COASTAL AND HEARTLAND NATIONAL ESTUARY PARTNERSHIP
Lower Charlotte Harbor Flatwoods Strategic Hydrologic Restoration Plan

PREPARED FOR:

Coastal & Heartland National Estuary Partnership
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JULY 2022

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JULY 2022

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INTRODUCTION

Water Science Associates was contracted by the Coastal & Heartland National Estuary Partnership (CHNEP) to develop a hydrologic restoration plan for the Lower Charlotte Harbor Flatwoods that will promote sheet flow enhancement and restore wetland hydroperiods in Babcock Webb and Yucca Pens Wildlife Management Area (WMA) and improve the timing and magnitude of flows to tidal creeks west of Yucca Pens WMA. Hydroperiod is defined as the number of days per year that water depths are more than 0.1 feet above ground surface. Hydroperiod units used in this memorandum are months, which is days/year divided by 12.

Portions of Fred. C. Babcock-Cecil M. Webb WMA (Babcock Webb) have altered hydroperiods due to blocked historic (pre-development) flow-ways in the southwestern portion of Babcock Webb, locally referred to as the South Walk-In Area. The South Walk-In Area of Babcock Webb experiences extensive inundation that has resulted in extended hydroperiods, resulting in negative habitat impacts for the quail, an important game bird in Babcock Webb. The Yucca Pens Unit WMA (Yucca Pens) has reduced wetland wet season water depths and wetland hydroperiods due to the blocked flow-ways from Babcock Webb as well as accelerated outflows via eroded all-terrain vehicle (ATV) trails. This project is intended to address those hydroperiod alterations.

Project Location. The project is located in the Charlotte Harbor and Caloosahatchee watersheds with a primary focus on Babcock Webb, Yucca Pens, and the tidal creeks to Charlotte Harbor in Charlotte and Lee Counties, FL. Figure ES-1 provides a location map of the study area.

Project Background. The Charlotte Harbor Flatwoods Initiative (CHFI) is comprised of multiple local, state and federal agencies, the Coastal & Heartland National Estuary Partnership, and other stakeholders. The CHFI was formed to initiate efforts to restore natural drainage across the Gator Slough Watershed with water that has been unnaturally impounded on the Babcock-Webb WMA and diverted from the Yucca Pens WMA, Caloosahatchee, and tidal creeks to Charlotte Harbor.

The objectives of the CHFI include improvements to area sheet flow, restoration of natural flows to Charlotte Harbor and the Caloosahatchee River to the extent practicable, and improvements to area water quality, groundwater recharge, high water levels, flooding, and fish and wildlife habitats. This project includes development of an updated integrated surface-groundwater hydrological model that will allow simulation of potential future conditions scenarios in the Lower Charlotte Harbor Flatwoods area. The outcomes from this work will provide guidance to resource management agencies for restoration and management of surface waters flowing from Babcock-Webb through Yucca Pens and into tidal creeks discharging into eastern Charlotte Harbor and the Caloosahatchee River.

Project Description. The goal of the project is to reduce pollution and hydrologic degradation to coastal watersheds in lower Charlotte Harbor through development of a science-based and data-driven integrated surface-groundwater hydrological model and the Lower Charlotte Harbor Flatwoods 'Strategic Restoration Planning Tool' Report. Modeling work includes hydropattern mapping of natural, current, and potential future conditions scenarios in the Lower Charlotte Harbor Flatwoods area. The outcomes from the Future conditions modeled scenarios will be known as the Lower Charlotte Harbor Flatwoods 'Strategic Hydrological Restoration Planning Tool' and Report. All data, models, and technical memos associated with this project along with the final report will be made publicly available through the CHNEP Water Atlas Charlotte Harbor Flatwoods Initiative page.

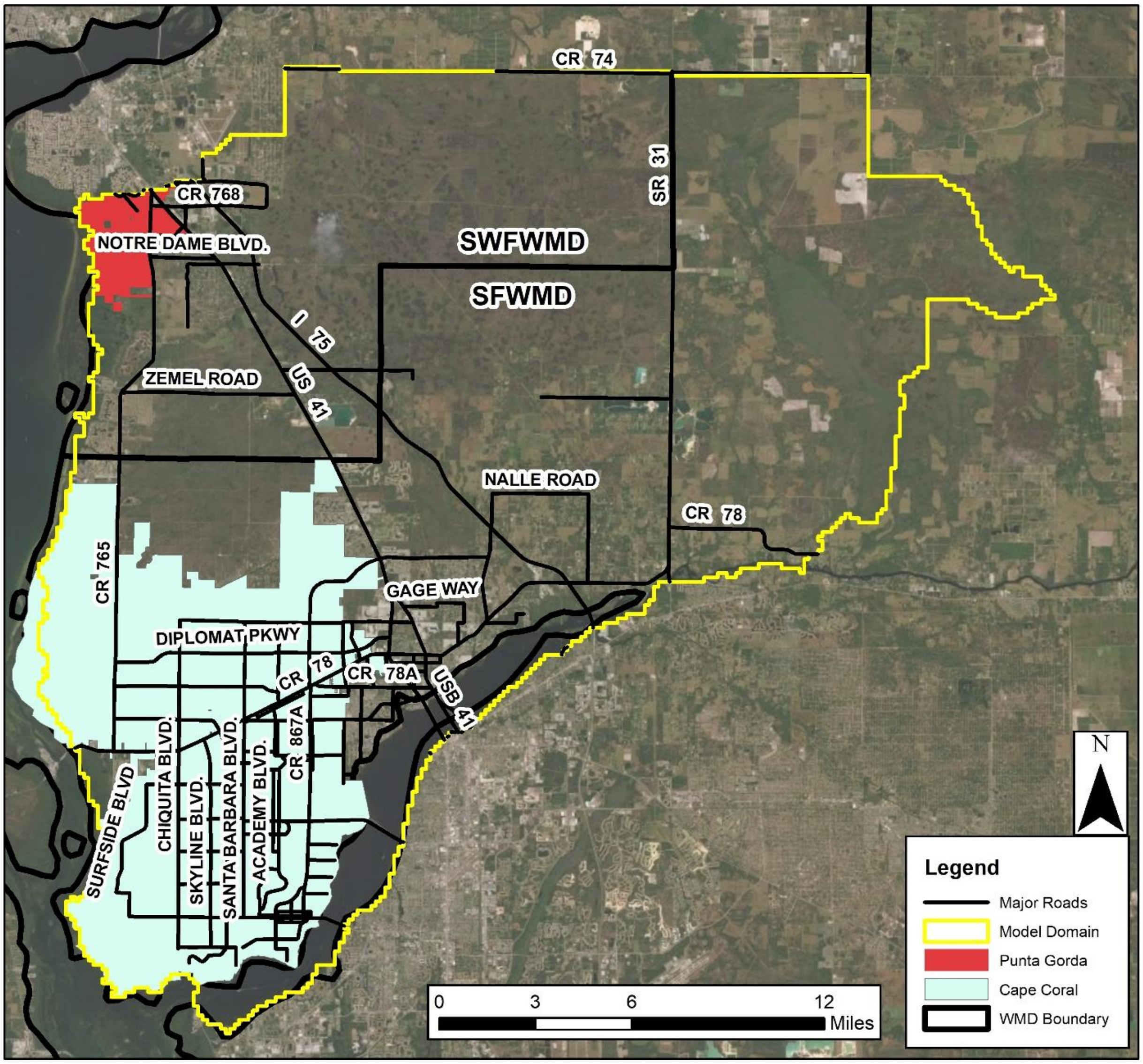


Figure ES-1. Location Map

The Report provides guidance to local governments and agencies for how best to restore connections and manage surface waters flowing from Babcock Webb and Yucca Pens through tidal creeks discharging into eastern Charlotte Harbor and the Caloosahatchee River.

Project Tasks and Deliverables. Project tasks include:

1. Compilation of existing hydrologic data,
2. Installation and of new surface and groundwater monitoring stations and rain gages,
3. Evaluation of vegetation indicators of wetland health,
4. Maintenance of the monitoring stations and downloading measured data,
5. Development of an existing conditions hydrologic model of the study area,
6. Evaluation of alternative management scenarios, and
7. Development of a Lower Charlotte Harbor Flatwoods Strategic Hydrological Restoration Planning Tool and Report.

Study Findings. The Data Collection task provided an extensive dataset for 40 monitoring stations in and around the Florida Fish and Wildlife Conservation Commission (FWC) Babcock Webb WMA and in Yucca Pens. Combined with on-going FWC data collections efforts at 23 other stations, this project has established a comprehensive database that was used for model development and calibration.

Field ecologic studies were conducted at 58 locations that have identified and surveyed vegetation indicators of average wet season water elevations during both dry and wet season conditions. Pre-development hydrologic conditions have been estimated that identified the extent of historic wetland conditions in both Babcock Webb and Yucca Pens. This information was combined with the groundwater and surface water monitoring data to identify areas in Babcock Webb and Yucca Pens that have experienced hydrologic/ecologic alterations.

An updated integrated surface/ground water model was developed that utilizes the most recent information. Model calibration is currently considered to be **good with many stations performing substantially above the minimum standards for good calibration.** The model was suitable for the scenario analyses part of this project.

Scenario Analysis. The calibrated model was utilized to analyze three future conditions scenarios. **Scenario 1** assumed that the 600-acre Bond Farm parcel on the southwest corner of Babcock Webb will be used to store a maximum of 4 feet of excess waters from the South Walk-In Area. Scenario 1 also included 25 weirs in Yucca Pens to retain more water on Yucca Pens, reduce wet season discharges, and increase baseflow discharges to tide. A seepage barrier was also assumed along the south end of Yucca Pens adjacent to Gator Slough to reduce over drainage of Yucca Pens by the Gator Slough Canal. **Scenario 2** was a refinement of Scenario 1 with additional storage of excess flows in the Southwest Aggregates mining property. Yucca Pens improvements from Scenario 1 were included in Scenario 2 with the location of one of the 25 weirs moved upstream to minimize impacts of higher water levels on private lands adjacent to Yucca Pens. **Scenario 3** included all features of Scenario 2 and assumed climate change impacts consisting of higher tidal water level boundaries and higher evapotranspiration rates.

Scenario 2 is recommended for implementation due to hydrologic improvements in both Babcock Webb and Yucca Pens. The hydrologic benefits include:

- Improved restoration of hydroperiods and water depths in the South Walk-In Area of Babcock Webb
- Greater restoration of wetland hydroperiod and water depths in Yucca Pens
- Increased discharges from Yucca Pens to tide during the late wet/early dry season

Based on the analysis described herein, Scenario 2 is recommended for further refinement during subsequent restoration planning and design efforts. Additional calibration is recommended to decrease uncertainties regarding groundwater hydraulic conductivities, and this effort may indicate that greater restoration can be achieved by Scenario 2. Recalibration may indicate more substantial Yucca Pens peak flow reductions at Burnt Store Road. In addition, refinements are recommended for the operating protocols for the Bond Farm Hydrologic Enhancement Impoundment (HEI) and Southwest Aggregates Reservoir inflow pumps so that filling the Bond Farm HEI has a higher priority than filling the Southwest Aggregates Reservoir.

1. GATHER EXISTING DATA

1.1 PRIOR STUDIES

A number of hydrologic studies have been completed for the Coastal & Heartland National Estuary Partnership (CHNEP) and surrounding areas. These include investigations by Florida Fish and Wildlife Conservation Commission (FWC), South Florida Water Management District (SFWMD), Southwest Florida Water Management District (SWFWMD), Florida Department of Transportation (FDOT), U.S. Army Corps of Engineers (USACE), and Lee County. This project used information from these various sources during the planning process. Typical information that is useful from previous studies include land use data, water level data, rainfall data, survey data including LiDAR, point elevation measurements, and surveyed cross sections of existing water conveyances. Available hydrologic information provided a basis for identification of existing data gaps, new data acquisition efforts, and provides a platform for subsequent analysis of all available data.

See **Appendix 1** for the full Task 1 memorandum which identified and described existing data, studies, and modeling information, as well as data gaps in space, time, or type of information for the Charlotte Harbor Flatwoods Initiative (CHFI) project area. Note that only limited analyses of data were conducted in the Task 1 memorandum as those efforts were documented in subsequent technical reports.

Prior studies summarized in the Task 1 memorandum included:

- 1983 – Cecil Webb Water Management Study
- 1990 – Lee County Interim Surface Water Management Master Plan
- 2002 – Tidal Caloosahatchee Basin Model
- 2004 – South Charlotte, North Lee County, and Babcock Webb Surface Water Management Conceptual Plan
- 2005 – NW Lee County Surface Water Management Plan
- 2006 – North Fort Myers Drainage Restoration Project
- 2007 – Matlacha Pass Hydrologic Restoration Project
- 2008 – Lower Charlotte Harbor SWIM Plan
- 2008 – Conceptual Management Plan for Fred C. Babcock – Cecil M. Webb Wildlife Management Area 2003 – 2008
- 2010 – North Fort Myers Surface Water Management Plan
- 2010 – Yucca Pens Hydrologic Restoration Plan
- 2010 – Yucca Pens ATV Trails Restoration
- 2013 – FDOT I-75 Widening Permit, Initial Bond Farm Modeling
- 2015 – Southwest Florida Comprehensive Watershed Plan, US ACE, CHNEP, Sarasota County Estuary Program, Tampa Bay Estuary Program
- 2015 – City of Cape Coral Stormwater Model
- 2015 – A Management Plan for Fred C. Babcock – Cecil M. Webb Wildlife Management Area, 2014- 2024
- 2015 – Tidal Creeks Land and Conservation Prioritization Report

- 2016 – Basis of Design Report – Southwest Aggregates Storage Reservoir
- 2016 – SWFWMD LiDAR
- 2017 – Cape Coral Emergency Water Delivery from Southwest Aggregates
- 2018 – Bond Farm Acquisition
- 2018 – Yucca Pens Hydrological Study
- 2018 – SFWMD 2018-2023 Strategic Plan
- 2019 – RESTORE funding proposal for Bond Farm construction
- 2019 – Executive Order 19-12: “Focus on rapid improvement for water quality, quantity, and supply
- 2019 – Yucca Pens Hydrogeological Assessment
- 2020 – Southwest Aggregates Water Use Permit Application
- 2020 – Bond Farm Environmental Resource Permit Application

1.2 EXISTING MONITORING DATA

Descriptions of the existing monitoring stations within the Babcock Webb and Yucca Pens Wildlife Management Area (WMA) are presented in **Table 1-1**. Monitoring stations outside of the WMA are presented in **Table 1-2**. Locations of existing monitoring stations both inside and outside of the WMA are presented in **Figure 1-1** and **Figure 1-2**. Hydrologic data from existing monitoring stations (stations existing as of February 2020) and rain gages within the vicinity of the WMA were summarized in the Task 1 Memorandum in Appendix 1. Maps and additional information are also available in Appendix 1.

1.3 SURVEY DATA

Cross sectional survey data for some existing monitoring stations were available from prior studies, including the FDOT I-75 widening project (ADA, 2013), US 41 and Gator Slough cross sections surveyed for Cape Coral (WSA, 2017), and 58 cross sections in Yucca Pens surveyed for FWC and CHNEP (WSA and Southwest Engineering & Design, 2019). During a 2019 survey of monitoring wells in the South Walk-In Area of Babcock Webb, five additional locations were surveyed and the surveyed elevations were compared to LiDAR elevations. Surveyed ground elevations were, on average, one foot lower than LiDAR elevations (see Appendix 1 for more detail). Based on these findings, additional surveying was conducted by Banks Engineering at 14 transects in the South Walk-In Area in February 2021 to check the accuracy of LiDAR elevation data (Banks Engineering, 2021). The Banks Engineering transect survey data was utilized during model development and is discussed further in Section 5.

Table 1-1. Existing Monitoring Stations in Babcock Webb and Yucca Pens

Existing Station Name	Updated Station Name	Year Installed	Date When Data Logger Installed
STA-6	No change	2017	2017
STA-7	No change	2019	2019
STA-8	No change	2019	2019
SR-6	No change	2011	2019
SP-13	SP-13	2019	2019
1	SP-15	2011	2019
2	SP-16	2011	2019
3	YP-1	2011	2019
5	SR-7	2011	2019
8	SR-8	2011	2017
9	SR-9	2011	2017
14	YP-2	2019	2019
30S, 30D	YP-7S, YP-7D	2019	2019
YP-3	YP-8	2018	2018
YP-1	YP-9	2018	2018
YP-2	YP-12D	2018	2018
23S, 23D	YP-10S, YP-10D	2019	2019
24S, 24D	YP-11S. YP-11D	2019	2019
29S	YP-12S	2019	2019
YP-5	YP-13	2019	2019

Table 1-2. Monitoring Stations near Babcock Webb and Yucca Pens

Station Name	Agency Maintaining Station	Year Installed
25100	SWFWMD	1989
25092	SWFWMD	1999
CH-323	USGS	2001
L-721	USGS	1970
Gator Slough, US-41	USGS/Lee County	2009
SW Aggregates wells	Cape Coral	2017
SW-1, -2, -3	Cape Coral	2017
CCI	Cape Coral	2020
Gator Slough Weir 11	USGS/Cape Coral	1992-2013
Gator Slough Weirs 19, 58, 11	Cape Coral	2014
Gator Slough Weir 4	Cape Coral	2018
1-GW1	Lee County	1991
5-GW1, 3, 5, 6, 8	Lee County	1991
17-GW3, 4, 18-GW2	Lee County	1991/1992
20-GW3, 22-GW1	Lee County	1992
27O-GW1, 28-GW2	Lee County	1997, 1993
Bayshore, Popash	Lee County	2011

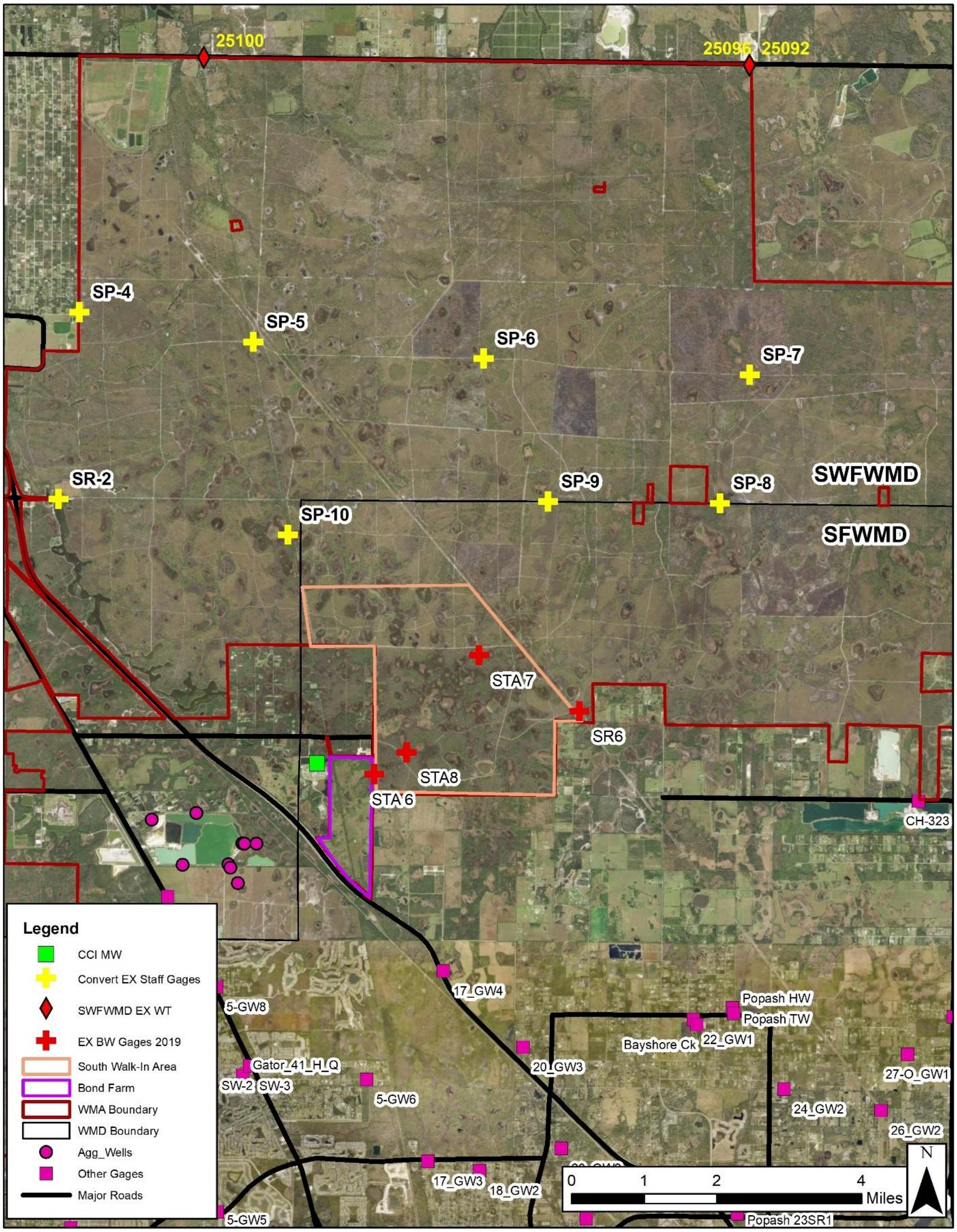


Figure 1-1. Existing Monitoring Stations in Vicinity of Babcock Webb

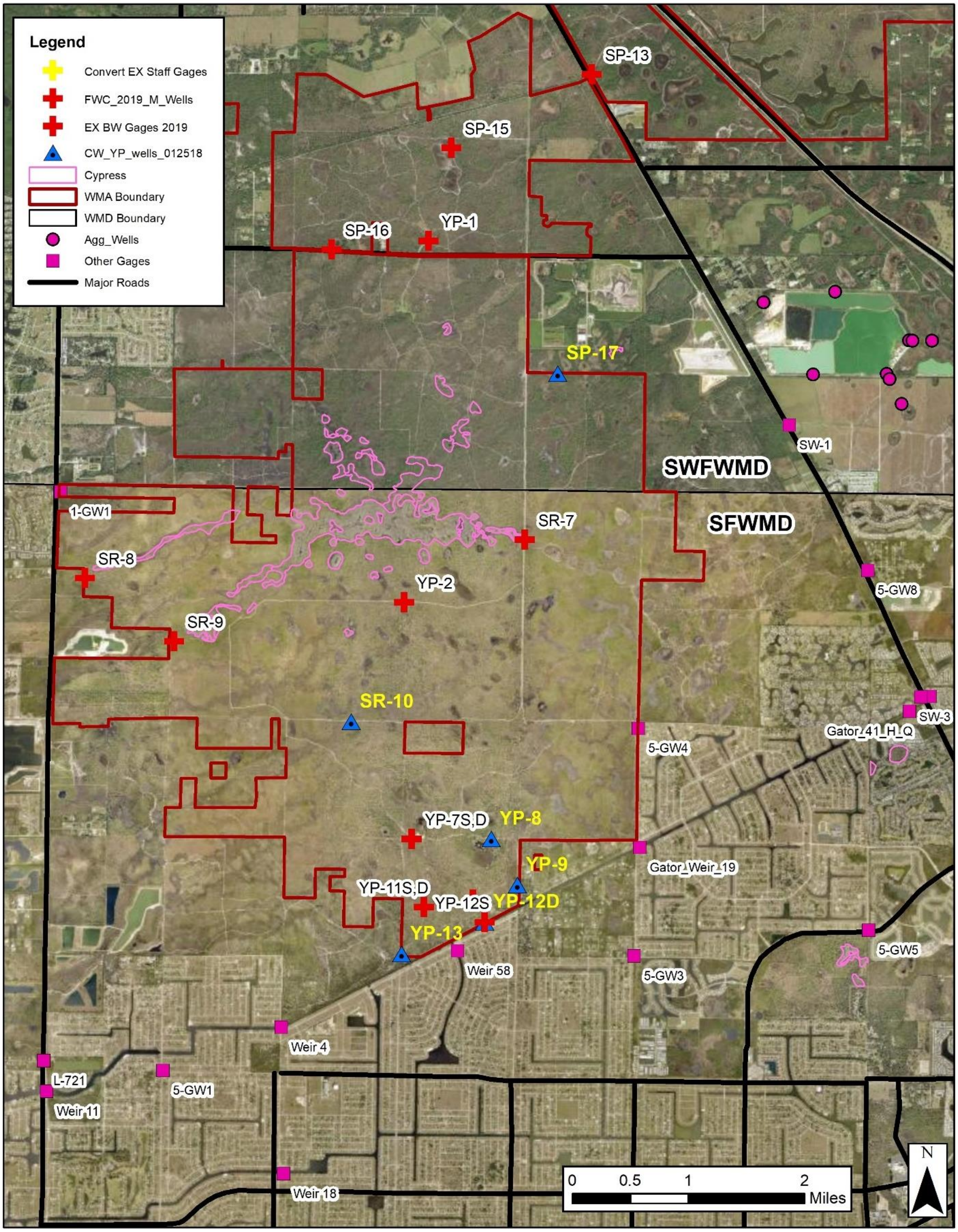


Figure 1-2. Existing Monitoring Stations in Vicinity of Yucca Pens

2. MONITORING, PLANNING, AND DEVICE INSTALLATION

2.1 GROUNDWATER MONITORING PLAN

A groundwater monitoring plan was developed to obtain an improved understanding of the range of groundwater elevations during the dry season and to better understand wet season water levels in the wetlands of the Wildlife Management Areas (WMAs). The groundwater monitoring plan included installation of groundwater monitoring wells at eight existing staff water level gages in Babcock Webb, and at 24 new monitoring stations in both Babcock Webb and Yucca Pens. The locations of the stations are shown in **Figure 2-1.**

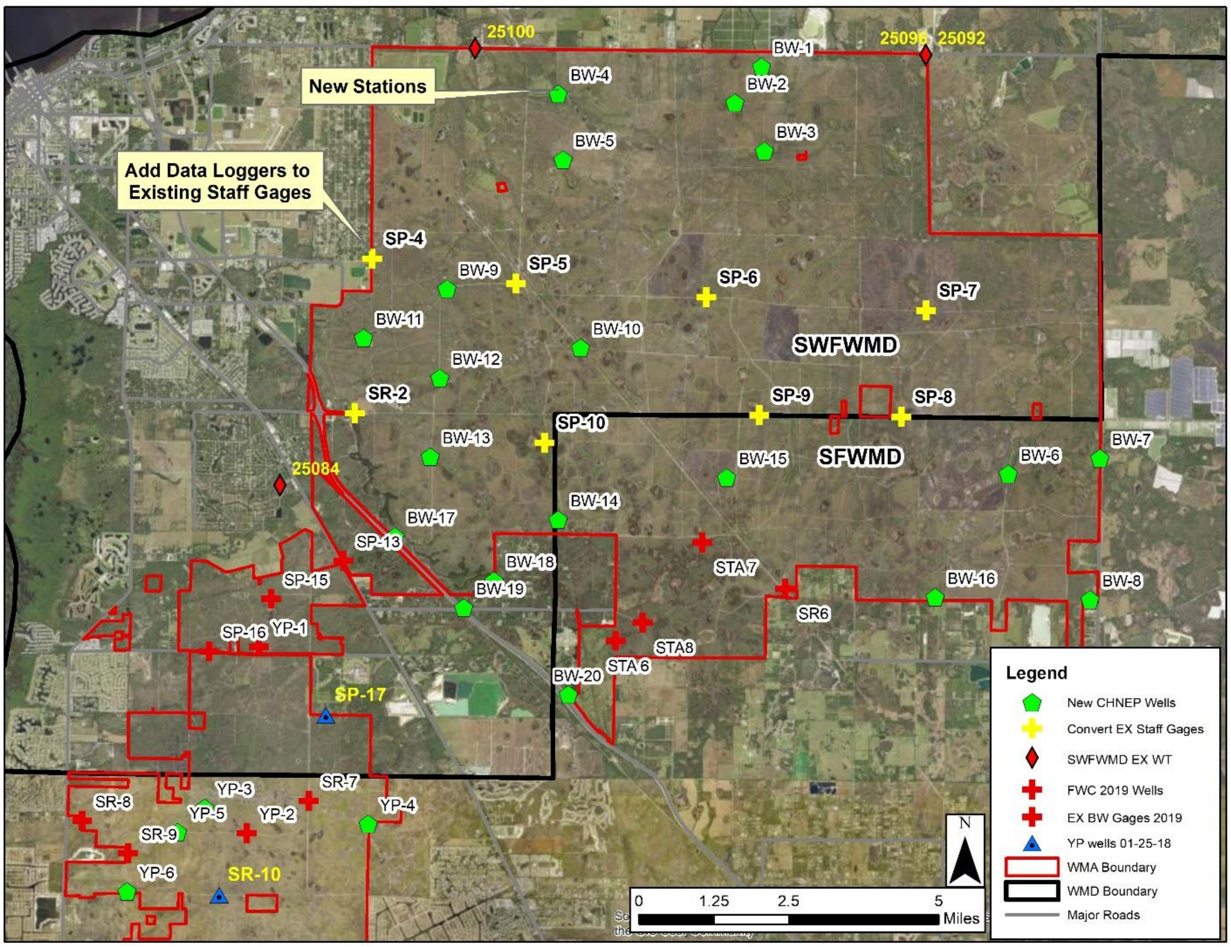


Figure 2-1. Groundwater Monitoring Stations in Babcock Webb and Yucca Pens

The plan called for installation of hand-augered monitoring wells up to 8 feet deep consisting of 2-inch diameter PVC casing at the top of the well and 5 feet of PVC screen with a screen size of 0.02 inches at the bottom of the well. Each monitoring well includes a 5-foot long, 4-inch square aluminum protective cover (Atlantic Supply A0727-004A), and an In-Situ Rugged Troll water level data logger. The screened portion of the well has 20/30 washed silica sand filter pack that extends above the top of the screen and a bentonite seal installed on top of the silica sand. On-site sandy cuttings were used to fill the remaining annulus up to ground surface. A 2x2 foot square concrete pad was installed to anchor the protective cover. Each well was surveyed to obtain a top of casing, top of protective cover, and ground elevation adjacent to the well.

In addition to the new groundwater monitoring stations, three rain gages were installed adjacent to groundwater monitoring stations SP-5, BW-18, and SR-7. Six quarterly data downloads were described in the plan. Full details of the groundwater monitoring plan and installation specifications are provided in **Appendix 2A**.

2.2 FLOW MONITORING PLAN

A flow monitoring plan was developed to obtain an improved understanding of hydrologic conditions in Babcock Webb, Yucca Pens, and discharges to tidal creeks west of the WMAs. Seven flow monitoring stations and one tidal flow monitoring station were identified in the plan. Locations are presented in **Figure 2-2**.

The flow monitoring plan included installation of a staff stream water level gage with elevations referenced to the North American Vertical Datum (NAVD) and a Rugged Troll data logger to provide continuous measurement of water levels. Flow measurements were stipulated for ten wet season events using USGS-approved methods. The plan called for development of flow rating curves so that a flow time series could be developed from the measured water level data. Details of the flow measurement techniques and the development of the flow rating curves are provided in **Appendix 2B**. The flow monitoring plan stipulated that the tidal flow monitoring station on Yucca Pens Creek west of Burnt Store Road have a continuously recording side-looking velocity meter that would have the ability to measure tidal velocities for both in-coming and out-going tides.

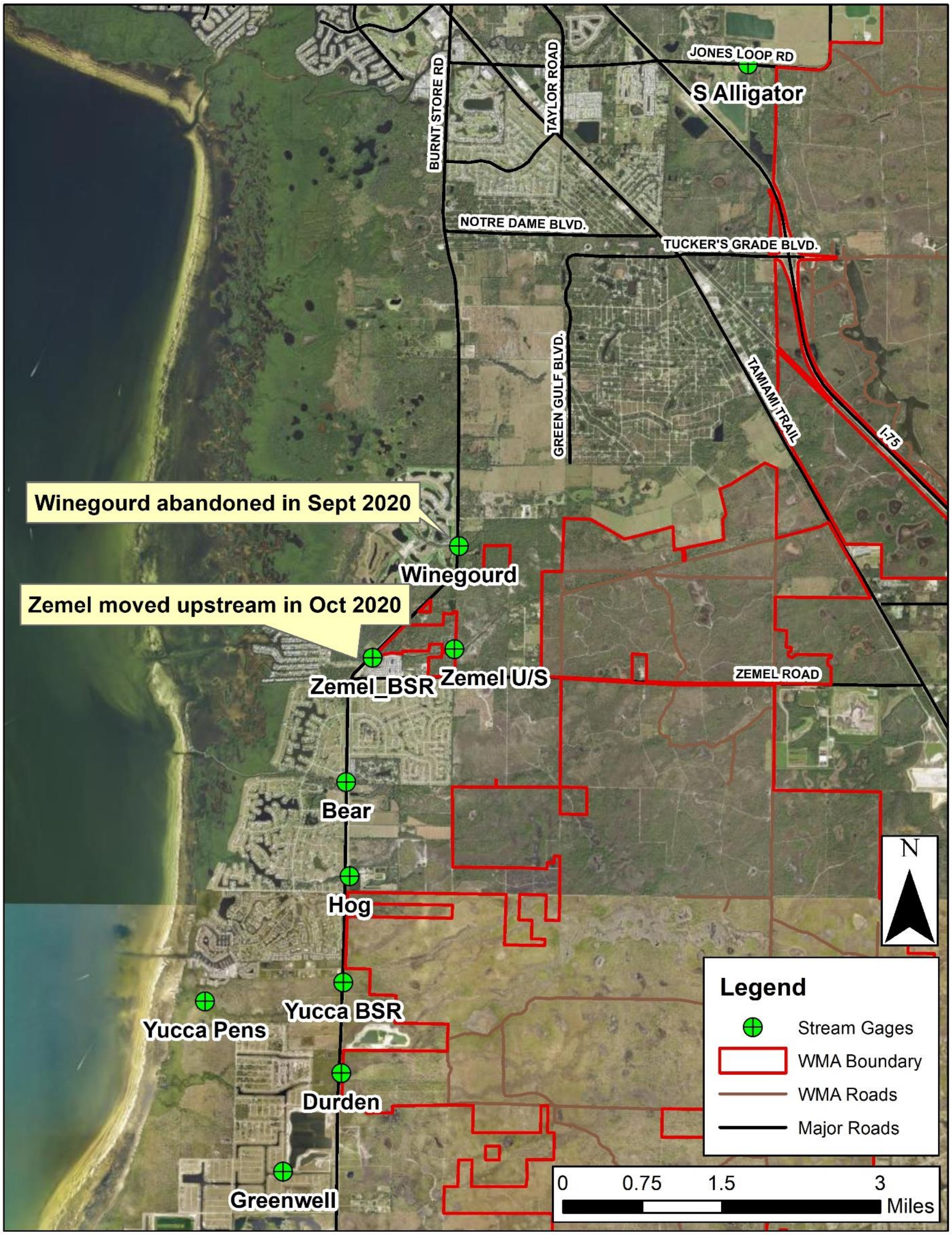


Figure 2-2. Flow Monitoring Stations

2.3 MONITORING DEVICE INSTALLATION

2.3.1 Groundwater Monitoring Stations

The groundwater monitoring stations were installed in March and April 2020, and data loggers were installed in late April and early May 2020. The monitoring stations were installed at the locations identified in the groundwater monitoring plan with some minor adjustments in station locations due to pockets of limestone close to the surface which makes installation cost-prohibitive.

Table 2-1. Surveyed Results for Groundwater Monitoring Stations

Station	Y SPFLW_ft	X SPFLW_ft	Top of PVC ft-NAVD	Ground ft-NAVD	Well Depth from TOC, ft
BW-1	948379.12	704343.75	36.09	32.90	12.9
BW-2	945192.31	702023.08	36.24	32.84	13.0
BW-3	940953.57	704668.66	39.65	35.64	13.1
BW-4	945823.75	686455.97	28.85	25.07	9.7
BW-5	940050.69	686909.80	30.42	27.03	12.2
BW-6	912684.30	726381.91	34.34	30.63	12.4
BW-7	914128.41	734437.26	34.19	30.81	13.0
BW-8	901669.36	733662.51	31.50	27.96	13.0
BW-9	928576.49	676788.58	28.37	25.71	13.0
BW-10	923437.07	688558.69	31.80	28.63	damaged
BW-11	924202.65	669459.03	27.67	24.13	10.5
BW-12	920721.96	676220.07	29.25	25.80	13.0
BW-13	913774.91	675415.34	28.43	25.87	13.0
BW-14	908327.70	686748.91	29.53	25.90	13.0
BW-15	912146.89	701562.51	31.56	27.97	13.0
BW-16	901762.04	720001.19	31.78	28.19	12.7
BW-17	906721.59	672385.33	27.69	23.94	12.7
BW-18	902910.66	681128.22	28.84	25.18	13.2
BW-19	892905.42	687730.05	26.68	23.35	12.7
BW-20	900496.45	678486.91	27.74	24.10	12.8
YP-3	882666.23	655808.26	19.81	16.12	12.1
YP-4	881413.02	669859.20	20.29	17.30	10.0
YP-5	880534.76	653412.02	18.07	15.18	10.7
YP-6	875246.64	648951.91	15.16	11.72	12.3

Note: SPFLW_ft: Coordinates are in State Plane Florida West, ft
Top of PVC: Top of PVC casing; Ground: Ground Elevation Adjacent to Well; TOC: Top of Protective Cover

One monitoring station, YP-4, was not able to be installed due to the presence of hard limestone five feet below ground surface. Since groundwater was encountered less than 4 feet below ground surface (bgs), a temporary shallow well was installed until a drill rig could be used to complete installation. The well was drilled in late April 2021, and the top of casing elevation of the temporary and new wells were surveyed so that data from the temporary well could be converted from depth below top of PVC to elevations in ft-NAVD. Station BW-10 was damaged in early November 2021 after which data was no longer collected at this location.

2.3.2 Flow Monitoring Stations

The flow monitoring stations were installed in April 2020 and were fully operational by early May 2020. The flow monitoring station in Winegourd Creek at Burnt Store Road was removed in September 2020 due to construction to widen Burnt Store Road. The equipment was later moved to Yucca Pens Creek at Burnt Store Road to provide more accurate flow measurements at the Yucca Pens Creek tidal flow monitoring station. The Zemel Canal freshwater flow monitoring station was also moved because initial water level measurements indicated that Zemel Canal is tidally influenced at Burnt Store Road. The station was moved approximately 4,100 feet upstream on October 10, 2020, to a location that is not subjected to tidal influences. The upstream Zemel Canal monitoring station was damaged during the high flow event of July 19, 2021. The station was re-installed, and the data logger was re-programmed based on a comparison of data logger and manual measurements at the time of the repair. The stream level staff gage at this station was re-installed and the station was re-surveyed in March 2022 as part of on-going monitoring being conducted for FWC (ESA and WSA, 2022).

Flow measurements were performed at each of the stations during the summer of 2020 and 2021. The flow measurements were made using standard USGS stream gaging techniques by personnel taking multiple velocity and depth measurements across the width of the streams/creeks. The flow monitoring equipment used at each station depended on the width and depth of the stream section. For narrow streams, a pygmy or Sontek FlowTracker meter with a top setting wading rod was used. For larger streams (Zemel Canal and the South Branch of Alligator Creek), a Teledyne RDI Stream Pro Acoustic Doppler Current Profiler was used.

The addition of the Yucca Pens Creek flow monitoring station at Burnt Store Road provides additional information that increases reliability of the flow monitoring program in Yucca Pens Creek. Moving this station solved challenges encountered during siting of the Yucca Pens Creek tidal flow monitoring station. However, establishing a reliable stage/discharge relationship has proven to be difficult at the tidal monitoring station for several reasons, including:

- The station location was chosen based on the closest publicly available location along the stream. An upstream location still within tidal influence was preferable due to the cross-section dimensions, however permission for the first alternative could not be obtained to utilize that location. An additional upstream location (**YP Constriction** shown below) was established that still provided necessary information to assist the analysis.

- The tidal flow monitoring station is difficult to access during the wet season due to the presence of water levels above the ground surface at the tidal flow monitoring station.
- The cross-section is very wide at this location with much of the flow occurring outside of the main channel. Velocities are very low in the over-bank due to vegetation resistance.

2.3.3 Rainfall Monitoring Stations

Three rainfall monitoring stations were installed for this project to augment existing rainfall data available from Lee County and Cape Coral rain gages. **Error! Reference source not found.** shows new rain gages that were installed adjacent to groundwater monitoring stations SP-5, BW-18, and SR-7.

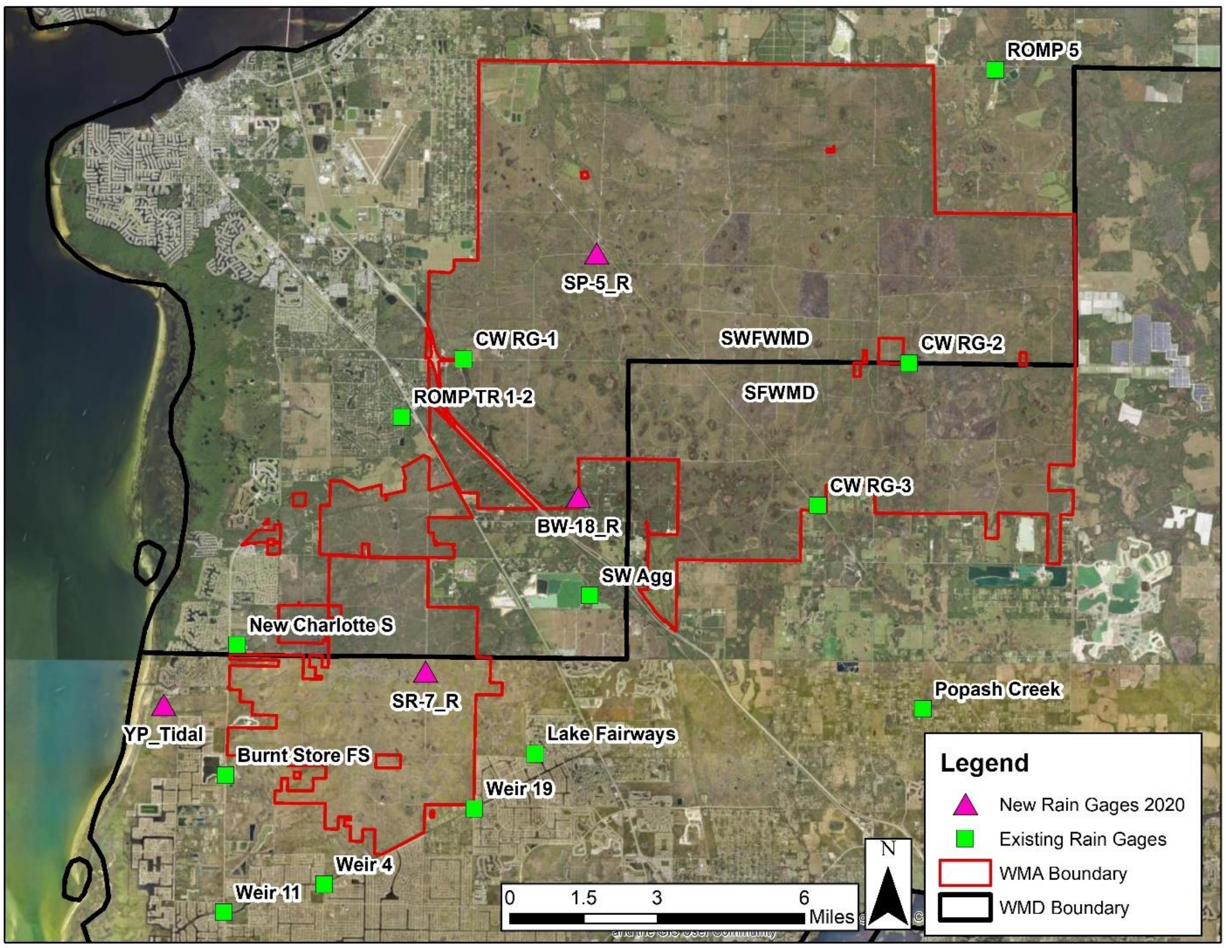


Figure 2-3. Rain Gages in Vicinity of Babcock Webb and Yucca Pens

3. WATER LEVEL FIELD VERIFICATION FOR SEASONAL HIGHS AND HISTORICAL HYDROPERIOD MAPPING

Dry and wet season field investigations were conducted to identify vegetation indicators of average wet season water levels and map historical (pre-development) hydroperiods. Results of these field investigations and estimated historic hydroperiods are provided below (see **Appendices 3A-C** for full detail of analyses and results).

