Santa Clara Valley
Urban Runoff
Pollution Prevention Program

APPENDIX F

Background for Developing Numeric Sizing Criteria for Stormwater Treatment System

APPENDIX F

BACKGROUND DEVELOPING NUMERIC SIZING CRITERIA FOR STORMWATER TREATMENT SYSTEMS

This Appendix describes the development of numeric hydraulic sizing criteria for stormwater treatment systems for conditions in the Santa Clara Basin, as required in the Program's NPDES Permit Provision C.3.d., and it applies the different criteria to several examples for comparison of the results.

After optimizing a project's site design with respect to stormwater treatment, treatment BMPs are selected as described in Chapter III. The sizing of the stormwater treatment systems must meet criteria identified in the NPDES permit's Provision C.3.d. The hydraulic sizing criteria that are required by the permit are identified.

This Appendix does not address the sizing of a treatment system that will also be used for flow control, as may be required by the Program's Hydromodification Management Plan (HMP). The design of dual-purpose systems will be addressed in the completed HMP report and added to Chapter V of this Handbook at a future date.

The Program acknowledges the assistance of GeoSyntec Consultants, who provided the technical analyses and report (GeoSyntec Consultants, 2003) that form the basis of this Appendix.

I. HYDRAULIC SIZING CRITERIA

The following are the hydraulic sizing criteria required by Provision C.3.d. The name assigned to each criterion is consistent with the nomenclature used in the 2003 California Best Management Practice (BMP) Manual for New Development and Redevelopment (CASQA, 2003) and is given in bold in the parentheses following each criterion.

C.3.d.i. Volume Hydraulic Design Basis: Treatment BMPs[1] whose primary mode of action depends on volume capacity, such as detention/retention units or infiltration structures shall be designed to treat storm water runoff equal to: Volume-based treatment BMPs are designed to treat a volume of runoff, which is detained for a certain period of time to effect settling of solids and associated pollutants. Examples of volume-based controls include wet ponds, detention basins, constructed wetlands, and bioretention systems.

- The maximum storm water quality capture storm water volume for the area, based on historical rainfall records, determined using the formula and volume capture coefficients set forth in *Urban Runoff Quality Management, WEF Manual of Practice No. 23 and ASCE Manual of Practice No. 87, (199*8), pages 175-178 **(URQM Approach);** or
- The volume of annual runoff required to achieve 80 percent or more capture, determined in accordance with the methodology set forth in Appendix D of the *California Stormwater Best Management Practices Handbook,* (1993) using local rainfall data. **(CA Stormwater BMP Handbook Volume Approach).**

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[1] For the purpose of this Chapter, a stormwater best management practice (BMP) is the same as a stormwater treatment measure, device, or control.

C.3.d..ii. Flow Hydraulic Design Basis: Treatment BMPs whose primary mode of action depends on flow capacity, such as swales, sand filters, or wetlands, shall be sized to treat:

- 10% of the 50-year peak flow rate **(Factored Flood Flow Approach)**; or
- The flow of runoff produced by a rain event equal to or at least two times the 85th percentile hourly rainfall intensity for the applicable area, based on historical records of hourly rainfall depths **(CA Stormwater BMP Handbook Flow Approach);** or
- The flow of runoff from a rain event equal to at least 0.2 inches per hour intensity **(Uniform Intensity Approach)**.

Flow-based treatment BMPs treat water on a continuous flow basis. Examples include vegetated swales, media filters, hydrodynamic separators and screened systems.[2]

II. LOCAL RAINFALL DATA: AVAILABILITY AND SELECTION

There are two (2) categories of rainfall data available in the Basin, data collected and compiled by the National Climatic Data Center (NCDC) and data collected as part of the ALERT rainfall network. The available NCDC rain gages are shown in Figure 1 (Chapter III, Attachment III-1) on an isohyetal map of the Santa Clara Basin. Information about the gages is contained in Table 1. The NCDC data are generally fixed-interval hourly data. The period of record of the data varies from three (3) years at Mount Hamilton to 53 years at the San Jose Airport.

There are numerous ALERT gages in the Basin. The format of the data varies, portions of the records are cumulative tipping-bucket data, while other portions are fixed interval data where the interval is usually one (1) hour, but may be as high as 24 hours. The different formats generally provide different precision; for instance, tipping-bucket rainfall data are recorded as multiples of 0.04 inch (1 mm), whereas fixed-interval data are typically multiples of 0.1 inch. Because the NCDC data provided more consistent data in terms of precision and time interval, the rainfall analysis was conducted using the NCDC data.

Table 1 -- Santa Clara NCDC Hourly Rain Gage Location Summaries

Rain Gage	Elevation (ft)	Lat. (N)	Long. (W)	Available Period of Record	Station Number	Mean Storm Event Precipitation (in)	Mean Annual Precipitation (in)
Gilroy 8 NE	1050	37:01	121:25	’48 - ’01	043419	0.684	18.2
Morgan Hill 6 WSW	640	37:06	121:45	’60 - ’75	045846	Not Analyzed	Not Analyzed
Morgan Hill	375	37:08	121:36	’48 - ’83, ’85 - ‘01	045853	0.760	19.5
Mount Hamilton	4206	37:20	121:38	’48 - ’51	045933	Not Analyzed	Not Analyzed
Palo Alto	25	37:26	122:08	’53 - ’75	046646	0.522	13.7
San Felipe Bell STN	371	37:01	121:20	’48 - ’75	047755	Not Analyzed	Not Analyzed
San Jose	67	37:21	121:54	’48 - ’01	047821	0.512	13.9

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[2] For clarification, flow-based treatment BMPs differ from flow control BMPs, which are used to limit the volume and rate of discharge from a development site, such as may be required by the Program’s HMP (see Chapter V).

III. VOLUME-BASED AND FLOW-BASED TREATMENT CONTROLS

The type of rainfall analysis required varies depending on whether the BMP is based on treatment of a volume of water or treatment of a flow of water. This distinction between volume-based and flow-based controls is not always clear, especially in a sequence of BMPs or a treatment train. The following are general guidelines for each type of control.

Volume-based treatment BMPs are designed to treat a volume of runoff, which is detained for a certain period of time to effect settling of solids and associated pollutants. Examples of volume-based controls include wet ponds, detention basins, constructed wetlands, and bioretention systems.

Flow-based treatment BMPs treat water on a continuous flow basis. Examples include vegetated swales, media filters, hydrodynamic separators and screened systems.[3]

IV. SIZING CRITERIA FOR VOLUME BASED CONTROLS

Urban Runoff Quality Management (URQM) Approach

Description. The URQM method estimates the "maximized stormwater quality capture volume" using the equation in *Urban Runoff Quality Management* (WEF/ASCE, 1998). The method is based on a combination of modeling and regression analysis conducted using long-term rainfall records from six (6) cities including San Francisco. For details regarding this method, the reader is referred to *Urban Runoff Quality Management*, pages 170-178.

The equations used in this method are:

$$P_o = \left(a \cdot C_w\right) \cdot P_6$$

$$C_w = 0.858i^3 - 0.78i^2 + 0.774i + 0.04$$

Where

P_o = maximized detention storage volume based on the volume capture ratio as its basis (watershed inches);
a = regression constant from least-squares analysis (unit less);
C_w = watershed runoff coefficient (unit less)[4];
P_6 = mean storm event precipitation volume (watershed inches); and
i = watershed impervious ratio (range: 0-1)

Parameter "*a*" reflects the effect of drain time on storage, and equals 1.963 for a drain time of 48 hours, 1.582 for a drain time of 24 hours, and 1.312 for a drain time of 12 hours.

Application of the URQM Method to the Santa Clara Basin. The mean storm event precipitation volume, P_6, can be determined by two ways: 1) using Figure 5.3 in *Urban Runoff Quality Management*; or, 2) by performing analysis on local historical rainfall data (preferred). To determine the mean precipitation, EPA's Synoptic Rainfall Analysis Program (SYNOP) was applied. In this method, the rainfall record is subdivided into discrete events separated by a dry inter-event period, which in this case was set to a minimum of six (6) hours. Small rainfall events defined as events whose depth was less than or equal to 0.10 inches were deleted from the record as such events tend to produce little if any runoff. This approach to defining minimum storm events that produce runoff is consistent with the URQM

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[3] For clarification, flow-based treatment BMPs differ from flow control BMPs, which are used to limit the volume and rate of discharge from a development site, such as may be required by the Program's HMP (see Chapter V).

[4] For the purpose of this Chapter, the watershed runoff coefficient is notated as "C_w" to avoid confusion with the runoff coefficient "C" used in the Rational Method.

Method. Values of the mean storm event size for selected rain gages in the Santa Clara Basin are provided in Table 1 and plotted in Figure 4 against the mean annual rainfall. Figure 4 along with the isohyetal map shown in Figure 1 can be used to estimate the mean storm event size at most locations within the Santa Clara Basin where development is likely to occur.

