DESIGN HYDROLOGY MANUAL

VENTURA COUNTY WATERSHED PROTECTION DISTRICT

VENTURA COUNTY, CALIFORNIA

UPDATED JULY, 2017

UPDATED DECEMBER, 2010

UPDATED DECEMBER, 2006

REPRINTED 1991

REPRINTED 1985

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Appendix F ERRATA F-1

ac.	Acres
ASCE	American Society of Civil Engineers
cfs	Cubic feet per second
cy	cubic yards
District	Ventura County Watershed Protection District
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
fps	Feet per second
Ft	Feet
HEC	USACE Hydrologic Engineering Center
HEC-HMS	Hydrologic Modeling System
HEC-RAS	River Analysis System
HSPF	Hydrologic Simulation Program- Fortran
in.	Inches
mg/l	milligrams/liter
mi.	Miles
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
SCS	Soil Conservation Service
sq. mi.	Square miles
Tc	Time of Concentration
USACE	U.S. Army Corps of Engineers
USBR	U. S. Bureau of Reclamation
USGS	U. S. Geological Survey
VCRat	Ventura County Modified Rational Method Model
VCWPD	Ventura County Watershed Protection District
Vw	Wave velocity

SECTION 1 INTRODUCTION

1.1 PURPOSE AND SCOPE

The intent of this manual is to present guidelines and sufficient input data for computing design hydrology in Ventura County (see Figure 1). The methods should be used for projects subject to Ventura County Watershed Protection District (District) requirements. Input data and design procedures are intended to be sufficiently flexible that the methods can be adopted for use by all agencies and engineering consultants engaged in the design of flood control works throughout the county. The methods can be used on all small, intermediate, and large size watersheds under various conditions of development. The methods are used in computer programs such as the District's VCRat program, the U.S. Army Corps of Engineers (USACE) HEC-HMS program, the Environmental Protection Agency's (EPA) Hydrologic Simulation Program – FORTRAN (HSPF) model, and the USACE HEC-SSP implementation of the Bulletin 17B method for flood flow frequency analyses.

The majority of watersheds considered in the flood protection program of cities, subdivision engineering, and the District's jurisdictional facilities generally range in size from a few acres up to about five to ten square miles. Projected development in those watersheds ranges from complete urbanization to urbanization interspersed with parks and open space land. Runoff conveyances consist of streets, pipes, concrete channels, and channels in their natural condition. For the analysis of design hydrology for small to intermediate size watersheds up to 5,000 acres (ac.) with urbanized areas, the flexibility and simplicity of the modified rational method (MRM) is useful for obtaining design peak flows and hydrographs. For intermediate to large size undeveloped watersheds, the District has developed unit-hydrographs and corresponding S-Graphs for use with the HEC-HMS program. For developed watersheds of any size, the EPA's HSPF continuous simulation model can be used in conjunction with design storm rainfall and provides the ability to model erosion, sediment scour, and water quality parameters. If stream gage data exist, those can be used to develop flow frequency analysis results for design following Bulletin 17B (USGS, 1982). The results can also be used to calibrate the above hydrology runoff models.

When appropriate, the District will use other methods in the formulation of project hydrology, especially if those methods are used in analyses of the large river systems of the county in conjunction with Federal agencies. The recommended approach in each case will be determined by the availability and expected reliability of necessary input data. Considerable engineering judgment will be necessary in formulating project hydrology for watersheds of approximately 5,000 acres or more to ensure that peak flows computed by the various appropriate methods are consistent and compatible.

Project design in the vicinity of watersheds with a high wildfire and erosion potential may need to consider the effect of debris bulking on peak flows. Techniques for bulking peak flows in Ventura County have been developed and are applied on a case-by-case basis. The District will determine the need for debris bulking and specify appropriate procedures in all cases.

Although it is anticipated that the overall approach described in this manual will not significantly change, any hydrologic process should be considered a dynamic process and subject to periodic refinement as additional input data become available. Techniques described in this manual will be continuously reviewed and updated, as necessary, to provide a thorough and complete package for hydrologic design.

1.2 ACKNOWLEDGMENT

The modified rational method presented in this manual for computing peaks and runoff hydrographs was developed by the Los Angeles Department of Public Works (formerly known as the Los Angeles County Flood Control District) over the past 50 years and is recommended by them for use in Los Angeles County. It has been adapted for use in Ventura County by the Hydrology Section of the Ventura County Watershed Protection District.

The District gratefully acknowledges the very generous cooperation of the then-named Los Angeles County Flood Control District in assisting with the development of necessary input data for adapting their method for use in Ventura County. Velocity-discharge relationships for natural channels, slope correction factors, and wave velocity relationships used in this manual were supplied by their staff. The computer program presented in this manual was supplied by them and originally adapted for use on the IBM 370 and Control Data Corporation 6600 computers, and currently for use on PCs.

Many of the procedures and data contained in this document were developed and refined under the direction of the longtime Hydrology Section Manager, Dolores Taylor, PE. She has been indispensable in training many of the engineers and hydrologists that have worked for the District in these techniques.

1.3 REPRINTS, REVISIONS, AND UPDATES

In August 1978, the first reprinting of the Hydrology Manual was done. Because of recent interest in 100-year peak flow rates, and the need for more guidelines in estimating overland flow velocities for computing times of concentration, certain additions were incorporated in the manual at that time. A plate was added to include intensity-duration curves for the 100-year storm event. A new plate, Exhibit 8, was added which shows suggested minimum overland flow velocities for use in consistently estimating time of concentration throughout a study area and from watershed to watershed. Appropriate revisions were made to each section in the text to support the added information.

In a previous Manual update (2006), the following procedures were updated:

1. The District's VCRat2.2 computer program was modified to create a more user-friendly Windows version (VCRat 2.5, updated into 2.6). The program still includes all of the specialized operations available in VCRat2.2 except areal reduction so that previous VCRat input files can be imported and yield the same results.
2. A Tc Calculator program has been developed to facilitate Tc calculations for the modified rational method program. Because the programs requires less time to calculate Tc's the number of required subareas with calculated Tc's has been increased to 75 percent of developed areas and 25 percent of undeveloped areas as described in Section Five.
3. Information and procedures for adjusting the hydrograph volumes to match the yield predicted by the SCS Curve Number method for the watershed have been added. This information is intended for use in designing detention facilities for developments receiving runoff from tributary areas less than one sq. mi. in size. The data required for use in the yield adjustment are provided in Appendix A.
4. The program requirements for performing areal reduction simulations are discussed.

5. The recommended effective imperviousness percents for use in hydrology analyses have been expanded to cover more land uses and reflect current construction techniques that lead to less pervious area in the watershed.

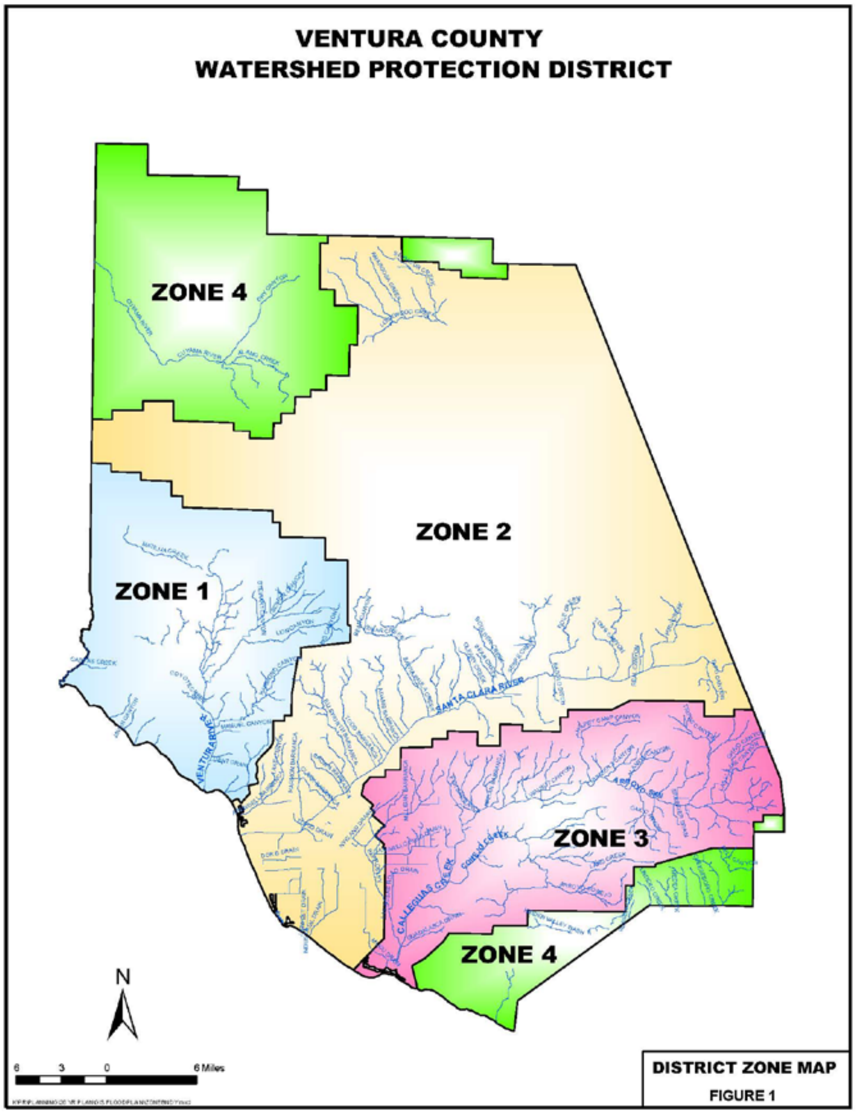


FIGURE 1

The 2010 Manual update provided the following additional information:

1. Design procedures using HSPF.
2. Design procedures using HEC-HMS.
3. Flow frequency analysis procedures and references.
4. Detention basin design procedures.

5. Simplified detention basin design procedures for small project areas.
6. Revised Curve Numbers (Exhibits 14a and b) for use in yield assessments
7. Areal reduction run procedures using VCRat2.2
8. Bulking factor information

The current update contains the following information:

1. The Zonal Rainfall concept used in the VCRat model has been updated to include 31 zones representing design rainfall variations across the County.
2. The C coefficients used in the VCRat model have been revised to show less runoff in pervious areas. This provides more reasonable peaks for larger watersheds with undeveloped areas than previous model results.
3. The regional skew coefficients used in flow frequency analyses of stream gage data have been updated to reflect the information in the USGS WRI report SIR2010-5260.
4. The VCRat program has been updated to run on 64-bit Windows computers (VCRat2.64).
5. The VCRat2.64 model can now use the legacy rainfall zones and C coefficients or the updated rainfall zones and C coefficients.
6. Spreadsheets have been developed to do Tc calculations and calculate a runoff hydrograph from one subarea and route it through a flow-through detention basin. The runoff spreadsheet also estimates the required size for a bypass detention basin.
7. A procedure has been developed to apportion the design sediment volume calculated with the District's methods to a clear water hydrograph, which results in a bulking factor to be used for design of channels and facilities. Spreadsheets have been developed to do this for VCRat hydrographs.

SECTION 2 DESIGN HYDROLOGY SUMMARY

The hydrology methods presented in this Manual yield peak flows and hydrographs that can be used for facility design or to show the impacts of proposed improvement projects. This section presents general information about the District models and their calibration and use in design studies. The historical data and studies referenced in this section can be downloaded from the District's website at http:/www.vcwatershed.org/. The information is provided in one of more of three locations: 1) The downloads section of the website; 2) The webpage listing models and studies for an individual watershed; and 3) The webpage for a major project in a watershed.

2.1 DESIGN HYDROLOGY MODELS

2.1.1 Modified Rational Method

The modified rational method (MRM) is appropriate for modeling partially- to fully-developed urbanized catchments of up to about 5,000 ac. It has been used on larger catchments in the past but those efforts required calibration of the model to stream gage analysis results. Given the other tools currently used by the District for larger watersheds, the MRM is not expected to be used on large watersheds in the future. The MRM requires intensive effort to digitize boundaries and calculate Tc's for the relatively numerous subareas.

