



Wastewater Enterprise  
URBAN WATERSHED MANAGEMENT PROGRAM

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COMBINED SEWER AREA BMP SIZING CALCULATOR:  
CALCULATION APPROACH  
using the  
SANTA BARBARA URBAN HYDROGRAPH METHOD

The San Francisco Public Utilities Commission (SFPUC) has developed the *Combined Sewer Area BMP Sizing Calculator for Quantity Control* (Sizing Calculator) to assist developers and design professionals working on projects that are served by the combined sewer system (CSS) to comply with the *San Francisco Stormwater Design Guidelines* (Guidelines). This Sizing Calculator is one of the accepted hydrologic calculation methods that San Francisco development projects served by the CSS may use to size selected BMPs to meet the stormwater management requirements outlined in the Guidelines. The Sizing Calculator may not be appropriate for use in the design of all sites, and may require supplemental engineering design and calculations. Please refer to *SFPUC Accepted Hydrologic Calculation Methods*, located at <http://sfwater.org/sdg> for information on when this or other methods are accepted by the SFPUC. The full text of the Guidelines is also available for download at <http://sfwater.org/sdg>.

## INTRODUCTION

The main objective of the performance measure for projects located in CSS area is to reduce the rate and volume of stormwater runoff prior to discharge to the CSS. In general, compliance with the CSS performance measure may be achieved by reducing the existing site imperviousness, by using rainwater to meet non-potable demands, or by implementing site appropriate stormwater BMPs.

The CSS performance measure is based on the LEED Sustainable Sites 6.1 Stormwater Quantity Credit (LEED c6.1) to be consistent with citywide green building requirements. The performance measure varies depending on the existing site conditions. For sites with 50 percent or less of impervious area, the post-project peak discharge rate and total volume must not exceed pre-project values for the 1- and 2-year, 24-hour design storms. For sites with over 50 percent of impervious area, the post-project runoff volume and peak flow must be 25 percent less than pre-project values for the 2-year, 24-hour design storm.

## **SIZING CALCULATOR APPROACH**

The Sizing Calculator assists project applicants in determining the mix of BMPs and reduction in percent imperviousness that will enable their sites to achieve the runoff reductions required by the Guidelines by:

1. Calculating the site's total runoff volume and peak runoff flow under existing and proposed project conditions (i.e., calculates pre-project and post-project runoff).
2. Calculating the percent runoff reduction that results from incorporating various BMPs at the site.

### **Determining Runoff Quantity**

To adequately achieve the first function, the timing of flows from the site's various drainage areas must be known so that they can be summed together to determine the peak flow and total volume leaving the site. This is accomplished in the Sizing Calculator by generating runoff hydrographs from each drainage area using the Santa Barbara Urban Hydrograph method. The hydrographs are then routed through the user-defined BMPs and summed at the point of discharge from the site.

Hydrograph generation requires the following data:

- Rainfall distribution (i.e., hyetograph)
- Runoff surface characteristics (e.g., surface area and runoff curve number)
- Time of concentration information (e.g., flow length and slope)

### **Determining Runoff Reduction**

Achieving the second function (i.e., determining the reductions in peak flow and volume from the BMPs) requires that the critical design parameters for the BMPs be defined.

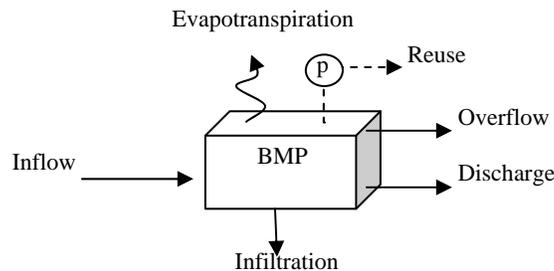
User-Defined BMP design parameters include:

- BMP surface area
- Drainage area
- Infiltration rate
- Ponding depth
- Media depth
- Drawdown time

The Sizing Calculator has been set up to either flag the user for entry of site specific data or will provide a default data value to generate the hydrographs and calculate a BMPs performance. Note: Default data values may be re-defined if site or design conditions are known to differ and can be adequately documented.

