OVERVIEW OF EPA SWMM SOFTWARE FOR STORM WATER MANAGEMENT

Y.R. Satyaji Rao
Deltaic Regional Centre
National Institute of Hydrology
Kakinada

Introduction

Environmental Protection Agency Storm Water Management Model (EPA SWMM) was first developed in the year 1971and has undergone several major upgrades since then. It continues to be widely used throughout the world for planning, analysis and design related to storm water runoff, combined sewers, sanitary sewers, and other drainage systems in urban areas, with many applications in non-urban areas as well.

The EPA Storm Water Management Model (SWMM) is a dynamic rainfall-runoff simulation model used for single event or long-term (continuous) simulation of runoff quantity and quality from primarily urban areas. The runoff component of SWMM operates on a collection of subcatchment areas that receive precipitation and generate runoff and pollutant loads. The routing portion of SWMM transports this runoff through a system of pipes, channels, storage/treatment devices, pumps, and regulators. SWMM tracks the quantity and quality of runoff generated within each subcatchment, and the flow rate, flow depth, and quality of water in each pipe and channel during a simulation period comprised of multiple time steps.

Capabilities of SWMM

SWMM accounts for various hydrologic processes that produce runoff from urban areas. These include:

- Time varying rainfall
- Evaporation of standing surface water
- Snow accumulation and melting
- Rainfall interception from depression storage

- Infiltration of rainfall in to unsaturated soil layers
- Percolation of infiltration water into ground water layers
- Inter flow between the ground water and the drainage system
- Non linear reservoir roughing of overland flow
- Capture and retention of rainfall/runoff with low impact development (LID) practices

SWMM also contain flexible set of hydraulic capabilities used to route runoff and external inflow through the drainage system network of pipes, channels storage/treatment units and diversion structures. These include the ability are:

- Handling network of unlimited size
- Use of wide variety of standard closed and open conduits shapes as well as channels
- Model special elements such as storage/treatment units, flow dividers, pumps, weir and orifices
- Apply of external flows and water quality inputs from surface runoff, groundwater interflow, rainfall dependent infiltration/inflow, dry weather sanity flow, and user defined inflow
- Utilize either kinematics wave or full dynamic wave flow route method
- Model varies regimes such as backwater, surcharging, reverse flow ,and surface ponding
- Apply user defined dynamic control rules to stimulate the operation of pumps, orifice openings and weir crest levels

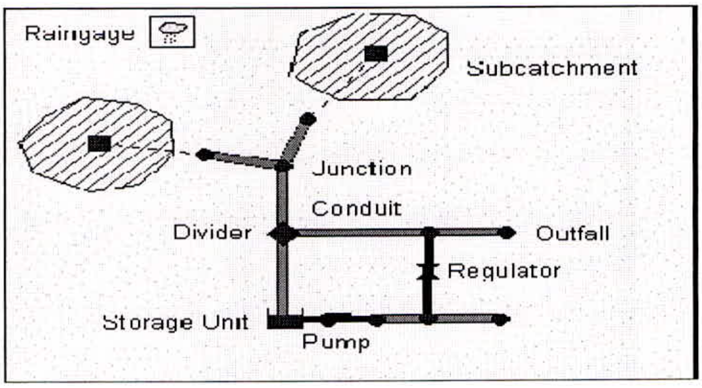
SWMM can also estimates the production of pollution loads associated with this runoff. The following process can be modeled for any number of user defined water quality constituents:

- Dry weather pollutant buildup over different land user
- Pollutant wash off from specific land uses during storm events
- Direct contribution of rainfall deposition

- Reduction in wash off due to BMPs
- Reduction in dry weather buildup due to street cleaning
- Entry of dry weather sanitary flows and user specified external flow at any point in the drainage system
- Routing of water quality constituent through the drainage system
- Reduction in constituent concentration through treatment in storage unit or natural processes in pipes and channels

Objects of SWMM

SWMM software uses the different types of objects. The following sections describe each of these objects:



1. Rain gauge

Rain Gages supply precipitation data for one or more subcatchment areas in a study region. The rainfall data can be either a user-defined time series or come from an external file. Several different popular rainfall file formats currently in use are supported, as well as a standard user-defined format.

