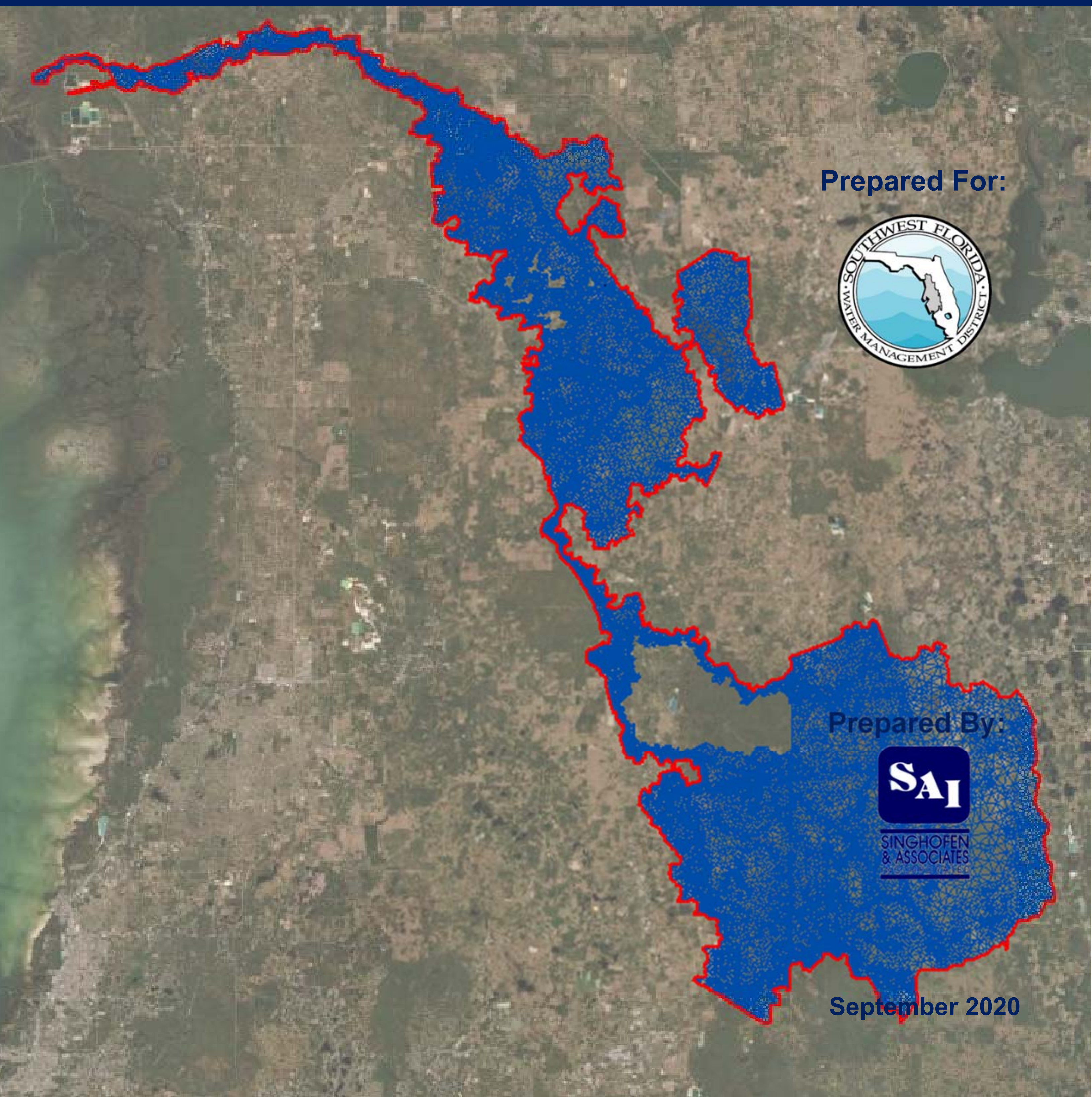
Withlacoochee River Watershed Initiative
Peer Review



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Figures

Section 1

Introduction and Background

1.1 Introduction

The Southwest Florida Water Management District (SWFWMD), in cooperation with local governments, implemented a Watershed Management Program for the Withlacoochee River as one of its Comprehensive Watershed Management initiatives. An important component of a Watershed Management Program is a Watershed Management Plan (WMP), which provides the methodology to evaluate the capacity of a watershed to protect, enhance and restore water quality and natural systems, protect water supply sources, and help meet flood protection levels of service. Nearly two decades ago, the District partnered with the U.S. Army of Corps of Engineers (USACE) to develop a feasibility study of the Withlacoochee River Watershed. The study identified watershed issues and potential strategies that required further evaluation. In response, the District embarked on the Withlacoochee River Watershed Initiative (WRWI), a multi-year effort to better understand the issues and how potential strategies would perform. To accomplish this, it was necessary to develop tools that could help provide a clear and comprehensive understanding of how the watershed functions and how changes would affect that function. To help address these needs, the District contracted with a consultant (PBS&J/Atkins) to develop hydrologic and hydraulic (H&H) models of the watershed. The models were developed using ICPR Version 4 which provides a framework for both 1-dimensional (1D) and 2-dimensional (2D) drainage analyses of a watershed.

Singhofen & Associates, Inc. (SAI) was contracted by SWFWMD to conduct a Peer Review of several models including existing-condition and various scenario models. The review also included supporting data (GIS files, reports, etc.) developed for the Withlacoochee River Watershed Initiative (WRWI).

The peer review was performed under contract with SWFWMD through Agreement No. 19CN0002073. This technical memorandum presents the findings of the review.

1.2 Background

Development of the WRWI and the models mentioned above included a remarkable level of effort. The river is approximately 160 miles long and collects runoff from approximately 2,100 sq mi over 8 different counties (See **Figure 1.1**). It extends from the Green Swamp to the Gulf of Mexico. Models of such scale have, traditionally, been developed using 1D methodologies on a "macro" scale with coarse levels of detail. Such approaches define hydrologic and hydraulic (H&H) properties at discrete locations (often referred to as "nodes") along a water resource. The H&H properties, including such things as runoff entry into the river or flood storage and conveyance, are then "averaged" between locations to provide estimates of changes along the overall water course.

The model developed for the WRWI includes a high level of discretization including a mix of 1D and 2D model approaches. Use of 2D methodologies along the river provides a much more accurate and detailed framework for H&H analyses than 1D approaches can provide. While "averaging" of H&H properties is still required at 2D node locations, the nodes defined for the WRWI are significantly denser than a 1D model would include. This increased node density provides a more continuous accounting of changes in H&H properties than can be provided between locations of "traditional" 1D model node locations. This is particularly important for river systems like the Withlacoochee which experiences a wide range of hydrologic conditions. Water levels in the river vary from low elevations that are primarily contained with the channel banks to periods of high water levels that overtop the banks and flow along wide swaths of floodplain. The 2D approach allows for a more accurate accounting of overbank flow conditions than "traditional" 1D analyses can typically provide.

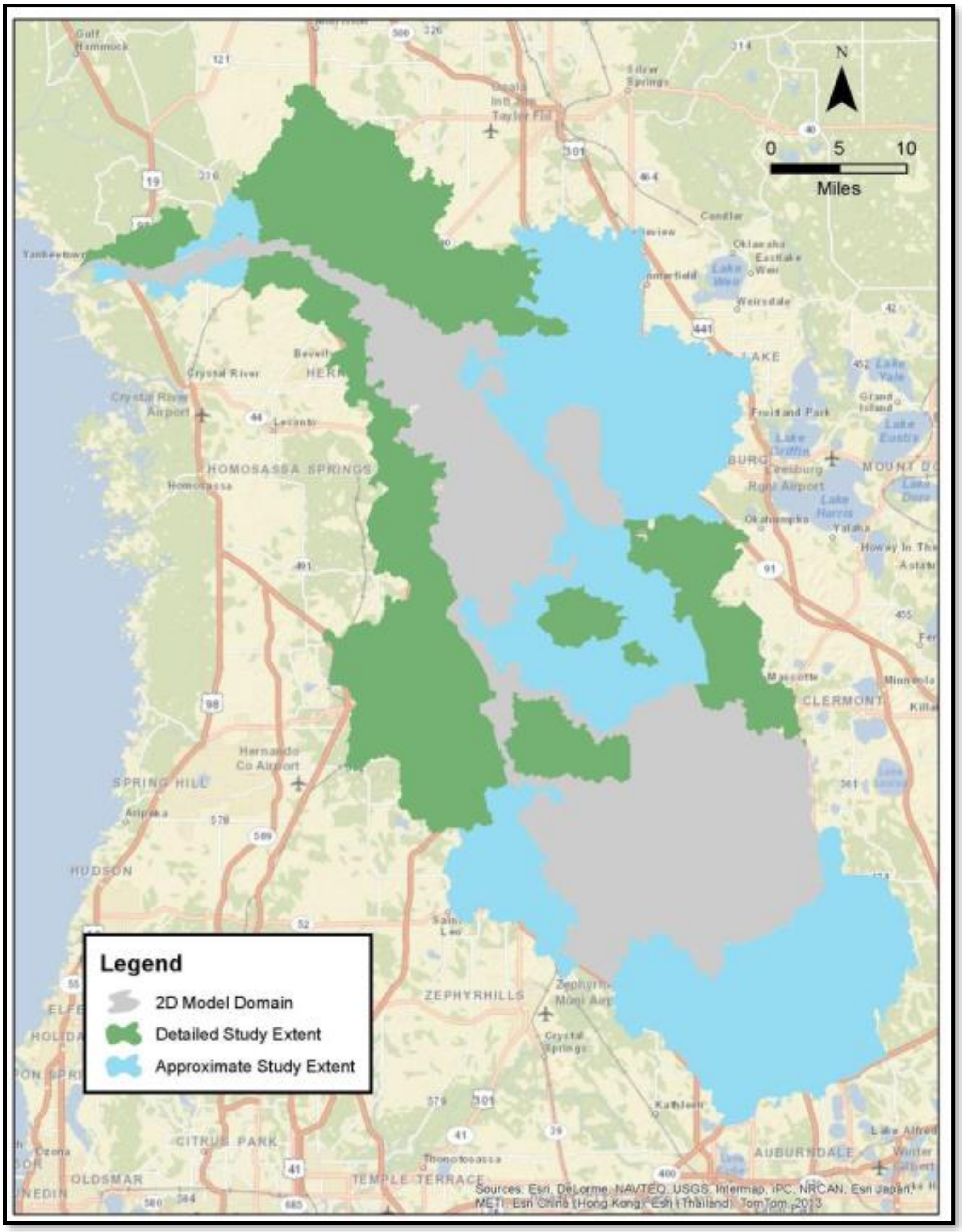


Figure 1.1 – Model Extent for the Withlacoochee River Watershed Initiative

The level of effort extended by the SWFWMD to develop the model included extraordinary amounts of data collection and field work. District staff spent 4 months during the summer of 2007 and 4 months during the summer of 2008 collecting river bottom elevations (See **Figure 1.2**) along the river from the Green Swamp to US 301. A private surveying company was hired to collect river bottom elevations for the remainder of the river during the summer of 2008. Initial plans were to collect channel cross section data only, as would normally be used for a 1D river model of this size, but it was later decided that the entire river bottom should be mapped to better address citizen inquiries and concerns. In total, over 50,000 channel bottom elevations were collected along the entire Withlacoochee River. In addition, more than 30,000 ground elevations were also collected in marsh areas (i.e. Tsala Apopka chain of lakes) to ensure the accuracy of terrain information and flood storage (See **Figure 1.3**).

