The Texas A&M University and U.S. Bureau of Reclamation Hydrologic Modeling Inventory (HMI) Questionnaire

December 19, 2009

This document is the Texas A&M University (TAMU)-U.S. Bureau of Reclamation (USBR) Hydrologic Modeling Inventory (HMI) Questionnaire. Your response to this questionnaire will provide the basis for the HMI on-line database accessed through the HMI Web page. Modelers can interactively obtain information about your model through this Web-enabled model inventory complete with search capabilities. The information you provide will hopefully foster wider interest in your model. A designated contact will be explicitly acknowledged and posted within the HMI Web page database.

Given more and more applications of GIS and remote sensing techniques to hydrologic modeling, water resources and watershed management, the Subcommittee on Hydrology has recently set up a workgroup to organize and publicize information on GIS applications in the fields of hydrology and hydraulics. This scope has been expanded to include related water quality, watershed management, and ecological sciences GIS applications. This work is intended to make information on GIS applications in hydrology and hydraulics more generally available. This questionnaire is also designed to gather limited but key information about a particular GIS application in order for a potential user to decide if the application fits his/her computer system, data requirements, and physical system to be modeled.

These applications should be public domain and supported by user documentation. Availability on the Web is not necessary if the application can be distributed on CD ROM or through e-mail requests. If a short abstract, fact sheet, or technical paper is available on the application, please attach a copy. Please respond this email before **22 January, 2010**.

Name of Model, Date, Version Number:
Integrated Water Flow Model (IWFM), 6/2008, version 3.01

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Brief Description:
IWFM is a water resources management and planning model that simulates groundwater, surface water, stream-groundwater interaction, and other components of the hydrologic system. IWFM models groundwater flow as a quasi three-dimensional system and solves the governing flow equation using the Galerkin finite element method. A unique feature of IWFM is the land use based approach of calculating water demand. IWFM simulates stream flow, soil moisture accounting in the root zone, flow in the vadose zone, groundwater flow, and stream-aquifer interaction. Agricultural and urban water demands can be pre-specified, or calculated internally based on different land use types. Water re-use is also modeled as well as tile drains and lakes or open water areas. Another notable feature of IWFM is a “zone budget” type of post-processor that includes subsurface flow computations across element faces.

Model Type:
Continuous integrated hydrologic model

Model Objective(s):
The objectives of IWFM are to simulate

- agricultural and urban water requirements as well as root zone and land surface flow processes under user-specified climatic, soil, land-use and water resources management characteristics
- groundwater and stream flow dynamics under stresses in terms of pumping and diversions as well as recharge to the aquifer and surface runoff into streams generated due to irrigation and precipitation
- the conjunctive use of groundwater and stream flows to meet the agricultural and urban water demands

Model Structure or Mathematical Basis:
IWFM is designed to simulate surface and subsurface flow dynamics, agricultural and urban water requirements along with the root zone and land-surface flow processes at developed basins (i.e. basins with a mixture of agricultural, urban and native vegetation lands) at regional scales. It is a continuous integrated hydrologic model where the simulated hydrologic processes are driven by precipitation and evapotranspiration as well

as pumping and stream diversions to meet the simulated agricultural and urban water demands. A quasi-three dimensional groundwater equation is coupled with one-dimensional stream flow equation. The coupled equations are discretized using finite-element method and the resulting set of equations is solved simultaneously using Newton-Raphson iteration method. The root zone component of IWFM computes agricultural and urban water demands, routes precipitation and irrigation water through the root zone, and simulates the precipitation runoff using SCS curve number method and irrigation return flow. The root zone component of IWFM acts as a linkage between the land surface, groundwater and stream flows (stream-groundwater interaction is computed separately through the linked stream and groundwater equations). The groundwater pumping and stream diversions are used as irrigation at grid cells with agricultural and urban lands in addition to precipitation. The surface runoff created by irrigation and precipitation becomes lateral inflow into modeled streams, whereas percolation through the root zone becomes recharge to the groundwater. This linkage between the root zone, aquifer and stream network allows IWFM users to effectively study the effects of conjunctive use programs, changes in land-use distributions and climate change.

Spatial Scale Employed in the Model:
The model domain is discretized using a finite-element grid. Conservation equations for surface and subsurface flows are solved simultaneously at each finite-element node.

Temporal Scale Employed in the Model:
The modeler can choose from pre-specified temporal scales that can be as little as 1 minute or as large as 1 year. Alternatively, the modeler can specify his/her own temporal scale.

