Withlacoochee River Watershed Initiative (H066)

Model Development and Verification Report

February 21, 2014

Plan Design Enable

Table of contents

Chapter **Page**

Tables

Figures

1. Introduction

1.1. Authorization

As part of the Withlacoochee River Watershed Initiative (H066), and the East Citrus Withlacoochee Watershed (N090), the Southwest Florida Water Management District (SWFWMD) and co-funding partners Citrus County and the Florida Fish and Wildlife Commission (FWC), authorized Atkins North America Inc. to develop a verified model to simulate hydrologic and hydraulic conditions for design event simulations along the Withlacoochee River and the Tsala Apopka Chain of Lakes, which included inflow models to the river 1,500 square miles. Work efforts are summarized for the Withlacoochee River Watershed Initiative (H066) in Work Orders #6 and #7.1 under agreement number 06CC0000017 and the East Citrus Withlacoochee River Watershed (N090), under Work Order #4 under agreement 09CC0000001.

1.2. Acknowledgements

This project could not have been successfully completed without key contributions from technical staff and project funding partners including:

Citrus County as a co-funding partner in the East Citrus Withlacoochee River Watershed project enabling an increased level of detail to be simulated within the Tsala Apopka Chain of Lakes, critical for the accurate calibration of the lake control structures during both high and low flows.

Florida Fish and Wildlife Conservation Commission (FFWCC), whose contributions enabled the evaluation of selected alternatives related to the Flying Eagle Wildlife Management Area and detail in the Tsala Apopka Chain of Lakes.

The SWFWMD Governing Board for endorsements of the project approach and supporting the vision to create a comprehensive watershed management tool capable of simulating the surface water conditions in the Green Swamp and Withlacoochee River Watersheds.

SWFWMD Project Managers – Gene Altman, P.E. and Ron Ferris, P.E. for navigating the interests of the watershed stakeholders while advancing the project development under the beta version of the InterConnected Pond Routing Model version 4 (ICPRv4). Recognizing that the only true way to understand the Withlacoochee River was through the development of a comprehensive watershed level model capable of predicting how watershed alterations will provide benefits to those living within the watershed.

SWFWMD Technical Staff – Dr. Harry Downing, PhD P.E. for technical contributions to the application of two dimensional modeling of the Withlacoochee River System. Dr. Mark Fulkerson, PhD P.E. for providing local expertise and guiding the data collection efforts necessary to identify and integrate key river conditions into the model development.

Streamline Technologies – Pete Singhofen, P.E. for providing access and technical support to the beta version of ICPRv4 and insights into model development and calibration.

1.3. Background

The Withlacoochee River was called by the Seminole Indians, “little, big water”, characterizing the great fluctuations between drought and flood that are commonly exhibited by the river due to changing hydrologic conditions. It is this range of conditions, coupled with public concerns of man-made alterations over the past 130 years, which prompted a study to provide a better understanding of the dynamics of the river. This “basin-wide” approach required a tool capable of simulating these wide ranging river conditions and the effects of these man-made alterations.

Beginning in 2000, the United States Army Corps of Engineers (USACE) initiated this effort in their Withlacoochee River Basin Feasibility Study and by 2004 had created an inventory of available data, identified hydrologic alterations to the river and recommended options for modeling the entire system. Later, as federal funding ceased, the Governing Board of the SWFWMD authorized and provided funding for the project to continue. In 2006, the SWFWMD retained Atkins to perform a watershed evaluation and watershed model development of the Withlacoochee Watershed. Joined by Citrus County as a co-funding partner in 2009, the project was able to expand to encompass a high level of detail through the Tsala Apopka Chain of Lakes.

1.4. Project Location and General Description

The Withlacoochee River, designated an Outstanding Florida Water by the Florida Department of Environmental Protection (FDEP), has a contributing watershed that covers approximately 2,100 square miles in eight counties including parts of Marion, Levy, Citrus, Hernando, Pasco, Lake, and Polk and all of Sumter County. The Withlacoochee River is approximately 150 miles long originating in the Green Swamp in Polk County and flowing westward and northward before eventually discharging into the Gulf of Mexico near Yankeetown, Florida.

The headwaters of the Withlacoochee River is the Green Swamp which covers a 900 square mile area. It primarily discharges to the Withlacoochee River, but also serves as the headwaters of three other major river systems in Florida including the Hillsborough, Peace, and Ocklawaha Rivers. Along the Withlacoochee River, additional inflows also occur through major tributaries, including the Little Withlacoochee River, Gum Slough, Jumper Creek, the Outlet River from Lake Panasoffkee, Gum Springs Run and the Rainbow River. Near Bonnet Lake the Withlacoochee River is either diverted into the Tsala Apopka Chain of Lakes through the Leslie Heifner and Orange State Canals or continues into the expansive marsh at River's Bends past Lake Panasoffkee and the Wysong-Coogler Water Conservation Structure. Water that entered the Tsala Apopka Pools rejoins the river after it passes through the S-353 structure through the C-331 canal system near Holder. The combined river flows channelized westward towards Dunnellon, Lake Rousseau and the completed portion of the Cross Florida Barge Canal. The overall watershed is seen in **Figure 1-1**.

Figure 1-1: Withlacoochee River Watershed Boundary

1.5. Purpose and Objective

Historical alterations due to navigation, logging, mining and ranching have occurred as far back as the 1800s in the Withlacoochee Watershed. One such alteration made it possible for the steamboat seen in **Figure 1-2** to enter the Orange State Canal. In addition to these alterations, the riverine system has experienced extreme high and low conditions in recent decades due to natural fluctuations in rainfall and groundwater levels. A series of public meetings held in the 1990s and early 2000s identified several critical issues that may be due to these natural or man-made changes. The intent of the Withlacoochee River Watershed Initiative and the East Citrus Withlacoochee River Watershed study is to better understand the dynamics of the river and watershed, identify how alterations have affected the system and evaluate alternatives to better manage the resources.

This project employs a holistic approach by examining the entire 2100 square mile watershed using field verified topography, historical information and state-of-the-art modeling software to simulate actual river conditions with and without these changes

Figure 1-2: Paddle-wheeled steamboat entering the Orange State Canal (c. 1880s)

2. Watershed Evaluation

2.1. Digital Terrain Model

2.1.1. SWFWMD Base LiDAR Data

Topographic information was collected by Light Detection and Ranging (LiDAR) which uses an optical remote sensing technology that measures properties of scattered light to find the range of a distant target. The prevalent method to determine distance to an object or surface is to use laser pulses. The range to an object is determined by installing the equipment on an airplane and measuring the time delay between transmission of a laser pulse sent from the air and detection of the reflected signal from the ground.

The SWFWMD procured LiDAR data over the Withlacoochee Watershed between 2003 and 2007 and provided digital versions of the data in LAS format. LiDAR data were collected by county or region over multiple years from multiple sources. In locations where boundaries overlapped, the SWFWMD made an evaluation of the data quality of each and kept the more accurate data set. These data were then processed by Atkins to generate a 5 foot by 5 foot grid of the entire watershed in the North American Vertical Datum of 1988 (NAVD88). The resulting digital terrain is located in the digital deliverable in the \DTM\DEM folder.

2.1.2. Terrain Updates

This project required accurate bare earth topography of the entire watershed including bottom elevations in areas typically inundated with water. One of the limitations of the LiDAR process is its inability to penetrate through water surfaces creating a topographic void. To achieve bare earth topography over these topographic void areas requires supplemental data sets, either in the form of hydrographic surveys or design plans depicting actual ground elevations. To supplement the LiDAR data within the Withlacoochee Watershed, bottom elevations were surveyed along 120 miles of the Withlacoochee River along with many of the lakes, marshes and canals adjacent to the river. The result is an unprecedented effort to depict actual ground elevations of the major water bodies within the watershed with an updated terrain consisting of both LiDAR and survey data. Details of the survey data collected to update the terrain are provided in Section 3 of this report.

2.1.3. QA/QC process

The multiple digital terrain input datasets were reviewed for consistency, data gaps and overlaps. Where errors or inconsistencies arose, data were reviewed with SWFWMD to reach a decision as to which data set should take precedence and how to fill data gaps. In addition, the Atkins project management team reviewed the terrain visually for errors and inconsistencies.

2.2. Characterization of the Withlacoochee River Watershed

Surface water generally flows from south to north in the Withlacoochee River Watershed. The main corridor of the Withlacoochee River and its adjacent floodplain represent the area used to develop the 2D river model for this project. This area, which includes the Green Swamp, Tsala Apopka and Lake Panasoffkee, forms approximately one quarter of the total watershed area. The remaining watershed area is made up of many individual planning units (smaller watersheds) that contribute surface flows to the Withlacoochee River under certain conditions. Detailed studies were available for several of these watersheds and that information was used to develop inflows to the river. Approximate studies were completed as part of this project for the planning units in the remaining watershed area, where detailed study information was not available. Each feature is described in more detail in the following subsections.

2.2.1. Green Swamp

The Green Swamp resides in portions of Polk, Lake, Sumter, Pasco and Hernando Counties while covering almost 900 square miles. It is generally bounded by four major highways; US 27, SR 50, US 301 and US 98 and is the headwaters to four distinct river systems, including the Withlacoochee, Hillsborough, Ocklawaha, and Peace Rivers. The boundary, as reproduced from the SWFWMD Green Swamp educational resource page, http://www.swfwmd.state.fl.us/education/interactive/greenswamp/greenswamp.html, is shown in green in **Figure 2-1**. The area is dominated by bay swamps and cypress swamps surrounded by mesic flatlands and uplands. Its unique combination of high elevation and shallow depth to the Floridan Aquifer allow it to provide groundwater recharge while sustaining flows to several major river systems. Topography ranges from 130 to 70 feet North American Vertical Datum of 1988 (NAVD 88), which gently and consistently slopes east to west. An image of the Withlacoochee

River within the Green Swamp, reproduced from the SWFWMD educational resource page, is seen in **Figure 2-2**.

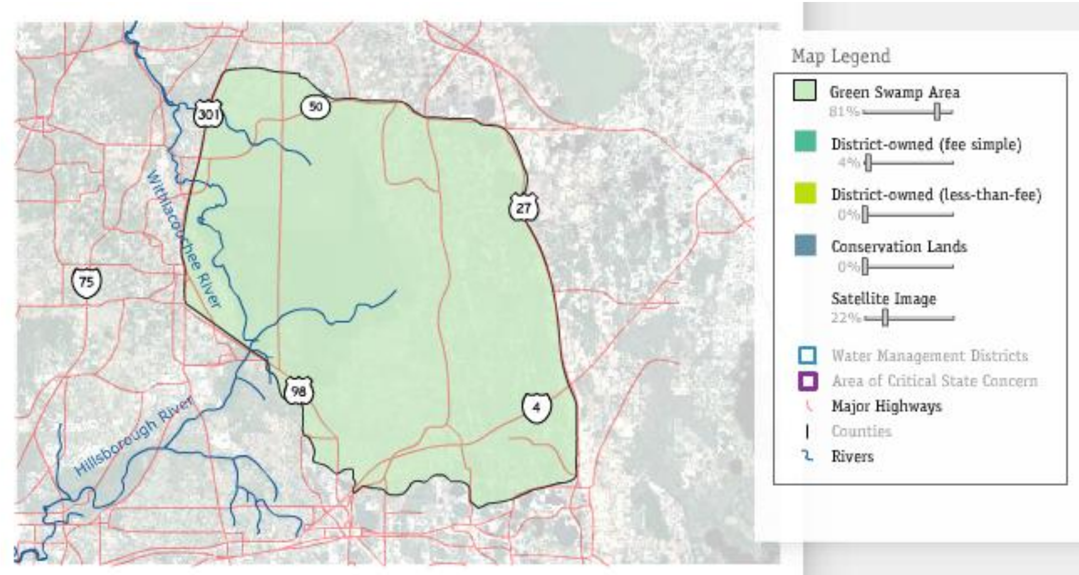

Figure 2-1: Green Swamp Boundary

Figure 2-2: Withlacoochee River's Beginning in the Green Swamp

2.2.2. Main River

As part of the watershed evaluation portion of the Withlacoochee River Watershed Initiative, the river was segmented into homogeneous river portions. This work divided the river into 11 segments based upon similar river characteristics, which were further subdivided into a 100 river reaches. The segments are described below and are shown in **Figure 2-3**. Images and further details of each river reach are provided in the Watershed Evaluation Report and Watershed Evaluation database located in the H066\ \Reports\Watershed_Evaluation folder of the digital deliverable.

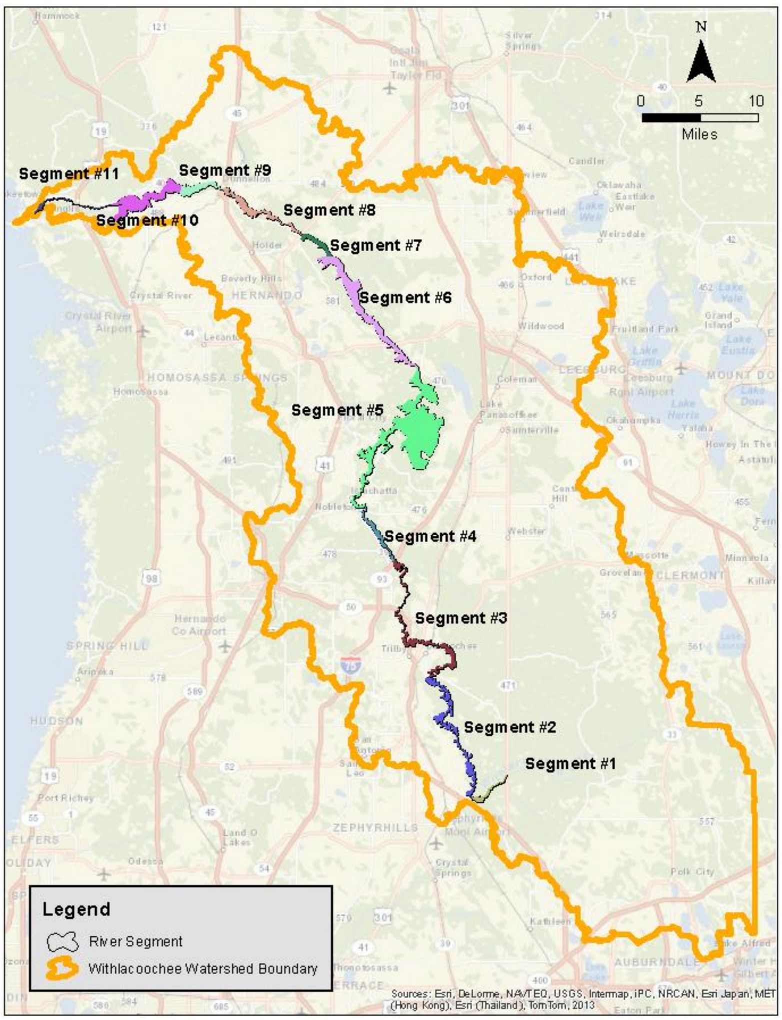

Figure 2-3: Withlacoochee River Segments

River Segment 1 extends through the Green Swamp to just downstream of the Hillsborough River Overflow at US 98.

Within the Green Swamp, the Withlacoochee River forms several small tributaries that turn into a broad drainage system. The river transitions from a defined channel, to poorly defined flow through forested wetlands and back again several times as it flows westward throughout much of this reach. During the dry season, groundwater contributions dominate the flow in this segment and it is common for portions of the main channel to be completely dry fluctuating with surficial groundwater levels.

River Segment 2 extends from just past the Green Swamp / Hillsborough River connection to Dobes Hole.

The Withlacoochee River in this segment flows northward along the western edge of the Green Swamp, east of Dade City. It is similar to Segment 1 in that the main channel is sometimes poorly defined and will dry up when water levels are low. Here the floodplain is very broad, and during high flow conditions the defined low flow channel is completely submerged as floodwaters spread out wide into the adjacent swamps.

River Segment 3 extends from Dobes Hole to the I-75 Overpass just northwest of Silver Lake

Downstream from Dobes Hole the Withlacoochee River flows eastward, forming a broad arc around the topographic high at the Town of Lacoochee. As the river flows through highlands, topographic relief increases and the river develops a meandering morphology that includes several alluvial river sections that have formed through a combination of fluvial and erosive processes. The floodplain is narrow in this segment and the channel is often incised with sandy banks. The Little Withlacoochee River joins the main channel near Silver Lake. Silver Lake is a large in-channel lake that marks the end of this segment.

River Segment 4 extends from the I-75 Overpass at Croom to the Nobleton Bridge

Downstream from Silver Lake, the Withlacoochee River is less constrained by topography and occupies a flat floodplain between ridges that parallel the river. The river loses sinuosity and changes into branching channels that form several small islands. Around Hog Island, for example, two distinct channels of roughly equal size are formed. This segment ends at the Town of Nobleton where the river reforms as a single channel.

River Segment 5 extends from the Nobleton Bridge to the Wysong-Coogler Water Conservation Structure

Downstream of Nobleton the river bends around the Tsala Apopka Chain of Lakes and becomes the border between Citrus and Sumter counties. The slope of the river channel is much flatter here as the floodplain widens out greatly. This segment contains the diversion channels to Tsala Apopka and the large tributaries of Gum Slough, Jumper Creek and the Outlet River from Lake Panasoffkee. The Wysong-Coogler Water Conservation Structure, capable of slowing the flow downstream, is the end of this segment.

River Segment 6 extends from the Wysong-Coogler Water Conservation Structure to the Southwest corner of Marion County

Between the Wysong-Coogler Water Conservation Structure and the southwest corner of Marion County, the Withlacoochee River is similar to Segment 5. The channel slope remains relatively flat with a wide reaching floodplain as the main channel braids around many in-stream islands and sediment deposits. Bryant Slough, a natural channel from Tsala Apopka that is now structurally controlled, enters the river just downstream of SR 44. Farther downstream, Gum Springs Run provides flow year-round from the Gum Springs complex, a second magnitude spring. At the end of this segment, several braided channels reform into a single channel near the SW corner of Marion County.

River Segment 7 extends from the Marion County Line to SR 200 Bridge at Holder

This segment is characterized by a much steeper bottom slope as compared to the previous two segments as the Withlacoochee River passes numerous rock outcroppings that act as natural water control devices. The Tsala Apopka Outfall Canal, which can provide flows to the river when the Tsala Apopka Chain of Lakes are at flood stage, enters just upstream of SR 200 near the end of this segment.

River Segment 8 extends from SR 200 Bridge at Holder to Dunnellon

Downstream from the SR 200 bridge, the river flows as a single, meandering channel with high banks on either side. The downstream portions of this segment are highly variable in nature and include areas with high banks, areas of wetlands and low relief, and remnant mining pits adjacent to the main channel that are now submerged year round. The Rainbow River, a first magnitude spring run, enters this segment just upstream from Dunnellon. Flow from Rainbow Springs averages nearly 700 cubic feet per second (cfs). The downstream end of this segment is the Dunnellon Gap, an important topographic pass that allows egress of the Withlacoochee River around the Brooksville Ridge.

River Segment 9 extends from Dunnellon to Upper Lake Rousseau

Downstream from Dunnellon, the Withlacoochee River morphology is that of a meandering channel. However, the backwater (Lake Rousseau) created by the Inglis Dam has submerged most of the original channel. This segment is characterized by standing dead timber, broad wetlands and floating vegetation. The segment ends where the old channel boundaries disappear completely, floating vegetation abates, and the open water portion of Lake Rousseau begins.

River Segment 10 extends from Upper Lake Rousseau to Lake Rousseau/ Inglis Dam

The single feature in this segment is the 3,600 acre Lake Rousseau. The completion of the Inglis Dam in 1909 by the Florida Power Corporation initially formed the lake and served to generate hydroelectric power up until 1965. The Lake Rousseau area was modified again in the 1960's as part of the Cross Florida Barge Canal Project. The lake was outfitted with the Inglis Lock and bypass facilities to allow boat passage between the Gulf of Mexico and Lake Rousseau. The lock is currently not functional and has been out of service since 1999. The bypass canal drains Lake Rousseau under normal hydrologic conditions. The control structure at Inglis Dam is used during high flow events to provide supplemental discharge capacity. Any flows released from the Inglis Dam control structure flow into the Cross Florida Barge Canal and then directly to the Gulf of Mexico bypassing the lower few miles of the original Withlacoochee River channel. The discharge exiting through the bypass canal around the Inglis Lock flows through a section of manmade canals before returning to the natural Withlacoochee River channel.

River Segment 11 extends from Lake Rousseau to the Gulf of Mexico

This reach is the original, natural channel of the Withlacoochee River between Lake Rousseau (Inglis Lock bypass) and the Gulf of Mexico. The river flows past the towns of Inglis and Yankeetown before reaching the Gulf of Mexico. This reach is tidally influenced downstream of Inglis. River bank morphology along this reach is characterized by low topographic relief and numerous limestone outcrops. Expansive coastal marshes exist along the last two miles of the river.

2.2.3. Tsala Apopka Chain of Lakes

The Tsala Apopka Chain of Lakes is comprised of a series of interconnected marshes, islands and open water pools covering nearly 22,000 acres. When water levels permitted, flow historically occurred between the Tsala Apopka marshes and the Withlacoochee River at several locations. There have been many man-made alterations in this area whereby several canals, berms and structures have been built resulting in significant changes to the natural hydrology of the region. Currently water can enter into Tsala Apopka through the Leslie Heifner and Orange State Canals and flow into the Floral City Pool, the first pool in the chain. Water flows into the second pool in the chain, the Inverness Pool, through the Moccasin Slough and Golf Course Structures. The Inverness Pool passes water into the final pool in the chain, the Hernando Pool, through the Brogden Bridge Structure and Brogden Culverts. Excess water can also be diverted from this pool back to the Withlacoochee River through the Bryant Slough Structure. Under high water conditions, the Hernando Pool can discharge through the Van Ness Structure towards Two Mile Prairie or through the S-353 structure to the Withlacoochee River near SR 200.

Structure operations in Tsala Apopka allow water from the Withlacoochee River to enter the Floral City Pool when there is a positive gradient between the river and the pool. Approximately one third of the flow entering Tsala Apopka is fairly appropriated to each of the three pools by the structures until they reach their target levels. When the Withlacoochee River is lower than the Floral City Pool, all of the structures are typically closed to conserve water in Tsala Apopka. During flood conditions the inflow structures are closed to prevent excess water from entering the pools and water is released as needed to assist with flood control in the area.

2.2.4. River Inflows from Contributing Areas

River inflows from planning units adjacent to the Withlacoochee River make up 1,500 square miles of the contributing area. Approximate studies, completed as part of this project, were prepared to estimate reasonable inflows to the primary study area, where previously approved detailed studies did not exist. **Figure 2-4** shows the extents of the approximate studies (Approx. 800 sq. mi.), previously completed detailed studies (Approx. 700 sq. mi.) and the 2D region (primary study area, Approx. 600 sq. mi.)

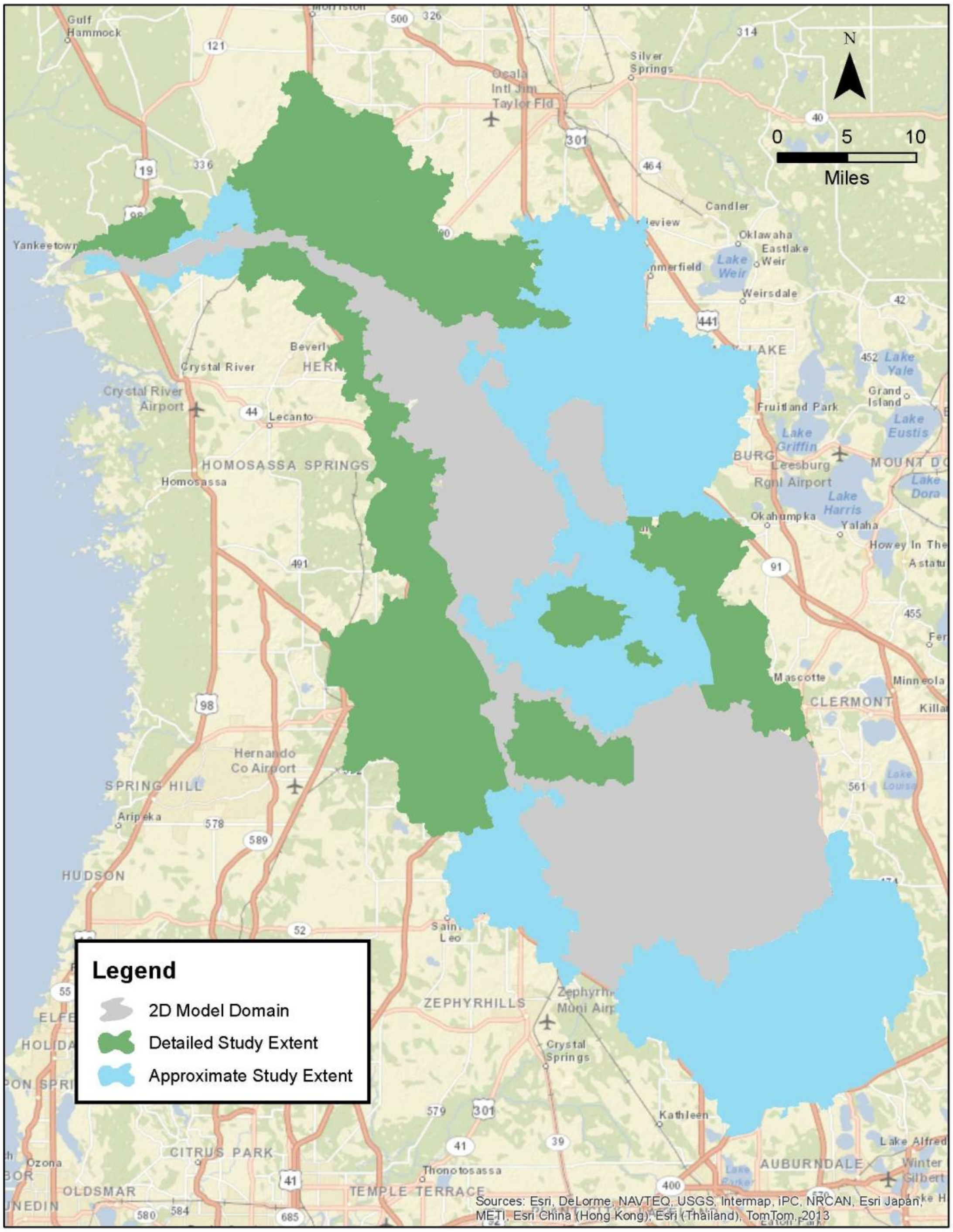

Figure 2-4: Limits of Detailed and Approximate Watershed Studies

2.2.4.1. Detailed Models

One of ways the SWFWMD manages water resources is through the Watershed Management Program, which includes inventory assessments and hydrologic and hydraulic modeling on a planning unit basis. These detailed studies follow the SWFWMD Guidelines and Specifications and generally capture storage to ½ foot and provide accurate representations of flooding down to the parcel level. These detailed studies often go through a peer review process and form the basis for FEMA floodplain map revisions. In the Withlacoochee Watershed, 15 of the 41 planning units that flow into the Withlacoochee River have SWFWMD approved detailed studies and watershed models developed for them. These detailed studies are shown in green in **Figure 2-4** and are listed in **Table 2-1**. The details of each of the detailed studies, developed by others, can be found in the Withlacoochee Digital Deliverable in the following two folder locations: \TSDN_Report\5_Misc_Ref_Materials\ GEN_DetailedStudies including GIS files and relevant study information and \TSDN_Report\ 5_Misc_Ref_Materials\ GEN_DetailedStudies_Models folder containing the ICPR models.

Table 2-1: List of Watersheds with Detailed Models

SWFWMD Planning Unit (Watershed)	County
East Hernando – Withlacoochee River	Hernando
Little Withlacoochee River	Hernando
Webster	Sumter
Bushnell	Sumter
Two Mile Prairie	Citrus
Blue Run	Marion
Yankeetown	Levy
Inverness	Levy
Withlacoochee River near Blue Run	Marion
Withlacoochee River in Marion Co.	Marion
Withlacoochee Region	Marion
Tsala Apopka Outlet	Citrus
Tsala Apopka – upland portion	Citrus
Inglis	Levy
Lake Bradley	Citrus

2.2.4.2. East Citrus Withlacoochee River Watershed

The East Citrus Withlacoochee River Watershed was originally part of the larger Tsala Apopka Watershed which included both the upland areas to the west and the pools to the east. The upland portion to the west was previously modeled by others as a detailed study and is included in the list in **Table 2.1**. The portion to the east that includes the Tsala Apopka Pools and their interaction with the Withlacoochee River was developed as part of this project, to the standards of a detailed study and simulated with the ICPRv4 software. The watershed was also divided into areas that were simulated as part of the 2D mesh and the portion modeled as “traditional” basins. The area highlighted in yellow in **Figure 2-5** shows the extent of the “traditional” basins while the remainder of the area within the overland flow region was modeled with the 2D overland flow mesh.

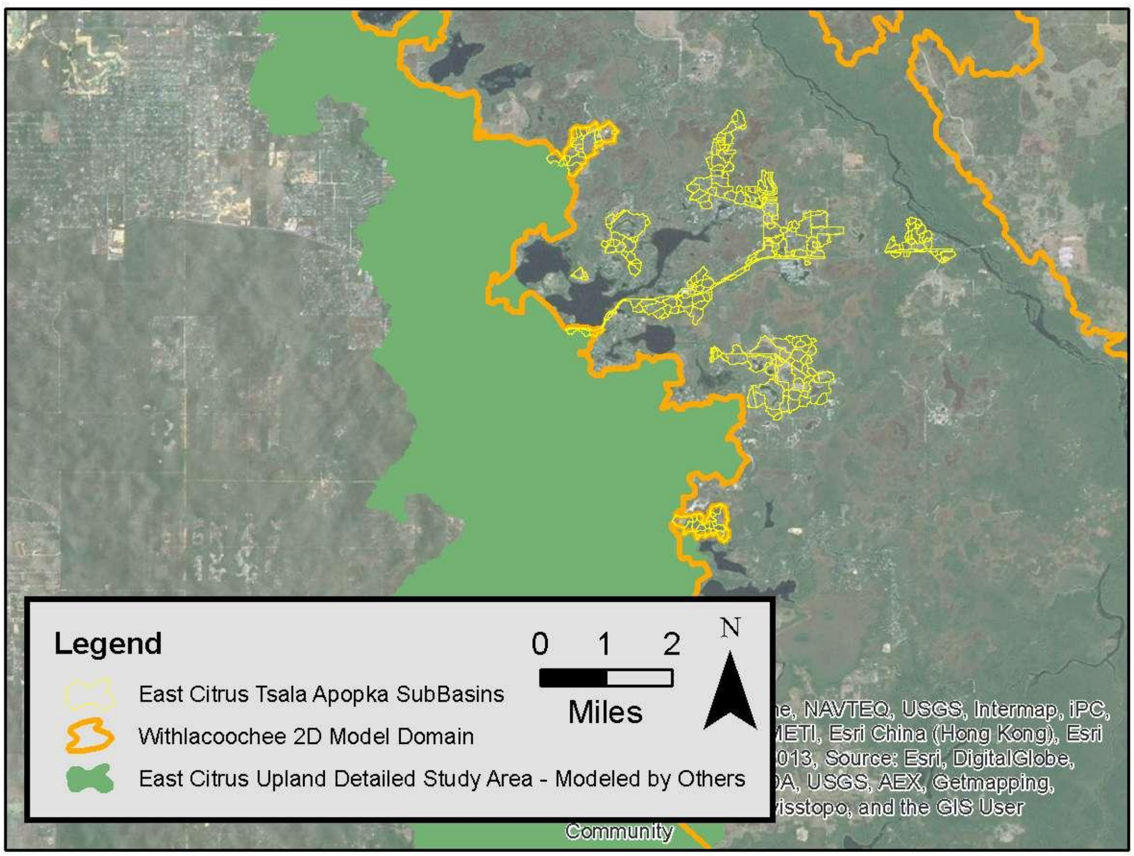

Figure 2-5: East Citrus - Tsala Apopka Subbasin

2.2.4.3. Approximate Study Models

Shown in blue in **Figure 2-4** and listed in **Table 2-2** are the approximate study basins. These include 26 planning units for which detailed studies were not available at the time of this study. Under this project, approximate studies were developed for these planning units, with the sole purpose of generating inflows into the river corridor 2D model.

Approximate studies generated for this project are similar to the detailed studies, in that desktop evaluations using ArcHydro methods combined with aerial imagery and street views were used to characterize storage areas, develop model connectivity, and watershed parameterizations. The difference being, these studies were mainly focused on the data necessary to accurately generate inflows rather than characterize flood conditions within these watersheds. As such, model detail was prioritized towards the watershed outlets into the 2D river corridor rather than further up in these watersheds. GIS data, parameterization data and model results of approximate studies are located in the digital deliverable in the \Geodatabase\Withlacoochee_1D_MiniWMP folder with models located in the \Models\Withlacoochee_1d folder.

Table 2-2: List of Approximate Study Modeled Planning Units

Planning Unit	
Bell Branch and Levy	Half Moon
Big Creek West	Jumper Creek Canal (east of I-75)
Big Jones	Jumper West of I-75
Big Prairie	Little Jones / Lake Okahumpka
Blanton Lake	Little Withlacoochee – Sumter Co
Citrus at Withlacoochee Segment 10 – 11	Outlet River
Devils Creek	Polk City
Duck Lake	Pony Creek
Gant Lake	Shady Brook
Gator Creek	Turner
Gator Hole	Withlacoochee River Segment 1
Gum Slough	Withlacoochee River Segment 2
Gum Swamp	Withlacoochee Segment 5-6

2.3. Hydrologic Inventory

2.3.1. Subbasin Delineation Process

Subbasin delineation evaluation techniques were performed over both the 2D River Model area and the approximate inflow models, with different objectives for each. Evaluation techniques were used in the area of the approximate inflow models to both identify significant storage and delineate 4,638 individual basins over the 800 square mile approximate study area. Within the 2D model domain the techniques were used to characterize the terrain to flag critical features such as ridges, valleys, roads, and ponds. The process resulted in 846 polygon basin features delineated along with 40,281 2D modeled basins or (honeycombs) to characterize the terrain.

Delineation results for approximate studies are found in the digital deliverable in the \Geodatabase\Withlacoochee_1D_MiniWMP folder and the 2D honeycomb basins in the \Geodatabase\Withlacoochee_2D_Region folder.

2.3.2. Land Use Characterization

Land use data were derived from the SWFWMD land use coverage 2009 and applied to both the approximate studies over each basin for the generation of Green Ampt runoff parameters, and the 2D zone as a dxf file read into the ICPRv4 program.

The ICPRv4 program uses the Land Use Coverage to generate runoff based upon an imperviousness lookup table. **Table 2-3** shows these parameters organized by Land Use FLUCC for the Withlacoochee Model.

Table 2-3: Land Use Imperviousness Table

FLUCC	FLUCCS Description	% Imp	DCIA	I_a	FLUCC	FLUCCS Description	% Imp	DCIA	I_a
1100	RESIDENTIAL LOW DENSITY	10	0	0	4100	UPLAND FOREST	0	0	0
1190	LOW DENSITY UNDER CONSTRUCTION	5	0	0	4110	PINE FLATWOODS	0	0	0
1200	RESIDENTIAL MED DENSITY	15	5	0	4120	LONGLEAF PINE - XERIC OAK	0	0	0
1300	RESIDENTIAL HIGH DENSITY	70	20	0	4200	UPLAND HARDWOOD FORESTS	0	0	0
1400	COMMERCIAL AND SERVICES	70	50	0	4340	HARDWOOD CONIFER MIXED	0	0	0
1500	INDUSTRIAL	77	72	0	4400	TREE PLANTATIONS	0	0	0
1600	EXTRACTIVE	0	0	0	5100	STREAMS AND WATERWAYS	100	100	0.2
1700	INSTITUTIONAL	70	65	0	5200	LAKES	100	100	0.2
1800	RECREATIONAL	5	2	0	5300	RESERVOIRS	100	100	0.2
1820	GOLF COURSES	5	2	0	6100	WETLAND FORESTS	100	100	0.2
1900	OPEN LAND	0	0	0	6110	BAY SWAMPS	100	100	0.2
2100	CROPLAND AND PASTURELAND	0	0	0	6150	STREAM AND LAKE SWAMPS	100	100	0.2
2110	IMPROVED PASTURES	0	0	0	6170	Mixed Wetland Hardwoods	100	100	0.2
2140	ROW CROPS	0	0	0	6200	WETLAND CONIFEROUS FORESTS	100	100	0.2
2200	TREE CROPS	10	10	0	6210	CYPRESS	100	100	0.2
2300	FEEDING OPERATIONS	10	10	0	6300	WETLAND FORESTS MIXED	100	100	0.2
2400	NURSERIES AND VINEYARDS	10	5	0	6410	FRESHWATER MARSHES	100	100	0.2
2500	SPECIALTY FARMS	10	5	0	6430	WET PRAIRIES	100	100	0.2
2510	HORSE FARMS	10	5	0	6440	EMERGENT AQUATIC VEGETATION	100	100	0.2
2550	TROPICAL FISH FARMS	0	0	0	6530	INTERMITTENT PONDS	100	100	0.2
2600	OTHER OPEN LANDS (	0	0	0	7400	DISTURBED LAND	0	0	0
3100	HERBACEOUS	0	0	0	8100	TRANSPORTATION	20	15	0
3200	SHRUB AND BRUSHLAND	0	0	0	8200	COMMUNICATIONS	5	2	0
3300	MIXED RANGELAND	0	0	0	8300	UTILITIES	5	2	0

2.3.3. Soils Characterization

Soil classification data used in both the approximate studies and the 2D model comes from the soils coverage available through the SWFWMD and Lookup table from the Department of Agriculture in the SSURGO database. **Table 2-4** shows a sampling of the values found in the lookup table for each soil category with the full table used presented in Appendix A.

Table 2-4: ICPRv4 Green-Ampt with Redistribution Lookup Table

Green-Ampt with Redistributions

Soil Category	Kv Saturated	MC Saturated	MC Residual	MC Field	MC Wilting	Pore Size Index	Suction Head	WT Initial
1414046	0.86	0.453	0.041	0.19	0.095	0.378	4.33	4.757218
1414048	9.48	0.437	0.02	0.062	0.033	0.694	1.93	4.757218
1414050	9.48	0.437	0.02	0.062	0.033	0.694	1.93	4.757218
1414051	0.86	0.453	0.041	0.19	0.095	0.378	4.33	4.757218
1414052	9.48	0.437	0.02	0.062	0.033	0.694	1.93	1.0170604
1414054	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.2624672
1414055	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.01
1414057	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.492126
1414058	0.86	0.453	0.041	0.19	0.095	0.378	4.33	4.757218
1414061	9.48	0.437	0.02	0.062	0.033	0.694	1.93	2.7559056
1414064	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.2624672
1414065	0.04	0.43	0.109	0.321	0.239	0.223	9.45	0.2624672
1414066	0.86	0.453	0.041	0.19	0.095	0.378	4.33	2.7559056
1414069	2.36	0.437	0.035	0.105	0.055	0.553	2.4	0.2624672
1414075	0.08	0.464	0.075	0.31	0.197	0.242	8.27	4.757218

Units: Kv Staurated: (ft-1); Moisture Content (MC) Saturated, Residual, Filed, Wilting: (volume fraction); Pore Size Index: (Brooks-Corey); Bubble Pressure: (inches); Water Table (WT) initial: (feet)

2.3.4. Runoff

Runoff is generated within the 2D grid once rainfall fills the soil voids or exceeds the rate at which water can infiltrate the ground. Runoff rates are determined by depth of flow using the St. Venant equations for overland routing and roughness. The Withlacoochee Model used the Land Use coverage as a surrogate for the roughness coverage, whereby roughness factors were a function of Land Use FLUCC along with shallow and deep Manning's coefficients for each. Specific overland flow values used in the Withlacoochee Model are seen in **Table 2.5**.

