HDR

Memorandum

DATE: June 9, 1992

TO: Jodi Polzin

FROM: Mark Deutschman *Mark*

SUBJECT: City of Minneapolis Storm Water Project
Storm Water Modeling Technical Memorandum

Attached for your review is a copy of the Technical Memorandum describing various storm water runoff quality models. After review of the available models, my recommendation is the City use the model P8. This recommendation is based on a review of model documentation and a discussion of model specifics with each model developer.

As with any model, P8 has some limitations. These limitations are primarily related to runoff hydrology. Therefore, we will need to pay attention to how well P8 calibrates to our observed runoff events and the magnitude of calibration parameters. Please call should you have comments concerning the memorandum. Thank you.

cc: Kent Mao, Seattle HDR
Ron Ott, Anchorage HDR
Ron Rossmiller, Seattle HDR

TECHNICAL MEMORANDUM
EVALUATION OF STORM WATER RUNOFF COMPUTER MODELS
CITY OF MINNEAPOLIS

1.0 Introduction

The City of Minneapolis, City of Columbia Heights, City of Richfield, Minneapolis Parks and Recreation Board, University of Minnesota, Minnesota Department of Transportation and Hennepin County (hereafter referred to as "Applicant") are co-applicants under the National Point Discharge Elimination System (NPDES) storm water permit program. The NPDES storm water permit application process consists of two parts; Part I and Part II. Part II requires the Applicant to estimate annual storm water pollutant loadings from characteristic drainage areas and make recommendations for the implementation of Best Management Practices (BMPs). BMPs are structural (e.g., building wet detention basins) and nonstructural (e.g., street sweeping) activities implemented to reduce the discharge of pollutants to receiving waters.

One method for estimating the quantity of pollutants washing off urban areas as a result of precipitation and entering surface waters, is to perform measurements. These measurements are of the concentrations of various contaminants in urban runoff and the amount of runoff. Measurements are presently being performed at eight (8) locations; six (6) within Minneapolis and two (2) within Richfield. Details of the monitoring program are described elsewhere (HDR Engineering, Inc., 1992).

Mathematical modeling using a computer is a second method for estimating the quantity of pollutants washing off urban areas. The use of mathematical models has the added advantage of being "predictive". The effectiveness of various BMPs can be evaluated where they presently do not physically exist and under a variety of hydrologic conditions (e.g., rainfall amount, soil moisture conditions) within the catchment. The purpose of this memorandum is to present an evaluation of storm water quality models available to the Applicant for estimating annual pollutant loads and evaluating the effectiveness of BMPs.

2.0 Modeling Philosophy, Models Considered and Discussion of Selection Criteria

2.1 Modeling Philosophy

The selected model must be capable of matching the intended modeling philosophy. For example, are absolute predictions of water quality needed? Or, is the comparison of relative water quality for a variety of BMPs important. Will the model be used to size storm water systems based on an accurate prediction of the peak runoff volume from a specific design storm? Or, are planning level estimates of the percentage reduction in the mass of total suspended solids the important criteria for evaluating BMP effectiveness?

Based on discussions with the Applicant, the following are general requirements of the selected model:

- The ability to physically represent the storm water piping system (e.g., flow splitters within manholes).
- The ability to model the BMPs of interest. The Applicant has tentatively identified street sweeping as a BMP of primary interest, with the use of grit chambers secondary.
- Some "physical" or deterministic basis for predicting contaminant build-up and wash-off.
- The user-friendliness of the model.
- Capability of modeling a diverse list of pollutants including sediments, trace metals and some characteristic organic contaminant.
- Moderate level of data requirements for model operation.
- Operation in a design mode where structural BMP design can be optimized to achieve a desired removal efficiency.
- Method for evaluating model error (sensitivity or uncertainty analysis).
- Some degree of peer acceptability.

Section 2.3, Discussion of Selection Criteria, presents important aspects of each of these criteria.

