Texas A&M University Hydrologic Modeling Inventory
Model Description Form
August 2007

Name of Model:

MODSIM vs. 8.1: Generalized River Basin Management Decision Support System

Model Type:

MODSIM is a comprehensive, generalized river basin management decision support system (DSS) under continuous development and enhancement since 1979 at Colorado State University.

Model Objective(s):

To provide a comprehensive tool capable of simultaneously simulating both physical operations in a river basin system as well as administrative and water right structures governing water allocation and use. MODSIM is designed to be flexible and robust, allowing a wide range of analyses from short-term daily operations requiring hydrologic flow routing to long-term monthly river basin planning and management. MODSIM is capable of modeling large-scale river basin systems by employing an efficient minimum cost network flow optimization algorithm for simulating allocation of water according to water rights, storage ownership contracts, interstate compacts, and economic valuation. An important objective in MODSIM development has been to provide an easy-to-use modeling platform for decision makers and managers by incorporating a powerful graphical user interface for network creation, data import and editing, and georeferenced graphical output results. MODSIM is capable of simulating stream-aquifer interactions for conjunctive use of surface water and groundwater. MODSIM software development under the MS .NET Framework enables extensive customization capabilities, allowing MODSIM to be integrated with water quality models such as QUAL2E and numerical groundwater flow models such as MODFLOW, as well as incorporation of complex operating rules and regulations.

Agency and Office:

Colorado State University, Department of Civil and Environmental Engineering; and U.S. Bureau of Reclamation, Pacific Northwest Region

Technical Contacts, Mailing and E-mail addresses:

John W. Labadie
Department of Civil Engineering
Colorado State University
Ft. Collins, CO 80523-1372
Email: labadie@engr.colostate.edu

Roger Larson
U.S. Department of the Interior
Bureau of Reclamation
Pacific Northwest Regional Office
1150 N. Curtis Rd.
Boise, ID 83706-1234
Email: rlarson@pn.usbr.gov

Model Structure or Mathematical Basis:

1. *The type of the basins for which the model has been developed.*
   MODSIM has been applied to a wide range of basins including municipal raw water distribution systems, river basins dominated by irrigated agriculture, and large-scale interstate basins
2. *The size of the basins for which the model applies.*
   There is no basin-scale limitation in MODSIM
3. *The nature of simulation that the model undertakes.*
   MODSIM essentially utilizes a network flow optimization algorithm to accurately simulate a priority-based water allocation system, while still providing mechanisms for equitable sharing of limited water resources. The computational speed and efficiency of the optimization algorithm provides for long-term risk evaluation and development flow-duration curves using Monte Carlo methods.
4. *Components of the hydrologic cycle represented in model formulation.*
   Unregulated inflows (generated using external watershed runoff models), evaporation loss, channel loss, reservoir storage, hydroelectric energy generation, hydrologic river routing, flow diversion and application, instream flow uses, infiltration, and stream-aquifer interactions.
5. *The underlying hypotheses (or the type of equations employed) that form the basis of the modeling approach to each component process:*
   MODSIM is based on the hypothesis that any complex river basin system can be represented in a network formulation composed of interconnected nodes and links. Storage nodes include reservoirs (both on-stream and off-stream), storage accounts, and groundwater aquifers. Nonstorage nodes include demand locations, points of inflow, diversion, confluence, or any intermediate point to better represent heterogeneity of basin characteristics. Any nonpoint basin characteristic such as channel losses and local storm runoff along a river reach are assumed to be aggregated at one or more nodes. Network links or arcs represent river reaches, canals, pipelines, and drains. The network flow structure is based on linear algebraic equations that conserve mass balance, while maintaining capacity bounds on flows throughout the system. Channel flow routing utilizes Muskingum type equations, while stream-aquifer interactions are calculated using the Glover model or USGS Stream-Depletion Factors.
6. *Mathematical formulation of the model components.*
   MODSIM is primarily a deterministic, spatially distributed model.

Model Parameters:

The primary parameters and inputs to be estimated in MODSIM are: unmeasured river channel gains and losses, channel loss coefficients, groundwater transmissivity and storage coefficients governing stream-aquifer interactions, recharge fractions from water applications, and flow routing coefficients.

Spatial Scale Employed in the Model:

Spatial scale in MODSIM is related to the density and distribution of nodes in the network topology. Characteristics of each node and link are assumed to be homogeneous. Spatially geo-referenced networks can be created in a geographic information system and imported into MODSIM. In addition, DEM layers developed from a GIS or images captured from Internet sources such as Google Earth™ can be loaded as background images in MODSIM for overlaying created network features.

Temporal Scale Employed in the Model:

MODSIM is a continuous simulation model designed to be run in daily, 5-day, weekly, 10-day or monthly time steps. The maximum number of time steps possible in a MODSIM simulation is limited only by the available RAM memory

Input Data Requirements:

MODSIM provides an intuitive object-oriented graphical user interface for input of all data. The river basin network components are constructed through point-and-click mouse control operations. The MODSIM Window provides menu items for File Control, Editing, General Settings, Utilities, Various View Options, and Help Menus. Data are assigned to each node and link network object by mouse control operations activating spreadsheet style data entry windows for that object.

