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STORMWATER POLLUTANT LOADING ESTIMATION: A SIMPLE CONTINUITY MODEL

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Abstract

Due to the increasing importance of computing pollutant loadings for urban storm runoff management, a simple rainfall-runoff volumetric model is linked to a water quality model to estimate pollutant loadings on a storm event basis. The synthetic water quality data is further used in evaluating Best Management Practice (BMP) performance. Because pollutant loadings are developed on a 24-hour basis, BMP performance can be modeled continuously. Calibration of the model is achieved by matching mean annual loadings to NURP estimates.

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INTRODUCTION

In applying for a National Pollutant Discharge Elimination System (NPDES) permit, the estimation of the quantity of pollutants discharged from stormwater drainage systems into creeks, rivers, lakes, and estuaries is required by the Federal Environmental Protection Agency (EPA). Due to the increasing importance of computing pollutant loadings, a simple rainfall-runoff volumetric model is linked to an urban runoff water quality model in order to estimate pollutant loadings on a storm event basis. The computer model is then used to develop multiple years of water quality synthetic data for use in evaluating Best Management Practice (BMP) performance. As an application, a selected BMP is analyzed by the computer model in order to evaluate the effectiveness in pollutant reduction.

MODEL OVERVIEW

The structure of the computer model is depicted in Figure 1. The first module is the rainfall-runoff model which estimates the 24-hour runoff volume at the point of concern for each 24-hour storm rainfall. The second module is the pollutant buildup model which tracks the accumulation of pollutants according to a prescribed buildup rate. The third module is the pollutant washoff model which approximates the pollutant washoff process based upon the runoff quantity estimated from Module #1. The fourth module estimates the long-term pollutant washoff rate. The fifth module computes average annual pollutant loadings based upon the National Urban Runoff Program (NURP) data and loading equations. The sixth module calculates the average pollutant loading for each storm event based upon the results from Module #4 and Module #5. Finally, the seventh module, which consists of the selected BMP performance relationships, examines the effectiveness in pollutant reduction on a daily storm basis. In the following sections, the above discussed modules will be examined in detail.