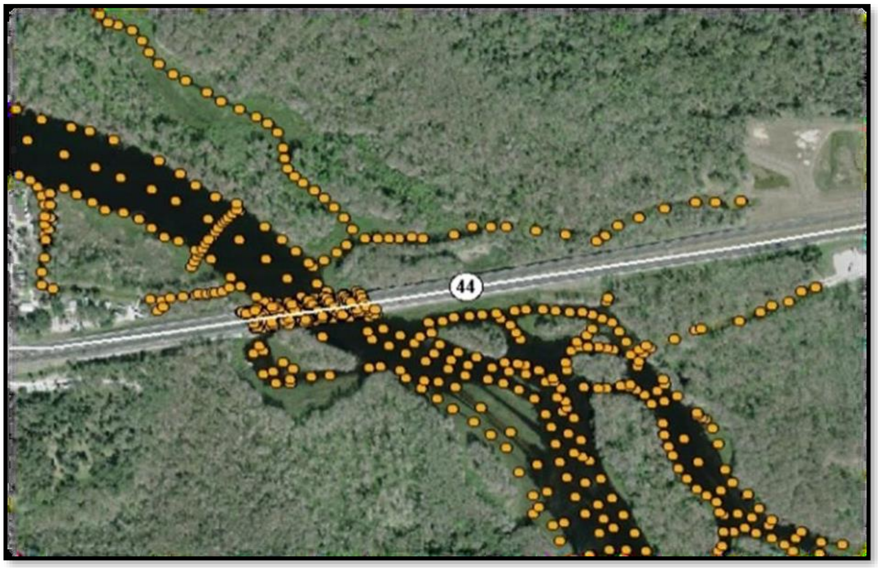


Figure 1.2 – Example of Hydrographic Surveys for the Withlacoochee River Watershed Initiative

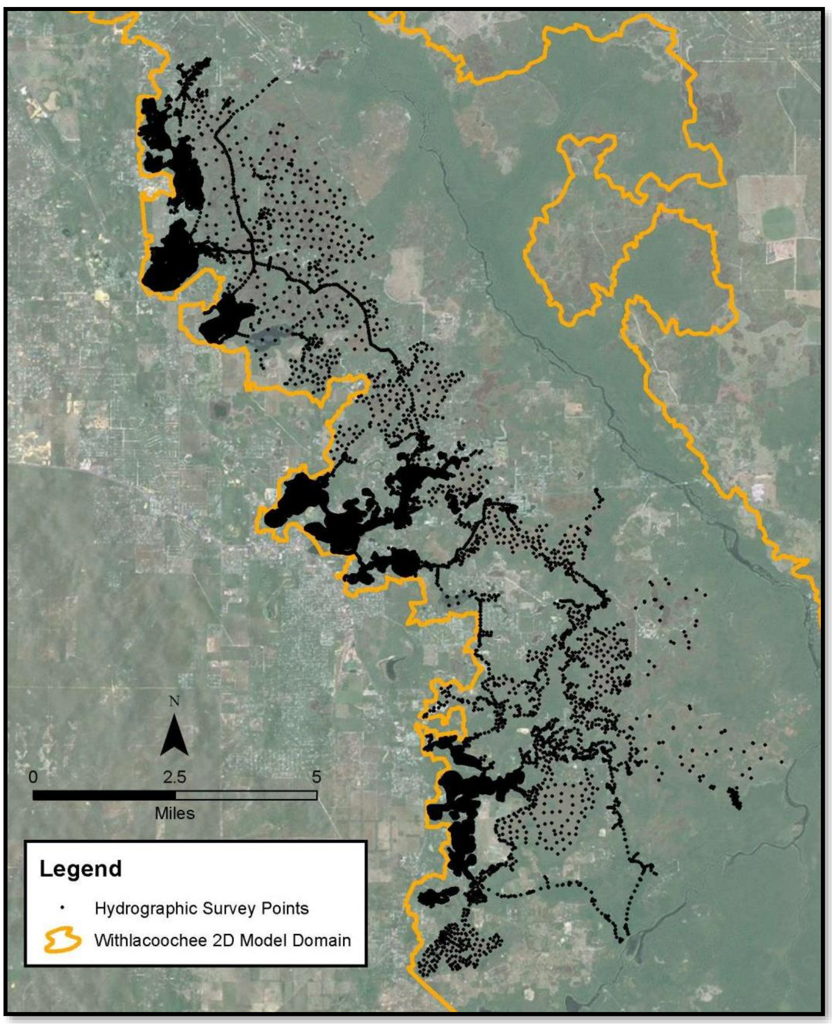


Figure 1.3 - Lake, Canal and Marsh Survey Points in the Tsala Apopka Lake Chain

As pointed out in the WRWI, "*the Withlacoochee has experienced extreme high and low conditions due to natural fluctuations in rainfall and groundwater levels*" and "*portions of the Withlacoochee River and its surrounding watershed have been altered in efforts to transform its natural function into one that benefited commercial navigation, industry and private needs*" (Atkins, 2015). As is the case with many natural resources, man-made alterations can create unintended and, often, adverse impacts to a resource. As a result, stakeholders, special interest groups and residents have identified critical issues and ideas believed to have either caused adjustments to water levels and flow along the River or that are needed to restore or further alter portions of the system. The WRWI was developed to help evaluate and address these concerns.

The main purpose of this peer review is to ensure the H&H modeling developed for the WRWI has been adequately prepared to reasonably simulate the watershed's response to various storm conditions. The WRWI also includes various scenario models that were developed to evaluate the effects of historic as well as potentially proposed alterations to the river system. This included development of 19 different scenario models. The peer review included evaluation of those models to determine if they reasonably simulate the reported or proposed modifications to the river system.

As alluded to above and explained elsewhere in this memorandum, the efforts required to prepare the WRWI models are the product of an extraordinary level of effort and incorporate a high level of detail and quality of work. Development of the WMP required a huge effort both by District staff and Atkins to prepare the models and ensure their ability to simulate responses of the watershed. Some modeling issues or potential problems were identified during the peer review and are discussed in this memorandum. It is important to note, however, that the issues identified are quite minimal and do not affect the model results or conclusions defined in the model scenarios.

As shown in **Figure 1.1**, the watershed modeling is divided into three general approaches including: a "2D Model Domain", a "Detailed Study Extent" and an "Approximate Study Extent". SAI was scoped to review the 2D portions of the model, which includes the main corridor of the river, the Green Swamp, the Tsala Apopka chain of lakes and Lake Panasoffkee. Runoff from the 1D areas (Detailed and Approximate study extents) were assigned to specific 2D locations using 2D external hydrograph data.

The scope of the peer review includes reviews of:

- Model Deliverable and Reports
- Parametrization Approach
- Model Network Review
- Model Results Review

The peer review was performed using documents and data provided to SAI by SWFWMD. The reviews are described in the following section(s) of this memorandum.

Section 2

Model Deliverable and Report

2.1 Reports

SAI was provided a copy of the full WRWI study deliverable by the SWFWMD. The deliverable included GIS maps (e.g. model networks, aerial maps, survey locations, DEM, and floodplains) as well as various reports and other documents (e.g. photo, survey data, report). ICPR models were also provided including the existing and verification models and scenario models. The reports used for the peer review are listed below:

- Watershed Evaluation Report (PBS&J, 2007)
  - Hydrographic features maps
  - Descriptions of River Segments, Reaches and Hydrographic Features
  - Field survey methodology mapping
- Model Development and Verification Report (Atkins, 2014)
- Design Storms Memorandum (Atkins, 2014)
- Flood Frequency Analysis (Atkins, 2014)
- East Citrus Justification Report (Atkins, 2015)
- Model Scenario Report (Atkins, 2015)

These reports provided important background information behind the decision making process and justification for modeling approaches used in development of the WRWI. This included commentary on "desktop" data collection and use in the modeling as well as hydrographic inventory processes (including field verification efforts). These reports also provided details on hydrologic and hydraulic parameterization considerations as well as verification and design storm selection, model simulations and adjustments, and presentation of results including design storm simulation results as well as results of the scenarios described previously.

2.2 Model Deliverables

Simulations of the various models were generated using both high and low initial water levels during the original study. The simulation results were provided in CSV text format. As the models were developed in an older version of ICPR (4.0.0), SAI was unable to obtain a version of the ICPR program that was compatible with the original models. SAI was, however, able to update the models to the latest version of ICPR (V.4.07.01) to allow easier review of the model data. That updated model was used to perform a large part of the peer review in addition to checks of the model results that were provided.

Section 3
Parameterization Review

The peer review focused on evaluation of the approaches used to develop hydrologic and hydraulic (H&H) parameters for the modeling effort and model results generated from the models. The review included checks of hydrologic model methodology including calibration/verification storm selection, synthetic storm volume and distribution determinations, the approach to rainfall excess calculations and supporting information including soil parameters. Checks of hydraulic parameterization included review of the model network used to characterize existing conditions along the river and changes to the network and supporting data for simulation of the various model scenarios required by the project. This included review of parameterization of model components including node and link features as well as overland flow parameterization (e.g., hydraulic roughness). Finally, model simulation control parameters were reviewed.

As mentioned previously, the version of the ICPR program used for the original study was one of the earliest versions of ICPR available. SAI was unable to obtain a copy of that program version to review the provided data. Consequently, the existing-condition and scenario models were converted to a more current version of the program (V4.07.01) to allow for a more efficient review of the model data. This conversion was unable to port the original simulation results. As a result, SAI used the provided result text files and GIS (GWIS) data provided by SWFWMD to review the model results. SAI was able to run the ported model and confirm the original model results were consistent with the provided simulation results. This confirmation of consistency in the results allowed for a more complete review of the study data.

The following sections present findings of the peer reviews.

3.1 2D Overland Flow Mesh Review

The peer review scope was limited to the 2D overland flow region in the ICPR models. As mentioned previously, the 2D region was abutted by areas of detailed studies and approximate studies. Those areas were modeled using 1D approaches and, as such, include “traditional” sub-basin boundaries. ICPR 2D regions do not. Consequently, the peer review of the 2D region focused on the final configuration of the overland flow mesh including model components related to its creation.

ICPR uses a non-uniform (i.e., flexible) triangular mesh to simulate overland flow. The vertices of the mesh triangles are treated as nodes in the model and the sides of the triangles are used as overland flow links. Mesh generation is automated in ICPR using a number of parameters (e.g., minimum triangulation angles, areas, etc.). The terrain for the overland surface is not considered during this process. Consequently, the 2D surface must be developed using certain 2D features to accurately characterize the overland flow surface. Special 2D features are used to enforce mesh components at critical locations such as swales or ridge lines. The most commonly used 2D features include breaklines and break points as well as channel and pond control volumes.

Once the mesh is created, ICPR automatically generates supporting layers that are used to calculate H&H parameters for the 2D nodes and links. These include a “honeycomb” layer that defines contributing areas for runoff calculations and diamond layers used to define link conveyance parameters. The honeycomb and diamond layers are parameterized using various map layers and related look up tables (Curve Number table, imperviousness, roughness, etc.) to simulate rainfall excess and account for travel through the mesh.

SAI reviewed the model mesh to confirm its ability to simulate flow through the watershed and meet the needs of the WRWI. This included a review of 2D features (e.g., break lines and break points, etc.) as well as supporting map layers (e.g., soils and land use) and table data (rainfall excess, roughness, etc.). All reviewed information was reasonable and well-suited to meet the purposes of the study.

The following presents a summary of issues identified during the review. All represent localized instances that could be improved in that area. With that said, the difference in results would be spatially and quantitatively limited and would not affect watershed results overall. All locations are provided in a “Comments” geodatabase which accompanies the deliverables for the peer review.

3.1.1 Breakline and 2D Mesh: **Figure 3.1** shows a location at which some additional breaklines or breakpoints could be used to create a more accurate mesh along a stream system. There is a stream flowing from east to west which then turns south. Break points were placed to generate 2D links along the thalweg, however, additional points or breaklines could have been placed along the bank and bottom of slope to better define conveyance in this small area similar to the approach used along the stream to the east and west. The issue is generally limited to the east-west portion of the stream, just west of a road crossing. After the stream turns south, the terrain "opens up" and the mesh is reasonable. Adjustments at this location would result in a localized change in stages but would not be expected to propagate far from this area.