The MRM provides a hydrograph characterized by a relatively sharp and narrow peak, and generally the yield under the hydrograph is less than would be expected from a NRCS yield evaluation using Curve Numbers. Therefore, the MRM program hydrographs cannot be used for detention basin design without being adjusted for yield- a process the District refers to as "fattening". For hydrographs from large watersheds, the District has developed special methods using HEC-HMS to provide design hydrographs as discussed later in this document.

The District has prepared MRM models for many of the developed areas of the County and generally has model results available by request. Some of the models were developed years ago and require updating of their outdated land use assumptions. Availability of the models can be checked by sending a data request to the District's hydrologic data request email at: Hydrodata@ventura.org.

The most ambitious study using the MRM was the preparation of 2000 and 2020 condition hydrology models of the 250 sq. mi. Calleguas Creek Watershed. Each model contains about 5,000 subareas. The hydrology supported the FEMA Flood Insurance Study (FIS) update for that watershed and the report and the model results are available on the District's website. The 2000 Condition Model was finalized and is considered official while the Future Condition Model has not been finalized and is still considered draft.

The MRM has a scale effect so the Tc used in the model is limited to range from 5 to 30 minutes, with subarea sizes of 20 to 80 acres recommended. If numerous very small subareas are used with 5-min Tc's to represent a development, a relatively high peak can result. Therefore, if a model is prepared with numerous small subareas to design local drainage for a development the results should not be submitted to the District for evaluation of the impacts to the District's jurisdictional facilities ("Redline" Channels).

The VCRat program has now been revised to run on 64-bit computers using Windows 7 and 10 operating systems. The implementation of the revised C coefficients and numerous rainfall zones in the updated

VCRat2.64 program means that the program could provide different results for design. The updated program is also able to run VCRat2.2 and 2.6 files.

2.2 HSPF MODELING

For developed and undeveloped watersheds of any size, the EPA's HSPF continuous simulation model can be used in conjunction with design storm rainfall to produce design storm peaks that also have reasonable yields. The District has generally used it to model watersheds on a regional scale. HSPF is a comprehensive watershed model of hydrology and water quality that includes modeling of both land surface and subsurface hydrologic and water quality processes, linked and closely integrated with corresponding stream and reservoir processes. HSPF has enjoyed widespread usage and acceptance, since its initial release in 1980, as demonstrated through hundreds of applications across the U.S. and abroad. HSPF is the primary watershed model included in the EPA BASINS modeling system and it has been incorporated into the U.S. Army Corps of Engineers Watershed Modeling System.

Subsequent sections in this Manual discuss topics relevant to using HSPF for design storm model such as preparation of design storm rainfall hyetographs, selection of modeling period to reflect antecedent moisture conditions for design storms, and undeveloped channel routing effects inherent in the program. Because HSPF is a more complex hydrologic model than the MRM, care must be taken in preparing and running the design storm model. However, good results and agreement with stream gage frequency results have been obtained for the Santa Clara Watershed (AQUA TERRA, 2009), and the Ventura River Watershed (Tetra Tech 2009 and VCWPD, 2010). A project to obtain design storm results for the Calleguas Creek Watershed Model was completed in 2012.

Many of the catchments in the three watersheds been evaluated in those regional models and the results are contained in the reports posted on the District's website in the pages for each watershed. These results can be used for design purposes. If detailed modeling results are required, the HSPF model can be refined appropriately.

2.3 HEC-HMS MODELING

For intermediate to large undeveloped watersheds, the District has developed unit-hydrographs and their associated S-Graphs for use with the HEC-HMS model. A District study (VCWPD, 2007, Draft) calibrated the unit hydrograph with a number of undeveloped watersheds using runoff data from the 2005 storms. Those storms had recurrence intervals ranging from 10- to 50-yrs depending on the location. The resulting unit hydrographs were then averaged into final unit hydrographs that can be used for undeveloped watersheds across the county. The method includes the use of the Snyder Unit Hydrograph, the USACE lag equation, and a uniform and constant loss approach so that the hydrograph yield matches that obtained through a NRCS Curve Number yield approach. Through this methodology, the District was able to create design storm models with peaks matching stream gage frequency analysis results within 10% or better for most of the gages included in the study.

USACE (2003) prepared a regional HMS model of the Calleguas watershed in support of the FEMA FIS update for that basin and to confirm the MRM results used in the FIS. This model presented results for the natural, existing, and future conditions and has been used for various studies in the watershed. The model used an S-Graph developed for Sespe Creek and design storm hyetographs using the alternating block technique. The resultant hydrographs are very peaky, similar to MRM hydrographs, and generally have yields that are much less than would be expected based on NRCS Curve Number yield analyses for the watersheds. Therefore, the hydrographs should not be used for hydrology and floodplain mapping studies requiring accurate volumetric hydrographs. The model did not explicitly include urban hydraulic constraints and required the use of the standard areal reduction factors and also a runoff calibration factor to match the peaks provided by the stream gage frequency analyses published in the USACE report.

2.4 2-D Modeling

Several 2-D hydrologic/hydraulic models have been developed for County watersheds using FLO-2D and TUFLOW. The modeled watersheds include the J Street (now Tsumas) Drain, the Franklin-Sudden-Brown-Clarke Barrancas, Arundell Barranca, and pilot areas in Simi Valley (City of Simi Valley Project). For the first 3 projects, other hydrology models were used to develop design flows that were used as input to the hydraulic portion of the FLO-2D program. If the hydrologic portions of the models are to be used, it will be important to use historic rainfall and stream gage data for model calibration. FEMA requires the 2-D models to be calibrated using high water mark data from historical storms when submitting the 2-D results for floodplain mapping. The District expects to take a similar approach when reviewing the results of 2-D models for CEQA and permit application purposes.

2.5 Stream Gage Flow Frequency Analyses

If stream gage data exist near a project site, those can be used to develop flow frequency analysis results for use in design following Bulletin 17B (USGS, 1982). The stream data can also be used to calibrate the hydrograph volumes. The resultant hydrographs and peak can then be used to calibrate hydrology models or for design of regional facilities. The District (VCWPD, 2007) has prepared a draft report that summarizes the frequency results and describes the methodologies used to provide the results for the stream gages operated by the USGS and VCWPD in Ventura County. The regional skew factors used in these analyses were updated by the USGS (2011) as presented in the District's 2013 report on proposed hydrology method updates. These reports can be obtained from the District upon request. The methodologies include the following:

1. Bulletin 17B (USGS, 1982) analyses of stream gages performed by the VCWPD on various stream gages using the regional skews updated by the USGS in 2011
2. U. S. Bureau of Reclamation (USACE, 2005) top-fitting of the seven highest historic peaks on the Ventura River to obtain design peaks flows for the two gages on the Ventura River mainstem. The topfitting model was used because the log Pearson III statistical model does not fit the data from the regulated watershed adequately. The USBR used historic hydrology modeling results to provide estimated flows at other intermediate locations between the two gages.
3. USACE (2003) graphical frequency analyses of the Calleguas Creek watershed stream gages that used engineering judgment and review of all of the Calleguas Creek stream gage data to plot of family of curves to obtain the design storm peaks.
4. The USGS is currently updating the Bulletin 17B method and is in the final stages of developing a Bulletin 17C report using the Expected Moment Algorithm (EMA) method. When finalized, the District will update the frequency values to use the EMA program embedded in the USGS's PeakFQ program. The methodology has also been added to the USCOE's HEC-SSP program.

2.6 WATERSHED MODEL SUMMARIES

Most of the official model results discussed in the following sections are available for download at the District's website. Unofficial model results are available through requests sent to HydroData@ventura.org.

2.6.1 Ventura River Models

The 2005 Condition HSPF Continuous model of the Ventura River watershed developed by Tetra Tech (2009) under contract to the District is the best source of design peak data for this watershed for subareas studied by FEMA. Model results have been used to provide design storm peaks after calibration with stream gage data and comparison to other hydrology model results. The peaks were provided to FEMA for their FIS study for many of the tributaries along the river. The model was also calibrated to match the mainstem 100-yr peaks provided to FEMA based on a stream gage frequency analyses done by the USBR. The model results were used in a FLO-2D model of the East Ojai area to revise the FEMA floodplain.

A recent VCRat study of Dent Drain using the criteria outlined in the District's 2006 Hydrology Manual is considered to be a good source of intermediate flows for that watershed. Design peak data for a number of subareas in the San Antonio River watershed are available from the VCRat model developed in the 1990s for intermediate flows. The VCRat model results were compared to the HSPF model results at coincident points during the HSPF model calibration and are considered to be secondary to the HSPF model results.

Various historical VCRat models of individual subareas in this watershed generally do not reflect current land uses or have sufficient backup information to consider them to be official model results and should not be used for design peak info without being updated using current criteria. A future conditions model of the Ventura River watershed is not available and there are currently no plans to develop one.

The District uses a HEC-1 model to forecast flow peaks due to predicted rain conditions and has recently converted the HSPF model of the watershed for the same purpose. It was tested during the 2009-2010 water year and has been used for forecasting in subsequent years.

2.6.2 Santa Clara River Models

The 2003 Condition HSPF Continuous model of the Santa Clara River watershed (Aqua Terra, 2009) is the best source of design peak data for this watershed. Model results have been used to provide design storm peaks after calibration with stream gage data and comparison to other hydrology model results. The peaks were provided to FEMA for their Flood Insurance Study for 5 of the streams. The peaks from most of the other major tributaries along the river were provided to the COE for additional floodplain mapping as part of the feasibility study. The model was also calibrated to match the mainstem 100-yr peaks provided to FEMA based on a stream gage frequency analysis done by the District in 2006. For the streams included in the HSPF report, this model is the source of the best design peak information for watersheds along the river.

Other available models for the Santa Clara River watershed include various historical VCRat, HEC-1, HEC-HMS, and COE models of individual watersheds that generally do not reflect current land uses or have sufficient backup information for them to be considered official model results. The results from these models should not be used unless they are updated according to the District's current criteria.

The District uses a HEC-1 model to forecast flow peaks due to predicted rain conditions and converted the HSPF model of the watershed for the same purpose during the fall of 2010. It has been used for forecasting in subsequent years.

2.6.3 Calleguas Creek Models

A HEC-HMS model of the watershed developed by the COE with regional-scale subareas providing natural, 2000, and 2050 condition design peaks for the watershed is considered to be the best source of regional-scale peak information for design studies. The model was calibrated for peaks only and does not have sufficient volume in the hydrographs to be used for studies requiring accurate volumetric data.

A VCRat model of the watershed representing 2000 conditions land use is considered to be the second best source of design peak data and also can provide intermediate peaks for smaller subareas. The hydrograph volumes are too low to be used for volumetric studies without yield adjustment following the District's methods.

Draft future condition peaks can be obtained from two additional VCRat models representing 2020 conditions developed in 2005, with one model using the channel routing assumptions from the 2000 conditions model (without project) and the other assuming that known hydraulic constrictions in the watershed were fixed (with project). These models were never made official and outside review by a consultant showed that a number of issues related to the ways that future conditions were represented in the model limited their usefulness for providing peak flows for design studies. Use of the peak information for project evaluation should be discussed with the District on a case-by-case basis. The model hydrographs cannot be used for volumetric studies unless adjusted as discussed for the 2000 condition model.

An HSPF model of the watershed providing design storm peaks has been developed. The model evaluates urban storage effects on peak flows as this is an important issue for the communities that are part of the Calleguas Creek watershed.

The District uses a HEC-1 model to forecast flow peaks due to predicted rain conditions and has converting the HSPF model of the watershed for the same purpose in 2011. It has been used for forecasting in subsequent years.

