		150			0.03	0.58	0.61	15.7		0.13	5.13	3.52
FDEP	11/14/2005	DO STUDY	0.01		125			0.008	0.4	0.408	11.3		0.11	6.15	1.4
FDEP	1/18/2007	TMDL		60			5.9		0.33		13	0.039	0.23	7.1	1.7
FDEP	6/14/2007	TMDL		80			6.4	0.049	0.43	0.479	10	0.19	0.17	7.34	1.5
FDEP	7/26/2007	TMDL		80			7.8	0.091	0.44	0.531	13	0.15	0.19	6.46	1.2
FDEP	9/20/2007	TMDL		100			11	0.11	0.7	0.81	15	0.11	0.13	6.37	6.6
FDEP	11/15/2007	TMDL		60			8.7	0.028	0.46	0.488	11	0.1		6.6	3
FDEP	11/20/2012	TMDL	0.012		110	0.44	7.1	0.017	0.31	0.327	9.9	0.11	0.13	6.36	
FDEP	2/21/2013	TMDL	0.012		120	0.93	8	0.018	0.32	0.338	11	0.091	0.11	6.8	
AVERAGE			**0.012**	**76**	**233**	**1.2**	**7.8**	**0.035**	**0.495**	**0.524**	**15.24**	**0.106**	**0.128**	**6.09**	**2.65**

7 Black Creek Crayfish

Black Creek supports an endemic species of crayfish, *Procambarus pictus*, the Black Creek crayfish. The species was originally collected and described from a tributary of Governor's Creek in Clay County, however it is mainly confined to small headwater streams of the Black Creek drainage. The species is unusual not only because of its restricted distribution, but also because it is thought to be an ancient species of crayfish that gave rise to the various troglobitic (hypogean, cave-dwelling) crayfish species found in the submerged caves associated with many Florida springs (Franz and Franz 1979).

Distribution

Franz and Franz (1979) conducted surveys for *P. pictus* in streams in Duval, Clay, Putnam and Marion Counties in the late 1970s. They found the crayfish only in the Black Creek drainage. The crayfish was most abundant in:

1) Headwater streams – occurring in detritus accumulations in pool areas between riffles.
2) Small tributary streams – occurring in detritus accumulations behind submerged logs and in tree root mats.
3) Larger tributaries; primarily the North and South Forks of Black Creek – occurring in eddies and the root systems of submerged and emergent aquatic plants.

In this survey, the crayfish was mainly found in areas upstream of the proposed diversion point, but collections of it were made at or near to the proposed withdrawal point.

Most recently, Nelson and Floyd (undated report) conducted sampling for *P. pictus* within the Camp Blanding Joint Training Center property in 2010-11. Their survey did not extend beyond the boundaries of the military base. They found the crayfish at several sites throughout their survey area. The animals were mostly observed at sites with low turbidity and siltation, high dissolved oxygen (DO) and water flow, and generally clearer water. Crayfish were primarily collected from headwater stream areas with leaf debris, woody debris, and root mats, similar to what Franz and Franz (1979) observed.

Habitat Characteristics

As noted in the previous section, *P. pictus* generally prefers to inhabit some type of structural habitat (detritus accumulations, root mats, aquatic vegetation). Nelson and Floyd (undated report) presented some quantitative data on other habitat characteristics from their collections (Table 8).

Table 8. Habitat characteristics associated with collection of *Procambarus pictus* on the Camp Blanding military base. Source: Nelson and Floyd (undated report).

Habitat Feature	Mean	Range
Water temperature (^{0}C)	19	8.1 - 26.7
Turbidity (NTU)	2.55	0.14 - 62.29
Dissolved O_2 (mg/L)	9.59	2.89 - 22.45
pH	6.9	3.55 - 10.47
Color (qualitative score*)	1.6	1 - 3
Maximum depth (m)	0.41	0.10 - 1.90
Current (m/sec)	0.18	0.00 - 0.62
Canopy cover (% closure)	70.6	12 - 88

*-color scored as 1=clear; 2=light; 3=dark

Franz and Franz (1979) characterize the streams where they collected *P. pictus* as “swift, cool” streams with a dense tree canopy over the stream channel that moderates water temperature. The data from Nelson and Floyd (Table 8) generally support this observation.

Impact Assessment

The fact that the crayfish appears to primarily occur upstream of the proposed diversion point suggests that impacts of the withdrawal on crayfish populations should be minimal. Surveys for the crayfish should be conducted in the area of the proposed withdrawal at SR16 and South Fork Black Creek, as historic work indicates the crayfish has been collected in the immediate area (Franz and Franz 1979).

Black Creek is a relatively high-gradient lotic ecosystem and so the effects of the withdrawal should not propagate upstream to any great extent. Based on the habitat descriptions, above, the crayfish appears to require some flow, but has been found in areas of zero flow (although this may be due to drought conditions present during the 2010-11 surveys). Water level and changes in water level are probably more important to preserve adequate amounts of preferred submerged habitat (debris accumulations, root mats, etc.). Reductions in water level should be kept to a minimum to preserve crayfish habitat. Removal of any tree canopy during construction should be mitigated by replanting the same species of trees once construction is complete to restore tree canopy shading.

Impingement/entrainment of adult or juvenile crayfish may be an issue, but appropriate design of the intake structure should mitigate this. Crayfish females hold their egg masses until the larvae mature and the juvenile crayfish hatch as fully-formed “mini adults”; there is no planktonic stage as found in many marine decapods.

Franz and Franz (1979) indicate that the crayfish is susceptible to water quality degradation, primarily siltation from landscape erosion and organic loading from discharge of poorly treated sewage or runoff from animal operations (e.g., dairies). Turbidity control should be aggressively implemented during construction to minimize downstream impacts and the potential for impact to any crayfish populations downstream (although they have not been reported from the mainstem of Black Creek to date).

Reference

Dobberfuhl, D., R. Chamberlain, G.B. Hall, C. Jacoby, R. Mattson, L. Morris, J. Slater, K. Moore and R. Virnstein. 2012. Chapter 9. Submerged Aquatic Vegetation, In, St. Johns River Water Supply Impact Study. Technical Publication No. SJ2012-1. . St. Johns River Water Management District, Palatka, FL.

Franz, R. and L.M. Franz. 1979. Distribution, habitat preference, and status of populations of the Black Creek crayfish, *Procambarus* (*Ortmannicus*) *pictus* (Decapoda: Cambaridae). Florida Scientist 42(1): 13-17.

Hackney, C. T. 2013. Tidal Wetland Community Response to Varying Levels of Flooding by Saline Water. Unpublished draft report. Department of Biology, University of North Florida.

Kinser, P., S. Fox, L. Keenan, A. Ceric, F. Baird, P. Sucsy, W. Wise and C. Montague, 2012. Chapter 10. Wetland Vegetation. In, St. Johns River Water Supply Impact Study. Technical Publication No. SJ2012-1. . St. Johns River Water Management District, Palatka, FL.

Nelson, E.B. and M.R. Floyd. Undated report. Final Report. Black Creek Crayfish Baseline Survey. FWRI Contract No. CFMO ENV-BCCBS. Report by the Florida Fish and Wildlife Conservation Commission, Gainesville, FL. 18 pp.

Noe, G. B., Gregory B.; Krauss, Ken W.; Lockaby, B. Graeme; Conner, William H.; Hupp, Cliff R. 2013. The effect of increasing salinity and forest mortality on soil nitrogen and phosphorus mineralization in tidal freshwater forested wetlands. Biogeochemistry, 114: 225 – 244.