SFWMD Response

to

Part I RSM Peer Review Panel Draft Report v.1.3

August 19, 2005

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Executive Summary

This document is a response to the draft scientific peer review report on the theory and formulation behind the the Regional Simulation Model (RSM), which is under development as the future model of choice for simulating the hydrology of South Florida. The peer review process was designed to improve the overall quality of the RSM by identifying strengths, weaknesses, and limitations in the model theory and conceptual formulation.

Strengths pointed out by the peer review panel are that there is no commercially available competing model that has all the features planned for the RSM and that it should be ideally suited for regional simulation of water resources in south Florida. Furthermore, the panel indicated that relative to the South Florida Water Management Model (SFWMM), the RSM offers improved process and hydraulic-structure representation, has increased spatial resolution, is easier to learn and is more amenable to development of additional hydrologic process modules by client users. The panel urged serious consideration of their recommendations to further improve the RSM and stated that the RSM is on track to become a state-of-the-art, essential and scientifically defensible tool for water resource management in south Florida.

Major recommendations for improvement to the RSM included the need for significant improvement to the model documentation and an urgent need to validate the RSM in south Florida. The peer review suggestion to improve model documentation has been carefully considered. A plethora of material was provided to the panel for review and it is agreed that this material needs to be better organized. A revised RSM documentation plan is included in the section responding to comments on the usefulness of model documentation. Calibration and validation of the of the RSM implementation for south Florida (SFRSM) is a high priority scheduled for completion in December 2005, followed by implementation of management features, after which the SFRSM calibration/validation will undergo peer review.

The Peer Review Panel Draft Report included several specific concerns, useful suggestions and recommendations to improve the RSM. Many specific suggestions were made to correct minor errors, to address inconsistencies between the model and its documentation, and to provide ways to better verify and validate the model. Each issue raised by the peer review panel has been discussed under the eight subsections in Section 2 of this response, with each section corresponding to one of the eight goals of the peer review. Furthermore, each issue is presented in more detail in Appendix B in an issue or comment statement, followed by a response summary and an action plan to fully address the issue raised.

It is hoped that the panel will find that the District has adequately addressed (or provided adequate assurance that they will address) all of the important issues and concerns raised by the panel. The District understands the immense effort that this peer review has taken and is very grateful to the peer review panel for their time and professional candid comments. Our Regional Simulation Model will be greatly improved as a result of this effort.

Preface

The peer review of the Regional Simulation Model (RSM) was conducted to improve the overall quality of the RSM by identifying strengths, weaknesses, and limitations in the model theory and conceptual formulation. The Peer Review Panel was presented with extensive documentation as well as access to a website with additional references, comprehensive responses to the peer review panel questions communicated via the peer review web board, and presentation of the RSM at the June 22-23, 2005 workshop, specifically designed to address peer review panel questions.

The early feedback comments from the peer review panel as well as the comments in the Peer Review Panel Draft Report point out strengths, weaknesses and possible limitations with both the model documentation and conceptual formulation. The Peer Review Panel Draft Report could be improved by more balanced presentation and highlighting more of the model strengths. We hope the Peer Review Panel Final Report will include further comments on the strengths of the RSM model and the applicability of the approach adopted in the RSM for regional long-term simulation of south Florida conditions.

The District feels that RSM theory as presented through the extensive documentation provided to the peer review panel, comprehensive responses to the peer review panel questions communicated via the peer review web board, and presentation of the RSM at a workshop specifically designed to address peer review panel questions, should have adequately demonstrated that the Regional Simulation Model is a ground-breaking innovative tool. Preliminary results indicate that the model *is applicable for its intended use* under south Florida conditions. The peer review panel has an opportunity to revise their final document based on this information.

1.0. Introduction

This document serves as a response to the Peer Review Panel on their Draft Report v.1.3. It also summarizes the peer review work done to date, and provides discussion to clarify some aspects of tasks given to the Peer Review Panel. After the Peer Review Panel submits their final report, this document will be updated to provide the official District response to the Peer Review Panel Final Report. The Peer Review Final Report document together with the SFWMD Final Response document will serve to capture the status of the Regional Simulation Model (RSM) at the end of the first of a three-part peer review. These two documents will be made available to panelists in the subsequent peer reviews.

1.1. RSM Development and Implementation Challenges

As a prelude to using the RSM, it is important to recognize the characteristics that distinguish this model from many others. At its core, the RSM is a hydrologic model built on object-oriented principles using state of the art computational methods. The object-oriented approach and the associated coding practices allow for a range of algorithms to be housed within a single code, to be invoked either as a single feature or as a complex mixture of features. As a result, the RSM can run either like an overland flow model, groundwater flow model, canal flow model, or any combination of these models. The ability of a single model to simulate many features is important because of the integrated nature of the south Florida system. Similarly, the ability to house many features under a single software umbrella is highly desirable to maintain standards and minimize the number of peripheral support tools.

While these capabilities allow for great flexibility in terms of computational algorithms, data, hydrologic process modeling, and other structure and operational control choices, peer review of the RSM becomes a much more complicated task. Traditional peer review of simpler, single-purpose models such as the overland flow model with a single numerical engine, is a relatively well-defined task. To mitigate this complexity, many of the critical components of the model such as the overland flow module, groundwater flow module and the canal flow module have been tested, verified and published separately in journals. The current peer review is mainly aimed at reviewing the theoretical aspects of the RSM. Attempting to assess all of the features simultaneously applied to a single application, is beyond the scope of the Part I peer review.

The development strategy employed by the RSM Development Team is to focus on single or simpler aspects first, one at a time, and then move to complex aspects slowly as applications need them. The 2-D overland flow, groundwater flow and canal flow are three of the simpler capabilities, and their interactions support some of the more complex capabilities. New objects are developed in response to user needs and specifications. As objects are developed, they are added to the existing assembly of RSM objects. Under the object-oriented framework, the selected objects are constructed at run time, based on input data specifications. Once instantiated, objects coexist in computer memory, carrying out assigned duties as prescribed by their design. Model extensibility is provided through object encapsulation and polymorphism. For example, groundwater flow, surface water flow, streambank flow, and control structures are all watermover objects that have their own data and computational methods encapsulated within their respective objects. Through polymorphism, the RSM processes all watermovers simultaneously and seamlessly. Groundwater flow watermover objects can automatically start behaving like overland flow watermovers when the water levels go above the ground elevation. Similarly, reach transmissivity is calculated automatically during the assembly of the watermovers when the correct connectivities are assigned to the canal segment and the groundwater cell.

The development and implementation of the RSM is predicated on the belief that complex systems can be represented through the assembly of relatively simple components. Applying the RSM to complex hydrologic systems requires decomposing system to some level of abstraction, building the RSM object counterparts, and assembling the objects into a complete model. The level of abstraction is a function of the questions being posed, data availability, time constraints, resources, etc. As modelers at the SFWMD, we are faced with all of these issues. The RSM was designed to maximize the modeler's ability to provide reliable modeling results in a timely manner.

1.2. Scope of Work

According to the Statement of Work (see Appendix A), this peer review is Part I of III, a scientific peer review on the Regional Simulation Model (RSM) theory, including the Hydrologic Simulation Engine (HSE) and the Management Simulation Engine (MSE) components. The intent of Part I was to objectively and independently evaluate and scrutinize the theoretical and the conceptual formulations of RSM and to examine the documentation and the papers that have been published, which contain further information on the theoretical foundations of the model. **The purpose of this work was to improve the overall quality of the RSM by identifying strengths, weaknesses, and limitations in the model theory and conceptual formulation.**

Specific goals were given to the peer review panel, again with the focus on finding strengths, weaknesses, and possible limitations. The goals identified in the Statement of Work were:

1. Determining if proper and sound scientific approaches were used in the development of RSM, making sure that a self-correcting open process is in place;
2. Evaluating if the conceptual framework of the model contains all of the important hydrological processes necessary to do regional scale modeling in South Florida;
3. Determining the appropriate use of the model in South Florida conditions;
4. Making suggestions on modifications and future improvements to the model, including any suggestions for improved computational methods, and future model expansion ideas;
5. Making suggestions on the usefulness of the model documentation, including whether the level of detail is sufficient or more is needed, whether the conceptual framework is clear, etc.
6. Suggesting any additional tests that may be desired to further validate RSM;
7. Suggesting tests for the HPM approach to simulating local hydrology and making recommendations for improvement or expansion of the approach; and
8. Evaluating whether the model is suitable for meeting client goals.

1.3. Information Provided to Panel

Panelists were given paper copies of materials to read, and were provided access to additional references electronically via a website[1] at the commencement of the peer review. Electronic feedback to an initial set of comments (see Appendix II of the Draft Panel Report) was also provided on the website. Handouts and presentations were provided during a two-day peer review workshop hosted in West Palm Beach on June 22-23, 2005. A short tour of the south Florida landscape via helicopter and airboat was organized to provide the peer review panel with an overview of the landscape to which the RSM is being applied.

The “required reading” mailed to the panelists at the onset of the peer review included the RSM Theory Manual, five of six supporting documents, which were attached as appendices to the RSM Theory Manual, and a two-page fact sheet on the South Florida Regional Simulation Model project, which is one implementation project of the RSM currently underway. The six supporting documents included three previously published, peer-reviewed papers, one paper currently in review, and two white papers developed for in-house use (one was sent late electronically). Table 1 shows these documents, along with additional materials made available later in the peer review process.

1.4. Feedback from Panel to District

The peer review was conducted “in the sunshine” (Florida Sunshine Law), with limited interaction between the panel members and District staff. A facilitator (Ken Black of the Jacobs Engineering Group) was selected to serve as a liaison between the Panel and the District. Aside from the two-day workshop and follow-up tour, all communications were captured on a web board[2], available to the public and advertised on the SFWMD external web site[3].

One of the tasks given to the peer review panel was to review the “required reading” materials, and provide an initial set of comments before the on-site workshop. These comments, along with District responses, are provided in Appendix II in the Peer Review Panel Draft Report, v.1.3.

At the workshop, panel members asked questions throughout the two days. These were captured in the workshop minutes, which are provided on the peer review website (and should be included as an appendix to the Peer Review Panel Draft Report, v.1.3).

After the workshop, the panel members communicated through the web board, assembling the Draft Report. Those communications are available on the web board, and will be archived electronically when the peer review is complete.

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[1] http://gwmftp.jacobs.com/Peer_Review/web_page/peer_review_sfwmd.htm

[2] http://oakweb04.jacobs.com/supportforums/

[3] www.sfwmd.gov

Table 1. Materials provided to Peer Review Panelists

Documents provided at beginning of peer review	Materials available electronically on peer review web site
1. RSM Theory Manual, with 5 of 6 technical reference papers included within Appendix C a. Weighted implicit finite-volume model for overland flow (Lal, 1998b) b. Numerical errors in groundwater and overland flow models (Lal, 2000) c. Case study: Model to simulate regional flow in South Florida (Lal et al., 2005) d. Determination of aquifer parameters using generated water level disturbances (Lal, 2005) e. Management simulation engine of the Regional Simulation Model: An overview (Park, 2005) 2. SFRSM Fact Sheet 3. Peer Review Statement of Work	1. RSM Theory Manual, 6th technical reference paper within Appendix C a. Hydrologic process modules of the Regional Simulation Model: An overview (Flaig et al., 2005) 2. HSE User Manual 3. MSE Controllers User Manual 4. MSE Supervisors User Manual 5. RSM Benchmark Guide 6. RSM Bibliography 7. Published papers a. Simulation of overland and groundwater flow in the Everglades National Park b. Selection of spatial and temporal discretization in wetland modeling c. Modification of canal flow due to stream-aquifer interaction 8. RSM Code 9. RSM XML Schema and XML Schema Primer 10. 1998 SFWMM Peer Review Report
Documents provided at peer review workshop	**Materials provided electronically after the workshop**
1. Slides of all presentations a. Role of RSM in SFWMD b. Goals of the Workshop c. RSM Theory d. HPM Theory e. RSM Documentation f. RSM Analytical Tests and Validation g. Water Management District Overview h. RSM Enhancements and Improvements i. SFRSM Implementation and Application 2. Acronyms 3. Preliminary responses to panelist pre-workshop comments 4. Statement of Work	1. Review of ET Methods and Selected ET Methodology 2. Example of a south Florida regional model application (Modeling in EAA) 3. Updated responses to panelist pre-workshop comments 4. Slides of all presentations

1.5. Format of this Response

As is evidenced in the material presented above, the peer review panel was given a daunting task. Their objective, constructive comments on the current model documentation are appreciated. The rest of this report is broken down as follows. Section 2 responds to the findings of the peer review panel, organized by the eight goals of the peer review. Section 3 responds to the Panel's conclusions and recommendations. Three appendices are provided as references, A) the peer review statement of work, B) a listing of specific issues (extracted from the peer review panel report) and District responses to each issue with action plans to further address the issues, and C) minor errors in the peer review panel draft report that should be corrected.

2.0. Suggestions from the Panel

The peer review panel formatted their report based on the original eight goals of the peer review (listed in section 1.1). We have responded to the panel's findings in this section, point by point, in a summary form. However, in order to ensure completeness, we have also extracted 53 individual "issues" from the Draft Report, and address each issue on a separate form within Appendix B. The Draft Report Conclusions and Recommendations are addressed in Section 3, as well as in issue #10 in Appendix B, and indicates which specific issue numbers address each of the bullet points in the Conclusions and Recommendations. Each issue provides an in-depth response to the encapsulated issue and an action plan by the District to improve the RSM.

2.1. Goal 1: Sound Scientific Approach

(see also issue response forms #11-24 in Appendix B)

One of the major concerns of the Peer Review Panel appears to be that the documentation provided to them was incohesive and, in its current state, provided inadequate presentation and discussion of all the equations in the model or present extensive validation examples. The Peer Review Panel commented on the scientific approach in sections on the basic equation formulation, diffusion-wave approximation, numerical methods and hydrologic process modules. The general issue of documentation is addressed first, followed by a summary response to issues raised in each subsection.

The RSM has been developed over the last decade and progress towards completion of RSM developments has also been documented in refereed journals (e.g., Lal, 1998b, 2000, and 2005). Documentation provided in the RSM Theory Manual was intentionally limited to a description of key theoretical concepts of the Hydrologic and Management Simulation Engines (HSE and MSE). The extensive supporting information in journal articles, unpublished papers, online user manuals and other documents was provided to more fully document the incremental theoretical development and verification of the RSM over time. The aim was to provide the reviewers with sufficient information to enable them to recognize the sound science that has gone into the RSM approach. District staff agrees with the Review Panel that the model documentation requires better organization. Section 2.5 of this document presents plans for more comprehensive model documentation.

Basic Equations and Formulation

Issues are raised by the Peer Review Panel related to basic equations and model formulation including: misstatement of several equations, assumptions related to isotropy, formulation of the canal seepage equations, single aquifer layer assumption and related overland and ground-water flow coupling concerns and use of the term "effective roughness". A summary of the District response to each issue is presented below with more detail provided in Appendix B, issues #11-24.

There was considerable concern about typographical errors in the documentation with the concern that those errors existed in the model source code. The RSM documentation has been corrected and the model code verified to be correct by carrying out a line-by-line checking of the source and also indirectly through verification tests. District staff believes that the code would not have worked in many cases if errors were present in the code.

The process of verification is used to find if the code solves the chosen problem correctly and the process of validation is used to find out if the model captures the physical phenomena with adequate fidelity (Post and Votta, 2005). The base formulation of the RSM has been verified through a substantial number of tests during the past decade (Table 2). These tests were conducted as each model component was developed and also on the entire RSM. These tests verified the numerical methods including mass balance, convergence and error assessment, and the formulations for overland flow, canal-overland flow interactions and groundwater flow.

Numerical Methods

The Peer Review Panel suggested that the integrated solution of the HSE equations in a single matrix could cause the model to become too numerically intensive as complexity of RSM model applications increase. They also suggested that an alpha value of 0.6 may be more appropriate than the value of 1.0 suggested by RSM model developers.

The Peer Review Panel identified three types of errors; numerical errors caused by round-off and truncation, physical errors attributed to inaccurate parameters and error due to poor or limited data. The Panel recommended that these errors be identified in RSM validation. As discussed in issue #55, these errors will be described more fully in the RSM documentation.

The simultaneous solution of all watermovers and waterbodies in a single global matrix is one of the strengths of the RSM. This solution requires a very good sparse matrix solver. The PetSc solver has performed very well over a wide range in RSM implementations. As an additional solution, implementation strategies need to be developed wherein the regional implementation of the RSM would be used to screen alternatives and the subregional implementations would be used to simulate water resource management at the project level.

Convergence errors that are referred to in the document as numerical errors, have been studied not only for variable alpha, but also for variable spatial and temporal discretizations (Table 2). Additional study of the impact of alpha will be conducted in the future. This issue is discussed in more detail in issues #21 and #58 in Appendix B.

Anisotropic conditions due to ridge and slough flow and hydraulic conductivity and transmissivity in subsurface flow can be important under certain conditions. In the first case, refined meshes can be used to capture anisotropic conditions in large ridge and slough systems. For the more general case, simulating anisotropic conditions at a smaller scale requires a tensor representation of the transmissivity and conductance parameters. To our knowledge no published model has done this in a theoretically correct way using tensors for an unstructured mesh. However, this has been done for regular grids. In the future, transmissivity and conveyance could be implemented as tensors; however, more research is needed in this area.

Table 2. Verification tests conducted on the Regional Simulation Model

	Verification Test	Reference
1	Comparison of an exact solution of canal-aquifer interaction to the RSM solution.	Lal (2001), Fig 9
2	Comparison between RSM and analytical solutions of the decay and phase behaviors of water waves traveling along a canal subjected to canal aquifer interaction, subjected to variable canal bottom sediment resistance.	Lal (2001), Fig 10
3	Comparison of RSM solution with the MODFLOW solution in the case of a textbook example that has pumping.	Lal (1998b) , test 1
4	Comparison of an axisymmetric overland flow problem solved using RSM 2-D overland flow module and an axisymmetric overland flow model (modified 1-D diffusion flow model) with a very high resolution. The same test of symmetry was used in Lal (1998a).	Lal (1998b), test 2, Fig 3, 4, Fig 6
5	Behavior of the numerical error calculated as the difference between the 2-D RSM overland flow module and the axisymmetric module, with the spatial and temporal discretizations.	Lal (1998b), Table 1, Fig 6
6	Verification of the model by testing the symmetry of an axisymmetric solution of an axisymmetric problem. This circle test was carried out at various resolutions.	Lal (1998b), Fig 5, Table 1, and internal technical documentation
7	Comparison of RSM solution for a Kissimmee basin problem with results of the RBFVM-2D model and the results of a physical model.	Lal (1998b), Table 2, Figs 7, 8, 9
8	Verification that the water balance conditions for an arbitrary cell and a segment.	Lal (2005a), Table 1
9	Comparison of RSM solution with an analytical solution for a sinusoidal boundary disturbance problem.	Lal (2005a), Table 2
10	Behavior of numerical error along distance from the boundary for a boundary disturbance problem, and comparison of the result with analytical error estimates. This test is carried out for a groundwater flow problem.	Lal (2005a), Fig 4
11	Numerical error of RSM under variable space and time discretizations, and comparison of the result with analytical error estimates.	Lal (2005a), Fig 5
12	Comparison of RSM solution for L-8 basin to observed data.	Lal (2005), Fig 8, 9
13	Comparison of the RSM solution with an approximate analytical solution for a water level disturbance problem in groundwater.	Lal (2005), Fig 7
14	Comparison of RSM solution and the RSM numerical error with the analytical solutions of both for a boundary disturbance problem.	Lal and Van Zee (2003), Table 1, Fig 2, 3

We believe that modifications of the canal seepage equations separately as in the case of MODBRANCH model are not applicable in RSM because the formulations are different and the RSM allows for the same modifications to take place seamlessly at the appropriate connection without having to manually introduce the equation. The accuracy of this approach was tested with analytical solutions solved for many conditions. Further details are discussed under issue #14 in Appendix B.

The RSM has the capability to simulate 3-D groundwater flow with multiple layers. However, the RSM version presented to the peer review panel was only a single layered version because the current implementation of the RSM to south Florida (SFRSM) does not require multi-layer groundwater flow. In this single-layer version, there is one head for both overland and groundwater flow, assuming that wetland or shallow water levels conditions prevail in south Florida, and that single head assumption applies under such conditions. Our previous experience indicates that adding model layers does not necessarily improve the solution unless there is a specific need (Lal, 2005).

Future subregional implementation of the RSM may require use of the 3-D layered feature, which is described in the HSE User Manual. Linkage between layers is accomplished through a watermover that considers vertical leakance.

The concern about not using the term “effective roughness” is noted as a helpful suggestion. Further discussion under issue 22 in Appendix B explains how an expression used by Kadlec and Knight (1996) can be used instead of the Manning’s equation to replace laminar and transient flow conditions. This formulation is available in RSM.

Diffusion-Wave Approximation

The Peer Review Panel comments on diffusion flow were considered extremely useful. As with any numerical approach, the diffusion flow method has its own limitations as recognized in the documentation and as pointed out by the reviewers. Since the RSM is being developed primarily for regional application with relatively large (daily) time steps, it is not expected to capture solutions at small spatial scales that are more likely to be dynamic and inertia dominated. Future enhancement may be considered to include inertial terms. More detailed discussion of the diffusion-wave approach and its appropriate application is presented in response to issues #19 and #21 in Appendix B.

Hydrologic Process Modules

The Review Panel identified six issues of potential concern related to the Hydrologic Process Modules: use of the NRCS curve number runoff generation method for continuous simulation, limitations to the use of v-notch weirs for agricultural impoundment discharge, incorrect equation for <mbrcell> HPM, evaporation from <unsat> HPM, incorrect water budget for <ramcc> HPM and incorrect units for <prr> estimate for maximum soil moisture capacity. Three of these concerns are a result of typographical errors in the documentation and the other issues will be addressed in the documentation and in the source code. Our response to the individual issues can be summarized as follows with more detail provided under issue #24, Appendix B.

The curve number approach for calculating runoff has been used in other continuous simulation models, SWMM, CREAMS/GLEAMS and others, where the maximum potential retention is adjusted on a daily basis. In <agimp> the curve number approach is used for a single design storm. In <mbrcell> the curve number method is used with potential retention equal to the available moisture storage. This approach requires additional validation as recommended by the Panel.

The Panel indicated there are limits to the use of the v-notch weir. Circular orifices are typically used more than v-notch weirs in south Florida. The source code and documentation will be modified to reflect the limitations in the use of the v-notch weir for impoundment discharge.

The equation for rainfall excess found in the HPM documentation for <mbrcell> is incorrect and will be removed from the documentation. It has been verified that the equation is not present in the current version of the source code.

In the current version of <unsat> the ET losses cease below the rooting depth. The source code for ET will be modified to provide for linearly reduced ET down to an extinction depth below the rooting depth.

The documentation of the <ramcc> water budget equation has an error in the sign for the upflux term, it has been corrected in the documentation. The documentation for the maximum soil moisture capacity in the <prr> section indicates the values are calculated in S.I. units and does not explain there is a unit converter in the sources code so that the model uses the correct units.

2.2. Goal 2: Conceptual Framework of the Model

(see also issue response forms #25-29 in Appendix B)

The Review Panel identified five issues of potential concern related to the conceptual framework: PET estimation, the role of the MSE, shear-stress effects of wind, conveyance in sloughs, and the effect of land use changes. Most of the issues raised are beyond the scope of our immediate challenge to develop a model that provides for long-term regional simulation functionality at a daily time step, as a future replacement for the South Florida Water Management Model (SFWMM). All of the recommendations will be included as part of the future model development process. Our response to the individual issues can be summarized as follows:

Modelers recognize that PET is often calculated within other models. Consistency of input between models is very important for the South Florida Water Management District as a whole. It was a conscious design decision to determine potential evapotranspiration outside of the RSM to ensure consistent PET inputs for many models used by the District. As the RSM is applied to a wider array of problems, it may become advantageous and desirable to include the PET calculation in the model.

The MSE continues to evolve and has not reached the same level of maturity as the HSE. Comprehensive documentation will become available as MSE features are developed and interactions with the HSE are fully defined. The hydraulic structures can in fact be operated in accordance with the MSE algorithms. However, given the constraint of a daily time step in the SFRSM model implementation, the challenge is to capture the fine timescale control of actual hydraulic structure operations. The current technical solution to this timescale difference is to develop and implement MSE assessors. Assessors are designed to use daily flow transfer functions that achieve structure flow control that is consistent with a temporally integrated small timescale control and response of the hydraulic structures.

Wind shear effects are not included in the RSM at this time. Until now, wind shear effects have been simulated in south Florida by relatively more detailed and site specific models such as the SICS model (Swain et al, 2003). The SFWMM has provided stage boundary conditions to the SICS (and other models) and this approach appears to be reasonable as wind stress affects the circulation more than simulated stage. The RSM should be able to provide similar boundary conditions to detailed models in the future.

The ridge and slough landscape can be represented in the RSM by implementing a very fine and appropriately discretized mesh. The current south Florida implementation of RSM (SFRSM) does not represent the individual ridges and sloughs because the goal is to represent the overall regional functionality. The option to represent ridge and slough features at a scale smaller than the scale of the model mesh cells could be built into the model as heterogeneous transmissivity and conveyance parameters in the future. Two main parameters in the current RSM are designed to capture what is lost from storage and resistance terms through spatial aggregation. The SV (stage-volume) converter captures the storage behavior of a cell as a function of water level. The conveyance and transmissivity parameters and their respective objects describe the flow resistance above and below ground. Currently, these are scalar parameters as opposed to tensor parameters and therefore can only describe isotropic behaviors. In the future both transmissivity and conveyance could be implemented as tensors, or detailed HPMs could be designed; however, more research is needed in this area.

The inclusion of changing topography, land use, canal configuration, etc, is commonly referred to as succession modeling. The RSM was originally envisioned to simulate hydrologic responses, e.g., changes in water levels and flows, in a fixed or static system configuration using time-varying climatological input and to a limited extent, time-varying structure operating rules in the course of a 36-year simulation. The model will be run for static systems from different historical datums (e.g., 1988, 1995, 2000). This is the same modeling technique used by the SFWMM. Dynamic physical attributes, both natural and man-made, may be significant for multi-decadal simulations and can be included in future versions of the model.

2.3. Goal 3: Use of the RSM in South Florida

(see also issue response forms #30-31 in Appendix B)

As pointed out by the review panel the validity of the RSM in South Florida (SFRSM) needs to be demonstrated in a subsequent peer review following completion of the calibration and validation effort in 2006. The District appreciates the positive review comments that the calibrated and validated SFRSM should be more useful than the SFWMM for water resource alternative simulations. The reviewers point out that there are two instances where the diffusive-wave assumption may not be appropriate in South Florida conditions: in canals with nearly zero bed slopes and in the tidally dominated mangrove zone along the southwest Gulf coast. Further discussion of these instances and proposed specific courses of action follow.

For canals of nearly zero bed slopes, diffusion flow is not applicable because the inertia term dominates over friction and gravity terms. The applicability of the diffusion-wave equation is maintained in the RSM as in many diffusion flow models (Akan and Yen, 1981) by setting a very small slope (10^{-9}). Theoretical work to identify appropriate applications of the diffusion wave approach has been presented by Ponce et al. (1978). To further demonstrate the applicability of the diffusive-wave approach, District staff plans to devise numerical and field benchmarks to investigate the impact of the full dynamic-wave equation versus the diffusive-wave equation.