## Model BMP Flow Diagram

Each user-defined BMP is treated as a storage box that receives runoff from a site's contributing drainage area. The volume of stormwater runoff stored in a BMP will change over time based on the inflow and outflow rate for each BMP. The inflow is equal to the runoff hydrograph generated from the BMP's delineated contributing drainage area. Possible outflows from the BMP can be by rainwater use, infiltration, evapotranspiration, controlled discharge, and overflow. The rates of outflow are determined by the site's user-defined infiltration characteristics, BMP type, and BMP design parameters. A schematic flow diagram displaying the BMP inputs and outputs is presented in Figure 1.



**Figure 1. User-Defined BMP Representation**

## SANTA BARBARA URBAN HYDROGRAPH METHOD

Pre-project and post-project runoff hydrographs are generated by the Sizing Calculator using the Santa Barbara Urban Hydrograph (SBUH) method. The SBUH method was developed by the Santa Barbara County Flood Control and Water Conservation District to determine a runoff hydrograph for small and medium-sized urban areas.

The SBUH method is based on the Soil Conservation Service (SCS) curve number (CN) approach. The SBUH method is generally easier to implement in a spreadsheet calculation procedure than the SCS approach because it computes the runoff hydrograph directly without going through the intermediate steps of generating unit hydrographs. It uses SCS equations for computing soil absorption and precipitation excess to generate incremental runoff depths for a given drainage area and design storm. The incremental runoff depths from the drainage basin are converted into instantaneous hydrographs that are then routed through an imaginary reservoir with a time delay equal to the drainage area's time of concentration. The corresponding outflows from each drainage area are then summed to determine the site's overall runoff hydrograph.

Key variables for the SBUH method include:

- Runoff curve numbers at the site
- Time of concentration
- Pervious and impervious land/surface areas
- Design storm

These variables are described in more detail in the following sections.

### Runoff Curve Number (Step 1)

Runoff curve numbers (CN) were developed by the Natural Resources Conservation Service (NRCS) after studying the runoff characteristics of various types of land. Curve numbers reduce diverse characteristics such as soil type, land usage, and vegetation into a single variable for doing runoff calculations.

Unless the surface type is completely impervious, the CN for a surface will vary based on the hydrologic soil group (HSG) of the native (or existing) soils at the site. The HSG is a NRCS classification system in which soils are categorized into four runoff potential groups. The groups range from A soils, with high permeability and little runoff production, to D soils, which have low permeability rates and produce much more runoff. The HSG for the site is entered in **Step 1** of the Sizing Calculator to determine the runoff curve numbers for the pervious surfaces at the site. The definitions of the HSGs are summarized in Table 1.

**Table 1 – HSG Definitions** (Source: SCS 1986)

Group	Soil Types	Description
A	Sand, loamy sand, or sandy loam	Low runoff potential. Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravels.
B	Silt loam or loam	Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well-drained soils with moderately fine to moderately coarse textures.
C	Sandy clay loam	Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine textures.
D	Clay loam, sandy clay, silty clay, or clay	High runoff potential. Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, and shallow soils over nearly impervious material.

The runoff curve numbers (CN) for surfaces used in the Sizing Calculator are based on values given for similar surfaces in the SCS document *Technical Release 55 – Urban Hydrology for Small Watersheds* (TR-55). The CN values used in the Sizing Calculator are summarized in Table 2.

**Table 2 – Runoff Curve Numbers**

Surface Type	Runoff Curve Number <sup>(a)</sup>			
	A	B	C	D
<b>Impervious Areas</b>				
Pavement (conventional)	98	98	98	98
Roof (conventional)	98	98	98	98
Gravel	76	85	89	91
<b>Pervious Areas</b>				
Grass/Lawn Areas <sup>(b)</sup>	49	61	74	80
Landscaped (Lower Density) <sup>(c)</sup>	39	56	70	77
Landscaped (Higher Density) <sup>(d)</sup>	35	48	65	73
Tree Well <sup>(e)</sup>	35	35	35	35

Notes:

- (a) Curve numbers are based on SCS *Technical Release 55 - Urban Hydrology for Small Watersheds* (TR-55).
- (b) Based on TR-55 CN values for “Open Space – Good Condition”.
- (c) Based on TR-55 CN values for “Brush – Fair Condition”.
- (d) Based on TR-55 CN values for “Brush – Good Condition”.
- (e) Based on TR-55 CN value for “Woods – Good Condition” for Type A soils.

