The Simple Method to Calculate Urban Stormwater Loads

Introduction

The Simple Method estimates stormwater runoff pollutant loads for urban areas. The technique requires a modest amount of information, including the subwatershed drainage area and impervious cover, stormwater runoff pollutant concentrations, and annual precipitation. With the Simple Method, the investigator can either break up land use into specific areas, such as residential, commercial, industrial, and roadway and calculate annual pollutant loads for each type of land, or utilize more generalized pollutant values for land uses such as new suburban areas, older urban areas, central business districts, and highways.

Stormwater pollutant concentrations can be estimated from local or regional data, or from national data sources. Tables 1 through 3 summarize pollutant concentration data for Total Suspended Solids (Table 1), Total Phosphorous (Table 2), and Total Nitrogen (Table 3) for residential, commercial, industrial, and roadway land uses, and identify default values. Table 4 identifies pollutant concentration values for Phosphorus, Nitrogen, COD, BOD, and some metals for more generalized land use categories. In general, the selected data sources are nationwide in scope, or are summaries of several regional studies. Some studies included in these data did not characterize stormwater concentrations for specific land uses, and instead reported a concentration for "urban runoff." In these instances, the data are reported as the same concentration for each land use in Tables 1 through 3.

Fecal coliform is more difficult to characterize than other pollutants. Data are extremely variable, even during repeated sampling at a single location. Because of this variability, it is difficult to establish different concentrations for each land use. Although some source monitoring data exists (Steuer *et al.*, 1997; Bannerman *et al.*, 1993), the simple method assumes a median urban runoff default value, derived from NURP data (Pitt, 1998), of 20,000 MPN/100ml. For more information on sources and pathways of bacteria in urban runoff, consult Schueler (1999).

The Simple Method estimates pollutant loads for chemical constituents as a product of annual runoff volume and pollutant concentration, as:

$$L = 0.226 * R * C * A$$

Where: L = Annual load (lbs)
R = Annual runoff (inches)
C = Pollutant concentration (mg/l)
A = Area (acres)
0.226 = Unit conversion factor

For bacteria, the equation is slightly different, to account for the differences in units. The modified equation for bacteria is:

$$L = 1.03 * 10^{-3} * R * C * A$$

Where: L = Annual load (Billion Colonies)
R = Annual runoff (inches)
C = Bacteria concentration (#/100 ml)
A = Area (acres)
$1.03 * 10^{-3}$ = Unit conversion factor

