

CENTRAL AND SOUTHERN FLORIDA PROJECT

COMPREHENSIVE EVERGLADES RESTORATION PLAN



B.2 HYDRAULICS
B.2.2 HYDROLOGIC
MODELING/METHODOLOGY REPORT

EVERGLADES AGRICULTURAL AREA
STORAGE RESERVOIRS - PHASE 1



US Army Corps of Engineers
Jacksonville District



South Florida Water
Management District

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(SFWMD Consultant Task 2.2.4)

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B.2.2.1 INTRODUCTION

The hydrologic modeling approach for PIR of the Everglades Agricultural Area Storage Reservoir – Phase 1 project must meet the goals and objectives of the project as stated in the Project Management Plan (PMP). These goals define a multipurpose facility that will influence the quantity, quality, and timing of water flows within the EAA and surrounding watersheds. The PMP goals are as follows:

1. Reduction of the Lake Okeechobee regulatory releases to the estuaries and back pumping from the EAA into Lake Okeechobee by sending the water to the south and into the reservoirs
2. Improved environmental releases through the storage of water and release to the Everglades during the dry season demand
3. Flow equalization and optimization of treatment performance of STA-2, STA-3/4, STA-5, and STA-6 by capturing peak storm event discharges within the reservoirs for control release to the STAs
4. Improved flood control and regional water supply for the agricultural community currently served by the EAA canals and other areas served by Lake Okeechobee

The development of an approach to model the hydrologic and hydraulic characteristics of the primary and secondary basins within the EAA is a critical element in the development of the PIR. Because of the PMP's multiple hydrologic and environmental goals for this project, a comprehensive computer model of these basins is needed.

As stated in the PMP, the South Florida Water Management Model (the SFWMM or the 2x2 model) will be used for establishing system-wide effects of Comprehensive Everglades Restoration Plan (CERP) project elements. The 2x2 model is referred to as the regional model. The 2x2 model is accepted as the state-of-the-art model for assessing the impacts of CERP project elements on a regional scale. The 2x2 model has been developed and calibrated specifically for the South Florida water management system and has undergone extensive peer review. It is accepted by the agricultural community, the environmental community, state and federal agencies, and the general public. The 2x2 model has been adopted by RECOVER as the modeling tool for periodic checks on the progress of all CERP projects with respect to overall CERP restoration goals.

The model to be used for evaluating the effect on the EAA of the storage reservoirs will be referred to herein as the sub-regional model. The sub-regional model will receive boundary conditions from the regional model and provide more detailed results back to the regional model. This draft report summarizes the development of the model and how the data described in Table B.2.2.1 is used in the modeling effort.

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Table B.2.2.1 MIKE SHE/MIKE 11 Model Data Input Requirements and Corresponding File(s) & Folder(s) Obtained

MIKE SHE - general data				
Input	Basic data requirement	Preferred for mat	Availability	Corresponding File(s) & Folder(s)
Rainfall distribution	Point/Polygon data (x,y) of rainfall stations or precipitation zones	ArcView GIS coverages, MIKE SHE .T2	Adequate data have been obtained	Shapefiles/met
Rainfall time series	Time series of precipitation	Excel spreadsheet, MIKE SHE .T0	Adequate daily and selected hourly data have been obtained	Onethreefivedata.xls, onethreefivedata_EAA_fromGIS
Model area	Horizontal extent of model area, polygon data (x,y)	ArcView GIS coverages, MIKE SHE .T2	Established. See below.	Shapefiles/ Boundary folder, Shapefiles/ Cultural folder

MIKE SHE OL - overland flow component				
Input	Basic data requirement	Preferred format	Availability	Corresponding File(s) & Folder(s)
Digital elevation model (DEM)	Contoured data or point data (x,y,z) of surface elevation.	ArcView GIS coverages	Must be synthesized from a variety of sources. Data collection completed	Shapefiles/ topo folder
Mannings surface roughness numbers	Land use map	ArcView GIS coverages	Obtained from the SFWMM	Obtained from the SFWMM

MIKE 11 - river hydraulics model				
Input	Basic data requirement	Preferred format	Availability	Corresponding File(s) & Folder(s)
Digitized river/canal network	Point/line/polyline data (x,y) of river branches	ArcView GIS coverages	Obtained from SFWMD GIS data base	Mike11/Images Folder, Shapefiles/ Canals folder, Shapefiles/ Hydro folder
Digitized horizontal extent of surface water bodies	Point/line/polyline data (x,y) of horizontal surface water body extent	ArcView GIS coverages	Obtained from SFWMD GIS data base	Mike11/Images Folder
Digitized river and surface water body cross sections	Cross section data (x,z) of main river, flood plains, lakes and reservoirs	Excel spreadsheet, MIKE11 ASCII format, MIKE11 cross section database (.xns11), or HEC-RAS	Obtained for Miami River, N New River, Cross, Bolles, Hillsboro & some L canals. Data for some L canals is old and	Shapefiles/ Cross_Sections folder

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			suspect.	
Hydraulic structure data	Location and geometry (x,z) of all structures, rivers, operational rules/schedules	Excel spreadsheet, MIKE11 input (.nwk11)	Obtained from SFWMD Structure Book	Mike11/StructureTime Series Folder, Mike11/OldStuff Folder
Surface water use data	Location (x,z) of diversion points, time series of water use	Excel spreadsheet, MIKE11 input (.nwk11)	Obtained from SFWMD permit files	Shapefiles/ Ag permits folder
Water stage and gauged flow data	Location and ID of gauging station, time series of data	Excel spreadsheet, MIKE11 input (.dfs0)	Daily data obtained from DBHYDRO. Selected hourly periods obtained from SFWMD	Mike11/StructureTime Series Folder

MIKE SHE UZ - unsaturated zone

Input	Basic data requirement	Preferred format	Availability	Corresponding File(s) & Folder(s)
Soil map - distribution of characteristic soil columns	Polygon data (x,y) of surface soil type.	ArcView GIS coverages	Obtained	Shapefiles/soils
Hydraulic conductivity data	Hydraulic conductivity curve, $K(\theta)$ for the soils	Excel spreadsheet, MIKE SHE UZ database	Some data found in studies for portions of EAA	Shapefiles/ Soils folder
Soil water retention data	Retention curve, $\theta(pF)$ for the soils	Excel spreadsheet, MIKE SHE UZ database	Available from C-43 Watershed MIKE SHE Model - S-4 Basin	Available from C-43 Watershed MIKE SHE Model - S-4 Basin

MIKE SHE ET – evapotranspiration

Input	Basic data requirement	Preferred format	Availability	Corresponding File(s) & Folder(s)
Potential ET distribution	Point/Polygon data (x,y) of ET stations or ET zones	ArcView GIS coverages, MIKE SHE .T2	Obtained from the SFWMM	Shapefiles/Met
Potential ET time series	Time series of potential ET	Excel spreadsheet, MIKE SHE .T0	Obtained from the SFWMM	Pet6595.xls
Land use map	Polygon data (x,y) of land use / vegetation cover	ArcView GIS coverages	Obtained from the SFWMD GIS data base	Provided under separate cover. See Deliverable 4.1.2.1.
Vegetation data	Time series of leaf area index (LAI) and root density function (RDF)	Excel spreadsheet, MIKE SHE vegetation database	Obtained from C-43 Watershed MIKE SHE Model - S-4 Basin	Obtained from C-43 Watershed MIKE SHE Model - S-4 Basin

MIKE SHE SZ - ground water

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Input		Basic data requirement	Preferred format	Corresponding File(s) & Folder(s)
3-D geological model	Point/contours (xyz) of upper and lower surfaces of all geological units	ArcView GIS coverages, MIKE SHE .T2	Some data found in studies for portions of EAA*	Groundwater folder
Hydraulic properties	Points/polygons/contours (xyz) of transmissivity based on e.g. pump test data	ArcView GIS coverages	Some data found in studies for portions of EAA	Groundwater folder
Groundwater withdrawal	Location of pumping wells (x,y), aquifer unit, time series of withdrawal	Excel spreadsheet, MIKE SHE (.T0)	Obtained from SFWMD ERP** permit files	Piezometer Well Information Report.xls, USGS_NWIS.xls, EAA_fgs_locations.xls
Drainage	Polygon or line (x,y) map of drain systems and drained/non-drained areas	ArcView GIS coverages, MIKE SHE .T2	Obtained from SFWMD ERP permit files	Gwl.xls, pz-okee.xls, GWLOverview.xls
Observed potential head data	Location of observation wells (x,y), aquifer unit, time series of heads	Excel spreadsheet, MIKE SHE (.T0)	Obtained from DBHYDRO, USGS, and IFAS	Groundwater folder, GWL.dfs0

* Studies are referenced in Section B.2.2.2.6

** ERP – Environmental Resource Permit

B.2.2.2 MIKE SHE/MIKE 11 MODEL DEVELOPMENT

B.2.2.2.1 General Data

The general data includes rainfall time series and the model grid. The rainfall time series have been obtained from a rainfall frequency analysis study (Pathak, 2001) and a data file of rainfall used in the 2x2 model (Personal Communication, D. Welter, 2002). The stations are presented in **Figure B.2.2.1**. In general, the model uses daily rainfall values. Hourly data may be used during selected periods of high intensity precipitation. The hourly data have been obtained from SFWMD. The number of periods of hourly data will be determined during calibration. Hourly rainfall will be used for intense precipitation that takes place over short time periods. The intensity that will initiate a switch to hourly data has not been established; however, rainfall over two inches/hour for a period of four hours is a possible trigger point.

Model Steering Committee members have had comments regarding use of rainfall data for modeling design storms. One concern was that the model is calibrated with daily rainfall, and therefore the model may not be appropriate for use in modeling rainfall conditions using hourly data. The model being calibrated does use daily rainfall, however the time step for the river model is five minutes, and rainfall is divided into

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four-hour increments (if daily rain = 1.2 inches, there are six 4-hour long rainfall pulses = 0.2 inches). The model will also be calibrated using hourly data for a three-month period that includes a major rainfall event. Accordingly, it is believed at this time that the model will be appropriate for design storms having hourly rainfall data.

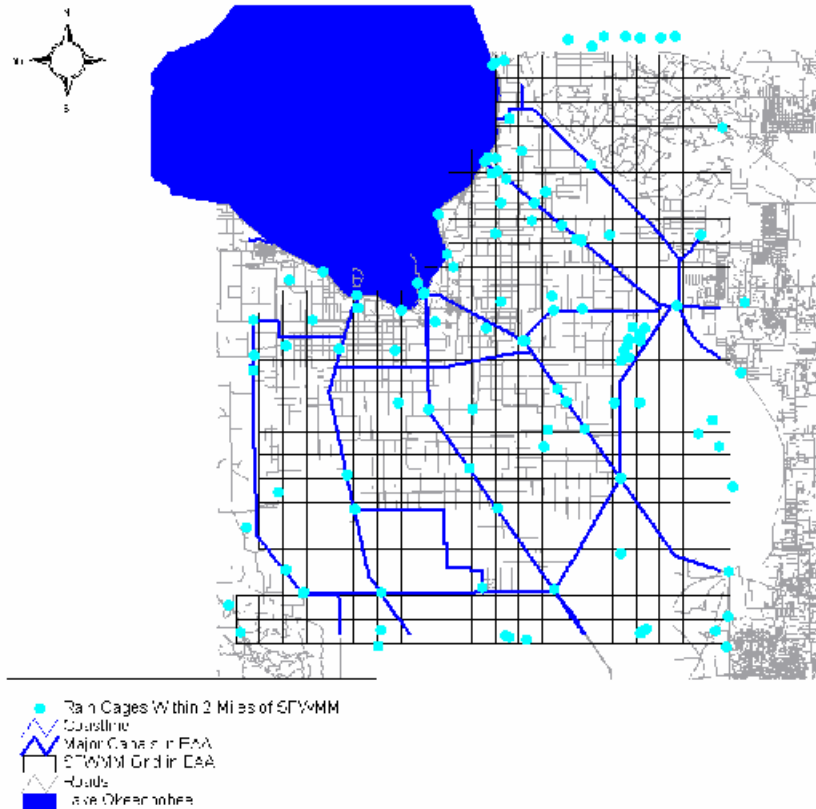


Figure B.2.2.1 – Selected Rainfall Stations from Pathak (2001)

The matrix time series of rainfall will be used. Where a rainfall monitoring station is present within a cell, the measured data is used. For cells between rainfall stations, a synthetic time series was generated using a SFWMD program. The time series for a synthetic cell is calculated using inverse distance weighting from three nearby rainfall stations surrounding the grid cell. The rainfall grid is 1x1 miles.

The extent and size of the model grid is presented in **Figure B.2.2.2**. The model grid has been set to lay right on top of the 2x2 grid so that data can be readily exchanged. In addition, the grid extends into the C-139 Basin and Water Conservation Areas 1, 2, and 3. Boundary conditions will be obtained from the 2x2 model for the calibration period June 1, 1996 to May 31, 2000 and the verification period June 1, 2000 to May 31, 2002.

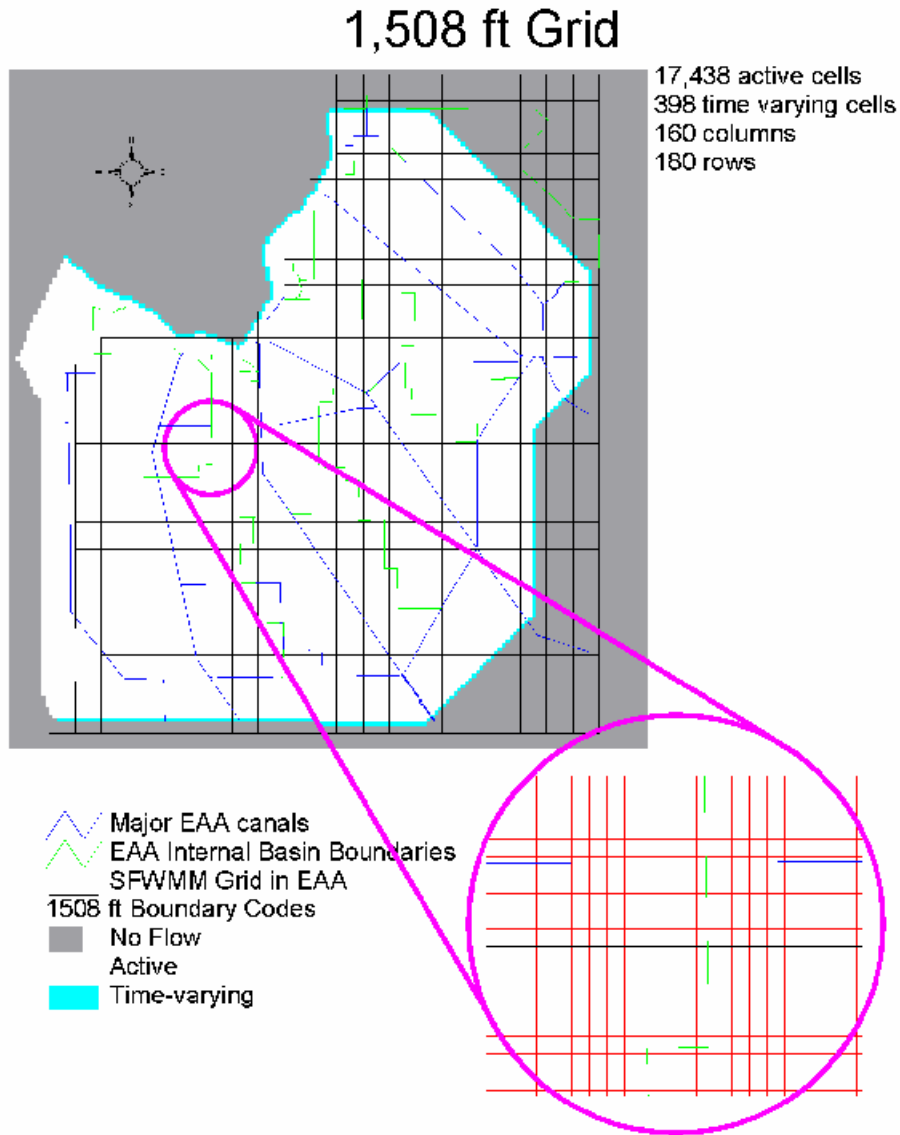


Figure B.2.2.2 – Potential MIKE SHE Grid for the EAA Basin

The western limit of the grid has been extended westward approximately two miles into the C-139 Basin. The purpose of extending the grid is to assure that groundwater seepage from the proposed western EAA Storage Reservoir (Cell C) is adequately described by the MIKE SHE model. There are three hydraulic control structures in the general vicinity of Route 846 that can be used to provide boundary conditions. These structures are the U.S. Sugar Corporation (USSC) Deerfence Structure, structure G-151 on L-2W, and structure G-96 on L-1. The one problem with extending the boundary to Route 846 is that there is little groundwater information along this boundary, and field observations indicate that the tailwater elevations for Deerfence, G-151, and G-96 are lower than the groundwater elevations between those structures. Reasonable assumptions on the time distribution of the boundary conditions were made based on land use and spatial density

of wetlands. There are two wells in the C-139 basin that have four individual water level values (spring and fall readings for two wells) for 2001 and there is another well in the C-139 Annex basin. The boundary condition structures and the wells proposed for model calibration are shown in **Figure B.2.2.3**. Additional details on the western boundary are presented in the draft calibration report.

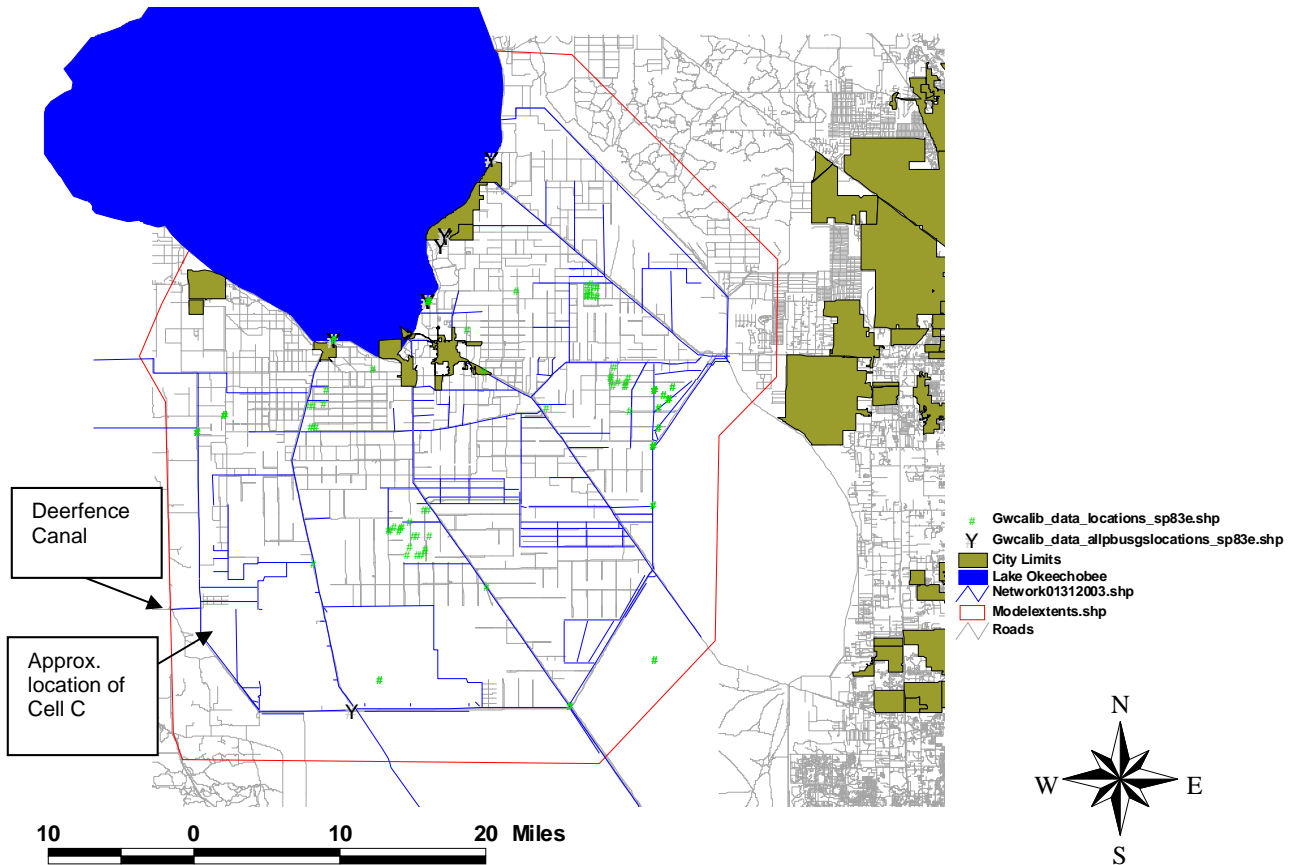


Figure B.2.2.3 – Groundwater Calibration Points

B.2.2.2.2 MIKE SHE OL - Overland Flow Component

The primary input data for specification of overland flow include the digital elevation model and Manning’s n values for the land surface. MIKE SHE/MIKE 11 requires a digital elevation model (DEM) that allows for reasonably accurate flood plain mapping. Topographic survey information is limited in the EAA; however, a reasonable DEM was generated by merging land surface elevation data from a number of sources, including permits, previous surveying efforts, and available data from the landowners. Cross sections along the Miami River, North New River, Bolles Canal, and Cross Canal have

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natural ground elevations taken outside the canal right-of-way. Meetings have been held with landowners to request accurate land surface elevations. Because of the lack of topographic relief in the EAA, having one to five elevation points within each of the farm permits will be sufficient for modeling purposes. Since all farms have a staff gage to measure water levels inside the farm, and most farmers can relate the average land surface elevation within their farm to that gage, the elevation of the farm can be approximated. **Figure B.2.2.4** presents the draft topographic map for the EAA. It should be noted that the topographic map is sufficient for planning level modeling and does not conform to USACE EM-1110-1-1005 Topographic Surveying or FAC Chapter 61G 17-6 Minimum Technical Standards.

Manning's n values have been obtained from an equation used in the 2x2 model (Brion, 2003). The equation is based on SFWMD measurements in the Everglades Nutrient Removal Project. The equation is land use specific, yielding different Manning's n values for different vegetative cover. This is discussed further in the calibration report.

B.2.2.2.3 MIKE 11 – River Hydraulics Model

The main input parameters are cross sections of canals, cross sections for STAs, specifications of the hydraulic control structures, water use data, and measured canal stage and flow data. **Attachment B.2.2.2** and **Figure B.2.2.5** list the structures that are included in the model. The modeling approach for weir/gate/pump operations is described in Attachment B.2.2.2. The operation of the structures is described in the SFWMD Structure Book, and structure operations in MIKE 11 are based on the Structure Book details. Additional sources of information include the Interim Action Plan for S-2 and S-3, interviews with SFWMD staff, and addendum files for structures not currently in the Structure Book (e.g. G-404).