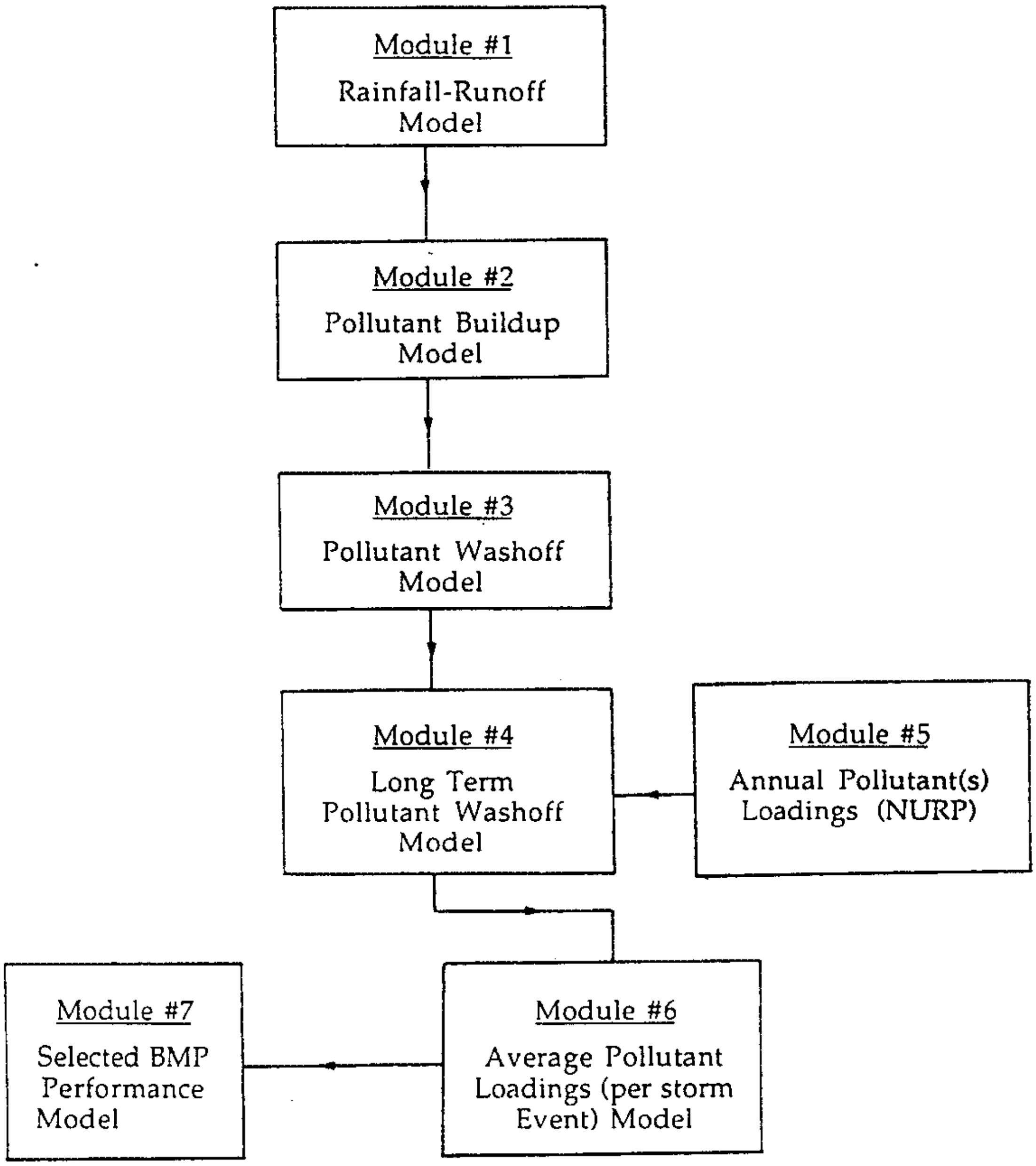

Figure 1. Computer Model Structure.

RAINFALL-RUNOFF MODULE

The rainfall data base consists of order pairs of (date, 24-hour rainfall depth), and in this application consists of about 50-years of daily rainfall records. The Soil Conservation Service (S.C.S.) storm runoff yield formula is used to compute 24-hour storm runoffs from daily rainfalls. Other rainfall-runoff models can be used to replace the S.C.S. storm runoff yield formula by straightforward algorithm replacement.

The S.C.S. storm runoff yield formula is given by

$$Y_j = \frac{(P_{24} - I_a)^2}{(P_{24} - I_a + S)\, P_{24}} \tag{1}$$

where Y_j = 24-hour storm runoff yield fraction for subarea A_j

P_{24} = 24-hour storm rainfall (inches)

I_a = initial abstraction

S = total soil capacity

The initial abstraction, Ia, is a function of land use, cover treatment, and antecedent soil moisture. An estimate for Ia is given by the SCS as

$$Ia = 0.2\, S \tag{2}$$

where S is an estimate of total soil capacity given by

$$S = \frac{1000}{CN} - 10 \tag{3}$$

where CN is the SCS curve number (CN) which represents the runoff potential for a particular soil group and cover complex.

If the area under study contains several (say n) CN designations, then the yield, Y, for the total area must represent the net effect of the several curve numbers.

By weighting each of the subarea yield values according to the respective areas, A_j,

$$Y = (Y_1 A_1 + Y_2 A_2 + \cdots + Y_n A_n) / (A_1 + A_2 + \cdots + A_n) \qquad (4)$$

where Y_j follows from Equation 1.

Runoff volume is obtained from (4) by multiplying the yield, Y, by the product of 24-hour rainfall and the total catchment area (acres).