3.1 DRY SEASON FIELD IDENTIFICATION OF SEASONAL HIGH-WATER LEVELS

Dry season field work was conducted in March and April 2020 to identify field indicators of hydrologic conditions. Special attention was made to evaluate the difference between vegetation indicators resulting from the high-water levels experienced during Hurricane Irma (September 2017) and vegetation indicators representing more typical wet season conditions. Recent wet season high water elevations caused by Irma were established by a nail driven into a tree or bush at the high waterline mark at two to three locations across the extent of the wetland. Stakes were also often set to mark the edge of the wetland. Field studies were conducted at 58 locations with multiple stakes or nails set at each location. Approximately 240 elevations were established and surveyed. Results of the dry season field investigations are provided in **Appendix 3A**.

Biological indicators were also utilized to estimate typical water level elevations for surveyed areas. These primarily included the inflection point of buttresses on pond-cypress (*Taxodium ascendens*), the lower limit of epiphytic moss collars on pond-cypress, the elevation of root crown bases of wax myrtle (*Myrica cerifera*), the uppermost adventitious root of sandweed (*Hypericum fasciculatum*), and the ground elevation of the upland/wetland limit. In all locations, a wide variety of vegetation indicators were evaluated including:

- Presence of moss and lichen on tree trunks
- Water marks and dirt deposits on bark
- Elevation of cypress buttress inflection
- Elevation of the root crown base of Fetter bush (*Lyonia lucida)*
- Thinning of the diameter of tree trunks
- Presence or absence of obligate and/or facultative wetland vegetation and presence of pond apple snail shells
- Abnormal branching
- Yellowing of leaves
- Presence or absence of hydric soils on the ground surface

The observed water depths appeared to be appropriate for northern Babcock Webb wetlands in the vicinity of Tuckers Grade. Water depths gradually increase south of Tuckers Grade Road, significantly exceeding optimum levels and causing a longer wetland hydroperiod and lower recession rate than natural in the South Walk-In Area of Babcock Webb (see **Figure 1.2** for location). Wetlands in the northern portion of Babcock Webb, which occur at higher elevations, appear less affected than wetlands in the southern portion of Babcock Webb. Indications of a prolonged hydroperiod included observations of apple snails (*Pomacea* spp.), vegetative stress, and lack of transitional plants near the wetland edge. Apple snails are considered a long hydroperiod taxon with limited capacity to survive prolonged periods of drought and were observed throughout Babcock Webb. Observations of apple snails in wetlands in the Yucca Pen study area, which appear to have a reduced hydroperiod, were less frequent. Stressed cabbage palm (*Sabal palmetto*) and slash pine (*Pinus elliottii var densa*) were noted in the central and southern portions of the Babcock Webb study area, presumably a result of prolonged inundation and saturation.

Yucca Pens wetlands also indicate varying levels of vegetative stress due to hydrologic alternations. However, vegetation indicators in the southern portion of Yucca Pens exhibit decreased wet season water depths and decreased wetland hydroperiods. One explanation for altered hydroperiods is that numerous ATV trails on the property act as rapid-flow water conveyances during the wet season causing water to leave Yucca Pens too quickly.

3.2 WET SEASON CONFIRMATION OF SEASONAL HIGH-WATER LEVELS

Field work was conducted during the late summer and fall of 2020 to compare actual measured wet season water levels to wet season water levels estimated during the dry season field effort. Results and analysis of the wet season field investigations are provided in **Appendix 3B**. Relatively normal rainfall was observed in late May and early June of 2020, which was then followed by less than normal rainfall during the remainder of June and early July. Higher than normal rainfall conditions occurred in fall of 2020, as shown below in **Table 3-1**. As such, the wet season was defined as August – November 2020 for the purposes of this study.

Table 3-1. Babcock Webb Observed and Average Rainfall for Fall 2020, Lee County Rain Gage Stations

Month	2020 Monthly Totals, Avg of RG-1, -2, -3	Lee County Historical Avg
October	9.30	2.68
November	5.14	1.81
December	4.27	1.72
Oct-Dec Total	18.71	6.21

Water depths in the South Walk-In Area ranged from 8 to 12 inches above vegetation indicators established during the dry season. Evidence of vegetative stress was common, including dead and stunted pine trees, reduced cabbage palm trunk and crown sizes, and hardwood leaf-cover reduction.

Across Yucca Pens, wetlands also indicated varying levels of vegetative stress due to hydrologic alternations (see **Figures 3-1 – 3-3**). Vegetation indicators in portions of Yucca Pens exhibit decreased wet season water depths and decreased wetland hydroperiods as indicated in the following locations below:

- Zemel Canal (with high-flow, short-duration stages, which limit hydrophytic vegetation establishment)
- Durden Creek (see points Y17A, Y19, Y-12, and Y-56 in **Figure 3-1**)
- Headwaters of Yucca Pens Creek (see point Y13 in **Figure 3-1**)

- Southern Yucca Pens (see red-circled area in **Figure 3-2**) was very dry with very little ponding of water above the land surface during the wet season.

In addition, numerous ATV and access trails act as shallow-water, rapid-flow conveyances during the wet season, contributing to the altered hydrologic conditions on the southern and western portions of Yucca Pens. Locations of these eroded ATV trails are identified in **Figure 3-3.** These locations were a focal issue during the initial scenario analysis, and proposed solutions are presented in **Section 6**.

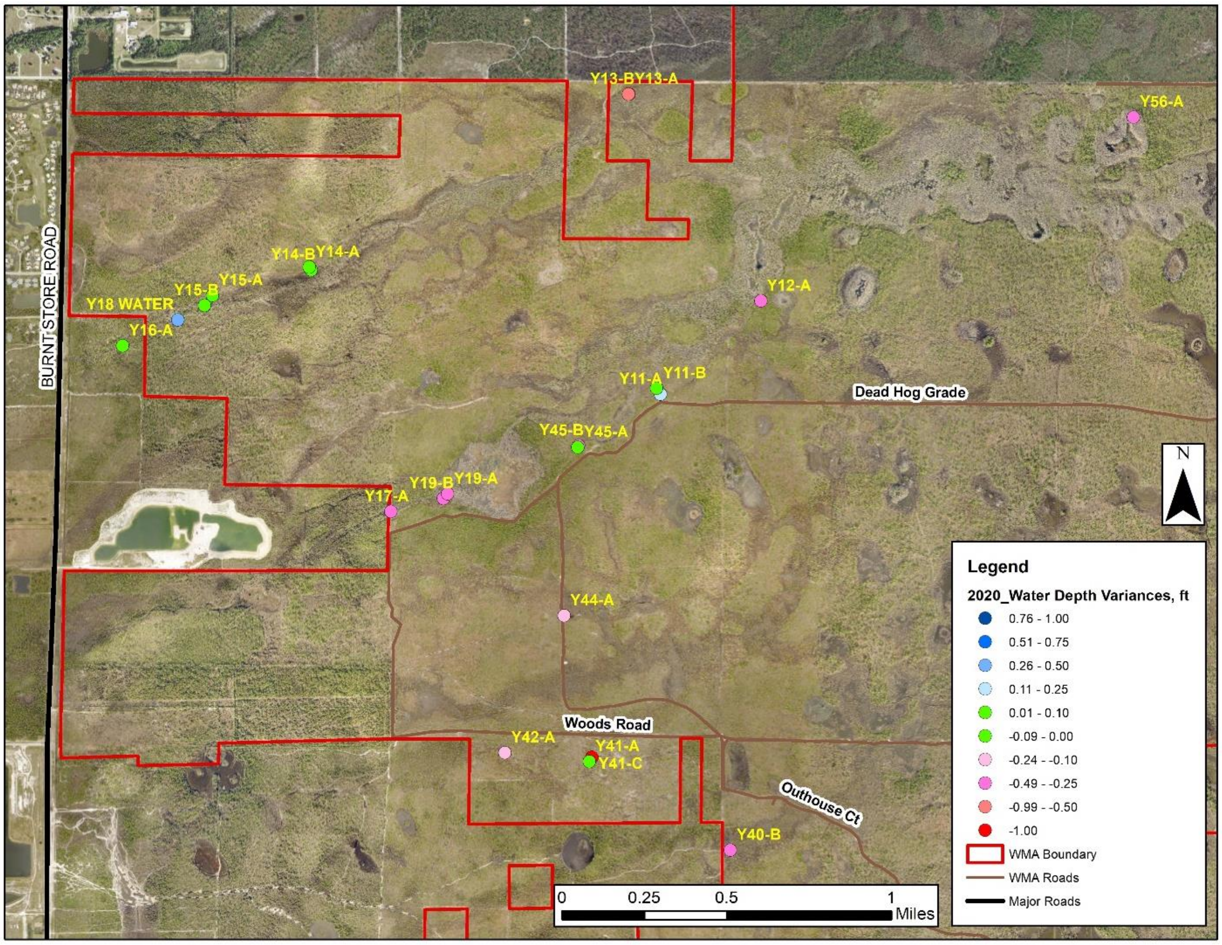


Figure 3-1. Map of Surveyed Wet Season Water Elevation Differences between Dry and Wet Season Vegetation Indicators on Western Yucca Pens WMA

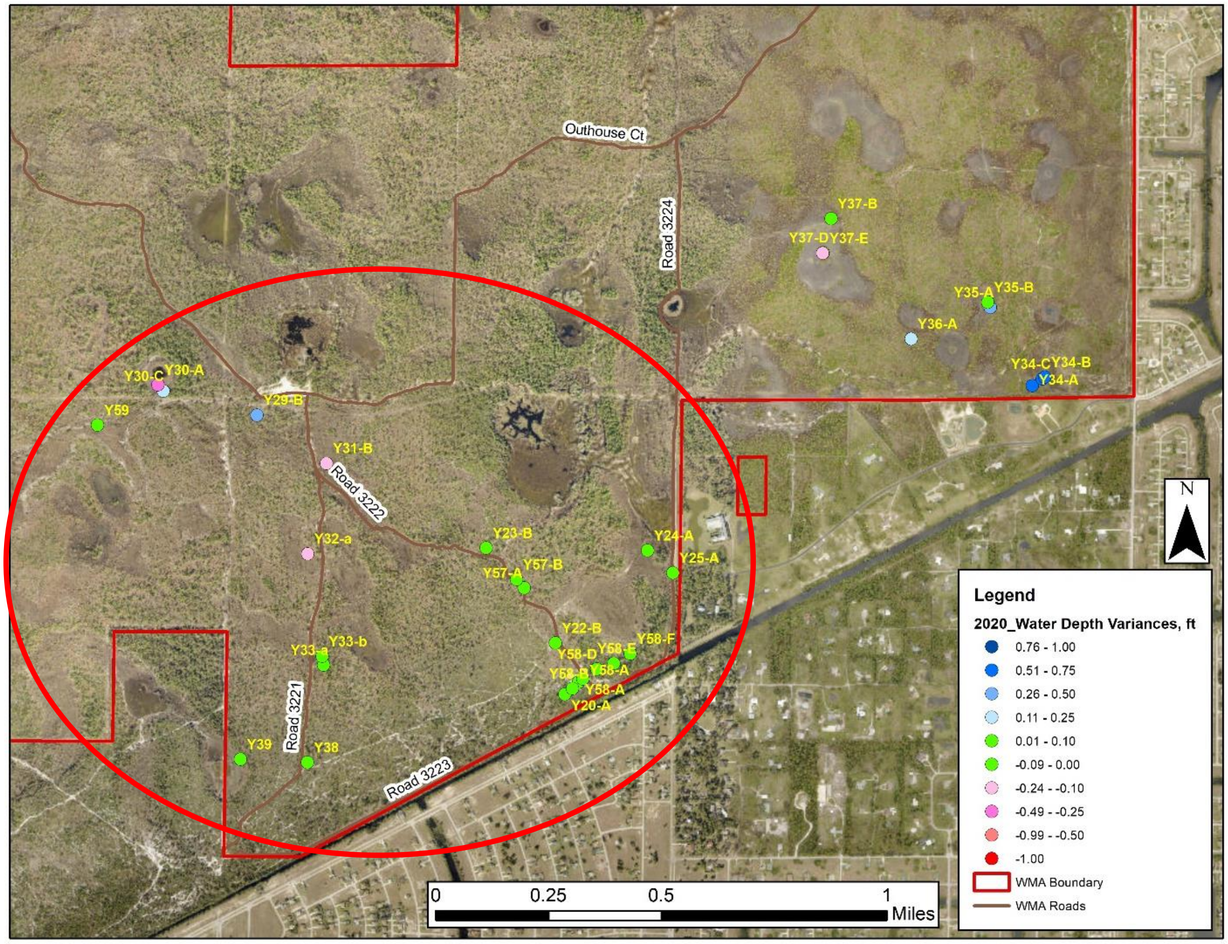


Figure 3-2. Map of Surveyed Wet Season Water Elevation Differences between Dry and Wet Season Vegetation Indicators on Southern Yucca Pens WMA

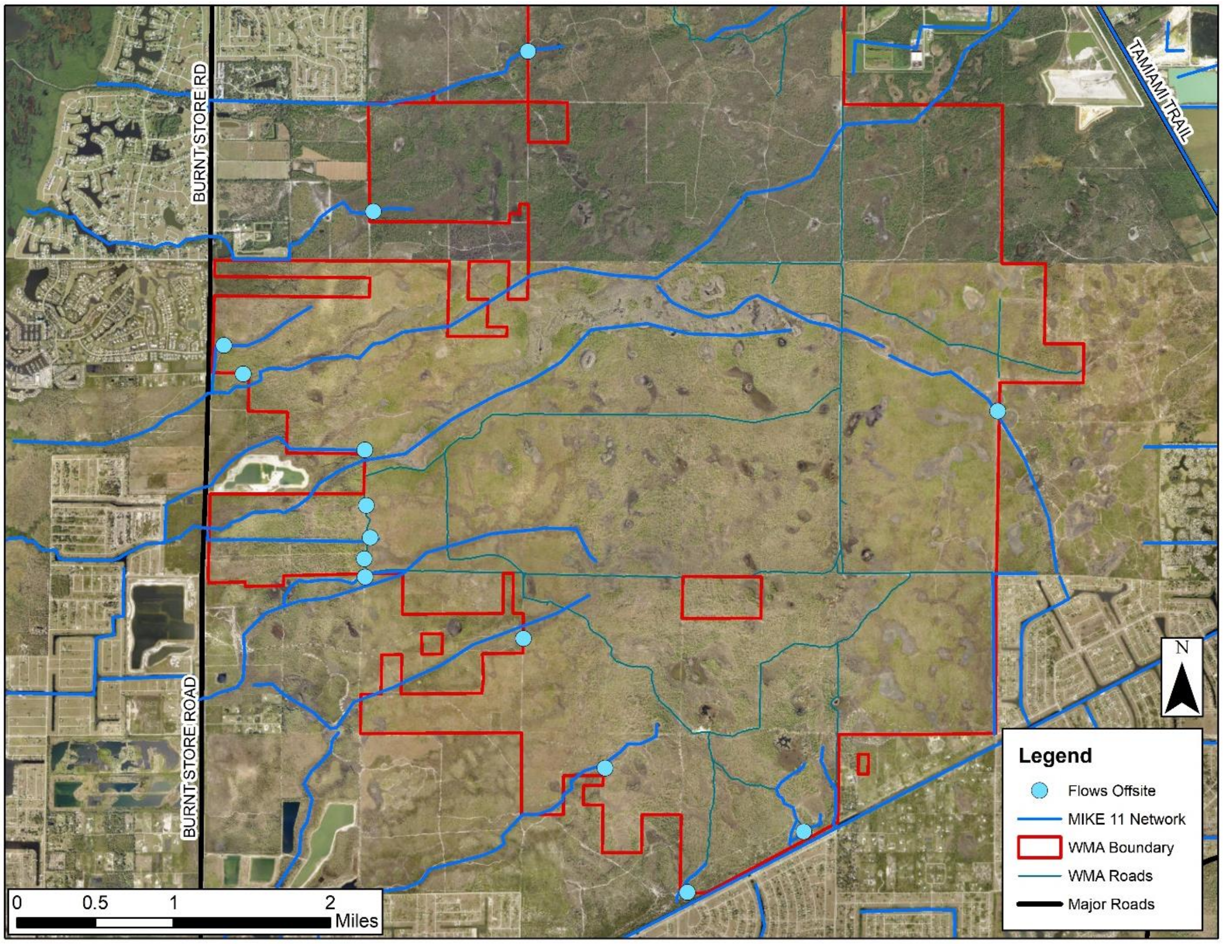


Figure 3-3. Map of Concentrated Outflow Locations from Yucca Pens via Eroded ATV Trails

3.3 MAP OF HISTORICAL HYDROPATTERNS

Results from the ecologic field investigations and the hydrologic monitoring program were utilized to map historic hydropatterns and identify areas where current water levels are higher or lower than optimum historic hydroperiods. Details of the analysis and the development of historic hydropattern maps are provided in Appendix 3C.

3.3.1 Historical Hydropatterns

Historic 1953 aerial photographs for Babcock Webb Wildlife Management Area (WMA) and the Yucca Pens Unit were geo-referenced by Tim Lieberman (formerly of SFWMD, retired) and Mike Kemmerer of the Florida Fish and Wildlife Conservation Commission (FWC), (personal communication, Kemmerer, 2019. Lieberman and Kemmerer developed four ranks of hydrologic condition based on observable vegetation, drainage and inundation, and USDA-NRCS soil survey maps. Rank 1 represents uplands and Rank 4 represents wetlands. Rank 2 was used for lands that experienced minor flooding, and Rank 3 was used for lands that were more often wet than dry.

The information in the SSURGO database used to assign a rank is explained below:

Rank 1. Uplands: 0% ponding frequency, no drainage limitations

Rank 2. Conifers: minor flooding, no drainage limitations

Rank 3. Marshland: frequent flooding, poorly drained

Rank 4. Wetlands: 98% ponding frequency, very poorly drained

Hydrologic rank based on visual signatures is evident in the historic aerial photographs, such as dark areas indicating inundation and light areas indicating dry conditions. **Figure 3-4** illustrates geo-referenced aerial photographs and hydrologic rank for a portion of southern Yucca Pens.

Hydrologic Rank was used as an indication of average wet season water depth. Average wet season water depth values were assigned to each Hydrologic Rank based on ecologic work conducted across Southwest Florida by Mike Duever (see **Figure 3-5** and **Table 3-2**).

This historical hydrological ranking system served as the datum for calculating differences between optimal historic water levels and observed water levels. Wet season depths average between 0 and 1.5 feet under optimal conditions, as outlined in **Table 3-2**.

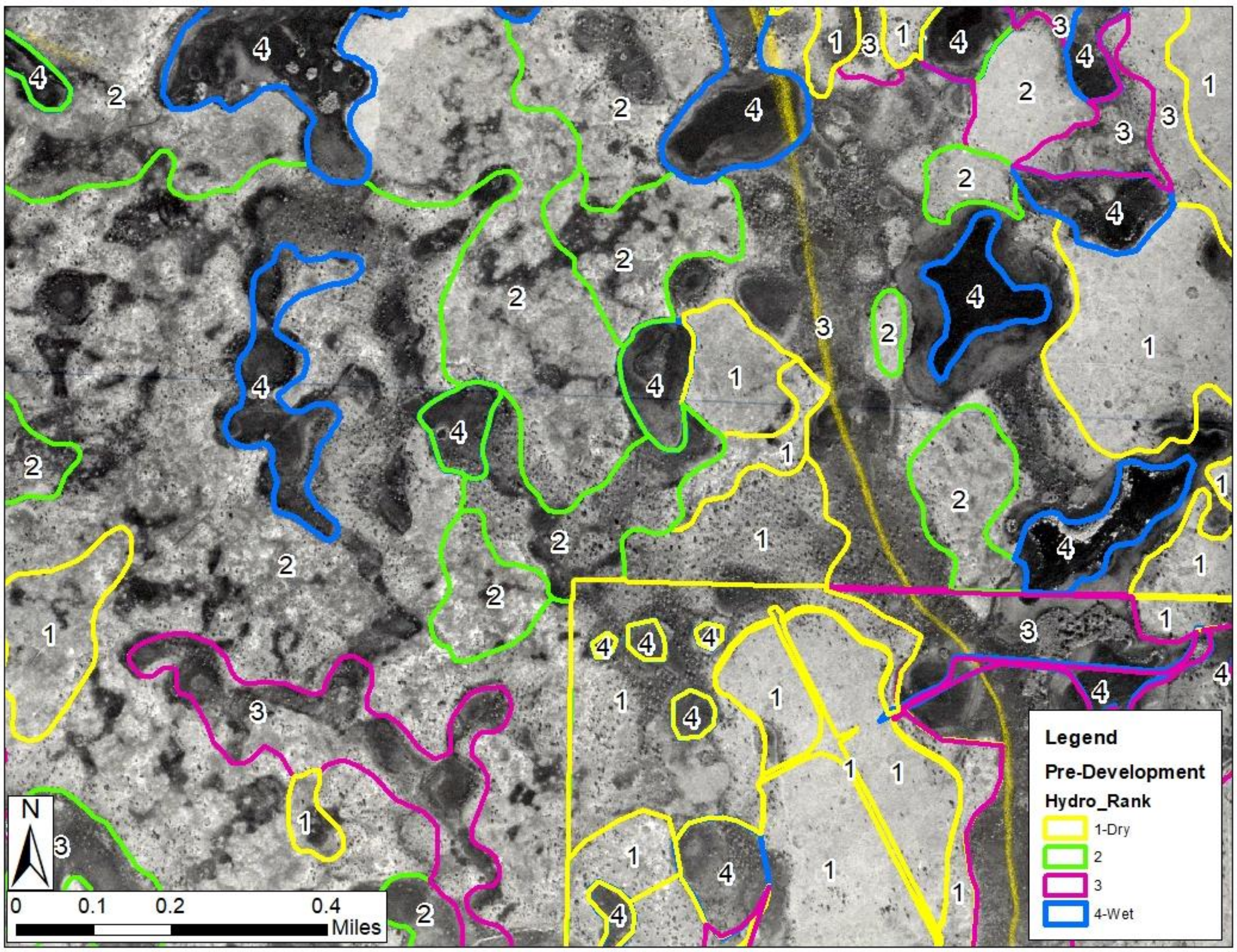


Figure 3-4. 1953 Geo-referenced Aerial Photos of Southern Yucca Pens and Pre-Development Hydro Rank Areas

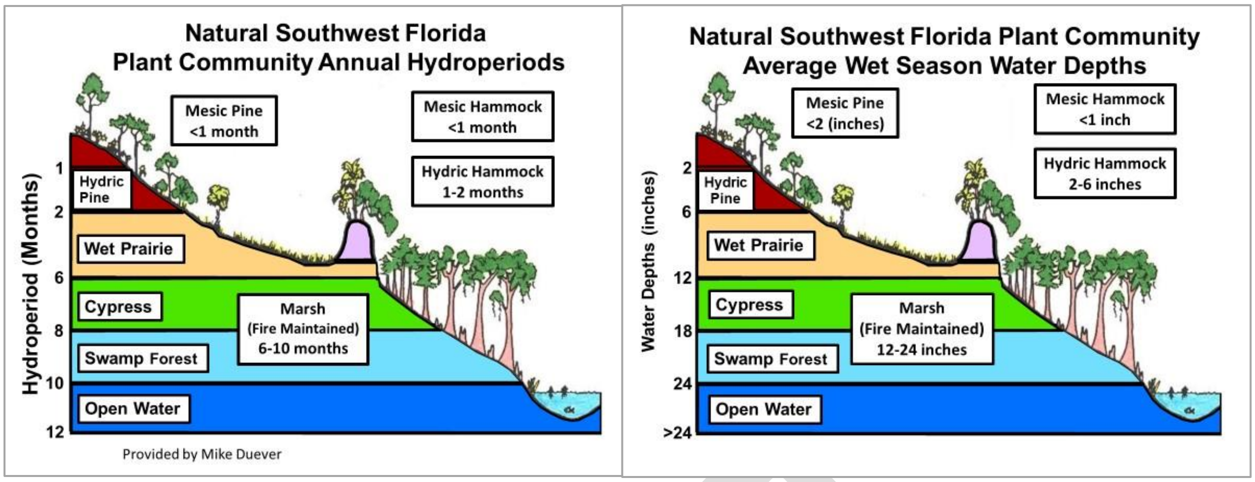


Figure 3-5. Optimum Wetland Hydroperiods and Average Wet Season Water Depths for South Florida Wetland Communities, Duever & Roberts (2013)

Table 3-2. Hydrologic Rank and Optimum Wet Season Average Depth, ft

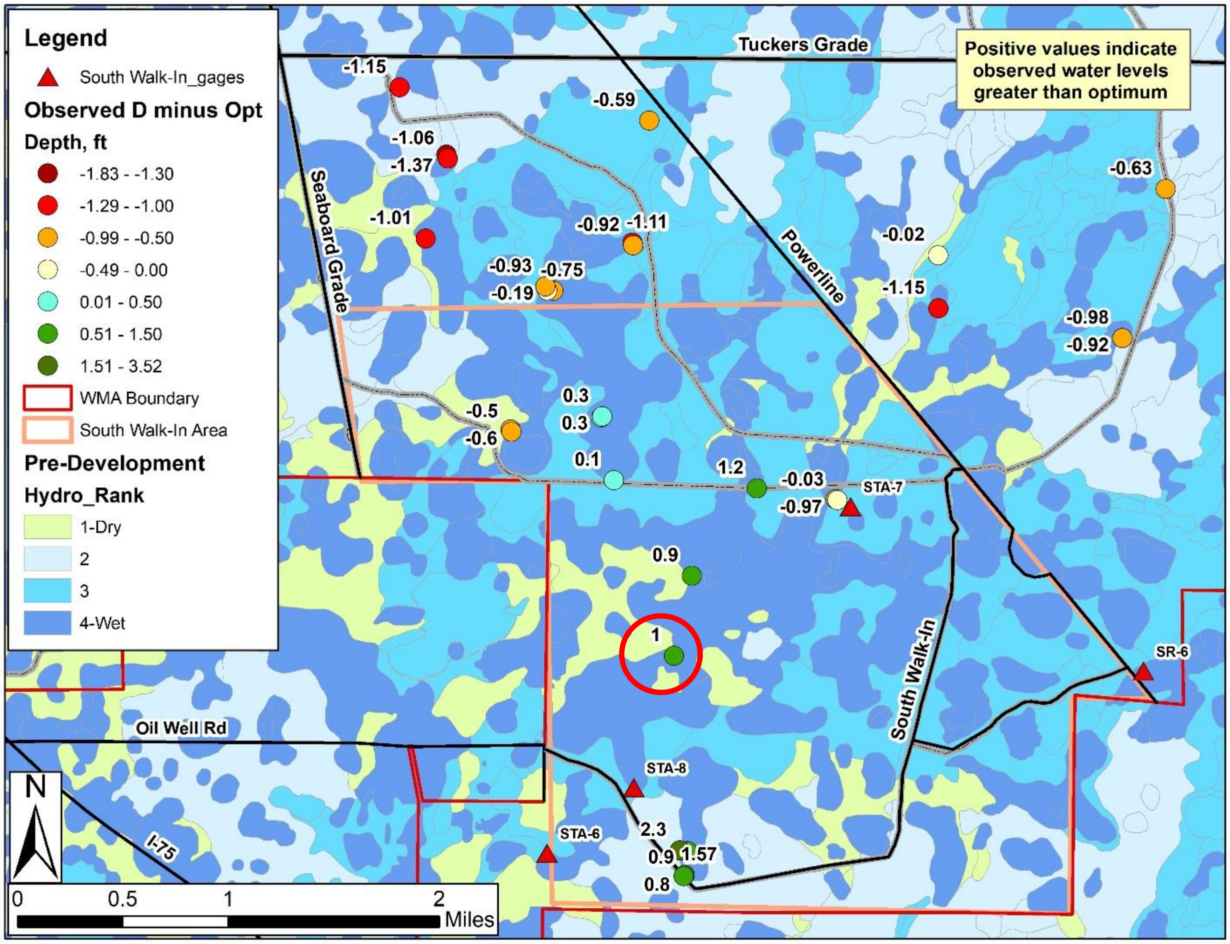
Hydrologic Rank and Typical Land Cover	Optimum Wet Season Average Water Depth, ft
1 – Mesic Flatwoods	0.0
2 – Hydric Flatwoods	0.33
3 – Marsh	0.75
4 – Cypress/Slough	1.5

Note: Optimum Wet season Average Water Depths were taken from Duever & Roberts (2013)

3.3.2 Areas with Hydropatterns Higher or Lower than Optimum

Vegetation indicator points located within the South Walk-In Area in Babcock Webb, presented in **Figure 3-6,** generally had higher water depths than optimum. Of the 14 points within the South Walk-In Area, 10 locations had observed water depths higher than optimum with exceedances ranging from 0.3 to 1.6 feet (mean = 0.6 feet). The four locations with 2020 observed water depths less than optimum were in the northern portion of the South Walk-In Area, and those points were evaluated in September 2020, when it was drier than typical wet season conditions.

Average wet season water depths in Yucca Pens in 2020 were more representative of a typical wet season due to different rainfall patterns (see explanation in section 3.2 above). Observed wet season average water depths in Yucca Pens in 2020 were drier than optimum conditions at 60% of the vegetation stations. Observed depth was, on average, 0.62 feet lower than optimum average wet season water depths (see **Figure 3-7**). The greatest negative deviations from optimum wet season water depth (areas that were drier than optimum) were located on the southern and western areas of Yucca Pens. This pronounced difference in such proximity to the area's boundaries suggests that drainage at ATV trail locations has a significant impact on wetland hydrology in Yucca Pens.



Note: In the **Figure 3-6** Legend, "Observed D minus Opt Depth" is Observed Depth minus Optimum Depth, which is equal to Average 2020 Wet Season Water Depth minus Optimum Depth. For example, see point in red circle above in **Figure 3-6.** Avg 2020 Wet Season Depth = 2.5 ft. Hydro Rank is 4, so optimum depth is 1.5 feet. Therefore, Observed Depth minus Optimum Depth = 1 ft

Figure 3-6. Comparison of Predevelopment Hydrologic Rank and Observed 2020 Wet Season Depths for the South Walk-In Area of Babcock Webb (in the legend, dots ranging from green to light blue have water depths higher than optimum)

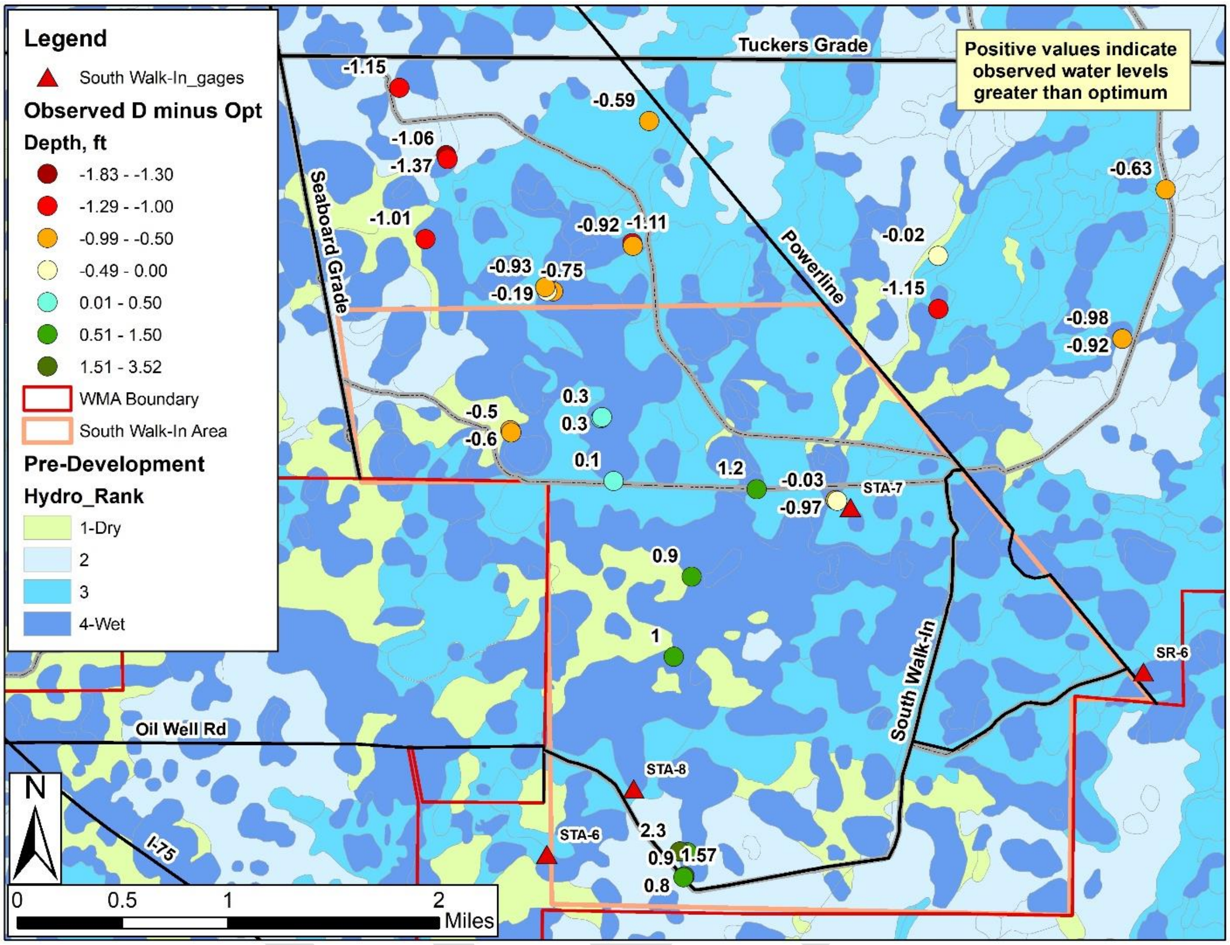


Figure 3-7. Comparison of Predevelopment Hydrologic Rank and Observed 2020 Wet Season Depths for Yucca Pens south of Zemel Road (in the legend, dots ranging from yellow to red have water depths less than optimum)

This analysis generally indicates that water depths are higher than optimum in the South Walk-In Area and less than optimum in portions of Yucca Pens. In addition to observed data used to generate hydro ranks, measured data from selected monitoring stations supports these findings. **Table 3-3** presents average wet season water levels minus and the average wetland elevation for STA-7 and STA-8 in the South Walk-In Area and SR-9, YP-6, and MW-29 in Yucca Pens (station locations are shown in **Figures 3-6** and **3-7**). Average wet season water depths were higher than the average wetland elevations in the South Walk-In Area meaning water was well above ground levels during the wet season and were less than average wetland elevations in Yucca Pens. This information is also presented in **Figures 3-8** through **3-12**.

Table 3-3. Average Wet Season Water Levels minus Average Wetland Elevation in 2020 and 2021

Station	Avg 7/1 to 11/15, 2020	Avg 7/1 to 11/15, 2021
STA-7	+1.7	2.0
STA-8	1.4	1.8
SR-9 (Durden Creek)	-0.5	-0.6
YP-6 (eroded ATV trail)	-0.7	-0.7
MW-29 (concrete weir)	-3.5	-3.0

Note that the elevation difference for MW-29 used the weir elevation for comparisons since there are no wetlands near this monitoring station

Measured water levels in South Walk-In Area monitoring stations STA-7 and STA-8 are consistently above wetland ground elevations during the wet season. Conversely, measured water levels in SR-9, YP-6, and MW-29 are lower. SR-9 water levels are above ground during most of the wet season but never reach the edge of the cypress wetlands of Durden Creek, which indicates that water levels at this location are below optimum conditions. YP-6 water levels are rarely higher than average wetlands elevations in the vicinity of the gage, evidence of the drainage effect of two eroded ATV trails adjacent to YP-6. Conditions are significantly lower at MW-29, suggesting negative impacts due to prevailing water levels (+/- 7 ft-NAVD) in nearby Gator Slough. MW-29 W shallow well water levels are consistently higher than the deep well levels (MW-29 E) which is likely due to seepage effects from Gator Slough. The complications of seepage combined with drainage from eroded ATV trails allow wet season water levels to drop quickly after rainfall events causing peak stages to rarely reach the overflow elevation of the concrete weir that is adjacent to the monitoring wells. These data for Yucca Pens monitoring wells indicate that Yucca Pens hydrology is below optimum conditions.