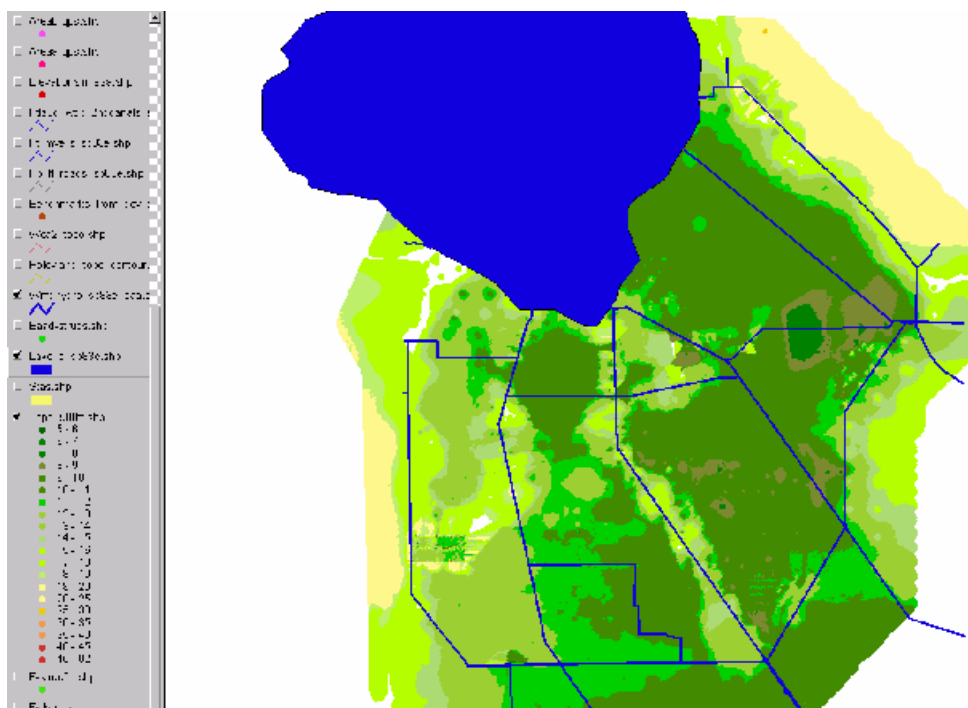


Figure B.2.2.4.a – Draft Topographic Map

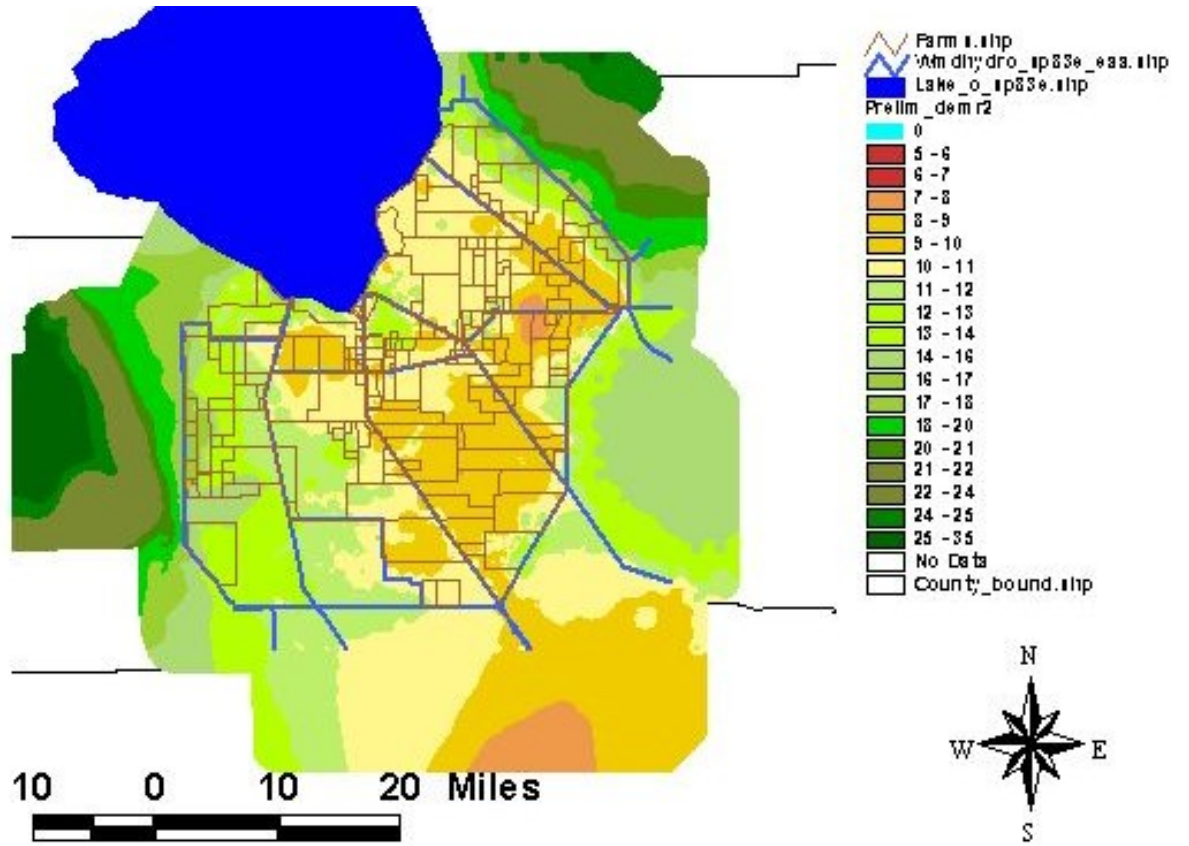


Figure B.2.2.4.b – Revised Topographic Map

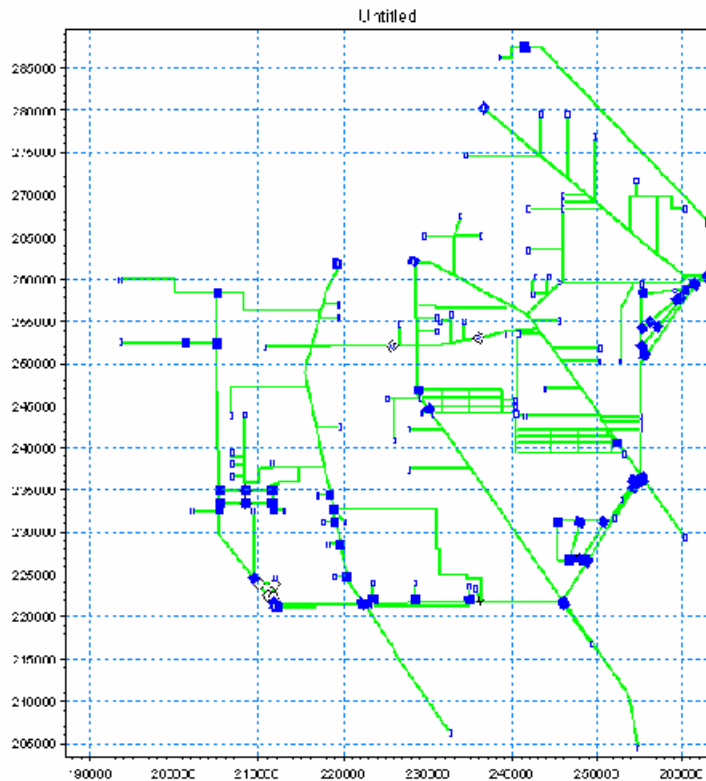


Figure B.2.2.5 – Map of Network and Structures in MIKE 11 Model as of March 19, 2003 (structures shown as blue squares, boundaries as open blue boxes)

Water use data are available from the SFWMD permit files for 292 discharge locations associated with 226 farm permits. At each discharge location, there may be a number of pumps to discharge water from the farm to the major SFWMD canals. The total number of pumps exceeds 600. Total pump flows to the major SFWMD canals are available from a SFWMD permit database.

A culvert or a pump at each farm provides irrigation inflow from the primary SFWMD canals. In general, these inflows are not measured; however, the gate operations are available from the SFWMD permit database. The dimensions of the gates and pumps are available from the text files describing each permit.

Each farm has a network of interior canals used for both drainage and irrigation flows. The largest canals are the interior main canals that are often in the range of 10 feet deep. The interior main canals drain the lateral canals, which in turn drain field ditches. The lateral canals are usually greater than five feet deep; however, the field ditches are usually only one or two feet deep. The length of the interior main canals and some of the lateral canals is available from a SFWMD GIS file. This GIS file was used to estimate the volume of canal storage within each farm. The MIKE 11 canal network includes a portion of the length of the interior main canals. The storage volume will be specified to represent the storage associated with the remainder of the interior main canal and the interior laterals. Since assumptions were made to estimate the storage volume, this parameter will be modified during calibration to understand the sensitivity of this

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parameter. The approach for modeling these farm structures is described below in the discussion of drainage presented in section 2.2.2.4.

Measured stage and flow data are available for many locations within the EAA. To date, data has been obtained for 122 stage recorders and 59 flow measurement stations. This information is summarized in Tables B.2.2.3 and B.2.2.4 of Attachment B.2.2.3.

STAs 1W, 2, 5, and 6 are currently treating runoff from the EAA and other sources runoff. STA-5 is currently treating runoff from the C-139 Basin. Table B.2.2.2 describes each STA and identifies when each began flow-through operations its period of operation. The Everglades Nutrient Removal Site Project began flow-through operations in 1994, and was incorporated into STA-1W in early 2000. STA-2 Cells 2 and 3 began flow-through operations in October 2000. Cell 1 of STA-2 began flow-through operations in July 2001. In mid 2001, however only cells 2 and 3 were discharging water. Cell 1 was used to hold water, however there were no discharges due to concerns regarding mercury. STA-5 and STA-6 have been operating for some times several years, and good hydrologic budgets have been published for these two facilities (Abteu et. al., 1998; Heubner, 2002; Imru, 2001). Operational plans have been developed for STA 1W, STA 2, STA 5, and STA 6 (SFWMD, 2000; SFWMD, 2001a; SFWMD, 2001b; and SFWMD, 2002a).

Table B.2.2.2 – STA Start-up Dates Flow-Through Operations

STA	Start-up Date Flow-Through Operations Began	Basins Treated
1W	19945 (ENR), July4/20001	ENR: 300 cfs. 1W will treat S-5A, portions of L-8 and C-51W runoff
2	Mid October 20002001	S-2/S-6, portions of S-5A and 298 Districts
5	October Mid 1999	Deerfence Canal, C-139
6	Early 1998December 1997	USSC Southern Division Ranch 2 (portion art of S-8) basin)

B.2.2.2.4 MIKE SHE - Unsaturated Zone

The main input parameters for the unsaturated zone include the following:

- soils description
- the thickness of soil and rock horizons within the unsaturated zone
- hydraulic conductivity of the soil, and
- soil water retention data.

These data have been obtained from multiple sources. Included are studies completed by the University of Florida Institute of Food and Agricultural Sciences (IFAS) (2001), USGS soil surveys, a previous MIKE SHE model of the C-43 watershed near Clewiston, Florida (DHI, 1999), and interviews with property owners and farmers in the EAA. Muck thickness and caprock elevation maps were obtained for over 24 farms within the EAA. Estimates of muck thickness were also obtained for a number of other farms.

Farm Drainage

Interior farm drainage coefficients are used in MIKE SHE to represent minor interior canals not explicitly defined in MIKE 11. The drainage feature in MIKE SHE allows for conveyance of water from the saturated zone to a farm discharge point in MIKE 11. The proposed approach for modeling drainage is to use data from selected farms that have detailed monitoring data for: 1) flows in and out of the farm, 2) interior canal levels, and 3) ground water levels. The interior main canals and lateral canals will be added to the MIKE SHE model for up to 16 farms if sufficient data is available. Currently, detailed data has been obtained for ten farms within the EAA. Water budgets for these farms will be developed based on the detailed interior networks and measured data. These farms will then be modeled with a parallel model that does not have the detailed interior canal networks but uses drainage coefficients to approximate the on-farm water table management practices. This data will then be used to estimate appropriate drainage coefficients for the remainder of the EAA. Initially drainage coefficients on the order of 14 days will be used. Currently a constant drainage depth of 0.5 feet below sea level (bsl) is being use but will be modified to reflect the typical water table elevation associated with the dominant vegetation type in a model grid cell (*e.g.* sugar cane, sod, *etc.*).

Canal to groundwater exchange in MIKE SHE/MIKE 11 is bi-directional where the canal accepts groundwater inputs if the water elevation in cells adjacent to the canal are higher than the canal elevation. The canal discharges to the aquifer if the canal level is higher than the water surface elevation in cells adjacent to the canal. The rate of exchange can be based on the transmissivity of the surficial aquifer, the permeability of the canal sediments, or a combination of both factors.

Muck accumulations in EAA canals may reduce canal-groundwater exchanges, however many canals have vertical walls cut into the caprock and porous Fort Thompson Formation sediments that have relatively high flow rates. Furthermore, the muck accumulations in the canals are unconsolidated and are easily resuspended. Accordingly, the farmers report significant changes in canal stages due to seepage. Certain farms report significant seepage from adjacent water conservation areas. If possible, canal to groundwater exchange coefficients consistent with previous values used in the seepage study of S-7 and empirical information available from EAA land managers will be used. Currently, constant coefficients for canal to groundwater exchange are being used. A study of seepage conducted as part of Task 4.1.6 will be utilized to assist in calibration.

B.2.2.2.5 MIKE SHE ET – Evapotranspiration

Potential ET distribution and time series data were obtained from a grid file from a coverage within the 2x2 model. This information was sub-divided into the smaller grid size used in the MIKE SHE sub-regional model. Land use data has been provided by the SFWMD GIS database. Vegetation data varies annually in the EAA subject to the crop rotation requirements of individual farmers.

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Sugar cane has a three to five year cycle. The cane is planted at the beginning of year one, and harvested after one year. The next two to four years of cane growth comes from the root system left in place after year one. The field is then disked and is usually leveled. The field may then be left fallow for a year, or may be planted in corn or vegetables for one or two years. Many farmers will flood the sugar cane fields for three to six months or grow rice after disking to kill off wire worms. Some farmers plant two cycles of sugar cane for a total of seven years (two 3-year cycles and one year of fallow).

Sod farmers keep a field in sod for a number of years until the weeds become resistant to the herbicides. At that point, the field is disked and planted in sugar cane or vegetables. Accordingly, the exact crop on any specific field varies from year to year, however some general trends remain constant.

In any given year, agricultural land use within the EAA generally consists of 70 percent sugar cane; the remaining 30 percent is split between rice, vegetables, and sod. Most farms are primarily sugar, while other farms are primarily sod or a mix of vegetables, sugar cane, and sod. Unless specific information is obtained from the farmer or SFWMD staff, the following assumptions will be utilized within the model:

1. The sugar cane farms will be modeled as 80% sugar cane, with the remainder either fallow, rice, or vegetables,
2. The vegetable farms will be modeled as 70% vegetables and 30% sugar cane, and
3. The sod farms will be modeled as 80% sod with the remainder in sugar cane (this may be modified).

The portion of the EAA bound by the L-canals has a total area of 616,000 acres, and the Holey Lands and the Rotenberger WMAs have an area of approximately 64,700 acres. The STAs, excluding STA 1E, have a combined area of approximately 40,500 acres. Urban land in the vicinity of Belle Glade and South Bay totals approximately 3,500 acres. This leaves approximately 507,300 acres of agricultural land in the EAA.

Crop specific ET parameters are available for the sugar cane areas located directly west of Clewiston, in the C-43 Basin watershed.

B.2.2.2.6 MIKE SHE SZ – Groundwater

Monitoring and groundwater pumpage data

The University of Florida Institute for Food and Agricultural Sciences (IFAS) has monitored groundwater at selected farms within the EAA. These farms are:

Farm	Basin ID Number
Boynton Farms, Inc.	50-038-01
Markham Sugar Farms, Inc.	50-042-01
Roth Farms, Inc.	50-035-02
Guerry	50-058-01
Florida Crystals	50-062-01

This IFAS well monitoring data for 53 wells has been obtained. Groundwater data from a seepage study at Pump Station S-7 conducted by SFWMD has been obtained (Krupa and Hill, 2002). Other data has been obtained from studies of ground water movement and drainage conducted by the SFWMD and IFAS (Rohrer, 1999; Garcia et. al., 2001). Data for a number of wells were obtained from the SFWMD DBHYDRO database. Groundwater monitoring stations are summarized in Table B.2.2.5 of Attachment B.2.2.3. Groundwater withdrawal is known to occur in South Bay and Belle Glade; however, the withdrawal data is not available and the wells are small residential users. Accordingly, these withdrawals have not been included in the model.

Hydrogeologic Data

Hydrogeologic data has been obtained from a number of sources. The designs for STA-2 and STA-3/4 included boring data and ground water modeling data. The models for these STAs were obtained. The USACE installed six borings in support of the EAA Storage Reservoir project. The USACE data were incorporated into the geologic model of the EAA.

The Florida Geological Survey (FGS) electronic well database has been reviewed and appropriate lithologic data was incorporated in the EAA geologic model. The FGS lithologic database includes data for 75, 87, 66, and 100 wells in Broward, Hendry, Martin, and Palm Beach Counties, respectively. Only the FGS wells with topographic elevation data were included in the EAA geologic model database. As a result, the FGS lithologic borehole data from only 19 wells in Broward, 26 wells in Hendry, 16 wells in Martin, and 43 wells in Palm Beach County were used in the EAA MIKE SHE model database.

Site specific data from STA-2 and STA-3/4, included geologic and/or muck thickness data for 106 soil borings and five test wells. The borings and test wells were advanced to support the design of these STAs. The thickness data was used in a qualitative fashion because the geologic information from STA-2 and STA-3/4 did not include formation determinations.

A number of significant hydrogeologic units were identified during review of the available geologic data. The units of interest included the muck soils that are significant within the EAA, the low permeability, indurated portions of the Fort Thompson Formation located near the surface in the EAA (caprock), Holocene sands outside of the EAA, the Fort Thompson Formation, and the lower Tamiami Formation.

Review of hydrogeologic data from wells in the EAA indicates the thickness of the caprock is variable throughout the area. However, well indurated/low permeability layers commonly extend some depth below the material that is referred to as caprock (Krupa and Hill, 2002). Because the lower permeability sediments are present below the caprock, the Fort Thompson Formation has been split into a lower permeability, upper Fort Thompson hydrogeologic unit, and a higher permeability, lower Fort Thompson hydrogeologic unit. The significant hydrogeologic units in the EAA are shown graphically in **Figure B.2.2.6**.

<i>Geologic Unit</i>	<i>Calculation Layers</i>
Muck/Surficial Sands	1
Caprock/Equivalent Sands	
upper Ft. Thompson	
lower Ft. Thompson	2
Tamiami	3

Figure B.2.2.6 Relationship of Geologic Units and Calculation Layers.

Hydrogeologic cross sections are presented below in Figures B.2.2.7 and B.2.2.8.

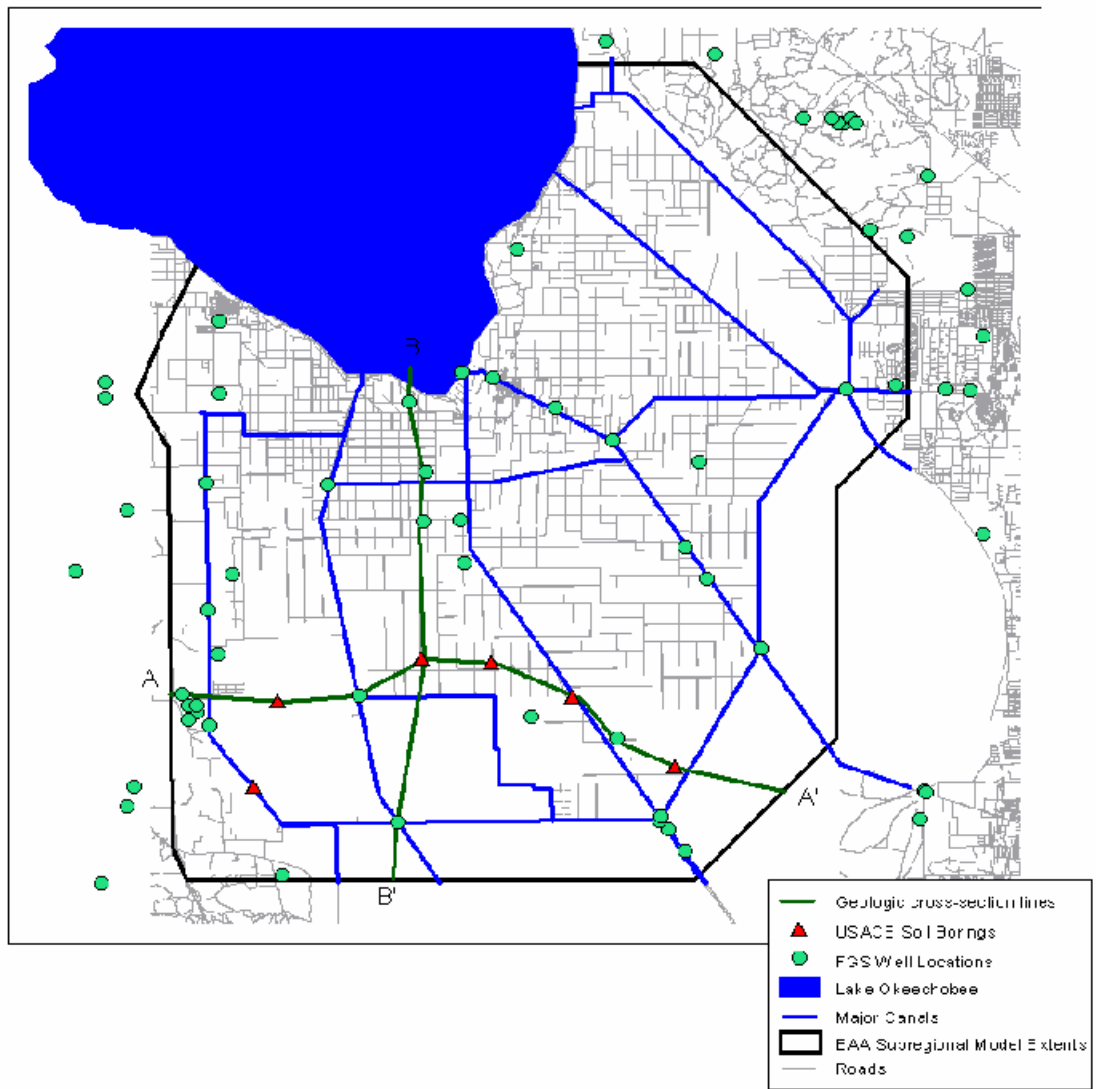


Figure B.2.2.7 – Location of Hydrogeologic Cross Sections in the EAA

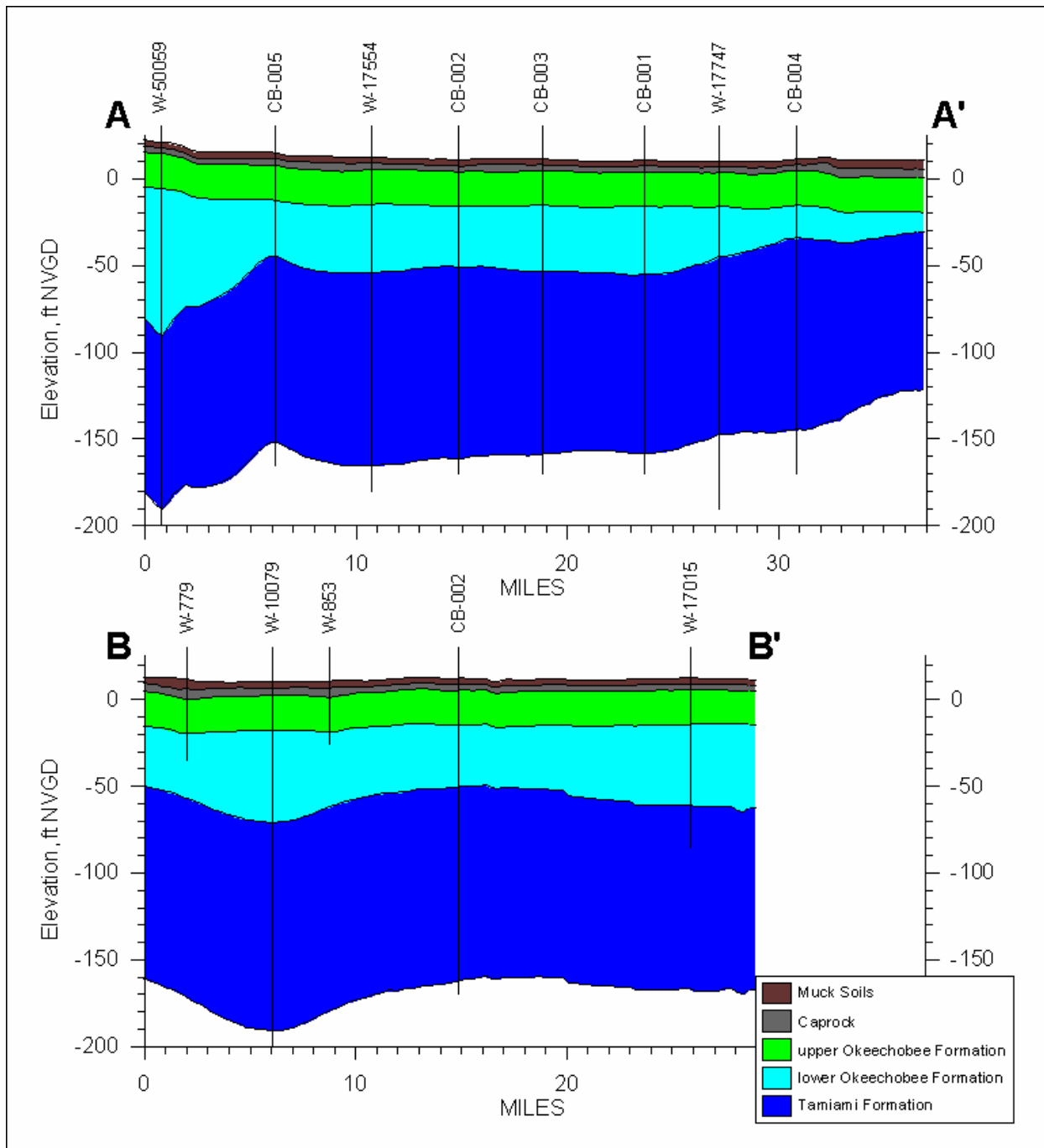


Figure B.2.2.8 – Hydrogeologic Cross Sections in the EAA

A brief description of each significant geologic unit is given below.