Table 2-5: Overland Flow Roughness Factors

FLUCC	Shallow Manning's	Deep Manning's	Area Reduction Factor		FLUCC	Shallow Manning's	Deep Manning's	Area Reduction Factor
1100	0.16	0.128	0.9		4100	0.45	0.36	0.9
1190	0.16	0.128	0.9		4110	0.45	0.36	0.9
1200	0.13	0.104	0.9		4120	0.45	0.36	0.9
1300	0.08	0.064	0.9		4200	0.45	0.36	0.9
1400	0.05	0.04	0.9		4340	0.45	0.36	0.9
1500	0.07	0.056	0.9		4400	0.45	0.36	0.9
1600	0.3	0.24	0.9		4400	0.45	0.36	0.9
1700	0.13	0.104	0.9		5100	0.07	0.05	0.9
1800	0.13	0.104	0.9		5200	0.07	0.05	0.9
1820	0.13	0.104	0.9		5300	0.07	0.05	0.9
1900	0.3	0.24	0.9		6100	0.45	0.36	0.9
2100	0.15	0.12	0.9		6110	0.45	0.36	0.9
2110	0.15	0.12	0.9		6150	0.3	0.24	0.9
2110	0.15	0.12	0.9		6170	0.3	0.24	0.9
2140	0.15	0.12	0.9		6200	0.35	0.28	0.9
2140	0.15	0.12	0.9		6210	0.35	0.28	0.9
2200	0.3	0.24	0.9		6300	0.3	0.24	0.9
2200	0.3	0.24	0.9		6410	0.06	0.048	0.9
2300	0.2	0.16	0.9		6430	0.06	0.048	0.9
2400	0.2	0.16	0.9		6440	0.06	0.048	0.9
2400	0.2	0.16	0.9		6530	0.06	0.048	0.9
2500	0.2	0.16	0.9		7400	0.3	0.24	0.9
2510	0.2	0.16	0.9		7400	0.3	0.24	0.9
2550	0.2	0.16	0.9		8100	0.15	0.12	0.9
2600	0.15	0.12	0.9		8100	0.15	0.12	0.9
3100	0.3	0.24	0.9		8200	0.15	0.12	0.9
3200	0.3	0.24	0.9		8300	0.15	0.12	0.9
3300	0.3	0.24	0.9					

2.3.5. Hydrology

Hydrology was generated for both the approximate models and the 2D model region using the Green Ampt method. The difference between the application of these two methods is that in the approximate studies using Advanced Interconnected Channel and Pond Routing Model (ICPRv3) there is a separate module for calculating runoff which is subsequently called, or referenced in the hydraulics module. The basin hydrology requires area inputs by basin for each unique soil and land use combination. In contrast, ICPRv4 calculates the hydrology and hydraulics at the same timestep, internally splicing the bulk soils and land use coverage by honeycomb (2D basin). Simulating the hydrology and hydraulics simultaneously provides the benefit of enabling the interaction of runoff and infiltration from adjacent cells to dynamically adjust available soil storage.

It is of note that simulations using ICPRv4 have a mechanism to recover the soil moisture through the dynamic extraction of water through evapotranspiration. This dynamic approach allows better simulations of longer term events. Unlike the ICPRv3 models which will not recover the soil moisture until the rainfall stops, which often has the opposite effect of fully recovering the soil storage too rapidly.

2.3.6. Hydrology QA/QC

Quality control was performed on the hydrology results and hydrologic parameterization through visual inspections of runoff hydrographs, reviews of land use conditions in the watershed for relative consistency against aerials and comparisons of modeled runoff volumes to anticipated runoff volumes.

2.4. Hydraulic Feature Inventory

2.4.1. Hydraulic Feature Inventory Development Process

As previously defined, the Withlacoochee River Watershed is a combination of three model types, which include completed detailed studies, approximate studies, and the 2D region analysis.

- Detailed Studies – Models approved by the SWFWMD and having completed an extensive peer review process, were taken, “as is” without additional detailed review. However, the down gradient limits of the study may have been adjusted if the area was covered by the

2D Region. Adjustments included truncating the detailed model and adjusting tailwater conditions as appropriate.

- Approximate Studies – Simulated for planning units without completed detailed studies to provide watershed inflows. Development of these models relied heavily upon digital techniques analyzing the digital terrain and limited field investigations.
- 2D region – Comprises the 2D model domain (Withlacoochee River and adjacent floodplain, Green Swamp, Tsala Apopka and Lake Panasoffkee) and the East Citrus Withlacoochee River Watershed.

Data for model development came from the following sources:

- GIS data from previous studies, the SWFWMD, National Hydrographic Dataset (NHD), Forest Service, municipal culvert inventories, etc.
- Digital Terrain – developed from SWFWMD acquired LiDAR between 2003 and 2007, supplemented with marsh, lake, and channel hydrography.
- Structure Surveys – available from field investigations both in the areas of approximate studies and 2D region.
- Environmental Resource Permits – for relevant roadways and developments of significance to the model inflows.
- SWFWMD data collection – River profile, culvert data collection and marsh survey data.
- Structure Profiles – Within the 2D model domain, 17 operable structures were simulated with data from SWFWMD structure profile reports and operational data from field data sheets recorded during the verification event.
- Google ®/ Bing ® Maps – supplementing the Digital Elevation Model (DEM) and field observations, used to assist with generating approximation and presence of structures present in approximate studies.

For the approximate studies, the naming convention for basins, nodes and links begins with an association to the SWFWMD planning unit name through a two digit assigned ID. The ID and corresponding planning unit name is listed in **Table 2-6**. Also, within the model, each element is assigned a model group using the same two digit ID for convenience. To keep the models at a manageable size, the approximate studies were split into five separate ICPR models, using logical topographic breaks to divide up the models. Combining models in this fashion enabled interconnections between planning unit models to occur without the need for excess boundary conditions. **Table 2-6** lists the ICPR model associated with each planning unit. Note: Some planning units fall in multiple models. This was done to retain the logical topographic split, while remaining consistent with the SWFWMD original planning unit designations.

Table 2-6: Approximate Study ICPR Group Name

Approximate Study ICPR GROUP	Planning Unit Name	ICPR MODEL
BB	Bell Branch	N1
BC	Big Creek West	S3
BJ	Big Jones	N2
BP	Big Prairie	N2 & S1
BL	Blanton Lake	S2
BU	Bushnell - (outside of detailed study)	S1
DL	Duck Lake	S2
GC	Gator Creek	S3
GL	Gant Lake	S1
GS	Gum Slough	S1
GW	Gum Swamp	N2
HM	Half Moon	N2
JC	Jumper Creek	S1
LD	Lake Deaton	N2
LJ	Little Jones creek	N2
LM	Lake Miona	N2
LO	Lake Okahumpka	N2
LW	Little Withlacoochee – Sumter Co	S1
OR	Outlet River	N2 & S1
PC	Pony Creek	S3
SB	Shady Brook	N2
TC	Turner Creek	N1
UW	Upper Withlacoochee River (Segment 2)	S2 & S3
WB	Webster - (outside of detailed study)	S1
WR	Withlacoochee River (Segment 1, 5, 6, 10 & 11)	N1, N2, S1, & S3

2.4.2. Summary of Conveyance Features

Within the approximate study watersheds conveyance features were simulated as channels, pipes, drop structures and weirs. **Table 2-7** lists the quantity of each model element within the approximate model simulations

Table 2-7: Conveyance Features within the Approximate Studies

Model Element	Count of Modeled Feature
Channel	131
Pipe	1,908
Drop Structure	22
Weir	11,783
Total	13,844

Within the 2D model domain, conveyance travels along the 2D overland flow mesh or within designated 1D elements integrated into the 2D model domain. Conveyance features simulated in the 1D portion, used in the Withlacoochee Model include, channels, pipes and weirs. Note: The operable control structures are inclusive of the weirs and pipes and also contain an operable top or bottom clip as appropriate. **Table 2-8** lists the quantity of each model element within the 2D model domain.

Table 2-8: Conveyance Features within the 2D Region

Model Element	Count of Modeled Feature
2D Overland Flow Reach	94,414
Channel	824
Pipe	385
Weir	36
Total	95,659

2.5. Model Geodatabase

The Geographic Watershed Information System (GWIS) geodatabase Version 1.6 is the standard for data parameterization and delivery of watershed models for the SWFWMD. This format was utilized for each of the existing detailed studies provided and setup for the approximate studies. The SWFWMD is currently working with ESRI on a data standard for Interconnected Channel and Pond Routing Model version 4.00.00 (ICPRv4). However a data standard does not currently exist. Consistent with previous deliverables, the Withlacoochee Model Verification 2D GWIS will be delivered as described in section 2.5.3 below.

2.5.1. Detailed Studies

The deliverable GWIS geodatabase from each of the detailed studies was used, “as-is” and is included in the TSDN as a digital reference in the \TSDN_Report\5_Misc_Ref_Materials \GEN_DetailedStudies folder.

2.5.2. Approximate Studies

The geodatabase deliverable for the approximate studies was formatted in the SWFWMD standard Version 1.6 format, shown in **Figure 2-6** and included in the digital deliverable in the \Geodatabase\Withlacoochee_1D_MiniWMP folder. Additional fields in the geodatabase schema include an indication of the associated model under the ICPR_BASIN shape and an IsSurveyed field in the HydroJunction shape, to indicate which structures were approximated and which were field data collected.

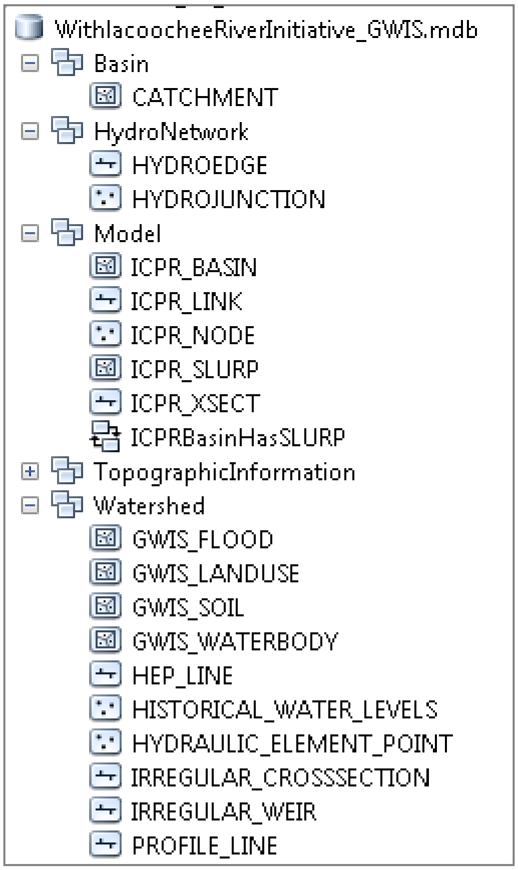

Figure 2-6: Approximate Study GWIS geodatabase

2.5.3. 2D Model Region

In lieu of a defined geodatabase format specific to the ICPRv4 computer simulation. A temporary version was created for this project, designed to be flexible in the transition to a standardized GWIS format at the time it is available. Each feature in the Geodatabase is described below.

- **BoundaryStage** table – contains the time series tailwater conditions for the 2D model.
- **ExternalHydrogaph** table – contains the time series inflows from the approximate and detailed study models.

- **ICPR_XSECT –** modeled after its 1D GWIS counterpart, this line feature class includes cross sections used in the 1D channel portion of the 2D model.
- **Point2D –** contains all of the point features necessary to generate the interior of the 2D mesh and serve as 1D nodes for channel nodes and ponding areas. The map atlas has these broken into various components by the Type field which include:
    - Breakpoint – this is a specified vertex within the 2D mesh. These points are typically placed to reflect significant changes in terrain slope to facilitate the accurate generation of the 2D mesh and make up the majority of the entries in the Point2D feature class.
    - OF_Nodes – like breakpoints, these points specify vertices within the 2D mesh. Unlike breakpoints, they also have a user specified name, and generate outputs similar to 1D node features. These points can also be called by different components of the model. For example, OF_nodes are used at the upstream and downstream end of pipes within the 2D mesh.
    - 1DNodes – similar to ICPRv3 Nodes, these features connect 1D specific model elements of storage ponds and channels within the 2D mesh.
- **Line2D** – contains the linear features in the 1D and 2D portions of the ICPRv4 model simulations. The map atlas has these broken into various components by LineType. LineTypes include:
    - Breaklines – Used to form the 2D mesh.
    - Channel – 1D channel centerline elements within the 2D mesh.
    - Pipe – Includes pipes both in the 1D portion of the model and 2D mesh.
    - Weir – Includes 1D weirs placed inline with channel elements in the 1D portion of the model. These are used in this simulation as operating structures and roadway overtoppings.
- **Polygon2D –** contains the polygon features used in the 2D mesh generation as well as to define the extents of the 1D channel and level pool regions. Specific types include.
    - Channel – surrounds channel elements.
    - Ponds – simulates level pools within the 2D mesh.
- **OF_Region –** Defines the extent of the overland flow region and exclusion areas (donut holes) within the 2D model domain. This includes areas such as portions of Tsala Apopka

modeled as 1D and portions of detailed studies surrounded by the 2D region. OF_region types include:

- **Exclusion** – donut holes within a 2D model domain.
- **OF_Region** – Withlacoochee is simulated as a single model region that encompasses the Exclusion areas and are drawn as overlapping features by design.

- **Link Tables –** These include channels, pipes and weirs and contain the data necessary to simulate the 1D elements within the ICPRv4 including.
  - **Link_Channel** – contains the model input data for Channel Links.
  - **Link_Pipe** – contains the model input data for Pipe Links.
  - **Link_Weir** – contains the model input data for weirs.
- **Line2D_pts, OFregion_pts** and **Polygon2D_pts** – the input data for ICPRv4 requires the use of vertex points rather than input lines, so these features are the processed versions of the Line2D, OFregion and Polygon2D features converted to points.
- **Stor_Exclusion** – is the coverage of storage exclusion used in the processing of the stage storage data as to not double count storage areas.
- **SA_Table** – stage storage data for 1D model elements of pond/lakes or channels, outside of channel storage.
- **With_RainGrid –** NexRad Rainfall Grid Cells used over the 2D mesh.
- **RESULTS_LinkTimeSeries** – contains the timeseries data for pipes, weirs, channels and drop structures simulated in the 2D model. This data is related to Line2D feature class by LineID.
- **RESULTS_LinkMax** – contains a table of maximum flow rates from the ICPRv4 model 1D reach elements.
- **RESULTS_NodeTimeSeries** – contains the timeseries data for 1D model nodes and overland flow nodes within the 2D mesh. This data is related to Point2D feature class by Nname field.
- **RESULTS_NodeMax** – contains a table of maximum stages and time to peak from the ICPRv4 model 1D elements and named 2D elements.

- **Vertex2D –** contain all of the vertices created by ICPRv4. This feature has been populated with peak stage at each vertex and it's time to peak.
- **Honeycomb** – contains the sides of the honeycomb representing the 2D mesh "basins" upon which rainfall is converted to runoff and loaded on the Vertex2D mesh nodes.
- **Diamonds** – Features used to define the width of the overland flow element.
- **Mesh2D –** contains the 2D mesh polygon triangles. Note: Flow in the 2D mesh occurs along the side of each triangle.
- **Verification Inundation Shape –** polygon feature created by creating a sloped surface using Vertex2D points with depths greater than 0.25' and intersecting the surface with the DEM.
- **USGS_Gauge** – contains locations of the USGS gauges in the Withlacoochee Watershed.

2.5.4. Geodatabase QC process

As data is parameterized in the GWIS geodatabase, it is reviewed and checked for accuracy against structure source data. Additionally, before an ICPR model is generated from a GWIS geodatabase, the geodatabase is run though a series of review queries for completeness and reality checks. Data flags are reviewed and corrected.

3. Description of Data Acquisition

3.1. Approximate Study Development

The approximate study boundaries cover about 800 square miles of the study area. The objective of these studies was to reasonably represent inflows into the river model from planning units without detailed studies. Maximizing the model accuracy within the allocated project budget required estimating a large number of culverts in the model and then optimizing the locations for which actual field data was obtained. This was accomplished by running a model sensitivity analysis with the estimated culverts to determine which have the largest impact on the river inflow hydrographs.

3.1.1. Field Reconnaissance for Approximate Studies

To the extent possible field work was performed to obtain structure size, material and invert elevations, relative to LiDAR Digital Terrain data, prioritizing the data collection effort to structures closest to the river and those that would have the largest impact on flows into the 2D model domain. In total 237 structures were visited and elevations obtained for inclusion into the model. The remaining structures were approximated based upon nearby structures, observations from imagery, street view Google maps and engineering judgement. To check that flows were not errantly held back in the watershed a sensitivity analysis was run on the structures to determine the change in headloss using the approximated pipe compared to a larger diameter pipe. Those structures that failed the sensitivity test were field measured by SWFWMD staff and structure sizes and inverts were updated based upon the gathered information.

Structures surveyed can be identified by the IsSurveyed field on the HydroJunction Feature Class equalling “Yes”. HydroJunction Feature Class is located in the Approximate Study GWIS located \Geodatabase\Withlacoochee_1D_MiniWMP. Details of the culvert sensitivity evaluation and subsequent field investigation results are located in the digital deliverable in the \TSDN_Report \5_Misc_Ref_Materials\GEN__MiniWMPs\SensitivityStudy\Withlacoochee_Culvert_Analysis folder. **Figure 3-1** shows the location of the 237 surveyed structures and their location relative to the approximate study boundary and the 2D model region.

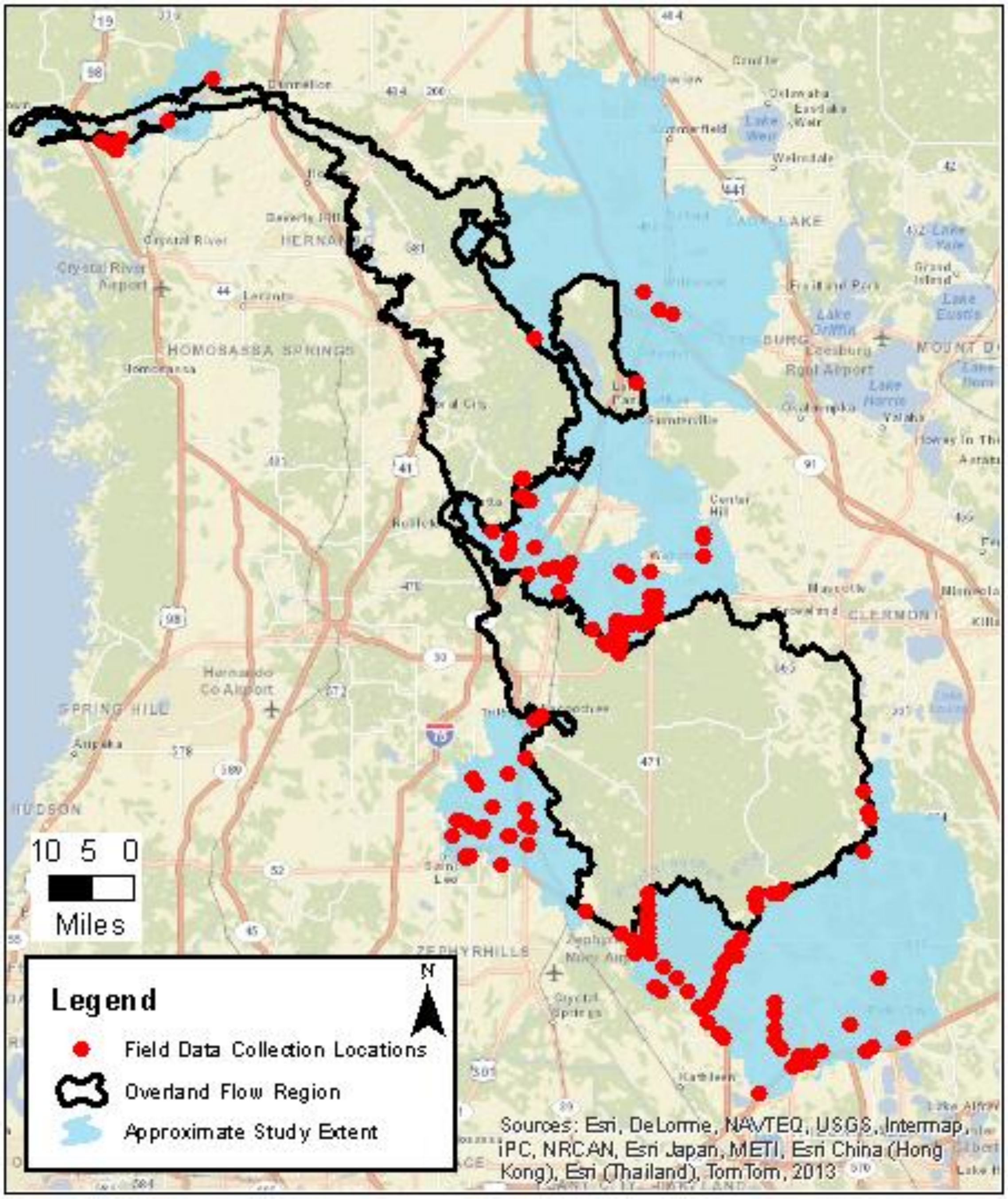

Figure 3-1: Locations of Approximate Study Field Data Collection

3.2. Main River 2D Region

3.2.1. Desktop Evaluation

The focus of the Withlacoochee River Watershed study is primarily to understand how the river corridor responds and reacts over time to hydrological inputs. To this end, the ICPRv4 model simulates the river using a combination of traditional one dimensional model elements and two dimensional elements for the vast overbank marsh areas that make up the Withlacoochee River Corridor. This model simulation will provide a critical understanding of the river and how past and future alterations would impact river conditions. The primary tool used to perform the desktop evaluation is the Digital Elevation Model (DEM) developed for the entire Withlacoochee Watershed. Processing this terrain and combining the results with other available information leads to an understanding of morphology of the river as it transitions from one segment to another. Withlacoochee River segmentation was discussed in Section 2.1.3. Other relevant data to the desktop process included:

- High resolution aerial photographic imagery
- Historic modeling of the Withlacoochee River
- The US Army Corps of Engineer's (USACE) Withlacoochee River Basin Feasibility Study
- Topographic data collection efforts that have been conducted by the SWFWMD.
- Data on locations of rock shoals and other river hydraulic control points collected by SWFWMD
- Data from the SWFWMD's Watershed Management Plans, completed or in progress, including computer modeling data
- Construction plans for FDOT and County roads
- FEMA regulatory floodplain map
- Tetratech photo index (included as part of the USACE river study)
- 1984 USACE soundings along the river main channel
- Construction plans for the existing control structures
- Historic Withlacoochee nodal diagram
- NHD hydro –inflows evaluation

- Map of Groundwater Recharge Zones
- USGS gauging data
- SWFWMD compiled high water marks

Each river reach was analyzed to identify hydrographic features relevant to the development of the ICPRv4 hydraulic computer model including: channel delineations, control points, conveyance ways, and storage locations. In addition, the evaluation focused on the identification of hydrographic survey and locations of inflow points to the main river from adjacent contributing basins. The hydrographic survey needs focused on development of the bare earth digital topography of the watershed and corresponding DEM that was subsequently used to define computer model input parameters. The inflow points were matched to contributing drainage areas, and were used as input to the river hydraulic model.

3.2.2. River Reach Field Investigations

From the desktop evaluation, 131 areas including 53 river control points and 91 cross sections were identified and physically visited in the field, either by car, foot, canoe, airboat or helicopter. Results of the field investigation are included in the Watershed Evaluation Report and database located in the digital deliverable in the \Reports\Watershed_Evaluation folder

3.2.3. River Profile Survey

In 2008, Morgan & Eklund, Inc., conducted a profile survey of approximately 80 miles of the Withlacoochee River from US 301 through Lake Rousseau. This effort included bridge surveys of Brown Bridge in the Green Swamp, CR 47, CR 48, CR 470, CR 476, CR 575, SR 44, SR 200 and SR 471. Digital results are included in the deliverable in the TSDN \5_Misc_Ref_Materials\GEN_RiverSurvey\Morgan_Ecklund folder. Data from the survey was used to generate bottom profile of the river and update the Withlacoochee Basin DEM. An example of point density of the profile survey is seen at SR 44 in **Figure 3-2** and resulting bathymetry updates for Silver Lake at I-75 is shown pre and post survey in **Figures 3-3** and **3-4** respectively.

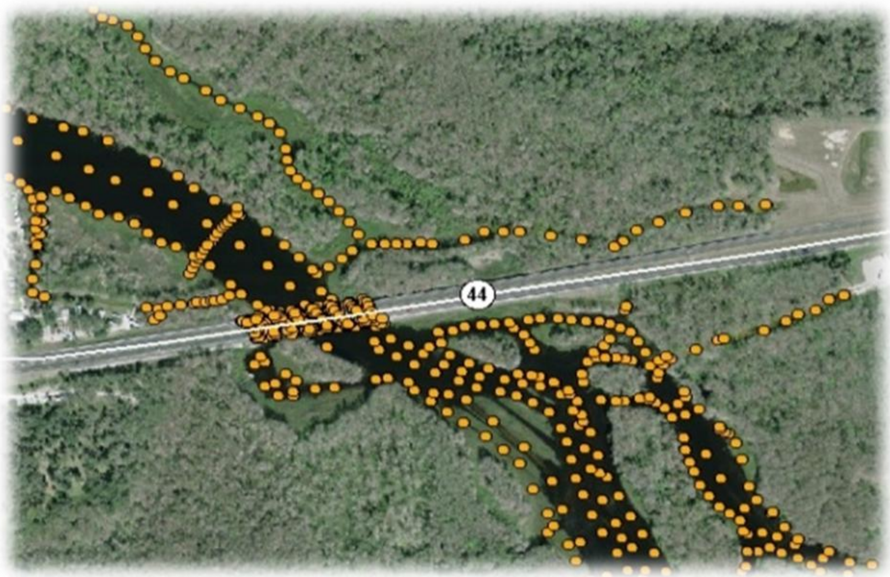

Figure 3-2: River Profile Survey Point Density

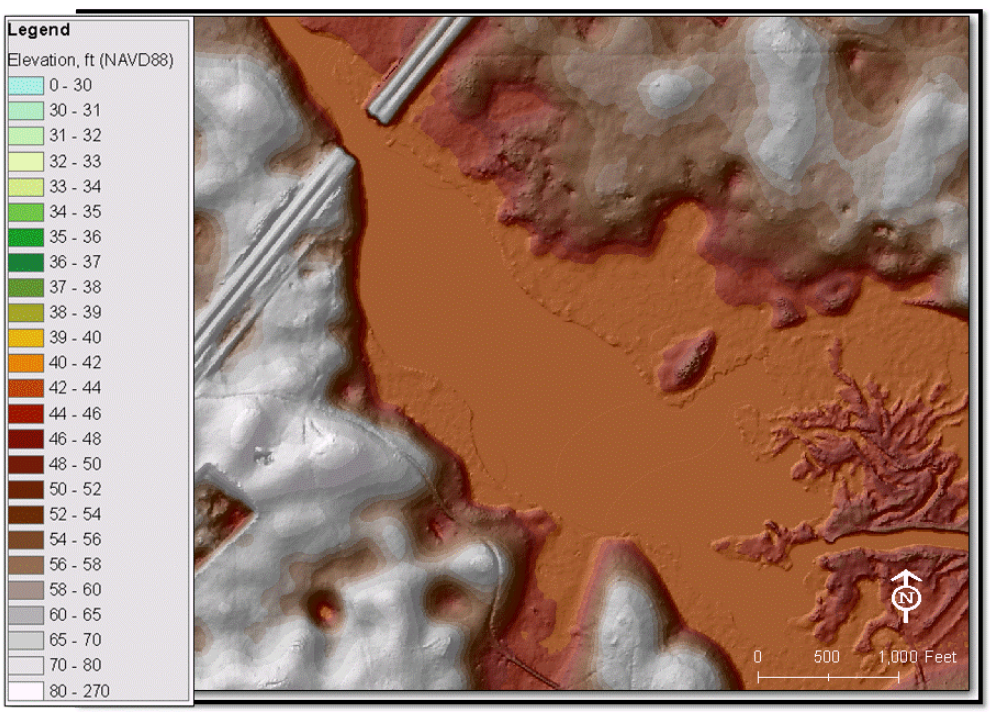

Figure 3-3: Silver Lake DEM prior to Bathymetric Survey

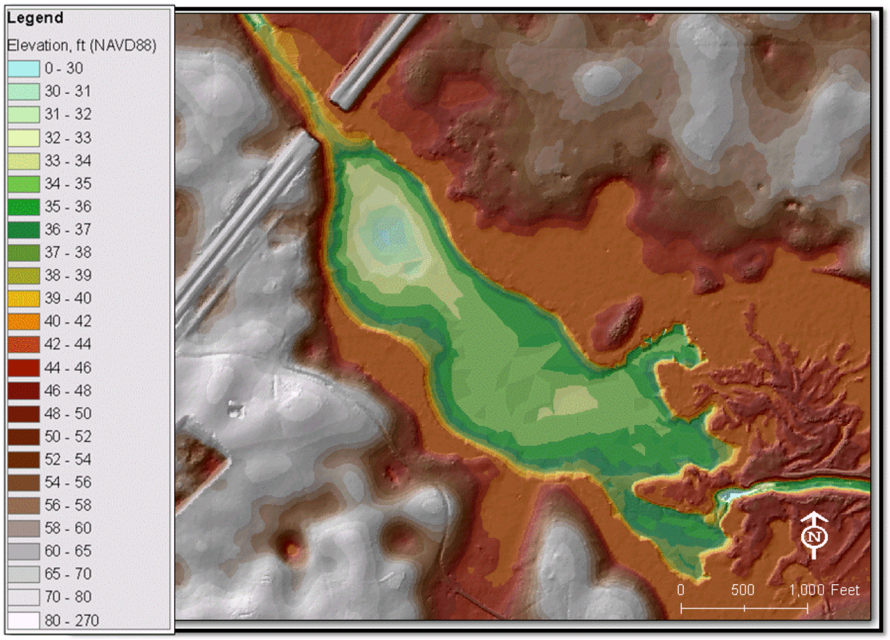

Figure 3-4: Silver Lake Bathymetry Update (Hernando County)

3.2.4. SWFWMD Control Structure Profile information

The Withlacoochee River and Tsala Apopka Chain of Lakes represent a natural system, altered by man to optimize the storage and movement of water to achieve beneficial uses of the water features. The main control of these alterations is through water conservation and control structures. Within the 2D model domain and the immediate surrounding area, there are 17 control structures relevant to model inflows and movement of water throughout the Withlacoochee River and Tsala Apopka Chain of Lakes. The structures shown in **Figure 3-5** include two structures in Sumter County along the Gant Lake outfall; three structures along the Withlacoochee River and Lake Rousseau and 12 adjacent to and within the Tsala Apopka Chain of Lakes. The following subsections show images of each of the control structures progressing hydrologically from south to north and a brief description of each.

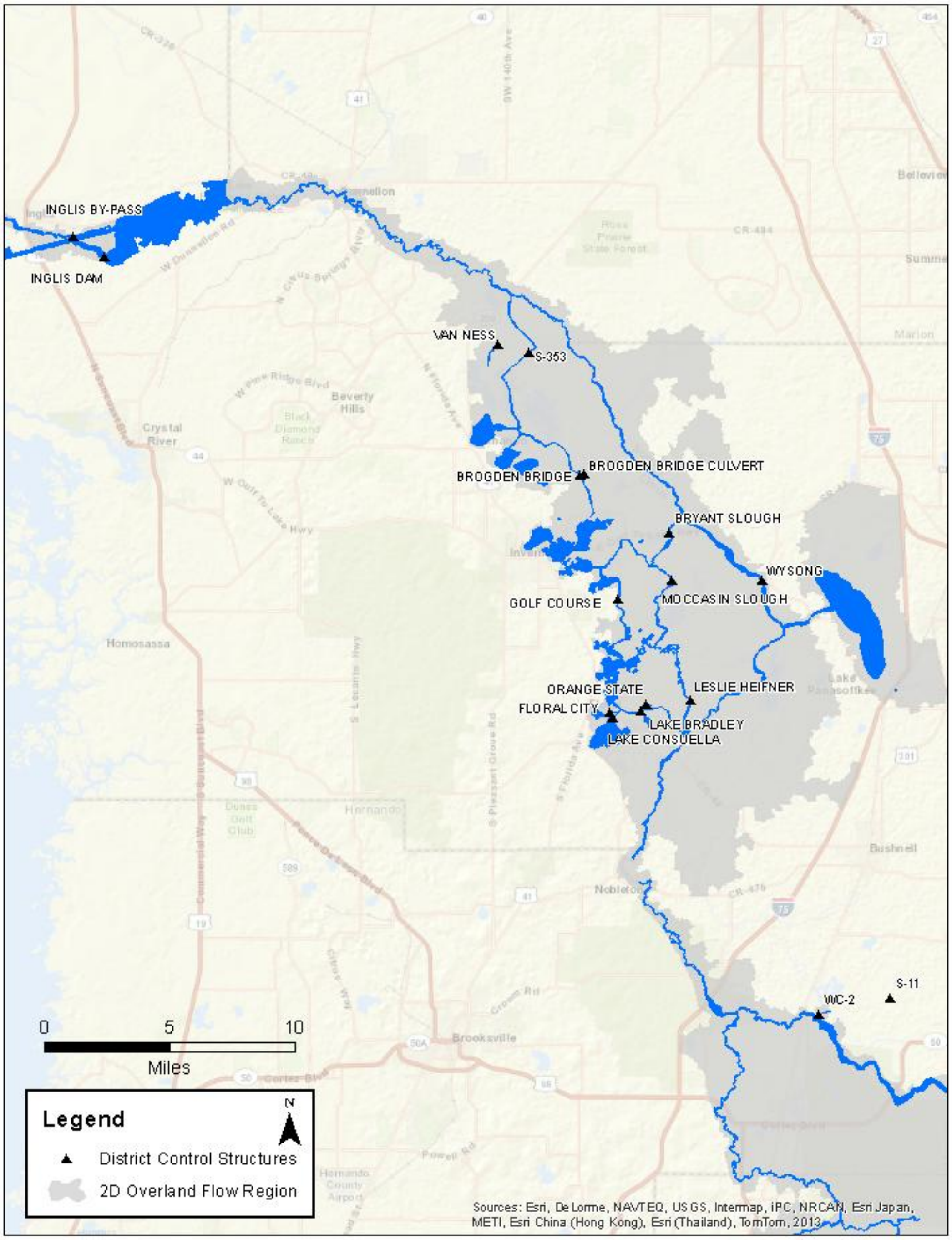

Figure 3-5: SWFWMD Control Structures along the Withlacoochee River

3.2.4.1. SWFWMD S-11 Structure

The water level in Big Gant Lake, in Sumter County is controlled by the S-11 structure. This structure, seen in **Figure 3-6**, has a design capacity to pass 600cfs. The structure consists of a sheet pile spillway controlled by three adjustable crest weir gates. The structure was originally built in 1970 and recently rebuilt to include operable gates in 2012. The structure is normally maintained in the fully closed position (gates fully up), and operated to maintain the established minimum water level of 74.96 ft NAVD88.

Figure 3-6: SWFWMD S-11 Structure

3.2.4.2. SWFWMD (WC-2) Structure

The WC-2 structure pictured in **Figure 3-7** is located on the Gant Lake outfall canal, it was originally constructed along with the S-11 structure in 1970 to maintain water flow from Big Gant Lake into the Little Withlacoochee River. The structure is configured with four radial gates 18ft x 5ft with a 3 ft face plate. This structure is operated in conjunction with the S-11 structure.

Figure 3-7: SWFWMD WC-2 Structure

3.2.4.3. SWFWMD Lake Bradley Structure

The Lake Bradley structure in Citrus County connects Lake Bradley to the Floral City Pool. The structure is used to maintain water levels in Lake Bradley and facilitate recreation and recharge. The structure consists of a single 5' x 4' weir gate pictured in **Figure 3-8**. The gate is normally kept in the fully closed position and mainly operated to fill up Lake Bradley when water levels in the Floral City Pool exceed those in Lake Bradley.

Figure 3-8: SWFWMD Lake Bradley Structure

3.2.4.4. SWFWMD Lake Consuella Structure

The Lake Consuella structure seen in **Figure 3-9** consists of a single 30” culvert with a bay with stop log slots that enable control of Lake Consuella higher than the invert of the culvert. Operation of the structure is to maintain water levels within Lake Consuella while also having the ability to bleed down the lake during flood events or in preparation of a flood event.

Figure 3-9: SWFWMD Lake Consuella Structure

3.2.4.5. SWFWMD Leslie Heifner Structure

The Leslie Heifner structure is constructed as a sheet pile water conservation structure with a 14’ x 9’ vertical lift gate, pictured in **Figure 3-10**. The structure was originally constructed by Citrus County in 1967. The structure is one of two main flow ways for water to enter the Tsala Apopka Chain of Lakes. The structure is normally operated in the fully open position for navigation when the river is higher than the Floral City Pool. During flood events or when the pool is higher than the river, this structure is closed. For high and low water events, the gate may be closed to either keep water from leaving the lakes or to prevent flooding conditions should the chain of lakes be full during high flow conditions in the Withlacoochee River.

Figure 3-10: SWFWMD Leslie Heifner Structure

3.2.4.6. SWFWMD Orange State Structure

The Orange State structure, pictured in **Figure 3-11**, consists of a 48" CMP with half pipe riser and weir boards connected to the upstream (Withlacoochee River end) of the culvert. It was constructed in 1966 to prevent localized flooding from the Orange State Canal into the Withlapopka Island wetlands, inside the Tsala Apopka Chain of Lakes immediately downstream of the Orange State culvert. This structure is manually operated when necessary.

Figure 3-11: SWFWMD Orange State Structure

3.2.4.7. SWFWMD Floral City Structure

The second main structure enabling water to pass between the Withlacoochee River and the Tsala Apopka Chain of Lakes is the Floral City structure constructed in 1959, which is operated in similar manner as the Leslie Heifner structure to allow recreation, mitigate Tsala Apopka Pool flooding, and retain water during low water conditions. The structure pictured in **Figure 3-12** consists of a single 14’ x 7’ lift gate sitting on a concrete pad.

Figure 3-12: SWFWMD Floral City Structure

3.2.4.8. SWFWMD Golf Course Structure

The Golf Course structure, pictured in **Figure 3-13** consists of four steel drop crest control gates. The structure originally constructed in 1965 has since been modified from its original stop log control to be an operable control gate. The structure is operated to maintain water levels within the Floral City and Inverness Pools and mitigate flooding. This structure is operated in conjunction with the other main control structures enabling the flow of water through the Tsala Apopka Chain based upon a SWFWMD operational guidance. Given the different conditions of the pools, , the structures are operated accordingly. For example, during fill mode, when water is entering the Floral City Pool through the Leslie Heifner or Floral City structures, the water is proportionally divided between the three pools equally. Similarly, during drain mode, structures in the chain are operated together to proportionally reduce flooding.

Figure 3-13: SWFWMD Golf Course Structure

3.2.4.9. SWFWMD Moccasin Slough Structure

The second outlet between the Floral City Pool and the Inverness Pool in the Tsala Apopka Chain of Lakes is the Moccasin Slough structure, pictured in **Figure 3-14**. This structure was constructed as a concrete bridge with wooden deck. It is configured as two fixed crest weir openings that measure12' x 1' and a center lift gate that measures 12' x 7'. The Moccasin Slough structure is operated in parallel with the Golf Course structure to maintain water levels in the Floral City and Inverness Pools.

Figure 3-14: SWFWMD Moccasin Slough Structure

3.2.4.10. SWFWMD Bryant Slough Structure

The Bryant Slough structure, which is located downstream of the Moccasin Slough structure, is pictured in **Figure 3-15**. The Bryant Slough structure serves as an outlet from the Inverness Pool and connects to the Withlacoochee River downstream of the Wysong-Coogler Water Conservation Structure. The structure, which is attached to two FDOT box culverts under SR 44, was originally constructed in 1953, with replacements being installed in 1968, 1973 and 1977.

Figure 3-15: SWFWMD Bryant Slough Structure

3.2.4.11. SWFWMD Brogden Bridge Culvert Control Structure

The Brogden Bridge Culverts under East Turner Camp Road are configured with stop logs on the upstream side as pictured in **Figure 3-16**. The track assembly can hold up to six logs and is operated only during normal water conditions. During flooding conditions, all logs are put in place, effectively closing off the structure. Water between the Inverness pool and Hernando Pool is then funnelled to the Brogden Bridge 0.2 miles west of the culverts on E. Turner Camp Road.

Figure 3-16: SWFWMD Brogden Bridge Culvert Control Structure

3.2.4.12. SWFWMD Brogden Bridge Structure

The Brogden Bridge structure, seen in **Figure 3-17** is the main control of water between the Inverness and Hernando Pools and is operated to maintain water levels in both pools. The structure is operated along with Golf Course, S-353 and the others in the Tsala Apopka Pools to facilitate water movement and storage during high and low flow conditions accordingly. The structure consists of two 75 inch lift gates operating as overflow weirs.

Figure 3-17: SWFWMD Brogden Bridge Structure

3.2.4.13. SWFWMD Van Ness Structure

The Van Ness structure is configured as a single lift gate measuring 14’ x 6’ with a maximum gate opening of 4.5’. The structure, pictured in **Figure 3-18**, connects the Hernando pool to a flowpath towards Two Mile Prairie and ultimately Jordan Sink, a direct connection to the Floridian Aquifer. It is operated during flood events as a first primary outfall for floodwaters to recharge the aquifer rather than flowing down to the Gulf of Mexico through the S-353 structure.

Figure 3-18: SWFWMD Van Ness Structure

3.2.4.14. SWFWMD S-353 Structure

The SWFWMD S-353 structure picture in **Figure 3-19**, consists of four 14' x 4' vertical lift gates. The structure located along the C-331 canal, was originally built by the Army Corps of Engineers in 1968 and after construction control was transferred to the SWFWMD. The construction of the C-331 outfall canal served to reroute outfalls from the Hernando Pool to the Withlacoochee River just upstream of SR 200. The structure is used, as with the others in the Tsala Apopka chain to maintain optimum resource management lake levels. During flooding events, such as the Hurricane season of 2004, the structure was used to discharge water from the Tsala Apopka Chain, once operational staff determines that the capacity of discharges through the Van Ness Structure are insufficient to manage water levels.