2.2 Models Considered

A variety of computer models for assessment, planning, and design have been developed for storm water since the beginning of the personal computer age in the early 1970s. An exhaustive list of computer urban drainage models is available (Kibler et al. 1992, see Appendix A). These models vary in complexity and functional ability; many can only simulate storm water runoff volume. Table 1 identifies models capable of predicting the quality of storm water runoff. Storm water quality models further evaluated within the Technical Memorandum are:

- Auto-QI
- Hydrologic Simulation Program Fortran (HSPF)
- Program for Predicting Polluting Particle Passage Through Pits, Puddles and Ponds (P-8)
- Simplified Particulate Transport Model (SIMPTM)
- Source Loading and Management Model (SLAMM)
- Storage, Treatment, Overflow, Runoff Model (STORM)
- EPA Storm Water Management Model (SWMM)

2.3 Discussion of Selection Criteria

Table 1 details the general complexity of the various storm water quality models, the availability of documentation, the level of technical support and the quality of the output graphics. These criteria are mainly functional and contribute to the user friendliness of the model. With respect information generated by each of these model, each of the models provides estimates of the event pollutant load, event runoff volume and event mean concentrations. These data can be generated for specific catchments or for all catchments combined.

As stated previously, Table 2 presents a technical evaluation of the models. The need is to select a model capable of a planning level estimates of event pollutant load, event mean concentrations, and to a lesser degree event volume. The main criteria for event volume is accurate prediction of the total storm volume, rather than accurate prediction of the time of peak concentration or shape of the hydrograph. (Since the model will not be used for design based on peak flow.) The models HSPF and SWMM are generally not considered as planning level models. They are derivatives of the old fortran card file system where input data must be specified in specific columns and row in the input deck; they are not menu driven. (Commercially available menu driven preprocessors are available for SWMM.) Each of these models is input data intensive. Although these models are perhaps the most detailed with respect to physical representation of the processes occurring within the environment (e.g., buildup, wash-off, sediment transport, hydrograph development, water quality routing), their detail seems unwarranted for the present application.

The remaining models are similar with respect to physical representation of processes occurring in the environment, although SIPTM and SLAMM are more detailed with respect to sediment transport and small watershed hydrology. Whether the additional detail in SIPTM overcomes model error associated with other processes (e.g., water quality routing) is unknown.

The models Auto-QI, SIMPTM, and SLAMM, generate storm water data at the outfall to the catchment; routing through a pipe network is not possible. Nor, is combining hydrographs or pollutant loads from multiple watersheds into a single pipe. (Note: SIMPTM, SLAMM, and P8 do route pollutants through BMPs and use mass balance equations to evaluate efficiency.) Therefore, these models are more limited in their ability to physically represent the existing pipe network than a model like P8. Auto-QI, SIMPTM, SLAMM, and STORM lack the ability to optimizing BMP design through the menu driven system. Optimize means back-calculation of structural BMP characteristics like size or volume by the model, given a desired pollutant removal efficiency.

Based on the review performed by HDR, it is our recommendation that the model P8 be selected for modeling storm water by the Applicant. This recommendation is based largely on the user friendliness of the model, the ability to optimize design, moderate data input requirements similar to SIPTM, SLAMM, STORM and Auto-QI, the ability to represent the pipe network, and the quality of the output graphics. The P8 model is capable of simulating the BMPs the Applicant anticipates implementing and is gaining peer acceptance.

The P8 model suffers from limitations like any model. Looped pipe networks can not be modeled. Also, flow is routed from upstream to downstream; backwater conditions are not considered or flagged during model operation (although the model does present data on water and pollutant conservation).

The largest limitation of P8, is accurate representation of the hydrology compared to SIMPTM and SLAMM (as per my conversation with Robert Pitt, University of Alabama). During application of P8, special attention needs to be given as to whether calibration parameters are within a reasonable range and independent of storm and watershed characteristics.

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TABLE 1

STORM WATER MANAGEMENT COMPUTER MODELS
GENERAL DESCRIPTION AND FUNCTIONAL EVALUATION

Model Name	Auto-QI	HSPF	P-8	SIMPTM	SLAMM	STORM	SWMM
Author	*Illinois State* Water Survey	EPA	IEP, Inc.	Otak, Inc.	Robert Pitt	HEC	*Metcalf & Eddy*; CDM; University of Florida; EPA
Latest Release Date	1990	1989	1990	1990	1990	1977	1991
Description	Urban runoff and pollutant loading simulation model	Hydrological Simulation Program, FORTRAN	Water quality routing model (Pollutographs/ Loadings)	Simplified particulate transport model	Source loading and management model	Storage, treatment, overflow, runoff model	Storm water management model
Degree of Complexity:							
Routing	N	M	L	N	N	L	H
Calibration	N	H	L	M	M	L	M
Data Requirements	L	H	M	M	M	M	H
General	L	H	M	M	M	M	H
Menu Driven	Yes	No	Y	Y	Y	N	Y
Documentation	Good	Fair	Good	Fair	Good	Good	Excellent
Output Display (Graphics)	Fair	Fair	Excellent	Fair	Fair	Fair	Good
Technical Support	Fair	Fair	Good	Good	Fair	Fair	Excellent

