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

May 4, 2010

Name of Model, Date, Version Number
Dynamic Watershed Simulation Model (DWSM) 2002

Contact (with e-mail, web site, and/or phone number)
Deva K. Borah, Woolpert, Inc.; deva.borah@woolpert.com; 757.284.1364

Brief Description
DWSM, the Dynamic Watershed Simulation Model, is a storm event, distributed, and physically based model for simulations of surface and subsurface storm water runoff, propagation of flood waves, soil erosion, and entrainment and transport of sediment and chemicals (nonpoint-source pollutants) in a watershed during single or a series of rainfall events. The watershed is divided into sub-watersheds based on drainage patterns and topographic features. Each sub-watershed is further subdivided into two one-dimensional overland planes and one one-dimensional channel segment as an open-book pattern where the overland planes discharge laterally into the channel, one from each side of the channel. Lakes, reservoirs, or detention ponds are part of the drainage network with overland planes and channel segments as separate units. The model simulates the hydrologic and hydraulic processes involved in the generation of storm water runoff, sediment, and chemical constituents throughout the watershed divisions, route those, and record their values from upstream to downstream, thus producing distributed hydrographs, sediment graphs, and pollutant graphs resulting from the simulated storm or storms. Descriptions of DWSM's theory (formulations) may be found in the literature. The hydrologic and sediment components have been extensively tested and published in the literature. Limited applications of the chemical component may also be found. Its efficient performances over other models have been documented by independent investigators.

Model Type
The DWSM is a physically based, event-based, distributed, and unsteady rainfall-runoff, flood routing, soil/sediment erosion-transport-deposition, and agrochemical mixing-transport model. Details of only the rainfall-runoff (DWSM-Hydro) component are listed here. For the sediment and agrochemical components, contact the model developer.

Model Objective(s)
1. To assess environmental conditions of a watershed, such as flooding, upland soil and stream erosion, sedimentation, and contamination of water from agrochemical.
2. To evaluate alternative land use and best management practice scenarios in reducing flood magnitudes, erosion of stream beds and banks, filing of stream beds and impoundments (reservoirs, lakes, detention ponds, etc.), and polluting water bodies.

3. To determine reliable design parameters (flow rate, flow velocity, flow depth, water and sediment volumes, etc.) for designing flood and erosion control measures and structures.

Model Structure or Mathematical Basis

1. DWSM was developed for rural and agricultural watersheds. It has been tested on rural, agricultural, and suburban watersheds. It would work on mountainous and certain urban watersheds as well.
2. DWSM has been extensively tested on small and medium watersheds and has potential for large watersheds.
3. DWSM simulation is event-based simulating single or series of single events.
4. The hydrologic cycle is fully represented in DWSM including precipitation, infiltration, evaporation, interception, detention storage, overland flow, and channel flow.
5. The mathematical formulations of the model components are distributed and deterministic employing the following principles or equations:

   Precipitation: Mean areal precipitation is estimated using Theissen polygon.

   Infiltration: DWSM has an alternative to use Smith-Parlange infiltration procedure. A simple alternative is to use SCS runoff curve number by lumping evaporation, interception, and detention storage with infiltration.

   Evaporation: As evapotranspiration (ET) not a sensitive factor in storm event simulations, a constant rate is input into the model in the Smith-Parlange infiltration procedure alternative. In the SCS runoff curve number alternative, ET is lumped with the curve number.

   Interception: In the Smith-Parlange infiltration procedure alternative, interception is simulated by assuming values for interception storage capacities of canopy and ground covers along with estimated densities of the covers. In the SCS runoff curve number alternative, interception is lumped with the curve number.

   Detention Storage: In the Smith-Parlange infiltration procedure alternative, detention storage is lumped with the interception storage capacities of canopy and ground covers. In the SCS runoff curve number alternative, detention storage is lumped with the curve number.

   Overland Flow: The overland flow is simulated using the kinematic wave theory and analytically solving the equations, which is more accurate and efficient than numerical solutions.

   Channel Flow: Flow routing in channels is done by using kinematic wave theory, analytically solving the equations, and introducing an approximate shock-fitting solution, which is also analytical, maintaining model accuracy and efficiency.

Groundwater Flow: Subsurface or base flow is simulated using Sloan et al.'s kinematic storage equation and linear reservoir theory with infiltration rate as the input.

Snow Melt Runoff: DWSM does not simulate snow melt runoff.

Reservoir Routing: DWSM uses storage-indication, Puls, or non-linear reservoir routing method for routing flow through reservoirs.

Spatial Scale Employed in the Model

In DWSM, the watershed is decomposed into a network of sub-watersheds, each further divided into two overland planes and a channel. Reservoirs, if present, are separate units but part of the network. Each overland plane, channel segment, or reservoir unit is assumed homogeneous having individualized parameters and processes.

Temporal Scale Employed in the Model

DWSM is an event-based model, simulating the rainfall-runoff relationships for an individual event with time steps of minutes to hours.

Series of rainfall events separated by days have been successfully simulated in a single DWSM run.