Muck soils

The muck soils in the EAA occur at land surface and range from fibrous to granular organic soils. The muck soils were derived in wetland regions from decaying plant matter and are primarily Histisols. Historically, the muck was found to have a thickness of up to 17 feet in the EAA (Stephens and Johnson, 1951). Since that time, soil losses have occurred, resulting from surface water level management practices in the EAA and

adjacent Water Conservation Areas (WCAs). Currently, the muck in the EAA and adjacent WCAs ranges in thickness from less than one foot to 13 feet. The muck soils are typically permeable, have a large storage capacity, and have a high capillary potential.

Fort Thompson Formation

The sediments that comprise the Fort Thompson Formation vary from unconsolidated, variably calcareous and fossiliferous quartz sands to well indurated, sandy fossiliferous marine and freshwater limestones to clayey sands and sandy clays (Scott, 2001). The relationships between the lithologies of the Fort Thompson Formation are complex and lateral correlation of individual beds is difficult. The caprock, where present, makes up the upper portions of the Fort Thompson Formation. In the EAA, the Fort Thompson Formation typically is present from the land surface to a range of approximately 15 to 190 feet below land surface (bls).

Tamiami Formation

The Tamiami Formation is a poorly defined lithostratigraphic unit containing a wide range of mixed carbonate-siliciclastic lithologies (Missimer, 1992). It occurs near land surface in Hendry County and at depth in Broward and Palm Beach Counties. Lithologies of the Tamiami Formation include 1) fine to coarse-grained fossiliferous sand, sandy clay, and clayey sand; 2) poorly consolidated fossiliferous limestone; and 3) well indurated, sandy, fossiliferous limestone. Phosphate is present in virtually all lithologies as sand- to gravel-sized grains (Scott, 2001). The limestones of the Tamiami Formation typically exhibit good intergranular and moldic porosity. In the vicinity of the EAA, the Tamiami Formation generally dips and thickens to the southeast. In the EAA, the Tamiami Formation is typically present from 15 to 190 feet bls to approximately 31 to 290 ft bls.

The geometry of the five significant geologic layers and initial hydrogeologic parameters are discussed briefly below.

Muck and Holocene sand geologic layer

The thickness of the muck soils and Holocene sands is shown on Figure B.2.2.9. The thickness of the muck soils was based on farm surveys, survey data collected as part of the EAA Reservoirs Project, and the EPA REMAP project (EPA, 1998). The muck thickness outside of the EAA is arbitrary, represents a minimum thickness of one foot and represents undifferentiated Holocene sands.

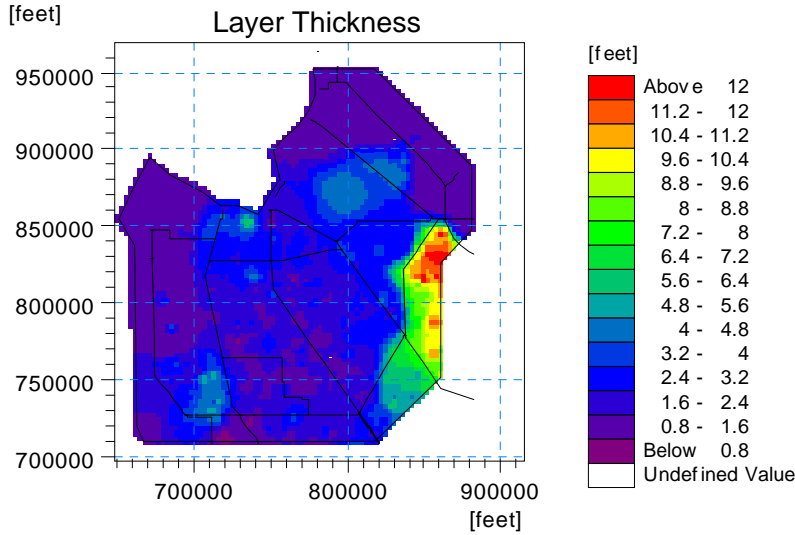


Figure B.2.2.9 Thickness of the Muck/Surficial Sand Geologic Layer

The lower surface elevation of the muck soils and Holocene sands is shown on Figure B.2.2.10. This surface was determined by subtracting the muck thickness shown in Figure B.2.2.9 from the Digital Elevation Model (DEM) developed for this project.

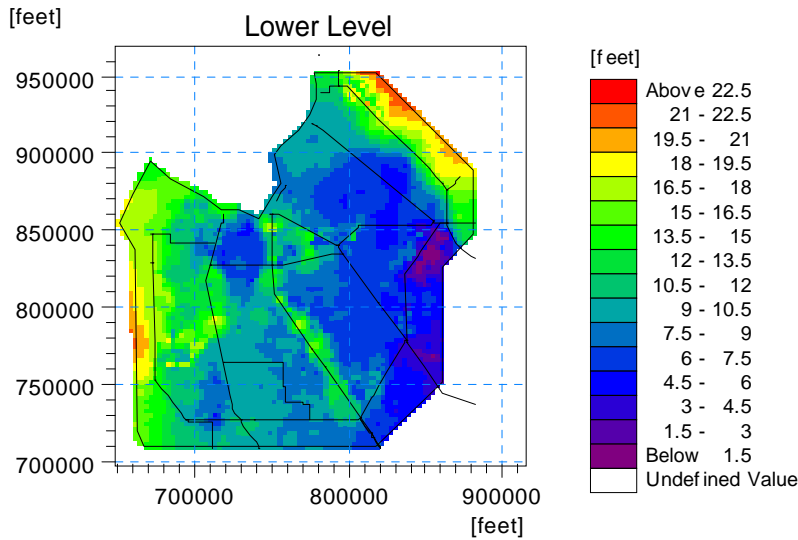


Figure B.2.2.10 - Lower Surface of the Muck/Surficial Sand Geologic Layer.

Initial horizontal hydraulic conductivities were based on the initial vertical saturated hydraulic conductivities used in the MIKE SHE unsaturated zone module. A horizontal to vertical hydraulic conductivity ratio of one and 10 were used for muck soils and

Holocene sands, respectively. The horizontal and vertical hydraulic conductivity are shown on **Figure B.2.2.11** and **Figure B.2.2.12**.

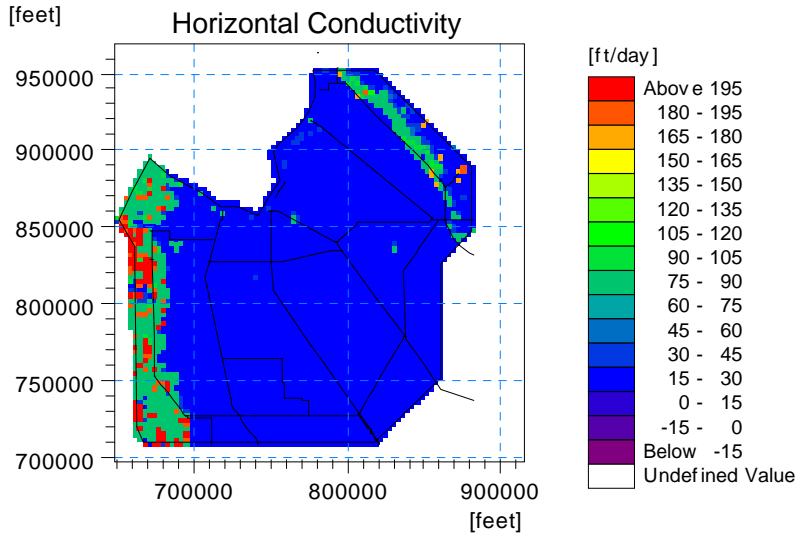


Figure 2.2.11 - Initial Horizontal Hydraulic Conductivity of the Muck/Surficial Sand Geologic Layer

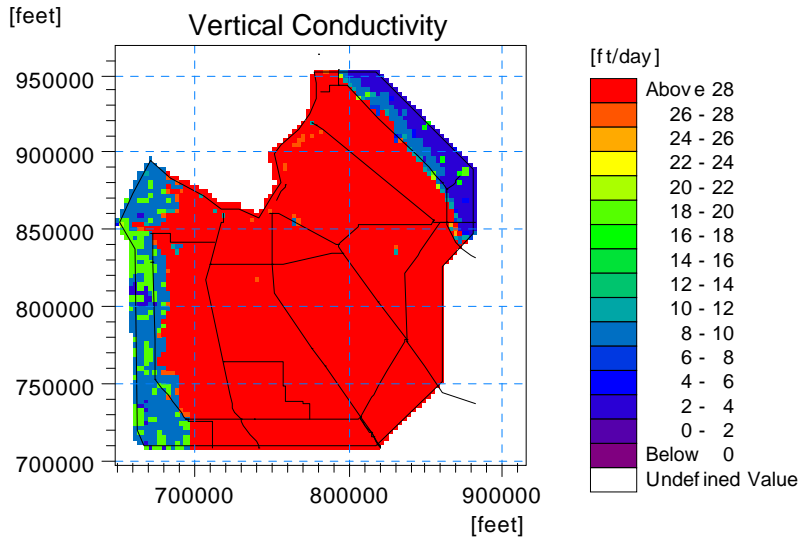


Figure B.2.2.12 - Initial Vertical Hydraulic Conductivity of the Muck/Surficial Sand Geologic Layer

Caprock geologic layer

The caprock layer represents caprock where muck soils are present and sand elsewhere. A constant caprock thickness of five feet was assumed throughout the model domain. A constant thickness was assumed because of the inconsistent lithologic descriptions in

FGS logs and other data sources that made it difficult to accurately determine the caprock thickness. An assumed caprock thickness is consistent with interviews with farmers and the few detailed logs that were available. The lower surface elevation of the caprock layer is shown on **Figure B.2.2.13**.

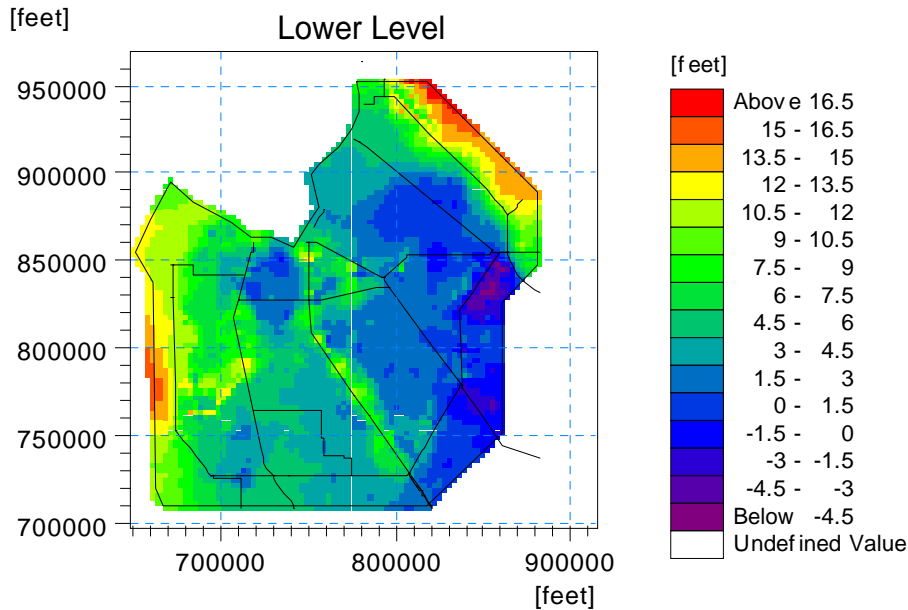


Figure B.2.2.13 - Lower Surface of the Caprock or Vertically Equivalent Surficial Sand Geologic Layer

Initial horizontal hydraulic conductivities of the caprock layer were based on the initial vertical saturated hydraulic conductivity values used in the MIKE SHE unsaturated zone module. A horizontal to vertical hydraulic conductivity ratio of 10 was used for the caprock and surficial sands. The distribution of horizontal and vertical hydraulic conductivity values are shown in **Figure B.2.2.14** and **Figure B.2.2.15**.

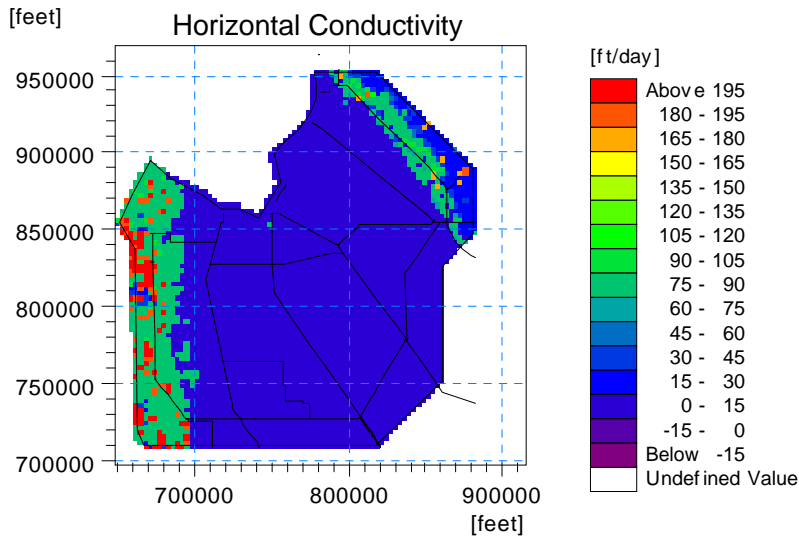


Figure B.2.2.14 - Initial Horizontal Hydraulic Conductivity of the Caprock or Vertically Equivalent Surficial Sand Geologic Layer

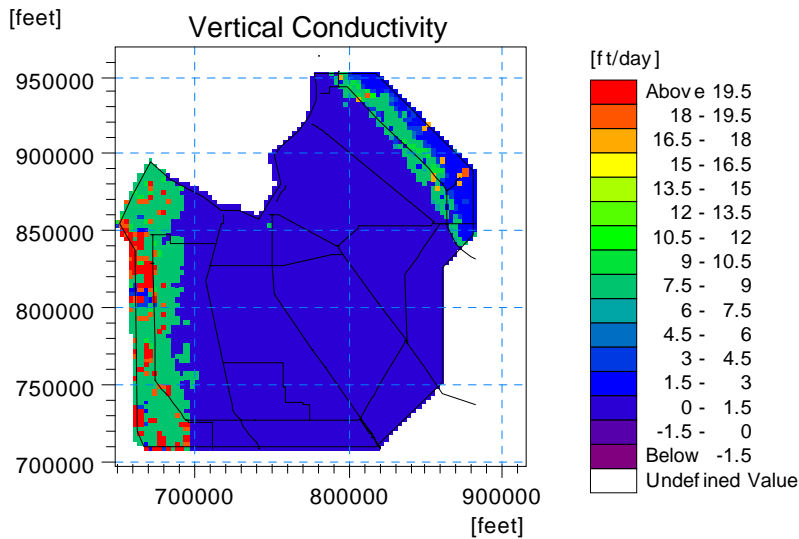


Figure B.2.2.15 - Initial Vertical Hydraulic Conductivity of the Caprock or Vertically Equivalent Surficial Sand Geologic Layer

Upper Fort Thompson Formation layer

The upper Fort Thompson layer represents the low permeability, upper portions of the Fort Thompson formation. A constant upper Fort Thompson thickness of 20 feet was assumed throughout the model domain. A thickness of 20 feet was assumed because of the variability observed during review of the detailed logs, and the difficulty in

developing a defensible surface. The lower surface elevation of the upper Fort Thompson formation is shown on **Figure B.2.2.16**.

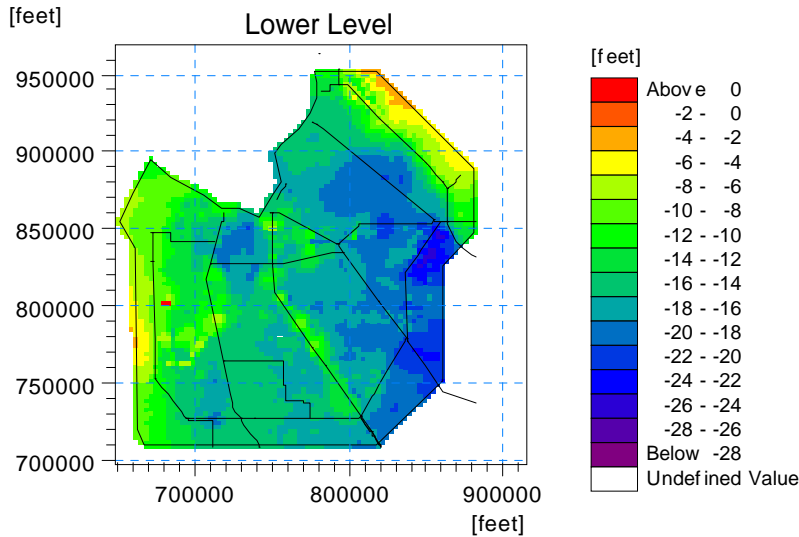


Figure B.2.2.16 - Lower Surface of the Upper Ft. Thompson Formation

Constant horizontal and vertical hydraulic conductivity of 11 and one foot/day, respectively, were assumed for the upper Fort Thompson Formation. These initial values are based on data summarized in Fish (1988).

Lower Ft. Thompson Formation layer

The lower Fort Thompson layer represents the higher permeability, lower portions of the Fort Thompson formation. The thickness of the lower Fort Thompson formation was based on the FGS and other well log data and is shown on **Figure B.2.2.17**. The lower surface elevation of the lower Fort Thompson Formation is shown on **Figure B.2.2.18**.

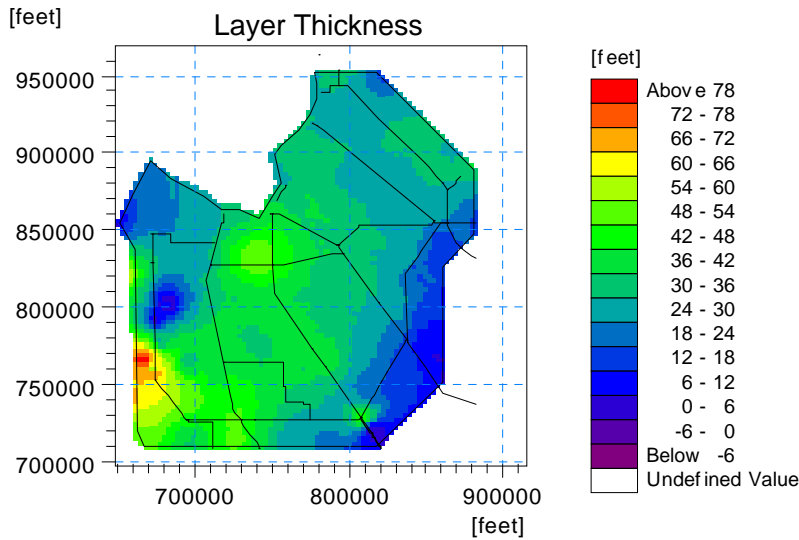


Figure B.2.2.17 - Thickness of the Lower Fort Thompson Formation

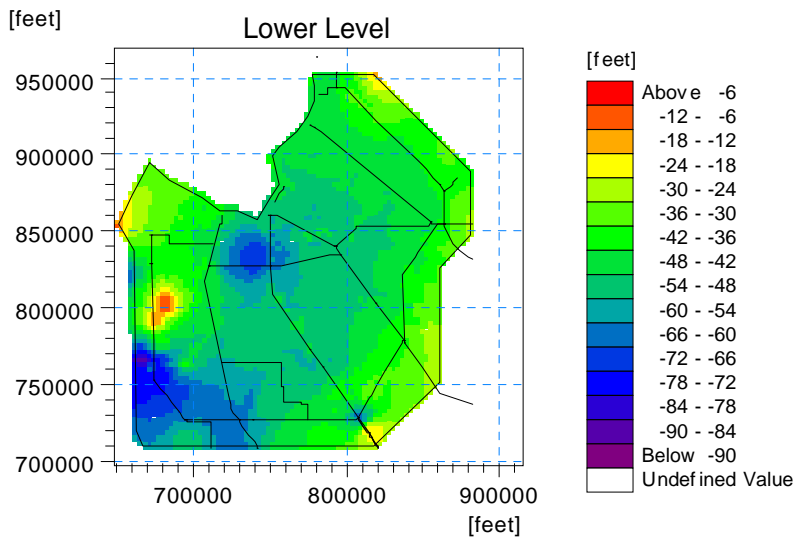


Figure B.2.2.18 - Lower Surface of the Lower Fort Thompson Formation

Constant horizontal and vertical hydraulic conductivities of 60 and six ft/day, respectively, were assumed for the lower Ft. Thompson Formation. These initial values are based on data summarized in Fish (1988).

Tamiami Formation Layer

The Tamiami formation layer represents the entire thickness of the Tamiami formation. The Tamiami formation was not subdivided into the upper confining layer and the lower permeable unit because of the lack of vertically distributed Tamiami calibration data. The thickness of the Tamiami formation was based on the FGS and other well log data

and is shown on **Figure B.2.2.19**. The lower surface elevation of the lower Fort Thompson formation is shown on **Figure B.2.2.20**.