District staff agrees that application of the RSM to the tidal or coastal areas such as the mangrove ecotone along the southwest Gulf coast between Cape Sable and Ten Thousand Islands necessarily neglects inertia terms. Given that the RSM will be applied regionally to south Florida using a daily time step, diurnal tidal fluctuations are relatively less important than would be the case for a local model, implemented at small time steps. It is proposed that the ocean boundary of the tidal zone be kept so as to provide a seamless boundary condition for the rest of the model. However, results from the tidal zone will be masked and precluded from output analysis and time series stage matching during calibration. This approach is preferred to the alternative of excluding the tidal zone completely from the computation due to the lack of data to use as a boundary condition at the land rim of the tidal zone.

2.4. Goal 4: Modifications and Future Improvements of the RSM

(see also issue response forms #32-38 in Appendix B)

The panel made useful suggestions for modifications and future improvements to the model in five main areas: water balance, post-processing, numerical solution, autocalibration and the input/output format. Several of the suggestions are consistent with District plans for both immediate and future enhancements while others are outside the scope of proposed modifications. The overall plan for RSM implementation enhancement is summarized briefly, followed by comments on the specific suggestions.

The RSM has been developed over the last decade with enhancements driven by progressively challenging and increasingly complex implementation of the model. The current priority is to have a calibrated verified implementation of the RSM over a large portion of south Florida (SFRSM) by December, 2005. To achieve this goal, several enhancements are essential while others are excluded due to the scope of the implementation goals. A natural system or pre-drainage implementation (NSRSM) of the RSM in south Florida is also under way as a parallel process to the SFRSM, and will also be complete by December, 2005.

During 2006, a peer review of the NSRSM implementation and peer review of the SFRSM calibration/validation will take place. Management features will be fully implemented in the SFRSM and documentation improved following comments and suggestions from this peer review. The process to migrate from use of the SFWMM as the primary regional model to the SFRSM will commence.

During 2007, the SFRSM will be ready for use in simulating water resource management alternatives in a production mode. Enhancements to include water quality and ecological features as part of RSM will occur during 2006 and 2007 and should be available in 2008. Once the south Florida implementations of the model are in production, it is anticipated that a small core group of developers will work on a prioritized list of enhancements to the model.

Several of the specific recommendations for future enhancements provided by the peer review panel will require research and testing prior to inclusion into the RSM. Response to specific suggestions for modifications and improvements follow.

Rain/ET in canal water balance. Analysis indicates that the canals represented in the RSM application to south Florida (SFRSM) occupy less than half a percent of total surface area of the model domain. Modelers agree that inclusion of rainfall and ET in the canal water balance could slightly improve model accuracy. More important is that when RSM is applied to smaller or specific domains where canals occupy a significant portion of the domain this could become important. Model developers plan to include rainfall and ET in the canal water balance in a future RSM release.

Future work will also include developing an HPM structure for canal segments. This is necessary to provide the HPM structure to link water quality biogeochemical processes to simulate solute transformation and transport. This enhancement will be further refined, documented and coded into the RSM, followed by testing and verification.

Flooding post-processing. The approach suggested by the peer review panel has been used with success previously in post processing of the South Florida Water Management Model output with more detailed micro-topography in the determination of species specific performance indicators. The approach will be considered in conjunction with client needs as performance measures are developed to meet the client model application needs. This enhancement will be further refined, documented and coded into the RSM, followed by testing and verification.

Numerical Solution Enhancements. It is true that the flow conditions in the most dynamic process will govern the time step and many models are decoupled, with two different time discretizations (or space discretizations) to capture the disturbances resulting from various governing equations in each model. Algorithms are then used to couple these modules. For example, MODFLOW and BRANCH models are coupled to create MODBRANCH. Although the time steps for each model are different enough to effect some computational time saving, the coupling has to be done iteratively, which in turns takes more computational time.

In the RSM, the coupling is carried out internally to the model, and an extremely efficient external sparse solver (PetSc) is used for numerical solution. Concerns expressed by reviewers regarding unnecessary flow computations are for the most part overcome by the fact that many modern sparse solvers include adaptive algorithms to automatically account for “unnecessary calculations” so that the time spent by the solvers to obtain the numerical solution is similar to those of uncoupled models (refer to issue #15, Appendix B for more detail). Dynamically variable time steps are critical in explicit models to improve model stability. In the RSM with a user specified fixed time-step, it has been observed that using the PetSc solver, numerical solution is extremely fast with few iterations during the dry season, and slower under ponded conditions.

A daily timestep is appropriate for application of the RSM to south Florida due to the availability of daily input data and the fact that the model is being applied region-wide for long simulation periods. It is recognized that using a fixed time step in RSM limits the time resolution of hydrologic applications to the specified time step.

Further potential numerical solution gains through decoupling will be tested in the future. If testing of decoupling proves beneficial to the RSM, these enhancements will be tested, verified, documented and coded into future RSM versions. The RSM development team agrees that sub-timing and domain decomposition would be a good enhancement and it will also be tested for potential computational gains.

GMS 6.0, SVD and Hydraulic Conductivity Enhancements. The GMS version 6.0 mesh discretization and PEST single value decomposition, suggested by the panel, appear to be powerful tools and we will look into using them along with a "pilot-point-based-approach" in the near future. Currently, we are set up to use an SVD inverse modeling tool, based on Lal (1995), developed to run on our Linux cluster, which has been extended to provide an interface to PEST.

Further research into how these tools could help with RSM usage will be pursued and where applicable, the RSM will be fitted with the appropriate application program interfaces (APIs) to use them.

Research will be conducted in how the hydraulic conductivity array is broken down into subsections. An optimal approach will be identified and subsequently implemented into the RSM.

File Format Support (XMDF). The RSM development team acknowledges that portable file formats used can in fact introduce performance enhancements for model runs. The team is currently researching the possibility of including the functionality to support the HDF5 format directly, given that it is the lower level format upon which NetCDF and XMDF sit. Research will also be conducted on the XMDF format in order to assess performance improvements. If the research proves beneficial to the RSM, file format enhancement will be further refined, documented and coded into the RSM, followed by testing and verification.

Other Enhancements Foreseen by the RSM Development Team. In addition to new functionality pertaining to water quality and ecology, there are additional areas that are being researched that may provide opportunities for further optimization and overall improvement of the RSM's performance. Most fall under the architectural design of the model's code. Potential areas for improvement are the memory and disk management schemes. Use of technologies such as shared memory or RAM disks could provide potential improvements in data throughput, particularly for situations that require concurrent model runs. Common data may be stored in a medium that is faster than disk and potentially even available across a fast network. This reduces that amount of secondary storage required for model runs and the level of disk access, which is traditionally known to be a major performance bottleneck in software.

Another area for potential optimization may include the more extensive use of threading technology. This could provide the ability to divide and conquer certain areas of the models code where parallelization may be applicable and may yield improved runtimes. From the technological standpoint, it is the goal of the development team to migrate the technologies utilized with the current pre and post processing tools to a commonly available open source standard. This would eventually allow users to effectively run the RSM and its ancillary tools without the need for proprietary software.

2.5. Goal 5: Usefulness of Model Documentation

(see also issue response forms #39-54 in Appendix B)

The panel discussed model documentation under three main points:
1) organization and content,
2) Hydrologic Process Modules, and
3) needs for additional material

Under the heading "HSE Theory and Concepts", a minor issue of notation was raised. We agree to the use of consistent notation in representing the volumetric flux and **E** will be replaced by **V** in all instances.

Organization and Content of RSM Documentation

One major concern noted (pages 14-15, line 1) was that the RSM model documentation is lacking in organization. We regret that the documentation was not more polished and complete at the commencement of the peer review, and have laid out plans to improve the full document set. This plan was shown at the workshop, but due to time constraints, was not discussed in detail. In response to peer review comments, the proposed RSM Document Set now consists of overview materials, technical reference, user manuals, implementation application reports, and background materials, as shown in Table 3.

Table 3. Proposed RSM Document Set

Category	Volume	Existing, Final	Existing, Requires Changes	Proposed
Overview Materials	RSM Fact Sheet			X
Technical Reference Manuals	RSM Theory Manual		X	
	RSM Verification Tests			X
	RSM Benchmark Guide		X	
	Guidelines for Managing Numerical Error			X
User Manuals	HSE User Manual		X	
	MSE User Manual		X	
	RSM Tutorial/Training Guide			X
Implementation Applications	Loxahatchee Watershed Report	X		
	Southern Everglades Model Report	X		
	South Miami-Dade Report	X		
	South Florida Regional Simulation Model (SFRSM)			X
	Natural Systems Regional Simulation Model (NSRSM)			X
Background Materials	RSM XML Primer		X	
	RSM Peer Review Report		X	
	RSM Bibliography		X	

Further explanation of how specific peer review comments on document organization and content will be addressed in the proposed documentation follows.

- A "Purpose and Scope" section will be included in the introduction to the RSM Theory Manual and a "RSM Fact Sheet", which provides an overview of the model, listing its major features, constraints, assumptions, and appropriate model applications.
- Hydrologic Process Modules (HPMs) are a component of the HSE, and we introduced the HPM concept in the HSE Theory and Concepts chapter of the RSM Theory Manual, with details provided in Appendix C.5 of the same manual. We agree that the importance and uniqueness of HPMs warrants that they be treated in a separate chapter instead of in an appendix, and this change will be made.
- During our early drafts, several sections of the RSM Theory Manual were removed from the Introduction and placed in Appendix A. These sections provide insight into our model development philosophy and process, but we feel that they are not vital to the model, and therefore should not be moved back into the Introduction chapter. They may be more useful as background information in a model developer's guide, which we may develop at some point in the future. They will either be left as is or removed entirely.
- Chapter 2 of the RSM Theory Manual covers the major theoretical conceptual framework of the HSE, focusing on the object-oriented approach. Early drafts started this chapter with a discussion of the traditional approach, but we moved it to Appendix B of the RSM Theory Manual, as it is not vital to the model. It is included to assist modelers accustomed to the traditional approach in making the transition to the object-oriented approach. We feel that the discussion is not vital to the model, and therefore should not be moved back into the Theory and Concepts chapter. It will either be left as is or removed entirely.
- We agree that the RSM Theory Manual's Appendices C.1, C.2, C.3, and C.4, which are four refereed journal articles, should be removed from the appendices and appropriate content incorporated into the appropriate chapters. They were placed in the Appendices for the convenience of the peer review panel since the content had not yet been combined. Model verification examples will be excerpted from these publications as appropriate.
- We agree that the LaTeX default name of "Bibliography" should be changed to "References" in the RSM Theory Manual. We have not yet learned how to override this default so that our "References" section can be appropriately named.
- As mentioned above, the HPM White Paper will be incorporated into a separate chapter of the RSM Theory Manual.
- MSE details presently found in the MSE White Paper, included as Appendix C.6, will be incorporated into the MSE Theory and Concepts chapter to provide greater detail. We intend to continually improve the quality of the graphics and figures to show the interactions between the HSE and MSE components of the RSM.
- The comparative analysis of RSM and other models will be revisited when the document is revised.
- The final RSM Theory Manual will be rendered using one consistent software package (LaTeX), with version control provided through CVS software.

- We intend to add a glossary and an index to the RSM Theory Manual, so that terms can be consistently applied, more easily understood, and cross-checked for accuracy. The glossary will include a list of symbols and variables used in the equations.
- Units will be double-checked for consistency across all equations. We agree to refer to units as SI instead of metric and US Customary instead of English.
- Peer Review suggestions have been considered and we now proposed a set of technical reference manuals, user manuals, implementation application reports, and other background materials (see Table 3).

Hydrologic Process Modules

Another major concern (page 16, lines 4-18) deals with documentation of the HPM validation. Since we have not yet completed the HPM validation, we have not reformatted the documentation to insert it. Details on recommendations for documentation of the HPM parameters can be found in the discussion of issue #41 of Appendix B. HPM validation plans are discussed in Section 2.7 of this document.

Most of the remaining comments in section 6.3 of the Peer Review Panel Draft Report were very specific and constructive and will assist in improving the overall quality of the documentation. Detailed responses can be found in Appendix B for the individual issues #42-48. They are summarized here:

HPM <unsat>, page 16, lines 22-26. We agree that the text and graphics in this section are confusing. The control volume graphic will be corrected to reflect water table depth and additional text will be added to better describe the reference elevations, and to describe the HPM assumptions and the conditions under which this HPM should be applied. See more details in the discussion of issue #42 of Appendix B.

HPM <layer5>, page 16, lines 30-31. Individual HPM objects have been described using terminology common to the source code for that specific object. That source code has come from other scientists, and is not consistent. The inconsistency in terminology across HPMs was intentional, in order to facilitate the understanding of the individual HPMs. We agree to revise the HPM documentation to be consistent across HPMs, and to provide crosswalk information to document original terminology. See more details in the discussion of issue #43 of Appendix B.

HPM <prr>, pages 16-17, lines 35-44, 1-5. Guidance for the selection of parameter values for PRR as well as other HPMs is provided in the HSE User Manual. Additional information will be included in the HSE User Manual to improve the parameter selection methods. See more details in the discussion of issue #44 of Appendix B.

HPM <pumpedditch>, page 17, lines 9-25. Instead of inches per day, we will use cubic feet per second (CFS) to express maximum pumping rates. Inconsistencies in Appendix C.5 of the RSM Theory Manual (HPM Overview) Table 6 definitions will also be corrected. See more details in the discussion of issue #45 of Appendix B.

HPM <agimp>, page 17, lines 29-39. Additional guidance will be provided in the HSE User Manual for estimation of available soil storage, denoted by S. The weir equations will be more fully described, including units of the variables, and several errors introduced during conversion from U.S. to S.I. units will be converted back to U.S. Customary units, and values in all HPM tables will be checked. See more details in the discussion of issue #46 of Appendix B.

HPM <mbrcell>, pages 17-18, lines 43-46, 1-2. Many of the HPM parameters are generated using a Geographic Information System (GIS) pre-processor. The GIS pre-processor is described in the HSE User Manual. The discussion of the algorithms for calculating the parameter values will be expanded to provide more detailed information. See more details in the discussion of issue #47 of Appendix B.

HPM <cu>, page 18, line 6. The parameter for the "septic" variable is actually a switch, not a numerical value. This will be clarified in Table 5.25 in the HSE User Manual. See more details in the discussion of issue #48 of Appendix B.

Need for Additional Documentation

Another concern noted by the panel (pages 18-19, lines 8-46, 1-18) was that a variety of additional information should be added to the RSM documentation. Again, the comments in section 6.4 of the Peer Review Panel Draft Report were very specific and constructive and will assist in improving the overall quality of the documentation. Detailed responses can be found in Appendix B for the individual issues 49-54. They are summarized here:

- **Numerical Error**, page 18, lines 10-18. The fact that numerical errors were analyzed should not imply that numerical errors are specific to the RSM. RSM is no different from other models, but the developers presented ways to avoid or manage the numerical errors in Chapter 1 of the RSM Theory Manual. See more details in the discussion of issue #49 of Appendix B. Because such a large volume of research has been done in this area, we propose adding a document called "Guidelines for Managing Numerical Error" to the RSM Documentation Set. This document will collect the information from published papers and provide a more specific discussion of model uncertainty and numerical error.
- **Model Assumptions**, page 18, lines 20-29. Assumptions behind the governing equations and the diffusion flow formulation are stated on page 21 of the RSM Theory Manual, and detailed in Lal (1998b). See more details in the discussion of issue #50 of Appendix B.
- **Verification Test/Documentation**, page 18, lines 31-37. As mentioned in Section 2, individual objects and components of the RSM have been individually tested. These have been (and will be) documented in a variety of ways—as benchmarks in the RSM Benchmark Guide, as verification tests in published papers, in the proposed RSM Verification Tests section of the RSM Technical Reference Manuals, and in future test bed documentation.

  A number of benchmarks have been constructed, which are used to test that the RSM behaves properly after each new feature is added to the model. A RSM Benchmark Guide has been written listing the current set of 59 benchmarks and the features they test. This manual will be revised as new benchmarks are added. In addition, the manual is currently available only on-line (available on the peer review website). We intend to auto-generate a hard copy of this manual so that benchmarks can be added as needed, and will be incorporated consistently when the manual is recompiled.

  Verification tests that have been completed and published, as well as tests that are unpublished, will be assembled in the proposed RSM Verification Tests section of the RSM Technical Reference Manuals. We are also constructing additional verification tests which will be carried out in the next year. As these tests are completed, they will be added to the list of tests. The list may be divided into groundwater tests, surface water tests, groundwater/surface water interaction tests, and HPM tests, as the panel has proposed, depending on the number of tests that are complete when documentation is updated.

As discussed at the workshop, a number of RSM Test Beds have been constructed. Documentation for these test beds is scattered and inconsistent. We are proposing a standard format for documenting each future test bed. The format will consist of:

- Purpose of test bed
- Extent and functions tested
- Defined scenarios
- Scenario results
- XML input files
- Appropriate output

See details in the discussion of issue #51 of Appendix B.

- **Numerical Techniques**, page 18, lines 39-41. RSM is based on a simple diffusion flow algorithm that has been described for rectangular meshes in a number of places, and triangular meshes in Lal (1998b). As mentioned above, sections of this paper will be excerpted and incorporated into the HSE Theory and Concepts chapter. Methods associated with assembling models of this magnitude are explained in texts such as Zienkiewicz et al. (2000). This reference will be added to the documentation.

- **Figures and background information**, pages 18-19, lines 43-46, 1-13. The RSM is intended to be a generic model that can be implemented in any geographic region. Obviously, the primary features we have developed to date have been ones useful to south Florida regional modeling. We may move information specific to south Florida to implementation and application documents, rather than keeping it in the RSM Theory Manual Introduction. It is also important to more clearly delineate between model development and model implementation features, and maintaining a consistent set of implementation-specific documents may help to distinguish between them. There will be an RSM Fact Sheet that describes the generic strengths and weaknesses of the model for application in other locations.

  We intend to provide three forms of documentation for each RSM implementation. First, there will be a Fact Sheet for the implementation. Second, the calibration/verification/ validation results for the implementation will be presented in a standard format. Third, if the implementation is peer-reviewed, the Peer Review Report will be published. We are currently building two regional RSM implementations, the South Florida Regional Simulation Model (SFRSM) and the Natural System Regional Simulation Model (NSRSM). The format for their documents will be finalized over the next six months. See more details in the discussion of issue #53 of Appendix B.

- **Editorial Comments/Technical Editor**, page 19, lines 15-18. We agree that a technical editor is needed to work on the RSM Documentation Set. We presented a draft document revision plan at the workshop, detailing a schedule of work for a contractual employee slated to be brought on board beginning with our new fiscal year on October 1, 2005.

The peer review panel flagged numerous typographical errors in the RSM Theory Manual, which have been reviewed and flagged for correction in the document; they are listed individually in the matrix in Appendix II of the Peer Review Panel Draft Report.

See more details in the discussion of issue #54 of Appendix B.

2.6. Goal 6: Additional Tests to Validate (Verify) RSM

(see also issue response forms #49, 55-59 in Appendix B)

Issues identified by the Peer Review Panel under the goal of suggesting additional tests to further validate RSM can be grouped into comments related to verification and comments related to validation. For clarity these terms as applied in this response are defined:

Verification

Is *the process used to determine if generic code accurately solves the mathematical equations that describe the basic processes of the physical system.*

Validation

Is *the process of applying the model to determine if it captures the physical phenomena with adequate fidelity.*

Peer review panel comments related to verification included the need for systematic benchmarking, verification comparison with analytical solutions or other numerical models and sensitivity tests to determine the impact of time lag on model predictions.

Comments from the panel relative to validation included the need for a validation procedure to account for numerical, physical parameter and input data errors. It was suggested that acceptable ranges of physical calibration parameters be specified or that these parameters be unconstrained. It was also suggested that a range of flow conditions be accounted for by using three-stage (low, average, and high) parameter calibration.

Verification, Benchmarking, and Sensitivity Analysis

RSM code verification has included comparisons of numerical solutions with analytical solutions, comparisons of model error with analytical estimates of model error, and methods of determining optimum discretization. This has been documented in refereed journal articles by Lal (2000; 2005; 2005a) and included as part of the RSM Theory Manual. Verification tests carried out during the development of RSM are summarized in Table 2 in Section 2.1 on the Sound Scientific Approach. The Peer Review Panel suggestion that nine HSE verification tests including surface water, groundwater and coupled surface-groundwater tests be undertaken and documented. As documented in Table 2 (Section 2.1) approximately five surface, six groundwater and one coupled flow verification test have already been undertaken and documented for the HSE. These and possibly other tests will be included as part of our proposed improved document set.

A sensitivity test to determine the impact of time lag (use of previous time step head value and matrix) on model predictions has already been conducted but is not documented. As a result of the test it was determined that the small improvement in accuracy gained by using the previous time step is not worth the extra computational effort related to updating the matrix. Further time lag tests may be undertaken in the future.

Validation and Parameter Calibration

The importance of identifying the three sources of error: numerical errors, parameter estimation error and data errors is recognized. As pointed out by the review panel numerical errors can be further split into round-off and truncation errors.

In developing the RSM, numerical errors have been analyzed and the effects of model discretization on numerical errors have been considered. Judicious choice of grid resolution and time step can minimize numerical errors (Lal, 2000). Numerical errors caused by round off and/or truncation have been verified using analytical methods (Lal, 2000, 2005, 2005a).

Physical errors, attributed to inaccurate parameter estimation uncertainty, can be minimized by the proper choice of parameter values during model calibration. Parameter error will be limited by using acceptable parameter ranges for SFRSM calibration. The importance of data-quality errors cannot be overemphasized and considerable time and effort has been invested in checking physical field data, against which the SFRSM implementation will be calibrated. Even so, errors that are traceable to limited or poor data quality can often be assessed only in a qualitative way. Tools for automatic calibration and parameter estimation analysis (SVD, LSQ, and optimization) and PEST are being used (Lal, 1995). These tools allow for optimal parameter estimation subject to upper and lower bounds or constraints on the parameters. Relative weighting of data at observed stations can be used in autocalibration to minimize the effect of poor quality data. Consideration is being paid to the panel suggestion of undertaking three-stage calibration (i.e., low, average, and high) to account for inherent nonlinearity of surface flow behavior.

Lessons learned from previous RSM application to the natural system (Lal et al., 1997) will be incorporated in the current SFRSM calibration and verification. For example, Lal et al. (1997) conducted a sensitivity and uncertainty estimation of lumped and distributed parameters using the first order method, Rosenblueth method, and Latin Hypercube sampling (LHS) method. In addition, Singular Value Decomposition was used to determine possible grouping of parameters. Standard validation procedures including minimizing numerical errors, calibrating using acceptable values of physical parameters and assessment of the physical data, similar to previous work (Lal, 2000 and Lal, 2005) will also be followed for SFRSM implementation.

2.7. Goal 7: Recommendations for Tests to Validate (Verify) HPMs

(see also issue response form #60 in Appendix B)

The Panel raised several issues associated with the formulation and development of HPMs and the need for further validation of the documented HPMs. The responses to these issues are summarized in this section and presented in detail in the issues section (see issue #60, Appendix B).

A principle concern of the Panel was the lack of evidence for the validation of HPMs. The HPM Overview document (Appendix C.5 of the RSM Theory Manual) was developed to provide the governing equations for the HPMs and simple implementation of each HPM. The document was not intended to be a comprehensive reference manual for the HPMs. As such, documentation of HPM development was not included.

Individual HPMs were developed to simulate the local hydrology and landscape water management to provide the appropriate demand and runoff for the regional water management simulations. These HPMs provide a set of modules for simulating the standard processes commonly accepted for local hydrologic processes. The HPMs were based on field studies and previous models, which is discussed on more detail in issue #41, Appendix B. The HPMs are expected to simulate the effective, or representative, field-scale processes to such a degree that typical water and land management decisions affecting local water management can be implemented. However, HPMs are not currently expected to accurately simulate site-specific behavior such as percolation and soil water redistribution, only the effective results of those processes at a field or small watershed scale.

The current set of HPMs has been demonstrated through previous model implementations, including the SFWMM, to provide adequate simulation of local hydrology. In particular, HPMs based on AFSIRS and SWMM have been shown to simulate the hydrology of landscapes in southeast Florida. Furthermore, the District is working with private consultants, USDA and universities to develop additional HPMs to better model the agricultural areas of south Miami-Dade and the Everglades Agricultural Area (EAA). For the purpose of evaluating the acceptance of HPMs for simulating local hydrology, HPM verification and validation and will be included in future revisions to RSM documentation.

Verification tests proposed to validate and verify the behavior of each HPM under different conditions include:

1. Sensitivity analysis and parameter range assessments,
2. Comparison of results among HPMs,
3. Comparison to other models,
4. Comparison to analytical solutions where applicable and
5. Comparison to field data.

Validation of the HPMs, including development of soil and land cover parameter values, would be greatly improved by the acquisition and application of field data collected from both site specific process investigations and small watershed hydrologic studies, such as the data collected by Chin and Patterson (2005).

2.8. Goal 8: Suitability for Meeting Client Goals

(see also issue response forms #61-62 in Appendix B)

District staff agrees with the reviewers' comments that client goals need to have clear documentation of all model assumptions, algorithms and appropriate applications. The proposed document set that will contribute significantly towards meeting client needs has been more fully discussed in Section 2.5 of this response document. Default parameter values and appropriate ranges of values that have already been presented in the HSE User Manual will be expanded as further testing is conducted. As the MSE User Manual is finalized, default parameter values and appropriate ranges of values will be added.

The RSM team is making excellent progress on development of a user-friendly graphical user interface. This has been demonstrated in several forums since the Peer Review Panel on-site workshop. Tutorials and training material will be assembled and made available to clients. The post processing GUI is being developed using open source software in order to be able to distribute the GUI with the model to clients and users.

Positive recognition by the review panel of the efforts that the development team is taking to solicit input from District users is appreciated. Once the model is satisfactorily calibrated, efforts will turn to ensuring the needs of non-District clients are met in developing performance measures to meet appropriate use requirements.

3.0. Summary and Conclusions

The Peer Review Panel has provided many useful suggestions and recommendations that will help improve the overall quality of the Regional Simulation Model. The District has carefully considered each comment and responded to them in sections that correspond to each of the eight main goals of the peer review. More detailed discussion of issues raised by the peer review panel is presented in individual numbered responses which include action plans to fully address the issues. The major recommendations from the Peer Review Panel Draft Report Summary and Recommendations Section are summarized in *italics* below, each followed by a response conclusion.

The need for better organized, more complete documentation that includes full descriptions of the model algorithms, assumptions and verification tests was recommended.

Although extensive documentation was provided, District staff agrees that overall documentation needs to be improved and has laid out an improved proposed documentation set. This documentation will greatly enhance the understandability and defensibility of the RSM and better meet our client needs.

Recommendations on the scientific approach and conceptual framework included suggestions to address the assumption of isotropy and consider including wind stress, rainfall and evapotranspiration algorithms within the RSM. It was recommended that the canal seepage watermover be based on reach transmissivity rather than sediment layer conductivity. Several issues related to the formulation and development of HPMs were raised, including the need to check the consistency of and validate specific HPMs. The role of the MSE was unclear to the review panel.

The RSM has been designed primarily to provide a replacement for the South Florida Water Management Model (SFWMM). The first step in this effort is to ensure that the RSM provides regional functionality similar to that of the SFWMM. Simulating anisotropic conditions under the continuum assumption is not within the scope of the RSM at this stage although in the future, transmissivity and conveyance could be implemented through the use of a tensor representation of the transmissivity and conductance parameters. Wind shear effects have been simulated in south Florida using more detailed and site specific models with boundary conditions to these models provided by regional models. We intend to continue this approach with the RSM, which should be able to provide adequate boundary conditions to more detailed models that include wind stress effects.