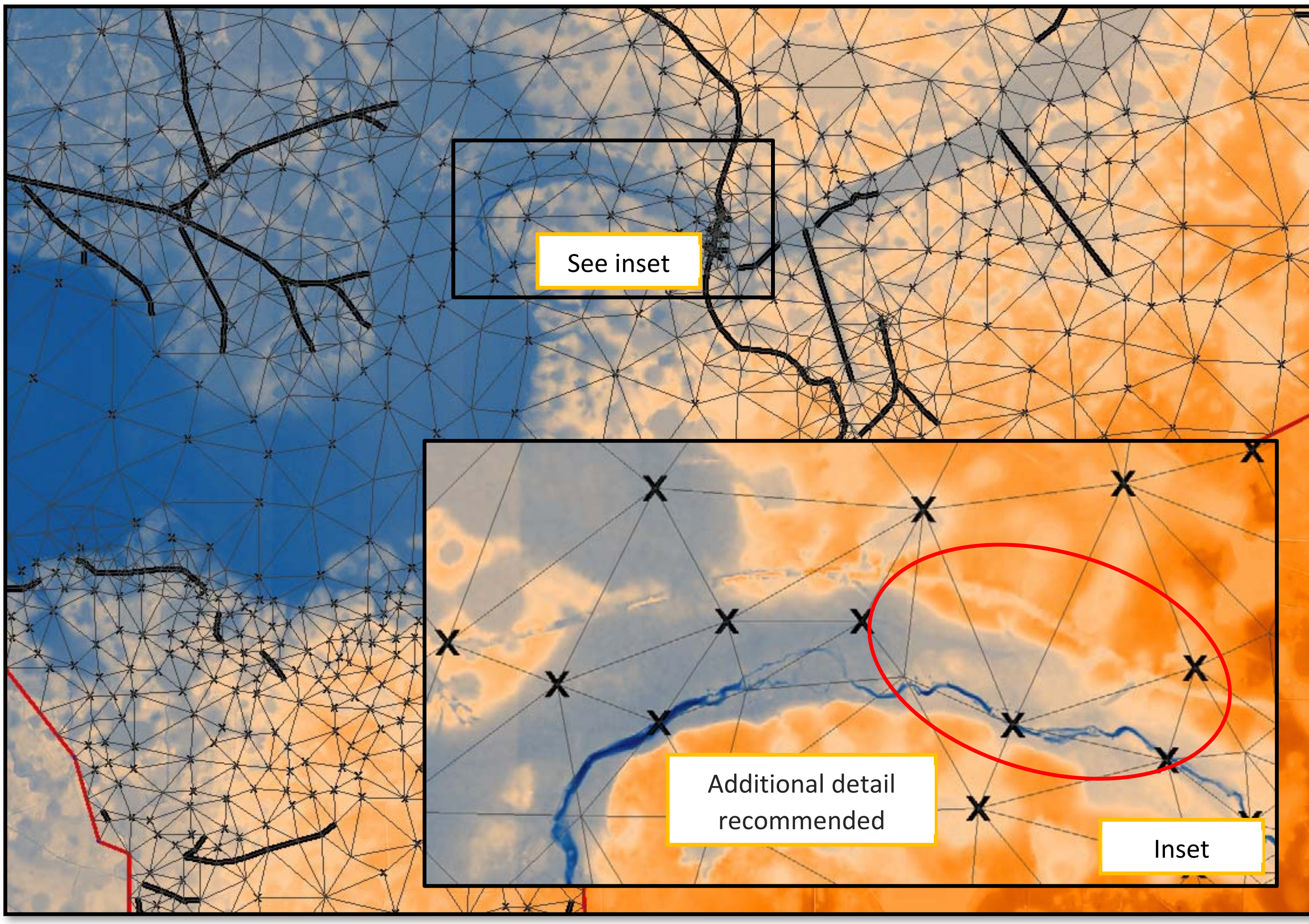


Figure 3.1 – Breakline to Improve Accounting for Conveyance

Figure 3.2 shows a location where the mesh "misses" a ridge/road creating a short-circuiting link between a large wetland system and isolated depression. Use of a breakline along the road would correct the problem. Overflow from the southern depression, however, is to the south and is well-configured.

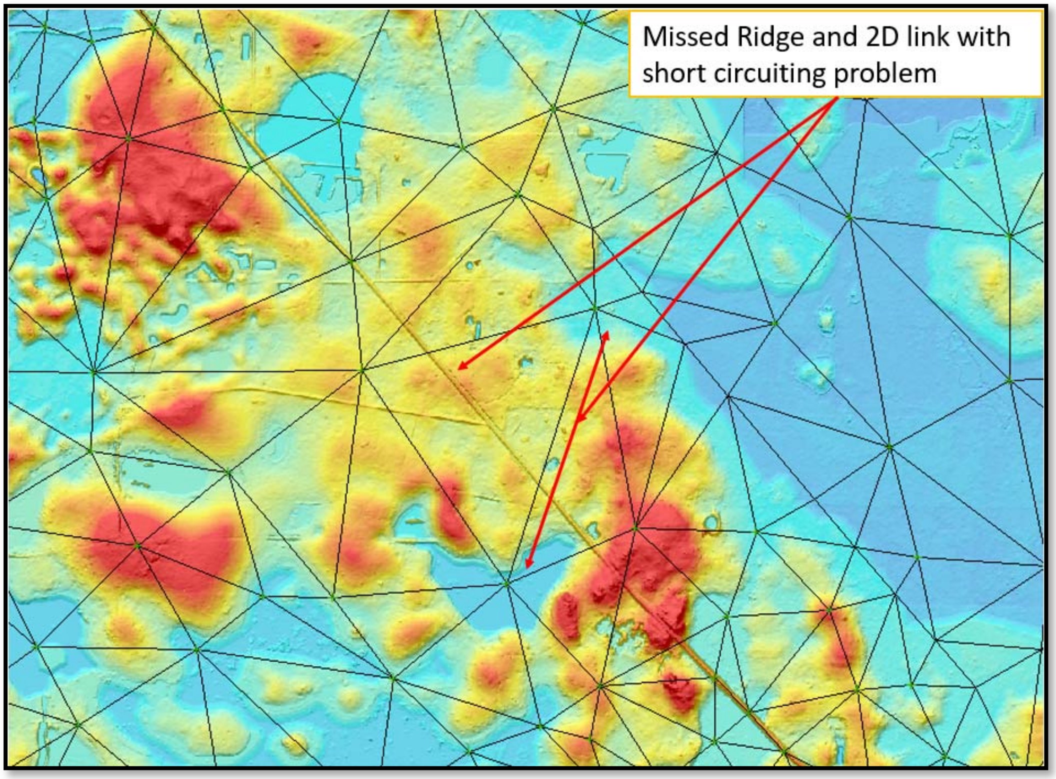


Figure 3.2 – Breakline to Account for Ridge and Prevent Short-circuit Flow

3.1.2 Pond Control Volume: **Figure 3.3** shows a couple of small ponds or depressional areas located adjacent to the river. The mesh generation did not result in placement of sufficient 2D nodes to represent all storage in that area. A more accurate approach would be to include a pond control volume feature to account for the offline storage along the channel. This feature would also tend to enhance model computational efficiency through increased node stability.

With that said, this area of the river is relatively narrow and accurate accounting for conveyance is key to modeling conditions through this reach. The mesh is reasonably configured to account for conveyance along this portion of the river. Additionally, some of the storage is accounted for in the mesh. As a result, while addition of a pond control volume would provide a bit more accuracy in the results, the modification would only yield a localized impact to staging in this area and would have minimal impacts to conditions upstream or downstream of this area.

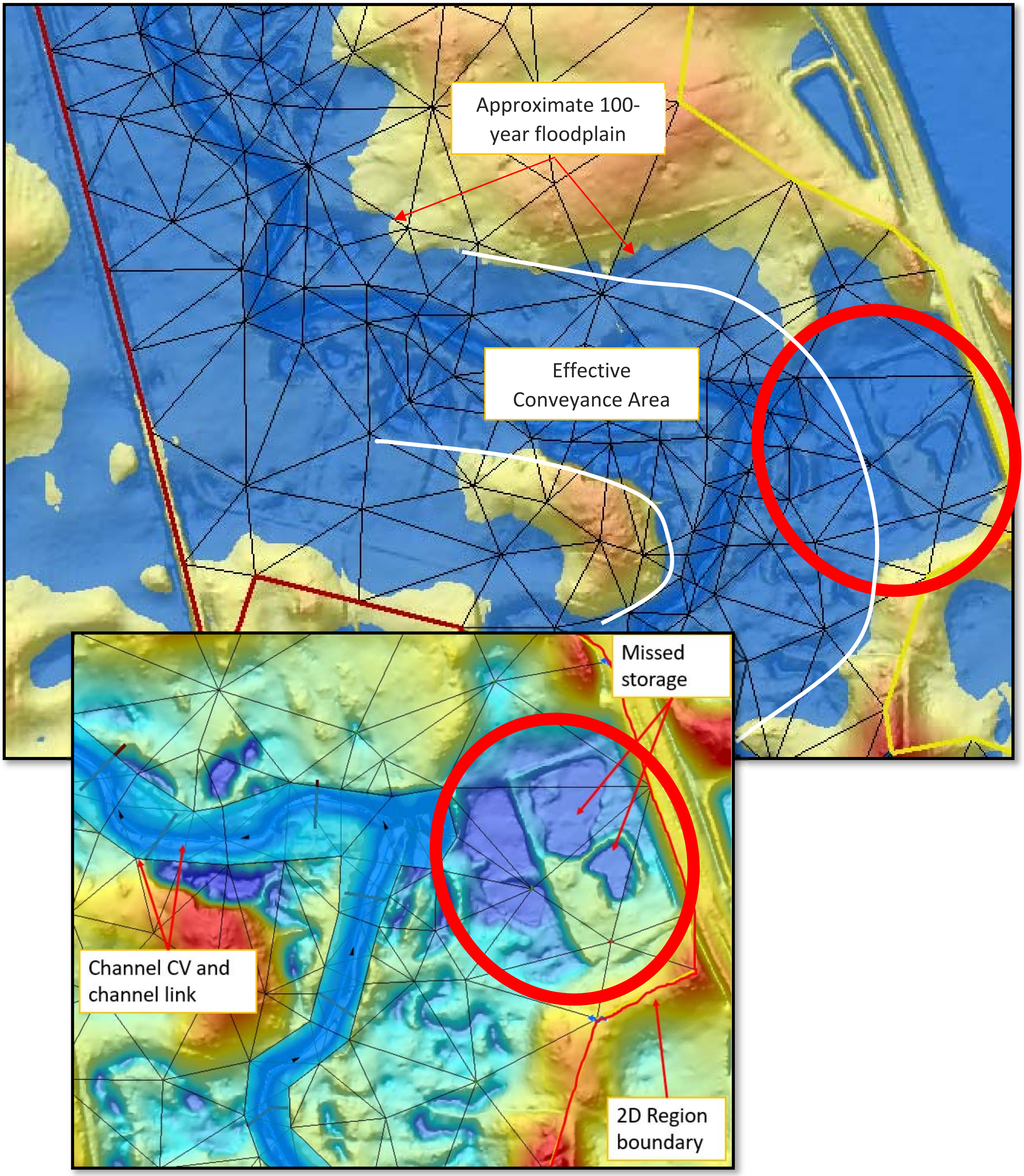


Figure 3.3 – Pond Control Volume to Account for Offline Storage

3.1.3 Cove Features: ICPRv4 includes a Cove feature to account for offline storage in ineffective flow areas along a channel. The cove feature is associated with the channel control volume and provides level pool storage at that location. Addition of a cove feature also helps improve stability at the channel and offline storage interface. **Figure 3.4** shows an area in the 2D mesh just south of the location mentioned above that would be better represented using a cove. This location includes an oxbow area of the stream along the main channel. It is not completely represented by the mesh. Use of a cove would allow more accurate accounting of the oxbow storage. With that said, this change would not significantly affect conveyance at this location and would, therefore, result in localized stage changes only.

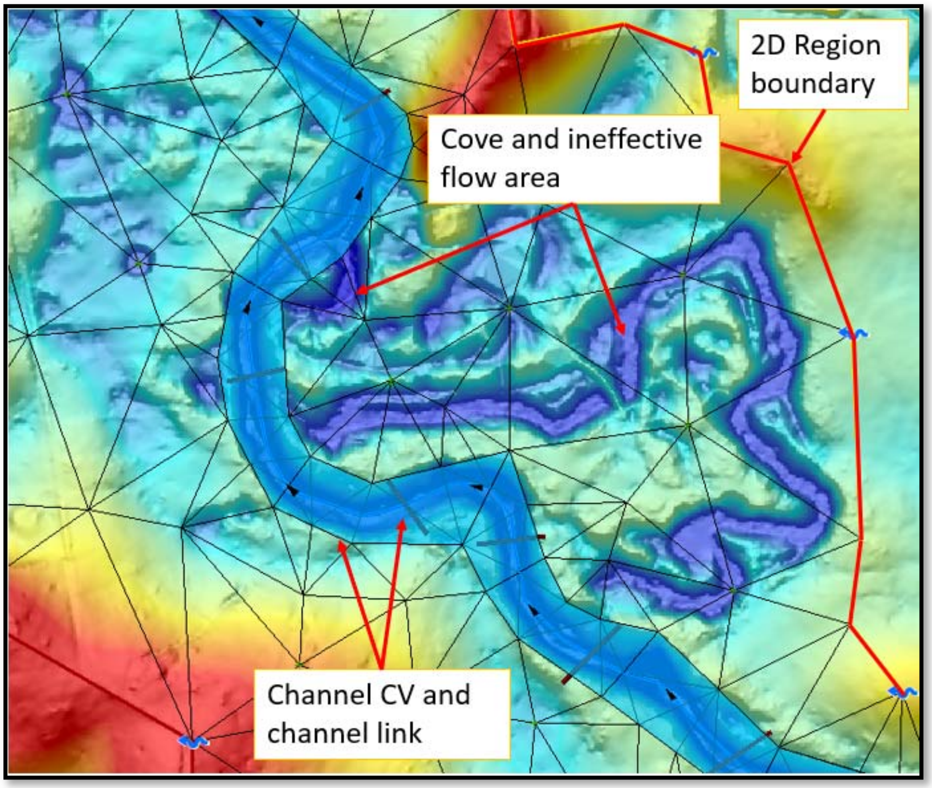


Figure 3.4 – Cove Feature to Account for Offline Storage

3.1.4 External Hydrograph Inflow: As mentioned, the peer review scope was limited to 2D model areas. Detailed and Approximate study areas were not included. With that said, SAI did review locations where flows from those study areas were assigned within the 2D mesh. The review did not identify significant problems. It is noted, however, that inflow points at some locations are placed on top of a berm or roadway rather than immediately adjacent to or at the stream (See **Figure 3.5**). This could result in some overland flow through upland mesh area before reaching the intended adjacent stream. While potentially problematic at the inflow point, this is not likely to be an issue locally or over the watershed.

