NORTH FLORIDA SOUTHEAST GEORGIA GROUNDWATER FLOW MODEL DEVELOPMENT PROJECT TASK AND TIME LINE WORK PLAN

Introduction

In 2009, a Groundwater Modeling Subgroup in response to a request by the North Florida Utility Coordination Group was assembled to discuss issues regarding the development and application of the St. Johns River Water Management District Northeast Florida Ground-Water Flow Model (SJRWMD NEF model). Application of the SJRWMD NEF model had indicated the potential for significant water resource related impacts in areas of both the Suwannee River Water Management District (SRWMD) and SJRWMD due to projected groundwater withdrawals within the model domain. The meetings of the Groundwater Modeling Subgroup, which were facilitated by the University of Florida Water Institute (FWI), occurred between August 2009 and February 2010 and enabled all stakeholders to come together for a series of meetings in which issues regarding the SJRWMD NEF model development and application were investigated. The stakeholders included a variety of groups, including water utilities, private industry, governmental organizations, and environment groups.

As a result of the facilitation process, a Summary Report on Groundwater Modeling Subgroup was prepared by Dr. Wendy Graham and Lisette Staal of the FWI. Several recommendations for further groundwater model development were included as part of the report. One of the recommendations stated that: “More time should be spent ‘up-front’ with stakeholders providing input on methods and model evaluation criteria than on defending and/or critiquing the end product. Given the sensitive hydrologic and ecological conditions at the boundary between the St. Johns and Suwannee River Water Management Districts, the two Districts should work toward developing a common North Florida model.” To this end, the SJRWMD and SRMWD have now undertaken the joint creation of a regional groundwater flow model developed through a cooperative process that includes all interested stakeholders.

As currently envisioned, the North Florida Southeast Georgia Regional Groundwater Flow Model (NFSGR) will serve at least two primary functions: (1) The model will enable the assessment of regional-scale cones of depression that result from the cumulative effect of the individual withdrawals that comprise regional pumping centers, and (2) The model will provide a regional framework for the development and application of subregional models to be used in the assessment of areas of special interest within the regional model domain. A detailed task description and timeline has been developed to guide the model-development process (Appendix A). The purpose of the present document is to provide the NFSGR Steering Committee and other interested parties with a background discussion concerning this task description and time line (Appendix A).

Approach

Until recently, ground-water model development within the USGS, Water Management Districts and other regulatory/science-based agencies were typically performed by one or maybe two hydrologists (Figure 1, Table 1). This approach enables model developers to move quickly through the planning and development process. A weakness, however, is that when the models are then put into production or application, the stakeholders affected by the water resource management decisions stemming from the use of the model sometimes express legitimate criticisms of the model. In that context, a significant amount of staff and stakeholder effort is consumed in the process of clarifying approaches and assumptions, demonstrating the model and making modifications to the model where appropriate. Regardless, what appears to be undeniable is that ground-water model development is complex, multifaceted, and, at least partly, qualitative in nature, and that these features of the work can result in differing viewpoints. Thus, expansion of the model-development team to a larger, more diverse group of scientists who participate in the development process from the beginning and throughout is a reasonable strategy for considering a wider variety of viewpoints from the outset. While such a process may prove to be more time consuming, the final result has the potential to be better conceived, better executed, more widely accepted and acknowledged, and ultimately, therefore, more useful.

The challenge, then, becomes one of maximizing the potential scientific benefits while minimizing any potential shortcomings of the larger group approach. In this case, a technical team comprised of a diverse group of scientists and engineers was convened to plan, develop, apply, and document the North Florida Ground-Water Flow Model (Appendix B - Charter for SJRWMD – SRWMD Cooperative Groundwater Model Development Project). The members of the technical team represent "stakeholder" groups from throughout the region of North Florida and South Georgia, including governmental organizations, water utilities, private industry, and environmental organizations. In addition to the technical team, an oversight committee or "steering committee" was also established (Appendix B). The members of both the steering committee and technical team are named in the project charter (Appendix B). The purpose of the project charter is to outline the broad objectives of the project, the roles and responsibilities of the principle project participants, and the ground rules for their interaction.