DEFINITIONS

Before discussing the pollutant buildup and washoff modules, the following terms are defined:

- Pollutant Recovery Period is defined as the time period (in days) wherein a pollutant accumulates from zero to its maximum buildup (100-percent). A straight-line buildup rate is assumed in this model.
- Pollutant Buildup Rate is defined as the reciprocal of the pollutant recovery period.
- Total Pollutant Washoff Runoff Amount is the runoff amount that will provide a hundred percent washoff of pollutants.
- Pollutant Washoff Rate is defined as the reciprocal of the total pollutant washoff runoff amount.

It should be noted that the above definitions are used for all the pollutants modeled. Of course, more complex definitions and relationships can be derived and implemented for each pollutant.

POLLUTANT BUILDUP MODULE

This model accumulates the pollutant buildup at the end of each rainfall record day. First, the number of days between rainfall events is calculated. Then the pollutant buildup between rainfall events is estimated by multiplying the number of days between rainfall events by the pollutant buildup rate. Finally, by adding the pollutant buildup between rainfall events to the remaining pollutant loading corresponding to the end of the previous rainfall event, the total pollutant buildup at the end of the current rainfall event can be estimated.

It is assumed that the pollutant buildup can only reach a maximum value of 100-percent; after which, the pollutant will be transported by wind, moving vehicles, or by other means. Thus, the maximum pollutant buildup at the end of each rainfall event will not exceed 100-percent.

POLLUTANT WASHOFF MODULE

At the end of each rainfall recording date, the runoff amount is estimated from Module #1. By multiplying the runoff amount with the pollutant washoff rate, the potential pollutant washoff is estimated. The potential pollutant washoff cannot exceed 100-percent because the accumulated pollutant buildup is limited to 100-percent. The pollutant washoff is the minimum value between the potential pollutant washoff and the accumulated pollutant buildup. Finally, the remaining pollutant can be calculated by subtracting the pollutant washoff from the accumulated pollutant buildup.

LONG TERM AVERAGE POLLUTANT WASHOFF RATE

Program modules 1 through 4 are repeated for each rainfall record, and the resulting pollutant washoff estimates are stored and accumulated to the end of the rainfall record. Next, the mean pollutant washoff (i.e., 100-percent of accumulated pollutant washoff) per year can be estimated by dividing the total record (e.g., 50 years) of accumulated pollutant washoff by the number of years of rainfall record.

LONG TERM AVERAGE ANNUAL POLLUTANT LOADINGS

Pollutant loadings for specific pollutants in the National Pollutant Discharge Elimination System (NPDES) can be estimated, based upon the State of California Storm Water Best Management Handbook, "Municipal," Appendix B, as:

$$R_L = [C_p + (C_I - C_p)\, IMP_L] * I \qquad (5)$$

where

R_L = total average annual surface runoff from land use L (in/yr)

IMP_L = fractional imperviousness of land use L (from Table 1)

I = long-term average annual precipitation (in/yr)

C_p = pervious area runoff coefficient

C_I = impervious area runoff coefficient

The nonpoint source loads (expressed as lbs/yr) vary by land use and the percent imperviousness associated with each land use. The pollution loading factor M_L is computed for land use L by the following equation:

$$M_L = EMC_L * R_L * K * A_L \qquad (6)$$

where

M_L = loading factor for land use L (lb/yr)

EMC_L = event mean concentration of runoff from land use L (mg/L); EMC_L varies by land use and by pollutant (see Table 1)

R_L = total average annual surface runoff from land use L computed from Equation 5 (in/yr)

K = 0.2266, a unit conversion constant

A_L = area of land use L (acres)

Twelve constituents are included in the module; namely,

- BOD
- COD
- TSS
- TDS
- Total-P
- Dissolved-P
- NO_2 and NO_3
- TKN
- Cadmium
- Copper
- Lead
- Zinc

Table 1 contains the event mean concentration (EMC) values and the impervious percentages assigned for each land use designation based upon the NURP data.

From Equations (5) and (6), the mean annual pollutant loading at any concentration point depends upon the tributary area land use designations. This NURP estimate can be used to calibrate the daily pollutant loading model.