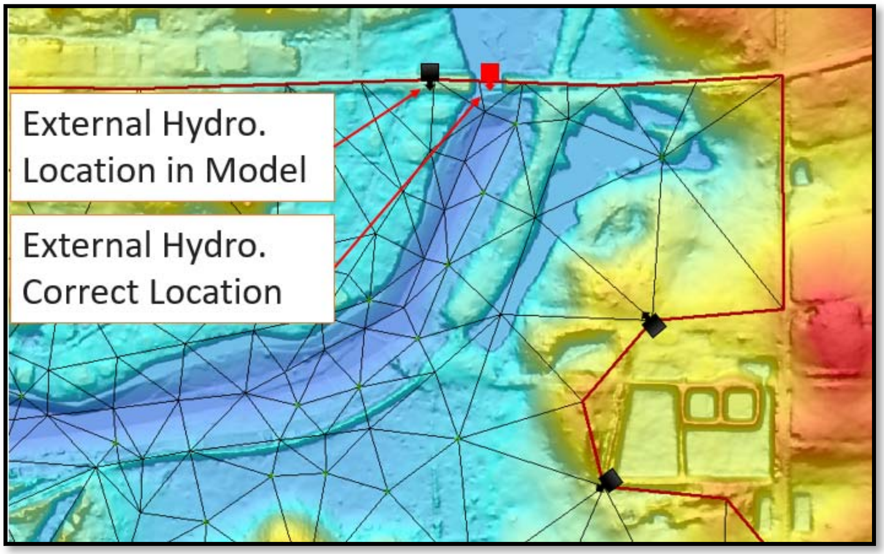


Figure 3.5 – Example of External Hydrograph Discharge Points

3.2 Hydrologic Model Parameters

The hydrologic model parameterization review included evaluation of rainfall excess methodology and supporting information including landuse and soil maps, storm selection and time of concentration calculations. The following presents findings of this review.

3.2.1 Storm Selection: Rainfall and flood stage information collected at gages within the study area were evaluated for selection of a verification event. The evaluation determined that the highest, most-recent flood stage in the watershed at the time of the study was associated with Tropical Storm Jeanne (2004). Initial model runs did not agree well with observed data. As a result, initial stages in the model were modified and the full hurricane season was simulated. Resulting model results were in much closer agreement with the gage data. Consequently, the period from August 4th, 2004 to November 24th, 2004 was used as the verification event. This period included approximately 27 inches of rainfall based on NEXRAD data. The selected verification period is reasonable. SAI also reviewed rainfall model input data and the verification model simulation set up and found no issues.

The design storm duration used for the WRWI was selected based on the overall size of the watershed as well as events that have historically caused flood level conditions along the river. Atkins' *Design Storm Memorandum* (Atkins, 2014) reported that baseflows in the river have historically exceeded 2,000 cfs during multiple wet years. Furthermore, it is typically during these conditions that locations in the watershed are most vulnerable to flooding. Atkins suggested that a long duration storm event would have the ability to create saturated conditions in the watershed leading to flood conditions whereas a single day event would not. As a result, a 5-day storm duration was selected for design storm simulations. This approach is reasonable given the both the size of the watershed and the conditions that have led to high flood levels in the watershed.

The model incorporates evapotranspiration (ET), however, the source of ET data is not clear. A full review of the ET implementation was not possible as the original modeling was performed using an early version of ICPR. With that said, SAI was able to review model results and determine the ET data used were not obtained from USGS data. **Figure 3.6** shows the evaporation simulated in the model versus total cumulative rainfall during the verification storm. This information was obtained from the model output data. Based on the results, total evaporation for the full period of the simulation was about 12" which is about 40 percent of the total rainfall. This value represents approximately 0.11" of ET per day, which is a reasonable value for this area according to available USGS data. Given the success of the verification model simulations, implementation of ET in the modeling appears accurate.

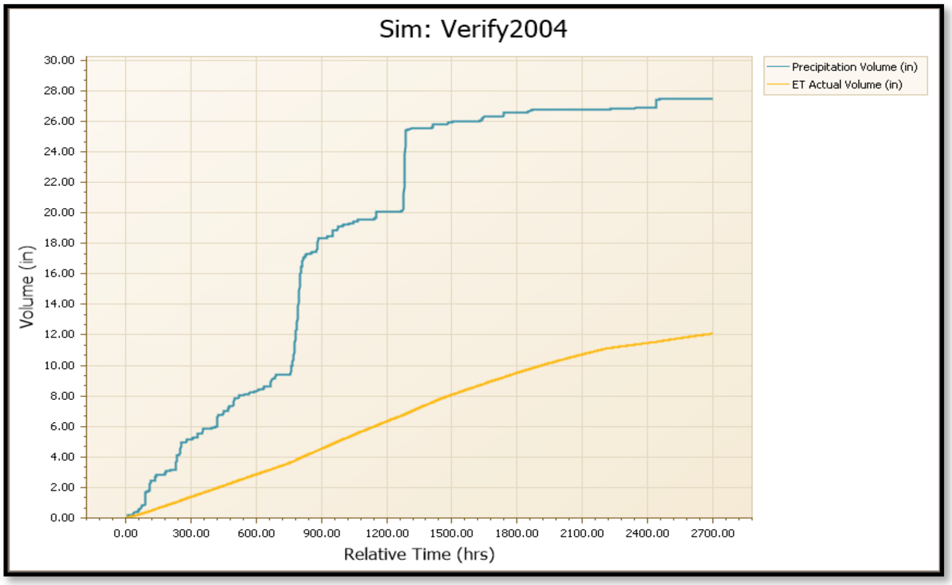


Figure 3.6 – Cumulation Rainfall and Actual Evaporation for the Verification Storm

3.2.2 Rainfall Excess Method: The WRWI models implemented the Green-Ampt method for rainfall excess calculations. Considering the verification storm spanned several storms over approximately 4 months, a method was required that would allow tracking and recovery of soil storage between storms. The Green-Ampt method is appropriate for use in this case. Furthermore, with the exception of hydrograph receding limbs in the upper reaches of the river following the last storm of the validation period, runoff volume results are consistent with observed flow data. The WRWI Model Development and Verification Report (Atkins, 2014) indicates that the discrepancy in the upper reaches is likely due to groundwater contributions from the Green Swamp which would seem to be a valid explanation. With that said, the discrepancy is not believed to affect peak stages or flow rates in the remainder of the watershed.

3.2.3 Landuse Characterization: The source of the landuse mapping used for the study was reportedly based on the District's GIS land use coverage from 2009. Updates were made as appropriate. The land use was used in the 2D region to define two parameters: overland flow roughness and % of total impervious and Directly-connected impervious area (DCIA). The land use mapping was imported into the ICPR v4 model. Roughness and impervious look-up tables in the model are consistent with values included in the Atkins report, excerpts of the which are included in **Appendix A-1** (See Atkins Tables 2-3 and 2-5).

SAI reviewed the roughness and impervious look-up tables. The total impervious and DCIA values reported for each land use category appear reasonable and are consistent with accepted guidance (e.g., TR-55). The Manning's roughness values for overland flow appear generally reasonable. A few of the values assigned to residential land use area appear a bit elevated, particularly for the "deep" values. Revisions to the elevated values would have a local impact only and would not have a significant impact overall. With that said, verification model results are very close to measured data and revisions are, therefore, not recommended.

3.2.4 Soil Characterization: The source of the soil data used in the WRWI modeling is based on the SWFWMD's GIS soils coverage which is based on NRCS soil survey map information. The soils data are imported into ICPR model using Mukey codes and this code is used to define the Green-Ampt soil property look up table. Refer to Table 2.4 (excerpt) of the Atkins verification report (**Appendix A-1**). SAI performed a random check of entries in the soil property look up table and the parameters were reasonable.

3.3 Hydraulic Model Parameters

The hydraulic model parameterization review includes evaluation of data for nodes including initial conditions, storage, and boundary conditions as well as model links. The following sections present findings of the review of these items.

3.3.1 Node Storage: The review was limited to the models' 2D overland flow regions. 1D nodes are limited in the area of review. 1D nodes in the 2D region are used within channel control volumes and pond control volumes. Storage in the former is automatically calculated within the program using the link parameters (e.g. length, cross section). Storage in the latter is limited to that defined by the pond control volume boundaries. SAI reviewed random 1D nodes to ensure the storage area for the pond control volumes were consistent with the terrain. The model data were confirmed.

3.3.2 Node Initial Conditions: Initial stages are defined in the verification model at 1D nodes and nodes within the 2D region. They were defined based on USGS observed gage data and daily readings in the Tsala Apopka Chain of Lakes. For the 2D region, an initial stage surface was created based on observed data at the start of the verification event. It should be noted that initial stages were, at this point in time, relatively low for the beginning of this storm as a result of dry conditions during the previous winter and spring seasons. This approach is reasonable, given the antecedent conditions leading up to the verification period.

Design storm runs of the existing conditions and scenario models were simulated using both low and high initial stage conditions, the latter being based on an 8-year average from observed data and the Tsala Apopka Chain of Lakes in "Filled Mode". The reader is referred to an excerpt from the Atkins' Design Storms Memorandum (Atkins, 2014) for more information (**Appendix A-2**).

The initial surface approach for the 2D region is generally acceptable. With that said, 1D interface node locations may be better suited to use the initial stage override option to avoid using the default elevation from terrain. The model data and results indicate this was not done and, as a result, limited instances of initial stage and initial flow problems were noted (See **Section 3.3.3**).

The initial stage and initial flow problems are significant at some locations but are local in spatial extent and primarily affect neighboring locations to which the affected 1D interface node is connected in the 2D mesh (e.g., US or DS of a road crossing). With that said, the verification model is simulated for a lengthy period before getting to Tropical Storm Jeanne. The model recovers from the initial stage and flow condition relatively quickly and well before the peak of storm.

3.3.3 Boundary Conditions: Two primary boundary locations are specified in the model including 1) a tidal area at the Withlacoochee River outlet in the Gulf of Mexico and 2) the Hillsborough River within the Green Swamp, downstream of SR 471. Tide data were used at the first boundary location; however, the gage name does not appear to be mentioned in Atkins' reports. The tide stages are much lower than stages at Lake Rousseau as a result of the dam and would, therefore, only be expected to affect locations in the river downstream of the structure. SAI checked a couple of NOAA tide gages to evaluate the boundary data and they appear reasonable. Data for the Hillsborough River were based on USGS gauge information (Station: 02311000) and are reasonable.

3.3.4 Channels and Manning's Roughness: Data for ICPR link information, including channel data, were compared to typical ranges of parameter values. Parameter ranges used for this review are somewhat subjective but are helpful in identifying extreme or "out of range" values in the model data that could be typographical errors. This section discusses results of the review for channels. It should be noted that, while all input data were reviewed, the following only highlights the locations that were deemed "out of range".

Channel entrance and exit loess coefficients are set to 0.1 for most of the channels. Channels used to model bridge locations have larger values (e.g., 1.0 - 2.0). Entrance and exit loss values for channels are typically very small or negligible and are commonly set to 0. Some exceptions exist (e.g., channels discharge into the ponds or large depressions). This is generally not the case in the model. SAI evaluated the effect of the loss coefficients by reviewing the channel flow velocity and applying the assigned loss coefficients in model. The results showed that for the cases at which loss coefficients were set to 0.1, the maximum loss through the channel was about 0.01' which is insignificant. It is possible that these coefficients were set to address stability issues in the modeling.

Bridges are modeled as open channels and bridge piles are not considered. It appears the increased loss coefficient values at these locations may have been intended to account for hydraulic losses due to bridge structural elements (e.g., piles, etc.). Channel links at bridge locations used values of 1.0 - 2.0 for entrance or exit losses. These values result in a maximum 0.4' of headloss which would appear reasonable for a typical bridge crossing.

The contraction and expansion loss coefficients for most of the channel links are set to 0.1 and 0.3, respectively. These values are typical. There were couple of cases at which higher values are used (Channels Channel_Brown, Channel_4840, Channel_4841). Based on the review by SAI, those locations include significant contraction and expansion conditions and the elevated values appear reasonable in those cases.

