SFWMD Regional Hydrologic Models 101: Modeling for Restoration Planning and Implementation

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Workshop
GEER 2008: Greater Everglades Ecosystem Restoration
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Workshop Outline

Part I

- Water Management System
- South Florida hydrology
- Regional Models
- Data

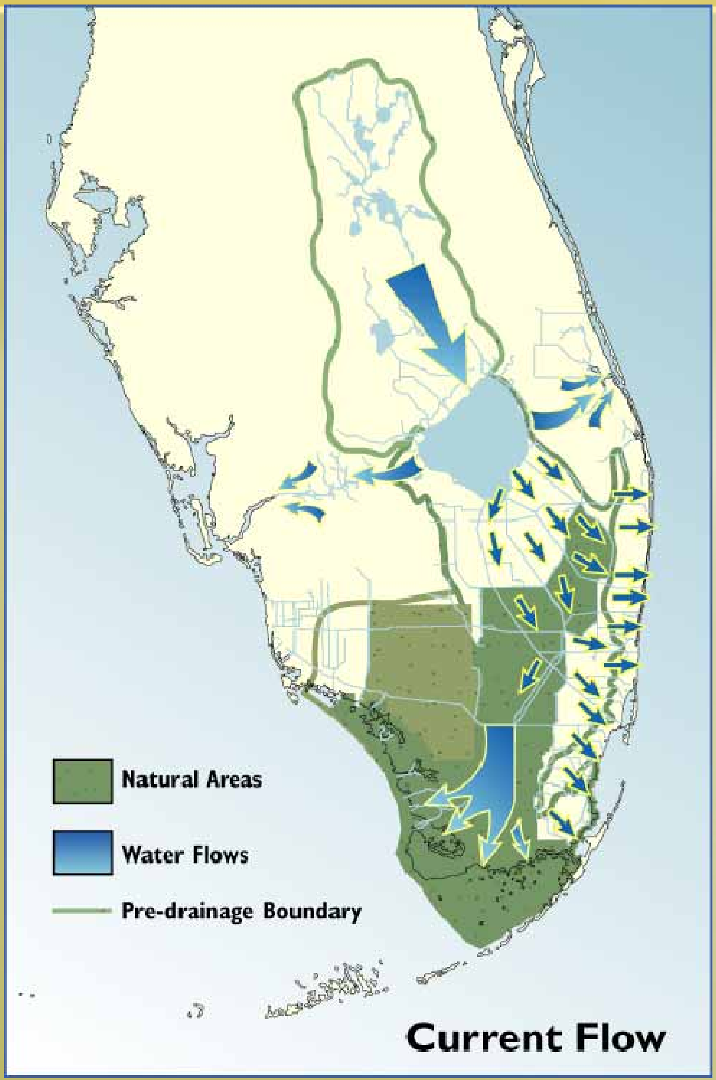
Part II

- South Florida Water Management Model (SFWMM)
- Application of SFWMM

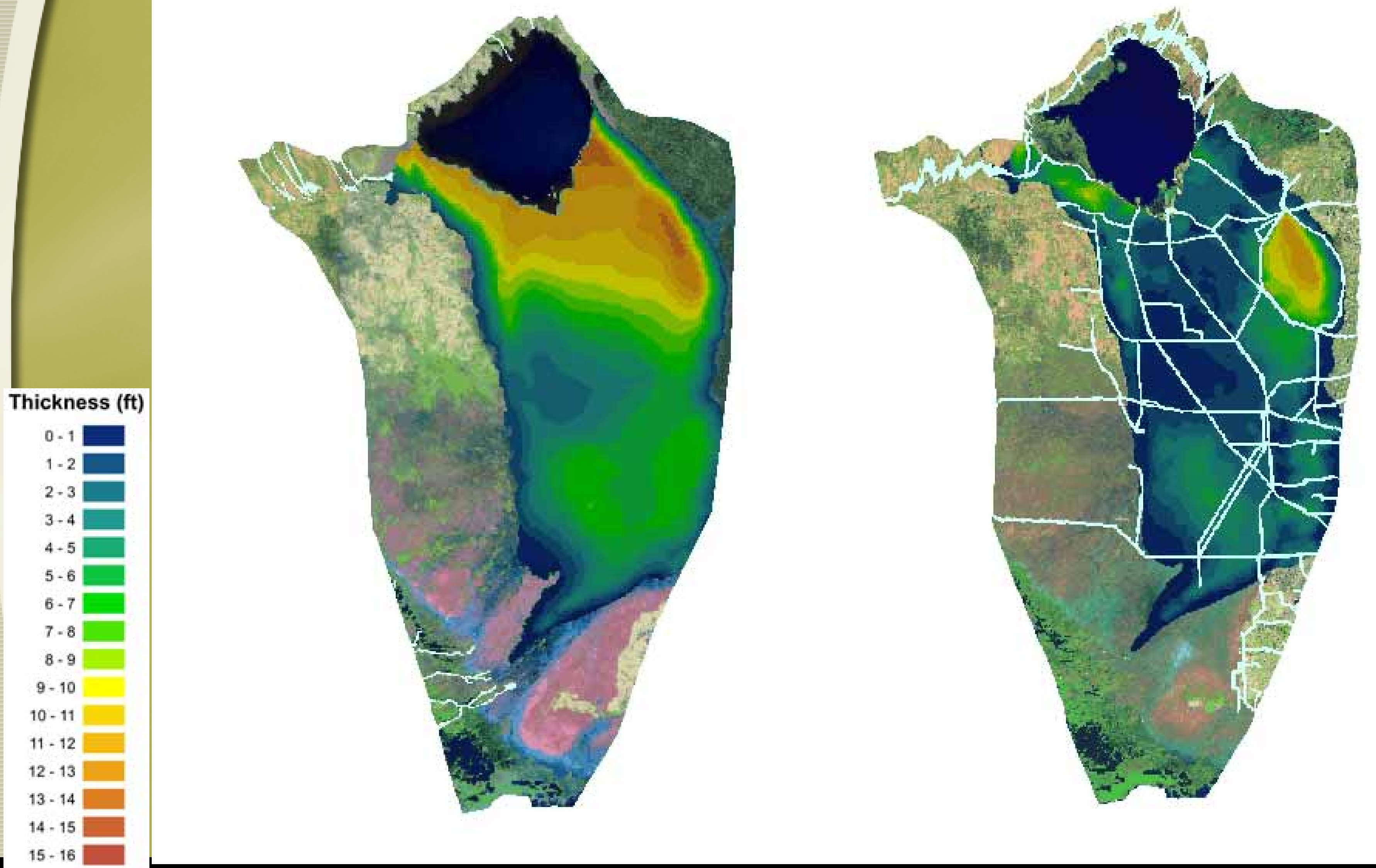
Part II

- Next generation tool : Regional Simulation Model (RSM)
- Challenges

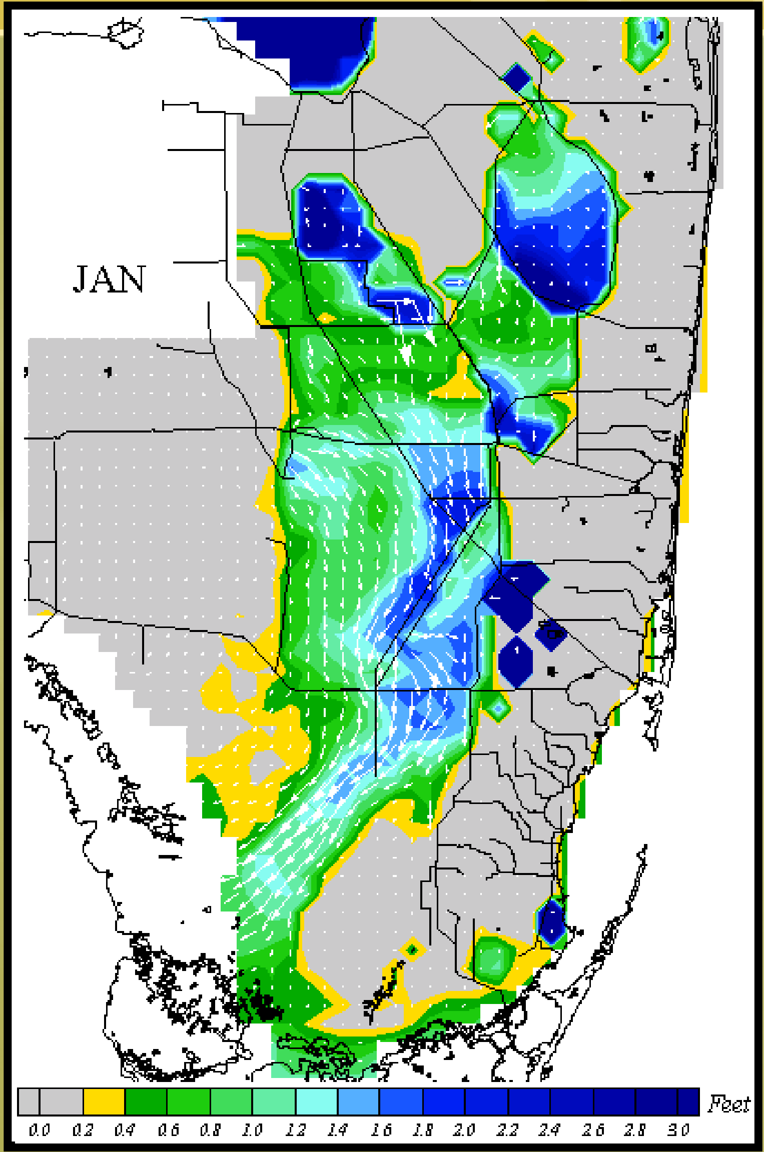
System Modifications



Peat Thickness: Natural & Current



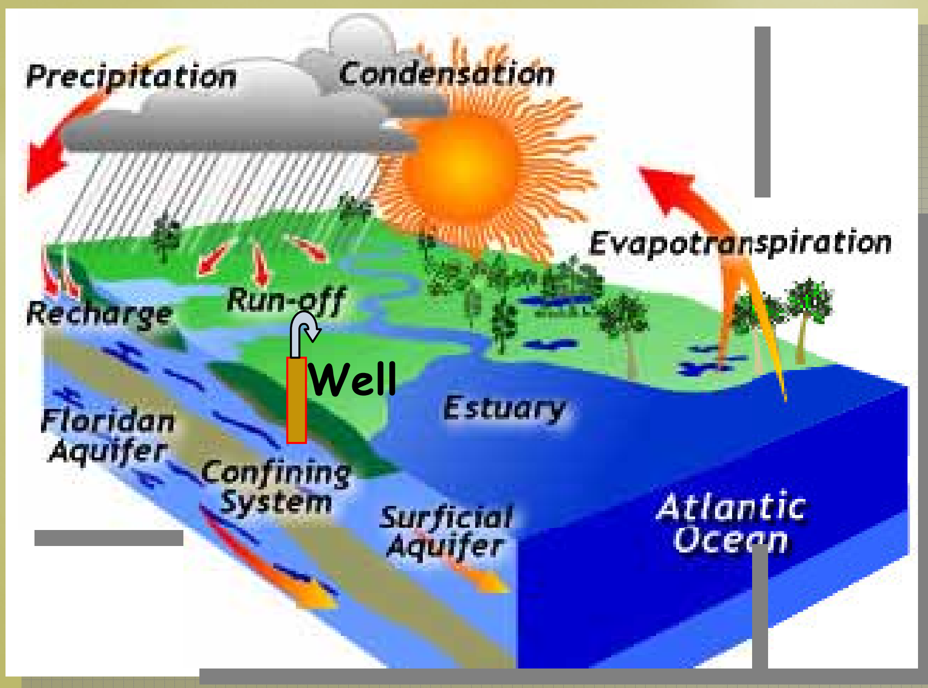
Monthly Hydropattern



Animation

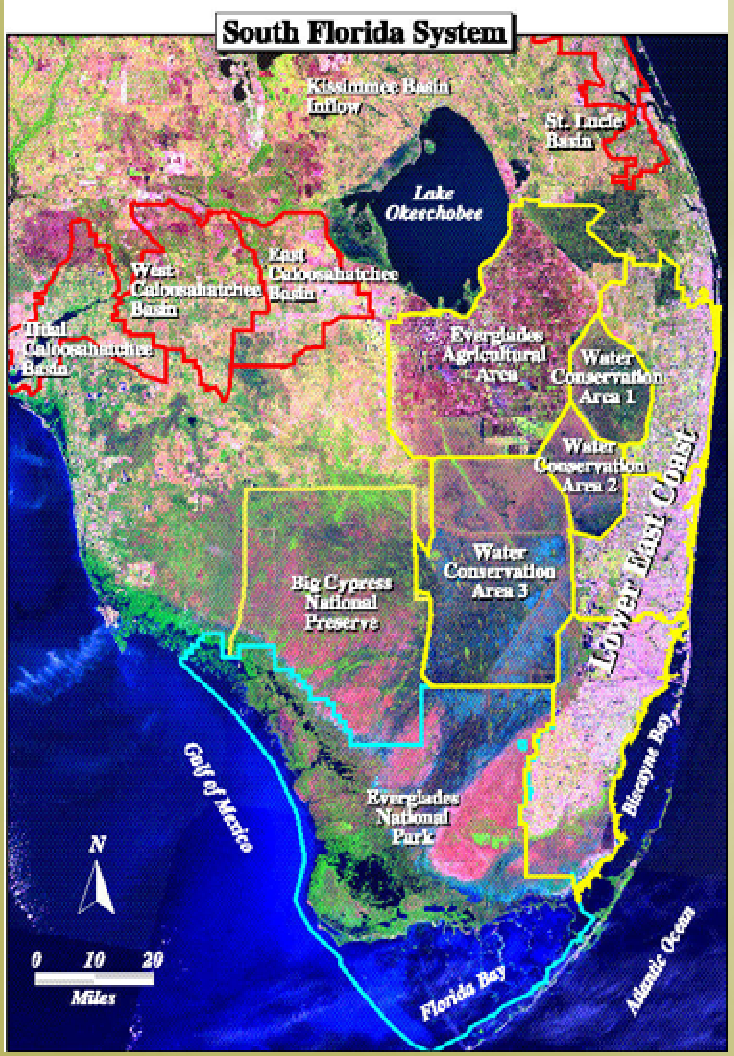
Characterizing Hydrology

- Land Phase of the Hydrologic Cycle:
  - Precipitation
  - Evapotranspiration
  - Flows, both below (groundwater) and above (surface water) the ground
  - System storage (in marshes: water depths and hydroperiod)
  - Ocean boundary
  - Wellfields (domestic uses, landscape irrigation)