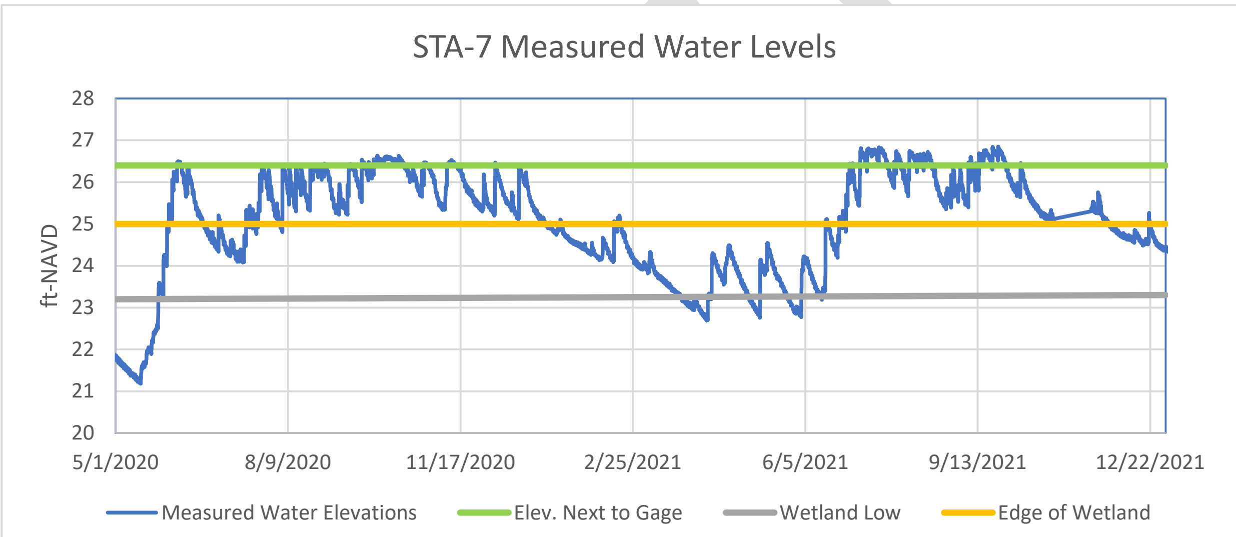


Figure 3-8. Measured Water Levels at STA-7 in North Portion of South Walk-In Area

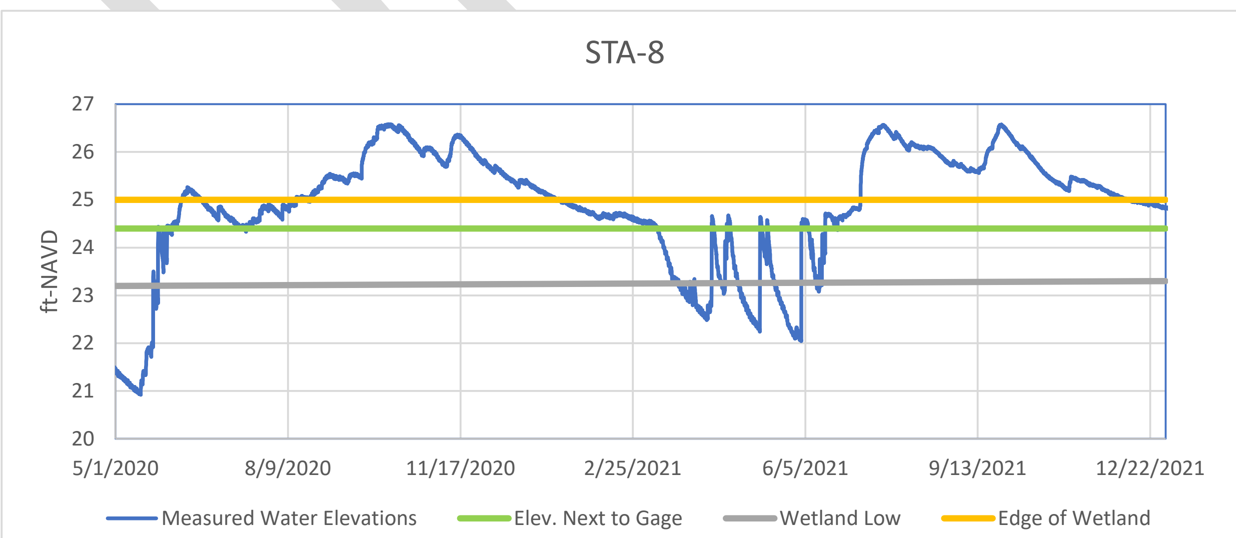


Figure 3-9. Measured Water Levels at STA-8 in South Portion of South Walk-In Area

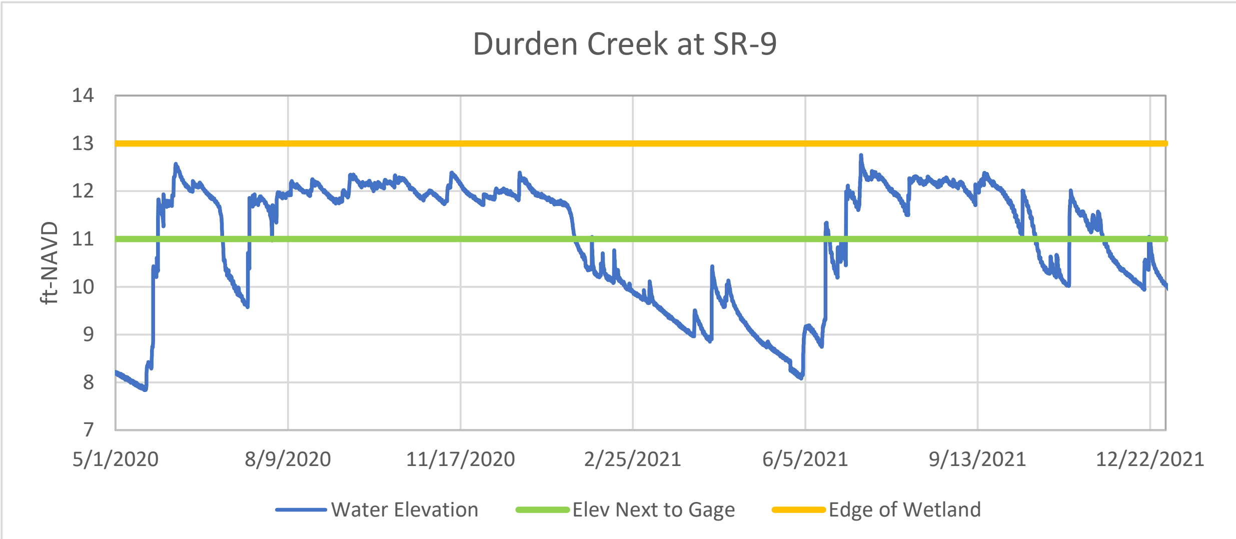


Figure 3-10. Measured Water Levels at SR-9 in Durden Creek at Western Limit of Yucca Pens

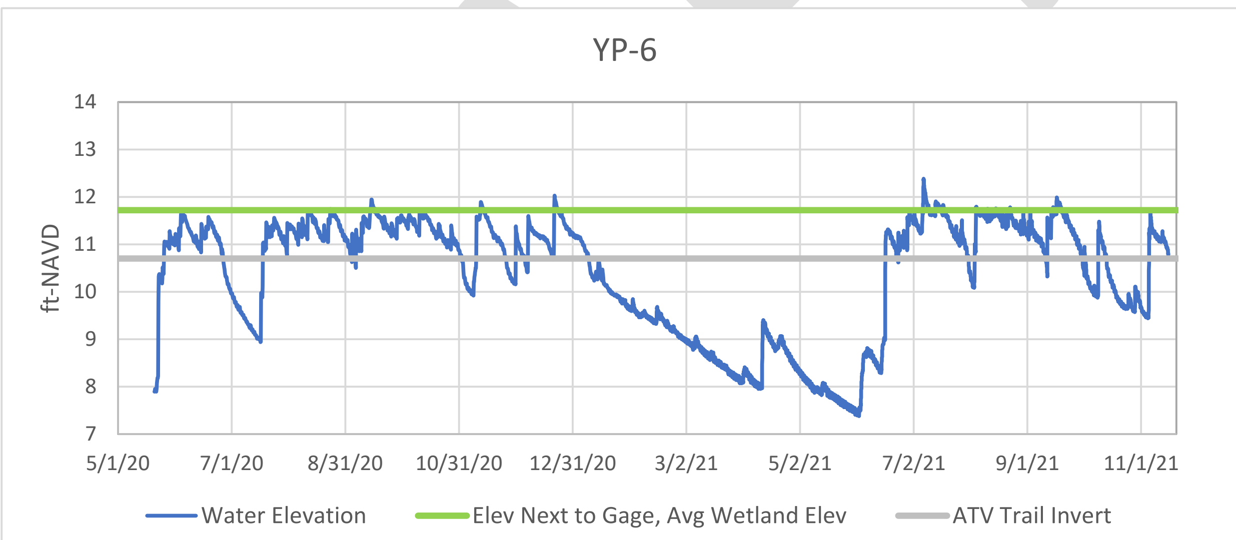


Figure 3-11. Measured Water Levels at YP-6 at Western Limit of Yucca Pens (south of SR-9)

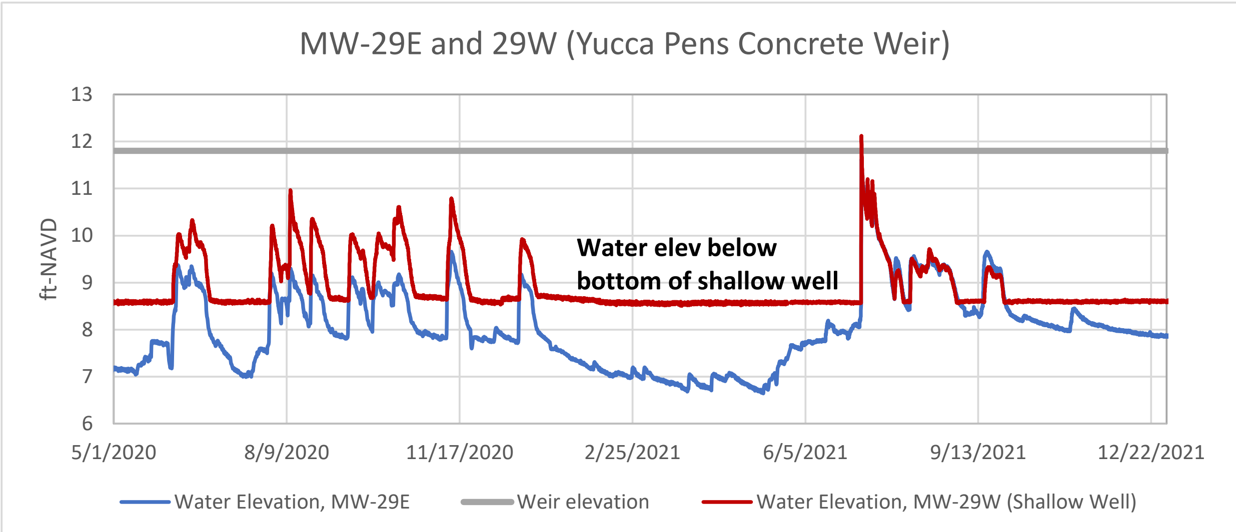


Figure 3-12. Measured Water Levels at MW-29 Adjacent to Concrete Weir at Southern Limit of Yucca Pens

4. DATA COLLECTION

4.1 DATA DOWNLOADS, QUARTERS 1 THROUGH 6

Groundwater monitoring was conducted from early May 2020 through mid-November 2021 at Babcock Webb groundwater monitoring stations BW-1 through BW-20 and at Yucca Pens stations YP-3 through YP-6. Water level monitoring was also completed at Babcock Webb staff gages SR-2, SP-4, -5, -6, -7, -8, -9, and SP-10 (for station locations, see **Figures 2-1** and **2-2**). The Task 4A–F memoranda present the full monitoring data collected during each quarter with analyses and graphs of measured data and can be found in **Appendix 4A–F**.

Graphs of measured data for all stations are provided again in **Appendix 6A**. Graphs of measured data for a few select stations are provided below.

The greatest variation between wet and dry season water levels was 6 ft at SP-4, the North Alligator Creek gated weir structure. Leakage through the underflow gates is the most likely reason for the higher variability observed at this station. **Figure 4-1** illustrates that water level variability at SP-4 (> 7 ft) is greater than the upstream stations BW-9 (5 ft) and SP-5 (4 ft). SP-4 is located at a corrugated metal pipe (CMP) riser structure that likely minimizes water level variability.

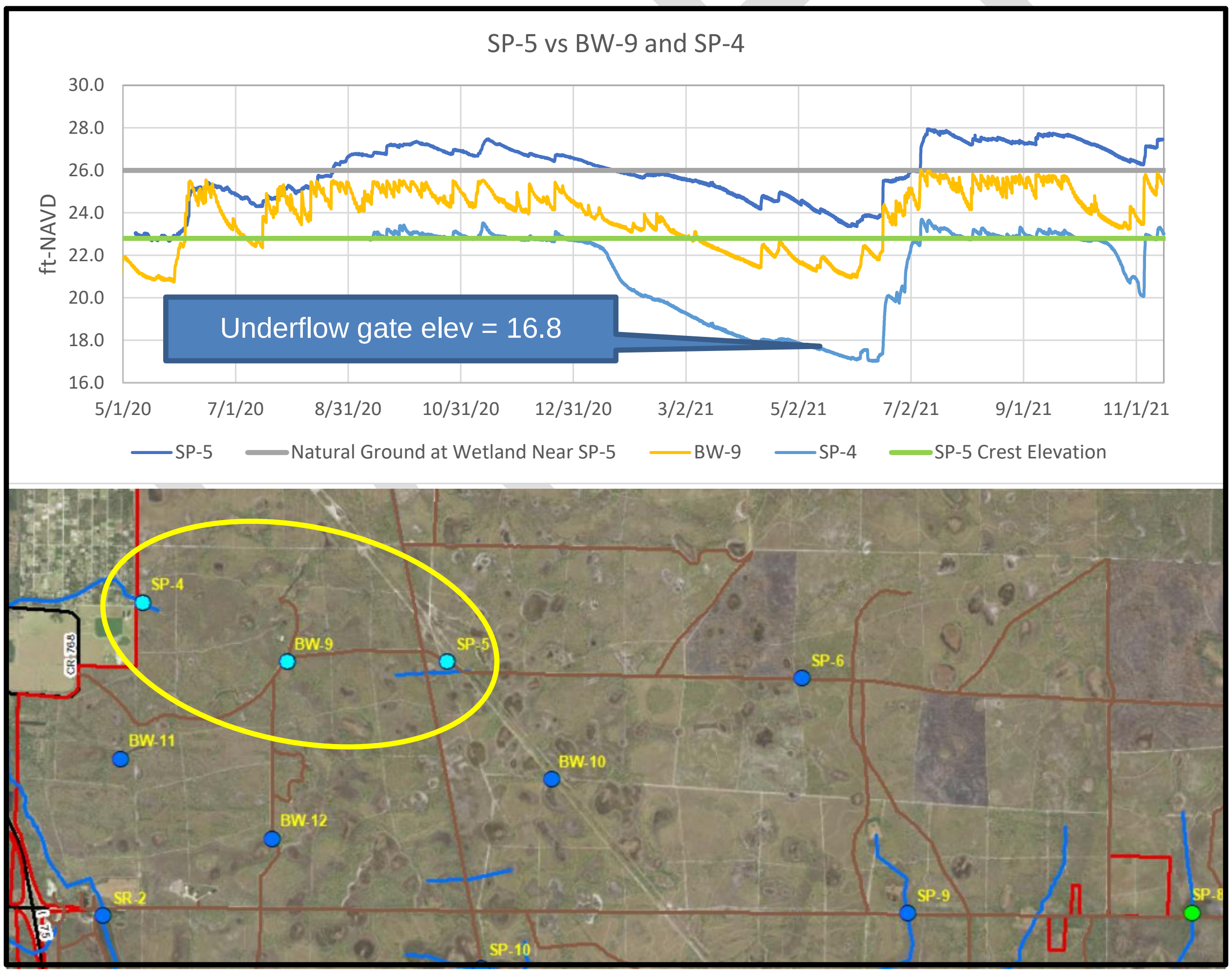


Figure 4-1. Measured Water Levels and Station Locations for SP-5, BW-9, and SP-4

Babcock Webb water levels varied the least at stations located at the downstream limit of water storage areas, such as station SR-2 at the Webb Lake weir at Tuckers Grade (**Figure 4-2**). Wet season water levels at station SP-8 at the Big Island Weir on eastern Tuckers Grade were relatively constant (**Figure 4-3**, see **Figure 4-1** for station locations). Dry season water levels at the Big Island Weir drop significantly due to the height of the CMP riser structure at SP-9?. BW-12 wet season water levels (**Figure 4-4**) show greater short-term variability than water levels at SR-2.

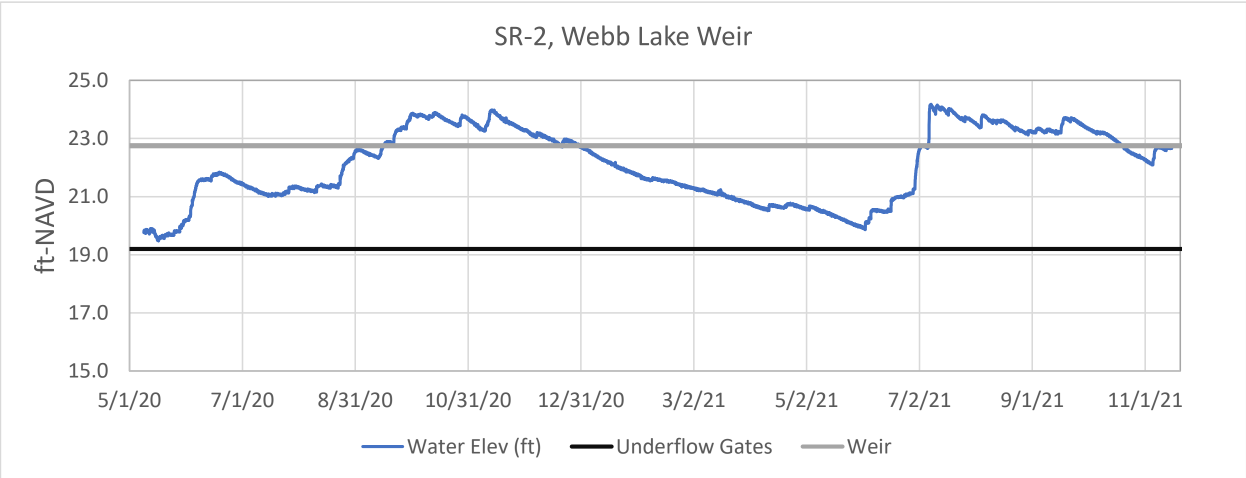


Figure 4-2. Measured Water Levels at Station SR-2 at the Webb Lake Weir

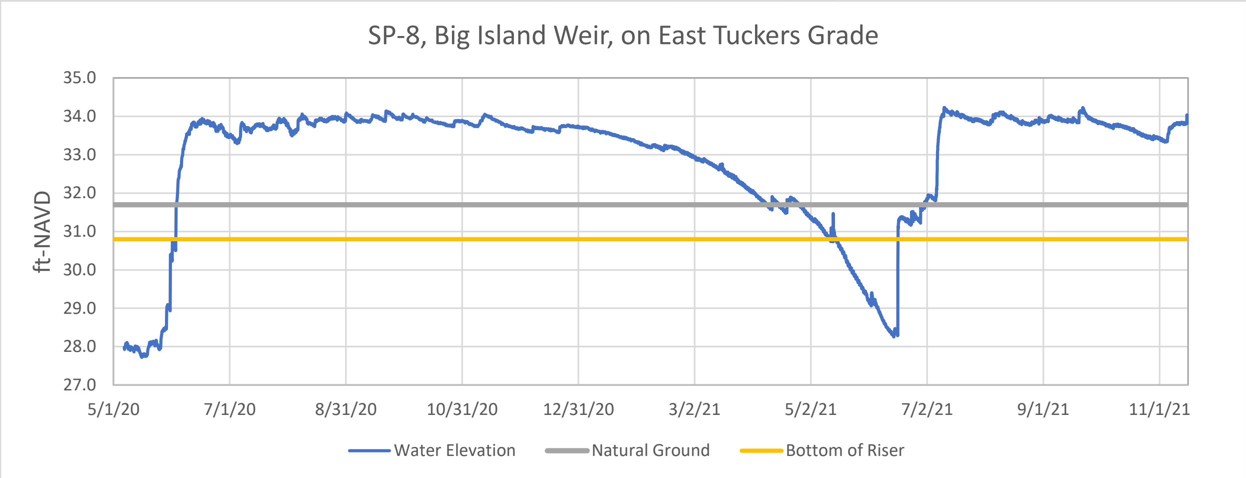


Figure 4-3. Measured Water Levels at Station SP-8 at the Big Island Weir

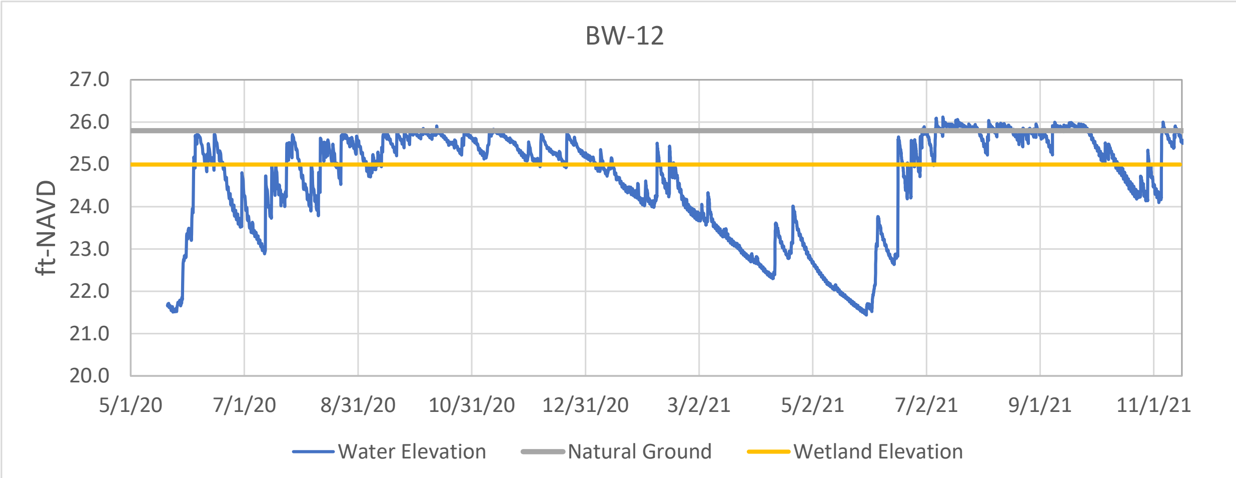


Figure 4-4. Measured Water Levels at Station BW-16, Located Northeast of SR-2

It is possible that the drainage effects of the North Prong Alligator Creek underflow gates impact dry season water levels at stations BW-9 and BW-12.

SP-9 is a CMP riser on the north side of Tuckers Grade, and BW-15, STA-7, STA-8, and STA-6 are located southwest of SP-9, with the STA stations located in the South Walk-In Area (data and locations shown in **Figure 4-5**). Wet season water levels vary least at SP-9, most likely due to the riser structure and impoundment effect of Tuckers Grade Rd. Water levels are all relatively similar at BW-15 and the STA stations, most likely due to the impounding effect of the current Bond Farm berm and a general lack of outflow conveyances around the gun firing range berm north of Bond Farm and the Charlotte Correctional Institute west of Bond Farm (see MW-CCI for location).

The data presented below for SP-9, BW-15, and the STA stations indicates the benefit of coordinated monitoring at existing FWC monitoring stations and monitoring stations described in Section 2.

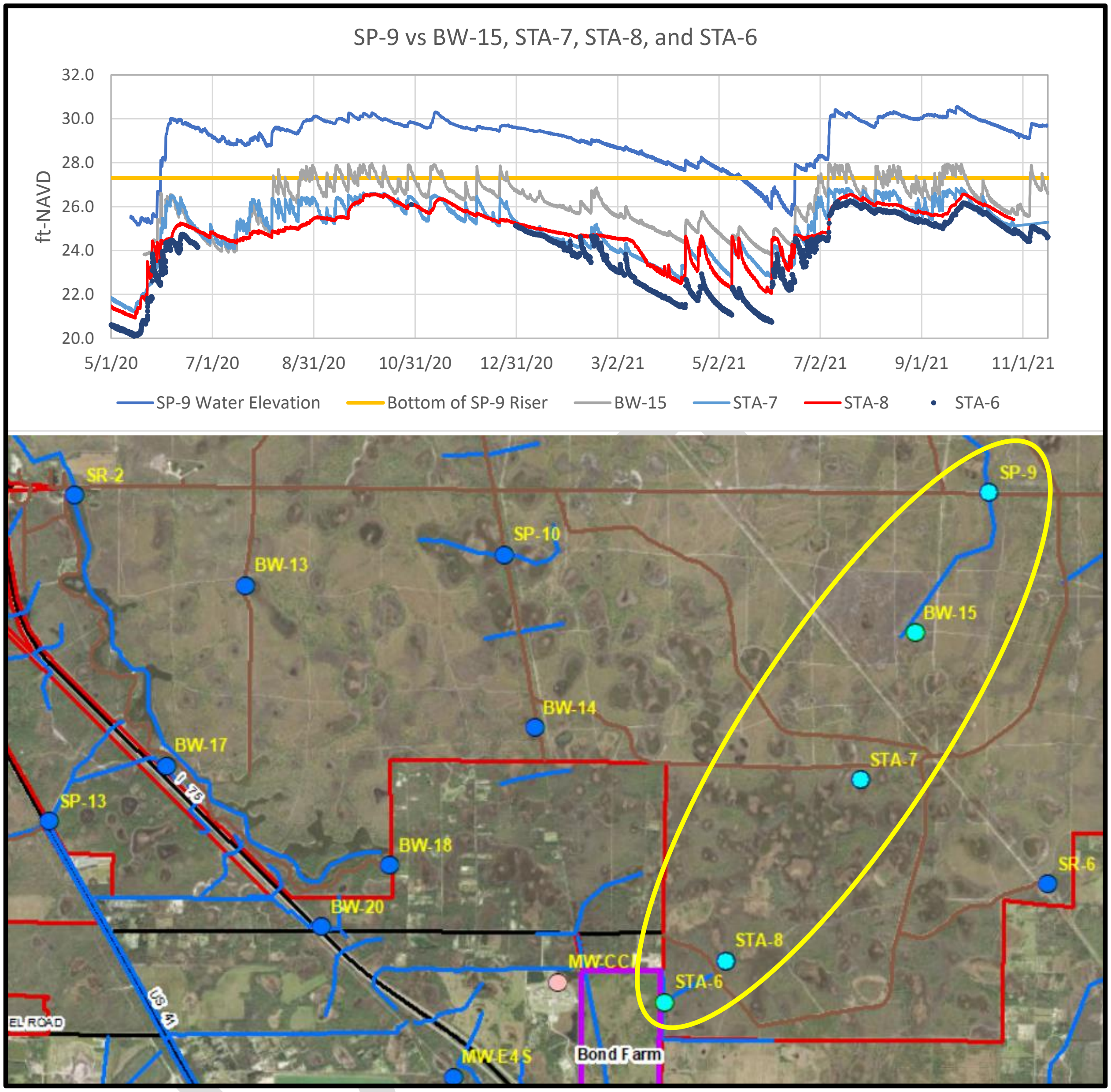


Figure 4-5. Measured Water Levels at Station Locations for SP-9, BW-15, and STA Stations

Water levels in Yucca Pens station YP-3 (**Figure 4-6**) were rarely above the edge of cypress at YP-3, which is also the ground elevation at YP-3. Data from this station confirms the above findings indicating that water levels in Yucca Pens cypress are below optimum conditions. Measured water levels at YP-4 (**Figure 4-7**), located on the eastern edge of Yucca Pens, and exhibited water level variations of 1 to 2 feet in between rain events during the wet season.

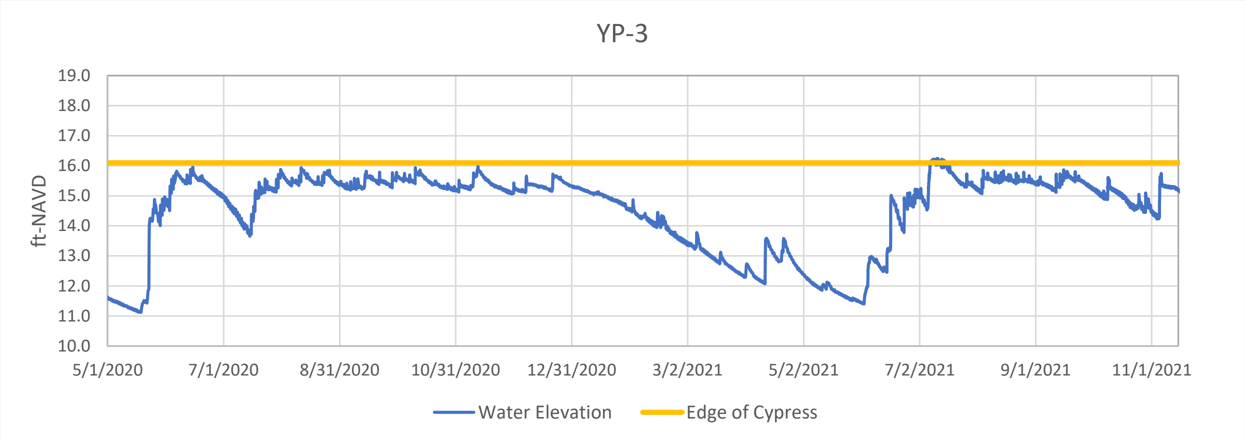


Figure 4-6. Measured Water Levels at Station YP-3

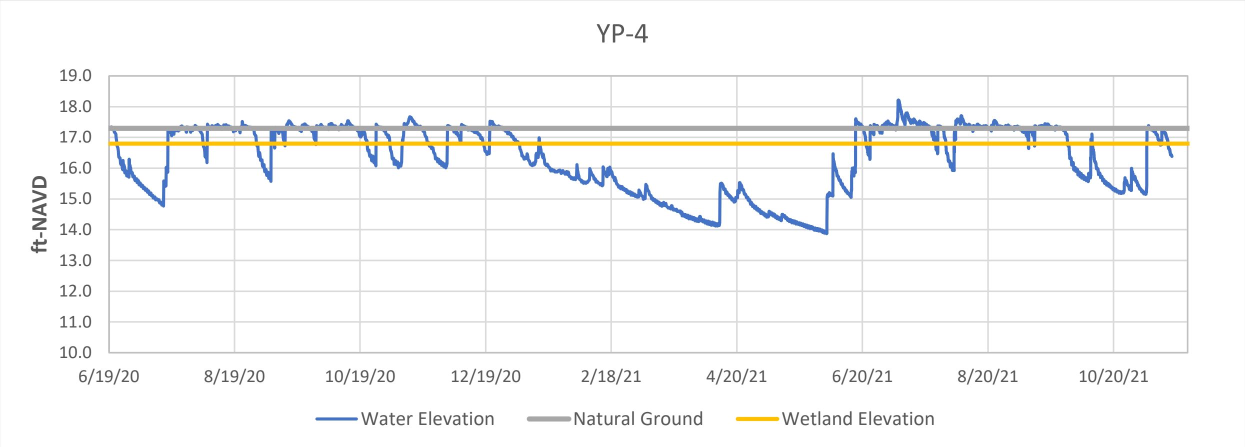


Figure 4-7. Measured Water Levels at Station YP-4

4.2 FLOW RATING CURVES

The collected flow measurement data yielded flow rating curves that were suitable for use in estimating stream flows. Flow rating curves were developed for Alligator Creek at South Jones Loop Road, Zemel Canal upstream of Burnt Store Road (BSR), Bear Branch at BSR, Hog Branch at BSR, Yucca Pens Creek at BSR, Yucca Pens Creek west of Burnt Store Road (tidal station), Durden Creek at BSR, and Greenwell Branch at NW 36th Avenue in Cape Coral. Flow rating curves for all of the stations mentioned above are provided in **Appendix 4G**. The stage/discharge plots for Zemel Canal and Hog Branch presented in **Figures 4-8** and **4-9** are good examples of typical flow rating curves. **Figure 4-10** for Greenwell Branch is an example of a flow rating curve that is impacted by external factors. That station is located within the Cape Coral canal system and the canal dimensions both upstream and downstream are wider and deeper than the other flow monitoring stations that were part of the monitoring program. The additional channel storage associated with the Cape Coral canal system is the likely explanation for the atypical stage/discharge relationship.

Note: CFS = cubic feet per second

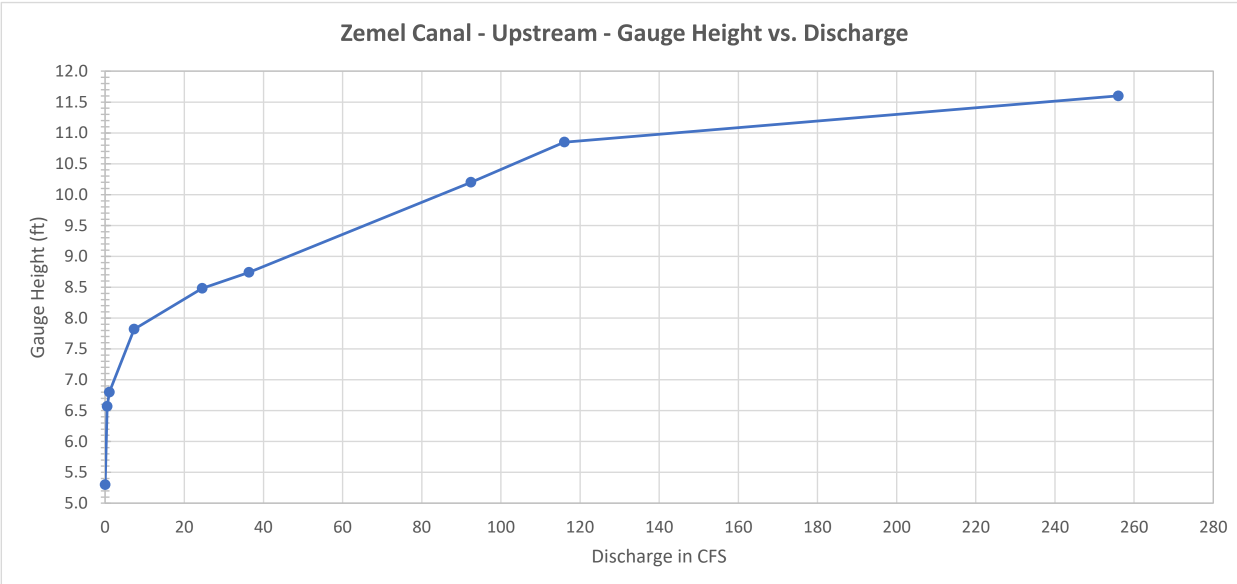


Figure 4-8. Stage/Discharge Relationship for Zemel Canal Upstream of Burnt Store Road

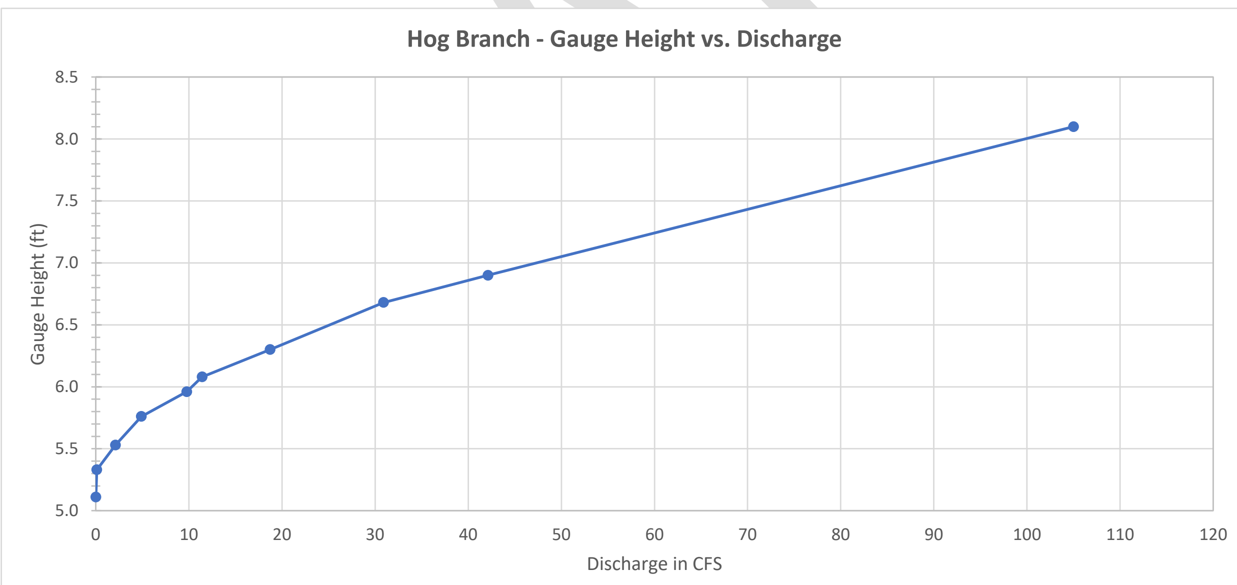


Figure 4-9. Stage/Discharge Relationship for Hog Branch Upstream of Burnt Store Road

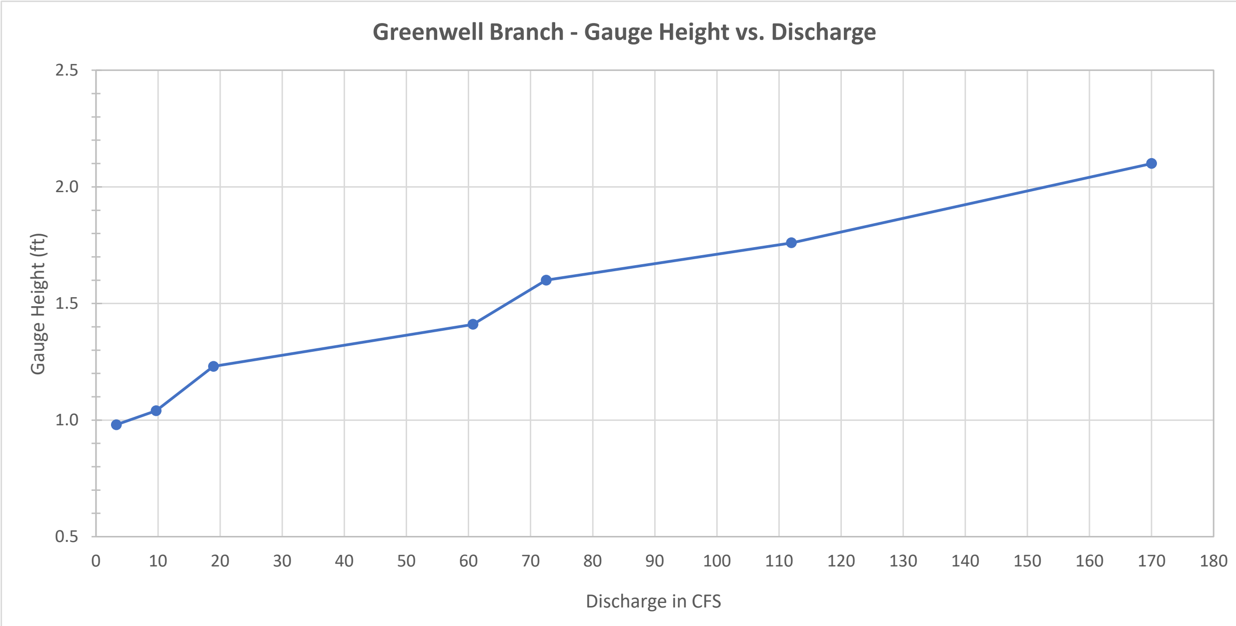


Figure 4-10. Stage/Discharge Relationship, Greenwell Branch, NW 36th Ave, Cape Coral

Rainfall Data. Rainfall data for the three stations installed as part of this project as well as data from nearby rainfall monitoring stations are presented below in **Table 4-1 and Table 4-2**.

Table 4-1. Monthly Rainfall Totals for all Monitoring Stations in Vicinity of Babcock Webb and Yucca Pens. (Sum.-Monthly Total in inches)

	Sum, in.	Sum, in.	Sum, in.	Sum, in.	Sum, in.	Sum, in.	Sum, in.	Sum, in.	Sum, in.	Sum, in.	Sum, in.	Sum, in.
Month	Lake Fairways	Popash Ck	Yellow Fev Ck	Big Is Weir	BSR FS #7	CW RG-1	CW RG-2	CW RG-3	N_Char	ROMP TR 1-2	Weir 19	Weir 4
5/31/2020	9.06	5.88	3.99	5.53	7.11	7.59	6.11	6.55	8.03	5.6	7.99	2.49
6/30/2020	9.73	5.96	8.48	5.18	11.21	7.26	7.89	6.48	8.05	6.94	8.7	N/A
7/31/2020	5.39	5.38	4.59	3.82	5.71	6.37	6.43	5.81	4.57	4.34	8	N/A
8/31/2020	7.9	6.11	7.93	7.32	4.89	8.99	9.73	8.23	4.86	9.41	8.51	N/A
9/30/2020	8.26	16.75	10.03	10.42	9.78	8.23	8.37	11.29	9.89	5.73	8.8	N/A
10/31/2020	5.02	5.23	3.73	3.94	3.44	6.32	4.31	4.8	4.26	4.97	5.13	3.98
11/30/2020	6.72	6.76	5.37	4.44	4.53	4.5	4.33	3.97	5.18	4.48	7.08	0.11
12/31/2020	4.5	4.29	2.55	2.81	4.08	3.07	2.63	3.37	4.19	3.06	4.7	1.24
1/31/2021	0.25	0.22	0.22	0.18	0.19	0.39	0.24	0.2	0.13	0.33	0.21	0.19
2/28/2021	1.32	2.13	1.05	1.85	0.39	1.23	2.04	1.32	0.81	1.09	0.83	0.65
3/31/2021	0.87	0.89	0.47	0.58	0.28	0.47	0.45	0.44	0.42	0.37	0.84	0.55
4/30/2021	4.1	3.74	2.9	4.87	3.14	3.62	3.44	3.31	3.61	3.2	3.95	3.01
5/31/2021	1.65	0.92	0.83	0.41	0.64	0.28	0.81	3.52	0.67	0.22	1.19	0.46
6/30/2021	9.71	11.74	6.74	9.12	11.32	10.85	7.9	8.62	12.24	14.02	8.79	7.69
7/31/2021	18.38	11.86	11.94	12.81	12.15	14.63	10.86	12.01	13.71	13.57	15.35	12.46
8/31/2021	10.53	8.37	7.92	10.55	8.11	7.65	7.28	4.64	10.43	8.75	9.03	10.43
9/30/2021	10.45	8.43	8.79	11.21	5.19	5.9	7.53	7.49	3.4	5.46	4.55	3.4
10/31/2021	1.99	3.07	3.03	3.53	2.84	2.07	1.37	2.14	3.56	0.94	2.22	3.56
11/31/2021	4.02	4.35	2.71	2.91	3.51	4.88	3.01	3.02	2.96	4.07	4.25	2.96

Table 4-2. Rainfall Data for installed BW-18, SR-7, and SP-5

Month	Sum, in Avg of Other Gages	Sum, in BW-18_R	Sum, in SR-7_R	Sum, in SP-5_R
5/31/2020	6.33	6.76	1.64	3.28
6/30/2020	7.81	5.35	8.83	7.43
7/31/2020	5.49	3.73	7.51	5.56
8/31/2020	7.63	7.36	3.44	4.87
9/30/2020	9.78	9.20	N/A	2.56
10/31/2020	4.59	5.74	N/A	2.93
11/30/2020	4.79	4.67	N/A	1.85
12/31/2020	3.37	0.03	N/A	0.63
1/31/2021	0.23	0.00	N/A	N/A
2/28/2021	1.23	0.65	NR	0.44
3/31/2021	0.55	0.30	NR	0.31
4/30/2021	3.57	1.78	NR	0.03
5/31/2021	0.97	N/A	N/A	N/A
6/30/2021	9.90	N/A	N/A	N/A
7/31/2021	13.31	N/A	N/A	N/A
8/31/2021	8.64	N/A	N/A	N/A
9/30/2021	6.82	8.04	5	9.65
10/31/2021	2.53	0.97	1.21	1.21
11/31/2021	3.55	3.6	3.06	6.63

Note: Average values in yellow-highlighted cells do not include stations with incomplete information

4.3 FINAL DATA DELIVERY

All data collected as part of this monitoring effort was delivered to the CHNEP in digital format and will continue to be made available upon request through the CHNEP Water Atlas. These data were also converted into a format required for model calibration. Details of the final data delivery are provided in **Appendix 4H**. The combination of data collected as part of this study as well as data available from other monitoring efforts provides a large dataset available for model calibration.

5. MODEL CALIBRATION AND EXISTING CONDITIONS MODEL

5.1 UPDATED MODEL FILES

The model calibration utilized data from the data collection effort commenced in May 2020 along with data from existing stations. Because the new monitoring stations installed as part of this project greatly increased the density of calibration stations, the calibration period used for this project was May 2020 through November 2021. To minimize initial conditions issues, the model simulation period for calibration simulations was January 2020 through November 2021. This modeling effort used the latest version of the MIKE SHE/MIKE 11 software from 2017 and the calibration simulation runs were conducted using the 2020 software version.

The model domain originally developed in 2013 (ADA, 2013) was modified in 2016 to extend the model domain north from Webb Lake outlet to Alligator Creek at Taylor Road in Punta Gorda (Tetra Tech and ADA, 2017). For this current modeling effort, the 2016 domain was extended north to CR 74, Bermont Rd, as shown in **Figure 5-1**.