Note: L = low requirements; M = moderate requirements, H = most extensive requirements, N = none

TABLE 2
COMPARISON OF STORM WATER QUALITY RUNOFF MODELS

Model	Continuous or Event Model?	Rainfall Hyetograph Method	Model Pervious and Impervious Areas?	Rainfall Volume Calculation
Auto-QI	Continuous/Event	Observed rainfall	Yes	Hyetograph times rainfall volume aft
HSPF	Continuous/Event	Observed rainfall or synthetic hyetograph	Yes	Hyetograph times rainfall volume aft
P8	Continous/Event	Observed Rainfall or synthetic hyetograph	Yes	SCS Curve Number
SIMPTM	Continuous/Event	Trapezoidal or Triangular	Yes	Hyetograph times rainfall volume aft
SLAMM	Continuous/Event	Trapezoidal or Triangular	Yes	Hyetograph times rainfall volume aft
STORM	Continuous/Event	Observed hourly rainfall	Yes	SCS curve no., runoff coeff., or con
SWMM	Continuous/Event	Observed rainfall or synthetic hyetograph	Yes	Hyetograph times rainfall volume aft

Model	Pollutants Simulated	Dry Weather Pollutant Build-up?	Wet Weather Wash-off?	Simulate Varying Land Use?
Auto-QI	Variable	Yes	Yes	Yes
HSPF	TDS, Cl, pesticides,DO, BOD, nutrients	Yes	Yes	Yes
P8	TSS,TP,TKN,Cu,Pb,Zn,Hydrocarbons	Yes	Yes	Yes
SIMPTM	Variable	Yes	Yes	Yes
SLAMM	Variable	Yes	Yes	Yes
STORM	SS, STS, BOD, N, OP, Coliforms	Yes	Yes	Yes
SWMM	Up to ten user supplied	Yes	Yes	Yes

Model	Water Quality Routing	Pipe Network Complexity	Handle Surcharge?	Optimize Design Mode?
Auto-QI	None	None	No	No
HSPF	Plug flow	None	No	No
P8	Mixed cells in device	Moderate	No	Yes
SIMPTM	Through Control Devices - Completely Mixed	None	No	No
SLAMM	Through Control Devices - Completely Mixed	None	No	No
STORM	Unit Hydrograph	None	No	No
SWMM	Mixed cells in channel/pipe	Moderate	No	No

Model	Detention/ Retention?	Street Cleaning?	Infiltration Basins?	BMP Evaluation Catch Basin Cleaning?
Auto-QI	Yes	Yes	Yes	No
HSPF	Yes	No	Yes	No
P8	Yes	Yes	Yes	No
SIMPTM	Yes	Yes	Yes	Yes
SLAMM	Yes	Yes	Yes	Yes
STORM	Yes	Yes	Yes	No
SWMM	Yes	Yes	Yes	Yes

Notes:

Pollutant type in Auto-QI specified by user defined build-up and wash-off parameters.
BMP effectiveness is expressed as user defined percentage reduction for model Auto-QI.
SWMM observed rainfall data may be time step of 15 minutes or longer.
Only available SWMM routing method when water quality is modeled. XTRAN can not be used.
SWMM can not handle surcharge conditions during water quality routing.
SLAMM and SIMTPM are continuous in the sense of long-term simulations through time can be performed. However, hourly rainfall data are prepi
SLAMM contains uniques algorithms for infiltration and routing developed for small watershed hydrology by Dr. Robert Pitt.
SLAMM and SIMPTM can model varying number of pollutants. User specifies pollutant mass fraction on sediment partical and dissolved pollutant
SLAMM, SIMPTM, SWMM, and P8 use mass balance equation using hydraulic characteristics of control device to evaluate device removal effici

Pollutant Codes:

TSS=Total Suspended Solids
COD=Chemical Oxygen Demand
TKN=Total Kjeldahl Nitrogen
TP=Total Phosphorus
PB=Lead
ZN=Zinc
Cu=Copper
SS=Suspended Solids
STS=Settable Solids
TR=Total Residue
OP=Ortho-phosphate
BOD=Biological Oxygen Demand
Al=Aluminum