Channels with bedslopes in excess of 2.5% were identified. Just one channel was found with a 4.5% bedslope (Channel_4777). SAI reviewed the DEM for this channel, and it appears that there is a large natural elevation change at this channel location. This slope appears reasonable (**Figure 3.7**).

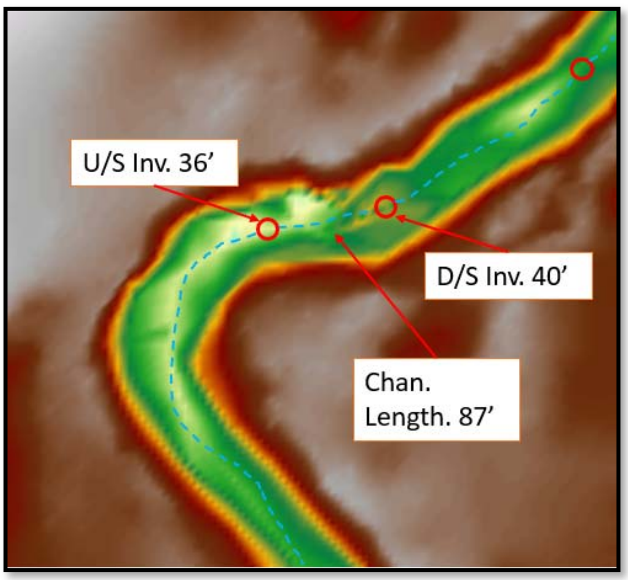


Figure 3.7 – Channel with Significant Bedslope (Channel_4777)

SAI also reviewed other parameters including channel width and depth and Manning's values for standard geometric sections as well as and channel inverts versus the channel cross section minimum elevation to ensure the data are reasonable and correctly defined.

3.3.5 Cross Sections: Manning's values were checked for all cross sections in the model. All values were found to be within reasonable range (i.e., between 0.012 to 0.25). Random checks were also conducted on a small number of channels using aerial map data to confirm Manning's values were appropriately assigned. All reviewed locations were appropriately parameterized.

3.3.6 Bridges: All bridges in the study area were modeled using irregular channels. Since the bridge low chord was not modeled, SAI reviewed all modeled channels at bridge locations against maximum flood stages to ensure flood stages are lower than the bridge low chord (i.e., pressure flow does not need to be considered). **Figure 3.8** shows one of the examples at which the surveyed bridge data were checked. The figure shows that the maximum flood stage is less than the bridge low chord elevation (48.5' max stage vs. 48.85' bridge low chord). No bridges experienced pressure flow.

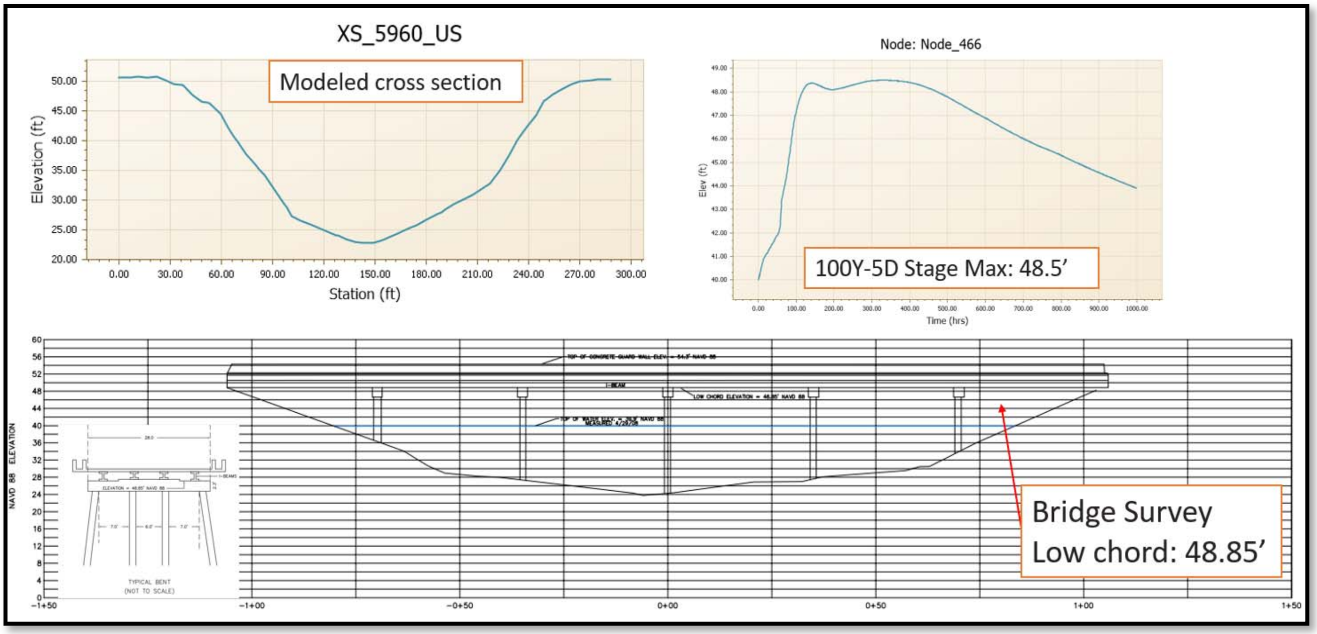


Figure 3.8 – Example of Bridge Data Surveyed with Model Input and Results

3.3.7 Pipe and Drop Structure: Pipe entrance loss values ranged from 0.2 and 1.0 while exit loss coefficients ranged from 0.3 and 1.0., all of which are within normal limits. A small number of pipes were reviewed to check the entrance loss coefficients with aerial map and Google Street View (i.e., based on shape of the end section). Pipes that discharged into ponds and/or water bodies were also checked to confirm an exit loss coefficient of 1.0 was used. SAI did not identify any "out of range values" for entrance or exit losses at the locations that were reviewed.

The Federal Highway Administration (FHWA) inlet edge code for all pipes were set to 0, regardless of pipe geometry and shape. This code is used when the flow regime is inlet controlled. Since SAI didn't have access to the original model, it's not clear if the parameter was lost in the conversion process or if this was even supported in the early version of ICPR used for the modeling. With that said, it is unlikely that many pipe locations in the watershed function under inlet control. In the absence of a flow code, ICPR will use critical depth or orifice flow, depending upon submergence condition, to establish inlet controlled flow rates through culverts. This is a reasonable approximation of FHWA inlet controlled calculations. As such, this issue is considered minor.

Pipe Manning's values were checked for all pipe and drop structure links. With two exceptions, all were found to be within reasonable ranges (i.e., between 0.012 to 0.024). Pipe links: RT1161A and RT1254A had values greater than the 0.024 maximum value used for this check (See **Appendix B - Table B.1).** The former location represents an outfall from a small pond into the 2D region while the latter is a side drain that provides flow along a shallow, roadside swale outside the 2D region. Both are 18" culverts and have no significant impact on the river system.

Two pipes were identified that had differences between the upstream and downstream geometric data (See **Appendix B - Table B.2**). These include differences in shape and/or dimensions. The first (Link: 051820_0001) is located just downstream of the S-353 outfall structure from Tsala Apopka and provides a low-level outfall from the Potts Preserve area. It appears the geometry was mistakenly set for one or the other end of the pipe as the span and rise dimensions are identical in the model if the geometries are revised to match. The difference in area is relatively small and it is unlikely to have a significant impact on stages. The second location (Link: JS_3_4) is around Two Mile Prairie Lake. As with the first location, it appears the geometry was mistakenly set for one or the other end of the pipe. It is a small culvert, also has a small difference in flow area for the two specified geometries and will not have a significant impact on flood stages.

Checks were also made of typical pipe dimensions. A total of six pipes had maximum depths (rise) or maximum widths (span) outside criteria established for this check which was arbitrarily set to range from 1ft to 6 ft (See **Appendix B - Table B.3**). SAI reviewed the identified locations and determined that it appears most of these locations are not standard pipes and, in many cases, are actually bridges or bridge/culverts which are modeled as box culverts. As a result, they appear reasonable as defined in the modeling.

3.3.8 Weirs: Weir discharge coefficients were checked to confirm they fall within reasonable ranges (e.g., 1.8 to 3.2). A random selection of weirs was also checked to confirm discharge coefficients of 3.2 were used for structural weirs. Some nonstructural weirs were also reviewed against aerial map information. Higher values are typically appropriate for “smooth” surfaces (e.g., 2.8 for asphalt) while values for vegetated or wooded areas can be as low as 1.8 (per the SWFWMD’s latest G&S).

Checks were also made of typical weir dimensions. Just one weir had a depth out of range (L-0250W). This weir was set to no flow because of berm failure. It seems that Atkins was aware of this weir and it was previously addressed.

The converted model SAI used for review has a technical issue that prevents exporting of the weir cross sections to CSV file. As a result, SAI could not review the full weir cross sections. Therefore, SAI conducted a random review of weir invert elevations for irregular weir links against the low point elevation of the corresponding cross sections (**Xsec LP**). This check is done to confirm the invert elevations is consistent with the cross section. SAI did not find any mismatched data during this check.

3.3.9 Percolation: No percolation links were included in the model.

Section 4

Model Results and Performance

4.1 Model Result Review

SAI reviewed model simulation results for continuity, simulation end times, flow reversals or sudden flow rate changes as well as stability issues and initial conditions. The WRWI floodplains were also compared to effective FEMA floodplains. Similar reviews were conducted for the scenario models with checks to ensure conclusions drawn in the Atkins reports from those models were supported by the model results.

As mentioned previously, SAI ported the provided models to a recent version of ICPR to facilitate the peer review. The conversion process did not port all model results successfully ported the verification storm results. SAI had access to the data that were provided by SWFWMD in GWIS, Excel or CSV file formats. Therefore, the review of node and link graphs, mass balance, maximum delta-z and other related parameters were conducted based on a mix of model results. A test simulation was also executed for the 100-year 5-day storm using the updated version of the verification model. A review of those results for the verification and design storms determined they are consistent with provided results. The following presents discussion of findings from these review efforts.

4.2 Model Performance

SAI used the verification storm results to review performance of the model. Initial flow and stage problems were identified at some links and nodes (**See Appendix C-1 and C-2**). They are typically associated with 1D interface nodes. As mentioned in **Section 3**, an initial surface was used to set initial stages for the 2D region which is typical. With that said, 1D interface node locations in the region are sometimes better suited to use the initial stage override option rather than use the elevation from terrain. This was not done in the modeling and, as a result, limited instances of initial stage and initial flow problems occur.

Interface nodes provide locations where 1D link connections can be provided between 2D nodes and 1D nodes outside the 2D region or other 2D nodes within the region. For these locations, initial stages are often set based on the initial condition surface used for the 2D region. If, however, the interface point represents a pipe outfall that has an invert below the initial condition surface and/or terrain, hydraulic head conditions can result causing an initial flow of water in the link. The best way to address these problems is by using the 1D interface override option to define the starting elevation or by running a “warmup” simulation with no rainfall for a short period of time, then use those results as a “hotstart” for the actual design storm simulation. That will correct most initial stage and flow problems.

Figures 4.1 and 4.2 show an example of initial stage and initial flow problems, respectively. The problem is short, temporary, and is spatially confined to the immediate vicinity of the interface nodes and does not affect overall model results.