DAILY POLLUTANT WASHOFF ESTIMATE AND CALIBRATION TO NURP

The average annual pollutant loading estimated from the previous module is used to calculate the pollutant loading for each complete pollutant washoff as follows:

Pollutant loading per one complete washoff

$$= \frac{\text{Average Annual pollutant loading (lbs/yr)}}{\text{Average Complete pollutant washoff per year}}$$

By multiplying the pollutant loading per one complete washoff to each rainfall event response (for each pollutant), the daily pollutant loading (for each rainfall recording date) can be estimated. Thus, the daily pollutant simulation model is calibrated to statistically represent annual loadings estimated by the standard NURP equations.

Table 1

Event Mean Concentrations and Impervious Percentages

		Oxygen Demand & Sediment				Nutrients					Heavy Metals		
Land Use	Percent Impervious	BOD mg/L	COD mg/L	TSS mg/L	TDS mg/L	TP mg/L	SP mg/L	TKN mg/L	NO23 mg/L	Pb mg/L	Cu mg/L	Zn m/L	Cd mg/L
Forest/Open	0.5%	8.0	51	261	100	0.23	0.06	1.36	0.73	0.00	0.00	0.00	0.00
Agriculture/ Pasture	0.5%	8.0	51	216	100	0.23	0.06	1.36	0.73	0.00	0.00	0.00	0.00
Cropland	0.5%	8.0	51	216	100	0.23	0.06	1.36	0.73	0.00	0.00	0.00	0.00
Low Density Residential	10.0%	10.8	83	140	100	0.47	0.16	2.35	0.96	0.189	0.05	0.18	0.002
Medium Density Residential	30.0%	10.8	83	140	100	0.47	0.16	2.35	0.96	0.18	0.05	0.18	0.002
High Density Residential	50.0%	10.8	83	140	100	0.47	0.16	2.35	0.96	0.18	0.05	0.18	0.002
Commercial	90.0%	9.7	61	91	100	0.24	0.10	1.28	0.63	0.13	0.04	0.33	0.002
Office/Light Industrial	70.0%	9.7	61	91	100	0.24	0.10	1.28	0.63	0.13	0.04	0.33	0.002
Heavy Industrial	80.0%	9.7	61	91	100	0.24	0.10	1.28	0.63	0.13	0.004	0.33	0.002
Water	100.0%	3.0	22	26	100	0.036	0.01	0.60	0.60	0.00	0.00	0.11	0.000
Wetlands	0.5%	8.0	51	216	100	0.23	0.06	1.36	0.73	0.00	0.00	0.00	0.00
Major Highways	90.0%	9.7	103	142	100	0.44	0.17	1.78	0.83	0.53	0.05	0.37	0.002

Source: State of California Storm Water Best Management Handbook, "Municipal," Appendix B.

BEST MANAGEMENT PRACTICES

In general, Best Management Practices (BMPs) are grouped into two broad categories: 1) source control and 2) treatment control. Source Control BMPs prevent contact between stormwater and pollutant source, and are generally 100% effective if implemented properly. Treatment Control BMPs are those that treat the stormwater to remove pollutants. They generally are not 100% effective, even if maintained and operated properly. The general approach is to identify the BMP needs by considering the site constraints, the receiving water, beneficial uses of the receiving water, potential water quality concerns, and other environmental factors. BMPs and procedures for the selection of BMPs are discussed in details in the State of California Stormwater Best Management Handbook (1993).

EXAMPLE APPLICATION

A study site with approximately 50 years of daily rainfall data is used to demonstrate the subject computer model. A particular stormwater filter system is selected as one of the potential BMPs to offset the effects of a proposed large scale land development project, and will be used as an example. At issue are pollutant removal efficiencies for using the stormwater filter. Table 2 shows the tributary watershed characteristics at the study site. Table 3 illustrates a portion of the daily rainfall data record (50 years total). Table 4 shows the pollutant removal rates for the selected stormwater filter system. Tables 1 through 4 are stored in four different data base files as input files for the subject computer program. The estimated daily pollutant loadings for existing conditions (pre-project), post-project conditions, and post-project with BMP are shown in Tables 5 through 7. The summary of the 50-year simulation results for the pre-project conditions, post-project conditions, and post-project with BMP are shown in Tables 8 through 10. In this application, the complete pollutant washoff runoff depth is assumed to be 0.5 inch and the pollutant recovery period is 15 days.