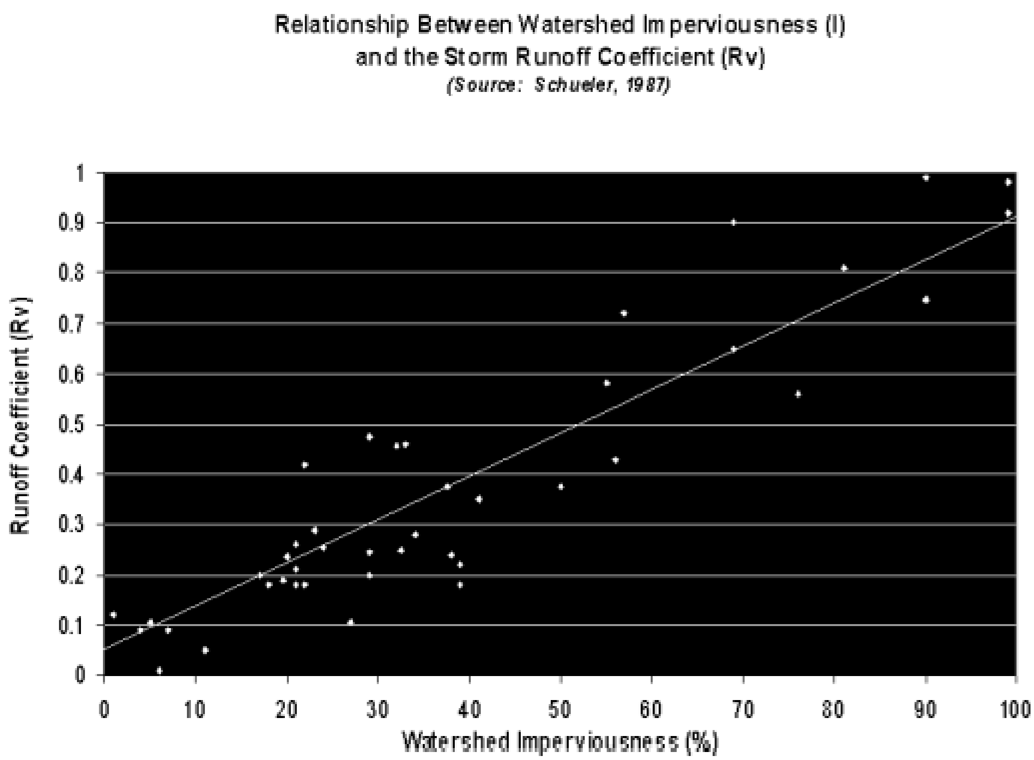
Annual Runoff

The Simple Method calculates annual runoff as a product of annual runoff volume, and a runoff coefficient (Rv). Runoff volume is calculated as:

$$R = P * P_j * Rv$$

Where: R = Annual runoff (inches)
P = Annual rainfall (inches)
P_j = Fraction of annual rainfall events that produce runoff (usually 0.9)
Rv = Runoff coefficient

In the Simple Method, the runoff coefficient is calculated based on impervious cover in the subwatershed. This relationship is shown in Figure 1. Although there is some scatter in the data, watershed imperviousness does appear to be a reasonable predictor of Rv.



The following equation represents the best fit line for the dataset (N=47, R^2=0.71).

$$Rv=0.05+0.9Ia$$

Where: Ia = Impervious fraction

Impervious Cover Data

The model uses different impervious cover values for separate land uses within a subwatershed. Representative impervious cover data, along with Model default values, are presented in Table 5. A study is currently being conducted by the Center for Watershed Protection under a grant from the U.S. Environmental Protection Agency to update impervious cover estimates for these and other land uses. The results of this study will be available by 2001. In addition, some jurisdictions may have detailed impervious cover information if they maintain a detailed land use/land cover GIS database.

Limitations of the Simple Method

The Simple Method should provide reasonable estimates of changes in pollutant export resulting from urban development activities. However, several caveats should be kept in mind when applying this method.

The Simple Method is most appropriate for assessing and comparing the relative stormflow pollutant load changes of different land use and stormwater management scenarios. The Simple Method provides estimates of storm pollutant export that are probably close to the "true" but unknown value for a development site, catchment, or subwatershed. However, it is very important not to over emphasis the precision of the results obtained. For example, it would be inappropriate to use the Simple Method to evaluate relatively similar development scenarios (e.g., 34.3% versus 36.9% Impervious cover). The simple method provides a general planning estimate of likely storm pollutant export from areas at the scale of a development site, catchment or subwatershed. More sophisticated modeling may be needed to analyze larger and more complex watersheds.

In addition, the Simple Method only estimates pollutant loads generated during storm events. It does not consider pollutants associated with baseflow volume. Typically, baseflow is negligible or non-existent at the scale of a single development site, and can be safely neglected. However, catchments and subwatersheds do generate baseflow volume. Pollutant loads in baseflow are generally low and can seldom be distinguished from natural background levels (NVPDC, 1979). Consequently, baseflow pollutant loads normally constitute only a small fraction of the total pollutant load delivered from an urban area. Nevertheless, it is important to remember that the load estimates refer only to storm event derived loads and should not be confused with the total pollutant load from an area. This is particularly important when the development density of an area is low. For example, in a large low density residential subwatershed (Imp. Cover < 5%), as much as 75% of the annual runoff volume may occur as baseflow. In such a case, the annual baseflow nutrient load may be equivalent to the annual stormflow nutrient load.