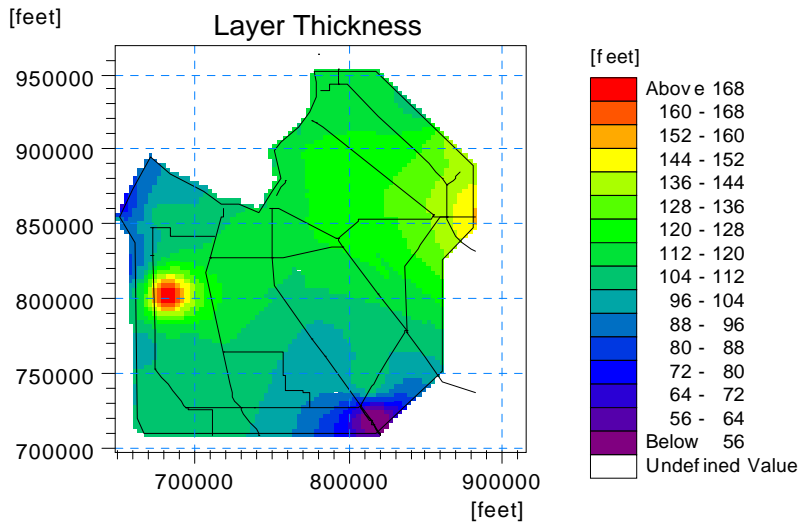


Figure B.2.2.19 - Thickness of the Tamiami Formation

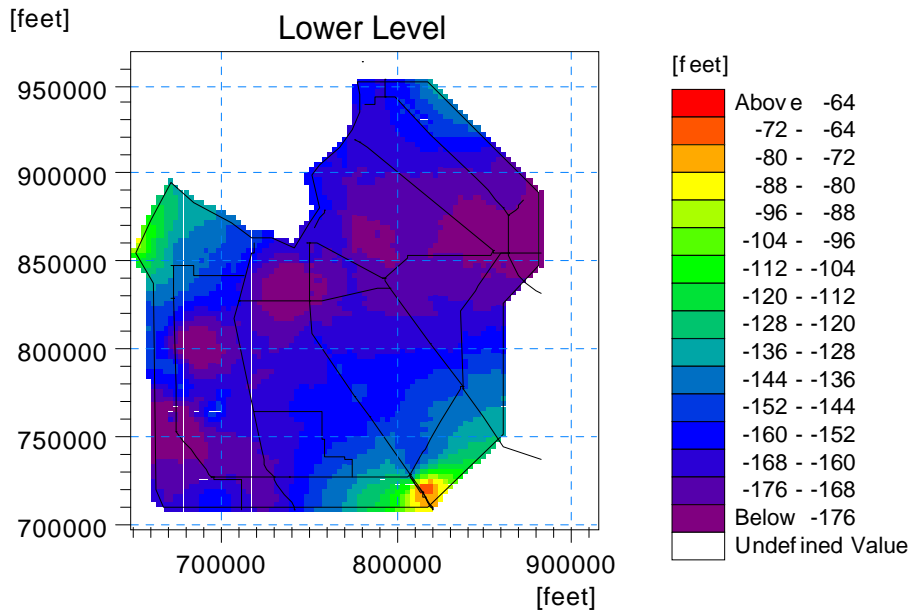


Figure B.2.2.20 - Lower surface of the Tamiami formation

Constant horizontal and vertical hydraulic conductivities of 570 and 57 feet/day, respectively, were assumed for the Tamiami Formation. These initial values are based on data summarized in Fish (1988).

Hydrogeologic model setup

In the EAA MIKE SHE model the five geologic units described above have been reduced to three calculation layers as a result of sparse groundwater calibration data. The correspondence of the geologic layers to the calculation layers is shown on **Figure B.2.2.6**. The base of the model is considered the base of the Tamiami formation. This is a result of the significant thickness of low permeability sediments below the Tamiami. This boundary is considered an effective no-flow boundary and is generally supported by significant head differences between the water table aquifer and the mid Hawthorn aquifer, and the lack of response of the water table aquifer to pumpage from the mid-Hawthorn aquifer.

B.2.2.3 METHODOLOGY

B.2.2.3.1 Overview

The model being used was selected by the Model Steering Committee and was documented in Deliverable 2.1.3, Final Model Evaluation Report. The methodology used for developing the EAA Basin hydrologic and hydraulic model is summarized below:

1. Develop the ground water model using information from the 2x2 model, hydrogeologic information from design reports for the STAs, and information from Florida Geologic Survey.
2. Develop the unsaturated zone using information provided from scientific studies of the EAA (for example Bottcher and Izunu, 1994), interviews with over 20 farmers who have detailed working knowledge of the EAA, and design information for the STAs.
3. Digitize the surface water network using existing GIS files from SFWMD. Utilize the sub-basin delineations defined by the sub-basin delineation completed under this contract (deliverable 2.2.1, Basin and Sub-basin Delineation).
4. Add details on structure dimensions and operation from the SFWMD Structure Book and interviews with SFWMD staff working on the 2x2 model and operations. The structure operations modeled in MIKE SHE are presented in Attachment B.2.2.2
5. Add details on interior farm structure operations from SFWMD permit records and discussions with the farmers.
6. Add rainfall and evapotranspiration values for long-term simulations that were provided to the KHA Team from SFWMD 2x2 modelers.
7. Utilize rainfall distribution and values for design events described in Deliverable 2.2.2, Rainfall Frequency Analysis for Storm Events.

B.2.2.3.2 Modeling Steering Committee Direction

Numerous meetings were held with the Model Steering Committee. Meetings were held approximately monthly from August, 2002 through February, 2003 and are on-going. These meetings have been a productive forum for detailed discussions on technical details of the modeling approach and have allowed incorporation of up-to-date

information from SFWMD and USACE modeling staff. In addition, valuable input has been provided by stakeholders representing local interests.

Key decisions from the Model Steering Committee include:

- Confirmation of the farms to be utilized for detailed modeling
- Calibration for a five-year period from 1995 through 2000 and validation in 2001-2002
- Design storm methodology
- Specification of boundary conditions – 2x2 water levels for WCA 1, 2A, and 3A, measured data on the western boundary, and Lake Okeechobee water levels.

B.2.2.3.3 Key Assumptions

Numerous assumptions have been made during the modeling process, and some of these assumptions may have to be changed during calibration. The key assumptions are discussed below.

Daily rainfall will be acceptable for most periods, and hourly rainfall may be needed during intense rainfall periods. Subsequent modeling suggests that use of hourly rainfall in simulations provide superior water level results for large rainfall events. Due to long simulation times, daily rainfall will be used for long-term water budget assessments for the entire EAA.

Rainfall and evapotranspiration can be distributed on a grid basis, with a daily rainfall time series for each grid cell. The decision to use grid rainfall and ET was made by the Model Steering Committee.

Drainage off EAA farms will not be modeled in detail and will be represented by empirical model coefficients. These coefficients are the drainage level and the drainage time constant. The values will be estimated using best professional judgment based on comparison of measured and simulated water levels in selected farms in the EAA where detailed information is available. Drainage was handled many different ways during calibration. A more detailed approach will provide better results and will result in long simulation times. See calibration report for more information.

Individual farm pumps will not be physically described in the model. The scope specifically excluded detailed modeling of the farm pumps. The assumption to not model individual farm pumps was based on the expectation that the model would run very slowly if all +/- 600 farm pumps were in the model. Not modeling the pumps in detail will reduce the accuracy of the model.

Water levels at the head water and tail water of SFWMD structures obtained from the DBHYDRO database are sufficiently accurate for calibration. It was assumed that the water levels at the head water and tail water of the SFWMD structures should be used because the model could not be calibrated without this data. SFWMD have stated that

B.2.2 HYDROLOGIC MODELING/METHODOLOGY REPORT

DBHYDRO data is accurate, so this assumption appears to be reasonable. If the data is wrong, then calibration may be affected. This problem cannot be avoided.

Unsaturated zone modeling will be performed using the Simplified Richards, which ignores capillary rise. The assumption to use the Simplified Richards equation was based on a balancing of model accuracy and simulation time. Use of the Full Richards equation increases model execution time by multiple orders of magnitude. The simplified Richards equation will provide slightly inferior results.

A thin layer with high transmissivity may be added between the muck and caprock layers to improve the ability to model field drainage during intense rainfall periods in selected farms. The appropriateness of this assumption will be assessed during calibration

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**Attachment B.2.2.1
Acknowledgements**

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Joel Arrieta, SFWMD
David Mohny, Sugar Cane Growers Cooperative

**Attachment B.2.2.2
MIKE 11 Structure Operations**

**Attachment B.2.2.2
MIKE 11 Structure Operations**

List of symbols:

“=” equal to, “<” smaller than, “>” greater than, “<=” smaller than or equal to, “>=” greater than or equal to, “<>” different from

Structure S-5A in the L-40 Canal at chainage 100’:

Description: The structure consists of a six unit pumping plant located on the south side of U.S. Highway 441 and Canal 51 (West Palm Beach Canal) between the canal and the borrow canals of Levees 7 and 40. It is located about 20 miles west of West Palm Beach. This structure pumps water from the West Palm Beach Canal from Lake Okeechobee and from agricultural lands surrounding pump station S-5A into WCA-1.

MIKE11 Description and Operation: The system consists of six discharge pumps, each with a maximum capacity of 800 cubic feet per second (cfs). The pumps are turned off when the water level in the WPB Canal, at chainage 110,000 feet, is lower than 10 feet. The pumps operate at maximum capacity (6 X 800 cfs) when the water level is higher than 12 feet. When the water level is between 10 and 12 feet, the pump rate is determined using a linear discharge/head (Q/H) relationship.

Structure S-5AS in the L-8 Canal at chainage 135,900’:

Description: This structure is a reinforced concrete, gated spillway with discharge controlled by two, cable operated, vertical lift gates. The gates are manually operated in accordance with the operational criteria. The structure is located on Levee 40 borrow canal, at the point where L-7 crosses that canal, on the northern perimeter of Conservation Area No. 1.

MIKE11 Description and Operation: The system consists of two underflow gates, each 22.8 feet wide. The sill level is at one foot. There are currently no operational requirements as the bottom of the gates are fixed at an elevation of two feet, allowing water to flow in two “culverts” (both one foot high by 22.8 feet wide).

Structure S-352 in the WPB Canal at chainage 100’:

Description: This structure is a reinforced concrete, gated spillway, with two vertical lift gates. It is located in LD9, the perimeter dike of Lake Okeechobee, at the north end of the West Palm Beach Canal at Canal Point. It is a replacement for the Hurricane Gate Structure (HGS)-5. The structure was completed on March 22, 1989.

MIKE11 Description and Operation: There are two underflow gates, each 23 feet wide, with a sill level of 5.2 feet. Currently, there are no operational requirements as the gates fixed in closed position.

Structure S-2 in the NNR Canal at chainage 100’:

Description: This structure is a four unit pumping plant located in the alignment of Lake Okeechobee South Shore Levee. It is located where the intersection of the Hillsboro and the North New River Canals (NNR) meets Lake Okeechobee. It is located in the western

section of Palm Beach County, 3.5 miles northwest of Belle Glade, Florida. Water is pumped from the NNR Canal into Lake Okeechobee.

MIKE11 Description and Operation: The system consists of four individually modeled discharge pumps each with a maximum capacity of 900 cfs. The four pumps, identified as Pumps A through D, are turned on and off, one by one, according to the following operational requirements:

PumpOffWL (water level when pump turns off) is defined as 10 feet
PumpOnWL (water level when pumps turn on) is defined as 13 feet

Pump A:

- 1) if $H \leq \text{PumpOffWL}$ and $Q(B) = 0$, then no pumping
- 2) if $H > \text{PumpOnWL}$, then pump
- 3) if points ≥ 21 , then pump
- 4) if points < 21 and $Q(B) = 0$, then no pumping
- 5) otherwise, leave condition unchanged

Pump B:

- 1) if $H \leq \text{PumpOffWL}$ and $Q(C) = 0$, then no pumping
- 2) if $H > \text{PumpOnWL}$ and $Q(A) < 0$, then pump
- 3) if points ≥ 21 and $Q(A) < 0$, then pump
- 4) if points < 21 and $Q(C) = 0$, then no pumping
- 5) otherwise, leave condition unchanged

Pump C:

- 1) if $H \leq \text{PumpOffWL}$ and $Q(D) = 0$, then no pumping
- 2) if $H > \text{PumpOnWL}$ and $Q(B) < 0$, then pump
- 3) if points ≥ 21 and $Q(B) < 0$, then pump
- 4) if points < 21 and $Q(D) = 0$, then no pumping
- 5) otherwise, leave condition unchanged

Pump D:

- 1) if $H \leq \text{PumpOffWL}$, then no pumping
- 2) if $H > \text{PumpOnWL}$ and $Q(C) < 0$, then pump
- 3) if points ≥ 21 and $Q(C) < 0$, then pump
- 4) if points < 21 , then no pumping
- 5) otherwise, leave condition unchanged

where,

H is the water level in the NNR Canal at chainage 1000'

Q(X) is actual pumping of pumpX

MaxQ is maximum capacity of each pump: 900 cfs

PumpOffWL (water level when pump turns off) is defined as 10 feet

PumpOnWL (water level when pumps turn on) is defined as 13 feet

Points are accumulated based on week, day, hour, water level, change in water level, and rain (current conditions and predicted rain) according to the District point system

Structure S-351 in the NNR Canal at chainage 100':

Description: This structure is a reinforced concrete, gated spillway, with three vertical lift gates, located in canal L-D2, the perimeter dike of Lake Okeechobee,. It is located at the north end of the Hillsboro and North New River Canals. It is a replacement for Hurricane Gate Structure (HGS)-4. The structure was completed on March 22, 1989. This structure allows discharges from the Lake into the NNR.

MIKE11 Description and Operation: The structure consists of three individually modeled underflow gates. Each is 20 feet wide, with a sill level of 4.5 feet. The three gates are opened and closed, one by one, according to the following operational requirements:

Gate A:

- 1) if Pump A of Structure S-2 is on, then Gate A of Structure S-351 stays closed
- 2) if $T > H$ and $H < \text{MaxLake}$ and $T > \text{MaxEAA}$, then open
- 3) if $T > H$ and $H < \text{MaxLake}$ and $T > \text{MinEAA}$ and $Q(A) \neq 0$, then open
- 4) if $T > H$ and $T \leq \text{MinEAA}$ and $Q(B) = 0$, then closed
- 5) if $T < \text{MinEAA}$ and $H > T$, then open
- 6) if $T < \text{MaxEAA}$ and $H > T$ and $Q(A) \neq 0$, then open
- 7) if $T > \text{MaxEAA}$ and $Q(B) = 0$, then closed
- 8) if $T \geq H$ and $Q(B) = 0$, then closed
- 9) otherwise, leave condition unchanged

Gate B:

- 1) if Pump A of Structure S-2 is on, then Gate B of Structure S-351 stays closed
- 2) if $T > H$ and $H < \text{MaxLake}$ and $T > \text{MaxEAA}$ and $\text{GateLevel}(A) \geq \text{MaxGateLevel}$, then open
- 3) if $T > H$ and $H < \text{MaxLake}$ and $T > \text{MinEAA}$ and $Q(B) \neq 0$ and $\text{GateLevel}(A) \geq \text{MaxGateLevel}$, then open
- 4) if $T > H$ and $T \leq \text{MinEAA}$ and $Q(C) = 0$, then closed
- 5) if $T < \text{MinEAA}$ and $H > T$ and $\text{GateLevel}(A) \geq \text{MaxGateLevel}$, then open
- 6) if $T < \text{MaxEAA}$ and $H > T$ and $Q(B) \neq 0$, then open
- 7) if $T > \text{MaxEAA}$ and $Q(C) = 0$, then closed
- 8) if $T \geq H$ and $Q(C) = 0$, then closed
- 9) otherwise, leave condition unchanged

Gate C:

- 1) if Pump A of Structure S-2 is on, then Gate C of Structure S-351 stays closed
- 2) if $T > H$ and $H < \text{MaxLake}$ and $T > \text{MaxEAA}$ and $\text{GateLevel}(B) \geq \text{MaxGateLevel}$, then open
- 3) if $T > H$ and $H < \text{MaxLake}$ and $T > \text{MinEAA}$ and $Q(C) \neq 0$ and $\text{GateLevel}(B) \geq \text{MaxGateLevel}$, then open
- 4) if $T > H$ and $T \leq \text{MinEAA}$, then closed
- 5) if $T < \text{MinEAA}$ and $H > T$ and $\text{GateLevel}(B) \geq \text{MaxGateLevel}$, then open
- 6) if $T < \text{MaxEAA}$ and $H > T$ and $Q(C) \neq 0$, then open

- 7) if $T > \text{MaxEAA}$, then closed
- 8) if $T \geq H$, then closed
- 9) otherwise leave condition unchanged

where,

H is S-351 headwater at chainage 0'

T is S-351 tailwater at chainage 1000'

Q(X) is flow thru gate X

GateLevel(X) is gate level for gate X

MaxLake is maximum water level in Lake Okeechobee = 11.5 feet

MinEAA is minimum water level inside EAA = 11.5

MaxEAA is maximum water level inside EAA = 12.5 feet

Open = MaxGateLevel = 11.5 feet

Closed = MinGateLevel = 4.5 feet

Structure S-3 in the Miami Canal at chainage 100':

Description: This structure is a three unit pumping plant located in the alignment of Lake Okeechobee South Shore Levee. It is located at point where the Miami Canal intersects Lake Okeechobee in the western section of Palm Beach County. This is just north of the town of Lake Harbor, Florida. The pumping station has three vertical pumps each rated for 890 cfs at 6.6 feet of static head. Water is pumped from the Miami Canal into Lake Okeechobee.

MIKE11 Description and Operation: There are three individually modeled discharge pumps. Each pump has a maximum capacity of 890 cfs. The three pumps, identified as Pumps A through C, are turned on and off, one by one, according to the following operational requirements:

PumpOffWL (water level when pump turns off) is defined as 10 feet

PumpOnWL (water level when pumps turn on) is defined as 13 feet

Pump A:

- 1) if $H \leq \text{PumpOffWL}$ and $Q(B) = 0$, then no pumping
- 2) if $H > \text{PumpOnWL}$, then pump
- 3) if points ≥ 21 then pump
- 4) if points < 21 and $Q(B) = 0$, then no pumping
- 5) otherwise leave condition unchanged

Pump B:

- 1) if $H \leq \text{PumpOffWL}$ and $Q(C) = 0$, then no pumping
- 2) if $H > \text{PumpOnWL}$ and $Q(A) < 0$, then pump
- 3) if points ≥ 21 and $Q(A) < 0$, then pump
- 4) if points < 21 and $Q(C) = 0$, then no pumping
- 5) otherwise leave condition unchanged

Pump C:

- 1) if $H \leq \text{PumpOffWL}$, then no pumping

- 2) if $H > \text{PumpOnWL}$ and $Q(B) < 0$, then pump
- 3) if points ≥ 21 and $Q(B) < 0$, then pump
- 4) if points < 21 , then no pumping
- 5) otherwise leave condition unchanged

where,

H is the water level in the Miami Canal at chainage 1000'

Q(X) is the actual pump discharge of pump X

MaxQ is maximum capacity of each pump: 890 cfs

PumpOffWL (water level when pump turns off) is defined as 10 feet

PumpOnWL (water level when pumps turn on) is defined as 13 feet

Points are accumulated based on week day, hour, water level, change in water level, and rain (current conditions and predicted rain) according to the District point system

Structure S-354 in the Miami Canal at chainage 100':

Description: This structure is a reinforced concrete, gated spillway, with two vertical lift gates. It is located in Canal LD9, the perimeter dike of Lake Okeechobee, at the north end of the Miami Canal at Lake Harbor. It is a replacement for Hurricane Gate Structure (HGS)-3. This allows flow from the Lake into the Miami Canal.

MIKE11 Description and Operation: There are two individually modeled underflow gates. Each is 23 feet wide with a sill level of 3.2 feet. The two gates are opened and closed, one by one, according to the following operational requirements:

Gate A:

- 1) if Pump A of Structure S-3 is on, then Gate A is closed
- 2) if $T > H$ and $H < \text{MaxLake}$ and $T > \text{MaxEAA}$, then open
- 3) if $T > H$ and $H < \text{MaxLake}$ and $T > \text{MinEAA}$ and $Q(A) \neq 0$, then open
- 4) if $T > H$ and $T \leq \text{MinEAA}$ and $Q(B) = 0$, then closed
- 5) if $T < \text{MinEAA}$ and $H > T$, then open
- 6) if $T < \text{MaxEAA}$ and $H > T$ and $Q(A) \neq 0$, then open
- 7) if $T > \text{MaxEAA}$ and $H > T$ and $Q(A) = 0$, then closed
- 8) otherwise leave condition unchanged

Gate B:

- 1) if Pump A of Structure S-3 is on, then Gate B is closed
- 2) if $T > H$ and $H < \text{MaxLake}$ and $T > \text{MaxEAA}$, then open
- 3) if $T > H$ and $H < \text{MaxLake}$ and $T > \text{MinEAA}$ and $Q(B) \neq 0$, then open
- 4) if $T > H$ and $T \leq \text{MinEAA}$, then closed
- 5) if $T < \text{MinEAA}$ and $H > T$, then open
- 6) if $T < \text{MaxEAA}$ and $H > T$ and $Q(B) \neq 0$, then open
- 7) if $T > \text{MaxEAA}$ and $H > T$, then closed
- 8) otherwise leave condition unchanged

where,

H is S-354 headwater at chainage 0' of the Miami Canal

T is S-354 tailwater at chainage 1000' of the Miami Canal

$Q(X)$ is flow thru gate X

MaxLake is maximum water level in Lake Okeechobee = 11.5 feet

MinEAA is minimum water level inside EAA = 11.5 feet

MaxEAA is maximum water level inside EAA = 12.5 feet

Open = MaxGateLevel = 11.5 feet

Closed = MinGateLevel = 3.2 feet

Structure S-6 in the Hillsboro Canal at chainage 125,314':

Description: This structure is a three unit pumping plant located in the alignment of the Hillsboro Canal. It located at the point where the Hillsboro Canal is intersected by Levee 6 and Levee 7, about 20 miles southeast of the town of Belle Glade in the South-Central section of Palm Beach County. The pumping station consists of three vertical lift pumps each rated for 975 cfs at a static head of 8.3 feet. Prior to 2001, this structure removed water from the EAA into the Hillsboro Canal southeast of the EAA. In 2001, this structure was modified to pump water into STA-2.