TABLE 2
WATER QUALITY RUNOFF MODELS

Rainfall yetograph Method	Model Pervious and Impervious Areas?	Rainfall Volume Calculation	Runoff Routing Hydrograph Method	Snowmelt Simulation?
served rainfall	Yes	Hyetograph times rainfall volume after losses	None	No
ll or synthetic hyetograph	Yes	Hyetograph times rainfall volume after losses	Overland-Chezy/Mannings; Channel-linear routing	Yes
ll or synthetic hyetograph	Yes	*SCS Curve Number*	*Linear storage in channels/pipes*	No
oidal or Triangular	Yes	Hyetograph times rainfall volume after losses	Mannings Equation	No
oidal or Triangular	Yes	Hyetograph times rainfall volume after losses	see Notes	No
ed hourly rainfall	Yes	SCS curve no., runoff coeff., or combination	Unit Hydrograph	Yes
ll or synthetic hyetograph	Yes	Hyetograph times rainfall volume after losses	Various methods	Yes

ry Weather Pollutant Build-up?	Wet Weather Wash-off?	Simulate Varying Land Use?	GIS Interface?
Yes	Yes	Yes	ARC/INFO
Yes	Yes	Yes	No
Yes	Yes	Yes	No
Yes	Yes	Yes	No
Yes	Yes	Yes	No
Yes	Yes	Yes	No
Yes	Yes	Yes	No

Pipe Network Complexity	Handle Surcharge?	Optimize Design Mode?
None	No	No
None	No	No
Moderate	No	Yes
None	No	No
None	No	No
None	No	No
Moderate	No	No

BMP Evaluation				
Street Cleaning?	Infiltration Basins?	Catch Basin Cleaning?	Grass Swales and Filter Strips?	Porous Pavement?
Yes	Yes	No	Yes	Yes
No	Yes	No	Yes	No
Yes	Yes	No	Yes	No
Yes	Yes	Yes	Yes	No
Yes	Yes	Yes	Yes	Yes
Yes	Yes	No	No	No
Yes	Yes	Yes	Yes	No

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Appendix A

Matrix Evaluation of Urban Runoff Models

Microcomputer Software in Urban Hydrology

*D. F. Kibler, M. E. Jennings, G. L. Louis, B. A. Tschantz, and S. G. Walesh**

Editor's Note: The following report was developed by a Task Committee of the American Society of Civil Engineers. It came to the Editor's attention through a circuitous route, and because of the shelf life of the material discussed in the article, we decided to publish it. Should any AWRA Working Groups care to develop similar reports, we would like to see them on the Editor's desk. For that matter, if any other ASCE committees – or anybody else – with similar, current, work-in-progress reports wishes to send them in the Editor's direction – please do so. I can always say "no" – but we'd like the opportunity to help our members stay technically current.

INTRODUCTION

With the profusion of microcomputer software in the urban hydrology field over the past five years, the design engineer is often frustrated by a lack of information on the most widely used software packages from which he or she can make an informed decision about software selection. The American Society of Civil Engineers (ASCE) Task Committee (TC) on Microcomputer Software in Urban Hydrology was formed in 1987 for the express purpose of developing a comprehensive inventory of software packages available from commercial vendors and public domain sources. In addition to the members listed above, the TC was assisted by corresponding members Paul DeBarry, RKR Hesse Associates, Stroudsburg, PA; Gerard Lennon, Civil Engineering Department, Lehigh University; and Lindell Ormsbee, Civil Engineering Department, University of Kentucky.

The primary mission of the TC was to compile an inventory of microcomputer software having the capability to: generate runoff peaks and hydrographs; analyze/design storm sewers; and analyze/design stormwater detention facilities. The TC compiled a list of prospective vendors and composed a detailed survey form which was sent to each vendor.

It should be pointed out as background that prior to formation of the Task Committee there was no single source of information which potential software users could consult. Lewis and Gilbert (1985) and Lewis (1988) have compiled two partial software inventories in urban hydrology, while Jennings *et al.* (1988), have presented an inventory of Federal agency software. Walesh (1988) has discussed the problem of maintaining computer capability in the private sector and the role of vendor software. A second phase of the TC project (not yet approved by ASCE) is aimed at bench-mark testing of individual software packages. Tschantz (1988) and Kibler *et al.* (1989), have further discussed the specific mission and overall goals of the TC.