2.7 MODEL CALIBRATION

For watersheds with stream gages, each hydrology model should be calibrated to the stream gage data, including flow frequency analysis results for design storm models and continuous data if it is a continuous model. The daily stream gage data for Ventura County are available from the District's website. For high resolution stream gage data at the 5-min level, files can be requested from the District. Some gages are operated by the USGS and the data are officially published by them. The District generally has copies of those data sets for use in our studies and will provide those to requestors. If the user wishes to obtain the USGS data sets they can be obtained from their website or by contacting them directly for high-resolution data.

For ungaged watersheds, design peak results from different models should be considered similar and adequate if they are within 5%. Because HSPF and HMS models of the District's watersheds developed so far tend to represent large watersheds with relatively few subareas, they are considered to be regional models. Calibration of ungaged watersheds in models is done by comparing the results to the following sources in order of preference subject to availability:

1. Stream gage results from gaged watersheds with similar characteristics.
2. Other model results for the same watershed,
3. Other model results from watersheds of similar size and hydrologic characteristics, and
4. Available USGS regression equations peaks.

For calibration of hydrograph volumes the NRCS Curve Number yields should be calculated and the hydrographs adjusted to match those values.

Due to the use of VCRat in many studies and channel design projects that have been found to perform well over time, VCRat model results for watersheds less than 5,000 ac are considered calibrated without any adjustment to the input parameters. The VCRat results should be checked against other models and stream gage frequency analysis peaks where available.

2.7.1 Urban Storage Effects

In developed watersheds where hydraulic constraints exist, the model results must be evaluated carefully before being used for design. This is especially important for models representing developed areas where culvert inlets are often designed for the 10-yr storm peak and any flow above that level is expected to be contained in the streets and be delayed in discharging to one of the District's jurisdictional facilities. Typical urban area models developed by the District represent theoretical peak flow results in that system storage is not modeled explicitly. For these results, it is the responsibility of the hydraulic engineer to evaluate system hydraulic constraints and adjust peaks and hydrographs provided by the hydrologist accordingly. In the limited cases where the hydrology model simulates explicit hydraulic constraints, the hydrology cannot be used to show the resultant flow once the system has been improved. If this is required, then the hydrologist should prepare two models, one representing pre-project conditions, and one showing post-project conditions.

At this time urban channel deficiencies are rarely represented in the District's hydrology models. At a very limited number of locations flow splits caused by hydraulic constrictions in the District's channels have been included in models such as the Tapo Canyon channel in the VCRat model of the Calleguas watershed and one location in the Oxnard Industrial Drain VCRat model. The urbanized watersheds in the Ventura River HSPF model were calibrated so that the peak matched the stream gage results, which required the adjustment of the stage-storage-discharge data for each channel to represent storage above the 10-yr level. This approach was also used in extending and calibrating the Calleguas HSPF model.

SECTION 3 MODIFIED RATIONAL METHOD AND VCRAT

The MRM is based on the rational equation that has been widely accepted for use in the design of flood protection measures. It is relatively simple, is in wide use, and has been found to provide reasonable results for project design. The basic equation is:

$Q = CIA$

where:

Q	=	Peak discharge in cubic feet per second (cfs).
C	=	Coefficient of runoff (dimensionless).
I	=	Average rainfall intensity for a duration equal to the time of concentration of the watershed (inches/hour).
A	=	Drainage area of the watershed (acres).

Dimensionally the equation is approximately homogeneous. Units of discharge are acre-inches per hour which converts to cubic feet per second with a conversion factor of 1.008. In view of the uncertainties associated with measurement of necessary input parameters, the conversion factor is usually ignored and flow rates are considered to be in units of cfs.

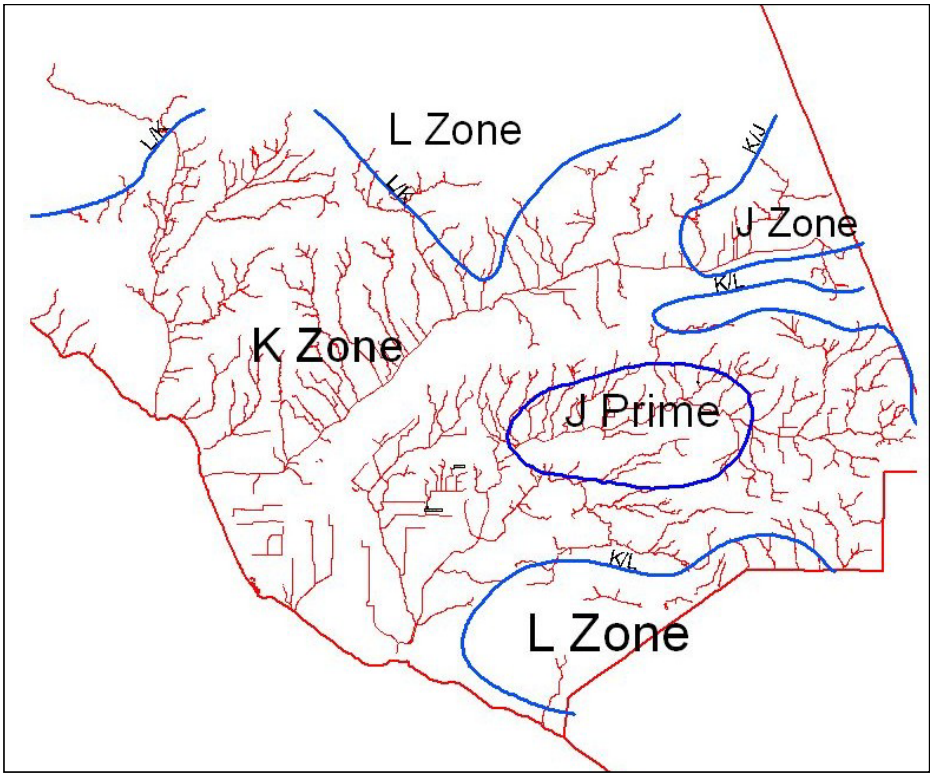
The rational equation is dependent upon the following basic assumptions: 1) The peak rate of runoff at any point in a subarea is a direct function of the average rainfall intensity during the time of concentration to that point; and 2), The time of concentration is the time required for runoff to become established and flow from the hydraulically-most-remote portion of the drainage area to the subarea outlet.

The method presented in this manual is based on input parameters developed specifically for soil types and rainfall characteristics in Ventura County. In addition to the watershed drainage area, input parameters for the rational equation include rainfall intensity-duration curves, runoff coefficient curves, and time of concentration. The rational equation has been enhanced through the use of rainfall mass curves so that a hydrograph is developed that can be routed downstream and combined with hydrographs from other subareas.

3.1 Rainfall Intensity-Duration

Most precipitation in the Ventura County developed areas results from general winter storms associated with extra-tropical cyclones that develop in the North Pacific during the months of November through April. Precipitation during these storms may occur over large areas and a major storm causing high flows and flooding can last four days or more. The first several days of the storm normally contain light, persistent rainfall of moderate intensities. Rainfall during this period satisfies the soil moisture deficiency. The latter portion of the storm is characterized by short periods of high rain intensities falling on saturated soils.

The rainfall data used in VCRat2.2 and 2.6 programs were developed using theoretical techniques proposed by the California Department of Water Resources. Intensity-duration-frequency relationships were computed for all long-term recording rain gage data in Ventura County. Frequency analyses used storm intensities for durations of 5, 10, 15, and 30 minutes, and for 1, 2, 3, 4, 5, 12, and 24 hours. From this analysis, intensity-duration curves were plotted for each gage for selected frequencies and similar curves from gages in similar rainfall regimes were averaged, resulting in a family of intensity-duration curves that were labeled J', J, K, and L. Using the 50-year, 24-hour isohyetal map of the county, and considering orographic influences, each curve was assigned to a specific area in the county. The curves are presented in this manual for the 100-, 50-, 25-, and 10-year events. The appropriate areas in the county for each curve are shown in the hydrology maps, Exhibit 1a through d and Appendix E maps. The intensities for the various design stormx and concentration times are listed in Exhibits 3 and 4.

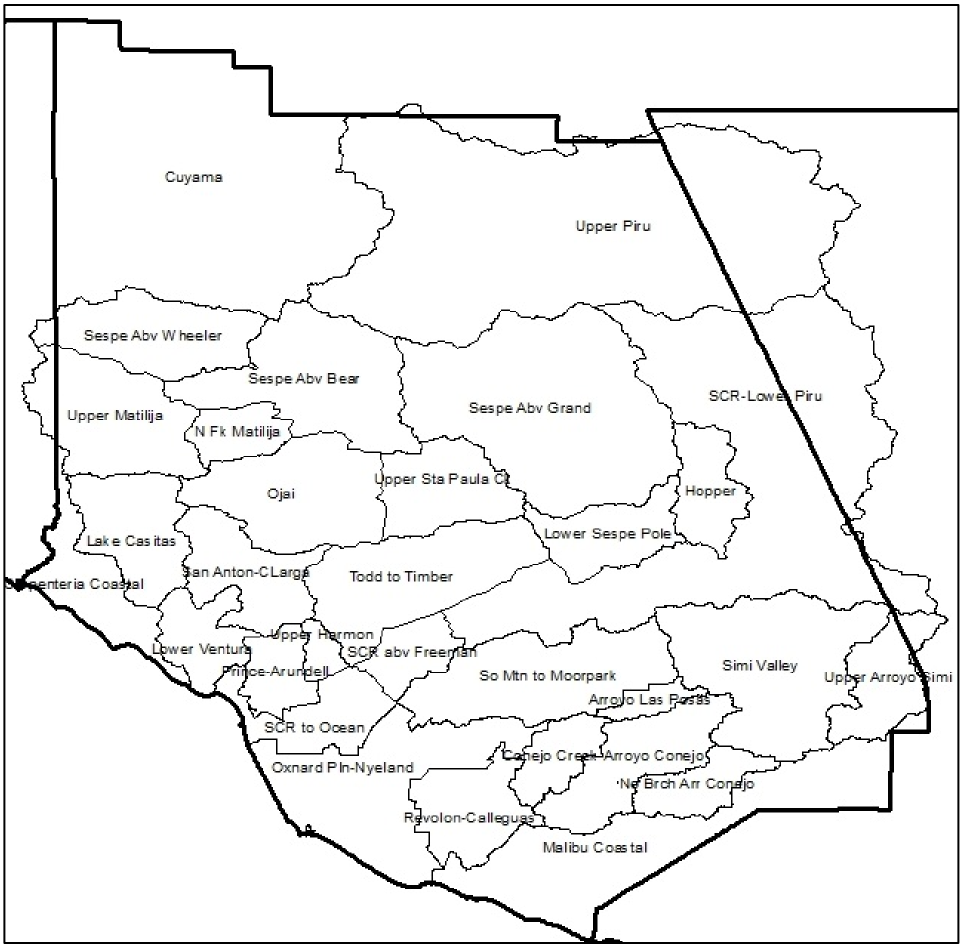


VCRat2.2 and 2.6 Rainfall Zone Map with VCWPD Jurisdictional (Redline) Channels

The intensity duration curves were originally used to developed 30-point mass curves for use in developing hydrographs in the modified rational method model. As more accuracy was needed in resolving the 100-yr peaks for design, a 200-pt mass curve was developed for each zone. The 100-yr mass curves are designed to produce 80% of the volume under the hydrograph at 80% of the hydrograph time (80/80) for the one-day simulations. This provided for a more conservative design of detention basins.

In 2011 the National Oceanographic and Atmospheric Administration (NOAA) presented the results of their analyses of California rain data, including data supplied from the District's rain gages. The availability of a rain data set covering the entire County and accounting for orographic effects and other factors was used to define multiple rain zones for hydrology modeling as shown below. The zones were defined by grouping areas with similar intensities according to watershed boundaries. Mass curves for the 10- 25-, 50-, and 100-yr design storms were developed using the 80/80 approach discussed above.

Most of the developed areas in the County that are studied with VCRat will now be represented primarily with one rain zone. Undeveloped areas with large topographic variations such as the Santa Clara River watersheds near Santa Paula may be represented by at least two rain zones.