Input Data Requirement

1. Watershed characteristics data (topographic map, drainage area, overland areas, channel lengths, overland and channel slopes, Manning's roughness coefficients for overland planes and channels, and stage-storage-discharge tables for reservoirs)
2. Climate data (rainfall intensity or breakpoint rainfall depths in time, as commonly available in rainfall records, and constant temperature for the rainfall event)
3. Stream flow data (measured discharge in regular or irregular time steps) for model calibration and validation
4. Soils data (hydrologic soil classification and antecedent moisture condition, or saturated hydraulic conductivity and sorptivity)
5. Land use data (canopy and ground cover densities from vegetation and impervious covers)
6. For the sediment model, watershed representative particle size distribution

Model Output

1. ***Watershed Summary:*** total rainfall at each rain gage (depth), total watershed runoff (depth), total outflow volume, peak outflow, time to peak outflow, sediment yield (weight), peak sediment discharge (weight per unit time), time to peak sediment discharge.
2. ***Summary for Each Overland Plane:*** drainage area, rainfall depth, rainfall excess depth, runoff volume, unit-width peak flow, unit-width sediment yield (weight), average sediment yield (weight per unit area).

3. ***Summary for Each Channel Segment or Reservoir Unit:*** drainage area (cumulative), runoff volume, peak flow, time to peak flow, peak sediment discharge, time to peak sediment discharge, sediment yield.
4. ***Time Series Tables for Selected Channel and/or Reservoir Outlets:*** Tables of average rainfall intensities, flows, and sediment discharges at the selected channel segment and/or reservoir outlets and at the constant computational time steps (minutes) throughout the entire computational period, from which hydrographs, hyetographs, and sediment graphs can be drawn.
5. ***Watershed Outflows and Sediment Discharges:*** Table of watershed average rainfall intensities, flows, sediment discharges, and sediment concentrations at the watershed outlet and at the constant computational time steps (minutes) throughout the entire computational period, from which watershed outflow hydrograph, hyetograph, and sediment graphs can be drawn.

Input Data Format
All input data are provided in model input formats (ASCII) as shown in the source code.

Output Data Format
Output results are provided in ASCII from which further analyses can be done and hydrographs, hyetographs, and sediment graphs can be drawn.

Parameter Estimation/Model Calibration

1. The model uses mostly physically measurable or estimable data and, therefore, uses only a few parameters needing calibration.
2. Initial parameter values are estimated based on literature and experience and parameter adjustments are made manually as described below.
3. Hydrology parameters are calibrated or adjusted to match model flows with observed flows, beginning at the uppermost monitoring station and working towards the watershed outlet depending upon the number of monitoring stations in the watershed.
4. Similarly, sediment parameters are calibrated or adjusted to match model sediment discharges with observed sediment discharges.
5. With the SCS runoff curve number option, the only hydrologic parameters are: (i) curve number and (ii) effective lateral saturated hydraulic conductivity for each of the overland planes and (iii) Manning's roughness coefficient for each of the overland planes and channel segments (all distributed).
6. With the infiltration-interception option, the hydrologic parameters are: (i) vertical saturated hydraulic conductivity, (ii) effective lateral saturated hydraulic conductivity, and (iii) soil sorptivity for each of the overland planes, and (iv) Manning's roughness coefficient for each of the overland planes and channel segments (all distributed).
7. For the sediment model, the calibrated parameters are: (i) raindrop detachment coefficient for each of the overland planes, and (ii) flow detachment coefficient for each of the overland planes and channel segments (all distributed).

Model Testing and Verification

- DWSM has been extensively tested and verified using split sampling data in many different watersheds. Most of its applications are presented in peer-reviewed literature.
- Test data sets are available to users for modeling use, training, and model operation confirmation.
- Several research groups have been using the model and its test data sets by contacting the model developer.
- Model documentation and cursory users' manual may be obtained by contacting the model developer.

Model Sensitivity
All the parameters listed above are sensitive to model results. Sensitivity analyses were conducted and reported (included) in the peer-reviewed publications and may be obtained by contacting the model developer.

Model Reliability
Model reliability is based on accuracy of the input data and observed flow and sediment discharge data with which model results are compared. It has been demonstrated in the peer-reviewed literature by the developer and independent user that DWSM is reliable, even more reliable than some of the popular models.

Model Application/Case Studies

1. DWSM can be applied to accomplish any of the objectives listed above. In addition to many research applications, the following two specific applications (Case Studies) of DWSM are noteworthy.
2. DWSM was applied in an Illinois watershed to prioritize sensitive land areas (overland planes) based on unit width peak runoff rates and unit width sediment yields (a more effective criteria than commonly used uniform unit area sediment yield and empirical delivery ratio) for conservation planning in Illinois Conservation Reserve Enhancement Program.
3. DWSM was applied in a New Jersey suburban watershed to evaluate and design flood control measures and develop a database of flood elevation against various design (frequency-duration) storms for preparedness and protection planning.

Platform/Operating System
DWSM is an efficient model needing minimal disk and memory spaces. It runs on any computer running DOS.

Programming language and software
DWSM was written in FORTRAN language and has been compiled with various FORTRAN compilers, recently with the Intel Visual FORTRAN Compiler.

Web-based or desk-top application?
DWSM is desk-top application model.

Is the application flexible to couple with external programs and user created executables?
DWSM source code can be combined with any other programs.

Are system and user documentation available? (Web site)
Peer-reviewed publications on DWSM are its documentations, available in the literature, and may also be obtained by contacting the developer. Additional cursory documentations and users' manual may be obtained by contacting the developer.

Are example applications available? (Web site)
Example applications and test data are available from the developer.

Is there a user group or hotline-type support? (Website)
There is no user or hotline support available, however the developer may be contacted with questions.

Other Comments
Interested parties may contact the developer in collaborating and further developing DWSM, including developing a graphical user interface.