SUMMARY OF VENDOR RESPONSES

The TC received completed survey forms from 40 vendors as of March 15, 1990. A summary version of the TC software inventory is shown in Table 1.

SUMMARY OF SOFTWARE CHARACTERISTICS

The primary characteristics of the 40 software packages inventories are listed in Table 2. Regarding the last item in Table 2, many vendors indicated that the work of testing their software against gaged data was actually performed by the agency where the hydrologic procedure originated. This was especially true for the software which emulates TR20, TR55, and HEC-1.

In terms of hydrologic capabilities, the software packages reviewed by the TC tended to support simple desk-top procedures for a single design storm. For example, the SCS curve number and Rational method C coefficient dominated the list of hydrologic abstraction methods, followed by Green and Ampt and Horton infiltration equations. Hydrograph synthesis tended toward use of the SCS unit hydrograph, followed by the modified Rational method, kinematic wave and other synthetic unit hydrograph techniques. Hydrograph routing was performed primarily by time-of-travel translation, Muskingum routing, or kinematic routing as opposed to dynamic routing with the Saint-Venant equations. This level of computation is very much in line with the indication by 72 percent of the vendors that private consulting firms were the most frequent user of their softare. Consultants were followed by state and federal agencies in terms of user frequency. However, many of these agencies were committed to microcomputer versions of larger packages such as EPA SWMM, USGS DR3M, ILLUDAS, and HSPF. The latter group of software also is included in the TC urban hydrology software inventory. Detailed tabulations on hydrologic methodologies are presented in Tables 3, 4, and 5.

In terms of software/hardware requirements, core size ranged from 64K to 3MB, with the latter reserved for the integrated CAD/software systems which appears in the vendor inventory. The median core size overall is 512 K bytes. Program languages included FORTRAN, PASCAL, BASIC, "C," ASSEMBLY, and LOTUS. FORTRAN and BASIC were the most frequent, with "C" being utilized for many graphics routines.

The summary in Table 2 indicates that only 12 of the 40 software packages inventories by the TC are public domain. The other 28 either have a copyright or are in the process of

*Respectively, Professor and Head, Dept. of Civil Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061-0105; Coordinator, Urban Studies Program, U.S. Geological Survey, Austin, TX, 78753 (member ASCE); Principal Engineer, Boyle Engineering Corporation, Lakewood, CO 80228 (member ASCE); Professor, Dept. of Civil Engineering, University of Tennessee, Knoxville, TN 37996 (Chairman of Task Committee; member ASCE); and Dean, College of Engineering, Valparaiso University, Valparaiso, IN 46383 (member ASCE).

Aicrocomputer Software in Urban Hydrology . . . . cont'd.

TABLE 1. Preliminary ASCE TC Inventory of Micro Software in Urban Drainage Design.