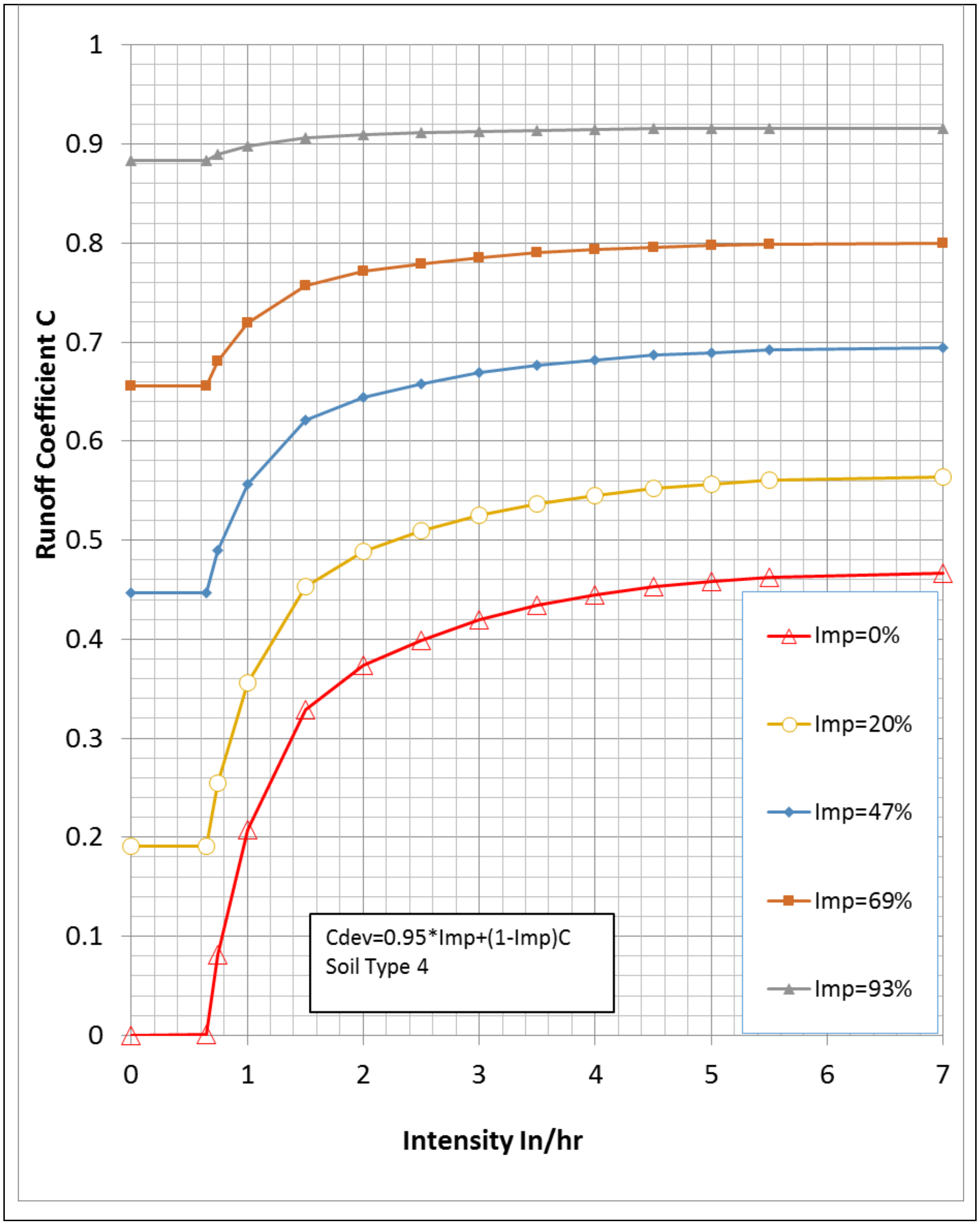


VCRat2.64 NOAA Rainfall Zone Map

3.2 RUNOFF COEFFICIENT CURVES

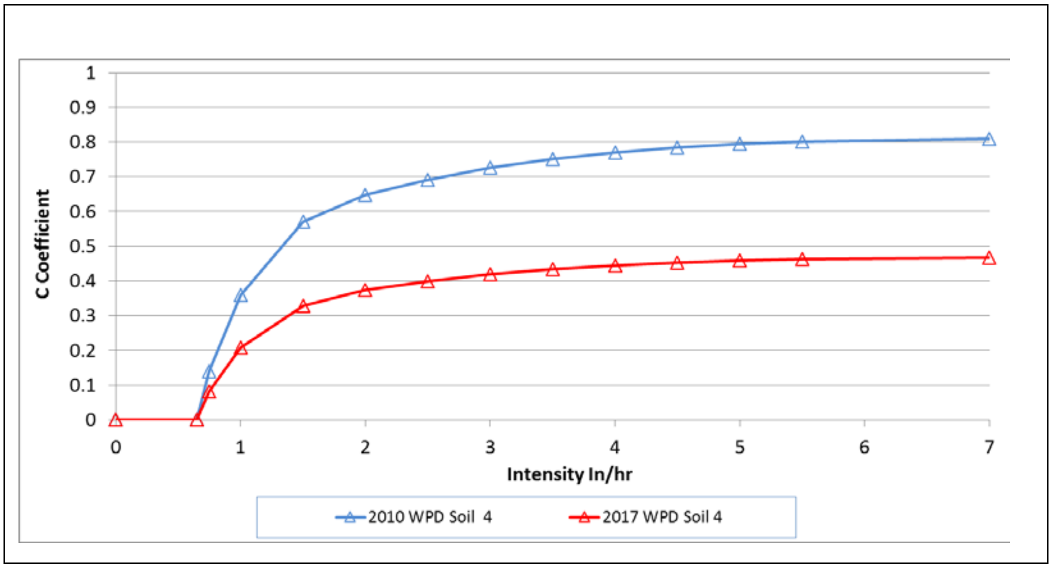
For each acre of drainage area, a runoff coefficient used in the rational equation represents the ratio of runoff to rainfall. It is the percentage of rainfall on a watershed that occurs as runoff and ranges from zero on very porous soils to 0.95 on impervious surfaces (where runoff is only limited due to depression storage and other abstractive losses). It includes the composite effect of such watershed variables as infiltration, ground slope, ground cover, surface and depression storage, antecedent precipitation and soil moisture, and shape of the drainage basin. Runoff is not a constant percentage of rainfall, but is the residual of rainfall remaining after losses. Losses increase as precipitation increases in minor storms, but the increase in losses is not proportional to the increase in rain. Therefore, the ratio of runoff to rainfall increases as storm intensity increases and in the method presented in this manual, the runoff coefficient is a function of intensity.

Using the Soil Survey completed by the SCS (now NRCS) of the U. S. Department of Agriculture in April 1970, soils in Ventura County were grouped into seven hydrologically homogeneous families. Two families were assigned to each SCS Hydrologic Soil Group A, B, and C; while only one family was assigned to SCS Hydrologic Soil Group D. In VCRat2.2 and 2.6, the upper and lower limits of the group of runoff coefficient curves for Ventura County were defined by considering a composite plot of all those developed by Los Angeles County Flood Control District using ring infiltrometer tests. Individual curves for undeveloped soils were determined theoretically by considering representative infiltration rates for various soil textures recommended by the SCS and the ASCE in their Hydrology Handbook. Some adjustment was necessary at high rainfall intensities to ensure a family of approximately parallel runoff coefficient curves.



Updated Runoff Coefficient Plot, Soil Type 4 (Exhibit 5d in Appendix A)

After publication of the 2010 Manual, the C coeffcients used in the VCRat models were compared to coefficients used across the United States in similar hydrology methods. The results showed that the District's C coefficients were generally higher for pervious areas than in most jurisdictions. A new set of C coefficients were developed based on data from other agencies. The change for soil type 4 is shown below. The maximum C coefficient for pervious areas with Soil Type 4 has changed from 0.81 in 2010 to 0.47 in VCRat2.64.



Historic and Updated Runoff Coefficient Comparison, Soil Type 4

For the 1992 Hydrology Manual, the hardcopy soil maps with their assigned VCWPD soil numbers were digitized so that they could be used in GIS analyses of the watersheds. Recent evaluation of those historic digital maps showed that the digitizing process resulted in some offset and skewing compared to the recent digital maps provided by the NRCS. Also, the historic maps did not cover the entire county and did not extend across County lines to provide coverage of watersheds located in both Counties. Therefore, as of 2010, the soils data was downloaded from the NRCS and a new digital soils map was developed for use in hydrology studies. The new soils GIS files are provided in Appendix E.

3.3 Time of Concentration

Time of concentration (Tc) is defined as the time required for runoff to travel from the hydraulically most distant point of a watershed to its outlet. It is a summation of the travel times associated with overland flow and concentrated flow in streets, pipes, and stream channels. Because of the complex flow paths associated with most watersheds, generalized charts and nomographs such as Kirpich are not considered adequate for computing travel times.

To determine time of concentration, the watershed is divided into contributing subareas using topographic barriers as well as streets, known improvement plans, and projected ultimate development. Ideally, the subarea size should range between 20 and 80 acres; however, the method can be used on smaller subareas providing the time of concentration is greater than five minutes. If the subarea of interest is too small to provide a Tc calculation greater than 5-minutes, a larger subarea should be evaluated and the discharge pro-rated based on the peak flow per unit area as described in Section Six. The upper limit on Tc is 30 minutes.

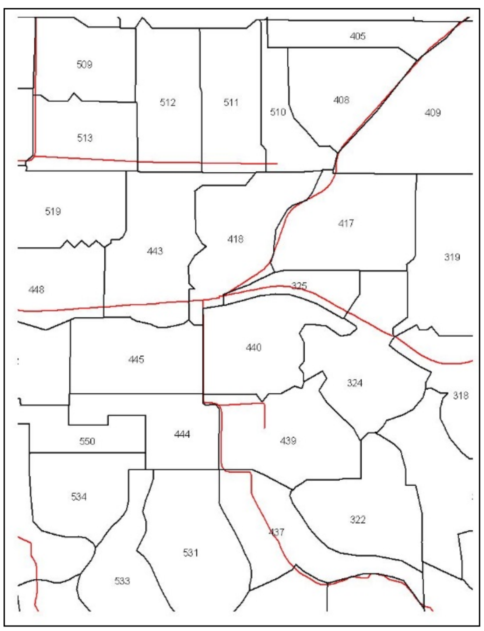
For any given subarea, the time of concentration must be computed by the method of successive approximations. For a given flow path and drainage area, the travel time is a function of the peak flow, which is itself a function of the rainfall intensity. Intensity is a function of the time of concentration. The proper approach for computing an appropriate time of concentration is discussed in more detail in below and demonstrated in Appendix B. Examples are also provided in the Tc Calculator Program Manual.

The rational equation computes an instantaneous flow rate based upon average rainfall intensity over a period equal to the time of concentration of a watershed. When the intensity is the maximum for a given storm, the associated flow rate represents the peak for that storm. When storm intensities that are less than the peak period intensity are used in the rational equation, the resulting flow rates represent some point on a theoretical storm hydrograph.

Every design storm is made up of a series of intensities that change more or less uniformly throughout. A mass curve of rainfall represents an accumulation of storm totals at any point in a storm and its slope at any point represents the rainfall intensity at that point. By determining intensities at representative times throughout a design storm, a runoff hydrograph can be generated using the rational equation.

Each of the intensity-duration curves used by VCWPD has an associated mass curve. The mass curves are included in the District's VCRat computer program and they are used to define intensities for all hydrographs developed by VCRat. Intensity tables may be used for hand computations of runoff hydrographs. A typical calculation is shown in Appendix B.

Once the runoff hydrograph is generated, additional subareas can be evaluated and added together using the timing information contained in the hydrographs. In this way the rational method can be extended for use in watersheds with numerous distinct subareas such is shown below. The use of the method to confluence the hydrographs from different subareas is known as the modified rational method.