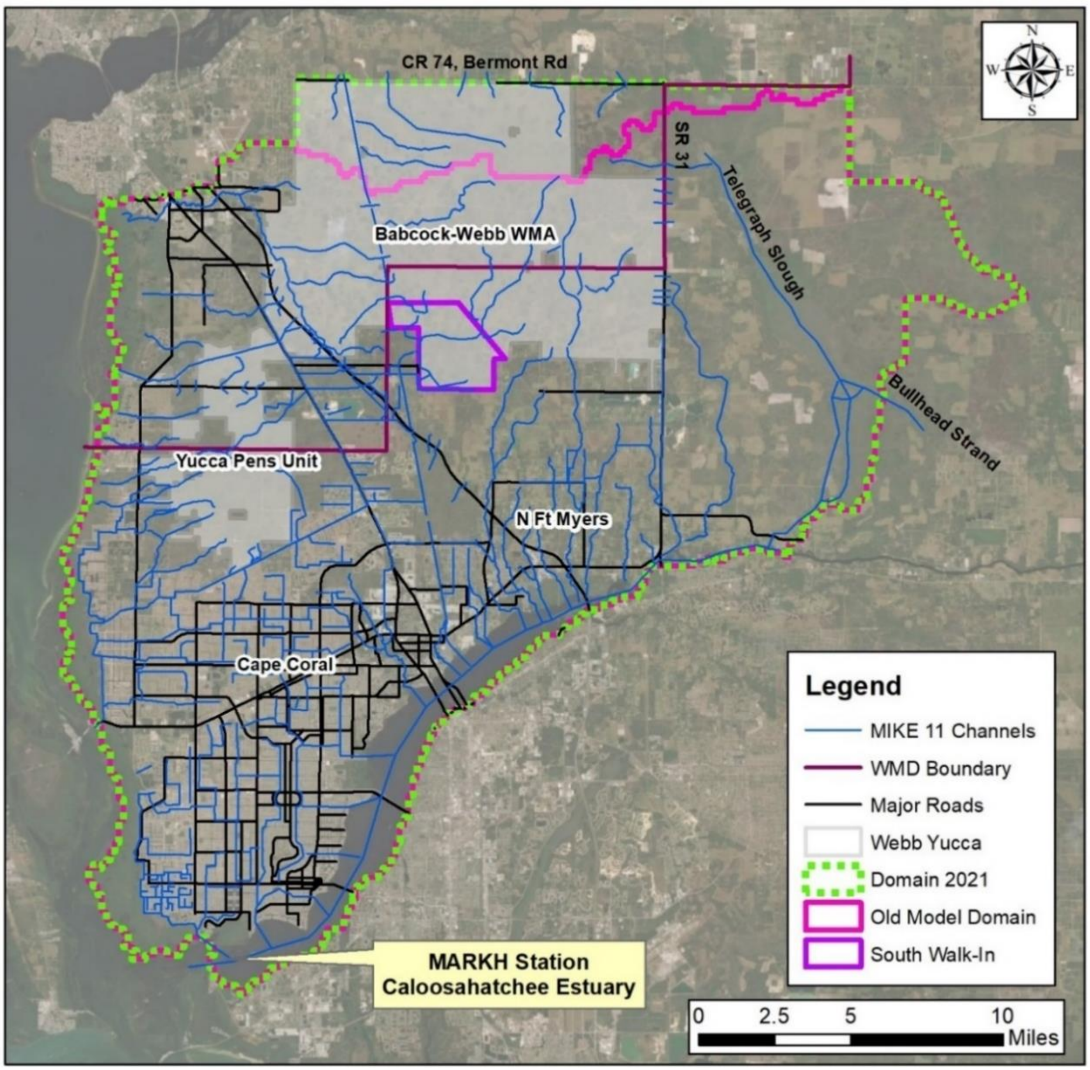


Figure 5-1. MIKE SHE Model Domain

Model Grid and Topographic Data. The model grid cell size is 750 feet by 750 feet with a total of 25,753 active cells. The topographic data set used for this project was developed by SFWMD in 2016 for the Charlotte Harbor Flatwoods Initiative. The topographic data includes Light Detection and Ranging (LiDAR) survey data from Lee County and Charlotte County. LiDAR elevations in low-lying areas of the South Walk-In Area of Babcock Webb were lowered by 1.5 feet based on transect surveys performed for FWC. Details can be found in the Task 5A memorandum (see **Appendix 5A**). During the calibration process, new LiDAR data from year 2018 was made available from the USGS that cover the lower half of the study area. This dataset includes recent changes in the topography and provides greater detail in low lying areas and roadside ditches. A decision was made to include new LiDAR data into the Digital Elevation Model (DEM) used for this study. New cross sections were cut from this LiDAR source for those MIKE 11 branches that are within the coverage of the new LiDAR data.

Climate: Next Generation Weather Radar (NEXTRAD) hourly rainfall data was used in the modeling effort. The grid size of this rainfall dataset is 2x2 kilometers. Reference evapotranspiration daily data were obtained from the United States Geological Survey (USGS) webpage. These data are also distributed in a 2-kilometer grid.

Vegetation and Land Use. Most of the model domain used 2014-2016 land use data available from SFWMD. Land use information for northern portions of the model domain were obtained from SWFWMD. FWC vegetation land cover information was used for the areas within the Babcock Webb and Yucca Pens.

Rivers and Flow-ways. Conveyance in rivers, canals, creeks, and defined flow-ways is simulated with MIKE 11, which is directly linked to MIKE SHE. At each time step, surface water and groundwater data are delivered between MIKE SHE and MIKE 11. The MIKE 11 files include a network file that defines flow pathways, cross sections that define channel and flow-way dimensions, and channel roughness coefficients. Extensive field work was conducted to confirm the flow pathways within the study area. Over 120 surveyed cross sections were obtained from a variety of sources, including a study for FDOT (ADA, 2013), modeling work for Cape Coral that provided surveyed cross sections of Gator Slough and U.S. 41 ditches (WSA, 2017), and investigations for FWC (SED and WSA, 2019).

Overland Flow Parameters. MIKE SHE uses a number parameters to manage communication between MIKE 11 and MIKE SHE, such as flood codes (used to govern exchanges during high flow periods), separated flow areas to limit overland flow across berms and roads, overland flow bed roughness, and detention storage. Details are provided in the Task 5A memorandum (see Appendix 5A).

Unsaturated Zone. The unsaturated zone (UZ) component governs vertical movement of water through the soil horizons. There are a number of methods for calculating water movement in the unsaturated zone that vary in complexity and affect the run time of the model. The Richards Equation method is used in this model, which is the most detailed computation approach for the infiltration process. Soils information was obtained from the Natural Resources Conservation Service (NRCS) Soil Survey webpage.

Saturated Zone. The geological layers definition in the previous MIKE SHE model (ADA and AIM, 2015) were mostly retained in the updated model together with their top and bottom elevations. The bottom elevation of the Water Table Aquifer was regenerated utilizing information from recent hydrogeological studies. The water table was split into two layers so that differences in conductivities for different components (e.g. sands, shell beds, and/or rock lenses) of the water table can be represented.

Observation Station Data. Water level and flow data are available from a number of sources, including the USGS, SFWMD, SWFWMD, Lee County, and stations monitored as part of this study. This modeling effort includes calibration data for many stations that were not available in prior calibration efforts, such as BW-1 through BW-20, YP-4 through YP-9, STA-6, STA-7, STA-8, MW-3, MW-14, MW-23, MW-24, MW-29, MW-30, SW-1, SW-2, SW-3, MW-CCI, Southwest Aggregates monitoring stations, and the 8 flow monitoring stations. In addition, manually-measured staff gages only recorded in the wet season in Babcock Webb and Yucca Pens were converted in 2019 and 2020 to automatic data logger monitoring stations, including SR-2, SP-4 through SP-13, SP-16, SP-17, SR-8, and SR-9.

Currently, the model calibration includes 110 groundwater and 34 surface water monitoring stations. The increase in the available data for model calibration greatly enhances the ability of the model to more accurately simulate overland runoff and groundwater flow processes within the study area. Model performance at these stations is used for calibration, verification, and to establish boundary conditions. Calibration station locations are shown in **Figures 5-2** and **5-3**. Note that the color of the monitoring station icons represents final calibration performance.

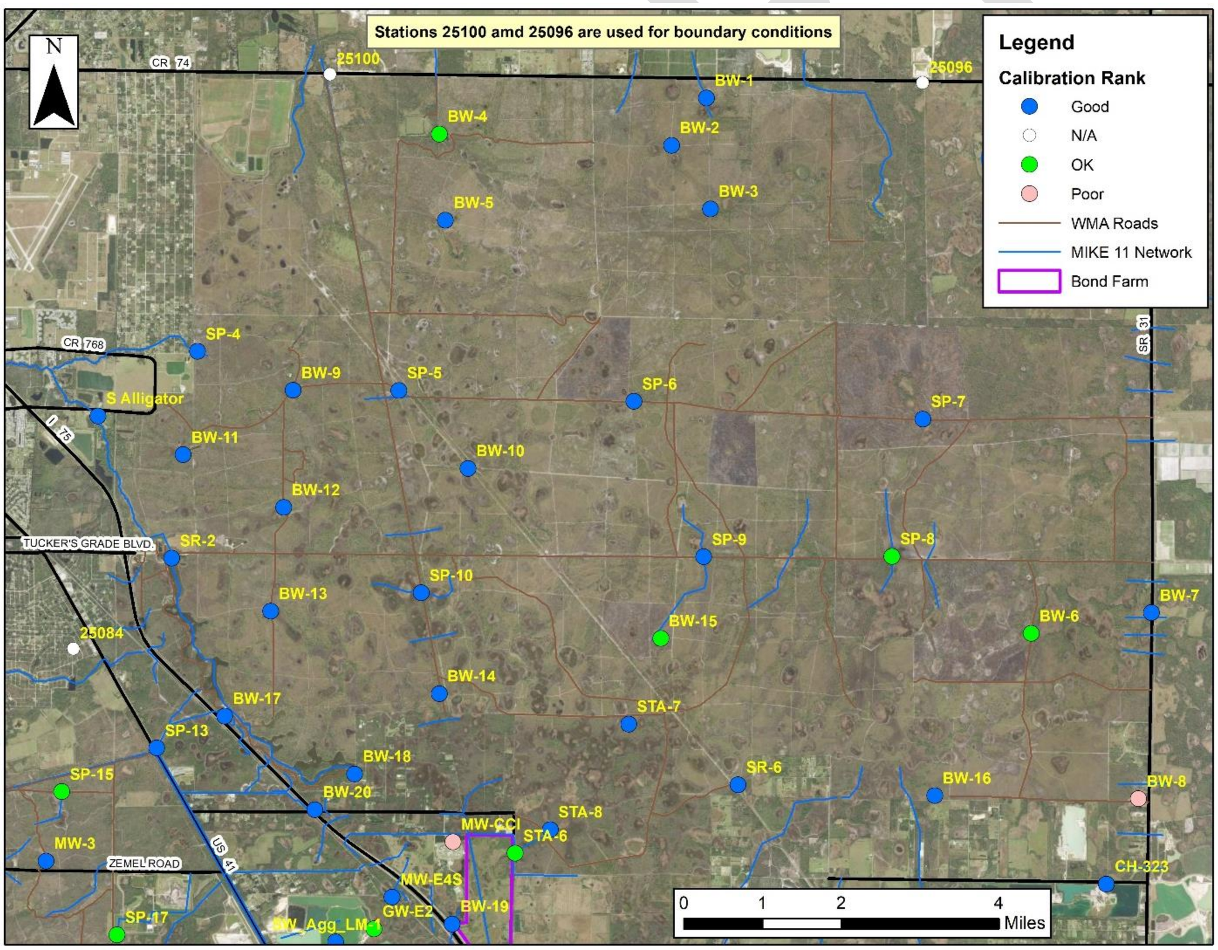


Figure 5-2. Calibration Stations and Model Performance in North Portion of Study Area

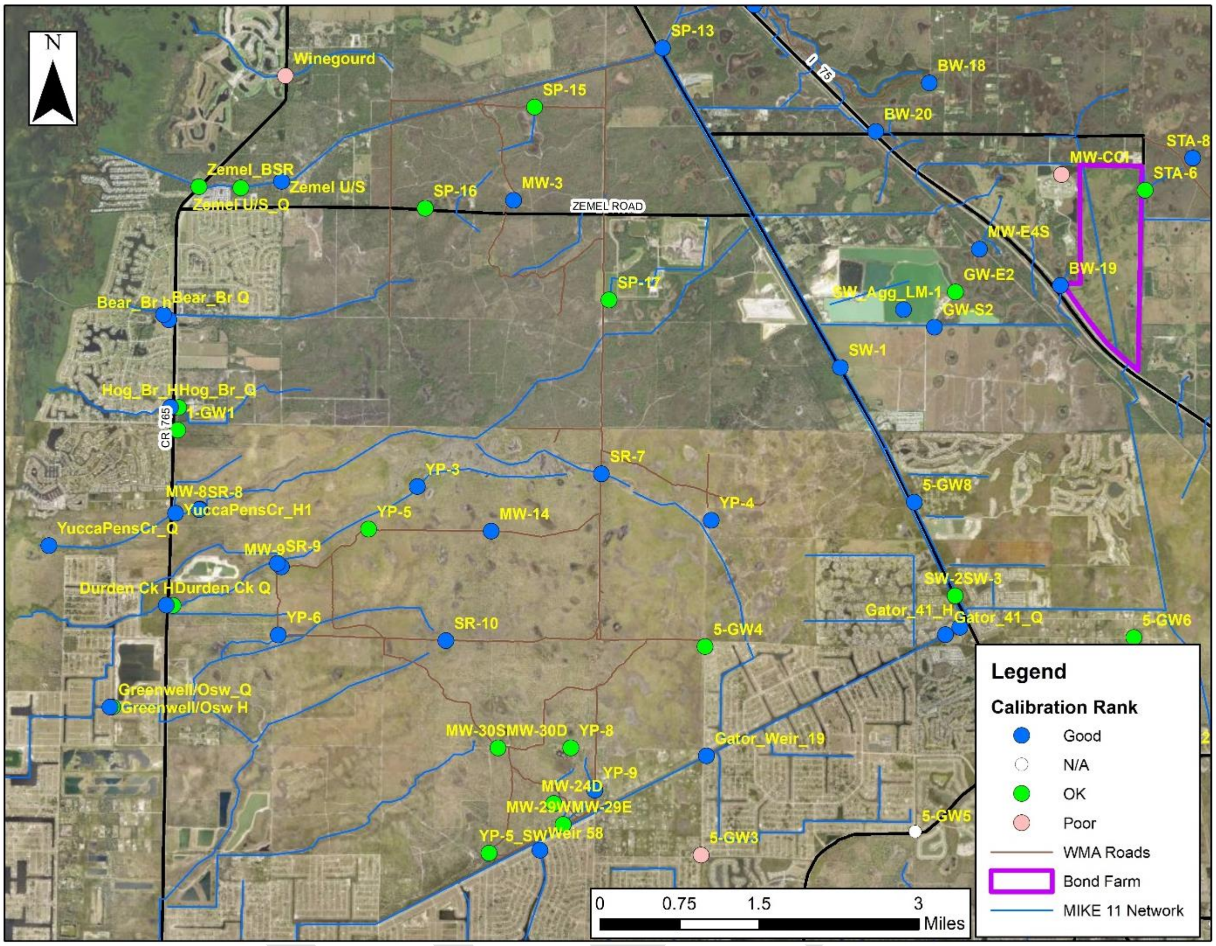


Figure 5-3. Calibration Stations and Model Performance in South Portion of Study Area

The calibration period was May 15, 2020 through November 15, 2021, which was the period that data was available for the stations installed as part of this project. Calibration within Cape Coral is limited to improving model performance in Gator Slough. In addition, a number of calibration stations are located in North Fort Myers (see **Figure 5-2** for the location of this area). Calibration in North Fort Myers was limited since this area does not have a significant effect on model performance in Babcock Webb Wildlife Management Area (WMA).

5.2 INITIAL MODEL CALIBRATION

Model calibration initially focused on refinement of input data, such as identifying areas where flows were restricted due to heavy vegetation in channels or revising culvert dimensions based on more recent information. Several field visits were conducted during this period to confirm field conditions. Details of these efforts can be found in the Tasks 5B (50% Calibration) and 5C (100% Calibration) memoranda in Appendix 5C.

After the initial calibration phase, the following activities were conducted to further improve the calibration:

- Testing differing computation methods for the unsaturated zone
- Modifying groundwater hydraulic conductivities
- Evaluating leakance coefficients that govern interactions between the surface layer and the saturated zone. Leakance is lower in areas where surface water infiltration is reduced

due to the presence of shallow layers of low permeability or in wetlands that have muck sediments.
- Additional improvements were made in the representation of surface water features (for example, additional surveyed cross sections were obtained for Zemel Canal west of U.S. 41).

Water balance tests were conducted to test several different unsaturated zone computation methods, and it was decided that the most advanced method (Richards Equation) should be used. Groundwater horizontal and vertical hydraulic conductivities were initially set to uniform values since most efforts were focused on improving the physical representation of hydrologic conditions. Once the majority of input file refinements had been completed, sensitivity tests were conducted for those uniform groundwater hydraulic conductivities to determine the optimum starting point for the groundwater calibration process that will vary groundwater conductivity on a spatial scale.

5.3 ANALYSIS OF CALIBRATION PERFORMANCE

The focus of calibration was to match simulated values to measured values of head elevation in the saturated zone, water elevations in MIKE 11 branches, and flows. Calibration performance was ranked according to the following criteria:

Good: MAE ≤ 0.75 ft, correlation coefficient r ≥ 0.8, and/or Nash Sutcliffe coefficient ≥ 0.3

OK: MAE 0.75- 1.0 ft, correlation coeff. r = 0.7 – 0.8, and/or Nash Sutcliffe coefficient = 0.2 - 0.3

Poor: MAE > 1.0 ft, correlation coeff. r ≤ 0.7 and Nash Sutcliffe coefficient < 0.0

Groundwater hydraulic conductivities were varied spatially to improve calibration. Two simulations were run varying horizontal and vertical conductivity values by a factor of 1.2 and 0.8. A statistical comparison using mean absolute error (MAE) was made for the initial simulation and the two sensitivity tests (1.2 and 0.8) at all calibration stations. Note that correlation coefficient (r) and Nash Sutcliffe coefficient values were also checked throughout this effort. Typically, the correlation coefficient and Nash Sutcliffe coefficient values improved as MAE improved. However, performance for all three statistical measures was constantly checked throughout the calibration process.

At each station, hydraulic conductivities were unchanged if there was no change in calibration performance (as measured by MAE) between the starting simulation and the high and low sensitivity tests. When the calibration performance improved either by increasing or decreasing hydraulic conductivity, the area surrounding that calibration station was modified accordingly using the Inverse Square Distance method. This process was repeated until there were no further improvements in overall model calibration.

Model performance gradually improved throughout the model calibration process, and the model calibration is currently considered to be **good with many stations performing substantially above the minimum standards for good calibration, as described above. Figure 5-4** presents a graph of the progression of model performance. Overall, average MAE for surface water and groundwater calibration stations within the focus area of this study was 0.64 ft, the average correlation coefficient, r, was 0.87, and the average Nash-Sutcliffe (NS) coefficient was 0.34. Average r for flow stations was 0.82 and NS was 0.62. Model performance **far exceeded the good threshold in many key areas near Babcock Webb and Yucca Pens**, such as Gator Slough at Weir 19, Zemel Canal upstream of Burnt Store Road, SP-4 (outflow from Babcock

Webb to North Alligator Creek), SR-2 (Webb Lake outlet), 16 of 20 Babcock Webb monitoring wells, STA-7 and -8 in the South Walk-In Area, SP-5 through 10, CH-323 south of Babcock Webb on Cook-Brown Road, Yucca Pens and Durden Creek stations SR-8 and SR-9, SR-7 in east Yucca Pens (a problem station in 2016), SR-10 in central Yucca Pens, YP-6 (next to eroded ATV trail on west Yucca Pens, YP-8 (south Yucca Pens outflow).

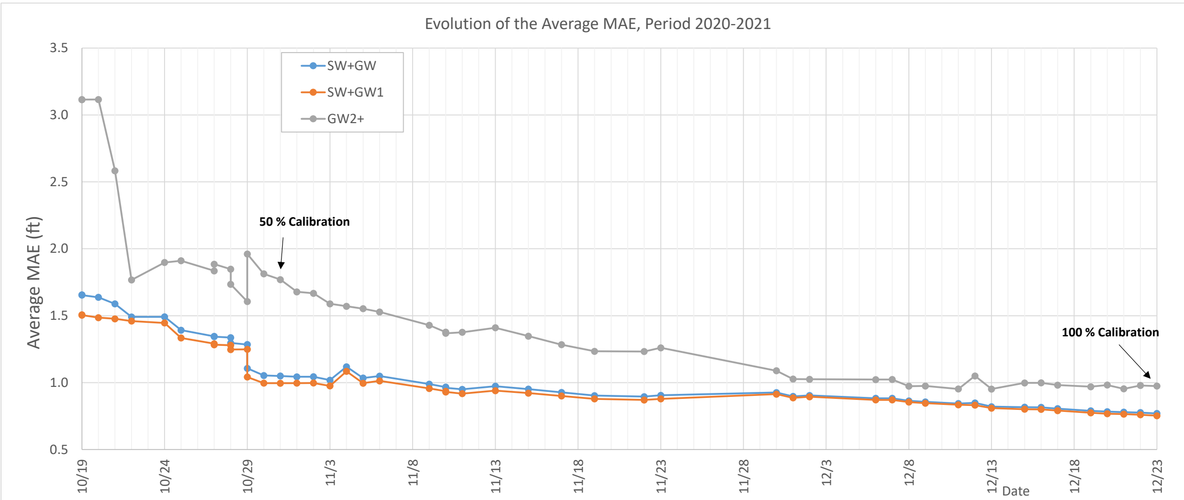


Figure 5-4. Progression of Model Performance During Calibration

Model calibration performance is summarized in **Table 5-1**. A number of stations in **Figure 5-4** are shown as NFA (Not Focus Area). Those stations are either stations used to establish boundary conditions for the model or are stations in North Fort Myers or Cape Coral that are far removed from the primary focus area of this modeling study (Babcock Webb and Yucca Pens) and do not affect the ability of the model to properly represent conditions in the WMAs. The summary of calibration performance indicates that 64% of the stations have **Good** calibration and 31% have **OK** calibration. More detailed information on model calibration is presented in **Tables 5-2** and **5-3**.

Overall, model performance is **Good** with many stations performing substantially above the minimum standards for good calibration (minimum standards for good calibration outlined above). Based on the statistical analysis of the model calibration, it was determined by the modeling team that the model was ready for scenario analysis.

Table 5-1. Summary of Model Calibration Performance

Statistic	Good	OK	Poor
Meeting Target	62	30	5
Number of Calibration Stations	97	97	97
Percent Meeting Target	64%	31%	5%

Table 5-2. Calibration Performance Statistics

Name	ME	MAE	RMSE	STDres	R_Corr	R2 NS	Overall
Bear Branch H	0.34	0.36	0.4473	0.2858	0.82	0.11	G
Durden Creek H	-0.32	0.84	1.1442	1.0999	0.87	0.61	OK
Gator_Weir11_H	0.45	0.53	0.6956	0.5327	0.61	-5.11	Poor
Gator_41_H	0.45	0.46	0.5008	0.2233	0.95	0.37	G
Gator_Weir_19	-0.13	0.17	0.1997	0.1480	0.96	0.87	G
Greenwell/Osw H	0.41	0.47	0.5420	0.3547	0.80	-0.62	OK
Hog Branch H	0.39	0.40	0.4962	0.3013	0.72	-0.36	OK
S Alligator	-0.54	0.67	0.8364	0.6370	0.88	0.61	G
SP-4	0.19	0.45	0.8879	0.8674	0.93	0.85	G
SP-8, BigWaterFord	0.75	0.97	1.1287	0.8456	0.88	0.54	OK
SP-13, Zemel at 41	-0.47	0.63	0.7820	0.6277	0.81	0.44	G
SR-2, WebbLake	0.27	0.46	0.5149	0.4406	0.94	0.83	G
SW-1, US_41	0.49	0.51	0.5549	0.2514	0.92	0.14	G
SW-2, US_41 E	0.52	0.62	0.6903	0.4530	0.88	-1.03	OK
SW-3, US_41 W	0.22	0.42	0.5157	0.4657	0.85	-0.04	OK
YuccaPensCr_H1	0.37	0.71	0.9766	0.9025	0.77	0.48	G
Weir 58	0.09	0.18	0.2216	0.2033	0.86	0.68	G
Winegourd	1.24	1.33	1.6633	1.1055	0.03	-5.43	Poor
Zemel U/S	-0.09	0.43	0.60	0.59	0.86	0.67	G
Zemel_BSR	-0.52	0.58	0.67	0.43	0.63	-1.25	OK
17-GW4	-0.14	0.80	1.0340	1.0249	0.76	0.48	OK
BW-1	-0.07	0.47	0.5821	0.5778	0.94	0.84	G
BW-2	-0.03	0.65	0.8106	0.8101	0.90	0.67	G
BW-3	0.36	0.50	0.7359	0.6409	0.94	0.73	G
BW-4	0.62	0.91	1.2609	1.0956	0.88	0.49	OK
BW-5	0.06	0.67	0.8994	0.8972	0.80	0.59	G
BW-6	-0.78	0.89	0.9985	0.6219	0.91	0.50	OK
BW-7	-0.20	0.53	0.6453	0.6122	0.94	0.81	G
BW-8	-1.14	1.15	1.4172	0.8439	0.90	0.33	Poor
BW-9	-0.31	0.66	0.8094	0.7491	0.87	0.71	G
BW-10	0.09	0.29	0.3903	0.3799	0.96	0.90	G
BW-11	0.05	0.69	0.9296	0.9280	0.86	0.58	G
BW-12	-0.17	0.45	0.6024	0.5783	0.90	0.80	G
BW-13	0.30	0.42	0.6191	0.5420	0.93	0.80	G
BW-14	-0.02	0.31	0.3830	0.3823	0.96	0.91	G
BW-15	-0.82	0.84	0.9600	0.5070	0.90	0.22	OK
BW-16	-0.42	0.46	0.5641	0.3759	0.96	0.80	G
BW-17	0.29	0.45	0.5915	0.5141	0.92	0.79	G
BW-18	0.26	0.38	0.5280	0.4569	0.95	0.86	G
BW-19	-0.36	0.57	0.6360	0.5253	0.93	0.74	G
BW-20	0.41	0.46	0.5646	0.3917	0.97	0.80	G
MW-23S	0.92	1.01	1.2912	0.9074	0.92	0.51	OK
MW-24S	0.84	1.00	1.3054	1.0024	0.89	0.30	OK
MW-29W	-0.21	0.54	0.6494	0.6155	0.43	-0.28	OK
MW-30S	0.44	0.82	1.0856	0.9913	0.82	0.04	OK
SP-5	-0.21	0.35	0.3938	0.3303	0.97	0.90	G
SP-6	-0.28	0.45	0.5087	0.4269	0.94	0.81	G
SP-7	-0.23	0.54	0.6241	0.5803	0.88	0.69	G

Table 5-3. Calibration Performance Statistics, continued

Name	ME	MAE	RMSE	STDres	R_Corr	R2 NS	Overall
SP-9	-0.11	0.26	0.3419	0.3231	0.97	0.92	G
SP-10	0.59	0.59	0.6462	0.2715	0.97	0.56	G
SP-16	-0.31	0.84	1.0115	0.9620	0.85	0.37	OK
SP-17	-0.77	0.93	1.0676	0.7438	0.56	-1.36	OK
STA-6	-0.92	1.07	1.1928	0.7568	0.82	0.19	OK
STA-7	-0.46	0.63	0.7761	0.6232	0.96	0.67	G
SW_Agg_LM-1	-0.47	0.51	0.7741	0.6135	0.83	0.50	G
YP-5_SW	1.13	1.13	1.2578	0.5622	0.97	0.55	OK
YP-8	0.88	0.91	1.2549	0.8924	0.91	0.22	OK
YP-9	0.31	0.63	0.8165	0.7564	0.96	0.77	G
1-GW1	0.79	0.95	1.1913	0.8924	0.87	0.20	OK
5-GW3	0.69	1.04	1.2936	1.0924	0.91	-0.18	Poor
5-GW4	-1.06	1.14	1.2980	0.7424	0.91	0.22	OK
5-GW6	-0.74	0.78	0.8841	0.4840	0.95	0.66	OK
5-GW8	0.59	0.65	0.8549	0.6229	0.92	0.47	G
16E-GW3	0.43	0.70	0.8819	0.7691	0.90	0.34	G
20-GW3	-0.38	0.64	0.7707	0.6699	0.97	0.82	G
CH-323	-0.01	0.58	0.7206	0.7206	0.81	0.65	G
L-721	-0.29	0.54	0.6533	0.5877	0.97	0.49	G
L-3207	0.08	0.21	0.2563	0.2441	0.91	0.82	G
MW-3	0.36	0.63	0.8621	0.7856	0.85	0.54	G
MW-8	0.57	0.64	0.9024	0.6963	0.89	0.40	G
MW-9	0.05	0.38	0.6883	0.6865	0.89	0.74	G
MW-14	0.28	0.48	0.6774	0.6154	0.89	0.70	G
MW-23D	0.81	0.94	1.2103	0.9031	0.93	0.55	OK
MW-24D	0.42	0.96	1.1185	1.0356	0.90	0.44	OK
MW-29E	-0.63	0.77	0.8818	0.6128	0.87	0.21	OK
MW-30D	0.45	0.76	1.0437	0.9409	0.84	0.18	OK
SP-15	0.73	0.89	1.0982	0.8222	0.89	0.36	OK
SR-6	-0.30	0.42	0.5505	0.4610	0.94	0.84	G
SR-7	-0.68	0.71	0.7859	0.4009	0.94	0.55	G
SR-8	0.00	0.54	0.6983	0.6983	0.91	0.73	G
SR-9	-0.09	0.42	0.5742	0.5672	0.92	0.83	G
SR-10	-0.10	0.37	0.4925	0.4823	0.90	0.79	G
STA-8	0.02	0.39	0.5123	0.5119	0.94	0.86	G
SW_Agg_MW-CCI	-1.50	1.50	1.5602	0.4369	0.95	-0.38	Poor
SW_Agg_MW-E4S	0.17	0.39	0.5407	0.5147	0.92	0.82	G
SW_Agg_GW-E2	-0.30	0.80	0.9057	0.8552	0.78	-0.01	OK
SW_Agg_GW-S2	-0.22	0.46	0.5956	0.5548	0.94	0.49	G
YP-4	-0.25	0.57	0.7829	0.7404	0.78	0.53	G
YP-6	0.16	0.62	0.9019	0.8868	0.84	0.55	G
Bear Branch Q	3.41	4.16	10.3116	9.7328	0.76	0.48	G
Durden Creek Q	0.17	3.00	7.1565	7.1545	0.86	0.72	G
Gator_41_Q	2.72	6.17	15.3197	15.0764	0.89	0.78	G
Greenwell/Osw_Q	-2.02	6.11	14.9905	14.8543	0.76	0.50	G
Hog_Q	2.20	2.49	7.5517	7.2249	0.81	0.53	G
NS Transfer	1.65	2.56	7.0252	6.8276	0.90	0.81	G
YuccaPensCr_Q	1.90	6.91	12.5021	12.3565	0.86	0.72	G
Zemel U/S_Q	-5.59	11.33	29.78	29.25	0.69	0.45	OK

5.4 EXISTING CONDITIONS MODEL RESULTS

5.4.1 Baseline Model Modifications

The final calibrated model was converted to a baseline existing-conditions model by incorporating the modifications described below. Results from the baseline existing-conditions model will be used to better understand areas of current management concerns and to compare current conditions to results from proposed future alternative management scenarios.

The calibrated model input files were used as a starting point for this analysis, with modifications to allow the model to simulate conditions outside of the May 2020 – November 2021 calibration period as described below:

- To minimize initial conditions issues, a 2-year model simulation period was run for January 2020 through November 2021.
- The 2-year simulation period was increased to 10 years. The calibrated model ran for May 2020 through November 2021, and the baseline model ran from January 2011 through January 2021. This longer period includes 9 more years of climate variability data inputs.
- Time series files were extended to cover the new simulation period (e.g. rainfall, evapotranspiration (ET), pumpage files for groundwater withdrawals, rooted depth and leaf area index values).

For Gator Slough Weirs 11 and 19, the calibrated model utilized known gate level positions provided by the City of Cape Coral. The gates at these two weir structures were modified to operate according to known gate operation protocols. Other changes were made to Cape Coral structures to enable the simulation to run for the 10-year period listed above, which are outlined in the Task 5D memorandum (**Appendix 5D**).

5.4.2 Hydroperiods and Wet Season Depths

Hydroperiod is defined as the number of days per year that water depths are more than 0.1 feet above ground surface. Hydroperiod units used in this memorandum are months, which is days/year divided by 12 months. ***Figures 5-5*** and ***5-6*** present the spatial distribution of simulated hydroperiod durations in Babcock Webb and Yucca Pens in the baseline existing-conditions model. ***Figures 5-7 and 5-8*** present mean water depth during the wet season (i.e., from July 1st through October 15th) in Babcock Webb and Yucca Pens, respectively. These maps were produced at a finer spatial resolution by comparing the simulated water levels each day in the 750-ft model grid with the 50-ft resolution topography. Hydroperiods in the South Walk-In Area are greater than 8 months, meaning that water depths are more than 0.1 feet above ground surface for 8 months out of the year. Peak wet season water depths in lower part of Yucca Pens are less than 0.3 ft. Wet season water depths are less than 1 foot in most of the cypress wetlands of Yucca Pens. Note that the definition of the wet season differs from the definition used in calibration (July 1st through November 30th) associated with this project. The hydroperiod used in calibration was based on observed rainfall patterns for 2020 and 2021 which experienced a late initiation of the wet season with rainfall continuing into December for 2020 and November for 2021. The analysis for the baseline simulation of 2011 through 2020 uses a more common definition of the wet season (i.e., from July 1st through October 15th) since rainfall patterns varied across the simulation period and did not always have the patterns observed in 2020 and 2021.

These results confirm and quantify stated management concerns and hypotheses that hydroperiods in Babcock Webb are longer than optimal (optimal conditions defined in Section 3) due to blocked historic (pre-development) flow-ways, especially in the South Walk-In Area of

Babcock Webb, resulting in negative impacts to vegetation as well as quail and other species. Yucca Pens has reduced wetland wet season water depths, which negatively impacts existing vegetation including cypress domes. Additionally, hydroperiods in Yucca Pens are shorter than optimal (optimal conditions defined in Section 3) due to the blocked flow-ways from Babcock Webb as well as accelerated outflows via eroded all-terrain vehicle (ATV) trails.

The next section of the report will compare changes in hydrology from the existing baseline conditions model to simulated future potential management scenarios to identify how to best address management concerns outlined above and support recommendations for management while accounting for future climate impacts. These hydroperiods will also be compared to pre-development reference maps created in a Natural Systems Analysis with the goal of meeting natural systems need to the extent possible.

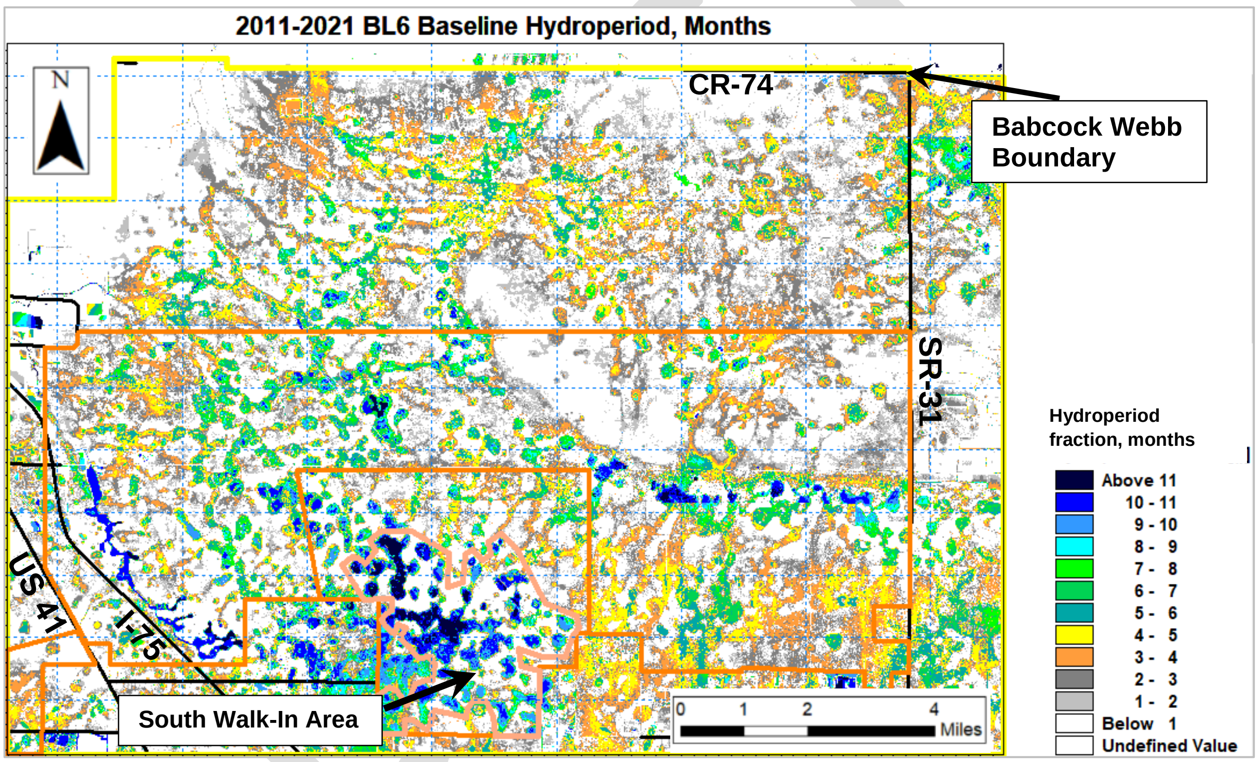


Figure 5-5. Average annual hydroperiod duration in Babcock Webb as predicted by the Existing Conditions Baseline Model during the period 2011-2020, at a 50-ft resolution.

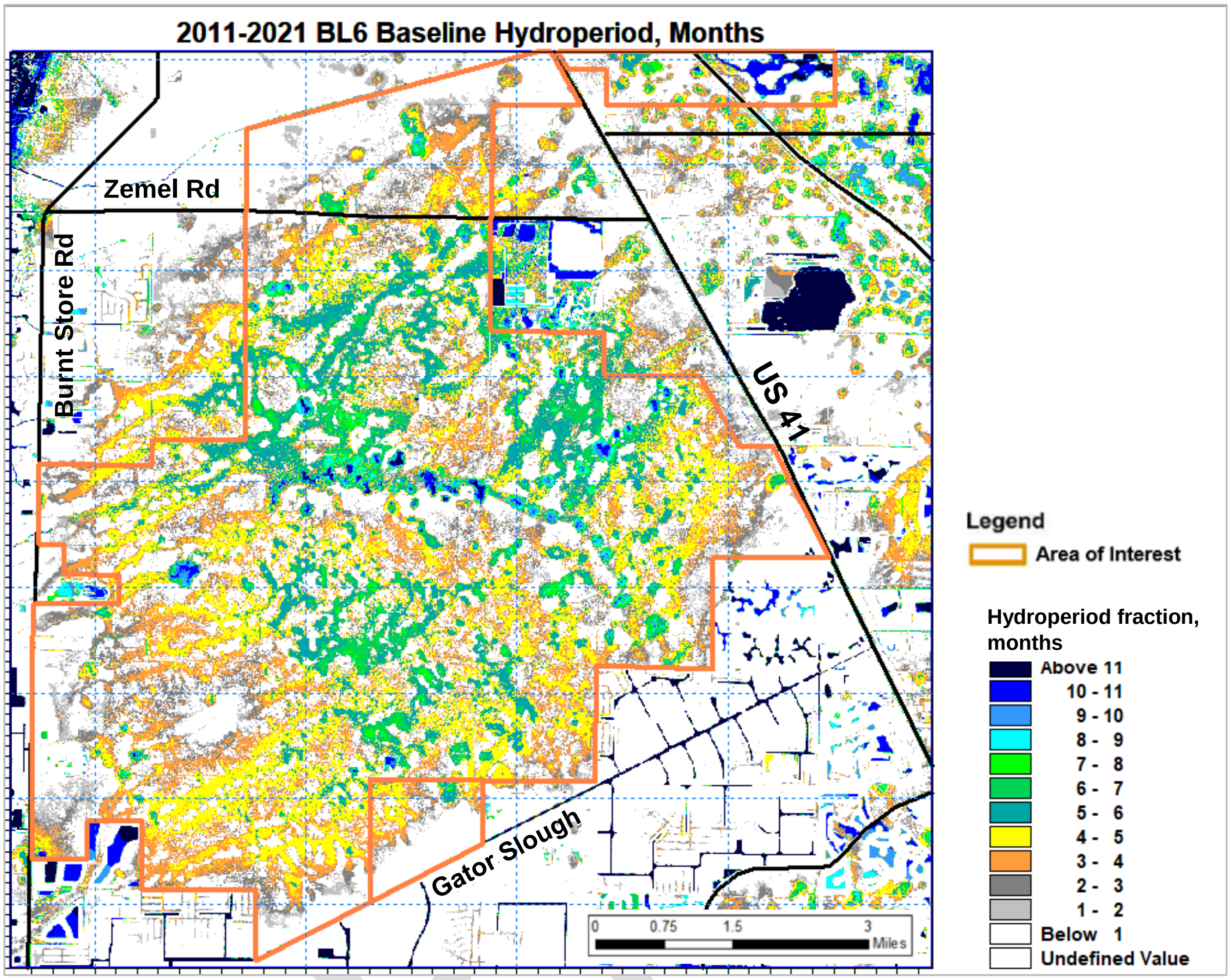


Figure 5-6. Average annual hydroperiod duration in Yucca Pens as predicted by the Existing Conditions Baseline Model during the period 2011-2020, at a 50-ft resolution.

