Name of Model: Hydrologic Modeling System (HEC-HMS)

Contact: www.hec.usace.army.mil/software/hec-hms

Model Type: The program began as an event-oriented, precipitation-runoff simulator for surface water hydrology studies. It now includes evapotranspiration, snowmelt, and infiltration models for continuous simulation studies. It is increasingly becoming a land surface process simulator operating for event and continuous time periods.

Model Objective: The program is designed to simulate the land surface processes of the hydrologic cycle. Consequently it contains components for precipitation, potential evapotranspiration, snowmelt, canopy interception, surface storage, infiltration, surface runoff, baseflow, channel routing, and channel losses. It also includes components for simulating reservoirs and diversions. Each phase of the hydrologic cycle can be described with a model of that specific process. Where ever possible, multiple model choices are available to allow the program to adapt to a wide range of geographic regions, data availability, spatial scales, temporal scales, and project requirements. It is intended to be used singly or in combination with other HEC software for studies of water availability, urban drainage, flow forecasting, environmental enhancement, future urbanization impact, reservoir spillway design, flood damage reduction, floodplain regulation, and system operation.

Model Structure or Mathematical Basis: The program includes a wide variety of mathematical models for representing the components of the hydrologic cycle. Each of the models is taken from the peer-reviewed literature. Individual components can be used if necessary for a specific watershed study, or left out to simplify the modeling process when possible. The main categories included in the modeling system are precipitation, potential evapotranspiration, snowmelt, canopy interception, surface storage, infiltration, surface runoff, baseflow, channel routing, and channel seepage. New energy-balance components are under development is several areas of the program and will result in new categories for short-wave and long-wave radiation. The model choices within each component area are:

- Precipitation
    - Frequency storm
    - Gage weights
    - Gridded
    - Inverse distance
    - SCS storm
    - Specified hyetograph
    - Standard project storm (Corps of Engineers)
- Potential Evapotranspiration
    - Monthly average rates
    - Priestley Taylor
- Snowmelt
    - Temperature index
- Infiltration

- Deficit and constant (regular and gridded)
- Exponential
- Green Ampt (regular and gridded)
- Initial constant
- SCS curve number (regular and gridded)
- Smith Parlange
- Soil moisture accounting (regular and gridded)

Surface Runoff
- Clark unit hydrograph
- Kinematic wave
- ModClark (gridded)
- SCS unit hydrograph
- Snyder unit hydrograph
- User-specified s-graph
- User-specified unit hydrograph

Baseflow
- Bounded recession
- Constant monthly
- Linear reservoir
- Recession

Channel Routing
- Kinematic wave
- Lag
- Modified Puls
- Muskingum
- Muskingum-Cunge
- Straddle stagger

Channel Seepage
- Constant volume per reach length
- Seepage rate per inundated area

Additionally the reservoir element can specify the individual components for discharging water from the reservoir, including: dam top, spillways (with gates), outlets, pumps, dam break, seepage, evaporation, plus user-specified outflow. The diversion element can remove water as a function of inflow or using a pump or using a lateral weir.

Spatial Scale Employed in the Model: The watershed is represented as a dendritic network of subbasins, reaches, reservoirs, diversions, sources, junctions, and sinks. Subbasins may use an area-averaged approach where all equations are solved once assuming the subbasin is homogeneous in all aspects. Alternately, the subbasin may use a grid cell approach where all equations are solved separately for each cell using separate parameters and boundary conditions for each cell. Past applications have included models of a single highway overpass for sizing a stormwater culvert, to a large reservoir inflow model covering over 45,000 km^2.

Temporal Scale Employed in the Model: The model can operate at simulation time intervals from 1 minute to 24 hours. A simulation time window can be specified for several days to cover a single event or span multiple decades to do a period-of-record analysis. The length of a simulation is limited only by available computer memory resources.

Input Data Requirements: The data input requirements vary according to the mathematical models selected for each phase of the hydrologic cycle. Some models have very few data requirements, while others require extensive data. The variety in models is intended to allow the program to adapt to the amount of data available in a particular study application. In general, the minimum application requires precipitation boundary conditions, some representation of infiltration, surface runoff, and baseflow in the subbasins, and channel routing.