Task and Time Line Discussion

The general approach to the project is to sequentially perform the stated work in the agreed upon work plan and then document the work performed in each task with a technical memorandum. In each case, the technical memorandum is to be presented in draft form initially, reviewed and revised by the technical committee, and then re-issued in final form. The technical team upon submission of the draft technical memorandum will determine the review period allotted for comment. As the production of a single final task memorandum is an objective that is common to all but the first task, task memoranda will not be mentioned subsequent to this paragraph, except in regards to Task10, the sole task of which will be the production of the project Executive Summary. The first task is unique in that two final documents will be produced. The two documents are the Technical Team Charter (TTC) and Technical Team Work Plan (TTWP), which is the present document. The purpose of the TTC will be to lay out the ground rules, general operating procedures, participant roles, and work expectations for all subsequent work performed by the technical team. The purpose of the present document, the TTWP, is, as stated previously, to provide background information and explanation concerning the components of the task description and time line.

Task 1: Technical Team Charter and Work Plan

> The primary objectives of this task segment are to create the TTC and TTWP. The TTC will include a delineation of the technical team's basic operating procedures, the roles and responsibilities of the team members, an outline of decision-making procedures, data-sharing plan and an outline of procedures for documenting team discussions and decisions. The TTWP will provide background information and explanation to the steering committee regarding components of the task description and time line.
>
> Estimated Time Line for Completion: September 2011 through October 2011 (Appendix A).

Task 2: Define Goals and Objectives

> The primary objectives of this task are to define the project goals and objectives, begin to discuss the modeling approach and consequent data needs and availability, and to identify critical areas of concern.
>
> Model Goal and Objectives: The modeling approach will be discussed in view of the identified project goals and objectives. Data needs will be discussed in only a general manner in Task 2; they will be addressed in detail in Task 3.
>
> Critical Areas of Concern: An "area of concern" is an area for which there is a particular concern regarding drawdown impacts due to regional and/or local pumping effects. Potential examples might be an area surrounding groups of lakes or an area surrounding a reach of an environmentally sensitive river. A given area of concern might be the focus of a later subregional modeling effort, so identifying it early in the regional model planning process is very helpful, as