Input Data Requirement:
Various input data requirements include

- Aquifer physical properties (aquifer layer thickness, vertical and horizontal hydraulic conductivity, specific yield, specific storage, elastic and inelastic storage coefficients)
- Data representing stream network, rating tables for stream flow versus stage, streambed conductance
- Initial and boundary conditions for the aquifer system
- Vadose zone physical properties (saturated hydraulic conductivity and porosity)
- Lake bed conductance, maximum lake surface elevation before lake outflow occurs
- Root zone soil properties (field capacity, porosity, saturated hydraulic conductivity, hydrologic soil group, SCS curve number)
- Land-use distribution (agricultural crop types, urban, native vegetation) and time-series areas for land-use types, rooting depths for each land-use type
- Agricultural water management data (time-series data for irrigation period, irrigation efficiency, re-use fraction for irrigation return flow and minimum soil moisture requirement)
- Climatic data (time-series potential evapotranspiration for each land-use type and precipitation at each grid cell)

- Groundwater pumping and stream diversion locations
- If specified in the simulation, time-series pumping and diversion rates; pumping and diversions can also be computed dynamically in IWFMto meet the agricultural and urban water demands

Model Output:
Extensive set of output data at each time step includes
- Groundwater and stream flow hydrographs at user-specified locations
- Groundwater heads at each finite element node
- Groundwater budget at user-specified zones
- Stream flow budget
- Land and water use budget
- Root zone moisture budget
- Lake budget

Input Data Format:
ASCII text files. Also, a finite element grid generator that is an add-on for ESRI's ArcMap software has been developed. The grid generator is also used to develop many of the spatial input data such as aquifer and soil properties, land-use distribution, etc .

Output Data Format:
ASCII text files. Also, graphical user interface (GUI) type tools have been developed to automatically transfer the output data into Microsoft Excel. Groundwater heads can be printed out to an ASCII text file in a format that is readable by Tecplot, a commercial software that can be used to animate the groundwater head surfaces.

Parameter Estimation/Model Calibration:
Parameter estimation and model calibration can be performed using Parameter ESTimation (PEST) program. Utilities have been developed to integrate PEST with IWFM for automated parameter estimation/model calibration. These utilities are downloadable from http://www.pesthomepage.org/Third_Party_PEST-Compatible_Software.php.

Model Testing and Verification:
Various components of IWFM has been tested and verified by comparing its results against exact solutions, where available. A report that discusses the results of the testing and verification runs can be found at http://baydeltaoffice.water.ca.gov/modeling/hydrology/IWFM/Publications/downloadables/Reports/IWFM_Verification.pdf.

Model Sensitivity:
A formal sensitivity analysis has not been performed.

Model Reliability:

The verification runs have shown that IWFM produces reliable and accurate results when compared to exact solutions, where applicable. In real-world applications, the reliability of IWFM results depends on the reliability of the input data and observed values.

Model Application/Case Studies:
IWFM has been used to understand the implications of hydrologic and water resources management scenarios such as the effects of conjunctive use programs, long-lasting droughts and climate change on the surface and subsurface water resources.

Platform/Operating System:
IWFM has been tested on PCs using Windows XP or earlier operating systems. Although the memory and storage requirements depend on the size of the model, currently (as of January 2010) available PCs are found to have adequate memory and hard-disk sizes that can handle most of the IWFM applications.

Programming language and software:
IWFM is written in Fortran 95. The executables as well as the source code is available to the public and can be downloaded at http://baydeltaoffice.water.ca.gov/modeling/hydrology/IWFM/IWFMv3_01/index_v3_01.cfm.

Web-based or desk-top application?
IWFM is a desktop application.

Is the application flexible to couple with external programs and user created executables?
Components of IWFM have been converted into dynamic link libraries (DLLs) and coupled to a reservoir operations model. Currently, only the root zone component of IWFM is available to the public for coupling with other models (see http://baydeltaoffice.water.ca.gov/modeling/hydrology/IWFM/IDC/IDCv4_0/index_IDCv4_0.cfm). Newer versions of IWFM will have more of its components available to public for easy coupling with other models.

Are system and user documentation available? (Web site)
Documentation, source code, executables, a sample problem and supporting tools can be downloaded from
http://baydeltaoffice.water.ca.gov/modeling/hydrology/IWFM/index.cfm.

Are example applications available? (Web site)
Yes. Please see above.

Is there a user group or hotline-type support? (Website)
There is a users group established for IWFM. Materials from previous users group meetings can be accessed at
http://baydeltaoffice.water.ca.gov/modeling/hydrology/IWFM/UsersGroup/index_UsersGroup.cfm.