Modeling of alternatives for the Development of LEC 2020 Regional Water Supply Plan

Introduction

Modeling the alternatives associated with the LEC 2020 Regional Water Supply Plan is a challenging task due to many reasons which include, but are not limited to, the following:

- South Florida hydrology is unique due to strong interactions between surface water and groundwater while models developed and used elsewhere in the country are not directly applicable here.
- The alternatives being considered for the above project may involve complex features including Aquifer Storage and Recovery systems, complex water conveyance systems, and underground Seepage Barriers, most of which have not been modeled adequately at a detailed level.
- An enormous amount of output from the model simulations is necessary to evaluate a given plan.

Previous modeling of the alternatives associated with regional water supply plans have been accomplished primarily using the South Florida Water Management Model (SFWMM). This is a regional scale model (Figure 1) which simulates the hydrology and water management in South Florida using a 2 mile by 2 mile grid on a daily basis for the 31-year period spanning years 1965 through 1995. Because the SFWMM mesh is too coarse to incorporate detailed information on a subregional scale, the District modelers are developing a series of high-resolution groundwater models using the popular MODFLOW model code along with its enhancements. These subregional models cover much of the urbanized Lower East Coast (Figure 2) and the Caloosahatchee Basin of the Lower West Coast Region (Figure 3). A Floridan Aquifer model covering the Lower East Coast region south of Lake Okeechobee is also being developed.

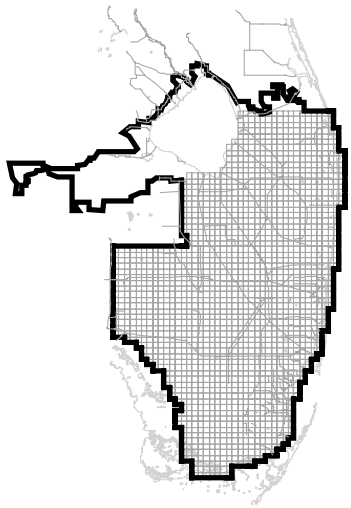

Figure 1. SFWMM model simulation boundary and the 2 mile x 2 mile grid

The evaluation of the alternatives for the LEC 2020 plan will require a linked application of SFWMM, and the subregional groundwater models. Most of the groundwater models under development will ultimately have a spatial resolution of 500 feet and up to 8 aquifer layers. These high resolution models will allow the modelers to simulate the land cover and the features of a plan in a great degree of detail which was not possible with the regional scale model, SFWMM. A sample comparison of the finer resolution groundwater model (500 ft.) and coarser the resolution SFWMM is shown in Figure 4.

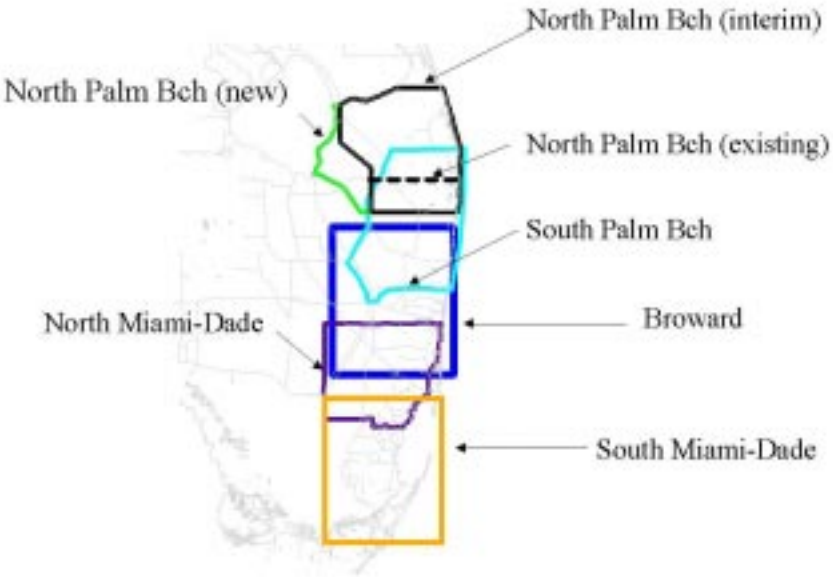

Figure 2. Approximate outer boundaries of the groundwater models in the Lower East Coast urbanized area.