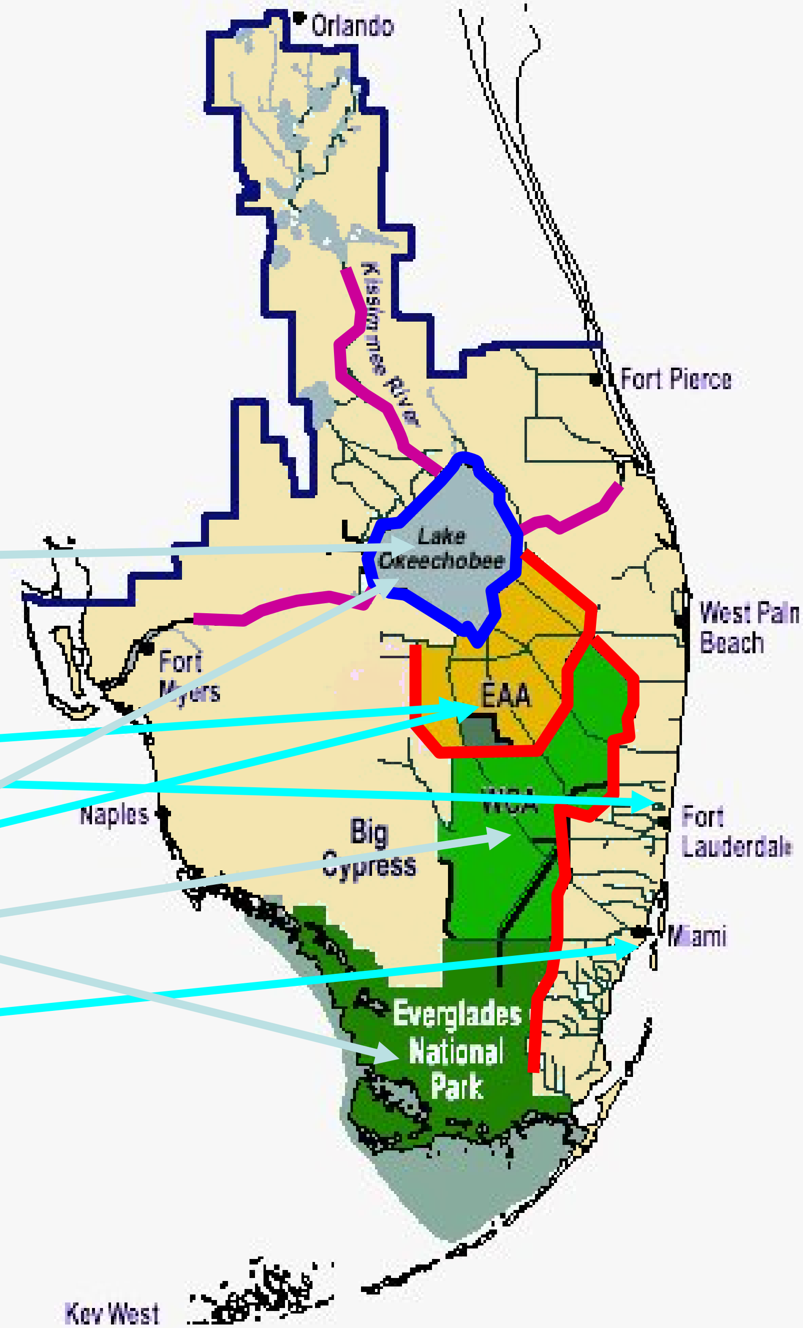
Why regional-scale modeling?

- Large subsystems:
  - Lake Okeechobee
  - Remenant Everglades
  - Agricultural
  - Urban
- Complex Operations with system-wide implications
- Multiple Objectives: optimization (time and space)

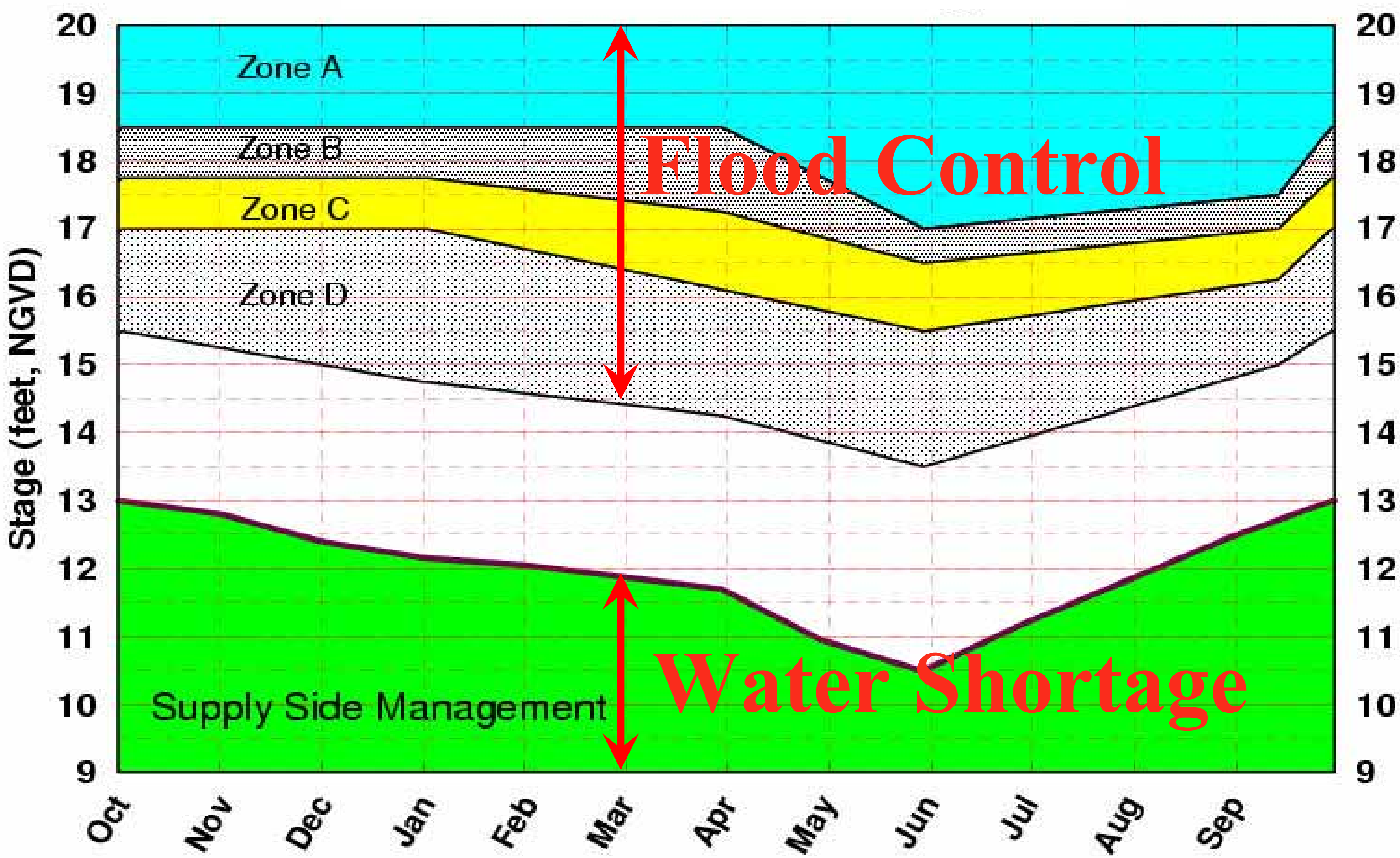


Lake Okeechobee is a Regional Multiple Purpose Water Resource

In lake Environment & Recreational Use



Lake Okeechobee
Management Zones (Rule Curves)