Table 2

Land Use Characteristics for Example Problem

Land Use	S.C.S. Curve Number	Area (Acres)
Natural	66.	189.6
Natural	77.	763.8 (729.75)
Natural	83.	300.6
5-7 DU/AC	69.	3.3
5-7 DU/AC	75.	7.6
Multiple Family	56.	11.6
Multiple Family	69.	70.0
Multiple Family	75.	48.2
Commercial	56.	14.3
Commercial	69.	5.7
Pavement	98.	0.0 (34.05)

Note: Values in ( ) indicate post-project conditions.

Table 3

Portion of Daily Rainfall Record for Example Problem

Date Month/Day/Year	Precipitation (inches)
'01/22/43'	2.60
'01/23/43'	4.14
'01/24/43'	.26
'01/27/43'	.79
'02/03/43'	.81
'02/08/43'	.63
'02/21/43'	1.04
'02/22/43'	1.67
'02/24/43'	.48
'03/03/43'	.13
'03/04/43'	1.13
'03/05/43'	.11
'03/10/43'	.13
'03/11/43'	.05
'03/17/43'	.11
'03/24/43'	.61
'04/06/43'	.56
'04/07/43'	.03
'04/14/43'	.26
'05/26/43'	.04
'10/19/43'	.29
'11/02/43'	.05
'11/18/43'	.20
'11/23/43'	.03
'12/07/43'	.41
'12/10/43'	.87
'12/11/43'	1.35
'12/21/43'	2.36
'12/28/43'	.34
'12/30/43'	.26
'01/04/44'	.52
'01/11/44'	.10
'01/25/44'	.21
'02/01/44'	.31
'02/08/44'	.51
'02/15/44'	.19
'02/20/44'	.15
'02/21/44'	1.13
'02/22'44'	.83
'02/23/44'	2.47
'02/24/44'	.37
'02/26/44'	.08
'02/27/44'	.52
'02/29/44'	.60
'03/07/44'	1.15
'03/14/44'	.36

Table 4

Selected Stormwater Filter Pollutant Removal Rates

Pollutant	Overall Mean Influent	Mean Effluent	Mean % Removal
Solids & Nutrients (mg/L)			
Total Dissolved Solids (TDS)	113.50	155.50	+37.0%
Total Suspended Solids (TSS)	231.23	15.35	93.4%
Chemical Oxygen Demand (COD)	134.49	41.47	69.2%
Total Phosphorus (Total P)	1.000	0.584	41.6%
Soluble Phosphorus (Soluble P)	0.105	0.354	+235.6%
Total Kjeldahl Nitrogen (TKN)	1.656	0.749	54.8%
Nitrite/Nitrate (N03)	0.457	1.022	+123.6%
Metals (μg/L)			
Copper (Cu)	25.68	8.81	65.7%
Lead (pt)	34.90	5.22	85.1%
Zinc (Zn)	173.62	27.12	84.4%