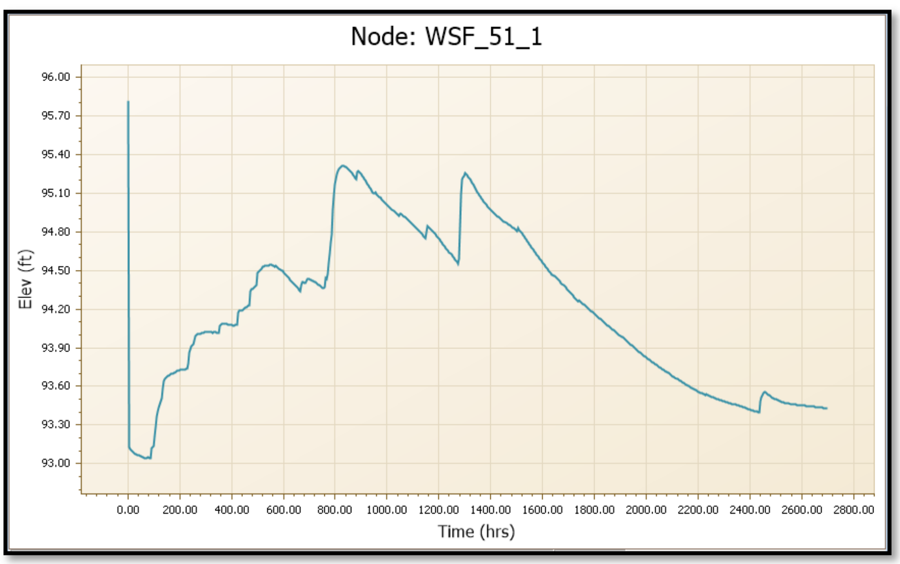


Figure 4.1 – Example Initial Stage in Node Hydrograph (Verification Storm 2004)

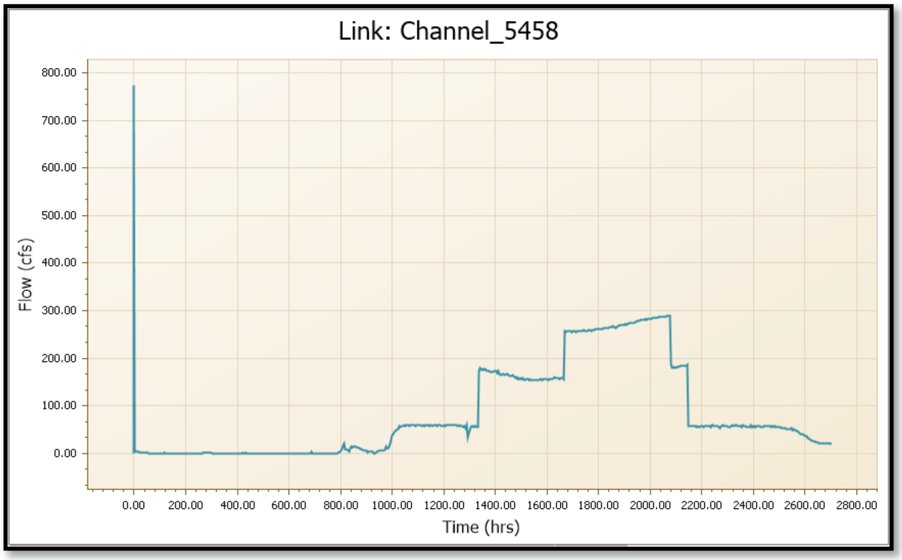


Figure 4.2 – Example Initial Flow in Link Hydrograph (Verification Storm 2004)

SAI reviewed results for potential instability in node stage and flow hydrographs using the node Maximum dz results and Maximum or Minimum flow rate changes. Some unstable flow was noted at locations in the study including, in a few cases, stage hydrographs (**See Appendix C-3** and **C-4**). It should be noted, however, that these instabilities do not lead to mass balance errors in the simulations. As shown in **Figure 4.3**, the maximum mass balance error is about -0.8 % and occurs at the beginning of simulation. This minimal error is primarily due to the initial stage problem mentioned above. The mass balance error for the remainder of the simulation is less than 0.4 % which is insignificant.

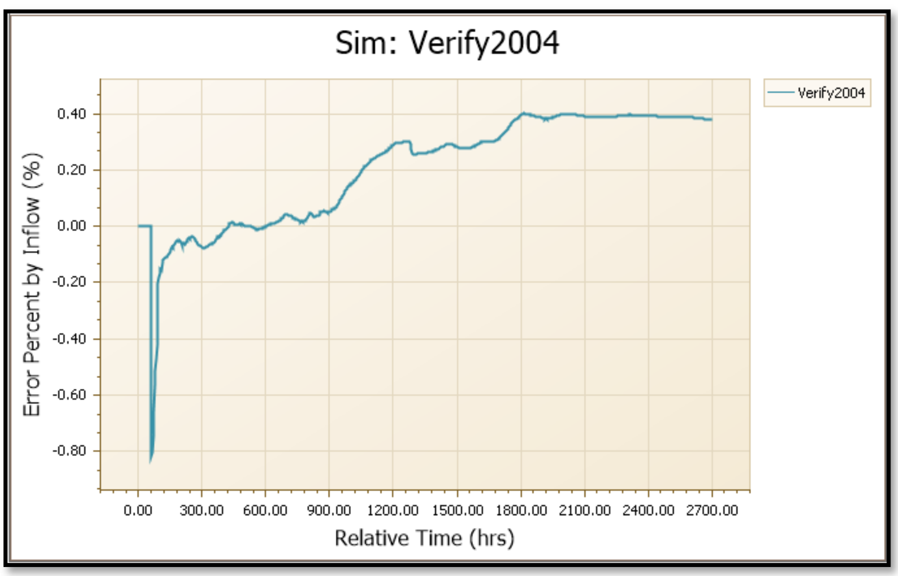
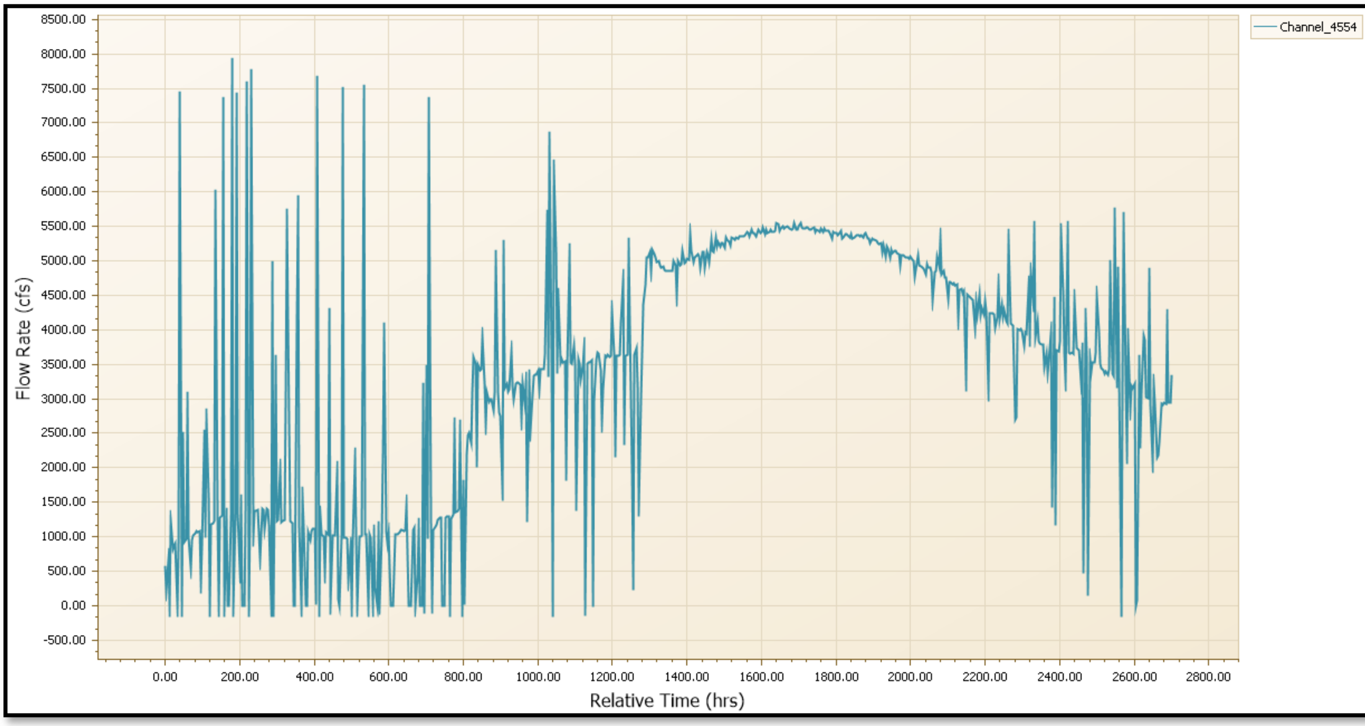


Figure 4.3 – Mass Balance Error for Verification Storm 2004

Figure 4.4 shows an example of channel link instability noted in the model. This location is in the area of US 41, a short distance upstream of Lake Rousseau. As shown in the figure, some surging is noted in flow during low water conditions. Those surges have a relatively small impact on node stages. As flood stages and flow rates increase to peak conditions, the instability is reduced or eliminated, and flood stages are stable. The stability issue is spatially limited to the short reaches through this general area. Flow rates in the longer reaches upstream and downstream of this location are stable during the entire simulation.



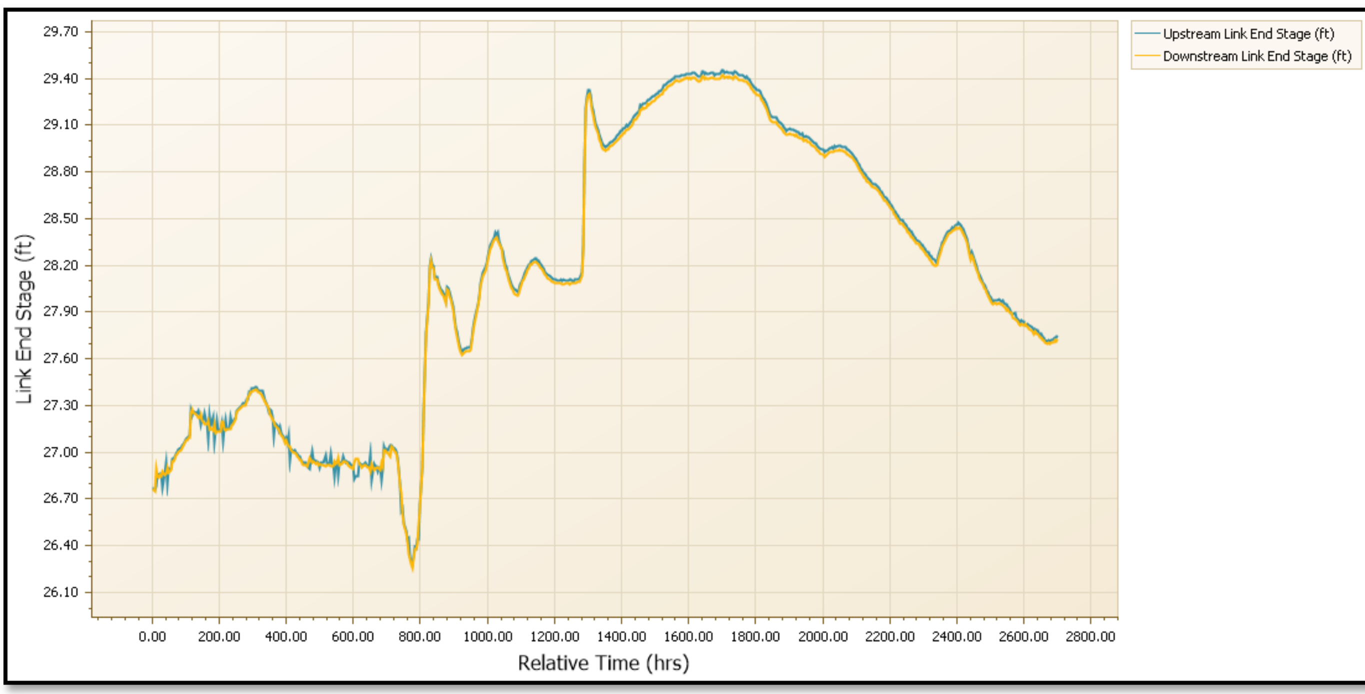


Figure 4.4 – Instability Example: Link: Channel_4554 - Flow and Stage Graph

Appendix C-4 lists three nodes at which significant stage instability was identified. One of the locations (Node_1639) has some instability in the rising limb of the hydrograph, however, stages during peak conditions stabilize. The other two locations (1D interface nodes OFNF-0260 and OF_Node_6471) exhibit stage instability through peak conditions (see **Figure 4.5**). These locations are just upstream a culvert identified in **Section 3.3.7** as having differing geometries defined in the link data (Link: 051820_0001). The location is just downstream of the S-353 outfall structure from Tsala Apopka and provides a low-level outfall from the Potts Preserve area. The worst case is located at Node: OFNF-0260, however, the impact is reduced with distance from that location (see **Figure 4.5**). Furthermore, flow out of this area, while somewhat impacted, is only marginally affected (see **Figure 4.6**) and has no impact on downstream locations.