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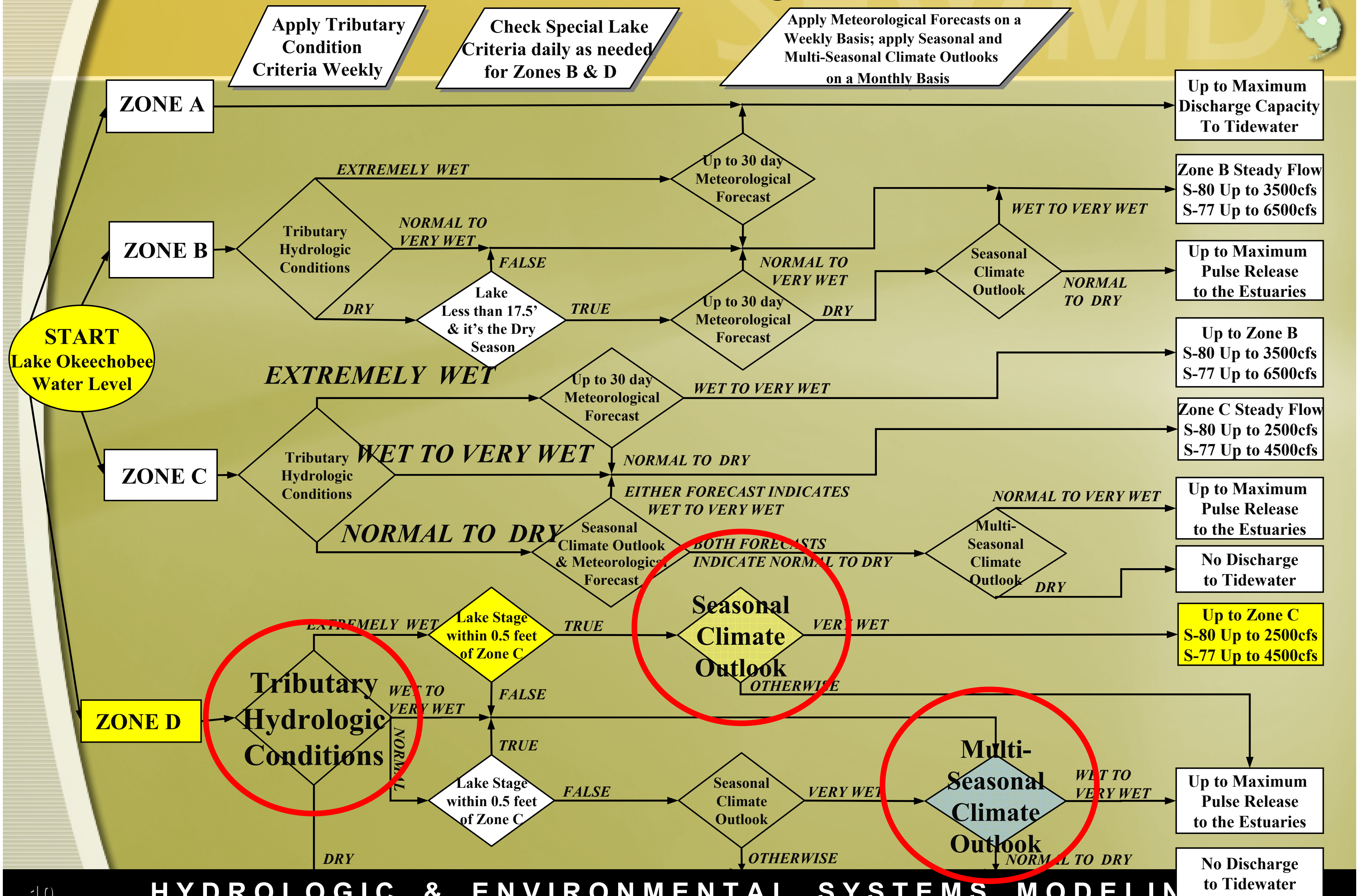
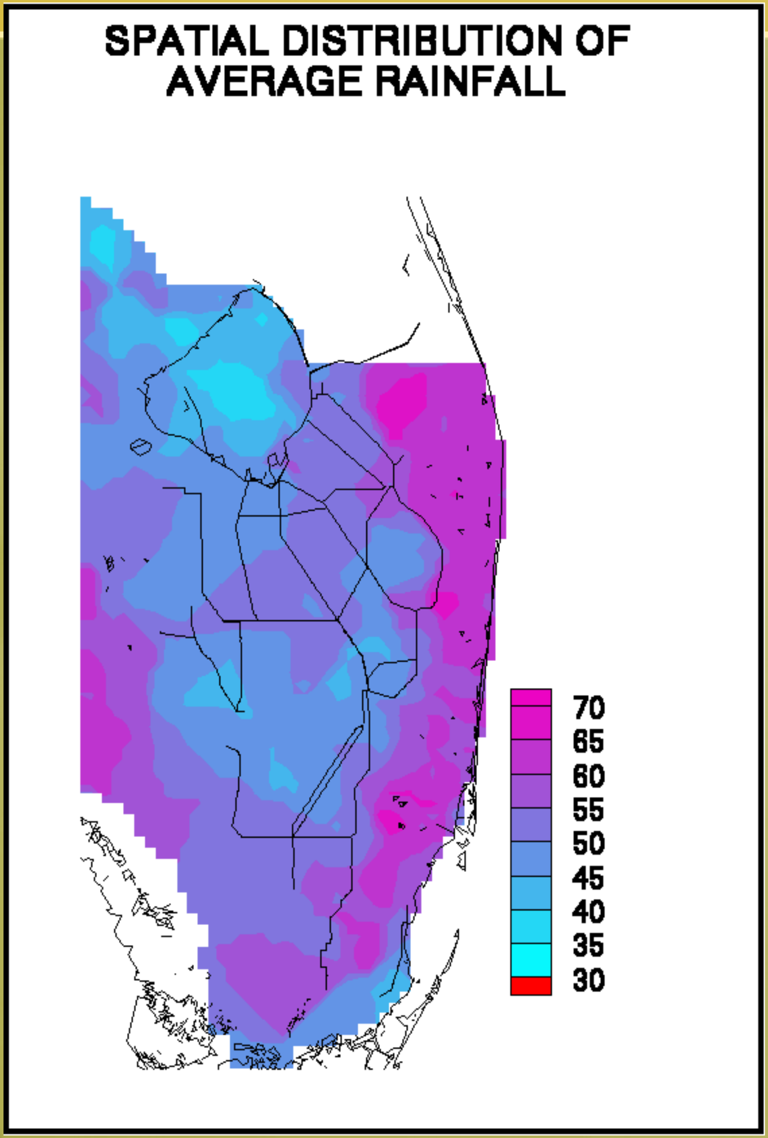
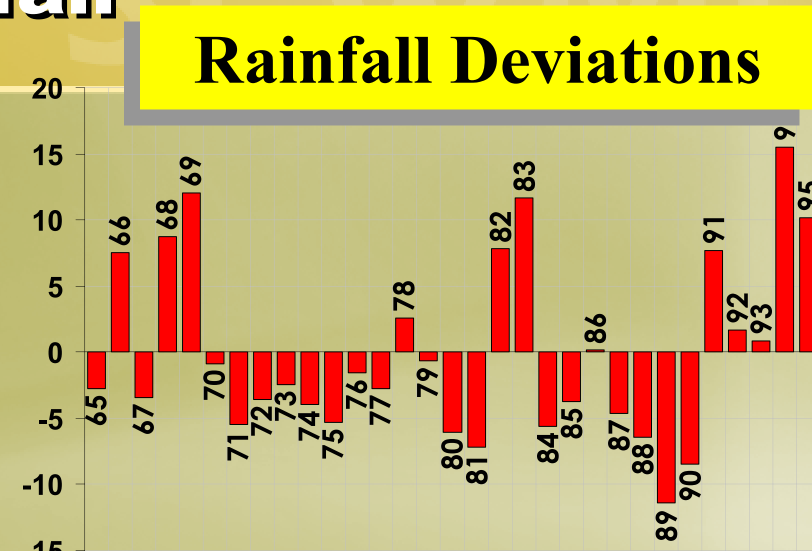
WSE Operational Guidelines Decision Tree

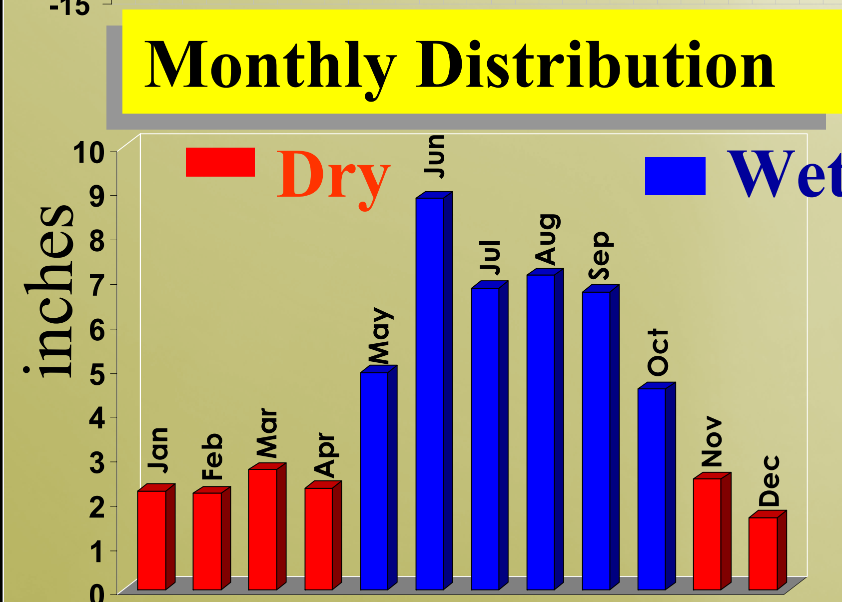
Part 2: Define Lake Okeechobee Discharges to Tidewater (Estuaries)