California Stormwater BMP Handbook Volume Approach (Adapted)

Description. Most water quality basins and other volume-based BMPs are designed to treat only a portion of the runoff from a given site, as it is not economically feasible to capture 100% of the runoff. The portion of runoff volume treated by a volume-based BMP is referred to as the "percent capture." The CA BMP Handbook Method estimates the design volume needed to achieve various levels of percent capture. Permit Provision C.3.d.i. requires capture of 80% or more of annual runoff.

In the California Stormwater Best Management Practices Handbook (2003), a proprietary version of the Storage, Treatment, Overflow, and Runoff Model (STORM) was used to generate sizing curves that form the basis for the volume-based BMP sizing criteria. The model results were presented as the relationship of "unit basin storage volume" to the percent capture volume of the BMP. The "unit basin storage volume" is then used to size the BMP, using the following equation:

$$\text{BMP Volume} = \text{Unit Basin Storage Volume} \cdot \text{Watershed Area}$$

For the Santa Clara Basin analysis, the Environmental Protection Agency's Stormwater Management Model (SWMM) was used to generate the design curves in place of STORM, as SWMM is a commercially available model and has some features that proved advantageous. For example, SWMM allows one to simulate the effects of soil type and slope. Comparison of the results from STORM and SWMM showed that the two models produced similar and consistent results, justifying the substitution of SWMM for STORM. Therefore, the approach used herein is considered an adapted version of the California BMP Handbook Approach.

Application of the California BMP Handbook Volume Approach to the Santa Clara Basin. Development of the design curves for this method takes into account several variables and therefore requires more explanation than the other methods. The following describes what those variables are, and the rationale for their estimation.

Factors that can affect the percent capture include:

- The rainfall characteristics at the site,
- The percent imperviousness of the site,
- The soil condition and associated infiltration rates (less important for highly impervious projects, or where grading compacts the soils),
- The slope of the site, and
- The design drain time for the volume based BMP.

The following describes how each of these factors was taken into account in developing the design curves.

Site-Specific Precipitation

Rainfall amounts and characteristics vary across the Basin in response to orographic effects associated with the Santa Cruz Mountains and the Mount Diablo Range, the directional patterns of storm fronts approaching the Basin, and other factors. These effects are illustrated in Figure 1, which shows the distribution of mean annual rainfall. Obviously, the location of the project site will dictate the local rainfall patterns and must be taken into account in developing the design sizing curves. For this purpose, rainfall records from several rain gages that represented a range of mean annual precipitation were analyzed.

Percent Imperviousness

The major factor affecting basin size is the percent imperviousness of the catchment (i.e., area draining to the BMP). Impervious surfaces include paved highways, streets, rooftops, and parking lots. The percent of the catchment area covered by such surfaces is termed the "percent imperviousness" and will vary depending on each project. If the runoff from an impervious surface drains directly into the storm drain system, this area is termed the "directly-connected imperviousness area" (DCIA). Values of percent imperviousness generally vary with the type of development. The numerical sizing curves shown are for a range of percent imperviousness (30% to 100%) corresponding roughly with low-density single family residential (30%) to commercial and/or industrial development (up to 100%).

Again, the basin (or other volume-based BMP) size is determined based on the percent imperviousness of the area draining to the BMP. If the runoff from pervious areas can be treated by infiltration and/or filtering and routed around the BMP, the design can be based on treating the runoff from the impervious area only.

Soil Infiltration and Compaction

The pervious portions of a site can infiltrate some of the rainfall depending on the infiltration characteristics of the soils and the levels of groundwater. For the purposes of characterizing infiltration, soil types have been classified into four Hydrologic Soil Groups (HSGs) by the Natural Resources Conservation Service (NRCS). A further subdivision of soils can be made in terms of soil texture as shown in Figure 1. Figure 1 shows that most soils in the Santa Clara Basin can be classified as clay, sandy clay, clay loam, silt loam, or loam.

Table 2 shows values of infiltration parameters used in the SWMM Model for various soil textures. SWMM uses the Green-Ampt Equation to compute the effective infiltration rate.

Table 2 -- Green-Ampt Infiltration Parameters Used in SWMM

Soil Texture	Hydrologic Soil Group	SUCTION (in.)	HYD CON (in/hr)	SMDMAX
Loam	B	3.50	0.520	0.463
Silt Loam	B	6.57	0.270	0.501
Clay Loam	D	8.22	0.079	0.464
Sandy Clay	D	9.41	0.047	0.430
Clay	D	12.45	0.024	0.475

SUCT = average capillary suction at the wetting front
HYD CON = saturated hydraulic conductivity of soil
SMDMAX = initial moisture deficit
Source: Maidment, David R. (1993), *Handbook of Hydrology*

An important consideration in the selection of an appropriate design curve based on soil type is the effect of soil compaction that can occur during site preparation and grading. Data provided by Pitt (2002) indicates that most urban soils are highly compacted. It is recommended that for sites where traditional site preparation practices are conducted, the design curves for poorly infiltrating soil, such as clay or sandy clay, be used. Where site planning allows for protecting natural areas and associated vegetation and soils, the design curves associated with the site-specific soil can be used. However, as can be seen on the design curves, the higher the percent imperviousness of the area draining to the BMP, the less important is the soil type and infiltration rate of the pervious area.

Slope

The slope of the land can affect runoff volumes and flow rates. For the purpose of this guidance, it was assumed that most development would occur either on the relatively flat valley floor or in upland areas where the slopes are generally mild. The SWMM model was run for two (2) slopes, 1% and 15%, with the idea that this would bracket most development sites. For intermediate slopes, results can be interpolated.

Drain Time

Drain time is the time required to drain a basin that has reached its design capacity; usually expressed in hours. Drain time is important as it is a surrogate for residence time, which affects the size of particle that could potentially be settled out in the basin. Estimates for design drain time vary, and ideally would be determined based on site-specific information on the size, shape, and density of suspended particulates in the runoff. This information is generally not available and estimates of appropriate ranges for drain time have relied on settling column information reported in the literature. In the WEF Method, equations are provided for 24, 48, and 72 hour drain times.

An important source of drain time information is settling column tests conducted by Grizzard, et. al. (1986) as part of the Nationwide Urban Runoff Program (NURP). He found that settling times of 48 hours resulted in removals of 80-90% of total suspended solids (TSS). Rapid initial removal was also observed in stormwater samples with medium (100 to 215 mg/L) and high (721 mg/L) initial TSS concentrations. For example, at settling times of 24 hours, the 80-90% removals were already achieved in samples with medium and high initial TSS, whereas only 50-60% removal was achieved in those with low initial TSS.

Limited local settling column tests were also conducted by Woodward Clyde Consultants and Kinetic Laboratories Incorporated (KLI) using samples obtained at four (4) stream monitoring stations (Calabazas Creek, Sunnyvale East Channel, Guadalupe River, Coyote Creek) in the Santa Clara Basin. The data were analyzed and reported in an internal Woodward-Clyde memorandum by E.D. Driscoll (1990). Driscoll’s analysis indicated that settling times of 48 hours resulted in removals of approximately 73-84% of TSS in four (4) tested stormwater samples (initial TSS concentrations of 22, 28, 69, and 85 mg/L). At 24-hour settling times, 83% TSS was removed in the sample with initial TSS of 85 mg/l, but only 64-69% TSS removals were achieved in the rest of the samples.

Given the data provided above, a drain time of 48 hours has been used in developing the curves herein. This is also consistent with recommendations of vector control agencies that structures be designed to drain in less than 72 hours, to minimize mosquito production.

It should be pointed out that basin outlet structures are designed to achieve the design drain time. It is recommended that, in order to achieve reasonable treatment for smaller storms that may only fill the basin partially, the outlet be designed to achieve a 24-hour drain time if the basin is only filled to half its design volume. This requirement can easily be achieved with a compound weir or riser with varying numbers and sizes of orifices.

Sizing Curves. Numeric sizing criteria for volume-based controls in the Santa Clara Basin are presented in the form of curves that plot the basin size, expressed as unit basin storage, corresponding to 80% capture as a function of site percent imperviousness, soil type, location (rain gage), and assumed slope. Unit basin storage is expressed in watershed inches (i.e., depth over the drainage area to the BMP), which allows design curves to be applied to a range of catchment sizes.

Figures 2-A through 2-D show the sizing curves for the San Jose Airport, Palo Alto, Gilroy, and Morgan Hill rain gages, respectively, assuming 1% slope. Figures 3-A through 3-D show the corresponding curves for 15% slope. For each gage, design curves are indicated for a range of soil textures.

V. SIZING CRITERIA FOR FLOW-BASED CONTROLS

Design Rainfall Intensity

The three (3) alternative sizing methods described in Provision C.3.d.ii. specify different ways of estimating a design rainfall intensity or rate (e.g., in inches per hour), which is then used to determine the flow of runoff to be treated. The application of the three methods in the Santa Clara Basin is described below.

