

Appendix A. Models Used with Performance Measures to Evaluate Alternative Plans

RECOVER currently uses the South Florida Water Management Model (SFWMM) version 5.4.3, Natural Systems Model (NSM) version 4.6 and Sens 4.0, Lake Okeechobee Water Quality Model (LOWQM), and Lake Okeechobee Environmental Model (LOEM) to evaluate performance of alternative plans (**Table A-1**). The Across Trophic Level Simulation System (ATLSS) models, South Florida Regional Simulation Model (SFRSM), and the Everglades Landscape Model (ELM) are being considered for future application (**Table A-1**). Brief descriptions of each of these models are provided below.

Table A-1. Models Used to Evaluate CERP Performance Measures

Model	Calibration/ Validation status	Peer Review Status	Notes
SFWMM	Documentation provided on the SFWMM web page	Peer review of updates conducted Sept. 21-22, 2005	http://www.sfwmd.gov/org/pld/hs/m/models/sfwmm/index.html
NSM		Based on peer review of SFWMM	http://www.sfwmd.gov/org/pld/hs/m/models/nsm/index.html
LOWQM	Completed and documented	Published in peer reviewed journals, based on US Environmental Protection Agency's Water Quality Analysis Simulation Program (WASP)	
LOEM			
SFRSM	Currently under development		Individual components are being developed independently and are in various stages of completion. http://www.sfwmd.gov/org/pld/hs/m/models/sfrsm/index.html
ATLSS	Mostly complete, some ongoing efforts	Additional peer review pending	Currently not being applied to performance measures, efforts are underway to move ATLSS spatially explicit suitability indices (SESI) models to the Interagency Modeling Center for regional evaluation production runs http://www.atlss.org
ELM		Peer review complete	Has been approved for limited CERP use.

South Florida Water Management Model

The SFWMM is a regional-scale computer model that simulates hydrology and management of water resources from Lake Okeechobee to Florida Bay (SFWMD 2005). It covers an area of 7,600 square miles using a grid of 2-mile by 2-mile cells. In addition, it includes inflows from Kissimmee River, and runoff and demands in Caloosahatchee River and St. Lucie Canal basins. The large scale and spatial extent of the model allows it to simulate system-wide effects.

The model simulates major components of South Florida’s hydrologic including rainfall, evapotranspiration, infiltration, overland and groundwater flow, canal flow, canal-groundwater seepage, levee seepage and groundwater pumping. It incorporates current or proposed water management control structures and current or proposed operational rules. The SFWMM simulates hydrology on a daily basis using climatic data for the 1965-2000 period, which includes both drought and wet periods. The model has been calibrated and verified using water level and discharge measurements at hundreds of locations distributed throughout the region within model boundaries. The SFWMM is widely accepted as the best available tool for analyzing regional-scale structural and/or operational changes to the complex water management system in South Florida.

Parameter uncertainty is estimated running a series of SFWMM simulations using historic flows assigned at major control structures where reliable flow records exist. Parameters are incrementally varied one at a time from original calibrated parameters to estimate the 90% certainty band for each parameter. Compartmentalization of South Florida’s hydrologic system by structures and levees presents a unique situation that allows effects of varying individual parameters within several regional compartments at the same time. The same parameter value is applied everywhere the physical characteristic is the same, restricting the range in which a specific parameter value may be varied without causing major impacts to calibration of one or more compartment. The effect of compartmentalization is to reduce uncertainty associated with selection of parameter values. Acceptable ranges of variation for key input parameters are presented in **Table A-2**. Uncertainty of a given model output variable can be represented by the half-width of the 90% uncertainty band. The general rule is the narrower the bands, the greater the level of certainty.