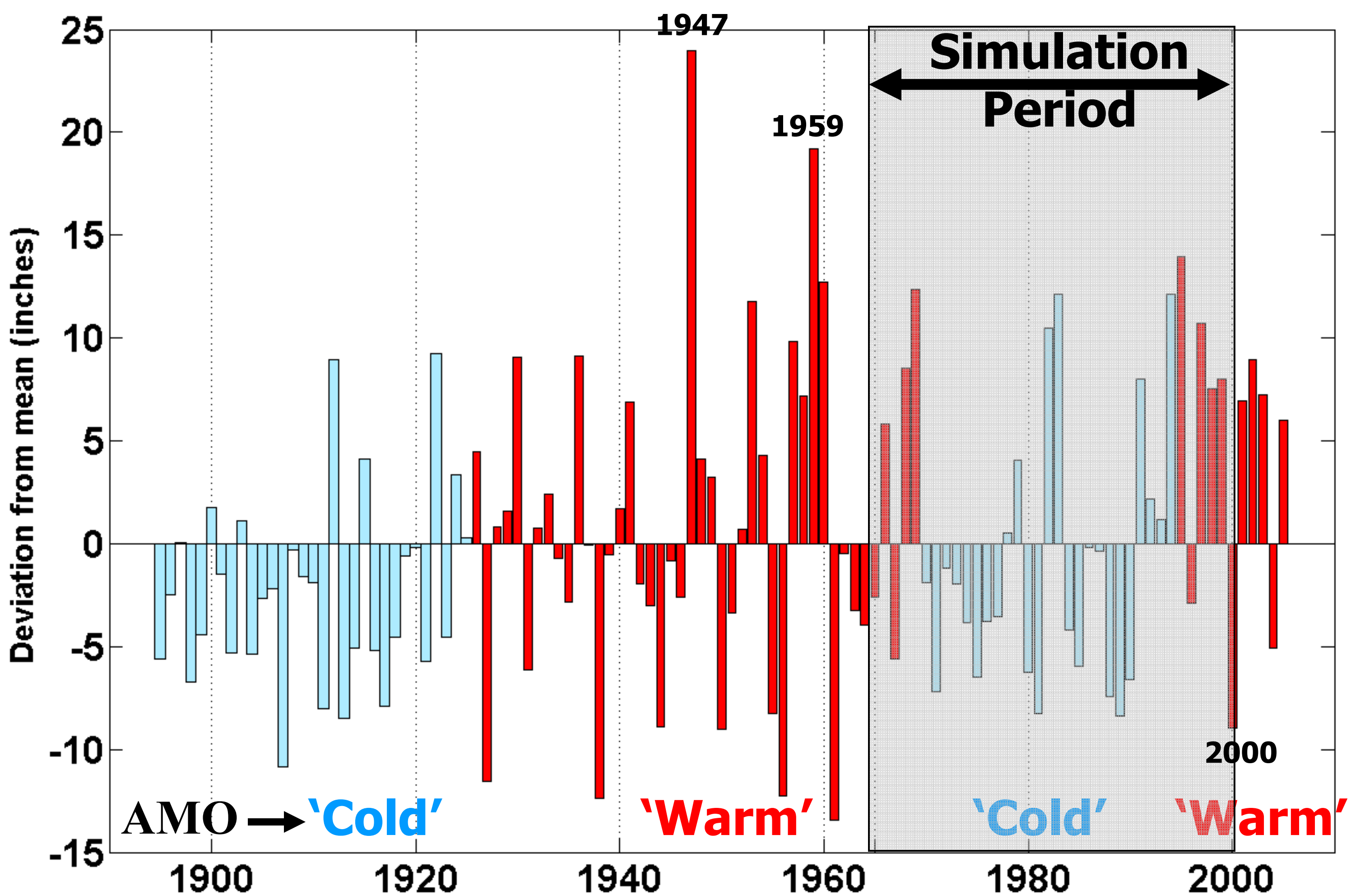
SF Hydrology: Rainfall

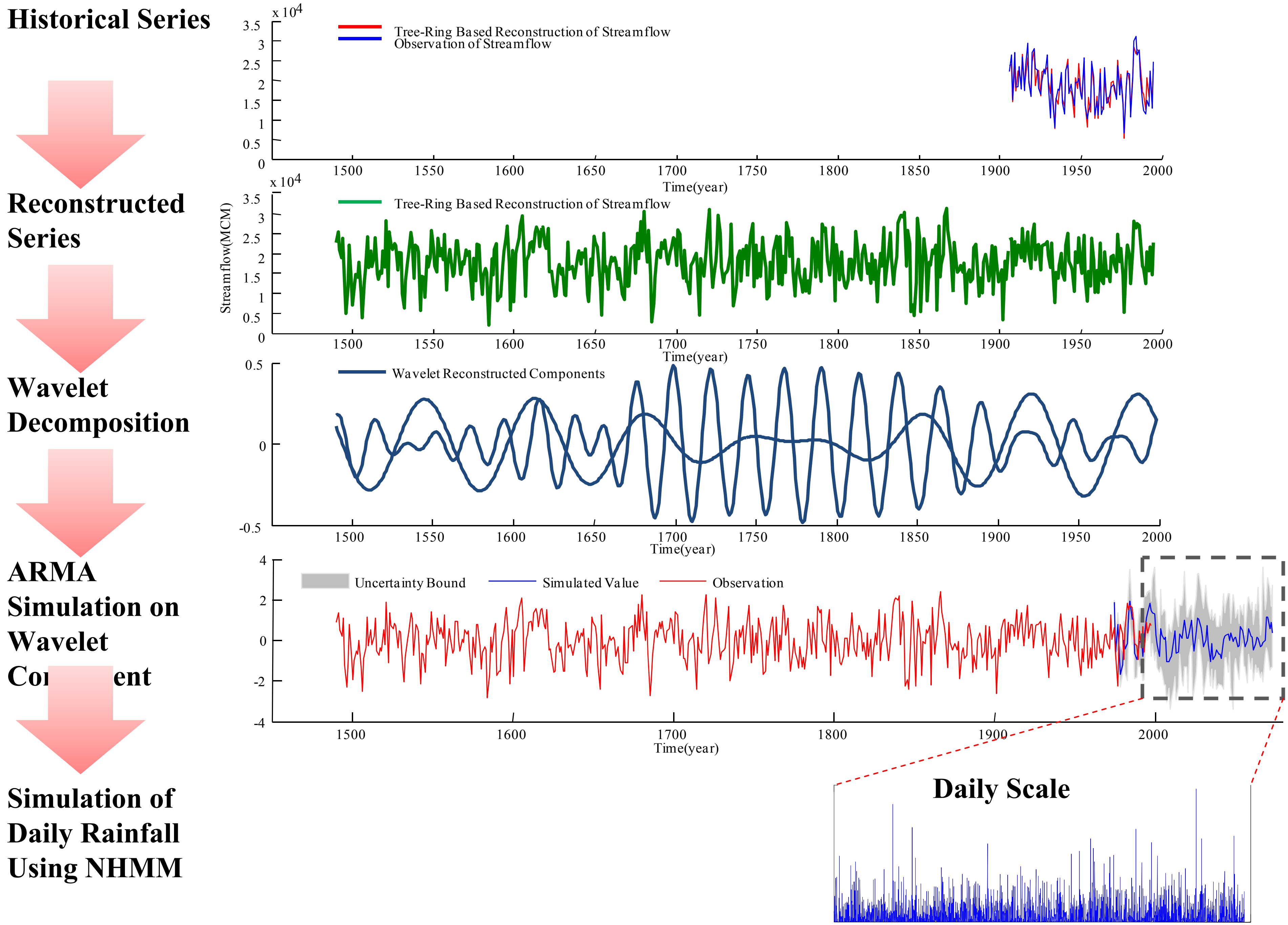






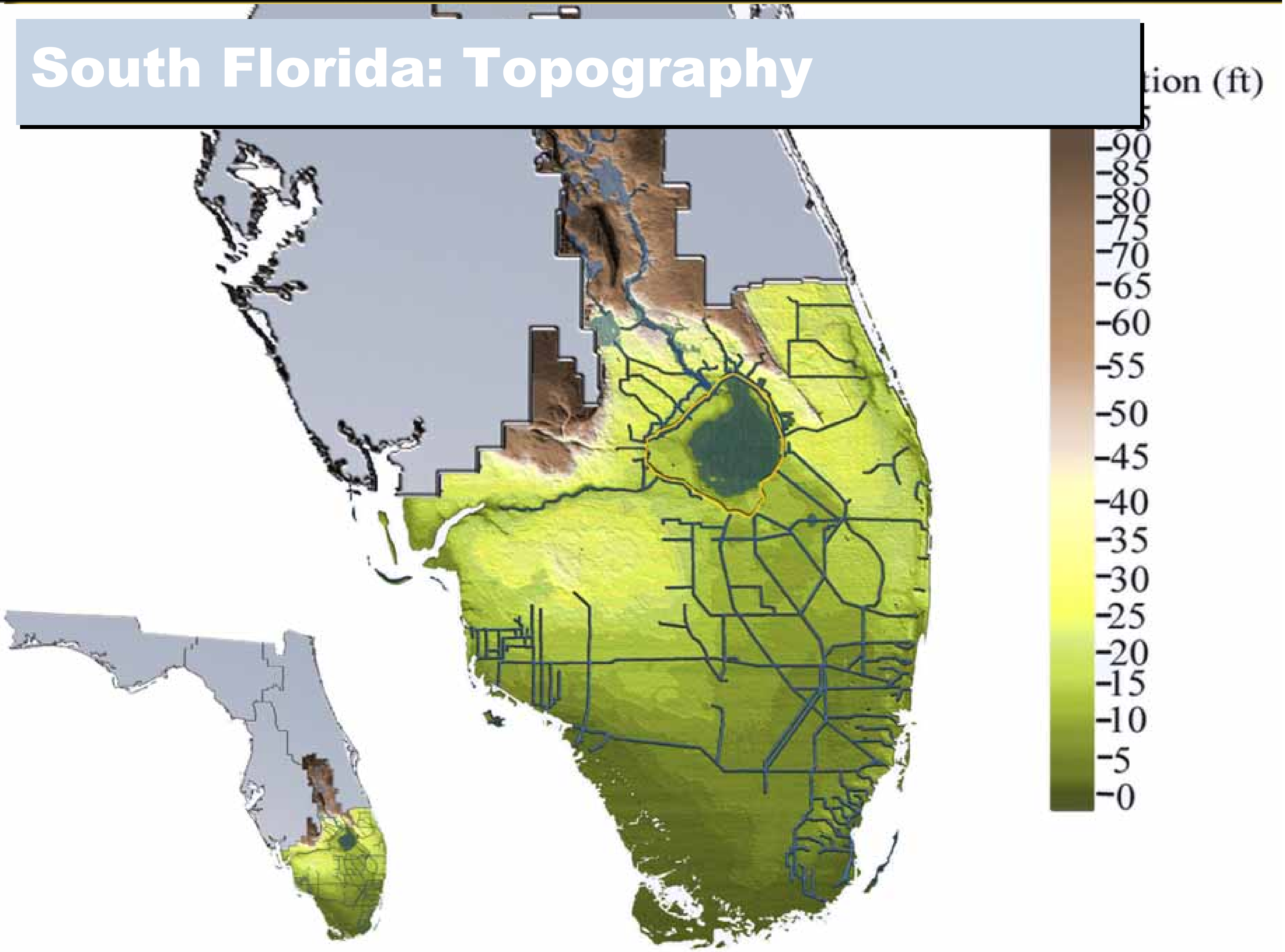
Long Term pattern of Rainfall





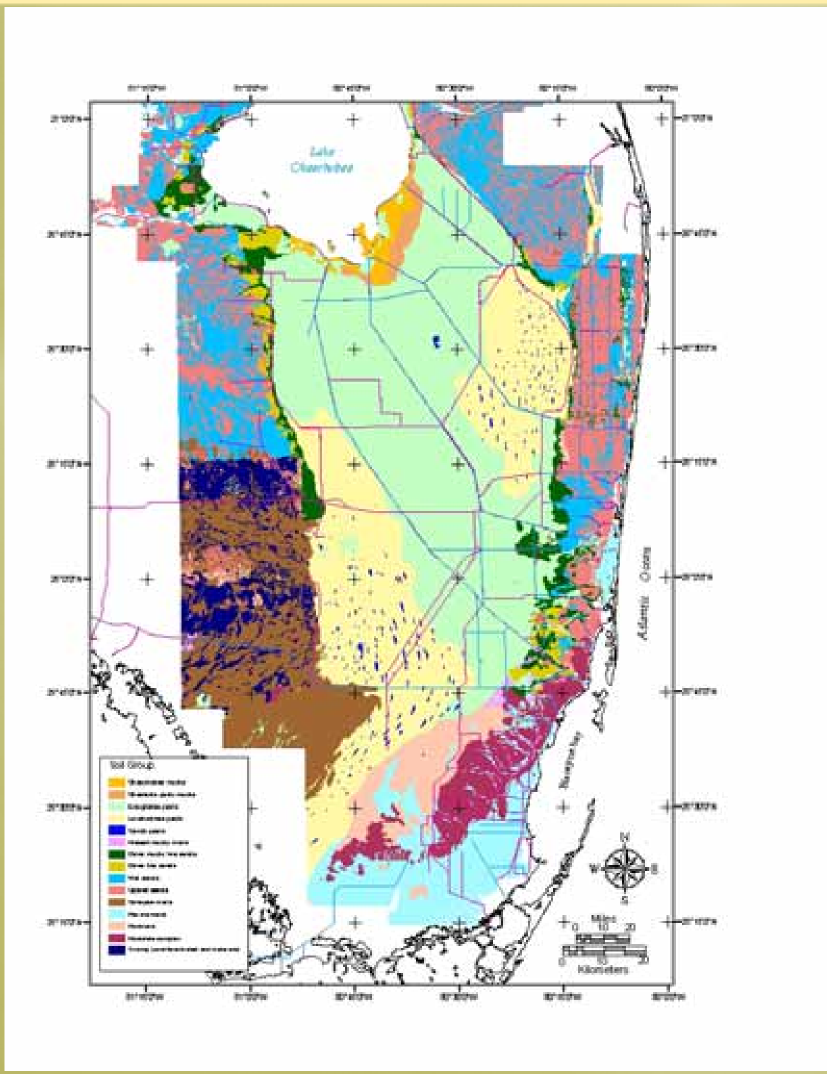
Historical Series
Reconstructed Series
Wavelet Decomposition
ARMA Simulation on Wavelet Co ent
Simulation of Daily Rainfall Using NHMM
Tree-Ring Based Reconstruction of Streamflow
Observation of Streamflow
Time(year)
Streamflow(MCM)
Wavelet Reconstructed Components
Uncertainty Bound
Simulated Value
Observation
Daily Scale