Subareas with Node I.D.s and Channels in Calleguas VCRat Model

3.4 VCRAT GENERAL DESCRIPTION

The VCRat computer program performs a number of functions in implementing the modified rational method, such as subarea hydrograph generation, channel routing, basin routing, and subarea confluencing. First, the consistency of input data that may include runoff coefficient curves, rainfall mass curves, and subarea and hydrograph data input are verified. When errors are encountered, processing is terminated and error messages are printed. After the input data have been verified to have enough information to do a simulation, the program proceeds with specified hydrologic calculations.

3.4.1 Conceptual Model of Runoff

The conceptual model of flow from a multiple subarea model is as follows: first an outflow hydrograph is generated for the most upstream subarea. Next, that hydrograph is routed through the next downstream subarea using the channel information provided as input. Then the program calculates a hydrograph for the downstream subarea and combines it with the routed hydrograph from the upstream subarea. The combined hydrograph is then routed through the next downstream subarea and so on. Based on this conceptual model, the runoff from a subarea does not add to the water level or affect velocities in a channel going through that subarea.

VCRat does not have the capability to easily model hydraulic constraints in the drainage system such as 10-yr storm curb inlet limitations, or undersized drainage pipes detaining flow and attenuating peaks. Therefore, with limited exceptions model results provide peaks assuming that all of the flow in the watershed can be discharged to the outlet in adequately sized pipes. This allows the hydraulic engineer to adjust the hydrographs as necessary to reflect constraints and also show the impacts of improving the drainage system on the downstream peak.

3.4.2 Computation Summary

The required input data for a subarea consists of the area, Tc, soil type, percent imperviousness, and design storm type. Channel routing information can be added if appropriate. For a specified design storm, VCRat calculates a runoff hydrograph at all subarea collection points within the watershed, combines hydrographs from each subarea, and routes the combined hydrograph through the channel system. The hydrographs are calculated assuming the Tc associated with the peak does not vary with intensity changes in the rainfall mass curve. The program accounts for channel storage and reports peak flow rates in each reach of each drain, coincident flow rates of tributaries at confluence structures, and hydrographs at subarea collection points as specified in the program input data.

Options are available for the computation of hydrographs for a multiple day design storm to obtain the runoff volume data necessary for retention basin and pump plant design. Separation of flow at the junction of two drains may be made by either specifying a percentage split of the inflow hydrograph, or a split with all flow up to a specified discharge placed in one drain and the remaining flow placed in the other.

If the type and size of a drain are not specified, the system will automatically begin routing flow in a street section in the upper limits of a watershed; change from street to pipe section when flow depth reaches the property line (located at the development boundary of an assumed 10-ft wide sidewalk adjacent to the street); from pipe to rectangular channel when a pipe diameter of 8 feet is exceeded; and from the hydraulically most efficient rectangular section to a rectangular section with a maximum depth of 13 feet deep when the depth reaches 13 feet. Consistency of drain type and size are automatically maintained such that a drain does not decrease in size in a downstream direction and drain type will progress continuously from street to pipe to rectangular channel as necessary.

3.4.3 Program Requirements

The VCRat2.2 and 2.6 programs were written in FORTRAN and compiled to run on PCs with minimal memory and storage requirements. Program VCRat2.2 was generated by revising and linking together a number of historic FORTRAN modules with a Visual Basic interface to run a composite input data file combining subarea information with rainfall and infiltration data. Historic operations such as hydrograph "fattening" and routing that were performed with separate codes were combined in VCRat2.2 so that all of the operations could be done in one simulation. These options were incorporated in VCRat2.6, which replaced VCRat2.5.

VCRat2.6 was a more user-friendly version of the program, a Windows-compliant program developed using Visual Basic.Net. VCRat2.64 is an updated version of 2.6 compiled to work on 64-bit computers. Minimum requirements are Windows 7 or 10 operating systems. It has minimal memory and file storage requirements.

3.4.4 Computer Output

Typical computer input and output data shown in Appendix B includes appropriate subarea input data, subarea Q's, and confluence Q's. At specified confluence structures, storm times and coincident Q's at the peak in each tributary are listed, and the time of peak and combined Q leaving the confluence are shown. Typical printed outputs of hydrograph data are also shown in Appendix B. Hydrograph data in an output file may be exported to be used as input for future runs.

Because of the conceptual model of flow where the program shows the results for a subarea before routing is done, if the model has successive subarea input data lines the possible attenuation of the peak due to channel routing is often obscured by the addition of another subarea hydrograph to the channel flow. If the user would like to see the effects of channel routing on the peak, a placeholder node can be added after the subarea node of interest. The flow peak printed out in the cumulative output for the placeholder node will show the routing effects.

3.4.5 Limitations of Program

The following computations should be specified separately and cannot be combined with any other computation:

1. Add two hydrographs at a confluence (combined hydrograph can be routed downstream).
2. Read hydrograph data input.
3. Modify a hydrograph at a relief drain junction and transfer a portion of the flow to the other drain.

A maximum of 200 points during the standard 1,500-minute-long storm period may be used to define rainfall mass curves and these same points must be used to define a storm runoff hydrograph. Selected times in the following table for storm patterns J through L apply to the 100-yr hydrograph data points. Mass curves for smaller design storms only have 40 points.

100-Yr Hydrograph Discretization

Time Period Minutes	Point Spacing Minutes	Number of Points
0 - 1000	100	11
1000 - 1100	50	2
1100 - 1130	10	3
1130 - 1300	1	170
1300 - 1400	10	10
1400 - 1460	20	3
1460 - 1500	40	1
		Total 200

3.4.6 Areal Reduction Simulations

Areal reduction reduces the peak flows to reflect the fact that the storm cells yielding the maximum historic intensities in the design storm rainfall mass curves are limited in extent. In the VCRat method, any watershed greater than about 1 sq. mi. is considered to have spatially variable rainfall that will result in a reduced peak flow/area ratio compared to a smaller watershed with the same runoff characteristics. The VCRat2.2 program applies a reduction factor to the 100-yr mass curve intensities and runs the model to show the AR peak at one location of interest per run. If repeated for a number of locations, an AR curve can be developed that can be used to estimate the AR values for intermediate locations and nearby watersheds with similar characteristics.

In order to use VCRat for areal reduction simulations, the modeler must remove any fattening and basin routing operations from the VCRat2.2 input file. If a basin exists in a model where an areal reduction run is desired, the procedure is as follows:

1. Apply appropriate areal reduction factors and fattening to the flow entering the basin.
2. Export the resulting basin outflow hydrograph
3. At the node corresponding to the basin, delete the basin routing info, clear the hydrograph bank, and import the basin outflow hydrograph to that node.
4. The AR run will then proceed correctly once it is activated in Column 67 as described below.
5. Do not enter the area associated with the basin in the hydrograph import information. Since AR has already been applied to this area, to determine the correct AR factors below the basin the program should only use the net area at the specified location.

Because VCRat2.6 and 2.64 can run VCRat2.2 files, this capability can be exploited to do AR runs using the legacy curves and C coefficients. VCRat2.6 and 2.64 output contains the VCRat2.2 format input data at the end of the file. This VCRat2.2 file can be copied and edited to set up an AR input file. VCRat2.6 and 2.64 can export basin outflow hydrographs in VCRat2.2 format.

The rainfall mass curves used in the AR run must be the 200-pt A97, B98, and C99 100-yr storms or the T01 50-yr storm (similar to K zone 50-yr rainfall) for the areal reduction simulation. AR should only be done for watersheds with a cumulative area of 640 ac or greater (except below a basin as noted above). The AR factor for a watershed of 600 ac is assumed to be 1.0. Between 600 and 640 ac, the AR factor varies linearly with area up to the calculated value for an area of 640 ac. The way to turn on areal reduction using VCRat2.2 is do the following to the first 006 data input line:

```
        10        20        30        40        50       60         70
1234567890123456789012345678901234567890123456789012345678901234567890
006  8822    1A 040  0  7612B981 1550005940                   G1 7
```

The "1" in column 65 prints the heading at the top of the input file in the output file. In column 67 at node 1A, any number from 1 to 7 will perform Areal Reduction. In column 64, "G" clears the memory of all the hydrographs stored in the system (this is not required when only running a single model at a time). Areal reduction will occur with or without the column 64 command.

At the point where AR results are desired, areal reduction is specified for a VCRat2.2 model location on an A line by entering a "1" for AR in column 67. If AR is desired for a B line, a "2" is used in column 67. When this is done, for any proceeding node on the specified drainage line, including dummies and confluences, the program recognizes that areal reduction is needed and will use the embedded rainfall reduction factors in the VCRATP.for program to obtain an Areal Reduction Factor for Rain (ARr). The factor will be applied to the model rainfall mass curve to reduce the intensities for the subareas in the line of interest. For this example provided in Appendix B, areal reduction was set for node 30AB. The program ran normally until it reached node 30AB and recognized the command for areal reduction. VCRat2.2 then ran again with reduced rainfall rates to provide an areally reduced peak. The output then shows the non-AR and AR results for the model.

```
1234567890123456789012345678901234567890123456789012345678901234567890
006  8822   30AB030         B985 1050002630200   800         11   1035035
006  8822   31A 030 23  1608B98                             2
```

The AR factor for flow (ARq) is calculated as the areally-reduced flow/unareally-reduced flow or in this case 1,467/1,583=0.9267 for an 851 ac watershed (from Appendix B). Another characteristic of an AR run is that the flow values up to the point where AR has been specified (1 in col 67) cannot be used to calculate ARq values because the ARr value is only good at the specified node point. Also, the flow values after where AR was specified are not valid model results and cannot be used for design or in ARq calculations.

If a hydrograph is printed for the node where AR is requested, the reduction factor printed at the top of the hydrograph is the ARr value for the node location, not the ARq value. The ARq value has to be hand calculated from the model output. The depth-area-reduction curve used in the VCRat program is obtained from the 1967 Hydrology Manual (Source: USDA SCS Engineering Handbook, Supp. A 1964). The VCRat2.2 program can be obtained from the District's Hydrology Section.

If there is a need to do an AR run using VCRAT2.2 for J zone rainfall (copying VCRAT2.6's VCRAT2.2 input file), VCRAINJZ.DAT file provided in Appendix E should be used in the model run. AR curves developed for 100-yr models are applied to the peak flow results for other recurrence intervals such as the 5-, 10- 25-, and 50-yr storms. It is assumed that the AR factors do not vary with design storm recurrence interval. Additional info on areal reduction simulations is provided in Section 3.12.14.