Figure 3-19: SWFWMD S-353 Structure

3.2.4.15. Wysong-Coogler Water Conservation Structure

Along the Withlacoochee River, adjacent to the Tsala Apopka Chain of Lakes, is the Wysong-Coogler Water Conservation structure, seen in **Figure 3-20**. The structure installed in 1963, was removed from the river in 1988 and replaced in 2002. The structure is a 250 foot wide dam consisting of a pivoting metal plate supported by an inflatable rubber bladder. The structure is operated to hold water in the marsh upstream of the structure and back into Lake Panasoffkee. The structure is regulated to maintain water levels upstream at 39.5 feet NGVD, when water exceeds this level, it is progressively lowered to maintain water levels.

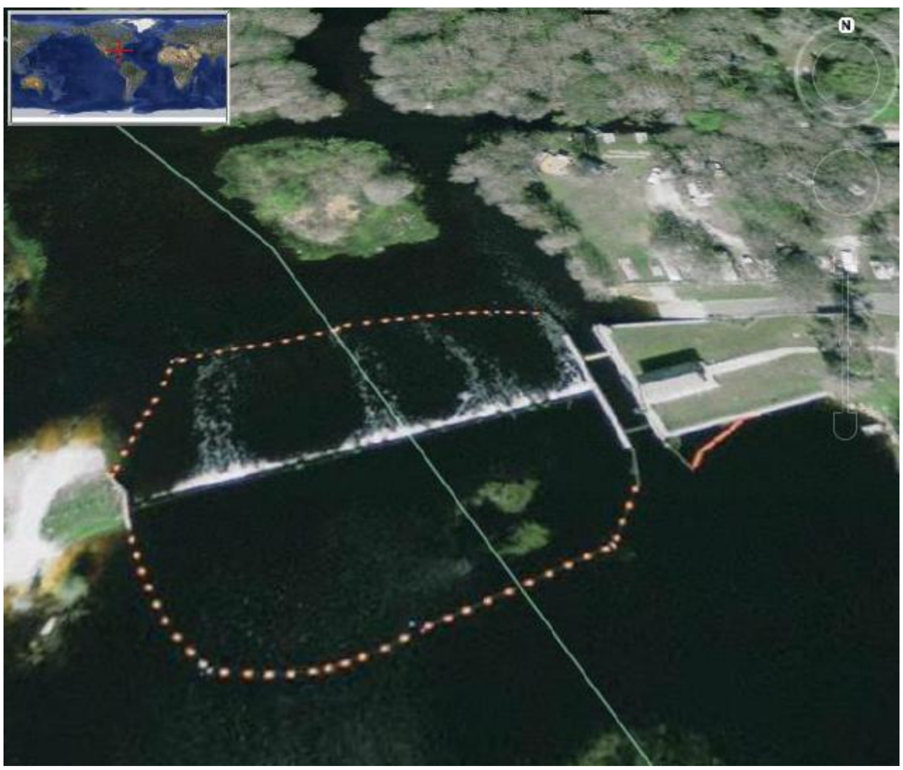

Figure 3-20: Wysong-Coogler Water Conservation Structure

3.2.4.16. SWFWMD Inglis Main Dam

The Inglis Main Dam spillway is a two-bay gated control structure with an ogee spillway, seen in **Figure 3-21**. Each bay contains a 40’ wide x 16.7’ vertical lift gate. The Dam, constructed in the 1960s as part of the Cross Florida Barge Canal project, replaced an original fixed spillway that was constructed in 1909, which originally created Lake Rousseau and served as a source of hydroelectric power, an operation that ceased in 1965. The Dam currently operates as a secondary option to maintain a water level in Lake Rousseau below 27.0 ft NAVD. It is operated once the capacity of the Inglis By-pass canal control structure reaches its capacity. Combined with the By-pass structure, the Inglis Main Dam discharged more than 6,000 cfs during the 2004 hurricane season.

Figure 3-21: SWFWMD Inglis Main Dam

3.2.4.17. Inglis By-Pass Structure

The Inglis By-Pass structure out of Lake Rousseau, maintains a freshwater discharge into the historic Withlacoochee River to prevent saltwater intrusion and is the primary water level control for Lake Rousseau. The structure seen in **Figure 3-22** consists of two vertical lift gates 14' x 7' each. The Inglis By-Pass Structure was originally constructed between 1965 and 1969 as part of the Cross Florida Barge Canal project severing the connection of the historic Withlacoochee River from the discharge downstream of the Main Gate, replaced by a straight barge canal.

Figure 3-22: SWFWMD Inglis By-Pass Structure

3.2.5. SWFWMD data collection

As an integral project partner, SWFWMD provided additional survey data and access to survey data collected as part of SWFWMD projects. Data collected by SWFWMD relevant to the 2D modeling included the profile of the Withlacoochee River in the Green Swamp and through the dense reaches of its headwaters; survey bottom elevations of the lakes, canals and marshes of Tsala Apopka; and the bathymetric survey of Lake Panasoffkee. Each of these pieces played a critical role in the project understanding or model calibration process, enabling the accurate simulation of hydrologic conditions on the river.

3.2.5.1. SWFWMD Green Swamp Profile

Supplementing the work by Morgan & Eklund, Inc., SWFWMD staff used similar procedures in 2007 and 2008 to gather channel profile elevations along the centerline of the river for 40 miles through the Green Swamp and downstream to US 301. Much of this portion of the river was dry during this effort and was traversed by foot. The path and points collected by the SWFWMD are presented in **Figure 3-23**. Field notes and photographs taken along the flow path are provided in the digital deliverable in the TSDN_Report\5_Misc_Ref_Materials\GEN_RiverSurvey\SurveyData\HydroSurvey_SWFWMD_GWIS sub folder.

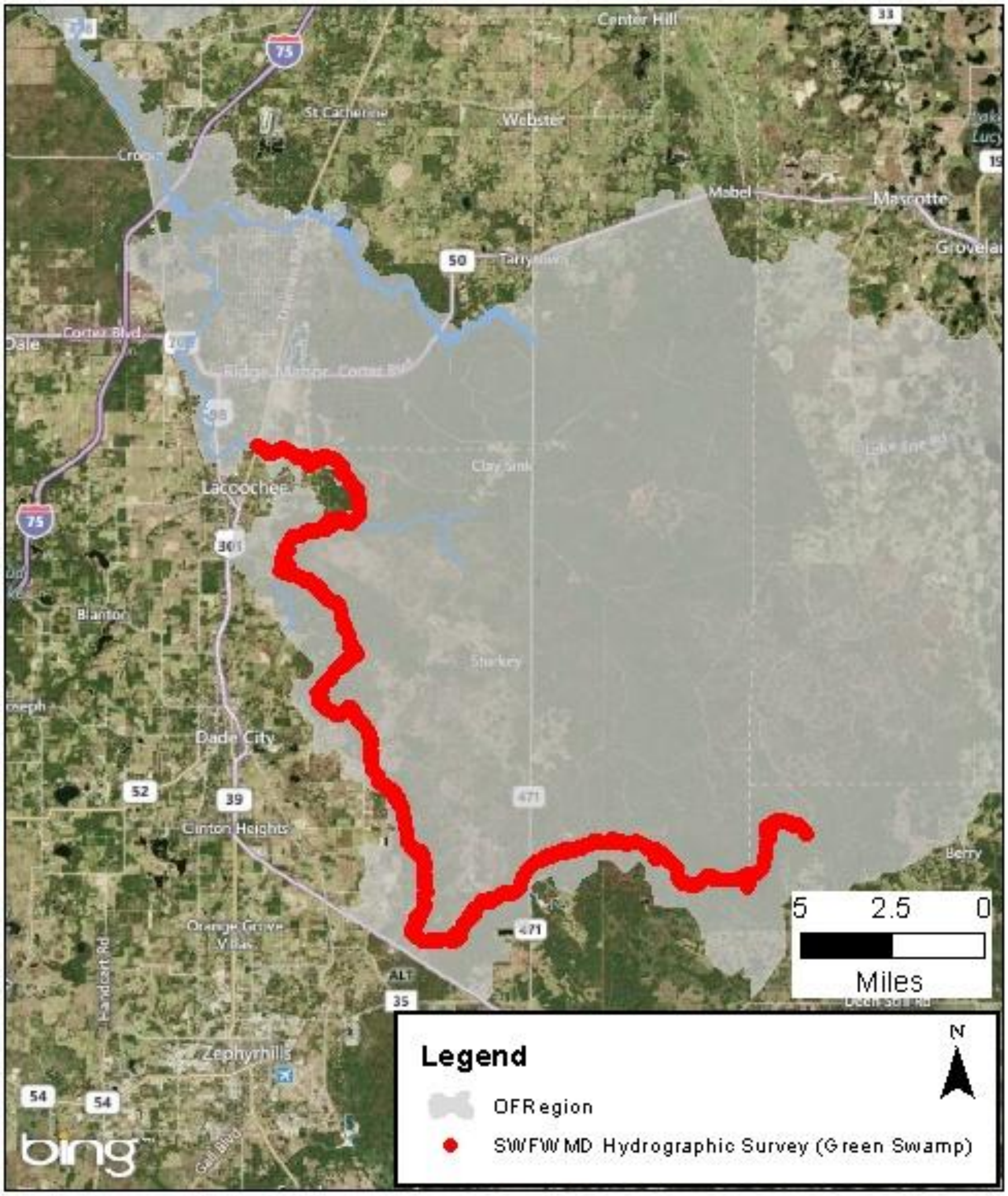

Figure 3-23: SWFWMD Hydrographic Survey (Green Swamp)

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3.2.5.2. Updates in Tsala Apopka

During the model calibration process, it was noted that the LiDAR data representing bare earth topography in marsh areas were not consistent with field observations in the field. This was specifically true in the marsh areas between the lakes adjacent to canals. In these areas, dense emergent vegetation masked the signature of an open water feature and LiDAR data was collected while they were inundated, thus true bottom elevations were not reported in the available topography. To update the LiDAR in these areas, a hydrographic survey was performed jointly between the SWFWMD and Atkins. The extents of the survey are shown in **Figure 3-24**.

The survey revealed that individual marsh areas had fairly consistent depths of water before natural ground was reached. To update the DEM a combination of marsh polygons, survey points, and breaklines (created from survey points) were used to create a replacement digital terrain for the area. An example of the resulting DEM with and without the update is shown in **Figure 3-25**. The green color in the image on the left represents the vegetated marsh elevation according to the LiDAR, whereas the image on the right represents the resulting DEM following the update with blue and purple colors representing the actual ground topography within the marsh. Enhanced LiDAR points representing the updated area and features collected in the field and generated to create the updated DEM are included in the digital deliverable in the \DTM\Enhanced_LAS folder.

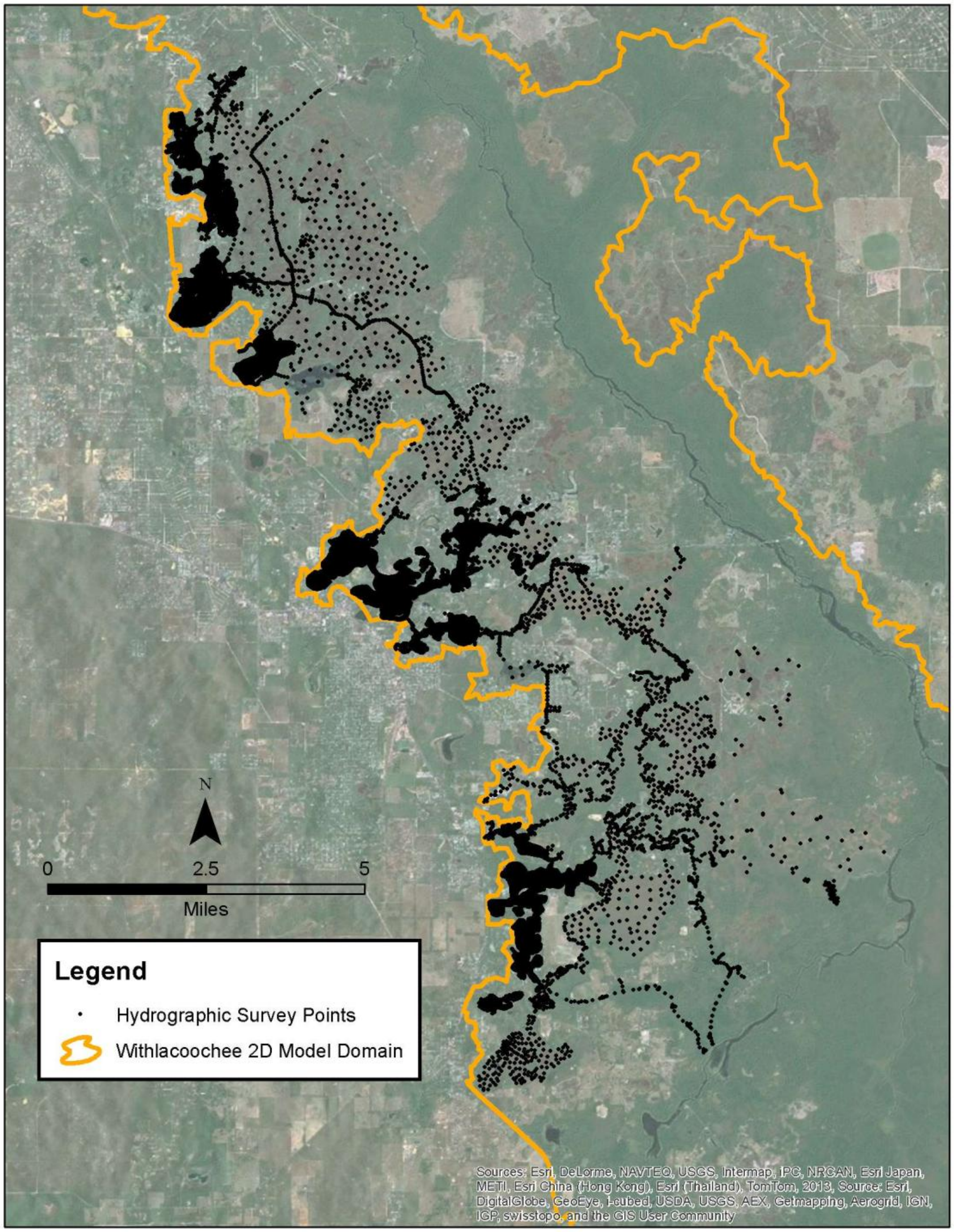

Figure 3-24: SWFWMD and Atkins Hydrographic Survey of Tsala Apopka Marsh

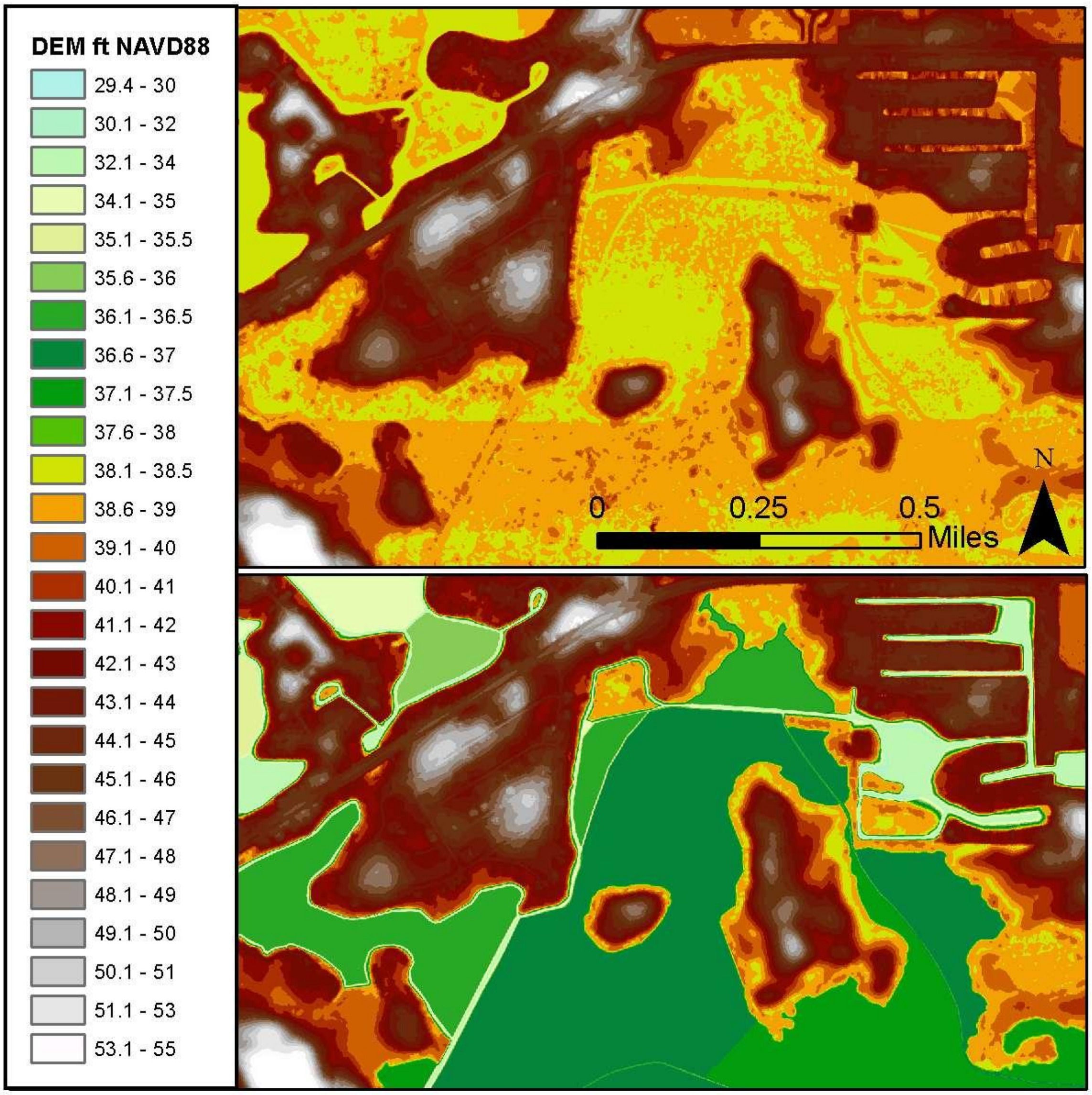

Figure 3-25: Tsala Apopka Marsh Survey - Pre / Post DEM

3.2.5.3. Lake Panasoffkee Bathymetric Mapping Project (W476)

Areas along the open water portion and centerline of the Panasoffkee Outlet, Big Jones Creek, and Little Jones Creek were surveyed using RTK/GPS survey techniques following USACE manual for Hydrographic Surveys EM110-2-1003. Data from the survey was used in conjunction with other data collected by SWFWMD in the marsh areas to generate an updated DEM for the Withlacoochee River Watershed in that area. The extent of the bathymetric data collected is seen in **Figure 3-26**.

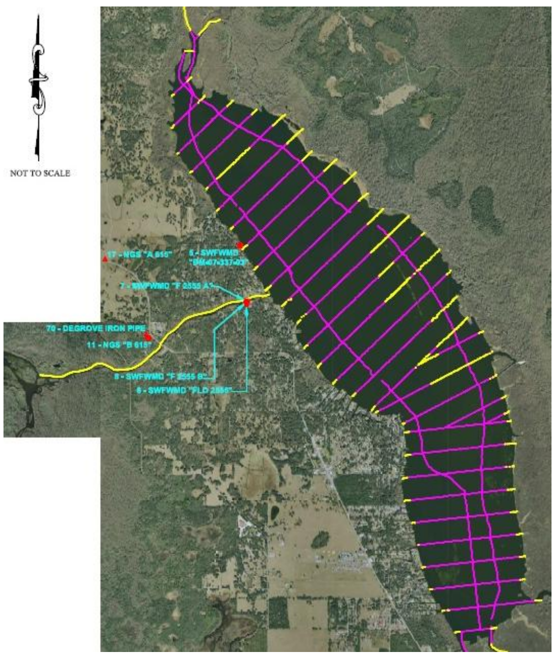

Figure 3-26: Lake Panasoffkee Bathymetric Survey

3.2.6. Culverts in the Green Swamp

The area modeled by ICPRv4 2D mesh in the Withlacoochee portion of the Green Swamp contains mostly land managed by either the SWFWMD or the Florida Division of Forestry (DOF). The DOF and SWFWMD have GIS coverages showing the locations of culverts within the land they manage with data fields to indicate culvert information such as size and material. Reviewing the data unfortunately showed many gaps in the data set. The data that was present combined with limited field work showed that the pipe material (CMP) was fairly standard along with roadway cover (1 – 1.5' below dirt road) as well as size (24" typical). These estimates were then used to fill in data gaps for material, inverts, and diameter. **Figure 3-27** shows the location of the 388 SWFWMD land culverts and the 90 DOF culverts in the proximity of the 2D region.

State Road 471 cuts through the Green Swamp and includes 79 roadway crossings for water to naturally flow down the slope of the Green Swamp from East to West, including major crossings at the Withlacoochee River, Gator Creek, Devils Creek and the Little Withlacoochee River. The culvert information was available through SR 471 plans and field recon with locations of each crossing down the center of the figure shown in red on **Figure 3-27**.

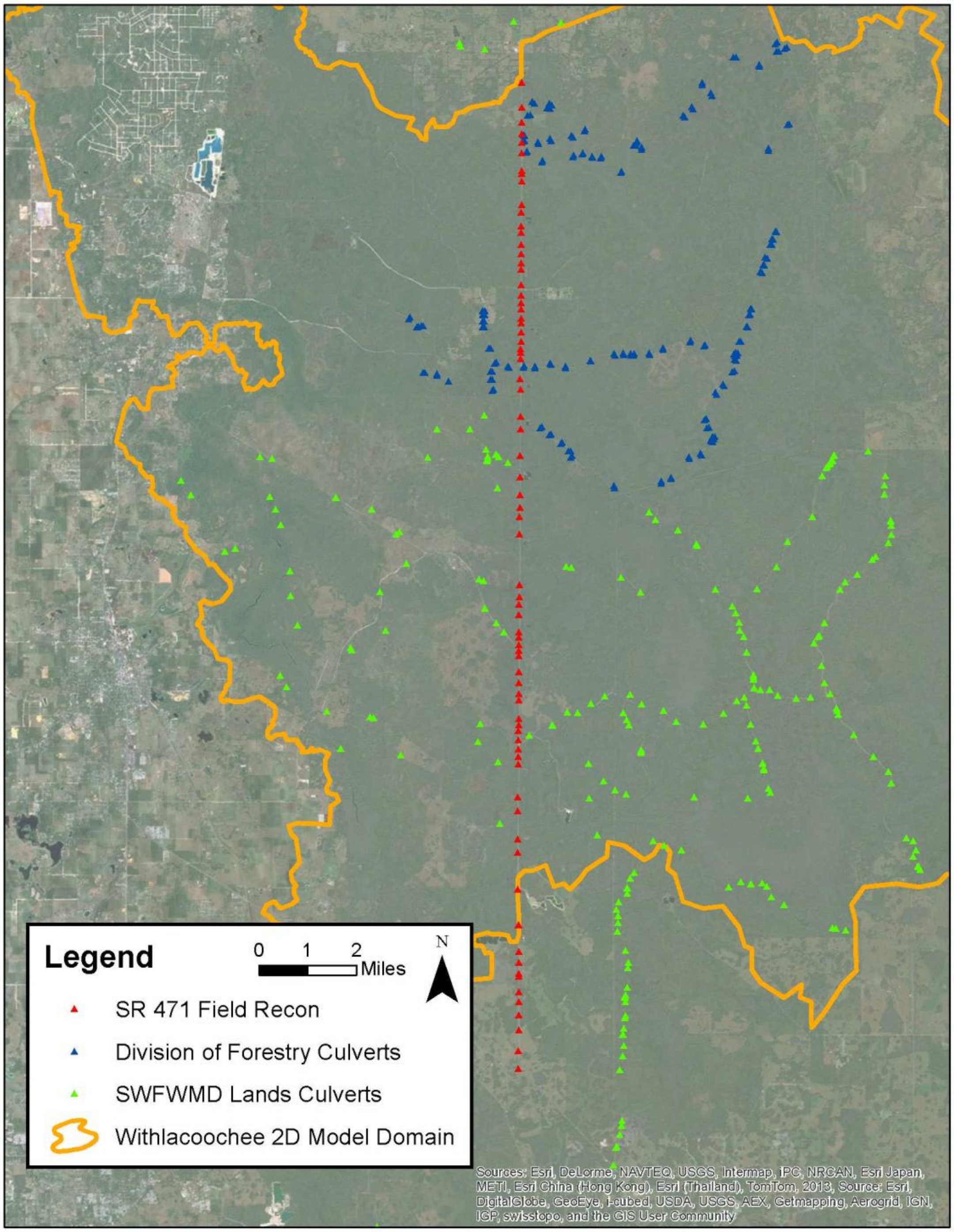

Figure 3-27: SR 471 Field Recon and SWFWMD Land Culverts

4. Watershed Model Development

This section describes the development and verification of the Withlacoochee River 2D model and the generation of its inflows. The 2D model domain covers approximately 600 square miles including the 150 mile long Withlacoochee River corridor, the Green Swamp, Tsala Apopka Chain of Lakes, East Citrus-Tsala Apopka detailed study, Lake Panasoffkee, Lake Rousseau, and the Little Withlacoochee River. Inflows into the 2D model from watershed planning units include both 800 square miles of detailed watershed management plans developed and approved by the SWFWMD and an additional 700 square miles of approximate studies developed as part of this project. The extents of modeling of the detailed studies, approximate studies and the 2D model domain are shown in **Figure 4-1.**

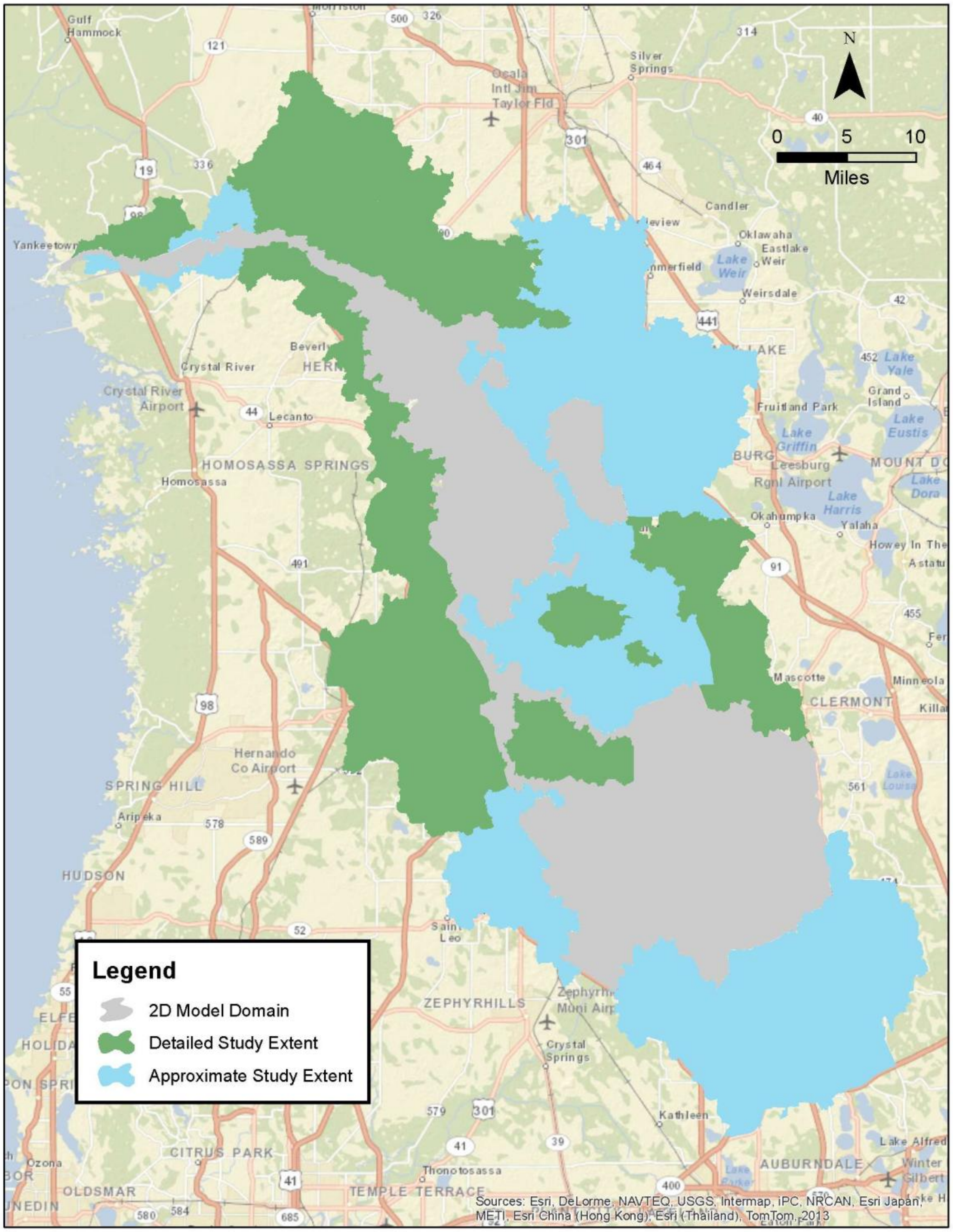

Figure 4-1: Extents of Detailed Studies, Unscheduled Planning Units and 2D Model Domain

4.1. Hydrologic and Hydraulic Model Development

4.1.1. Model selection

4.1.1.1. Inflow Models – or contributing watershed

The detailed study inflow models were developed using the ICPRv3 Model version 3.1 service pack 10 (ICPRv3). For consistency, the approximate study models were also developed using ICPRv3, generating the input files from ArcHydro and SWFWMD developed tool sets for model parameterization and data storage in the SWFWMD GWIS format.

4.1.1.2. River Corridor Model

The ICPRv4 model version 4.00.00 was used to generate the 2D model domain which simulated the river corridor and the wide expanse of the flood way including the Green Swamp, the Tsala Apopka Chain of Lake, Lake Panasoffkee and Lake Rousseau through to the Gulf of Mexico.

The ICPRv4 model contains a combination of hydraulics and hydrology and simulates both traditional one dimensional model elements of channels, pipes, weirs, drop structures, as well as, two dimensional elements. Within the two dimensional area the model uses a finite volume approach to track flow, and utilizes a triangular flexible mesh to characterize and discretise the terrain. The mesh is connected to and passes flow between one dimensional and two dimensional elements.

The model was selected in conjunction with the SWFWMD as the most appropriate tool for simulating the Withlacoochee Watershed in that it enables extended detail where it is needed and enables a more expansive mesh where homogeneous ground conditions exist. Also, given the extreme flow regimes in the Withlacoochee River, the use of ICPRv4 enables simulating both one dimensional flows for low flow conditions and expansive two dimensional flows during high water conditions. As of the writing of this report, ICPRv4 has expanded to include a groundwater module, which is a critical element in the understanding of long term simulations in the future, particularly of water coming into and out of the Green Swamp. This verified model, designed to run single events or a single season is sufficient as a surface condition only model.

4.2. Hydrology

4.2.1. Verification Rainfall Event

A verification event in a watershed should be a storm of recent memory and provide a tangible linkage between model simulated results and actual flood extents along the river. The event should be of significant magnitude and should take place during a typically wet time of the year. Candidates for the verification event for the Withlacoochee River corridor included, one of the hurricanes in 2004, events in the summer of 2005, a winter event in 2006, or the events in July 2009. The Withlacoochee River water level at Nobleton is shown between 2004 and 2009 as **Figure 4-2**. Each of the candidate events are seen in this figure which is fairly representative of all gauges along the river during this time period. Logistically, the 2006 single event was the most straight forward event to simulate, in that it had a sharp rise in stream elevation in response to a rainfall event then a recession limb without much interference from other significant events over the next month. The event in 2006 however was not as large as the peak flow conditions experienced on the river after Hurricane Jeanne in 2004, which produced eight times as much flow as the 2006 storm. The difficulty with simulating Hurricane Jeanne was in setting the initial conditions, which were already at design levels throughout the watershed as the result of Hurricanes Charley and Frances. Similarly, simulating either of the first two hurricanes would not have captured the peak stage related to the entire 2004 hurricane season and thereby inconsistent with observed high water marks. Also, neither the 2005 nor the 2009 event reached the watershed peak stages seen in 2004. Thus, given the size of the Withlacoochee River Watershed and the observed flow regime of a quick river rise, followed by a long recession curve, the choice of simulating the entire hurricane season in 2004 was chosen. This entire event captured the full range of storm dynamics starting at low flow conditions with multiple peaks from Hurricanes Charlie, Frances and Jeanne followed by a complete recession limb.

According to NexRAD grid cells the events accumulated approximately 27 inches of rain over a 4 month verification simulation period, between August 4th, 2004 and November 24th, 2004. Flow hydrographs are shown in **Figure 4-3** at various stations in the watershed over this period, showing low flow conditions, multiple storm peaks and a delayed recession limb.

For ICPRv3 models, GIS tools developed by ESRI in conjunction with the SWFWMD were used to generate basin specific rainfall files for each subbasin in both the detailed planning unit models and the approximate studies. In contrast, ICPRv4 only requires the Next-Generation Radar (NexRAD) grid, soils and land use to generate runoff. NexRAD 2 km grid cells imported into ICPRv4 are shown in **Figure 4-4**.

Figure 4-2: Stage Record - Withlacoochee River at Nobleton (2004 - 2009)

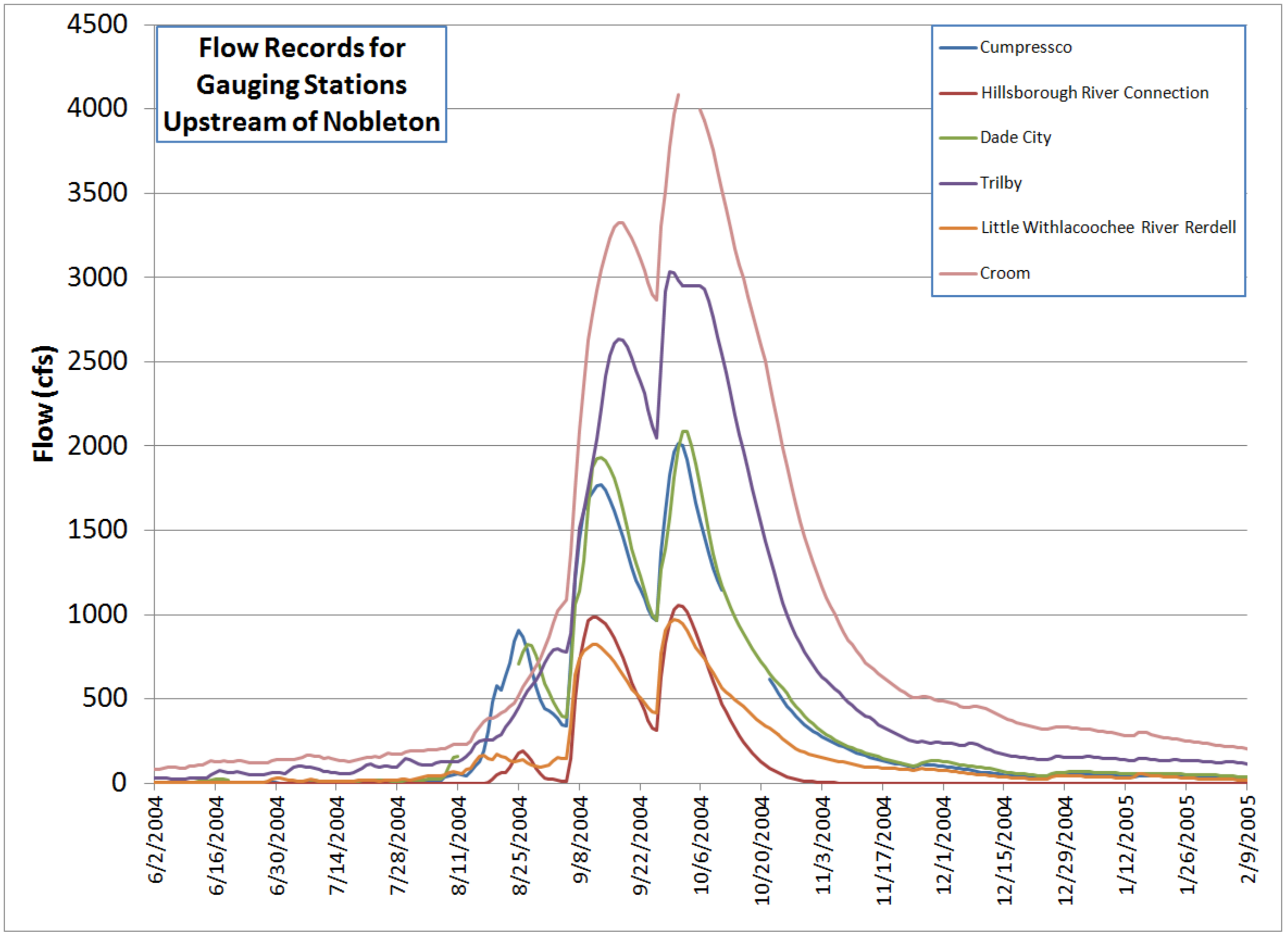

Figure 4-3: Representative USGS Flow Gauges during the Hurricane Season of 2004

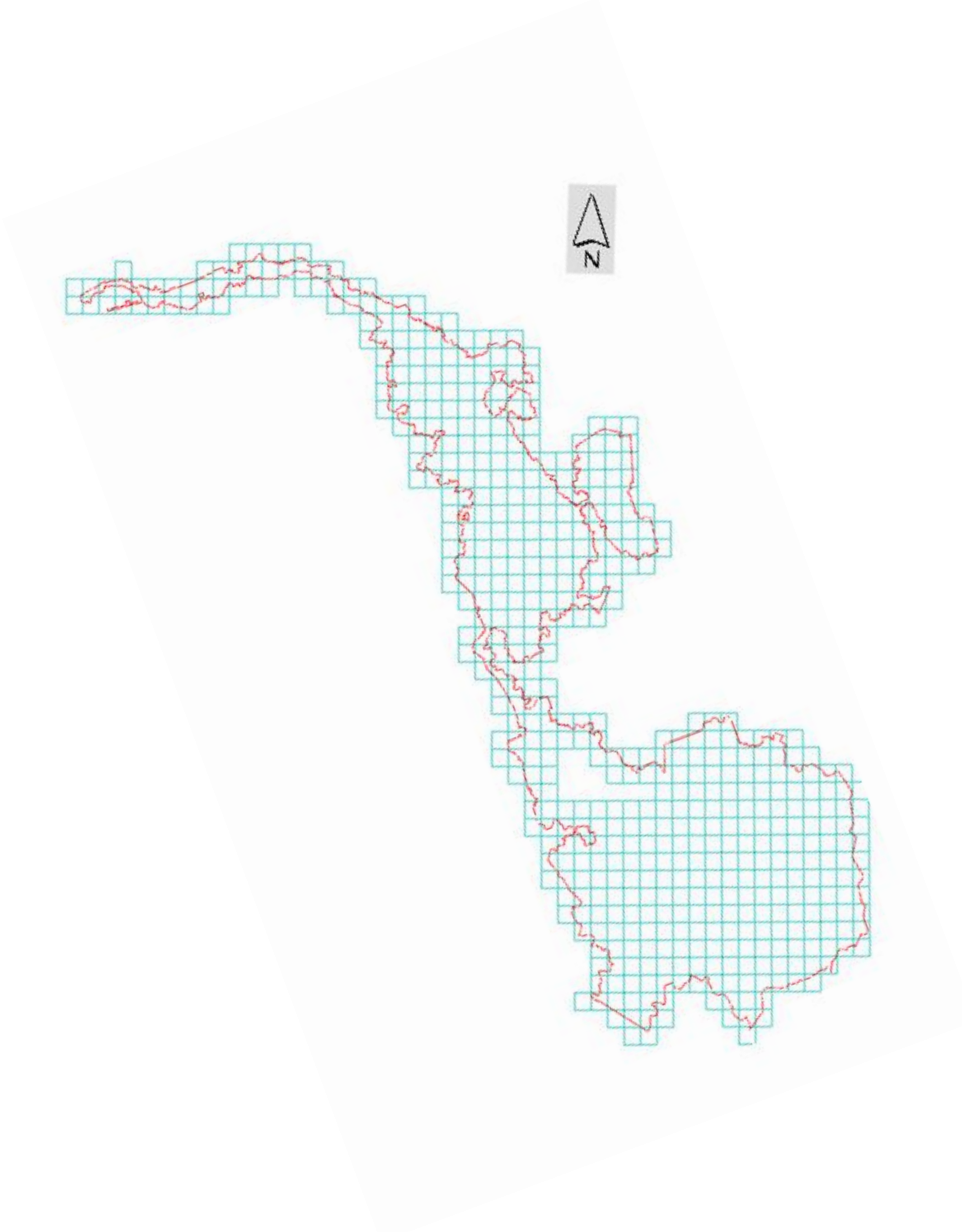

Figure 4-4: NexRAD Grid Cells Covering the 2D Simulation Extent

4.2.2. Rainfall Excess

Rainfall excess is calculated in the ICPRv3 approximate study models using the Green Ampt hydrologic rainfall abstraction method, as incorporated in the ICPRv3 software. Soil characteristics (cut-off depth, hydraulic conductivity, adjusted effective porosity and suction head) were obtained using the SSURGO soils lookup tables and ArcHydro tools provided by the SWFWMD. Then within the model, ICPR generates runoff for over each subbasin for each unique contribution of soil and land use fraction.