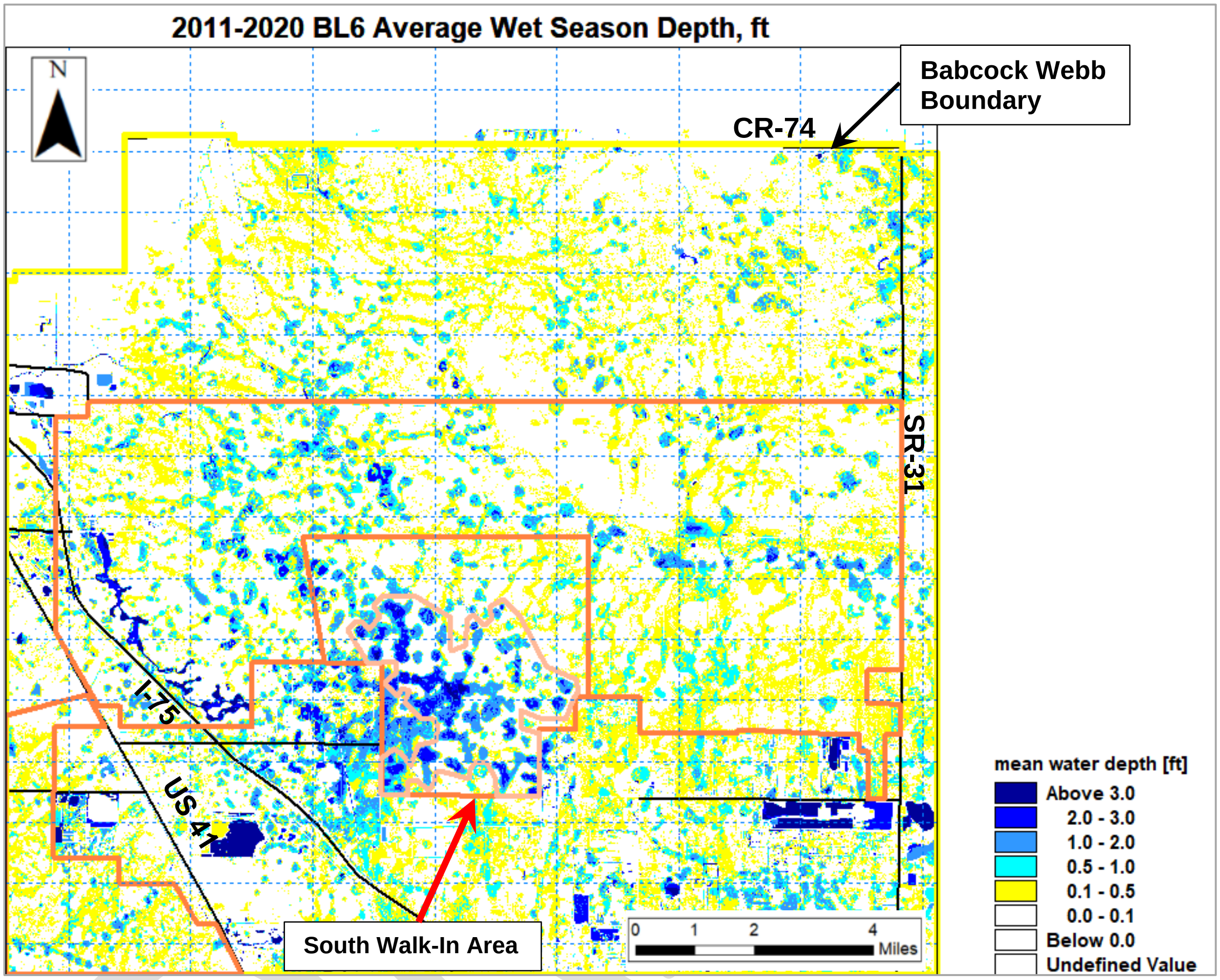


Figure 1-7. Mean water depth in Babcock Webb during the wet season (July 1 – Oct. 15) as predicted by the Existing Conditions Baseline Model during the period 2011-2020, at a 50-ft resolution.

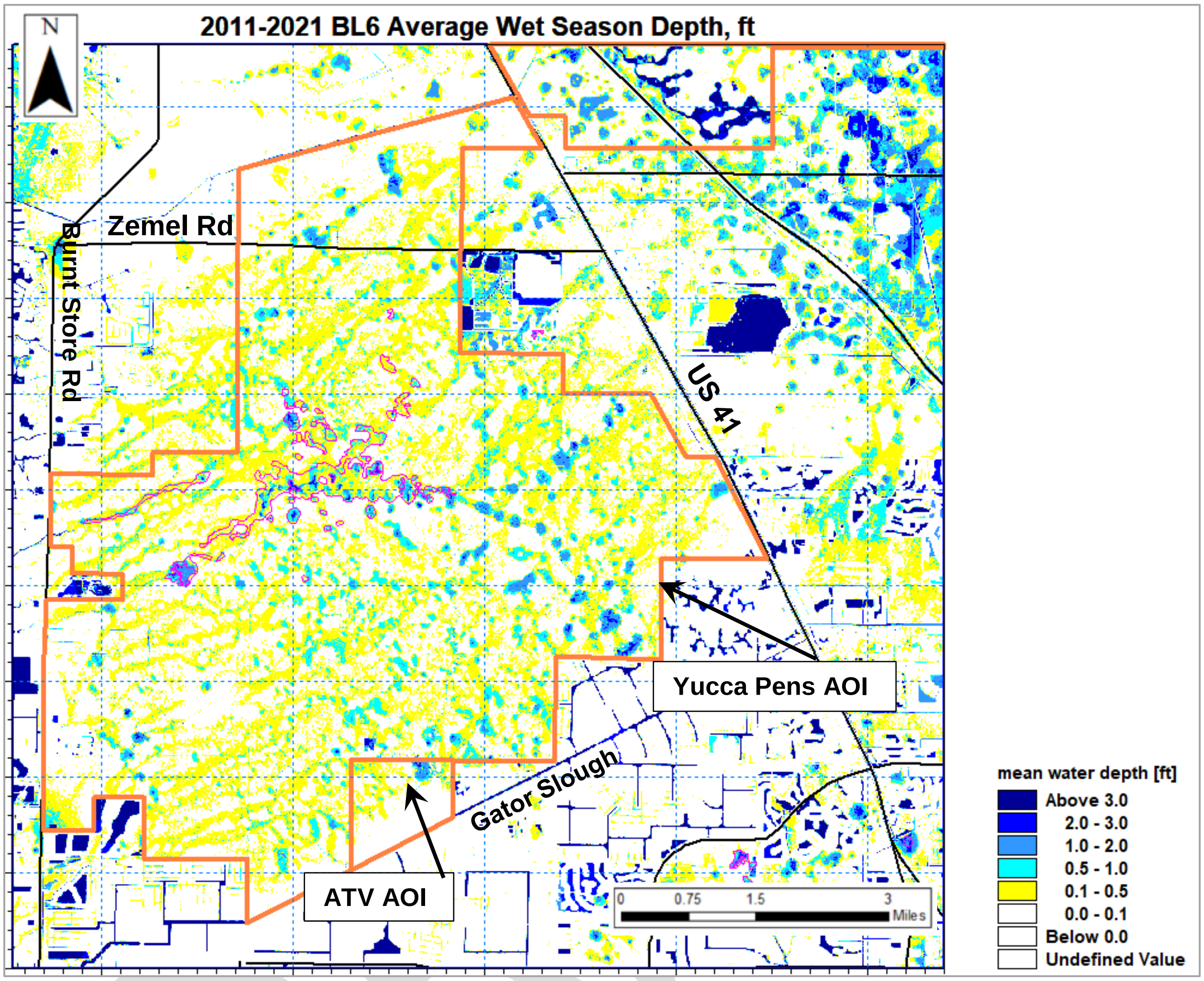


Figure 5-8. Mean water depth in Yucca Pens during the wet season (July 1 – Oct. 15) as predicted by the Existing Conditions Baseline Model during the period 2011-2020, at a 50-ft resolution.

6. NATURAL SYSTEMS ANALYSIS & FUTURE CONDITIONS MODELS

The project involved mapping and comparing natural pre-development conditions and comparing to current conditions to better understand management concerns. To address these management concerns, three potential future management/conditions scenarios were selected by stakeholders and modeled. Future Conditions Scenarios include restoration projects that are set to be completed in the near future (including Bond Farm hydrological restoration) as well as potential feasible projects that can be completed to address additional concerns. Those results were compared to the baseline existing conditions model results in order to form management recommendations which appear in the final section of this report.

The three future conditions scenarios include the following:

1. Scenario 1 models ATV channel blocks and low water fords in Yucca Pens to minimize excessive drainage caused by eroded all-terrain vehicle (ATV) trails. The Bond Farm Hydrologic Enhancement Impoundment (HEI) was programmed in Scenario 1 to store water pumped from the southwestern portion of Babcock Webb WMA during the wet season and to release water during the dry season. The initial conceptual restoration plan developed in 2014 (ADA, 2014) included a proposed flow-way from Bond Farm west to Yucca Pens with the intention that outflows would be released during the early part of the dry season (December and January) to extend hydroperiods in Yucca Pens. Scenario 1 did not include flow deliveries from Bond Farm to Yucca Pens so that Scenario 1 could clearly identify the hydroperiod benefits from reducing over-drainage of Yucca Pens via eroded ATV trails. In addition, securing property easements or purchasing a flow-way west of U.S. 41 was expected to be difficult. Therefore, Scenario 1 was designed to evaluate the positive and negative impacts of discharging water south under I-75 towards Prairie Pines Preserve in the dry season only. If the simulation does not indicate sufficient restoration in Yucca Pens, a groundwater seepage barrier will be added at the Gator Slough Canal. These projects were identified as high priority by stakeholders that were likely to be completed in the near future. If a limited response is seen in Babcock Webb and Yucca Pens key areas and management needs are not met, then Scenario 2 will model additional storage and other solutions.
2. As management needs for Babcock Webb and Yucca Pens were not met, Scenario 2 models Scenario 1 improvements plus additional storage for flooded areas of Babcock Webb in the Southwest Aggregates mine and a flow-way from Bond Farm to Yucca Pens for additional hydroperiod restoration in Yucca Pens.
3. Scenario 3 models Scenario 2 improvements along with future rainfall, evapotranspiration and sea level rise assumptions associated with climate change.

The following sub-sections of this section describe the results of the scenario analysis.

6.1 NATURAL SYSTEMS ANALYSIS

Pre-development Conditions. A GIS analysis was conducted to compare the results for the existing conditions model to a natural systems GIS shape file of optimum hydroperiods and average wet season water depths. Methodology is discussed in further detail later in this section. Kemmerer and Liebermann (2018) collated a group of 1953-vintage aerial photographs for the

Babcock Webb and Yucca Pens area and referenced the photographs to a horizontal datum using ArcGIS. A GIS soils database was then overlain on top of the aerial photos and was modified to create a map of hydrologic conditions, ranked from dry to wet (Kemmerer and Liebermann, 2018). The four hydrologic rank categories along with typical vegetation, hydroperiods, and average wet season depths from Duever and Roberts (2013) are listed below in **Table 6-1**. Pre-development wetland hydroperiods from Duever and Roberts (2013) are presented in **Figure 3-5**.

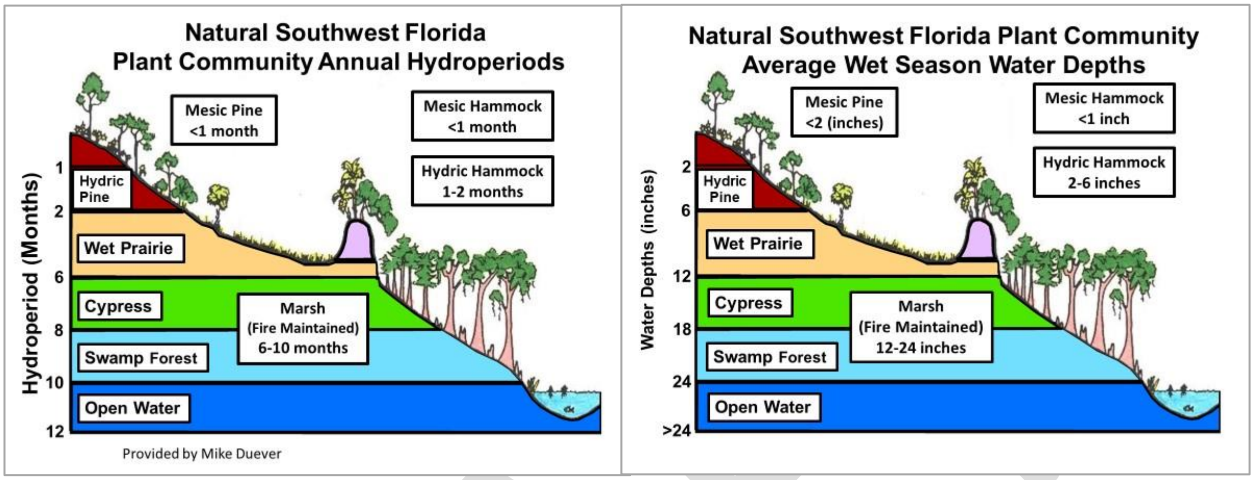


Figure 6-0. Optimum Wetland Hydroperiods and Average Wet Season Water Depths for South Florida Wetland Communities, Duever & Roberts (2013)

Table 6-1. Pre-Development Hydrologic Regimes (Duever and Roberts, 2013)

Rank	Hydrologic Condition	Typical Vegetation	Typical Hydroperiod, months	Typical Wet Season Depth, ft
1	Dry	Mesic Flatwoods	0-1	0
2	Slightly wet	Hydric Flatwoods	1-2	0.2 – 0.5
3	Moderately wet	Wet Prairie, Cypress, Marsh	2-6	0.5 – 0.8
4	Wet	Cypress, Marsh	6-10	1 - 2

A MIKE SHE/MIKE 11 natural systems model was not developed because flow patterns have been altered by man-made canals that have significantly re-aligned drainage basin divides and hydrologic conveyance. Modification of the existing conditions MIKE SHE/MIKE 11 model would have required many assumptions including extensive changes to the ground topography and an entirely new network of surface water conveyances. The changes were so significant that stakeholders agreed resulting hydrologic simulation outcomes would have a high level of uncertainty. Therefore at a CHFI meeting, partners made the decision to use a GIS analysis rather than development of a MIKE SHE/MIKE 11 model.

The mapped pre-development hydrologic ranks (established in Section 3) are presented in ***Figure 6-1***. Babcock Webb wetlands appear as a series of isolated wetlands connected by narrow flow-ways. The northern portion of Babcock Webb flows northwest towards what is now known as Myrtle Creek. A number of wide, moderately wet, flow-ways flow southwest from Babcock Webb toward Yucca Pens and the historic headwaters of Yellow Fever Creek. In addition, there is a wide flow-way to the south towards Powell Creek and Nalle Road (North Fort Myers). Yucca Pens wetlands appear as relatively narrow strands that flow west towards Burnt Store Road (see Durden Creek on ***Figure 6-1***). The southeastern portion of Yucca Pens flows south towards

Yellow Fever Creek, west towards Burnt Store Road (BSR), and west via a flow-way as artificially channelized by the Gator Slough canal.

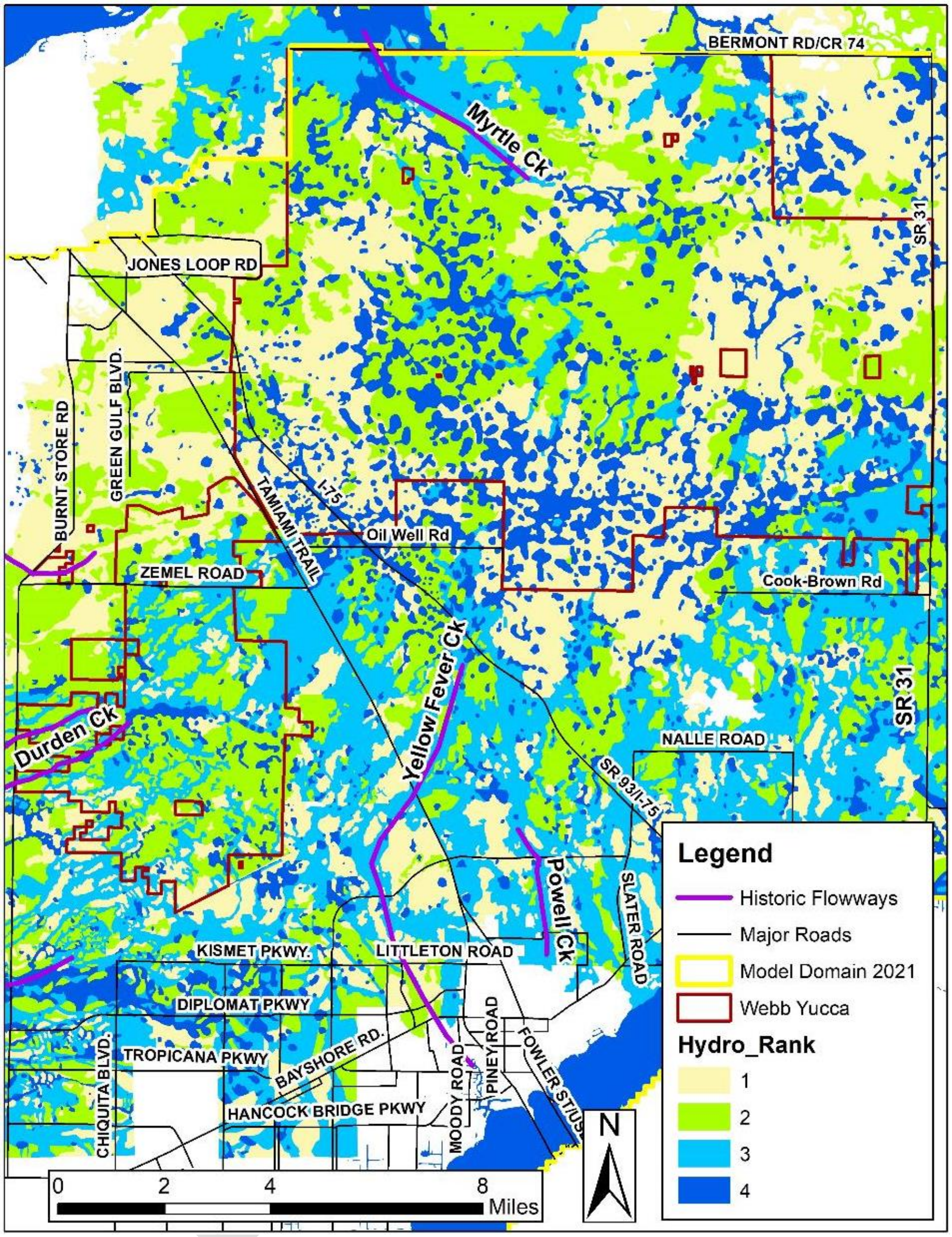


Figure 6-1. Pre-Development Hydrologic Ranks

Hydroperiods and Wet Season Water Depths. Key focal areas or Areas of Interest (AOI) were defined to assist in the comparison of simulated hydroperiods and water depths to historic hydrologic rank areas. All AOIs are discussed in detail in the Task 6A memorandum in Appendix 6A. This discussion will focus on hydroperiods and water depths in the South Walk-In Area (Reduced) in Babcock Webb, Yucca Pens Cypress, and Yucca Pens ATV AOIs as shown in ***Figure 6-2***. The South Walk-In Area (Reduced) AOI is an area of Babcock Webb with updated topography based on results from field surveys (discussed in Section 5 and Appendix 5D) and that reduced area is a further refinement of the South Walk-In Area. These three AOI's are discussed herein because these areas demonstrate the most significant hydrologic alterations compared to previously established optimum conditions and are the focus of the hydrologic restoration efforts evaluated as part of Scenarios 1, 2, and 3.

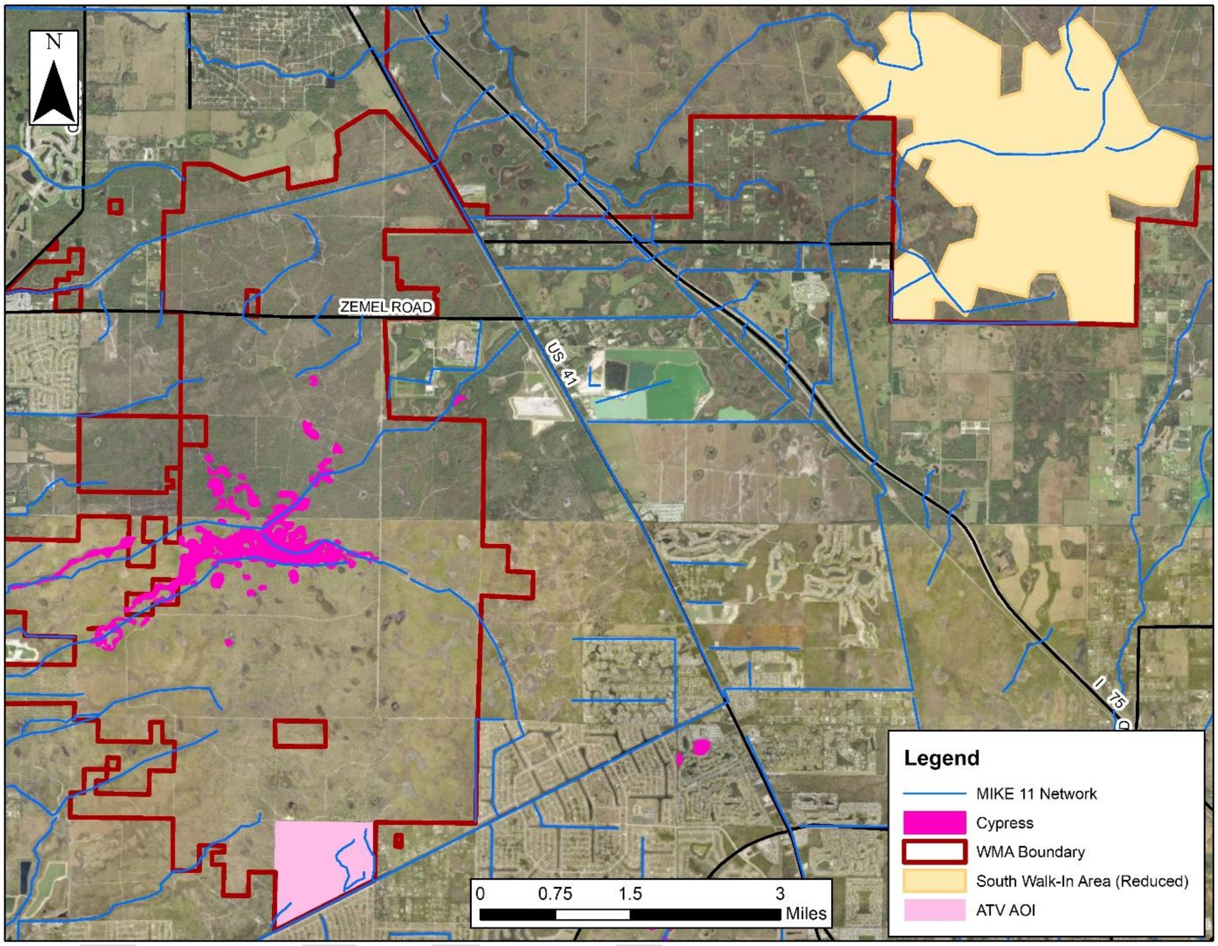


Figure 6-2. AOI's for Babcock Webb South Walk-In Area (Reduced), Yucca Pens Cypress, and Yucca Pens ATV

Expanded views of hydro rank classes for the Babcock Webb South Walk-In Area, Yucca Pens Cypress, and Yucca Pens ATV are shown below in **Figures 6-3** through **6-5**, respectively.

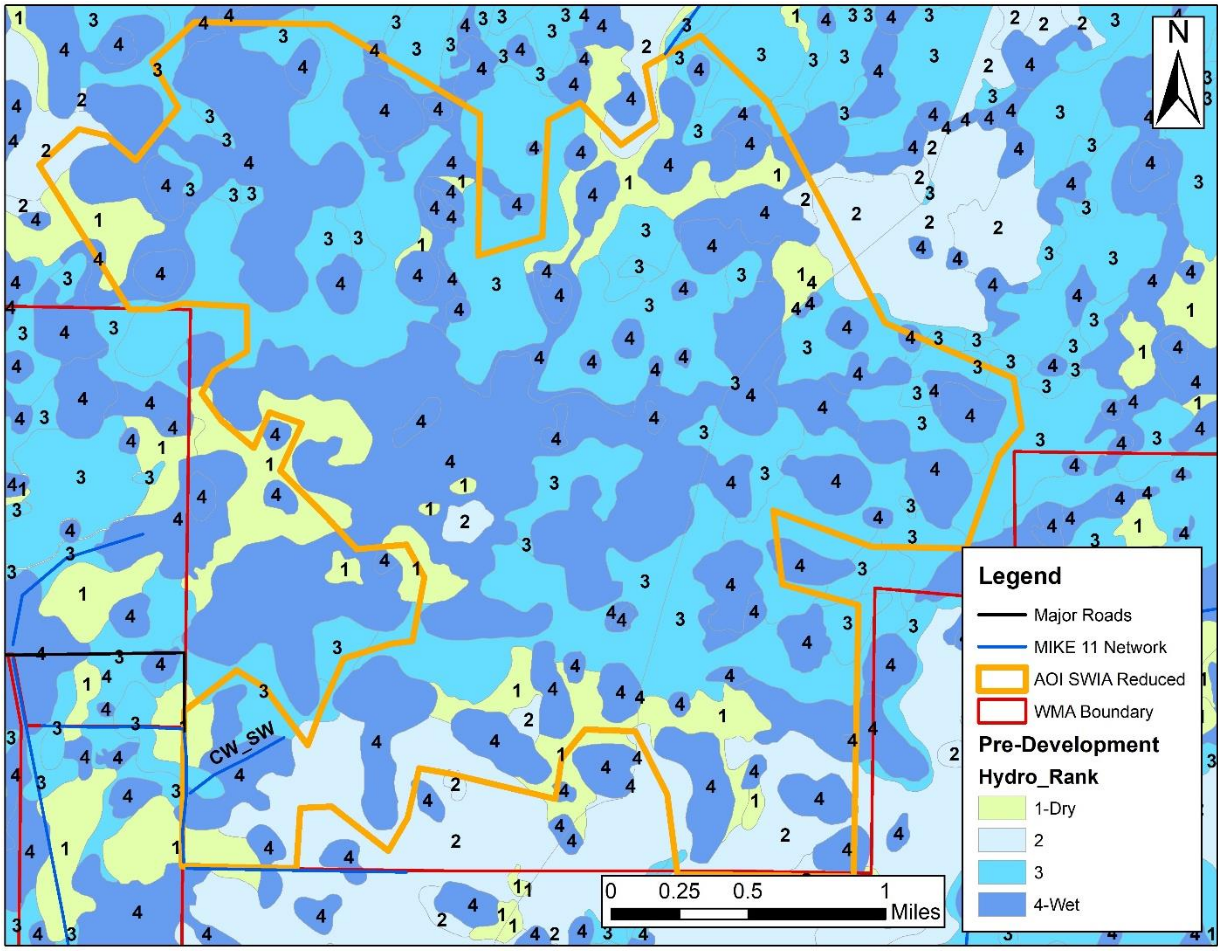


Figure 6-3. AOI for Babcock Webb South Walk-In Area (Reduced)

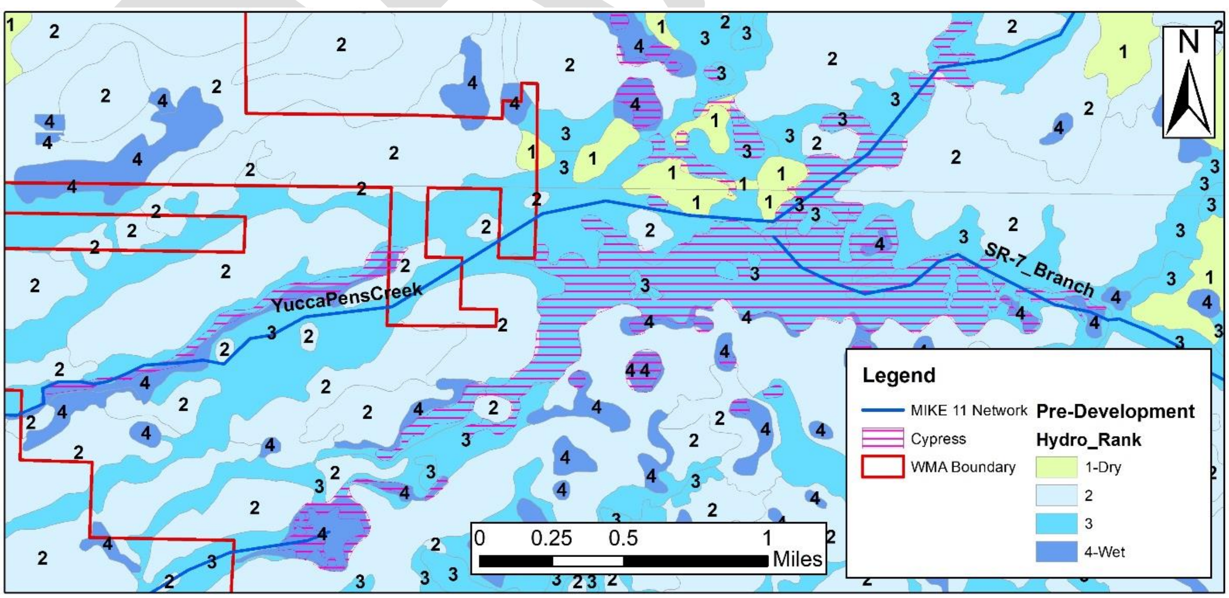


Figure 6-4. AOI for Yucca Pens Cypress

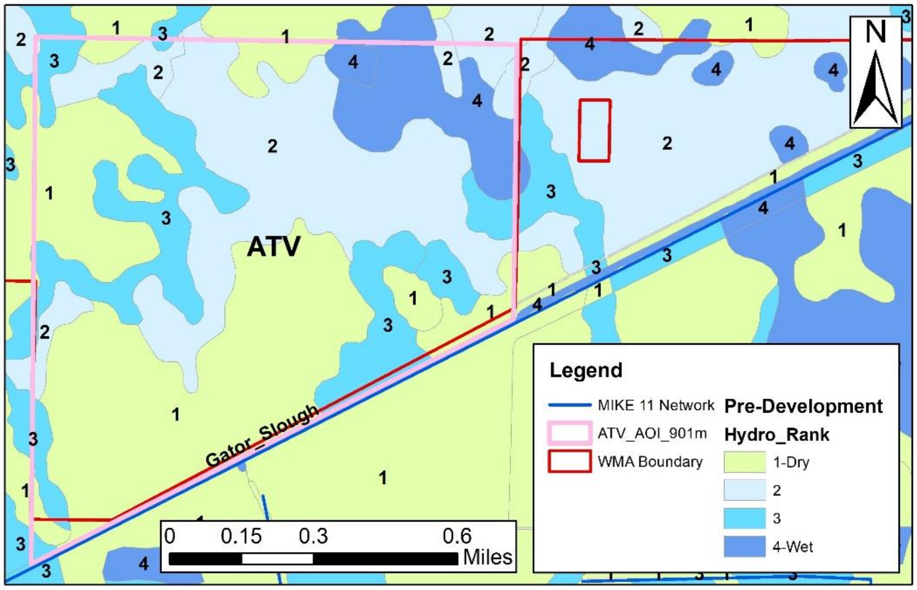


Figure 6-5. AOI for Yucca Pens ATV area

Simulated hydroperiods from the baseline existing conditions model outputs were compared to historic (pre-development) hydroperiods using the methodology summarized below:

- Converted the hydrologic rank shape file to a 50-ft resolution grid file. This is then compared with similar output files of simulated hydroperiods from baseline existing conditions model.
- In each selected Area of Interest (AOI), the simulated hydroperiod value was matched to the corresponding Hydrologic Rank.
- Histograms are made to compare the distribution of hydroperiod values among Hydrologic Ranks inside each AOI.
- This same procedure was also used for average wet season water depths.

Hydroperiod histogram results are presented in **Figures 6-6** through **6-8**. General observations are summarized below:

- Hydro rank 4 for the South Walk-In Area (Reduced) have simulated hydroperiods that most commonly are greater than 10 months. The optimum hydroperiod for these wetland areas (hydro rank 4) is 6 to 10 months. This means that the hydroperiod in this AOI is longer than optimum for even the wettest habitats.
- The Cypress area of Yucca Pens simulated hydroperiods for hydro rank 3 and 4 are most commonly 5.5 and 6 months. The optimum hydroperiod for cypress (hydro rank 4) should be 6 to 8 months. This means that the hydroperiod in this AOI is shorter than optimum for these cypress wetlands.
- The ATV area of Yucca Pens simulated hydroperiods for hydro rank 3 are commonly in the range of 4 to 5 months. The optimum hydroperiod for these wet prairies (hydro rank 3) should be 2 to 6 months. This means that the hydroperiod in this AOI is shorter than optimum for these wet prairies.

Note for hydroperiod histograms below:

- light blue bar is the optimum hydroperiod for hydro rank 3
- dark blue bar is the optimum hydroperiod for hydro rank 4

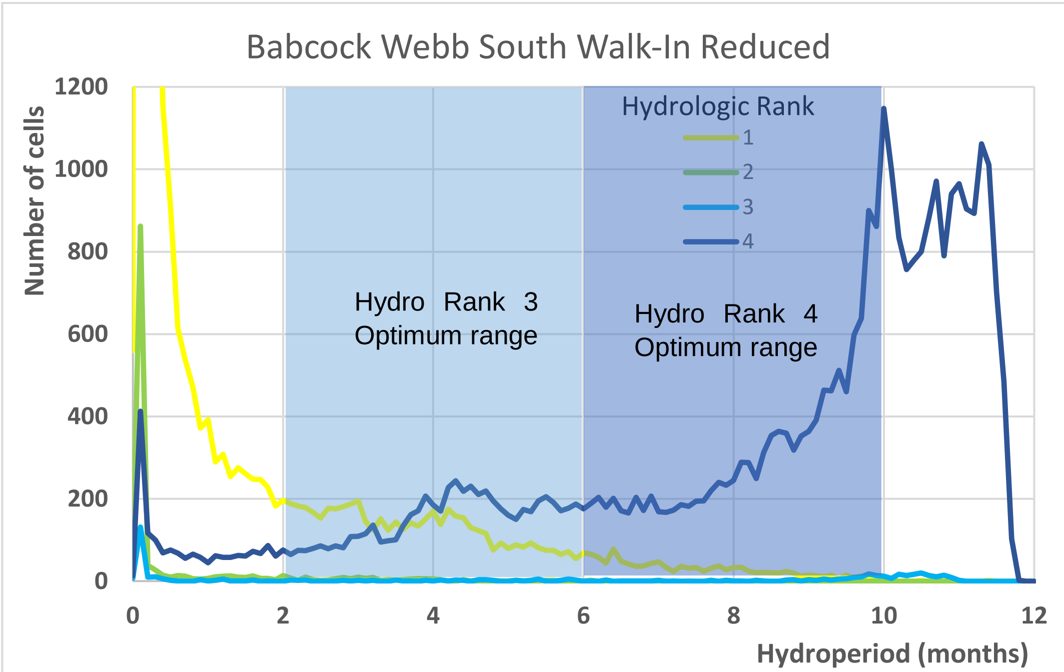


Figure 6-6. Hydroperiod Histogram for Babcock Webb South Walk-In Area (Reduced)

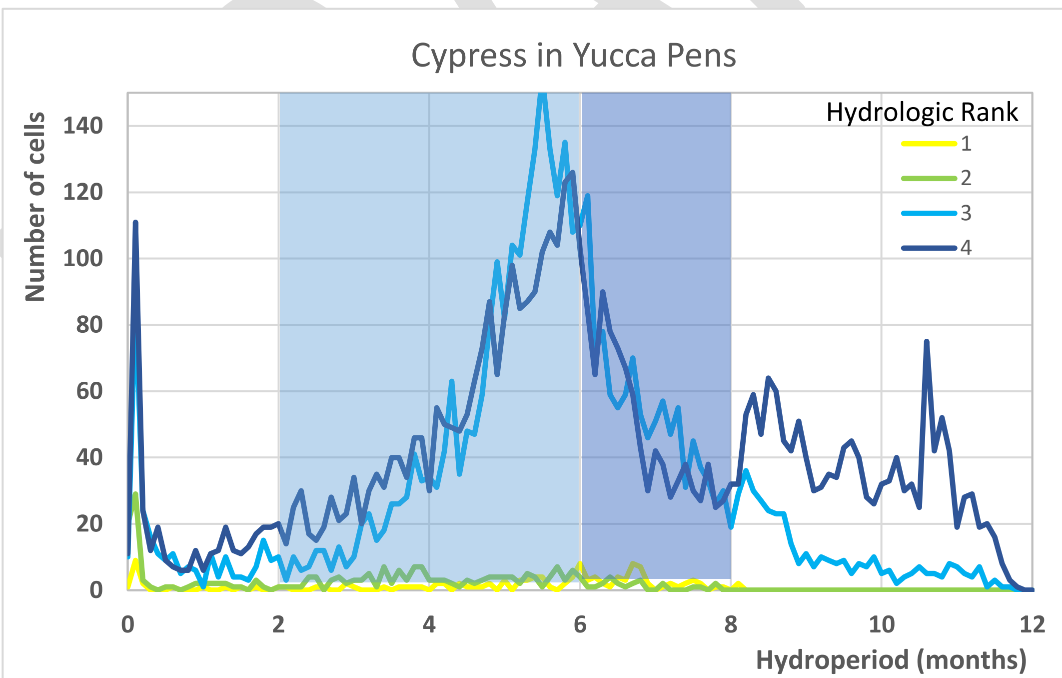


Figure 6-7. Hydroperiod Histogram for Yucca Pens Cypress

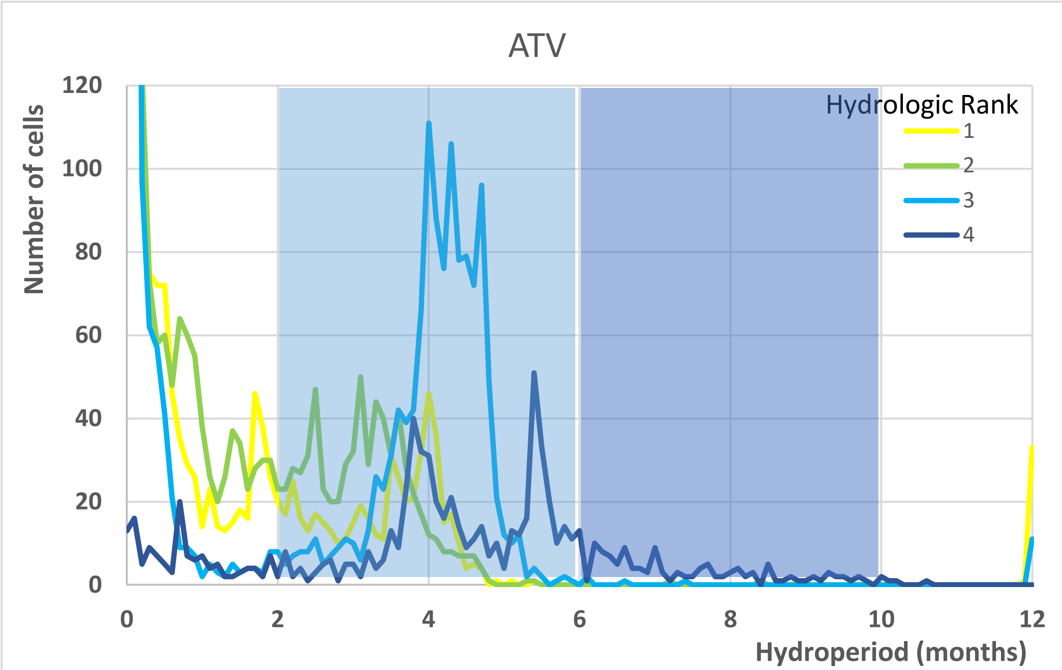


Figure 6-8. Hydroperiod Histogram for Yucca Pens ATV

Water depth histograms are presented in **Figures 6-9** through **6-11**. Observations are summarized below:

- For Babcock Webb South Walk-In (Reduced), the most common simulated depths for hydro rank 4 range from approximately 1.5 ft to 2.5 feet, which is too wet (hydro rank 4 optimum depth range is 1 to 2 feet).
- The most common simulated depths for hydro rank 3 for Cypress in Yucca Pens and the ATV area are less than 0.5 feet, which is too dry (hydro rank 3 optimum depth range is 0.5 – 0.8 feet)
- The most common simulated depths for hydro rank 4 for Cypress in Yucca Pens and the ATV area are less than 1 foot, which is too dry (hydro rank 4 optimum depth range is 1 to 2 feet).

The histogram analysis confirms the findings of the ecologic analysis in Section 3, and the water level findings in Section 4, which is that there is too much water in the South Walk-In Area, and more water is needed in Yucca Pens Cypress and the southern Yucca Pens ATV AOI. These results guided the alternatives analysis for Scenarios 1, 2, and 3.