Table 5

Estimated Storm Event Pollutant Loadings for Pre-Project Conditions

Pollutant Loadings (lbs) for each Runoff Event

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
01/22/43	2.60	.78	100.0	100.0	.0	644.	4435.	12854.	7103.	22.	7.	120.	57.	5.	1.	6.	0.
01/23/43	4.14	1.86	6.7	6.7	.0	43.	296.	857.	474.	1.	0.	8.	4.	0.	0.	0.	0.
01/24/43	.26	.00	6.7	.0	6.7	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1/27/43	.79	.02	26.7	3.8	22.8	25.	170.	492	272.	1.	0.	5.	2.	0.	0.	0.	0.
02/03/43	.81	.02	69.5	4.4	65.2	28.	193.	560.	309.	1.	0.	5.	2.	0.	0.	0.	0.
02/08/43	.63	.00	98.5	.9	97.5	6.	42.	122.	67.	0.	0.	1.	1.	0.	0.	0.	0.
02/21/43	1.04	.06	100.0	12.8	87.2	83.	568.	1648.	910.	3.	1.	15.	7.	1.	0.	1.	0.
02/22/43	1.67	.28	93.8	56.0	37.9	361.	2483.	7198.	3978.	12.	4.	67.	32.	3.	1.	3.	0.
02/24/43	.48	.00	51.2	.1	51.1	1.	4.	13.	7.	0.	0.	0.	0.	0.	0.	0.	0.
03/03/43	.13	.00	97.8	.0	97.8	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
03/04/43	1.13	.09	100.0	17.3	82.7	111.	767.	2223.	1228.	4.	1.	21.	10.	1.	0.	1.	0.
03/05/43	.11	.00	89.4	.0	89.4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
03/10/43	.03	.00	100.0	.0	100.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
03/11/43	.05	.00	100.0	.0	100.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
03/17/43	.11	.00	100.0	.0	100.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
03/24/43	.61	.00	100.0	.8	99.2	5.	34.	98.	54.	0.	0.	1.	0.	0.	0.	0.	0.
04/06/43	.56	.00	100.0	.4	99.6	3.	19.	56.	31.	0.	0.	1.	0.	0.	0.	0.	0.
04/07/43	.03	.00	100.0	.0	100.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
04/14/43	.26	.00	100.0	.0	100.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
05/26/43	.04	.00	100.0	.0	100.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
10/19/43	.29	.00	100.0	.0	100.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
11/02/43	.05	.00	100.0	.0	100.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

(1): Storm Event Date
(2): 24-hour Rainfall (inches)
(3): Total Daily Runoff (inches)
(4): Pollutant Buildup (%)
(5): Pollutant Washoff (%)
(6): Pollutant Buildup Remaining (%)
(7): BOD (lbs)
(8): COD (lbs)
(9): TSS (lbs)
(10): TDS (lbs)
(11): Total-P (lbs)
(12): Dissolved-P (lbs)
(13): TKN (lbs)
(14): N02&N03 (lbs)
(15): Lead (lbs)
(16): Copper (lbs)
(17): Zinc (lbs)
(18): Cadmium (lbs)

Table 6

Estimated Storm Event Pollutant Loadings for Post-Project Conditions without Selected Stormwater Filter System

Pollutant Loadings (lbs) for each Runoff Event																	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
01/22/43	2.60	.82	100.0	100.0	.0	607.	4470.	11657.	6630.	22.	7.	113.	53.	8.	2.	8.	0.
01/23/43	4.14	1.91	6.7	6.7	.0	40.	298.	777.	442.	1.	0.	8.	4.	1.	0.	1.	0.
01/24/43	.26	.00	6.7	.5	6.1	3.	24.	64.	36.	0.	0.	1.	0.	0.	0.	0.	0.
1/27/43	.79	.03	26.1	6.6	19.5	40.	295.	770	438.	1.	0.	7.	4.	1.	0.	1.	0.
02/03/43	.81	.04	66.2	7.2	59.0	44.	322.	841.	478.	2.	1.	8.	4.	1.	0.	1.	0.
02/08/43	.63	.02	92.3	3.1	89.3	19.	136.	356.	202.	1.	0.	3.	2.	0.	0.	0.	0.
02/21/43	1.04	.08	100.0	16.5	83.5	100.	739.	1928.	1096.	4.	1.	19.	9.	1.	0.	1.	0.
02/22/43	1.67	.31	90.1	61.6	28.5	374.	2753.	7181.	4084.	13.	4.	69.	33.	5.	1.	5.	0.
02/24/43	.48	.01	41.9	1.5	40.3	9.	69.	180.	102.	0.	0.	2.	1.	0.	0.	0.	0.
03/03/43	.13	.00	87.0	.1	86.9	1.	6.	15.	9.	0.	0.	0.	0.	0.	0.	0.	0.
03/04/43	1.13	.11	93.5	21.3	72.2	129.	953.	2485.	1413.	5.	1.	24.	11.	2.	0.	2.	0.
03/05/43	.11	.00	78.9	.1	78.8	1.	4.	10.	6.	0.	0.	0.	0.	0.	0.	0.	0.
03/10/43	.03	.00	100.0	.0	100.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
03/11/43	.05	.00	100.0	.0	100.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
03/17/43	.11	.00	100.0	.1	99.9	1.	4.	10.	6.	0.	0.	0.	0.	0.	0.	0.	0.
03/24/43	.61	.01	100.0	2.8	97.2	17.	124.	324.	184.	1.	0.	3.	1.	0.	0.	0.	0.
04/06/43	.56	.01	100.0	2.2	97.8	14.	100.	260.	148.	0.	0.	3.	1.	0.	0.	0.	0.
04/07/43	.03	.00	100.0	.0	100.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
04/14/43	.26	.00	100.0	.5	99.5	3.	24.	64.	36.	0.	0.	1.	0.	0.	0.	0.	0.
05/26/43	.04	.00	100.0	.0	100.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
10/19/43	.29	.00	100.0	.7	99.3	4.	29.	77.	44.	0.	0.	1.	0.	0.	0.	0.	0.
11/02/43	.05	.00	100.0	.0	100.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