MIKE11 Description and Operation: This structure consists of three individually modeled discharge pumps, each with a maximum capacity of 975 cfs. The three pumps, identified as pumps A through C, are turned on and off, one by one, according the following operational requirements:

Pump A:

- 1) if $H < \text{PumpOffWL}$ and $Q(B)$, then no pumping
- 2) if $H > \text{PumpOnWL}$, then pump
- 3) if $Q(A) > 0$, then pump
- 4) otherwise, leave the condition unchanged

Pump B:

- 1) if $H < \text{PumpOffWL}$ and $Q(C) = 0$, then no pumping
- 2) if $H > \text{PumpOnWL}$ and $Q(A) \geq \text{MaxQ}$, then pump
- 3) if PumpB is on and $Q(A) \geq \text{MaxQ}$, then pump
- 4) otherwise, leave the condition unchanged

Pump C:

- 1) if $H < \text{PumpOffWL}$, then no pumping
- 2) if $H > \text{PumpOnWL}$ and $Q(B) \geq \text{MaxQ}$, then pump
- 3) if $Q(C) > 0$ and $Q(B) \geq \text{MaxQ}$, then pump
- 4) otherwise , leave the condition unchanged

where,

H is the water level measured at chainage 124320' in the Hillsboro Canal

$Q(X)$ is the actual pump discharge of pumpX

MaxQ is maximum capacity of each pump: 975 cfs

PumpOffWL (water level when pump turns off) is defined as 10 feet

PumpOnWL (water level when pumps turn on) is defined as 12.5 feet

Structure S-7 in the NNR Canal at chainage 150,826':

Description: This structure is a pumping plant with a gated spillway that allows flows to bypass the pumps under certain conditions. This structure is located in the alignment of North New River Canal at its intersection with Levees 5, 6, and 18. It is located about 26 miles south of the town of Belle Glade and just east of U.S. Highway 27 at the Palm Beach - Broward County Line. The pumping station consists of three horizontal pumps each rated for 830 cfs at a static head of 5.3 feet. This structure pumps water from the EAA into the NNR Canal SE of the EAA and into WCA 2A.

MIKE11 Description and Operation: This structure consists of three individually modeled discharge pumps; each with a maximum capacity of 830 cfs. In addition to the pumps, there is a gated spillway (underflow gate) that is 15.2 feet wide with a sill level of 2.8 feet. The three pumps, identified as pumps A through C, and the gate are turned on and off, one by one, according to the following operational requirements:

Pump A:

- 1) if $H < \text{PumpOffWL}$ and $Q(B) = 0$, then no pumping
- 2) if $T \geq H$ and $H > \text{PumpOnWL}$, then pump
- 3) if $T \geq H$ and $H > \text{PumpOffWL}$ and $Q(A) > 0$, then pump
- 4) if $H > \text{PumpOnWL}$ and $\text{GateLevel}(S-7) \geq \text{MaxGateLevel}$, then pump
- 5) if $Q(A) > 0$ and $\text{GateLevel}(S-7) \geq \text{MaxGateLevel}$, then pump
- 6) otherwise, leave the condition unchanged

Pump B:

- 1) if $H < \text{PumpOffWL}$ and $Q(C) = 0$, then no pumping
- 2) if $T \geq H$ and $H > \text{PumpOnWL}$ and $Q(A) \geq \text{MaxQ}$, then pump
- 3) if $T \geq H$ and $H > \text{PumpOffWL}$ and $Q(B) > 0$ and $Q(A) \geq \text{MaxQ}$, then pump
- 4) if $H > \text{PumpOnWL}$ and $\text{GateLevel}(S-7) \geq \text{MaxGateLevel}$ and $Q(A) \geq \text{MaxQ}$, then pump
- 5) if $Q(B) > 0$ and $\text{GateLevel}(S-7) \geq \text{MaxGateLevel}$ and $Q(A) \geq \text{MaxQ}$, then pump
- 6) otherwise, leave the condition unchanged

Pump C:

- 1) if $H < \text{PumpOffWL}$, then no pumping
- 2) if $T \geq H$ and $H > \text{PumpOnWL}$ and $Q(B) \geq \text{MaxQ}$, then pump
- 3) if $T \geq H$ and $H > \text{PumpOffWL}$ and $Q(C) > 0$ and $Q(B) \geq \text{MaxQ}$, then pump
- 4) if $H > \text{PumpOnWL}$ and $\text{GateLevel}(S-7) \geq \text{MaxGateLevel}$ and $Q(B) \geq \text{MaxQ}$, then pump
- 5) if $Q(C) > 0$ and $\text{GateLevel}(S-7) \geq \text{MaxGateLevel}$ and $Q(B) \geq \text{MaxQ}$, then pump
- 6) otherwise, leave the condition unchanged

Gate S7:

- 1) if $H < \text{MinEAA}$, then closed
- 2) if $T \geq H$, then closed
- 3) if $H > \text{MaxEAA}$ and $H > T$, then open

- 4) if $H > \text{MinEAA}$ and $H > T$ and $Q(\text{Gate-S7}) > 0$, then open
- 5) otherwise, leave the condition unchanged

where,

H is the S-7 headwater measured at chainage 150520'

T is S-7 tailwater measured at chainage 150826'

Q(X) is actual pump discharge of pump X

MaxQ is maximum capacity of each pump: 830 cfs

PumpOffWL (water level when pump turns off) is defined as 10 feet

PumpOnWL (water level when pumps turn on) is defined as 12.5 feet

MinEAA is minimum water level inside EAA = 10 feet

MaxEAA is maximum water level inside EAA = 12.5 feet

Open = MaxGateLevel = 12.3 feet

Closed = MinGateLevel = 2.8 feet

Structure S-8 in the Miami Canal at chainage 138,663':

Description: This structure is a pumping station with a gated spillway that allows flows to the pumps under certain conditions. The structure is located in the alignment of the Miami Canal where it intersects Levees 4, 5, and 23. It is about 30 miles southwest of the town of Belle Glade and 15 miles west of U.S. Highway 27 at the Palm Beach-Broward County line. The pumping station consists of four horizontal pumps rated for 1,040 cfs at a static head of 4.5 feet. This structure pumps water from the EAA into the Miami Canal south of the EAA.

MIKE11 Description and Operation: There are four individually modeled discharge pumps, each with a maximum capacity of 1,040 cfs. In addition, there is a gated spillway (underflow gate) that is 16.5 feet wide, with a sill level of 1.0 foot that allows bypass flow under certain conditions. The four pumps, identified as pumps A through D, and the gate are turned on and off, one by one, according to the following operational requirements:

Pump A:

- 1) if $H < \text{PumpOffWL}$ and $Q(B) = 0$, then no pumping
- 2) if $T \geq H$ and $H > \text{PumpOnWL}$, then pump
- 3) if $T \geq H$ and $H > \text{PumpOffWL}$ and $Q(A) > 0$, then pump
- 4) if $H > \text{PumpOnWL}$ and $\text{GateLevel}(S-8) \geq \text{MaxGateLevel}$, then pump
- 5) if $Q(A) > 0$ and $\text{GateLevel}(S-8) \geq \text{MaxGateLevel}$, then pump
- 6) otherwise, leave the condition unchanged

Pump B:

- 1) if $H < \text{PumpOffWL}$ and $Q(C) = 0$, then no pumping
- 2) if $T \geq H$ and $H > \text{PumpOnWL}$ and $Q(A) \geq \text{MaxQ}$, then pump
- 3) if $T \geq H$ and $H > \text{PumpOffWL}$ and $Q(B) > 0$ and $Q(A) \geq \text{MaxQ}$, then pump
- 4) if $H > \text{PumpOnWL}$ and $\text{GateLevel}(S-8) \geq \text{MaxGateLevel}$ and $Q(A) \geq \text{MaxQ}$, then pump
- 5) if $Q(B) > 0$ and $\text{GateLevel}(S-8) \geq \text{MaxGateLevel}$ and $Q(A) \geq \text{MaxQ}$, then pump

- 6) otherwise, leave the condition unchanged

Pump C:

- 1) if $H < \text{PumpOffWL}$ and $Q(D) = 0$, then no pumping
- 2) if $T \geq H$ and $H > \text{PumpOnWL}$ and $Q(B) \geq \text{MaxQ}$, then pump
- 3) if $T \geq H$ and $H > \text{PumpOffWL}$ and $Q(C) > 0$ and $Q(B) \geq \text{maxQ}$, then pump
- 4) if $H > \text{PumpOnWL}$ and $\text{GateLevel}(S-8) \geq \text{MaxGateLevel}$ and $Q(B) \geq \text{MaxQ}$, then pump
- 5) if $Q(C) > 0$ and $\text{GateLevel}(S-8) \geq \text{MaxGateLevel}$ and $Q(B) \geq \text{MaxQ}$, then pump
- 6) otherwise, leave the condition unchanged

Pump D:

- 1) if $H < \text{PumpOffWL}$, then no pumping
- 2) if $T \geq H$ and $H > \text{PumpOnWL}$ and $Q(C) \geq \text{MaxQ}$, then pump
- 3) if $T \geq H$ and $H > \text{PumpOffWL}$ and $Q(D) > 0$ and $Q(C) \geq \text{MaxQ}$, then pump
- 4) if $H > \text{PumpOnWL}$ and $\text{GateLevel}(S-8) \geq \text{MaxGateLevel}$ and $Q(C) \geq \text{MaxQ}$, then pump
- 5) if $Q(D) > 0$ and $\text{GateLevel}(S-8) \geq \text{MaxGateLevel}$ and $Q(C) \geq \text{MaxQ}$, then pump
- 6) otherwise, leave the condition unchanged

Gate S8:

- 1) if $H < \text{MinEAA}$, then closed
- 2) if $T \geq H$, then closed
- 3) if $H > \text{MaxEAA}$ and $H > T$, then open
- 4) if $H > \text{MinEAA}$ and $H > T$ and $Q(\text{Gate-S8}) > 0$, then open
- 5) otherwise, leave the condition unchanged

where,

H is the S-8 headwater measured at chainage 138170'

T is the S-8 tailwater measured at chainage 138663'

Q(X) is actual pump discharge of pump X

MaxQ is maximum capacity of each pump: 1,040 cfs

PumpOffWL (water level when pump turns off) is defined as 10 feet

PumpOnWL (water level when pumps turn on) is defined as 12.5 feet

MinEAA is minimum water level inside EAA = 10 feet

MaxEAA is maximum water level inside EAA = 12.5 feet

Open = MaxGateLevel = 12 feet

Closed = MinGateLevel = one foot

Structure S-76 in Canal L-8 at chainage 14,000':

Description: This structure is a reinforced concrete, gated spillway, with discharge controlled by three stem operated, vertical lift gates. The gates are manually controlled and operated in accordance with seasonal operational criteria. The structure is located on the borrow pit of Levee 8, about 2 miles east of Lake Okeechobee. This structure allows from the Lake into the L-8 Canal.

MIKE11 Description and Operation: The structure consists of three overflow gates, each 12 feet wide with a sill level of seven feet. Currently, there are no operational requirements as the gates are fixed in the open position.

Structure S-150 in the WCA3A_S150 Canal at chainage 1,000’:

Description: This structure consists of a five-barrel corrugated metal pipe (CMP) culvert, located through L-5 on the north perimeter of Conservation Area 3. It is located approximately 24 miles southeast of South Bay, Florida. Water level elevation is controlled by manually operated sluice gates mounted on a steel frame erected on the upstream side of the structure. This structure allows for water to flow between Canal L-5 (on the south end of the EAA) and WCA-3A.

MIKE11 Description and Operation: The structure is modeled as a single underflow gate, 27.5 feet wide with a sill level of three feet. The single structure is used to control flow to the CMP culverts. The gate is opened or closed according to the following operational requirements:

Structure S-150:

- 1) if $H > 11$ feet in L-5 Canal (measured at chainage 76003’) and $H < 10$ feet in WCA3A (measured at chainage 2000’), set gate elevation to 10 feet (open)
- 2) if $H < 9$ feet in L-5 Canal and $H > 11$ feet in WCA3A, set gate elevation to 10 feet (open)
- 3) otherwise, set the gate elevation to 3 feet (closed)

Structure G-88 in the L-4 Canal at chainage 400’:

Description: This structure is a four-barreled, CMP culvert, located at the northwest corner of Conservation Area 3A. Stop logs, in a CMP riser pipe, are used to control water level elevations. The structure controls flow from the L-3 Canal at “Confusion Corner” to the L-4 Canal. If gate G-88 is open and STA-6 is discharging, then water may flow from the L-4 Canal into the L-3 Canal.

MIKE11 Description and Operation: The structure consists of four individually modeled overflow gates. Each is six feet wide with a sill level of 5.5 feet. Time series data allows the gates to be modeled according to measured gate elevations at specific time intervals, or the gate is modeled in a fixed position of 14.8 feet, depending on the status (0 or 1) of the file. Time series and elevation data for this structure are found in the file named ‘GateLevelSchedule.dfs0’.

Structure G-89 in the L-28 Canal at chainage 200’:

Description: This structure is a three-barreled, CMP culvert located at the northwest corner of Conservation Area 3A. Stop logs, in a CMP riser pipe, control water level elevations. This structure has the ability to direct water from “Confusion Corner” into the L-28 Canal.

MIKE11 Description and Operation: The structure consists of three individually modeled overflow gates. Each gate is six feet wide with a sill level of 7.85 feet. Time series data

allows the gates to be modeled according to measured gate elevations at specific time intervals, or the gate is modeled in a fixed position of 16 feet, depending on the status (0 or 1) of the file. Time series and elevation data for this structure are found in the file named 'GateLevelSchedule.dfs0'.

Structure G-136 in the L-1 East Canal at chainage 100':

Description: This structure is a three-barreled, CMP culvert, located at the bend in the L-1 Canal, about 3 miles north of State Road 832. Stop log risers in each culvert control water level elevations. This structure is used to control flow from the L-1 Canal into the L-1 East Canal.

MIKE11 Description and Operation: The structure consists of three individually modeled overflow gates. Each is seven feet wide with a sill level of eight feet. Gates can be modeled according to measured gate elevations depending on the status (0 or 1) of the file 'GateLevelSchedule.dfs0'. If the measured gate elevations are not used, the gates will be set to 14 feet if the water level of the G-136 tailwater (L-1 east chainage 200') is greater than 15.5 feet. Otherwise the gates will be set to 13 feet.

Structure G-150 in the L-2 Canal at chainage 100':

Description: This structure is a three-barreled, CMP culvert located at the divide line of the L-1 and L-2 Canals. Slide gates, at the south end of the culverts, control water level elevation.

MIKE11 Description and Operation: The structure consists of three underflow gates. Each is seven feet wide with a sill level of 8.5 feet. The gates are kept closed if the headwater of structure G-136 (L-1 East Canal at chainage 0) is lower than 14 feet. Otherwise the gate is open.

Structure G-151 in the L-2 West Canal at chainage 26,600':

Description: This structure consists of two concrete box culverts located beneath County Road 846 where it crosses the L-2 West canal. Flashboard risers, located on the west side of the box culverts, are used to control water level elevations. This structure allows for water to drain into L-2 from the C-139 basin that is drained by the L-2 West Canal.

MIKE11 Description and Operation: The structure consists of two overflow gates. Each is 10 feet wide with a sill level of 16 feet. Gate elevations are set to 18.5 feet during the dry period (November 1st to May 14th) and to 16 feet (flash boards removed) during the wet period (May 15th to October 31st).

Structure G-155 in the L-3 Canal Extension at chainage 100':

Description: This structure is a "U" shaped concrete flume with fourteen flashboard overflow gates located at the west end. The structure is located at the northwest corner of Conservation Area 3A. Flashboards control water level elevations. This structure allows water to flow from "Confusion Corner" into WCA3A thru the L-3 Extension.

MIKE11 Description and Operation: The 14 flashboard gates in this structure (each 5.73 feet wide) are modeled as one, 80.2 foot wide, overflow gate. The sill level is located at

9.92 feet. The gate(s) can be modeled according to measured gate elevations depending on the status (0 or 1) of the file 'GateLevelSchedule.dfs0'. Data from flashboard gate 13 can be used to create a representative gate elevation record. If measured gate elevation data are not used, the gate(s) are set to 14.5 feet in the dry period (November 1st to May 14th) and 10.09 feet (removed) in the wet period (May 15th to October 31st).

Structure G-200A in the Holeyland Canal at chainage 100':

Description: This structure is described as a three unit pumping station located at the northwest corner of the Holey Land. The station is located on the east side of the L-23 (Miami Canal) levee, about 7 miles north of pumping station S-8. Water is pumped from the Miami Canal into the Holey Land.

MIKE11 Description and Operation: The structure consists of three pumps, each with a maximum capacity of 250 cfs. If the tailwater of structure G-200A (measured at chainage 1000' of the Holeyland Canal) has a head less than 10.5 feet, the pumps are running. **Operation is also dependent on Lake Okeechobee level. Will modify later. ROC.** Otherwise the pumps are off.

Structure G-200B in the Holeyland Marsh1 Canal at chainage 100':

Description: This structure is a three unit pumping station located at the northwest corner of the Holey Land. The station is located at the east side of the L-23 levee, about seven miles north of pumping station S-8. G-200B pumps water from a seepage collection canal that surrounds the Holey Land back into the Holey Land.

MIKE11 Description and Operation: This structure consists of three pumps, each with a maximum capacity of 25 cfs. The three pumps, identified as pumps A through C, are turned on and off, one by one, according the following operational requirements:

Pump A:

- 1) The pump starts when the water level exceeds 10.0 feet at chainage 100'.
- 2) The pump stops when the water level drops below 8.0 feet at chainage 100'.

Pump B:

- 1) The pump starts when the water level exceeds 10.5 feet at chainage 100'.
- 2) The pump stops when the water level drops below 8.0 feet at chainage 100'.

Pump C:

- 1) The pump starts when the water level exceeds 10.8 feet at chainage 100'.
- 2) The pump stops when the water level drops below 8.0 feet at chainage 100'.

Structure G-201 in the Holeyland Marsh5 Canal at chainage 100':

Description: This structure is a three unit pumping station at the southeast corner of the Holey Land. The station is located at the north side of the L-5 levee, about 9 miles east of pumping station S-8. This structure also pumps water from the Holey Land seepage canal back into the Holey Land.

MIKE11 Description and Operation: This structure consists of three pumps. Pumps A and C have a maximum capacity of 70 cfs. Pump B has a maximum capacity of 35 cfs.

The pumps, identified as pumps A through C are turned on and off, one by one, according to the following operational requirements:

Pump A:

- 1) The pump starts when the water level exceeds 9.0 feet at chainage 0'
- 2) The pump stops when the water level drops below 8.5 feet.

Pump B:

- 1) The pump starts when the water level exceeds 9.5 feet.
- 2) The pump stops when the water level drops below 9.0 feet

Pump C:

- 1) The pump starts when the water level exceeds 9.0 feet.
- 2) The pump stops when the water level drops below 8.5 feet.

Structure G-204 in the Holeyland Marsh2 Canal at chainage 500':

Description: This structure is a four-barreled CMP culvert, located under the L-5 levee. Water level elevations are controlled by flashboards. This structure releases water from the Holey Land into Canal L-5.

MIKE11 Description and Operation: The structure consists of four CMP culverts, each with a flashboard riser, overflow gate. Each gate is six feet wide with a sill level of 11.5 feet. The gates are set to an elevation of 11.5 feet during the wet season (May 15th to October 31st) and to an elevation of 13.5 feet during the dry season (November 1st to May 14th).

Structure G-205 in the Holeyland Marsh3 Canal at chainage 500':

Description: This structure is a six-barreled CMP culvert, located under the L-5 levee. Water level elevations are controlled by flashboards. This structure releases water from the Holey Land into Canal L-5.

MIKE11 Description and Operation: The structure consists of six CMP culverts, each with a flashboard riser, overflow gate. Each gate is six feet wide with a sill level of 11.5 feet. The gates are set to an elevation of 11.5 feet during the wet season (May 15th to October 31st), and to an elevation of 13.5 feet during the dry season (November 1st to May 14th).

Structure G-206 in the Holeyland Marsh4 Canal at chainage 500':

Description: This structure is a five-barreled CMP culvert, located under the L-5 levee. Water level elevations are controlled by flashboards. This structure releases water from the Holey Land into Canal L-5.

MIKE11 Description and Operation: The structure consists of five CMP culverts, each with a flashboard riser, overflow gate. Each gate is 5.5 feet wide with a sill level of 11.5 feet. The gates are set to an elevation of 11.5 feet during the wet season (May 15th to October 31st) and to an elevation of 13.5 feet during the dry season (November 1st to May 14th).

Structure G-357 in the G-357 Canal at chainage 500':

This structure consists of two underflow gates. Each is 10 feet wide with a sill level of three feet. This structure allows water to flow by gravity between the Miami Canal and L-4.

MIKE11 Description and Operation: Prior to 2000 the gate elevations were set to 19 feet; a dummy value reflecting that the gates are fully open. After 2000, the gates are opened or closed, according to the following operational requirements:

- 1) If the water level is higher in the Miami Canal (at chainage 137092') than in the L-4 (at chainage 32774'), and the Pump Station G-404 (in the L-4 Canal) is not pumping; then the gate elevations are set to 13 feet (open).
- 2) Otherwise, the gate elevations are set to three feet (closed).

Structure G-402A in the G-402A Canal at chainage 1,200':

Structure G-402B in the G-402B Canal at chainage 1,200':

Structure G-402C in the G-402C Canal at chainage 1,200':

Structure G-402D in the G-402D Canal at chainage 1,200':

Description: Each of these structures consists of a single underflow gate. These structures began operation in year 2000 to release water from the Rotenberger Tract into the Miami Canal. The width and sill level of each structure is as follows:

- 1) Structure G-402A: underflow gate width is 4.5 feet with a sill level of 7.13 feet.
- 2) Structure G-402B: underflow gate width is 4.5 feet with a sill level of 7.23 feet.
- 3) Structure G-402C: underflow gate width is 4.5 feet with a sill level of 7.57 feet.
- 4) Structure G-402D: underflow gate width is 3.5 feet with a sill level of 6.01 feet.

MIKE11 Description and Operation: All four of these gates are operated in a identical fashion. The operational requirements for gates G-402A through D are described as follows:

- 1) if year < 2000, then gate set to sill level (closed)
- 2) if year >= 2000, and if dry season (November 1st to May 14th), then closed
- 3) if year >= 2000, and if wet season (May 15th to October 31st), and if H > RHWSL, then open
- 4) if year >= 2000, and if wet season, and if RLWSL < H < RHWSL and if the stage is falling, then open
- 5) if year >= 2000, and if wet season, and if RLWSL < H < RHWSL and if stage is rising, then closed
- 6) if year >= 2000, and if wet season, and if H < RLWSL, then closed

where:

H is measured at chainage 0' of each canal

RHWSL is Rotenberger High Wet Season Level (12.3 feet)

RLWSL is Rotenberger Low Wet Season Level (12.05 feet)

Structure G-404 in the L-4 Canal at chainage 33,500':

Description: This structure consists of three discharge pumps. Each has a maximum capacity of 190 cfs. This pumping station is located on the Miami Canal in Broward County, at the confluence with the L-4 borrow canal. The station is located adjacent to structure G-357 and is just north of the S-8 pump station. It is also adjacent to the southeastern corner of the Rotenberger Wildlife Management Area." This structure pumps water from L-4 into the Miami Canal.

MIKE11 Description and Operation: The structure consists of three discharge pumps, each with a maximum capacity of 190 cfs. The pumps operate in the following manner:

- 1) After 1999, the pumps operate at full capacity when the structures G-344ABCD (STA-5) are active, i.e., when water is flowing through the underflow gates in STA-5.
- 2) Otherwise, the pumps are off.

Structure G-406 in the L-3 Canal at chainage 10,500':

Description: The structure consists of two underflow gates. Each gate is 10 feet wide with a sill level at 6 feet.

MIKE11 Description and Operation: The gates can be modeled according to measured gate elevations depending on the status (0 or 1) of the file 'GateLevelSchedule.dfs0'. Prior to 1999, if the measured gate elevations are not used, the gate elevations are set to 19 feet (dummy value set to fully open). Hereafter, the gate elevations are described as a function of the G-406 headwater in the following manner:

- 1) if H of the G-406 headwater (measured at chainage 10451') is < 16 feet, the gate elevations are set to 6 feet (closed).
- 2) if H of the G-406 headwater (measured at chainage 10451') is > 17 feet, the gate elevations are set to 15 feet (open).
- 3) if H is 16 feet < H < 17 feet, the gate elevations will be vary linearly between 6 feet and 15 feet.