Note for water depth histograms below:

- light blue bar is the optimum depth range for hydro rank 3
- dark blue bar is the optimum depth range for hydro rank 4

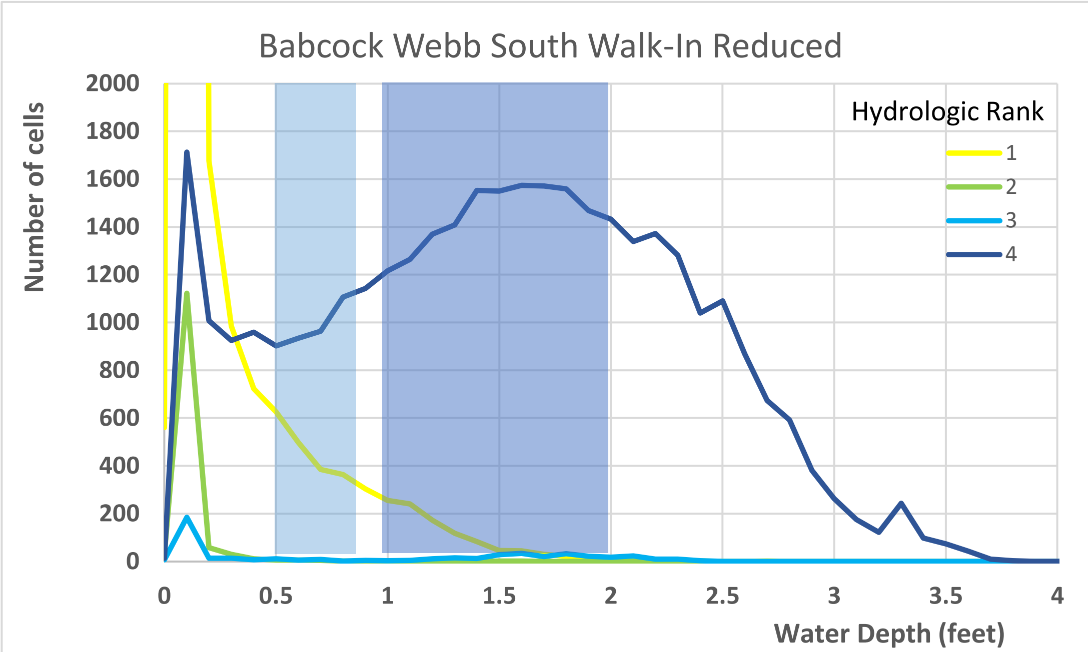


Figure 6-9. Wet Season Water Depth Histogram for Babcock Webb South Walk-In Area (Reduced)

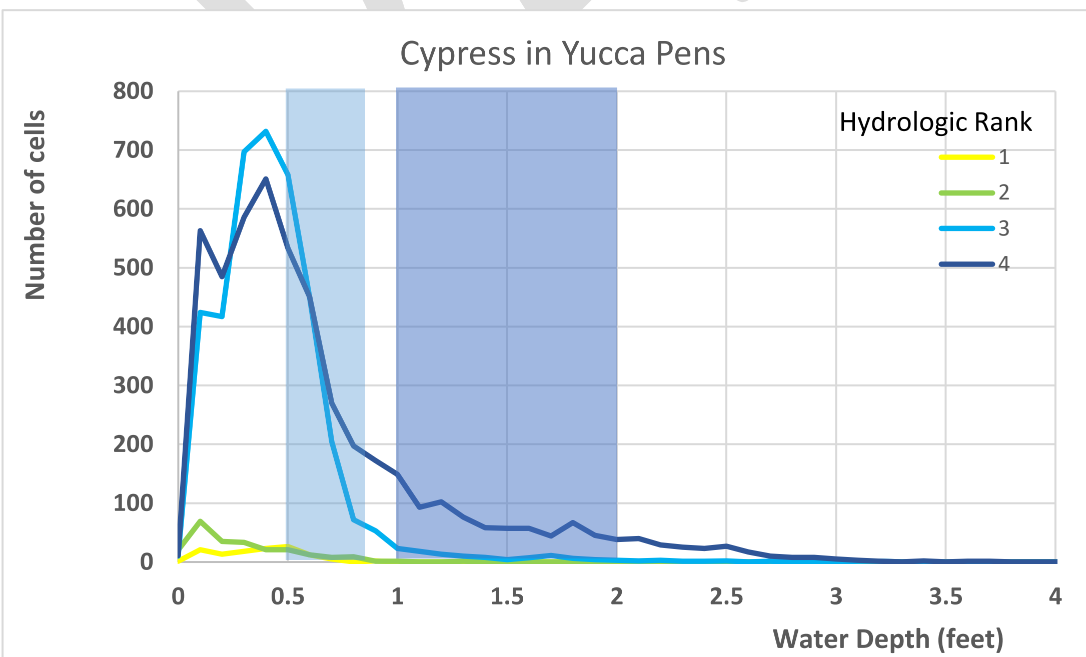


Figure 6-10. Wet Season Water Depth Histogram for Yucca Pens Cypress

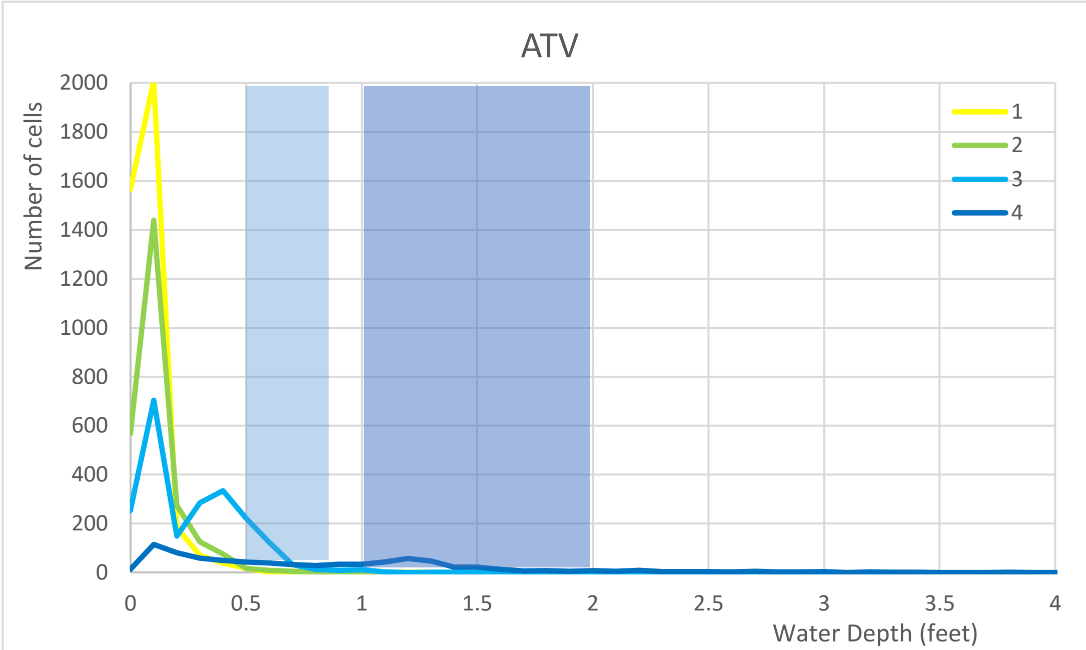


Figure 6-11. Wet Season Water Depth Histogram for Yucca Pens ATV

6.2 FUTURE CONDITIONS SCENARIO 1

Scenario 1 models ATV channel blocks and low water fords in Yucca Pens to minimize excessive drainage caused by eroded all-terrain vehicle (ATV) trails, The Bond Farm Hydrologic Enhancement Impoundment (HEI) was programmed in Scenario 1 to store water pumped from the southwestern portion of Babcock Webb WMA during the wet season and to release water during the dry season. The initial conceptual restoration plan developed in 2014 (ADA, 2014) included a proposed flow-way from Bond Farm west to Yucca Pens with the intention that outflows would be released during the early part of the dry season (December and January) to extend hydroperiods in Yucca Pens. Scenario 1 did not include flow deliveries from Bond Farm to Yucca Pens so that Scenario 1 could clearly identify the hydroperiod benefits from reducing over-drainage of Yucca Pens via eroded ATV trails. In addition, securing property easements or purchasing a flow-way west of U.S. 41 was expected to be difficult. Therefore, Scenario 1 was designed to evaluate the positive and negative impacts of discharging water south under I-75 towards Prairie Pines Preserve in the dry season only. If the simulation does not indicate sufficient restoration in Yucca Pens, a groundwater seepage barrier will be added at the Gator Slough Canal. These projects were identified as high priority by stakeholders that were likely to be completed in the near future. If a limited response is seen in Babcock Webb and Yucca Pens key areas and management needs are not met, then Scenario 2 will model additional storage and other solutions.

During the development of Scenario 1, the following assumptions were made:

1. The Bond Farm HEI will have a maximum storage depth of 4 feet, which translates to a storage volume of 2,400 acre-feet.
2. The Bond Farm HEI inflow pump station will be located on the east side of Bond Farm approximately 1,300 feet south of the northern property line of Bond Farm (locations shown in **Figure 6-12**).

3. The Bond Farm HEI inflow pump station operation will gradually increase from no flow (0 cfs) to 20 cfs between upstream stages of 24.5 and 25 ft-NAVD. No flow will be permitted if water levels within the impoundment are above 28 ft-NAVD. The pump will only operate between June and November (wet season).
4. The Bond Farm HEI outflow will be directed south towards Prairie Pines Preserve (PPP) at a constant flow of 20 cfs during the early part of the dry season in December and January. No outflow will be permitted during the wet season unless a major storm event is anticipated. If discharges south to PPP are ultimately the recommended route, the period of discharges and the discharge rate should be based on optimal hydroperiod conditions in PPP and flow augmentation needs during the dry season in the ultimate receiving waters (Caloosahatchee Estuary or Gator Slough) without reducing flood protection to nearby or downstream communities.

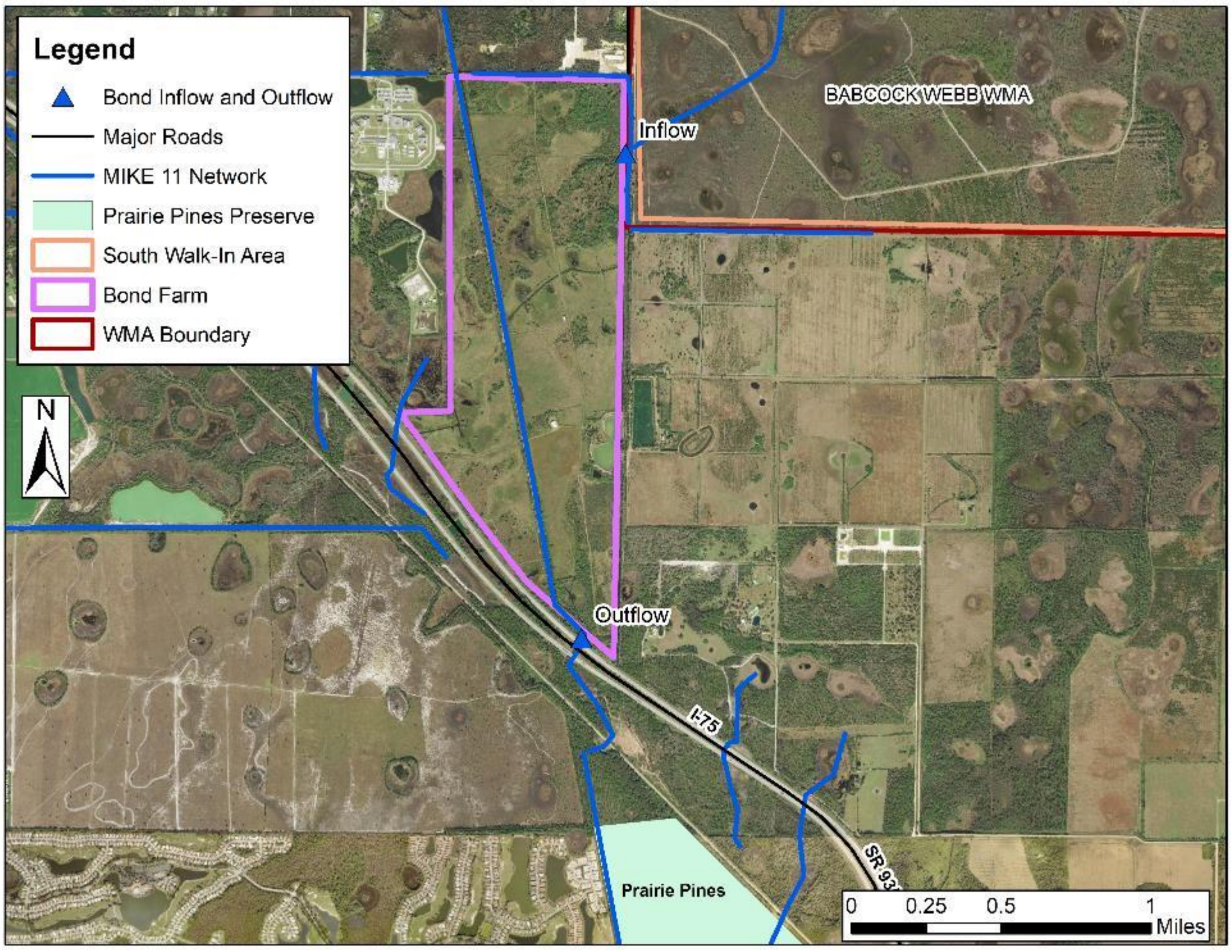


Figure 6-12. Bond Farm Hydrologic Enhancement Project

5. A number of weirs representing either low-water fords or constructed weirs were added in Yucca Pens. Locations are presented in **Figure 6-13**. Additional information is provided in the Task 6B memorandum (see **Appendix 6B**).
6. Isolated wetlands on Yucca Pens that are drained by existing ATV trails will be restored with small ATV channel blocks to increase detention. The location of those identified isolated wetlands is presented in **Figure 6-13**.
7. Initial testing of ATV channel blocks in south Yucca Pens indicated that higher groundwater

levels as a result of the increased detention was resulting in higher groundwater elevations in private lands west of southern Yucca Pens (see **Figure 6-14** for location of the private lands). As a result, a seepage barrier was included in the model along the southern portion of Yucca Pens as shown in **Figure 6-14**. The seepage barrier will be created by drilling bore holes at a predefined spacing (e.g. 10 feet) and backfilling the bore hole with concrete, which will move away from the borehole through permeable rock that will form a partial flow barrier. Additional information is presented in the Task 6B memorandum (see Appendix 6B).

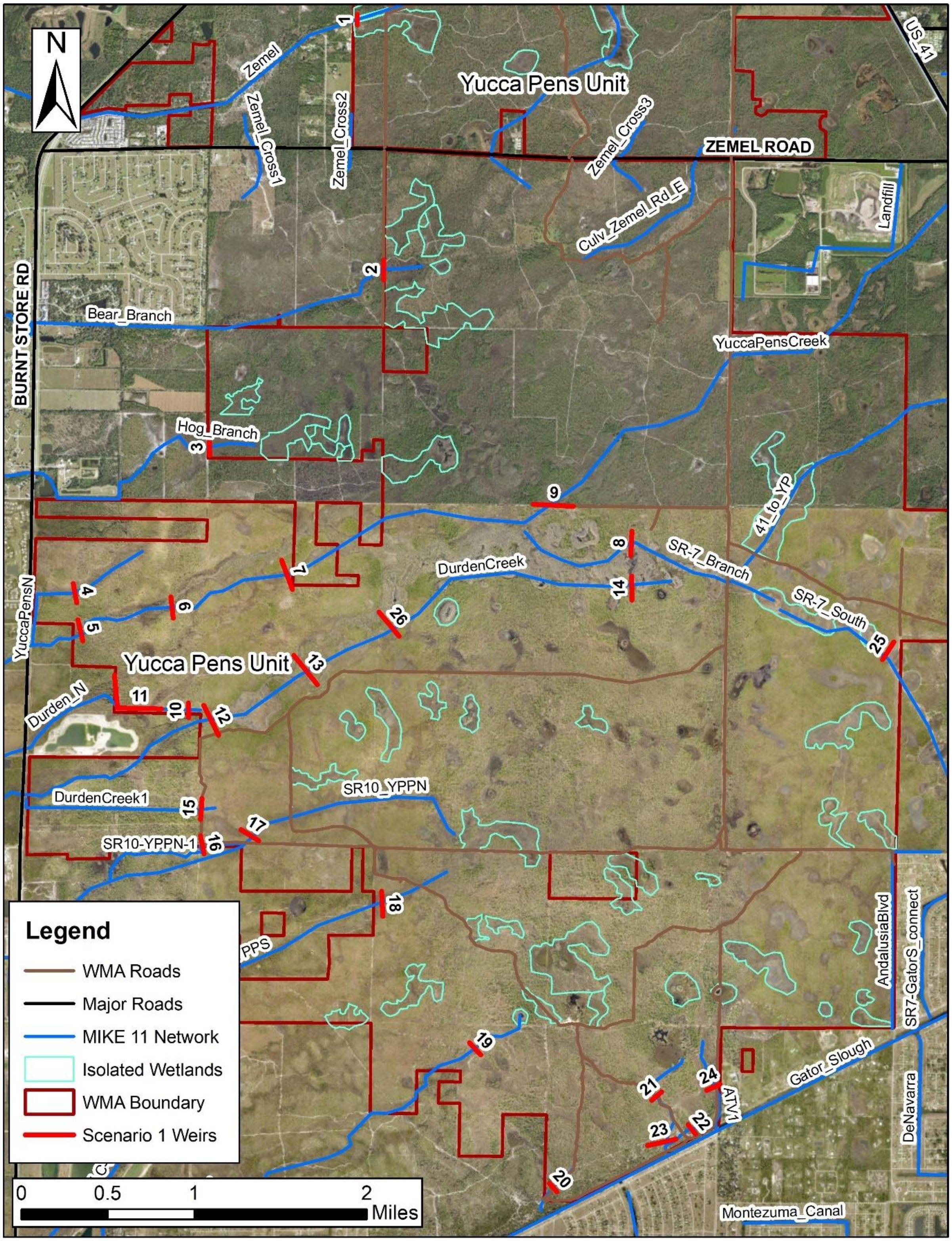


Figure 6-13. Map of Proposed Weirs/Low Water Fords in Yucca Pens

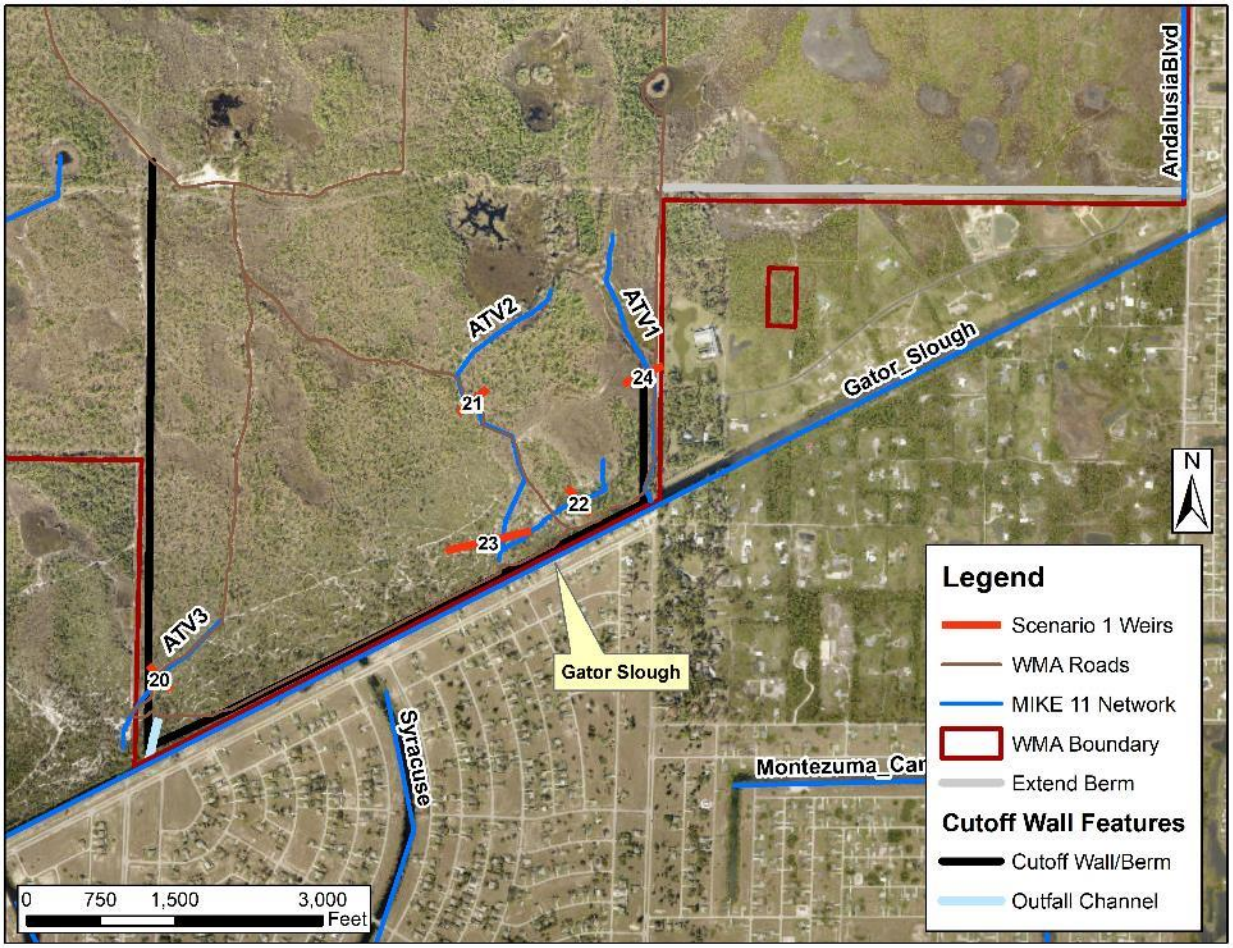


Figure 6-14. Restoration Measures in South Yucca Pens

Scenario 1 Results. Scenario 1 resulted in improved wetland hydroperiods and water depths in Yucca Pens, as shown in **Figure 6-15**, **6-16** and **6-17**. Quantitative summaries of the Scenario 1 changes are presented below in **Table 6-2**. Although specific quantitative acreage targets were not identified as a project goal, acreage totals are presented below in order to further demonstrate hydrologic restoration. Hydroperiod increases of greater than one month are predicted for 2,568 acres of Yucca Pens. Water table levels in March and April (end of dry season) are predicted to be greater than 1 foot for 411 acres and to increase by more than 0.25 feet for 4,229 acres. Scenario 1 did not have any beneficial impacts on wetland hydroperiods and only minor water level changes in the South Walk-In Area of Babcock Webb.

Table 6-2. Summary of Scenario 1 Hydroperiod and March – April Water Level Improvements in Yucca Pens

Hydroperiod Difference	Area, ac.	Avg months
>2 months	863	2.77
1 - 2 months	1,705	1.4
0.5 - 1 months	2,517	0.72
0.25 - 0.5 months	5,956	0.24
Water Level Difference	**Area, ac.**	**Avg, ft**
> 1.5 ft	131	1.66
1 - 1.5 ft	279	1.24
0.5 - 1 ft	838	0.65
0.25 - 0.5 ft	3,091	0.34
0.1 - 0.25 ft	8,403	0.16

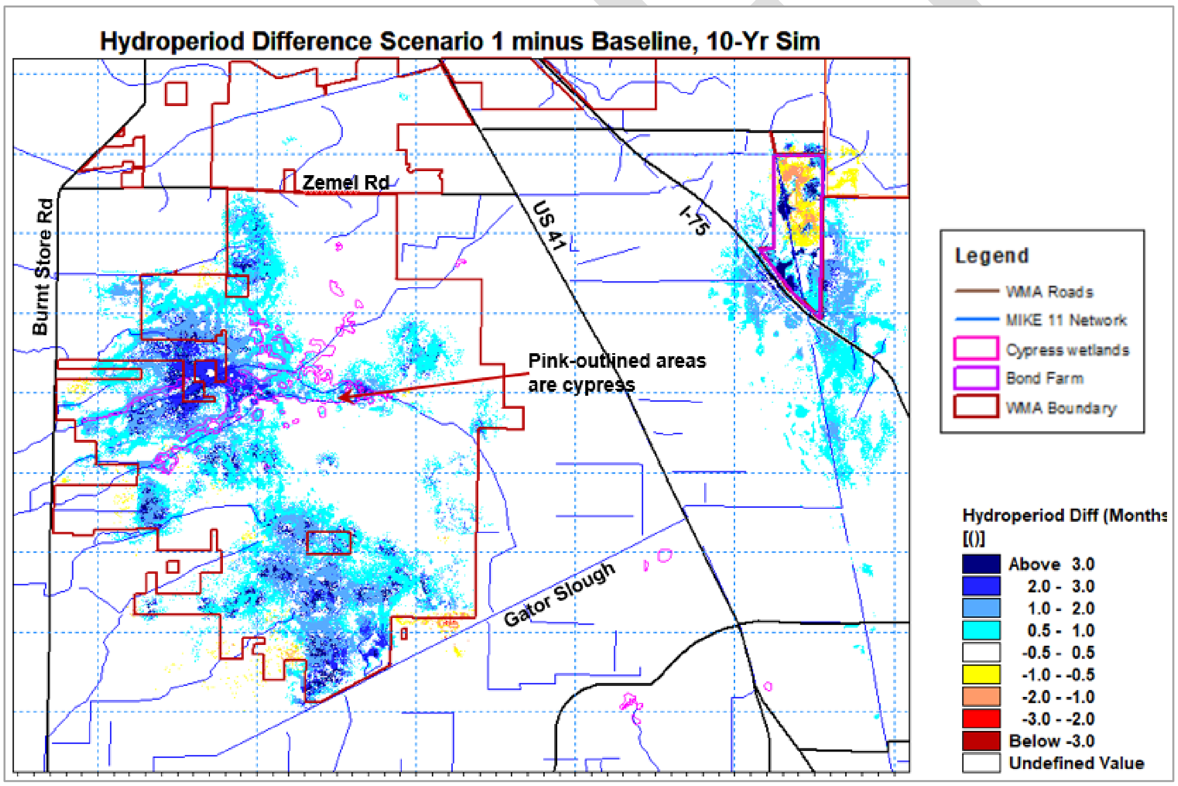


Figure 6-15. Scenario 1 minus Baseline average annual hydroperiod difference at a 50-ft resolution during the period 2012-2021

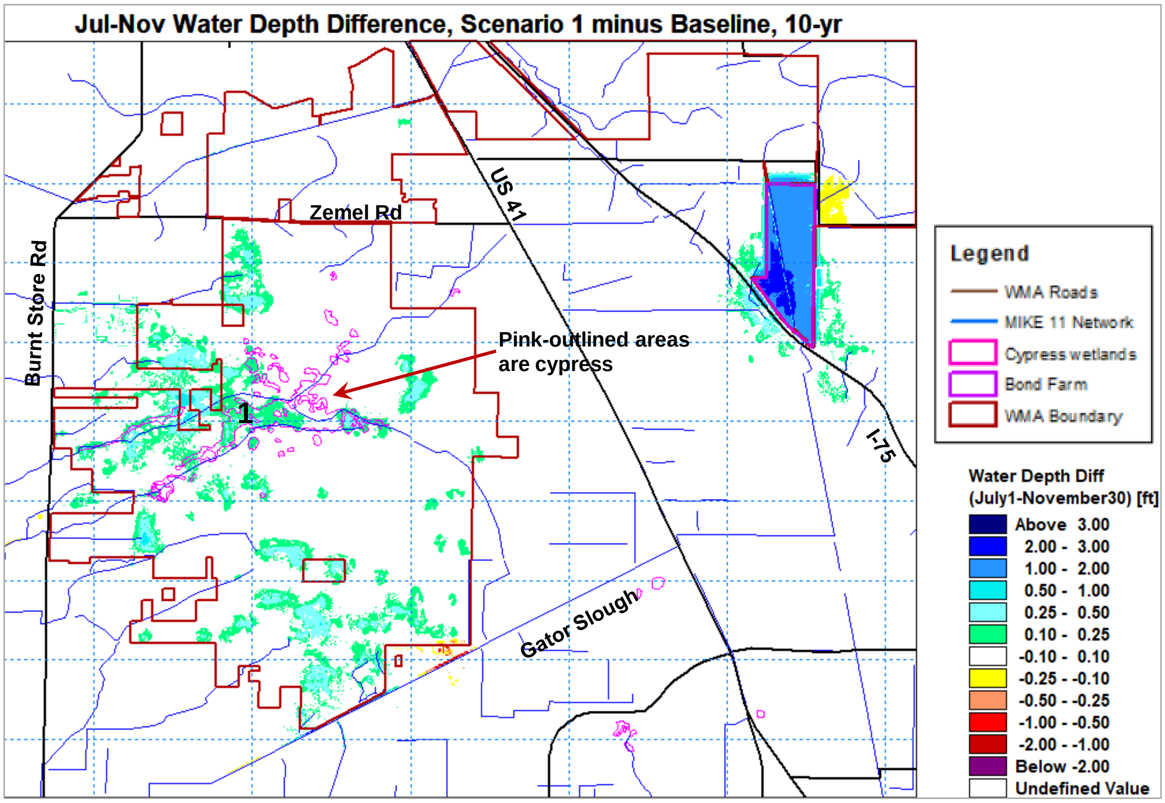


Figure 6-16. Scenario 1 minus Baseline average water depth differences for the wet season (July 1 – November 30) during the period 2012-2020

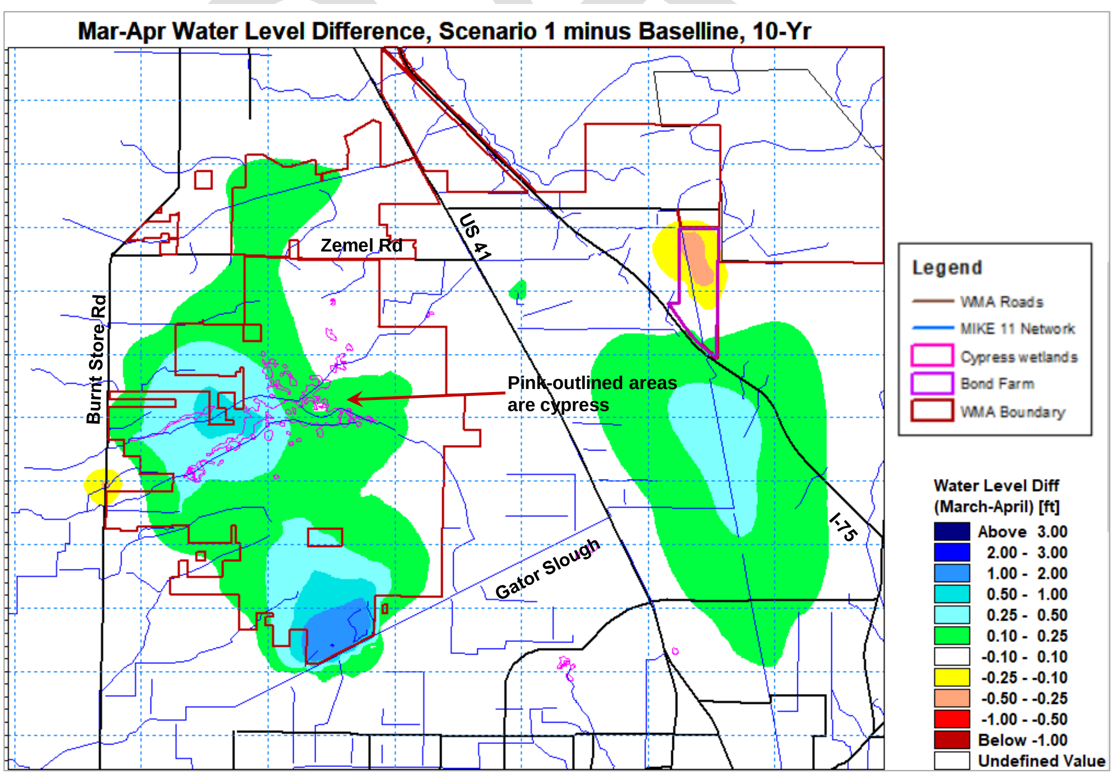


Figure 6-17. Scenario 1 minus Baseline water table level difference during the dry season months of March - April during the period 2012 – 2021

To evaluate the performance of Scenario 1, simulated Scenario 1 results were compared to the Baseline existing condition results for hydrologic ranks 3 and 4. Comparisons are presented for Yucca Pens Cypress and ATV AOIs for hydro rank levels 3 and 4 in **Figure 6-18** histograms.

The most common hydroperiod in Yucca Pens Cypress Hydro Rank 3 was approximately 5.5 months for the Baseline existing condition scenario, while the distribution of hydroperiods for Scenario 1 was wider with peaks at 5.6 months and 7.7 months. The optimum hydroperiod for cypress in hydro rank 3 should be 2 to 6 months. This means that the hydroperiod range in this AOI is now closer to optimum conditions for these cypress wetlands.

The Cypress Hydro Rank 4 Baseline most common hydroperiod was 5.9 months, and increased in Scenario 1 to 8.9 and 10.8 months in some areas. The optimum hydroperiod range for cypress in hydro rank 4 should be 6 to 10 months. This means that the hydroperiod range in this AOI is now closer to optimum conditions for these cypress wetlands.

The most common hydroperiod in Yucca Pens ATV Hydro Rank 3 was approximately 4.5 months for the Baseline existing condition scenario, while the distribution of hydroperiods for Scenario 1 increased to 6.3 months. Again, the optimum hydroperiod range for hydro rank 3 should be 2 to 6 months. This means that the hydroperiod range in this AOI is now closer to optimum conditions for these wetlands. The ATV Hydro Rank 4 Baseline common hydroperiods were at 3.9 and 5.7 months. The Scenario 1 most common hydroperiod was 4.9 to 9 months

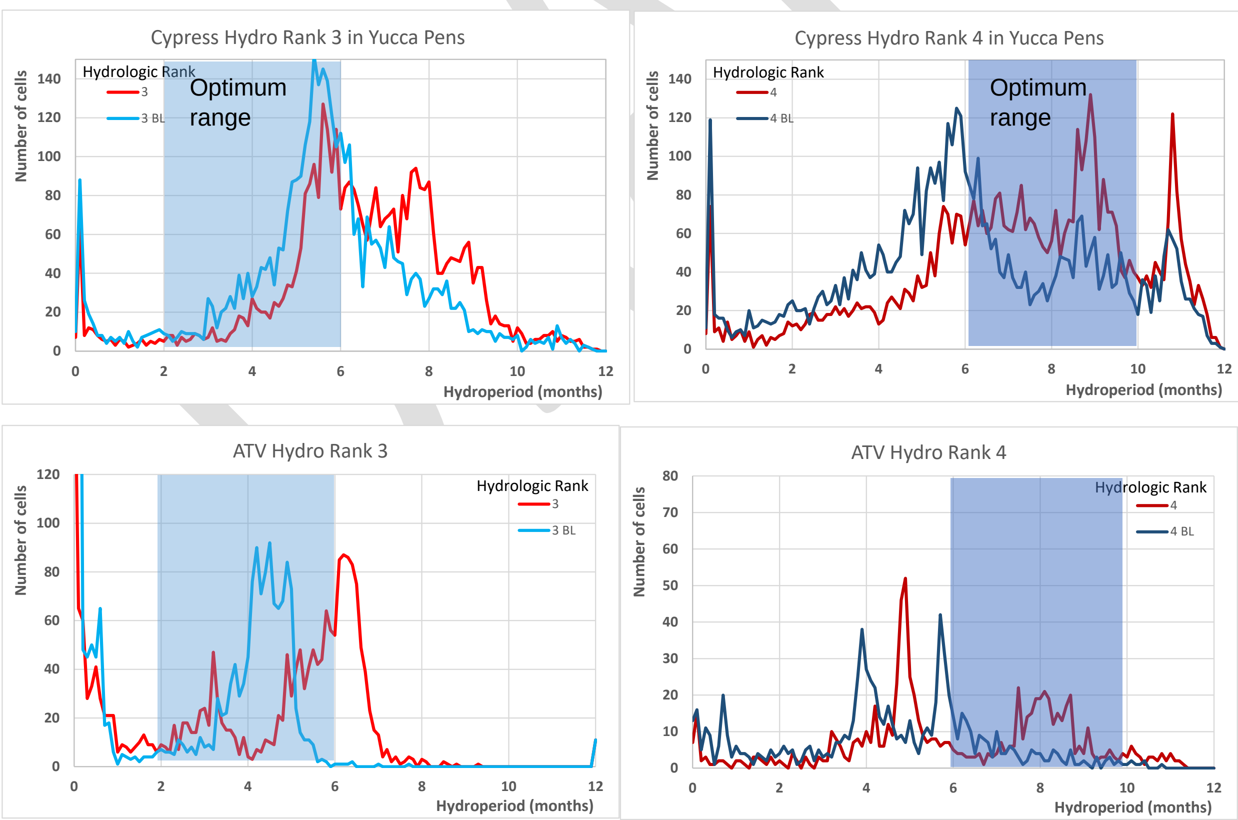


Figure 6-18. Scenario 1 and Baseline Hydro Rank 3 & 4 Hydroperiods for Yucca Pens Cypress and ATV AOIs

The Bond Farm HEI was programmed in Scenario 1 to store water pumped from the southwestern portion of Babcock Webb Wildlife Management Area (WMA) during the wet season and to release water during the dry season. The initial conceptual restoration plan developed in 2014 (ADA, 2014) included a proposed flow-way from Bond Farm west to Yucca Pens with the intention that outflows would be released during the early part of the dry season (December and January) to extend hydroperiods in Yucca Pens. Scenario 1 did not include flow deliveries from Bond Farm to Yucca Pens so that Scenario 1 could clearly identify the hydroperiod benefits from reducing over-drainage of Yucca Pens via eroded ATV trails. In addition, securing property easements or purchasing a flow-way west of U.S. 41 was expected to be difficult. Therefore, Scenario 1 was designed to evaluate the positive and negative impacts of discharging water south under I-75 towards Prairie Pines Preserve in the dry season only (location shown in **Figure 6-15**). Since a portion of the water discharged from Bond Farm HEI to the south ultimately would flow during the early dry season towards the Caloosahatchee River estuary via Powell Creek, these flows could have a beneficial impact on restoration of the salinity regime in the Caloosahatchee estuary.

The Scenario 1 simulated inflows and outflows for Bond Farm during the period of 2012 – 2021 are summarized below in **Table 6-3**. Outflows are less than 50% of inflows for the original calibrated model (assumed lower water table hydraulic conductivity in Bond Farm only). The majority of the losses (i.e., difference between inflows and outflows) are due to groundwater seepage. **Table 6-3** also presents results for a simulation with water table horizontal hydraulic conductivities around Bond Farm capped at 297 ft/day (see **Exhibit 1** for discussion of Scenario 1 analysis using the Reduced Hydraulic Conductivity model files). That simulation indicates lower overall losses to groundwater. Simulated outflows in year 2013 were 81% of simulated inflows for the reduced hydraulic conductivity simulation.

Table 6-3. Simulated annual inflows and outflows from Bond Farm HEI

	Original Calibration		Reduced Hydraulic Conductivity	
Period	**Inflow, Ac-ft**	**Outflow, Ac-ft**	**Inflow, Ac-ft**	**Outflow, Ac-ft**
10-yr Avg	4,080	1,528	2,842	1,877
Year 2013	3,675	1,313	2,183	1,762

Note: original calibration model described in Task 5c memorandum in Appendix 5C (WSA & CHNEP, 2022b). Reduced hydraulic conductivity simulations changed any horizontal hydraulic conductivity values greater than 297 ft/day to 297 ft/day.

Flows from Yucca Pens area tidal creeks under Burnt Store Road (Greenwell Branch, Durden Creek, Yucca Pens Creek, and Hog Branch) for Scenario 1 are less than they are for the Baseline condition scenario, and the recession limb of the flow after each storm event has been extended due to the restoration measures. One example of this is the ATV ditch blocks which slow flow out of Yucca Pens wetland areas and help retain water. This essentially demonstrates that flashiness in streams is reduced so that there is more moderate flow in these streams rather than extreme high and low flow events. The average reduction in peak flows for 74 modeled rain or storm events over the 10-year period was 15% (25th percentile = 8%, 75th percentile = 22%). Scenario 1 combined flow discharges under Burnt Store Road from Greenwell Branch to Hog Branch also showed that slowing of water leaving Yucca Pens did not reduce flows during the early dry season period of November 1 through January 31.

Summary of Scenario 1 Results. Scenario 1 assumed that the Bond Farm Hydrological Enhancement Impoundment (HEI) would be used to store water up to a depth of 4 feet with water discharged south through Prairie Pines Preserve only during the early dry season. Scenario 1 also assumed addition of 25 weir-structures in Yucca Pens to increase on-site detention in the historic wetlands of Yucca Pens. Such structures will include, but not be limited to, ditch blocks in eroded ATV trails, low water fords, and concrete weirs. The design details at each of the proposed weir locations will be determined during subsequent design studies. Scenario 1 also includes a seepage barrier along the southern portion of Yucca Pens just north of Gator Slough. At this point, it is anticipated that this seepage barrier will not be a complete barrier to groundwater flow, but it will reduce seepage rates to the degree that hydroperiods are increased in Yucca Pens wetlands north of Gator Slough.

The Scenario 1 analysis indicated that changes to hydroperiods and water depths in the Babcock Webb South Walk-In Area northeast of Bond Farm would be minor. This finding is substantiated by the hydroperiod difference map shown in **Figure 6-15**, the wet season water depth difference map in **Figure 6-16**, the quantitative analysis presented in **Table 6-2**, and the histogram analysis presented in **Figure 6-18**. Additional storage will be needed to accomplish this restoration goal, which will be explored further as part of the Scenario 2 analysis.

Yucca Pens hydroperiods and dry season water table levels will increase because of the proposed restoration measures described above. Hydroperiod increases of greater than 1 month are predicted for 2,568 acres of Yucca Pens. Water table levels in March and April are predicted to be greater than 1 foot for 411 acres, and water depths are predicted to increase by more than 0.25 feet for 4,229 acres. Histogram analysis predicted hydroperiod improvements in the Yucca Pens Cypress and ATV areas (see **Figure 6-18**).

Flows from Yucca Pens tidal creeks under Burnt Store Road (Greenwell Branch, Durden Creek, Yucca Pens Creek, and Hog Branch) for Scenario 1 are less than the flow for the Baseline condition scenario, and the recession limb of the flow after each storm event has been extended due to the restoration measures.

6.3 FUTURE CONDITIONS SCENARIO 2

Scenario 2 was a refinement of Scenario 1. As management needs for Babcock Webb and Yucca Pens were not met, Scenario 2 models Scenario 1 improvements plus additional storage for flooded areas of Babcock Webb in the Southwest Aggregates mine and a flow-way from Bond Farm to Yucca Pens for additional hydroperiod restoration in Yucca Pens. Most elements of Scenario 1 are retained in Scenario 2, and additional features are added to increase the benefits beyond those benefits achieved by Scenario 1. Scenario 2 has the potential to be implemented if private and public landowners in the region of the proposed flow-way are willing to work with regional partners to secure property easements, publicly acquire land or and permits in order to allow water to move from Bond Farm to Yucca Pens. Three key items were added in Scenario 2: 1) Bond Farm HEI outflows are directed west to Yucca Pens during the dry season, 2) more storage for wet season Babcock Webb flows, and 3) modification of one weir in Yucca Pens. The new features of Scenario 2 are described below:

1. The Bond Farm HEI gravity outflow will be directed west towards Yucca Pens at a constant flow of 20 cfs during December and January. No outflow will be permitted during the wet season. The flow-way from Bond Farm to Yucca Pens will be along the southern border of the Southwest Aggregates mine property, will pass under U.S. 41, and will be routed west through a new flow-way south of the Charlotte County Landfill. A new 7-ft x 3-ft box culvert is assumed under U.S. 41. Dimensions of this culvert may be modified during the design phase.

2. The Southwest Aggregates mine (shown in ***Figure 6-19***) will be converted to a reservoir for the City of Cape Coral. The flow-way on the southern border of that property will be used to convey water from Bond Farm to Yucca Pens and also used as an inflow canal for water that will be pumped from Bond Farm into the existing pits on the Aggregates property. The depth range will be 15 to 25 ft-NAVD. The inflow rate will be limited to 35 cfs between June and November, and the outflow rate between March and May will be limited to 26 cfs. The outflow will be directed via a proposed pipeline from the Southwest Aggregates reservoir to Gator Slough just west of U.S. 41, however the pipeline is hypothetical and thus the simulation described herein utilized the U.S. 41 ditches as the conveyance in its place.
    - Gated culverts on the west side of Bond Farm will open during the wet season to allow water from Babcock Webb to flow west into the Southwest Aggregates Reservoir using the above mentioned flow-way. The dimensions of the culverts associated with this structure were taken from the Bond Farm HEI design plans.
    - A gate on the east side of the Southwest Aggregates south ditch will open during wet season flow deliveries to the Reservoir or during flow routing from Bond Farm HEI to Yucca Pens in the early dry season. This gate will be 24 feet wide with a sill elevation of 22 ft-NAVD, and a maximum elevation of 26 ft-NAVD. The width of this gate may be able to be reduced during the design phase.
    - Gated weirs will be needed in the U.S. 41 ditches north and south of the flow-way to direct the Bond HEI outflows to Yucca Pens. These gates will be closed blocking flow north and south to these U.S. 41 ditches, instead directing water west via the proposed flow-way during the time period that the flows would be directed to Yucca Pens (typically December and January). Gates for this purpose have been discussed in prior Charlotte Harbor Flatwoods Initiative meetings.
3. A number of proposed weirs representing either low-water fords or constructed weirs were modeled in Future Conditions Scenario 1 to minimize excess drainage from eroded ATV trail in Yucca Pens. The proposed weirs for Scenario 2 are identical to those included in Scenario 1 with the exception of Yucca Pens New Weir 3. Yucca Pens New Weir 3 was moved 1,325 meters (4,347 feet) upstream (east) from the location used in Scenario 1 for two reasons: a) the Scenario 1 location was too close to private lands, and b) the new Scenario 2 location is along an existing fire-break that is already disturbed and would be easier to access, so land will not need to be disturbed for construction of a new weir. The location of this weir is #7 in **Figure 6-20**.