**Time of Concentration (Step 2)**

The time of concentration ( $T_c$ ) is the time for a drop of water to travel from the farthest point on the upstream end of the drainage area to the downstream end.  $T_c$  influences the shape and peak of the runoff hydrograph. Development and urbanization typically decreases  $T_c$ , thereby increasing the peak discharge.  $T_c$  varies based on the type of flow path at the site (e.g., overland, channel, or pipe), and the slope, roughness, and length of that flow path. User-defined site information is entered into **Step 2** of the Sizing Calculator to allow for an estimation of the time of concentration from the conventional surfaces at the site. Because the Sizing Calculator is intended for small, urban sites, the pre-project  $T_c$  at these sites will be low (typically between 5 and 15 minutes). The Sizing Calculator therefore does not allow for multiple node flow paths.

For **overland flow less than 300 feet**, the Sizing Calculator uses the following Manning’s kinematic sheet flow equation to calculate the  $T_c$  of the site’s conventional surfaces:

$$T_c = \frac{0.42 \times (L \times P)^{0.8}}{P^{0.8} \times s^{0.4}}$$

Where,

- $T_c$  = Time of concentration [min]
- $n$  = Friction slope (Manning’s  $n$  for shallow flow depths)
- $L$  = Flow length [ft]
- $P$  = 2-year, 24-hour rainfall depth [inches]
- $s$  = Land slope (along flow path) [ft/ft]

For **pipe and channelized flow** or **flow lengths greater than 300 feet**, the Sizing Calculator uses the following TR-55 Shallow Concentrated Flow equation to calculate the  $T_c$  of the site's conventional surfaces:

$$T_c = \frac{L}{60 \times V} \text{ where } V = K_v \sqrt{s}$$

Where,

$T_c$  = Time of concentration [min]

$V$  = Average velocity [ft/sec]

$L$  = Flow length [ft]

$s$  = Land slope (along flow path) [ft/ft]

Design Note: Increasing pervious area and adding stormwater BMPs that detain runoff will increase the site's  $T_c$ . As discussed earlier, the BMP measures are treated in the Sizing Calculator as storage devices that delay runoff based on their design configuration. The post-project  $T_c$  calculations include the delay from BMP measures implemented at the site.

### Land / Surface Areas (Step 3)

The pervious and impervious areas are entered into **Step 3** of the Sizing Calculator in order to evaluate the contributing drainage areas, selected LID approaches, and the resulting site runoff. The pervious and impervious areas are analyzed separately, and their resulting hydrographs are combined to determine the total site hydrograph. Conventional impervious or pervious areas input into the Sizing Calculator are represented as a homogenous surface type by determining the weighted average. These weighted averages are used to represent the make-up of impervious and pervious drainage areas directed to each LID measure.

### Design Storms

The SBUH method requires a design storm to perform the runoff calculations. The requirements of the Stormwater Design Guidelines are based on performance for the 1-year and 2-year, 24-hour design storms. These design storms have been established for San Francisco based on more than 100 years of local historical rain gauge data. Neighborhood specific (micro-climate) design storm data are not provided in the Sizing Calculator. The design storm data are provided in the "Rainfall and Hydrographs" worksheet tab of the Sizing Calculator. The excel spreadsheet *Design Storms: 1-year and 2-year 24-hour Design Storms* is available for download at <http://sfwater.org/sdg>.

## REFERENCES AND RESOURCES

HydroCAD Software Solutions LLC. 2004. *HydroCAD Stormwater Modeling System Version 7 - Owner's Manual*.

Portland Bureau of Environmental Services. 2004. "Stormwater Management Manual". Adopted July 1, 1999; Revised September 1, 2004: Appendix C – Santa Barbara Urban Hydrograph Method.

San Francisco Public Utilities Commission. 2010. "Stormwater Design Guidelines". January 2010.

Soil Conservation Service. 1986. *Technical Release 55 - Urban Hydrology for Small Watersheds*. June 1986.

Washington State Department of Ecology. 2001. "Stormwater Management in Western Washington – Volume III". August 2001: pgs. 2-31 to 2-39.