Factored Flood Flow Approach. In this method, a design intensity equal to 10% of the intensity obtained from a local intensity-duration-frequency (IDF) curve for a 50-year storm event is used to estimate the design flow. To obtain this value, one enters the IDF curve for the 50-year return period, selects the intensity that corresponds to a duration equal to the time of concentration for the drainage area to the BMP, and multiplies it by one-tenth.

The time of concentration is the travel time from the most remote portion of area that drains into the treatment BMP, to the BMP. For urban drainage, the time of concentration may include an overland flow portion and a portion in which the flow occurs in drainage pipes leading to the BMP. The time of concentration should be determined using procedures approved by local agencies or using standard hydrologic methods such as those described in WEF/ASCE, 1992.

Figure 5 shows IDF Curves for 50-year return period events based on rainfall analyses conducted by Santa Clara Valley Water District (SCVWD) staff. These and similar curves for other rain gages apply to this method. Summaries of the four (4) rain gages used for the IDF curves are shown in Table 3.

California Stormwater BMP Handbook Flow Approach. In this method, a design intensity of 2 times the 85th percentile hourly rainfall intensity is used to estimate the design flow. The factor of 2 is intended to account for the fact that average rainfall intensities increase for shorter duration events, and intensities estimated from hourly data tend to under-predict flow rates in small catchments where the time of concentration is less than one (1) hour.

Figure 6 shows the smoothed “Cumulative Distribution Function” (CDF), or curve of cumulative frequency of rainfall intensity for the Palo Alto, San Jose, Gilroy, Morgan Hill, and Haskins Ranch rain gages. The dashed line on the figure corresponds to the 85th percentile values, which are listed in Table 4.

Table 3 -- SCVWD Hourly Rain Gage Location Summaries

Rain Gauge	Elevation (ft)	Lat. (N)	Long. (W)	Available Period of Record	SCVWD Station #	Mean Annual Precipitation (in)
San Jose Airport	95	37:34	121:90	’36 - ’84	6086	13.72[5]
Maryknoll	184	37:33	122:08	’57 - ‘92	6053	16.74
Shanti Ashrama	2300	37:32	121:47	’65 - 92	6098	20.46
Haskins Ranch	2000	37:40	121:76	’64 – ‘92	6034	24.44

Table 4 -- Design Rainfall Intensity for Four Rain Gages

Rain Gage	Rainfall Intensity (in/hr) (85th Percentile)	Design Rainfall Intensity (in/hr) (2 x 85th percentile)
Palo Alto	0.096	0.19
San Jose	0.087	0.17
Gilroy	0.11	0.21
Morgan Hill	0.12	0.24
Haskins Ranch	0.13	0.26

Uniform Intensity Approach. In this method, a design rainfall intensity of 0.2 in/hr is used to estimate the runoff flow rate, without regard to location or time of concentration.

The Rational Method

The three (3) methods of estimating design rainfall intensity can be converted to a flow rate using the Rational Method, a simple, well known, easy to apply formula that predicts flow rates based on rainfall intensity and drainage area characteristics. The Rational Method equation is as follows:

$$Q = CiA$$

Where:

Q = flow, cubic feet per second (cfs)
C = runoff coefficient (unitless)
i = rainfall intensity, in/hr
A = drainage area, acres

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[5] The mean annual precipitation in Table 3 for San Jose Airport differs from that shown in Table 1 because the value in Table 3 was calculated based on a shorter period of record.

The Rational Method is widely used for hydrologic calculations, but does have a number of limitations, as described in the CA Stormwater BMP Handbook (CASQA, 2003). For stormwater treatment BMP design, a key limitation is the ability of the Rational Method equation to predict runoff from undeveloped or pervious areas, where runoff coefficients vary highly with storm intensity and antecedent moisture conditions. The BMP Handbook recommends that for drainage areas with runoff coefficients of 0.50 or less, the Rational Method should primarily be used for drainage areas less than 25 acres. For drainage areas with higher runoff coefficients, say 0.75-1.00, the Rational Method can be applied to drainage areas as large as 100 acres (CASQA, 2003).

In addition, runoff coefficients in most textbooks were developed for large storm events (e.g., those used for sizing storm drains) and not the frequent, small storms used in stormwater treatment BMP design. Runoff coefficients for these frequent small storms are likely to be lower than the coefficients for large storms; however, there are little available data on the proper coefficients. One (1) reference recommends using the lower end of the published range of coefficients for various paving surfaces (CDM, 2003). Where available, locally developed small storm runoff coefficients should be used.

Suggested coefficients or “C-factors” are presented in Tables 5a and 5b. It is more accurate to compute an area-weighted “C-factor” based on the surfaces in the drainage area (Table 5a) than to assume a composite “C-factor” such as those in Table 5b, especially for small drainage areas.

Table 5a – Estimated Runoff Coefficients for Various Surfaces During Small Storms (CDM, 2003)

Surface	Runoff Coefficient (C Factor)
Concrete	0.80
Asphalt	0.70
Pervious Concrete	0.60
Cobbles	0.60
Pervious Asphalt	0.55
Natural Stone (without grout)	0.25
Turf Block	0.15
Brick (without grout)	0.13
Unit Pavers on Sand	0.10
Crushed Aggregate	0.10
Grass	0.10
Roofs (from WEF/ASCE, 1992)	0.75

Notes: The above C-factors were estimated by selecting the lower range of the best available C-factor for each paving surface. These C-factors are only appropriate for small storm treatment BMP design, and should not be used for flood control sizing. Where available, locally developed small storm C-factors for various surfaces should be used.

Table 5b – Estimated Composite Runoff Coefficients for Small Storms by Land Use (WEF/ASCE, 2003)

Description of Area	**Runoff Coefficient (C Factor)**
Business:	
Neighborhood	0.50
Downtown	0.70
Residential	
Single Family	0.30
Multi-unit, detached	0.40
Apartment	0.50
Multi-unit, attached	0.60
Industrial	
Light	0.50
Heavy	0.60
Parks, cemeteries	0.10
Playgrounds	0.20
Unimproved	0.10

Notes: The above C-factors were estimated by selecting the lower range of the runoff coefficients listed for various land uses in WEF/ASCE, 1992. Where available, locally developed small storm C-factors for various land uses should be applied.

For more discussion of the appropriate use and limitations of the Rational Method, see WEF/ASCE, 1992.

VI. COMPARISON OF SIZING METHODS

Comparison of Volume Based Methods

For comparison, the two (2) volume-based sizing methods were applied to two examples, a residential example and a commercial example. The assumed project data are as follows:

Residential Example: Area = 100 acres; % Impervious = 50; Drain time of the BMP = 48 hours; Rainfall data: San Jose International Airport; soils=clay; slope=1%.

Commercial Example: Area = 10 acres; % Impervious = 80; Drain time of the BMP = 48 hours; Rainfall data: San Jose International Airport; soils=clay; slope=1%.

The required volume of the BMP using the two (2) methods is shown in Table 6.

The table shows that no one method tends to be higher in both examples. For the residential example, the basin size using the CA BMP Handbook Approach is the highest. For the commercial example, the basin size using the URQM Method is the highest. The maximum difference between the methods is about 20%.

There are a variety of factors that could account for this ordering. The adapted CA BMP Handbook Method is the least empirical of the methods, and takes into account more factors such as slope, soil type, and effects of "back to back" rainfall events. For the residential example, where the impervious percentage is only 50%, the runoff from the soils becomes important, and in this case we have assumed the soils to be clay, which is less infiltrative than other soils. The result is higher runoff predicted than the other method, and a larger basin. In the commercial case where the site is largely impervious, the effect of soils is less important, and the adapted CA BMP Handbook Method prediction is the lowest.

Table 6 -- Comparisons of Volume Based Sizing Methods

Method	BMP Volume Required (acre-ft)	
	Residential: 100 AC; 50%IMP	Commercial: 10 AC; 80%IMP
1) URQM method	2.84 acre-ft (C=0.34)	0.50 acre-ft (C = 0.6)
2) CA BMP Handbook (adapted)	3.33 acre-ft (Clay, 1% slope)	0.42 acre-ft (Clay, 1% slope)

Comparison of Flow-Based Sizing Methods

For comparison, the three alternative flow-based sizing criteria also were applied to a residential and a commercial example. In these examples, however, the size of the drainage was limited to two (2) acres because many flow-based controls are intended to be integrated into smaller areas within the development project. Data from the San Jose Airport rain gage were used, and a typical runoff coefficient for each land use was assumed. For the Factored Flood Flow Approach (Method 1 in Table 6), it was assumed that the time of concentration for the 2-acre commercial example was five (5) minutes, and for the 2-acre residential example, 10 minutes. The results are summarized in Table 7.