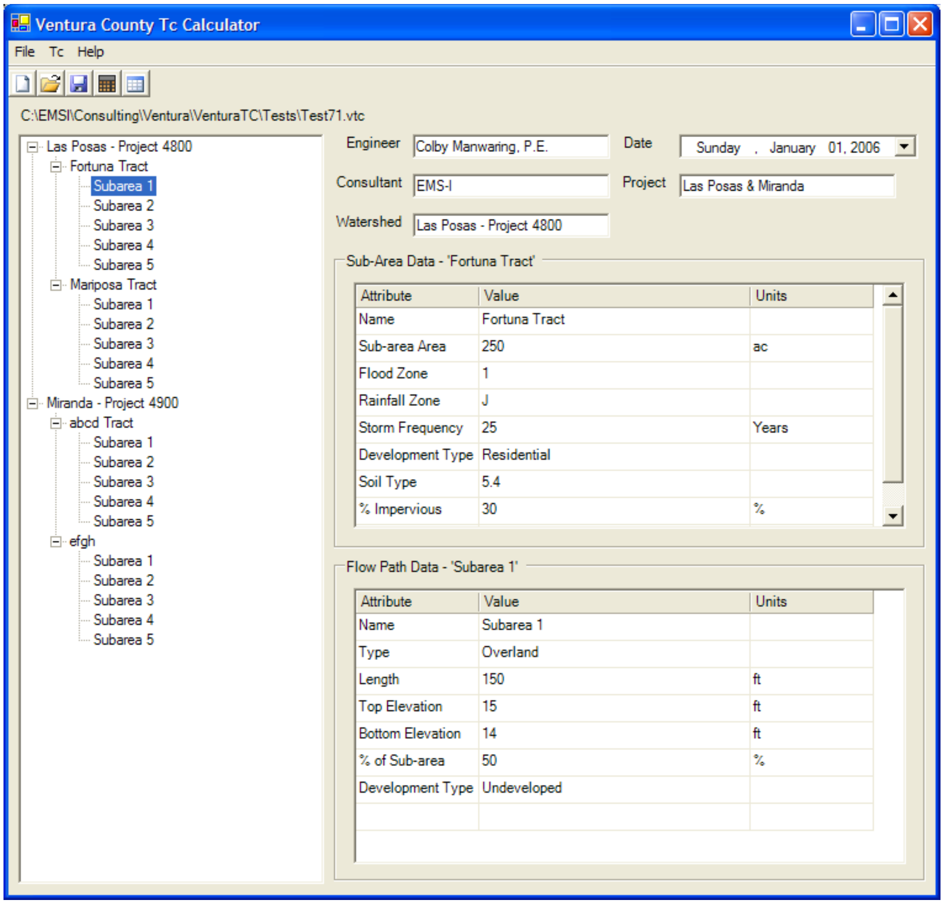
Recent testing with VCRat2.64 showed that some of the legacy files with data input lines that ended with slope data in position 41 (slope information can extend to position 43) were misinterpreted by the VCRat FORTRAN program after being recompiled with the 64-bit compiler. The fix to this is to add spaces to the data input lines with this problem to position 43 or more. It turns out that importing a VCRat2.2 file into VCRat2.64 and running it, produces an output file with the VCRat2.2 input file appended to the end. This VCRat2.2 input file has the required spaces in it.

3.5 TIME OF CONCENTRATION (TC) CALCULATIONS

The iterative hand calculations that were required to provide Tc data for the VCRat model were replaced in 2006 through the development of a Tc calculator program. The Tc calculator program was developed using Microsoft Visual Studio.NET 2003 and was written in Visual Basic programming language. The program was designed to run on Microsoft Windows 2000/XP with .NET Framework. The current program has not been revised to run on 64-bit machines with the NOAA rainfall mass curves. The program can be run on 64-bit and 32-bit machines with Windows 7 Pro which allows the establishment of a Virtual XP Mode using only the legacy rainfall mass curves.

The interface uses a data tree style of organizing the watershed with its sub-areas and flow-paths and is a user-friendly tool to facilitate hydrologic studies in Ventura County. A complete report describing the Tc Calculator methodology (EMSI, 2006) is provided with the VCRat2.6 program download.

The Tc Calculator program is a self-contained executable intended to be run from a folder on the local PC's harddrive after a simple installation process. It is not guaranteed to work if launched across a network. The following files are required for program execution: VenturaTc.exe – the program executable; and VCRAIN.DAT – data file containing soil and rainfall data compatible with VCRat2.6- available from the District's website. These two files may be placed in any folder on the local computer. The program is run by executing VenturaTc.exe (double-click this file or create a desktop shortcut that can be double-clicked).

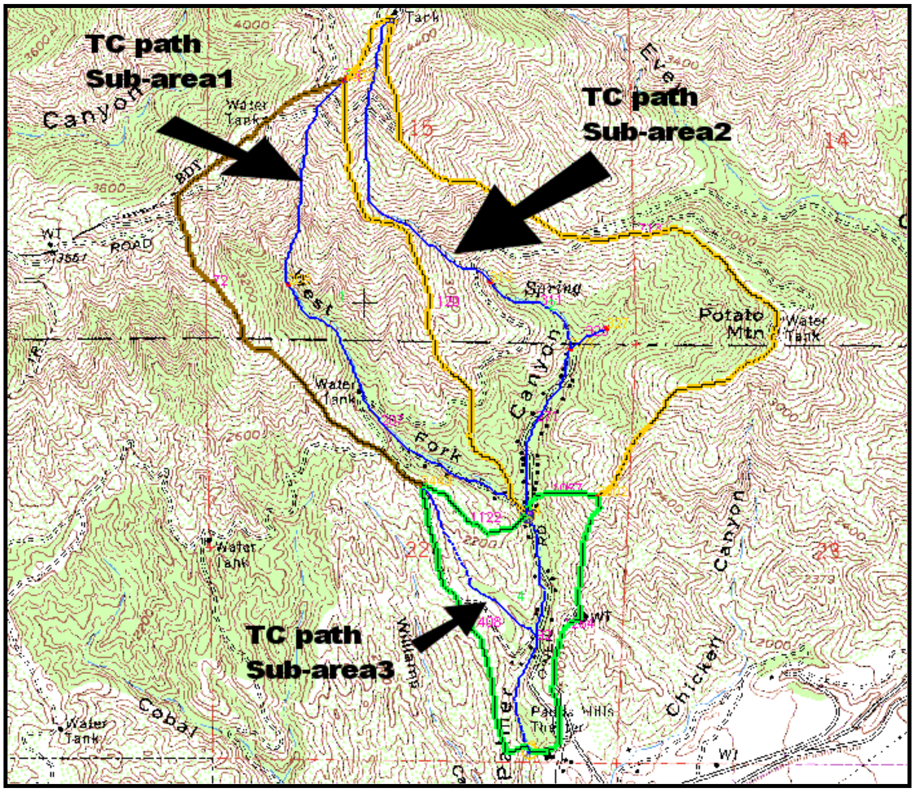


Sample Tc Calculation Window from Tc Calculator

3.5.1 Tc Calculation Methodology

Information about the watershed and its subareas is collected according to the guidance in this manual. It is then required that the subareas be subdivided into flow-path segments. These flow-paths are created according to the type of flow that exists or the proposed type of flow. After suitable data are collected and the subarea is divided into flow-paths, the calculation of a time of concentration is done. This process will be described briefly below along with a description of the preparatory work that is done to collect data. The process is described in more detail in the Tc Calculator Manual provided with the program.

Collection of data usually involves obtaining a representation of the terrain and creating a map of the watershed and subarea boundaries, sub-dividing the subareas into segments that contribute to each time of concentration flow-path.



Sub-areas with Tc flow-paths

As shown in the figure above, the longest flow-path in each subarea must be determined for Tc calculations. The flow-path in each subarea should be subdivided based on flow type (overland, natural channel, street, pipe, etc.) and the direct runoff area to each segment determined. This flow-path information and runoff data are the basics needed for the calculation of Tc with the Tc Calculator program.

Travel times are based on flow velocities associated with overland flow and flow in various watershed conveyance facilities modified by wave velocity considerations. Overland flow on a canyon side slope or undeveloped hillside is dependent upon slope, topography, cover conditions, and travel distance. Previous versions of this Manual did not provide a length limit on the overland flow-path used in the Tc calculation. Some calculations used flow-path lengths of 1,500-ft or more. The District is currently limiting the maximum overland flow-path for undeveloped areas to 1,000 ft for the following reasons:

1. The selection of an overland flow-path length is critical to the results because the overland flow-path portion of the calculation is generally responsible for most of the time in a resultant Tc, and because the resultant peak flow is very sensitive to the Tc.
2. It is likely that overland flow in undeveloped areas will be channelized after a flow distance of 1,000-ft or less.

Minimum overland flow velocity for undeveloped overland flow areas is shown in Exhibit 8 for various frequency storm events. These are minimum values that apply to slopes with dense vegetal growth. Using engineering judgment, velocities assumed for bare slopes and slopes with sparse vegetal growth should be increased consistent with the reduced surface resistance. The length of the undeveloped overland flow-path is further limited for mountain channels (slopes greater than five percent) by evaluating the point where there is sufficient tributary area to produce flow with a scouring velocity of six to eight feet per second in a natural mountain channel. If there is enough flow to exceed the scour velocity, it is assumed that channelization will develop and the overland flow assumption is invalid. In this case the area contributing runoff to the flowpath must be decreased.

It is recognized that because the flow used to determine if the scour point has been reached is based on a pro-rated value from the entire subarea under evaluation, the scour velocity point will change depending on downstream conditions. The scour velocity point will also change with design storm due to the changes in peak intensities and their effects on peak flows. The current 1,000 ft limit will minimize these effects to some extent. The maximum overland flow-path length in developed areas is limited to 200-ft. These limits are embedded in the Tc Calculator Program and are discussed in more detail in the Manual provided with the Program.

Parking lots or large paved areas such as are found in commercial or industrial areas have a sheet flow velocity of a minimum of 1.0 foot per second for 50- and 100-yr storms. For these storms, sheet flow in areas of extreme low relief where overland flow at 1.0 foot per second may exceed street flow velocity, an overland flow velocity of 0.5 foot per second for these storms may be acceptable if previously approved by the Hydrology Section. The minimum velocity for these areas for 25- and 10-yr storms is 0.25 fps.

In determining average travel velocities for streets, pipes, and open channels, uniform flow is assumed. Average velocity data for natural mountain channels are shown in Exhibit 9; natural valley channel velocity data are shown in Exhibit 10. To account for drops and falls that develop in steep mountain channels, slopes greater than ten percent determined from topographic information must be adjusted. Effective slopes were determined empirically from a survey of typical steep mountain channels in the San Gabriel Mountains and a correction curve is shown in Exhibit 7.

Using Manning's Equation and typical street cross sections from the Ventura County Road Standards Manual, normal velocities in common street sections were determined. The velocities were related to discharge and slope, and graphs of the data are shown in Exhibits 11a-d for streets of 32- and 40-foot widths, and six- and eight-inch curbs. Since graphs, tables, and programs are readily available from a variety of sources for determining flow velocities in pipes and lined channels, these data were not included in this manual.

Because a hydrograph represents a translatory flood wave, travel time between subarea collection points is based on wave velocity. Wave velocities for rectangular channels, trapezoidal channels, and pipes were determined theoretically by the Los Angeles County Flood Control District and checked using controlled experiments. The relationships are shown in Exhibits 12a-c. Wave velocities for natural mountain channels, natural valley channels, and for street sections are considered to be 1.5 times the average velocity.

3.5.2 Calculation Process

Once a watershed has been delineated and flow-paths determined, the Tc calculation is performed based on flow-path properties (length, slope, type, etc.), rainfall, and soil data. Several parameters are needed for input as follows:

Zone number, rainfall zone, and soil type are obtained by locating the area on the maps included in this Manual. If a weighted soil number is calculated for the subarea, it can be rounded to the nearest whole number or else it will not match the results from the VCRat program that only uses whole numbers. For zones J, Jp, K, and L, use historic soil numbers 1-7. For NOAA rainfall zones, the program will automatically use the revised soil numbers to obtain the C coefficients.

A desired rainfall frequency storm is selected for analysis or all frequencies can be done.

The fraction of actual impervious area from calculations from development plans and Exhibits 14a and b (Appendix A) if you are using the NOAA rainfall mass curves. If you are using the historic J, Jp, K, and L mass curves, use the effective impervious values from those Exhibits.

A generalized development type of the area is needed (Residential, Commercial, Undeveloped, Industrial).

Total area of the basin. (20-80-acres recommended, minimum 5 ac, maximum 300 ac)

1. Each subarea is divided into flow-path segments and each flow-path is specified as one of the following types and required data must be entered: Overland Flow; Natural Channel; Street; Pipe; and Channel. Overland is the first flow-path and is required; the other flow-path types are optional.

Areas, lengths, and beginning and ending elevations for each flow-path must be calculated and entered.

A Tc between 5 and 30 minutes based on the required range in the Hydrology Manual is assumed. The rainfall intensity for the assumed Tc is obtained from the file VCRAIN.DAT compatible with VCRat2.6 corresponding to the rainfall zone and design storm recurrence interval. A Runoff Coefficient for the basin for pervious area is determined automatically from the file VCRAIN.DAT through linear interpolation of the values in the file. The runoff coefficient is dependent on the given intensity and soil type. The runoff coefficient that is used for the subarea is altered by the given % effective impervious area as follows:

C total = C * (1-% Impervious/100) + 0.95*(%. Impervious/100)

Total flow for the assumed Tc is calculated using the rational equation.