Table A-2. Ninety Percent Confidence Range for Variation in the SFWMM

Parameter/Process	% Change from Calibrated Values
Manning's <i>n</i>	50%
Wetland evapotranspiration	6%
Coastal evapotranspiration	15%
EAA evapotranspiration	5%
Detention parameter	50%
Canal-groundwater hydraulic conductivity	50%
Aquifer permeability	50%
Levee seepage	50%

The estimate of performance measure uncertainty was made with version 2.4 of the SFWMM. Structural flows were estimated based on operational rules in place at the time of the simulations (1995) for high and low values recommended from sensitivity analysis. Parameter uncertainty was estimated by comparing water levels measured at a particular site to those simulated with the calibration version (historical flows assigned to major structures) of the SFWMM for the 2-by-2 mile cell that contains the measurement site. A large portion of uncertainty that exists in simulated water levels in this analysis is associated with scaling, process aggregation, location of gauging site within the cell, and estimates of regional rainfall and evapotranspiration. These types of uncertainty can be reduced by considering 1) regional performance measures that include model output simulated at several cells and 2) relative benefits of system performance measures between an alternative and the base condition or between alternatives.

When considering uncertainty of simulated performance measures, it is important to realize that the certainty of meeting individual performance measures depends on the priority that a particular water management objective has relative to other water management objectives. Therefore, simulated performance measure uncertainty associated with the SFWMM is estimated by replacing historical flows of the calibration version of the model with simulated flows estimated within the operational version of the model and varying parameters. The same exercise would need to be completed for each alternative as performance measure uncertainty will vary with each alternative. This can require a great deal of effort that may not be practicable when considering cost-benefit ratios of taking on such a task and considering that other causes of uncertainty outside the modeling realm may be greater than those of the modeling realm. A large portion of uncertainty that exists in estimating performance measures is caused by such factors as natural climate variability, anthropogenic climate change and sea level rise.

Natural System Model

The NSM simulates the hydrologic response of a pre-drainage Everglades system (VanZee 1999). It does not attempt to simulate pre-drainage hydrology, since input data necessary to perform such a simulation do not exist. Rather, more recent climatic data is used to simulate pre-drainage hydrologic response to current hydrologic input. Use of recent data allows for meaningful comparisons between the current managed system and the natural system under identical climatic conditions.

The landscape of present day South Florida has been greatly affected by land reclamation, flood control and water management activities that have occurred since the early 1900s. The complex network of canals, structures and levees in the current system are replaced in the NSM with rivers, creeks and transverse glades that were present prior to the construction of drainage canals. Vegetation and topography are based on pre-drainage conditions, except for topography south of Tamiami Trail, which is the same as that used in the SFWMM. Recent updates (version Sens 4.0) to topography account for subsidence. Land cover simulated by the model is static, i.e., the model does not attempt to simulate vegetation succession.

Use of the NSM is closely linked to the SFWMM. They use the same climatic input, model parameters and computational methods. Since traditional calibration/verification methods cannot be applied to the NSM, model parameters are based on the SFWMM.

Lake Okeechobee Water Quality Model

The LOWQM simulates average, lake-wide phosphorus, nitrogen and phytoplankton concentrations. It simulates eutrophication processes in both the water column and underlying sediments (James et al. 1997). It can be applied to SFWMM's simulations, but because observed water quality data for Lake Okeechobee are limited prior to 1972, it only simulates the 28-year period from 1973 to 2000.

This model simulates the lake on a lake-wide average scale. Significant changes are observed in this model only if nutrient loads to the lake change significantly. This model does not consider unique zones that occur in the lake. Nor does it have features that explicitly respond to changes in water level, and it does not include submerged or emergent plants. It is expected that the LOWQM will continue to be used for planning studies that require long-term (e.g., 25 or more years) model runs.

Lake Okeechobee Environmental Model

The LOEM is a spatially-explicit hydrodynamic, sediment-transport and water quality model of the ecosystem (Jin et al. 2000, Jin et al. 2002, Jin and Ji 2004). It simulates nutrient and algal dynamics, as well as growth of submerged aquatic plants. It is anticipated that the LOEM will more accurately simulate impacts of lake level on lake water quality than the LOWQM.