As with the volume-based methods, no one method is consistently higher or lower. For the residential example, Methods 1 and 2 are in agreement, and Method 3 predicts a flow rate about 20% higher. In the commercial example, the range of estimates is larger. Method 1 predicts the highest flow rate, a value that is about 40% higher than the lowest estimate given by Method 2.

Table 7 -- Comparison of Flow Based Sizing Methods

Method	Residential: 2 AC; 50%IMP; C = 0.34		Commercial: 2 AC; 80%IMP; C = 0.60	
	Design Rainfall Intensity	Design Flow	Design Rainfall Intensity	Design Flow
1) Factored Flood Flow	0.170 in/hr	0.116 cfs	0.241 in/hr	0.289 cfs
2) CA BMP Handbook	0.174 in/hr	0.118 cfs	0.174 in/hr	0.209 cfs
3) Uniform Intensity	0.200 in/hr	0.136 cfs	0.200 in/hr	0.240 cfs

VII. RECOMMENDATIONS

Use of any of the sizing methods specified in Permit Provision C.3.d., when properly applied, are in compliance with the permit requirements. However, the various sizing methods have advantages and disadvantages to their use, and local agencies may wish to specify a preference for particular methods in order to standardize development project submittals. For this reason, this Chapter presents a summary of the advantages and disadvantage of the methods, and recommendations.

For volume based controls, the adapted CA Stormwater BMP Handbook Volume Method is recommended because it takes into account rainfall characteristics, percent imperviousness, drainage time, soil infiltration conditions, and slope. All of these factors can be relatively easily determined for a site, and the design curves provided in this report should be sufficient for sizing basins and other volume-based controls. Also, the method simulates the operation of a basin under realistic conditions, and it is reasonable to assume that basins designed using this method will achieve the desired percent capture specified in the permit. Lastly, the method explicitly incorporates a drain time that allows an appropriate level of treatment while avoiding vector control concerns.

For flow-based controls, the CA Stormwater BMP Handbook Flow Method is recommended, using the values estimated for each of the rain gages. This method is based on local rainfall data and achieving treatment of small storms consistent with the permit requirements. Table 8 summarizes the advantages and disadvantages of the various sizing methods.

Attachment IV-1 in Volume 1 of the C.3 Stormwater Handbook contains worksheets to assist municipal staff and development project proponents in sizing various treatment systems using all five (5) of the alternative sizing methods. Attachment IV-2 contains worksheets completed for an example of a single-family residential project in Santa Clara Valley.

Table 8-- Advantages and Disadvantages of Alternative Sizing Methods

Volume Based Methods

	Advantages	Disadvantages
1) Urban Runoff Quality Management (UQRM) Method	Based on modeling and regression analysis using long-term rainfall records in six cities including San Francisco. Takes into account drain time. Easy to apply.	Does not simulate performance under local rainfall patterns, but estimates volume based on average storm event size. Does not consider soil type or slope.
2) CA Stormwater BMP Handbook Volume Method (adapted using SWMM Model)	Most comprehensive method. Takes into account drain time, slope, and soil types. Based on continuous simulation of detention storage, outflow, and bypass using local long-term rainfall records.	Most complex method of the two candidate methods. Curves are provided that should cover most applications.

Flow Based Methods

	Advantages	Disadvantages
1) Factored Flood Flow Approach (10% of 50-year rainfall intensity)	Intensity-duration-frequency curves are very familiar to most engineers. Takes into account local rainfall conditions.	Not based on achieving any given level of treatment of small storms. Sensitive to time of concentration estimate, which could make it more difficult for development review agency.
2) CA Stormwater BMP Handbook Flow Approach (2 times 85th percentile rainfall intensity)	Takes into account local rainfall conditions.	Some question regarding appropriateness of factor of 2.
3) Uniform Intensity Approach (0.2 inches/hr)	Simplest of methods.	Does not take into account local rainfall patterns and statistics. “One size fits all.”

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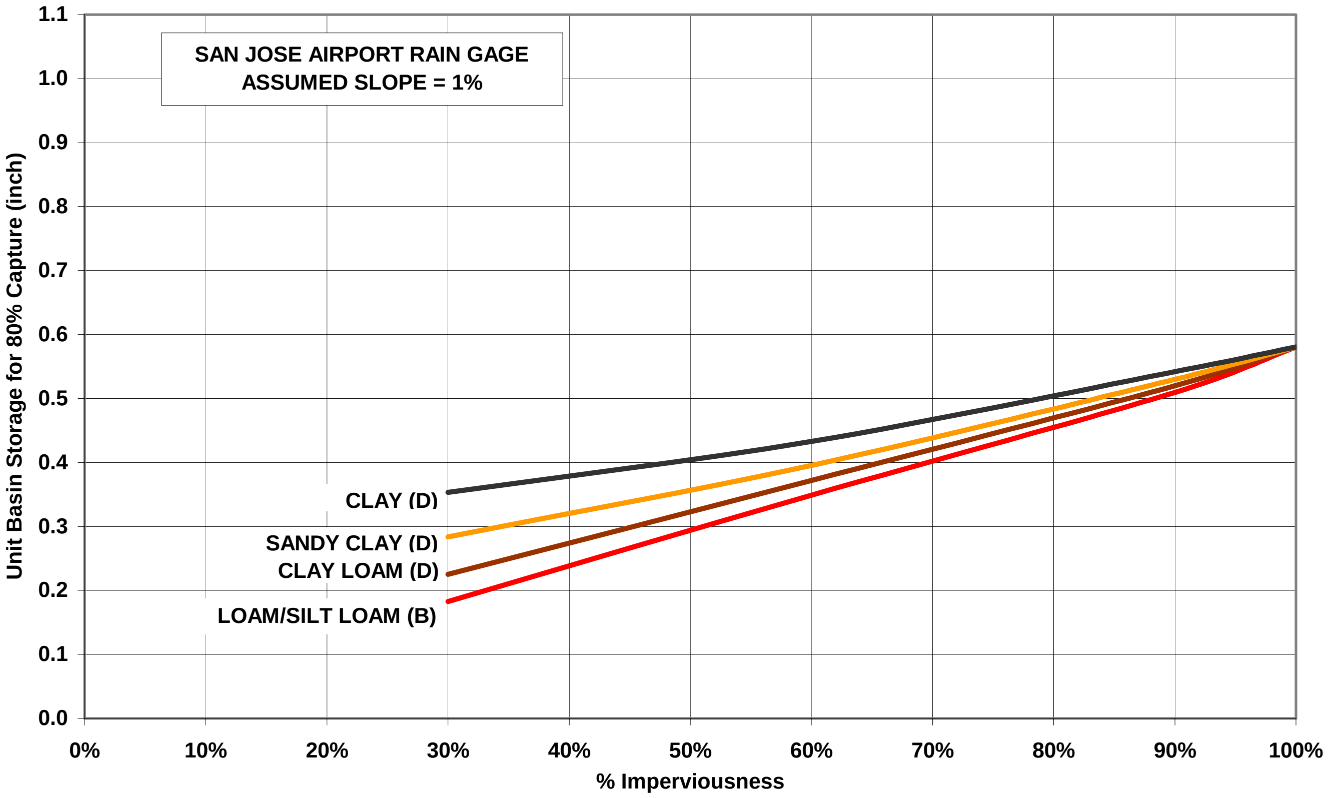