The principal input properties of rain gages include

- Rainfall data type (e.g., intensity, volume, or cumulative volume)
- Recording time interval (e.g., hourly, 15-minute, etc.)
- Source of rainfall data (input time series or external file)
- Name of rainfall data source

2. Sub catchment

Sub catchments are hydrologic units of land whose topography and drainage system elements direct surface runoff to a single discharge point. The user is responsible for dividing a study area into an appropriate number of sub catchments, and for identifying the outlet point of each subcatchment. Discharge outlet points can be either nodes of the drainage system or other sub catchments.

Sub catchments can be divided into pervious and impervious sub areas. Surface runoff can infiltrate into the upper soil zone of the pervious sub area, but not through the impervious sub area. Impervious areas are themselves divided into two sub areas - one that contains depression storage and another that does not. Runoff flow from one sub area in a subcatchment can be routed to the other sub area, or both sub areas can drain to the subcatchment outlet.

Infiltration of rainfall from the pervious area of a subcatchment into the unsaturated upper soil zone can be described using three different models

- Horton infiltration
- Green-Ampt infiltration
- Curve Number infiltration

The other principal input parameters for sub catchments include:

- Assigned rain gage

- Outlet node or subcatchment
- Assigned land uses
- Tributary surface area
- Imperviousness
- Slope
- Characteristic width of overland flow
- Manning's n for overland flow on both pervious and impervious areas
- Depression storage in both pervious and impervious areas
- Percent of impervious area with no depression storage.

3. Junction Nodes

Junctions are drainage system nodes where links join together. Physically they can represent the confluence of natural surface channels, manholes in a sewer system, or pipe connection fittings. External inflows can enter the system at junctions. Excess water at a junction can become partially pressurized while connecting conduits are surcharged and can either be lost from the system or be allowed to pond atop the junction and subsequently drain back into the junction.

The principal input parameters for a junction are:

- Invert elevation
- Height to ground surface
- ponded surface area when flooded (optional)
- External inflow data (optional).

4. Outfall Nodes

Outfalls are terminal nodes of the drainage system used to define final downstream boundaries under Dynamic Wave flow routing. For other types of flow routing they behave as a junction. Only a single link can be connected to an outfall node. The boundary conditions at an outfall can be described by any one of the following stage relationships

- The critical or normal flow depth in the connecting conduit
- A fixed stage elevation
- A tidal stage described in a table of tide height versus hour of the day
- A user-defined time series of stage versus time.

The principal input parameters for outfalls include:

- Invert elevation
- Boundary condition type and stage description
- Presence of a flap gate to prevent backflow through the outfall.

5. Flow Divider Nodes

Flow Dividers are drainage system nodes that divert inflows to a specific conduit in a prescribed manner. A flow divider can have no more than two conduit links on its discharge side. Flow dividers are only active under Kinematic Wave routing and are treated as simple junctions under

Dynamic Wave routing.

The flow diverted through a weir divider is computed by the following equation

$$Q_{div} = C_w (f H_w)^{1.5}$$

Where Q_{div} = diverted flow, C_w = weir coefficient, H_w = weir height and f is computed as

$$f = \frac{Q_{in} - Q_{\min}}{Q_{\max} - Q_{\min}}$$

Where *Qin* is the inflow to the divider, *Qmin* is the flow at which diversion begins, and $Q_{\max} = C_w H_w^{1.5}$. The user-specified parameters for the weir divider are Q_{min}, H_w, and C_w

6. Storage Units

Storage Units are drainage system nodes that provide storage volume. Physically they could represent storage facilities as small as a catch basin or as large as a lake. The volumetric properties of a storage unit are described by a function or table of surface area versus height

The principal input parameters for storage units include:

- Invert elevation
- Maximum depth
- Depth-surface area data
- Evaporation potential
- Ponded surface area when flooded (optional)
- External inflow data (optional).

7. Conduits

Conduits are pipes or channels that move water from one node to another in the conveyance system. Their cross-sectional shapes can be selected from a variety of standard open and closed geometries.

The principal input parameters for conduits are:

- Names of the inlet and outlet nodes
- Offset height or elevation above the inlet and outlet node inverts

- Conduit length
- Manning's roughness
- Cross-sectional geometry
- Entrance exit losses (optional)
- Presence of the flap gate to prevent reverse flow (optional)

SWMM uses the Manning equation to express the relationship between flow rate (*Q*), cross-sectional area (*A*), hydraulic radius (*R*), and slope (*S*) in all conduits. For standard U.S. units

$$Q = \frac{1.49}{n} AR^{2/3} S^{1/2}$$

Where *n* is the Manning roughness coefficient. The slope *S* is interpreted as either the conduit slope or the friction slope (i.e., head loss per unit length), depending on the flow routing method used.