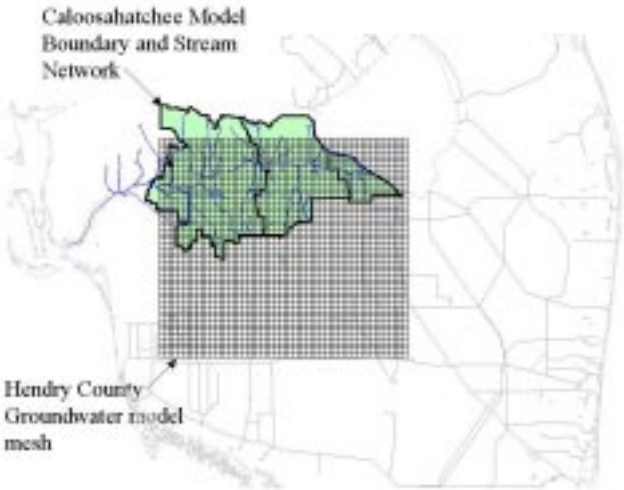

Figure 3. Boundaries of the Caloosahatchee Basin MIKE-SHE model (developed by Danish Hydraulic Institute) and the Hendry County groundwater model

Figure 4. Comparison of the SFWMM mesh (2 mile x 2 mile) and the mesh of of the high-resolution MODFLOW models (500 ft. x 500 ft.)

Model Specifications

Specifications of the high-resolution models that are being developed for analyzing the alternatives associated with the LEC 2020 Plan are presented in (Table 1). As the completion time for some of these models vary, efforts are underway to use the existing models with or without modifications for initial investigations. In all cases, the best available information is being used to develop the input data sets. Most models are based on the MODFLOW-96 code with modifications developed and implemented by South Florida Water Management District, its contractors and other agencies. In particular, a key enhancement made to the MODFLOW-96 code is the development and implementation of the Wetland Module which simulates the surface water levels and flows in large wetlands. Other enhancements being developed are discussed below.

Enhancement to MODFLOW code

1. The new Wetland Module (complete-developed jointly with Florida Atlantic University)

This new module simulates surface water movement in a wetland and its interaction with underlying aquifer and slough channels. The module combines a Manning's type equation for simulation of friction in flow through vegetative surfaces with the mathematical formulation of MODFLOW. The complete package includes flow routing, export and import of water, and evapotranspiration from wetlands. In addition, a comparison was made between the wetland module solution and a solution from a two-dimensional surface water model based on the diffusion-wave equation. A paper on this module was published in the September-October 1998 issue of Ground Water journal. The module is currently being improved.

2. Lake Package (complete)

The Modflow Lake Package was developed by GeoTrans and is a completely modified version of the original Lake package, with notable improvements in the steady-state solution of the lake stage, the input file structure and output options. The package has been modified to make the lake stage solution fully

implicit. This modification precludes the need to use much finer time steps for the lake package as compared to the ground water model when using it in areas where there is considerable interaction between ground and surface water.

3. Seepage Barrier (complete)
This is an official USGS Package.

4. New River Package (under development-jointly with Florida Atlantic University)
Modifications to the existing river package are currently underway to allow for dynamic simulation of the operational rules of numerous water control districts in the South Florida region. A series of operational rules will be input to the model at the beginning of the simulation period. At the end of each stress period, the model will evaluate the antecedent conditions at one or several predetermined nodes within the canal basin and determine the operational rules to be imposed for the next stress period (i.e., modify canal stages).

5. Trigger Module
In 1992, the South Florida Water Management District initiated an effort to develop a "Trigger Module" for both MODFLOW code and the South Florida Water Management Model (SFWMM) Code. The purpose of the trigger module was to simulate the implementation of water shortage policies in the form of water use cutbacks during periods when increased threat of salt water intrusion along the coastal belt of the Lower East Coast occurs. Because the current versions of the MODFLOW code being used at the District do not simulate the salt water front along the coast directly, groundwater levels at selected "trigger locations" will be used to indicate the threat of salt water intrusion and the possible implementation of water use cut backs. The code was fully developed and implemented in the SFWMM and has been a valuable tool for many projects including the Lower East Coast Regional Water Supply Plan (LECRWSP) and the C&SF Restudy. Although the module was also developed and tested for the MODFLOW groundwater code, it has not yet been used used for any major application. The Trigger Module developed in 1992 will be modified and implemented in the new MODFLOW-96 code for the LEC 2020 Plan.