(1): Storm Event Date
(2): 24-hour Rainfall (inches)
(3): Total Daily Runoff (inches)
(4): Pollutant Buildup (%)
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(15): Lead (lbs)
(16): Copper (lbs)
(17): Zinc (lbs)
(18): Cadmium (lbs)

Table 7

Estimated Storm Event Pollutant Loadings for Post-Project Conditions with Selected Stormwater Filter System

Pollutant Loadings (lbs) for each Runoff Event																	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
01/22/43	2.60	.82	100.0	100.0	.0	607.	1377.	769.	9083.	13.	24.	51.	119.	1.	1.	1.	0.
01/23/43	4.14	1.91	6.7	6.7	.0	40.	92.	51.	606.	1.	2.	3.	8.	0.	0.	1.	0.
01/24/43	.26	.00	6.7	.5	6.1	3.	8.	4.	50.	0.	0.	0.	1.	0.	0.	0.	0.
1/27/43	.79	.03	26.1	6.6	19.5	40.	91.	51	600.	1.	2.	3.	8.	0.	0.	0.	0.
02/03/43	.81	.04	66.2	7.2	59.0	44.	99.	55.	655.	1.	2.	4.	9.	0.	0.	0.	0.
02/08/43	.63	.02	92.3	3.1	89.3	19.	42.	23.	277.	0.	1.	2.	4.	0.	0.	0.	0.
02/21/43	1.04	.08	100.0	16.5	83.5	100.	228.	127.	1502.	2.	4.	8.	20.	0.	0.	0.	0.
02/22/43	1.67	.31	90.1	61.6	28.5	374.	848.	474.	5595.	8.	14.	31.	73.	1.	0.	1.	0.
02/24/43	.48	.01	41.9	1.5	40.3	9.	21.	12.	140.	0.	0.	1.	2.	0.	0.	0.	0.
03/03/43	.13	.00	87.0	.1	86.9	1.	2.	1.	12.	0.	0.	0.	0.	0.	0.	0.	0.
03/04/43	1.13	.11	93.5	21.3	72.2	129.	293.	164.	1936.	3.	5.	11.	25.	0.	0.	0.	0.
03/05/43	.11	.00	78.9	.1	78.8	1.	1.	1.	8.	0.	0.	0.	0.	0.	0.	0.	0.
03/10/43	.03	.00	100.0	.0	100.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
03/11/43	.05	.00	100.0	.0	100.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
03/17/43	.11	.00	100.0	.1	99.9	1.	1.	1.	8.	0.	0.	0.	0.	0.	0.	0.	0.
03/24/43	.61	.01	100.0	2.8	97.2	17.	38.	21.	253.	0.	1.	1.	3.	0.	0.	0.	0.
04/06/43	.56	.01	100.0	2.2	97.8	14.	31.	17.	203.	0.	1.	1.	3.	0.	0.	0.	0.
04/07/43	.03	.00	100.0	.0	100.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
04/14/43	.26	.00	100.0	.5	99.5	3.	8.	4.	50.	0.	0.	0.	1.	0.	0.	0.	0.
05/26/43	.04	.00	100.0	.0	100.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
10/19/43	.29	.00	100.0	.7	99.3	4.	9.	5.	60.	0.	0.	0.	1.	0.	0.	0.	0.
11/02/43	.05	.00	100.0	.0	100.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