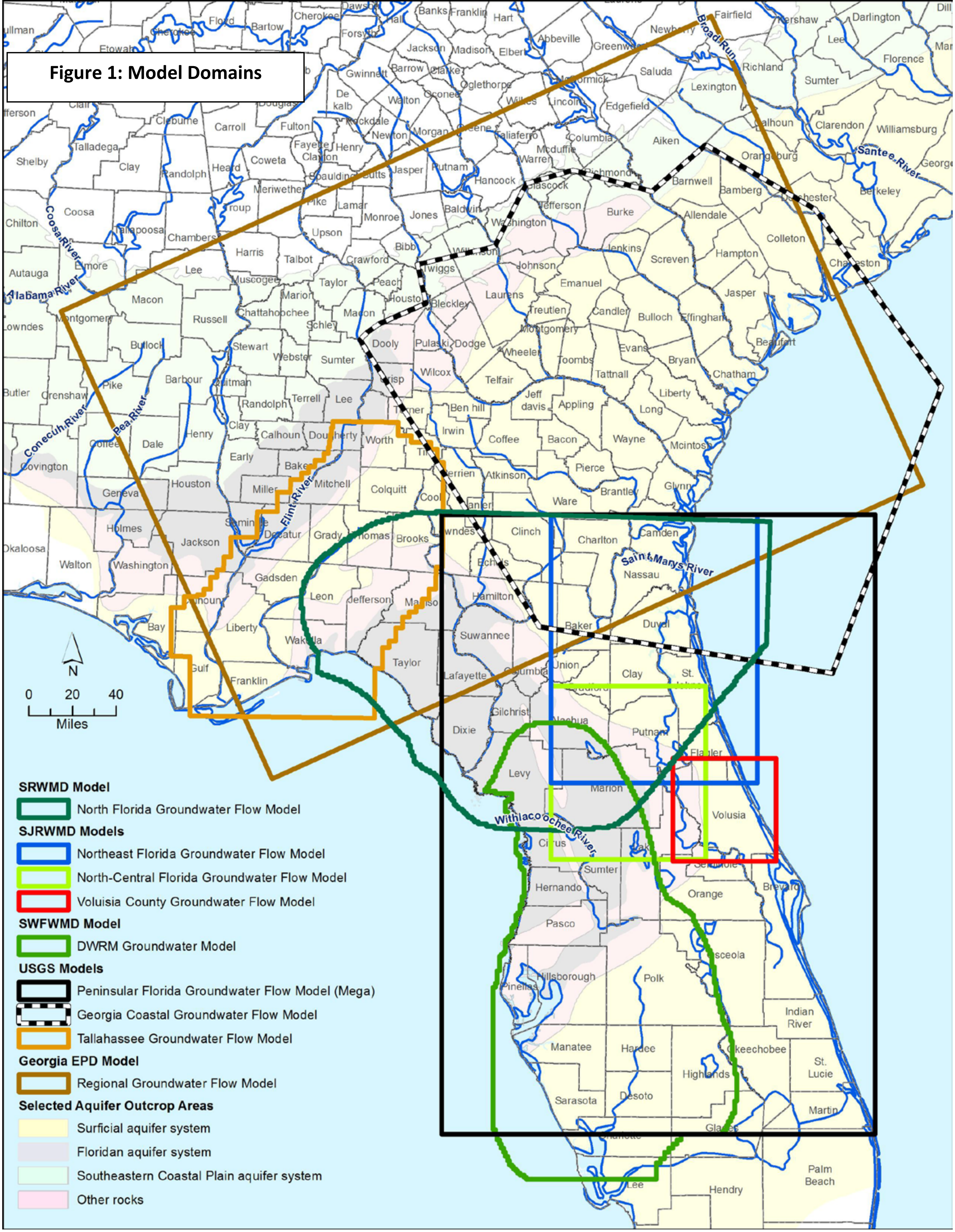

Figure 1: Model Domains

early planning can enable any peculiar aspects of the area in question to be accounted for better in the regional model planning process. Discussion of data availability in this connection is also very helpful, as data needs in regards to areas of concern can begin to be addressed early in the process.

Estimated Time Line for Completion: November 2011 through February 2012 (Appendix A).

Task 3: Data Review and Analysis

The primary objectives of this task are to determine the extent of the model domain, review existing ground-water and/or surface-water modeling approaches for potential application within the proposed model domain, compile available data, display available data through graphs, tables and/or maps, present model input data, and determine the model discretization level and timing (i.e., steady-state/transient).

Desired Model Domain: The extent of the model domain will be dependent largely on the project goals and objectives. The extent, once determined, will have significant bearing on discussions of data needs and availability, as some data may or may not be available within certain subareas of the overall extent. The modeling approach will also have a significant bearing on discussions of data needs, as some approaches require more data than others. The desired extent of model domain will be determined based on project goals and objectives. Depending on the availability of data and discussions on modeling approaches, the extent of the model domain may need to be revised in the subsequent task.

Review of Available Data within Desired Model Domain: The types of data that are needed for the model-development process include observed water levels, withdrawal rates and locations, stream-flow rates, spring-flow rates, rainfall amounts, and aquifer-performance test results, to name just a few. Water level, stream-flow and spring-flow, and withdrawal data are specific to the locations of their observation. Aquifer-performance tests, likewise, are conducted at specific locations. Hence, we have the need to "map" the data. Water level, stream-flow, and spring-flow observations are crucial to the model development because they are used as a basis of comparison to model-simulated flows. The process of adjusting the various aquifer parameters as represented in the model to enable the model to match field observations is called "calibration." Withdrawal-rate observations are crucial as well because withdrawals represent a significant component of the overall mass balance of the aquifer flow system. Thus, accurate representation of withdrawal rates and locations is crucial to an accurate representation of the overall aquifer system. Aquifer-performance test results are important because they provide "real-world" measurements of aquifer parameters with which to guide the model calibration process. Examples of aquifer parameters that can be estimated using aquifer-performance tests include transmissivity, storativity, and leakance. Transmissivity is a measure of the ease with which water can move horizontally through a semi confined or confined aquifer under a given horizontal flow gradient. Leakance is a measure of the ease with which water can move vertically across a semi confining unit under a given vertical flow gradient. Storativity is a measure of the ability of a semi confined or confined aquifer to release water from storage per unit surface area of aquifer and per unit decline in aquifer water level The set of parameters available for initial model set up are usually of interest, as these represent the potential ranges for model parameter values... Hence, there is a need to map these parameters over the extent of the model domain. Existing groundwater and surface-water models within the desired model domain will be compiled and reviewed. The use of those models in development of NFSGR groundwater model will be evaluated.

Model Spatial Discretization: Horizontal model discretization is the degree of resolution of the model grid. Large-scale, deterministic ground-water flow models are generally numerical in nature, meaning that the differential equation that describes ground-water flow is approximated by a numerical method, as analytical solutions of this equation in its more general forms are not available due to its mathematical complexity. In MODFLOW, which employs a finite-difference numerical method for representing the ground-water flow equation, the model domain is broken out horizontally into a grid of rectangular cells. The dimensions assigned to the grid cells constitute the level of horizontal discretization. Greater levels of horizontal discretization (i.e., smaller-sized grid cells) represent higher levels of resolution and a more accurate numerical representation of the ground-water flow equation. Higher levels of discretization are more data-intensive and require greater amounts of computing power, so practical limitations apply to the total size of the area that can be included within the model domain given a particular level of horizontal discretization. Hence, larger study areas are generally represented with larger-sized grid cells. Numerical models are generally discretized vertically by use of layering schemes. The layers can represent entire aquifers or portions of aquifers. The level of vertical discretization is also limited by practical considerations such as available computing power and data availability.