South Florida: Topography

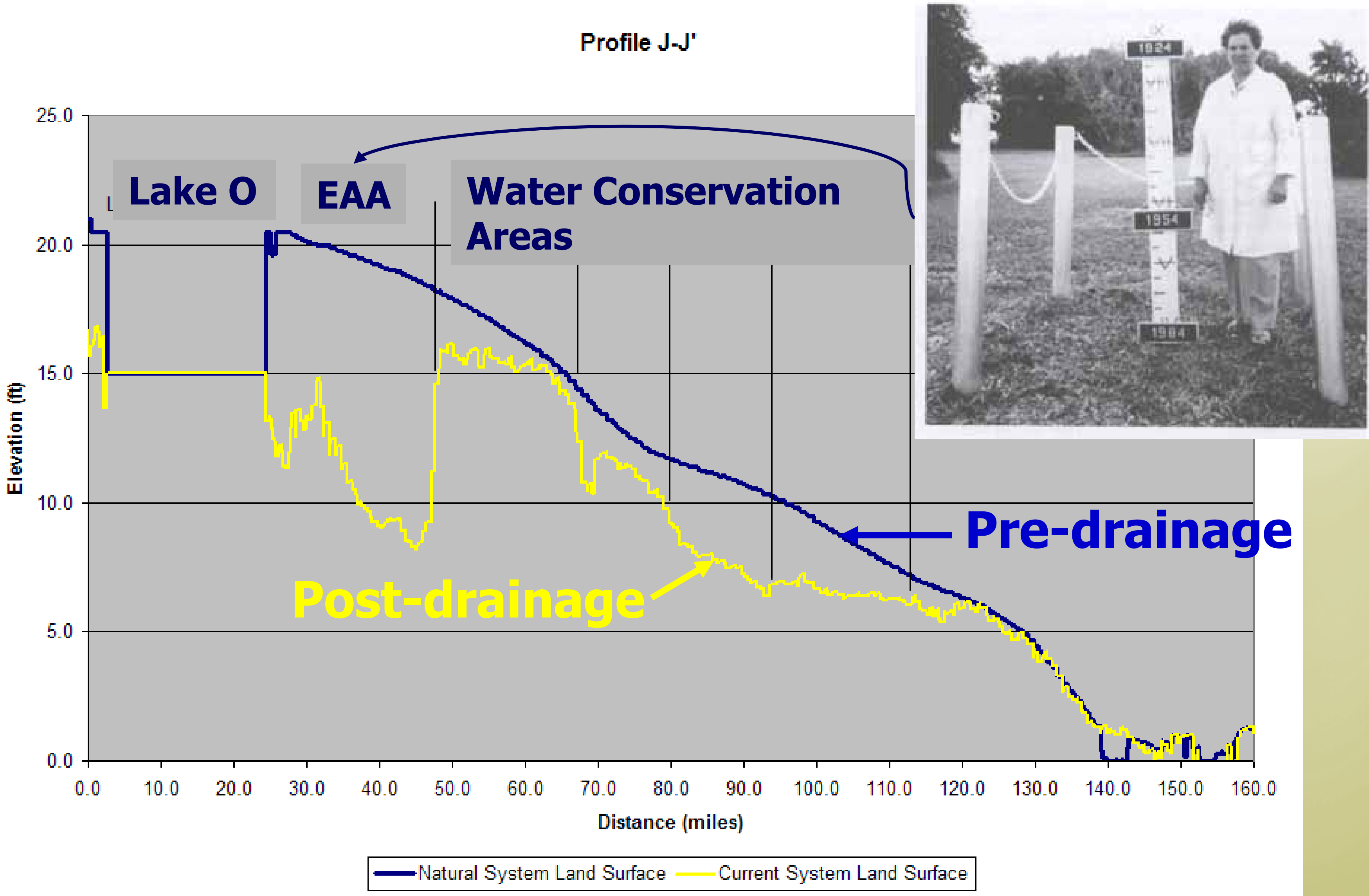


South Florida: Soils

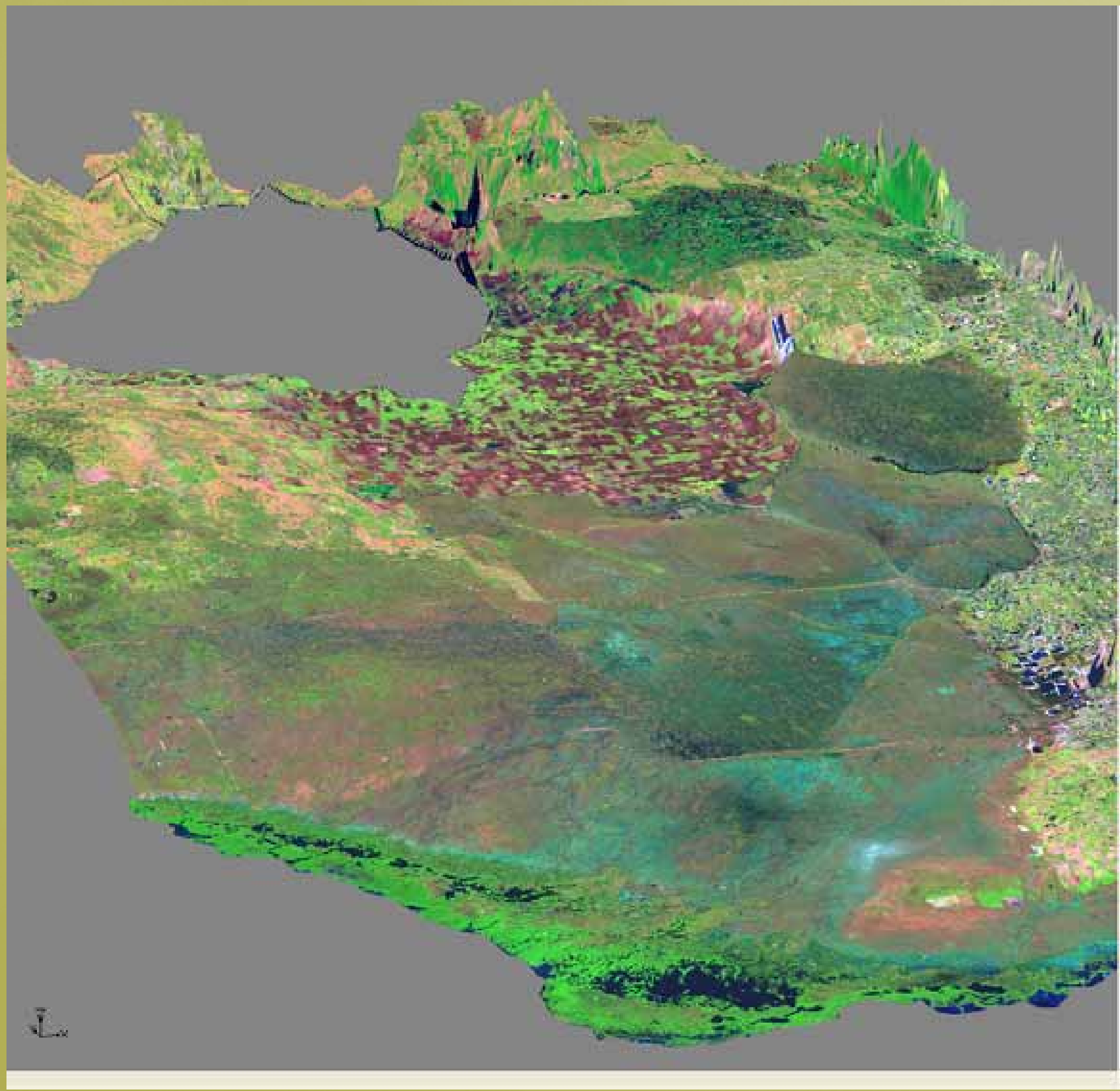
- Sandy Soils on the Coast
- Peat Soils in the remnant Everglades and the EAA



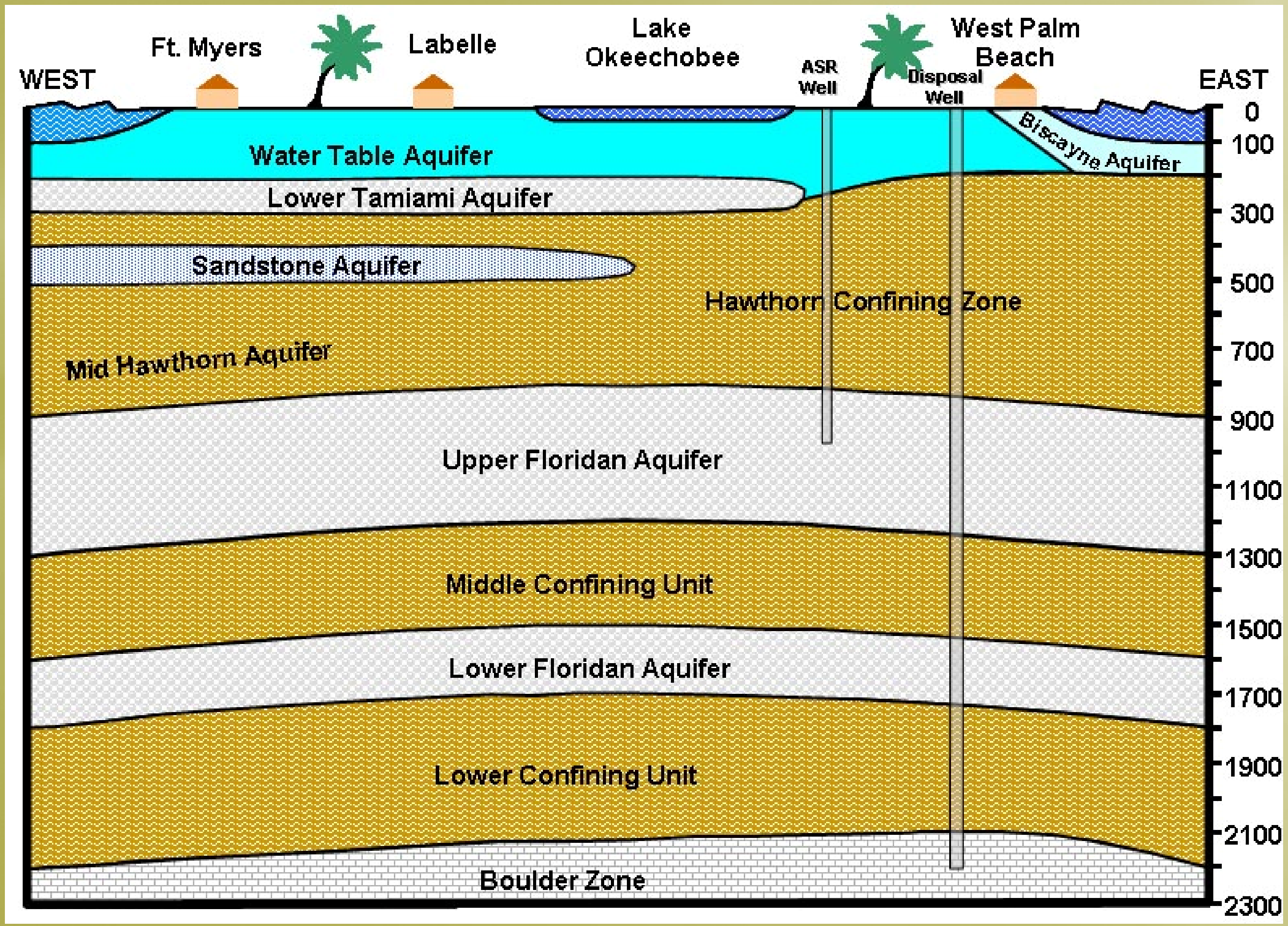
Soil Subsidence



Land Subsidence in EAA

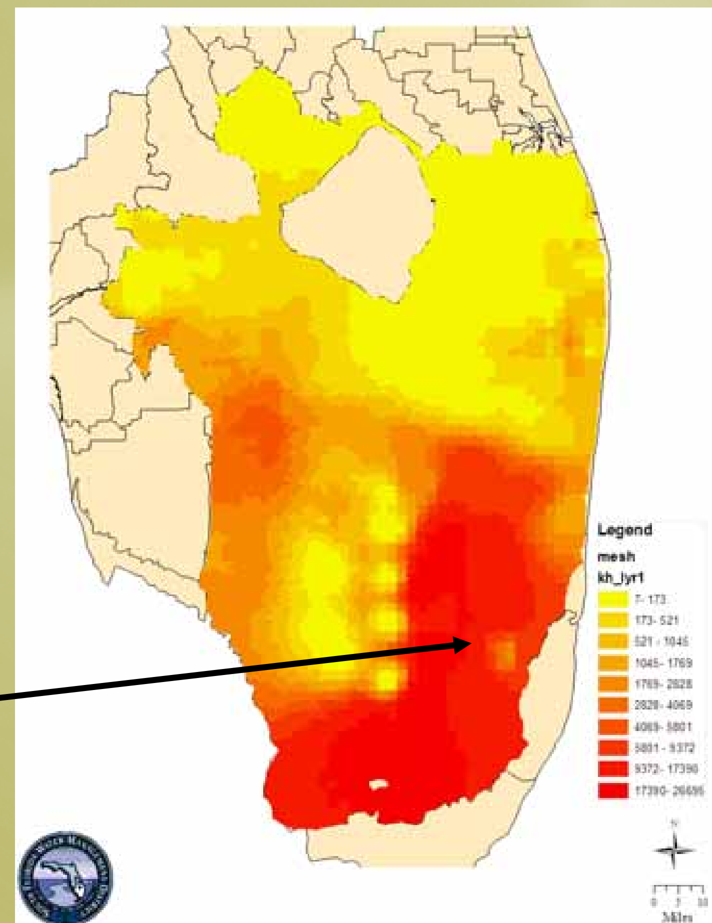


South Florida: Hydrogeology (simplified)



Biscayne Aquifer: Hydraulic Conductivity

- Limestone
- Solution holes
- Highly transmissive



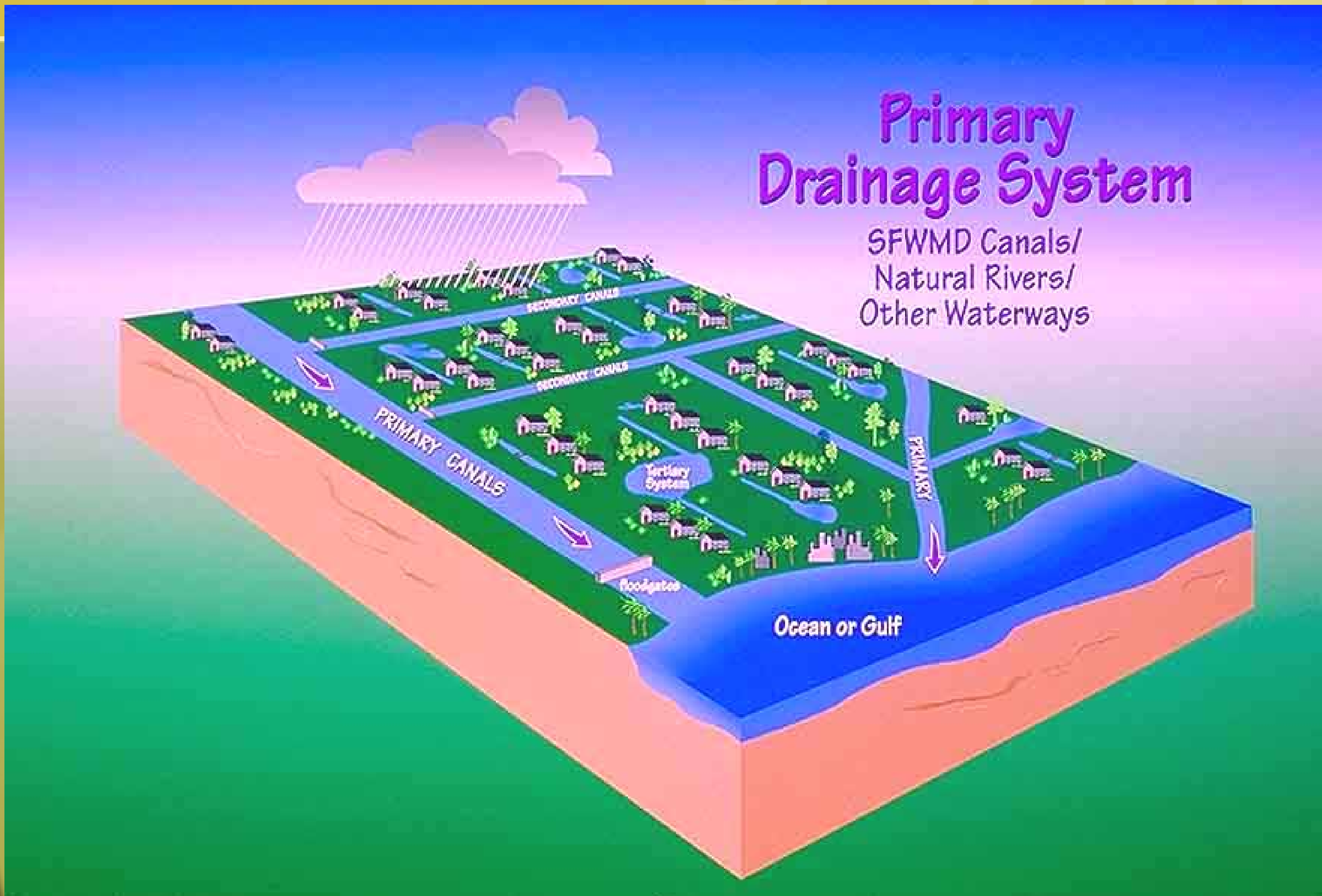
Complex Water Management System

- Primary System is more than just the C&SF Project
- 1,969 miles of canals & levees
- 160 major drainage basins
- 501 major structures
  - 206 remotely operated
  - 295 manually operated or fixed structures
- 50 pump stations
  - Almost ½ with remote operation capability