Model Output: A variety of graphs, summary tables, and time-series tables are available for visualizing the simulation results. A tool is also available within the program to create custom graphs and time-series tables. The actual data that is available depends on the simulation components that have been selected and may be extensive. In general, the minimum available output includes the precipitation, infiltration, surface excess, surface runoff, baseflow, subbasin outflow, and stream flow at all downstream components.

Input Data Format: The program includes a rich interface with a variety of tools for entering parameter and boundary condition data. All data entered by the user is stored in files within the program directory. While the files are in plain text and could be viewed by the user, it is much more efficient to work with the program interface for entering and viewing the data.

Output Data Format: All simulation results are stored in the output Data Storage System (HEC-DSS) file. The file includes a wide variety of time-series data. The data include internal state variables from the simulation components, as well as output variables. Some gridded results are also available. The application programming interface (API) for HEC-DSS is available. It is relatively simple for software developers to modify their programs to write to or read from the HEC-DSS format. The HEC-DSSVue utility program is available to manage and visualize HEC-DSS files.

Parameter Estimation/Model Calibration: The Technical Reference Manual gives some advice on manual parameter estimation and calibration techniques. The program also includes an automated calibration tool that uses optimization techniques. The user may select an objective function that compares the simulated stream flow and observed stream flow. Parameters at any element upstream of the location for the observed flow can be included for optimization. Two different search methods are available for guiding the search process. When concluded, there are several graphical results designed to help the user assess the quality of the optimization search.

Model Testing and Verification: The development team maintains an extensive suite of tests to validate the program. Each test in the suite has been checked by hand or by using other software that has itself been independently validated. A new version of the program is not released until it has passed all of the tests in the validation suite. Complete details of the test suite can be found in the Validation Guide available from the program website. All of the data necessary for users to independently review the validation suite is also available for download.

Model Sensitivity: Model sensitivity is an important part of calibrating a watershed model and should be part of every study. The magnitude of the sensitivity will depend on which models are selected to represent the components of the hydrologic cycle, and the suitability of those choices to an individual study. Sensitivity may also depend on the scale at which the model is applied. Currently there are no automatic tools within the program to assist with evaluating sensitivity. The program user should nevertheless perform the sensitivity analysis manually.

Model Reliability: Model reliability depends primarily on the ability of the program user to correctly select the model for each component of the hydrologic cycle given conditions in the study watershed. Reliability also depends heavily on the availability of accurate boundary conditions such as precipitation. Given accurate boundary condition data and correct application of the modeling components, the program can reliably predict stream flow. The program is best at predicting stream flow in medium to large watersheds.

Model Application/Case Studies: The program is downloaded thousands of times per year from the website and used in every country in the world. Within the Corps of Engineers it is used on more than 200 projects annually. It is probably one of the most widely applied hydrologic simulation programs in the world. Many individual projects have been documented in the peer-reviewed literature by researchers with no connection to the development team.

Platform/Operating System: The program is available for Microsoft Windows, Sun Microsystems Solaris (SPARC) and Linux.

Program Language and Software: The program is written in the Java programming language. It uses some libraries in FORTRAN and C.

Web-based or desk-top application? Desk-top application.

Is the application flexible to couple with external programs and user created executables? The program has the ability to start from the command line with the interface invisible, and a control script can be passed. The program will start, execute the script, and then shutdown. The script is formatted for the Python script interpreter.

Are system and user documentation available? The documentation set for the program includes a Quick Start Guide for new users, a User's Manual with detailed instructions on using the program, a Technical Reference Manual that describes the technical foundation of the models included in the program, an Applications Guide describing how to conduct engineering studies with the program, and other supporting documentation. All documentation is available from the program website for no charge. www.hec.usace.army.mil/software/hec-hms

Are example applications available? The program includes the option to install several sample projects that demonstrate various aspects of the program capabilities. These samples can be installed from the "Help" menu. The Quick Start Guide contains detailed instructions for constructing one of the sample projects that can be installed in finished form. The Applications Guide contains information on using the program to conduct various types of common applications.

Is there a user group or hotline-type support? The Hydrologic Engineering Center is not able to provide technical support to users outside the Corps of Engineers. However, the development team will respond to any user that has found a possible problem or error with the software. Users can contact the development team through the website. www.hec.usace.army.mil/software/hec-hms

Other Comments: Surface erosion, sediment transport, and nutrient simulation are under development.