Figure 2-A Unit Basin Volume for 80% Capture - **San Jose Airport** Rain Gage

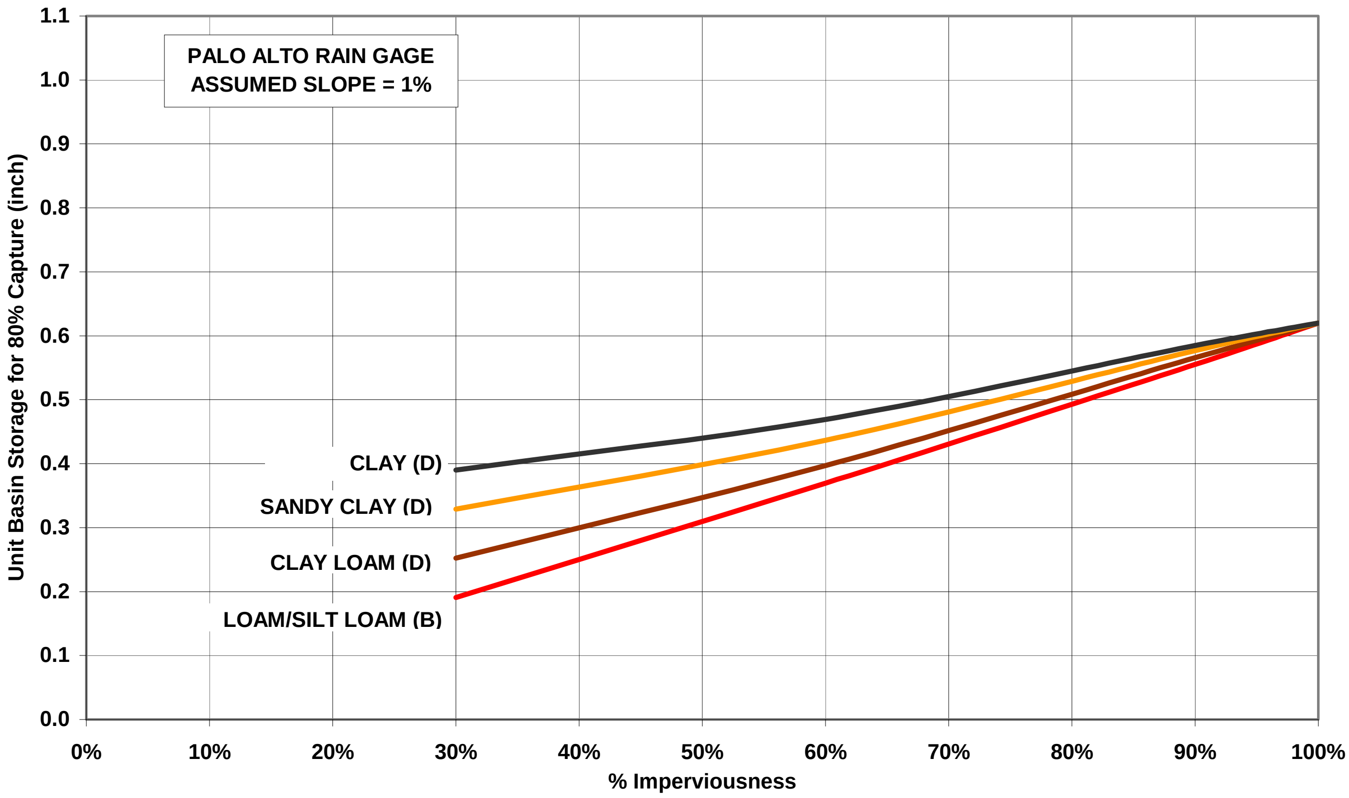

Figure 2-B Unit Basin Volume for 80% Capture - **Palo Alto** Rain Gage

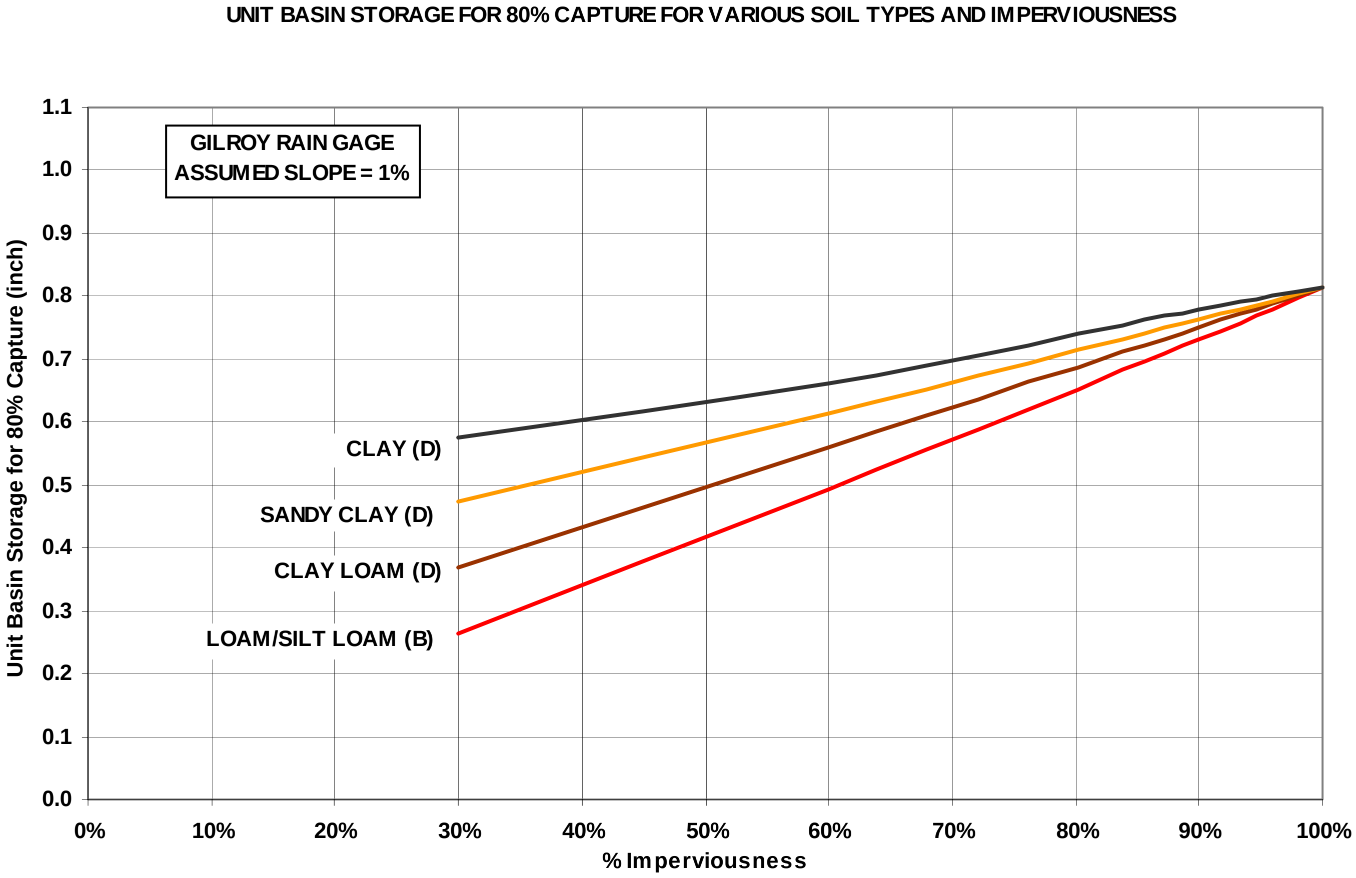

Figure 2-C Unit Basin Volume for 80% Capture - **Gilroy** Rain Gage

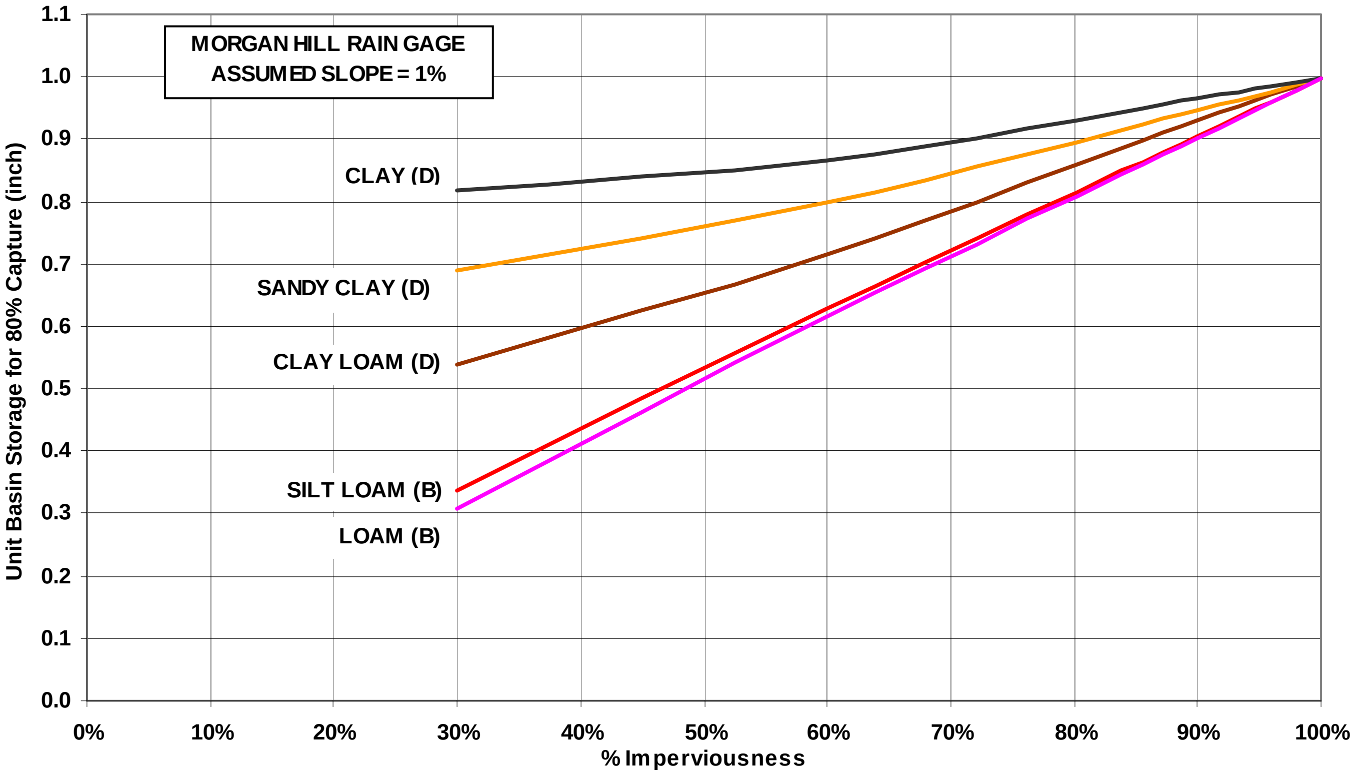