Structure G-410 in the G-410 Canal at chainage 100':

Description: This structure consists of two from the STA-5 outflow into the Rotenberger Tract.

MIKE11 Description and Operation: The structure consists of two discharge pumps. The pumps operate in the following manner:

- 1) After1999, the pumps operate at full capacity when the structures G-344C and G-344D (both in STA-5; Cell 2) are active; i.e., when water is flowing through the underflow gates in STA-5.
- 2) After1999, the pumps operate at full capacity when the Rotenberger water levels are below the interim schedule (12.3 feet to 13.48 feet).
- 3) Otherwise, the pumps are off.

Stormwater Treatment Area Number 1 West (STA-1W)

Structure G-251 in the STA 1W G-251 Canal at chainage 2,500':

Description: This structure is a six unit pumping station located at the southeast corner of the Everglades Nutrient Removal Project. The station was completed in 1993. Operation of the station began on August 18, 1994. This structure has been revised in STA-1W construction (1997 - 2000).

MIKE11 Description and Operation: In order to simplify calculations, this structure is modeled as one (1) discharge pump. The one pump has the same capacity as the combined capacity of the six pumps actually in existence. Currently there is no operation, but discharge inputs are based on measured pumpage from 8/17/1994 to 12/2/2002.

Structure G-253AJ in the STA 1W Cell 1_3 Canal at chainage 14,000':

Description: This structure consists of 10 overflow gates. Each gate is six feet wide with a sill level of 5.5 feet.

MIKE 11 Description and Operation: Prior to 2000 the gate levels are set to 19 feet (closed). From 2000, going forward, the gates are set at 5.5 feet (open).

Structure G-254AI in the STA 1W Cell 2_4 Canal at chainage 13,600':

Description: This structure consists of nine overflow gates. Each gate is six feet wide with a sill level of 5.5 feet.

MIKE11 Description and Operation: Prior to 2000 the gate levels are set to 19 feet (closed). From 2000 going forward, the gates are set at 5.5 feet (open).

Structure G-255AG in the STA 1W Cell 2_4 Canal at chainage 100':

Description: This structure consists of seven overflow gates. Each gate is six feet wide with a sill level of 5.5 feet.

MIKE11 Description and Operation: Prior to 2000 the gate levels are set to 19 feet (closed). From 2000 going forward, the gates are set at 5.5 feet (open).

Structure G-258 in the STA 1W Cell 2_4 Canal chainage 17,500':

Description: This structure consists of one underflow gate,. The gate is six feet wide with a sill level of 5.7 feet.

MIKE11 Description and Operation: The gate can be modeled according to measured gate elevation depending on the status (0 or 1) of the file 'GateLevelSchedule.dfs0'. If measured gate elevation data is not used, the gate level is set to 5.7 feet (closed) prior to 2000. From 2000 going forward, the gate level would be set to 11.7 feet (open).

Structure G-259 in the STA 1W Cell 1_3 Canal at chainage 23,700':

Description: The structure consists of one underflow gate. The gate is six feet wide with a sill level of 5.7 feet.

MIKE11 Description and Operation: The gate can be modeled according to measured gate elevation depending on the status (0 or 1) of the file 'GateLevelSchedule.dfs0'. If measured gate elevation data is not used, the gate level is set to 5.7 feet (closed) prior to 2000. From 2000 going forward, the gate level would be set to 11.7 feet (open).

Structure G-300 in the L-40 Canal at chainage 2,400':

Description: The structure consists of two underflow gates. Each gate is 20 feet wide with a sill level of 11 feet.

MIKE11 Description and Operation: The gates can be modeled according to measured gate elevations depending on the status (0 or 1) of the file 'GateLevelSchedule.dfs0'. If the measured gate elevation data are not used, the gate levels are set to 19.4 feet (open).

Structure G-301 in the L-7 Canal at chainage 6,300':

Description: The structure consists of three underflow gates. Each gate is 22 feet wide with a sill level of 7.7 feet.

MIKE11 Description and Operation: The gates can be modeled according to measured gate elevation data depending on the status (0 or 1) of the file 'GateLevelSchedule.dfs0'. If measured gate elevation data are not used, the gate levels are set to 19.4 feet (open).

Structure G-302 in the STA 1W Inflow Canal at chainage 100':

Description: This structure consists of two underflow gates. Each gate is 20 feet wide with a sill level 9.4 feet.

MIKE11 Description and Operation: The gates can be modeled according to measured gate elevation data depending on the status (0 or 1) of the file 'GateLevelSchedule.dfs0'. Prior to 2000, if the measured gate elevation data are not used, the gate levels are set to 9.4 feet (closed). From 2000 going forward, the gate level would be set to 19 feet (open).

Structure G-303 in the STA 1W Cell 1_3 Canal at chainage 100':

Description: The structure consists of two underflow gates. Each gate is 16 feet wide with a sill level of 9.1 feet.

MIKE11 Description and Operation: The gates can be modeled according to measured gate elevation data depending on the status (0 or 1) of the file 'GateLevelSchedule.dfs0'. If measured gate elevation data are not used, the gate levels, prior to 2000, are set to 9.1 feet (closed). From 2000 going forward, the gate levels are set to 17.1 feet (open).

Structure G-304AJ in the STA 1W Cell 15 Canal at chainage 100':

Description: The structure consists of 10 underflow gates. Each gate is six feet wide with a sill level of 11.25 feet.

MIKE11 Description and Operation: The gates can be modeled according to measured gate elevation data depending on the status (0 or 1) of the file 'GateLevelSchedule.dfs0'. If measured gate elevation data are not used, the gate levels, prior to 2000, are set to

11.25 feet (closed). From 2000 going forward, the gate levels will be set to 17.25 feet (open).

Structure G-306AJ in the STA 1W Cell 5 at chainage 16,600’:

Description: The structure consists of 10 underflow gates. Each gate is six feet wide with a sill level of 7.8 feet.

MIKE11 Description and Operation: The gates can be modeled according to measured gate elevation data depending on the status (0 or 1) of the file ‘GateLevelSchedule.dfs0’. If the measured gate elevation data are not used, the gate levels, prior to 2000, are set to 7.8 feet (closed). From 2000, going forward, the gate level will be set to 13.8 feet (open).

Structure G-308 in the STA 1W Cell 1_3 Canal at chainage 23,700’:

Description: This structure consists of one underflow gate. The gate is 14 feet wide with a sill level of 7.4 feet.

MIKE11 Description and Operation: The gate can be modeled according to measured gate elevation data depending on the status (0 or 1) of the file ‘GateLevelSchedule.dfs0’. If the measured gate elevation data are not used, the gate level, prior to 2000, is set to 7.4 feet. From 2000, going forward, the gate elevation will be set to 14.07 feet (open).

Structure G-309 in the STA 1W Cell 2_4 Canal at chainage 17,500’:

Description: This structure consists of one underflow gate. The gate is 14 feet wide with a sill level of 7.6 feet.

MIKE11 Description and Operation: The gate can be modeled according to measured gate elevation data depending on the status (0 or 1) of the file ‘GateLevelSchedule.dfs0’. If the measured gate elevation data are not used, the gate level, prior to 2000, is set to 7.6 feet (closed). From 2000, going forward, the gate level will be set to 14.27 feet (open).

Structure G-310 in the STA 1W Discharge Canal at chainage 28,700’:

Description: The structure consists of one discharge pump.

MIKE11 Discharge and Operation: Prior to 2000, there was no pumping. From 2000 going forward, pumpage is based on measured data from 7/6/2000 to 9/30/2002.

Stormwater Treatment Area Number 2 (STA2)

Structure G-329AD in the STA2 Cell 1 at chainage 100’:

Description: This structure consists of four underflow gates. Each gate is six feet wide with a sill level of six feet.

MIKE 11 Description and Operation: The gates can be modeled according to measured gate elevation data depending on the status (0 or 1) of the file ‘GateLevelSchedule.dfs0’. If the measured gate elevation data are not used, the gate levels, prior to 2000, are set to six feet (closed). From 2000, going forward, the gate level is set to 12 feet (open).

Structure G-330AE in the STA Cell 1 Canal at chainage 17,000’:

Description: This structure consists of five overflow gates. Each gate is three feet wide with a sill level of nine feet.

MIKE11 Description and Operation: The gates can be modeled according to measured gate elevation data depending on the status (0 or 1) of the file ‘GateLevelSchedule.dfs0’. If the measured gate elevation data are not used, the gate levels are set to 12 feet (closed).

Structure G-331AG in the STA2 Cell 2 Canal at chainage 100’:

Description: This structure consists of seven underflow gates. Each gate is 5.5 feet wide with a sill level of 6 feet.

MIKE11 Description and Operation: The gates can be modeled according to measured gate elevation data depending on the status (0 or 1) of the file ‘GateLevelSchedule.dfs0’. If the measured gate elevation data are not used, the gate levels, prior to 2000, are set to six feet. From 2000, going forward, the gate level is set to 11.5 feet (open).

Structure G-332 in the STA2 Cell 2 Canal at chainage 15,000’:

Description: This structure consists of two underflow gates. Each gate is 16 feet wide with a sill level of 7.5 feet.

MIKE11 Description and Operation: The gates can be modeled according to measured gate elevation data depending on the status (0 or 1) of the file ‘GateLevelSchedule.dfs0’. If the measured gate elevation data are not used, the gate levels, prior to 2000, are set to 7.5 feet (closed). From 2000, going forward, the gate elevation is set to 14.4 feet (open).

Structure G-333AE in the STA2 Cell 3 Canal at chainage 100’:

Description: This structure consists of five underflow gates. Each gate is 5.5 feet wide with a sill level of six feet.

MIKE11 Description and Operation. The gates can be modeled according to measured gate elevation data depending on the status (0 or 1) of the file ‘GateLevelSchedule.dfs0’. If the measured gate elevation data are not used, the gate levels, prior to 2000, are set to six (6) feet (closed). From 2000, going forward, the gate level is set to 11.5 feet (open).

Structure G-334 in the STA2 Discharge Canal at chainage 4,500’:

Description: This structure consists of two underflow gates. Each gate is 16 feet wide with a sill level of 6.75 feet..

MIKE11 Description and Operation: The gates can be modeled according to measured gate elevation data depending on the status (0 or 1) of the file ‘GateLevelSchedule.dfs0’. If the measured gate elevation data are not used, the gate levels, prior to 2000, are set to 6.75 feet (closed). From 2000, going forward, the gate level is set to 4.4 feet (open).

Structure G-335 in the STA2 Discharge Canal at chainage 10,500’:

Description: This structure consists of one discharge pump.

MIKE11 Description and Operation: There currently is no operation. However, discharge rates were estimated using measured pumpage data from 11/14/2000 to 11/11/2002.

Structure G-336AF in the WCA2A Canal at chainage 100':

Description: The structure consists of six underflow gates. Each gate is 10 feet wide with a sill level of 12 feet.

MIKE11 Description and Operation: Prior to 2000 the gate levels are set to 12 feet (closed). From 2000, going forward, the gate level is set to 17 feet (open).

Structure G-336G in the L-6 17 Canal at chainage 500':

Description: The structure consists of one overflow gate. The gate is 40 feet wide with a sill level of minus four feet.

MIKE11 Description and Operation: Prior to 2000 the gate level is set to minus four feet (fully open). From 2000, going forward, the gate level is set to 14.25 feet.

Structure G-338 in the S-6 Diversion Canal at chainage 100':

Description: The structure consists of one underflow gate. The gate is 14 feet wide with a sill level of seven feet.

MIKE11 Description and Operation: Prior to 2000 the gate level is set to seven feet (closed). From 2000, going forward, the gate level is set to 19 feet (open).

Structure G-339 in the S-6 Diversion Canal at chainage 2,500':

Description: The structure consists of two underflow gates. Each gate is 18 feet wide with a sill level of eight feet.

MIKE11 Description and Operation: Gates can be modeled according to measured gate elevations depending on the status (0 or 1) of the file 'GateLevelSchedule.dfs0'. If measured gate elevations are not used, the gate levels, prior to 2000, are set to eight feet. From 2000, going forward, the gate level will be set to 19.5 feet (open).

Structure "L-7 Dummy1" in the L-6 Canal at chainage 54,260':

Description: This structure consists of one **non-existent** underflow gate. This dummy gate is 90 feet wide with a sill level of minus nine feet.

MIKE11 Description and Operation: Prior to 2000, the gate level is set to 19 feet (open, with no restriction to flow). From 2000, going forward, the gate level is set to minus nine feet (canal blocked). The purpose of this non-existing structure is to block the flow in L-6 caused by G-339 after STA2 was built.

Structure "L-7 Dummy2" in the L-6 Canal at chainage 54,060':

Description: This structure consists of one **non-existent**, underflow gate. The gate is 90 feet wide with a sill level of minus nine feet.

MIKE11 Description and Operation: Prior to 2000 the gate level is set to 19 feet (open, with no restriction to flow). From 2000, going forward, the gate level is set to minus nine feet (canal blocked). The purpose of this non-existing structure is to block the flow in L-6 caused by G-339 after STA2 was built.

Structure “S-6 Diversion Dummy3” in STA2 Supply Canal chainage 100’:

Description: This structure consists of one **non-existent** overflow gate. The gate is 50 feet wide, with a sill level of minus four feet.

MIKE11 Description and Operation: Prior to 2000 the gate level is set to 20 feet (closed - canal blocked). From 2000, going forward, the gate level is set to minus four feet (open, no restriction to flow). The purpose of this non-existing structure is to only allow water to flow in the STA2 Supply Canal after STA2 was built.

Stormwater Treatment Area Number 5 (STA5)

Structure G-342AB in the STA5 Cell 1 Canal at chainage 100’:

Description: This structure consists of two underflow gates. Each gate is 10 feet wide with a sill level of 7.25 feet.

MIKE11 Description and Operation: The gates can be modeled according to measured gate elevations depending on the status (0 or 1) of the file ‘GateLevelSchedule.dfs0’. If measured gate elevations are not used, the gate elevation, prior to 1999, is set to 7.25 feet (closed). From 1999, going forward, the gate elevation is set to 13.25 feet (open).

Structure G-342CD in the STA5 Cell 2 Canal at chainage 100’:

Description: This structure consists of two underflow gates. Each gate is 10 feet wide with a sill level of 7.25 feet.

MIKE11 Description and Operation: The gates can be modeled according to measured gate elevations depending on the status (0 or 1) of the file ‘GateLevelSchedule.dfs0’. If measured gate elevations are not used, the gate levels, prior to 1999, are set to 7.25 feet (closed). From 1999, going forward, the gate elevation is set to 13.25 feet (open).

Structure G-343ABC in the STA5 Cell 1 Canal at chainage 10,100’:

Description: This structure consists of three overflow gates. Each gate is five feet wide with a sill level of 11 feet.

MIKE11 Description and Operation: Currently there are no operational requirements for this structure. The gates are fixed at elevation 11 feet (open).

Structure G-343DEF in the STA5 Cell 2 Canal at chainage 10,100’:

Description: This structure consists of three overflow gates. Each gate is five feet wide with a sill level of 11 feet.

MIKE11 Description and Operation: Currently, there are no operational requirements for this structure. The gates are fixed at elevation 11 feet (open).

Structure G-344AB in the STA 5 Cell 1 Canal at chainage 20,100’:

Description: The structure consists of two underflow gates. Each gate is 10 feet wide with a sill level of zero.

MIKE11 Description and Operation: The gates can be modeled according to measured gate elevations depending on the status (0 or 1) of the file ‘GateLevelSchedule.dfs0’. If measured gate elevations are not used, the gate levels, prior to 1999, are set to zero (closed). From 1999, going forward, the gate levels are set to 10 feet (open).

Structure G-344CD in the STA5 Cell 2 Canal at chainage 20,100’:

Description: The structure consists of two underflow gates. Each gate is 10 feet wide with a sill level of zero.

MIKE11 Description and Operation: The gates can be modeled according to measured gate elevations depending on the status (0 or 1) of the file ‘GateLevelSchedule.dfs0’. If measured gate elevations are not used, the gate levels, prior to 1999, are set to zero. From 1999, going forward, the elevation is set to 10 feet (open).

Stormwater Treatment Area Number 6 (STA6)

Structure G-600 in the STA6 Supply Canal at chainage 100’:

Description: This structure consists of one discharge pump with a maximum capacity of 500 cfs.

MIKE11 Description and Operation: This pump is turned on and off according to the following requirements:

- 1) if year < 1998, then no pumping
- 2) if G-600 headwater > “high”¹⁾, then pump
- 3) if “low”²⁾ < G-600 headwater < “high” and stage is falling, then pump
- 4) if “low” < G-600 headwater < “high” and stage is rising, then no pumping
- 5) if G-600 headwater < “low”, then no pumping

¹⁾ High water level in STA6 Supply Canal is defined as 10.2 feet

²⁾ Low water level in STA6 Supply Canal is defined as 8.7 feet from March 16th to October 20th and 7.7 feet from October 21st to March 15th (harvest season).

Structure G-604 in the STA6 Supply Canal at chainage 12,000’:

Description: The structure consists of one overflow gate. The gate is 11 feet wide with a sill level of 11 feet.

MIKE11 Description and Operation: This gate is always closed (gate level 18 feet) under normal conditions. Currently there are no operational requirements. This structure was first introduced when STA6 was built; therefore, prior 11/1/1997, the gate level is set to 11 feet. After 11/1/1997, the gate level is fixed at 18 feet.

ATTACHMENT B.2.2.3 – ADDITIONAL TABLES

Table B.2.2.3 – Stage Data Obtained for Use in Calibration [Roger: what do the red flags mean? – DWS]

Record #	Station	DBKEY(s)	Start	End	Days	Min. (ft)	Max. (ft)	Comments
1	MIAMI.15	4140, 3722	1/1/1980	9/3/2002	8033	7.65	12.54	
2	S2_H	425, 6562, 12644	5/31/1985	9/3/2002	6218	8.87	13.15	Only 6562 used (425 starts 10/1/1980)
3	S2_T	6566	5/31/1985	9/3/2002	6235	9.39	18.90	
4	S8_H	4342, 6697	8/31/1985	6/30/2002	6043	7.91	12.97	
5	S8_T	4344, 6698	8/31/1985	6/30/2002	6007	6.99	14.92	
6	ROTT.N	6966, JA333	5/23/1985	9/4/2002	5659	10.43	13.80	
7	ROTT.S	6967, JA335	5/23/1985	9/4/2002	5320	10.52	13.71	
8	L1-1	3712	11/5/1981	7/28/1995	4758	10.64	19.89	
9	G136_H	6943, 15968	4/20/1983	7/8/2002	7020	9.88	17.35	
10	G136_T	6944, 15969	4/20/1983	7/8/2002	6906	8.82	15.57	
11	G151_H	15309	5/2/1989	9/23/2002	4852	13.01	19.60	
12	G151_T	15310	5/2/1989	9/23/2002	4853	10.45	18.90	
13	USSSUGA R	15243	1/15/1992	5/13/2002	3772	-20.32	20.61	Data questionable?
14	S169_H	7846, 15591	3/1/1988	6/30/2002	4932	8.87	16.40	
15	S169_T	7847, 15592	3/1/1988	6/30/2002	4916	8.34	13.97	
16	INDUST	2746	1/1/1980	12/31/1999	7230	10.03	18.81	
				9				
17	HGS2	7698	3/1/1988	4/18/1998	2226	10.41	18.92	
18	S236_H	3978	1/1/1980	4/7/2000	7212	1.33	10.80	
19	S236_T	3980	11/11/198	4/7/2000	6532	10.31	18.84	
			1					
20	S3_H	6633	5/31/1985	7/10/2002	6154	8.14	13.03	
21	S3_T	537	1/1/1980	4/14/2002	7998	7.76	17.64	Head and tail similar
22	S351_H	M7418	3/22/2000	7/10/2002	841	9.35	15.44	
23	S351_T	M7419	3/22/2000	7/10/2002	841	8.96	12.49	
24	S352_H	13088, FF579	12/1/1989	4/4/2001	4143	10.01	18.58	
25	S352_T	M7431, FF580	5/6/1997	7/11/2002	1893	7.90	14.32	
26	G96_H	6933	7/1/1986	5/20/2002	5656	10.73	18.01	

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27	G96_T	6934	7/1/1986	5/20/2002	5588	10.02	16.20	
28	G150_H	15521	12/13/199	7/8/2002	3039	9.67	17.38	
			2					
29	G150_T	15522	12/13/199	7/8/2002	3051	10.68	18.75	
			2					
30	S5A_H	318, 6676	1/1/1980	7/2/2002	8219	7.07	12.75	
31	S5A_T	320	1/1/1980	2/28/2002	8095	10.08	18.83	
32	S6_H	356	10/25/199	4/9/2002	4127	7.78	12.68	
			0					
33	S6_T	4968, 6685	1/1/1980	7/10/2002	8132	9.75	18.16	
34	S10E_H	5554	2/19/1985	4/4/1995	3668	11.30	18.24	
35	S150_H	4942, 7622, 16558	1/2/1981	7/10/2002	5642	7.36	14.16	
36	S150_T	4944, 7940, 15458	1/3/1984	7/10/2002	6734	6.80	13.98	
37	S190_H	4520, 15986	1/1/1984	7/2/2002	5337	10.69	16.26	
38	S190_T	4522, 15985	1/1/1984	7/2/2002	5337	8.51	14.49	
39	S339_H	3984, 15561	10/23/198	5/7/2002	7685	5.61	13.83	
			0					
40	S339_T	3986, 15562	10/23/198	4/3/2002	7772	5.31	13.46	
			0					
41	G205_H	15055	6/7/1991	7/17/2001	3694	7.82	13.46	Head and tail similar
42	G205_T	15056	6/7/1991	7/17/2001	3694	7.89	13.57	
43	G204_H	15052	6/7/1991	7/17/2001	3651	8.68	13.14	Head and tail similar
44	G204_T	15053	6/7/1991	7/17/2001	3651	7.88	13.77	
45	G88_H	6936	1/1/1980	4/10/1996	5945	9.90	16.04	
46	G88_T	6937, 15794	1/1/1980	7/18/2002	8227	7.77	14.68	
47	G206_H	15058	6/7/1991	7/17/2001	3694	7.21	13.58	
48	G206_T	15059	6/7/1991	7/17/2001	3632	7.09	13.34	
49	G604_H	GA117	11/24/199	8/15/2001	1357	8.99	16.16	
			7					
50	G607_H	FI260	5/13/1997	7/30/2002	1878	7.77	14.86	Head and tail similar
51	G607_T	FI261	5/13/1997	7/30/2002	1878	7.79	14.71	
52	G328_H	MQ897	7/10/2001	8/6/2002	365	5.26	9.01	
53	G328_T	MQ898	7/17/2001	8/6/2002	386	10.88	17.80	
54	G332_H	N3458	3/1/2001	7/31/2002	518	9.32	13.77	
55	G332_T	N3459	3/1/2001	7/24/2002	511	7.79	13.18	