No. and Name of Vendor	Address and Telephone of Vendor	Name of Program	Software Package Cost	Hydrograph Synthesis Method	Storm Sewer Design Option?	Detention Basin Option?
.) Hydrologic Engineering Center, U.S. Army Corps of Engineers	609 2nd St. Davis, CA 95616 (916) 551-1748	HEC-1 Flood Hydrograph Package	Variable	Kinematic Wave Clark UH Synder UH SCS UH User Specified	No	Yes
(2) Dodson and Associates, Inc.	7015 W. Tidwell Suite 107 Houston, TX 77092 (713) 895-8322	ProHEC1 Professional HEC-1 System	$495 List Discounts Apply	Kinematic Wave Clark UH Synder UH SCS UH	No	Yes
(3) Dodson and Associates, Inc.	7015 W. Tidwell Suite 107 Houston, TX 77092 (713) 895-8322	ProPIBS	$795 Discounts are Available	Time Area Curve	Yes	Yes
(4) Dodson and Associates, Inc.	7015 W. Tidwell Suite 107 Houston, TX 77092 (713) 895-8322	Dodson Hydro Calc Hydrology Library	$295 Discounts are Available	Clark Synder SCS Diam. U.H.	No	Yes
(5) Galileo Software	16 Ranch Rd. Chelesford, MA 01824 (508) 256-7801	Hydropak	$500 All Six Modules or $100 Per Module	SCS Curvilinear Unit Hydrograph	No	Yes
6) Advanced Engineering Software (R.E.S.)	17782 Sky Park Circle Irvine, CA 92714 (714) 385-3546	RES Hydrology and Hydraulics	Variable	S-Graph Clark U.H. SCS Curvilinear U.H.	Yes	Yes
(7) Haestad Methods Inc.	37 Brookside Rd. Waterbury, CT 06708 (800) 727-6555	Pond2 Quick TR-55 Link-2	QTR-55 $495 Pond2 $990 Package QTR-55/ Pond2 $995 Link-2 $795	1986 TR-55 Tabular Hyd. Any Method Supported by HEC-1 and SCS	No	Yes
(8) Haestad Methods Inc.	37 Brookside Rd. Waterbury, CT 06708 (800) 727-6555	The Friend	Program $495 Interfaces to The Friend are N/C With Model Purchase	HEC1 TR20	Thysys HEC2	HEC1 TR20
(9) Myers Engineering Co.	3829 Birch St. Newport Beach, CA 92660 (714) 662-3627	Garden Variety Software Drain Check	$50	N/A	Yes	No
(10) B. Tanovan Water Resources Consultants	11995 SW Burnett Lane Beaverton, OR 97005 (503) 643-3149	Water-Drainage	Approximately $600	SCS Curvilinear U.H.	Yes	Yes
(11) Center for Exposure Assessment USEPA	College Station Rd. Athens, GA 30613 (404) 546-3123	Storm Water Management Model Version 4 SWMM4	Free EPA $40 from U of FL Documentation $56 from U of FL	Nonlinear Reservoir	Yes	Yes
(12) Center for Exposure Assessment USEPA	College Station Rd. Athens, GA 30613 (404) 546-3123	Hydrologic Simulation Program Fortran HSPF	Free From EPA	Stanford Watershed Model	Yes	Yes

TABLE 1. Preliminary ASCE TC Inventory of Micro Software in Urban Drainage Design (cont'd.).

No. and Name of Vendor	Address and Telephone of Vendor	Name of Program	Software Package Cost	Hydrograph Synthesis Method	Storm Sewer Design Option?	Detention Basin Option?
(13) Civil Concepts	P.O. Box 483 Sacramento, CA 95803 (916) 427-1011	Civil Concepts' Hydrology Planner	Hydrology Planner $295 Hplot $95	Application of Santa Barbara Urban Hydrograph Method	No	Yes
(14) Intergraph Corporation	One Madison Industrial Pk. Huntsville, AL 35807-4201 (800) 526-3515	Inflow Storm Drainage Design	Inflow $3000 Database $600	Modified Rational to Compute Runoff Hydrograph	Yes	Yes
(15) McTRANS The Center for Microcomp. on Transp.	Univ. of Florida 512 Weil Hall Gainesville, FL 32611 (904) 392-0378	Highway Drainage Micro Programs	To be Determined	Synder UH (Constants Application) USGS Semi-Arid UH	Yes	No
(16) Computational Hydraulics Inc.	36 Stuart St. Guelph, Ontario Canada N1E 4S5 (519) 767-0197	Stormwater Management Model for the IBMPC PCSWMM3	$780	SWMM3	Yes	Yes
(17) Penn State Univ. Dept. of Civil Engineering	212, Sackett Bldg. Univ. Park, PA 16802 (814) 863-2786	Penn State Urban Hydrology Model PSUHM	$550 for Short Course and Software Package	1986 TR55 Tabular Hydrog. SCS Curvilinear UH Universal Rational Mod. Rational	Yes	Yes
(18) Abacus Computer Service	P.O. Box 1137 Sebastopol, CA 95472 (707) 823-6731	Hydrol Hydrau	Check with Vendor	Variation of the Rational Method	Yes	No
(19) Applied Microcomp. Systems	Page Hill Rd. Chocorua, NH 03817 (603) 323-8666	HydroCRO Stormwater Modeling System	$2795	SCS Curvilinear UH Rational Method	Yes	Yes
(20) NTIS US Dept. of Commerce	Springfield, VA 22161 (703) 487-4650	Hydrology for Small Urban Watersheds TR-55 1986 Ver.	$90	SCS Curvilinear UH	No	Yes
(21) Sierra-Misco Inc.	1900 Point West Way Suite 208 Sacramento, CA 95815 (800) 422-5111	Enhanced ALERT Data Collection and Analysis	$3500	Sacramento Soil Moisture Accounting Model with Unit Hydrograph	No	No
(22) IRRISCO	632 W. Slaughter Lane Suite 206 Austin, TX 78748 (512) 282-0809	PC-DAMBRK NETWORK/ DWOPER	$50	N/A	Yes	No
(23) Penn State University Dept. of Civil Engineering	212 Sackett Bldg. Univ. Park, PA 16802 (814) 863-2932	Penn State Runoff Model PSRM	$75	Overland Flow by by Kinematic Wave	Yes	Yes
(24) Scientific Software Group	P.O. Box 23041 Washington, DC 20026-3041 (703) 620-9214	SWAMP Stormwater Management	SWAMP $795 IDF-PAR $200 POND $275 CHICAGO $200 SANITY $275 STORM $275	Information N/A	Yes	Yes