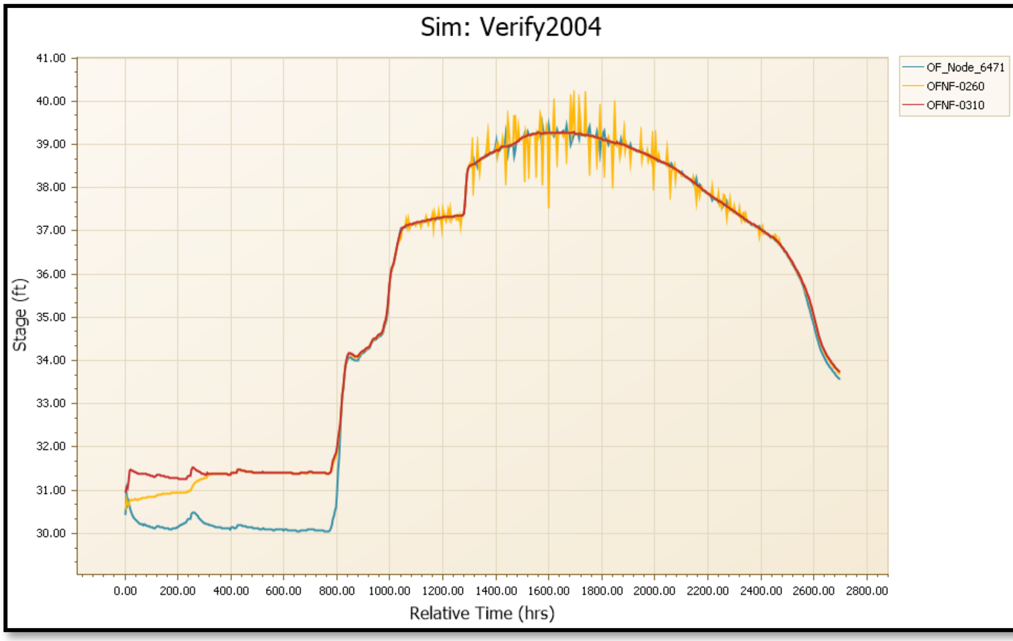


Figure 4.5 – Node Stage Instability (Verification Storm)

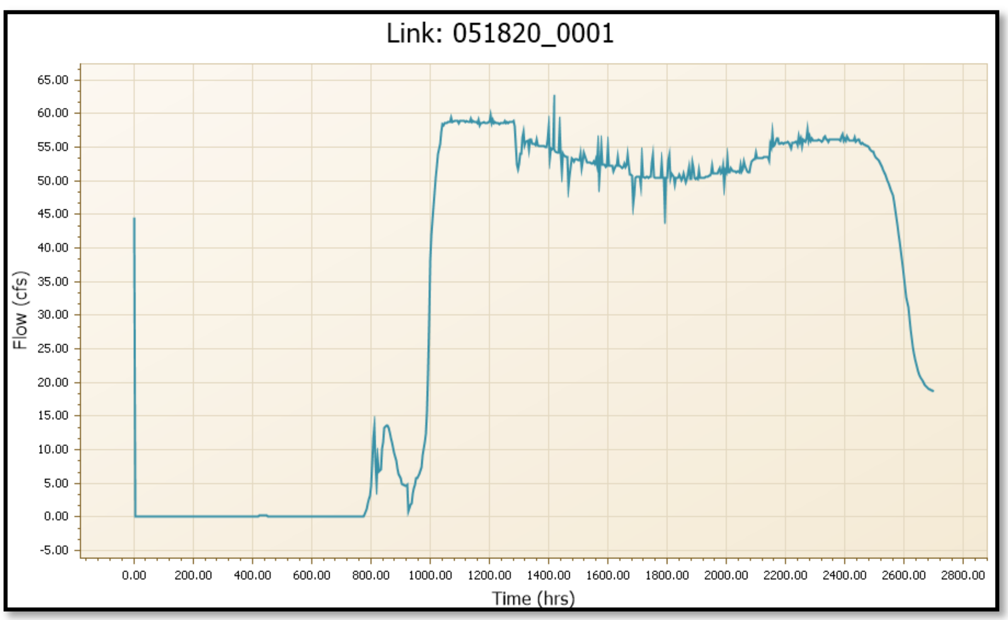


Figure 4.6 – Outflow from Stage Instability Location (Verification Storm)

4.3 Model Results Review Summary

While some issues in model results were identified above (e.g., initial conditions, stability, etc.), they are generally limited in spatial extent and do not materially affect overall results of the WRWI model, particularly in main areas of concern. Despite surges in flow and, to a lesser extent, stage, model mass balance is quite good.

Atkins used three sources of observed information (USGS gages, SWFWMD gages and high-water marks) to evaluate accuracy of the verification model results. Several statistical measures (e.g. Mean Absolute Error, Nash, Root Mean Square) were used to compare model results for stage and flow to these measured data. As discussed in the WRWI verification report, the model results are rated as “good” for the vast majority of stations in the watershed. Considering that the verification period includes three named storm events, the complex geohydrologic setting of the Green Swamp and the river itself, and the numerous unknowns that are inherent in a model of this size and actual conditions during storms, the results are really quite good. These findings lend credence to simulation results of the design conditions model as well as the scenario model results discussed in the next section.

As an additional check, the floodplain information provided with the WRWI deliverable was compared to effective FEMA floodplain information (**See Figure 4.7**). Generally speaking, the map limits for the two sources agree very well, lending further credence to the modeling results.

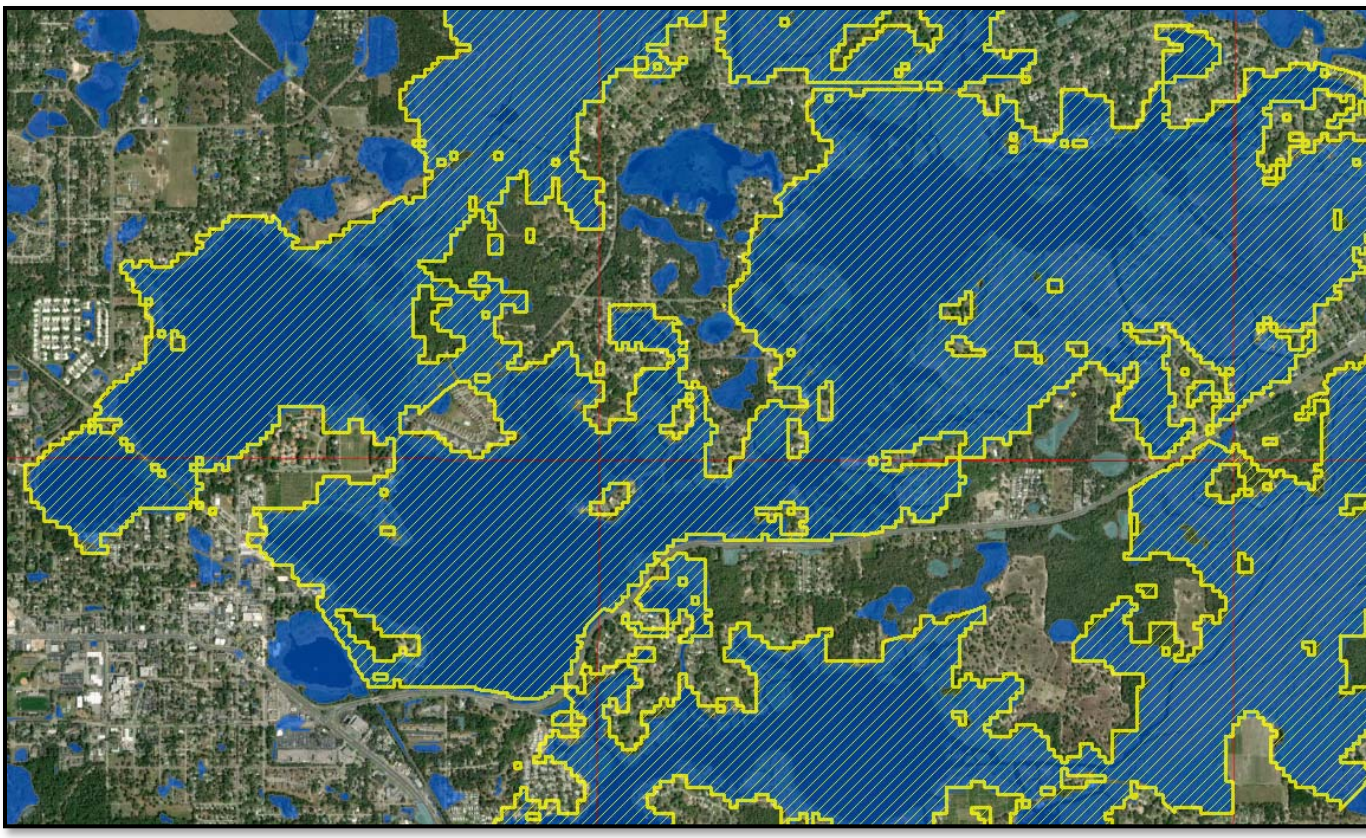


Figure 4.7 – Comparison of FEMA Floodplains and WRWI (100 year - 5 day)
Tsala Apopka - Hernando Pool

Section 5
Model Scenarios

5.1 Introduction

The verification model network and input data provided to SAI by the SWFWMD were subjected to a comprehensive review, as discussed in previous sections of this memorandum. That model was used by Atkins to develop various scenario models to evaluate the effects of historic as well as potentially proposed alterations to the river system. The scenarios fell into four general categories:

- Removal of berms, bridge pilings and constrictions
- Tsala Apopka Structure operation and pre-settlement condition evaluations
- Lake Rousseau Bypass Spillway evaluation
- Structure operations at various locations

SAI reviewed each design scenario model to ensure changes made adequately reflect the intention of the associated scenario. SAI used two approaches to determine the changes that were made. First, a visual check was made of the verification and scenario model 2D networks using the provided GIS mapping information. This provided an efficient means of determining where differences occurred (i.e., model changes) and if those changes were reasonable. Secondly, SAI used ICPRv4's Scenario Difference tool (available in the latest ICPR version) to identify changes to 1D model features. The tool checks the two models and generates a PDF report showing all "Deletions", "Modifications" and "Additions" from the verification model to the scenario models.

5.2 Review of Model Scenarios

The visual reviews and inspections of the Scenario Difference reports showed the model networks for all model scenarios have been developed sufficiently to simulate the intention of the scenarios. Revisions included changes to the terrain used to generate the 2D mesh (i.e., the ground surface) to simulate removal of berms, embankments, or other similar topographic features (See **Figure 5.1**). Other revisions included adjustments to cross section information (e.g., at bridge crossings), removal of culverts or addition of new conveyance (e.g., adding channels, increasing existing culvert conveyance). A limited number of scenarios evaluated changes in operational protocols of various water control structures or diversion of river water during high stage events via creation of reservoir storage or by way of a pumped alternative.

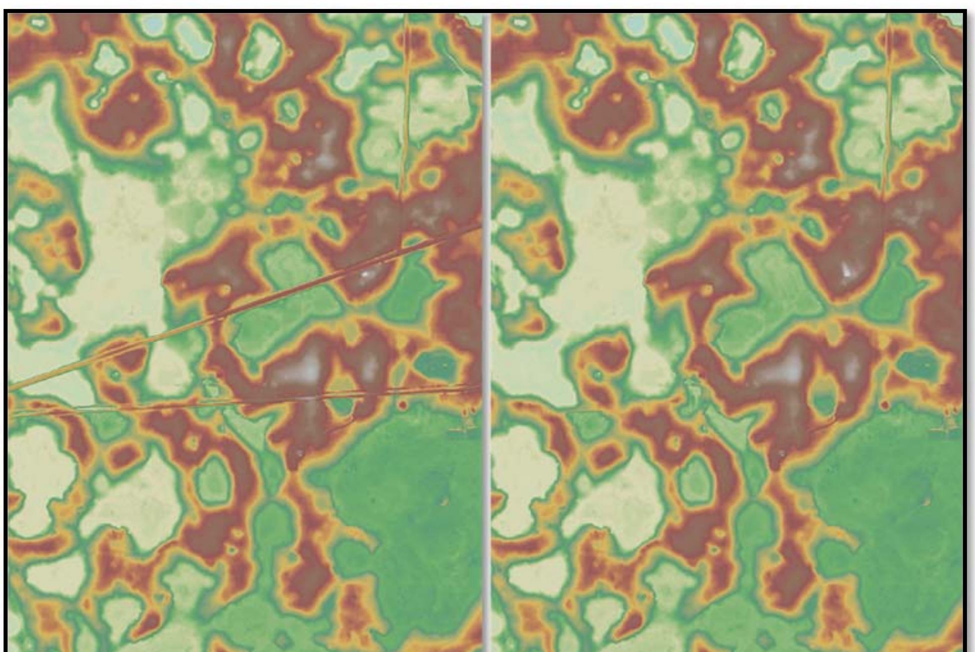


Figure 5.1 – Terrain Adjustments for Model Scenario Evaluations
(Source: Withlacoochee River Watershed Initiative (HO66) – Model Scenario Report, Atkins, 2015)

Cursory reviews of the model changes were conducted. All inspected data were found to be reasonable and consistent with the goals of the model scenarios as described in the Atkins report. In addition to the local changes made to the models for each scenario, SAI also noted that initial elevations throughout the models varied. This was due to use of various starting conditions that were employed during the WRWI analyses. That includes one set for conditions at the start of the verification event (August, 2004), one for low water levels (set based on low flow channels and normal pools in managed lake systems) and high water levels (results of mean annual event starting at low water conditions).