For pipes with Circular Force Main cross-sections either the Hazen-Williams or Darcy-Weisbach formula is used in place of the Manning equation for fully pressurized flow. For U.S. units the Hazen-Williams formula is:

$$Q = 1.318 C A R^{0.63} S^{0.54}$$

Where *C* is the Hazen-Williams C-factor, which varies inversely with surface roughness and is supplied as one of the cross-section's parameters.

8. Pumps

Pumps are links used to lift water to higher elevations. A pump curve describes the relation between a pump's flow rate and conditions at its inlet and outlet nodes.

The principal input parameters for a pump include:

- Names of its inlet and outlet nodes
- Name of its pump curve
- Initial on/off status

- Startup and shutoff depths.

9. Flow Regulators

Flow Regulators are structures or devices used to control and divert flows within a conveyance system.

They are typically used to:

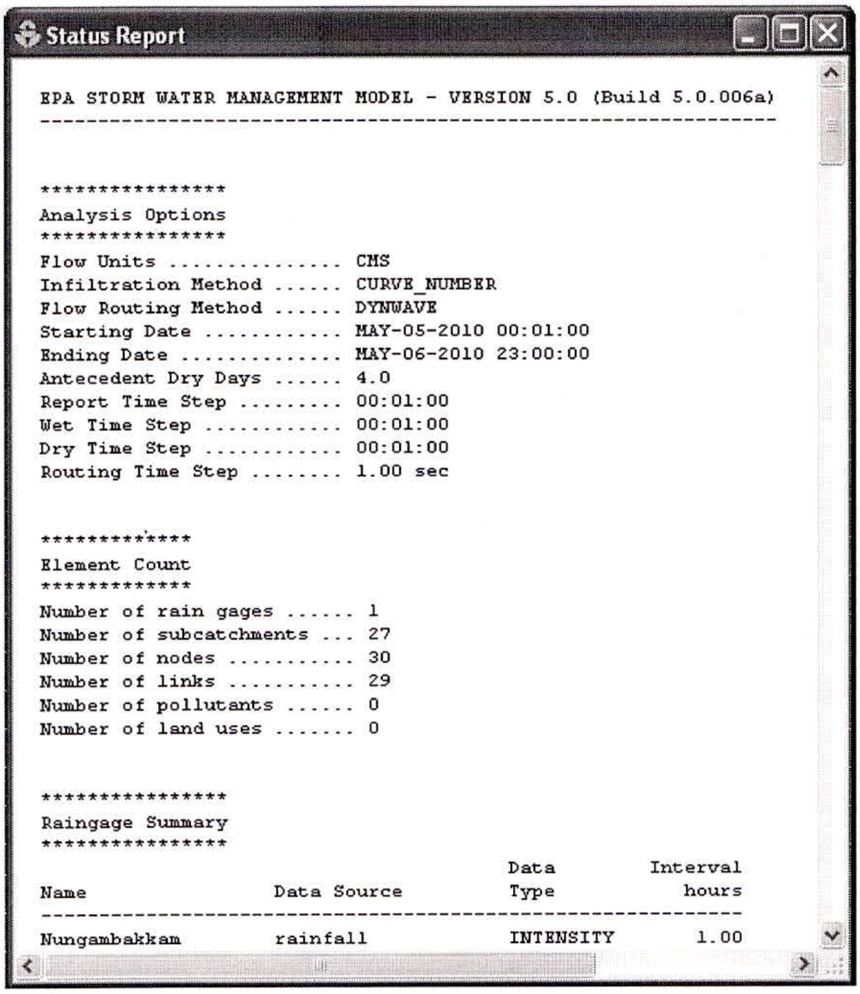
- Control releases from storage facilities
- Prevent unacceptable surcharging
- Divert flow to treatment facilities and interceptors

Viewing The Result

A Status Report is available for viewing after each simulation. It contains:

- A summary of the main Simulation Options that are in effect
- A list of any error conditions encountered during the run
- A summary listing of the project's input data (if requested in the Simulation Options)
- A summary of the data read from each rainfall file used in the simulation
- A description of each control rule action taken during the simulation (if requested in the Simulation Options)
- The system-wide mass continuity errors for:
    - runoff quantity and quality
    - groundwater flow
    - conveyance system flows and water quality
- The names of the nodes with the highest individual flow continuity errors
- The names of the conduits that most often determined the size of the time step used for flow routing (only when the Variable Time Step option is used)
- The names of the links with the highest Flow Instability Index values
- Information on the range of routing time steps taken and the percentage of these that were considered steady state.