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Table 1: Pollutant Concentrations by Land Use: Total Suspended Solids (mg/l)					
	Land Use				
Source	**Residential**	**Commercial**	**Roadway**	**Industrial**	**Notes**
Schueler, 1987 mean	100[1]	-	-	-	This value reflects an estimate based on 25 data points from a wide range of watershed sizes. Data reflect instream concentrations. A small watershed size (i.e., 10 acres) was assumed to minimize the influence of the channel erosion component.
Gibb *et al.*, 1991 mean	150	-	220	-	These values represent recommended estimates for planning purposes and are based on an analysis of mean concentrations from over 13 studies from the US and British Columbia.
Smullen and Cave, 1998 median	55	55	55	55	This study probably represents the most comprehensive data set, with 3,047 event samples being included from across the nation. Data includes pooled NURP, USGS, and NPDES sources. The value is a median of EMCs and applies to general urban runoff (i.e., mixed land uses). The low concentration relative to other data can be attributed to the fact that, while NURP data represent small watersheds where channel erosion may play a role, NPDES data are collected as "end of the pipe" concentrations for very small drainage areas of a uniform land use. The NPDES concentrations were approximately 70% lower than concentrations from NURP or USGS..
US EPA, 1983 median	101	69	-	-	These values represent NURP data for residential and commercial land use. NURP data were collected in the early 1980s in over 28 different metropolitan areas across the US.
Claytor and Schueler, 1996	-	-	142	124	The roadway value is the un-weighted mean of 8 studies conducted by the FHWA. The industrial value is the mean value from 6 storms monitored at a heavy industrial site in Auckland, NZ.
Barrett and Malina, 1998	-	-	173	-	This data reflects a study of vegetative swales treating highway runoff in Austin, TX. Value represents average of the mean inflow concentrations measured at 2 sites. Data were collected over 34 storm events.
Caraco and Schueler (1999). Arid Climates	242	242	242	242	This value represents an average of EMC data collected from 3 arid climate locales (Phoenix, Boise, and Denver). A total of 90 data points are used, with each site having at least 16 data points. Value applies to general urban runoff (i.e., mixed land uses).
Driscoll, 1986	-	-	242	-	This value is the average of 4 median EMCs collected from highway sites in Nashville, Denver, Milwaukee, and Harrisburg. A total of 93 data points were used to develop value, with each site having at least 16 data points.
Shelley and Gaboury, 1986	-	-	220	-	This value is the median value of 8 highway studies from across the US. Some of the data from the Driscoll study (1986) is included.
Whalen and Cullum, 1988	228	168	-	108	These data are from an assessment of urban runoff quality that looked at NURP and State of Florida data. The NURP data are presented. Residential and commercial values are mean values for specified land

					uses and reflect between 200 and 1,100 sampling events depending on the parameter and land use. Industrial values are from 4 NURP sites and generally represent light industrial land use.
Model Default Value[2]	**100**	**75**	**150**	**120**	

1: Concentration based on a 10-acre drainage area

- The model default values represent best professional judgement, and give additional weight to studies conducted at a national level. Data do not incorporate studies on arid climates.

Table 2. Pollutant Concentrations by Land Use: Total Phosphorus (mg/l)					
	Land Use				
Source	Residential	Commercial	Roadway	Industrial	Notes
Schueler, 1987 mean	0.26	-	0.59	-	These values are taken from a Washington DC NURP study in 1980-81. At least 27 storm events were sampled at multiple sites within the specified land use.
Gibb *et al.*, 1991 mean	0.33	-	0.59	-	These values represent recommended estimates for planning purposes and are based on analysis of mean concentrations from over 13 studies from the US and British Columbia.
Smullen and Cave, 1998 median	0.26	0.26	0.26	0.26	This study probably represents the most comprehensive data set, with 3,047 event samples being included from across the nation. The data includes pooled NURP, USGS, and NPDES sources. The value is a median of EMCs and applies to general urban runoff (i.e., mixed land uses).
US EPA, 1983 median	0.38	0.201	-	-	These values represent NURP data for residential and commercial land use. NURP data were collected in the early 1980s in over 28 different metropolitan areas across the US.
Barrett and Malina, 1998	-	-	0.4	-	This data reflects a study of vegetative swales treating highway runoff in Austin, TX. Value represents average of the mean inflow concentrations measured at 2 sites. Data were collected over 34 storm events.
Caraco and Schueler, 1999	0.65	0.65	0.65	0.65	This value represents an average of EMC data collected from 3 arid climate locales (Phoenix, Boise, and Denver). A total of 90 data points are used, with each site having at least 16 data points. The value applies to general urban runoff (i.e., mixed land uses).
Whalen and Cullum, 1988	0.62	0.29	-	0.42	These data are from an assessment of urban runoff quality that looked at NURP and State of Florida data. The NURP data summaries are what is shown. Residential and commercial values are mean values for specified land uses and reflect between 200 and 1,100 sampling events depending on the parameter and land use. Industrial values are from 4 NURP sites and generally represent light industrial land use.
Model Default Value	**0.4**	**0.2**	**0.5**	**0.4**	
1: The model default values represent best professional judgement, and give additional weight to studies conducted at a national level. Data do not incorporate studies on arid climates.					