Figure 2-D Unit Basin Volume for 80% Capture - **Morgan Hill** Rain Gage

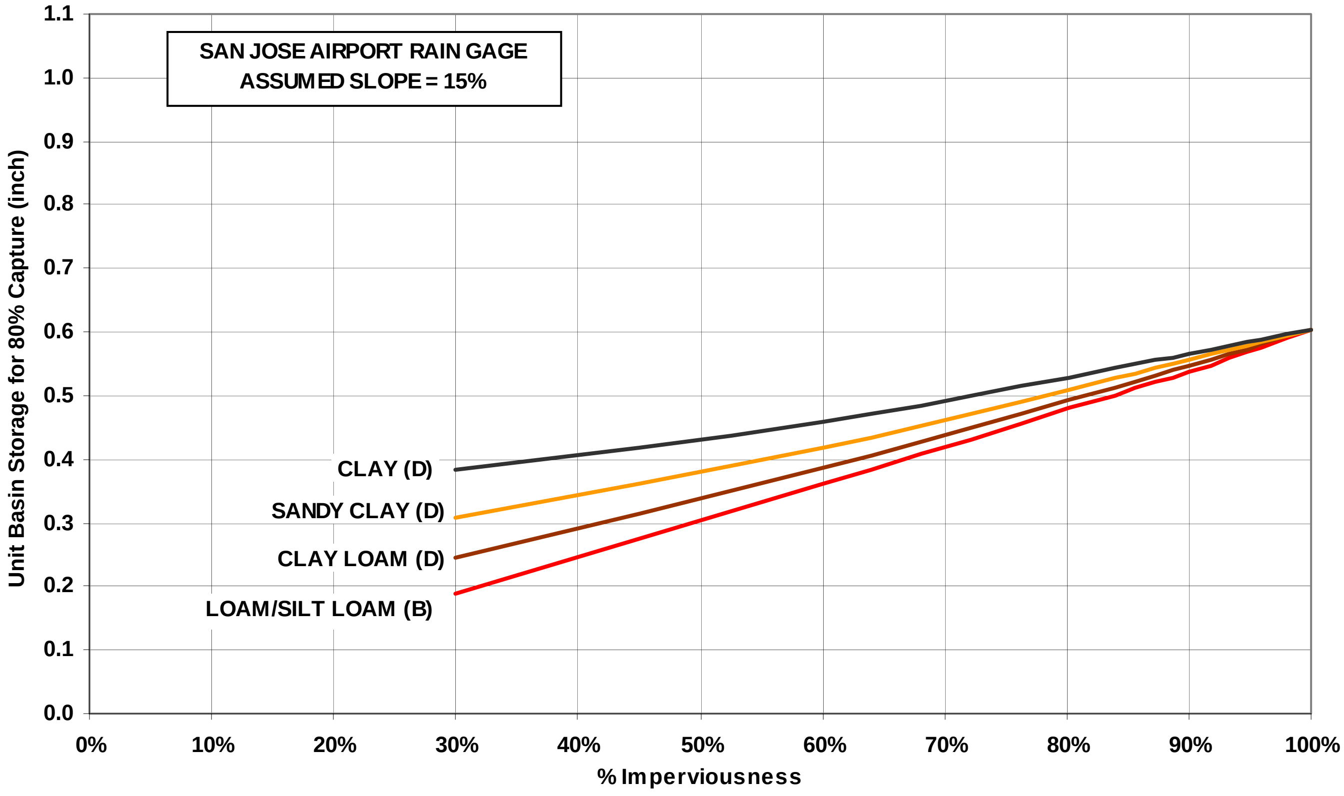

Figure 3-A Unit Basin Volume for 80% Capture - **San Jose Airport** Rain Gage

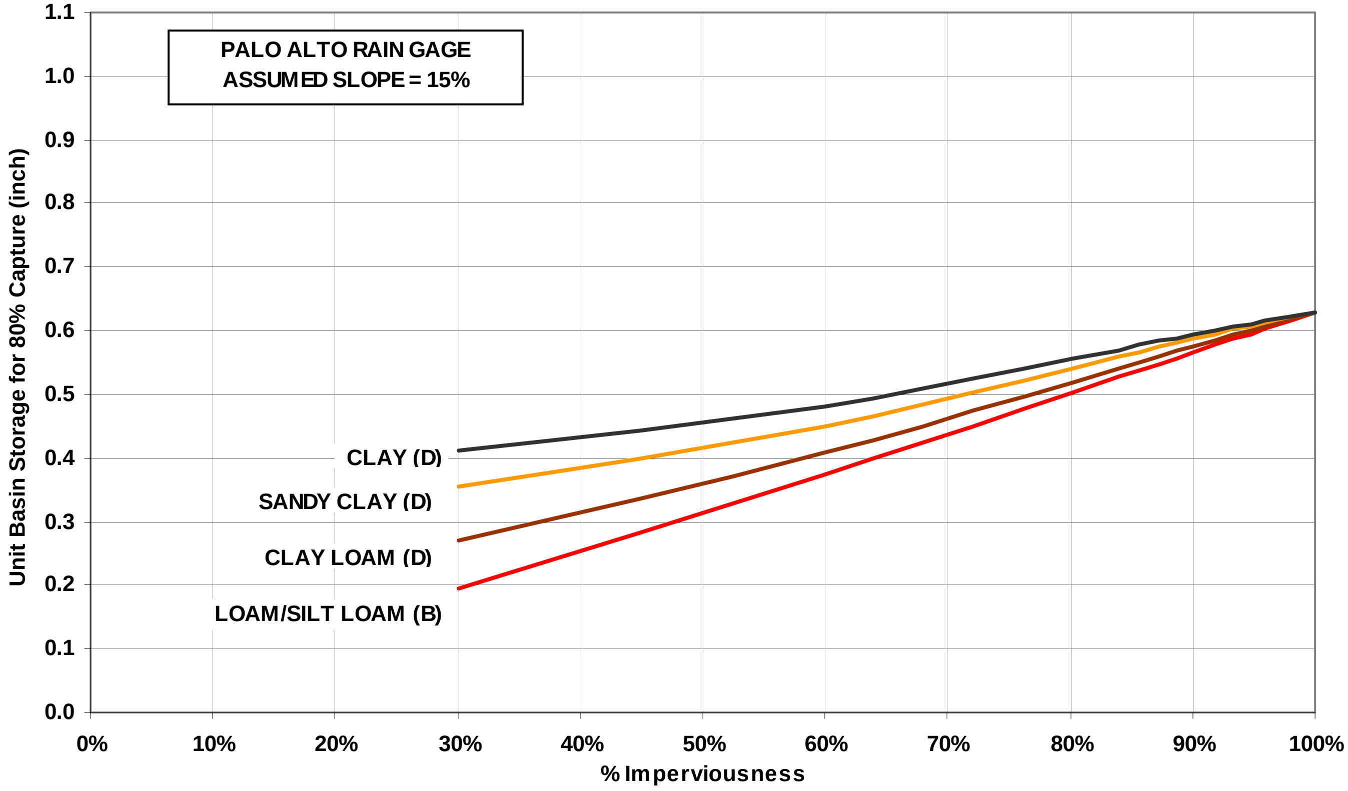

Figure 3-B Unit Basin Volume for 80% Capture - **Palo Alto** Rain Gage