Primary System Oprations

- Modes of Operation:
  - Drainage & Flood Control
  - Water Supply
- Regulation Schedules for major water bodies (Lakes, Water Conservation Areas)
  - Flood Control, Water Supply, “Minimum”
- Canals (Maintenance Levels)
- Structures (Opening and closing of gates for water supply and flood control)
- Pre-storm drawdown

Drainage Responsibilities



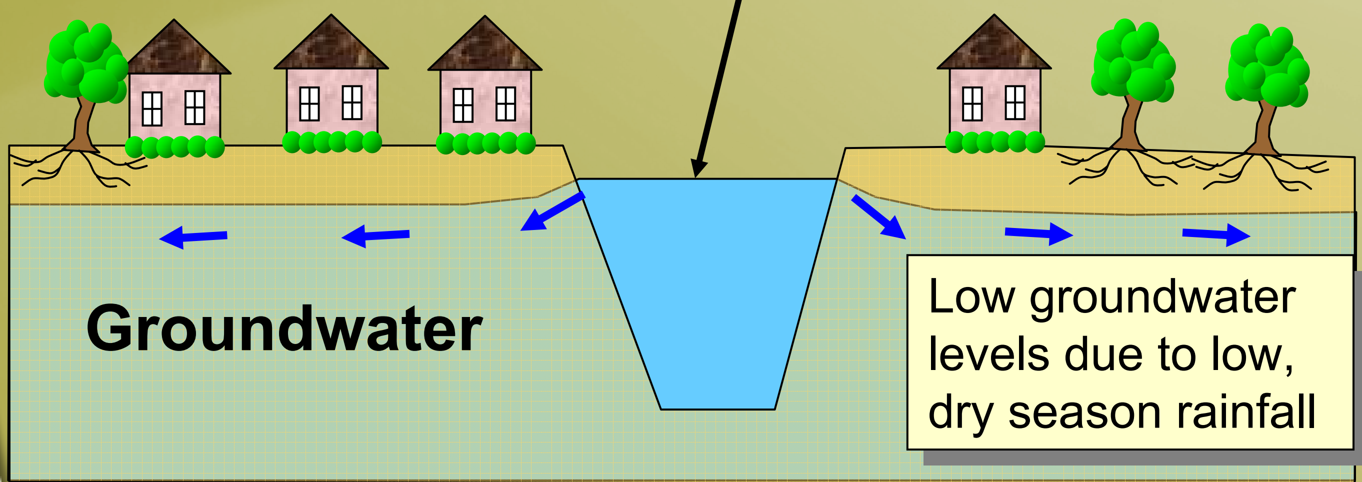
Canal/Groundwater Interaction

Normal Dry Season Operations

Canals serve two primary purposes….

1. **Flood Control**
2. **Water Supply**

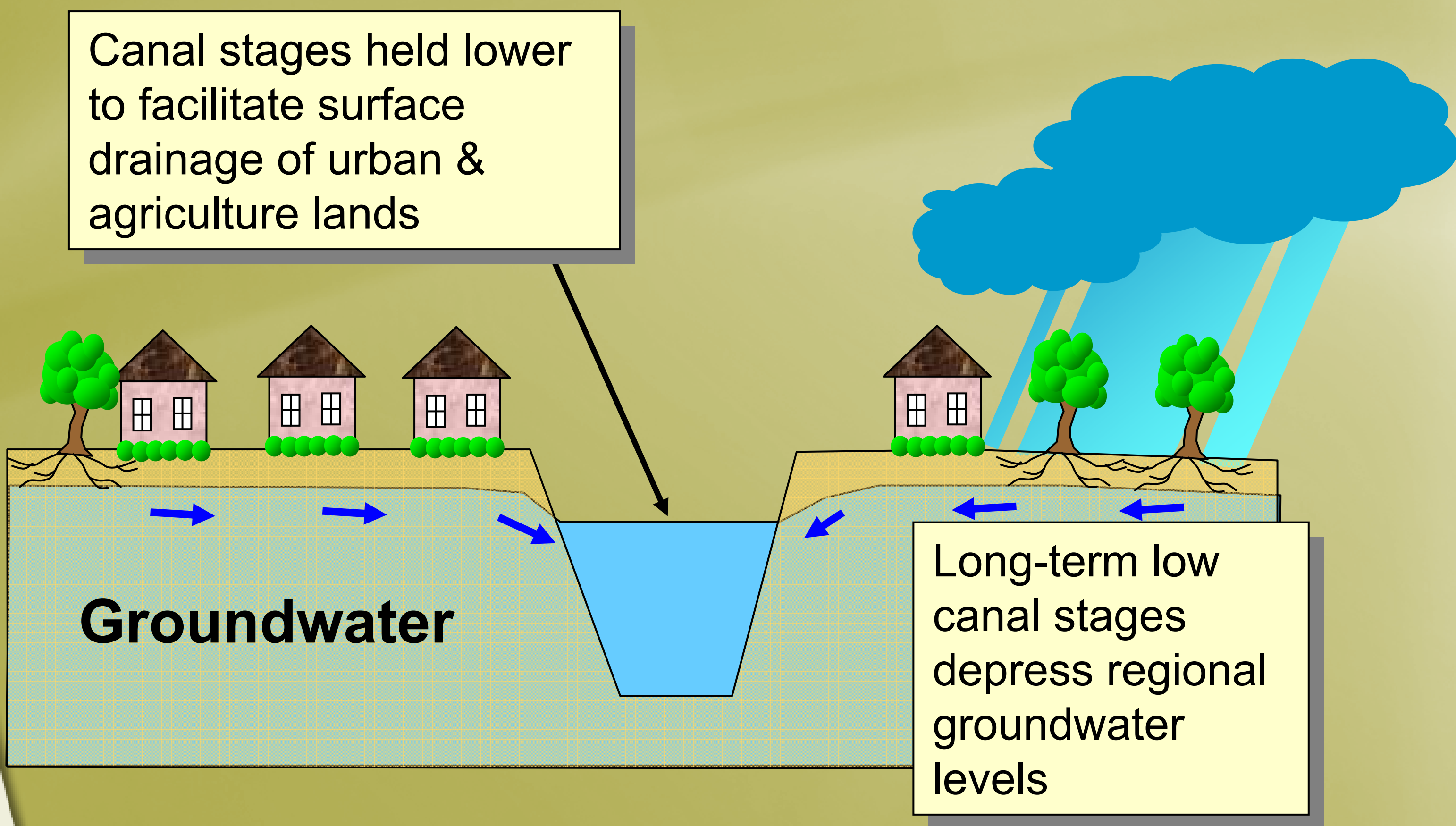
Canal stages held high to facilitate groundwater recharge and assist supplemental irrigation



Low groundwater levels due to low, dry season rainfall

Canal/Groundwater Interaction

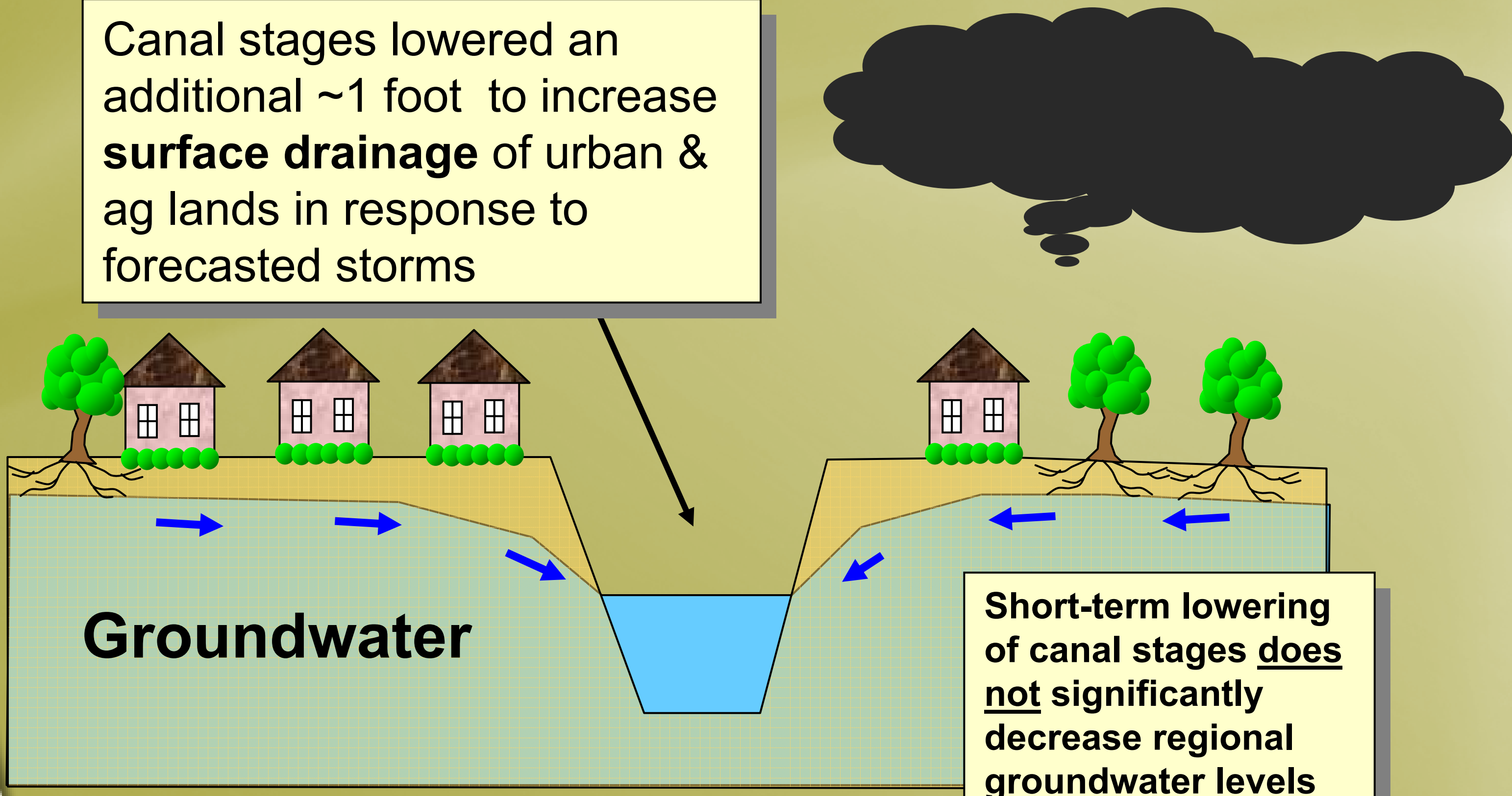
Normal Wet Season Operations



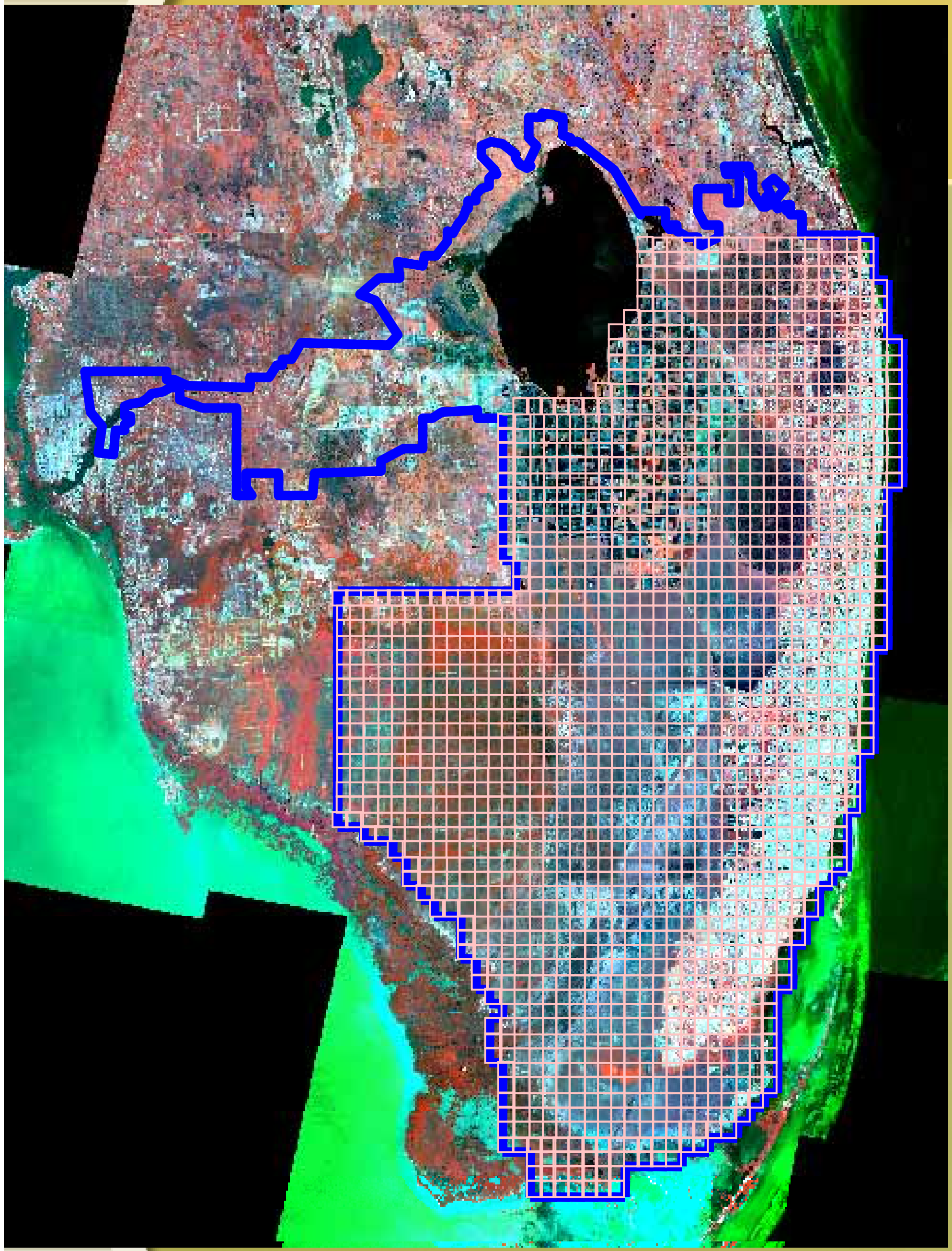
Canal/Groundwater Interaction

Pre-Storm Drawdown Operations

Canal stages lowered an additional ~1 foot to increase **surface drainage** of urban & ag lands in response to forecasted storms