Within the 2D model domain, ICPRv4 internally intersects the soil coverages with the honeycomb mesh and applying Green Ampt abstraction with parameters defined by unique SSURGO MUKEY, as shown in Appendix A. Unlike ICPRv3, the moisture in the soil is tracked, dynamically, and recovered. Initial soil storage conditions are based upon specific soil conditions as provided in SSURGO. Unless a groundwater module is present, soil moisture recovery is exclusively through evapotranspiration (ET) and percolation as an outfall when sink holes are simulated. The current ICPRv4 model for the Withlacoochee River Watershed does not utilize the groundwater module.

4.2.3. Runoff Generation

In ICPRv3 simulations, runoff is calculated in a hydrology module inside the ICPRv3 model and stored for use in hydraulic computations. During hydraulic computations, the hydrology time series results are loaded on a node and routed through the hydraulics simulation as a one way input.

In ICPRv4, the hydrology and hydraulics modules are calculated simultaneously, and allow for runoff from adjacent basins to interact and impact the rainfall excess quantities. Runoff is generated along 2D elements using overland flow equations as described in Section 2.3.4 and in **Table 2-2**.

4.3. Hydraulics

4.3.1. One Dimensional Flow Model Elements

The hydraulics in the Withlacoochee Watershed includes a combination of one dimensional and two dimensional model components. The one dimensional hydraulics portion of the ICPRv4 model functions similarly to those in the ICPRv3 model using the same connectivity structure of nodal storage elements linked together by conveyance elements. The following discusses the basic 1D hydraulic elements:

4.3.1.1. Nodes

Model storage elements were placed at the upstream and downstream ends of links and isolated storage areas. Nodes are also the loading points for basin generated runoff and baseflow. Node initial conditions are established from normal or observed water conditions set at the beginning of the storm simulation.

4.3.1.2. Links

Hydraulic conveyance elements used in the Withlacoochee Watershed Simulation include channels, pipes, weirs, and drop structures. Model data is parameterized from collected data including construction plans, field reconnaissance, structure surveys, or structure estimations.

4.3.1.3. Cross-sections

Cross sectional data is used in both overland weir connections and channel cross sections. The data is extracted from the DEM and formatted per ICPR requirements, then referenced by either a weir or channel link.

4.3.1.4. Operable Control Structures

The SWFWMD operates 17 control structures in the Withlacoochee River Watershed 2D extents. These structures, discussed in Section 3.2.4 are applied to traditional link elements of pipes or weirs and become operable by having either a time varying or stage varying clip to simulate structure opening or closing. During the verification event, structure operation reports were used to derive the time varying clip operations. During normal operations or during simulated design storm events, the structure operations will default to the SWFWMD established structural protocols.

4.3.2. Two dimensional Flow Model Elements

ICPRv4 input requirements within the 2D region serve to define the modeling extents, characterize the terrain, or connect to outside data or interior 1D features. From these inputs, ICPRv4 generates a triangulated mesh and parameterizes the 2D space with 2D channel elements defined by triangle edges, diamond wedges and basin honeycombs serving as basins to aggregate runoff to each 2D vertex. Descriptions of each ICPRv4 2D model element used in the Withlacoochee Simulation are described in Appendix B.

4.3.3. Boundary Conditions 2 D Model

The Withlacoochee simulation is mostly contained within the 2D overland flow boundary with water leaving the 2D region in three directions: towards the Hillsborough River, Gulf of Mexico and Jordan Sink.

Hillsbororugh River – Within the Green Swamp, downstream of SR 471, the Withlacoochee River makes a sharp curve from the west towards the north. When the water level at this location is above approximately 76.7’ NAVD88, flow can split from the Withlacoochee River and flow towards the southwest at the headwaters of the Hillsborough River. For the verification event, the USGS gauge at this location (02311000) was used as a tailwater condition and produced an average flow rate of 264 cfs throughout this event.

Gulf of Mexico – Downstream of Lake Rousseau the Withlacoochee River flows to the Gulf of Mexico either straight through the barge canal or down the remnants of the original Withlacoochee River through Yankeetown. The Gulf is tidally influenced with the same tidal condition is used for both of these outfalls. It is of note that the discharge from Lake Rousseau is however, virtually a free discharge condition as the highest recorded storm surge during the verification event reached only 10’ NAVD88’, while the inverts of the control structures are 10.39’ NAVD88 at the Main Gate and 20.09’ NAVD88 at the bypass structure.

Jordan Sink – Per the operational protocol for managing water in the Tsala Apopka Chain of Lakes, during high flow conditions, water will be diverted through the Van Ness Structure towards Two Mile Prairie. As flood conditions escalate, this area may also see water back up from the Withlacoochee River and when levels are high enough flow can occur to Jordan Sink, which is a direct connection and recharges to the Floridian Aquifer. Measured data during the verification event was utilized from the SWFWMD water level gauge (SID#23584).

4.3.4. Boundary conditions inflow models

The detailed studies and approximate studies enter the 2D model domain at ICPRv4 external hydrograph point features. While most of the inflows freely discharge into the 2D model domain, a few are more channelized, having submerged discharges and tailwater effects that need to be considered, otherwise the freely discharging flows from the planning units will be overstated. ICPRv3 tailwater conditions for both the detailed studies and the approximate studies were set iteratively, using the results from the 2D model to populate the ICPRv3 models.

Due to the nature of flows in the various watersheds, the timing of the peak elevation and receding limbs did not consistently align. While the natural system had backflow interactions between the river and the planning unit model, this had the consequence of creating water in the planning unit models, which were later released when the river began to recede, causing an undue spike in flows late in the storm event. The remedy for this was to set the reaches flowing to tailwater nodes as positive flow only reaches. This modification combined with utilizing time stage data from the 2D model domain at the tailwater had the benefit of correctly simulating the water quantity from the planning unit models without overstating flows. Then the 2D model tailwater condition would govern the elevation at which discharge began rather than a freely discharging set-up.

Alternative solutions would necessitate the migration of planning unit ICPRv3 models into ICPRv4 basins creating a combined fully integrated surface water model, which was beyond the scope of this project.

4.3.5. Node Initial Conditions and Baseflows

Model initial conditions were set by using measured water level data from the USGS gauging stations along the river and the daily readings in the Tsala Apopka Chain of Lakes to create an initial conditions surface, which served as a data input into ICPRv4. The ICPRv4 model then set initial conditions based upon the higher of the initial conditions surface or the ground elevation.

Initial conditions in the approximate studies were set based upon visual observations in the watershed. These elevations were approximated based upon wetland extents, water surface elevations and engineering judgement.

In 2010 the SWFWMD issued a *Groundwater Flow and Transportation Model for the Northern District Water Resources Assessment Project Area Version 2.*0 by HydroGeologic, Inc. The evaluation included a groundwater model of the Withlacoochee River, with one of the outputs being monthly baseflow conditions at points along the Withlacoochee River corresponding to USGS gauging locations. Using the time period in 2004 corresponding to the Verification event, the baseflow data was applied evenly to the number of ICPRv4 1D channel nodes upstream of each of the USGS gauging stations. **Table 4-1** shows the baseflow added at each USGS gauging station, number of nodes between gauging stations and baseflow rate in cfs applied to each node.

Additional baseflow was added at the Rainbow River to capture the flow from this first magnitude spring that was not incorporated into the detailed study. Comparing the gauged flow during the verification event with the modeled results simulated over the verification period, a gap of 200 cfs was noted and added as baseflow at the outlet of Blue Run (Rainbow River).

Given the size of the watershed, it is normal to simulate a start-up period to stabilize the flows prior to the simulation of the main flooding events. This period for the Withlacoochee simulation was August 2004. Prior to this time, it was noted that stages at the inlet to the Tsala Apopka Chain were lower than measured values. A baseflow of 700 cfs was added to achieve the initial stage for the August 2004 start-up simulation.

Table 4-1: Withlacoochee River Baseflow Conditions August to November 2004

USGS Gauge	Baseflow	Number of Nodes Upstream	Baseflow per Node
Withlacoochee near Cumpressco	4.68	13	0.37
Withlacoochee near Dade City	2.46	29	0.09
Withlacoochee at Trilby	24.49	100	0.25
Withlacoochee at Croom	54.80	192	0.29
Withlacoochee near Floral City	0.00	88	0
Withlacoochee at Wysong-Coogler	108.75	27	4.03
Withlacoochee near Holder	310.29	65	4.78

4.4. Model Verification

Modeled stages were compared to USGS or SWFWMD gauges at 25 locations within the 2D model domain. Flow data were available for comparison at 13 of these sites. In addition, surveyed high water marks were available at numerous locations throughout the watershed.

4.4.1. Description of the Model Verification Event

The Hurricane season of 2004 recorded the highest stages in recent memory along the Withlacoochee River and within the Tsala Apopka Chain of Lakes. The first Hurricane, Charley, contained strong winds causing debris to block to river at certain locations. Before the debris could be lifted, the second and third hurricanes, Frances and Jeanne occurred and deposited significant amounts of rainfall, compounding the river’s diminished conveyance. The 2004 hurricane tracks are shown in **Figure 4-5** converging on the Green Swamp at the headwaters of the Withlacoochee River. Hurricanes Frances and Jeanne, which brought the majority of the rainfall are shown roughly following the flowline of the river through the heart of the Withlacoochee River Watershed.

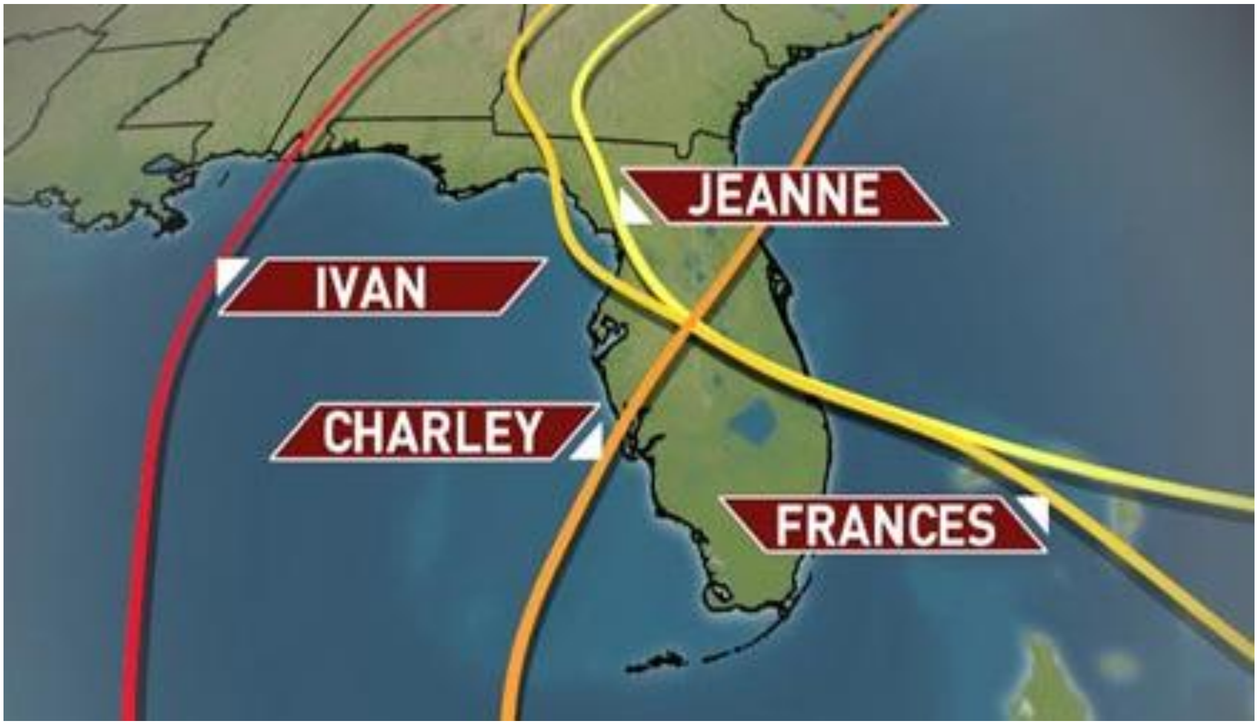

Figure 4-5: 2004 Florida Hurricane Tracks (The Weather Channel)

The combination of USGS and SWFWMD gauging data from stations along the Withlacoochee River, Little Withlacoochee River and Tsala Apopka Lakes was used for verification of the Withlacoochee River ICPRv4 model. **Table 4-2** lists the verification stations used and their associated model nodes and map IDs, which correspond to their locations in **Figure 4-6**.

Table 4-2: Withlacoochee River Verification Gauging Stations

Map ID and Name	USGS / SWFWMD Site ID	ICPRv4 Model Node	Stage	Flow	Notes
01 WR AT MAIN GRADE	SWFWMD_17533	HWM_7787	Yes		Hourly
02 WR NR CUMPRESSCO	USGS_02310947	Node_1	Yes	Yes	Hourly
03 WR NR DADE CITY	USGS_02311500	Node_71	Yes	Yes	Hourly
04 WR AT TRILBY	USGS_02312000	Node_260	Yes	Yes	Hourly
05 WR AT RITAL	USGS_02312300	Node_166	Yes		Hourly
06.1 L. WITH. TARRYTOWN	USGS_02312180	LWR_0020	Yes	Yes	Hourly
06.2 L. WITH. AT RERDELL	USGS_02312200	Node_2121	Yes	Yes	Hourly
07 WR AT CROOM	USGS_02312500	Node_392	Yes	Yes	Hourly
08 WR AT NOBLETON	USGS_02312558	Node_466	Yes		Hourly
09 WR AT CR 48	SWFWMD_23419	Node_3483	Yes		Hourly
10 LESLIE HEIFNER UPSTREAM	SWFWMD_23501	Node_1494	Yes		Hourly
11 WR NR FLORAL CITY	USGS_02312600	Node_3459	Yes	Yes	Hourly
12 LAKE PANASOFFKEE (Stage)	USGS_02312698	Panasoffkee	Yes		Hourly
LAKE PANASOFFKEE (Flow)	USGS_02312700	Panasoffkee		Yes	Daily
13 WR AT WYSONG DAM	USGS_02312720	Node_3507	Yes	Yes	Hourly
14 WR NR INVERNESS	USGS_02312762	Node_3327	Yes	Yes	Hourly
15 LESLIE HEIFNER DOWNSTREAM	SWFWMD_23502	Node_1493	Yes		Hourly
16 TSALA APOPKA FLORAL CITY	USGS_02312800	Node_700	Yes		Daily
17 TSALA APOPKA INVERNESS LAKE	SWFWMD_23481	Node_703	Yes		Daily
18 TSALA APOPKA AT HERNANDO	USGS_02312950	Node_708	Yes		Daily
19 TSALA APOPKA CANAL AT S-353	USGS_02312975	Node_769	Yes		Hourly
20 WR NR HOLDER	USGS_02313000	Node_3361	Yes	Yes	Hourly
21 WR AT DUNNELLON	USGS_02313200	Node_3401	Yes		Hourly
22 LAKE ROUSSEAU	USGS_02313230	Rousseau	Yes	Yes	Hourly
22.1 WR BYPASS CHANNEL	USGS_02313250	Node_1392	Yes	Yes	Hourly
23 INGLIS DAM DOWNSTREAM	USGS_02313231	OF_Node_6356	Yes		Hourly

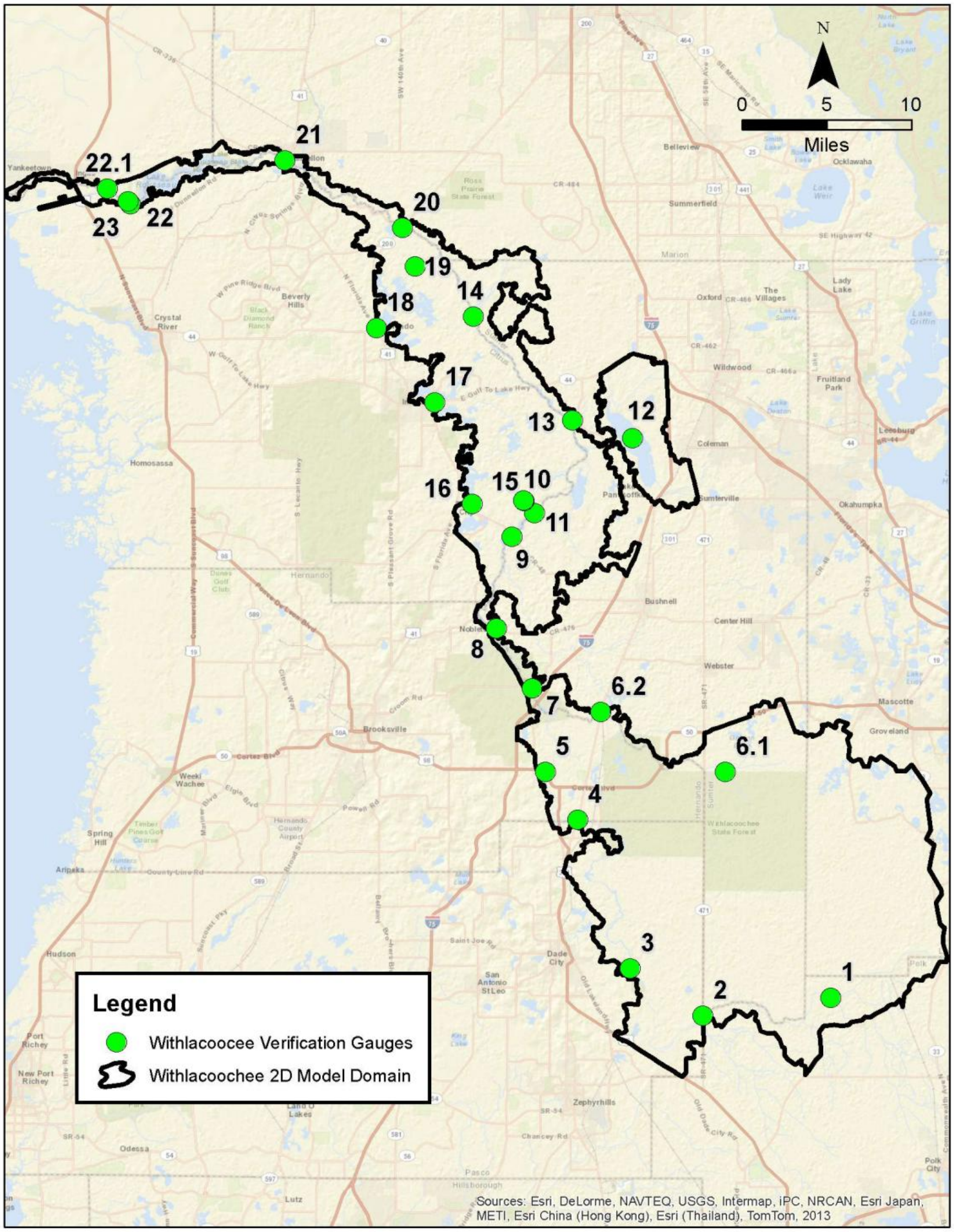

Figure 4-6: Verification Gauging Stations along the Withlacoochee River

4.4.2. Basis of Comparison between Simulated and Observed Conditions

Simulated and observed conditions were compared both visually and using statistical methods. Visual comparisons included comparing the general shape, time of stage increases in response to hurricanes, magnitude of rise, peak stage, peak flow and total storm volume. Comparisons on a statistical basis include the Mean Error, Mean Absolute Error, Root Mean Square Error, Correlation Coefficient, Coefficient of Determination, and Nash Sutcliffe metric. Statistical measures are described below along with target ranges for each statistical metric.

Mean Error –is an estimate of model bias. It is calculated by summing the differences at every time increment between measured and modeled results. If two data sets trend together, yet one has an apparent offset, the Mean Error will go up. This could be caused by external factors such as hurricane debris, which could cause an apparent phase shift in measured data, which would not have been replicated in the modeled data.

Mean Absolute Error – is another measure of bias. This measurement differs from the Mean error in that it is calculated as the sum of the absolute value of the difference between measured and modeled data. This metric is useful in cases where a Mean Error calculation might cancel out the error by having conditions where the measured data is too high early in a storm event and alternatively too low at a later point in the storm event.

Root Mean Squared Error – is the square root of the mean squared error and is an indicator of the overall accuracy of a models ability to estimate measured data. The measure aggregates the magnitudes of the error or difference between predicted and measured value.

Coefficient of Determination (r^2) **–** indicates how well data points fit a predicted set of defined values, presuming the observed values follow a defined progression or curve. Values range from 0 to 1, where a value of 1 indicates a perfect correlation and 0 represents no discernable correlation between the data values.

Nash-Sutcliffe – is a measure of model efficiency used in hydrodynamic models. As the metric approaches 1, signifies an identical match between measured and modeled data, and an indicator of excellent model accuracy with measured data. Large negative values indicate the model simulation is a poor predictor or measured data.

Percent Difference Cumulative Flows – Calculates the sum of the flows over a time period of model calibration as compared to measured data over the same period. It is a measure to indicate how well the total quantity of water simulated matches the measured data.

Normalized Error, 10th Percentile Flows – indicates how well flows are matching lower flows as normalized by the median flow. This statistic is a measure of the rising and tailing limb metric to see how well the 10th percentile, flow that is exceeded 90% of the time, compares to the measured data.

4.4.2.1. Calibration Targets

Levels of uncertainty are common in any simulation where the real world is being approximated by a model simulation. To the extent practical and within the accepted range of values, model parameters were adjusted to match measured conditions. The objective of the calibration process is to minimize the error and adjust parameters such that model conditions reasonably predict measured data results so that the model can be used to predict system performance during design storm events. Calibration targets are listed as Good, Fair, and Poor. Given that each metric measures a different aspect of the total calibration, it is the combination of the metrics with site specific observations and visual comparisons between the measured and modeled data that ultimately determines good model calibration.

Considerations in evaluating targets should be given to both the model input data source and the accuracy of the USGS measured data and flow ratings. The verification model was based significantly on the use of digital topography, where the developed DEM has a reported accuracy of plus or minus 0.5 feet. The measured flow data, as well, has a number of complications when comparing flow data to extreme events. The flow gauges in the Withlacoochee River are based upon a flow-stage rating curve and although the rating curves are frequently calibrated and adjusted, they are less apt to precisely capture the peak conditions and stream alterations that occur during a hurricane event, much less three hurricane events. Additionally, by the nature of the application of the rating curve, the flow rate is based upon a direct reading of measured stage. In practice, particularly for extreme hurricane type events, stream systems may not respond the same during the rising and falling limbs and a hysteresis condition often occurs, whereby similar tailwater conditions during the rising and falling limbs of an event cause significantly different flow rates to occur.

Consistent with the accuracy of the underlying model input data, measured data, and the Myakka River Watershed Initiative, the targets for stage and flow calibration are listed in **Tables 4.3** and **4.4** respectively.

Table 4-3: Calibration Targets for Surface Water Stages

Metric	Good	Fair	Poor
Mean Error	<0.50’	< 0.50’ , 1.00’ >	>1.00’
Mean Absolute Error	<0.75’	< 0.75’ , 1.50’ >	>1.50’
Root Mean Squared Error	< 0.00’ , 1.00’ >	< 1.00’ , 2.00’ >	>2.00’
Nash Sutcliffe Coefficient	>= 0.0	< -1.00 , 0.00 >	< -1.0
Coefficient of Determination (R^2)	< 0.60 , 1.00 >	< 0.40 , 0.60 >	< 0.40

Table 4-4: Calibration Targets for Surface Water Flows

Metric	Good	Fair	Poor
% Difference in Cumulative Flows	<10%	< 10% , 25% >	>25%
Normalized Q_{10}	<0.10	< 0.10 , 0.20 >	>0.20
Nash Sutcliffe Coefficient	>= 0.0	< -1.00 , 0.00 >	< -1.0
Coefficient of Determination (R^2)	< 0.75 , 1.00 >	< 0.50 , 0.75 >	< 0.50

4.4.3. Model Calibration Process

The goal of this calibration process was to refine the hydraulic model such that it produced reasonable results as compared to observed conditions. This is critical because how well the model is verified defines how accurate the design flood events and model scenarios will be in future stages of this project.

The model calibration process started with an assessment of volume of runoff in the watershed generated within the ICPRv4 model domain and inflowing from the planning units. Adjustments were made to the approximate study models to include the impact of evapotranspiration (ET) over the four month verification period. Next, storage volume within the 2D mesh was considered both from the accuracy of the mesh's ability to reflect the digital terrain surface and the accuracy of the digital terrain surface. Finally, using independent flow ratings at each of the water control structures in the Tsala Apopka Chain, developed by the SWFWMD, flows through each of the structures were calibrated for low and high flow conditions.

As a result of various aspects of the calibration process, the adjustments were not simple parameter adjustments, but required additional field work to correct or enhance model input data before calibration could proceed. For example, when storage in the watershed was suspected as a calibration limitation, a survey of the Tsala Apopka marsh revealed that what appeared as solid ground in the digital terrain was actually a heavily vegetated marsh containing roughly three feet of standing water, a critical element in the complete understanding and simulation of the system. These corrections, as well as the others described above, lead to improved model accuracy and a better understanding river system.

4.4.3.1. Inflow Model Refinement

The first step in the calibration process was to determine if the quantity of, water as measured by the USGS gauging stations, was reasonably approximated by inflows to the river model and the runoff generated by ICPRv4. An initial observation showed modeled stages and flows were higher than measured data from USGS gauges in the central portion of the watershed, indicating the water balance needed an adjustment.

The next step in analyzing the water balance was to verify that the Doppler rainfall reported by the NexRAD grid accurately represented ground measurements. This was done at measured locations within the Tsala Apopka Chain of Lakes. During the times of peak rainfall intensity surrounding hurricanes Frances and Jeanne, there was an insufficient difference between the measured and Doppler data to suggest that it was the cause of the data discrepancy.

Next, the approximate studies were evaluated. These studies were generated with the purpose of generating inflows into the river, and initially it was presumed that the level-of-detail may have impacted the flow rates into the river both in terms of both total volume, and inflow hydrograph timing. Evaluations of the level-of-detail and additional surveys were conducted at critical locations in the approximate models by the SWFWMD to improve the accuracy of the models.

Next, ET was incorporated into the inflow model through an adjustment to the rainfall amounts, whereby rainfall into the inflow models was reduced based upon monthly ET potential rates used in the 2D portion of the model. This approximation, while not appropriate for evaluating specific site conditions within the approximate planning units, was deemed an appropriate approach to correcting the resulting inflow hydrographs into the ICPRv4 model.

Next, inflow model timing was evaluated, particularly the inflows from approximate studies flowing into the Green Swamp. The inflow models were adjusted by decreasing selected overland weir coefficients, attenuating volume and delaying the peak discharge, to ultimately match the hydrograph measured at USGS gauge at Cumpressco at the SR 471 bridge. Results significantly improved the modeled shape of the hydrograph under SR 471 during the second hurricane (Frances). However, while the shape improved for the third hurricane (Jeanne), it did not match the peak rate as measured by the USGS gauging station. Based on these results, it is suspected that the groundwater influence from the Green Swamp is more of a driver of the receding limb of hydrographs in the upper portion of the Withlacoochee River Watershed than the surface inflows. The groundwater component in the Green Swamp appears to only affect the final receding limb of the simulation and is not necessarily a significant contributor to the peak stages or flow rates in the remainder of the watershed. To accurately extend the model to simulate a longer term condition, would require using the groundwater component of ICPRv4. While the groundwater module is available at the writing of this report, it was not available when the verification model initiated development.

4.4.3.2. DEM Refinement

With the inflow volume calibrated to the extent possible, the resulting stages were evaluated. At the USGS gauging station on the Withlacoochee River near Floral City (USGS 02312600), it was observed that the modeled flow was matching the measured flow reasonably well; however the modeled stage was high. This same condition was also present in the Wysong gauge (USGS 02312720). These two gauges, seen in **Figure 4-7**, represent a large portion of the Withlacoochee River near Tsala Apopka. The river profile at this location is extremely flat with a normal inundation area greater than 4 miles in width; therefore even a slight change in the ground profile, as reflected in the DEM, would have a large change in the overall storage volume in the system as seen from the bathymetric survey of the Tsala Apopka marsh. Areas were identified and surveyed to verify the presence of standing water below the DEM “ground” elevation. The difference in depth ranged from 0.5 feet to 3.0 feet and was applied throughout the representative marsh areas in the Withlacoochee River near Tsala Apopka. Following the update of the DEM elevations in the marsh area, modeled stages upstream were much more consistent with observed conditions in the river.

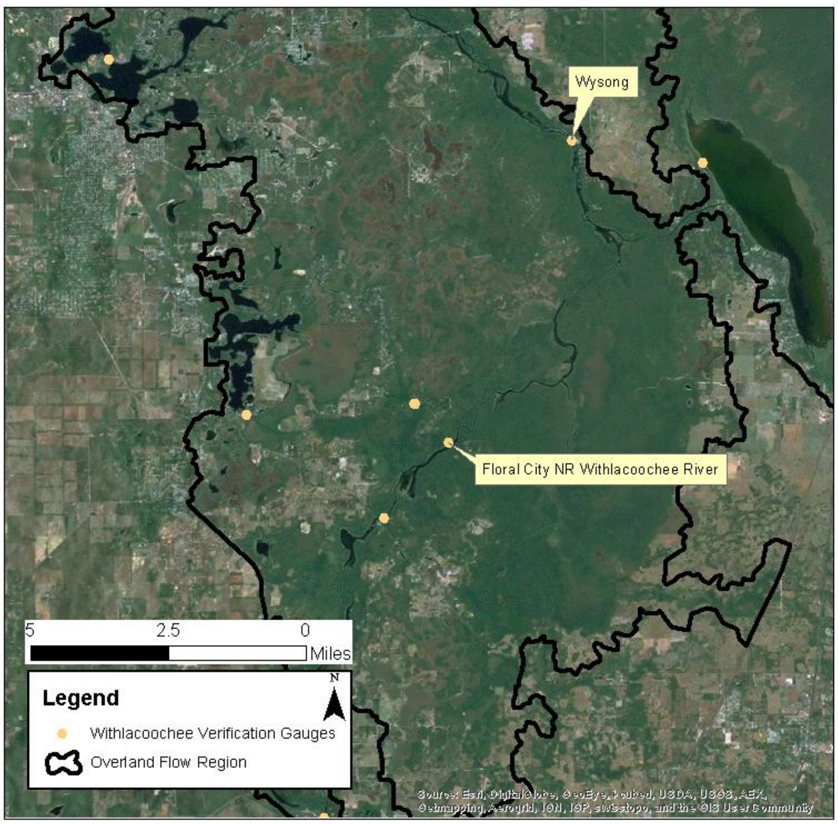

Figure 4-7: Withlacoochee River near Tsala Apopka

Next, it was observed that the modeled stage in the Floral City Pool continued to rise late in the storm event, compared to the measured data, which showed a recession limb even with the Leslie Heifner and Floral City structures closed. This was identified as additional model inflow to the Floral City Pool over the Flying Eagle Berm, which was greatly overstated as compared to actual observations during the 2004 hurricanes. The berm was subsequently surveyed, and the DEM updated to reflect this critical condition. This alteration resulted in flow only minimally overtopping the berm which better represented actual conditions during the verification event.

To verify that the storage volume in the model matched that in the DEM, an extent of inundation shape was created. Using the GIS cut and fill tool, the volume between the initial shape surface and the inundation shape was determined. This volume was then compared to the peak volume stored in the model. Results, following the DEM updates, are shown in **Table 4-5** and indicate that the ICPRv4 simulation accounts for 95% of the actual volume measured under the peak inundation shape. It is of note that the model peak volume occurred at a moment in time, whereas the volume calculated from the inundation shape was developed from the extracted peak conditions throughout the watershed consequently, the modeled volume presented in the table for comparison is slightly understated.

Table 4-5: Volume Comparison DEM vs ICPRv4 Model

	Volume (ac-ft)
DEM volume under inundation shape	665,989
less DEM initial water volume	(111,151)
	554,839
ICPRv4 Model - peak storage volume	529,313
Ratio of model volume to DEM volume	95%

4.4.3.3. Refinement of 2D Mesh

The 2D mesh as modeled by ICPRv4 is generated to both reasonably represent the terrain and drainage patters in the overland areas. The first of these two conditions was addressed by the results of storage volume shown in **Table 4-5**. However, the second condition can only be evaluated through observations and comparisons of the simulated results with historic accounts or available stream gauge data. Because the flow paths occur linearly along 2D mesh triangle elements, an inefficient mesh can either short circuit a storage area within the mesh, or block a flow path. Using the results and resulting inundation area as a guide, the watershed was evaluated to identify locations where the mesh was drawn inefficiently and the necessary corrections were made, such as adding breakpoints or adjusting breakpoint locations .

4.4.3.4. Structure Ratings

Elements of critical importance to the operations of lake levels at Lake Rousseau and within the Tsala Apopka Chain of Lakes are the performance of the operable control structures. For Lake Rousseau these are the Inglis Dam and Inglis Bypass control structure. For the Tsala Apopka Chain of Lakes, discussed in Section 3.2.4, these are; the Leslie Heifner and Floral City Structures which control water from the river into the Floral City Pool; the Golf Course and Moccasin Slough structures which control water into the Inverness Pool; the Brogden Bridge and Bryant Slough which control water leaving the Inverness Pool; and the Van Ness and S-353 structures, which control water leaving the Hernando Pool.

The first step in calibrating these areas was to verify that the reported structure operations, which came from several sources both electronic and hand written, were accurate. This was done through reasonableness checks, whereby the timing of the structure observations was compared to measured changes in water level. Inconsistencies were noted and reviewed with SWFWMD staff, and were adjusted as appropriate. Concurrently, the SWFWMD revisited all of the historic structure operations and attempted to track down and resolve any other inconsistencies.

As a tool to enhance ongoing structure operations within the Tsala Apopka Chain of Lakes, the SWFMWD recently developed flow ratings for each of the control structures using measured stages in each pool, channel geometry and field measured flows under a variety of gate openings. This provided a way to independently review the results of the model at both low and high stage conditions, and provide assurances that the model would adequately reproduce scenarios simulated under these conditions.

During high stage conditions, the pools are effectively level, whereby most of the headloss occurs at the structure. During these conditions and with all other variables removed, each of the structures produced flow rates similar to those generated by the structure ratings. It was during the lower stage / filling condition, where a difference was noted between the modeled and structure rating flow rates. During this time, which occurred in the initial rising limb of the verification model, it was the combination of the structure and headloss in the channels that combined to control the flow between the Tsala Apopka Pools. Adjustments to the Manning's roughness coefficients within the 1D channels leading up to and leaving each structure provided reasonable calibration at each of the structures.

The Inglis Dam and Bypass structures are effectively freely discharging sluice structures flowing over an Ogee spillway. The orifice discharge coefficient for these spillways was used as a calibration parameter to match the measured flows for given headwater conditions.

4.4.3.5. ICPRv4 Beta Version

One of the opportunities and limitations of developing a model simulation using a beta version of software is that concurrent with the development of model inputs, the software is being refined and improved. Throughout the model development of the Withlacoochee 2D model, the ICPRv4 modeling software evolved to include, among other enhancements, an integrated groundwater component (not utilized in this model, but currently publically available) and an improved hydrology component integrated with surface runoff. These, in addition to other software modifications led to the generation of a better and more accurate hydraulic model simulation of the watershed. Additionally, with each successive improvement to the software, additional diagnostics were made available along with more detailed output data, to help identify potential model errors. However, the input data schema needed to be upgraded to match the latest model input configuration to take advantage of the refinements, requiring additional time in model development.

4.4.4. Comparison between Simulated and Observed Conditions

This section of the report presents the results of the stage and flow model comparisons to measured data within the 2D model domain. In total, 25 USGS or SWFWMD stage locations were evaluated, of which, 13 also contained flow measurements. Locations of USGS and SWFWMD stations were shown previously in **Figure 4-6** (section 4.4.1) and tabulated in **Table 4-2**. Presented in the table, the stations are discussed from upstream to downstream (from the Green Swamp to the Gulf of Mexico) including tributary inflows from the Little Withlacoochee River, Lake Panasoffkee and the Tsala Apopka Chain of Lakes.

The statistical measures described in section 4.4.2 and calculated for each gauging station. The resulting observed hydrographs show the complexity of the Withlacoochee River Watershed and the unique conditions surrounding the verification period, where three hurricanes converged over the watershed in a single hurricane season. This led to a calibration that required matching the many varying hydraulic conditions in the river. Prior to the second hurricane, Hurricane Frances, the stages in the Withlacoochee River were still relatively low and the intense rainfall lead to a sharp rise in many stages and flow hydrographs. Then, during the initial portion of the receding limb of the hydrographs, Hurricane Jeanne occurred, showing the river’s response to a storm event occurring during both saturated and high water conditions. Finally, the end of the 2004 hurricane season, without any additional significant rainfall occurring, the river competed its long receding limb and water levels returned to normal.

The results of calculating the stage statistical metrics are presented in **Table 4-6**. Comparison results for the coefficient of determination metric shows good calibration. The calibration target for the coefficient of determination metric considers 0.6 a good match, which is exceeded at all stations with most of the r^2 values exceeding 0.9. This indicates an excellent measure of the models ability to match the shape, not only in peak conditions, but from the rising limb, through both peaks and through the recession limb.

Similarly, for the Nash Sutcliffe measurement a value above 0 is considered good model calibration, and many of the gauges approach 1.0, which represents a model’s ability to represent a stream’s response to the inflow hydrographs, with all metrics falling in the “good” range.

The only stage metrics falling in the poor or fair range are those in the Green Swamp, (Main Grade and Cumpressco), and those just downstream of the Cumpressco gauge at Dade City and Trilby. These metrics, as seen in the comparison hydrographs, show a shift in the measured and modeled data. It is suspected that this is the result of changing conditions in the river through the hurricane season and the dense vegetation that makes up the centerline of the river between Cumpressco and Dade City USGS gauges.

Along the Little Withlacoochee at Rerdell, the metrics for Mean Error, Mean Absolute Error and Root Mean Error show a fair rating, while the visual inspection of the gauge matches extremely well through hurricanes Frances and Jeanne. It appears as though the difference prior to hurricane Frances is more related to the limit of the detailed hydrographic survey on the Little Withlacoochee River rather than the stream's response to inflows. In both the measured and modeled conditions, the water level appears at or near the bottom of the river at this location.

Table 4-6: Stage Statistical Metrics

Station Name	Mean Error		Mean Absolute Error		Root Mean Square Error		Coefficient of Determination (r^2)		Nash Sutcliffe	
WITHLACOOCHEE RIVER AT MAIN GRADE	1.01	poor	1.01	fair	1.05	fair	0.95	good	0.19	good
WITHLACOOCHEE RIVER NR CUMPRESSCO	0.65	fair	0.90	fair	1.19	fair	0.86	good	0.74	good
WITHLACOOCHEE RIVER NR DADE CITY	1.77	poor	1.77	poor	1.85	fair	0.92	good	0.30	good
WITHLACOOCHEE RIVER AT TRILBY	2.03	poor	2.06	poor	2.15	poor	0.97	good	0.76	good
WITHLACOOCHEE RIVER AT RITAL	0.40	good	0.73	good	0.93	good	0.97	good	0.96	good
L. WITHLACOOCHEE RIVER NR TARRYTOWN	0.55	fair	0.57	good	0.63	good	0.81	good	0.21	good
L. WITHLACOOCHEE RIVER AT RERDELL	0.87	fair	1.04	fair	1.25	fair	0.91	good	0.71	good
WITHLACOOCHEE RIVER AT CROOM	0.55	fair	0.89	fair	0.99	good	0.93	good	0.83	good
WITHLACOOCHEE RIVER AT NOBLETON	0.71	fair	0.72	good	0.82	good	0.97	good	0.85	good
WITHLACOOCHEE RIVER AT CR 48	0.07	good	0.19	good	0.22	good	0.99	good	0.98	good
LESLIE HEIFNER UPSTREAM	0.08	good	0.18	good	0.21	good	0.99	good	0.98	good
WITHLACOOCHEE RIVER NR FLORAL CITY	0.02	good	0.16	good	0.18	good	0.99	good	0.99	good
LAKE PANASOFFKEE (USGS)	0.17	good	0.20	good	0.24	good	0.99	good	0.96	good
WITHLACOOCHEE RIVER AT WYSONG DAM	0.16	good	0.49	good	0.64	good	0.96	good	0.88	good
WITHLACOOCHEE RIVER NR INVERNESS	0.64	fair	0.65	good	0.70	good	0.99	good	0.92	good
LESLIE HEIFNER DOWNSTREAM	0.04	good	0.13	good	0.18	good	0.98	good	0.96	good
TSALA APOPKA FLORAL CITY	0.15	good	0.15	good	0.19	good	0.99	good	0.97	good
TSALA APOPKA INVERNESS LAKE	0.06	good	0.14	good	0.16	good	0.98	good	0.96	good
TSALA APOPKA AT HERNANDO	0.10	good	0.14	good	0.18	good	0.96	good	0.94	good
TSALA APOPKA CANAL AT S-353	0.25	good	0.25	good	0.29	good	0.96	good	0.85	good
WITHLACOOCHEE RIVER NR HOLDER	0.35	good	0.73	good	0.87	good	0.98	good	0.95	good
WITHLACOOCHEE RIVER AT DUNNELLON	0.24	good	0.31	good	0.37	good	0.94	good	0.84	good
INGLIS DAM DOWNSTREAM	0.16	good	0.66	good	0.98	good	0.94	good	0.89	good
INGLIS DAM UPSTREAM-LAKE ROUSSEAU	0.21	good	0.38	good	0.49	good	0.74	good	0.56	good
WITHLACOOCHEE RIVER BYPASS CHANNEL	0.39	good	0.46	good	0.54	good	0.73	good	0.35	good

The flow statistical metrics seen in **Table 4-7** show a good overall correlation to measured data. With the exception of the bypass channel and Panasoffkee Outlet River Gauge, each of the r^2 values and Nash Sutcliffe Coefficients are in the "Good" range. Given the limitations on the use of the USGS rating curves, mentioned in Section 4.4.2.1, to exactly match rising and falling limb conditions, the result presented represent reasonable model calibration.