Q total = C total * Intensity * Area

Amount of flow for each flow-path is calculated.

Q segment = Q total * Fraction of total area

Wave velocity is calculated for each flow-path except for the initial overland flow-path segment. Travel time for each flow-path is computed by:

Travel Time = Length / Wave Velocity

Summation of travel times is equal to the calculated Tc. If the calculated Tc is within 0.5 minutes of the assumed Tc, it can be used in the hydrology calculation. If calculated Tc is not within 0.5 minutes of assumed Tc, the assumed Tc is adjusted, then the above steps are repeated:

The resultant Tc from the calculations must be greater than 4.5 minutes and less than 30.5 minutes. Subarea extents may have to be adjusted to produce a Tc in this range. Specific steps in launching and using the Tc Calculator program are described in the Time of Concentration Calculation Report (EMSI, 2006).

3.5.3 Tc Calculator Spreadsheet

As part of this update, the District has developed a Tc Calculator spreadsheet to use in design hydrology work that runs on 64-bit machines. An example of the spreadsheet use is provided in Appendix B and the spreadsheet is available for download as part of the Appendix E materials.

3.6 VCRAT PROGRAM INPUT DATA

The structure of the VCRat2.2 program is complex and input data must be in the correct fields in order to get the program to execute successfully. Input data must be included in the order shown in Appendix B. VCRat2.6, and subsequently VCRat2.64 have been designed to be user-friendly programs that do the required formatting and build the input data file for the user with the following features:

1. System Data.
2. Page Heading Data.
3. Hydrograph Header Data. (Optional)
4. Hydrograph Import Data. (Optional).
5. Location Data.
6. Subarea Data
7. Confluence Data
8. Channel Routing Data
9. Runoff Coefficient Curve Data.
10. Rainfall Mass Curve Header Data.
11. Rainfall Mass Curve Data.

Additional features provided in the VCRat2.6 and 2.64 programs include the following:

1. Performs the yield calculation for a watershed given a rainfall depth and SCS Curve Number to apply yield adjustment to a hydrograph
2. Header information can be assigned to each model node as desired and are no longer limited to nodes where hydrograph data output is desired. Header information is printed in the output so that it is not necessary to refer to the input to find the hydrograph or node description information
3. Can launch the Tc calculator in the VCRat2.6 and 2.64 data input windows (need to revise before finalizing.
4. Provides additional channel routing and time-of-peak data in the output
5. Indicates in the output where a routing channel type has been changed by the program during machine routing
6. Provides additional reservoir routing info in the output
7. Can run an existing VCRat2.2 file without altering it

8. Can import an existing VCRat2.2 file, evaluate it to see if any complex routing assumptions or data outside the recommended ranges were used, and provide a report to the modeler
9. Displays the input and output hydrographs in a data window
10. Has additional error checking capabilities over VCRat2.2
11. Has an extensive help file that explains the various parameters and options
12. Can import and export hydrographs in Excel-compatible formats for additional analysis

Additional features provided in the VCRat2.64 program include the following:

1. Allows the user to select up to 4 NOAA rainfall zones for use in the model run
2. The program will select the appropriate C Coefficient curves depending on whether the historic J, Jp, K, or L zones are selected or if NOAA mass curves are used
3. The reservoir routing information has been revised to allow the use of 3 decimal places for the volume data. This increases the accuracy of the routing analysis for smaller basins because the smallest volume change is now 44 cf
4. The programs has added user-friendly features to facilitate model creation and editing

Detailed information about the program is provided in the VCRat2.64 Help Manual available after launching the program. The technical details of how the program operates are still the same as provided in the description of VCRat2.2 included in Appendix B.

3.7 Computation Procedures

3.7.1 Storm Rainfall Relationships

The VCRat2.2, 2.6, and 2.64 interfaces construct an input data file from the subarea and mass curve data input files called vcrat.dat and launch the VCRATP.EXE FORTRAN executable. The VCRATP.EXE executable has numerous subroutines (names provided in Appendix B) that are called to perform the hydrologic calculations. The VCRat programs interpolate rainfall mass curve data entered as data input in the VCRAIN.DAT file and constructs a system storage table of accumulated total rainfall by one-minute increments from zero rainfall to the time of the last point indicated by input data. Historical design storm rainfall mass curve data included in VCRAIN.DAT have cumulative rainfall totals as shown in the following table. These rainfall totals were obtained after building the VCRat rainfall hyetograph using rain frequency analysis results in the alternating block method and did not match N-yr 24-hr rain depths across the County.

Historical Zone **Design Storm Fourth Day Rainfall Total, Inches**

Rainfall Zone	100-Year Storm	50-Year Storm	25-Year Storm	10-Year Storm
J	7.00	5.0	3.91	3.17
J’ (J prime)	6.66	6.0	5.28	4.38
K	10.60	8.0	6.41	5.53
L	15.00	11.0	8.81	7.21

The average rainfall intensity for any specified duration (time of concentration) at a selected storm time is calculated as follows:

1. Determine the cumulative storm rainfall from the mass curve at the selected time
2. Determine the cumulative storm rainfall at an earlier storm time by the length of the specified duration
3. Rainfall intensity in inches per hour is calculated as the incremental cumulative storm total, times 60 (minutes in an hour) divided by the specified duration.

For the design storm, rainfall intensities are reduced if computations for other than the fourth day (maximum day) rainfall are specified. The reduction factor is 0.10, 0.40, 0.35, and 1.00 for the first through fourth day, respectively.

In 2011, NOAA published an update of the Altas 14 Vol 6 showing rain frequency data for California. The District evaluated the data set and grouped it into 31 zones of similar rain intensities using watershed boundaries. These 31 zones can be used by VCRat2.64 to characterize the design storm rainfall for the 10- through 100-yr storms. The intensity data for these zones is given in Appendix A, Exhibit 2. The rainfall totals from the 31 NOAA mass curves included with this Manual match the N-Yr 24-hr rain depths provided by NOAA. The Zones are shown in Appendix A and also on the County's website: http://vcwatershed.net/publicMaps/data/.

3.7.2 Rainfall-Runoff Relationships

The system linearly interpolates runoff coefficient curve data as a function of intensity entered as data input in VCRAIN.DAT and constructs a system storage table with up to 14 points, with one curve for each soil type. Infiltration rate (loss rate) data may be specified as data input as an alternative to runoff coefficient curve data. Through use of this table, runoff rate may be computed for a specified rainfall intensity by either (a) runoff coefficient times rainfall intensity or (b) rainfall rate minus infiltration rate (loss rate).

The watershed acreage, effective impervious area of the watershed, and time of concentration data plus systems tables provide the information necessary for the system to compute watershed discharge using the rational formula. The following equations are used to compute runoff rates:

$$Q = CIA$$

$$R = I - f$$

$$C = R/I = (I-f)/I \text{ (No Impervious Area)}$$

$$C_{imp} = P(0.95) + C(1-P)$$

$$Q = [P(0.95)I + (1-P)R]A$$

where:

A = Watershed area in acres.

C = Runoff coefficient.

f = Infiltration rate in inches per hour; f varies with intensity for each soil.

I = Rainfall intensity in inches per hour

P = Percent imperviousness/100.

Q = Flow rate in cubic feet per second.

R = Runoff rate in inches per hour.

3.7.3 Impervious Values

VCRat2.2 and 2.6 used effective impervious values in the model input. Effective imperviousness is less than total impervious area because some of the impervious area runoff was assumed to pass through pervious areas where infiltration can occur. For example, roof drains that discharge onto a lawn may see a reduction in runoff due to infiltration. Roof drains that discharge onto a driveway provides no opportunity for infiltration and thus the effective impervious area would be the same as the total impervious area. Compaction is also generally done uniformly across the development site, decreasing the amount of infiltration that can occur, even in a pervious area. These and other applicable factors should be evaluated by the engineer prior to calculating the impervious values.

VCRat2.64 uses the actual impervious values in the runoff calculations due to the relatively small amount of pervious area associated with current development. A recent hydrology study in the City of Oxnard showed development designated as Low Density Residential has 6 units per acre compared to the historical average of 5 units per acre. The improvement square footage is also larger now than in older neighborhoods. The use of the actual imperviousness is also consistent with many other agencies in their hydrology methods.

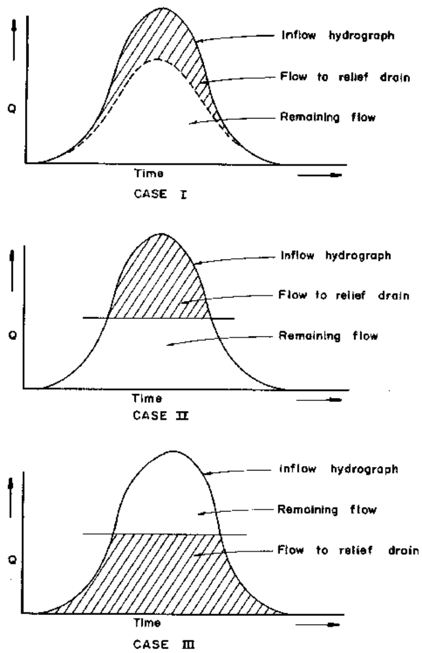
Computations evaluate runoff from pervious and impervious portions of the watershed separately. It is assumed that 5 percent of rain falling on impervious surfaces will not appear as runoff due to evaporation and surface storage. Recommended impervious percentages generally used for projected ultimate development are provided in Appendix A in Exhibits 14a and b for use in VCRat modeling. However, it is the responsibility of the hydrologist to evaluate the impervious area of their project if it is different than the recommended values.

3.8 CONFLUENCE AND DIVERSION STRUCTURE FLOWS

Flow rates calculated for a subarea at specified storm times provide the storm runoff hydrograph from the subarea. At each collection point, subarea hydrographs are added to the flow present in the drain system from upstream portions of the watershed. Where detailed confluence output is specified, coincident peak flow rates are printed at the peak flow rate time of each hydrograph for use in hydraulic design of the drain system. Confluence inflow and outflow hydrographs are printed and output files generated as needed. Confluence information provided by the program includes the following three sets of data:

1. At the time of peak flow in primary drain, flow information includes primary peak flow, combined flow, and flow in lateral.
2. At the time of peak flow in lateral drain, flow information includes lateral drain peak flow, combined flow, and flow in primary drain.
3. At the time of peak combined flow in primary drain, flow information includes combined peak flow, primary drain flow, and lateral drain flow.

At the junction of two drains where one of the drains functions as a relief drain, the hydrograph may be separated into two parts as shown below. The input data required to specify the various options are shown in Appendix B.



Split Flow Cases:

Case I- Specified percent of flow remains in main drain, excess is transferred to relief drain

Case Ia- Program compares drain peak to specified flow value (smaller than peak), calculates percent, and transfers flow above that percent to relief drain.

Case II – Flow in excess of specified value to relief drain

Case III – Flow in excess of base (= peak - specified value) remains in channel, remainder to relief drain.

3.9 FLOOD ROUTING

Specific channel sections, including natural mountain channel, natural valley channel, standard street section, circular pipe and rectangular or trapezoidal channels, may be specified as water conveyances. The pipe diameter or channel side slopes, bottom width, and depth may be specified. In the case of a trapezoidal section with an unlined bottom, the maximum velocity to control scour through use of drop structures, and various composite lining roughness values may be specified. The channel length and slope plus channel section data provide the information necessary for the system to route the hydrographs in a drain from one subarea to the next. The program uses the Modified Puls or storage-indication method for channel routing.

3.9.1 Machine Routing

If machine routing is specified, the system will begin flood routing in a drain at the upstream limits of the watershed using a 40 ft wide street section and will automatically change from street to pipe section when flow depth reaches the property line (at the sidewalk limit), from pipe to rectangular channel when pipe diameter of 8 feet is exceeded, and from the hydraulically most efficient rectangular section to a rectangular section with maximum depth of 13 feet when that depth is reached. To maintain consistency of drain type and size, the system checks the type of drain used in the preceding upstream channel reach, and retains that section if it is large enough to contain the flow. In a rectangular or trapezoidal section, the upstream reach bottom width is retained until flow depth increases by more than one foot from the previous reach depth.