Each set of adjustments was consistent with the intended purpose of the model scenario and specific condition under review.

5.3 Model Scenario Conclusions

As mentioned previously, SAI converted the ICPR models provided by the SWFWMD to a recent version of ICPR for facilitating this peer review, since the original model was developed in an older version. Model time series information was available in CSV format; however, maximum stage reports were not available, and the time series report files were too large for available software to open. As a result, the evaluation was limited to results summary files provided for each model scenario which compared water levels and flows for the scenario results with existing condition results at critical locations. SAI reviewed this information to ensure the conclusions for each design scenario were reasonable. SAI also reviewed the Atkins report to confirm reported results were consistent with the results summary files. As a result of this review, it appears the approaches used to model the scenarios and conclusions drawn from the model results are reasonable.

Section 6
Summary

6.1 Summary

The Withlacoochee River Watershed Initiative (WRWI) has resulted in the development of detailed hydrologic and hydraulic (H&H) models of the watershed. The models include both 1-dimensional (1D) and 2-dimensional (2D) model domains that provide a robust tool for performing drainage analyses of this complex watershed. This tool helps provide a clear and comprehensive understanding of how the watershed functions and how changes affect that function.

Development of the models included a remarkable level of effort and has resulted in a high level of discretization, including a detailed 2D model domain along the river. It is of note that, during calibration / validation efforts, the District and consultant realized base terrain data was lacking in the accuracy thought necessary to address the project's needs. As a result, many months of effort were expended conducting field inspections and surveys that supplemented the available terrain data so that much more accurate information could be incorporated into the modeling.

The level of detail included in the modeling provides a much more accurate and detailed framework for H&H analyses than 1D approaches can provide. In addition, the approach taken in the WRWI study accounts for a wide range of hydrologic conditions allowing analyses of low water elevations that are primarily contained within channel banks to periods of high water levels that overtop the banks and flow along wide swaths of floodplain. The 2D approach allows for a more accurate accounting of these overbank flow conditions than "traditional" 1D analyses can typically provide.

The model has been verified against multiple sets of observed data and provides a very good approximation of conditions across the model extent. This is particularly impressive when one considers the verification period includes three named storm events as well as the recovery periods between those storms. In addition, it provides a level of assurance to the design storm simulations that were performed using the verified model as well as a multitude of model scenarios that were evaluated across the watershed.

While this peer review identified some issues with the model and/or simulation results, those issues are spatially or temporally limited and do not affect overall results. This includes minor issues related to model network development of both the base model as well as the model scenarios and their parameterization and simulation results based on those models. None of the issues identified are expected to have a substantial impact on overall results or conclusions that are drawn from those model results. Therefore, conclusions included in the WRWI study, in terms of how the watershed functions and how historic or proposed changes affect that function, can be relied upon for use by the District in managing this important resource.

Appendix A

Parameterization Review

Withlacoochee River Watershed Initiative (H066)

Model Development and Verification Report

February 21, 2014

Plan Design Enable

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					

Design Storms Memo

Project:	Withlacoochee River Initiative (H066) and East Citrus Watershed Master Plan (N090)	**To:**	Mark Fulkerson, P.E., PhD.
Subject:	Design Storm Simulations	**From:**	Joe Walter, P.E.
Date:	February 21, 2014	**cc:**	Harry Downing, P.E., Gene Altman, P.E.

This purpose of this technical memorandum is to summarize the results of simulating design storm rainfall events of five day duration on the Withlacoochee Watershed. The simulation builds upon the Withlacoochee River Initiative and East Citrus Watershed Master Plans and utilized the same set of initial conditions and soil conditions in the watershed as the verification event (August 2004 to November 2004). The only exception is the initial conditions in the Tsala Apopka Chain of Lakes, which were lowered to represent conditions more typical of recent years, and have the lakes operating in “Fill Mode”. Specific input parameters associated with these design storm simulations and the simulation results are presented below.

Design Storm Model Setup

The following subsections list the input parameters used in the design storm simulations.

Initial Conditions

The initial water elevations in the watershed were set based upon the initial conditions in the verification event, which included relatively low water levels throughout the watershed and normal soil moisture conditions. The only exception to this set of initial water levels from the verification event occurred in the Tsala Apopka Chain of Lakes, in which conditions started lower than those in the verification event as to represent levels observed over the past 8 years and simulate the lakes in “Fill Mode.” Initial conditions for the three pools were set as follows:

- Floral City Pool – 38’ NAVD
- Inverness Pool – 37’ NAVD
- Hernando Pool – 36’ NAVD

Storm Duration

Given both the size of the Withlacoochee Watershed and the events that have caused flood level conditions throughout the Southwest Florida Water Management District (SWFWMD), a multiday event was considered appropriate for the Withlacoochee River. Historic observations in the watershed indicate that during multiple wet years, base flow conditions in the river can exceed 2,000 cfs. It is during these conditions that the watershed is most vulnerable to flooding. It is anticipated that a multiday event will first generate saturated conditions, then produce flood conditions that a single event would not be able to do alone.

Appendix B

Model QC Review

Table B.1: Pipes with Out of Rane Manning Values

Feature Name	Type	Problem	Out of range value	Acceptable Range
RT1161A	Pipe link	Suspect Manning Value	0.12	0.011-0.024
RT1254A	Pipe link	Suspect Manning Value	0.12	0.011-0.024

Table B.2: Pipes with Geometery Problem

Feature Name	Type	Problem	Description
051820_0001	Pipe Link	Different US & DS pipe size and pipe Geometry	
JS_3_4	Pipe Link	Different US & DS pipe Geometry	

Table B.3: Links with Suspect Maximum Width or Depth

Feature Name	Type	Problem	Out of range value (ft)	US Depth (ft)	DS Depth (ft)	Acceptable Range (ft)
321720_0001	Pipe Link	Large Max Width or depth	12	12	12	1 - 6
351719_0001	Pipe Link	Large Max Width or depth	8	8	8	1 - 6
351719_0059	Pipe Link	Large Max Width or depth	8	8	8	1 - 6
GW01010Ma	Pipe Link	Large Max Width or depth	7	7	7	1 - 6
Pipe_5281	Pipe Link	Large Max Width or depth	12	12	12	1 - 6
PIPE_SR471_20	Pipe Link	Large Max Width or depth	10	10	10	1 - 6

Appendix C

Model Results and Performance Review

Table C-1: Links with Initial Flow Problem

Link Name	Maximum Flow Rate	Time to Maximum Flow Rate
	CFS	HR
Channel_5458	752.65	0.0285
Channel_8014	1661.11	0.0028
Channel_5455	288.58	0.007
Channel_5424	274.21	0.012
GS05010M	64.73	0.0169
Channel_5414	193.04	0.0028
Channel_5363	247.65	0.1061
WSF_90	11.47	0.0028
GS10048M	10.86	0.0028
GS07001M	11.71	0.0028
GS07007M	13.68	0.0576
WSF_56	1.6	0.0028
GW03045M	1.73	0.0403
WSF_85	2.07	0.0028
GS08022M	1.87	0.0028
GW06068M	6.87	0.0028
WSF_18	11.75	0.0028
GS11006M	8.79	0.0028
GW01016M	6.83	0.0028
GS05014M	3.96	0.0028
GW01013M	4.48	0.0449
GS11002M	10.65	0.0028
WSF_51	25.25	0.0028
WSF_88	4.65	0.0028
GW02035M	8.38	0.0028
WSF_87	5.01	0.0028
GS08023M	19.32	0.0028
GS05002M	13.32	0.0028
GS05016M	10.45	0.0028
GW01032R	5.36	0.0028
GS05015M	8.01	0.0028
311720_0005	48.24	0.0028
GS07003M	9.23	0.0028
GS10046M	6.17	0.0028
WSF_03	21.76	0.0028
WSF_47	20.3	0.0028
WSF_68	18.33	0.0028
WSF_04	12.16	0.0028
WSF_97	13.6	0.0028
WSF_39	7.45	0.0028
WSF_74	9.96	0.0028
WSF_96	9.11	0.0028
WSF_49	8.31	0.0028
WSF_72	8.69	0.0028
WSF_06	3.85	0.0028
GS11003M	27.93	0.0028
WSF_75	11.57	0.0028
GS02013M	31.38	0.0028
311720_0006	28.47	0.0028
GS11005M	28.49	0.0028
GS11004M	16.28	0.0028
GS05013M	14.57	0.0028
GS05017M	11.25	0.0028
GS08012M	11.45	0.0028
WSF_92	0.92	0.0336

Table C-1: Links with Initial Flow Problem

Link Name	Maximum Flow Rate	Time to Maximum Flow Rate
	CFS	HR
GW01018M	43.88	0.0028
GS07006M	41.62	0.0028
GS07002M	37.98	0.0028
GS10050M	63.01	0.0028
GS10052M	30.76	0.0028
Channel_5364	575.58	0.0028
GS11007M	24.69	0.0028
Channel_5321	194.06	0.0028
301720_0010	38.53	0.0028
311720_0008	60.3	0.0028
GW03061M	30.96	0.0028
WSF_36	44.04	0.0028
Channel_5365	118.89	0.347
GS10047M	57.3	0.0028
GW06063M	34.84	0.0028
Channel_7838	235.96	0.0341
WSF_19	50.44	0.0028
WSF_43	32.97	0.0028
GW03062M	72.02	0.0028
241179_0002	143.21	0.0028
GW01010M	65.81	0.0028
GS10055M	156.59	0.0028
GS10054M	96.74	0.0028
Channel_5456	553.09	0.0028
WSF_37	54.94	0.0028
Channel_5423	1207.39	0.0028
GS05018M	21.41	0.0228
Channel_4848	4670.46	0.0028
321720_0001	293.32	0.0028
GW01010Ma	50.67	0.0046
PIPE_SR471_20	18.67	0.0057
Channel_5457	1160.17	0.0028
Channel_4878	3979.04	0.0028

Table C-1: Node with Initial Stage Problem

Node Name	Maximum Stage	Initial Stage
	FEET	FEET
GW01030M_2	88.54	88.53
GW01010Ma_1	84.82	84.82
GS10055M_1	104.75	104.67
OF_Node_6427	36.2	35.21
OF_Node_6436	37.67	37.36
GS10054M_1	108.26	108.26
GW03047R_2	80.46	80.43
GS10050M_1	98.99	98.99
GW03050M_2	88.16	87.74
GS07002M_1	99.15	98.87
OF_Node_6461	37.62	37.5
GW01018M_1	87.46	87.46
GS07006M_1	100.3	100.3
GS02013M_1	95.61	95.21
GS11005M_1	108.4	105.32
GW02034M_2	94.74	94.74
GS11003M_1	107.58	103.05
WSF_51_1	95.82	95.82
WSF_03_1	96.71	96.71
WSF_47_1	96.72	96.24
GS08023M_1	99.36	99.36
LWR_0020	85.19	84.1
GS07001M_1	99.26	98.72
WSF_18_1	77.46	76.86
GS10048M_1	96.51	96.04
GS11006M_1	108.46	105.07
GS07007M_1	103.47	102.43
GS10043M_1	95.27	94.29
GS07004M_1	99.89	99.01
GS10049M_1	98.58	96.9
GS10053M_1	108.48	107.58
GW03048M_2	92.01	90.29
GS02012O_1	96.08	94.34
Node_2278	61.13	58.46
HWM_7744	36.54	36.54
Node_2282	58.88	56.33
JS8	36.54	36.54
Node_2279	59.77	57.36
JS7	36.54	36.54
GS07007M_2	102.27	101.29

Table C-3: Examples of Links with Instability Problem

Link Name	Maximum Flow Rate	Time to Maximum Flow Rate	Min/Max Change in Flow Rate	Time to Maximum Change in Flow Rate
	CFS	HR	CFS	HR
Channel_4554	12860	235	12860	235
Channel_4553	9632	147	9632	147
Channel_4921	5630	1968	5630	1968
Channel_4920	5387	2012	5387	2012
Channel_4349	5157	1987	5157	1987
Channel_4910	4619	1365	4086	1354
Channel_5299	2926	451	2926	451
Channel_4744	3204	1092	-1848	1075
Channel_4550	7692	1723	-2571	1313
Channel_4911	4458	1354	-2743	1403

Table C-4: Node with Instability Problem

Node Name	Maximum Stage	Min/Max Change in Stage	Time to Maximum Change in Stage
	FEET	FEET	HR
Node_1639	40.12	2.7843	312.8775
OFNF-0260	40.97	-2.0603	1581.5993
OF_Node_6471	39.74	-0.6475	1647.9346