THE ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM

U.S. Environmental Protection Agency

NSF International

ETV Joint Verification Statement

TECHNOLOGY TYPE:	**STORMWATER WASTEWATER MANAGEMENT MODEL**		
APPLICATION:	**WET WEATHER URBAN RUNOFF MODELING**		
TECHNOLOGY NAME:	**XP-SWMM STORMWATER WASTEWATER MANAGEMENT MODEL, VERSION 8.2, 2000**		
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NSF International (NSF), in cooperation with the U.S. Environmental Protection Agency (EPA), operates the Water Quality Protection Center under EPA's Environmental Technology Verification (ETV) Program. As part of the Center's activities in verifying the performance of wet weather flow technologies, NSF evaluated the performance of the XP-SWMM Stormwater Wastewater Management Model, Version 8.2, 2000 (XP-SWMM). This verification statement provides a summary of the test results for the XP-SWMM. Crawford Engineering Associates (CEA) performed the verification test under contract with NSF.

EPA created the ETV Program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV program is to further environmental protection by accelerating the acceptance and use of improved and cost-effective technologies. ETV seeks to achieve this goal by providing high quality, peer-reviewed data on technology performance to those involved in the design, distribution, permitting, purchase, and use of environmental technologies.

ETV works in partnership with testing organizations and stakeholder advisory groups consisting of buyers, vendor organizations, and permitters, and with the full participation of individual technology developers. The program evaluates the performance of innovative technologies by developing test plans that are responsive to the needs of the stakeholders, conducting field or laboratory tests (as appropriate), collecting and analyzing data, and preparing peer-reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance/quality control (QA/QC) protocols to ensure that data of known and adequate quality are generated, and that the results are defensible.

TECHNOLOGY DESCRIPTION

The following technology description is provided by the vendor and does not represent verified information.

XP-SWMM is a commercial software package used throughout the United States and around the world for simulation of storm, sanitary and combined sewer systems. It was designed based on the EPA Storm Water Management Model (EPA SWMM), but has enhancements and additional algorithms for the analysis of urban runoff and drainage. Simulation models like XP-SWMM are used for planning new systems, extending existing systems to accommodate growth, and to mitigate undesirable overflows and adverse water quality impacts. Models are also used for the study and design of wet weather facilities, including the sizing of conveyance systems, storage facilities, pump stations and treatment plants. In practice, the model selected to perform an evaluation is often chosen with little understanding of the background processes involved in producing rainfall-runoff responses or conveyance through a collection system.

XP-SWMM is a collection of computer programs that simulate rainfall-runoff processes in urban watersheds in addition to the transport of the runoff through pipes and channels. The programs are referenced by a graphical user interface (GUI) that assists the user in visualizing the system, in adding data needed to perform the simulation, and in extracting and plotting model results. The GUI assists the user to understand the processes and determine the data necessary for adequately simulating system responses. Prior to using XP-SWMM, however, model users should be familiar with basic hydrologic and hydraulic concepts such as: infiltration; conveyance of flow through pipes and channels, including open channel flow; and flow under backwater conditions.

The XP-SWMM GUI creates a 'card-image' data file that is read by a FORTRAN program that is called by XP-SWMM. The FORTRAN program (and additional subprograms that are called when referenced) performs the required analyses and produces results that are stored in text and binary output files. Additional programs called by the XP-SWMM GUI read binary output result files.

The program has many subprograms. They can be grouped into four main categories:

- UTILITIES for processing data and performing statistical analyses (such as long period rainfall event analysis)
- RUNOFF for determining flow generated from rainfall in a defined watershed or catchment. RUNOFF can use user-selected rainfall-runoff algorithms including EPA SWMM Runoff, Santa Barbara Urban Hydrograph, Soil Conservation Service (SCS) Hydrology, and the rational formula. RUNOFF also performs water quality modeling based on land-use and pollutant build-up/wash-off techniques
- SANITARY for performing collection system routing using kinematic wave routing methods
- HYDRAULIC for performing collection system routing using techniques that solve the St. Venant equations for flow continuity and momentum.

The four main categories can be linked, but RUNOFF and HYDRAULIC are the two primary categories used in most modeling studies. Each of these categories has many components, not all of which were tested in this study. The components tested during the ETV evaluation are believed to be the most commonly used components in urban modeling.

PERFORMANCE VERIFICATION

Testing of the XP-SWMM software was conducted from May through July 2002 at the offices of CEA.

In order to verify the performance of XP-SWMM in real world conditions, the software was applied to real systems and monitored data. This verification method provided insight into how the model supports the user, simulates conditions, and presents the results to the user. Since applying software to real-world situations is subject to a variety of calibration and validation parameters and a certain degree of uncertainty, this testing methodology was not intended to calibrate model parameters.

The goals of the verification were to:

- Identify components of the model (XP-SWMM);
- Review key algorithms to insure they are implemented correctly in XP-SWMM; and
- Compare the model results with off-line calculations, where applicable/possible.