For consistency with other models implemented by the SFWMD, calculation of rainfall and potential evapotranspiration was intentionally left as an input to the RSM. Actual evapotranspiration is determined within the RSM.

We believe that separate modifications on the canal seepage equations are not applicable in RSM because the formulations are different.

Most of the comments related to Hydrologic Process Modules were very specific and constructive and will be used to improve the overall quality of the HPMs. The current set of HPMs has been demonstrated through previous model implementations to provide adequate simulation of local hydrology. For the purpose of evaluating the acceptance of HPMs for simulating local hydrology HPM verification and validation will be included in future revisions to RSM documentation.

The MSE continues to evolve and has not reached the same level of maturity as the HSE. Hydraulic structures can already be operated in accordance with the MSE algorithms, however, challenges to capture the fine timescale control of actual hydraulic structure operations are still being addressed. Comprehensive documentation will become available as MSE features are developed and interactions with the HSE are fully defined.

Panel suggestions to improve numerical and overall model efficiency included the use of an explicit solution, sub-matrix solution, decoupling of surface and groundwater solutions, dynamic time steps, and the use of recent developments in GMS, PEST and XMDF software.

Various levels of semi-implicit implementations have already been investigated (Lal, 1998b, 2000). However, their potential benefits will be further investigated later in detail. Concerns expressed by reviewers regarding unnecessary flow computations are for the most part overcome by the fact that the RSM uses a very fast external solver (PetSc), which includes smart adaptive algorithms and produces numerical solution times similar to those of uncoupled models. Although dynamic time steps can be investigated as a possible future enhancement, it is believed that dynamically variable time steps would not benefit the RSM as much. The PetSc solver already has fewer iterations with very fast solution during the dry season, and slower (more iterations) solution under ponded conditions. Use of the latest versions of GMS and PEST will be considered. The team is currently researching expanding RSM functionality to include different formats including HDF5 and XMDF to assess potential performance improvements.

Dynamically variable time steps are critical, especially if the model is explicit, required to meet a stability criterion, or if the model is unstable with large time steps for some other reason. Prior to PetSc, when using the SLAP (Lawrence Livermore lab solver), the second condition was true, and dynamic time steps were used to make the model stable. Neither of these conditions apply with RSM. Selection of the daily time step was initially prompted by the daily data availability, and later by the fact that regional models simulating long periods cannot afford very small time steps for performance reasons. It should be recognized that a fixed daily time step can only capture solutions of certain specific known resolutions or lower.

Recommendations relative to the application of the RSM to south Florida, the diffusion-wave approach and consideration of land use changes during the period of simulation.

To demonstrate the applicability of the diffusive-wave approach, District staff plans to devise a benchmark to investigate the impact of the full dynamic-wave equation versus the diffusive-wave equation. Furthermore, for model implementation in domains with dominant dynamic terms such as tidal or coastal areas, results will be masked and precluded from output analysis and stage matching during calibration. This approach is preferred to the alternative of excluding the tidal zone completely from the computation domain due to the lack of data to use as a boundary condition at the land rim of the tidal zone.

The RSM was originally envisioned to simulate hydrologic responses in a static system configuration rather than as a succession model. Dynamic physical attributes, both natural and man-made, may be significant for multi-decadal simulations and can be included in future versions of the model.

All peer review panel recommendations have been carefully considered. In most cases the District agrees with the panel recommendations and have either already addressed the concerns or have action plans (Appendix B) to fully address the issue. In cases where our opinion differs from those of the panel we have explained our opinion in the issue responses. The peer review panel has an opportunity to revise their final document based on this response. It is hoped that the panel will find that the District has adequately addressed, or provided adequate assurance that they will address, all of the important issues and concerns raised by the panel. The District understands the immense effort that this peer review has taken and is very grateful to the peer review panel for their time and professional candid comments. The Regional Simulation Model will be greatly improved as a result of this effort.

Appendix A: Statement of Work for Part I of III Scientific Peer Review of the RSM

Office of Modeling
Statement of Work (SOW)
for Part I of III Scientific Peer Review of the Hydrologic Simulation Engine (HSE) and Management Simulation Engine (MSE) of the Regional Simulation Model (RSM)

Project Manager:	Wasantha Lal, Lead Engineer
Requesting Office:	Office of Modeling (OoM)
Project Name:	Independent Scientific Peer Review of Version 2.2.9 of the Hydrologic Simulation Engine (HSE) and Management Simulation Engine (MSE) of the Regional Simulation Model (RSM)
Date:	May 16, 2005

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Statement of Work Summary

This Statement of Work (SOW) defines services to perform Part I of III of a scientific peer review on the Regional Simulation Model (RSM) theory, including the Hydrologic Simulation Engine (HSE) and the Management Simulation Engine (MSE) components. The Part II peer review will occur in 2005 and will focus on the Natural Systems Regional Simulation Model (NSRSM) implementation validation, and Part III peer review will begin in late 2005 and will focus on the South Florida Regional Simulation Model (SFRSM) implementation calibration. This work will be detailed in separate SOWs.

RSM has been created and is maintained by the South Florida Water Management District (SFWMD) in West Palm Beach, Florida. This model is a new generation computational tool that can be used to simulate a wide variety of hydrologic situations. As part of the development life cycle of this model, a scientific panel of experts will be chosen to evaluate and scrutinize the theoretical and the conceptual formulations and to examine the documentation and the papers that have been published which contain further information on the theoretical foundations of the model. The purpose of this work is to improve the overall quality of the RSM by identifying the strengths, weaknesses, and limitations in the model theory and conceptual formulation.

The panelists' scope of work shall consist of the tasks specified in section 3. These tasks include:

1. Reading the RSM Theory Manual, journal and conference papers, and white papers.
2. Preparing questions or editorial comments on this information prior to the interactive planning and training session in West Palm Beach.
3. Participating in the interactive planning and training session during June 22-24 2005, in West Palm Beach, Florida.
4. Assisting in the organization and development of a draft panel report.
5. Writing the final panel report after receiving comments from the District on the draft report.

1.0 Introduction

By December 2005, the SFWMD (aka "the District") will complete a two-year project of finalizing numerical model development (the RSM) and an initial regional model implementation for South Florida. This implementation is titled the South Florida Regional Simulation Model (SFRSM).

The numerical model code used to solve the SFRSM implementation has been under development for approximately ten years. This model code is titled the Regional Simulation Model (RSM) and is currently composed of two principal components that include the Hydrologic Simulation Engine (HSE) and the Management Simulation Engine (MSE). The HSE and MSE are coupled within the RSM C++ object-oriented code and do not exist as separate models. User input dictates if MSE components are used in conjunction with an HSE simulation. At this time, the RSM model is running only on the Red Hat Linux 9.0 platform, while pre- and post-processing codes run on both the Linux and Windows platforms.

The HSE simulates the coupled movement and distribution of groundwater and surface water throughout the model domain. With significant testing completed, the HSE source code is now considered to be in maintenance mode. The less-mature MSE provides methods that can simulate operational decisions and/or alternative management decisions for the regional water distribution system. Although the MSE is undergoing development at this time and is less mature than the HSE, it will be included in this peer review. The project scope and goals of the RSM Development and Implementation Project are discussed below, followed by a discussion of the peer review goals.

1.1 RSM Project Scope

The scope of the RSM Development and Implementation Project is to develop a flexible and powerful numerical model that can be used to accurately simulate a natural hydrologic system on a regional scale, including the effects of the water control structures present in South Florida. The HSE is capable of simulating the natural hydrologic system effectively, whereas new code is still being written for the MSE to simulate the management of man-made water control structures.

During the past year, an initial technical review of the HSE was completed by the Jacobs Engineering Center of Modeling Excellence in Oak Ridge, TN. This review evaluated the governing equations and numerical approximations used to simulate all hydrologic objects in the model. The review also developed additional documentation for the model, and performed some numerical testing of the HSE. This work was completed partially to prepare the HSE for external peer review. One of the goals of this work was to identify possible deficiencies in the theory and formulation of the RSM. Results and technical information from this review can be accessed on-line at the RSM Peer Review web site.[1]

The RSM is a regional model that will be used to predict the hydrologic responses to planning and operational scenarios while considering competing water management priorities and issues. This model represents the next generation of integrated water management modeling and provides the ability to simulate the complexity of the South Florida hydrologic system and is necessary to support decision-making processes well into the future.

1.2 RSM Model Components

The RSM is composed of several parts. The two main parts are:

- The Hydrologic Simulation Engine (**HSE**), which simulates the hydrology of the modeled area, including the canals, structures, levees and other barriers to flow.

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[1] http://gwmftp.jacobs.com/Peer_Review/web_page/peer_review_sfwmd.htm

- The Management Simulation Engine (**MSE**), which simulates different operational heuristics and regulation schedules to give water managers a decision making tool for planning, water management and operation of the water resources system.

The RSM "toolbox" also includes tools still under development (and therefore not part of this review), such as:

- The Graphical User Interface (**GUI**), which provides a simple, easy to use tool for setting up a model run and providing a mechanism to view results graphically, as well as providing a mechanism for batch processing sensitivity runs.
- A **Geodatabase**, which provides a convenient storage and retrieval facility of spatial data for the modeled area. This is especially useful in model domains with many thousands of cells, as input dataset updates can be automated as spatial data changes.

1.3 RSM Project Goals

One of the primary goals of the RSM is that it must be both flexible and adaptable to changing conditions within South Florida. With the expansive planned changes to the South Florida basins under the Comprehensive Everglades Restoration Plan (CERP) and new water supply strategies, it is necessary to develop a model that can be adapted to simulate whatever new conditions develop. It is imperative that this model be easier to use than the existing water management model, South Florida Water Management Model (SFWMM), with shorter learning curves and improved documentation and examples. The object-oriented design of the RSM allows an implementation to consist of an assembly of different water management objects that can be interchanged as the model evolves. There will be no hard-wiring of site or operational conditions within the RSM or its implementations to allow maximum flexibility in model application. The following provides a list of the primary hydrologic processes that can be modeled in the RSM:

- Two-dimensional overland flow over arbitrary water bodies.
- Two-dimensional or three-dimensional groundwater flow coupled to surface water bodies.
- One-dimensional diffusion flow in canal networks.
- Independent layouts of 2-D meshes and 1-D flow networks overlapping fully or partially. The model can be used to simulate overland flow, canal flow, lake flow or any combination of them. The model is fully integrated, and all the equations for regional flow are solved simultaneously.
- Constant or variable storage coefficients that can describe soil storage capacity varying with depth. The variation can be described using lookup tables.

- Various overland flow conveyance behaviors based on Manning's equations, wetland flow equations and look-up table type functions with values varying with depth.
- Various transmissivity functions for confined and unconfined aquifers including lookup table type functions with values changing with depth.
- Reservoirs, or large water bodies, in full interaction with aquifers.
- Ponds or small water bodies residing within meshes but in full interaction.
- Many common types of structures, weirs, pipes, bridges etc. with more than one flow regime. All the structure types used in National Weather Service (NWS) models and the CASCADE model are available for use. Some of the USACE models are available as well.
- Virtual water movers based on 1-D, 2-D, or water level difference based lookup table functions. These water movers can move water from any water body to any other water body controlled by state variables in a third water body. A lookup table is used as a mapping function. A number of pumping and flood control conditions can be simulated using these lookup tables.
- Full three-dimensional simulation of groundwater flow, with any number of layers. Different numbers of layers can cover different parts of the horizontal domain.
- Water budget features that can track the movement of water throughout the model.
- A feature known as Hydrologic Process Modules (HPMs) that can capture a wide variety of local hydrologic functions associated with urban and natural land use, agricultural management practices, irrigation practices, and routing.
- Features capable of simulating detention storage and unsaturated moisture within HPMs.

To achieve these project goals, the RSM computational engines need to be peer-reviewed by subject matter experts. The peer reviewers will try to identify the strengths, weaknesses, and necessary enhancements in the model conceptualization/formulation and in the software implementation.

2.0 Peer Review Panelist Expectations and Guidelines

The objective of this work is to perform a peer review and to improve the overall quality of the RSM. This will be accomplished by a scientific panel of subject matter experts in the relevant topics described in Section 2.1. This review will consider the conceptual and mathematical framework of the model and the prospects for successful applications of the model.

The peer review panelists will be chosen by Jacobs Engineering from a list of qualified candidates that have appropriate education and experience in the topics listed in section 2.1. Jacobs Engineering is assisting the SFWMD in conducting the peer review and will fulfill a role of unbiased and independent facilitators of the review. Jacobs Engineering has been chosen for this role because they are familiar with the model after having completed the preliminary technical review of the code. Jacobs has not been on the development team for RSM and therefore does not have any conflict of interest in this peer review.

All panelists will receive a fixed-price honorarium for their participation on the review panel. From this panel, one individual will be selected as the chairperson, to be a single point of contact between Jacobs and the panel. The chairperson will have additional duties compared to normal panel members and will therefore receive a larger honorarium. It is anticipated that each panelist will have areas of expertise that will be utilized to more fully evaluate specific parts of the RSM. The panel as a group will evaluate the entire model but certain sections of it will be scrutinized in more detail by individuals specializing in that subject matter. Each panelist will be assigned certain responsibilities by the chair during the on-site interactive planning and training session (IPTS).

All panelists will be expected to attend a two-day on-site interactive planning and training session (IPTS) in West Palm Beach, Florida, in June 2005. This session will help the panelists gain a better understanding of the RSM, its capabilities, and its existing applications. The panelists are expected to collectively define additional, specific goals of the peer review. These specific goals will include assigning topics for each panelist to evaluate more thoroughly. It will be expected that once individuals have been selected to the panel and have accepted their position, they will begin studying the model documentation to prepare themselves for the IPTS that will occur after the panel is finalized.

During the IPTS, RSM demonstrations will be provided to educate the panelists. Topics to be covered may include the theoretical basis for the HSE and MSE, model XML input and output, site-specific model assembly, discussions of benchmarks, and an overview of the printed and internet model documentation. The training sessions will be conducted by RSM developers and implementation specialists so that the panelists can have access to the people responsible for developing and using RSM. To maximize the benefit of the IPTS, all panelists should be prepared to take notes and ask questions about RSM.

The SFWMD has organized the peer review process in accordance with typical scientific review practices. Care will be taken by Jacobs Engineering in selecting the panel members to assure that reviewers are independent of the District. Panelists should have no substantial personal or professional relationship with the District. The panel can therefore be reasonably assumed to be objective in evaluating materials presented in the model and documentation. Such objectivity is the cornerstone of any true peer review process.

Panel review, as opposed to review by individual experts, is done by a group which reviews the model and documentation independently and then interacts with one another to formulate opinions on the state of the model. The panel will collaborate to author recommendations and proposed changes to the model and/or documentation. Based on this collaboration, a draft report to the District will be prepared so that the RSM development team can respond and comment on the panel's findings. The panel chair will then write a final report incorporating District responses and the panel's final conclusions.

This Statement of Work will serve as the task instructions for the panel until the IPTS. Any questions need to be submitted in writing to Jacobs, and no private discussion between panel members is allowed before the IPTS. The Peer Review Panel will communicate initially during the IPTS. Subsequent to this meeting, a web board will be used as the only medium for the panelists to exchange questions and comments and to document their progress. This web board will allow panel interactions to be conducted in accordance with Florida 'government in the sunshine' statutes. Jacobs Engineering will provide a set of instructions for using the web board at the IPTS. The public can stay informed by reviewing the RSM Peer Review web site[2] and may wish to interact with the panel throughout the peer review process.

2.1 Peer Reviewer Areas of Expertise Requested

People selected to be peer review panelists must have demonstrated education and experience in one or more of the following areas:

- Surface water modeling, with 2D overland flow
- Watershed modeling
- Numerical simulation of coupled surface water and groundwater systems;
- Numerical techniques (including the finite volume method) used to simulate flow within and between natural and man-made objects such as lakes, canals, dams, weirs, pumping wells, etc;
- Local hydrology modeling
- Model applications that simulate water flow in flat-lying topographic settings, which are similar to conditions that exist in South Florida;
- Application of regional models for the purposes of water resources management and planning, water supply allocation, flood prevention, drought management, environmental restoration, and local-scale (sub-regional) model boundary condition specifications,
- Optimization methods, control theory, adaptive and feedback control, and other methods that can be used in operational control and water management.
- A working knowledge or familiarity with the following computer software and data storage methods: Linux, XML, C++, Python, GMS, DSS, and NetCDF files.

Additional expertise is beneficial in the following areas: auto-calibration techniques, calibration of regional models, numerical model error analysis, and innovative model post-processing techniques.

[2] http://gwmftp.jacobs.com/Peer_Review/web_page/peer_review_sfwmd.htm

2.2 Peer Review Goals

Although the peer review panelists will be instrumental in expanding the goals of the review during the IPTS, several peer review goals have already been determined. The focus of the review is on finding strengths, weaknesses, and possible applications. Recommendations for resolving clearly defined problems are desired. These goals include:

1. Determining if proper and sound scientific approaches were used in the development of RSM, making sure that a self-correcting open process is in place;
2. Evaluating if the conceptual framework of the model contains all of the important hydrological processes necessary to do regional scale modeling in South Florida;
3. Determining the appropriate use of the model in South Florida conditions;
4. Making suggestions on modifications and future improvements to the model, including any suggestions for improved computational methods, and future model expansion ideas;
5. Making suggestions on the usefulness of the model documentation, including whether the level of detail is sufficient or more is needed, whether the conceptual framework is clear, etc.
6. Suggesting any additional tests that may be desired to further validate RSM;
7. Suggesting tests for the HPM approach to simulating local hydrology and making recommendations for improvement or expansion of the approach; and
8. Evaluating whether the model is suitable for meeting client goals.

2.3 Anticipated Benefits

The final collaborative peer review report will guide the SFWMD modeling group toward a higher quality model that is scientifically defensible, more reliable, and easier to use and maintain. Benefits likely to result from the peer review process are:

- Confirmation on the use of the governing equations and the theoretical foundation used in RSM to be appropriate for South Florida conditions and the SFWMD mission.
- Confirmation on the use of RSM as a framework for regional model implementation at SFWMD.
- Better documentation, making the model easier to understand and modify.
- Development of an open environment to incorporate new and evolving modeling concepts for changing conditions

2.4 Additional Peer Review Resources

The Jacobs RSM Peer Review web site[3] will contain useful information for the Peer Review panelists to help guide their work and shorten their RSM learning curves.

[3] http://gwmftp.jacobs.com/Peer_Review/web_page/peer_review_sfwmd.htm

3.0 Scope of Work (Duties and Tasks of Panelists and Chair)

During this project, panelists and the Chair will be asked to conduct the following work:

1. **Read the introductory materials packet sent to you by the Peer Review Facilitators.** This packet will include the RSM Theory Manual and important papers considered "Required Reading".

2. **Read the HSE and MSE additional references** to determine if they are adequate for the purposes intended, or to identify their limitations and make recommendations if enhancements are necessary. This includes the RSM Theory Manual, four published papers, and two white papers. Documents are provided on the Jacobs RSM Peer Review web site[4].

3. **Prepare questions or editorial comments on all information prior to the IPTS.** It is expected during the IPTS that specific portions of the documents will be assigned to individual subject-area experts. Panelists should also prepare brief written comments on the materials for which they are primary reviewers and submit these to the Panel Chair. These comments can be incorporated into the panel report. The Panel Chair will organize such written products and will guide their submission onto the Web Board.

4. **Participate in the Interactive Planning and Training Session During June 22-24, 2005, in West Palm Beach.** Panelists will participate in the IPTS to learn about the model and to ask questions about it. It is expected that all panel members will have studied the model papers and documentation by the time the IPTS begins.

5. **Assist in the organization and development of a Draft Panel Report.** Panelists and the Chair will work collaboratively to complete the report which addresses the goals of this peer review as well as the goals determined by the panelists, using a Web Board as their means of communication**.**

6. **With organization by the Chair, the panel will collaborate in writing the Final Panel Report after receiving comments from the District on the Draft report.** The Panel Report will include a summary, conclusions and recommendations. The Panel Chair will organize the compilation and editing of the final report and will use the Web Board to communicate with the panelists.

3.1 Payment for Services

An honorarium will be paid to the panelists for participating in the meeting and panel report preparation.

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[4] http://gwmftp.jacobs.com/Peer_Review/web_page/peer_review_sfwmd.htm

Table 1: Peer Review Project Schedule and Responsibilities

Task	Responsible Party	Date Range
Contact and Select Panel Members	Jacobs	1/1/2005 to 4/15/2005
Execution of Purchase Orders	SFWMD Procurement	5/13/2005
Read RSM Documentation and prepare preliminary comments and questions. (DELIVERABLE #1)	Panelists	5/18/2005 through 6/21/2005
Attend 2-day Interactive Planning and Training Session (IPTS) in West Palm Beach, Florida	Panelists	6/22/2005 and 6/23/2005
Attend an optional helicopter and airboat tour to review field conditions	Panelists	6/24/2005
Submit sections for draft report—panelist conclusions, recommendations and narrative (DELIVERABLE #2)	Panelists	7/1/2005 through 7/15/2005
Draft Panel Report Assembly	Panel Chair	7/15/2005 through 7/29/2005
District Response to Draft Report	Jacobs, SFWMD	8/1/2005 through 8/19/2005
Panelists final input to Chair	Panelists	8/22/2005 through 8/31/2005
Final Report Submitted to SFWMD (DELIVERABLE #3)	Panel Chair, Jacobs	9/9/2005

Appendix B: Individual Issues, Responses, and Action Plans

Issue ID #_10__ Short Description: Summary & Conclusions

Comment/Issue: Some key panel recommendations for improving the RSM and its documentation are as follows:

1. Several equations are not stated correctly in the RSM documentation. The seriousness of this situation depends on whether these errors are simply typographical or whether these errors exist in the RSM code.
2. The validity of the RSM assumption that subsurface geology is isotropic throughout the model domain is questionable.
3. The canal-seepage watermover should be based on reach transmissivity and not on sediment-layer conductivity.
4. The diffusion-wave approach used by the RSM is not applicable over the entire South Florida domain. Specifically, flows in coastal areas influenced by tides cannot be simulated using the diffusion-wave approximation and simulation of certain flow conditions in low-gradient highly regulated canals could be inaccurate using a diffusion-wave model.
5. The numerically intensive computational performance of the RSM applications to date appears to be excessive. The computational advantage of the diffusion-wave approach might be outweighed by the numerical intensity of the global-matrix solution of the RSM. Alternative sub-matrix solutions should be considered.
6. Use of an explicit numerical scheme should be considered in addition to a fully implicit scheme.
7. The soundness of basic formulations of the <agimp>, <mbrcell>, <unsat>, <ramcc>, and <prr> hydrologic process modules are questionable.
8. Computation of potential evapotranspiration should be considered for inclusion in the RSM.
9. The role of the management simulation engine needs to be clarified. There is a significant concern that the hydraulic structures in the canal network are not capable of being operated in accordance with the MSE algorithms, hence the utility of the MSE in regional simulation is limited.
10. The effects of wind-stress forcing on the large open water bodies should be included in the RSM.
11. Conveyance in sloughs should be treated explicitly rather that being lost in the storage-volume relationship.
12. Land-use changes during the period of simulation should be accommodated by the RSM.
13. Consideration should be given to incorporating rainfall and ET in the canal water balance.
14. To improve model run times and efficiency, consideration should be given to partially decoupling the surface-water and ground-water solutions to allow different time steps to be used in these components. In addition, consideration should be given to making the RSM time step dynamically variable.
15. Recent developments in GMS, PEST, and XMDF software could be used to improve RSM efficiency.
16. The model documentation needs significant improvement in organization and content. Several specific suggestions are provided in this report.
17. Model assumptions, numerical methods, model calibration, numerical errors, and model validation should be more fully explained in the RSM documentation.
18. Local studies need to be performed and documented to validate the hydrologic process modules.
19. The current model and documentation needs further improvement to meet client goals.

Report Version _1.3___ page _22-23_ lines # _23-46,1-46__

Response assigned to: Pattie

Response Summary: These bullets are each addressed individually on separate issue forms.

Bullet 1 is addressed in issue 12
Bullet 2 is addressed in issue 13
Bullet 3 is addressed in issue 14
Bullet 4 is addressed in issues 19, 30, and 31
Bullet 5 is addressed in issue 20
Bullet 6 is addressed in issue 21
Bullet 7 is addressed in issues 24, 44, 45, 46, and 47
Bullet 8 is addressed in issue 25
Bullet 9 is addressed in issue 26
Bullet 10 is addressed in issue 27
Bullet 11 is addressed in issue 28
Bullet 12 is addressed in issue 29
Bullet 13 is addressed in issue 32
Bullet 14 is addressed in issues 15, 34, and 35
Bullet 15 is addressed in issues 36, 37, and 38
Bullet 16 is addressed in issues 11, 39, and 54
Bullet 17 is addressed in issues 50 (model assumptions), 52 (numerical methods), 56 and 57 (model calibration), 49 and 55 (numerical errors), 51, 58 and 59 (model validation), and 11 (model documentation)
Bullet 18 is addressed in issues 41 and 60
Bullet 19 is addressed in issues 53, 61, and 62

Resolution Plan (Proposed Action): See individual action plans for the issues listed.	
Signoff list	
Technical review: Zaki	date
Editorial review:	date
Management review: Ken T.	date: 8/19/05
☐Action completed	date
by:	approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:	

Issue ID #_11___ Short Description: Inadequate material provided to panel

Comment/Issue: "It was difficult to completely assess the scientific soundness of the RSM from the information provided by the SFWMD. The draft documentation, referred to as the Theory Manual, did not present a complete cohesive description of the model. The model documentation in its current draft state does not provide adequate coverage of the equations solved by the model and the numerical techniques used to affect their solution. Extensive descriptions of validation examples were not provided. *However, a significant amount of supporting information in the form of journal articles, unpublished papers, and online documents was provided and/or identified for panel use*. Based on this information, the panel attempted to assess the scientific soundness of the model."

Report Version __1.3__ page _4___ line # __29-37__

Response assigned to: Pattie F. 7/19/05

Response Summary:

1. a great deal of information was provided to the panel, both on paper and electronically (see Table 2). Model documentation was discussed explicitly during the workshop (see slides 13-24 of Fulton Documentation presentation). However, the material was not presented in a single document nor was it provided is a single package of written material.
2. many of the questions that were posed in the initial set of 776 comments have specific answers within the documents provided to the Panel.
3. the panel asked for responses to an initial set of 776 questions, most of which were provided between 6/22 and 7/6/2005, because many of the errors that were addressed in the early responses were also presented in the Draft Peer Review Report. (see Appendix II of Draft Peer Review Report v.1.3, matrix of responses to pre-workshop comments)
4. the proposed set of RSM documentation consists of 8 RSM manuals, 5 of which were made available to the panelists (see Figure 1). The review suffered from not having all documentation in one unit.

The RSM Theory Manual was created very recently, just before the beginning of the peer review. The information provided in the RSM Theory Manual was originally included in the HSE User Manual, but during the internal peer review process, it was determined that the documents should be split so that a separate Theory Manual could be presented, supported by published journal articles. A great deal of effort went into producing the RSM Theory Manual specifically for the peer review, but time was not available for editorial review. We certainly agree that there were a number of typographical errors and some inconsistencies and redundancies in document structure, which served as distractions to reviewing the content of the manual. Because of our recognition of this weakness, one of the goals of this peer review was for the panel to recommend a better structure for our documentation. These will be discussed in Issues #39, 51, and 53.