Table 3. Pollutant Concentrations by Land Use: Total Nitrogen (mg/l)					
	Land Use				
Source	Residential	Commercial	Roadway	Industrial	Notes
Schueler, 1987 mean	2.0	2.17	-	-	These values are taken from a Washington DC NURP study in 1980-81. At least 27 storm events were sampled at multiple sites within the specified land use.
Gibb *et al.*, 1991 mean	1.5	-	2.72	-	These values represent recommended estimates for planning purposes and are based on analysis of mean concentrations from over 13 studies from the US and British Columbia.
Smullen and Cave, 1998 median	2.0	2.0	2.0	2.0	This study probably represents the most comprehensive data set, with 3,047 event samples being included from across the nation. The data includes pooled NURP, USGS, and NPDES sources. The value is a median of EMCs and applies to general urban runoff (i.e., mixed land uses).
US EPA, 1983 median	2.6	1.75	-	-	These values represent NURP data for residential and commercial land use. NURP data were collected in the early 1980s in over 28 different metropolitan areas across the US.
Barrett and Malina, 1998	-	-	3.48	-	This data reflects a study of vegetative swales treating highway runoff in Austin, TX. Value represents average of the mean inflow concentrations measured at 2 sites. Data were collected over 34 storm events.
Caraco and Schueler (1999). Arid Climates	4.06	4.06	4.06	4.06	This value represents an average of EMC data collected from 3 arid climate locales (Phoenix, Boise, and Denver). A total of 90 data points are used, with each site having at least 16 data points. The value applies to general urban runoff (i.e., mixed land uses).
Whalen and Cullum, 1988	2.03	2.3	-	2.53	These data are from an assessment of urban runoff quality that looked at NURP and State of Florida data. The NURP data summaries are what is shown. Residential and commercial values are mean values for specified land uses and reflect between 200 and 1,100 sampling events depending on the parameter and land use. Industrial values are from 4 NURP sites and generally represent light industrial land use.
Model default Value[1]	**2.2**	**2.0**	**3.0**	**2.5**	
1: The model default values represent best professional judgement, and give additional weight to studies conducted at a national level. Data do not incorporate studies on arid climates.					

Table 4. Urban "C" Values for Use With the Simple Method (mg/l)

Pollutant	New Suburban NURP Sites (Wash., DC)	Older Urban Areas (Baltimore)	Central Business District (Wash., DC)	National NURP Study Average	Hardwood Forest (N. Virginia)	National Urban Highway Runoff
Phosphorus						
Total	0.26	1.08	-	0.46	0.15	-
Ortho	0.12	0.26	1.01	-	0.02	-
Soluble	0.16	-	-	0.16	0.04	0.59
Organic	0.10	0.82	-	0.13	0.11	-
Nitrogen						
Total	2.00	13.6	2.17	3.31	0.78	-
Nitrate	0.48	8.9	0.84	0.96	0.17	-
Ammonia	0.26	1.1	-	-	0.07	-
Organic	1.25	-	-	-	0.54	-
TKN	1.51	7.2	1.49	2.35	0.61	2.72
COD	35.6	163.0	-	90.8	>40.0	124.0
BOD (5 day)	5.1	-	36.0	11.9	-	-
Metals						
Zinc	0.037	0.397	0.250	0.176	-	0.380
Lead	0.018	0.389	0.370	0.180	-	0.350
Copper	-	0.105	-	0.047	-	-

Table 5. Impervious Cover (%) for Various Land Uses							
Land Use	**Density (dwelling units/acre)**	**Source**					
		Northern Virginia (NVPDC, 1980)[1]	**Olympia (COPWD, 1995)**	**Puget Sound (Aqua Terra, 1994)**	**NRCS (USDA, 1986)**	**Rouge River (Kluitenberg, 1994)**	**Model Default[2]**
Low Density Residential	<0.5	6	-	10	-	19	**10**
	0.5	-	-	10	12		
	1	12	-	10	20		
Medium Density Residential	2	18	-	-	25		**30**
	3	20	40	40	30		
	4	25	40	40	38		
High Density Residential	5-7	35	40	40	-	38	**40**
Multifamily	Townhouse (>7)	35-50	48	60	65	-	**60**
Industrial	--	60-80	86	90	72	76	**75**
Commercial	--	90-95	86	90	85	56	**85**
Roadway							**80**

1: NVPDC data measure effective impervious cover (i.e., rooftops are not included in residential data)

2: Model default values are approximately equal to the median of Olympia, Puget Sound, NRCS, and Rouge River data, with adjustments made where studies estimate impervious cover for a broad range of densities.