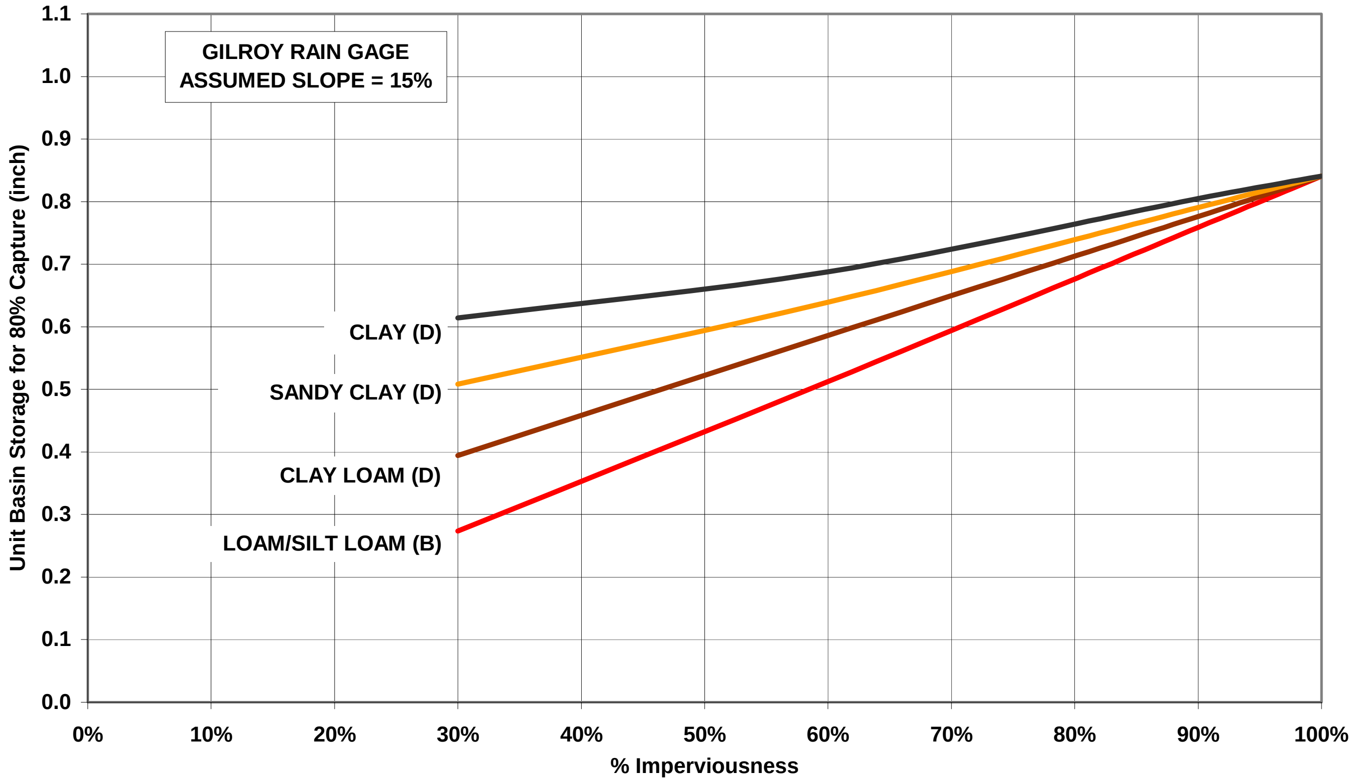

Figure 3-C Unit Basin Volume for 80% Capture - **Gilroy** Rain Gage

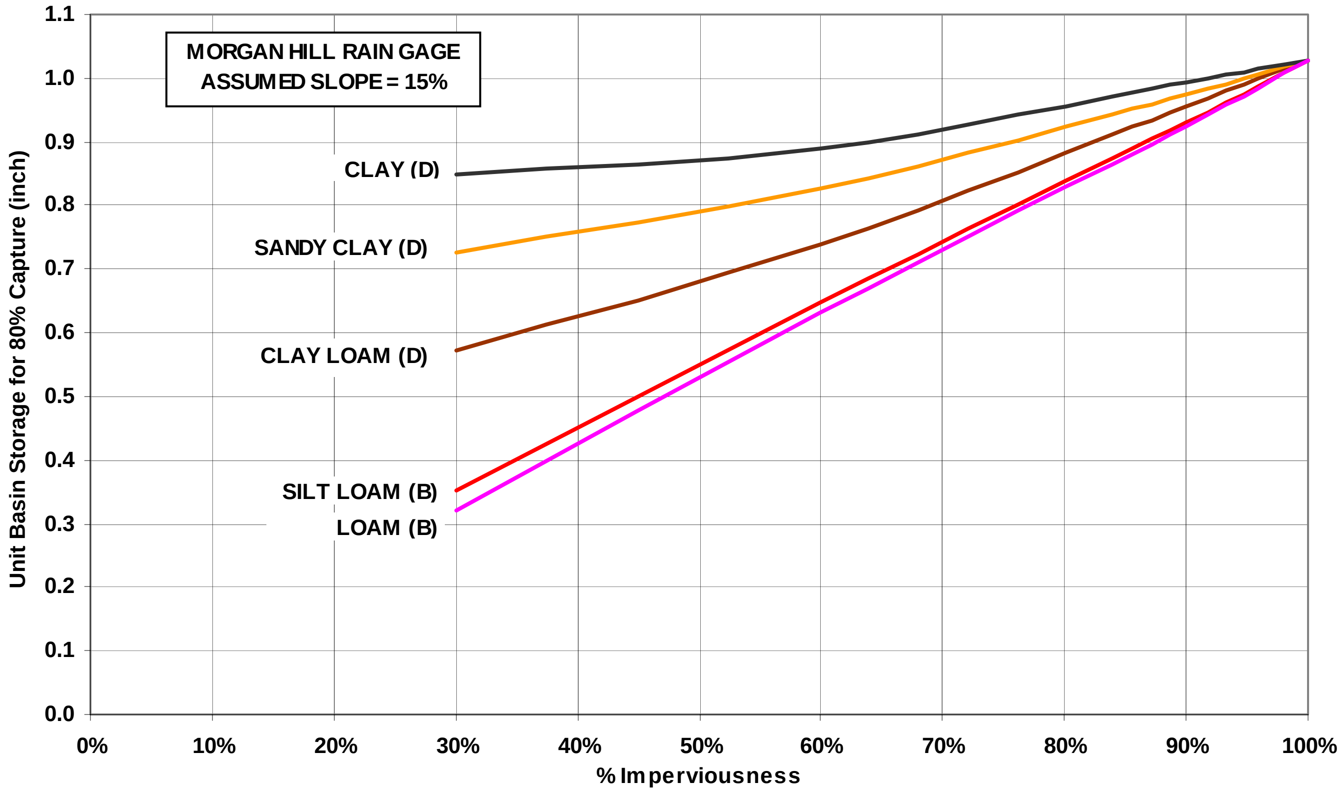

Figure 3-D Unit Basin Volume for 80% Capture - **Morgan Hill** Rain Gage

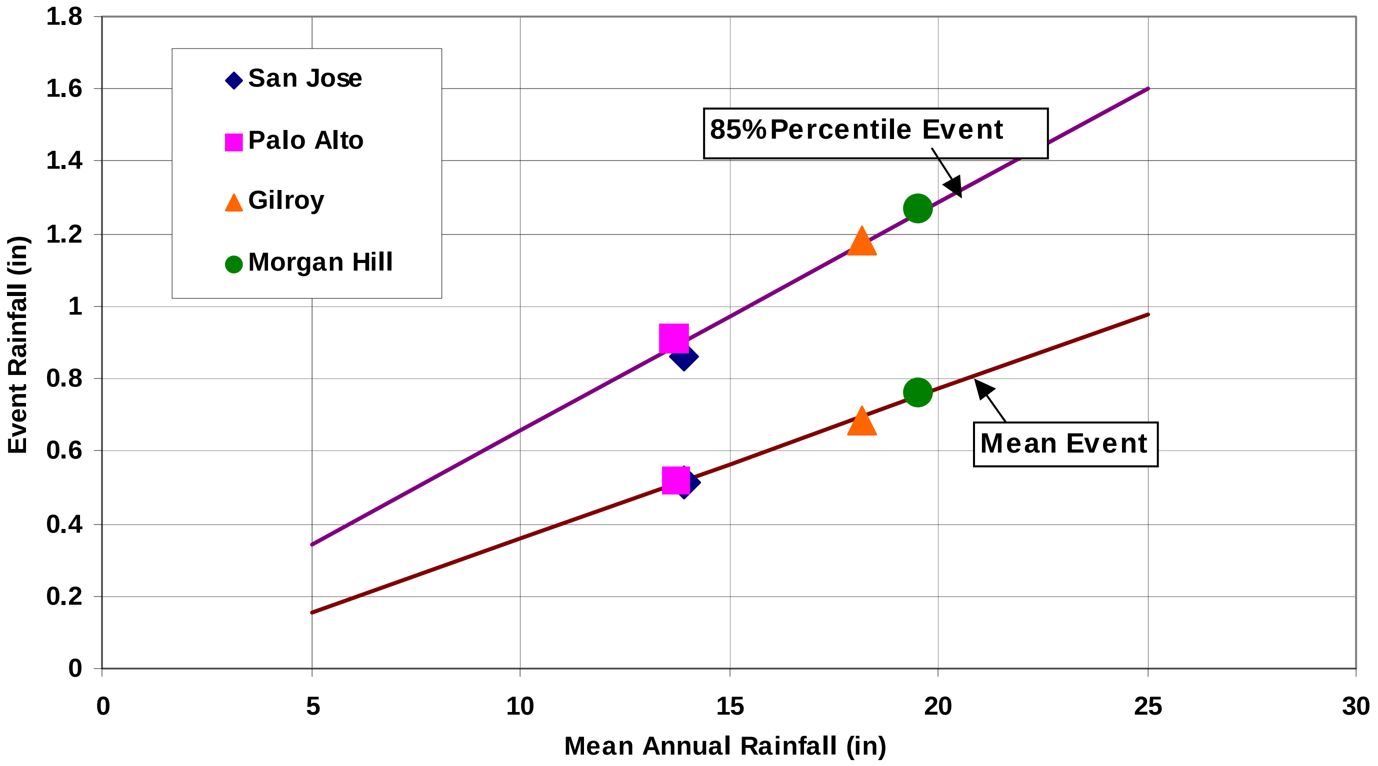

Figure 4 85th Percentile Storm Depth vs. Mean Annual Rainfall