This model will not replace the existing Lake Okeechobee Water Quality Model (LOWQM), but rather, will be used in tandem with it. The LOEM will be used to provide critical information about spatial variation in responses of the lake, in terms of physical, chemical and biological (submerged vegetation) conditions, for relatively short (1-5 year) simulation periods. The LOWQM will provide more coarse-scale information, but can be used for long-term (decades or even centuries) simulations of lake response to management alternatives.

South Florida Regional Simulation Model

The SFRSM will be the next generation SFWMM. It is expected that the SFRSM will eventually replace the existing SFWMM. As did the SFWMM, the SFRSM model simulates hydrology and manmade water control features of South Florida to determine consequences of implementing physical and operational alternatives designed to address changing water management priorities and issues.

The SFRSM is being developed using recent advances in computer technology, in particular, geographic information systems (GIS), databases, and object-oriented model development. The new SFRSM will also make use of more realistic, accurate and

efficient numerical algorithms to simulate hydrology and water management in South Florida using a variable mesh structure. Existing algorithms and procedures in SFWMM that are efficient and accurate will be duplicated while searching for ways to improve them or develop new ones.

The SFRSM is a component-based model. It will be an assembly of different components that can be swapped in and out as the model evolves. Individual components are being developed independently and are in various stages of completion. Years of development and testing will be needed before SFRSM becomes fully operational for the entire system.

Key processes that will be modeled by the SFRSM are overland and groundwater flow, precipitation, evapotranspiration, infiltration, levee seepage and canal and structure flow.

Four major project components are being developed concurrently. They include the following:

- Hydrologic Simulation Engine (HSE) - simulates the hydrology in South Florida, including Central and South Florida (C&SF) Project canals, structures and levees
- Management Simulation Engine (MSE) - simulates management activities in South Florida, including operation of the C&SF Project
- Graphical User Interface (GUI) - a simple, easy to use tool for graphically setting up a SFRSM model and interpreting its results
- DataBase (DB) - a convenient storage and retrieval facility of SFRSM data

Across Trophic Level Simulation System Models

ATLSS models integrate three approaches for different trophic levels of the system: 1) process models for lower trophic levels, including benthic invertebrates, periphyton and zooplankton, 2) structured population models for five functional groups of fish and macroinvertebrates, and 3) individual-based models for large consumers, such as wood stork, great blue heron, white ibis, American alligator, white-tailed deer and Florida panther. Models are integrated across freshwater landscapes of the Everglades and Big Cypress Swamp and coupled to GIS maps for cover type. Spatial scales of resolution for models are as small as 100 meters, with the capability to vary this based upon scale of available input data. The system is then coupled to a hydrology model, and used to assess effects of alternative proposed restoration scenarios on trophic structure. SFWMM hydrologic output is converted to high resolution hydrology and then input into ATLSS models.

Everglades Landscape Model

The ELM is a process-based, spatially distributed simulation of ecosystem dynamics across a heterogeneous landscape at a grid resolution 10 times finer than the SFWMM

(Fitz and Trimble 2006a, 2006b). Everglades' hydrology, soil, periphyton, plants and nutrients are evaluated using a set of interacting physical, chemical and biological processes. Hydrology and water quality are two principal "landscape drivers" that are simulated in the ELM. Because of uncertainty of many details and complexity of parameterizing them, the model simplifies the system into a small number of interacting ecological modules. While each module is a great simplification of natural system dynamics, they are designed to capture fundamental ecological processes in a changing environment. Important to ELM functionality are positive and negative feedbacks among these fully-integrated ecological processes.

A variety of summary statistics indicated that the ELM can be effective in simulating principal spatial gradients of water quality across the landscape, capturing long-term seasonal dynamics. A principal component of the uncertainty of historical simulations of water quality observations was sparse model input data on nutrient loads. Applications of ELM and other models should be based on relative performance of alternative scenarios, not on precise results at specific spatial or temporal locations.

A peer review of ELM version 2.5 was completed in January 2007 (Mitsch et al. 2007). The model has been approved for limited use by the CERP program with specific constraints outlined in Mitsch et al. (2007). RECOVER will determine if and how the model will be used with the Greater Everglades water quality performance measures.

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