Table 11.1

<u>Paper Documents provided at the beginning of the peer review (5/19/05)</u>:
RSM Theory Manual, with Appendix C.5 missing
Peer Review Statement of Work
SFRSM Fact Sheet

<u>Electronic Documents provided during the first two weeks of the peer review (5/19/05 – 6/2/05)</u>
Appendix C.5
HSE User Manual
MSE Controllers User Manual
MSE Supervisors User Manual

RSM Benchmark Guide, containing 63 validation and test cases
RSM Bibliography
Published papers on:

1. subregional implementation of RSM in Everglades National Park
2. Spatial and temporal discretization
3. stream-aquifer interaction

RSM Code
RSM XML Schema
XML Schema Primer
1998 SFWMM Peer Review Report
2003 Strategic Modeling Plan
Modeling and Peer Review Protocols

<u>Paper Documents provided at the peer review workshop (6/22-23/05)</u>
Slides of all presentations

- Role of RSM in SFWMD
- Goals of the Workshop
- RSM Theory
- HPM Theory
- RSM Documentation
- RSM Analytical Tests and Validation
- Water Management District Overview
- RSM Enhancements and Improvements
- SFRSM Implementation and Application

Acronyms
Preliminary responses to panelist pre-workshop comments
Statement of Work

<u>Electronic Documents provided after the workshop, while the Draft Report was being prepared and refined (6/24-7/15/05)</u>
Review of ET Methods and Selected ET Methodology
Example of a south Florida regional model application (Modeling in EAA)
Updated responses to panelist pre-workshop comments (7/6 and 7/15/05)
Slides of all presentations

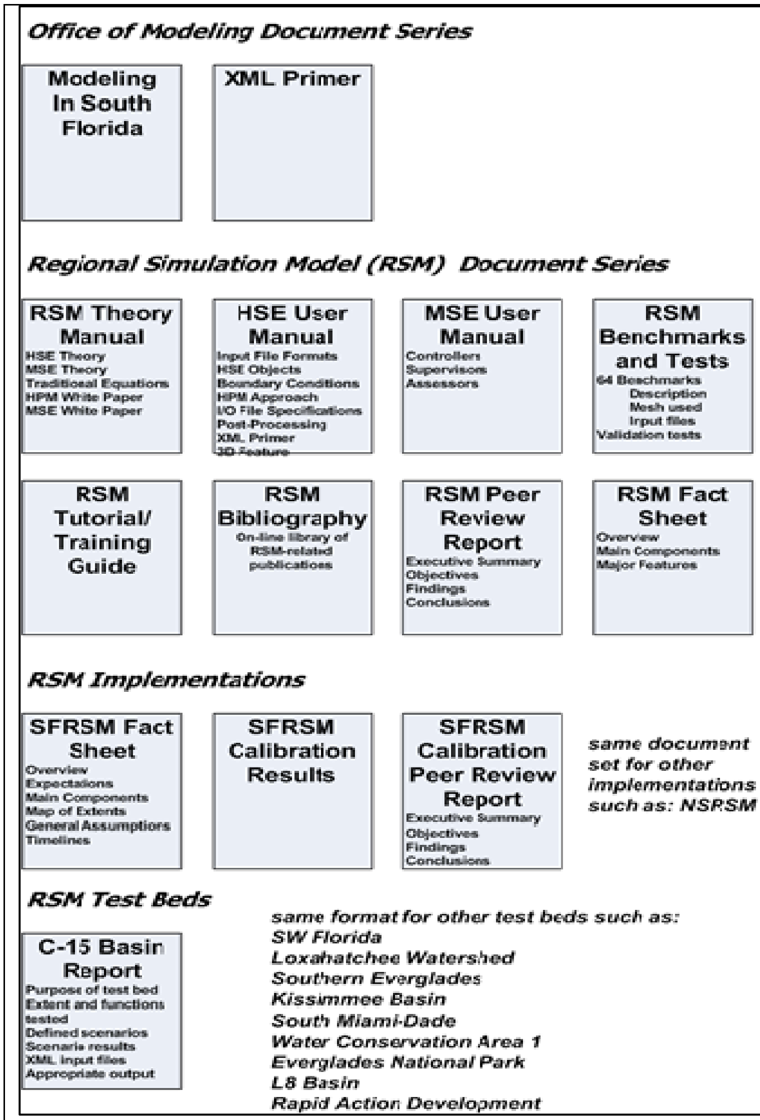

Figure 1. Draft Illustration of the Proposed RSM Documentation Set.

Resolution Plan (Proposed Action)

- ☐ Figure 1 will be included on the inside front cover of all RSM documents
- ☐ the RSM Theory Manual will go through restructure and editorial review starting in October, 2005 (see issue #39)
- ☐ components of the MSE User Manual will be consolidated, and new components added, starting in October, 2005
- ☐ the RSM Benchmark Guide will be updated and a new Guidelines for Managing Numerical Error document will be written (see issue #51)
- ☐ a new "Modeling in South Florida" document will be written (see issue #53)
- ☐ an RSM Tutorial/Training Guide will be written in 2006 (see issue #62)
- ☐ an RSM Fact Sheet will be written in 2005
- ☐ the SFRSM Fact Sheet will be revised in 2005 to distinguish between the RSM model development and the SFRSM model implementation facts

☐ in the future, RSM Test Bed reports will be assembled for individual test-beds through which RSM is refined	
Signoff list	
Technical review: Zaki	date: 8/19/05
Editorial review:	date
Management review:	date
☐Action completed	date
by:	approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:	

Issue ID #__12__ Short Description: Typos in RSM Equations

Comment/Issue: Several equations are not stated correctly in the RSM documentation. The seriousness of these discrepancies depends on whether *they are simply typographical errors* or whether these errors exist in the RSM code. Specific equations of concern are as follows:

- There is a ΔL variable missing from Equation 2.30 in the Theory Manual
- The exponent in Equation 2.39 in the Theory Manual should be 2/3 instead of 5/3

Report Version _1.3___ page _4-5_ line # _41-46, 1-2_

Response assigned to: Pattie F. 7/19/05

Response Summary:

- Both of the specific errors listed above are typographical errors, and were identified as such in the District's response to pre-workshop comments (see items # 12 and 13 in Appendix II of Draft Peer Review Report v.1.3, matrix of responses to pre-workshop comments)
- Additional typographical errors identified by the panelists have also been flagged for update in the next revision to the RSM Theory Manual (see Appendix II of Draft Peer Review Report v.1.3, matrix of responses to pre-workshop comments)
- The RSM source code will be reviewed to ensure that specific errors in equations are identified as typographic errors do not occur in the RSM code.

Resolution Plan (Proposed Action):

1. developer has checked code to verify that equations in the code are correct
2. flagged errors in the documentation will be corrected (see issue #11)

Signoff list	
Technical review: Randy (check code)	date 8/15/05
Editorial review:	date
Management review: Zaki	date 8/19/05
☐Action completed	date
by:	approved by:

Released in ☐ version ____ of code and/or ☐ version ____ of document:

Issue ID #_13___ Short Description: Isotropy/Anisotropy	
Comment/Issue: The ground-water component of the RSM assumes that the subsurface geology is isotropic. The validity of this assumption throughout the model domain is questionable. Secondary solution cavities will certainly be oriented in the direction of historical flows, leading to anisotropic hydraulic conductivities and transmissivities. If anisotropy cannot be incorporated into the model, then the validity and limitations of assuming isotropy should be stated clearly in the Theory Manual. Report Version _1.3___ page __5__ line # __4__	
Response assigned to: Randy	
Response Summary: This is a simplifying assumption mainly due to lack of data (see for example USACOE Biscayne Bay Coastal Wetland ground model application for a small region of WASH123 Model application). Experience has shown that this is a reasonable assumption to make for regional groundwater model applications in South Florida. This assumption needs to be clearly stated in model documentation, for as the reviewer correctly states, this may be a questionable assumption in many areas. This issue will be more fully addressed in future versions of the RSM.	
Resolution Plan (Proposed Action): • Update model documentation • Fully address anisotropy in future version of the RSM	
Signoff list	
Technical review: Lal	date
Editorial review:	date
Management review: Zaki	date 8/19/05
☐Action completed	date
by:	approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:	

Issue ID #_14___ Short Description: Canal-seepage formulation

Comment/Issue: The canal seepage watermover is based on the following linear relationship between seepage rate per unit length of the canal, q_l, and the difference between the water-surface elevation in a canal, H_i, and the water level in the adjacent cell, H_m (Equation 2.40 in the Theory Manual):

$$q_l = \frac{k_m p}{\delta}(H_i - H_m)$$

where k_m is the sediment-layer conductivity, p is the perimeter of the canal, and δ is the sediment-layer thickness. The canal-seepage formulation should be stated in terms of reach transmissivity (Chin, 1991), since leakage is not solely dependent on sediment characteristics (for example, leakage occurs even when the sediment-layer thickness is zero). Dependence of the leakage coefficient on the size of the grid cell is lost when the above equation is used e.g. larger cells should have smaller leakage coefficients. These dependencies become clear when the leakage formulation is cast in terms of a reach transmissivity.

Report Version _1.3___ page _5___ line # __11__

Response assigned to: Lal.

Response Summary:

Equation (2.40) was written for resistance across the segment layer between a cell and a segment. In the model formulation using watermovers, it is expressed as the equation governing flow in a watermover. When the governing equations are expressed, ΔH is the head drop across the sediment layer, and K/δ is a single parameter that relates the head drop due to the discharge.

In the RSM model, Equation 2.40 exists only if one chooses to include a sediment layer in the model. If there is no sediment layer, the last cell is connected to the canal through a groundwater flow water mover, and the formulation still stands correct. If there is a sediment layer, the last cell is connected to the canal through a sediment layer water mover, and the series type resistance is calculated inside the model without having to do it externally using ”reach transmissivity”. The ”reach transmissivity” is derived by combining both these resistances into one. In other words, it is not necessary to create a reach transmissivity external to the model because the model internally calculates a combined transmissivity.

The term ”reach transmissivity” is also an artifact of the numerical discretization, and depends on the size of the cell. If the cell size is infinitely small as in the limiting case of differential form of the equations, the meaning of the term ”reach transmissivity” ceases to exist, and only an equation of the form (2.40) will be useful. Terms $K\delta$ can be defined for both numerical and analytical models. The formulation 2.40 is also the way sediment resistance behavior is explained in the MODFLOW model.

Results of numerical error analysis show that use of a large cell size can increase the numerical error significantly. Use of small cells close to the canals is found to be extremely important when accurate results of canal-aquifer interaction are important. When the cell size is small, it is possible to show that the analytical solution of the canal-aquifer interaction problem matches with the numerical solution using RSM and MODFLOW models without the use of reach transmissivity (Lal 2000 and Lal 2005). This analytical solution that is based on calculus, and assumes Δx

When a solution is obtained using analytical methods, the terms ”reach transmissivity” cease to exist. The need for a reach transmissivity arises only when the discretized cell is too large in a numerical formulation. The use of reach transmissivity will solve the numerical problem partially. It will modify the existing $K\delta$ term to accommodate for a large cell size. But it can be shown that this modification will not completely solve the discretization problems. Figures 5 and 6 of Lal (2005) show that $k_s\ \delta$ as represented using the dimensionless term σ can be modified to mimic any amplitude behavior. But the same modification does not get the phase behavior correct as shown in the same figures. This shows that deficiency in discretization cannot be completely compensated using a modified transmissivity such as a reach transmissivity, and one really has to discretize the groundwater domain with small cells.

RSM and MODNET are the only models that have already been verified against the analytical solution for dynamic canal-aquifer interaction. MODFLOW model with a simulated canal and a canal sediment layer was also checked as demonstrated in Lal (2000). A MODFLOW-like implicit model was also tested by Lal (2005) to give similar results. Comparing against an analytical solution is the only trusted way for model verification as demonstrated in the earlier experiences where MODBRANCH and Pinder and Sauer (1967) solutions were used for the comparison. The primary reason for developing an analytical solution for Canal-Aquifer interaction was to obtain a reliable verification method for numerical model and not to relying on other numerical model solutions coming from MODBRANCH and Pinder and Sauer (1967).

Resolution Plan: No action required.	
Signoff list	
Technical review: Dave	date
Editorial review:	date
Management review: Eric Zaki	date: 8/18/05 date: 8/19/05
☐Action completed	date
by:	approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:	

Issue ID #__15__ Short Description: Coupling of overland and groundwater flow
Comment/Issue: Coupling of overland and groundwater flow in the RSM currently assumes continuity of head for the overland and ground-water domains, since there is only one head value computed for each waterbody. This assumption is different from that used in competing models such as MODHMS and MIKE-SHE, where the head in the overland and subsurface-flow domains can be different for a single finite-difference cell, which is the *analogue of a waterbody in the RSM*. In these other models, the overland and ground-water domains are linked by a fluid-flow term, similar to that currently used in the RSM to link a canal and a cell (see **Equation 2.40 of the Theory Manual**). When a 2D model is used, coupling the overland and ground-water domains with this linking term, and computing two different head values, can produce simulations where the overland domain is recharging the ground-water domain or where ground water recharges the overland domain. Such exchange of flow between domains cannot be as readily simulated with a 2D model that assumes continuity of head between overland and ground-water domains. Furthermore, solving for two head values per waterbody would allow using different time steps to solve the overland and groundwater flow equations, which is not currently possible. Report Version _1.3___ page __5__ line # __27__
Response assigned to: Lal
Response Summary: The RSM version explained for the peer review was only a single layered version because the 2005 implementation does not require multi-layered groundwater flow. In this single layered version, there is *only one* head for both overland and groundwater flow, assuming that wetland or shallow water levels conditions prevail in south Florida, and that single head assumption applies under such conditions. It has been previously experienced that adding layers to a model does not contribute to improve a solution unless there is a calculated need. A mathematical criterion for deciding the need of multiple layers is given by Lal (2005). RSM also has a 3-D model option as in other models such as MDDFLOW. However, the current RSM implementation for South Florida (i.e., SFRSM) is based on a single layered formulation for now. The reasons are partly technical and partly to do with compatibility with previous applications of the SFWMM. For regional models in wetland using large cells, multiple layers were not considered to be improving anything for the solution. The mathematical condition for which multiple layers become necessary is given in Lal (2005, Table 1 row 1) as η=005 or a similar low value. The 3-D or layered features of the groundwater flow are explained in the user manual posted in the peer review web site. In the 3-D model, water levels are different in different layers. As suggested, and as carried out in competing models, RSM has the linkage between layers accomplished through a water mover that considers vertical leakance. Whether the multi-layer formulation will be used for SFRSM in the future remains to be seen. In the RSM, the coupling of surface water and groundwater flows is carried out internally to the model, and an extremely efficient external sparse solver is used to obtain the numerical solution. Concerns expressed by reviewers regarding unnecessary flow computations are for the most part negated by the fact that many modern sparse solvers have “learning algorithms” built into the solver to automatically account for “unnecessary calculations” and therefore the time spent by those solvers to obtain the numerical solution is similar to that of uncoupled models. The primary reason for the enhancement has to do with the fact that modern sparse solvers are based on optimization methods as opposed to elimination methods, and they rely on pre-conditioners and gross error minimization methods using reduced swap operations to solve the problem. Many of these solvers including PetSc are immune to some of the reviewers concerns. With PetSc, it is already possible to see the model running extremely fast with a handful of iterations during the

dry season, and slowing down as rainy season and ponded pools start to appear.

Sparse solvers are part of the actively researched, and many new features including MPI parallel processing, and smart learning algorithms are added to them on a daily basis. But as new functions are added, keeping an eye on the solver speed and run time from time to time is always a good idea.

Domain decomposition methods and multigrid methods have been shown in a number of occasions to be speeding up model computations when the computational scales are extremely variable throughout the domain. At the same time, sparse solvers are also gaining certain capabilities that can recognize these behaviors within the solver itself, and not having to manually decompose the problem. The district team intends to pay attention to developments within all these fields to make sure that the best capabilities are utilized.

Resolution Plan (Proposed Action)	
Signoff list	
Technical review: Randy	date
Editorial review:	date
Management review: Zaki	date 8/19/05
☐Action completed	date
by:	approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:	

Issue ID #__16__ Short Description: Manning equation	
Comment/Issue: In practice, the term "effective roughness parameter for overland flow" is often used, and *N* is substituted for *n* to indicate that the flow is not fully turbulent. Since many of the potential overland-flow applications of the model are not fully turbulent flow, it is recommended that *N* be used instead of *n*. Report Version _1.3___ page __6__ line # _2-6_	
Response assigned to: Pattie F. 7/19/05	
Response Summary: The Manning friction values used in the Everglades have always been high, sometimes getting close to 1, according to the SFWMM model calibrations. The high values have been justified in thick vegetation types in the Everglades consisting of sawgrass, cattail, etc. For some vegetation types, the Manning values were described as a function of depth with the Manning value decreasing as the depth increased. It is true that a better term to use here is the "effective Manning roughness", denoted by *N* instead of *n*.	
Resolution Plan (Proposed Action): 1. Global replacement of "Manning's N" and "Manning's coefficient" with "effective roughness parameter" 2. In RSM Theory Manual, update *n* to *N* in equations where the equation describes effective roughness rather than theoretical roughness. 3. Check HPM Overview paper for additional references to *n* and Manning's coefficient	
Signoff list	
Technical review: Eric	date 8/17/05
Editorial review:	date
Management review: Zaki	date 8/19/05
☐Action completed	date
by:	approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:	

Issue ID #__17__ Short Description: HPM equation sign direction	
Comment/Issue: The model developers indicated in oral presentations that hydrologic process modules (HPMs) provide source water to the HSE cells according to the following relation $S_i = R_{rechg} - Q_{irr} + Q_{ws} + R_{ro}$ where S_i is the source flux into the HSE cell, R_{rechg} is the recharge, Q_{irr} is the irrigation withdrawal, Q_{ws} is the water supply withdrawal, and R_{ro} is the runoff. The sign before Q_{ws} should be changed to negative to be consistent with the definition figure (Figure 2.12) in the Theory Manual. Report Version __1.3__ page __6__ line # _8-16_	
Response assigned to: Pattie F. 7/19/05	
Response Summary: The equation in the presentation was inconsistent with Figure 2.12. The default sign should be negative for Q_{ws} . The equation in the slide will be modified before being used in any further presentations.	
Resolution Plan (Proposed Action): No action planned	
Signoff list	
Technical review: Eric	date 7/21/05
Editorial review: Karen	date 7/27/05
Management review: Zaki	date 8/19/05
☐Action completed	date
by:	approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:	

Issue ID #_18___ Short Description: Equation B.2 (HPM)

Comment/Issue: The governing equation for overland flow is given in Appendix B (Equation B.1) using R_{rchg} to represent the source term per unit area. This source term is not correctly represented by Equation B.2, which should be changed to

$$R_{rchg} = RF - ET - q_{int} - f$$

where f is the infiltration rate.
Several statements in Appendix B are not correct. Specifically, statements to the effect that the continuity and momentum equations can be combined to produce a momentum equation and that the momentum equation can be integrated along a streamline to yield the energy equation are incorrect.

Report Version __1.3__ page _6___ line # __18__

Response assigned to: Lal

Response Summary:

Appendix B was included to show how the governing partial differential equations can be explained using traditional methods. In Appendix B, the source and sink terms in the equations were explained as simple algebraic functions explaining the stress on the regional system. The point that has to be stressed is that the concept of a control volume is not built into a PDE because a PDE is applicable at a point. In this case, the stress acting on the 2-D flow system is given by $RF - ET - q_m$, assuming that the seepage into canals q_m is taken out of the 2-D system. Infiltration is not part of this external stress because infiltration takes place within the entire control *volume*.

Statements with respect to the continuity and momentum equations on p62 in Appendix B are directly from Lal (2000) (RSM Theory Manual, Appendix C1, pg 5). This paper shows that the continuity and momentum equations can be combined to produce a *vector* momentum equation (Equation B.5 and Equation 4 in Appendix C.1 of the RSM Theory Manual). The steps in obtaining the vector momentum equation are presented by Panton (1984) as referenced by Lal (2000). A mis-statement in Appendix B (and Lal, 2000) was that the momentum equation can be integrated along a stream line to yield the energy equation. The correct wording should have been "kinetic energy" equation. It is a standard practice to integrate the momentum equation to produce the kinetic energy equation. Thermodynamics are needed only in the formulation of the total energy equation, which would include heat energy.

The traditional approach with an attempt to include kinetic energy in the overland flow equations were included in Appendix B of the RSM Theory Manual because this was an approach in which an attempt was made to add the velocity head to diffusion flow during the development of the RSM, but is no longer relevant because this approach is not used in the RSM. The diffusion flow approach used in RSM is based on H (water level) (equations 2.8 to 2.29 in the RSM Theory Manual) instead of E (energy).

Resolution Plan (Proposed Action):

- Omit Appendix B from the RSM Theory Manual
- Include only the approach used in RSM in future and ensure that it is fully explained.

Signoff list	
Technical review: Ken T.	date
Editorial review:	date
Management review: Zaki	date 8/19/05
☐Action completed	date
by:	approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:	

Issue ID #_19__ Short Description: Diffusion Equation, Local and convective acceleration terms.

Comment/Issue: **2.~~2~~ 3 Diffusion-Wave Approximation**

Local and convective acceleration (inertia) terms are neglected in watermover equations that simulate overland and canal flow. These watermovers use a special type of diffusion-wave approach where the volume flux is proportional to the head gradient. Omission of the local acceleration term limits RSM to the simulation of slowly varying transients, and neglecting the convective acceleration term limits the ability of RSM to simulate spatial variability in flow conveyance accurately. The *diffusion-wave approach is suited for overland flow in steep to mild slopes, making it compatible for use in most inland flow systems and water bodies in South Florida under most conditions*. <u>Exceptions arise where and when the inertial effects are significant</u>. Flows in coastal areas influenced by tides cannot be simulated by the diffusion-wave approximation due to the importance of the local and convective acceleration terms. Inertial effects in flows through structures also could be significant, dependent on the structure-discharge rate, the converging and diverging channel geometry at the structure, and the nonlinear behavior of the structure. Furthermore, the RSM strategy of recovering some of the convective inertia through the use of the flux vector, E, instead of the head vector, H, as described by Lal (1998), might be ***<u>unwise</u>***. In one-dimensional flow, fully dynamic diffusivity (including all inertial terms) is closer to kinematic hydraulic diffusivity (neglecting all inertial terms) than a convective-only (partial inertia) model (Ponce, 1990).

The diffusion-wave applicability criteria used in the RSM (Ponce et al., 1978) should be qualified as an extension from one-dimensional to two-dimensional flow. Although the convective and diffusive properties of one-dimensional surface flow are well known, the same is not true for two-dimensional surface flows. For instance, how the diffusivity in one dimension (Ponce, 1989) is resolved in two dimensions is uncertain.

In one-dimensional canal flow, the use of lookup tables in the RSM renders the simulation kinematic and, therefore, not subject to physical diffusion. Any hydrograph diffusion manifested in the simulation would necessarily be a function of grid size (Cunge, 1969). Therefore, an assessment should be made of how the use of lookup tables is reconciled with the diffusion-wave assumption, which has built-in physical diffusion through hysteresis in the rating.

In summary, adopting the diffusion-wave approach for RSM development imposes some limitations on the use of RSM in South Florida. However, *this concern must be balanced with experience*, which suggests that the *diffusion-wave assumption is reasonable for simulating regional overland flows in South Florida under most conditions*. Nonetheless, potential client users must be cautioned about limitations of the RSM stemming from the diffusion-wave approximation.

Report Version _1.3___ page __6__ line # _31___

Response assigned to: Lal.

Response Summary:

> Local and convective acceleration (inertia) terms are neglected in watermover equations that simulate overland and canal flow. These watermovers use a special type of diffusion-wave approach where the volume flux is proportional to the head gradient. Omission of the local acceleration term limits RSM to the simulation of slowly varying transients, and neglecting the convective acceleration term limits the ability of RSM to simulate spatial variability in flow conveyance accurately.
>
> The diffusion-wave approach is suited for overland flow in steep to mild slopes, making it compatible for use in most inland flow systems and water bodies in South Florida under most conditions. Exceptions arise where and when the inertial effects are significant. Flows in coastal areas influenced by tides cannot be simulated by the diffusion-wave approximation due to the importance of the local and convective acceleration terms.

These comments are true and useful. Diffusion flow was selected for South Florida for a number of reasons. The reasons and assumptions are explained in different parts of the technical manual and the user manual. Tides are specially subjected to this limitation. Fortunately, tides are limited to the coastal zones, and the time step of one day currently used for the model also eliminates the imposition of tidal stresses. During the study by Lal (2000, WRR, p-1245) it was shown that the diffusion flow models are applicable (in 1-D, Ponce, 1978) in the Everglades in most internal areas except the deep sections of the Everglades. It was also shown that as long as the disturbances in the system are slower than 4 day period events, the diffusion flow assumption is reasonable. This study was prompted by the non-convergence of the SFWMM results in this area. As a result of the observation, the time step in the SFWMM model was cut down to 6 hrs. Fortunately, there is natural check against using diffusion flow models in truly dynamic conditions. The model becomes numerically unstable when both the friction terms and the gravity terms reach small values, because there is no inertia terms available to balance the true physical form of the equations. If someone decides to keep using diffusion flow models under dynamic conditions, these numerical conditions will prevent any attempt to do so.

> Inertial effects in flows through structures also could be significant, dependent on the structure discharge rate, the converging and diverging channel geometry at the structure, and the nonlinear behavior of the structure.

Head loss due to large local flow velocities around structures is mostly considered as part of the structure flow equation (e.g., culverts and bridges). Local high flow velocities however do not influence regional flows in many occasions.

> Furthermore, the RSM strategy of recovering some of the convective inertia through the use of the flux vector, E, instead of the head vector, H, as described by Lal (1998), might be unwise. In one-dimensional flow, fully dynamic diffusivity (including all inertial terms) is closer to kinematic hydraulic diffusivity (neglecting all inertial terms) than a convective-only (partial inertia) model (Ponce, 1990).

As suggested in the comment, it is true that the attempt to recover some of the convective terms by using E instead of H is unwise. This was observed first hand while trying to run the model with these terms, because the model was found to be unstable. The same comment was also made by the ASCE reviewers. The model currently uses H and not E.

> The diffusion-wave applicability criteria used in the RSM (Ponce et al., 1978) should be qualified as an extension from one-dimensional to two-dimensional flow. Although the convective and diffusive properties of one-dimensional surface flow are well known, the same is not true for two dimensional surface flows. For instance, how the diffusivity in one dimension (Ponce, 1989) is resolved in two dimensions is uncertain.

This is true. This has to be qualified in the document. The reason for continuing to use the 1-D formulation was the absence of a 2-D formulation. What are missing in the 1-D based formulation are the effects of divergence and vorticity type terms that are present only in 2-D flows. Unless these terms are significant, the assumptions can be reasonable until more accurate formulations are available.

> In one-dimensional canal flow, the use of lookup tables in the RSM renders the simulation kinematic and, therefore, not subject to physical diffusion. Any hydrograph diffusion manifested in the simulation would necessarily be a function of grid size (Cunge, 1969). Therefore, an assessment should be made of how the use of lookup tables is reconciled with the diffusion-wave assumption, which has built-in physical diffusion through hysteresis in the rating.