Model Temporal Discretization: The representation of steady-state vs. transient-state conditions must be taken into account in the planning process. The term "steady state" refers to an aquifer state in which conditions (e.g., water levels and/or pumping rates) do not change with respect to time. Generally speaking, such states do not actually exist, at least not for long periods of time. Usually, however, limited periods can be identified in which conditions approximate steady state adequately enough to justify the representation of the system as steady-state. A transient state, by contrast, is one in which conditions within the aquifer system change with respect to time. Decisions regarding steady-state vs. transient-state representation, of course, must be weighed in view of the pros and cons of each type of representation. Steady-state representation is inherently simpler. Steady-state representation enables the modeler to focus on certain aspects of the flow system not related to temporal changes in water levels or withdrawal rates. This type of representation can be used to get a handle on many basic aspects of the ground-water flow system prior to introducing the more complex and data-intensive transient process. In ground-water flow modeling, transient-state simulation requires an additional parameter not used in steady-state simulation—the storage coefficient--and can be much more demanding in terms of data-handling requirements and required computing power. Nevertheless, transient-state simulation has the advantage of forcing the modeler to successfully represent a series of aquifer states as opposed to just one or two, thereby testing the accuracy of the model representation to a much greater extent than steady-state simulation alone. Generally, when enabled by observed conditions, the preferred approach is to begin the model development process with the steady-state representation in order to attain a basic level of accuracy in the system representation. Once achieved, the results of the steady-state simulation are used as the starting point of a transient simulation, which will presumably be used to make further refinements in the aquifer-system representation.

Estimated Time Line for Completion: January 2012 through May 2012 (Appendix A)

Task 4: Conceptual Model Development

The primary objectives of this task include the definition of the hydrologic and hydrogeologic conceptualizations, the model domain and layering scheme, the steady-state and transient calibration periods, transient initial conditions, and model boundary conditions. The specification of these model features will have major bearing on the model's limitations and capabilities. The limitations and capabilities of the model will be documented explicitly, particularly in regards to assumptions and simplifications of reality inherent to the aquifer-system representation. This process will lead naturally to the selection of the model code, the program used to represent the aquifer system and to simulate ground-water flow. The compilation of data and information regarding the aquifer system will be finalized in Task 4. A bibliography of existing geologic, hydrogeologic, hydrologic, modeling, and any other relevant studies focusing on areas that fully or partially encompass the study area will be compiled, and the listed reports will be reviewed.

Hydrologic Conceptualization: The hydrologic conceptualization is the hydrologic system as represented in the model. The hydrologic conceptualization will not constitute a perfectly accurate and complete representation of the true hydrologic system, as a perfect representation of the true hydrologic system is neither feasible nor possible. Instead, the hydrologic conceptualization will be limited generally to only those aspects of the true hydrologic system that are required for accomplishment of the project objectives. The method of representing the unsaturated zone is an example of an aspect of the hydrologic conceptualization that will require careful consideration. The unsaturated zone is the zone that lies above the water table of the surficial aquifer. This zone contains water too, but it is less than fully saturated, hence its name. Common modeling practice is to ignore the details of infiltration through this zone by introducing recharge estimates directly into the surficial aquifer. This approach is often preferred because, as compared to the representation of saturated flow, the representation of unsaturated flow is relatively complex both mathematically and numerically. In addition, observations of hydrologic parameters that govern flow through the unsaturated zone are usually of limited availability due to a lack of observations. Nevertheless, in reality, water generally flows through an unsaturated zone before reaching the surficial aquifer. A more rigorous representation of the infiltration process can result in better recharge estimates. Additionally, in transient simulations, knowledge concerning the time delay between the entry of water into the unsaturated zone and the point at which it reaches the water table may prove helpful in achieving a more accurate model calibration. The advantages of introducing additional rigor into the hydrologic conceptualization are readily apparent. However, on the downside, additional rigor usually results in the need for additional physical parameters, many of which, as mentioned in regards to the unsaturated zone, are difficult to estimate due to a lack of field observations. Numerically, greater rigor can also lead to significant increases in computing time and, sometimes, to an inability to achieve a numerical solution at all. Other aspects of the hydrologic conceptualization, for example, that require consideration include the method for representing surface-water flows and the method for representing the process of recharge and evapotranspiration. There are numerous others. In each case, the technical team will carefully review possible approaches and pros and cons will be identified. Then the final decision that is consistent with accomplishing the project objectives will be made as outlined in TTC.