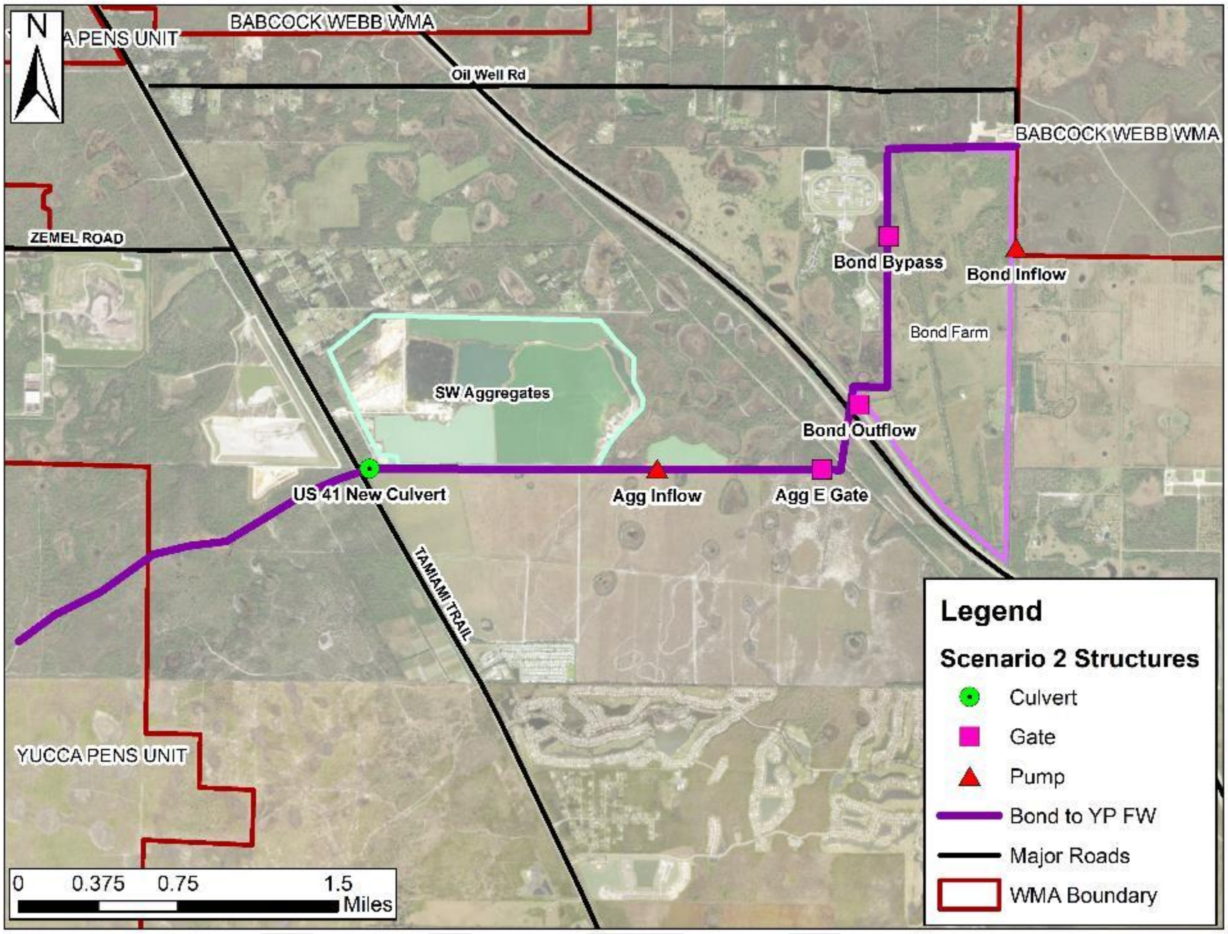


Figure 6-19. Scenario 2 Modeled Storage Areas and Flow-ways

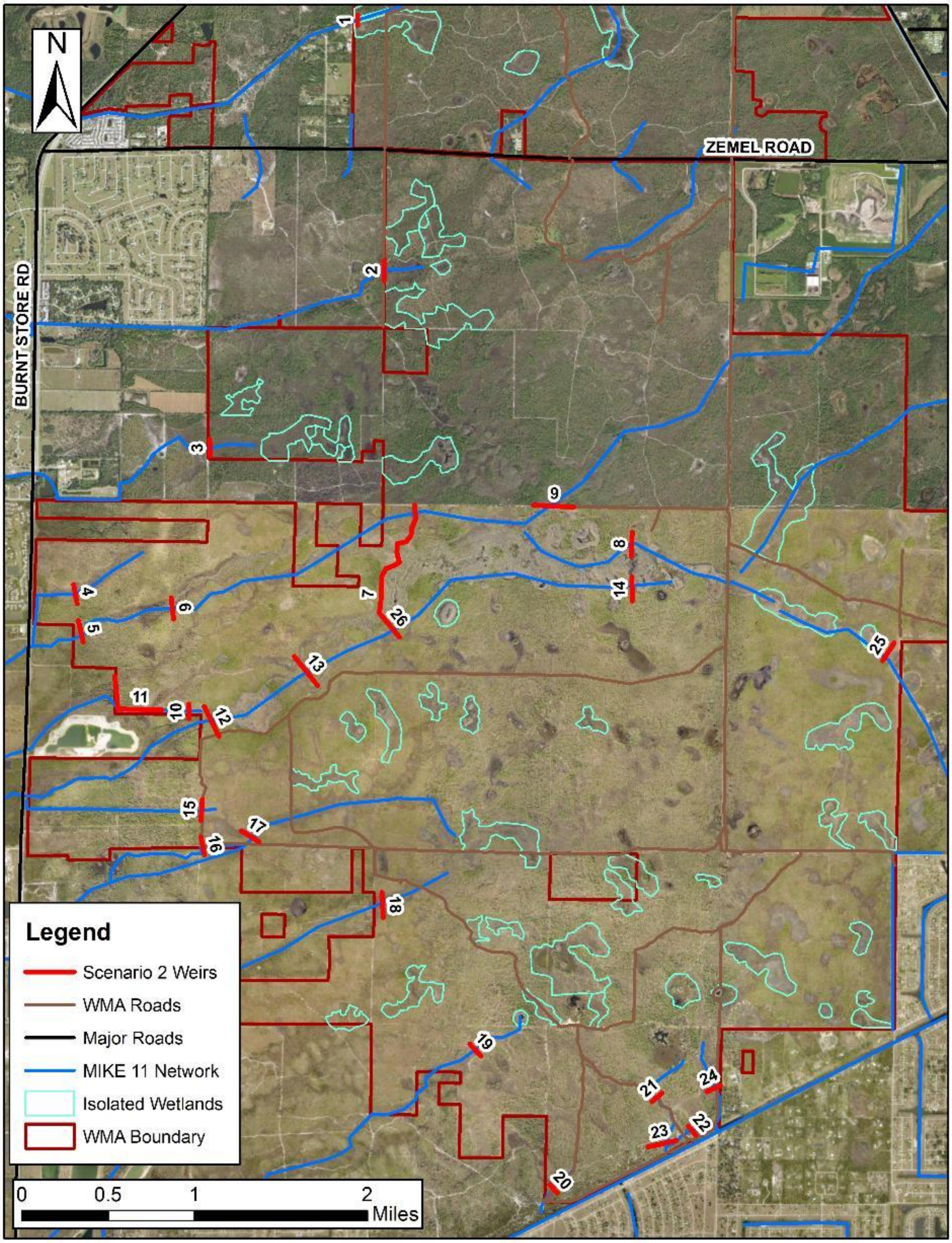


Figure 6-20. Map of Proposed Weirs/Low Water Fords in Yucca Pens

Scenario 2 simulations were run for 2012 – 2021. The simulation results were compared to the baseline existing conditions model results and the Scenario 1 model results to determine the hydrologic response of the Scenario 2 restoration measures as described above. The difference between simulated hydroperiods in Yucca Pens for Scenario 1 and 2 is presented in **Figure 6-21**.

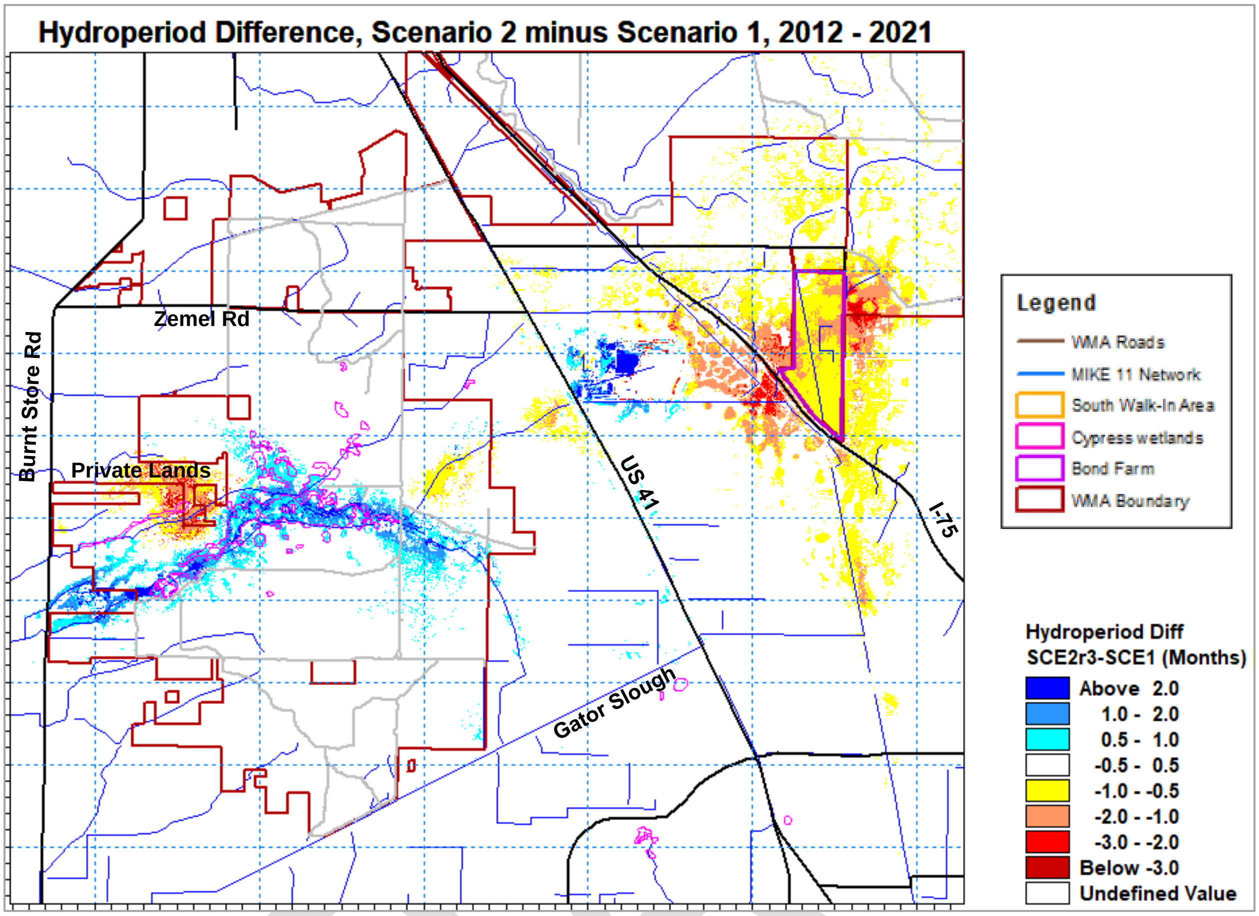


Figure 6-21. Scenario 2 minus Scenario 1 Hydroperiod Difference at a 50-ft resolution during the period 2012 - 2021

Quantitative summaries of the Scenario 2 improvements/changes in Yucca Pens are presented below in **Table 6-4**. Although specific quantitative acreage targets were not identified as a project goal, acreage totals are presented below in order to further demonstrate hydrologic restoration. Hydroperiod increases of greater than one month are predicted for 3,465 acres of Yucca Pens in Scenario 2 model results (improvements were seen in 2,559 acres for Scenario 1). Water levels in March and April (end of dry season) are predicted to be greater than 1 foot for 431 acres in Yucca Pens, and water levels are predicted to increase by 0.25 to 0.5 feet for 5,440 acres in Yucca Pens. This means that the hydroperiod range and water levels in Yucca Pens are now closer to optimum conditions for these areas.

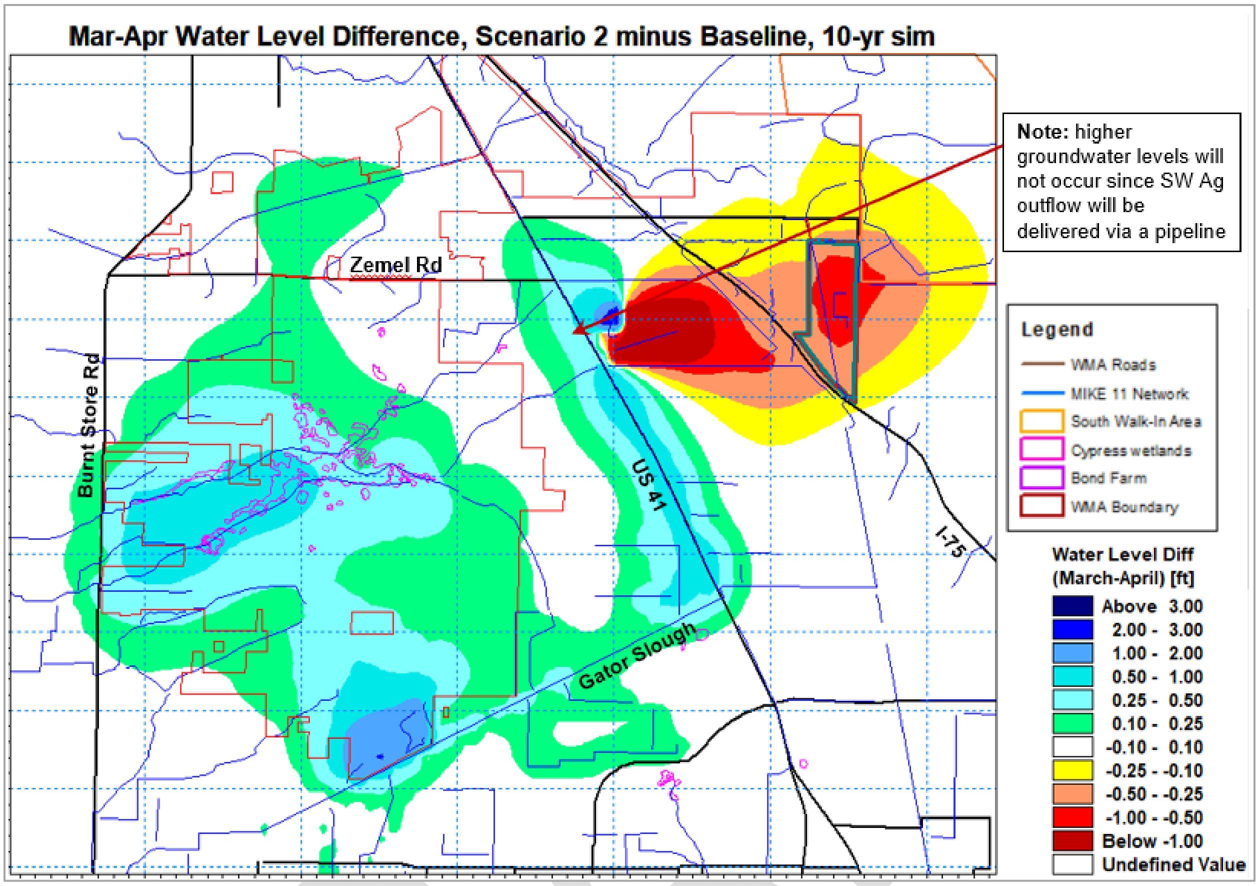


Figure 6-22. Scenario 2 minus Baseline Water Level Differences during March – April during the period 2012 - 2021

NOTE: Higher groundwater levels will NOT occur near U.S. 41 since Southwest Aggregates outflows will actually be delivered via a proposed pipeline and not via the drainage ditches as the pipeline is hypothetical and thus the simulation described herein utilized the U.S. 41 ditches as conveyance in its place.

Table 6-4. Summary of Scenario 2 Hydroperiod and March – April Water Level Improvements in Yucca Pens

Hydroperiod Difference	Area, ac.	+/- from S1, ac.	Avg Hydroperiod Change, months
>2 months	1,081	+221	2.89
1 - 2 months	2,385	+686	1.4
0.5 - 1 months	2,799	+303	0.72
0.25 - 0.5 months	2,435	-5,794	0.37
>0.25 months	8,700	-3,793	1.08
Water Elevation Difference, March - April	**Area, ac.**	**+/- from S1, ac.**	**Avg Elevation Change, ft**
> 2.0 ft	2	+1	2.04
1 – 2 ft	429	19	1.38
0.5 - 1 ft	2,210	+1,399	0.65
0.25 - 0.5 ft	5,440	+2,399	0.34
0.1 - 0.25 ft	7,550	-679	0.17
> 0.1 ft	15,361	3,139	0.33

Quantitative summaries of Babcock Webb hydroperiod and water level changes due to the modeled Scenario 2 restoration measures are presented below in **Table 6-5**. Although specific quantitative acreage targets were not identified as a project goal, acreage totals are presented below in order to further demonstrate hydrologic restoration. Reduced wetland hydroperiods and decreased water levels are predicted in a portion of the Babcock Webb South Walk-In Area because of water deliveries to both the Bond Farm HEI and the proposed Southwest Aggregates Reservoir. The Scenario 2 results suggest that additional off-line storage will be needed to achieve more substantial hydrologic restoration of the Babcock-Webb South Walk-In Area.

Table 6-5. Babcock Webb hydroperiod and water level changes

Hydroperiod Decrease	Area, ac.	Average Hydroperiod Change, months
>2 months	89	-2.5
1 - 2 months	208	-2.4
0.5 - 1 months	440	-0.7
0.25 - 0.5 months	935	-0.36
Water Elevation Difference, July 1 – Nov 30	**Area, ac.**	**Average Elevation Change, ft**
0.5 - 1 ft	40	-0.61
0.25 - 0.5 ft	123	-0.36
0.1 - 0.25 ft	1,674	-0.18

Scenario 2 simulated flows at Burnt Store Road for Greenwell Branch, Durden Creek, Yucca Pens Creek, and Hog Branch were compared to Scenario 1 simulated flows for these same creeks. A statistical comparison of the changes in peak flows for both Scenarios 1 and 2 is presented in **Table 6-6**. While there is slightly less reduction of peak flows in Scenario 2 as compared to Scenario 1 which is related to more water being delivered to Yucca Pens, the recession limb of the flow after each storm event has been extended due to the restoration measures. One example of this is the ATV ditch blocks which slow flow out of Yucca Pens wetland areas and help retain water. This essentially demonstrates that flashiness in streams is attenuated or reduced so that there is more moderate flow in these streams rather than extreme high and low flow events.

Table 6-6. Comparison of Reductions in Peak Flows Between Scenario 1 and Scenario 2, 2012 - 2021

Statistic	Scenario 1	Scenario 2
Average Change in Peak Flow, %	15%	1%
25th Percentile Change in Peak Flow, %	8%	-8%
75th Percentile Change in Peak Flow, %	22%	10%

A detailed evaluation of simulated flows during the late wet/early dry seasons (November 1 through January 31) was conducted to highlight the differences between Scenarios 1 and 2. Flows for November 1 through January 31 for each simulation year under Burnt Store Road from Greenwell Branch, Durden Creek, Yucca Pens Creek, and Hog Branch for Scenarios 1 and 2 are compared in **Table 6-7**. Scenario 2 provides, on average, 87% more flow to tidal creeks during the late wet season and early dry season than Scenario 1. While Scenario 1 conditions result in higher water levels in Yucca Pens wetlands, the additional conditions in Scenario 2 (added storage, additional delivery of water via flow-way to Yucca Pens, modified Weir 3 location) provide further restoration benefit by extending the duration of positive discharges from Yucca Pens to tidal creeks during the early dry season.

Table 6-7. Simulated flows under Burnt Store Road for Scenarios 1 and 2, Greenwell Branch to Hog Branch

Flows November 1 to January 31, acre feet		
Year	**Scenario 1**	**Scenario 2**
2012	199	1,538
2013	138	1,041
2014	1,450	2,905
2015	10,018	13,590
2016	84	678
2017	563	2,155
2018	173	1,373
2019	469	1,552
2020	4,947	8,925
Averages	**2,005**	**3,751**

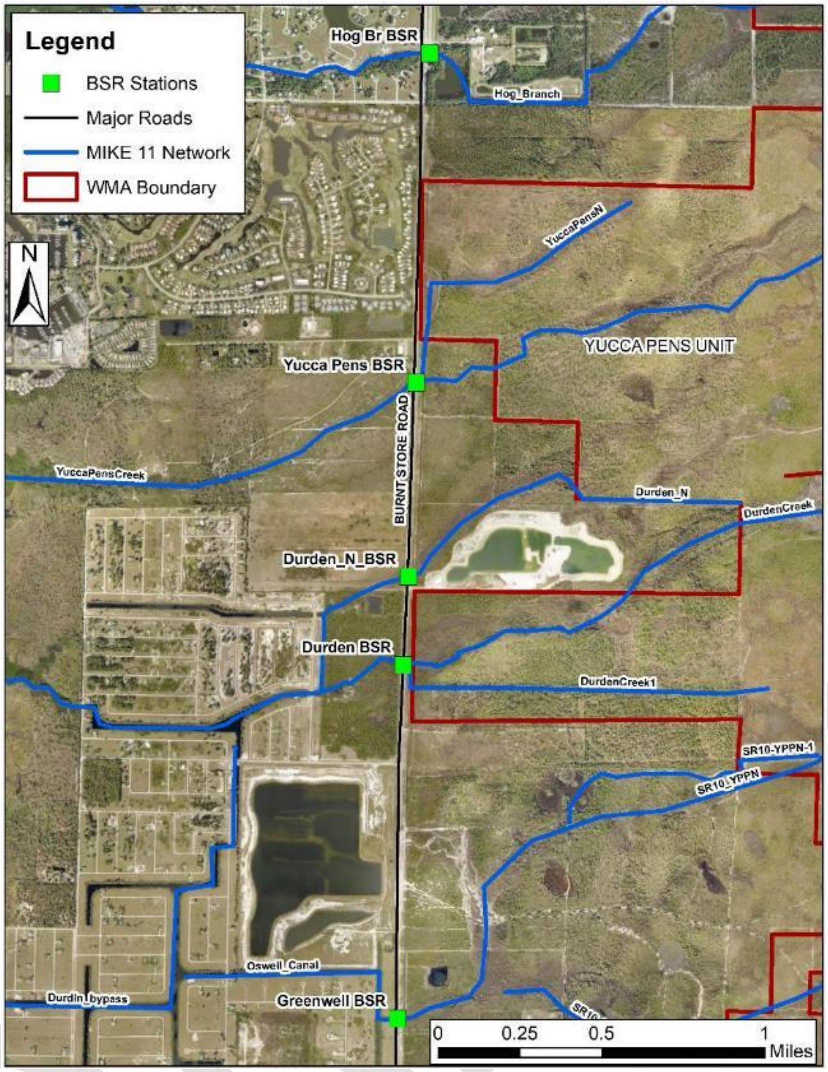


Figure 6-23. Map of Greenwell Branch, Durden Creek, Yucca Pens Creek, and Hog Branch at Burnt Store Road

Histogram Analysis of Scenario 2. The Natural Systems analysis presented in Technical Memorandum 6A (Appendix 6A) provided a comparison of the Baseline existing conditions simulated hydroperiods and average wet season water depths to optimum hydroperiods and depths expected under pre-development conditions. The Natural Systems analysis results were presented as a series of histograms for Areas of Interest (AOIs) within Babcock Webb and Yucca Pens.

In order to evaluate the performance of Scenario 2, simulated Scenario 2 results were compared to the Scenario 1 and Baseline existing condition results for Hydro Ranks 3 and 4. Comparisons are presented for Babcock Webb South Walk-In (Reduced) for Hydro Rank levels 3 and 4 in **Figure 6-24**. Results for Yucca Pens Cypress and the Yucca Pens ATV AOIs are also presented in **Figure 6-24**.

Scenario 2 simulated hydroperiods in the Babcock Webb South Walk-In Area (Reduced) decreased for both Hydro Ranks 3 and 4. This is an improved result compared to Scenario 1 outcomes, which did not yield decreased wetland hydroperiods for the excessively inundated

South Walk-In Area (Reduced). The most common hydroperiod for the Baseline existing conditions scenario for Hydro Rank 3 was 10.8 months, which was decreased to 10.1 months in Scenario 2. The most common hydroperiod for the Baseline existing conditions and Scenario 1 results for Hydro Rank 4 was 11.5 months, and the Scenario 2 hydroperiods were more broadly distributed with two peaks at 9.5 and 11.4 months. These results suggest that some of the wetlands in the Babcock Webb South Walk-In Area (Reduced) experienced reduced hydroperiods while the remaining wetlands throughout the remainder of Babcock Webb did not change substantially. This is consistent with the hydroperiod difference map shown above in **Figure 6-21**.

The most common hydroperiod for the Baseline existing condition scenario for Hydro Rank 3 was approximately 5.5 months in Yucca Pens Cypress area, and Scenario 2 hydroperiods were more broadly distributed with two peaks at 5.4 months and 8.5 months. The most common hydroperiod for the Baseline existing conditions scenario for Hydro Rank 4 was 5.9 months in Yucca Pens Cypress, Scenario 2 hydroperiods were more broadly distributed with peaks at 9.1 and 10.9 months. Scenario 2 simulated hydroperiods were longer than Scenario 1 simulated hydroperiods for Yucca Pens. This means that the hydroperiod ranges in Yucca Pens Cypress are now closer to optimum conditions for these areas.

The most common hydroperiod for the Baseline existing condition scenario for Hydro Rank 3 was approximately 4.5 months in the Yucca Pens ATV areas, while the most common hydroperiod for Scenario 2 increased to 5.6 months. The most common hydroperiods for the Baseline existing conditions scenario were 3.9 and 5.7 months in the Yucca Pens ATV area, while the most common hydroperiod for Scenario 1 was 4.7 months with more broadly distributed peaks between 4.7 and 7.7 months. The Yucca Pens ATV AOI performed relatively similar in both Scenarios 1 and 2, with a slight improvement for Scenario 2 as evidenced by the difference map presented in **Figure 6-25**. This means that the hydroperiod ranges in Yucca Pens ATV AOI are now closer to optimum conditions for these areas.

Note for hydroperiod histograms below:

- light blue bar is the optimum hydroperiod for hydro rank 3
- dark blue bar is the optimum hydroperiod for hydro rank 4

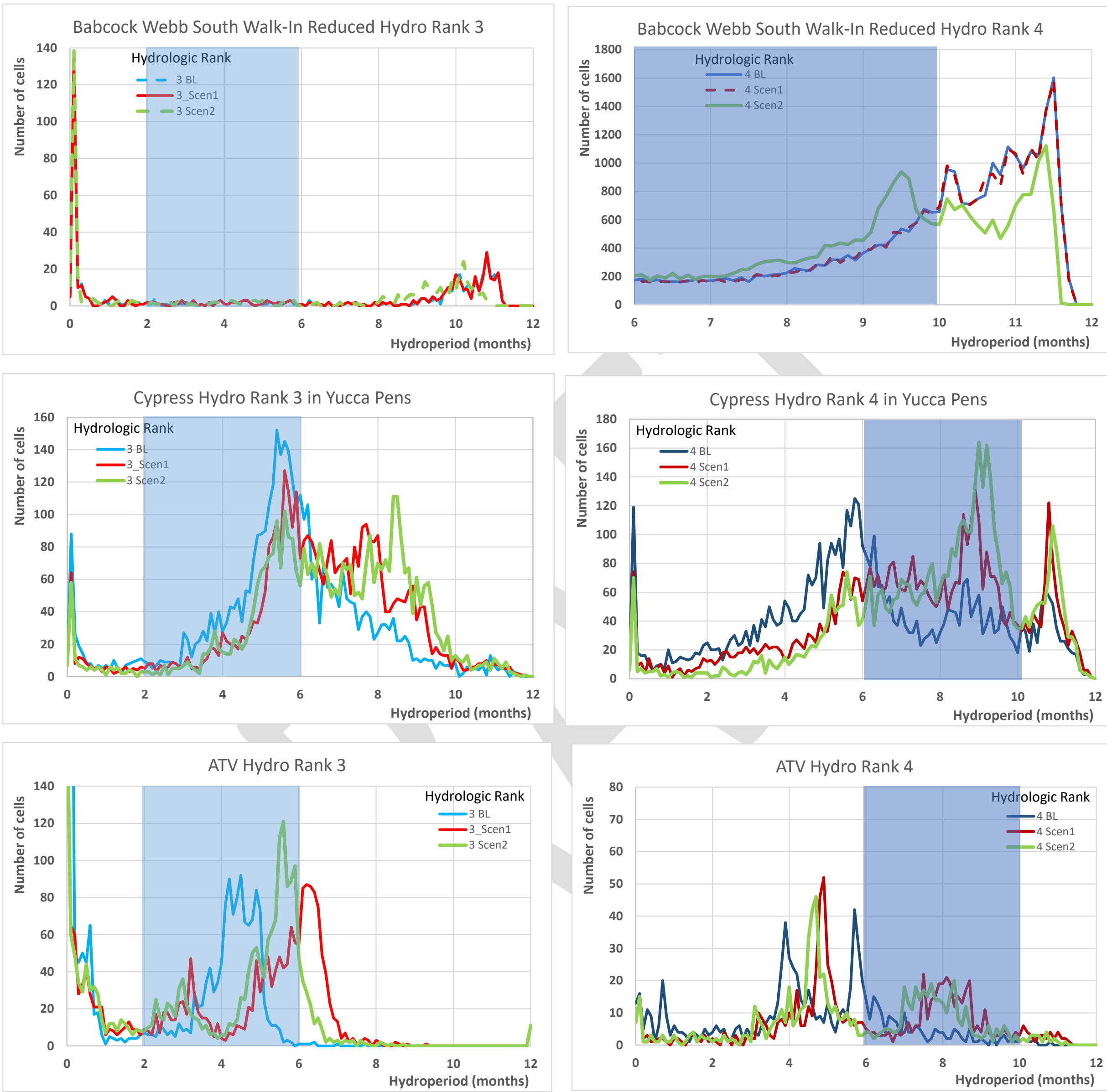


Figure 6-24. Comparison of Scenarios 1 and 2 for Babcock Webb South Walk-In Area (Reduced), Yucca Pens Cypress, and Yucca Pens ATV AOIs, for Hydro Rank 3 and Hydro Rank 4

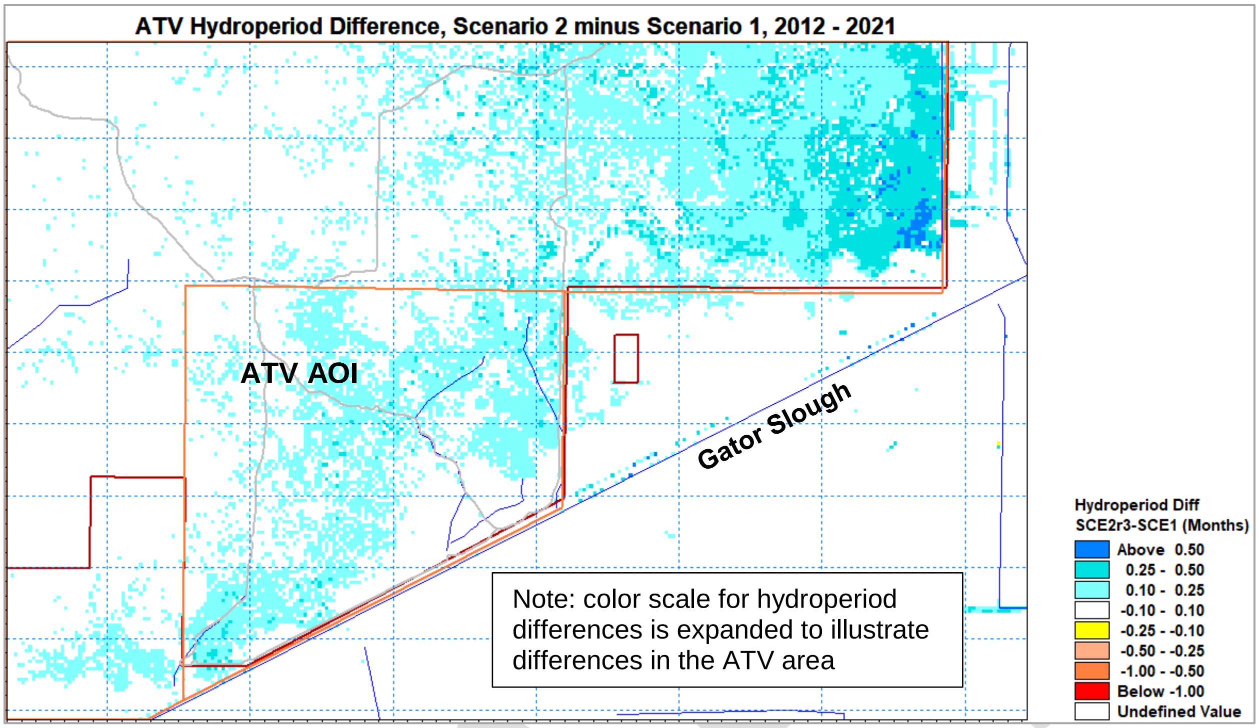


Figure 6-25. Scenario 2 minus Scenario 1 Yucca Pens ATV hydroperiod differences during the period 2012-2021 (note finer color scale than prior figures)

Simulated Performance for the Bond Farm HEI and the Southwest Aggregates Reservoir. The Bond Farm HEI was programmed to store water pumped from the southwestern portion of Babcock Webb with water depths up to 4 feet during the wet season and to release water during the dry season. Scenario 2 includes a flow-way west from Bond Farm to Yucca Pens. Scenario 2 also includes storage of up to 4,700 acre-feet in the proposed Southwest Aggregates Reservoir. Scenario 2 storage results are summarized in **Table 6-8**. Outflows are less than 50% of inflows for the original calibrated model (assumed lower water table hydraulic conductivity in Bond Farm only). The majority of the difference between inflows and outflows is due to groundwater seepage. The simulation with capped conductivities indicates lower overall losses to groundwater. On average, simulated Bond Farm outflows were 62% of simulated inflows for the reduced hydraulic conductivity simulation.

Table 6-8. Simulated Inflows and outflows for Bond Farm HEI and Southwest Aggregates Reservoir

Year	Bond In	Bond Out		SW Agg In	SW Agg Out
Average, Original Calibration	3,299	1,042		6,800	4,744
Average, Modified Calibration	2,448	1,524		6,413	4,744

Note: original calibration model described in Task 5c memorandum in Appendix 5C (WSA & CHNEP, 2022b). Reduced Hydraulic conductivity simulations assumptions described in Task 6B memo in Appendix 6B. Additional discussion in **Exhibit 1**.

Summary of Scenario 2 Results. Scenario 2 includes storage of excess water from Babcock Webb in Southwest Aggregates in addition to storage in Bond Farm HEI (also included in Scenario 1). Scenario 1 did not result in significant measurable decreases in water depths or wetland hydroperiods in the South Walk-In Area of Babcock Webb. The analysis of Scenario 2 simulation results indicated that hydroperiod decreases greater than 0.5 months are predicted for 737 acres in the South Walk-In Area of Babcock Webb, meaning hydroperiods are closer to optimum conditions due to increased removal of water from Babcock Webb. However, hydroperiods in Babcock Webb were still not optimal and additional storage may be needed to provide greater restoration of the Babcock Webb South Walk-In Area.

In Yucca Pens, hydroperiods and water depths will increase as a result of the proposed restoration measures described above in Scenario 2. Hydroperiod increases of greater than one month are predicted for 3,465 acres of Yucca Pens, which closer to optimum conditions and therefore a greater level of restoration than predicted for Scenario 1. Water table levels in March and April (dry season) are predicted to be greater than one foot for 431 acres, and water levels are predicted to increase by more than 0.25 feet for 8,082 acres in Yucca Pens.

A comparison of discharges to tidal creeks during the late wet/early dry season was conducted for Scenarios 1 and 2. That analysis suggests that Scenario 2 provides an 87% increase in freshwater flow to tidal creeks during the late wet season and early dry season as compared to Scenario 1. While Scenario 1 conditions result in higher water levels in Yucca Pens wetlands, the additional conditions in Scenario 2 (added storage, additional delivery of water via flow-way to Yucca Pens, modified Weir 3 location) provide further restoration benefit by extending the duration of positive discharges from Yucca Pens to tidal creeks during the early dry season.

Based on the analysis described herein, Scenario 2 is recommended for implementation due to hydrologic improvements in both Babcock Webb and Yucca Pens. Further model refinements of Scenario 2 are recommended during subsequent restoration planning and design efforts. Additional calibration is recommended to decrease uncertainties regarding groundwater hydraulic conductivities, and this effort may indicate that greater restoration can be achieved by Scenario 2. Recalibration may indicate more substantial Yucca Pens peak flow reductions at Burnt Store Road. In addition, refinements are recommended for the operating protocols for the Bond Farm HEI and Southwest Aggregates Reservoir inflow pumps so that filling of either may have dynamic priorities. Further explanation on the need for these model refinements can be found in **Section 7.2** Recommendations.

6.4 FUTURE CONDITIONS SCENARIO 3

Scenario 3 includes Scenario 2 improvements along with rainfall, evapotranspiration (ET) and sea level rise assumptions associated with climate change. The Task 6D memorandum provided a detailed discussion of the climate change assumptions (see **Appendix 6D**). A summary of climate change assumptions is provided below:

- Rainfall will remain unchanged. Currently, there are too many uncertainties and conflicting studies to confidently assume how rainfall will change. This assumption should to be revisited in future climate change scenario analyses if scientific investigations are able to reduce the uncertainty in predicting how rainfall will change due to climate change.
- Sea levels will rise 1.64 feet by 2050, based on the NOAA case of intermediate/High Sea Level Rise with Low Accretion Rate. This assumption is similar to other recent regional studies.
- Evapotranspiration (ET) will increase by 6.3% by 2050. This assumption is similar to other regional studies (ESA & CHNEP, 2020).

Scenario 3 Hydroperiods and Wet Season Water Depths. Scenario 3 and baseline simulations were run for 2012 – 2021, and the simulation results were analyzed to determine the hydrologic response of the Scenario 3 climate change assumptions. **Figure 6-26** presents the difference between Scenario 3 and the Baseline existing conditions scenario, simulated wetland hydroperiods for 2012 – 2021 appear below. Scenario 3 simulated hydroperiods are predicted to decrease slightly across much of Babcock Webb, and hydroperiod changes in the Babcock Webb South Walk-In Area are more prominent than for either Scenario 1 or 2. The difference between Scenarios 2 and 3 was evaluated as well, and overall hydroperiods are reduced in both Babcock Webb and Yucca Pens by 0.5 -1 month due to projected changes in climate. Scenario 3 simulated hydroperiods are increased in tidally influenced areas west of Burnt Store Road and adjacent to the Caloosahatchee Estuary as compared to both Baseline existing conditions and Scenario 2 simulations.

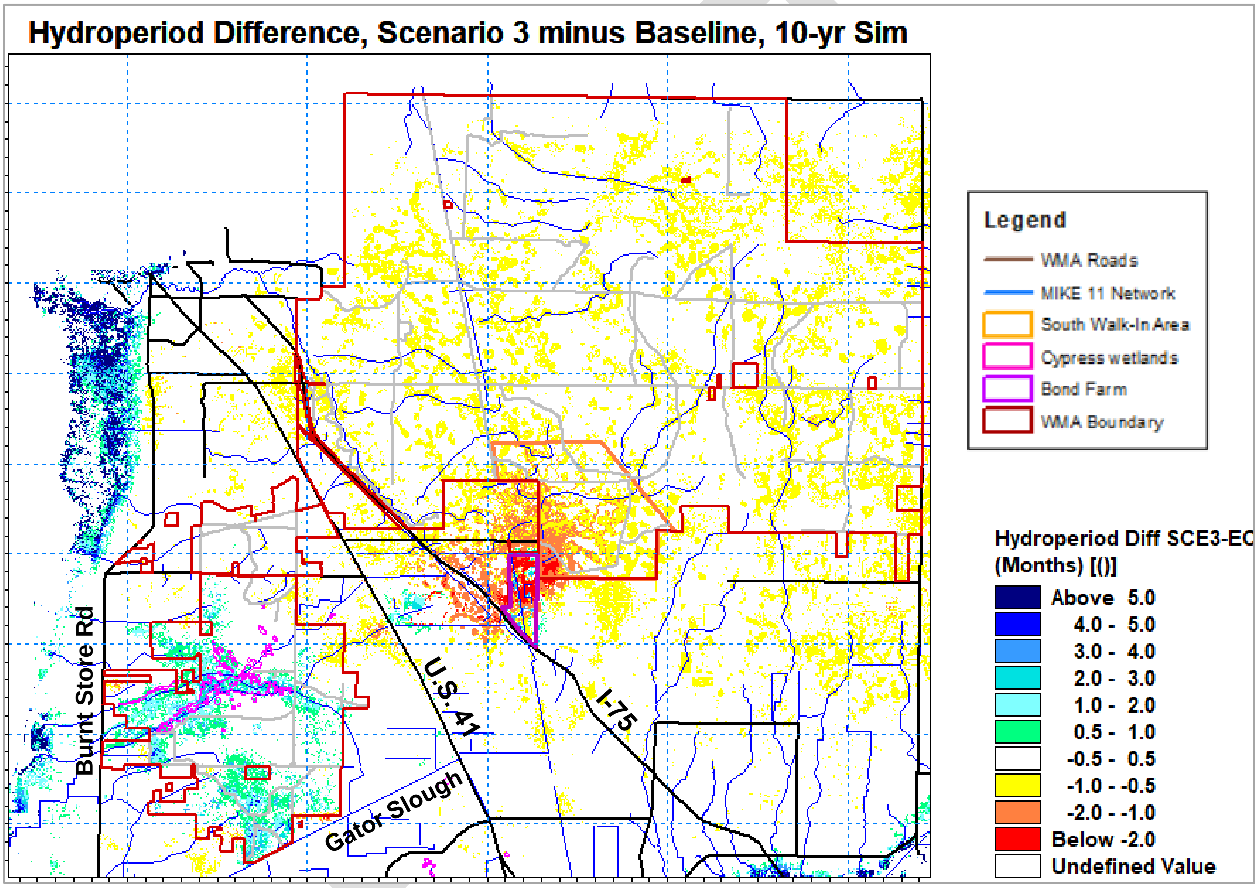


Figure 6-26. Scenario 3 minus Baseline Average Hydroperiod Difference for 2012-2021, at a 50-ft Resolution

Wet season water depth differences associated with Scenario 3 relative to Baseline conditions are presented in **Figure 6-27**. The restoration goals of reduced water depths in the South Walk-In Area of Babcock Webb and increased water depths in Yucca Pens that were achieved in Scenario 2 were still maintained in Scenario 3 with slight differences. The most significant difference between Scenario 2 and Scenario 3 is the increased water depths predicted in tidally influenced lands west of Burnt Store Road. Minor decreases in water depths are predicted for the Babcock Webb South Walk-In Area. Wet season water depth differences between Scenarios 2 and 3 are less than 0.1 feet in Yucca Pens Cypress and the most southern area of Yucca Pens.