This statement is true. However, the use of lookup tables is not in the plans for the south Florida implementation. The lookup table option was made available considering the large variety of wetland flow equations available for South Florida, and the considerable amount of experiments under way by USGS and other entities. It may be possible in the future to understand the behavior of the friction equations by studying physical diffusion in the Everglades.

> In summary, adopting the diffusion-wave approach for RSM development imposes some limitations on the use of RSM in South Florida. However, this concern must be balanced with experience, which suggests that the diffusion-wave assumption is reasonable for simulating regional overland flows in South Florida under most conditions. Nonetheless, potential client users must be cautioned about limitations of the RSM stemming from the diffusion-wave approximation

This is true and will be stated clearly under RSM Limitations and Assumptions section in the RSM documentation.

Resolution Plan (Proposed Action): Future enhancements may be considered to include inertia terms	
Signoff list	
Technical review: Randy	date 8/19/05
Editorial review:	date
Management review:	date
☐Action completed	date
by:	approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:	

Issue ID #__20__ Short Description: Numerical Solution/Run Time
Comment/Issue: The solution of all watermover and waterbody equations in the HSE is integrated into one global matrix as opposed to sub-matrix solutions coupled by boundary fluxes. This approach could cause the model to become too numerically intensive as the mesh size is refined or the size and complexity of the model domain increases. The diagonal dominance of the global matrix will likely be diminished as the number of canal segments increases and a greater number of more sophisticated water-control structures are added, potentially resulting in an increased number of iterations required for convergence. *Sixty percent of the processing time in the RSM application to South Florida (SFRSM) is expended in matrix inversion and 40-60 iterations are required for convergence*. The numerically intensive computational performance of the SFRSM, which is still under development, appears excessive and is likely a symptom of increasing system complexity and/or linear assumptions made in the RSM. Typically, the factors that increase the computational run times of numerical models are the nonlinear terms, which are not included in the diffusion-wave approximation of the RSM. Report Version _1.3___ page _7__ line # _24-37__
Response assigned to: Randy
Response Summary: The simultaneous solution of all water watermovers and waterbodies in a single global matrix is one of the strengths of the RSM. Making this work requires a **very** good sparse matrix solver. So far, given a wide range of applications, the Petsc solver has stood up very well. There are many compelling reasons managing the levels of complexity – the reviewer rightly points to computational performance as an example. Implementation strategies need to be developed wherein regional implementations of the RSM would be used to screen alternatives and sub-regional implementations would be used to refine and design at the project level. The RSM must effectively deal with complexity and nonlinearities in the system. HPM's are designed to deal with some of this complexity. Other approaches for dealing with nonlinearities are under consideration, including iterations. The MSE is designed to address operational complexities.
Resolution Plan (Proposed Action): • Develop implementation strategies • Continued development to address complexity and nonlinearity issues
Signoff list
Technical review: Dave W. date
Editorial review: Karen date
Management review: Zaki date 8/19/05
☐Action completed date
by: approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:

Issue ID #__21__ Short Description: Numerical Scheme (Implicit vs. Explicit); convergence vs. stability.
Comment/Issue: The use of an implicit versus explicit numerical solution scheme is a tradeoff that needs to be assessed judiciously. Implicit schemes ($0 < \alpha \leq 1$) are usually unconditionally stable, whereas explicit schemes ($\alpha = 0$) are not. Therefore, if stability is the issue, an implicit scheme is the preferred choice. However, in numerical modeling, *stability is usually achieved at the expense of convergence (O'Brien et al., 1950)*. Once the focus shifts from stability to convergence, an explicit scheme can compete effectively with an implicit scheme. *An explicit scheme will usually achieve convergence at the same time as stability*, whereas an implicit scheme might be stable throughout a wide range of grid resolutions, while remaining nonconvergent for some subrange. Therefore, *it should not be assumed a priori that implicit schemes are altogether better than explicit schemes*. The objective in the RSM numerical solution technique should be to *seek a balance between stability and convergence, and not to pursue one at the expense of the other*. This balance should be obtained through the simultaneous minimization of round-off and truncation errors (O'Brien et al., 1950). The use of a fully-implicit model ($\alpha = 1$) as the default case for numerical solution is justified only when results of sensitivity analysis clearly show that the tradeoff is an acceptable one, that is, improved stability without unduly sacrificing convergence. It is recommended that the tradeoffs between the use of $\alpha = 1$ and that of a more convergent value such as $\alpha = 0.6$ be investigated and reported. Report Version _1.3___ page _7___ line # _39___
Response assigned to: Lal
Response Summary: The use of an implicit versus explicit numerical solution scheme is a tradeoff that needs to be assessed judiciously. Implicit schemes ($0 < \alpha \leq 1$) are usually unconditionally stable, whereas explicit schemes ($\alpha = 0$) are not. Therefore, if stability is the issue, an implicit scheme is the preferred choice. The value of α is an implementation choice, and the user can select any value depending on the intended use. The user manual and some of the journal manuscripts have suggested values and their implications. This is the extent to which most other models describe α in their technical descriptions, because it is not understood to the fullest extent. The idea of weighting between the implicit and explicit schemes probably started with the evolution of Crank Nicholson methods for solving linear diffusion equations. Crank Nicholson equations are second order accurate in time when compared to fully implicit or explicit methods, which are only first order accurate. However, Crank Nicholson methods (α =0.5) are sometimes unstable when the equations are non-linear as in the case of the Preissmann scheme. The α value was moved above 0.5 in order to make the model stable, at the expense of some accuracy. In Priessmann schemes, this was accomplished successfully. In the early days of RSM, the goal was to keep close to α= 0 5 as much as possible for reasons of accuracy, and move higher only if strong oscillations are present. There were oscillations whenever rapid dynamic flow conditions were present, even when the solution was non oscillatory at other times. RSM does not have the same type of oscillations present in the Priessman scheme because RSM does not have the inertia terms. This is the same method used by NWS models when the Froude number is close to 1, when the inertia terms are gradually tapered based on some function. Alpha (α) was introduced into RSM to make it behave like the Crank-Nicholson scheme using central differencing (hopefully to achieve α= 05 if possible). If this is not possible, α is to be pushed higher to make the model more stable, sacrificing the accuracy for increased stability. This was found to be true for RSM as demonstrated by most of the benchmarks, which still use α= 05. Equation (9) of Lal (2000, WRR) shows numerical errors (described as non-convergence errors by O'Brien et al., (1950)). As more complicated nonlinear equations were added to the list of equations solved simultaneously, the increase of α has limited success, because the instability or the oscillations had to do with the nonlinear nature of various other terms and not just the diffusion flux terms. As a result, the α values had to be left at

almost 1.0 to keep the model non-oscillatory.

The oscillatory nature of the α=05 could be explained by the fact that α=05 will not only eliminates the first order error terms making linear problems to be second order accurate, it also takes away the damping associated with the even order derivatives associated with the residual terms in the Taylor Series expansion of the second derivative. This clearly shows the influence of the first order error acting as a friend in this case damping the oscillations in the model even if the model sacrifices the second order accuracy status.

> However, in numerical modeling, stability is usually achieved at the expense of convergence (O'Brien et al., 1950). Once the focus shifts from stability to convergence, an explicit scheme can compete effectively with an implicit scheme. An explicit scheme will usually achieve convergence at the same time as stability, whereas an implicit scheme might be stable throughout a wide range of grid resolutions, while remaining nonconvergent for some sub range. Therefore, it should not be assumed a priori that implicit schemes are altogether better than explicit schemes. The objective in the RSM numerical solution technique should be to seek a balance between stability and convergence, and not to pursue one at the expense of the other. This balance should be obtained through the simultaneous minimization of round-off and truncation errors (O'Brien et al., 1950). The use of a fully-implicit model (α = 1) as the default case for numerical solution is justified only when results of sensitivity analysis clearly show that the tradeoff is an acceptable one, that is, improved stability without unduly sacrificing convergence. It is recommended that the tradeoffs between the use of α = 1 and that of a more convergent value such as α = 0.6 be investigated and reported

Lal (2000) echoed the same sentiments in a number of occasions. The following statements are from the same paper (p-1237 WRR): "Various unconditionally stable numerical methods using implicit other models have made it possible for modelers to use almost any discretization with computer models. Unlike explicit models where there is some error control because of the stability condition, implicit models, such as the three dimensional groundwater flow model MODFLOW need guidelines to select discretization so that the error is known and controlled." And later, "The subject of error analysis and output evaluation has become increasingly important because the space and time discretizations used in some model applications are arbitrarily chosen. The use of unconditionally stable implicit methods has also complicated the use of the stability condition as an error control."

These statements are true, and the same idea is captured by Lal (1998, 1998a, 2003, 2001, and 2000). These papers were written with the consideration of the importance of the statement. None of the error analysis work will change the model or the numerical algorithms, only the way it ought to be used. They will provide guidance to the model user to be aware of potential errors. The only place error analysis is built into the algorithm is in adaptive mesh generations and error controlled solution of initial value problems (as in Runge-Kutta-Fehlberg methods). In the case or RSM, this idea was extended into a problem of error analysis (sometimes referred as a type of uncertainty), and a problem of optimum selection of spatial and temporal descretizations.

The work of O'Brien (1950) is similar to that of Lal (2000). I regret not finding this paper myself and thank Dr. Ponce for pointing it out for me. I was inspired to work on the error analysis because of the need to understand the influence of "2 mile cells" in the 2x2 model at SFWMD, and the work by Richtmyer and Morton (1967) and Hirsch (1989). The influence of α was studied using the equation for linear diffusion equations as described in Lal (2000) eq 9, and it was determined that maintaining a higher order of accuracy in integrated models is an impossible task. One of the reasons was the fact that this is possible only around a narrow band of α= 0.5), α= 1 was the final choice, and all the numerical tests conducted in these papers (Lal, 1998, 1998a, 2003, 2001, and 2000) were based on α= 1.

The errors resulting from non-convergence and other causes listed have already been studied and are in many papers. The error behavior for MODFLOWwith a fully implicit scheme is exactly the same as the error behavior of the RSM with right triangular meshes. The MODFLOW error behavior is described in Fig 4 of Lal (2000) and many of the equations. Many of the problems listed by the reviewer are not different whether it is the MODFLOW model or the RSM model.

Resolution Plan (Proposed Action): 1. Add “Guidelines for Managing Numerical Error” to RSM Documentation Set..	
Signoff list	
Technical review: Randy	date
Editorial review:	date
Management review: Zaki	date: 8/19/05
☐Action completed	date
by:	approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:	

Issue ID #__22__ Short Description: Manning's n = 1
Comment/Issue: The use of unrealistically high values of Manning's *n*, such as *n* = 1, in overland-flow cells, and the use of α = 1 for fully forward implicit solution in the South Florida application of the RSM (SFRSM) are symptomatic of attempts to overcome numerical instabilities. The Manning's *n* value of one is too large, and use of fully forward weighting (α = 1) will damp wave propagation. Effects of both of these conditions on model results need to be investigated. Report Version _1.3___ page __8__ line # _15___
Response assigned to: Lal
Response Summary: The value of Mannings n=1 is neither hard coded to the code at any place nor recommended in any way. The user is free to use any value of Mannings he or she chooses. RSM model is not tied to any particular value of the Mannings constant. The reference to *n*=1 probably came from an old test problem used with the SFWMM model which was used to test overland flow under wetland conditions. There is no justification for using large values of Manning's n if bed friction is the only form of friction against flow. The original experiment by mannings was in fully turbulent rivers, and the use of $S^{0.5}$ with such rivers was fully justified. Kadlec and Knight (1996) explained how the Manning's equation was stretched to accommodate wetland flows where flow friction was provided by the stem or the roots of the vegetation, and the power of 0.5 was increased along with the Manning coefficient to accommodate for laminar or transition flow conditions. The reviewer does not provide evidence to back up the claim that *n* =1 and α = 1 were used in an attempt to control instabilities. The reviewers were not provided with any evidence on oscillations in RSM, and this statement is purely conjectural on their part. Furthermore there is no proof that oscillations are going to go away by either mechanism. When calculating numerical errors, it was pointed out by Lal (2000) and Lal (1998) that the variable controlling error and instability is not just *n* but a combination of variables such as the water depth, Mannings and the slope in the case of diffusion flow. It is true that increasing *n* and α would definitely improve stability of conventional numerical schemes, but to believe that this should eliminate all numerical problems is a total fallacy. Different parts of the depth averaged flow equations generate instabilities under different conditions. The traditional α=1 limit is suitable for making the convective acceleration components stable. Even this fails close to Froude numbers close to 1 in Priessmann schemes. The structure equations with various nonlinear equations cause more instabilities than the depth averaged flow equations. At very shallow depths, friction equations can become stiff, and instabilities can be caused by that too. The bottom line is that instabilities are caused by a variety of reasons in any integrated model. There are no quick fixes to these instabilities, and some of them only work on a temporary basis. One should understand from the volume of peer reviewed publications of error analysis alone that the developers were trying to quantify and analyze it as opposed to hiding it. RSM developers are the only people who published so much about numerical errors of hydraulic models. The numerical errors of RSM under the α=1 conditions are the same as the numerical errors of the much celebrated MODFLOW model (McDonald and Harbaugh, 1984).
Resolution Plan (Proposed Action): No action required.
Signoff list
Technical review: Randy date
Editorial review: date
Management review: Zaki date 8/19/05

☐Action completed	date
by:	approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:	

Issue ID #__23__ Short Description: use of previous vs. current head values.

Comment/Issue: Waterbody mass-balance matrices should be evaluated with updated H values to accelerate convergence, which does not seem to be the case in the current version of the RSM. As described in Equation 2.47 of the Theory Manual, it appears that matrices A and M on the left-hand side of the equation are evaluated with previous head values at time n, rather than updated values at time n+1.

Report Version _1.3___ page _8___ line # __22__

Response assigned to: Lal

Response Summary:

Making M^{n+1} to be the same as M^{n} was found to be a good approximation during the early part of development where a couple of iterative cycles were used to update M^{n+1} with the correct value. During the period, it was found that the error generated by this assumption was smaller than the discretization error (first order error), and therefore could be neglected. As an alternative to the iteration, it was decided to carry out a thorough error analysis with rapidly varying flows (high frequency components) in the solution, and understand the behavior of the error before making a decision. The error analysis showed that the model error without iteration was in the same range as the errors of the linear problems. It is possible to show that even if iterations were added to improve the nonlinear behavior of the diffusion flow model for example, the numerical error will still be within the first order range.

Further studying of this is planned with rapidly varying diffusion flows and dynamic flows. These are the types of flows where flow variations are going to be rapid and the iteration is going to be significant. With the results of this study, it will be easy to check how adding dynamic terms compare with adding iterations to nonlinear diffusion flow.

Resolution Plan (Proposed Action):

1. Revisit issue when addressing rapidly varying diffusion flows and dynamic flows.

Signoff list

Technical review: Randy	date 8/19/05
Dave W.	date
Editorial review:	date
Management review: Zaki	date 8/19/05
☐Action completed	date
by:	approved by:

Released in ☐ version ____ of code and/or ☐ version ____ of document:

Issue ID #__24__ Short Description: HPM

Comment/Issue:

(item 1) The <agimp> and the <mbrcell> modules utilize the NRCS curve number method, which is strictly applicable only to event modeling. There is no such thing as a fixed "curve number" or a constant "maximum potential retention", and a curve number obtained through calibration might not be applicable in the validation phase, unless all events happen to have a similar antecedent moisture condition (AMC). *The demonstrated discrepancies ?? between simulated and recorded flows could be partly attributed to the variability in AMC (Ponce and Hawkins, 1996).*

(Item 2) The <agimp> module uses the V-notch weir equation to calculate the angle of the V-notch weir to be used in the compound-weir equation. The module should place limitations on the calculated notch angle, since the assumed relationship is not valid for all angles and heads, and some weir angles might not be practical.

(Item 3) The <mbrcell> module uses the following empirical relationship to calculate the rainfall excess (*Appendix C.5, Equation 42*),

$$ER = \frac{(P_{tot} - 0.2S_{pa})^2}{P_{tot} + 0.8S_{pa} + uns}$$

where ER is the excess rainfall, P_{tot} is the daily rainfall, S_{pa} is the potential abstraction, and uns is the water storage in the unsaturated zone. This equation differs from the conventional NRCS curve number equation (Chin, 2000) in that the variable "uns" is included. Additional scientific justification needs to be provided for deviating from conventional engineering practice.

(Item 4) The <unsat> module assumes that evapotranspiration (ET) is zero when the water depth is greater than the root depth (Equation 13). This formulation is questionable since it has been demonstrated that evaporation can still be significant well below the root depth (Chin and Patterson, 2004).

(Item 5) The <ramcc> HPM calculates the daily water budget for each soil zone according to the relation

$$STO_{t,i} = STO_{t-1,i} + P_t + IRR_t - ET_{t,i} -/+ Redist_{t,i} - Perc_{t,i} - Upflux_{t,i}$$

This equation is incorrect, since the minus sign before $Upflux_{t,i}$ should be a plus sign.

(Item 6) The <prr> HPM uses the NRCS curve number method to estimate the maximum soil moisture capacity, L_{max}, according to the relation

$$L_{max} = \frac{1000}{CN} - 10$$

This equation is valid only for U.S. Customary units and not for SI units. The appropriate conversion factor should be included in the model.

Report Version _1.3_ page __7__ line # _30___

Response assigned to: Eric F.

Response Summary:

Item 1: Concerns about Use of Curve Number:

The Panel was concerned that the curve number approach used in the <agimp> and <mbrcell> HPMs may not be applicable because these are continuous models rather than event models and the use of a constant "maximum potential retention" is not appropriate and a curve number obtained through calibration would only apply to events with the same antecedent moisture condition (AMC).

The curve number is used in <agimp> to estimate the volume of runoff for a single storm event to determine the appropriate size for the impoundment. An average value of the initial abstraction (I = 0.2S) and an average value of the antecedent moisture content (AMC=II) are used to estimate the runoff volume for the single storm.

The curve number approach is used in the <mbrcell> HPM to estimate daily runoff on a daily basis. The method used in <mbrcell> adjusts the maximum potential retention (S) based on the available soil moisture storage above the water table. As Ponce and Hawkins (1996) point out, the NRCS runoff method using the curve number is not designed for long-term simulation, but it has been used successfully in urban areas where the potential retention is adjusted for changes in soil moisture content (Haith and Shoemaker, 1987). The SWMM model uses the curve number approach to estimate infiltration taking into account the available soil moisture storage, soil hydraulic conductivity and the time it takes to fill that storage (Rossman, 2004). The curve number method has also been used successfully in the CLEAMS/GLEAMS and EPIC models for continuous simulation. In <mbrcell> HPM it is assumed that the infiltration capacity of the soil is high and rarely exceeded by the rainfall rate, which is reasonable for most soils in south Florida where the water table is close to the land surface and runoff is estimated on a daily basis. Under these conditions, runoff is controlled by available soil moisture. The <mbrcell> has not been thoroughly validated with field data. This will be addressed as part of the verification/validation studies proposed in Issue 41.

Item 2: Use of V-notch Equation in <agimp>: The implementation of the v-notch weir for discharge from an agricultural impoundment depends on the size of the impoundment, which is determined in RSM by the size of the agricultural land draining to the impoundment. For small impoundments, the size of v-notch weir can become too small and become easily clogged with debris and difficult to build. The typical restriction is that the weir angle can not be less than 20 degrees or the area of the v-notch less than six square inches. If so, a circular bleeder with a 2.75-in diameter orifice is used. Currently, the size of impoundments is limited in the GIS preprocessor to limit the selection of small impoundments. The preferred approach would include code in the agricultural impoundment section of the model which would check impoundment discharge and select the appropriate orifice type. This feature will be included in a future release of the RSM.

Item 3: Empirical equation for rainfall excess in <mbrcell>
The equation for excess rainfall (42) is not correct and will be deleted from the HPM documentation. The calculation of excess rainfall was a term from a previous version of <mbrcell> that was still in the documentation, but not in the source code. The source code has been verified.
The method for calculating runoff is based on the following relationship:

$$F/S_{pa} = Q/P_e \qquad (38)$$

Where Q is runoff, S_{pa} is potential retention, P_e is total rainfall and F is actual retention. In the documentation S_{pa} was mislabeled as potential abstraction. Runoff is calculated using the frequently used equation

$$Q = (Ptot - 0.2S_{pa})^2 / (Ptot + 0.8S_{pa}) \qquad (39)$$

where initial abstraction $Ia = \lambda\ S_{pa}$ and the initial abstraction ratio, λ, is assumed to equal 0.2 in. The value for potential retention is calculated at each time step as the volume of available soil water storage above the water table minus the amount of water held in the unsaturated zone. This adjusts the potential retention for every day rather than assuming a constant value.

Item 4: Evapotranspiration in <unsat>: The formulation for <unsat> was created to preclude ET from below the root zone for those locations where there is rock layer through which there is little water movement, or a layer of coarse sand which has a very low unsaturated hydrologic conductivity and thus a very small upward flux when the water table is below the root zone. In these conditions, ET essentially stops when the water table is below the root zone. However, because there are many locations where ET can occur when the water table is below the depth of the roots, the <unsat> source code will be modified to include an extinction depth similar to the <layer1nsm> HPM. This will make the <unsat> more comparable to <layer1nsm> and in the case where ET ceases below the root depth, the extinction depth can be set equal to the rooting depth.

Item 5: Water budget equation in <ramcc> HPM: The sign on the Upflux term is incorrect in the equation in the documentation. This has been verified in the source code.

Item 6: Units in curve number in <prr> HPM:
The documentation presents the equation with U.S. Customary units. Although the equation for Lmax is presented in the documentation in U.S. Customary units, it is written in the source code in S.I. units with a conversion to U.S. Customary units if "English" is selected as the units for the specific implementation of RSM. In the example presented in the documentation Lmax is used in U.S. Customary units. This will be clarified in the documentation.

Resolution Plan (Proposed Action):

1. Discuss and provide justification in the HPM documentation for the use of curve number approach in continuous modeling in RSM.
2. Revise the HPM documentation adding the limitation of using the v-notch weir and modify the source code to use the circular orifice for small impoundments.
3. Revise the HPM documentation for <mbrcell> HPM describing the correct algorithm.
4. Change sign for Upflux in the water budget equation for <ramcc> HPM.
5. Included conversion factor and verified in SFRSM code for <prr> HPM
6. Update document

Signoff list	
Technical review: Randy Van Zee	date 8/17/05
Editorial review:	date
Management review: Zaki	date 8/19/05
☐Action completed	date
by:	approved by:
Released in ☐ version _____ of code and/or ☐ version _____ of document:	

Issue ID #__25__ Short Description: PET calculation (within or outside model)

Comment/Issue: In most regional-scale models, it is commonplace for the potential evapotranspiration (PET) to be calculated by the model based on climatic input, such as maximum and minimum temperature. It is recommended that calculation of PET be incorporated into the RSM, rather than specifying it as input data, especially since fairly simple relationships currently are being used to estimate PET. PET might vary temporally in a long-term model application, particularly as land-use changes and ecosystem-restoration practices are implemented. Furthermore, the inclusion of PET calculations in the model would allow the consideration of climate-variability scenarios. If historical PET estimates were derived using different methodologies than incorporated in the RSM, then it would be appropriate to include the historical PETs as input to the RSM. In addition, if computation of PET within the model significantly increases the RSM run time, then calculation of the PET outside of the RSM would be justified.

Report Version _1.3___ page _9___ line # _33___

Response assigned to: Ken T.

Response Summary:

Modelers recognize that PET is often calculated within the model. Consistency of input between models is very important for the South Florida Water Management District as a whole. It was a conscious design decision to determine potential evapotranspiration outside of the model to ensure consistent PET inputs for many models used by the District. Actual evapotranspiration is already determined dynamically within the RSM based on the input PET, water availability, land cover or vegetation type and seasonal variation in vegetation water requirements. Climate variability can currently be tested using different PET input sets each representing a different climate variability scenario. See issue 29 for a discussion of land use changes.