This aspect of the work comes down essentially to which aquifer layers will be represented explicitly in the model and the method of representation, including areal extent. The surficial aquifer is an example of an aquifer system that could be represented in more than one way in portions of the model domain due to differences in its hydrogeological manifestation at various locations. In some locations, the surficial aquifer consists of a single layer that is comprised primarily of loose, unconsolidated sediments (i.e., sand and/or gravel) throughout its vertical extent. In other locations, however, it consists of an upper and lower layer, the upper layer being comprised primarily of loose, unconsolidated sediments, the lower layer being comprised primarily of limestone and/or dolomite, and the two being separated by low-permeability clay beds. The decision must be made as to whether the surficial aquifer can be represented adequately as a “vertically averaged” single model layer throughout the model domain or if representation of the two-layer form of the surficial aquifer is required in areas where it is present. Another aspect of the hydrogeologic conceptualization that must be addressed is the representation of the intermediate semi-confining unit, which is the unit that confines the Floridan aquifer system and separates it from the overlying surficial aquifer. This semi-confining unit is comprised primarily of the Hawthorn Group throughout most of the potential model domain in which it is present. Common modeling practice has been to represent the intermediate semi-confining unit as a “leakance layer,” which has the effect of representing only the vertical component of ground-water flow and, in cases of transient simulations, neglecting the storage properties of the intermediate semi-confining unit. In reality, on a regional scale at least, vertical flow does tend to predominate within this hydrogeological unit, so in that regard, the representation of the intermediate semi-confining unit as a leakance layer is justifiable.

However, due to its great thickness in many areas (in Duval County, Florida, and Camden County, Georgia, for instance), the intermediate semi-confining unit possesses significant storage properties. This means that drawdown originating in the surficial aquifer or Floridan aquifer cannot be assumed to propagate across the intermediate semi-confining unit instantaneously and that neglecting the resulting time lag could lead to inaccuracies, both in the model calibration and application. This concern, however, applies only in regard to transient-state simulations, as storage properties are not a factor in steady-state simulations. Yet another concern regarding the representation of the intermediate semi-confining unit is that it contains at some locations aquifers of relatively low permeability and limited areal extent from which domestic self-supply withdrawals are obtained. Springs are believed to discharge from these aquifers in some cases also. Representation of the intermediate aquifer system as a leakance layer prevents the explicit representation of these features.

A method for addressing all of these concerns is to represent the intermediate semi-confining unit as an aquifer layer in its own right rather than simply as a leakance layer. Another aspect of the hydrogeologic conceptualization is the nature of the Floridan aquifer system, which is comprised in many locations of more than one internal aquifer separated by internal semi-confining units. These internal aquifers and semi-confining units are generally of regional but, nevertheless, limited areal extent, and their thicknesses and top and bottom elevations vary throughout their areal extent. Miller (1986) has mapped them in detail, and, currently, the St. Johns River Water Management District is in the process of updating the work of Miller within the St. Johns River and Suwannee River Water Management Districts (Boniol and Davis, in progress). Because their thicknesses vary, the internal aquifers and semi-confining units are subject to pinch-out, meaning that their thicknesses can eventually decrease all the way to zero. Hence, a given internal aquifer or semi-confining unit may be present in some parts of the model domain but not in others. The pinch-out of aquifer layers that comprise the Floridan aquifer system will need to be addressed in the model as well, and, fortunately, this is possible. The intermediate semi-confining unit is thick in some parts of the potential model domain but, as with the internal aquifers and semi-confining units of the Floridan aquifer system, is not present in others (i.e., it too pinches out within the potential model domain). This hydrogeological feature must be addressed also, and, again, is possible. As with the hydrologic conceptualization, all issues regarding the hydrogeologic conceptualization must be decided in full view and consideration of the project objectives.

<u>Model Code Selection:</u> The U.S. Geological Survey ground-water modeling code MODFLOW is a likely choice for the modeling code, but the potential use of other codes is open to discussion too. The ultimate choice of the modeling code depends on the full list of project goals and objectives to be agreed upon by the technical team.