TABLE 1. Preliminary ASCE TC Inventory of Micro Software in Urban Drainage Design (cont'd.).

No. and Name of Vendor	Address and Telephone of Vendor	Name of Program	Software Package Cost	Hydrograph Synthesis Method	Storm Sewer Design Option?	Detention Basin Option?
(25) Pizer Inc.	3214 W. McGraw Suite 900 Seattle, WA 98199 (800) 222-5332	HYDRA	HYDRA Ver1 $495 HYDRA Ver2 $495 HYDRA Ver3 $990 HYDRA Ver4 $1295 Includes Ver 1, 2, 3	Continuous Simulation, SCS Method- (Santa Barbara Modifications) Rational Method	Yes	Yes
(26) Alan A. Smith Inc.	1463 Ontario St. Burlington, Ontario Canada I7S 1G6 (416) 333-4191	Microcomp. Design of Urban Stormwater Systems	$750 (Canadian)	SCS Triangular UH Rectangular UH Single Linear Reservoir UH EPA SWMM Runoff	Yes	Yes
(27) PLUS III Software Inc.	One Dunwoody Park Suite 250 Atlanta, GA 30338 (800) 235-4972	HYDRO/PLUS	$1595	SCS Curvilinear DEKALB Rational Method Variations	No	Yes
(28) Joseph B. Bonadiam & Software Associates, Inc.	250 S. Lena Court San Bernardino, CA 92408 (714) 889-4661	Civil Design Civil Cadd	Unit Hydrology $595 Rational Progm. $845 L.A. Cnty. WSPG $625	SCS Curvilinear UH S-Graph Formulated by U.S. Army Corps of Engineers	Yes	Yes
(29) Western Hydrologic Systems	3037 Grass Valley Hwy. Suite 8701 Auburn, CA 95603 (916) 885-2480	Computation of Surface Water Resources	Several Prices for Packages $100-$10,000 Digitizers ($1,000-$2,500)	Information N/A	No	No
(30) U.S. Geological Survey	Building 2101 Stennis Space Center, MS 39529 (601) 688-1508	National Flood Frequency NFF	No Charge	USGS Dimensionless Hydrograph Verified in Six States	No	Yes
(31) U.S. Geological Survey	Building 2101 Stennis Space Center, MS 39529 (601) 688-1508	Distributed Routing Rainfall-Runoff Model DR3M	No Charge	Kinematic Wave Technique	Yes	Yes
(32) Engineering & Surveying Computer Systems Inc.	191 Woodport Rd. Sparta, NJ 07871 (800) 537-6166	Design Plus	$1495	TR-55 1986 Ver. SCS UH Modified Rational Method	Yes	Yes
(33) Texas Computer Consultants	3165 Greenwood St. Winter Park, FL 32792 (407) 677-7759	Rational	$250	Rational Method (no hydrograph is produced)	No	No
(34) Texas Computer Consultants	3165 Greenwood St. Winter Park, FL 32792 (407) 677-7759	Drainage	$160	Synder Unit Hydrograph	Yes	No
(35) James C. Y. Guo	Campus Box 113 Civil Eng. Dept. Univ. of Colorado Denver, CO 80204 (303) 556-2849	Urban Drainage/ Hydrology Library	$150/Package There are seven packages for this library.	Rational Method Synder UH - Colorado Urban Hyd. Procedures Kinematic Wave	Yes	Yes

TABLE 1. Preliminary ASCE TC Inventory of Micro Software in Urban Drainage Design (cont'd.).