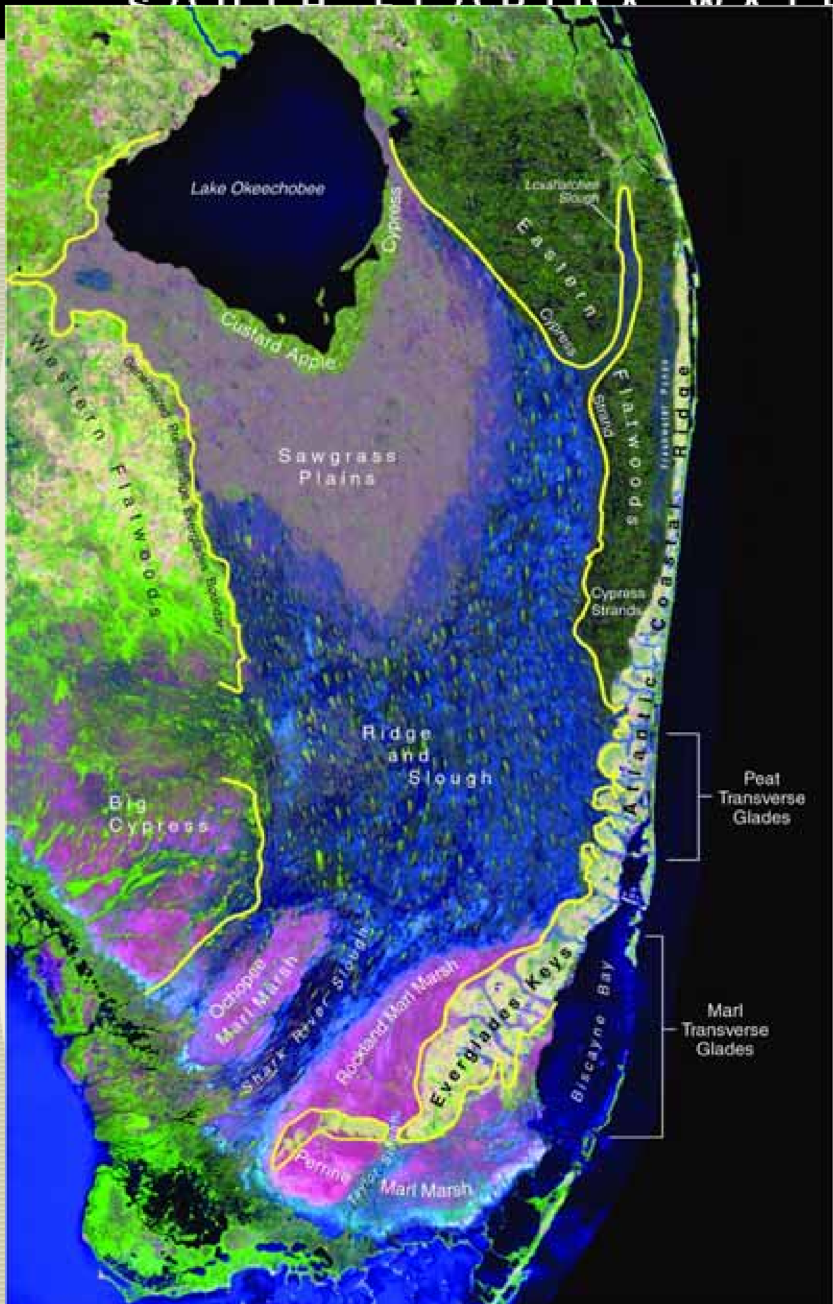
Short-term lowering of canal stages does not significantly decrease regional groundwater levels



South Florida Water Management Model

- Regional scale
- Distributed
- Continuous simulation
- Surface water/groundwater

- Lake Okeechobee to Florida Bay
- 2 mi. x 2 mi. grid cells
- (> 7000 square miles)
- time step: 1day
- period of simulation: 1965-2000

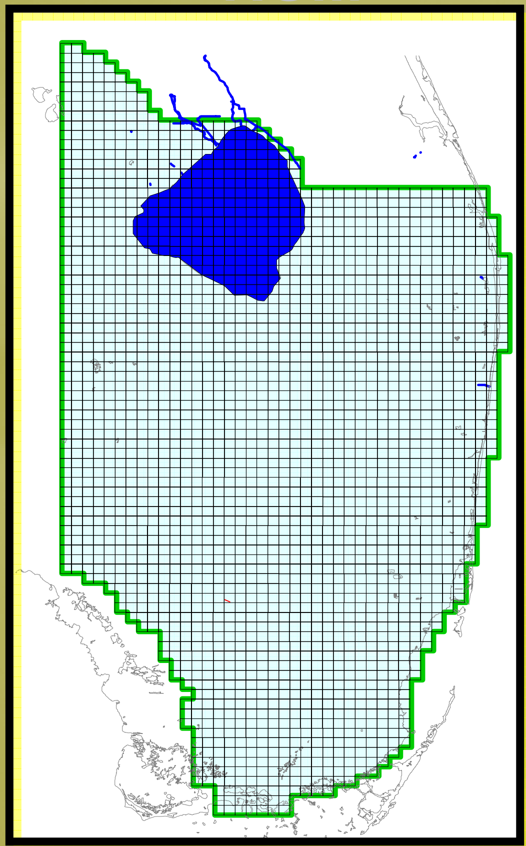


Natural System Model (NSM)

- A computer model of the pre-drainage system
- Integrated surface and ground water hydrologic model
- 2,382 2 mile x 2 mile grid cells
- Lake Istokpoga to Florida Bay

Relationship between NSM and SFWMM (2x2)

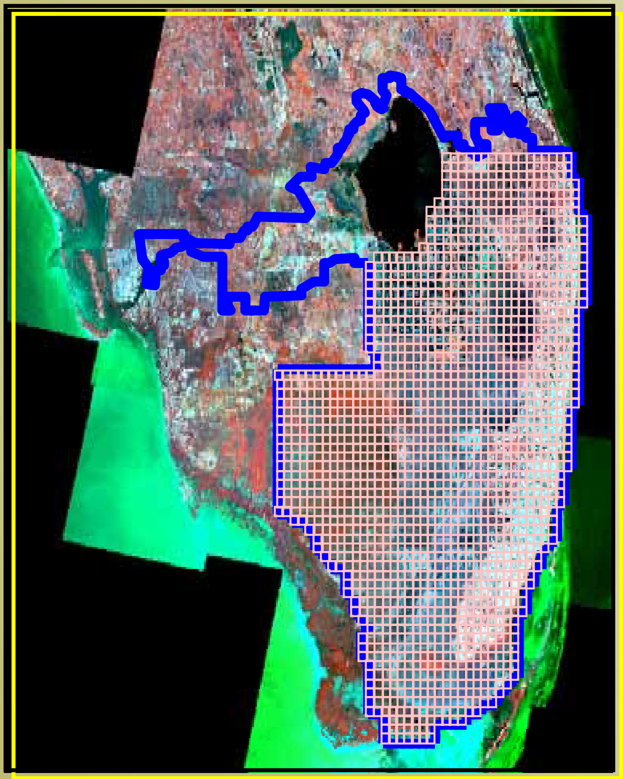
NSM



Parameter

Values

SFWMM (2x2)



Same climatic input to both models

Input Data for SFWMM

- Static Data

  topography, landuse, aquifer characteristics, location and attributes of canals, levees, structures and reservoirs

- Time Dependent Data

  daily rainfall, daily reference ET, well pumpages, boundary flows and stages

- Operations-Related Rules & Policies

  regulation schedules, water restriction trigger levels, water delivery targets and canal maintenance levels

Spatio-Temporat Rainfall Dataset

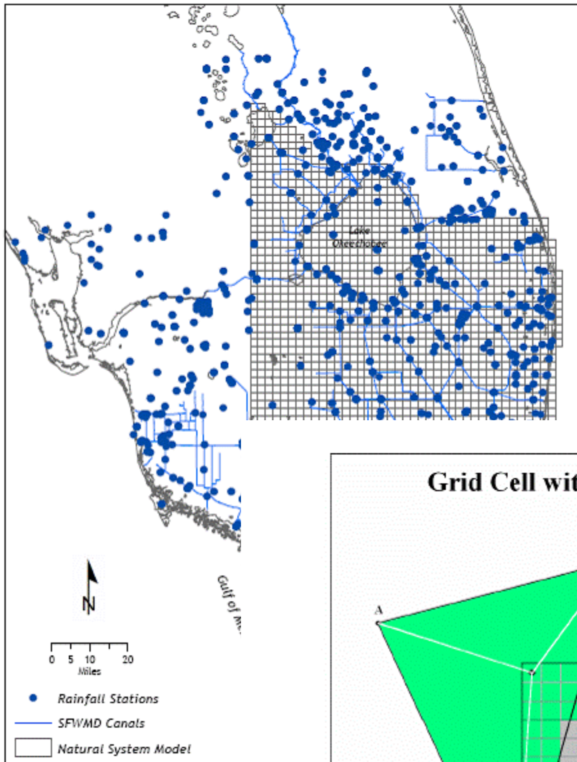


Figure 2.2.1.1 Location of Rainfall St

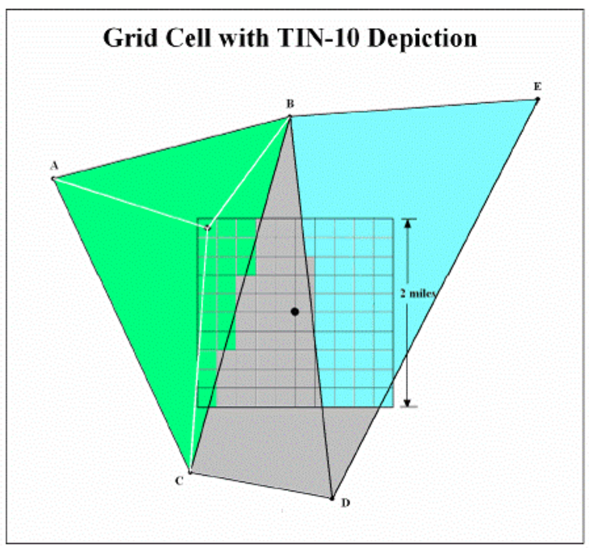


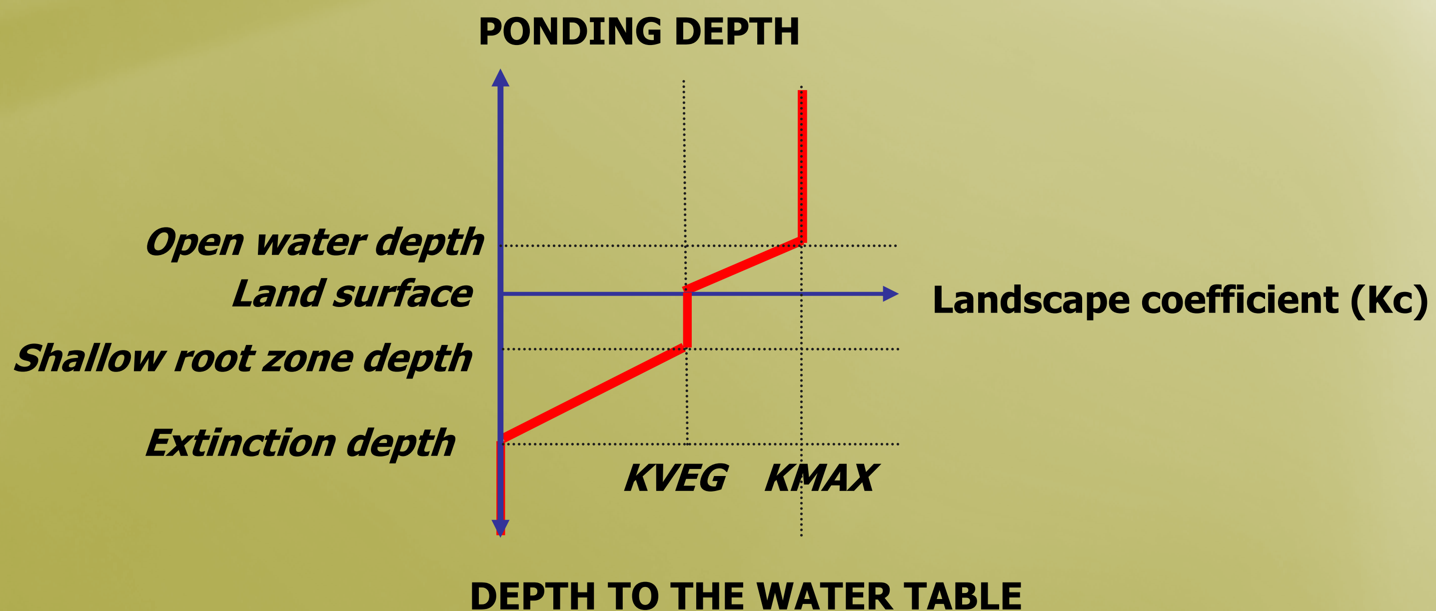
Figure 2.2.2.1 Example of TIN-10 Estimation for Model Grid Cell