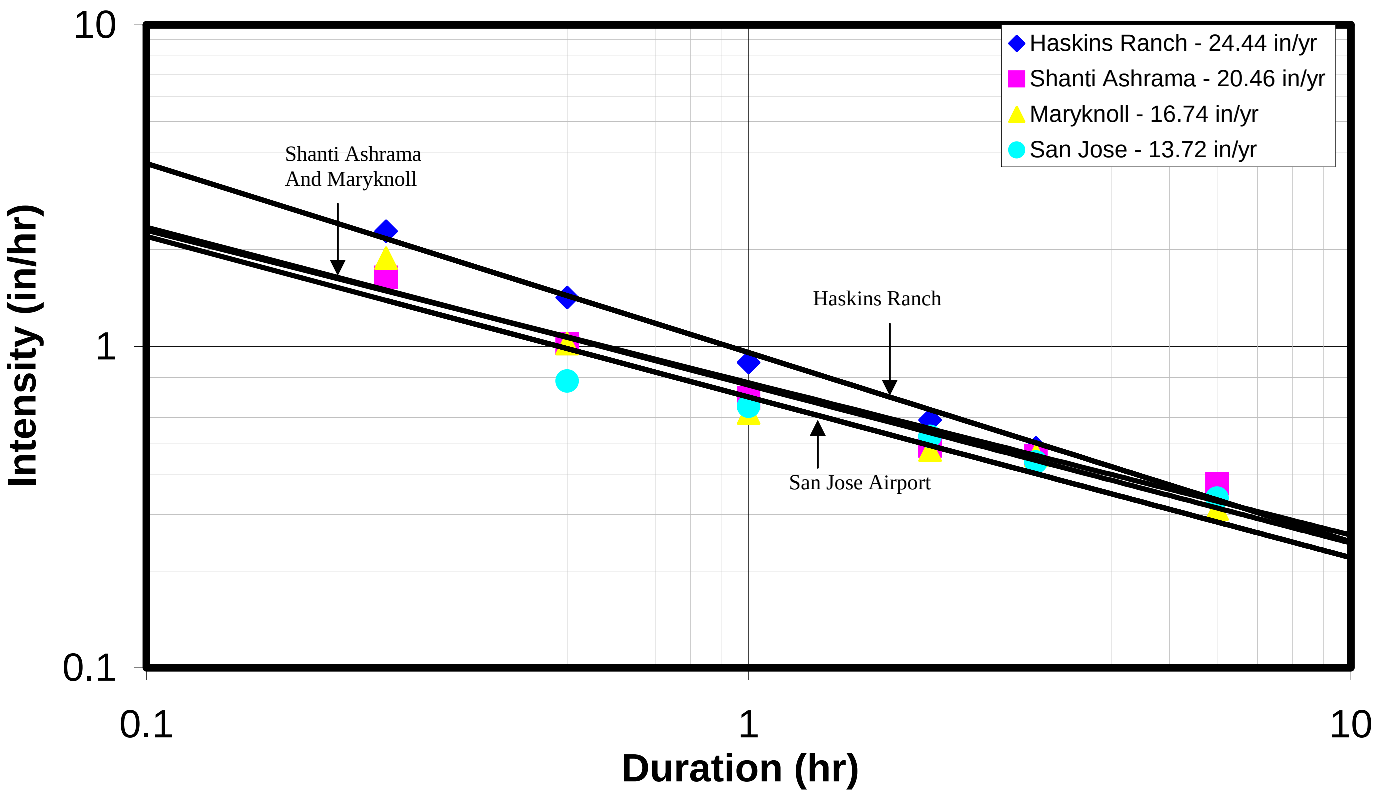

Figure 5 Intensity-Frequency-Duration Curves for a 50-Year Return Period for Haskins Ranch, Shanti Ashrama, Maryknoll, and San Jose Airport Rain Gages

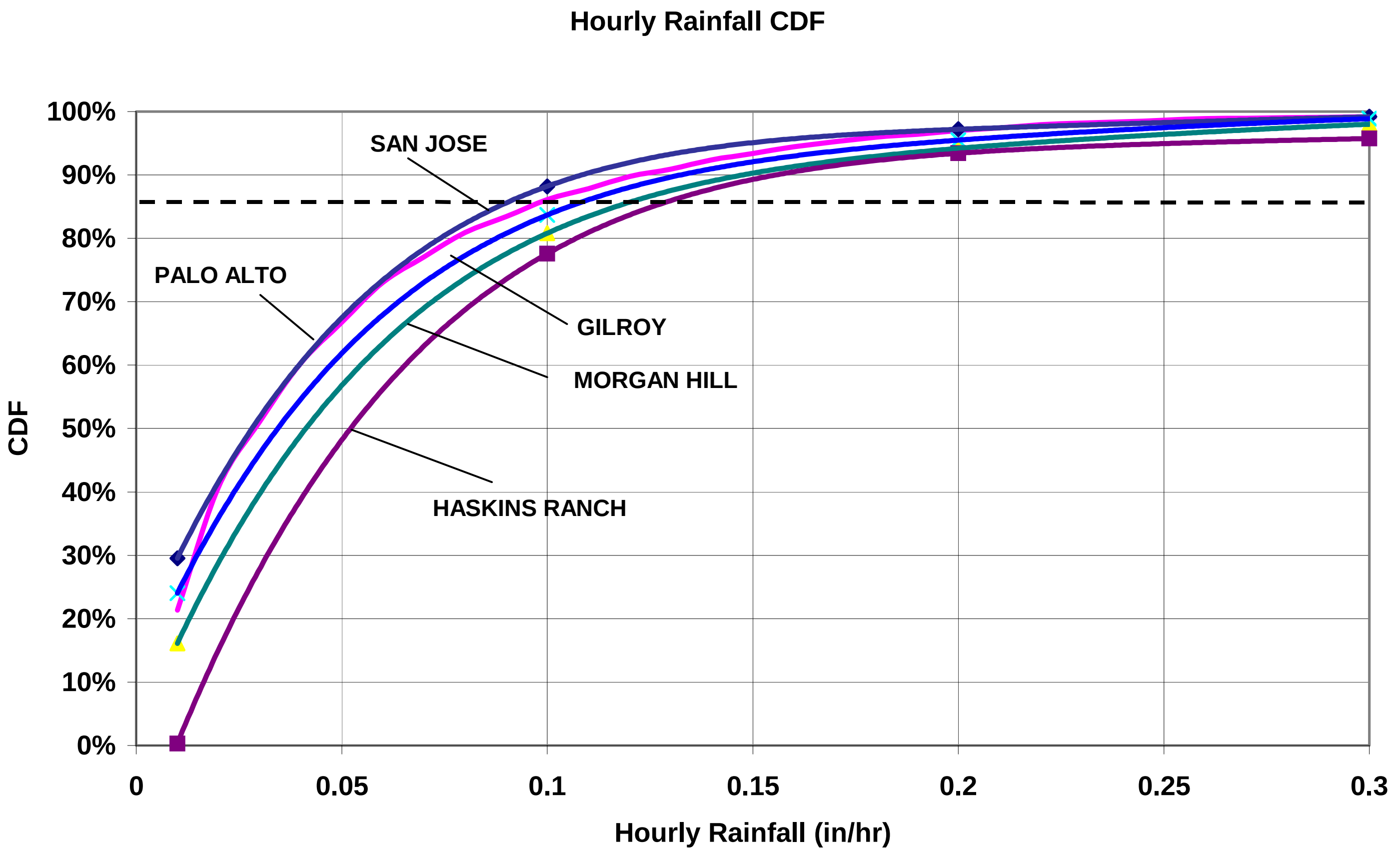

Figure 6 “Smoothed” Cumulative Distribution Function (CDF) Plots of Hourly Rainfall Intensity