The difference seen in the bypass channel metrics appears to be due to the timing of the abrupt changes in flow rates. While the overall trend follows fairly well, visually, the limitations on the structure operations reporting caused the statistical measures to drop from the good range.

The difference seen in the Panasoffkee Outlet appears to be more reflective of the manner in which the USGS station calculated the flow rather than an indicator of a significant difference in model calibration.

The percent difference from cumulative flows, on whole are fair to good with isolated differences emerging, either as a result of flows from the Green Swamp, noted earlier, or suspect data reporting. The gauge that is most reflective of streamflow conditions in the entire watershed is the gauge at Holder, which is the last stream gauge removed from the heavy effects of Inglis Dam on Lake Rousseau. The Holder gauge combines the flow out of the Green Swamp, Little Withlacoochee River, most of the inflow tributaries, from Lake Panasoffkee and the Tsala Apopka chain. As seen in **Table 4-7** the flow deviation at this gauge is less than 5%.

Table 4-7: Flow Statistical Metrics

Station Name	Percent Difference in Cumulative Flows		Normalized Q10		Coefficient of Determination (R2)		Nash Sutcliffe Coefficient	
WITHLACOOCHEE RIVER NR CUMPRESSCO	-30%	poor	0.11	fair	0.91	good	0.75	good
WITHLACOOCHEE RIVER NR DADE CITY	-22%	fair	0.04	good	0.87	good	0.78	good
WITHLACOOCHEE RIVER AT TRILBY	-21%	fair	0.12	fair	0.96	good	0.87	good
L. WITHLACOOCHEE RIVER NR TARRYTOWN	-45%	poor	0.49	poor	0.92	good	0.67	good
L. WITHLACOOCHEE RIVER AT RERDELL	14%	fair	0.05	good	0.87	good	0.63	good
WITHLACOOCHEE RIVER AT CROOM	-22%	fair	0.01	good	0.92	good	0.82	good
WITHLACOOCHEE RIVER NR FLORAL CITY	-25%	fair	0.12	fair	0.89	good	0.72	good
LAKE PANASOFFKEE OUTLET	-4%	good	0.00	good	0.48	poor	0.39	good
WITHLACOOCHEE RIVER AT WYSONG DAM	-10%	good	0.09	good	0.87	good	0.81	good
WITHLACOOCHEE RIVER NR INVERNESS	-24%	fair	0.10	good	0.98	good	0.69	good
WITHLACOOCHEE RIVER NR HOLDER	-3%	good	0.08	good	0.98	good	0.94	good
INGLIS DAM UPSTREAM-LAKE ROUSSEAU	-4%	good	0.03	good	0.95	good	0.93	good
WITHLACOOCHEE RIVER BYPASS CHANNEL	-16%	fair	0.00	good	0.13	poor	-0.81	fair

4.4.4.1. Withlacoochee River at Main Grade (Trial Ford)

The SWFWMD gauge on the Withlacoochee River at Main Grade (SID 17553) is shown in **Figure 4-8** and measures the gauge height at the Main Grade crossing in the Green Swamp. The portion of the Withlacoochee River in the Green Swamp upstream of this gauge was not included in the update of the DEM and the low elevation shown in early August represents the DEM ground level, which rises as the runoff begins to accumulate and the stage responds. Main Grade remained wet throughout the remainder of the simulation. The volume difference at stages below 96’ NAVD88 at this location is considered minimal compared to the volume in the flood extents and not significant to the overall calibration. Also, there is some discrepancy in the measured data in late August which caused an abrupt three foot rise in the stage and a subsequent fall later in the month causing an inconsistency in the calibration metrics.

The general trend and timing of the stream response and the peak elevation is within reasonable results.

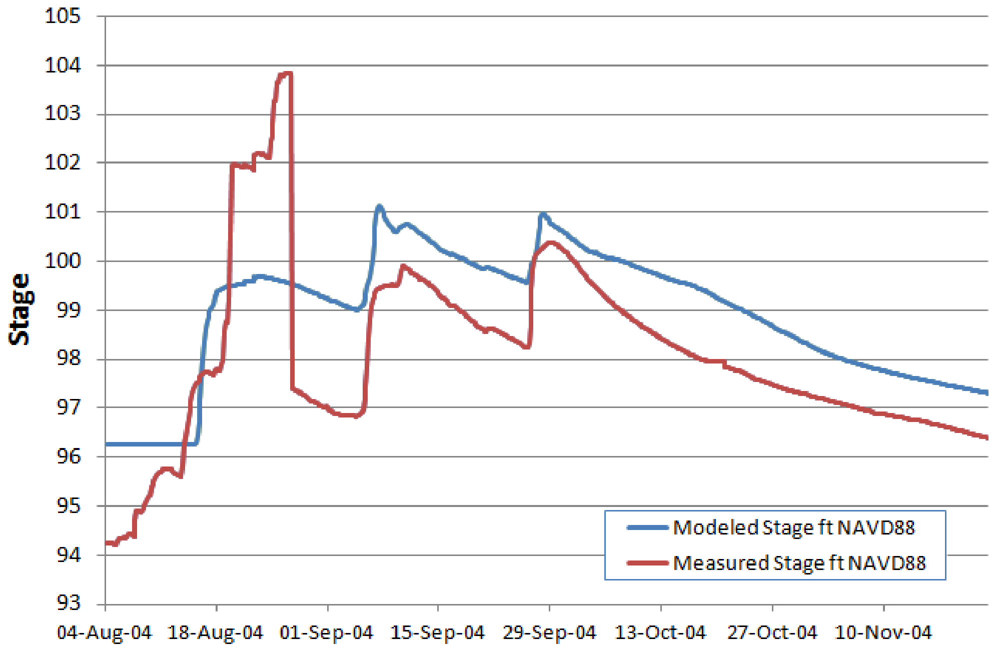

Figure 4-8: Stage Calibration Graph Main Grade

4.4.4.2. Withlacoochee River near Cumpressco

The USGS gauge at SR471, USGS#02310947 captures the stage and flow of water within the Green Swamp seen in **Figures 4-9** and **4-10**. As discussed previously, the shape of the hydrograph within the the Green Swamp is not flashy, but much more delayed as water slowly finds its way, emerging as groundwater back into the main channel or trickling through dense vegetation as the main channel of the Withlacoochee river is not consistently defined in this portion of the watershed.

The flow hydrograph comparison shows good model response to rainfall events, particularly during the second hurricane, where the rising limb of the hydrograph and the resulting peak and recession limb match well to the measured data. The timing of the rise and the peak modeled elevations are within reasonable ranges.

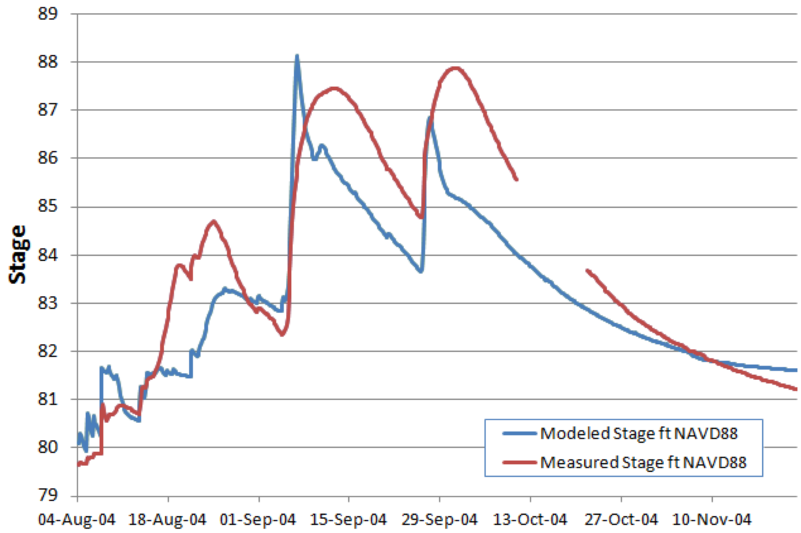

Figure 4-9: Stage Calibration Graph Cumpressco

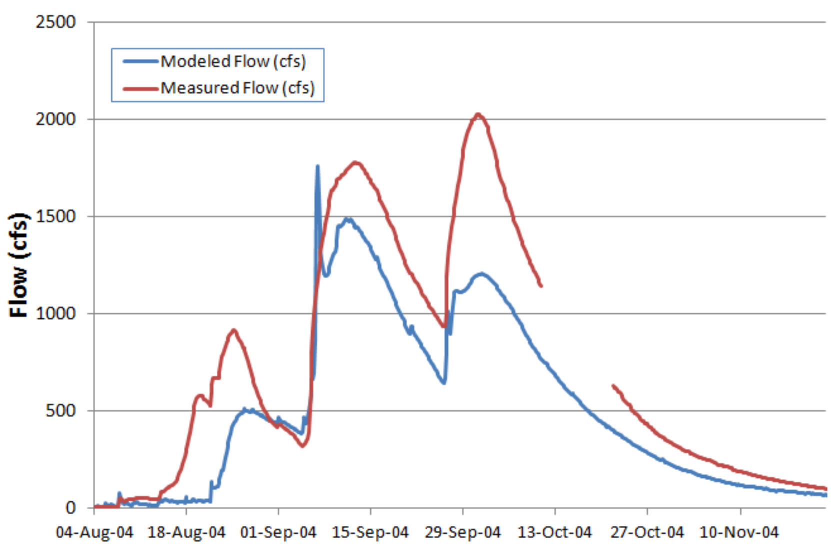

Figure 4-10: Flow Calibration Graph Cumpressco

4.4.4.3. Withlacoochee River near Dade City

Downstream of the flow split with the Hillsborough River the Withlacoochee River passes through the USGS gauge near Dade City (USGS#02311500). The stage and flow graphs are seen in **Figures 4-12** and **4-13** respectively. Unlike the Main Grade site, where the DEM is above the measured ground elevation, here the surveyed profile shows a ground elevation at the beginning of the simulation a foot lower than the measure data. This trend continues all the way to the peak, which is modeled lower than the measured peak. This may be due to log jams in the channel that are prevalent throughout the Green Swamp as seen in **Figure 4-11**.

Overall there is good agreement between the measured and modeled stages and flows. Also, the flow graph for the third hurricane appears to be more of a reflection of the Cumpressco gauge than something isolated to Dade City.

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Figure 4-11: Withlacoochee River Main Channel Upstream of Dade City

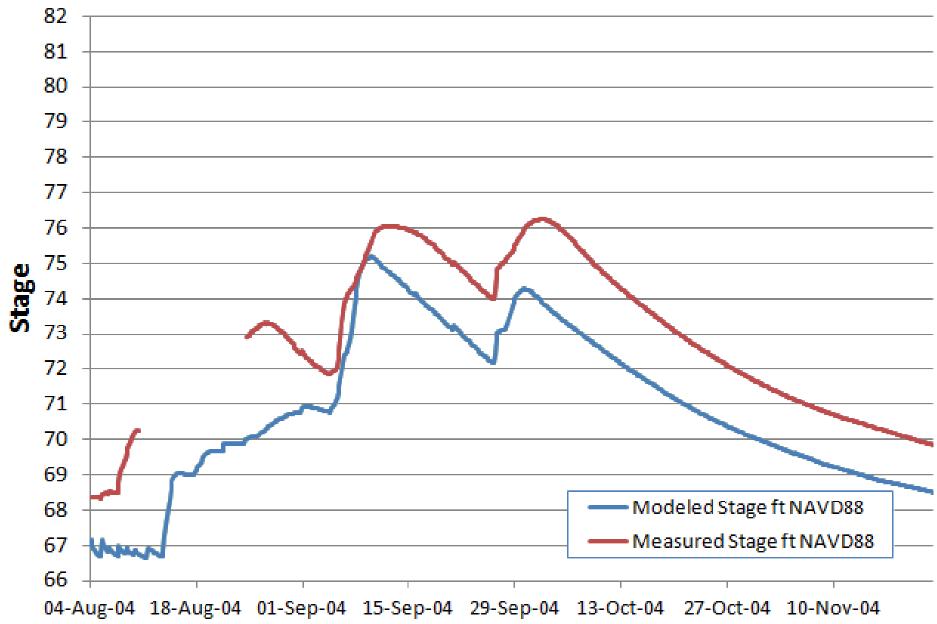


Figure 4-12: Stage Calibration Graph Dade City

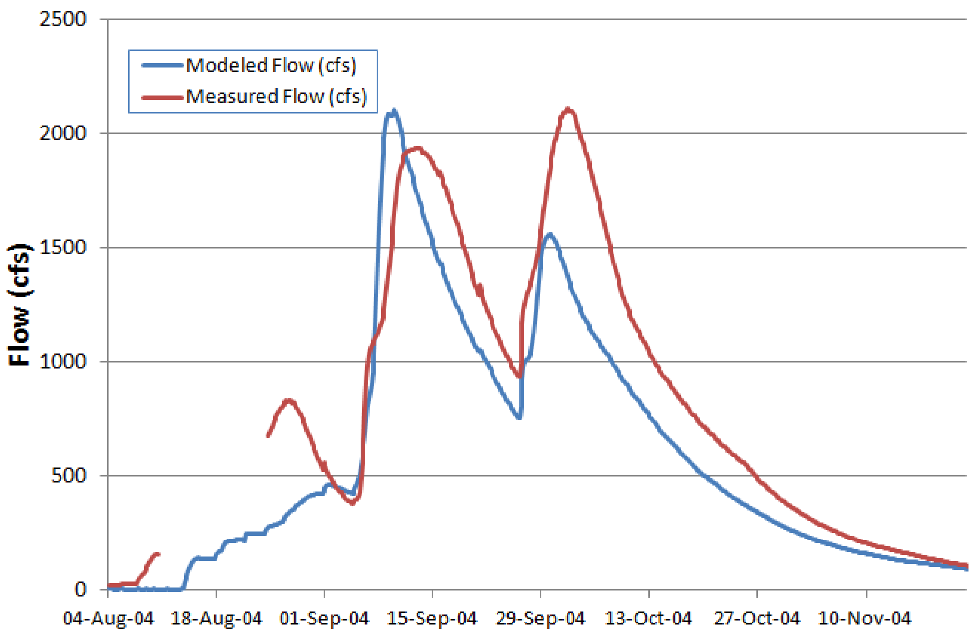


Figure 4-13: Flow Calibration Graph Dade City

4.4.4.4. Withlacoochee River at Trilby

Downstream of the Dade City gauge is the USGS gauge at US 301 in Trilby, (USGS#02312000). The river at this location is completely contained within the channel and flows westward after collecting additional Green Swamp flows from Devil's Creek and Gator Hole Slough. This portion of the river is one of the steeper and deeper segments as well. As seen in **Figure 4-14** during the storm events, the stage rises over 10 feet, without leaving its banks.

The shape of the stage hydrograph and flow hydrograph, seen in **Figure 4-15** show a good match with the measured data. The stage consistently tracks lower than the measured data, and although Manning's values were adjusted to simulate the channel roughness, it had little impact on the elevation or flow at this location. Likely additional storm debris in this stretch of the river caused the decrease in conveyance and higher stages for the verification event, which is not anticipated under normal conditions.

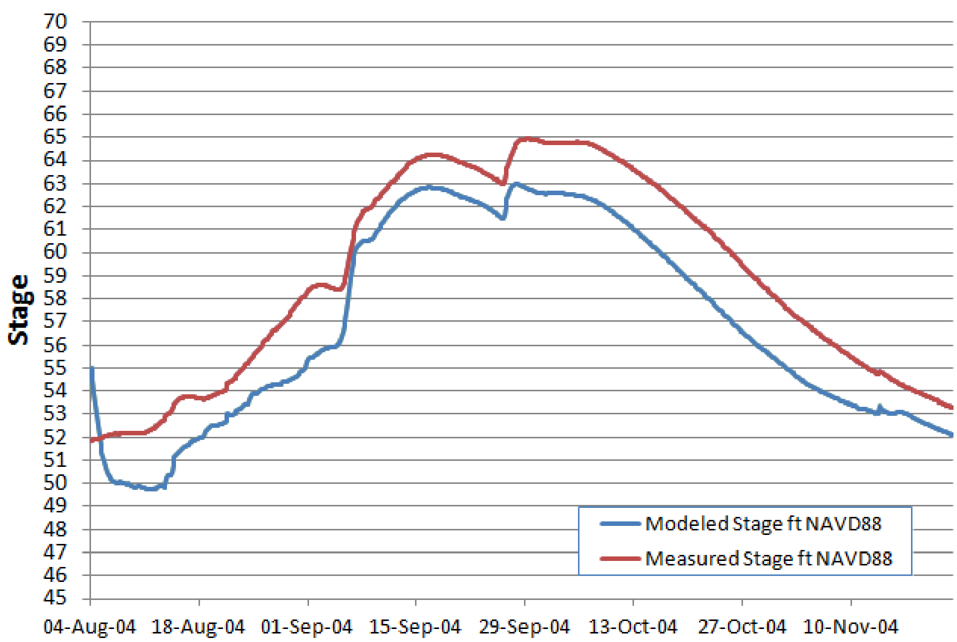


Figure 4-14: Stage Calibration Graph Trilby

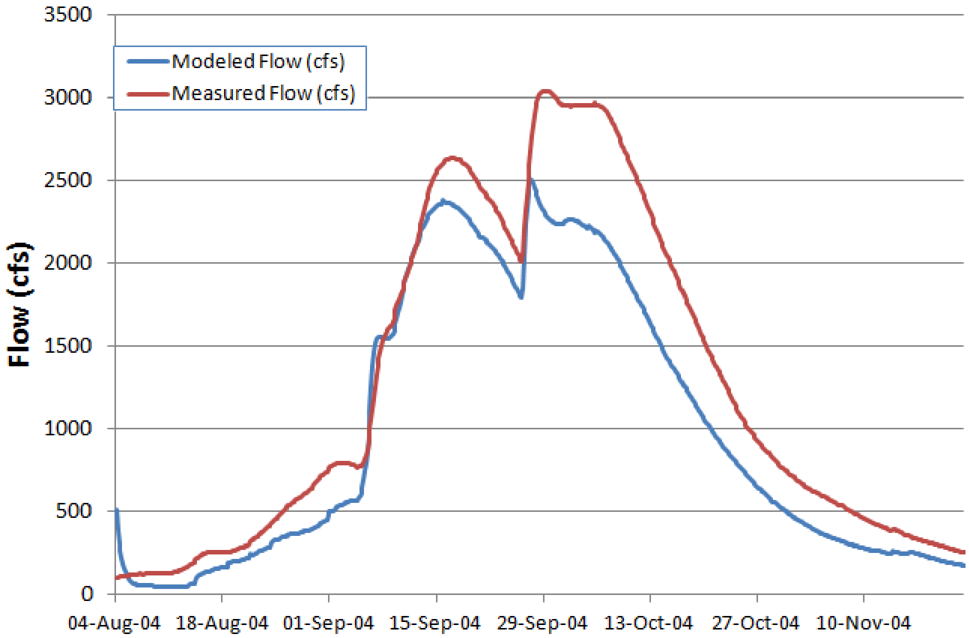


Figure 4-15: Flow Calibration Graph Trilby

4.4.4.5. Withlacoochee River at Rital

The USGS gauge at Rital, SR50, (USGS#02312300), measures stage only. The flows are likely similar to the Trilby gauge as there are no significant inflows into the river between the two gauges. The river here is still very channelized and flows are contained within the river banks. The stage graph seen in **Figure 4-16** tracks the measure data very well during both the rising and falling limbs of the hydrograph, with only a slightly elevated peak stage compared to the USGS data, yet within reasonable range for good calibration. The elevated stage is likely related to the transference of water too efficiently from the Trilby gauge as compared to conditions during the debris laden storm event simulations.

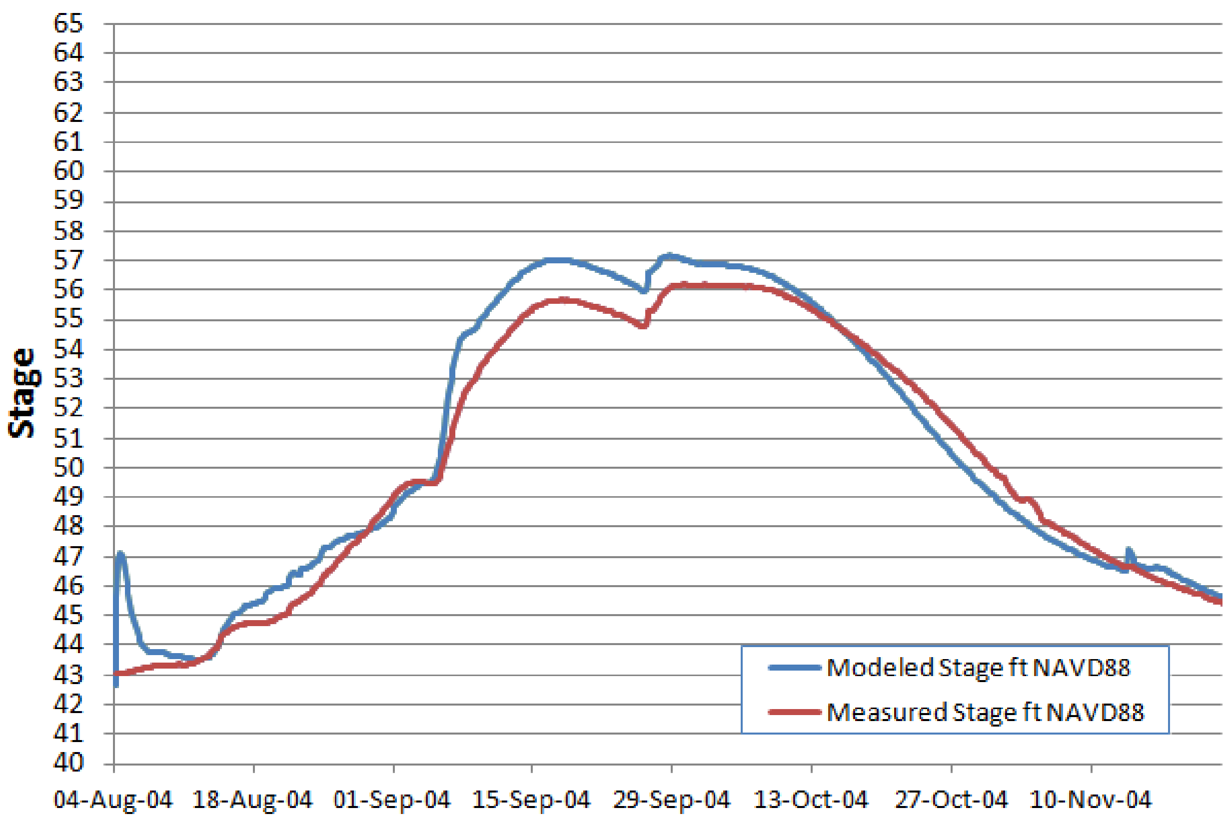


Figure 4-16: Stage Calibration Graph Rital

4.4.4.6. Little Withlacoochee River near Tarrytown

The USGS gauge for the Little Withlacoochee River near Tarrytown (USGS#02312180) in the Green Swamp is measured at SR 471, for both stage and flow as seen in **Figures 4-17** and **4-18**. The stage graph shows good visual agreement between the measured and modeled stages, while the flow graph under predicts the flow at the peaks.

This is inconsistent with the results at the Rerdell gauge downstream on the Little Withlacoochee River and the Croom gauge on the Withlacoochee River, just downstream of the Little Withlacoochee confluence. According to the documentation provided by USGS on the gauge, flow reported during high water conditions also includes the multiple culverts to the north and south of the SR471 crossing. This expansion of the flow measurement, could explain the discrepancy. The culverts to the north of the SR471 crossing were originally incorporated within the approximate study for the Little Withlacoochee River, but were included into the 2D mesh during the ICPRv4 model development. The culverts to the south of the gauge are included in the East Hernando detailed study and used as an ICPRv4 inflow. The East Hernando Withlacoochee River detailed study would need to be integrated into the 2D mesh to fully incorporate the dynamic flows at this location. However, maintaining them separately does not appear to have a significant impact on results further down the river.

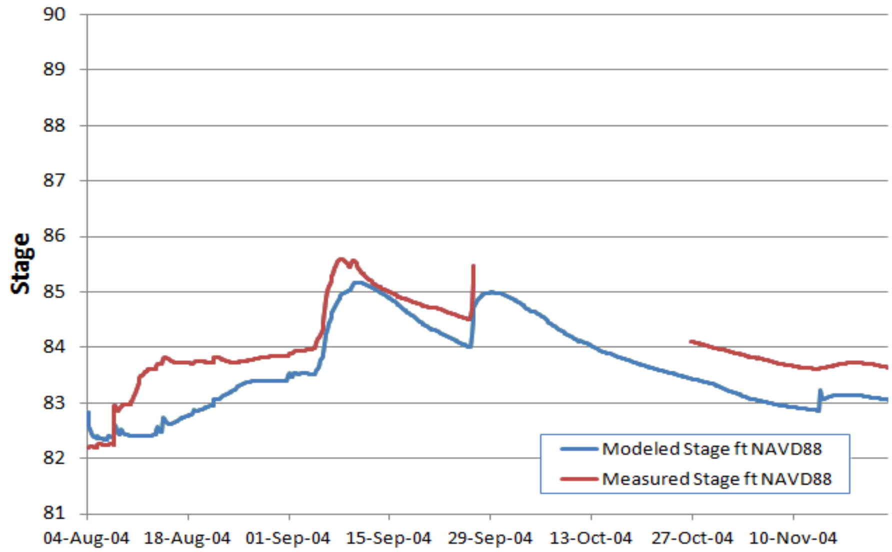


Figure 4-17: Stage Calibration Graph Tarrytown

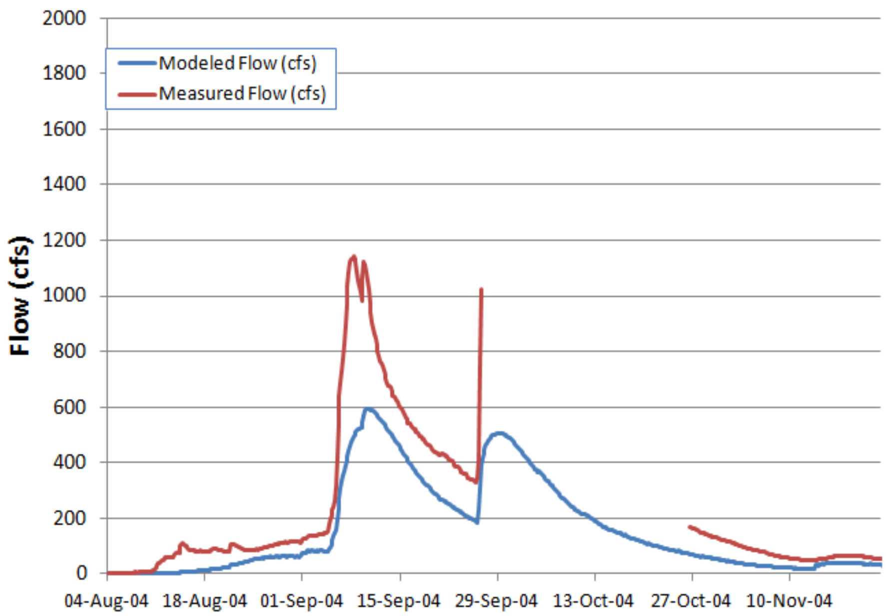


Figure 4-18: Flow Calibration Graph Tarrytown

4.4.4.7. Little Withlacoochee River at Rerdell

The USGS gauge at Rerdell, (USGS#02312200) is the second of two USGS gauges on the Little Withlacoochee River and is located just downstream of the Gant Lake outfall canal. Downstream of the Rerdell gauge, the Little Withlacoochee joins the Withlacoochee River between the USGS gauges at Rital and Croom, just upstream of Silver Lake. Visual inspection of the stage graph shows a good correlation between the measured and modeled stages at the gauge for the second and third hurricanes. The only exception was the relatively dry period in August of 2004 where modeled results remained above elevation 63 ft NAVD88 representing the invert of the simulated channel and the raw LiDAR, “best available” ground elevation. The USGS gauge at Rerdell also represents the limit of the Withlacoochee River’s detailed hydrographic survey performed by Morgan and Eklund. This minor difference in the bottom elevation of the cross section does not appear to have any impact on the simulated flow, as the flows track well in early August as seen in **Figure 4-20** or on the stage results, as the stage graph beyond August matches very well.

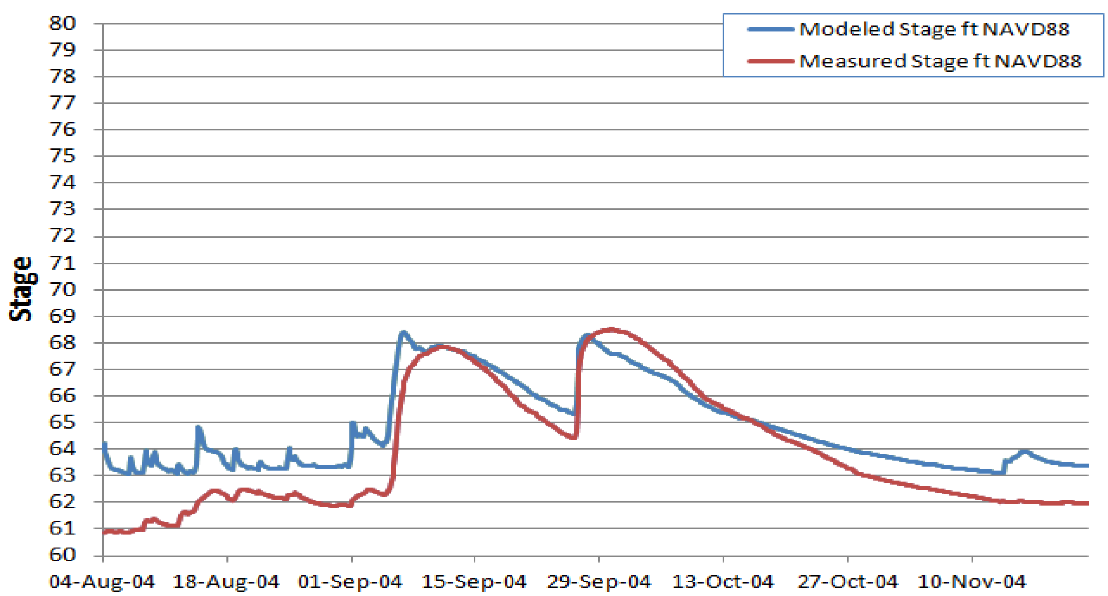


Figure 4-19: Stage Calibration Graph Rerdell

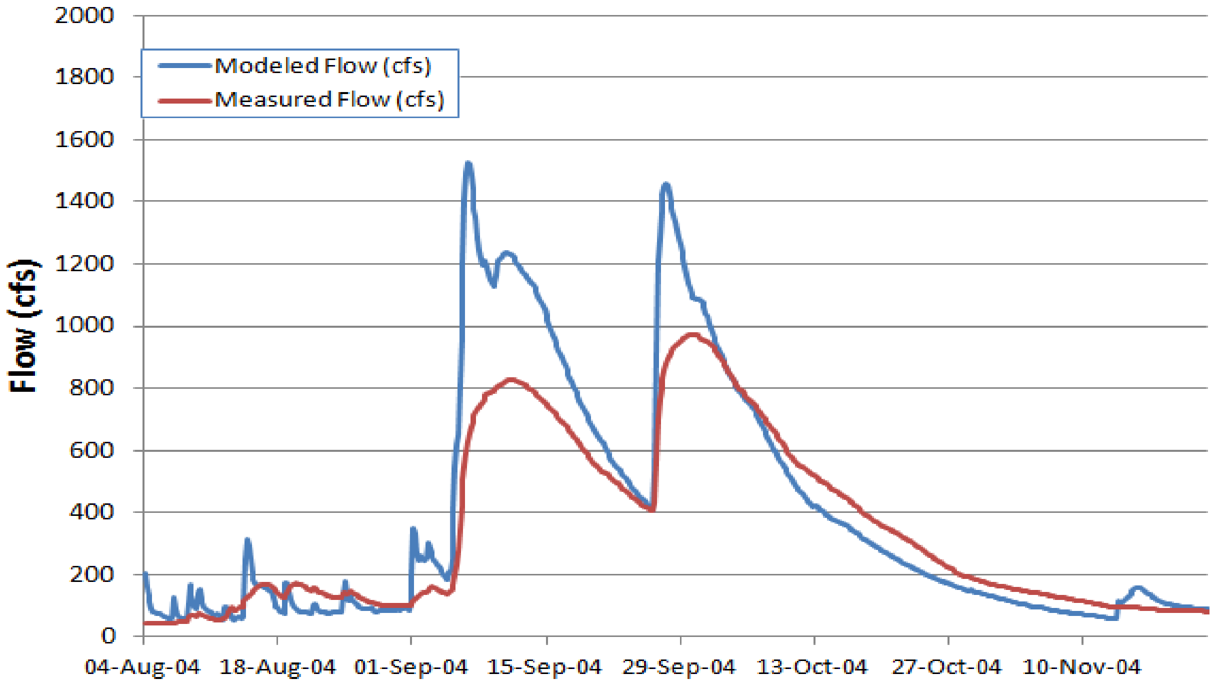


Figure 4-20: Flow Calibration Graph Rerdell

4.4.4.8. Withlacoochee River at Croom

Downstream of the confluence with the Little Withlacoochee River is the USGS gauge (USGS#02312500) at Croom. This gauge was deemed of critical importance to the modeled calibration, based upon this location being downstream of this confluence and inclusive of flows from the entire Green Swamp flowing down the Withlacoochee River. Results of the calibration, seen in **Figures 4-21** and **4-22** show good agreement between the measured and modeled stages and flows here represent reasonable verification model results.

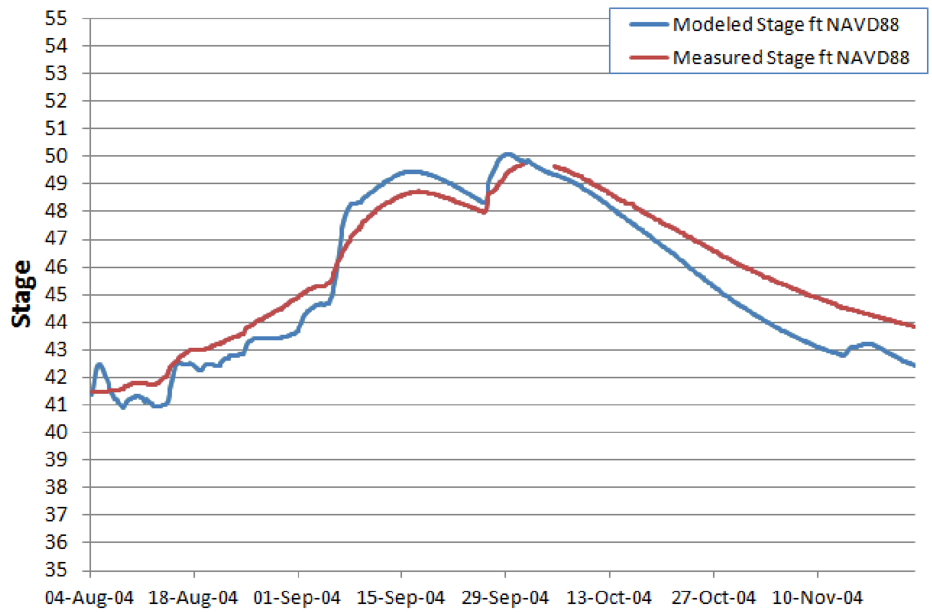


Figure 4-21: Stage Calibration Graph Croom

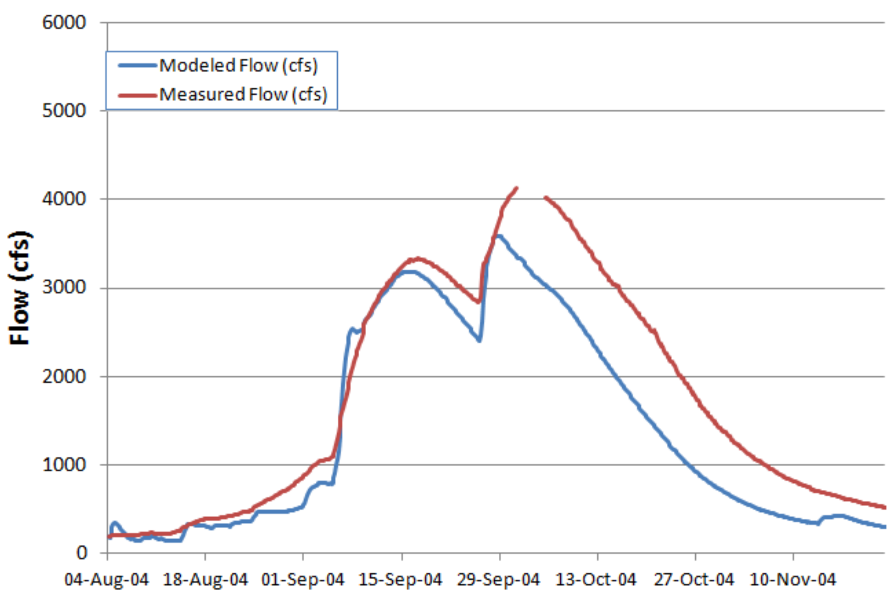


Figure 4-22: Flow Calibration Graph Croom

4.4.4.9. Withlacoochee River at Nobleton

As with the gauge at Croom, the flow at Nobleton is completely channelized and contained within the banks of the river. The Nobleton USGS gauge (USGS#02312558), seen in **Figure 4-23**, matches the buildup through the August 2004 time period, in advance of hurricane Frances. Hurricane Frances in early September then tracks almost identically and follows the trend line of the recession limb from the end of September through November, showing good visual hydrograph match to the measured data.

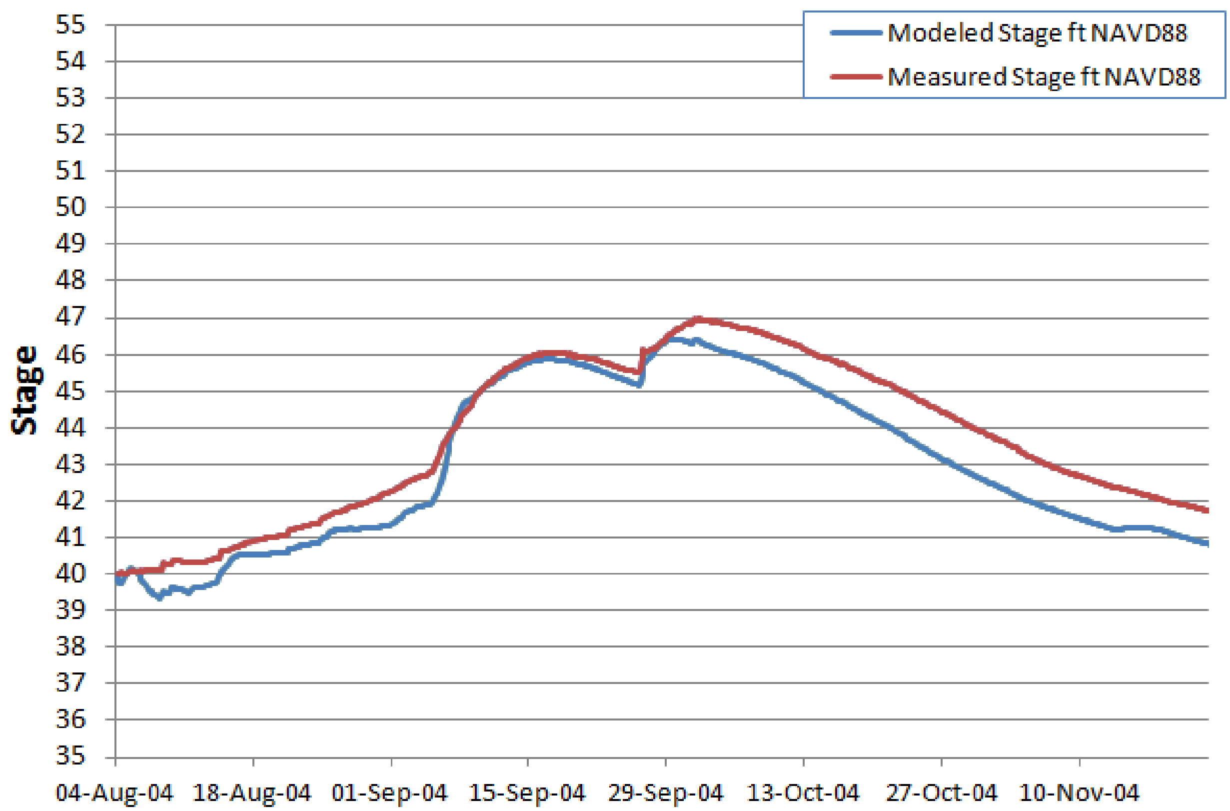


Figure 4-23: Stage Calibration Graph Nobleton

4.4.4.10. Withlacoochee River at CR48

The SWFWMD gauge, (SWFWMD#23419) at CR48 is just downstream of the Nobleton gauge and the last gauge before the inflow canals to the Tsala Apopka Chain of Lakes. Stage recording, seen in **Figure 4-24**, is almost an identical match to the measured stage data at all points of the rising limb, through both hurricanes and through the receding limb of the 2004 hurricane season. This excellent calibration was also reflected in the 0.99 coefficient of determination statistical metric.