6. DSS Interface (complete)
The primary purpose of this package is to allow the user to specify a period of time within the model simulation where heads at designated locations should be output in a format that can be readily imported into HEC-DSS. This database was developed and is used extensively by the U.S. Army Corps of Engineers for storing and retrieving hydrologic data. The DSS package operates independently from MODFLOW's existing output control, so only heads at locations of interest are saved at the desired time steps as opposed to heads for the entire grid. Additionally, the module affords the option of computing layer-based weighted average heads at designated locations in order to enhance history matching at observation wells that are open to more than one model layer. The current version of this package only works with a constant time step equal to 1 day.

7. Seepage Return Module
The Seepage Return module was developed for the purpose of allowing ground water flow captured by canals to be routed to specified active cells within the model domain. In particular, the initial intent is to use the module to simulate, as part of the initial LEC alternative, the return (via pumping) of captured reservoir seepage back into the reservoirs. This module is simply a modification of the original Drain package where ground water flow removed from the ground water flow system by the drains is continually quantified during the simulation and routed to any set of user-specified active cells within the model domain (specified in the input data set for each canal reach).

Linkage of SFWMM to Subregional Models

Investigation of subregional features in the LEC 2020 Plan and the associated regulatory applications require a careful consideration of the interaction of these features with the regional system alternative being contemplated for a particular planning horizon. The regional system as a whole will be simulated by the regional model, SFWMM. The corresponding results of the SFWMM will provide the necessary boundary conditions for the simulation of a subregional plan in greater detail using the high-resolution

models. The necessary boundary conditions may include water levels, and in some cases the discharges, at the outer boundaries of the high-resolution model, and the water levels in the major canals within the model boundary. For consistency, the results of the SFWMM will be compared with those of the subregional models. In particular, the following checks will be made:

(a) Comparison of water supply quantities required by the LEC canals to meet local demands (as obtained from the "canal budgets" in the groundwater model) against the water supply to the LEC via structures at the N-S levee as simulated by SFWMM

(b) Ensure that the water levels within the remaining Everglades are not severely impacted by the hydrologic effects resulting from the features of a local plan (e.g., New wellfields)

Table 1. Specifications of the high-resolution groundwater models

Geographical Area	Model	Resolution	Number of Rows	Number of Columns	Number of Layers	Calibration period(s)	Primary Developers	Status of Development
Palm Beach County	North Palm Beach (existing)	1/2 mile	40	58	6	87-95	SFWMD	Complete
Palm Beach County	North Palm Beach (expanded)	1/4 mile	80	116	6	87-95	SFWMD	30% complete
Palm Beach County	South Palm Beach	500 ft.	430	324	5	7/88-6/89 (dry) 7/94-6/95 (wet)	SFWMD	Initial version completed. Calibration underway
Broward County	Broward	500 ft.	456	371	6	88-92	Jointly by FAU & SFWMD	Ready for simulating initial alternatives
Miami-Dade County	North Miami-Dade	500 ft.	328	364	8	7/88-6/89 (dry) 7/93-12/94 (wet)	SFWMD	Initial calibration complete. Ready for simulating initial alternatives
Miami-Dade County	South Miami-Dade	500 ft.	~450	~400	5	88-92	Jointly by FAU & SFWMD	50% complete
Caloosahatchee Basin	Caloosahatchee MIKE-SHE	1500 ft.	150	210	4	86-90 94-98	Contracted to DHI	95% complete
Hendry County	Hendry (expanded)	500 ft.	506	570	4	1/86-12/88	Contracted to Engineering & Applied Science	25% complete
South Florida	Floridan	1 mile	166	99	9	95-97 (Steady State)	SFWMD	Calibration Complete. Documentation 50% complete