Resolution Plan (Proposed Action):

1. Consider PET calculation inside the model as a future enhancement

Signoff list

Technical review: Randy	date
Editorial review: Karen	date 10 AUG 2005
Management review: Pattie	date: 8/18/2005
☐Action completed	date
by:	approved by:

Released in ☐ version ____ of code and/or ☐ version ____ of document:

Issue ID #__26__ Short Description: MSE role
Comment/Issue: The role of the Management Simulation Engine (MSE) needs to be clarified. This well documented component of the RSM is designed to **utilize the results of the HPM simulation** to optimize operation of hydraulic structures to achieve some desired outcome. As presently configured, the hydraulic structures are not capable of being operated in accordance with the MSE algorithms; hence, the current utility of the MSE in regional simulation is limited. However, if the effectiveness of the MSE in achieving water-management objectives can be demonstrated, operational features of the hydraulic structures could be modified to incorporate the MSE algorithms, thereby producing a much more efficient water management system in South Florida. Report Version _1.3___ page _10___line # _2___
Response assigned to: Michelle
Response Summary: There seems to be confusion not about the MSE, but about 1) its interaction with HPMs, and 2) "the hydraulic structures are not capable of being operated in accordance with the MSE algorithms". 1) It is not true that: "component of the RSM is designed to utilize the results of the HPM simulation to optimize operation of hydraulic structures." Although the MSE may include HPM results as part of its operational control decision making, HPM results are not directly used to optimize the operation of hydraulic structures. The optimization of hydraulic structure operations has clearly been demonstrated with the use of canonical feedback controllers and LP supervisors. 2) It is not the case that: "the hydraulic structures are not capable of being operated in accordance with the MSE algorithms". A more accurate statement would be: "Given the constraint of a daily timestep in the SFRSM model implementation, it is problematic to encapsulate the fine timescale control of actual hydraulic structure operations." If the model were simulated at timescales consistent with actual hydraulic operational controls, this issue would not be relevant. Therefore, it isn't that the structures are not capable of being simulated in accordance with actual operational control algorithms, it is that the SFRSM daily timestep constraint prevents this. The currently pursued technical solution to this timescale conflict is the development and implementation of MSE assessors. Assessors are designed to use daily flow transfer functions that achieve structure flow control that is consistent with a temporally integrated small timescale control and response of the hydraulic structures.
Resolution Plan (Proposed Action): 1) Improve the quality of graphics and figures showing the interactions between the HSE and MSE components 2) Update MSE documentation as new features are being developed
Signoff list
Technical review: Randy date: 8/17/05 Joseph P. date: 8/11/05
Editorial review: Karen date
Management review: Pattie date: 8/18/05
☐Action completed date
by: approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:

Issue ID #__27__ Short Description: Wind Effects
Comment/Issue: The shear-stress effects of winds on surface flows are not accounted for in the RSM. Slowly varying flows are potentially subject to wind forcing that could cause setup, particularly in sparsely vegetated wetland sloughs, in lakes and reservoirs, and in canal segments between water-control structures. Given that wind forcing is not accounted for in reservoirs and lakes, this omission could be particularly problematic in the SFRSM in that Lake Okeechobee is treated as a reservoir. Winds effects on Florida Bay are an important forcing mechanism that produces backwater effects along the coast. The present conceptual framework of the RSM excludes treatment of wind-stress forcing in all watermovers. Report Version _1.3___ page __10__line # _12-20_
Response assigned to: Dave W.
Response Summary: The RSM has been designed to provide a replacement for the South Florida Water Management (SFWMM). The first step in this effort is to ensure that the RSM provides regional functionality similar to that of the SFWMM. More detailed and site specific models such as the SICS model have used the SFWMM to provide stage boundary and this appears to be reasonable as wind stress affects the circulation more than stage. The RSM should be able to provide these boundary conditions in the future. If it becomes necessary to include wind stress directly in the RSM this feature can be added at a later time.
Resolution Plan (Proposed Action): To be addressed in future release of RSM (if needed)
Signoff list
Technical review: Randy date
Editorial review: Karen date
Management review: Pattie date: 8/18/05
☐Action completed date
by: approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:

Issue ID #__28__ Short Description: Ridge & Slough
Comment/Issue: Conveyance in sloughs traversing through overland-flow cells is not accounted for; sloughs are treated simply as surface depressions in the storage-volume relationship of the RSM. Therefore, representation of the ridge and slough wetland landscape needs to be factored into the mesh-generation and flow-simulation processes. Report Version _1.3___ page _10___line # __22__
Response assigned to: Lal
Response Summary: The ridge and slough landscape can be represented in the RSM by implementing a very fine and appropriately discretized mesh. The current South Florida implementation of RSM (SFRSM) does not represent the individual ridges and sloughs because the goal is to represent the overall regional functionality. The option to represent ridge and slough features at a scale smaller than the scale of the model mesh cells could be built into the model as heterogeneous transmissivity and conveyance parameters in the future. Two main parameters in the current RSM are designed to capture what is lost from storage and resistance terms through spatial aggregation. The SV (stage-volume) converter captures the storage behavior of a cell as a function of water level. The conveyance and transmissivity parameters and their respective objects describe the flow resistance above and below ground. Currently, these are scalar parameters as opposed to tensor parameters and therefore can only describe isotropic behaviors. In the future both transmissivity and conveyance could be implemented as tensors; however, more research is needed in this area.
Resolution Plan (Proposed Action) 1. Consider future research into implementing transmissivity and conveyance as tensors to capture resistance heterogeneity in mesh.
Signoff list

Technical review: Dave Randy	date date
Editorial review: Karen	date
Management review: Pattie	date: 8/18/05
☐Action completed	date
by:	approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:	

Issue ID #__29__ Short Description: Dynamic Landuse

Comment/Issue: The need for long-term regional simulations of 35-40 years is essential in assessing South-Florida water demands, and historical trends indicate that land use constantly changes as agricultural land is converted to urban use, marshes, or reservoirs. Such land-use changes should be accounted for in South Florida applications of the RSM. Therefore, the following RSM capabilities are desirable:

- The land-surface mesh configuration and definition in the HSE of RSM should be dynamically adjustable to account for topographic and physical changes during the course of a simulation
- Physical changes due to natural catastrophic events such as wetland fires and hurricanes that alter the landscape should be treated by dynamically varying the RSM mesh configuration and applicable parameters
- Structure, levee, and canal configurations should be dynamically adjustable during long-term simulations

Report Version _1.3___ page _10___ line # __27__

Response assigned to: Lehar date: August 4, 2005

Response Summary: The reviewers are proposing a succession model whose physical description of the area being modeled, e.g. topography, land use, canal configuration, etc. changes in the course of the simulation. However, the RSM was originally envisioned to simulate hydrologic responses, e.g. changes in water levels and flows, in a fixed or static system configuration using a time-varying climatological input (rainfall and ET) and to a limited extent, time-varying structure operating rules in the course of a 36-year simulation period. The model was not originally designed to simulate physical response, e.g. changes in Manning's roughness, due to the same input. Catastrophic events (such as hurricanes that change the landscape) and new infrastructure projects (such as construction of Stormwater Treatment Areas which alter the plumbing system) that occur within the simulation period are not considered in the current model. Dynamic physical attributes (both natural and man-made) may be significant for multi-decadal simulations and may be included in future versions of the model. In the interim, the model will simulate hydrologic responses to a time-varying climate as stressor-based on a static physical system.

Resolution Plan (Proposed Action):
1. Consider further research to incorporate physical system changes within the simulation period
2. Add this description of the functioning of RSM to the "Scope and Purpose" section of the RSM Theory Manual and the RSM Fact Sheet

Signoff list

Technical review: Randy date: 8/17/05

Editorial review: Karen date:

Management review: Pattie date: 8/18/05

☐Action completed date:

by: approved by:

Released in ☐ version ____ of code and/or ☐ version ____ of document:

Issue ID____#30___Short Description: Assumptions for the Diffusion Equation.

Comment/Issue: There is an urgent need to perform theoretical work to identify the convective and diffusive properties of such waves and to build the canal model on these principles. Barring this, an alternative is to implement full dynamic-wave modeling in the canals, with all the attendant nonlinearities, which will likely impose the additional data requirements and increased numerical efforts typically associated with dynamic-wave computations.

Report Version____1.3___page__11____line # _____21____

Response assigned to: Lal

Response Summary:

A substantial amount of theoretical work on the amplitude and phase behaviors of diffusion waves has already been carried out by Ponce (1978) and others, mainly on 1-D flows. The condition of applicability derived by Ponce was the result of maintaining the propagation behaviors of diffusion waves as close as possible to the propagation behaviors of full dynamic waves. So long as some of the conditions are followed, it is expected that diffusion flow behaves similarly to dynamic flow behaviors.

The wave propagation behaviors are affected by canal seepage. Lal (2001) investigated the influence of canal seepage on the amplitude and the phase lag of propagating waves. Field and numerical experiments will be conducted to understand all these effects.

There may be applications for which it is not possible to follow all the required conditions for diffusion flow. Under these conditions, we have already recognized that introduction of full dynamic capability may become an essential next step.

Resolution Plan (Proposed Action):

1. Some benchmark tests and field tests are in the plan
2. Dynamic flow capability may become necessary

Signoff list

Technical review: Randy date

Editorial review: Karen date 17 AUG 2005

Management review: date

☐Action completed date

by: approved by:

Released in ☐ version ____ of code and/or ☐ version ____ of document:

Issue ID # 31 Short Description: Tidal Transition Area

Comment/Issue: The computational domain of the RSM in the SFRSM application includes the tidally dominated mangrove ecotone along the southwest Gulf coast between Cape Sable and Ten Thousand Islands. Use of the RSM in coastal areas is not justified within the context of the diffusion-wave assumption, and the computational domain of the SFRSM should not be shown to include the tidal transition zone.

Report Version 1.3 page 11 line # 28.

Response assigned to: Lal 7/27/05

Response Summary:

The SFRSM domain was extended to the coastline after assessment of two opposing considerations. The diffusion flow formulation of the RSM is based on depth averaged shallow water flow equations without the inertia terms. As a result, RSM cannot simulate the dominant inertial effects in tidal zones. It can only simulate the effects of both friction and gravity terms. The result of the extended area in the tidal zone is mainly to drop the inertia effects from the depth averaged equations. As long as the results of the tidal zone are dropped from RSM, and as long as any nonlinear effects of tidal solution on the long term water levels are small, the boundaries extension provides a seamless boundary (not the ocean boundary) of the tidal zone. If this assumption is valid, the current boundary is valid, as long as the results of the tidal zone are dropped. If this assumption is extremely wrong, it is necessary to find a suitable bc for the diffusion flow-based regional model somewhere at the end of the tidal zone. It is unclear at this time if the work on the tidal model is complete and useable as an alternative boundary condition applied at the rim of the tidal boundary.

The opposing view partially discussed above stops the model before the tidal zone and provides an appropriate bc at the boundary. Unfortunately, availability of data or information at such a boundary is uncertain. This avenue must be pursued after checking the progress of the USGS work.

The third approach was to use a uniform flow bc at the rim of the tidal zone, assuming that overland flow leaves the model domain subjected to uniform flow conditions.

Resolution Plan (Proposed Action):

1. Flows in coastal areas influenced by tides cannot be simulated by the diffusion-wave approximation due to the importance of the local and convective acceleration terms. Areas influenced by tide in south FL are areas outside the model domain region where model calibration, scenarios, and prediction are needed.
2. Exclude ecotone area from model domain in figure
3. Update document

Signoff list

Technical review:	date
Editorial review: Karen	date 17 AUG 2005
Management review:	date
☐Action completed	date
by:	approved by:

Released in ☐ version ____ of code and/or ☐ version ____ of document:

Issue ID #__32__ Short Description: Rain/ET in Canal water balance.

Comment/Issue: With such a large number of canals in South Florida, and given the long simulation period, both rainfall and ET should be considered in the canal water balance. This is simple to implement, and it should slightly improve model accuracy.

Report Version _1.3___ page _11__ line # _41___

Response assigned to: Ken T.

Response Summary: Analysis indicates that the canals represented in the RSM application to south Florida (SFRSM) occupy less half a percent of total surface area of the model domain. Modelers agree that inclusion of rainfall and ET in the canal water balance could slightly improve model accuracy. More important is that when RSM is applied to smaller or specific domains where canals occupy a significant portion of the domain this could become important. Model developers plan to include rainfall and ET in the canal water balance in a future RSM release.

Future work will also include developing an HPM structure for canal segments. This is necessary to provide the HPM structure to link to water quality biogeochemical processes to simulate solute transformations and transport

Resolution Plan (Proposed Action):

1. Modification of code to include these features is relatively low on the priority list. (They will be entered into our enhancement data base “bugzilla” for future update)
2. Include rain and ET in canal water balance, and verify in model code
3. Update model documentation

Signoff list

Technical review: Eric	date
Randy	date
Editorial review:	date
Management review:	date
☐Action completed	date
by:	approved by:

Released in ☐ version ____ of code and/or ☐ version ____ of document:

Issue ID #_33___ Short Description: Flooding / Post-Processing	
Comment/Issue: If an objective of the RSM is to simulate the extent of surface flooding, consideration should be given to using a GIS model component to give better resolution of the spatial distribution of water on the land surface. The water-surface elevation calculated for each cell using the RSM model could be combined with a more detailed subcell GIS land-surface elevation coverage to yield more refined estimates of the spatial extent of flooding. Report Version _1.3___ page __11__line # _45___	
Response assigned to: Ken T.	
Response Summary: This approach has been used with success previously in post processing of South Florida Water Management Model output with more detailed mico-topography to in the determination of species specific performance indicators. The approach will be considered in conjunction with client needs as performance measures are developed to meet the needs of clients for RSM applications	
Resolution Plan (Proposed Action): 1. Will meet with Comprehensive Everglades Restoration Plan evaluation teams and other potential clients (Water Supply and Operations Departments) to develop appropriate performance measures during 2006 transition year. 2. Document will need to be developed describing performance measures.	
Signoff list	
Technical review: Dave	date
Editorial review:	date
Management review:	date
☐Action completed	date
by:	approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:	

Issue ID #_34___ Short Description: Dynamic time-stepping.
Comment/Issue: The RSM solves all equations for regional flow simultaneously. Formulation of the surface-water, ground-water, and canal-flow equations for coupled-matrix solution forces the simulation to be conducted at a unique time step for all waterbodies within the system. Flow conditions in the most dynamic waterbody of the system should govern the chosen time step. Thus, unnecessary flow computations will be carried out in the other waterbodies, e.g., ground-water flow solutions are typically required much less frequently (daily stress periods) than surface-water flow solutions (hourly or smaller time steps). Given that reduced computational run time is a high priority issue for RSM development, *decoupling* the ground-water and surface-water solutions could be advantageous. Furthermore, consideration should be given to making the time step in the RSM dynamically variable during the simulation. It is more computationally efficient and accurate to adjust the simulation time step dynamically to closely match the flow conditions. For example, longer time steps ($\Delta t > 24$ hours) in dry seasons and shorter time steps in wet seasons ($\Delta t < 24$ hours) and during periods of extreme weather, flow, and control events should be considered. Report Version _1.3___ page __12__line # _6___
Response assigned to: Lal
Response Summary: **Issue (34)** It is true that the flow conditions in the most dynamic process will govern the time step. Considering that a system consist of spatial and temporal disturbances of varying scales in the solution, the model developer has the responsibility to select the spatial and temporal discretizations necessary to capture as much of the solution as accurately as possible. The developer also has to consider the fact that spatial and temporal scales of the disturbances are connected through the governing equations (Lal, 2000). So, even if a single time step is selected, it is not supposed to violate conditions described in Lal (2000). Earlier models were mostly decoupled, and two different time discretizations (or space discretizations) could be used to capture the disturbances resulting from various governing equations in each model. Algorithms to couple these modules were developed later. MODFLOW and BRANCH models coupled to create MODBRANCH is an example. In these cases, the time steps for each model was different enough to have some savings, but the coupling had to be done iteratively spending more time. With RSM, the coupling is carried out internal to the model, and the sparse solver is extremely efficient in carrying it out. The efficiency loss due to an over-discretization is compensated by the fast solution speed of the solver. Many of the fast solvers came into existence very recently, and there are many features to increase the computational speed. The ultimate solution of this problem could be known only after testing.
Resolution Plan (Proposed Action): 1. Accept as recommendation. Decoupling techniques may be considered in the future to address computational issues.
Signoff list
Technical review: Randy date
Editorial review: date
Management review: date
☐Action completed date
by: approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:

Issue ID #__35__ Short Description: Sub-timing and domain decomposition.
Comment/Issue: Other numerical enhancements that can be considered in future developments of the RSM include sub-timing and domain decomposition. Sub-timing has been described in Bhallamudi et al. (2003) for subsurface flow and transport simulation. The objective of sub-timing is, for a single global time step, to take smaller time steps for regions of the domain where flow processes are faster (say the surface) and larger time steps for slow flow regions (for example, the subsurface). Domain decomposition is another technique that becomes attractive for large-scale simulations of coupled surface and subsurface flows that potentially require very large simulation times. It consists of splitting the total flow domain into several pieces or subdomains, for example using the boundaries of sub-watersheds, solving for flow for each subdomain individually, and then linking all subdomains using an iterative approach. Report Version _1.3___ page __12__line # _21___
Response assigned to: Randy
Response Summary: Agree.
Resolution Plan (Proposed Action) • Recommendation to be included in future development work.
Signoff list
Technical review: Dave W. date
Editorial review: date
Management review: date
☐Action completed date
by: approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:

Issue ID #_36___ Short Description: Future enhancement (GMS version 6.0 and SVD)
Comment/Issue: Preliminary applications of the RSM in South Florida have primarily focused on two-dimensional ground-water flow, with the intention of building more three-dimensional models in the future, particularly in certain regions of the aquifer system. The U.S. Department of Defense Groundwater Modeling System (GMS) software (http://chl.erdc.usace.army.mil/CHL.aspx?p=s&a=Software;l) is currently used to construct the triangular meshes for the ground-water component of the RSM and, as three-dimensional components are constructed in the future, the subsurface characterization will become more challenging. There are new tools in version 6.0 of GMS (released in July 2005) that should work well with the RSM. These tools are associated with the "Horizons" feature of GMS, which makes it possible to utilize boreholes, hand-sketched cross-sections between boreholes, and user-defined or interpolated surfaces in the form of triangulated irregular networks (TINs) to create three-dimensional representations of the complex geologic layering present in some parts of the aquifer system. The very nature of South Florida and the complexity of the RSM make it a classic example of a highly parameterized system. A new parameter-estimation algorithm called "SVD-Assist" (= "Single Value Decomposition – Assist") is available and is designed to work with highly parameterized systems. Applications of this new algorithm have shown remarkable success. SVD-Assist is able to calibrate systems with thousands of parameters in a stable fashion and relatively quickly. The algorithm can be accessed in the most recent version of the parameter estimation utility PEST (http://www.sspa.com/pest/). Report Version _1.3___ page _12-13___ line # _32-45, 1-8_
Response assigned to: Dave W.
Response Summary: GMS ver . 6.0 and PEST assist sound like powerful tools and we will look into using them along with a "pilot-point-based-approach" in the future. Currently we are setup to use an SVD inverse modeling tool developed to run on our linux cluster which has been extended to provide an interface to PEST.
Resolution Plan (Proposed Action): Alternative tools will be developed as part of the long term RSM development
Signoff list
Technical review: date
Editorial review: date
Management review: date:
☐Action completed date
by: approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:

Issue ID #37 Short Description: Future enhancement (hydraulic conductivity; PEST)	
Comment/Issue: In calibrating the ground-water model, breaking the hydraulic conductivity (K) array into multiple polygons results in abrupt discontinuities in the K values along the polygon boundaries. This seems to be an arbitrary way to break up the K array into subsections. The PEST parameter-estimation program provides a number of tools for performing pilot-point-based parameter estimation.	
Report Version _1.3___ page _13___line # _10-12 & 27-29__	
Response assigned to: Dave W.	
Response Summary: GMS ver . 6.0 and PEST assist sound like powerful tools and we will look into using them along with a "pilot-point-based-approach" in the future. Currently we are setup to use an SVD inverse modeling tool developed to run on our linux cluster which has been extended to provide an interface to PEST.	
Resolution Plan (Proposed Action): Alternative tools will be developed as part of the long term RSM development	
Signoff list	
Technical review:	date
Editorial review:	date
Management review:	date
☐Action completed	date
by:	approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:	

Issue ID #__38__ Short Description: Future enhancement (XMDF).
Comment/Issue: The eXtensible Model Data Format (XMDF) and Application Programming Interface (API) (http://www.wes.army.mil/ITL/XMDF/) could be used to replace the NetCDF portion of the RSM input/output file format. Based on current experience with XMDF, it is likely that this would result in much smaller file sizes than the currently used NetCDF data format. Report Version _1.3___ page _13___line # __31__
Response assigned to: Randy
Response Summary: Agree.
Resolution Plan (Proposed Action): • Recommendation to be included in future development work.
Signoff list
Technical review: Dave date
Editorial review: date
Management review: date
☐Action completed date
by: approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:

Issue ID #__39__ Short Description: Theory Manual Structure

Comment/Issue: The panel recommends the following modifications to the layout of the Theory Manual:

- A "Purpose and Scope" section should be added to the documentation, wherein limitations and restrictions on use of the model, imposed by assumptions in the model formulation, are identified. Potential users should be advised of the types of analyses that can be appropriately conducted with the model and cautioned about inappropriate uses.

- Descriptions of the HSE and HPM should be in separate chapters.

- Appendix A (Regional Simulation Model Philosophy), particularly A.2 (Scope of the RSM), should be part of Chapter 1 (Introduction).

- Appendix B (Governing Equations Using the Traditional Approach) should be part of Chapter 2 (Hydrologic Simulation Engine Theory and Concepts).

- Reference papers should be listed as references and copies of these papers should not be part of the Appendix. The Theory Manual suffers significantly by having technical papers describing critical aspects and concepts related to the RSM development attached as appendices. Concepts vital to documenting the model formulation, guiding use of the model, and investigating potential numerical errors should be excerpted and incorporated directly into the Theory Manual for continuity and clarity.

  In naming the "References" section, it should be noted that there is a difference between "Bibliography" and "References." "Bibliography" is a list of published works that are related to the topic, but not necessarily quoted in the text. "References" is the list of published works that have been specifically referred to in the text. The Theory Manual would be expected to have only a list of references. If a bibliography is deemed necessary, it should be contained in a separate appendix.

- The HPM white paper (Appendix C.5) should be assimilated into the main body of the Theory Manual as a separate chapter.

- The MSE white paper (Appendix C.6) should be assimilated into the main body of the Theory Manual as a separate chapter.

  In the MSE white paper, the fact that the models used for comparative analyses with the RSM were not developed with the same purpose and scope as the RSM should be noted. Most of the models listed in Tables 1 and 2 of the MSE white paper can be classified as hydrodynamic-simulation models rather than hydrologic-management models, since the purpose and scope driving their developments were quite different from those of the RSM. Although these other models are capable of simulating all or part of the South Florida ecosystem, they might not be as efficient and easy to use for water management as the RSM since the main purpose for their development was quite different.

- Uniform document standards should be applied to all parts of the Theory Manual. This would include using the same word processor for all parts of the document. The LaTex typesetting program is clearly superior to other programs when used for large, high-technical-content documents such as the Theory Manual.

- A list of symbols with units of measure would significantly improve the Theory Manual. Defined variables could be limited to those used in equations.

- Consistent terminology should be used throughout the Theory Manual and supporting documentation. A glossary would make the Theory Manual easier to understand and unambiguous.

- Use one set of units in the Theory Manual, either "English units" (which should properly be called U.S. Customary units) or "metric units" (which should properly be called SI units). If both systems are used in the RSM, the Fact Sheet should state so. Both systems of units should be used if the model is going to be applied outside of South Florida.

The name "Theory Manual" might not be the best way to describe the model-supporting document. Consideration should be given to having two sets of manuals: One manual titled "User's Manual" containing a description of how to run the model and a second manual titled "Technical Reference Manual" or simply "Reference Manual". The Technical Reference Manual would contain all the information that is necessary to understand the model, but not necessarily to run it. Portions of the theory that are deemed necessary for understanding the model should be included in the Technical Reference Manual.

Report Version _1.3___ page _14-15_ line # _7-44, 1-37_

Response assigned to: Pattie F.

Response Summary:

A "Purpose and Scope" section will be added to the RSM documentation (i.e., RSM Theory Manual), which will provide an overview of the model, listing the major model features, constraints and assumptions, and typical model applications.

We agree that the importance and uniqueness of HPMs warrants that they be treated in a separate chapter instead of in an appendix, and this change will be made. Hydrologic Process Modules (HPMs) are a component of the HSE, and the HPM concept is introduced in Chapter 2. A more complete description of HPMs was provided in Appendix C.5. We intended to limit the HPM discussion in Chapter 2 to the conceptual framework of HPMs and their interaction with other HSE objects, so the discussion is not comprehensive. One concern that has arisen regarding the description of individual HPM objects is that they are described using terminology common to the source code for that specific object. Therefore, the inconsistency in terminology across HPMs is intentional, in order to ease the understanding of the HPMs by traditional modelers. We agree to revise the HPM documentation to be consistent across HPMs, and to provide crosswalk information to modelers as a footnote or through some other means to aid in their understanding.

Because of extensive early testing of various RSM components, this strength was also introduced in the Introduction. Several sections were removed from the Introduction and placed in Appendix A. These sections provide insight into our model development process, but we feel that they are not vital to the model, and therefore should remain in Appendix A or be removed entirely.

Chapter 2 of the RSM Theory Manual covers the major theoretical conceptual framework of the model, focusing on the object-oriented approach. We originally started this chapter with a discussion of the traditional approach, but moved it to Appendix B, as it is also not vital to the model. They are included to assist modelers accustomed to the traditional approach in making the transition to the object-oriented approach. We feel that they are not vital to the model, and therefore should remain in Appendix B or be removed entirely.

We feel that the object-oriented approach is not emphasized enough in the figures and graphics in Chapter 2. We intend to continuously refine our graphic representation of the model's features and the model objects' interaction to make the object oriented approach more recognizable and understandable.

We accepted the LaTeX default name of "Bibliography" for our references. We will attempt to override this default so that our "References" section can be appropriately named. The final RSM Theory Manual will be rendered using one consistent software package. It will include a cover, copyright page, and a "road map" showing the entire document set and what information can be found in each document. We intend to use LaTex typesetting program for all parts of the RSM documentation, with version control provided through CVS software.

As mentioned above, the HPM White Paper will be incorporated into a separate chapter of the RSM Theory Manual.

Chapter 3 of the RSM Theory Manual describes the MSE component of the RSM. Because the MSE is still under development, we deliberately limited the amount of information provided here. This section will be revised as new features are added. The current features are valid, but most likely will not be the features most typically applied to south Florida management problems. The MSE White Paper, included as Appendix C.6, will be incorporated into this chapter to provide greater detail. Again, we intend to continually improve the quality of the graphics and figures to show the interactions between the HSE and MSE components of the RSM.

We agree that appendices C.1, C.2, C.3, and C.4, four refereed journal articles, should be removed from the appendices and appropriate content incorporated into the appropriate chapters. They were placed here for the convenience of the peer review panel since the content had not yet been combined. Model verification examples will be excerpted from these publications as appropriate.

We intend to add a glossary and an index to the RSM Theory Manual, so that terms can be consistently applied, more easily understood, and cross-checked for accuracy. The glossary will include a list of symbols and variables used in the equations.

Units will be double-checked for consistency across all equations in model documentation. We agree to refer to units as SI instead of metric and US Customary instead of English. This has already been submitted to our Change Control Board, since it requires a change in variable names. RSM code provides a choice to the modeler to use SI or US Customary units.

Table 1 provides a summary of RSM manuals breakout, for both existing and proposed.

Table 1. Proposed RSM Document Set

Category	Volume	Existing, Final	Existing, Requires Changes	Proposed
Overview Materials	RSM Fact Sheet			X
Technical Reference Manuals	RSM Theory Manual		X	
	RSM Verification Tests			X
	RSM Benchmark Guide		X	
	Guidelines for Managing Numerical Error			X
User Manuals	HSE User Manual		X	
	MSE User Manual		X	
	RSM Tutorial/Training Guide			X
Implementation Applications	Loxahatchee Watershed Report	X		
	Southern Everglades Model Report	X		
	South Miami-Dade Report	X		
	South Florida Regional Simulation Model (SFRSM)			X
	Natural Systems Regional Simulation Model (NSRSM)			X
Background Materials	RSM XML Primer		X	
	RSM Peer Review Report		X	
	RSM Bibliography		X	

Resolution Plan (Proposed Action):

1. Procure technical editing services beginning 10/1/05. Deliver current document with flagged corrections from pre-workshop panel comments.
2. Update RSM Theory Manual per flagged corrections and additional revisions listed above.
3. Perform internal review RSM Theory Manual
4. Synchronize future manual updates with code updates, as necessary

Signoff list	
Technical review: Zaki	date 8/17/05
Editorial review:	date
Management review: Eric	date 8/18/05
☐Action completed	date
by:	approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:	

Issue ID #__40__ Short Description: Editorial – E vs. V vector	
Comment/Issue: The vectors **E** and **V** both represent the volumetric flux, but they are not used consistently in theoretical equations derived from the Reynolds transport theorem. Although the equations are correct, a consistent notation should be used to avoid confusion on the part of the reader. <u>It is recommended that **E** be replaced by **V** in all instances</u>. Report Version _1.3___ page _15___line # __41__	
Response assigned to: Lal	
Response Summary: This was a true typographical error, and will be corrected as suggested. During the time of creation of the user manual, there were some theoretical work associated with momentum and other fluxed which lead to the confusion.	
Resolution Plan (Proposed Action): 1. Replace E with V in RSM Theory Manual.	
Signoff list	
Technical review: Pattie	date 8/19/05
Editorial review:	date
Management review: Eric	date 8/18/05
☐Action completed	date
by:	approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:	

Issue ID #__41__ Short Description: HPM

Comment/Issue: Many of the equations used as a basis for the HPMs are heuristic and have not been validated in the field. Although this does not rule out using these equations, the lack of validation and references to validation studies should be made clear in the documentation. In addition, many of the parameter values suggested for use in the HPMs are presented without references that describe the context in which the cited parameters were derived. All tabular presentations of suggested parameter values should have a "References" column.

Validation experiments are specific to individual HPMs. There is only one set of HPM validation experiments in the documentation. Since these validation experiments apply only to the <prr> module, it is recommended that the <prr> validation be documented in the section where the <prr> module is described. In general, HPM validation experiments should be reported in the section where the basis of the HPM is described. The duration of the rainfall and the head boundary conditions in the <prr> validation experiments need to be specified in the documentation.

Report Version _1.3___ page _16___line # __4-18__

Response assigned to: Eric F.