<u>Model Domain and Layering:</u> The determination of the model domain and layering scheme are related because, as stated previously, the presence of aquifers and semi-confining units varies depending on location within the potential model domain. In regards to the size of the model domain, again, the project objectives must be kept in mind. Presumably, an important objective will be to evaluate the westward extent of drawdowns emanating from regional pumping centers in Northeast Florida and Southeast Georgia. Until now, the ability to do this has been hampered because a widely accepted single model that represents the entire area has not been available. Hence, the ability to address this concern requires that the model of the present project span the areas of Northeast Florida/Southeast Georgia as well as a considerable portion of the Suwannee River Water Management District and South Georgia to the west of the Okefenokee Swamp. Assuming that a single model layer is used to represent each major aquifer or semi-confining unit, then the vertical layering of the model could be as follows: Layer 1—surficial aquifer; Layer 2—intermediate aquifer system/semi-confining unit; Layer 3—Upper Floridan Aquifer (UFA), Layer 4--Middle Semi-confining Unit 1 (MCU1), Layer 5--Avon Park Permeable Zone (APPZ); Layer 6—Middle Semi-confining Unit 2 (MSCU2); Layer 7—Upper Zone of Lower Floridan Aquifer (LFA); Layer 8—lower semi-confining unit; Layer 9: Fernandina permeable zone.

The results of previous modeling studies have indicated that explicit representation of the Fernandina permeable zone is probably not necessary. Hence, elimination of model layers 8 and 9 may be possible. Of course, additional layers could be added as well, depending on the level of vertical resolution desired in the representations of the surficial aquifer and/or intermediate aquifer system. The ability to implement additional resolution in this regard would of course be contingent on the availability of the requisite hydrogeological data. In regards to the potential extent of the model domain, it is conceivable that the domain might extend from the Atlantic Ocean on the east to the Gulf of Mexico on the west and from the area of Central Georgia on the north to the area of North Central Florida on the south.

<u>Calibration Time Period:</u> Thorough review of rainfall and aquifer water-level data will be required to determine time periods that are suitable for representation as steady-state vs. transient-state. Generally, in steady-state periods, rainfall amounts tend to approximate long-term averages and aquifer water levels tend towards long-term stability (i.e., no major trends either up or down). These are relative considerations, as rainfall amounts are rarely exactly average, at least not at many locations, and aquifer water levels usually exhibit some level of fluctuation. But, generally, if

rainfall amounts are near average at most locations and aquifer water levels do not show long-term, major trends either up or down, despite daily or weekly fluctuations, then steady-state conditions are probably being approximated, and the period in question can therefore be selected as a “steady-state calibration period.” Given the potential size of the model domain, steady-state conditions may conceivably prevail within certain areas but not in others in any given period. Therefore, arriving at the best possible steady-state period for use in the steady-state calibration may involve some compromise. Once the steady-state calibration has been completed, transient simulations will probably be desirable to enable further testing and refinement of the model. As transient simulations represent changing water levels, flow rates, etc., “initial conditions” or “starting” water levels, flow rates, etc., must be supplied. Preferably, the initial conditions would be the steady-state water levels, flow rates, etc., as simulated in the steady-state version of the model. However, because of the large potential size of the model domain, a steady-state or transient condition that prevails within a given subarea may not prevail simultaneously throughout the model domain. Thus, subareas of similar transient behavior may require delineation for representation in separate transient simulation periods. The initial conditions supplied to such simulations may need to be based on field observations rather than steady-state simulation results.

Lateral Boundary Conditions: Models cannot simulate conditions outside of their domains; hence, conditions at the boundaries must be specified. Broadly speaking, boundary conditions in numerical, deterministic models may be categorized as either lateral or internal. Lateral boundary conditions are specified at the lateral boundaries of the model domain, while internal boundary conditions are applied within, or internal to, the model domain. In ground-water flow models, such boundary conditions are usually of the specified water level or flow variety (i.e., “specified head” or “specified flux”). A hybrid boundary-condition type, the head-dependent flux boundary condition, is also available. In this type of boundary condition, a source head (i.e., a water level from which flow originates or into which it terminates) and flow-resistance term are specified by the modeler. The flux into or out of the model is then calculated based on the water-level difference between the source head and the simulated head of the model grid cell to which the boundary condition is assigned. A major consideration in regards to model boundary conditions is that the conditions they represent are subject to change during the time periods represented by model simulations. Attempted solutions to this problem should be applied with careful consideration for their inherent limitations. One possibility involves attempting merely to ensure that the lateral boundaries of the model are as far away from major pumping centers as possible. Unfortunately, this is not always possible, because influential pumping centers tend to be widely scattered about nowadays. Another approach is simply to accept that major pumping centers will likely be located near the model lateral boundaries, and, instead, focus on positioning the lateral boundary conditions as far away as possible from areas of critical interest within the model domain.