- Daily Rainfall (1965-2005)
- Spatially interpolated to create a spatial dataset for each day
- Binary format for efficiency
- Triangulated dataset available

Reference Evapotranspiration

- **Hydrologic models are run in predictive mode so atmospheric control on ET must be isolated from the effects of landscape control. Therefore, long-term (at least 1965-2005) daily estimates of Reference ET (RET) are required.**

Landscape Coefficient Function for Wetlands

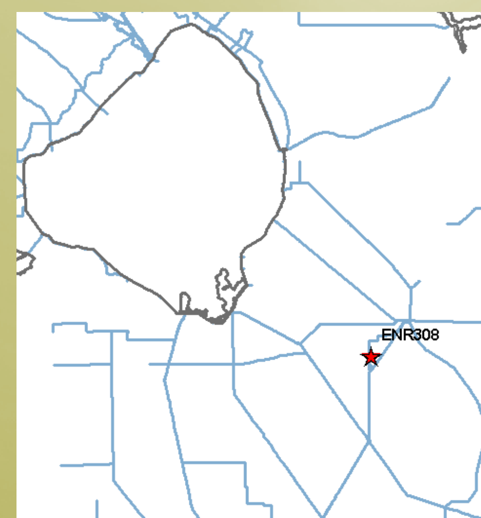


Reference Evapotranspiration (RET) : Previous Efforts

- Previous efforts limited by lack of distributed meteorological data for long periods of simulation required for modeling (40+ years).
- Previous estimates have been based on the District's Simple Method (Abtew, 1996) wet-marsh PET with readily-available daily temperature range as surrogate for solar radiation (Hargreaves and Samani, 1982)

$$ET_p = \frac{K_1 * R_s}{\lambda}$$

$$R_s = \tau R_a = K_r (T_{max} - T_{min})^{0.5} R_a$$



Hydrologic & Environmental Systems Modeling

Alternative Methods for RET Estimation

- **Penman-Monteith Combination Method (Monteith, 1981) – Combines energy and aerodynamic aspects of ET and includes aerodynamic resistance to heat and vapor transfer and surface resistance to vapor transfer.**

$$ET_p = \frac{\Delta(R_n - G) + \rho c_p (e_a - e_d) 1/r_a}{\lambda[\Delta + \gamma(1 + r_c/r_a)]}$$

FAO 56 P-M (Smith, 1991) and ASCE-PM standardized reference equation (Itenfisu, 2003) define reference grass parameters

- **Priestley-Taylor Method (Priestley and Taylor, 1972) – Assumes aerodynamic component is a constant fraction of energy component. Not applicable to arid areas where advection of sensible heat to a crop is important (α would be > 1.26).**

$$ET_p = \alpha \frac{\Delta(R_n - G)}{\lambda[\Delta + \gamma]}; \alpha = 1.26$$

Hydrologic & Environmental Systems Modeling

What Is Different Now?

- Recent advances in global and regional atmospheric reanalysis and regional surface hydrologic data assimilation
- Three datasets evaluated include:
  1. NLDAS - 1996-2005, ~12 km, 1 hr – North American Land Data Assimilation (NLDAS) system with meteorological forcing from NCEP's Eta regional atmospheric model which produces 3-hourly data on a 40 km grid.
  2. Hydro51 – 1948-1998, ~12 km, 1 hr - NLDAS system with meteorological forcing based on spatially interpolated Global Reanalysis data (2.5 degree or ~265 km in South Florida) and measured rainfall.
  3. NARR – 1979-2005, ~32 km, 3 hr - North America Regional Reanalysis which couples the Eta atmospheric model with the Noah land surface model with remotely sensed meteorological data being assimilated directly.

Hydrologic & Environmental Systems Modeling

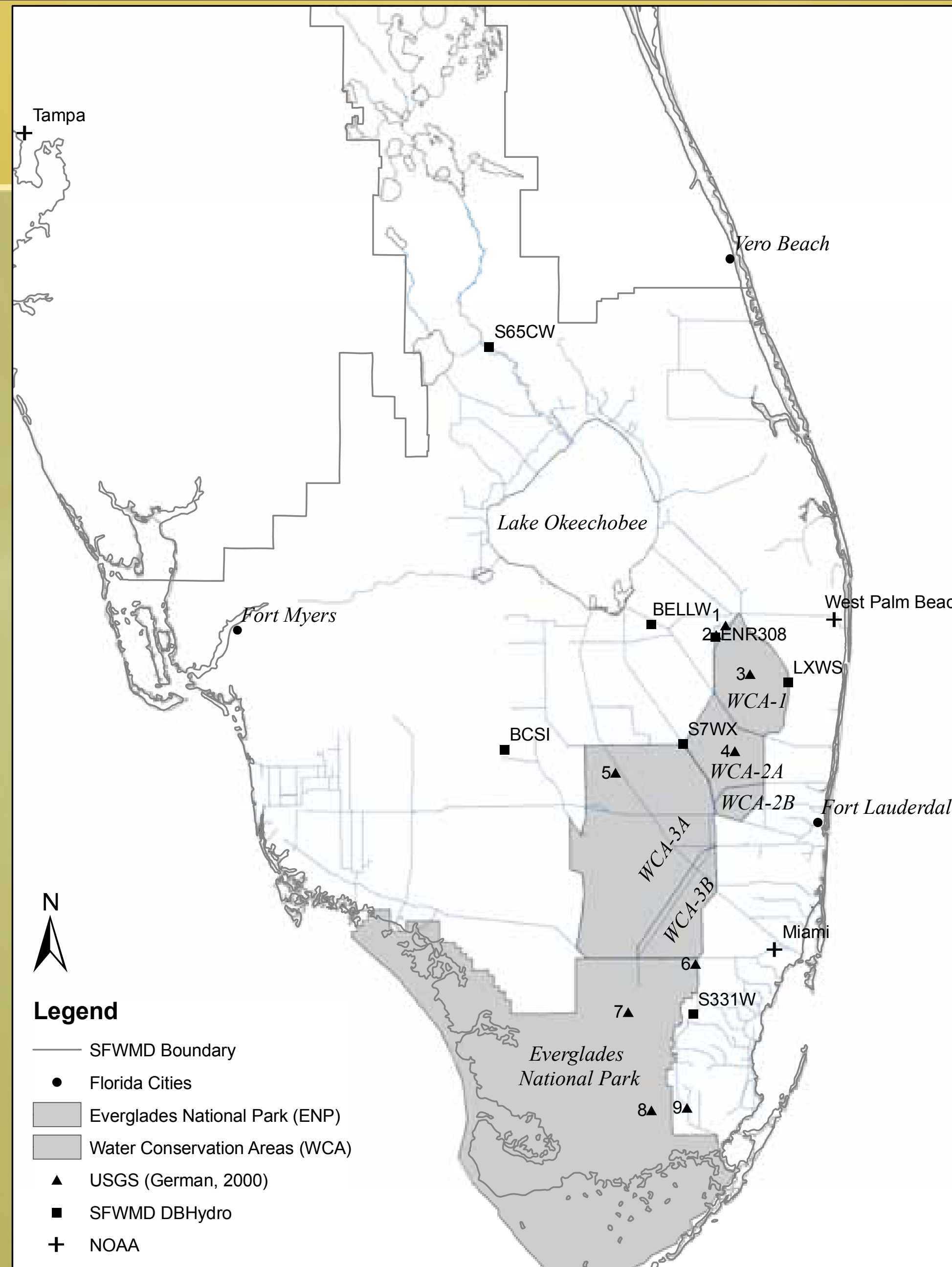
Dataset Validation

Solar radiation

Wind speed

RHmax, RHmin

Tmax, Tmin



Generating the RET Dataset

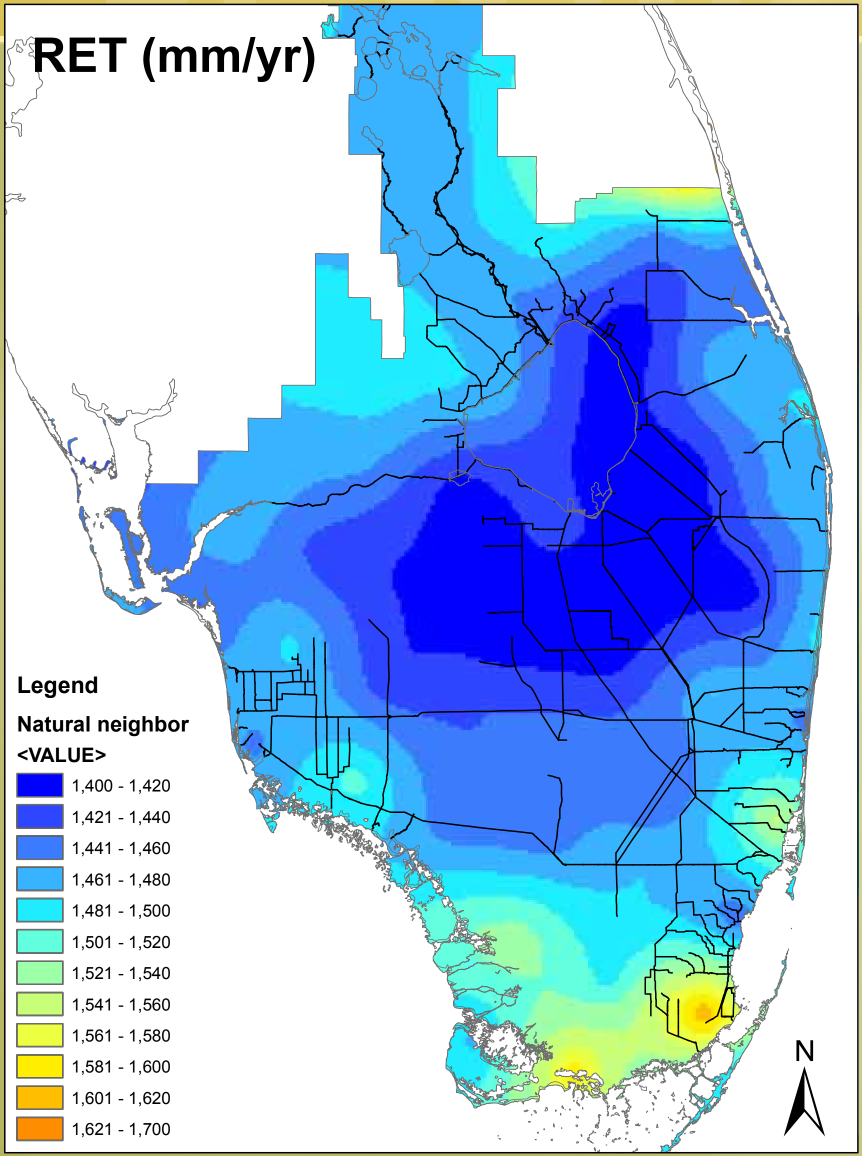
- Penman-Monteith was selected for RET estimation with reference grass parameters as defined by FAO-56 (Smith, 1991), which closely tracks ASCE P-M standardized reference equation. Note that no corrections were performed for non-reference conditions at drained/urbanized areas.
- Since NARR only covers the period 1979-2005, it had to be supplemented with Hydro51 for the period 1948-1978. Hydro51 RET (12 km) was first aggregated up to the NARR resolution (32 km) and then rescaled to match monthly means and stdev in NARR RET.

$$H' = \frac{(H - \overline{H})}{\sigma_H}\sigma_N + \overline{N}$$

Hydrologic & Environmental Systems Modeling

RET Dataset

- 1948-2005 dataset generated based on Natural Neighbor interpolation



Part II

SFWMD