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56	G334_H	N3452	2/26/2001	7/28/2002	518	9.74	13.23
57	G335_H	MR463	7/20/2000	8/1/2002	743	6.83	13.93
58	G335_T	MR464	7/20/2000	8/1/2002	743	9.21	16.65
59	G339_H	MS575	3/6/2001	7/23/2002	492	10.85	17.81
60	G339_T	MS576	3/6/2001	7/23/2002	493	11.17	16.29
61	G155_H	15004, 15790	7/3/1989	7/21/2002	4763	7.84	16.13
62	G155_T	15005, 15791	7/3/1989	7/21/2002	4767	7.84	15.79
63	G406_T	JJ155	7/15/1999	7/22/2002	1099	10.95	17.41
64	G200A_H	13152	9/24/1990	7/1/2002	4297	7.82	12.48
65	G200A_T	13153	8/20/1990	7/1/2002	4330	8.43	13.77
66	G201_H	15284	3/15/1991	5/27/2002	4090	7.44	11.05
67	G201_T	15700	3/1/1992	5/28/2002	3739	6.20	13.70
68	G89_H	6939	1/1/1980	10/2/1995	5754	9.90	15.28
69	G89_T	6940, 15795	1/1/1980	10/25/199	6873	8.00	12.72
				8			
70	G108_H	JJ822	6/29/1999	8/4/2002	1133	12.40	19.73
71	G108_T	JJ823	6/29/1999	8/4/2002	1133	10.70	16.22
72	G342A_H	JJ112	6/16/1999	7/9/2002	1120	10.79	17.50
73	G342A_T	JJ113	6/16/1999	7/9/2002	1111	12.18	15.81
74	G342B_H	J6396	11/20/199	7/9/2002	1328	10.72	17.51
				8			
75	G342B_T	J6397	11/20/199	7/9/2002	1319	10.65	15.89
				8			
76	G342C_H	JJ122	6/29/1999	5/28/2002	1065	11.52	17.51
77	G342C_T	JJ124	6/29/1999	6/11/2002	1070	12.33	15.99
78	G342D_H	J6399	11/20/199	7/9/2002	1328	10.35	17.55
				8			
79	G342D_T	J6403	11/20/199	7/9/2002	1315	11.09	16.07
				8			
80	G344A_H	JJ132	6/16/1999	7/9/2002	1120	10.64	15.00
81	G344A_T	JJ134	6/16/1999	7/9/2002	1120	7.97	12.76
82	G344B_H	JJ137	6/16/1999	7/9/2002	1120	10.77	15.00
83	G344B_T	JJ139	6/16/1999	7/9/2002	1120	8.01	12.77
84	G344C_H	JJ143	6/15/1999	7/9/2002	1121	8.42	14.25
85	G344C_T	JJ144	6/16/1999	7/9/2002	1120	8.03	12.82

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86	G344D_H	JJ147	6/16/1999	7/9/2002	1120	8.76	14.24
87	G344D_T	JJ149	6/16/1999	7/9/2002	1120	8.07	12.81
88	G349A_H	JJ156	6/2/1999	7/7/2002	1122	8.59	11.22
89	G349A_T	JJ157	6/2/1999	7/7/2002	1132	10.88	15.75
90	G349B_H	JJ802	5/6/1999	7/9/2002	1148	8.08	12.84
91	G349B_T	JJ803	5/6/1999	7/9/2002	1149	8.57	11.43
92	G350A_H	JJ160	6/19/1999	8/7/2002	1146	8.59	11.47
93	G350A_T	JJ161	6/19/1999	8/7/2002	1138	10.74	15.99
94	G350B_H	JJ810	5/6/1999	7/1/2002	1153	8.04	12.83
95	G350B_T	JJ811	5/6/1999	7/1/2002	1153	8.46	11.47
96	NNCR.SFS	4296, 5581	1/1/1980	9/3/2002	8143	7.29	13.20
97	HILL.6MI	4136, 4588	1/1/1980	9/2/2002	7651	6.25	14.08
98	BLSE	15460, G5163	8/26/1992	8/29/2002	3171	8.49	14.30
99	BLSW	15462, G5164	8/26/1992	8/29/2002	3149	8.84	13.40
100	G152_H	LK428	12/31/1999	8/5/2002	949	14.71	22.60
			9				
101	G152_T	LK429	12/31/1999	8/5/2002	949	14.42	19.69
			9				
102	L3DF	16242	5/16/1995	2/6/2002	2459	9.37	17.97
103	3A-10_B	5108, KS831	1/1/1980	7/31/2002	7990	8.89	13.47
104	3A-NE_B	5100, LX277	1/1/1980	7/23/2002	7739	6.30	13.81
105	3A-NW_B	5098, LA369	1/1/1980	4/24/2002	7828	8.41	14.13
106	I-7	15808	7/1/1991	6/17/2002	3963	14.88	18.21
107	ENR006	15844	11/18/1999	7/2/2002	3135	3.65	18.99
			3				
108	NTCIN	DU538	12/30/1999	6/1/2002	1597	14.00	24.27
			5				
109	CA2A-159	J8199	1/7/1999	6/25/2002	1266	10.96	14.96
110	HOLEY1	13001, JA348	10/12/1998	9/2/2002	4516	10.05	13.56
			9				
111	HOLEY2	13002, JA350	10/11/1998	9/3/2002	4657	9.70	13.57
			9				
112	G404_H	M9911	5/6/2000	5/1/2002	713	8.08	12.68
113	G404_T	M9912	5/6/2000	5/1/2002	713	9.21	14.92
114	L006	12519	6/29/1990	9/13/2002	3724	8.86	18.68

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115	G134_H	6963	7/1/1986	9/20/2002	5773	17.03	22.11
116	G134_T	6965	7/1/1986	11/4/2002	5739	15.43	20.83
117	G135_H	6930	7/1/1986	9/23/2002	5814	15.38	20.58
118	G135_T	6931	7/1/1986	11/4/2002	5777	12.53	19.04
119	S7_H	4330, 6695	1/1/1980	7/9/2002	8226	7.36	12.74
120	S7_T	4332, 6696	1/1/1980	7/9/2002	8219	7.00	15.97
121	S5AE_T	326	1/1/1980	3/5/2002	7639	7.44	17.22
122	S5AS_T	4678, 6693	2/1/1984	11/21/200	6761	9.89	18.98

Data after 9/30/2000 questionable?

2

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Table B.2.2.4 – Flow Data Obtained for Use in Calibration

Record #	Station	DBKEY(s)	Start	End	Days	Min. (ft ³ /s)	Max. (ft ³ /s)	Comments
1	S150_C	15041	1/1/1980	1/26/1991	4044	-285	1575	
2	S2 Total	15021	1/1/1980	4/30/2002	8156	-4030	3440	
3	S2_NNR	436	1/1/1980	1/4/2002	8031	-3460	2920	
4	S3	15018	1/1/1980	4/30/2002	8156	-2620	1860	
5	S5AW_C	322	10/1/1990	2/28/2002	3803	-593	810	
6	S5AX_C	4892	5/31/1985	5/5/1999	3285	-718.1	806.61	
7	S6	15034	1/1/1980	6/30/2002	8217	-835.75	2920	
8	S7	15037	1/1/1980	4/30/2002	8156	-711.34	2861.4	
9	S8	15040	1/1/1980	4/30/2002	8156	-369	4060	
10	ESHORE2	LX273	12/20/2001	4/30/2002	132	-1.00E-30	351.25	
11	ESPS2_P	NQ194	12/20/2001	8/23/2002	247	-1.00E-30	492.47	
12	G155_W	12843, 15789	8/1/1989	2/7/2001	4205	-359.35	1374.79	15789 not used, bad data overlap
13	G200A_P	15154	10/28/1991	8/20/2002	3945	-1.00E-30	772.67	
14	G200B_P	15155	10/28/1991	12/13/2001	3695	-1.00E-30	63.95	
15	G201_P	15156	2/12/1992	5/28/2002	3759	-1.00E-30	128.09	
16	G328	J0718	4/1/2000	5/31/2002	791	-1.00E-30	419	
17	G328_P	MQ903	7/10/2001	9/4/2002	404	-1.00E-30	290.53	
18	G328R_O	LI214	12/14/2000	5/2/2001	127	-1.00E-30	29.76	
19	G329A_C	N0748	12/12/2000	9/2/2002	609	-28.13	223.28	
20	G329B_C	LG703	12/12/2000	9/2/2002	630	-26.1	220.02	
21	G329C_C	LG704	12/12/2000	9/2/2002	627	-26.9	220.84	
22	G329D_C	LG705	12/12/2000	9/2/2002	630	-28.83	223.95	
23	G330A_C	LG706	8/31/2001	10/31/2001	43	-1.61	4.83	
24	G330B_C	LG707	2/23/2001	11/5/2001	256	-23.71	154.52	
25	G330C_C	LG708	3/1/2001	11/5/2001	250	-36.86	147.76	
26	G330D_C	LG709	3/1/2001	11/5/2001	250	-36.89	132.37	
27	G330E_C	LG710	3/1/2001	11/15/2001	260	-28.61	49.88	
28	G331A_C	LG711	1/6/2001	9/2/2002	605	-76.29	246.45	
29	G331B_C	LG712	1/6/2001	9/2/2002	589	-70.99	241.37	
30	G331C_C	LG713	1/6/2001	9/2/2002	583	-36.54	249.34	
31	G331D_C	LG714	1/6/2001	9/2/2002	605	-88.64	247.65	

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32	G331E_C	LG715	1/6/2001	9/2/2002	605	-93.5	250.66	
33	G331F_C	LG716	1/6/2001	9/2/2002	605	-87.16	246.15	
34	G331G_C	LG718	1/6/2001	9/2/2002	321	-5.7	230.15	
35	G332_S	LG719	3/1/2001	8/29/2002	547	-35.77	1152.08	
36	G333A_C	LG720	12/12/2000	7/24/2002	585	-6.33	255.98	
37	G333B_C	LG721	12/12/2000	7/24/2002	585	-4.41	243.6	
38	G333C_C	LG722	12/12/2000	7/24/2002	585	-5.95	250.58	
39	G333D_C	LG723	12/12/2000	7/24/2002	585	-5.14	250.55	
40	G333E_C	LG724	12/12/2000	7/24/2002	585	-5.54	252.84	
41	G334_S	LG725	3/1/2001	8/11/2002	526	-149.27	1139.09	
42	G335_P	N0659	7/1/2001	5/31/2002	335	-1.00E-30	2986.16	
43	G357_C	LX263	1/3/2001	4/30/2002	483	-1.00E-30	281.61	Only two values different from zero
44	G402A_C	LX264	7/20/2001	5/1/2002	286	-1.00E-30	125.56	
45	G402B_C	LX265	7/20/2001	4/30/2002	285	-1.00E-30	121.65	
46	G402C_C	LX266	7/20/2001	5/1/2002	286	-1.00E-30	107.28	
47	G402D_C	LX267	7/20/2001	4/30/2002	285	-1.00E-30	60.56	
48	G406_C	JJ151	6/15/1999	8/11/2002	1083	-2.76	869.17	
49	G410_P	LX270	7/17/2001	6/30/2002	349	-1.00E-30	263.36	
50	G88_C	15196	1/1/1980	4/30/2002	8156	-168.31	914.6	
51	HGS3	6490	6/1/1984	12/31/1991	2758	-151.00	1230	
52	HGS4	6477	6/1/1984	3/31/1992	2840	-672.00	3150	
53	HGS5X	15068	1/1/1980	4/30/2002	8156	-1310.00	1100	
54	L3BRS_O	16245	6/22/1995	8/8/2002	2578	-84.73	1723.15	
55	L3DF_O	16243	1/6/1996	6/26/2000	1634	-30.60	1104.12	
56	S351_S	13030	2/8/1989	4/30/1998	3349	-1079.71	2560.53	
57	S352_S	13031, FF581	12/1/1989	9/3/2002	4653	-752.05	1076.46	M7434 not used
58	S354_S	13032, H6940	6/1/1990	7/10/2002	4417	-343.97	1682.83	Overlap in April 1998, but not similar values
59	G151_C	12840	5/3/1989	9/4/2001	4505	-160.62	580.41	

Table B.2.2.5 – Groundwater Data Obtained for Use in Calibration

Record #	Station	DBKEY(s)	Start	End	Days	Min. (ft)	Max. (ft)	Comments
1	CA2A-159	5408	3/4/1981	1/7/1999	5785	10.44	15.56	
2	PB-506_G	5424	2/16/1984	1/17/1999	4885	10.46	13.58	
3	MOP2GW1	H1967	12/9/1997	6/21/2002	1610	9.50	14.49	
4	MOP2GW2	H1970	12/9/1997	6/21/2002	1592	9.49	14.46	
5	MOP2GW3	H1971	12/9/1997	6/21/2002	1629	9.40	14.59	
6	ENR202W1	H1982	12/9/1997	7/2/2002	1656	6.60	9.43	
7	ENR202W2	H1983	12/9/1997	7/2/2002	1656	6.41	11.13	
8	ENR202W3	H1984	12/9/1997	6/11/1999	520	7.26	10.78	
9	ENR202W4	H1985	12/9/1997	7/2/2002	1656	5.51	11.01	
10	ENR203GW	H1986	12/10/1997	7/1/2002	1665	10.58	14.24	
11	ENR204GW	H1989	12/11/1997	7/1/2002	1658	10.57	14.18	
12	ENR303GW	H1991	12/10/1997	7/1/2002	1659	10.43	13.71	
13	ENR401GW	H1992	12/11/1997	7/1/2002	1665	10.43	14.08	
14	MP2GW1	H1995	1/28/1998	7/8/2002	1593	10.24	13.87	
15	MP2GW2	H1996	1/28/1998	7/8/2002	1612	10.60	14.30	
16	MP2GW3	H1997	1/28/1998	7/8/2002	1612	10.67	14.40	
17	WF1_G	L7522	12/14/1999	5/16/2002	829	23.83	29.16	
18	ENR202R3	MC601	1/23/2001	7/2/2002	526	9.06	11.08	
19	PB-506	2684	1/1/1980	9/30/1986	1966	7.44	12.60	
20	HE-339_G	2502	1/29/1980	3/29/1988	76	10.95	15.11	
21	PB-203_G	2646	5/13/1980	5/13/1980	1	69.10	69.10	Only one value!
22	PB-507_G	2690	1/2/1980	9/4/1980	9	36.11	39.23	
23	PB-508_G	2691	1/2/1980	9/4/1980	9	10.69	12.94	
24	PB-509_G	2686	1/2/1980	9/4/1980	9	24.68	27.44	
25	IFAS stations	Hourly well data obtained from IFAS available for 5 farms. 53 Wells are available from early 7/1993 through 12/31/99						

**ATTACHMENT B.2.2.4 –
Simulation Evaluation of Unsaturated Zone Modeling Method**

MEMORANDUM

Date : 17 January, 2003
To : David Stewart, Kimley-Horn
From : Roger Copp, Joseph Hughes
Our Ref. : 4021.171
Subject : Simulation Evaluation of Unsaturated-saturated zone Modelling Methods

Detailed unsaturated-saturated zone (UZ-SZ) models were developed for IFAS farms UF9203A, UF9209A, and UF9209A. For each of the models, observed stage, groundwater levels, and rainfall data collected on each farm were used as input or output data. The setup of the models and results are discussed below. It should be kept in mind that the parameters and results presented below are preliminary values that may be altered/revised during calibration of the sub-regional EAA MIKE SHE model. Furthermore, the parameters presented below were derived from published data (Guardo and Rohrer, 2000; and Montgomery Watson, 1997a, 1997b, and 1999) and qualitative evaluation of observed and simulated values. Quantitative evaluation of simulated and observed values was not undertaken because of uncertainties in topography, lithology, and canal geometry across UF9203A, UF9209A, and UF9209A.

Several numerical methods for simulating unsaturated zone (UZ) flow were evaluated in the detailed UZ-SZ farm models. The UZ methods evaluated included the full Richards equation method, the simplified Richards equation method, and the two-layer water balance method. All of the methods available in MIKE SHE are one-dimensional in form. The full Richards equation method is the most computationally intensive of the three available methods but is the most accurate when unsaturated flow is dynamic. The simplified Richards equation method is similar to the full Richards equation method except the pressure term (capillary forces) in the Richards equation is ignored and gravity is the only driving force for unsaturated flow. The full and simplified Richards equation methods require moisture-retention and unsaturated hydraulic conductivity data that are discretized into multiple calculation cells within vertical soil profiles defined for each grid cell. The two-layer water balance method is suitable when the water table is shallow and groundwater recharge is primarily influenced by evapotranspiration in the root zone. A linear relationship between moisture content and water table depth is used in the two-layer water balance method. A single soil profile (not vertically discretized into multiple calculation cells) that represents average soil properties for the entire UZ is defined for each grid cell. In cases where the water table is very dynamic and/or spatially variable, the full or simplified Richards equation methods are the best methods. However, the Richards equation methods increase computation times during simulation.

Evapotranspiration (ET) from the UZ is handled by the three UZ methods. The full and simplified Richards equation methods use the empirical ET equations of Kristensen and Jensen (1975). The two-layer water balance method uses a storage based top-down ET

method to allocate ET. Vegetation properties are assigned spatially in both methods and can vary temporally. Both ET methods account for ET losses from canopy storage, detention storage, root zone storage, and the groundwater system and require root depths and leaf area indices (LAI) for each vegetation type. The Kristensen and Jensen (1975) ET method also requires three empirical coefficients that are related to soil hydraulic properties.

2 Vertical Discretization of the Unsaturated-Saturated Zone and Associated Hydraulic Properties

The saturated zone (SZ) model was discretized into three layers with a constant horizontal grid spacing of 1000 ft. The muck, caprock and lower permeability siliciclastic sediments below the muck were combined in layer 1. Layer 2 represented lower permeability sediments of the upper Okeechobee formation beneath the caprock or lower permeability sands underlying muck. Layer 3 represented more permeable sediments of the Okeechobee formation and was 50 feet thick. Hydraulic properties for the SZ model are summarized in Table 1.

The unsaturated zone (UZ) model explicitly included the muck, the caprock where present, low permeability siliciclastic deposits beneath the muck where present, and upper Okeechobee sediments. UZ cell sizes ranged from 0.05 ft at the top of the profile to 2 ft at the bottom of the profile and monotonically increased with depth. A maximum of 33 UZ cells were simulated in each profile. Unsaturated zone properties for the UZ model are summarized in Table 1.

Table 1. Hydraulic conductivities and unsaturated zone properties used in detailed UZ-SZ farm models

Zone	Horizontal Hydraulic Conductivity Kh (ft/day)	Vertical Hydraulic Conductivity Kv (ft/day)	Saturated Moisture Content (θs)	Residual Moisture Content (θr)	Moisture Content at Field Capacity (θfc)	Moisture Content at Wilting Point (θw)
Muck	54	28	0.77	0.15	0.66	0.2
Transition zone	>10,000	28	0.25	NA	NA	NA
Caprock	50	0.50	0.12	0.03	0.12	0.10
Sand below muck	50	8.0	0.37	0.03	0.15	0.06
Upper Okeechobee	125	12.5	0.12	0.03	0.11	0.10
Lower Okeechobee	200	150	0.25	NA	NA	NA

NA – Not applicable

In addition to using the full Richards formulation for simulating unsaturated zone flow, the unsaturated zone was also approximated using the two-layer water balance method. The two-layer water balance method is generally only capable of representing average responses to rainfall events, evapotranspiration, and water level changes but is attractive because of reduced numerical overhead. The two-layer water balance method is most appropriate for systems with high water-tables and limited calibration data and is potentially appropriate for the sub-regional EAA MIKE SHE model. Parameters for the two-layer water balance method represent effective parameters for the entire unsaturated zone properties and can be thought of as vertically weighted values.

B.2.2 HYDROLOGIC MODELING/METHODOLOGY REPORT

Parameters for the two-layer water balance method used in the detailed UZ-SZ farm models are summarized in Table 2.

Table 2. Two-layer water balance parameters

Zone	Infiltration Rate Kv (ft/day)	Saturated Moisture Content (θ_s)	Moisture Content at Field Capacity (θ_{fc})	Moisture Content at Wilting Point (θ_w)
Muck over caprock	5	0.3	0.2	0.1
Muck over fine sand	8	0.18	0.15	0.1

3 Potential Evapotranspiration and Vegetation Properties

Daily PET rates calculated by the SFWMD for the Belle Glade station were used in all detailed UZ-SZ farm models. District PET data was not available for 1997; 1995 data was used for simulations in 1997.

Garcia (2000) reports that sugar cane is the primary crop grown on UF9203A, UF9209A, and UF9209A. LAI and root depths for sugar cane were taken directly from the calibrated Central Broward County MIKE SHE model. Sugar cane LAI and root depths used in the detailed UZ-SZ farm models are shown in Figure 1.

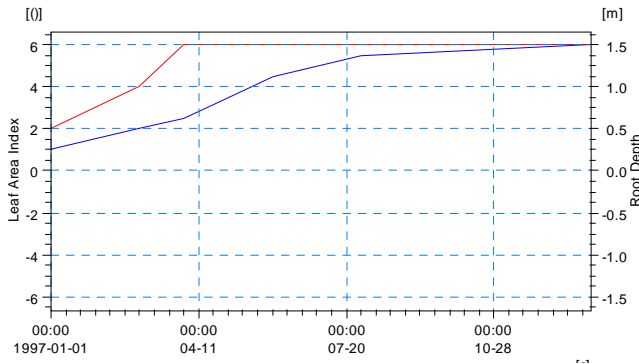


Figure 1. Sugar cane LAI (red) and root depths used in the detailed UZ-SZ farm models.

4 IFAS Farm UF9203A

A detailed UZ-SZ model of the northern portion of UF9203A was put together. A constant topography of 10.2 feet above mean sea level (amsl) was used throughout the model domain and a constant muck thickness of 1.75 feet was used. Caprock with a thickness of 5 feet was assumed to be constant throughout the model domain and the model was extended 65 feet below the base of the caprock at 3.5 ft amsl.

Constant head boundary conditions were used for all external boundaries in the saturated zone model. Observed stages from the main district discharge canal at pump station NR15.5TW were used for constant head boundaries along the northeast edge of them model. Observed water levels from interior farm canal well CW03W1 were used for all other constant head boundaries.

B.2.2 HYDROLOGIC MODELING/METHODOLOGY REPORT

Synthetic hourly rainfall data was derived from daily rainfall data collected at pump station NR15.5TW. Rainfall was distributed over a three-hour period with the peak rainfall volume at 4 p.m. every day.

Simulated results for the period from November 1, 1997 to December 1, 1997 using the full Richards equation are shown in Figure 2. Simulated results match observed results fairly well except when water is ponded on the land surface.

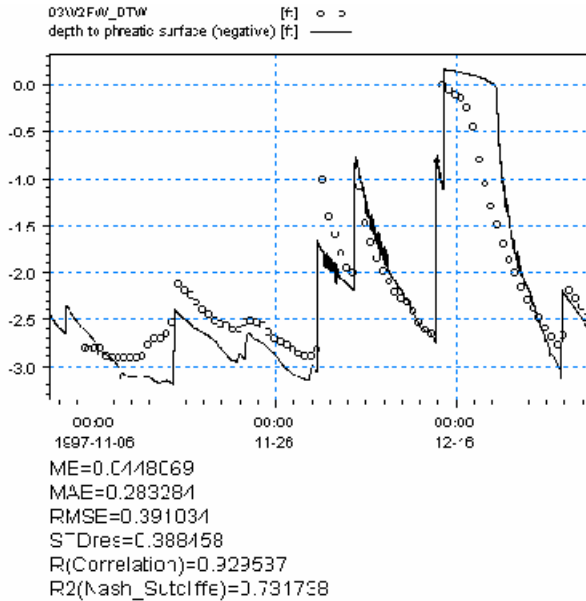


Figure 2. Simulated results for UF9203A using the full Richards solution.