Response Summary:

The HPM Overview document was developed to provide the governing equations for the HPMs and simple implementation of the each HPM. The document was not intended to be a comprehensive reference manual for the HPMs. As such, documentation of HPM development was not included.

The Peer Review Panel has recommended that HPM document be expanded to include the origins of the HPMs and discussion of the hydrologic models and field studies from which the HPMs were derived. The HPMs were developed based on field studies and other model (Table 1) that have been applied in south Florida with the exception of PRR (Table 1). The essential component of each process has been implemented in the HPM and the HPM has been validated in an RSM benchmark. The benchmarks ensure that the HPM performs correctly and any further HSE development does not change the HPM behavior. Discussion of the development and validation of the individual HPMs will be included in the revision of the RSM documentation.

Table 1. Field studies used for development and verification of RSM Hydrologic Process Modules.

	HPM	Supporting studies
1	Layer1nsm	Based on natural systems application of the SFWMM (SFWMD, 1998)
2	Unsat	Based on the layer1nsm HPM with an enhancement accounting for water storage and use from unsaturated soil. Although this HPM has been validated against layer1nsm HPM, it has not been verified with field data.
3	Layer5	Based on the layer1nsm HPM with an enhancement accounting for multiple soil horizons with distinctly different physical characteristics. It has not bee verified with field data.
4	Mbrcell	Based on the Cascade model (Fanson and Welter 2001) and the Multibasin Routing Model (Tomasello et al. 1988).
5	Prr	Based on the NAM model created by DHI (2003)
6	Afsirs	Based on the AFSIRS model created by Smajstrla (1990)
7	Ramcc	Based on the AFSIRS model (Smajstrla 1990) and additional field studies Obreza and Admire (1985), Obreza and Pitts (2002)
8	PumpedDitch	Based on field work by Flaig (2001a, 2001b and 2001c)
9	agImp	
10	Imperv	Based on the SWMM model (Huber and Dickinson, 1988)
11	urbanDet	Based on SFWMD ERP Basis of Review Design Aids (SFWMD, 2000)
12	agHub	Based on field work by Flaig (2001a and 2001c)
13	urbanHub	Based on the SWMM model (Huber and Dickinson, 1988)

The Panel also recommended that references for the parameter values for each HPM be included in the model documentation. The parameter values are based on data from the literature or previous model implementations. The references for these values will be included in the attribute table for each HPM with a description of the source studies in the text of the revised HPM Overview document.

The PRR model implementation was added to the HPM Overview document as an example of the implementation of an HPM. The details of the example implementation were not included in the HPM Overview document due to limitations on space and the emphasis on the theory. The full description of the PRR implementation will be included in the revised HPM documentation. Additional verification examples will be provided for each HPM in the revised documentation.

Resolution Plan (Proposed Action):

1. Include supporting document and references used in the development, validation and verification of the HPMs.
2. Add a "Reference Column" to all tabular presentations of suggested parameter values
3. Add HPM development documentation.
4. Provide additional statements regarding "additional" tests/validation, which will be conducted in the near future.
5. Relocate the <prr> implementation to the same section where the <prr> module is described and include all of the details of the implementation.
6. Update/revise model documentation.

Signoff list	
Technical review: Ken T.	date 8/17/05
Editorial review:	date
Management review:	date
☐Action completed	date
by:	approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:	

Issue ID #__42__ Short Description: HPM **<unsat>**	
Comment/Issue: Variable names and document terminology should be changed to differentiate between depth and elevation. Report Version _1.3___ page _16___line # __26__	
Response assigned to: Eric	
Response Summary: The modelers agree that the text in the HPM documentation is confusing. The graphic description of the control volume for the <unsat> HPM water budget references the ground surface elevation (z) and the elevation of the water table (H) while the mathematical description of the HPM water budget refers to the thickness of the unsaturated zone in the soil which is defined by the water table depth. The control volume graphic will be corrected to reflect water table depth and additional text will be added to better describe the reference elevations. Additional text will be added will be added to describe the HPM assumptions and the conditions under which this HPM should be applied.	
Resolution Plan (Proposed Action): 1. Revise text & model documentation	
Signoff list	
Technical review: Ken T.	date
Editorial review:	date
Management review: Pattie	date 8/19/05
☐Action completed	date
by:	approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:	

Issue ID #__43__ Short Description: HPM **<layer5>**

Comment/Issue: The symbols Θ_{cap} and Ew are both used to represent the extractable water in the soil column. To avoid confusion, one or the other variable should be used.

Report Version ____ page _16___line # __30__

Response assigned to: Eric

Response Summary:

The RSM has been developed with a variety of HPMs for simulating local hydrology and water management at different levels of complexity. It is possible to use different HPMs for the same parcel in RSM. There is no single "best" method for simulating local hydrology for all implementations. The flexibility of RSM also allows for the development of additional HPMs when additional detailed water management is appropriate.

The philosophical approach originally adopted for the development and implementation of HPMs was to adapt the algorithms from the original context of the selected model components and use the original parameter symbols in the HPM using those algorithms. In this way the modelers that have used the selected model components in the past (AFSIRS, SWMM, PRR, etc…) would recognize the familiar parameters in the standard symbol set. It was felt that this approach was necessary because of the variety of HPMs available in RSM for simulating the surface hydrology depending on the objectives of the RSM implementation.

The Panel indicated that it would be preferable to provide a single set of parameter symbols for all HPMs and HPMs that used the same symbol would need to be reconciled to unique values.

A glossary will be developed to define the symbols and parameters used in the HPMs. The glossary will be cross-referenced to each HPM so users can see only those symbols and parameters that pertain to each HPM. Where possible the HPM documentation will have a single, consistent set of parameters. However, where clarity is improved by maintaining the parameters and symbols used in the original source model or reference, those symbols will be preserved in the HPM documentation with a cross-reference to the common set of HPM symbols.

Resolution Plan (Proposed Action):

1. Identify all HPM parameters that have multiple symbols and where possible, convert to a single consistent set of symbols. Where clarity is improved by maintaining symbols from original work these will be maintained and cross-referenced to common HPM symbols.
2. Develop a common symbol glossary.
3. Update model documentation.

Signoff list

Technical review: Ken T.	date
Editorial review:	date
Management review:	date
☐Action completed	date
by:	approved by:

Released in ☐ version ____ of code and/or ☐ version ____ of document:

Issue ID #__44__ Short Description: HPM **<prr>**

Comment/Issue: The suggested values for the maximum infiltration rate, K_{0inf}, in Table 4 of the HPM white paper are off by at least an order of magnitude. The results of Chin and Patterson (2004) for Miami-Dade could be used as one reference for estimating this parameter.

Several parameters given as "typical values" in Table 4 of the HPM white paper depend on local conditions within individual cells; guidance should be provided for selecting these variables. Specifically, the variable Lmax depends on the depth to the water table and soil type and the variables CKOL, CKIF, and CKBF depend on local surface and subsurface conditions. Guidance in selecting these variables, preferably based on their functional relationship to other variables, should be presented in the documentation.

The <prr> module quantifies the soil-water upflux from the water table into the root zone as a wedge of water placed into the root zone due to the placement of the water table at the beginning of each time step. However, there is no description of how the wedge is used, how the wedge is parameterized, and what methodology should be used for estimating the wedge parameters.

Report Version _1.3___ page _16___line # __35_& 39_

Response assigned to: Eric F.

Response Summary:

The suggested range and typical values for all parameters in Table 4 will be checked and corrected for South Florida conditions. The values in the paper were adapted from a calibrated version of PRR implemented in a different location. The results Chin and Patterson (2005) will be included in this HPM and others, as appropriate.

The guidance for the selection of the parameter values for <prr> and the other HPMs is provided in a separate document, the RSM User's Manual. Additional information will be included in the User's Manual to improve the parameter select methods.

Although we did not include soil water upflux in the <prr> HPM, it can be an important component in the water budget, particularly where the vegetation typically obtains water for evapotranspiration from a shallow water table. There is no specific reference to a wedge in the <prr> representation in the HPM documentation for referring to upflux, but the description of upflux as a wedge is a potential simplification of the process. The preferred approach for modeling upflux is as follows using the equation (DHI 2003):

$$\text{Upflux (mm/day)} = (1 - L/L_{max})^{0.5}\ (GWL/GWL_{max})^{-a}$$

$$A = 1.5 + 0.45\ GWL_{max}$$

Where Lmax is lower zone water storage max, GWL is groundwater table depth, and GWL_{max} is groundwater table depth at which upflux -> 0.

Resolution Plan (Proposed Action):

1. Check and correct values in Table 4 (K_{0inf}).
2. Verify values in table 4 and include literature references.
3. Verify values listed in table 4 with values used in RSM.
4. Provide guidance (use reference if available) for selecting typical values listed in table 4 (Lmax, CKOL, CKIF, CKBF).
5. Implement water upflux in <prr> HPM using the method described above..
6. Update model documentation.

Signoff list

Technical review: Ken T.	date
Editorial review:	date
Management review:	date
☐Action completed	date
by:	approved by:
Released in ☐ version _____ of code and/or ☐ version _____ of document:	

Issue ID #__45__ Short Description: HPM **<pumpedditch>**

Comment/Issue: Expressing maximum pumping rates in terms of inches per day is questionable; m^3/s seems to be more appropriate.

Several definitions seem incorrect, specifically:

- for "fcPumpoff" change "water supply pump turn-on" to "collector ditch turn-off"
- for "fcPumpOn" change "water supply pump turn-on" to "collector ditch turn-on"
- for "fcPumpoff" change "Trigger elevation for water supply pump turn-on" to "Trigger elevation for water supply pump turn-off"
- for "maxLevel" change "Trigger elevation for water supply pump turn-on" to "Trigger elevation for pump turn-on"
- for "minLevel" change "Trigger elevation for water supply pump turn-on" to "Trigger elevation for pump turn-off".

Report Version _1.3___ page _17___line # __9-25__

Response assigned to: Eric F.

Response Summary:

Unfortunately, the text in the HPM documentation is incorrect as a result of a cut-and-paste edit. The specific definitions for the pumpedDitch HPM are as follows:

Attribute	Definition	Suggested Range	Typical value
hpID	HPM ID	100,000 – 200,000	134768
percentarea	Percent area of farm occupied by collector ditches (%)	0.0 – 15.0	8.5
runoff	destination of runoff	Any water body	Homecell
rks	Seepage Coefficient (1/day)	0.001 – 0.1	0.05
wsPump	Pump rate for water supply pump (ft^3/s)	0.0 – 12.0	6.0
fcPump	Pump rate for flood control pump (ft^3/s)	0.0 – 12.0	6.0
fcPumpOff	Trigger elevation for flood control pump turn-off (ft-NAVD)	3.0 – 18.0	13.0
fcPumpOn	Trigger elevation for flood control pump turn-on (ft-NAVD)	<= 0	14.0
wsPumpOff	Trigger elevation for water supply pump turn-on (ft-NAVD)	0 – 150	12.0
wsPumpOn	Trigger elevation for water supply pump turn-on (ft-NAVD)	0 – 150	15.0
maxLevel	Trigger elevation for excess water to become recharge to homecell (ft-NAVD)	0 – 150	24.0
minLevel	Trigger elevation for HPMs to obtain water from pumpedDitch (ft-NAVD)	0 – 150	6.0
bottom	Bottom Elevation of ditch (ft-NAVD)	0 –150	3.0

The text refers to pump size based on inches/day rather than m3/s. This will be changed to cubic feet per second (cfs) in examples cited in the documentation, since SFWMD uses U.S. Customary units instead of SI. Modelers outside SFWMD are free to use SI units. The size of the flood control pumps is based on

the allowable discharge for any development based on the drainage capacity of the primary canal system in South Florida. These values are published by the SFWMD (SFWMD, 2000). The size of the water supply pumps are based on the volume of water required to meet daily ET demands. Using GIS these values can be used to provide the fcpump and wspump parameter values for each HPM. This additional information will be included in the User's Manual.
Resolution Plan (Proposed Action): 1. Flag revisions in Appendix C.5 (HPM Overview) for the next round of revisions

Signoff list	
Technical review: Pattie	date: 8/17/05
Editorial review:	date
Management review:	date
☐Action completed	date
by:	approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:	

Issue ID #__46__ Short Description: HPM <**agimp**>

Comment/Issue: The NRCS curve number method is given as a basis for calculating the runoff (Q) from the 25-year 3-day rainfall amount (r25y3d), with the available soil storage denoted by S. The documentation further states that S is determined from the soil series. In South Florida, S is typically taken to be a function of the depth to the water table, not a function of the soil series.

The weir equations given in the documentation are not dimensionally homogeneous; hence, the *units of the variables* in these equations must be given.

A typical value of 5.2 m for a 25-year 3-day storm, as stated in Table 7 of the Theory Manual, *is not correct*.

Report Version _1.3___ page _17___line # __29__

Response assigned to: Eric F.

Response Summary:

The value of soil storage is a function of the soil texture, soil structure and depth to the water table. The two most important factors are soil texture and depth the water table. For the typical Flatwoods soil that have a sandy surface soil, the depth to the water table is the most important factor. Other soils, loams near Ft. Myers, clay marls in South Miami-Dade and organic soils in the Everglades Agricultural Area. The soil physical characteristics are related to the soil series. Additional guidance will be provided in the User's Manual for estimation of S. The function describing S will be verified.

The weir equations will be more fully described including the units of the variables.

The values in all of the HPM document tables, including Table 7, will be checked. Several errors occurred during the conversion from English to metric. The HPMs were originally setup using native parameter units (e.g., inches) but are now converted to metric (SI) units as the base units. The HSE Users Manual will provide interpretive information for deriving the appropriate values and SI equivalences. The value of 5.2 m was originally 5.2 inches and will be converted back to inches.

Resolution Plan (Proposed Action):

1. Verify the function describing "S."
2. Improve documentation of weir equation and provide units/dimensions for all variables in US Customary units.
3. Revise HPM attribute tables and verify the typical values listed in table 7.
4. Update model documentation.

Signoff list

Technical review: Ken T. date

Editorial review: date

Management review: date

☐Action completed date

by: approved by:

Released in ☐ version ____ of code and/or ☐ version ____ of document:

Issue ID #__47__ Short Description: HPM **<mbrcell>**
Comment/Issue: Specifically, the time of concentration could be given as a function of cell dimension and ground slope, and the water content at field capacity could be given as a function of the depth to the water table.
Report Version _1.3___ page _17___line # __7__
Response assigned to: Eric F.
Response Summary: The Panel has identified an important issue in the implementation of the RSM that many of the HPM parameters require GIS preprocessing to provide the appropriate values for the model. In the case of <mbrcell>, the time of concentration is a function of the cell dimensions and local soil characteristics. The GIS pre-processor is presented in the HSE User Manual. The discussion of the algorithms for calculating the parameter values as part of the preprocessor will be expanded to provide more detailed information.
Resolution Plan (Proposed Action): 1. Provide functional relationship for time of concentration to be used in the GIS preprocessor. 2. Update model documentation.
Signoff list
Technical review: Ken T. date
Editorial review: date
Management review: date
☐Action completed date
by: approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:

Issue ID #__48__ Short Description: HPM <**cu**>	
Comment/Issue: A suggested range and a typical value for the variable "septic" are needed. Report Version _1.3___ page _18___line # __6__	
Response assigned to: Eric F.	
Response Summary: The "septic" variable in the HPM is a toggle variable; either "on" or not included. If septic = on, then the return water from urban consumptive use is added to the permeable area HPM of the urban Hub. If septic = off, then the return water is directed to the water body identified in the Hub header. This information will be added to the HPM documentation.	
Resolution Plan (Proposed Action): 1. Update model documentation.	
Signoff list	
Technical review: Ken T.	date
Editorial review:	date
Management review: Pattie	date 8/19/05
☐Action completed	date
by:	approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:	

Issue ID #_49___ Short Description: Numerical Error.

Comment/Issue: The Theory Manual asserts that a challenge in modeling complex hydrologic systems is to maintain an acceptable level of numerical errors. However, no guidance is given on what is an acceptable level of numerical errors and what numerical errors to expect in applying the RSM. In addition, there is no clear statement on the sources of numerical errors in the RSM. Identification of suspicious numerical behavior and manifestations of numerical errors in RSM simulations should be provided in the documentation. Any numerical errors specific to the RSM theory assumptions should be identified and their manifestations in model simulations *should be discussed* in the main body of the Theory Manual.

Report Version _1.3___ page _18___line # _10___

Response assigned to: W. Lal

Response Summary:

The idea of an acceptable error was presented as a recognition of reality in running numerical models. One has to balance between the accuracy of the solution and the resources measured by run times spent on the method of solution before deciding error and run time. Table 2 Page 346 of Lal (1998) shows how accurate models are expensive and cheap models are not quite accurate for explicit, ADE, ADI and SOR methods simulating overland flow. The behavior for RSM is exactly the same, and one has to select a proper descretization based on a number of practical considerations (Lal, 1998a).

The fact that numerical errors were analyzed should not imply that the errors are specific to the RSM. The truth is that RSM is not different from other models. Dr Ponce pointed out the paper by O'Brien, et al (1950) which describes exactly the same error that any numerical model would have, except that in the case of RSM, the developers were upfront about it, and presented smart ways to avoid it or manage it. The discussion on α in Lal (2000) equation (9) or Lal (1998) in equation (32) is to show one of the parameters influencing it.

The understanding and quantification of error has been an integral part of RSM development from the beginning. As a result, a collection of studies, papers, and tools have been produced to serve as guidelines for the proper application of the RSM. This collection will be consolidated into a single volume as distributed as part of the RSM documentation set.

Resolution Plan (Proposed Action):

1. Consolidate relevant error analysis documentation into single volume "Guidelines for Managing Numerical Error".

Signoff list

Technical review: Randy	date
Editorial review:	date
Management review: Eric	date: 8/18/05
☐Action completed	date
by:	approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:	

Issue ID #__50__ Short Description: Model Assumptions.

Comment/Issue: All the *assumptions* behind the application of RSM to simulate regional flow in South Florida should be *clearly stated and justified*. It is not a weakness to simplify the description of a given flow process if it is justified, but it can be a weakness if the conditions under which the assumptions are valid are not stated clearly. *Model limitations* that arise from neglect of the inertia terms, and the consequences of these limitations in operational water management and restoration planning, must be *clearly identified* and *discussed*. Clearly stated model assumptions and limitations will facilitate comparative evaluations with other models that do not require the same assumptions. For example, MODHMS or MIKE-SHE can simulate more complex subsurface flow processes, such as variably saturated flow, and MODFLOW has some options that are not in RSM.

Report Version _1.3___ page __18__line # _20-29_

Response assigned to: Lal

Response Summary:

The assumptions behind the governing equations and the diffusion flow formulation are stated on page 22 of the RSM Theory Manual, as well as in Lal (1998b). The applicability criteria have been mentioned in the same manual as given by Ponce (1978) at least under 1D flow conditions. The applicability condition was derived in Lal (2000, page 1245). The numerical consequences due to discretization and computational error are also described in the documents. The user has the responsibility to follow these guidelines and make sure that the model is applicable under the conditions. The model cannot prevent a user from applying a model under the wrong conditions.

Different models have different assumptions. Assumptions associated with RSM were clearly stated, and there is no need to repeat them more than necessary. Other models obviously have other assumptions, and may not need the same assumptions. RSM does not have to consider the assumptions of the other models because RSM is designed for a specific set of conditions that do not have to consider “more complex subsurface flow processes such as variably saturated flow.” If the intention of the RSM were to simulate such flow conditions, there was no hesitation or unwillingness to use such assumptions or methods. Competition with other models was never a goal for RSM development. It was merely attempting to simulate flow conditions in south Florida in the most efficient manner because of the need to simulate a large system for long periods of time.

Resolution Plan (Proposed Action):

1. Add “Purpose and Scope” section to Introduction of RSM Theory Manual and to a new “RSM Fact Sheet” to list
    a. Overview of model
    b. Major features
    c. Constraints
    d. Assumptions
    e. Appropriate model applications

Signoff list

Technical review: Zaki date
Ken T. date

Editorial review: Karen date

Management review: Pattie date 8/18/05

☐Action completed date

by: approved by:

Released in ☐ version ____ of code and/or ☐ version ____ of document:

Issue ID #__51__ Short Description: Validation Test/Documentation.

Comment/Issue: *Additional* documentation is needed to describe the validation of the RSM. Currently available validation examples in South Florida should be described in sufficient detail to allow users of RSM to *reproduce* the same results. Reproducing all documented examples builds model confidence and identifies any irregularities that might result from using different computer platforms. The documentation of validation examples also should be sufficient to allow users of other models (for example MIKE-SHE) to simulate these scenarios for *comparative* purposes.

Report Version _1.3___ page _18___line # _31___

Response assigned to: Zaki 8/15/05

Response Summary:

A concern noted by the panel was that additional information should be added to describe the validation of the RSM.

Validation Test/Documentation Individual objects and components of the RSM have been individually tested. These have been (and will be) documented in a variety of ways—as benchmarks in the RSM Benchmark Guide, as verification tests in published papers, in the proposed RSM Verification Tests section of the RSM Technical Reference Manuals, and in future test bed documentation.

A number of benchmarks have been constructed, which are used to test that the RSM behaves properly after each new feature is added to the model. A RSM Benchmark Guide has been written listing the current set of 59 benchmarks and the features they test. This manual will be revised as new benchmarks are added. In addition, the manual is currently available only on-line (available on the peer review website). We intend to auto-generate a hard copy of this manual so that benchmarks can be added as needed, and will be incorporated consistently when the manual is recompiled.

Validation tests that have been completed and published, as well as tests that are unpublished, will be assembled in the proposed RSM Verification Tests section of the RSM Technical Reference Manuals. We are also constructing additional validation tests which will be carried out in the next year. As these tests are completed, they will be added to the list of tests. The list may be divided into groundwater tests, surface water tests, groundwater/surface water interaction tests, and HPM tests, as the panel has proposed, depending on the number of tests that are complete when documentation is updated.

As discussed at the workshop, a number of RSM Test Beds have been constructed. Documentation for these test beds is scattered and inconsistent. We are proposing a standard format for documenting each future test bed. The format will consist of:

- Purpose of test bed
- Extent and functions tested
- Defined scenarios
- Scenario results
- XML input files
- Appropriate output

See details in the discussion of issue #51 of Appendix B.

All completed and proposed verification tests shall be included in one document "RSM Validation Test", which is part of the proposed documentation set for "RSM Technical Reference Manual.

Resolution Plan (Proposed Action): 1. Identify model validation tests from Lal's previous publications. 2. Explain how we intend to document existing and proposed verification tests. 3. Update model documentation.
Signoff list
Technical review: Lal date 08/19/2005
Editorial review: date
Management review: date
☐Action completed date
by: approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:

Issue ID #_52__ Short Description: Numerical Techniques.
Comment/Issue: The numerical techniques used in the model need to be documented in significantly more detail. Specifically, it should be clearly stated *how the different matrices are assembled* for the waterbody mass-balance equation. Report Version _1.3___ page __18__line # _39___
Response assigned to: Lal
Response Summary: RSM was based on a simple diffusion flow algorithm that has been described for rectangular meshes in a number of places, and triangular meshes in Lal (1998b). The assembly of the matrix and the implicit formulation are described in the RSM Theory Manual. Methods associated with assembling models of this magnitude are explained in texts such as Zienkiewicz et al. (2000).
Resolution Plan (Proposed Action):
Signoff list
Technical review: Randy date
Editorial review: date
Management review: date
☐Action completed date
by: approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:

Issue ID #__53__ Short Description: Documentation (Figures & background info.)	
Comment/Issue: Since the RSM is generic and potentially useful in regions that are similar to South Florida, a description of the main hydrological features of South Florida would be helpful. Such a description should be supported by *figures showing the main areas* in South Florida (Lake Okeechobee, Everglades agricultural area, water conservation areas, Everglades National Park, and urban areas), the main canals and control structures, and a short description of the geology. References should be made to other documents that present more details on the system, to allow the interested reader to get more information without lengthening the Theory Manual. Unique characteristics of the South Florida area that are particularly relevant to the RSM and that could be described in the Theory Manual are: (1) the competing objectives for water use (flood control, water supply, water quality, and environmental protection); (2) the extremely shallow-gradient topography; (3) the proximity of extensive wetlands and urban areas, which correspond to very different hydrologic regimes; (4) the presence of the low-permeability layer, muck, overlying the bedrock in the water conservation areas (WCA) and Everglades National Park (ENP); (5) the nature of the aquifer which is extremely permeable near the coast, and (6) the potential for salt-water intrusion which cannot be simulated at regional scale but that is addressable at local scale. Report Version _1.3___ page __18__line # _43___	
Response assigned to: Pattie	
Response Summary: The RSM is intended to be a generic model that can be implemented in any geographic region. The features we have developed to date have been ones useful to south Florida regional modeling. The information describing the important hydrologic characteristics of south Florida will be included in the model documentation as that information elucidates the strengths and weaknesses of the model. This will allow other modelers to better understand the applicability of RSM to other locations. We may move most of the detailed information specific to south Florida to implementation and application documents, rather than keeping it in the RSM Theory Manual Introduction. It is also important to more clearly delineate between model development and model implementation, and maintaining a consistent set of implementation-specific documents may help to distinguish between them. We intend to provide three forms of documentation for each RSM implementation. First, there will be a Fact Sheet for the implementation. Second, the calibration/verification/ validation results for the implementation will be presented in a standard format. This document will describe the details of the implementation including the important characteristics of that implementation. Third, if the implementation is peer-reviewed, the Peer Review Report will be published. We are currently building two regional RSM implementations, the South Florida Regional Simulation Model (SFRSM) and the Natural Systems Regional Simulation Model (NSRSM). The format for their documents will be finalized over the next six months.	
Resolution Plan (Proposed Action): See action plan for issue #11	
Signoff list	
Technical review: Eric	date 8/19/05
Editorial review:	date
Management review:	date
☐Action completed	date
by:	approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:	

Issue ID #_54___ Short Description: Editorial Comments/Technical Editor.

Comment/Issue: Detailed editorial comments on the RSM documentation submitted by the panel to the SFWMD prior to 22 June 2005 are presented in Appendix II. It is recommended that the manual be reviewed by a competent technical editor to resolve problems with language, grammar and consistency of scientific terminology.

Report Version _1.3___ page _19___line # _15-18_

Response assigned to: Pattie

Response Summary:

Agreed. This was discussed at the workshop on 6/22; a technical editor is slated to join our RSM team in fiscal year 06, beginning 10/1/05. See Table 1 below for proposed workload for technical editor for first eight months (from Fulton Documentation presentation, slide 10). The 517 editorial comments that were provided by the panelists have been reviewed, and flagged in various documents so that they will be incorporated in the next round of changes.