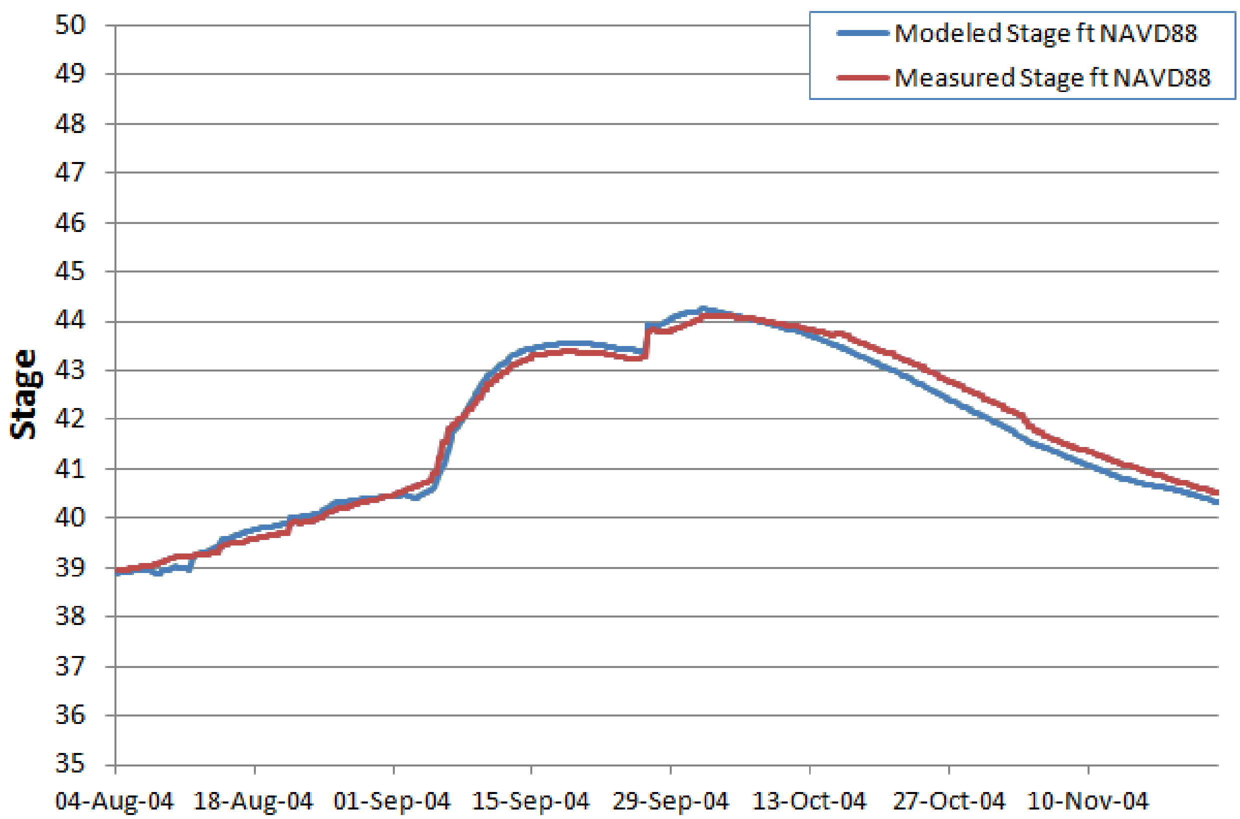


Figure 4-24: Stage Calibration Graph CR48

4.4.4.11. Withlacoochee River upstream of the Leslie Heifner Structure

Downstream of CR 48, the inflow channels from the Withlacoochee River to the Tsala Apopka Chain of Lakes begin at on open water body in the river called Bonnet Lake. The flow into the diversion channel on the upstream side of the Leslie Heifner Structure is measured at SWFWMD gauge (SWFWMD#23501). As shown in **Figure 4-25**, just like the CR48 gauge, the stage is almost an identical match to the measured data at all points during the four month verification simulation. This indicates an excellent model calibration at this gauge.

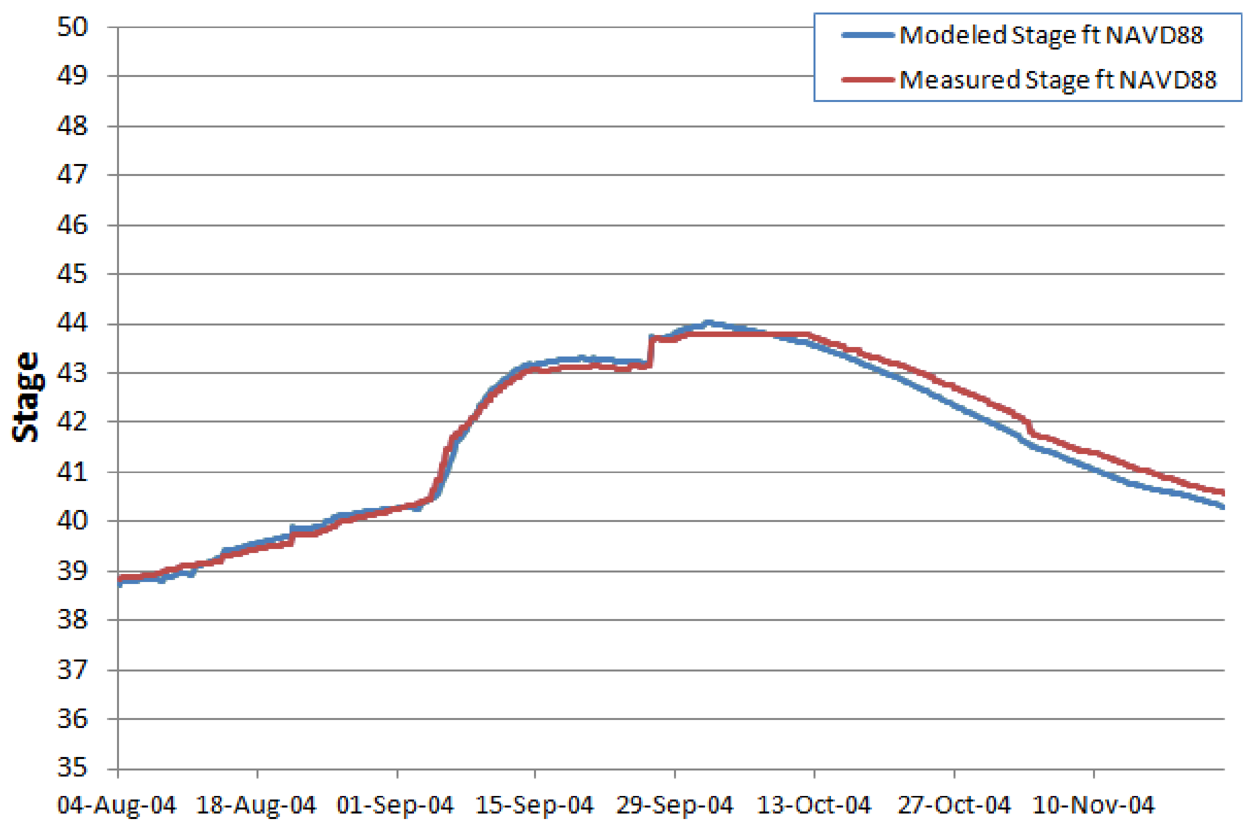


Figure 4-25: Stage Calibration Graph Leslie Heifner Structure (upstream)

4.4.4.12. Tsala Apopka Pool downstream of the Leslie Heifner Structure

On the downstream side of the Leslie Heifner structure is the SWFWMD gauge (SWFWMD#23502), shown in **Figure 4-26**. This gauge reflects the headloss through the structure when it is open and the response of the inflow channel to equalize with the Floral City pool, when the structure is closed. Calibration was performed on the roughness in the inflow channel, as well as the structure weir coefficient which resulted in both an excellent calibration at the gauge and matching the SWFWMD structure rating through the Leslie Heifner structure during both low and high flow conditions. It is of note that some of the structure operation records were suspect and in conjunction with the SWFWMD's review of the operations, best estimates of the actual operations were simulated for the verification event.

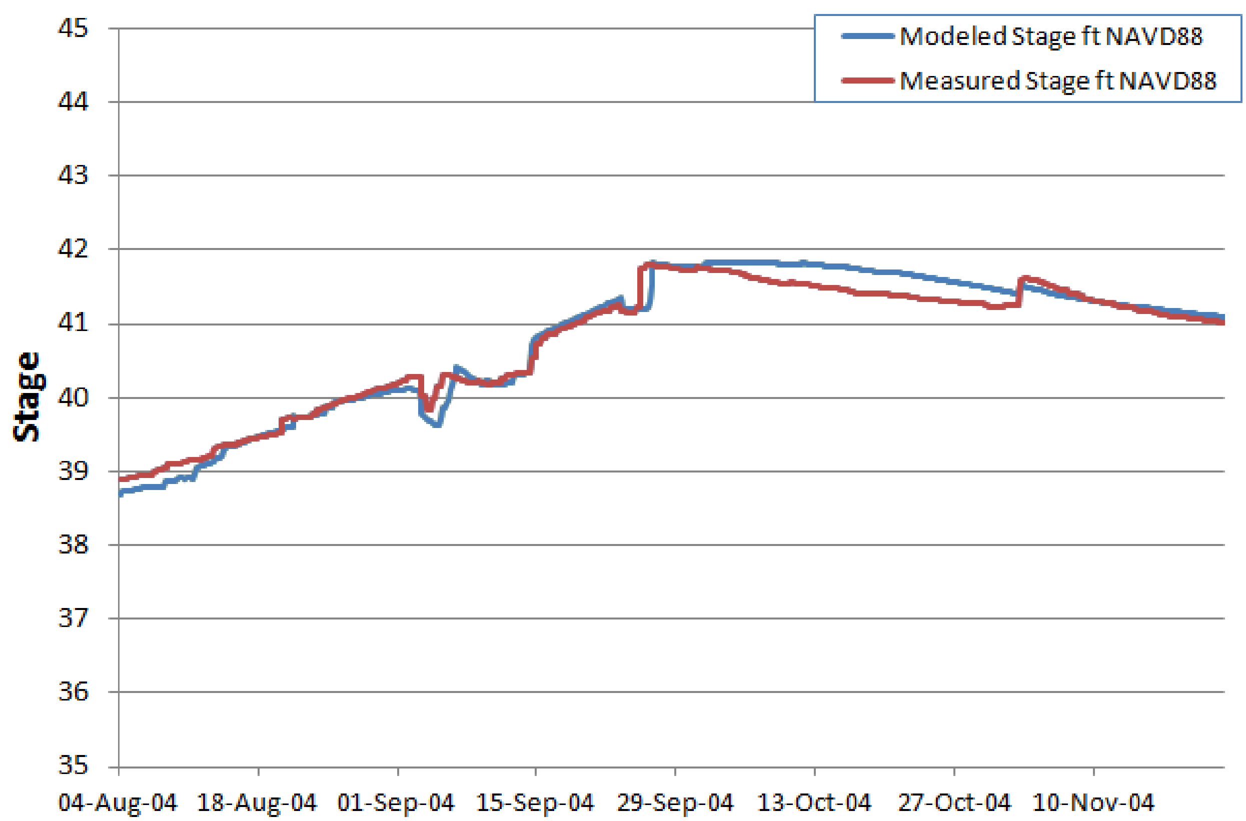


Figure 4-26: Stage Calibration Graph Leslie Heifner Structure (downstream)

4.4.4.13. Tsala Apoka – Floral City Pool

Downstream of the Leslie Heifner gauge is the Floral City pool, measured daily by SWFWMD gauge (SWFWMD#22908) is seen in **Figure 4-27**. As part of the model verification, model calibrations were performed on both the inlet structures (Leslie Heifner and Floral City) and the outlet structures (Golf Course and Moccasin Slough); along with the incorporation of the marsh survey to accurately represent the ground conditions in the Tsala Apopka marsh. This resulted in the modeled data accurately simulating the measured data. This is particularly seen in the pool's immediate response to rainfall associated with Hurricanes Frances and Jeanne, shown by the sharp rises associated with the peak rainfall rates during both hurricanes.

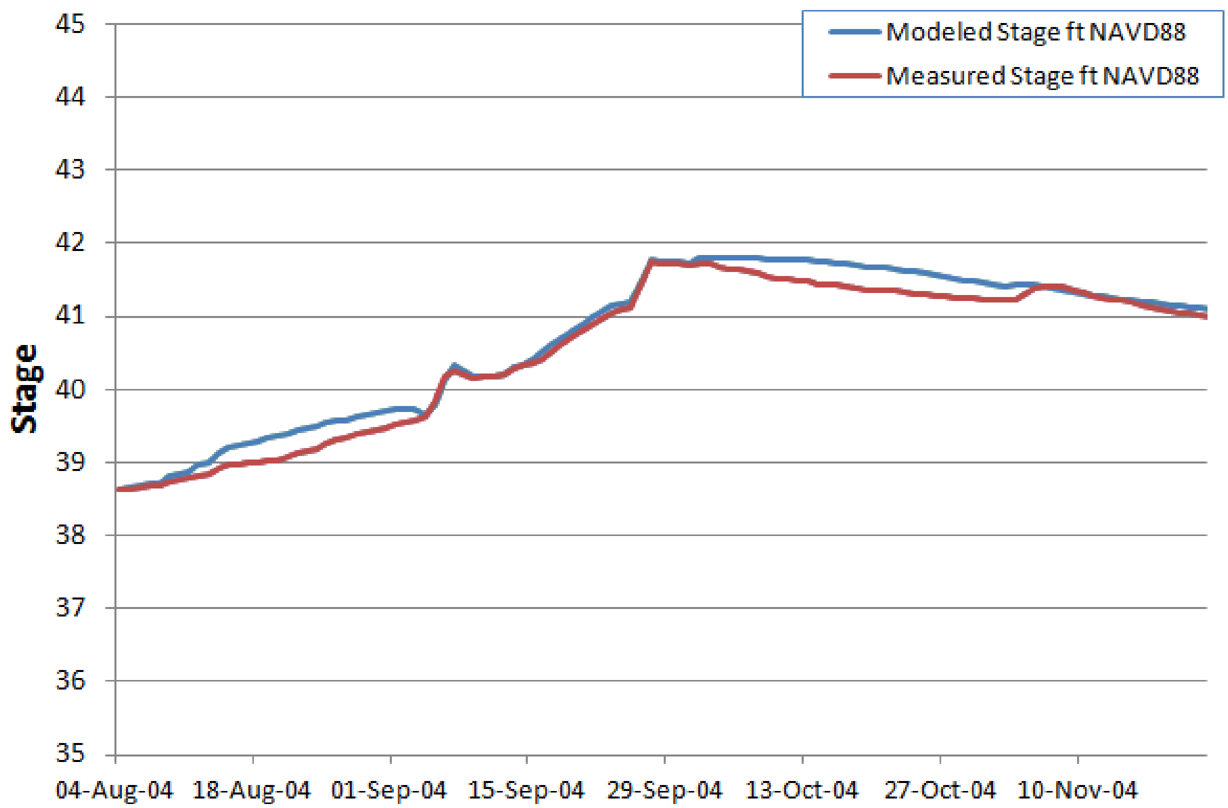


Figure 4-27: Stage Calibration Graph Floral City Pool

4.4.4.14. Tsala Apopka – Inverness Pool

The second pool in the Tsala Apopka chain is the Inverness pool, measured daily at SWFWMD gauge (SWFWMD#23481), seen in **Figure 4-28**. As with the calibration of stages in the Floral City Pool, calibration was performed such that the structure ratings for the Brogden Bridge Structure accurately matched the low and high flow conditions as independently developed by the SWFWMD for the structure. As with the Floral City Pool, the Inverness Pool calibrated very well to the verification event, particularly during the sharp rises in stage in response to the second and third hurricanes (Frances and Jeanne).

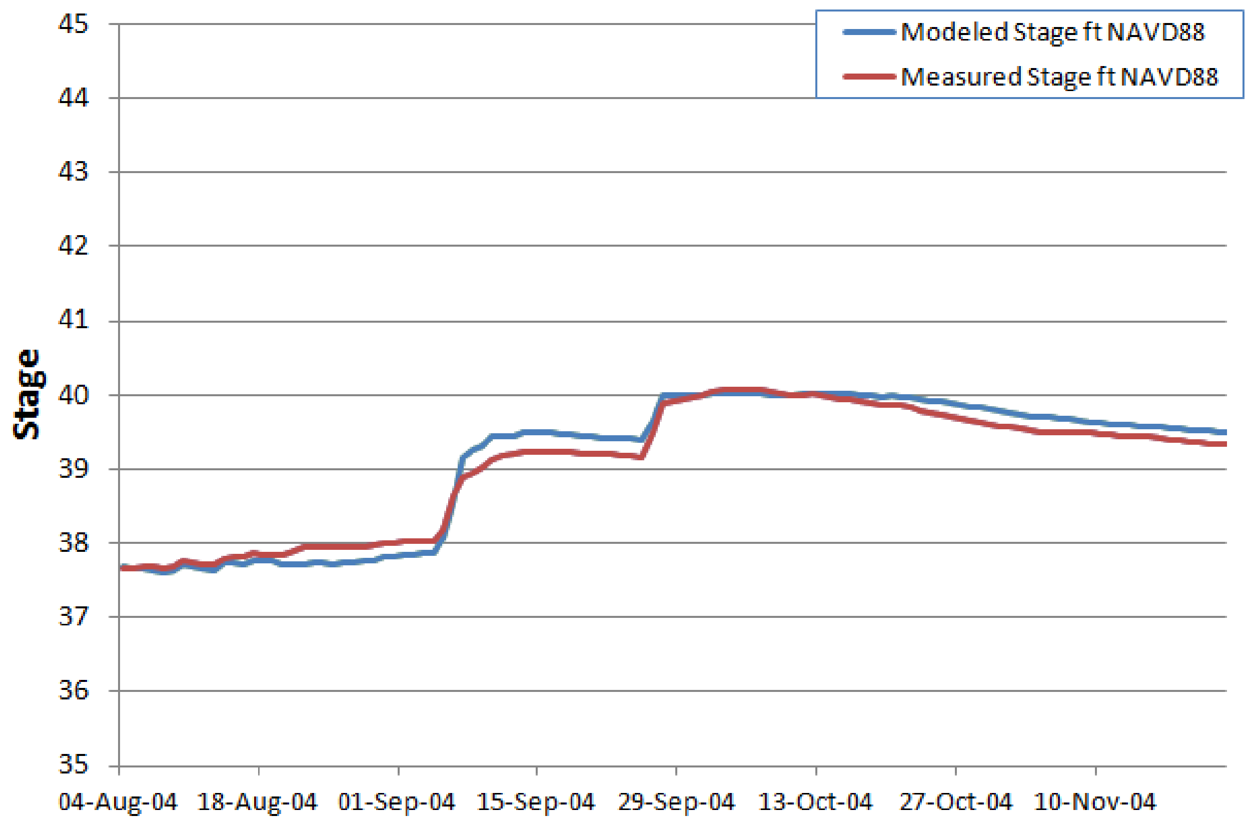


Figure 4-28: Stage Calibration Graph Inverness Pool

4.4.4.15. Tsala Apopka – Hernando Pool

Downstream of the Inverness Pool through the Brogden Bridge structure is the Hernando Pool SWFWMD gauge (SWFWMD#23609) controlled by the Van Ness and S-353 Structures. Per structure protocol, flow first goes to Van Ness then though the S-353, as was the case during the verification event. As with the previous two pools, the modeled stages in the Hernando Pool tracks the measured data very well, seen in **Figure 4-29**, including both the rising of the lake levels in response to the hurricane events. The drawdown during the receding limb, which was aided by the S-353 structure bleeding down the pool at various rates towards the end of the hurricane season also tracks the measured data well.

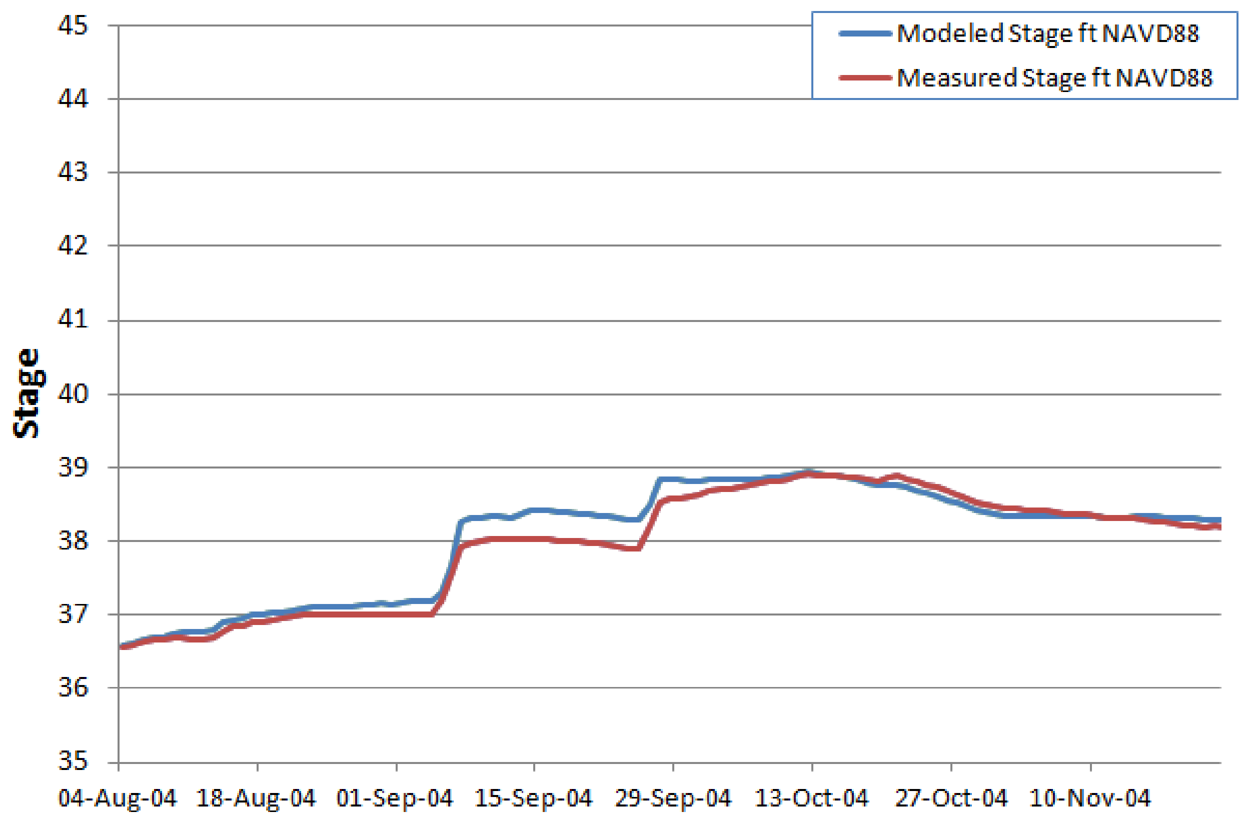


Figure 4-29: Stage Calibration Graph Hernando Pool

4.4.4.16. Tsala Apopka outlet S-353 Structure

USGS gauge (USGS#02312975), measures the stage at the upstream side of the S-353 structure. This structure was closed for much of the verification storm event as flows were initially sent towards Two Mile Prairie through the Van Ness Structure. When the structure is closed, the stage on the upstream side of this structure is reflective of the stage in the Hernando pool with only slight differences occurring when the gate is opened. As with the Hernando gauge, model simulation values tracked measured values for good model calibration results as seen in **Figure 4-30**.

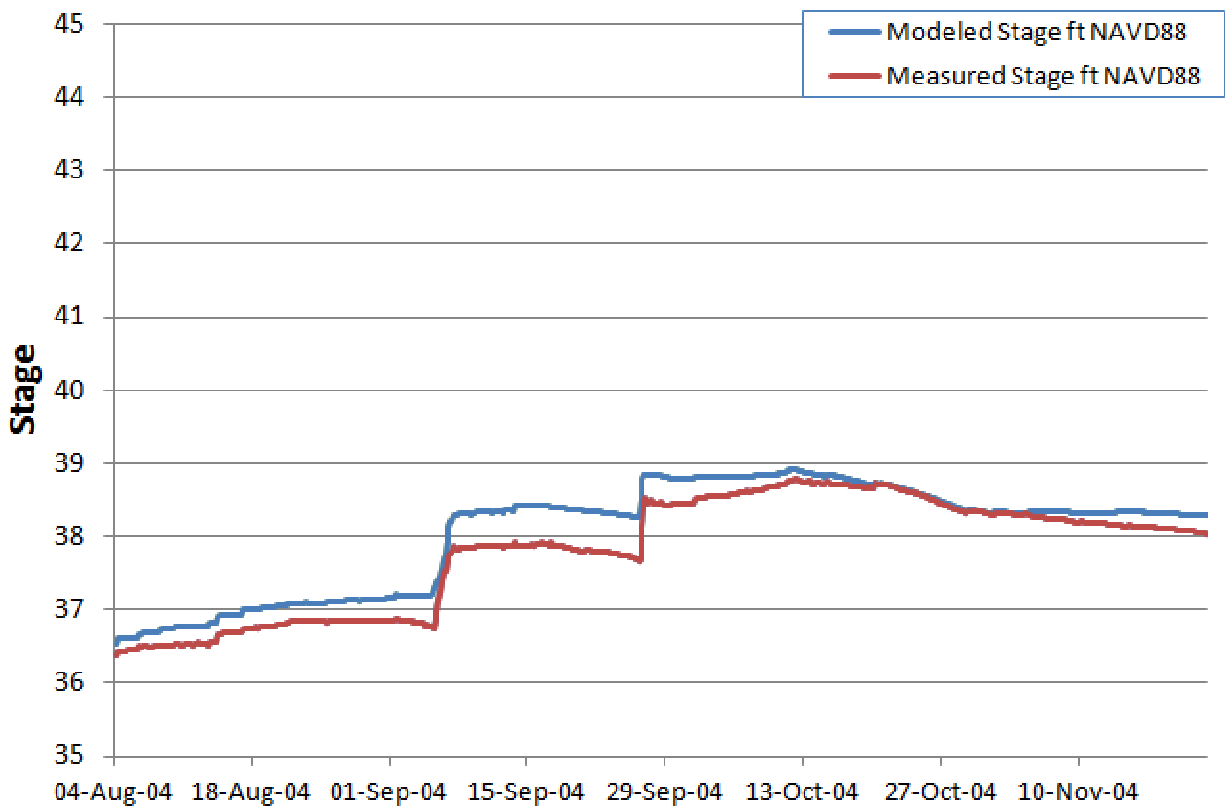


Figure 4-30: Stage Calibration Graph S-353

4.4.4.17. Withlacoochee River near Floral City

The USGS gauge at the Withlacoochee River near Floral City (USGS#02312600) represents stages and flows in the river just downstream of the inflow canals to the Tsala Apopka Chain of Lakes. **Figure 4-31** shows the modeled and measured stage matching nearly identically throughout the entire simulation. The modeled flows also match well through Hurricane Frances, yet under predict the peak for Hurricane Jeanne. This is likely due to the limitations of the USGS rating curve which extrapolated the flow at the higher observed river stages, overall however, calibration at the USGS gauge near Floral City is very good.

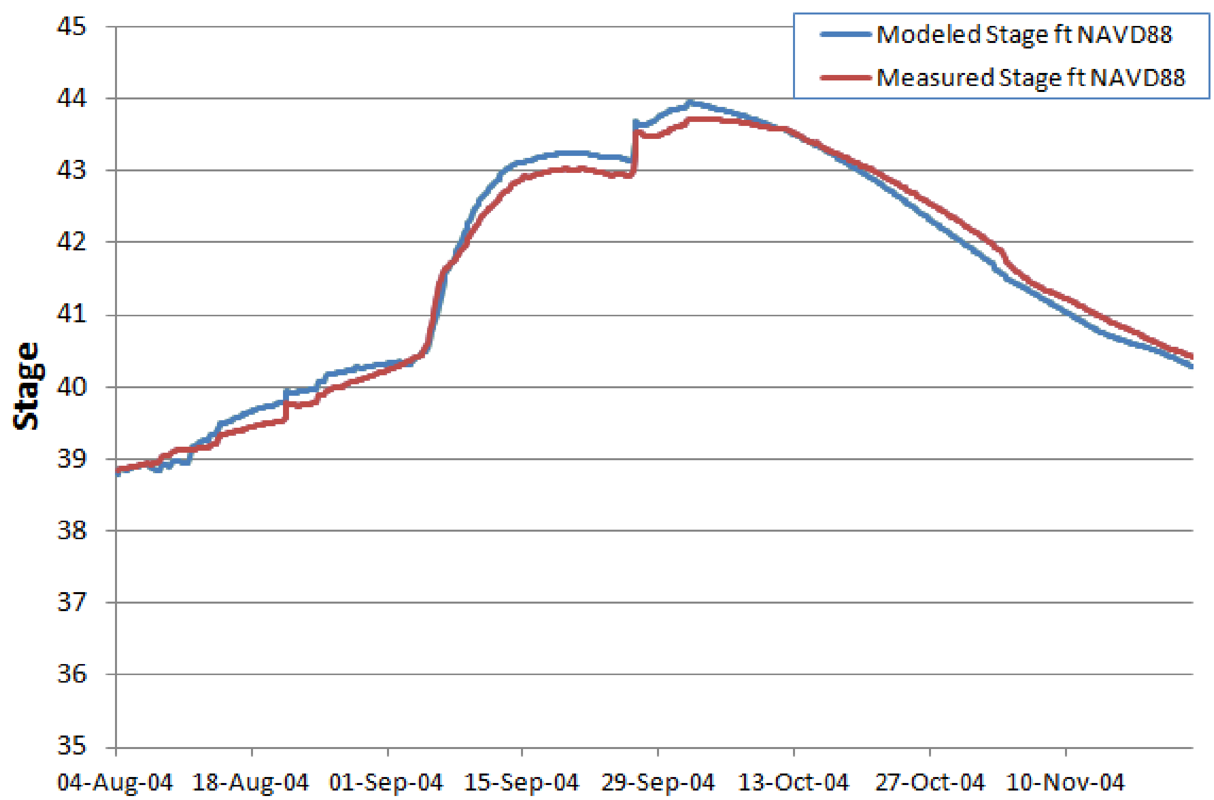


Figure 4-31: Stage Calibration Graph near Floral City

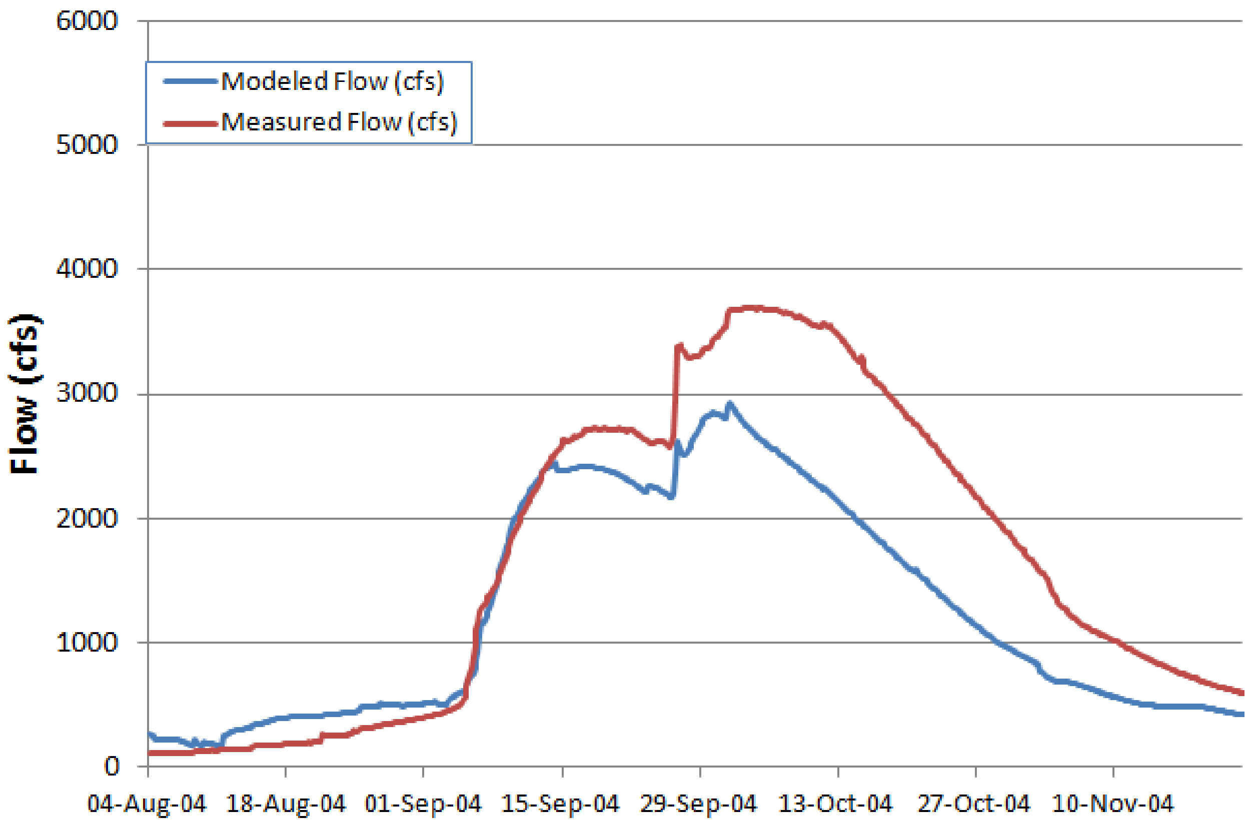


Figure 4-32: Flow Calibration Graph near Floral City

4.4.4.18. Lake Panasoffkee

Lake Panasoffkee is connected to the Withlacoochee River through the Outlet River. Stages in the lake are controlled by the Wysong-Coogler Water Control Structure located downstream of the Outlet River. USGS gauge (USGS#02312698) measured the stage in the lake, as seen in **Figure 4-33**. The modeled results for Lake Panasoffkee almost identically match the measured data through each of the rises in response to the second and third hurricanes, as well as, the entire receding limb. Flow data in the Outlet River at USGS gauge (USGS#02312700), which only reported daily flow values show a general agreement in the trend without matching the specific shape likely due to the method USGS uses to calculate the flow rather than a error in the calibration.

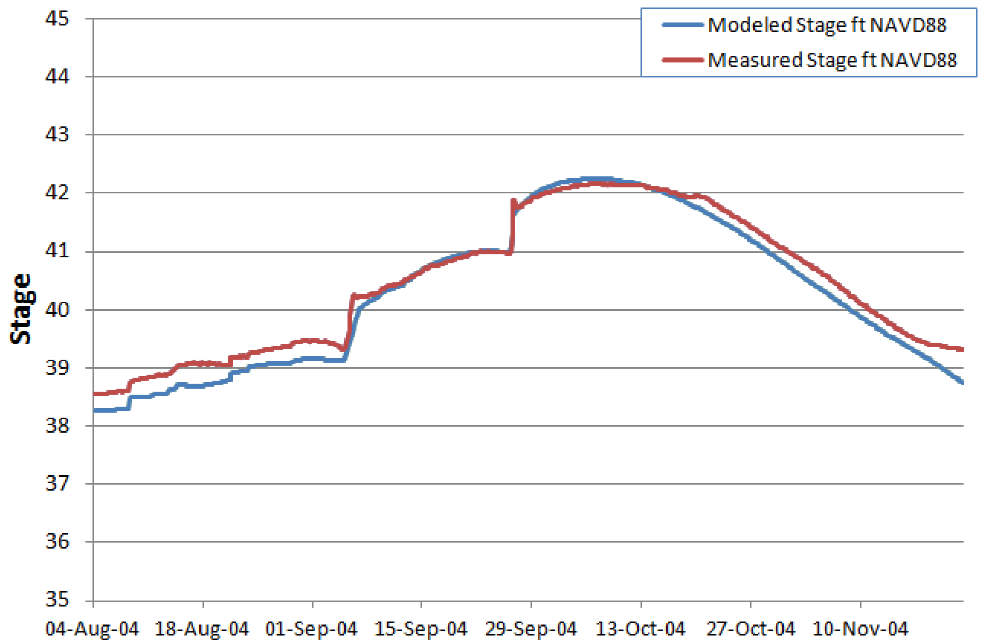


Figure 4-33: Stage Calibration Graph Panasoffkee

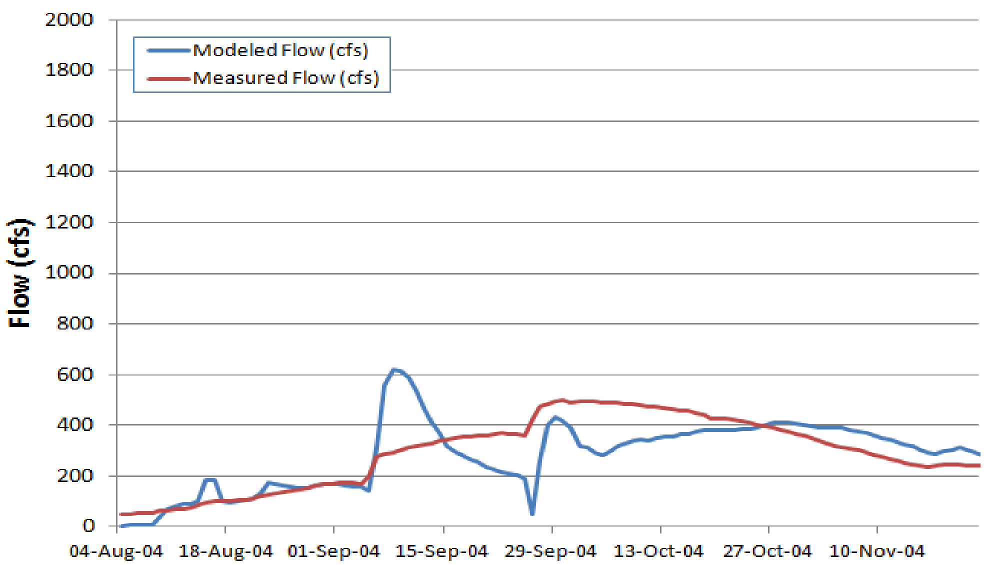


Figure 4-34: Flow Calibration Graph Outlet River

4.4.4.19. Withlacoochee River at the Wysong-Coogler Water Conservation Structure

The USGS gauge, (USGS#02312720), measures stage and flow at the Wysong-Coogler Water Conservation Structure. Similar to the Lake Panasoffkee gauge, the gauge at Wysong tracks the measured stage very well, as seen in **Figure 4-35**. The flow graph seen in **Figure 4-36** shows a consistent trend, compared to the rating derived measured flows. However, recognizing that the USGS reported flows at Wysong have a degree of variability due to the difficulty in accurately setting the height of the structure, irregularities in the inflation of the overflow weir and the inconsistency of the USGS ratings, the calibrated verification model reasonably simulates stages and flows at the Wysong-Coogler Water Conservation Structure.