(1): Storm Event Date
(2): 24-hour Rainfall (inches)
(3): Total Daily Runoff (inches)
(4): Pollutant Buildup (%)
(5): Pollutant Washoff (%)
(6): Pollutant Buildup Remaining (%)
(7): BOD (lbs)
(8): COD (lbs)
(9): TSS (lbs)
(10): TDS (lbs)
(11): Total-P (lbs)
(12): Dissolved-P (lbs)
(13): TKN (lbs)
(14): N02&N03 (lbs)
(15): Lead (lbs)
(16): Copper (lbs)
(17): Zinc (lbs)
(18): Cadmium (lbs)

Table 8

Mean Annual Pollutant Loadings for Pre-Project Conditions with 50 Years of Rainfall Record

Summary Statistics

Total Rainfall (Inches)		=	595.54
Total Runoff (Inches)		=	49.07
Total Pollutant Washoff (%)		=	7110.38
Total Pollutant Washoff (lbs):			
BOD	= 45784.		
COD	= 315333.		
TSS	= 913969.		
TDS	= 505082.		
TOTAL - P	= 1569.		
DISSOLVED - P	= 487.		
TKN	= 8502.		
N02&N03	= 4034.		
LEAD	= 354.		
COPPER	= 100.		
ZINC	= 433.		
CADMIUM	= 4.		

Table 9

Mean Annual Pollutant Loadings for Post-Project Conditions with 50 Years of Rainfall Record

Summary Statistics

Total Rainfall (Inches)		=	595.54
Total Runoff (Inches)		=	59.67
Total Pollutant Washoff (%)		=	8507.67
Total Pollutant Washoff (lbs):			
BOD	= 51641.		
COD	= 380266.		
TSS	= 991719.		
TDS	= 564043.		
TOTAL - P	= 1846.		
DISSOLVED - P	= 596.		
TKN	= 9586.		
N02&N03	= 4532.		
LEAD	= 709.		
COPPER	= 133.		
ZINC	= 681.		
CADMIUM	= 5.		

Table 10

Mean Annual Pollutant Loadings for Post-Project Conditions with Selected Stormwater Filter System using 50 Years of Rainfall Record

Summary Statistics		
Total Rainfall (Inches)	=	595.54
Total Runoff (Inches)	=	59.67
Total Pollutant Washoff (%)	=	8507.67
Total Pollutant Washoff (lbs):		
BOD	=	51641.
COD	=	117122
TSS	=	65453
TDS	=	772740.
TOTAL - P	=	1078.
DISSOLVED - P	=	2000.
TKN	=	4333
N02&N03	=	10133.
LEAD	=	106.
COPPER	=	46.
ZINC	=	106.
CADMIUM	=	5.

CONCLUSIONS

The subject computer program consists of seven interconnected modules. Each module consists of a simple relationship between variables which can be replaced by more complex relationships. The four data base files can be modified to reflect other changes in the watershed land use characteristics, or the NURP equation event mean concentrations, the selected BMP removal rates, or to include additional rainfall data.

As the effluent pollutant data becomes available, such as through water quality monitoring, the complete pollutant washoff runoff depths and the pollutant recovery period can be calibrated for future analysis.

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