RESULTS

Evaluation of the XP-SWMM components provided insight into the interaction of many 'basic' functions commonly used in building models of actual systems. Examples of basic functions include the WIDTH parameter, used in RUNOFF to determine flow rates from a watershed, and infiltration simulations. Relationships between these types of functions are generally not transparent or even recognized by many potential modelers or users of models. Some of these interrelationships were revealed and highlighted during the testing of XP-SWMM to enhance user confidence in the model.

The results from the testing conducted on the model components were comparable overall to results achieved with off-line calculations. In many instances, the model results were identical to the off-line results, as depicted in Table 1. For the model components listed in Table 1, the values in the column titled "% Comparison" reflect the degree of similarity between the results obtained from the model simulations compared to those obtained through off-line calculations. The model's performance for a particular function may or may not be appropriate given that each function is different and has a different level of inherent uncertainty as a calculation or process.

Table 1. Summary of XP-SWMM Testing

Module	Component	Process	% Comparison	Notes
RUNOFF	Rainfall	Event	100	
		Interface	>99	Small rounding errors encountered.
		Continuous	100	Raw data check recommended to ensure no deviant data values.
		Standard format	99	Standard formats are most likely changed by collecting agencies.
		Statistics	100	
	Infiltration	Horton	No value	Horton equation represented appropriately. However, infiltration and excess rainfall were influenced by value used for WIDTH parameter.
		Green-Ampt	>99	Green-Ampt equation represented appropriately. WIDTH parameter not an issue with Green-Ampt.
	Runoff	Runoff	90	Clarification on how the WIDTH parameter affects runoff volume for pervious areas is needed.
		SBUH	95	Within expected modeling technique variation.
		SCS	95	Within expected modeling technique variation.
		Calibrated model	95	Monitored results duplicated when model parameters selected with care and with proper basin definition.
HYDRAULIC - nodes	Node inflows	Diurnal pattern	99	Minor time shift (one hour).
		Gauged inflow	95	Generally appropriate but possible misrepresentation may impact some simulations.
		Interface	100	
	Node loss coefficients	Minor loss simulations	90	Calculated head loss greater than simulated values.
	Storage node	Constant area	98	Water levels predicted are dependent on volume used in upstream and downstream links.
		Depth-area	95	Time step for reporting flow results has a significant impact on spreadsheet accuracy.
		Power function	95	
	Node inlet capacity	Maximum value	99	
		Rating curve	99	
	Node control	Flooding allowed	99	
		Sealed	100	

Module	Component	Process	% Comparison	Notes
		Surface ponding	99	
	Outlet control	Free outfall	100	
		Fixed backwater	95	
		Tidal changes	90	Generation of tidal values not working in program.
		Variable water level	95	
HYDRAULIC - links	Manning's Roughness	Manning's Equation	100	
	Pressure and open channel flow	St. Venant's Equation	95-100	
	Flow direction	Upstream, downstream and free flow	100	
	Flow routing for conduit shapes	Basic and user-defined shapes	90	Misreporting of some maximums for some shapes.
	Gauged flow for calibration plots	Input of external data for comparison of results.	95	
HYDRAULIC - special links	Multiple conduits	Parallel pipes	95	
	Pump simulations	Type 1	Not tested	Not recommended. Use Type 4.
		Type 2	Not tested	Not recommended. Use Type 4.
		Type 3	100	
		Type 4	100	
		Type 5	No value	Use with caution.
	Weir simulations	Side weir	98	
		Transverse weir	99	
	Orifice simulations	Bottom orifice	98	
		Side orifice	98	

QUALITY ASSURANCE / QUALITY CONTROL (QA/QC)

During completion of this verification, CEA personnel duplicated program calculations by hand calculations, checked or duplicated data entry into the model to ensure the model data correctly compared to data used in hand calculations, and checked or duplicated entered data and calculations used in spreadsheets (e.g. checked fields referenced in formulas).

Original signed by Sally Gutierrez	*9/2/05*	*Original signed by Thomas G. Stevens*	*9/7/05*
Sally Gutierrez	Date	Thomas G. Stevens, P.E.	Date
Acting Director		Program Manager	
National Risk Management Research Laboratory		ETV Water Quality Protection Center	
Office of Research and Development		NSF International	
United States Environmental Protection Agency			

Availability of Supporting Documents

Copies of the *ETV Protocol for Verification Testing for Urban Runoff Models* dated October 2000, the verification statement, and the verification report are available from the following sources:

ETV Water Quality Protection Center Manager (order hard copy)
NSF International
P.O. Box 130140
Ann Arbor, Michigan 48113-0140

NSF web site: http://www.nsf.org/etv (electronic copy)

EPA web site: http://www.epa.gov/etv (electronic copy)

(NOTE: Appendices are not included in the verification report. Appendices are available from NSF upon request.)