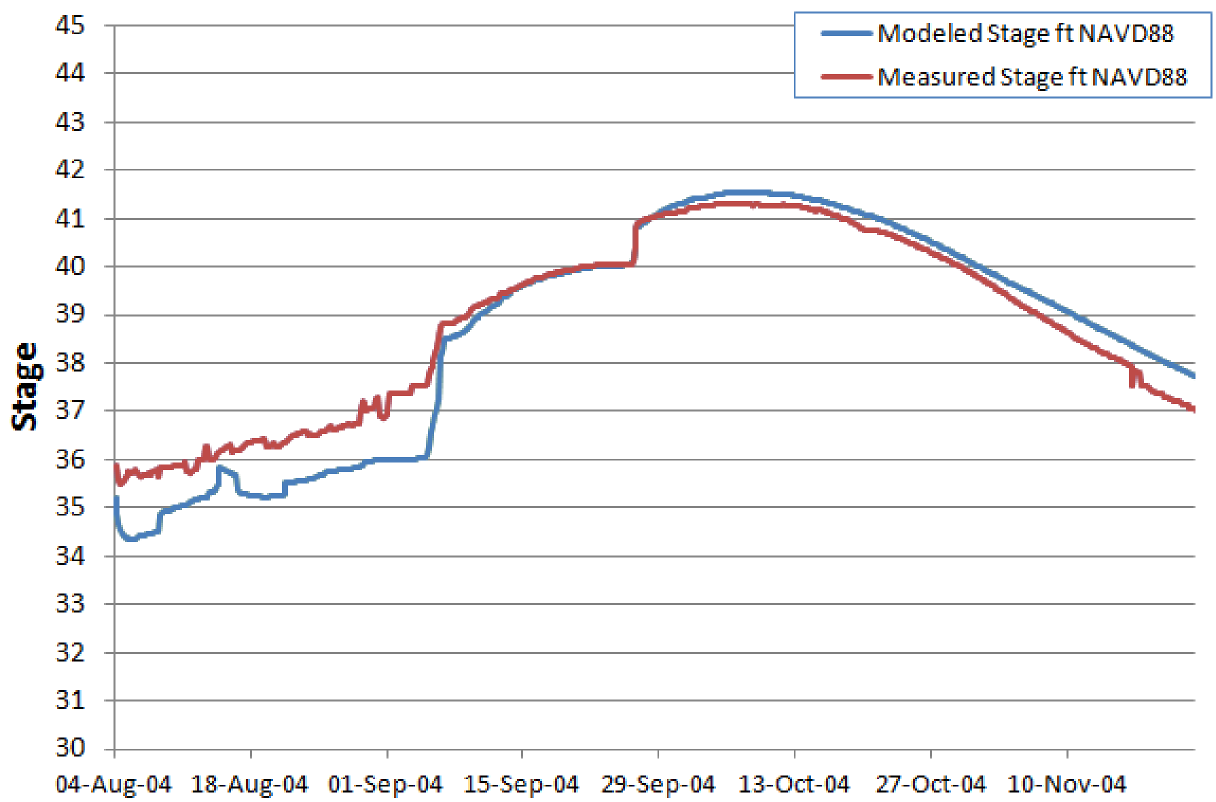


Figure 4-35: Stage Calibration Graph Wysong

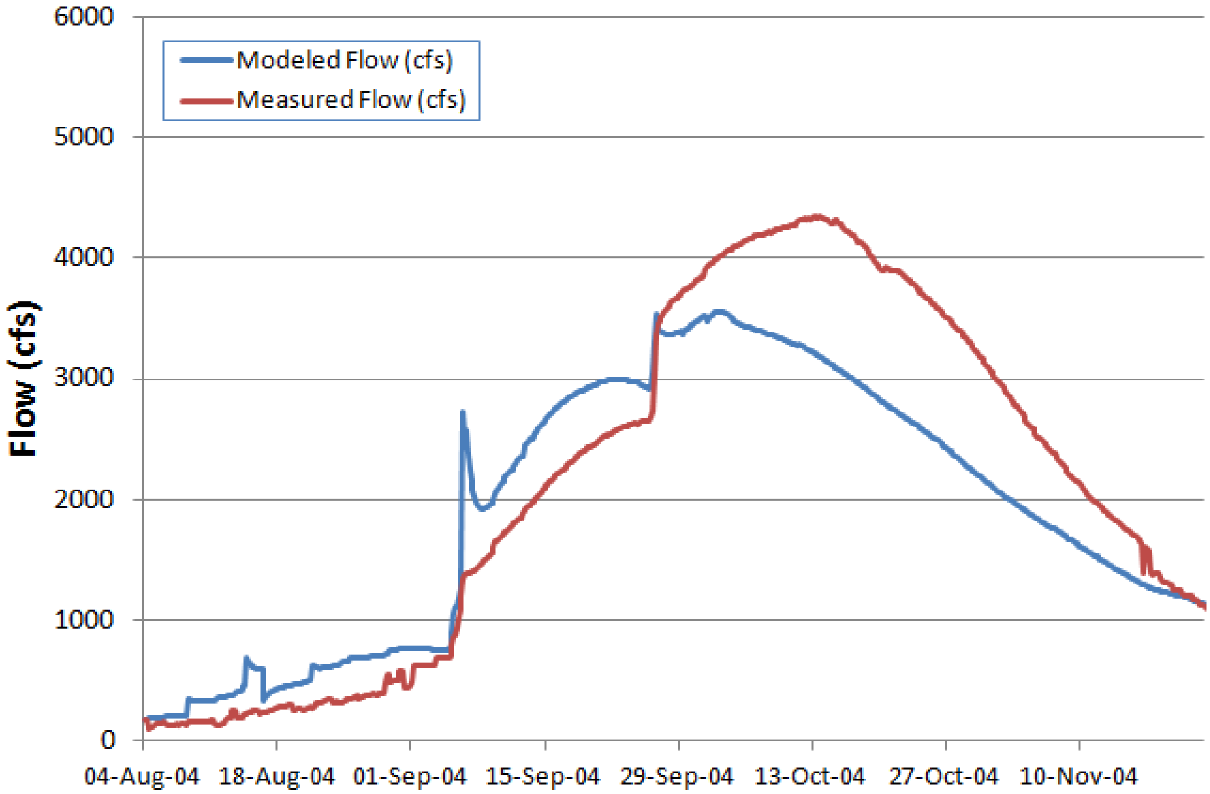


Figure 4-36: Flow Calibration Graph Wysong

4.4.4.20. Withlacoochee River near Inverness

The Inverness gauge (USGS#02312762), downstream of the Wysong-Coogler Water Conservation structure, measures river stage, as seen in **Figure 4-37**. The river in this reach, upstream of Holder, is channelized and the bed slope contains many rock outcroppings. With an r^2 value of 0.99 along with modeled peak stage within 0.5 feet of measured results, it was concluded that this portion of the model reasonably simulates measured stages at the Withlacoochee River near Inverness.

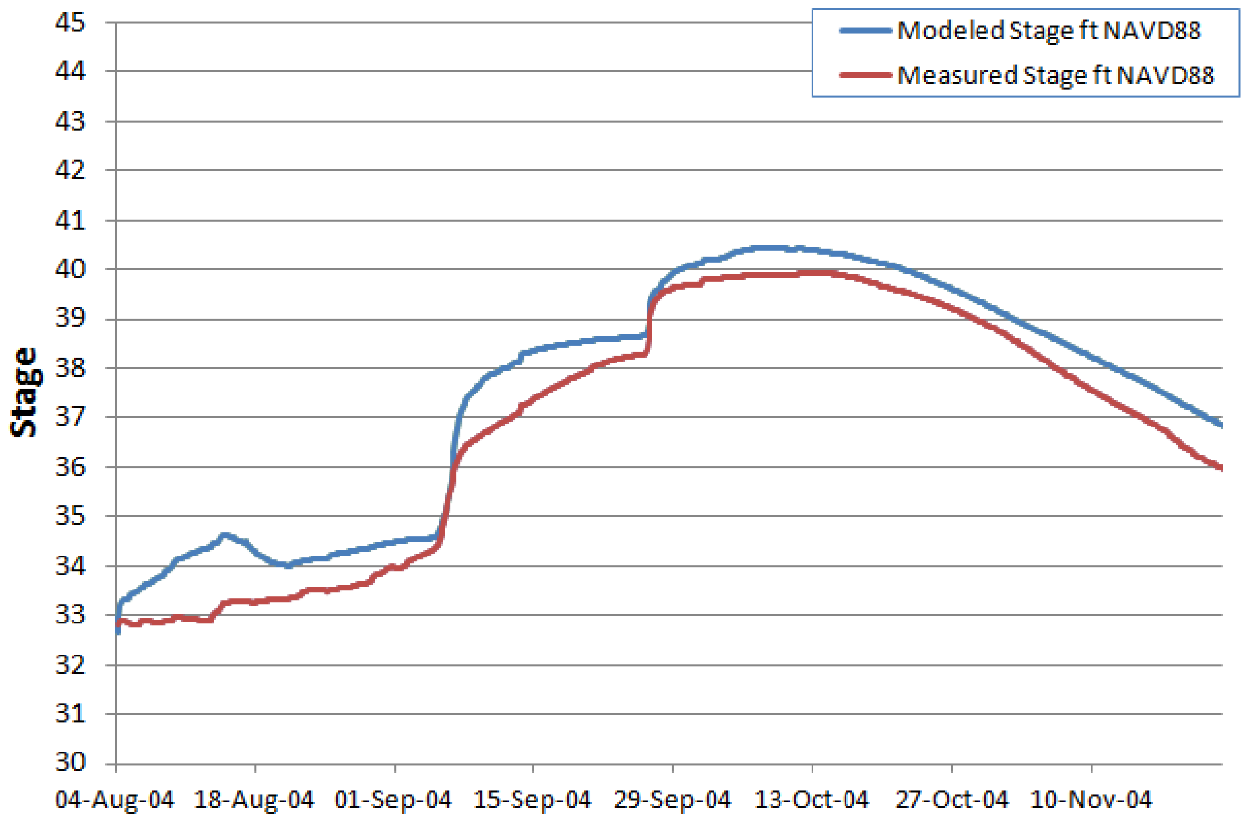


Figure 4-37 Stage Calibration Graph Inverness

4.4.4.21. Withlacoochee River at Holder

The USGS gauge at Holder (SR 200) is at the confluence of the outfall of the Tsala Apopka Chain of Lakes through Structure S-353 with the Withlacoochee River. Stage results indicated good comparisons of the measured and modeled data at USGS structure (USGS#02313000), shown in **Figure 4-38**. River flow rates seen in **Figure 4-39** also generally track measured data, with the exception of the time period between the second and third hurricanes, where the modeled flows rise slower than the measured flows. It is possible that this additional flow is related to slowly seeping baseflow from the numerous springs along the river or groundwater seeping into the river from the river banks due to the saturated ground conditions at this point in the simulation. Both of these elements are beyond the scope of the surface modeling performed herein and do not diminish the quality of the calibration at Holder for stage and flows.

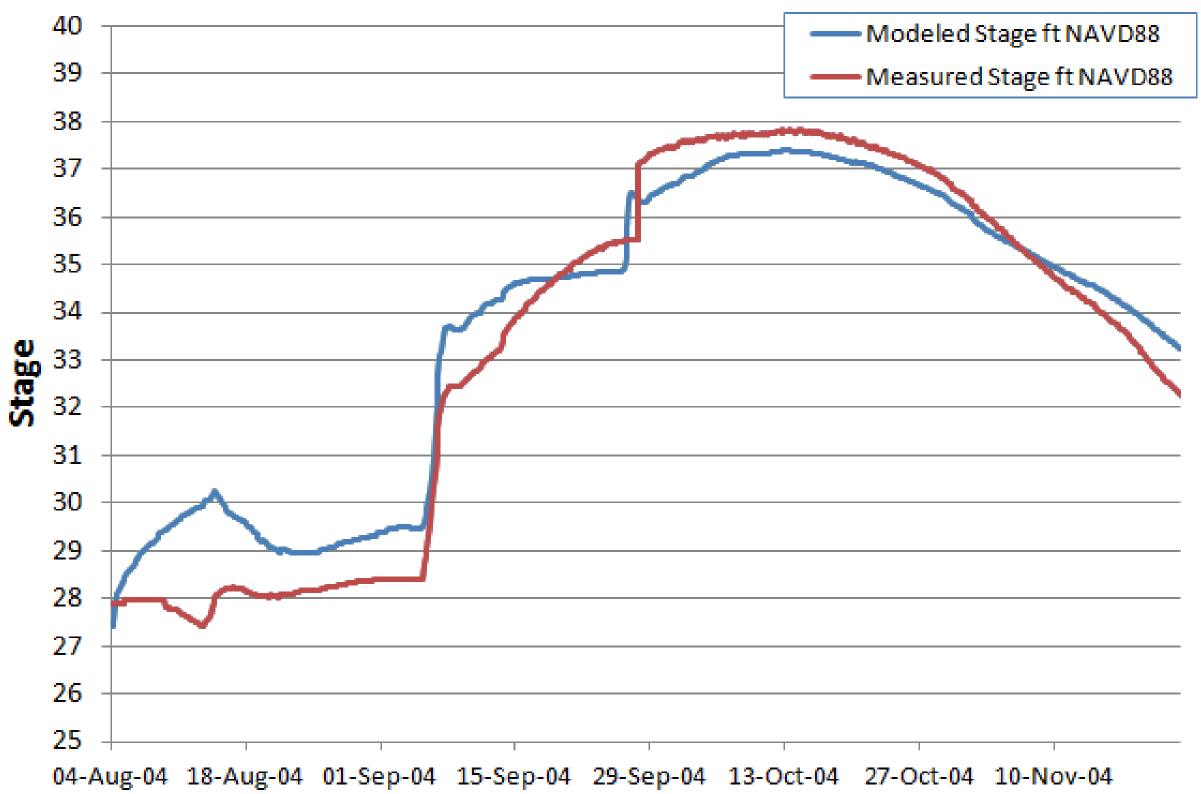


Figure 4-38: Stage Calibration Graph Holder

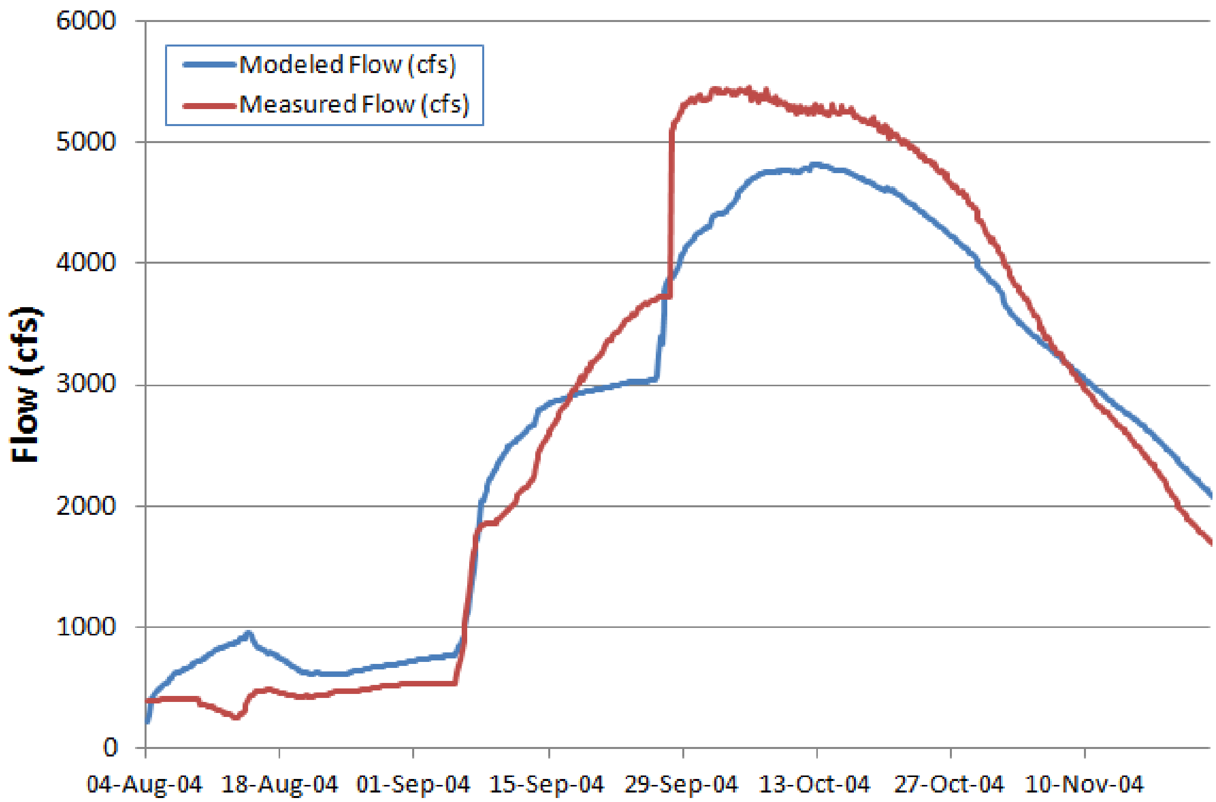


Figure 4-39: Flow Calibration Graph Holder

4.4.4.22. Withlacoochee River at Dunnellon

The USGS gauge at Dunnellon (USGS#02313200) is located at the US 41 bridge, North Florida Avenue, crossing of the Withlacoochee River. The gauge's contributing area includes virtually the entire Withlacoochee River including the Rainbow River (fed by a first magnitude spring). This gauge represents a point on the river just before the river becomes, Lake Rousseau. Stages at Dunnellon generally track the stages in Lake Rousseau, except for times when the Inglis control structures are significantly opened or a large flow rate is coming from upstream. Results of the model simulation, as compared to the measured data shown in **Figure 4-40**, reasonably track each other throughout the verification storm event and show good model calibration at Dunnellon.

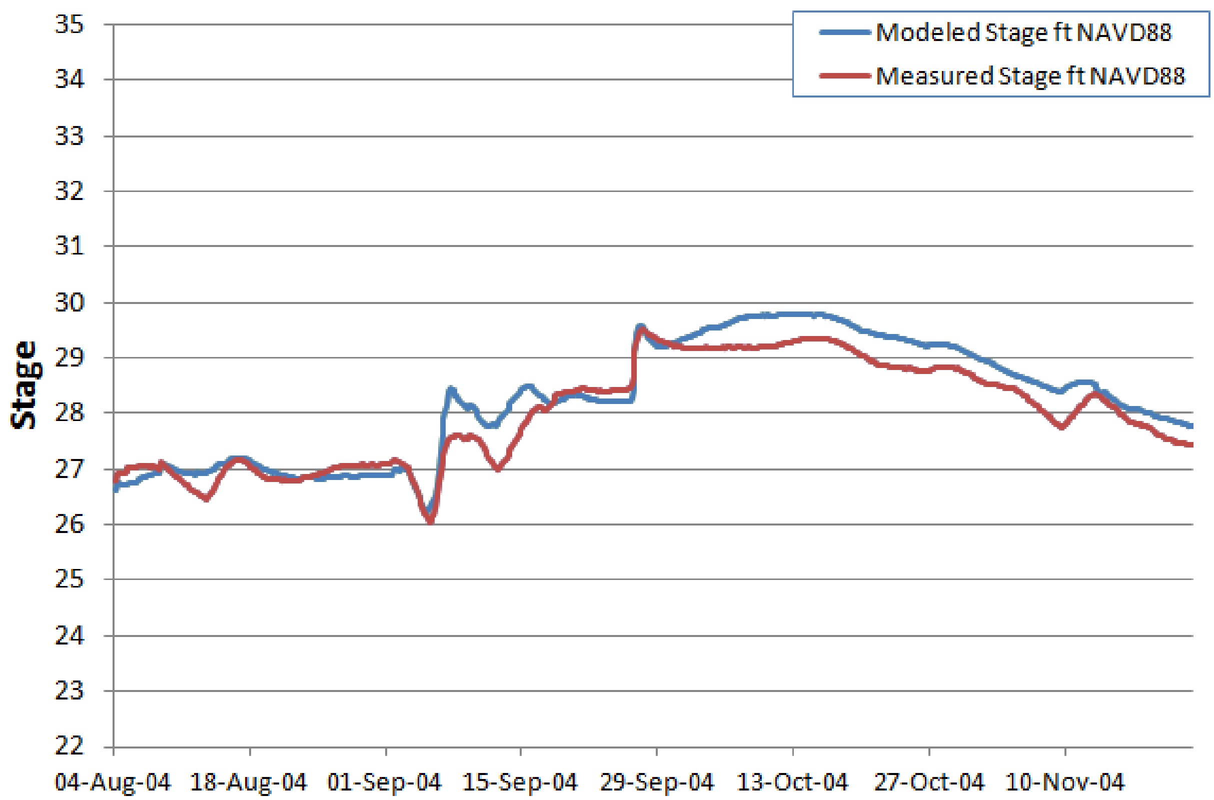


Figure 4-40: Stage Calibration Graph Dunnellon

4.4.4.23. Withlacoochee River at Lake Rousseau

Lake Rousseau was constructed in 1909 by Florida Power Corporation damming the river to create a source of hydropower. This power facility ceased operations in 1965. The lake was also intended to be part of the Cross Florida Barge Canal, as designed by the Army Corps of Engineers. However, the only portion affecting the Withlacoochee Study area that was completed is the lock system and the barge canal between the Lake Rousseau Dam and the Gulf of Mexico. Lake Rousseau is controlled by the Inglis bypass structure, which sends water down the historic Withlacoochee River through Yankeetown and through the Inglis Dam Main Gate sending water to the barge canal. Combined, these gates have sufficient capacity to maintain the lake at or around an elevation of 26.65 ft NAVD virtually independent of inflow rate.

The lake is measured by USGS gauge (USGS#02313230) on the upstream side of the Inglis Main Gate. Results for Lake Rousseau show a good correlation between measured and modeled data, as seen in **Figure 4-41**, particularly during the Hurricane Frances and Jeanne when the combine flow rate out of the Lake exceeded 6000 cfs. This demonstrates that the verification model simulation is a good predictor of measured data.

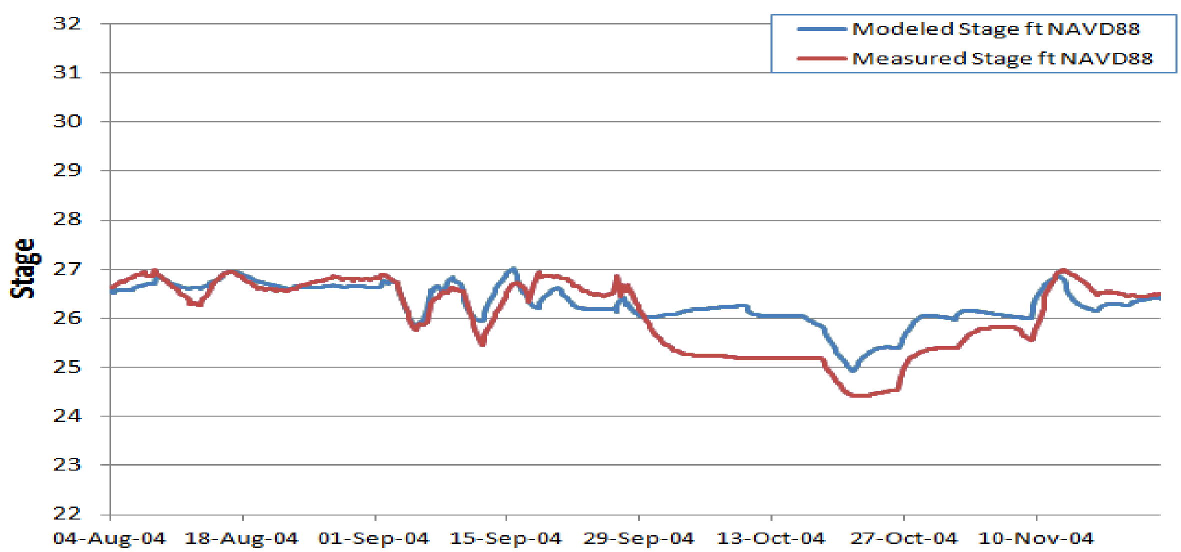


Figure 4-41: Stage Calibration Graph Lake Rousseau

4.4.4.24. Withlacoochee River at Main Dam

The Inglis Main Dam outlet from Lake Rousseau is measured via rating curve associated with gate operations and USGS gauge (USGS#02313230). The gate is operated only during events when the bypass structure is discharging at the high end of its operable range. Under this condition, this structure becomes the main control to maintain Lake Rousseau's water level. The flow comparison though the main gate is seen in **Figure 4-42** and shows good correlation between measured and modeled data, particularly during operational control changes, representing good model calibration at the Inglis Dam.

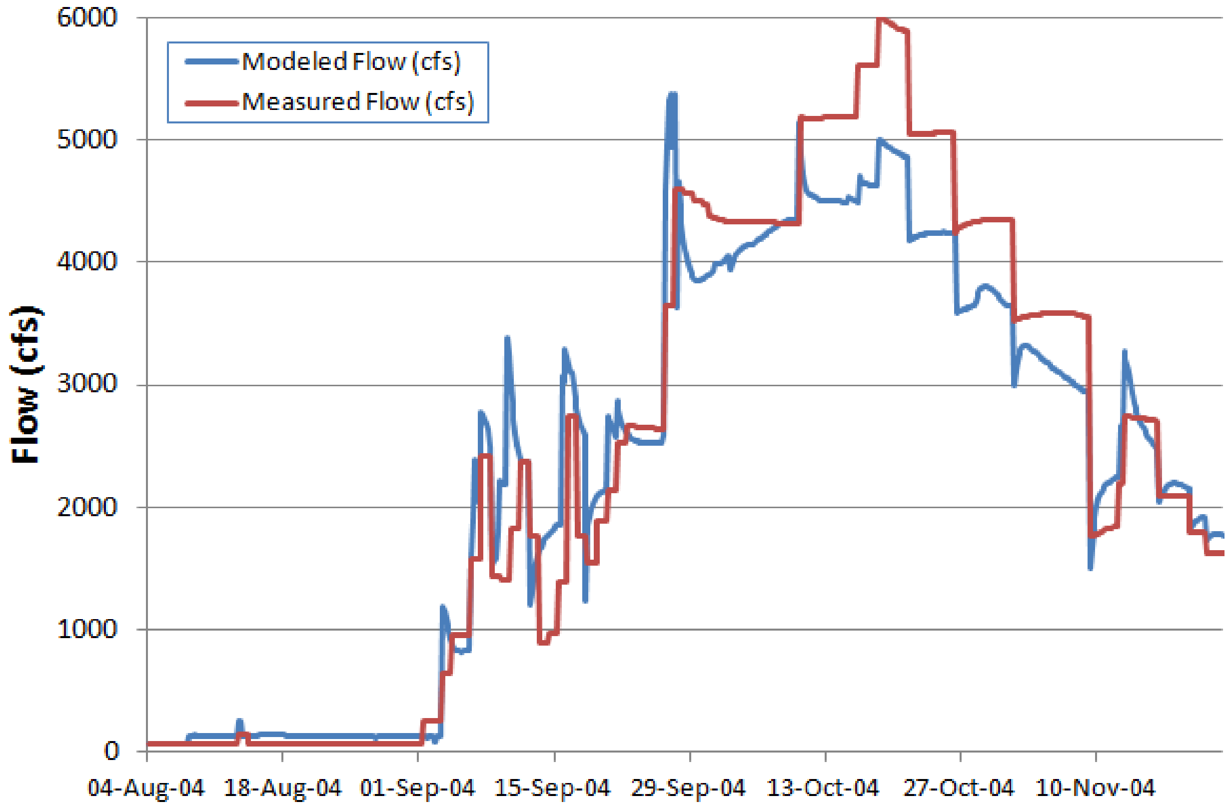


Figure 4-42: Flow Calibration Graph Inglis Main Gate

4.4.4.25. Withlacoochee River Bypass Structure

Flow through the bypass channel and Inglis Bypass structure flows down to the historic Withlacoochee River, through Yankeetown and to the Gulf of Mexico, this gauge is measured by USGS gauge (USGS#02313250). During the model calibration, many of the structure operation reports contained suspect or conflicting information as to the actual operations of the bypass gate during the 2004 hurricane season. Part of the calibration involved coordination with SWFWMD operations staff to rectify the discrepancies, such that the operations were as consistent as possible to the measured data. Visual results show decent agreement with the measured data, such that the model reasonably simulates actual conditions. Flow results comparing measured and modeled flows are seen in **Figure 4-43**.

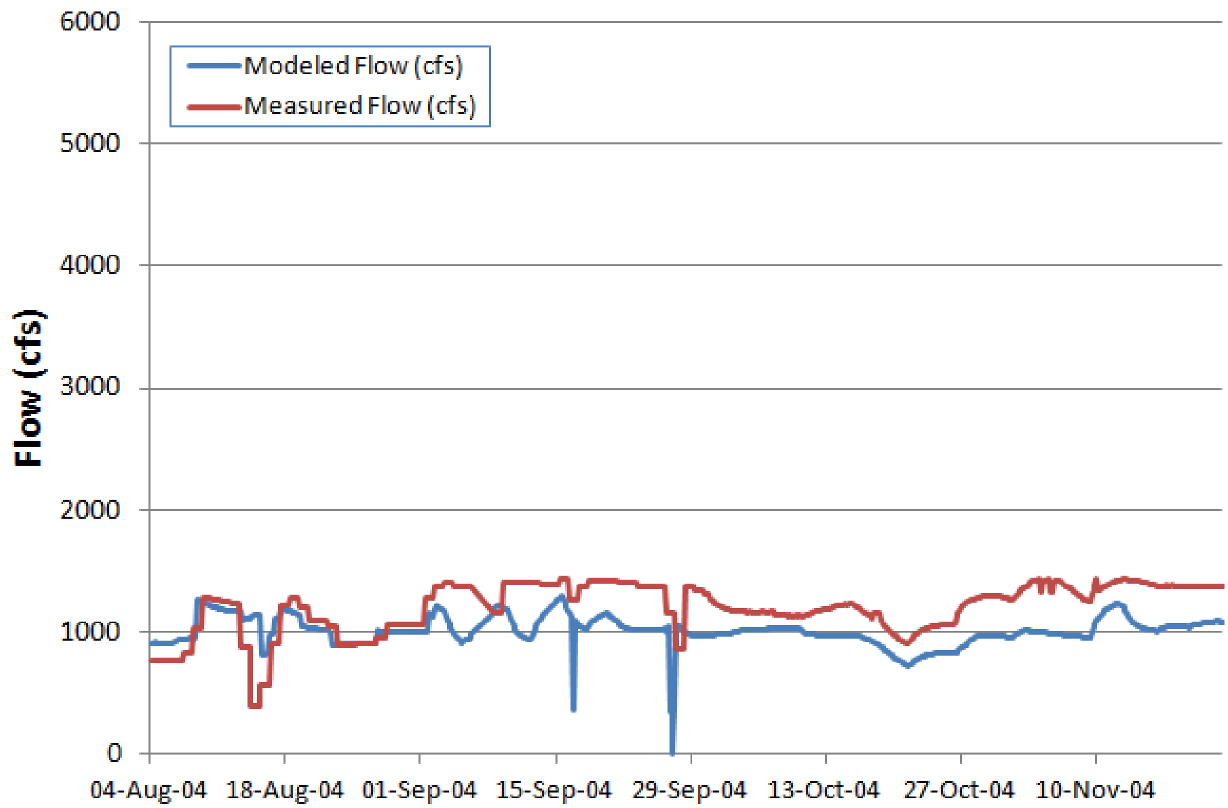


Figure 4-43: Flow Calibration Graph Ingles Bypass Canal

4.4.4.26. Withlacoochee River Barge Canal

The Barge Canal, downstream of the Inglis Main Dam is tidally controlled, being connected to the Gulf by seven miles of constructed canal. Modeled elevations here are tailwater driven and under normal or limited flow regimes will match the tidal data almost exactly. Stage data as seen in **Figure 4-44**, shows modeled results dictated by measured tailwater data.

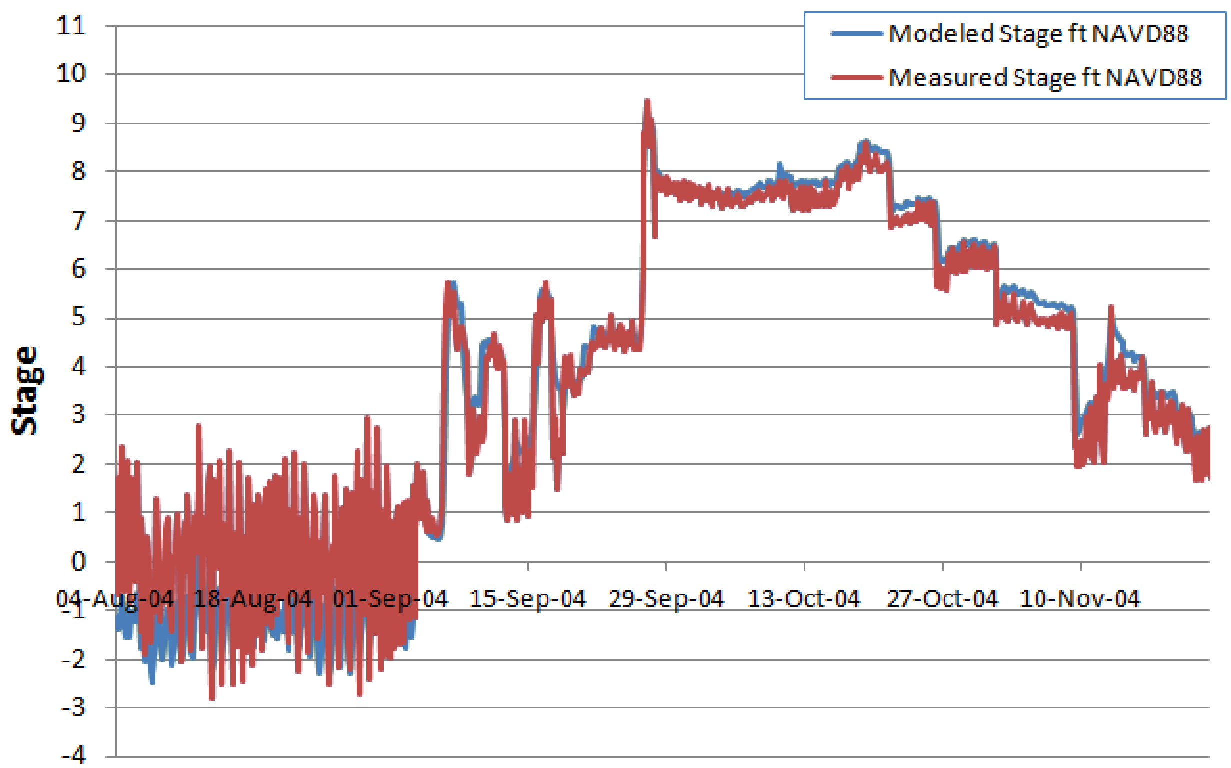


Figure 4-44: Stage Calibration Graph Barge Canal

4.4.5. Comparison to High Water Marks

High water marks (HWMs) were available throughout the watershed and were provided by the SWFWMD in their Historical Water Levels Database. This database spatially documents high water data over many decades from multiple sources in both gauged and ungauged systems. In addition to the HWMs previously available within the watershed and along the river, new HWMs were collected along the river during the bathymetric survey efforts of this project. Many of the available HWMs were attributed to the 2004 hurricane season and included wetland gauges, stain lines on trees, personal accounts and flood photos. **Table 4-8** presents a comparison of the 2004 HWMs to modeled peak stages at these same locations. In general, the modeled stages compared well to the measured HWMs despite the variability in sources and techniques used to capture the high water data and discrepancies between modeled and measured stage data presented in previous sections. To highlight the largest differences between the measured and modeled data, **Table 4-8** is sorted ascending by difference between measured and modeled stage.

Table 4-8: High Water Mark Comparison

Model Node	Modeled Max Stage	Measured HWM	Diff. (feet)	App. Event Date	FSPW Easting	FSPW Northing
Node_288	61.24	64.13	-2.9	09/26/2004	591730	1508802
Node_287	61.30	63.96	-2.7	09/26/2004	591381	1508302
Node_267	62.38	64.70	-2.3	10/2004	596536	1508015
Node_299	60.26	62.40	-2.1	10/2004	590644	1512403
Node_293	60.71	62.70	-2.0	10/2004	592626	1509946
Node_263	62.75	64.70	-2.0	10/2004	598246	1507090
Node_290	61.09	63.00	-1.9	10/2004	591669	1509443
Node_275	62.02	63.90	-1.9	10/2004	593821	1506387
Node_285	61.45	63.20	-1.8	10/2004	591453	1507277
Node_304	59.85	61.60	-1.7	10/2004	591743	1514344
Node_286	61.37	63.10	-1.7	10/2004	591385	1507859
Node_315	58.88	60.50	-1.6	10/2004	589923	1516263
Node_345	52.89	54.40	-1.5	10/2004	591401	1533090
Node_320	58.57	59.90	-1.3	10/2004	589504	1518324
Node_338	53.44	54.70	-1.3	10/2004	592146	1532109
Node_2194	52.01	53.10	-1.1	10/2004	589371	1536922
Node_352	52.43	53.50	-1.1	10/2004	589918	1534923
Node_160	57.76	58.60	-0.8	10/2004	588865	1521346
Node_357	51.88	52.70	-0.8	10/2004	590116	1537981
Node_326	58.31	59.10	-0.8	10/2004	587824	1519548
Node_172	56.83	57.60	-0.8	10/2004	590175	1523060

Model Node	Modeled Max Stage	Measured HWM	Diff. (feet)	App. Event Date	FSPW Easting	FSPW Northing
HWM_7780	54.98	55.73	-0.7	09/26/2004	593859	1529194
Node_205	54.91	55.60	-0.7	10/2004	593147	1529526
HWM_7782	59.85	60.50	-0.7	09/26/2004	590426	1518536
Node_3356	38.23	38.70	-0.5	10/2004	549611	1690034
Node_3359	37.66	38.10	-0.4	10/2004	546607	1691877
Node_3360	37.56	38.00	-0.4	10/2004	545739	1691722
HWM_7745	35.18	35.54	-0.4	10/20/2004	536013	1688355
Node_768	37.58	37.91	-0.3	10/20/2004	548514	1680224
Node_3370	36.48	36.80	-0.3	10/2004	538465	1697044
Node_186	56.06	56.30	-0.2	10/2004	591474	1526066
Node_3358	37.86	38.10	-0.2	10/2004	547812	1691254
Node_3294	45.40	45.60	-0.2	10/2004	572662	1578208
Node_3355	38.40	38.60	-0.2	10/2004	550526	1689276
Node_3364	37.11	37.30	-0.2	10/2004	542023	1693643
Node_3361	37.39	37.55	-0.2	09/26/2004	544346	1692418
Node_365	51.44	51.60	-0.2	10/2004	591529	1539230
Node_3357	38.05	38.20	-0.2	10/2004	548613	1690441
Node_1355	37.46	37.60	-0.1	10/2004	544706	1692116
Node_2121	68.42	68.53	-0.1	09/26/2004	606233	1540968
Node_699	41.89	41.97	-0.1	9/28/2004	562626	1603900
LWR_0100	77.40	77.47	-0.1	09/05/2004	625023	1523747
HWM_7768	45.78	45.80	0.0	10/2004	567636	1570978
Node_380	50.56	50.58	0.0	09/05/2004	586591	1542875
Node_3375	35.58	35.60	0.0	10/2004	533674	1699042
Node_3379	34.99	35.00	0.0	10/2004	530127	1699835
Node_3468	43.20	43.20	0.0	10/2004	595969	1608934
Node_3452	44.42	44.40	0.0	10/2004	578125	1594904
Node_3349	38.93	38.90	0.0	10/2004	554930	1686751
Node_3421	27.35	27.30	0.0	10/2004	495648	1711961
Node_3354	38.55	38.50	0.0	10/2004	551783	1688426
Node_3351	38.81	38.70	0.1	10/2004	553714	1686634
HWM_7826	74.77	74.64	0.1	9/21/2004	612973	1462419
Node_3454	44.33	44.20	0.1	10/2004	578607	1595979
Node_3345	39.24	39.10	0.1	10/2004	556564	1682386
Node_3446	44.77	44.60	0.2	10/2004	576106	1587462

Model Node	Modeled Max Stage	Measured HWM	Diff. (feet)	App. Event Date	FSPW Easting	FSPW Northing
Node_3385	34.23	34.05	0.2	09/26/2004	527577	1702641
Node_1494	44.02	43.84	0.2	9/30/2004	582510	1606821
HWM_7747	38.06	37.88	0.2	09/26/2004	547675	1690384
Node_458	46.70	46.50	0.2	10/2004	572486	1564683
Node_3507	41.55	41.34	0.2	10/6/2004	597304	1632191
Node_428	48.43	48.20	0.2	10/2004	578492	1556472
Node_381	50.56	50.33	0.2	9/30/2004	586571	1543357
Node_3453	44.39	44.15	0.2	10/2/2004	578516	1595874
Node_3450	44.44	44.20	0.2	10/2004	576223	1592736
Node_3479	42.06	41.80	0.3	10/2004	598424	1626232
Node_1350	42.22	41.91	0.3	10/5/2004	601868	1622145
Node_454	47.18	46.80	0.4	10/2004	574586	1562415
US98-2	80.61	80.22	0.4	9/13/2004	624504	1431336
HWM_7744	32.44	32.03	0.4	11/25/2004	534486	1695162
Node_445	47.93	47.50	0.4	10/2004	576788	1559470
Node_3300	41.45	40.90	0.5	10/2004	593695	1634294
Node_3401	29.79	29.23	0.6	09/26/2004	507617	1713217
Node_3334	40.16	39.60	0.6	10/2004	563226	1673213
Node_392	50.07	49.50	0.6	10/2004	585021	1548496
Node_407	49.08	48.50	0.6	10/2004	580951	1552807
HWM_7750	41.32	40.70	0.6	10/2004	586891	1642332
Node_3482	41.77	41.14	0.6	10/6/2004	597526	1631906
Node_3339	39.73	39.10	0.6	10/2004	561031	1677940
Node_3321	40.75	40.10	0.7	10/2004	569914	1658287
Node_3338	39.87	39.20	0.7	10/2004	561961	1676870
Node_3333	40.20	39.50	0.7	10/2004	563767	1672001
Node_3329	40.33	39.60	0.7	10/2004	565734	1667127
Node_13	68.48	67.74	0.7	09/05/2004	606750	1540754
Node_3317	40.99	40.20	0.8	10/2004	577038	1652651
Node_3393	31.39	30.60	0.8	10/2004	514082	1709782
OF_Node_6356	9.25	8.40	0.9	10/19/2004	458727	1700196
Node_3325	40.55	39.70	0.9	10/2004	568085	1661551
HWM_7751	41.27	40.38	0.9	09/26/2004	584522	1642580
Node_3309	41.25	40.35	0.9	10/12/2004	583857	1643315
HWM_7775	58.70	57.67	1.0	09/26/2004	597555	1539708

Model Node	Modeled Max Stage	Measured HWM	Diff. (feet)	App. Event Date	FSPW Easting	FSPW Northing
Node_465	46.49	45.38	1.1	09/05/2004	573549	1567022
Node_2295	51.23	49.90	1.3	10/2004	592021	1541048

NAD_1983_HARN_StatePlane_Florida_West_FIPS_0902_Feet (FSPW)

4.4.6. Numerical Stability

Reviewing the node verification model stage hydrographs showed little or no oscillations indicative of model instability. . Also, the mass balance report showed a reported error of 0.06%, an indicator of good model stability.