Storage node data include:

- Reservoir name, minimum volume, maximum volume, and initial contents
- Reservoir seepage rates
- Hydropower efficiency tables related to flow and head on turbines, including consideration of tailwater conditions
- Target storage tables and operating rules
- Reservoir storage priorities and conditional operating rules
- Surface area, capacity, head, hydraulic outlet capacity tables
- Net evaporation rate tables
- On-peak hours of generation for hydropower plants
- Reservoir balance tables dividing reservoirs into several zones for balanced operations in a multi-reservoir system

Nonstorage node data include:

- Node name and description
- Unregulated inflows
- Instream flow (flow-through) demands and associated priorities
- Consumptive demands and associated priorities

- Infiltration rates for irrigation applications
- Groundwater pumping capacity
- Stream-aquifer parameters governing streamflow depletion from pumping and return flows from excess irrigation

Link or arc data include:

- Link name, minimum and maximum capacity
- Time variable capacity information
- Channel loss coefficients
- Costs per unit flow
- Water right priority dates
- Seasonal capacity limitations
- Designation of return nodes for channel losses
- Hydrologic routing parameters
- Administrative information on storage accounts and exchanges

Users can select metric or English conventions, and a wide variety of volume and discharge units. An extensive range of units over any desired time step can be selected, which can differ depending on the type of network object. For example, variable capacity link data can be entered as ft^3/s, representing the average flow rate over the time increment specified, or demand data can be entered in ac-ft/month, or other suitable units. MODSIM automatically interpolates or aggregates, as appropriate, any time series data to the model simulation time step and internally converts the data into the default units employed in the model simulation runs.

Computer Requirements:

The MODSIM DSS operates under Microsoft Windows 2000, XP, or Vista and is comprised entirely of native, object-oriented code written in Microsoft Visual C++.NET. Pentium or AMD processors operating at 1.6 GHz or higher are recommended, along with at least 512 MB of RAM. The graphical user interface for MODSIM is developed in Visual Basic.NET, and includes both native code and code requiring a developer license, but allowing free distribution of runtime applications without imposing licensing requirements or any costs to the user.

Model Output:

MODSIM provides both graphical plots and tabular output of time series information on: storage, flow, reservoir releases, inflows, demands, shortages, groundwater contributions, and storage contract information. For large networks, users may select the desired network objects for inclusion in the model output. Users are provided many types of chart options for graphical output display, including 3-dimensional and multi-axis displays. In addition to time series results, probability and flow-duration curves are also available. After successful completion of a MODSIM run, activation of a graphing mode feature allows rapid display of graphical results by simple left-mouse click on any network object. A powerful scenario analysis tool allows comparative evaluation of the results from several MODSIM runs under different management schemes. Output displays can also be displayed in any desired units, independent of the original time series data units. An animated output feature is now available in vs. 8.1 which displays movie of the simulation run, with changing sizes and colors of network objects depicting changing flow and storage conditions.

Parameter Estimation / Model Calibration:

Automatic calibration capabilities are not provided in MODSIM, although the flow-through demand construct allows import of measured flows at streamflow gages and specification of measure reservoir volumes as target levels given a high priority. In this way, parameters can be adjusted and deviations between simulated and measured flows and storage levels analyzed. Although all calibration is conducted by the user through trial-and-error adjustments, the graphical user interface incorporated within MODSIM greatly facilitates this process.

Model Testing and Verification:

MODSIM has been in continuous use for over 25 years, and has been extensively tested and is in current active usage by a large number of organizations and agencies, including private, local, state, federal, and international. Numerous verification procedures have been carried which not only authenticate the ability of MODSIM to simulate complex physical operations in a river basin, but also to model challenging administrative, legal, and contractual issues.

Model Sensitivity:

Generalized sensitivity analyses have not been conducted with MODSIM. All sensitivity studies have been carried out for specific applications of MODSIM.

Model Reliability:

MODSIM was first developed in the late 1970's, and has undergone numerous updates and improvements since then. The lengthy history of usage of MODSIM over many years by numerous organizations has produced a high degree of confidence in its reliability.

Model Application/Case Studies:

MODSIM has been extensively applied to water rights evaluation and water supply planning by a number of municipalities, conservation districts, and private engineering consulting firms, and is a continuing water supply planning tool for several municipalities including the Cities of Fort Collins, Greeley, and Colorado Springs. MODSIM is being applied by agencies such as the U.S. Bureau of Reclamation for studying instream flow requirements, storage ownership issues, water banking alternatives, group ownership contracts, reallocation of diversion entitlements, and a number of other complex river basin operational and administrative issues. SIAM (System Impact Assessment Model), developed for the Klamath River basin, Oregon and California by the U.S. Geological Survey and the U.S. Bureau of Reclamation, links MODSIM with the HEC-5Q reservoir water quality model, an aquatic habitat model, and the SALMOD fish production model. MODSIM evaluates system operations in SIAM for improving summer/fall water quality conditions to benefit declining anadromous fish populations. A wide range of studies have been conducted in the South Platte River basin, the Upper Snake

River basin, the Lower Arkansas River basin in Colorado, the Poudre River basin, the Colorado-Big Thompson project, the Upper Colorado River Basin, the Gunnison River basin, the Rio Grande River Basin, the Carson-Truckee River system, portions of the Central Valley Project in California, the Imperial Irrigation District, El Centro, California; the Deschutes River basin, Oregon; the Payette River basin, Idaho; the San Pedro basin in Arizona, and the Cumberland River basin, Kentucky. Several international agencies and organizations have applied MODSIM in South Korea, the Philippines the Dominican Republic, Mexico, Brazil, Portugal, Egypt, and Canada.

Documentation:

The install file for MODSIM v. 8.1 is downloadable free of charge at: http://modsim.engr.colostate.edu/. Also included for download is a comprehensive and up-to-date user manual detailing all features of MODSIM, several tutorial exercises, appendices providing extensive technical details, and documentation on the custom code editor included with MODSIM, along with several examples of custom code development for a variety of applications. Several sample networks are included with the tutorial exercises. Several additional papers and reports are available for download that document successful applications of MODSIM.