The Status Report can be viewed by selecting **Report** >> **Status** from the Main Menu.



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EPA STORM WATER MANAGEMENT MODEL - VERSION 5.0 (Build 5.0.006a)
----------------------------------------------------------------


****************
Analysis Options
****************
Flow Units ............... CMS
Infiltration Method ...... CURVE_NUMBER
Flow Routing Method ...... DYNWAVE
Starting Date ............ MAY-05-2010 00:01:00
Ending Date .............. MAY-06-2010 23:00:00
Antecedent Dry Days ...... 4.0
Report Time Step ......... 00:01:00
Wet Time Step ............ 00:01:00
Dry Time Step ............ 00:01:00
Routing Time Step ........ 1.00 sec


*************
Element Count
*************
Number of rain gages ...... 1
Number of subcatchments ... 27
Number of nodes ........... 30
Number of links ........... 29
Number of pollutants ...... 0
Number of land uses ....... 0


****************
Raingage Summary
****************
                                          Data        Interval
Name                 Data Source          Type           hours
-------------------------------------------------------------
Nungambakkam         rainfall             INTENSITY       1.00
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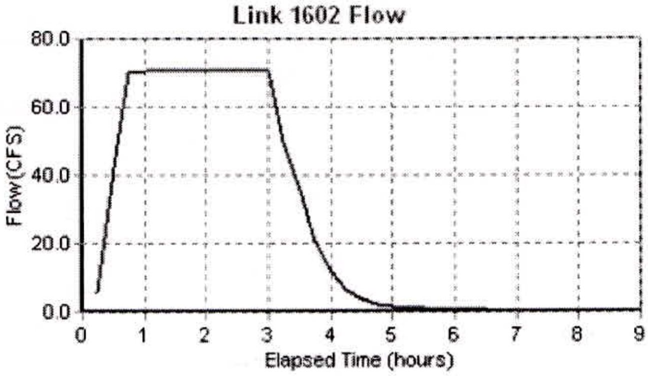
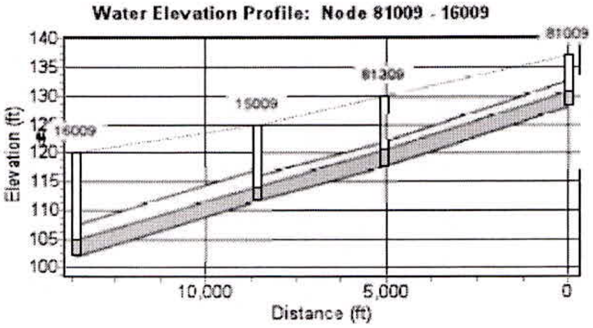
Viewing the result with a map

Analysis results can be viewed using several different types of graphs

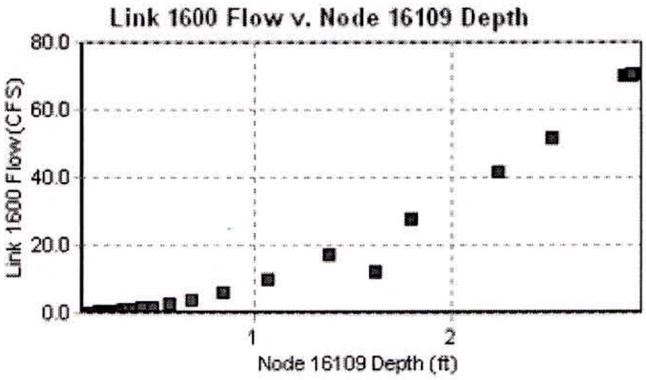
Time Series Plot



Profile Plot:



Scatter Plot:



Reference:

Storm water Management Model User's manual version 5.0 (2004) by Lewis A. Rossan, Water Supply and Water Resources Division, National Risk management Research Laboratory, Cincinnati, OH 45268.