4.4.7. Model Verification Conclusions

The verification analysis at the 25 UGSG and SWFWMD gauges predicts the measured values reasonably well, even over a four month calibration period. Within the Withlacoochee River corridor the model predicts measured data within reason and will be well suited to simulate the various model scenarios to better understand and manage the water resources in the river.

5. References

Chow, V.T. (1959). *Open Channel Hydraulics*. McGraw-Hill

Department of the Army. (August 1976). *Flood Hazard Information: Withlacoochee River, Nobleton to Gulf of Mexico, Florida.*

Department of the Army. (September 1962). *Four River Basins, Florida.*

Hydrogeologic, Inc.. (November 1997). *Development Of A Computer Model of the Regional Groundwater Flow System In Hernando County Water Resources Assessment Project, Phase III: Development, Calibration, And Testing of a Regional Groundwater Flow Model*.

NRCS (1986). *Technical Release 55: Urban Hydrology for Small Watersheds*. USDA

NRCS (2009) *Hydrology National Engineering Handbook*

Singhofen, P.J. (2009). *ICPRv4 Users Manual*

Singhofen, P.J. (2009). *Modeling Two-Dimension Overland Flow in ICPRv4.*

SWFWMD (1996) *Environmental Resource Permitting Information Manual – Management and Storage of Surface Waters*

SWFWMD (2002) *SWFWMD Guidelines and Specifications for Digital Topographic Information, Watershed Evaluations, Watershed Management Plan, Watershed Management Plan Database Maintenance and Watershed Model Updates*.

SWFWMD (2004) *Hydrologic Conditions*.

SWFWMD. (2001). *Withlacoochee River Comprehensive Watershed Management Plan*.

SWFWMD. (April 1998). *Analysis of Flows Between the Withlacoochee And Hillsborough Rivers AT U.S. 98 and S.R. 54 Bridges.*

Tetra Tech, Inc. (June 2004). *Withlacoochee River Basin Feasibility Study: Hydrology and Hydraulics Data Collection and Review - Final Report*.

USGS (1989) *Guide for Selecting Manning's Roughness Coefficients for natural Channels and Flood Plains.* US Geological Survey.

Appendices

Appendix A. – Green Ampt Parameters

MUKEY	Saturated Vertical Conductivity (in/hr)	Moisture Content Saturated (dec)	Moisture Content Residual (dec)	Moisture Content Field Capacity (dec)	Moisture Content Wilting Point (dec)	Pore Size Index (bars)	Suction Head (in)	Initial Depth to Water Table (ft)
321046	0.04	0.43	0.109	0.321	0.239	0.223	9.45	0.01
321047	9.48	0.437	0.02	0.062	0.033	0.694	1.93	4.76
321048	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.23
321049	2.36	0.437	0.035	0.105	0.055	0.553	2.4	0.01
321050	9.48	0.437	0.02	0.062	0.033	0.694	1.93	4.76
321051	0.86	0.453	0.041	0.19	0.095	0.378	4.33	3.25
321052	0.04	0.43	0.109	0.321	0.239	0.223	9.45	0.01
321053	0.12	0.398	0.068	0.244	0.148	0.319	8.66	3.74
321054	0.04	0.43	0.109	0.321	0.239	0.223	9.45	1.02
321055	0.86	0.453	0.041	0.19	0.095	0.378	4.33	2.53
321056	9.48	0.437	0.02	0.062	0.033	0.694	1.93	2.76
321057	0.001	0.4	0.02	0.2	0.1	0.1	4	0.01
321058	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.23
321061	0.12	0.398	0.068	0.244	0.148	0.319	8.66	3.74
321062	0.08	0.464	0.075	0.31	0.197	0.242	8.27	0.01
321063	9.48	0.437	0.02	0.062	0.033	0.694	1.93	2.76
321064	0.08	0.464	0.075	0.31	0.197	0.242	8.27	2.49
321065	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.23
321066	9.48	0.437	0.02	0.062	0.033	0.694	1.93	2.76
321067	9.48	0.437	0.02	0.062	0.033	0.694	1.93	2.76
321068	0.86	0.453	0.041	0.19	0.095	0.378	4.33	2.53
321070	0.12	0.398	0.068	0.244	0.148	0.319	8.66	2.00
321071	0.86	0.453	0.041	0.19	0.095	0.378	4.33	2.53
321072	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.23
321073	0.08	0.464	0.075	0.31	0.197	0.242	8.27	2.49
321074	0.08	0.464	0.075	0.31	0.197	0.242	8.27	0.26
321075	0.08	0.464	0.075	0.31	0.197	0.242	8.27	1.02

MUKEY	Saturated Vertical Conductivity (in/hr)	Moisture Content Saturated (dec)	Moisture Content Residual (dec)	Moisture Content Field Capacity (dec)	Moisture Content Wilting Point (dec)	Pore Size Index (bars)	Suction Head (in)	Initial Depth to Water Table (ft)
321076	9.48	0.437	0.02	0.062	0.033	0.694	1.93	2.76
321078	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49
321079	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.01
321080	2.36	0.437	0.035	0.105	0.055	0.553	2.4	0.49
321081	9.48	0.437	0.02	0.062	0.033	0.694	1.93	1.02
321082	2.36	0.437	0.035	0.105	0.055	0.553	2.4	0.49
321083	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49
321084	0.04	0.43	0.109	0.321	0.239	0.223	9.45	1.02
321085	9.48	0.437	0.02	0.062	0.033	0.694	1.93	1.02
321086	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.01
321087	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49
321088	0.04	0.43	0.109	0.321	0.239	0.223	9.45	1.02
321089	2.36	0.437	0.035	0.105	0.055	0.553	2.4	0.49
321090	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.01
321091	9.48	0.437	0.02	0.062	0.033	0.694	1.93	1.02
321092	0.08	0.464	0.075	0.31	0.197	0.242	8.27	1.02
321093	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.01
321094	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.01
321095	0.08	0.464	0.075	0.31	0.197	0.242	8.27	2.00
321096	9.48	0.437	0.02	0.062	0.033	0.694	1.93	4.49
321097	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.49
321098	2.36	0.437	0.035	0.105	0.055	0.553	2.4	0.26
321100	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.72
321101	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.26
321102	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.26
321103	0.001	0.4	0.02	0.2	0.1	0.1	4	0.01
322071	9.48	0.437	0.02	0.062	0.033	0.694	1.93	2.76
322072	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49
322074	0.01	0.475	0.09	0.378	0.272	0.165	12.6	0.49
322076	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49
322077	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.26

MUKEY	Saturated Vertical Conductivity (in/hr)	Moisture Content Saturated (dec)	Moisture Content Residual (dec)	Moisture Content Field Capacity (dec)	Moisture Content Wilting Point (dec)	Pore Size Index (bars)	Suction Head (in)	Initial Depth to Water Table (ft)
322079	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.49
322080	0.86	0.453	0.041	0.19	0.095	0.378	4.33	1.02
322081	0.12	0.398	0.068	0.244	0.148	0.319	8.66	2.00
322082	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.49
322086	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.49
322087	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49
322091	0.86	0.453	0.041	0.19	0.095	0.378	4.33	0.49
322092	0.86	0.453	0.041	0.19	0.095	0.378	4.33	0.49
322095	9.48	0.437	0.02	0.062	0.033	0.694	1.93	2.76
322098	0.01	0.475	0.09	0.378	0.272	0.165	12.6	2.00
322099	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49
322100	0.86	0.453	0.041	0.19	0.095	0.378	4.33	2.53
322101	0.86	0.453	0.041	0.19	0.095	0.378	4.33	0.01
322102	0.04	0.43	0.109	0.321	0.239	0.223	9.45	0.49
322106	0.08	0.464	0.075	0.31	0.197	0.242	8.27	0.01
322108	9.48	0.437	0.02	0.062	0.033	0.694	1.93	2.76
322109	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49
322110	9.48	0.437	0.02	0.062	0.033	0.694	1.93	4.00
322112	0.04	0.43	0.109	0.321	0.239	0.223	9.45	2.53
322113	0.86	0.453	0.041	0.19	0.095	0.378	4.33	2.53
322114	9.48	0.437	0.02	0.062	0.033	0.694	1.93	4.76
322117	0.86	0.453	0.041	0.19	0.095	0.378	4.33	1.02
322118	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.49
322123	0.001	0.4	0.02	0.2	0.1	0.1	4	0.01
322124	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.49
322125	0.86	0.453	0.041	0.19	0.095	0.378	4.33	1.02
322126	9.48	0.437	0.02	0.062	0.033	0.694	1.93	2.76
322127	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49
323177	0.86	0.453	0.041	0.19	0.095	0.378	4.33	0.23
323178	0.12	0.398	0.068	0.244	0.148	0.319	8.66	1.02
323179	9.48	0.437	0.02	0.062	0.033	0.694	1.93	2.76

MUKEY	Saturated Vertical Conductivity (in/hr)	Moisture Content Saturated (dec)	Moisture Content Residual (dec)	Moisture Content Field Capacity (dec)	Moisture Content Wilting Point (dec)	Pore Size Index (bars)	Suction Head (in)	Initial Depth to Water Table (ft)
323180	9.48	0.437	0.02	0.062	0.033	0.694	1.93	2.76
323181	9.48	0.437	0.02	0.062	0.033	0.694	1.93	2.76
323182	9.48	0.437	0.02	0.062	0.033	0.694	1.93	4.76
323183	9.48	0.437	0.02	0.062	0.033	0.694	1.93	4.76
323184	0.86	0.453	0.041	0.19	0.095	0.378	4.33	0.01
323185	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.23
323186	0.08	0.464	0.075	0.31	0.197	0.242	8.27	2.76
323187	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.23
323188	0.04	0.43	0.109	0.321	0.239	0.223	9.45	0.23
323190	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.23
323191	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.23
323192	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.01
323193	9.48	0.437	0.02	0.062	0.033	0.694	1.93	6.00
323195	9.48	0.437	0.02	0.062	0.033	0.694	1.93	2.76
323196	2.36	0.437	0.035	0.105	0.055	0.553	2.4	0.01
323197	0.08	0.464	0.075	0.31	0.197	0.242	8.27	0.01
323199	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.23
323200	0.86	0.453	0.041	0.19	0.095	0.378	4.33	0.01
323201	9.48	0.437	0.02	0.062	0.033	0.694	1.93	2.76
323202	9.48	0.437	0.02	0.062	0.033	0.694	1.93	2.76
323203	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.26
323204	0.86	0.453	0.041	0.19	0.095	0.378	4.33	0.23
323208	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.26
323209	2.36	0.437	0.035	0.105	0.055	0.553	2.4	0.23
323210	0.01	0.475	0.09	0.378	0.272	0.165	12.6	0.23
323211	0.08	0.464	0.075	0.31	0.197	0.242	8.27	0.01
323212	9.48	0.437	0.02	0.062	0.033	0.694	1.93	2.76
323213	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.26
323216	9.48	0.437	0.02	0.062	0.033	0.694	1.93	2.53
323218	0.86	0.453	0.041	0.19	0.095	0.378	4.33	3.74
323219	0.86	0.453	0.041	0.19	0.095	0.378	4.33	0.23

MUKEY	Saturated Vertical Conductivity (in/hr)	Moisture Content Saturated (dec)	Moisture Content Residual (dec)	Moisture Content Field Capacity (dec)	Moisture Content Wilting Point (dec)	Pore Size Index (bars)	Suction Head (in)	Initial Depth to Water Table (ft)
323220	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.23
323223	2.36	0.437	0.035	0.105	0.055	0.553	2.4	0.01
323225	0.04	0.43	0.109	0.321	0.239	0.223	9.45	1.02
323229	0.86	0.453	0.041	0.19	0.095	0.378	4.33	0.01
323230	0.86	0.453	0.041	0.19	0.095	0.378	4.33	2.49
323231	9.48	0.437	0.02	0.062	0.033	0.694	1.93	4.76
323232	2.36	0.437	0.035	0.105	0.055	0.553	2.4	0.01
323233	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49
323235	0.86	0.453	0.041	0.19	0.095	0.378	4.33	0.01
323236	0.12	0.398	0.068	0.244	0.148	0.319	8.66	2.53
323237	2.36	0.437	0.035	0.105	0.055	0.553	2.4	0.01
323238	0.12	0.398	0.068	0.244	0.148	0.319	8.66	2.00
323240	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.26
323241	0.86	0.453	0.041	0.19	0.095	0.378	4.33	4.23
323242	0.86	0.453	0.041	0.19	0.095	0.378	4.33	2.53
323243	2.36	0.437	0.035	0.105	0.055	0.553	2.4	0.01
323244	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.26
323245	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.26
323246	9.48	0.437	0.02	0.062	0.033	0.694	1.93	2.76
323250	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.01
323251	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.23
323252	0.001	0.4	0.02	0.2	0.1	0.1	4	0.01
323617	0.12	0.398	0.068	0.244	0.148	0.319	8.66	2.53
323618	0.12	0.398	0.068	0.244	0.148	0.319	8.66	2.53
323619	0.12	0.398	0.068	0.244	0.148	0.319	8.66	4.76
323620	9.48	0.437	0.02	0.062	0.033	0.694	1.93	4.76
323621	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.23
323622	9.48	0.437	0.02	0.062	0.033	0.694	1.93	2.76
323623	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.26
323625	0.86	0.453	0.041	0.19	0.095	0.378	4.33	0.01
323627	9.48	0.437	0.02	0.062	0.033	0.694	1.93	5.02

MUKEY	Saturated Vertical Conductivity (in/hr)	Moisture Content Saturated (dec)	Moisture Content Residual (dec)	Moisture Content Field Capacity (dec)	Moisture Content Wilting Point (dec)	Pore Size Index (bars)	Suction Head (in)	Initial Depth to Water Table (ft)
323628	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.26
323629	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.26
323630	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.26
323631	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49
323632	0.86	0.453	0.041	0.19	0.095	0.378	4.33	0.26
323633	0.86	0.453	0.041	0.19	0.095	0.378	4.33	0.26
323634	0.04	0.43	0.109	0.321	0.239	0.223	9.45	2.26
323636	0.86	0.453	0.041	0.19	0.095	0.378	4.33	0.49
323637	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.26
323638	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49
323639	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.26
323640	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49
323641	0.04	0.43	0.109	0.321	0.239	0.223	9.45	2.53
323642	9.48	0.437	0.02	0.062	0.033	0.694	1.93	1.51
323643	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49
323644	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.49
323645	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49
323646	0.08	0.464	0.075	0.31	0.197	0.242	8.27	2.26
323647	2.36	0.437	0.035	0.105	0.055	0.553	2.4	0.01
323648	0.86	0.453	0.041	0.19	0.095	0.378	4.33	4.76
323649	0.86	0.453	0.041	0.19	0.095	0.378	4.33	0.49
323650	9.48	0.437	0.02	0.062	0.033	0.694	1.93	2.76
323651	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49
323652	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.26
323653	0.04	0.43	0.109	0.321	0.239	0.223	9.45	2.76
323654	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.26
323655	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49
323656	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.49
323657	0.86	0.453	0.041	0.19	0.095	0.378	4.33	0.49
323658	2.36	0.437	0.035	0.105	0.055	0.553	2.4	0.01
323659	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49

MUKEY	Saturated Vertical Conductivity (in/hr)	Moisture Content Saturated (dec)	Moisture Content Residual (dec)	Moisture Content Field Capacity (dec)	Moisture Content Wilting Point (dec)	Pore Size Index (bars)	Suction Head (in)	Initial Depth to Water Table (ft)
323660	0.08	0.464	0.075	0.31	0.197	0.242	8.27	0.01
323662	9.48	0.437	0.02	0.062	0.033	0.694	1.93	4.76
323663	0.86	0.453	0.041	0.19	0.095	0.378	4.33	0.01
323664	9.48	0.437	0.02	0.062	0.033	0.694	1.93	2.76
323665	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.49
323666	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49
323667	0.01	0.475	0.09	0.378	0.272	0.165	12.6	0.49
323669	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.49
323670	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.49
323671	2.36	0.437	0.035	0.105	0.055	0.553	2.4	0.26
323672	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49
323673	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49
323674	0.86	0.453	0.041	0.19	0.095	0.378	4.33	0.49
323675	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49
323676	0.86	0.453	0.041	0.19	0.095	0.378	4.33	0.49
323677	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.26
323678	0.86	0.453	0.041	0.19	0.095	0.378	4.33	0.49
323679	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49
323680	0.04	0.43	0.109	0.321	0.239	0.223	9.45	1.02
614520	0.001	0.4	0.02	0.2	0.1	0.1	4	0.01
1414046	0.86	0.453	0.041	0.19	0.095	0.378	4.33	4.76
1414048	9.48	0.437	0.02	0.062	0.033	0.694	1.93	4.76
1414050	9.48	0.437	0.02	0.062	0.033	0.694	1.93	4.76
1414051	0.86	0.453	0.041	0.19	0.095	0.378	4.33	4.76
1414052	9.48	0.437	0.02	0.062	0.033	0.694	1.93	1.02
1414054	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.26
1414055	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.01
1414057	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.49
1414058	0.86	0.453	0.041	0.19	0.095	0.378	4.33	4.76
1414061	9.48	0.437	0.02	0.062	0.033	0.694	1.93	2.76
1414064	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.26

MUKEY	Saturated Vertical Conductivity (in/hr)	Moisture Content Saturated (dec)	Moisture Content Residual (dec)	Moisture Content Field Capacity (dec)	Moisture Content Wilting Point (dec)	Pore Size Index (bars)	Suction Head (in)	Initial Depth to Water Table (ft)
1414065	0.04	0.43	0.109	0.321	0.239	0.223	9.45	0.26
1414066	0.86	0.453	0.041	0.19	0.095	0.378	4.33	2.76
1414069	2.36	0.437	0.035	0.105	0.055	0.553	2.4	0.26
1414075	0.08	0.464	0.075	0.31	0.197	0.242	8.27	4.76
1414077	9.48	0.437	0.02	0.062	0.033	0.694	1.93	2.53
1414080	0.86	0.453	0.041	0.19	0.095	0.378	4.33	0.26
1414081	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.98
1414084	0.08	0.464	0.075	0.31	0.197	0.242	8.27	0.49
1414088	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49
1414089	0.08	0.464	0.075	0.31	0.197	0.242	8.27	0.01
1414091	0.08	0.464	0.075	0.31	0.197	0.242	8.27	2.53
1414098	9.48	0.437	0.02	0.062	0.033	0.694	1.93	5.02
1414101	0.08	0.464	0.075	0.31	0.197	0.242	8.27	0.26
1414102	0.86	0.453	0.041	0.19	0.095	0.378	4.33	1.51
1414103	0.08	0.464	0.075	0.31	0.197	0.242	8.27	0.26
1414112	0.08	0.464	0.075	0.31	0.197	0.242	8.27	2.00
1414117	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49
1414122	0.001	0.4	0.02	0.2	0.1	0.1	4	0.01
1414233	0.001	0.4	0.02	0.2	0.1	0.1	4	0.01
1424994	0.86	0.453	0.041	0.19	0.095	0.378	4.33	2.53
1424995	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49
1424996	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49
1424997	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.49
1424998	0.26	0.463	0.027	0.232	0.117	0.252	3.5	0.01
1424999	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49
1425001	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49
1425002	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.49
1425005	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.01
1425006	0.86	0.453	0.041	0.19	0.095	0.378	4.33	2.53
1425007	9.48	0.437	0.02	0.062	0.033	0.694	1.93	4.76
1425009	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49

MUKEY	Saturated Vertical Conductivity (in/hr)	Moisture Content Saturated (dec)	Moisture Content Residual (dec)	Moisture Content Field Capacity (dec)	Moisture Content Wilting Point (dec)	Pore Size Index (bars)	Suction Head (in)	Initial Depth to Water Table (ft)
1425010	0.26	0.463	0.027	0.232	0.117	0.252	3.5	0.01
1425012	9.48	0.437	0.02	0.062	0.033	0.694	1.93	1.02
1425014	9.48	0.437	0.02	0.062	0.033	0.694	1.93	1.02
1425017	0.12	0.398	0.068	0.244	0.148	0.319	8.66	3.74
1425018	0.86	0.453	0.041	0.19	0.095	0.378	4.33	0.01
1425021	9.48	0.437	0.02	0.062	0.033	0.694	1.93	2.76
1425022	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.01
1425023	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.01
1425025	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.01
1425026	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.01
1425030	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49
1425032	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49
1425033	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49
1425034	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.49
1425037	0.86	0.453	0.041	0.19	0.095	0.378	4.33	0.01
1425045	0.08	0.464	0.075	0.31	0.197	0.242	8.27	0.01
1425049	0.86	0.453	0.041	0.19	0.095	0.378	4.33	1.02
1425053	2.36	0.437	0.035	0.105	0.055	0.553	2.4	0.49
1425060	9.48	0.437	0.02	0.062	0.033	0.694	1.93	4.76
1425062	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.49
1425063	0.01	0.475	0.09	0.378	0.272	0.165	12.6	0.49
1425065	0.86	0.453	0.041	0.19	0.095	0.378	4.33	0.49
1425067	0.86	0.453	0.041	0.19	0.095	0.378	4.33	0.01
1425068	0.86	0.453	0.041	0.19	0.095	0.378	4.33	0.01
1425069	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49
1426111	0.001	0.4	0.02	0.2	0.1	0.1	4	0.01
1454702	0.001	0.4	0.02	0.2	0.1	0.1	4	0.01
1542261	9.48	0.437	0.02	0.062	0.033	0.694	1.93	2.26
1542266	9.48	0.437	0.02	0.062	0.033	0.694	1.93	2.26
1542269	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.49
1542274	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.23

MUKEY	Saturated Vertical Conductivity (in/hr)	Moisture Content Saturated (dec)	Moisture Content Residual (dec)	Moisture Content Field Capacity (dec)	Moisture Content Wilting Point (dec)	Pore Size Index (bars)	Suction Head (in)	Initial Depth to Water Table (ft)
1542278	0.86	0.453	0.041	0.19	0.095	0.378	4.33	0.23
1542282	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.23
1542286	0.01	0.475	0.09	0.378	0.272	0.165	12.6	0.01
1542288	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.49
1542292	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.23
1542294	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.01
1542295	9.48	0.437	0.02	0.062	0.033	0.694	1.93	2.76
1542296	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.23
1542298	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.01
1542299	9.48	0.437	0.02	0.062	0.033	0.694	1.93	4.23
1542301	0.86	0.453	0.041	0.19	0.095	0.378	4.33	0.23
1542302	0.86	0.453	0.041	0.19	0.095	0.378	4.33	0.23
1542303	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.23
1542304	0.001	0.4	0.02	0.2	0.1	0.1	4	0.01
1603127	0.12	0.398	0.068	0.244	0.148	0.319	8.66	2.26
1603130	2.36	0.437	0.035	0.105	0.055	0.553	2.4	0.01
1603131	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.01
1603132	0.86	0.453	0.041	0.19	0.095	0.378	4.33	0.23
1603133	9.48	0.437	0.02	0.062	0.033	0.694	1.93	4.23
1603135	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.01
1603136	9.48	0.437	0.02	0.062	0.033	0.694	1.93	4.23
1603144	0.86	0.453	0.041	0.19	0.095	0.378	4.33	3.74
1603157	0.86	0.453	0.041	0.19	0.095	0.378	4.33	4.00
1603158	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.01
1603160	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.23
1603164	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.23
1603166	0.86	0.453	0.041	0.19	0.095	0.378	4.33	1.02
1698337	0.08	0.464	0.075	0.31	0.197	0.242	8.27	0.01
1712886	9.48	0.437	0.02	0.062	0.033	0.694	1.93	2.49
1712887	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.26
1712888	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.01

MUKEY	Saturated Vertical Conductivity (in/hr)	Moisture Content Saturated (dec)	Moisture Content Residual (dec)	Moisture Content Field Capacity (dec)	Moisture Content Wilting Point (dec)	Pore Size Index (bars)	Suction Head (in)	Initial Depth to Water Table (ft)
1712891	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.01
1712892	9.48	0.437	0.02	0.062	0.033	0.694	1.93	3.02
1712893	0.08	0.464	0.075	0.31	0.197	0.242	8.27	0.01
1712896	2.36	0.437	0.035	0.105	0.055	0.553	2.4	0.49
1712905	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.26
1712906	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.26
1712907	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.26
1712908	0.04	0.43	0.109	0.321	0.239	0.223	9.45	0.49
1712909	0.04	0.43	0.109	0.321	0.239	0.223	9.45	2.76
1712923	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.26
1712925	0.86	0.453	0.041	0.19	0.095	0.378	4.33	3.51
1712931	0.04	0.43	0.109	0.321	0.239	0.223	9.45	0.49
1712936	2.36	0.437	0.035	0.105	0.055	0.553	2.4	0.49
1712939	2.36	0.437	0.035	0.105	0.055	0.553	2.4	0.26
1713202	2.36	0.437	0.035	0.105	0.055	0.553	2.4	0.49
1713203	0.12	0.398	0.068	0.244	0.148	0.319	8.66	0.01
1713204	9.48	0.437	0.02	0.062	0.033	0.694	1.93	0.01
1713206	0.86	0.453	0.041	0.19	0.095	0.378	4.33	3.25
1713209	9.48	0.437	0.02	0.062	0.033	0.694	1.93	4.76
1713210	2.36	0.437	0.035	0.105	0.055	0.553	2.4	0.26
1713214	2.36	0.437	0.035	0.105	0.055	0.553	2.4	0.26
1713215	0.001	0.4	0.02	0.2	0.1	0.1	4	0.01

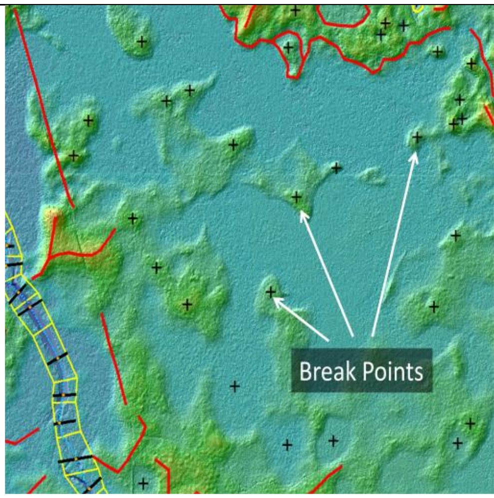
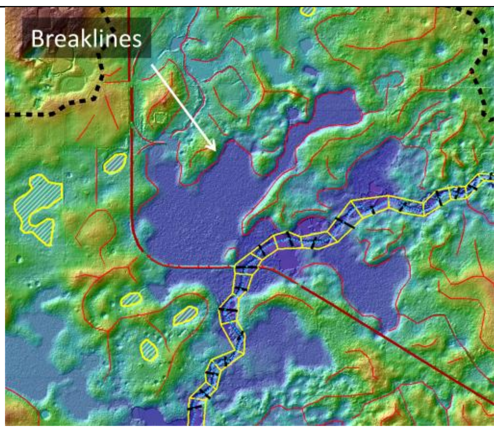
Appendix B. ICPRv4 2D Model Inputs

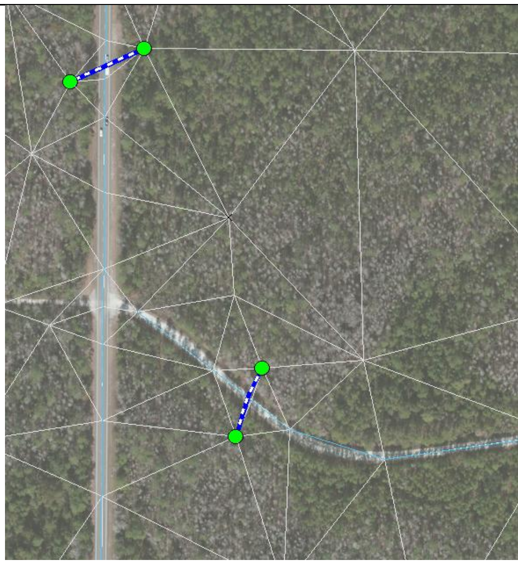
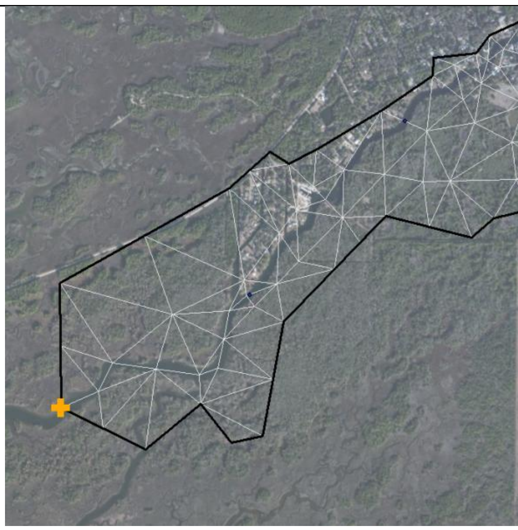
The ICPRv4 model has the capability of simulating both 1D model components as well as 2D overland flow. The 1D portion of the model is similar to the ICPRv3 model input requirements. This technical appendix describes relevant features that are used to define the 2D mesh features necessary to characterize the terrain within the Withlacoochee River Corridor.

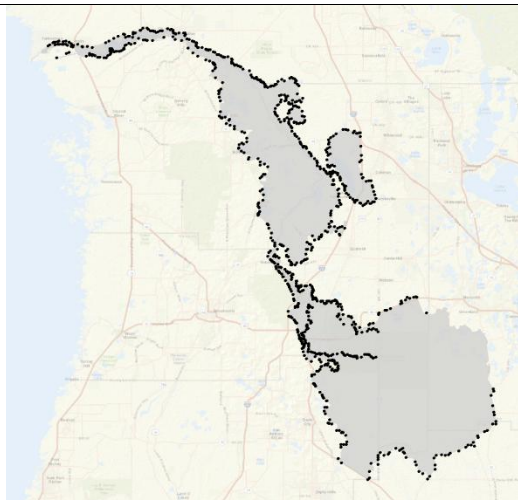
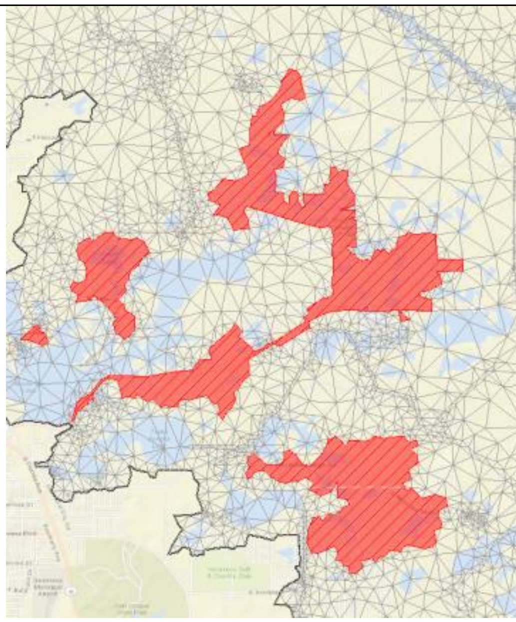
The ICPRv4 2D overland flow mesh is made up of triangular elements, creating a flexible mesh structure to provide more detail to characterize minute terrain changes as well as larger elements to improve computational speed. Examples of areas requiring a more detailed mesh include roadways that overtop, micro storage depressions within the overland flow terrain or tight river switchbacks. Examples of terrain features where larger elements are sufficient, enabling computational efficiency include homogeneous terrain features, such as gently sloping hills at a consistent overland slope or flat terrains.

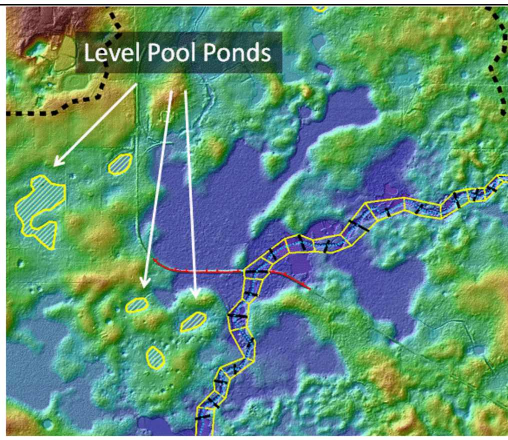
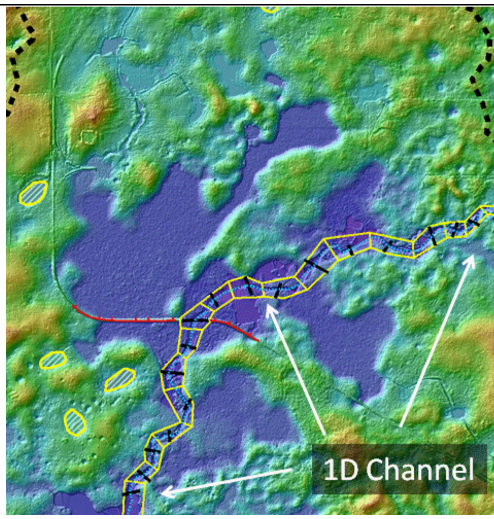
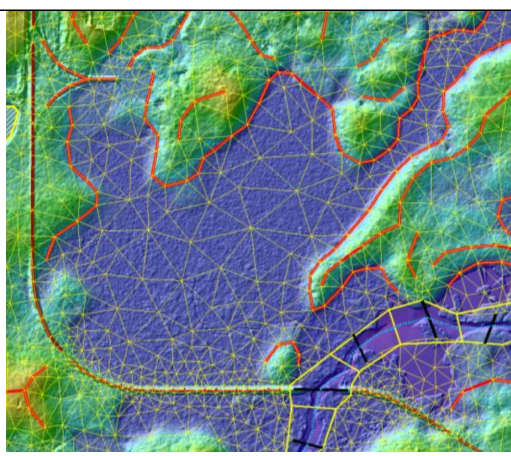
Input features specific to the 2D model include those features that characterize terrain, features that link internal and external data together, and regions of the 2D mesh associated with traditional 1D elements. Features that characterize the terrain begin with an overland flow boundary, defining the extent of the 2D region to be simulated, and also include terrain characterization features such as breakpoints, breaklines and exclusion zones. Features that link together internal and external data include: external hydrograph points, boundary points and overland flow nodes. Features that define a transition to an area simulated with traditional 1D elements include ponds and channel control volumes.

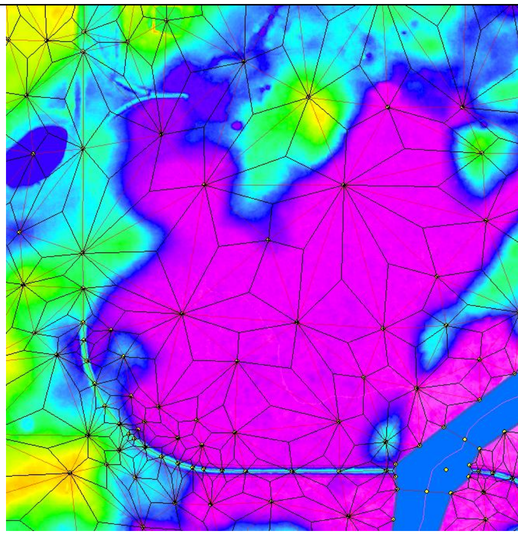
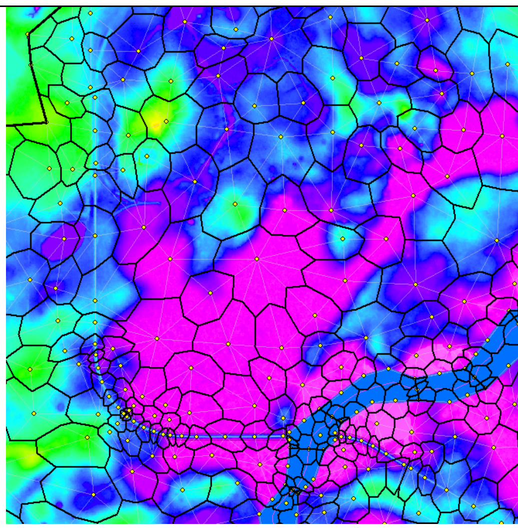
The result of the terrain characterization is a 2D triangular mesh, where each triangle edge represents an overland flow element. The characteristics of the overland flow element are defined by the elevations at either end of the triangle edge and a diamond created from areas of adjacent triangles. Surrounding each triangle vertex is a honeycomb which represents the “basin” used in overland flow hydrologic calculations. Each of these features is seen pictorially and described in more detail below.

<table>
<tr><td></td><td>Overland Flow Region – Defines the extent of the 2D analysis boundary and the extent of the 2D analysis. Although connections can be made across the boundary using other features such as external hydrographs and overland flow nodes with associated 1D model elements. The model is set up such that the Overland Flow Region by itself is a no flow boundary condition. Each vertex that makes up the overland flow boundary is also a 2D vertex that will build the triangulated mesh.</td></tr>
<tr><td>
</td><td>Breakpoints – Add detail to the 2D mesh by manually specifying the locations of 2D mesh vertices. These are generally placed at high points, low points and along characterizing terrain features such as significant changes in slope. While ICPRv4 will internally generate additional 2D vertex points within the 2D mesh to avoid violating the 2D mesh minimum triangle angle, Breakpoints guarantee a vertex at a specified location.</td></tr>
<tr><td>
</td><td>Breaklines – Similar to break points in that these features are used to characterize the terrain using each vertex of the breakline as a 2D mesh vertex. Breaklines also use the line itself as a fixed triangle edge. If the internal ICPRv4 mesh generation process requires an additional vertex, within the area of a breakline, the additional point will be created on the breakline to preserve the flowline or</td></tr>
</table>

	ridge terrain feature that the Breakline represents.
	**Overland Flow Nodes –** Are similar to breakpoints in that they force the location of vertexes within the 2D mesh. Unlike breakpoints, these elements have a unique element name which can be referenced internally or externally by other model elements. For the example pictured, the green circles are overland flow nodes, they define vertexes within the overland flow mesh, as well as, serve to connect a 1D subsurface element (a pipe shown as dashed blue and white lines) across a roadway.
	**Boundary Stage Point –** has the properties of a breakpoint in that it also forces the location of a vertex within the 2D mesh. However its main purpose is to serve as a tailwater location to enable water exit the overland flow region. The location shown in the image to the left is the time-stage overland flow boundary point representing the Gulf of Mexico tidal stage for the ICPRv4 simulation. Other boundary stage points used in the Withlacoochee Model are Jordan Sink and the Hillsborough River.

	**External Hydrograph Point –** These points represent inflow hydrograph locations. The Withlacoochee Model receives inflows from adjacent detailed and approximate studies. Each of the inflows from the ICPRv3 models was set to inflow along the boundary of the 2D mesh. Locations are shown as black dots in the adjacent image.
	**Exclusion Feature –** is similar to the overland flow boundary, in that its edge defines the 2D mesh and represents a no flow boundary. For the Withlacoochee ICPRv4 model, exclusion zones were used to represent areas of detailed studies, such as the East Citrus, Tsala Apopka detailed study shown in the adjacent image. As the East Citrus detailed study was modeled within ICPRv4 with unmapped basins, it is connected to the 2D mesh with overland flow nodes placed at locations where flow from the detailed study would enter the 2D mesh.

	**Pond Control Volume –** Represents areas of level pools within the 2D simulation. The edge of these level pools is incorporated into the 2D mesh similar to breaklines. On the inside of the pool, the user specifies the stage storage relationship to characterized pool dimensions. During the simulation, all points along the edge of the pool will have the same water surface elevation as it interacts with adjacent features.
	**Channel Control Volume –** These features are similar to pond control volumes in that the extents of the control volume are used to characterize the 2D mesh and contain storage associated with a model node. Where they differ from pond control volumes is that these features are associated with 1D channel features and the vertices along the edge of the control volume are assigned an elevation based upon the sloping water surface elevation of the associated channel.
	**2D Mesh –** The combination of all terrain characterization features forms the framework for the 2D mesh. Internal to ICPRv4, the triangulation is checked to verify that the minimum computational angle is not violated, if it is then additional vertices are added to the mesh to optimize the triangulation.

	**2D Diamonds –** While the 2D mesh defines the flow framework within the 2D region, the diamonds shown in the adjacent figure represent the characterization of the mesh flow element along a triangle edge. The diamond is used to set the width of the flow channel ensuring reaches are not double counting flow area.
	**2D HoneyCombs** – The honeycomb elements serve as “Basins” within the 2D mesh and zones that generate runoff characteristics to be applied to mesh vertices. The Honeycombs, analogous to Thiessen polygons are generated by connecting the midpoint of the triangle edge with the centroid of the triangle.

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