Internal Boundary Conditions: The specification of internal boundary conditions is fraught with difficulties similar in nature to those associated with lateral boundary conditions. Internal boundary conditions can include representations of rivers, springs, lakes, oceans, wells, and the processes of recharge and evapotranspiration. Rivers, springs, lakes and ocean bodies are typically represented using some form of head-dependent flux or specified-head boundary condition. As discussed in regards to lateral boundary conditions, a drawback of this type of boundary condition is that the water level represented by the source head is subject to change with time. Internal boundary conditions represent specific locations within the aquifer system, so they cannot be strategically located at arbitrary locations. If pumping centers happen to be nearby, then some level of error may simply be inevitable. Recognition of this limitation and bracketing of the errors associated with internal boundary conditions through uncertainty analysis may be the most practical options. Another, more complex approach in handling internal boundary conditions is through the use of “fully or partially integrated surface-water/ground-water flow models.” This type of model simulates elements of the surface-water flow system as well as the ground-water flow system, thereby enabling a more realistic representation of the interaction between the two. Hence, surface-water and groundwater levels in such model can respond temporally to stresses imposed on the surface-water and/or groundwater flow systems. The major drawbacks of fully or partially integrated surface-water/ground-water flow models are added complexity, numerical difficulty, and expanded data-handling requirements.

Evaluation of Need for Additional Data: After conceptual model is developed, the need for additional data will be discussed and a plan to acquire the additional data will be developed. The plan may include additional monitoring, installation of new monitoring wells, boring logs to better characterize hydrogeology at certain areas and aquifer performance tests, etc.

General Capabilities of the Conceptual Model: The capabilities and potential limitations of the model will be assessed so that additional tools such as subregional models needed to meet the model objectives and goals can begin to be discussed early in the process. The ability of the conceptual model to address the questions developed by the Project Owners and Stakeholders presented in Appendix B will be evaluated and the questions that cannot be addressed by the conceptual model will be identified.

Additional Tools Needed to Meet Goals and Objectives: Additional tools needed to address the questions that cannot be answered by the model will be identified as much as practical and feasibility of developing those tools in conjunction with the regional model will be discussed.

Estimated Time Line for Completion: May 2012 through August 2012 (Appendix A).

Task 5: Initial Model Construction

The primary objectives of this task include the assembly and review of the data to be incorporated into the model. This will include the creation of the model grid, the interpolation of top and bottom elevations of the various aquifer and semi-confining-unit layers, the estimation of horizontal and vertical hydraulic-conductivity fields, the compilation of water-use data, the compilation of stream- and lake-stage data, the compilation of ground-water level data, the estimation of recharge amounts, and the compilation of stream and spring discharge data, each of which will be performed for the entire model domain. The data, once compiled, must be formatted in a manner that is consistent with the chosen model code. These files will require debugging to enable the program to run to completion without crashing.

Estimated Time Line for Completion: August 2012 through December 2012 (Appendix A).

Task 6: Model Calibration

The primary objectives of this task include the definition of the calibration metrics and goals, determination of the calibration approach, determination of the parameter-sensitivity approach, model calibration, review of the calibration, revision and finalization of the calibration, and performance of the parameter uncertainty analysis. Model calibration is the process in which estimates of model hydraulic parameters are adjusted and fine-tuned to enable the model to simulate an observed steady-state and/or transient-state hydrologic conditions to within a specified degree. The objectives of the calibration include enabling the model to match observed water levels, vertical head gradients, and stream- and spring-discharge rates. The results of aquifer-performance tests should be incorporated into the model-calibration process. Aquifer-performance tests involve observing the reaction of the aquifer at a given location to an imposed pumping stress. The known stress and observed reaction (i.e., the resulting drawdown) become inputs in an analysis that results in estimates of aquifer hydraulic parameters in the general vicinity of the test site. Example hydraulic parameters include aquifer transmissivity and storativity and semi-confining-unit leakance (see Task 4 discussion for definitions).

Calibration Approach, Metrics and Goals: The ability of the model to reflect observations is typically judged based on the sizes of hydraulic-head and flow-rate “residuals.” A residual is the difference between an observed water level or flow rate and the corresponding simulated value. Statistics are usually determined based on a number of such residual values. Such statistics include the mean, standard deviation, mean of the absolute values, and root mean square of the hydraulic-head residuals. Once all or most of the statistics are within an acceptable range, the model is deemed to be calibrated. The acceptable range of the statistics constitutes the calibration metrics and goals. These are usually determined qualitatively prior to calibration based on past experience and consideration of the project objectives.