Table 1. Draft Plan for First Eight Months of Technical Editor Contractual Services

Work Product	Dates
Revise RSM Theory Manual	10/1/05-11/15/05
Revise HSE User Manual	10/1/05-11/15/05
Assemble SFRSM Calibration Report	10/1/05-1/31/06
Assemble and Revise NSRSM Validation Report	8/1/05-12/31/05
Assemble RSM Tutorial/Training Manual, Revise RSM Benchmark Guide, Revise XML Primer	1/1/06-4/30/06
Revise SFRSM Calibration Report	5/1/06-5/31/06

Resolution Plan (Proposed Action):

1. flag all editorial changes from panelists in documents
2. revise RSM Theory Manual 10/1/05 – 11/15/05
3. revise HSE User Manual 10/1/05 - 11/15/05
4. assemble SFRSM Calibration Report 10/1/05 – 1/31/06
5. assemble and revise NSRSM Validation Report 8/1/05 – 12/31/05
6. assemble RSM Tutorial/Training Manual, revise RSM Benchmark Guide, revise XML Primer 1/1/06 – 4/30/06
7. revise SFRSM Calibration Report 5/1/06 – 5/31/06

Signoff list

Technical review: Zaki date 8/19/05

Editorial review: date

Management review: Eric date 8/19/05

☑Action 1 completed date 7/13/05 by PEF
☐Action 2 completed date by
☐Action 3 completed date by
☐Action 4 completed date by
☐Action 5 completed date by
☐Action 6 completed date by
☐Action 7 completed date by

approved by:

Released in ☐ version ____ of code and/or ☐ version ____ of document:

Issue ID #__55__ Short Description: Model Error (see also ID #49 & 51)

Comment/Issue: There are three types of errors in modeling: (1) numerical errors caused by round off and/or truncation, (2) physical errors attributed to inaccurate parameter estimation, and (3) errors that are traceable to limited amounts of data or to poor data quality. RSM calibration and validation examples should identify these three sources of errors. Numerical errors can be minimized by a judicious choice of grid resolution and time step, physical errors can be minimized by the proper choice of parameter values, and data-quality errors usually can be assessed only in a qualitative way, however, the *importance of data-quality errors* cannot be overemphasized. Full *model validation requires explicit separation of errors*; otherwise, one could be calibrating numerical errors against physical and/or data-quality errors. The validation procedure should take into account the following considerations: (1) to the extent possible, eliminate any numerical errors; (2) calibrate to acceptable values of physical parameters; and (3) if necessary, assess the quality of measured input data.

Report Version _1.3___ page _19___line # _25___

Response assigned to: Lal

Response Summary:

The general approach that the District has already started to follow considering the three types of errors identified by the Panel is as follows. The proposed tests are listed after each error type.

1. Numerical error caused by round off and truncation: An evaluation of the impact of mesh discretization has been developed. This type of error has to be reduced by optimal selection of discretizations (Lal, 2000). Extremely fine discretization however can increase the run times exponentially.
2. Physical error attributed to inaccurate parameters: This error has to be reduced by using careful calibration and independent field tests such as the canal test (Lal, 2005). Every attempt has to be made not to calibrate against data errors, as suggested by the Panel. The proposal for field tests using generated disturbances as suggested by Lal (2005) is particularly aimed at resolving this problem.
3. Error that can be tracked to poor data: There is no easy solution to this problem, except to do everything to increase the quality and use generated disturbance tests as often as possible.

The results of these tests will be included in the RSM validation documentation.

The verification of RSM also included understanding the error and stability behaviors. O'Brien et al. (1950) introduced a number of terms that have to be compared against the terms used in the current context. They referred to the difference between exact (analytical) solution and the "difference equation solution" as the truncation error. They also referred to the difference between the "difference equation solution" and the numerical solution as the numerical error. Lal (2000) referred to the difference between the analytical and the numerical solutions as a percentage of the amplitude as the numerical error, with the idea that it is the sum total of the effects of discretization and computational process. This derivation included analytical error estimates per time step, and analytical error estimates of the solution itself. Either can be used according to the need.

Post and Votta (2005) listed five common verification techniques for quantifying numerical error. They are described below with examples showing how each method has been used in the verification of RSM.

1. Comparing code results to a related problem with an exact answer. Lal (2000a) showed a comparison of an exact solution of canal-aquifer interaction to the RSM solution.
2. Establishing that convergence rate of the truncation error with changing grid spacing is consistent with expectations. Lal (1998b) showed this behavior for the RSM model. Lal (2005a) and Lal and Van Zee (2003) shows the same behavior in a contour plot of dimensionless discretizations.
3. Comparing calculated with exact results for a problem specially manufactured to test code. The canal water level disturbance test (Lal, 2005, Lal 2005a) was designed to create a sinusoidal

disturbance and check the analytical solution to RSM solutions.

4. Monitoring conserved quantities and parameters, preservation of symmetry properties and other easily predictable outcomes. Lal (1998b) was carried out to test the symmetry of the solution in a 2-D plane by checking if it remains circular.
5. Benchmarking or comparing results with those from existing codes that can calculate similar problems. Lal (1998b) shows a comparison with MODFLOW and a comparison with model solutions of RBFVM-2D.

Full model validation requires explicit separation of errors. The procedures used for RSM validation take into account minimizing numerical errors; calibration to acceptable values of physical parameters; and assessment of the quality of measured input data. Several journal articles documented the assessment of the numerical errors in the validation of RSM. The detailed calibration procedures are described in issue #56. The input data used in RSM has been thoroughly reviewed and archives at the District as MOD1 data.

Resolution Plan (Proposed Action):

1. Provide a paragraph for each error type (general not specific to RSM); there are numerous articles written regarding data-quality errors and physical/parameters error; use these articles to describe each error and what is expected as reported in literature.
2. Provide a paragraph for each type of error in RSM, give range found during model testing/validation, report & compared it with other well-known models error range.
3. Revise model documentation.
4. Revise the description of the error assessment in the RSM documentation.

Signoff list	
Technical review: Zaki	date: 8/19/05
Randy	date
Editorial review: Karen	date
Management review: Eric	date 8/19/05
☐Action completed	date
by:	approved by:

Released in ☐ version ____ of code and/or ☐ version ____ of document:

Issue ID #__56__ Short Description: Future Enhancement (parameter constraints)	
Comment/Issue: The issue of calibrating to acceptable values of physical parameters is controversial. One group of individuals with expertise in this area would argue that the constraints on the physical parameters should be limited to realistic values. This allows modelers to determine the parameter values that best fit the observed data. Then these optimal parameters can be compared to realistic parameter ranges in order to assess the conceptual validity of the model. Another group of experts would argue that physical parameter values should be constrained to enforce the conceptual basis of the model. In this case, extreme, but still realistic, values of the optimal parameters would serve as an indication that conceptual problems might exist in the model. To accommodate both of these views, consideration should be given to including the option in the RSM of either specifying acceptable ranges of physical parameters or not constraining these parameters at all. The modeler would then interpret the estimated physical parameters accordingly. Report Version _1.3___ page __19__line # _39___	
Response assigned to: Randy	
Response Summary: Agree. The RSM currently provides features similar to this recommendation. The tools for calibration and parameter estimation analysis, singular Value Decomposition, LSQ and PEST are being used.	
Resolution Plan (Proposed Action): • The inclusion of tools/techniques to constrain model parameters values to acceptable ranges such as these are part of the long term RSM development. • Additional guidance will be provided in the RSM User Manual to select the appropriate values for each parameter.	
Signoff list	
Technical review: Dave Lehar	date date
Editorial review:	date
Management review:	date
☐Action completed	date
by:	approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:	

Issue ID #__57__ Short Description: Stage & Flow Calibration Issues.

Comment/Issue: The diffusion-wave approach of the RSM is a single-equation solution for one unknown in which a simplified term for flow velocity is incorporated in the continuity equation. Flows are computed in terms of change in head and flow velocities or discharges are not computed directly. In this approach, the Manning equation for overland or canal flow, for instance, becomes primarily a calibration term for computed water levels. Derived flow velocities are a result of this water-level calibration and are not calibrated directly as in the case of unsteady-flow models. This fact could cast doubt on the validity of RSM flow results to define transport rates for future planned extensions of the model with water-quality process modules (WQPMs) to address water-quality restoration issues.

The behavior of surface flow is nonlinear or quasi-linear, implying that parameters defining the flow properties might not remain constant throughout the range of possible flow conditions. A clear example of this variability is demonstrated in diffusion-wave routing in a natural channel, where the Muskingum-Cunge parameters vary not only with stage, but also with rate-of-change in stage. Conventional parameter estimation approaches will miss the peaks and valleys of the flow variability. A three-stage parameter calibration (low, average, and high) might be more appropriate in the RSM to account for the inherent nonlinearity of surface-flow behavior.

Report Version _1.3___ page _20___line # __6__

Response assigned to: Randy

Response Summary: Calibrating hydrologic models to stage is a common practice. The fact that there is only one parameter to calibrate is a problem not only in diffusion flow, but also in full dynamic flow. Fortunately, for full dynamic flow, once the calibration is carried out for either the amplitude in head or the phase (hydrograph peak or hydrograph lag), the calibration can be considered to be complete for all behaviors in both head and flow, provided the model is numerically accurate. Unfortunately in diffusion flow, there is still the same one variable, but calibrating for the amplitude of head does not automatically imply the calibration of phase lag. We believe once the conditions for diffusion flow are satisfied, the diffusion and dynamic models behave approximately the same, while if they are not satisfied, this problem persists until a dynamic model is introduced. There are plans to use a full dynamic flow mode, in the future. It is true that the serious attention has to be paid in simulating water quality using diffusion flow models especially if the diffusion flow assumptions are not followed.

The non-constant behavior of friction parameters is a concern in the Everglades for a number of reasons. Perhaps the primary reason has to do with wetland vegetations types, where overland flow does not exactly following the Mannings relationship. The second reason is that even if there is no wetland vegetation, the laminar/turbulent transition conditions for flow do not follow strict Mannings relationships. The third reason is the use of diffusion routing itself affecting the flow behaviors. There can be a variety of physical conditions for which the flow does not to strictly follow some of the modeled conditions. The suggested three-stage calibration is definitely a good step towards better calibration under theses conditions.

Resolution Plan (Proposed Action):

- The three-stage parameter calibration will be implemented, per the Panel's recommendation.
- The implications of the diffusion flow assumptions will be assessed as part of the water quality development and implementation.

Signoff list

Technical review: Eric	date 8/17/05
Editorial review:	date
Management review:	date
☐Action completed	date
by:	approved by:

Released in ☐ version ____ of code and/or ☐ version ____ of document:

Issue ID #__58__ Short Description: Verification Tests (see also ID #21)

Comment/Issue: Systematic benchmarking should be used to ensure that modifications to the RSM code do not introduce errors in the solution. Verification examples are needed to show that the RSM can reproduce results from analytical solutions or other numerical models. Consideration should be given to incorporating nine HSE verification examples in the Theory Manual: three examples for surface flow, three examples for subsurface flow and three examples for coupled surface and subsurface flow. Documenting *more* verification examples as the model evolves should be a priority.

Tests should be done to demonstrate the significance of errors introduced by using the HSE solution from the previous time step, (i.e., previous day for a daily time step) to compute water balance in model cells. These demonstrations should resolve accuracy issues as well as questions such as whether the time lag constrains the HSE time step. In addition, sensitivity tests should be conducted to determine the effect of this time lag in RSM applications.

Report Version _1.3___ page _20___line # _25___

Response assigned to: Lal

Response Summary:

> Systematic benchmarking should be used to ensure that modifications to the RSM code do not introduce errors in the solution. Verification examples are needed to show that the RSM can reproduce results from analytical solutions or other numerical models.

A number of benchmarks are set aside for comparing the numerical solution to the analytical solution because this is probably the best and the most appropriate tool to verify that modifications to RSM code do not introduce errors in the solution. Two applications of the idea can be explained using available RSM benchmarks. Benchmark 6 for example is designed to test the steady state groundwater solution with two head boundaries against the numerical solution. The steady state solution for this example is parabolic. Benchmark 11 is designed to test the model using the analytical solution for canal-aquifer interaction derived by Lal (2000a). The properties of the analytical solution are similar to the properties of the problem posed by Pinder and Sauer (1971). Passing of this benchmark test indicates that the groundwater solution, canal flow solution, and the interaction between groundwater flow and canal flow as calculated by RSM are all comparable with the analytical solutions.

> Consideration should be given to incorporating nine HSE verification examples in the Theory Manual: three examples for surface flow, three examples for subsurface flow and three examples for coupled surface and subsurface flow. Documenting more verification examples as the model evolves should be a priority.

Adding verification examples to the theory manual is a good idea. The reason for keeping them in journal papers has been because they were new. Many times the derivation of the analytical solution itself was not a simple matter but one that involved complicated mathematical formulations that belong only in a peer reviewed journal.

> Tests should be done to demonstrate the significance of errors introduced by using the HSE solution from the previous time step, (i.e., previous day for a daily time step) to compute water balance in model cells. These demonstrations should resolve accuracy issues as well as questions such as whether the time lag constrains the HSE time step. In addition, sensitivity tests should be conducted to determine the effect of this time lag in RSM applications.

In the early versions of RSM, matrix $\mathbf{M}^{n+1}$ in equation (13) of Lal (2005a) for example was updated in an iterative manner within the same time step. Calculations for next step started only if the previous step converged to a solution. In the case of groundwater flow problems with constant transmissivity, no iterations are necessary because the matrix $\mathbf{M}^{n+1}$ is constant. In the case of overland flow problems, iterations make the solution different because **M** is a function of H. But since it is a weak function of H for slowly varied flow, it was found that the solution with and without updating **M** were not much different. In addition, the solution of the implicit solution in RSM is only first order accurate. The effect of a modification to an iterative solution would still be first order accurate, and would not improve the order of accuracy of the error. Even if the updating was abandoned sometime in the past, it makes sense to carry out some investigations to clearly understand the effect.

The previous day values are the values used in the first iteration of the implicit solution. Using previous day's values is standard in explicit modeling. It is possible to obtain an explicit solution method by using the previous time step values in the matrix. This was indeed an actual test problem used in the early days of development to check the matrix and the model formulation. Mixing the previous and current days values to obtain a weighted value is supposed to be an enhancement in accuracy over the explicit solution. The fully implicit solution is however a choice for stable model formulations. In explicit methods, everything that is used in the solution is from the previous time step as α is set to zero. Parameter α controls how much of the matrix **M** is added to the solution matrix in equation (9). The double sweep method used prior to the Preissman method is an example where a limited updating of the matrix is used to save run time.

Resolution Plan (Proposed Action):

1. Move verification examples from appendices to a "Model Validation tests," which demonstrate/show RSM results compared to analytical solution and other models.
2. Devise a benchmark to show RSM sensitivity to the water budgets.
3. Update model documentation.

Signoff list	
Technical review: Zaki Randy	date 8/15/05 date 8/17/05
Editorial review:	date
Management review:	date
☐Action completed	date
by:	approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:	

Issue ID #__59__ Short Description: RSM Validation (need definition in glossary for validation, verification, benchmark, .etc.).
Comment/Issue: Validation of the RSM requires applying the model to a particular area, calibrating the model, and then comparing predicted and simulated hydrologic variables. As of the time of this panel review, *validation of the RSM has not been accomplished and documented*. An RSM implementation to current conditions in South Florida (SFRSM) and an RSM application to historic conditions (natural system) in South Florida (NSRSM) will be documented and submitted for peer review in the near future. The outcomes of these forthcoming peer reviews will be a key and essential basis for assessing the validity of the RSM. Report Version _1.3___ page _20___line # __40__
Response assigned to: Ken T.
Response Summary: Initial SFRSM calibration and validation will be complete by December 2005. These results will be fully documented. Peer review of the calibration and documentation will be undertaken once management features have been fully incorporated into the SFRSM.
Resolution Plan (Proposed Action): 1. Agree RSM validation, will be conducted and documented in 2006. 2. Calibration and validation documentation will be produced.
Signoff list

Technical review: Lehar	date
Editorial review: Karen	date 10 AUG 2005
Management review:	date
☐Action completed	date
by:	approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:	

Issue ID #_60___ Short Description: HPM Validation Tests.
Comment/Issue: Very limited evidence is presented to validate the documented HPMs. For example, there is no evidence that the hydrology of agricultural areas in south Miami-Dade County can be described accurately by any of the HPMs identified in the RSM documentation. *Addition of validation results, either directly or by reference, into the model documentation would justify application of the HPMs.* The validity of the HPMs should be assessed by conducting more studies like Chin and Patterson (2004) at various locations within the RSM application to South Florida. Such studies address the quantitative relationships between hydrologic variables and these relationships can be included either as new HPMs or adapted to existing HPMs. Report Version _1.3___ page _21___line # _10___
Response assigned to: Eric F.
Response Summary: The philosophy behind the development of HPMs was that RSM would not contain only a single HPM for simulation of local hydrology and landscape water management, but that there would be several HPMs that offered alternative modules with specific solutions or different numerical solutions for local hydrology from simple regressions to detailed process descriptions. In keeping with this philosophy, different HPMs will have different levels of verification and different degrees of validation with field data. The information provided in the HPM Overview document (Appendix C.5 of the RSM Theory Manual) was restricted to the model theory and the description of the behavior and performance of each HPM. It was thought that the inclusion of the discussion of the origin and validation of each HPM would produce an excessively long document. The documentation will be revised to include information describing the verification and validation of the individual HPMs. There are two requirements for the acceptance of HPMs for simulating local hydrology; verification and validation. The verification refers to the determination and testing that the HPMs accurately represent and model the hydrologic processes that they are intended to simulate. The verification of each HPM is demonstrated in the RSM benchmarks. In a benchmark the behavior of the individual HPMs is demonstrated verifying the HPM. Documentation of all HPM verification will be included in the revised documentation. Validation is the process of comparing the HPMs to field data to ensure that they can successfully simulate real world conditions. Most of the HPMs have been validated with field experiments. A few of the HPMs, unsat, layer5 and mbrcell, have not been adequately tested and verified. The additional verification and validation tests are discussed below. Documentation of all HPM validation will be included in revision of the RSM documentation. The individual HPMs were developed to simulate the local hydrology and landscape water management to provide the appropriate demand and runoff for the regional water management simulations. The HPMs are expected to simulate the effective, or representative, field-scale processes to such a degree that typical water and land management decisions affecting local water management can be implemented. However, HPMs are not currently expected to accurately simulate site-specific behavior such as percolation and soil water redistribution, only the effective results of those processes at a field or small watershed scale. The current HPMs, particularly layer1nsm and afsirs HPMs, have been validated through application of SFWMM to provide adequate simulation of local hydrology throughout south Florida. Additional HPMs; urban Hub, PRR, ramcc and AgHub, have been created with more detailed processes to better model local hydrology. The field studies upon which these HPMs are based are listed in Issue 41. The surface hydrology

and water management practices vary considerably among the different regions of south Florida. In particular, the EAA, south Miami-Dade, Everglades, Caloosahatchee River and Lower East Coast basins have distinctly different land use types, agricultural practices, soils, hydrostatigraphy and topography. There are no data that suggests that the available HPMs can not adequately model the local hydrology for these regions. Additional HPMs are being developed to meet the specific requirements of different areas.

Verification is an important component of the HPM development and testing process. Five tasks were presented to the Panel for verification/validation of HPMs. These were as follows:
1) Conduct reasonableness tests on each HPM and vary the parameter values.
For each HPM there is a simple benchmark that verifies that the HPM produces the expected hydrologic response under simple conditions. For each HPM, a more complete benchmark needs to be developed that demonstrates the reasonableness of the HPM under normal conditions i.e., irregular cells, variable soils, landuse, hydrogeology. This will include a simplified sensitivity analysis. An inclusive sensitivity analysis can only be implemented for each specific RSM implementation because the HPMs are sensitive to the regional water levels and water management characteristics.

2) Compare results among HPMs.
The RSM was developed to be flexible with the opportunity to implement alternative HPMs for the same landscape (landuse, soil, water management). As such, there is more than one HPM that is reasonably suitable for application to each landscape. Using the complete benchmark discussed in (1), several HPMs' results will be compared to demonstrate differences and similarities in the implementation of HPMs. This provides an opportunity to compare HPMs that are adapted from well known models (SWMM) with less well known HPMs or locally developed HPMs (<unsat>). This task will provide the necessary information for the selection of the HPM parameter values through the GIS pre-processor.

3) Compare HPM output for single HPMs and Hubs to other models.
The Hub HPM type provides considerable flexibility and functionality in the modeling of local hydrology and water management. The Hub can include several simple HPMs to construct an effective description of the local hydrology and water management. A benchmark should be developed to compare results obtained from different Hub configurations with the simple HPMs to demonstrate the advantages and disadvantages with the utilization of comprehensive Hub HPMs. The Hubs will be developed for multi-cell agricultural and urban developments as well as for single cell Hubs representing complex landscapes.

4) Compare HPMs to field data where possible.
The validation of HPMs to field data is an important component of model testing. This is also a very time-consuming activity. There are various field-scale studies that have been conducted to evaluate the water use and runoff for selected landuses and water management practices. These can be converted into test data sets for HPM calibration. The field studies include agricultural land (citrus, pasture, sugar cane, dairy and vegetables) and urban land (urban subdivisions and commercial mall). There are other field data that describe runoff behavior for sub-basins, but these data are not field-scale data with complete water budgets. Other field data, such as developed by Chin and Patterson (2005) and Savabi et al. (2005) can be used to provide parameter values for selected HPMs and used to verify HPMs in selected regions such as south Miami-Dade County.

5) Sensitivity of HPMs on the regional solution.
It is important to complete sensitivity analysis of HPMs. It is important to understand the sensitivity of the HPMs within the context of each subbasin. This is discussed in detail in the Hydrologic Process Module Calibration Strategy (Feb 2005) and in the HPM Sensitivity Analysis Proposal (18May 2005). This analysis has been conducted in some detail by the SFRSM Regional Basin Subteams, which should be compiled into a

single document.

6) Comparison to other models
Given the difficulty in verifying the HPMs with analytical solutions, another opportunity is to compare the RSM-HPMs to other simulation models with similar local hydrology. Candidate comprehensive models include HydroGeoSphere, ModHMS, HSPF, SWMM, WASH123 and MikeSHE. Other models specific application models include LEACHM, DrainMOD, AFSIRS, SWAT and WamView that emphasize specific processes. Other models with specific application to South Florida can be used for comparison. Comparison to the results of accepted models will provide more support that the HPMs have been developed in a reasonable way and with the appropriate parameter values, provide a reasonable match

7) Comparison to analytical solutions.
Although there are no analytical solutions available for HPMs that model local hydrology, there are analytical solutions for individual components of the local hydrology. These include infiltration, percolation, filed drainage and simple runoff. The HPMs, even applied on a daily time step, should produce the same water budgets as the analytical solution run for the same duration. For daily infiltration in sandy soil this will not be interesting, but for infiltration into marl this could be a useful comparison. These analytical solutions will be necessary when the RSM uses a sub-daily time-step. For drainage, the analytical solution is an important check for ramcc and EAA-field HPMs.

Resolution Plan (Proposed Action):

1. Revise the HPM documentation to include verification and validation
2. The strategy for HPM verification has been developed and will be executed.
3. Currently RSM uses four types of HPMs, layer1, prr, ramcc and Hubs. Our tests will focus on these four HPMs, while consultants focus on the others, which are being developed for future use.
4. We are developing a comprehensive work plan for verifying and validating the HPMs

Signoff list	
Technical review: Lal	date
Ken T.	date
Editorial review:	date
Management review: Zaki	date: 8/19/05
☐Action completed	date
by:	approved by:

Released in ☐ version ____ of code and/or ☐ version ____ of document:

Issue ID #_61___ Short Description: Client Needs (see also ID #50)
Comment/Issue: all clients expect clear statements on the model assumptions, and also statements regarding what the model does and does not simulate. It should be made clear in the documentation that the intended use of the RSM is evaluation of long-term effects of management decisions that impact conflicting water-control issues such as flood protection, water supply, water quality, irrigation, and ecosystem conservation and restoration. Clients expect that all equations solved or used in the model be written somewhere in the documentation and in such a way that a user/client knows exactly how each input parameter is incorporated into the model. More work needs to be done on addressing client needs in the documentation. Report Version _1.3___ page _21___line # _29-37_
Response assigned to: Pattie
Response Summary: District staff agrees with the reviewers comments that clients need to have clear documentation of all the model assumptions, algorithms and appropriate applications. The proposed document set that will contribute significantly towards meeting client needs is discussed in issues 39-54. Default parameter values and appropriate ranges of parameter values already presented in the HSE User Manual will be expanded as further testing is conducted. As the MSE User Manual is finalized, default parameter values and appropriate ranges of values will be added.
Resolution Plan (Proposed Action):
Signoff list

Technical review:	date
Editorial review:	date
Management review: Pattie	date 8/18/05
☐Action completed	date
by:	approved by:

Released in ☐ version ____ of code and/or ☐ version ____ of document:

Issue ID #__62__ Short Description: Graphical User Interface.
Comment/Issue: In order to make the model more user-friendly, a graphical user interface is essential, and systematic tutorials covering simple and potentially complex model applications would be useful for most clients. The goals of non-District users of the model are diverse, and their goals are likely to depend on their particular application of the model. Most non-District users will likely desire a well-documented, scientifically sound, validated, and user-friendly model. More work needs to be done in these areas for the RSM to meet these anticipated non-District client goals. Report Version _1.3___ page _21-22__ line # _39-44, 1-8_
Response assigned to: Pattie
Response Summary: The RSM team is making excellent progress on development of a user-friendly graphical user interface. This has been demonstrated in several forums since the Peer Review Panel on-site workshop. Tutorials and training material will be assembled and made available to clients. The post-processing GUI is being developed using open source software in order to be able to distribute the GUI with the model to clients and users. Once the model is satisfactorily calibrated, efforts will turn to ensure the needs of non-District clients are met in developing performance measures to meet appropriate use requirements. See RSM Project website for updates to the GUI work in progress (www.sfwmd.gov/site/index.php?id=457)
Resolution Plan (Proposed Action):
Signoff list
Technical review: date
Editorial review: date
Management review: Pattie date 8/18/05
☐Action completed date
by: approved by:
Released in ☐ version ____ of code and/or ☐ version ____ of document:

Appendix C: Minor Errors in Peer Review Panel Draft Report

There are a few instances where we feel that the Draft Report is in error, or could be clarified slightly. These instances are listed here.

Add model strengths where appropriate (see discussion in section 1.2 above).

On page 4, line 1, please emphasize that the model is designed to be *easier to learn*, instead of mentioning that it has a steeper learning curve. While the wording may be technically correct, a “steeper” learning curve has a negative connotation that was not intended in our original design for the model.

The correct acronym for the South Florida Water Management Model is SFWMM, not WMM.

The reference is incorrect to Chin and Patterson. The published year is 2005, not 2004, according to the report, and the correct USGS reference number is 2004-5191.

Values used in RSM for Manning’s n and alpha are implementation-specific, not hard-wired into the code. How a particular implementation behaves based on n and alpha values selected will be peer reviewed individually in later phases of this project. The discussion in the Peer Review Panel Draft Report on page 8, lines 15-20 appears to be referring to multiple alphas. More information can be found in Appendix B, issue #22.

In section 6.1, the panel recommends creating two new types of manuals, a User Manual and a Reference Manual, instead of one Theory Manual. However, we currently have both a set of User Manuals and an RSM Theory Manual (the HSE and MSE User Manuals were provided on the website and were listed in the “Proposed RSM Document Set” in the workshop presentation on Documentation). The panel should either agree that the current breakout is appropriate, or suggest rearrangement of various components between the two types of manuals. The current wording seems to indicate that we need to create what already exists, or that the panel was not aware of the existence of the User Manuals. In addition, the primary documentation for the RSM model is much more than just the Theory Manual, so this sentence (line 3, page 14 of version 1.3) should be reworded to state that “The RSM Theory Manual is one of the primary documents describing the RSM model.”

Appendices need to be physically incorporated into the panel’s draft document. If these appendices are dropped from the final report, they still need to appear in the draft. There is no need to provide the District response as an appendix, since we will maintain it as a separate document. It may be more appropriate to provide the minutes from the workshop instead.

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