No. and Name of Vendor	Address and Telephone of Vendor	Name of Program	Software Package Cost	Hydrograph Synthesis Method	Storm Sewer Design Option?	Detention Basin Option?
(36) Engenious Systems Inc.	P.O. Box 30188 Seattle, WA 98103 (206) 628-0167	WaterWorks	$850 Complete	Santa Barbara UH SCS Curvilinear UH	Yes	Yes
(37) Walker Properties Inc.	9040 Executive Pk. Dr. Suite 209 Knoxville, TN 37923 (615) 690-7342	TENN-U	$295	Normalized Unit Response Function Convolution	No	No
(38) BIG "O" INC.	254 Thames Rd. East Exeter Ontario Canada N0M 1S3 (800) 265-7622	BOSS	No Charge	SCS Triangular UH with dynamic variation of TC	Yes	Yes Used for recharge/ detention storage
(39) Illinois State Water Survey	2204 Griffith Dr. Champaign, IL 61820 (217) 333-4959	Illinois Urban Drainage Area Simulator	$200 to $375	Routed time-area UH convolution	Yes	Yes
(40) Advanced Engineering Technologies Inc.	5456 Hoffner Ave. Suite 202 Orlando, FL 32812 (407) 273-9338	Adv. ICPR/ RUNNYD	$995 to $1995	SCS UH Santa Barbara UH Kinematic Wave	Yes	Yes

TABLE 2. Summary of Software Characteristics.

Number of Public Domain Packages	12
Number of Commercial Packages W/Copyright	25
Number of Commercial Packages W/O Copyright	3
Number of Packages Offering Some Technical Support	38
Number of Packages With Full Hydrograph Option	35
Number of Packages With Storm Sewer Option	28
Number of Packages With Detention Basin Option	31
Number of Packages Tested Against Gaged Data	30

TABLE 3. Summary of Hydrologic Abstraction Methods.

Hydrologic Abstraction Methods	No. of Times Used
SCS Curve Number	17
Rational Method C Coefficient	7
Green-Ampt Infiltration Equation	6
Horton Infiltration Equation	6
Constant/Uniform Loss Rate	5
Initial Loss	3
Holtan Infiltration Equation	3
HEC 1 Exponential Loss Function	2
Phi-Index	1
Depression Storage Loss Function	1
Stanford Watershed Model	1
Sacramento Soil Moisture Accounting Model	1

TABLE 4. Summary of Hydrograph Synthesis Methods.

Hydrograph Synthesis Methods	No. of Times Used
SCS UH	14
Rational Method	9
Snyder UH	6
Kinematic Wave	5
Clark UH	4
TR55 Tabular Hydrograph (1986)	3
S-Hydrograph	2
Santa Barbara Urban Hydrograph Method	2
SWMM4	2
User-Specified UH	2
Time-Area Curve	1
Nonlinear Reservoir	1
Stanford Watershed Model	1
USGS Semi-Arid UH	1
Sacramento Soil Moisture With UH	1
Continuous Simulation	1
Rectangular UH	1
Single Linear Reservoir UH	1
USGS Dimensionless Hydrograph	1
Colorado Urban Hydrograph Procedure	1

acquiring copyright. While 74 percent of all vendors reported that their software originated in-house, they also reported that algorithms were based computationally on established hydrologic methods found in such programs as HEC1, SWMM4, TR20, or TR55. User manuals and technical support in some form were available from all but two vendors.

The price of vendor software ranged from zero for public domain software to $10,000 and up for copyright software integrated with CAD systems. A median price is approximately $500.

Further details on the full report of the Committee are available from the Chairman B. A. Tschantz, Dept. of Civil Engineering, University of Tennessee, Knoxville, TN 37996; and from D. F. Kibler, Dept. of Civil Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061-0105.

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TABLE 5. Summary of Hydrograph Routing Methods.

Hydrograph Routing Methods	No. of Times Used
Time-of-Travel Translation	10
Muskingum	9
Kinematic Wave	7
Modified Puls	4
Storage Indication	2
Convex	2
Full Hydrodynamic Saint-Venant Equations	2
Average Ordinates	1
Working R&D	1
Tatum	1
Straddle-Stagger	1
Normal Depth	1
SCS Travel Time in TR55	1
Gutter Routing	1
Nonlinear Reservoir	1
Linear Time Shift	1
SWMM4	1