Parameter Sensitivity Analysis: Prior to undertaking the calibration and, perhaps, in the process as well, it is advisable to test the level of sensitivity of the model to the various hydraulic parameters subject to modification in the calibration process. The determination of the relative sensitivity of the model to the calibration parameters is the "parameter-sensitivity analysis." The results of the parameter-sensitivity analysis enable the modeler to prioritize his or her focus on parameters that wield greater influence over the model output.

Final Calibration: The concept of "non-uniqueness," which is the concept that a given calibration result cannot be viewed as reality, as similar residual statistics can usually be attained based on other combinations of the aquifer-system hydraulic parameters. The uncomfortable truth is that, at best, "reality" is something that we can know only partially in regards to ground-water flow systems. The job of the ground-water hydrologist, then, is to represent the ground-water flow system in a manner that is reasonable and consistent with available data, while recognizing the potential for error in the representation as well as the potential for alternative representations that are also consistent with the available data. Once an initial calibration result has been attained, it will be presented to the technical team for review. Suggestions for improvements are expected, and a process of further testing and modification will take place as a result. Once the final calibration is attained, a series of predictive simulations will be performed. The model predictions will take account of aquifer parameter uncertainty, to be determined in a process known as the "predictive uncertainty analysis." .

Estimated Time Line for Completion: January 2012 through December 2013 (Appendix A)

Task 7: Model Verification

The objectives of this task include determination of the verification time period(s), determination of verification metrics and goals, performance of the verification simulation(s), and review and revision of the verification simulation(s). The verification simulation is performed once calibration has been attained to "verify" that the model is, in fact, an acceptable representation of the ground-water flow system.

Verification Time Period, Metrics and Goals: Preferably, the groundwater flow system of the verification period would differ significantly from that of the calibration period, particularly concerning withdrawal rates and/or distribution. Significant climatic differences are desirable too, particularly in the form of rainfall amounts. The ability of the model to simulate the effects of withdrawal configurations that differ significantly from that of the calibration period is an important test of the quality of the calibration.

Verification Simulations In the unfortunate event that the verification simulation(s) fail to meet the assigned metrics and goals, then additional calibration effort will be brought to bear.

Estimated Time Line for Completion: January 2012 through December 2013 (Appendix A)

Task 8: Predictions

The objectives of this task include the definition of the predictive scenarios, the development of the predictive uncertainty approach, compilation of data to be used in the predictive uncertainty simulations, performance of predictive uncertainty simulations, and analysis and review of the results.

Predictive Simulation and Uncertainty Analysis Approaches: The model predictions will address the potential for drawdown impacts due to projected withdrawal scenarios. The additional data that will be required for these simulations will include scenarios of projected pumping within the model domain.

Predictive Simulations: The projected withdrawal scenarios developed by the Technical Team will be simulated and the results will be discussed.

Predictive Uncertainty Analysis: The primary objective the predictive uncertainty analysis will be to address the potential for error in model predictions that stems from uncertainty in the model representation of the aquifer system. The result will be a range of predicted drawdowns per withdrawal scenario.

Estimated Time Line for Completion: October 2013 through April 2014 (Appendix A)

Task 9: Model limitations and Recommendations

The objectives of this task include the delineation of model capabilities and limitations, delineation of additional data required for model improvements, and identification of other tools needed for model improvements. As stated previously, no ground-water flow model is a perfect representation of the ground-water flow system, and the model resulting from the present project will not be an exception in this regard.

Model Capabilities and Limitations: The capabilities and limitations of the model will be clearly defined. The ability of the model to address the questions developed by the Project Owners and Stakeholders presented in Appendix B will be evaluated and the questions that cannot be addressed by the model will be identified.

Model Applications: In light of model's capabilities and limitations defined above, the use of the model in permitting and planning processes will be evaluated.

Additional Data Needs: The primary deficiencies of the model will presumably be attributable to the unavailability of data, hence the objectives regarding the expected need for additional data. In fact, an important side benefit of model studies is the determination of data deficiencies that can be used to guide future data-collection activities.

Other Tools Required to Address Model Limitations: Additional tools needed to address the questions (developed by the Project Owners and Stakeholders and presented in Appendix B) which are identified as not being able to be answered by the model in this task will be discussed as much as practical.

Estimated Time Line for Completion: March through April 2014 (Appendix A)

Task 10: Report

The primary objective of this task is the production of an Executive Summary Memorandum. As stated previously, each of the other tasks will result in a final task memorandum that will summarize the work performed and the results thereof. The Executive Summary Memorandum will tie all of the other memoranda together to provide an overview of the work performed and summary of the project results.

Estimated Time Line for Completion: March through June 2014 (Appendix A)