Hydraulic parameters were adjusted to reduce the period of time the field was inundated without success. After review of Guardo and Rohrer (2000), a high conductivity transition zone 0.10 ft thick was added between the muck and caprock in order to simulate lateral flow along the interface. Simulated results for the period from November 1, 1997 to December 31, 1997 using the full Richards equation and the transition zone are shown in Figure 3. Simulated results match observed results better and represent system response under ponded conditions better with the transition zone. Utilizing the high conductivity transition zone provides results that are not significantly worse under non-ponded conditions.

B.2.2 HYDROLOGIC MODELING/METHODOLOGY REPORT

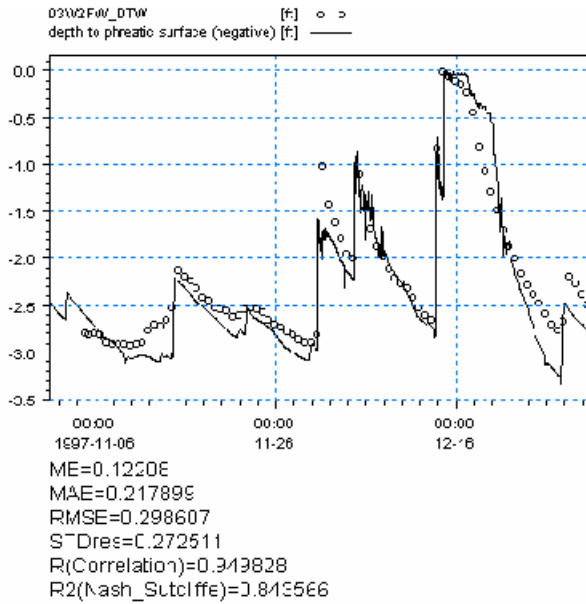


Figure 3. Simulated results for UF9203A using the full Richards solution and the transition zone of Guardo and Rohrer (2000).

Simulated results for UF9203A using the simplified Richards equation method without and with the transition zone are shown in Figure 4 and Figure 5, respectively. Results are very similar to the full Richards equation solutions except numerous numerical spikes are present. The numerical spikes may be a result of dynamic water table changes and ignoring the pressure term which may be significant in the muck soils.

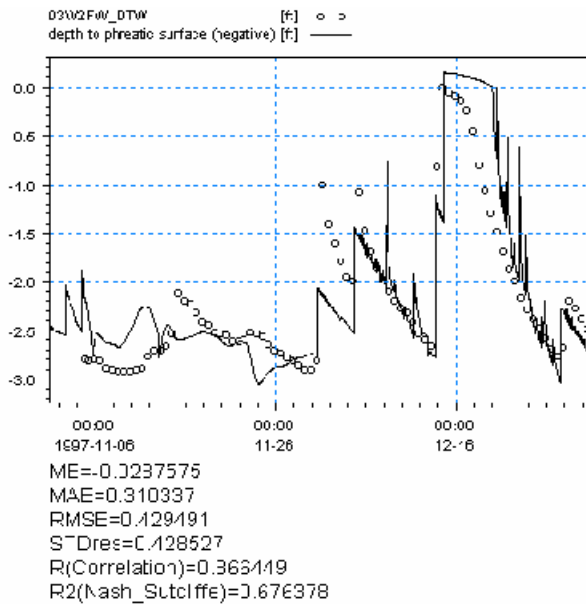


Figure 4. Simulated results for UF9203A using the simplified Richards solution.

B.2.2 HYDROLOGIC MODELING/METHODOLOGY REPORT

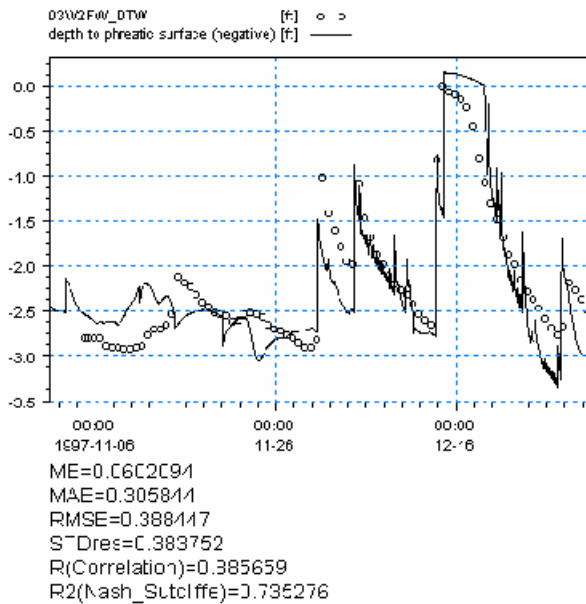


Figure 5. Simulated results for UF9203A using the simplified Richards solution and the transition zone of Guardo and Rohrer (2000).

Simulated results for UF9203A using the two-layer water balance method are shown in Figure 6. The large event in late December 1997 is well simulated with the two-layer water balance method but other small events are not as well represented. Smaller events may not be well simulated as a result of using relatively high moisture contents for the entire unsaturated zone. Addition of the transition zone between the muck and caprock was not found to have a significant effect on simulated results.

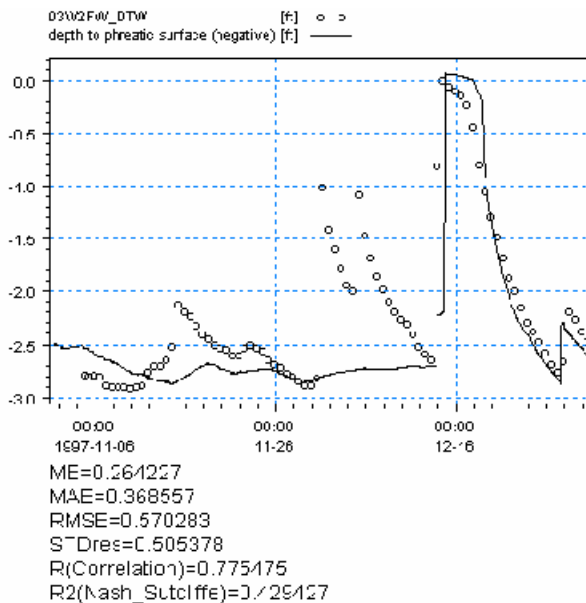


Figure 6. Simulated results for UF9203A using the two-layer water balance method.

Run times for the full Richards solution without the transition zone, full Richards solution

with the transition zone, the simplified Richards solution without the transition zone, the simplified Richards solution with the transition zone, and the two-layer water balance method without the transition zone were 396 seconds, 190 seconds, 44 seconds, 50 seconds, and 18 seconds, respectively. The UZ component required approximately 34%, 36%, 24%, 28%, and 4% of the total run time for the full Richards solution with and without the transition zone, the simplified Richards solution with and without the transition zone, and the two-layer water balance method, respectively.

5 IFAS Farm UF9206AB

A detailed UZ-SZ model of the northern portion of UF9206AB was put together. A constant topography of 8 feet amsl was used throughout the model domain and a constant muck thickness of 3.0 feet was used. Based on the Palm Beach County Soil Survey a low permeability fine sand layer with a thickness of 5 feet was assumed to be present beneath the muck and constant throughout the model domain and the model was extended 65 feet below the base of the low permeability sand at 0.0 ft amsl.

Constant head boundary conditions were used for all external boundaries in the saturated zone model. Observed stages from the main district discharge canal at pump station OC04.1TS01 were used for constant head boundaries along the southeast edge of them model. Observed water levels from interior farm canal well DW06W1 were used for all other external constant head boundaries. Internal general head boundaries (GHBs) were used in layer 1 for all internal farm canals. Observed water levels data from canal wells DW06W1, DW06W3, DW06W4, DW06W9, and DW06W10 were used for internal GHBs and were assigned to the grid based on proximity to the observation well. A leakage coefficient of 0.864 ft/day was used for all GHBs.

Synthetic hourly rainfall data was derived from daily rainfall data collected at pump station OC04.1TS01. Rainfall was distributed over a three-hour period with the peak rainfall volume at 4 p.m. every day.

Simulated results for the period from November 1, 1994 to December 31, 1994 using the full Richards equation are show in Figure 7. Simulated results match observed results fairly well except during and after two high intensity events in November and December 1994 when water is ponded on the land surface.

B.2.2 HYDROLOGIC MODELING/METHODOLOGY REPORT

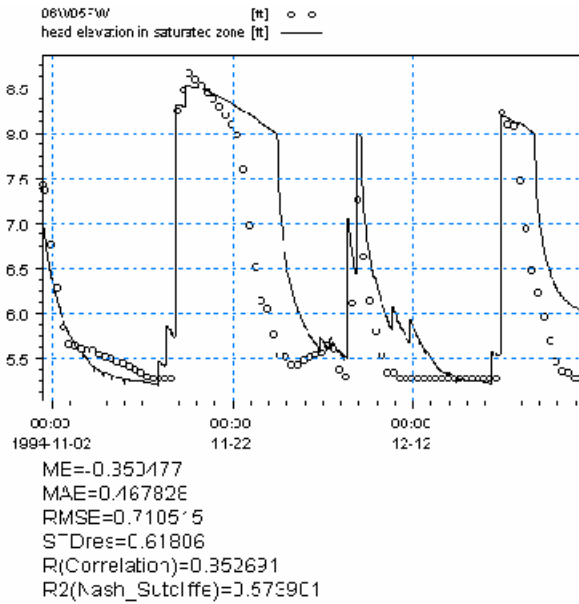


Figure 7. Simulated results for UF9206AB using the full Richards solution.

Hydraulic parameters were adjusted to reduce the period of time the field was inundated without success. As with UF9203A, a high conductivity transition zone 0.10 ft thick was added between the muck and caprock in order to simulate lateral flow along the interface. Simulated results for the period from November 1, 1994 to December 31, 1994 using the full Richards equation and the transition zone are shown in Figure 8. Adding the high conductivity transition zone improved simulated results. The differences between observed and simulated values were reduced, indicating that the high conductivity transition zone allows the model to better represent system response under both ponded and non-ponded conditions.

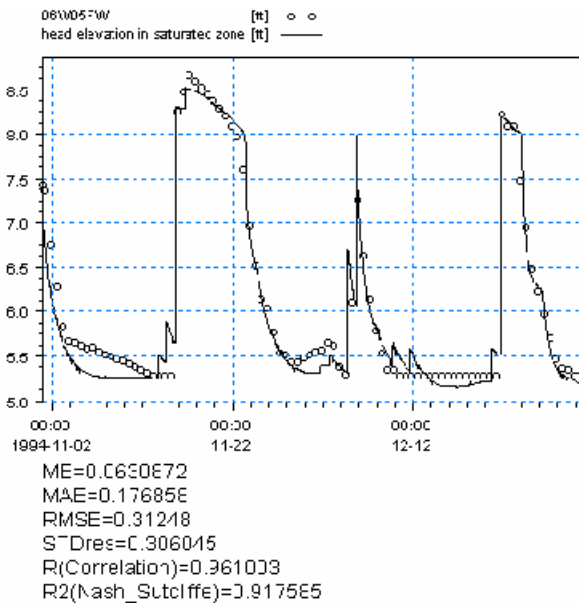


Figure 8. Simulated results for UF9206AB using the full Richards solution and the transition zone of Guardo and Rohrer (2000).

The simplified Richards equation method was not evaluated for UF9206AB. Simulated results for UF9206AB using the two-layer water balance method are shown in Figure 9. The large events in late November and December 1994 are reasonably well simulated with the two-layer water balance method but other small events are not as well represented. The magnitude of the smaller event in early December 1994 is reasonably well simulated but the recession is a little long. As with UF9203A, all aspects of smaller events may not be well simulated since relatively high moisture contents for the entire unsaturated zone are only accurate in an average sense. Addition of the transition zone between the muck and underlying sand was found to have a significant effect on simulated results (Figure 10).

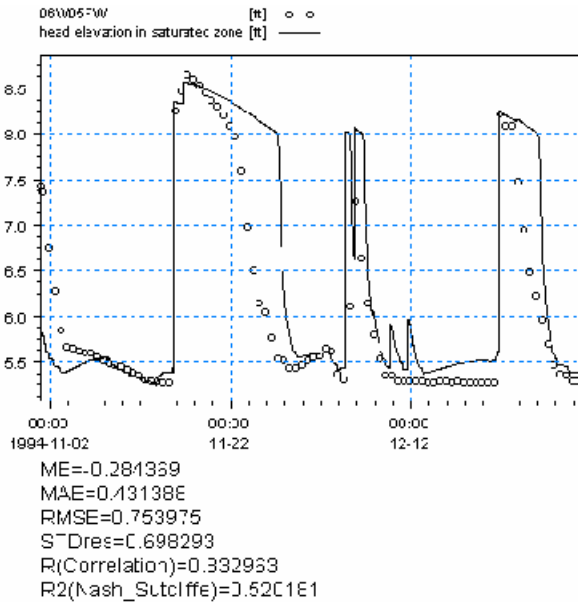


Figure 9. Simulated results for UF9206AB using the two-layer water balance method.

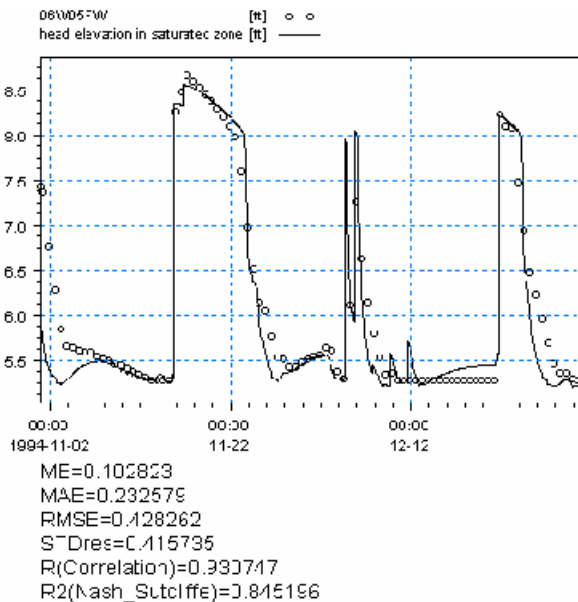


Figure 10. Simulated results for UF9206AB using the two-layer water balance method and the transition zone of Guardo and Rohrer (2000).

Run times for the full Richards solution without the transition zone, full Richards solution with the transition zone, and the two-layer water balance method without the transition zone were 200 seconds, 216 seconds, and 62 seconds, respectively. The UZ component required approximately 32%, 32%, and 4% of the total run time for the full Richards solution, with and without the transition zone, and the two-layer water balance method, respectively.

6 IFAS Farm UF9209A

A detailed UZ-SZ model of the northern portion of UF9209A was put together. A constant topography of 9 feet amsl was used throughout the model domain and a constant muck thickness of 3.0 feet was used. Based on the Palm Beach County Soil Survey (USDA, 1978) a low permeability fine sand layer was assumed to be present beneath the muck on approximately half of UF9209A in the northwestern portion of the farm (Figure 11). Caprock was assumed to present under the muck on the remainder of UF9209A (Figure 11). The low permeability sand and caprock were assumed to have a thickness of 5 feet throughout the model domain and the model was extended 65 feet below the base of the low permeability sand/caprock at 1.0 ft amsl.

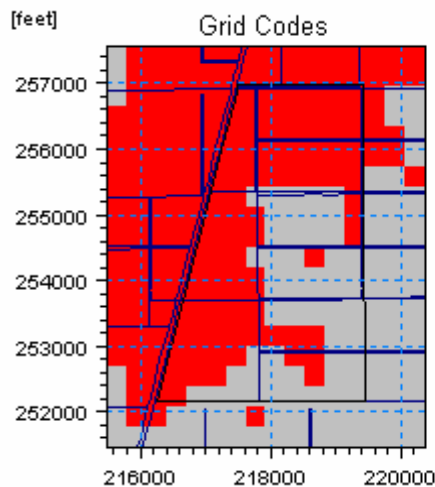


Figure 11. Spatial distribution of low permeability sands below muck (red) and caprock below muck (gray) at UF9209A. Distribution is based on the Palm Beach Soil Survey (USDA, 1978).

Constant head boundary conditions were used for all external boundaries in the saturated zone model. Observed stages from the main district discharge canal at pump station MC23.0TE were used for constant head boundaries along the western edge of them model. Observed water levels from interior farm canal wells CW09W3 and CW09W5 were used for the north and west external boundary and the south external boundary, respectively. Internal GHBs were used in layer 1 for all internal farm canals.

B.2.2 HYDROLOGIC MODELING/METHODOLOGY REPORT

Observed water levels data from canal wells CW09W3 and CW09W5 were used for internal GHBs and were assigned to the grid based on proximity to the observation well. A leakage coefficient of 0.864 ft/day was used for all GHBs.

Synthetic hourly rainfall data was derived from daily rainfall data collected at pump station MC23.0TE. Rainfall was distributed over a three-hour period with the peak rainfall volume at 4 p.m. every day.

Simulated results for the period from November 1, 1997 to December 31, 1997 using the full Richards equation are shown in Figure 12. Simulated results match observed results fairly well during the period simulated. The offset between simulated and observed values is probably a result of an inaccurate estimate of farm topography.

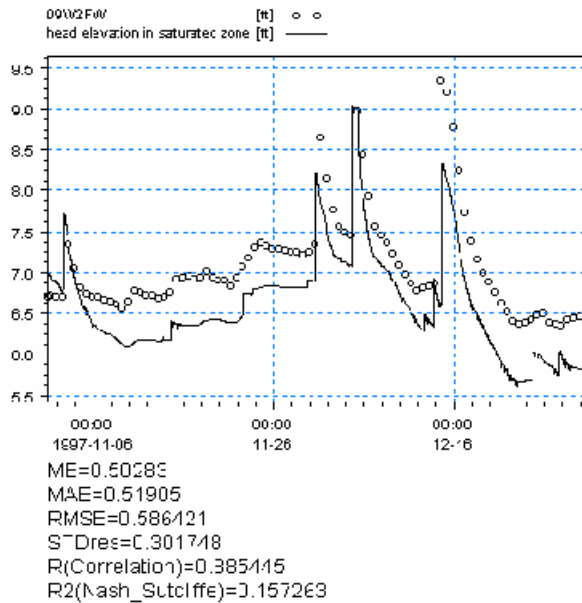


Figure 12. Simulated results for UF9209A using the full Richards solution.

To be consistent with detailed models of UF9203A and UF9206AB, a high conductivity transition zone 0.10 ft thick was added between the muck and caprock in order to simulate lateral flow along the interface. Simulated results for the period from November 1, 1997 to December 31, 1997 using the full Richards equation and the transition zone are shown in Figure 13. Simulated results with the transition zone are not significantly different from those without the transition zone.

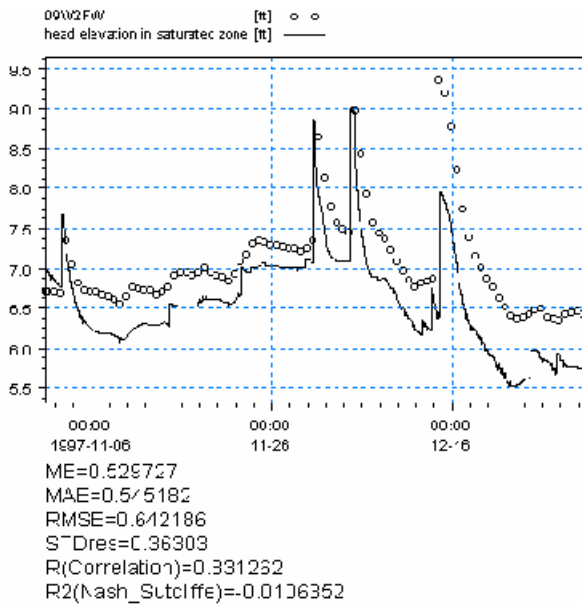


Figure 13. Simulated results for UF9209A using the full Richards solution and the transition zone of Guardo and Rohrer (2000).

The simplified Richards equation method was not evaluated for UF9209A. Simulated results for UF9209AB using the two-layer water balance method are shown in Figure 14. The magnitude of the large event in mid December 1994 is reasonably well simulated with the two-layer water balance method but other small events are poorly represented. As with UF9203A and UF9206AB, all aspects of smaller events may not be well simulated average values are being used for the entire unsaturated zone. The two-layer water balance results for UF9209A suggest that parameters should be different from UF9206AB. The same values as UF9206AB were used so all simulations could be compared to each other. A simulation which included a transition zone between the muck and underlying sand and the two-layer water balance method was not run since the transition zone had little impact on the full Richards solution simulations.

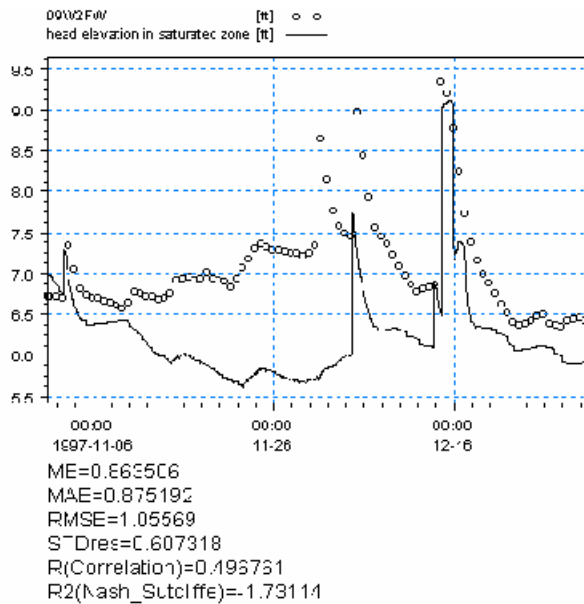


Figure 14. Simulated results for UF9209A using the two-layer water balance method.

Run times for the full Richards solution without the transition zone, full Richards solution with the transition zone, and the two-layer water balance method without the transition zone were 677 seconds, 723 seconds, and 49 seconds, respectively. The UZ component required approximately 39%, 39%, and 4% of the total run time for the full Richards solution, with and without the transition zone, and the two-layer water balance method, respectively.

7 Summary and Conclusions

It is possible to simulate observed water level responses on three farms with detailed stage, groundwater levels, and rainfall data using either the full Richards equation solution, the simplified Richards equation solution, or the two-layer water balance method. Simulated results were better when a transition zone between the muck and underlying material (utilized by Guardo and Rohrer, 2002 in STA 3/4) was included in MIKE SHE datasets for UF9203A and UF9206AB and suggest this transition zone may be an important feature in portions of the EAA.

Simulations that used the full Richards solution were better able to simulate water level responses for both high and low intensity events. The simplified Richards equation method was capable of simulating observed groundwater levels but exhibited numerical spikes that may be related to dynamic water table changes and significant capillary forces in the muck. The two-layer water balance method was able to simulate most high-intensity events but generally did a poorer job on low-intensity events. On average, the two-layer water balance method was able to simulate the water level responses and appear to be a reasonable method to apply in the EAA because of generally high water table conditions and the apparent high correlation of groundwater levels and canal stages.

Run times with the Simplified Richards solution were approximately an order of magnitude less than run times than simulations that used the full Richards solution. Given the complexity of the MIKE 11 network that will be used in the sub-regional EAA MIKE SHE model, use of the Simplified Richards solution may be warranted to have reasonable run times. .

7.1

Further investigations are being conducted at this time to provide additional information. One possible approach may be to construct an EAA model using the 2-layer approach since the set-up time for the unsaturated zone portion of the model will be relatively quick. If the 2-layer approach appears to be unsuitable for the full-scale model, then the unsaturated zone model can be revised to include either the full or simplified Richards equation.

7.2

7.3 References

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