Dry season groundwater level differences between Scenario 3 and Baseline existing conditions are presented in **Figure 6-28**. Groundwater levels are predicted to increase in the tidally influenced lands west of Burnt Store Road and adjacent to the Caloosahatchee Estuary. Decreases in water levels are predicted in most of Babcock Webb in Scenario 3, with groundwater levels decreasing by an average of 0.25 – 0.5 feet in the dry season during the months of March and April. Scenario 3 Yucca Pens dry season groundwater levels are still predicted to be higher than Baseline existing conditions in the southern portion and in the Durden and Yucca Pens Creek watersheds. Yucca Pens Scenario 3 groundwater levels are predicted to decrease between 0.1 and 0.25 feet in the vicinity of Zemel Road and along the eastern border of Yucca Pens. Higher water levels are predicted along U.S. 41, which is an aberration of the simulated conveyance of Southwest Aggregates reservoir water through the US 41 ditches. The outflow from the Southwest Aggregates reservoir will be conveyed via pipeline to Gator Slough. Therefore, the simulated rise in groundwater elevations along U.S. 41 is not expected once the reservoir project is implemented. This is discussed in more detail in **Section 6.3**.

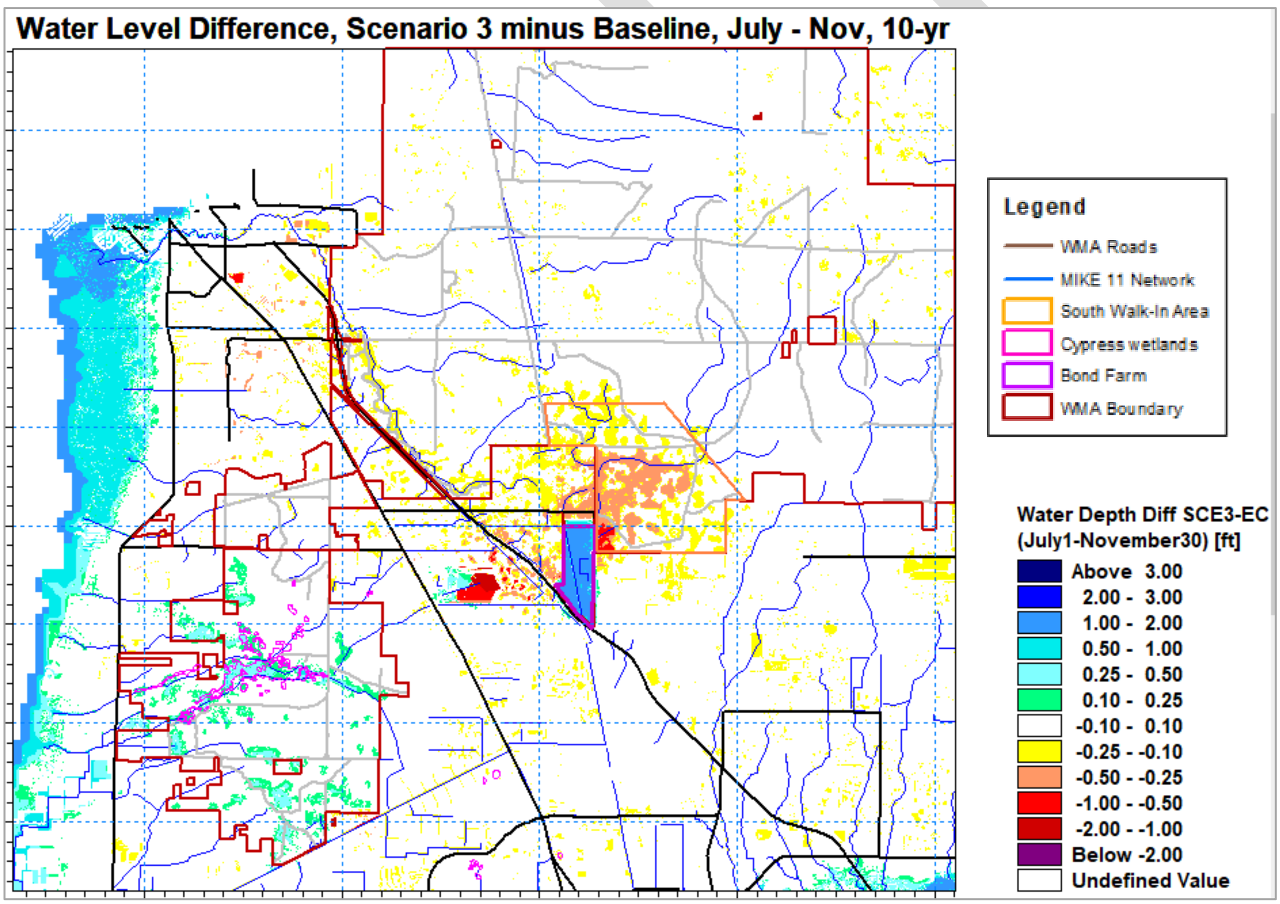


Figure 6-27. Scenario 3 minus Baseline Average Annual Wet Season Water Depth Difference for 2012-2021, at a 50-ft Resolution

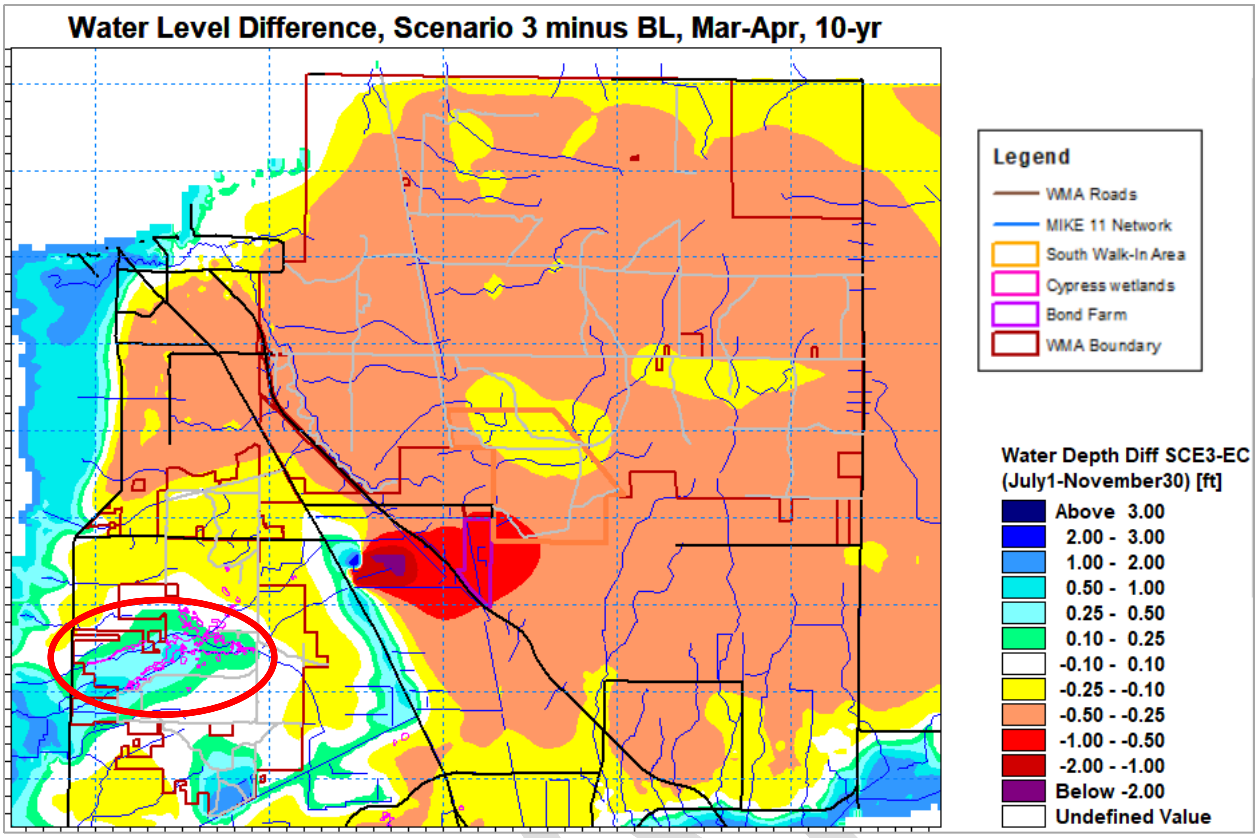


Figure 6-28. Scenario 3 minus Baseline water level difference March - April during the period 2012 – 2021 (red ellipse indicates Yucca Pens Creek and Durden Creek watersheds)

Quantitative summaries of the changes in Yucca Pens are presented below in **Table 6-9**. In Yucca Pens 2,163 acres saw hydroperiod improvements greater than one month, compared to 3,465 acres that were improved for Scenario 1. This is a 38% **decrease** in area improved in Yucca Pens. Water levels in the late dry season of March and April are still predicted to improve by greater than 1 foot for 304 acres.

Quantitative summaries of the changes in Babcock Webb in Scenario 3 are presented in **Table 6-10**. Scenario 2 improvements in hydroperiods and water levels were maintained and slightly increase overall in Scenario 3. In Scenario 3, wetland hydroperiods and water depths were reduced throughout most of Babcock Webb. Hydroperiods in Scenario 3 will be 1 - 2 months shorter than Baseline existing conditions in 692 acres. Hydroperiods in Scenario 3 will be 0.5 - 1 month shorter than Baseline existing conditions for 14,155 acres. Water depths in Scenario 3 will decrease by 0.25 - 0.5 feet for 56,364 acres in Babcock Webb as compared to Baseline existing conditions.

Simulated combined flows at Burnt Store Road for Greenwell Branch, Durden Creek, Yucca Pens Creek, and Hog Branch are presented in **Table 6-11**. In Scenario 3, peak flows are reduced for most rainfall or storm events, demonstrating a slight decrease in benefits gained in Scenario 1. However, the recession limb of each rain or storm event has been extended due to restoration measures from Scenario 1 and 2 and this overall benefit appears to continue for Scenario 3. Despite climate change impacts on the hydrology of both Babcock Webb and Yucca Pens, restoration measures continue to provide additional hydrologic benefits in Yucca Pens in extending the duration of positive discharges to tide during the early dry season.

Table 6-9. Summary of Scenario 3 hydroperiod and March – April water level improvements in Yucca Pens relative to Baseline Existing Conditions

Hydroperiod Difference	Area, ac.	+/- from S2, Ac	Avg Hydroperiod Change, months
>2 months	754	-327	2.87
1 - 2 months	1,409	-975	1.39
0.5 - 1 months	1,850	-949	0.73
0.25 - 0.5 months	1,508	-928	0.36
>0.25 months	5,463	-3,237	1.07
Water Elevation Difference, March - April	**Area, ac.**	**+/- from S2, Ac**	**Avg Elevation Change, ft**
> 2 ft	0	-2	0.00
1 - 2 ft	304	-124	1.24
0.5 - 1 ft	963	-1,248	0.66
0.25 - 0.5 ft	2,285	-3,155	0.36
0.1 - 0.25 ft	2,761	-4,789	0.17
> 0.1 ft	6,313	-9,318	0.36

Table 6-10. Summary of Scenario 3 hydroperiod and March – April water level improvements in Babcock Webb relative to Baseline Existing Conditions

Hydroperiod Difference	Area, ac.	+/- from S2, Ac	Avg Hydroperiod Change, months
<-2 months	94	5	-2.65
-2 to -1 months	692	484	-1.23
-1 to -0.5 months	14,155	13,715	-0.63
Water Elevation Difference, March - April	**Area, ac.**	**+/- from S2, Ac**	**Avg Elevation Change, ft**
-1 to -0.5 ft	319	279	-0.62
-0.5 to -0.25 ft	56,364	56,241	-0.29
-0.25 to -0.1 ft	10,839	9,165	-0.22

Table 6-11. Comparison of changes in peak flows for rain or storm events, 2012 – 2021

Statistic	Scenario 1	Scenario 2	Scenario 3
Average Change in Peak Flow, %	15%	1%	13%
25th Percentile Change in Peak Flow, %	8%	-8%	2%
75th Percentile Change in Peak Flow, %	22%	10%	20%

Simulated Performance for the Bond Farm HEI and the Southwest Aggregates Reservoir. Bond Farm HEI and Southwest Aggregates Reservoir operations for Scenario 3 are unchanged from Scenario 2. The Scenario 3 simulated inflows and outflows for Bond Farm during the period of 2012 – 2021 are summarized below in **Table 6-12**. Outflows are less than 50% of inflows for the original calibrated model which assumed lower water table hydraulic conductivity in Bond

Farm only. The majority of the difference between inflows and outflows is due to groundwater seepage.

Table 6-12. Simulated Inflows and outflows for Bond Farm HEI and Southwest Aggregates Reservoir

Year	Bond In	Bond Out		SW Agg In	SW Agg Out
Average, Original Calibration	3,066	943		6,016	4,744
Average, Modified Calibration	2,353	1,418		5,719	4,744

Note: original calibration model described in Task 5c memorandum in Appendix 5C (WSA & CHNEP, 2022b). Reduced Hydraulic conductivity simulations assumptions described in Task 6B memo in Appendix 6B.

The simulation with capped conductivities indicates lower overall losses to groundwater. On average, simulated Bond Farm outflows were 62% of simulated inflows for the reduced hydraulic conductivity simulation. Scenario 3 assumptions result in a 10% decrease in the volume of water stored in Bond Farm and the Southwest Aggregates Reservoir as shown below:

Total Stored Bond plus SW Agg Scenario 2: 10,099 acre-feet

Total Stored Bond plus SW Agg Scenario 3: 9,082 acre-feet

The climate change scenario analysis of year-by-year water budgets for the two storage areas indicated that Bond Farm would not fill during 2014, a year with low wet season rainfall. Refinements are recommended in **Section 7.2** for the operating protocols for the Bond Farm HEI and Southwest Aggregates Reservoir inflow pumps so that filling the Bond Farm HEI has a higher priority than filling the Southwest Aggregates Reservoir.

Summary of Scenario 3 Results. The Scenario 3 simulation results suggest that:

- Improved wet season water depths from Scenario 2 will not change substantially in either Babcock Webb or Yucca Pens due to Scenario 3 climate change assumptions.
- Dry season water levels will decrease by 0.25 to 0.50 feet in most of Babcock Webb due to Scenario 3 climate change assumptions.
- Scenario 3 dry season water levels will still be higher than Baseline existing conditions in most of Yucca Pens south of Zemel Road, however the water level improvements will be lower than for Scenario 2.
- Scenario 3 discharges under Burnt Store Road are 12% less than Scenario 2 between November 1 and January 31. However, discharges under Burnt Store Road during this period are still 65% higher than Baseline existing conditions.
- Scenario 3 assumptions result in a 10% decrease (relative to Scenario 2) in the combined volume of water stored in Bond Farm and the Southwest Aggregates Reservoir.

Based on the analysis described herein, while restoration benefits will be maintained, climate change assumptions will present additional challenges to future restoration planning and design efforts. Significant uncertainties exist when attempting to predict the changes in rainfall due to climate change. Climate change assumptions should be reviewed throughout the preliminary and final design of proposed restoration projects and effects of climate change on restoration measures should be evaluated using the best available information on future changes in tidal fluctuations, rainfall, and evapotranspiration.

6.5 SUMMARY OF SCENARIO ANALYSIS

The scenario analysis task defined optimum conditions for Babcock Webb and Yucca Pens. Baseline existing condition model hydroperiods and average wet season water depths for a 10-year simulation period were compared to optimum conditions. The analysis confirmed the findings of the ecologic analysis in Section 3, and the water level findings in Section 4, which is that there is too much water in the South Walk-In Area, and more water is needed in Yucca Pens Cypress and southern Yucca Pens. These results guided the alternatives analysis for Scenarios 1, 2, and 3.

Scenario 1 assumed that the 600-acre Bond Farm parcel on the southwest corner of Babcock Webb will be used to store a maximum of 4 feet of excess waters from the South Walk-In Area. However, outflows resulting from the Bond Farm storage are assumed to be directed south to the Caloosahatchee River providing no direct impact to Yucca Pens. Scenario 1 also included 25 weirs in Yucca Pens to retain more water, reduce wet season discharges, and increase baseflow discharges to tide. A seepage barrier was also assumed along the south end of Yucca Pens adjacent to Gator Slough.

Scenario 2 was a refinement of Scenario 1 with additional storage of excess flows in the Southwest Aggregates mining property and redirection of water stored in Bond Farm and Southwest Aggregated to Yucca Pens. The Yucca Pens improvements from Scenario 1 were included in Scenario 2 with the location of one of the 25 weirs moved upstream to minimize impacts of higher water levels on private lands adjacent to Yucca Pens.

Scenario 3 included all features of Scenario 2 but also assumed climate change impacts, consisting of higher tidal water level boundaries and higher evapotranspiration rates.

Scenario 1 did not provide hydroperiod benefits to the South Walk-In Area (SWIA) of Babcock Webb but did provide hydroperiod benefits and increased water levels in Yucca Pens. Peak flow reductions to tide were predicted for Scenario 1.

Scenario 2 provided decreases in wetland hydroperiods and wet season water depths in the SWIA of Babcock Webb. Scenario 2 also provided additional restoration benefits in Yucca Pens above and beyond the Scenario 1 hydrologic benefits. This was due primarily to the additional storage of wet season runoff from Babcock Web. Scenario 2 discharges to tide during the early dry season (November 1 through January 31) are greater than for Scenario 1. Wet season peak flow discharges are less significant for Scenario 2 than for Scenario 1.

Scenario 3 results in lower wet season hydroperiods and decreased dry season water depths across most of the model domain except for portions of Yucca Pens (Yucca Pens and Durden Creek watersheds).

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

Data Collection provided an extensive dataset for 40 monitoring stations in and around the Florida Fish and Wildlife Conservation Commission (FWC) Babcock Webb Wildlife Management Area (WMA) and in the Yucca Pens Unit of the WMA. Combined with on-going FWC data collections efforts at 23 other stations, this project has established a comprehensive database that was used for model development and calibration.

Field ecologic studies were conducted at 58 locations that have identified and surveyed vegetation indicators of average wet season water elevations during both dry and wet season conditions. Pre-development hydrologic conditions have been estimated that identified the extent of historic wetland conditions in both Babcock Webb and Yucca Pens. This information was combined with the groundwater and surface water monitoring data to identify areas in Babcock Webb and Yucca Pens that have experienced hydrologic/ecologic alterations.

An updated integrated surface/ground water model was developed that utilizes the most recent information. Model calibration is currently considered to be good with many stations performing substantially above the minimum standards for good calibration. Overall mean absolute error (MAE) for surface water and groundwater calibration stations within the focus area of this study was 0.64 ft, the average correlation coefficient r was 0.87, and the average Nash-Sutcliffe (NS) coefficient was 0.34. Average r for flow stations was 0.82 and NS was 0.62. Model performance far exceeded the good threshold in many key areas, such as Gator Slough at Weir 19, Zemel Canal upstream of Burnt Store Road, SP-4 (outflow from Babcock Webb to North Alligator Creek), SR-2 (Webb Lake outlet), 16 of 20 Babcock Webb monitoring wells, STA-7 and -8 in the South Walk-In Area, SP-5 through 10, CH-323 south of Babcock Webb on Cook-Brown Road, Yucca Pens and Durden Creek stations SR-8 and SR-9, SR-7 in east Yucca Pens (a problem station in 2016), SR-10 in central Yucca Pens, YP-6 (next to eroded ATV trail on west Yucca Pens, and YP-8 (south Yucca Pens outflow). Based on the statistical analysis of the model calibration, it was determined that the model was ready for scenario analysis.

The calibrated model was utilized to analyze three future conditions scenarios. **Scenario 1** assumed that the 600-acre Bond Farm parcel on the southwest corner of Babcock Webb will be used to store a maximum of 4 feet of excess waters from the South Walk-In Area. Scenario 1 also included 25 weirs in Yucca Pens to retain more water on Yucca Pens, reduce wet season discharges, and increase baseflow discharges to tide. A seepage barrier was also assumed along the south end of Yucca Pens adjacent to Gator Slough. **Scenario 2** was a refinement of Scenario 1 with additional storage of excess flows in the Southwest Aggregates mining property. Yucca Pens improvements from Scenario 1 were included in Scenario 2 with the location of one of the 25 weirs moved upstream to minimize impacts of higher water levels on private lands adjacent to Yucca Pens. **Scenario 3** included all features of Scenario 2 and also assumed climate change impacts, consisting of higher tidal water level boundaries and higher evapotranspiration rates.

7.2 RECOMMENDATIONS

Based on the analysis described herein, Scenario 2 is recommended for further refinement during subsequent restoration planning and design efforts. Scenario 2 provides additional hydrologic restoration benefits to those benefits provided by Scenario 1. Those benefits include:

- Improved restoration of hydroperiods and water depths in the SWIA of Babcock Webb due to greater storage capacity for wet season runoff from the SWIA.
- Greater restoration of wetland hydroperiod and water depths in Yucca Pens
- Increased discharges from Yucca Pens to tide during the late wet/early dry season

While the model is suitable for the scenario analyses as part of this project, there are some areas where model performance can be improved. The key issue is inaccurate topography, which is most apparent in areas with extended hydroperiods, such as the South Walk-In Area (SWIA). Topography in the SWIA wetlands was improved, but more ground surveying is needed in other wetland areas not surveyed as well as areas with higher ground elevations that still experience inundation. More information is needed on surface water conveyances and hydrogeology in the vicinity of Bond Farm (located west of the SWIA, see location in ***Figure 42***). A full-scale seepage study that fills in the gaps of existing geotechnical reports for Bond Farm and provides new information on the project site conditions is recommended to verify hydraulic conductivity rates. Additional surveying is also needed in the cypress wetlands of Yucca Pens. Additional surveys may be needed of channel dimensions in some streams such as upstream and downstream of the gaging stations on Burnt Store Road. Also, additional geotechnical field work is recommended in southern Yucca Pens to provide new data for modeling to better understand the interaction between the Yucca Pens and Gator Slough Canal hydrology. Borings are needed in Yucca Pens north of Gator Slough to identify the depth and effect of low and high permeable strata within the surficial aquifer sediments of the area. Initial conditions issues also affected model calibration. This can be resolved by having a longer time period of data available for calibration. Data collection at the Babcock Webb and Yucca Pens monitoring stations has continued without interruption via an on-going FWC monitoring contract at all stations except BW-10 which was destroyed in November 2021. Once additional data are available, model calibration can be extended into 2022 to confirm that the model can properly represent the increase in groundwater elevations during the late dry season and early part of the wet season.

The model should be re-calibrated once more detailed survey information is available in the vicinity of the SWIA to accomplish the following objectives:

- Obtain more detailed topographic information in the SWIA. Additional transects were surveyed in early 2022, and more transects are likely needed for both low-lying areas and higher ground.
- Surveying is needed to determine the outflow conveyances from the SWIA. This is needed because observed dry season water levels at monitoring station STA-6 have been observed below the known elevations of flow-ways that drain the SWIA.
- Field observations at the end of the wet season are recommended to augment the field survey effort both at the outflow conveyances as well as in locations between the lowest elevations of wetlands within the SWIA.

The recommended weirs in Yucca Pens should be evaluated in greater detail using a local-scale sub-model with a grid size of approximately 100 ft. This grid size should enable the model to evaluate drainage impacts of Gator Slough more accurately in the southern portion of Yucca Pens. In addition, the design assumptions of the groundwater seepage barrier at Gator Slough should be evaluated as the next steps in development of the seepage barrier concept and design.

EXHIBIT 1

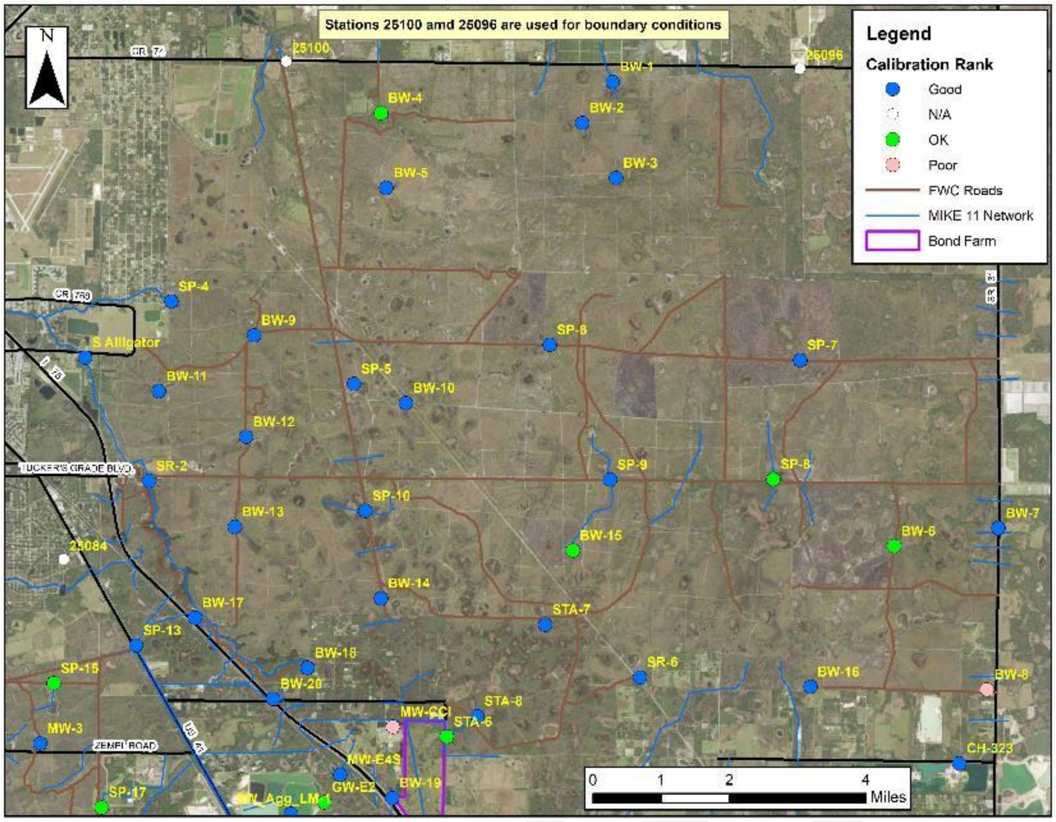
Explanation of Modified Hydraulic Conductivities Referenced in Table 3 Bond Farm HEI Inflows/Outflows

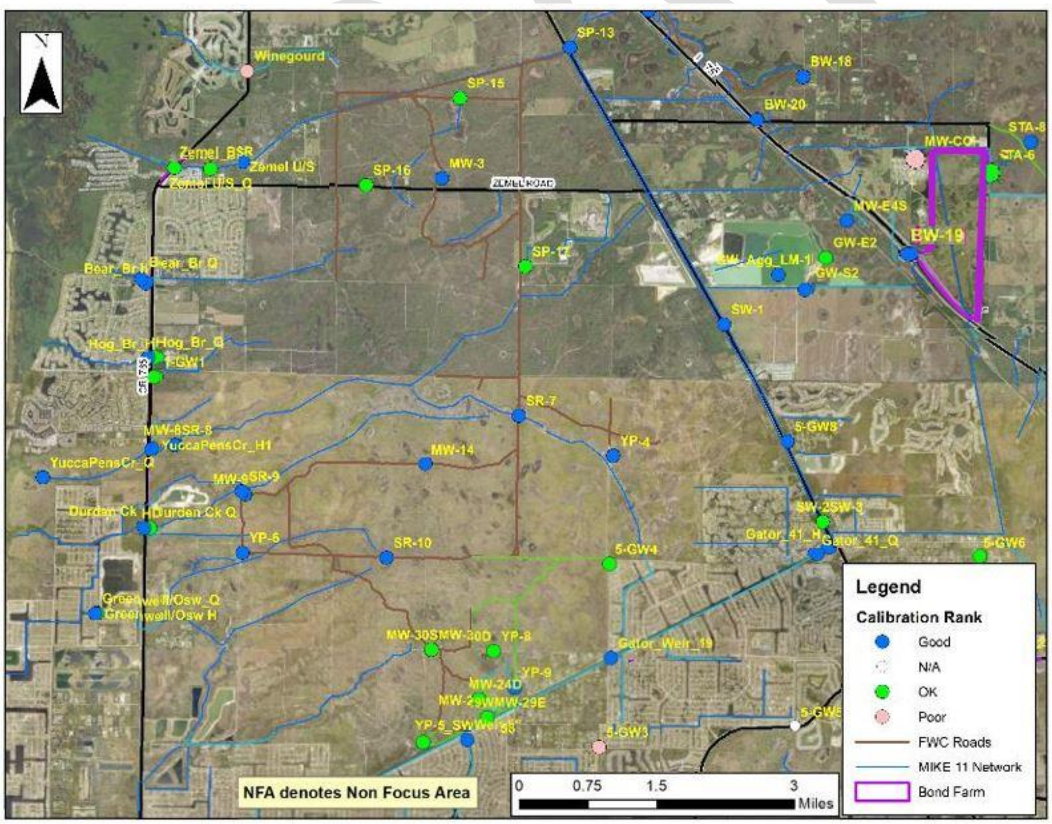
The initial analysis of Scenario 1 used the calibrated model (see Appendix 5C, WSA, 2022b). Maps of calibration stations are shown below, and tables comparing the calibrated model to a model with lower hydraulic conductivities follow the maps of calibration station locations. The calibrated model had upper water table horizontal hydraulic conductivities ranging from 456 to 1,500 ft/day with vertical conductivity values 10 times less than horizontal values. Lower water table horizontal hydraulic conductivity values ranged from 123 to 543 ft/day. Model calibration was best with these lower water table hydraulic conductivities, and resulted from an effort to match measured dry season water levels at numerous stations, most notably at stations STA-6, -7, and -8 northeast of Bond Farm. The adjustment of hydraulic conductivity values was performed after all surface water conveyance details had been added to the model and all other model input files had been vetted and sensitivity testing had been completed. However, during scenario analysis of Bond Farm, seepage rates from Bond Farm were significantly greater than expected.

Hydrogeologic studies of the Bond Farm area included lithologic descriptions of multiple borings around the perimeter of the proposed impoundment as well as field permeability measurements. Field permeability testing in Bond Farm estimated a permeability rate of 40 ft/day for the limestone layer (HDR, 2020), however there have not been any full scale studies looking at seepage throughout Bond Farm. A zone of lower water table horizontal hydraulic conductivity (35 ft/day) was used for only the area of Bond Farm based on the Bond Farm hydrologic investigation along with findings from a previous study in the nearby Southwest Aggregates mining cells which calculated horizontal hydraulic conductivities of 35 ft/day (WSA, 2017). The project area and larger Charlotte County is known to have porous shell layers. Therefore, conservative hydraulic conductivities were used to avoid over-estimating the capacity of Bond Farm to hold water. Additional studies are recommended to quantify groundwater seepage rates throughout Bond Farm and the project area (see RECOMMENDATIONS section for more information).

Because seepage losses from Bond Farm were higher than what was deemed to be appropriate in additional testing of Scenario 1, it was decided to test Scenario 1 with lower hydraulic conductivities. Two iterations of the entire model domain were conducted, one with a maximum horizontal hydraulic conductivity of 35 ft/day and another with the maximum set to 300 ft/day. Then, two iterations were simulated that varied horizontal hydraulic conductivity between 35 and 300 ft/day, and the resulting best calibration was for a simulation with the maximum horizontal hydraulic conductivity value of 297 ft/day for the upper water table. The resulting lower water table aquifer horizontal hydraulic conductivities ranged from 70 to 292 ft/day.

All results in the scenario analysis memoranda (Appendices 6B–D) use the original calibration with horizontal hydraulic conductivity capped only under Bond Farm at 35 ft/day. Results from the reduced hydraulic conductivities were only presented for Bond Farm HEI and Southwest Aggregates Reservoir water balance results presented in **Tables 6-3 and 6-8**.


Stations 25100 amd 25096 are used for boundary conditions
Legend
Calibration Rank
Good
N/A
OK
Poor
FWC Roads
MIKE 11 Network
Bond Farm
Miles


NFA denotes Non Focus Area
Legend
Calibration Rank
Good
N/A
OK
Poor
FWC Roads
MIKE 11 Network
Bond Farm
Miles

Calibration Comparison presented below. Calibration is better at 14 stations, and was worse at 13.

	Orig	Lower Kh	Orig	Lower Kh	Orig	Lower Kh		
Name	**MAE**	**MAE**	**R_Corr**	**R_Corr**	**R2 NS**	**R2 NS**	**Overall**	**Change?**
Bear Branch H	0.36	0.37	0.82	0.84	0.11	0.11	G	Same
Durden Creek H	0.84	0.95	0.87	0.88	0.61	0.57	OK	Same
Gator_Weir11_H	0.53	0.62	0.61	0.50	-5.11	-6.05	Poor	Same
Gator_41_H	0.46	0.60	0.95	0.94	0.37	-0.08	G	Worse
Gator_Weir_19	0.17	0.63	0.96	-0.10	0.87	-1.04	G	See note
Greenwell/Osw H	0.47	0.57	0.80	0.75	-0.62	-1.37	OK	Same
Hog Branch H	0.40	0.38	0.72	0.71	-0.36	-0.28	OK	Same
S Alligator	0.67	0.57	0.88	0.91	0.61	0.71	G	Same
SP-4	0.45	0.82	0.93	0.87	0.85	0.71	G	Worse
SP-8, BigWaterFor	0.97	0.65	0.88	0.88	0.54	0.75	OK	Better
SP-13, Zemel at 41	0.63	0.61	0.81	0.88	0.44	0.50	G	Same
SR-2, WebbLake	0.46	0.58	0.94	0.92	0.83	0.72	G	Same
SW-1, US_41	0.51	0.40	0.92	0.93	0.14	0.45	G	Better
SW-2, US_41 E	0.62	0.62	0.88	0.86	-1.03	-1.19	OK	Same
SW-3, US_41 W	0.42	0.45	0.85	0.84	-0.04	-0.39	OK	Same
YuccaPensCr_H1	0.71	0.67	0.77	0.89	0.48	0.52	G	Same
Weir 58	0.18	0.26	0.86	0.83	0.68	0.39	G	Same
Winegourd	1.33	1.11	0.03	0.00	-5.43	-3.75	Poor	Same
Zemel U/S	0.43	0.41	0.86	0.90	0.67	0.72	G	Same
Zemel_BSR	0.58	0.48	0.63	0.70	-1.25	-0.74	OK	Same
17-GW4	0.80	0.91	0.76	0.74	0.48	0.39	OK	Same
BW-1	0.47	0.55	0.94	0.93	0.84	0.81	G	Same
BW-2	0.65	0.61	0.90	0.91	0.67	0.74	G	Same
BW-3	0.50	0.33	0.94	0.96	0.73	0.91	G	Better
BW-4	0.91	0.66	0.88	0.89	0.49	0.79	OK	Better
BW-5	0.67	0.66	0.80	0.84	0.59	0.68	G	Better
BW-6	0.89	0.82	0.91	0.89	0.50	0.60	OK	Same
BW-7	0.53	0.54	0.94	0.93	0.81	0.80	G	Same
BW-8	1.15	1.20	0.90	0.90	0.33	0.28	Poor	Same
BW-9	0.66	0.71	0.87	0.90	0.71	0.67	G	Same
BW-10	0.29	0.29	0.96	0.96	0.90	0.90	G	Same
BW-11	0.69	0.68	0.86	0.85	0.58	0.65	G	Same
BW-12	0.45	0.48	0.90	0.91	0.80	0.79	G	Same
BW-13	0.42	0.42	0.93	0.92	0.80	0.84	G	Same
BW-14	0.31	0.34	0.96	0.96	0.91	0.89	G	Same
BW-15	0.84	0.72	0.90	0.90	0.22	0.40	OK	Better
BW-16	0.46	0.45	0.96	0.96	0.80	0.82	G	Same
BW-17	0.45	0.42	0.92	0.92	0.79	0.82	G	Same
BW-18	0.38	0.31	0.95	0.96	0.86	0.92	G	Same
BW-19	0.57	0.98	0.93	0.85	0.74	0.22	G	Worse
BW-20	0.46	0.37	0.97	0.94	0.80	0.80	G	Same
MW-23S	1.01	0.86	0.92	0.91	0.51	0.61	OK	Better
MW-24S	1.00	0.98	0.89	0.89	0.30	0.35	OK	Better
MW-29W	0.54	0.82	0.43	0.46	-0.28	-1.71	OK	Worse
MW-30S	0.82	0.73	0.82	0.81	0.04	0.29	OK	Better
SP-5	0.35	0.30	0.97	0.97	0.90	0.92	G	Same
SP-6	0.45	0.56	0.94	0.93	0.81	0.68	G	Same
SP-7	0.54	0.63	0.88	0.80	0.69	0.55	G	Same

Gator Slough at Weir 19: performance deteriorated because revised model used program logic rather
Than known gate operations. Drop in performance not considered valid.

	Orig	Lower Kh	Orig	Lower Kh	Orig	Lower Kh		
Name	MAE	MAE	R_Corr	R_Corr	R2 NS	R2 NS	Overall	Change?
SP-9	0.26	0.33	0.97	0.95	0.92	0.89	G	Same
SP-10	0.59	0.60	0.97	0.96	0.56	0.53	G	Same
SP-16	0.84	1.09	0.85	0.83	0.37	-0.01	OK	Worse
SP-17	0.93	1.24	0.56	0.47	-1.36	-3.21	OK	Worse
STA-6	1.07	1.24	0.82	0.80	0.19	-0.09	OK	Worse
STA-7	0.63	0.56	0.96	0.96	0.67	0.74	G	Same
SW_Agg_LM-1	0.51	0.75	0.83	0.79	0.50	0.18	G	Same
YP-5_SW	1.13	0.68	0.97	0.96	0.55	0.78	OK	Better
YP-8	0.91	0.79	0.91	0.90	0.22	0.40	OK	Better
YP-9	0.63	0.70	0.96	0.96	0.77	0.74	G	Same
1-GW1	0.95	0.90	0.87	0.85	0.20	0.31	OK	Same
5-GW3	1.04	1.33	0.91	0.84	-0.18	-0.66	Poor	Same
5-GW4	1.14	1.49	0.91	0.89	0.22	-0.25	OK	Worse
5-GW6	0.78	0.97	0.95	0.94	0.66	0.47	OK	Same
5-GW8	0.65	0.73	0.92	0.85	0.47	0.18	G	Same
16E-GW3	0.70	0.71	0.90	0.88	0.34	0.25	G	Same
20-GW3	0.64	0.99	0.97	0.94	0.82	0.55	G	Worse
CH-323	0.58	0.54	0.81	0.82	0.65	0.66	G	Same
L-721	0.54	1.37	0.97	0.92	0.49	-2.20	G	Worse
L-3207	0.21	0.29	0.91	0.90	0.82	0.70	G	Same
MW-3	0.63	0.54	0.85	0.87	0.54	0.70	G	Same
MW-8	0.64	0.62	0.89	0.88	0.40	0.52	G	Same
MW-9	0.38	0.46	0.89	0.89	0.74	0.74	G	Same
MW-14	0.48	0.50	0.89	0.88	0.70	0.70	G	Same
MW-23D	0.94	0.83	0.93	0.92	0.55	0.64	OK	Same
MW-24D	0.96	0.99	0.90	0.90	0.44	0.44	OK	Same
MW-29E	0.77	1.08	0.87	0.87	0.21	-0.49	OK	Worse
MW-30D	0.76	0.69	0.84	0.83	0.18	0.40	OK	Better
SP-15	0.89	0.72	0.89	0.89	0.36	0.63	OK	Same
SR-6	0.42	0.49	0.94	0.95	0.84	0.81	G	Same
SR-7	0.71	0.80	0.94	0.94	0.55	0.46	G	Same
SR-8	0.54	0.67	0.91	0.90	0.73	0.61	G	Same
SR-9	0.42	0.44	0.92	0.93	0.83	0.82	G	Same
SR-10	0.37	0.42	0.90	0.88	0.79	0.72	G	Same
STA-8	0.39	0.43	0.94	0.94	0.86	0.84	G	Same
SW_Agg_MW-CCI	1.50	1.72	0.95	0.95	-0.38	-0.77	Poor	Same
SW_Agg_MW-E4S	0.39	0.45	0.92	0.91	0.82	0.79	G	Same
SW_Agg_GW-E2	0.80	1.09	0.78	0.71	-0.01	-0.69	OK	Worse
SW_Agg_GW-S2	0.46	0.92	0.94	0.92	0.49	-0.80	G	Worse
YP-4	0.57	0.57	0.78	0.79	0.53	0.52	G	Same
YP-6	0.62	0.67	0.84	0.82	0.55	0.60	G	Same
Bear Branch Q	4.16	3.92	0.76	0.83	0.48	0.53	G	Better
Durden Creek Q	3.00	4.28	0.86	0.89	0.72	0.59	G	Same
Gator_41_Q	6.17	6.84	0.89	0.89	0.78	0.78	G	Same
Greenwell/Osw_Q	6.11	6.02	0.76	0.79	0.50	0.59	G	Same
Hog_Q	2.49	2.32	0.81	0.81	0.53	0.61	G	Same
NS Transfer	2.56	4.36	0.90	0.82	0.81	0.63	G	Same
YuccaPensCr_Q	6.91	7.66	0.86	0.83	0.72	0.60	G	Same
Zemel U/S_Q	11.33	10.46	0.69	0.74	0.45	0.51	OK	Better