Pipe sizes used by the system increase in 3-inch increments from 2.0 to 8.0-feet. Rectangular and trapezoidal bottom widths used by the system increase in 2-foot increments from 2 to 30 feet, 10-foot increments from 30 to 80 feet, 50-foot increments from 100 to 300 feet, and 100-foot increments from 300 to 1000 feet.

Machine routing is selected by leaving the channel type blank in the 006 data line (VCRat2.2) or subarea editing window in VCRat (2.6 or 2.64) but entering a channel length and slope to be used in flow routing. Additionally, a channel type can be selected in the 006 data input line or editing window but the width or diameter left blank. In this case, the program will size the specified channel. If the flow is too large for the type of channel selected, the program will automatically select a larger channel type and size it appropriately. VCRat 2.6 and 2.64 shows the channel change by adding the "#" symbol to the output. However, if street routing is specified with an assigned street width the program will not select a different type of channel- the flow, no matter how large, will be analyzed with the street routing equations.

3.9.2 Wave Velocity and Flood Routing

Because the VCRat hydrograph constitutes a translatory flood wave, routing is performed at wave velocity. At the lower end of each reach the hydrograph is checked for a time shift and redefined by interpolation to obtain flow rates at storm times as specified by hydrograph data points. The hydrograph, as affected by channel storage, is next computed using a reservoir routing method (Modified Puls), with time periods for routing determined by spacing of rainfall data input.

3.9.3 Flood Routing Equations

The following equations are used for flood routing purposes:

Equation	**Application**
$T=L/(60Vw)$	Travel time in minutes
$V=Q/A$	Velocity, ft/sec
$V=5.6Q^{0.333}S^{0.5}$	Natural Mountain Channels
$V=(7+8Q^{0.352})S^{0.5}$	Natural Valley Channels
$V=11.9Q^{0.191}S^{0.411}$	40-ft Street Sections
$V=1.486R^{0.667}S^{0.5}/n$	Manning's Equation for pipes,rectangular, and trapezoidal channels
$D=B/\{2[(Z^2+1)0.5-Z]\}$	Most Efficient Open Channel Section
$n=[n_1B+n_2(2\ell)]/(B+2\ell)$	Composite Lining of Trapezoidal Channel
$Vw=1.5V$	Wave Velocity- Natural Mountain and Valley Channels and Streets
See Appendix A	Wave Velocity, Partially Full Pipe
See Appendix A	Wave Velocity, Rectangular and Trapezoidal Channels
$I_1+I_2+2S_1/t-O_1=2S_2/t+O_2$	Storage Routing Equation

Equation	Application
$\Theta=4\sin^{-1}(D/d)^{0.5}$	Angle in Radians for Partially Full Pipe

Where:

A	=	cross section area in square feet
B	=	channel bottom width in feet
D	=	flow depth in feet
D	=	pipe diameter in feet
I	=	inflow to channel reach in cfs
I_1	=	instantaneous inflow at beginning of time period t.
I_2	=	instantaneous inflow at end of time period t.
L	=	length of channel reach in ft
$\mathcal{L}$	=	length of wetted channel wall in ft
n	=	channel roughness coefficient
n_1	=	roughness coefficient for channel bottom
n_2	=	roughness coefficient for channel walls
O	=	outflow from channel reach in cfs
O_1	=	instantaneous outflow at beginning of time period t
O_2	=	instantaneous outflow at end of time period t
Q	=	flow rate in cubic feet per second
R	=	hydraulic radius
S	=	slope of channel reach in feet per foot
S_1	=	channel storage at beginning of time period t
S_2	=	channel storage at end of time period t
T	=	travel time in minutes
t	=	time period for routing purposes in minutes
V	=	mean velocity in fps
Vw	=	wave velocity in fps
Z	=	channel side slope computed as horizontal projection of wall divided by depth in feet per foot

3.10 FLOOD ROUTING METHODS AND LIMITATIONS IN VCRAT

The use of the Modified Puls method of routing for channels in VCRat treats the channel like a long linear reservoir. It is not possible to enter in irregular channel cross-sections with overbank areas in the routing input so the routing scheme applied to prismatic channels results in relatively little peak flow attenuation. The largest peak attenuation observed in the VCrat model is for relatively wide channels with low slopes such as the Camarillo Hills Drain adjacent to the Camarillo Airport. A peak flow of about 4,500 cfs at the upstream end of the 1-mi reach was reduced to about 4,250 cfs at the downstream end, a reduction of less than six percent. When using the hydrology data in a hydraulic model, the attenuation can be simulated in the model by applying the upstream and downstream discharge and using linear interpolation for any intermediate cross-sections. Additional issues and methods for modeling hydraulic constraints in the drainage system are discussed in Sections 6.1 and 6.2.

If significant peak attenuation is suspected of occurring due to extensive overbank flow in a study reach, the hydrograph from the hydrology model can be exported and a better estimate of attenuation obtained from an unsteady-state hydraulic model run.

3.11 WATERSHED YIELD ADJUSTMENT

The MRM hydrograph produces a conservative peak flow for use in drainage system design. The hydrograph has a relatively short duration peak due to the shape of the design storm hyetograph. Because of this, the volume under the hydrograph is generally smaller than the watershed yield obtained through application of other hydrological methods such as the NRCS (formerly SCS) curve number (CN) approach. Because the hydrograph volume is critical in detention and storage facility design, the District has developed the VCRat programs to adjust the yield of the resultant hydrograph (often called hydrograph “fattening”) for use in basin design. This methodology should not be used in the design of regional detention and storage facilities. For those facilities, other standard hydrologic methods pre-approved by the District should be used to generate the design inflow hydrograph so that the outlet works design is done correctly. Design of these facilities should be undertaken after consultation with District staff.

For small developments and basins, however, the VCRat method can be used to generate a yield-adjusted design hydrograph as shown in Appendix B with the following steps:

1. Use VCRatX.X to produce an inflow hydrograph for the design storm and tributary watershed.

Find the total design storm rainfall depth (N-yr 24-hour) at the centroid of the tributary watershed.

Use shapefile or maps supplied by the District to find the average soil type in the watershed.

Generate a list of land uses, associated areas, and NRCS AMC II CNs from Exhibits 14a and b that represents the weighted soil type from Step 3 and calculate an areally-weighted average CN for the watershed.

Use Exhibit 13 to find the watershed yield in inches using the weighted CN from Step 4 and the total design storm rainfall depth from Step 2.

Enter this as a yield adjustment factor in the model data input file above for VCRat2.2 or VCRat2.6 and 2.64. In 2.6 and 2.64 the user can also enter the rainfall and curve number directly and the program will calculate the resultant yield following the assumption that the initial abstraction is 0.2 times the total abstraction.

As a check, the volume of the output hydrograph should equal the yield adjustment factor times the area of the tributary watershed after the units are converted.

VCRat performs the yield adjustment by increasing or decreasing the hydrograph ordinates adjacent to the peak until the desired volume is achieved. The peak of the hydrograph is not changed but flow values in the vicinity of the peak can be increased up to the peak if necessary to provide the desired volume. AMC II conditions best represents yields from District watersheds, even during the most extreme storm events occurring over the last 15 years.

3.11.1 VCRat Yield Adjustment – Advanced Topics

The yield under the VCRat hydrograph is smaller than the watershed yield calculated through an NRCS CN approach except for areas of the County where the 100-yr 1-day rainfall depth is 6 inches or less (mainly in the vicinity of the City of Oxnard), or in highly developed areas. If the hydrograph yield is adjusted for those watersheds, the VCRat hydrograph volume can even be decreased slightly depending on the type of development. As the user are trying to match the yield from the NRCS CN method during yield adjustment, a small decrease in volume is considered acceptable.

In a related issue, it was noticed that the algorithm used to adjust the hydrograph volumes to match the calculated NRCS yield could result in small negative values at early and late times in the hydrograph. The VCRat2.6 and 2.64 program was then revised to check the yield adjusted hydrographs for negative values and reset them to 0 if they are found. This process only changes the hydrograph volumes by a small amount so has no effect on facility design.

As the VCRat hydrology model only has a simulation length of 24-hrs, some portion of the runoff hydrograph is truncated at the end of the run. Because the peak rainfall does not occur until 80% of the one-day run has occurred, for large watersheds with significant lag times the peak can occur relatively late and the truncation of the receding limb of the hydrograph includes more volume. This effect causes unrealistic shapes of hydrographs during yield adjustment. The District has found that it is not possible to create a realistic yield-adjusted hydrograph for watersheds that are bigger than 70 to 80 sq mi. If a hydrograph is needed for mainstem locations with large tributary areas it is necessary to use another hydrology model to provide it as discussed below in Section 5.

In 2010, the CNs used to calculate the yield to be applied to the VCRat hydrographs were revised to vary with infiltration rate more smoothly than the previous CNs provided in the District's 2006 Manual. Additional land use categories were also added to reflect General Plan land use files provided by the County and Cities.

3.12 VCRAT2.2 PROGRAM COMPLEXITIES

The flexibility of the VCRat2.2 and 2.6 and 2.64 programs has led to a number of possibly unexpected results from historic models as described in the following subsections.

3.12.1 Machine Routing Specified But n Value or Sideslope Specified

A model can be prepared using the machine routing capability by not specifying a channel type in a subarea data input line but providing a channel length and slope. If the user enters a channel side slope and/or an n value, this information is ignored until the routing routine has enough flow to select the use of an open channel. At that point, any specified values are applied to the channel.

3.12.2 Stage-Storage-Discharge Curve

VCRat expects the first point on a stage-storage-discharge curve to correspond to 0.0 ac-ft. If it is not 0.0 ac-ft, the program cannot interpolate the stage-storage curve correctly and provides erroneous results for the maximum spill elevation reached during outflow. This error can also affect the length of spill and peak outflow information provided in the output. These errors do not affect the actual basin outflow hydrograph and routing results in the program.

VCRat2.2 does not require the reservoir spillway elevation to be entered in the input file. This can result in inaccurate spill durations provided in the output because the program defaults to a spillway elevation of 0 feet. The peak flow of the output hydrograph is not affected by this.

VCRat2.2 does not require sequential points in the stage-storage-discharge data to increase or be the same value. This allows the user to enter elevations that are lower than the previously entered values without causing a fatal error. This results in inaccurate routing through the reservoir by the program.

VCRat2.2 or 2.6 does not warn the user that not enough data points were provided in the stage-storage-discharge curve so the upper limit of storage was reached during the run. At the time-step where the storage is exceeded the discharge is reset to 0.0 cfs and remains there for the rest of the simulation. The easiest way to make sure this does not happen during a run is to review the outflow hydrographs to make sure they do not drop to 0.0 cfs during the run. The modeler can also compare the basin inflow volume to the outflow volume to make sure they are similar. If the outflow volume is much less than the inflow volume, it is possible it is due to the outflow being set to 0.0 cfs when the maximum storage value in the input data set is exceeded.

3.12.3 Incorrect Rainfall Mass Curve Information

In certain cases, an incorrect rainfall mass curve designation can be entered into the data input file for VCRat2.2 and the program might still run and not indicate any problems. For example, instead of A97, a curve B97 can be specified which is not defined in VCRain.dat. VCRat2.2, when using mass curves beginning with a letter between A-I, only checks the numerical value following the letter (in this case 97) and thus would use rainfall curve A97 in this example (J' Zone- 100-Yr) instead of B98 (K Zone-100-Yr) for this subarea. Currently, the VCRat2.6 and 2.64 import programs also use the number following the letter designation to determine which mass curve to use for a subarea but adds an issue/warning message to let the user know that there may be an issue with the design storm specification.

3.12.4 Specifying Width for Road Routing

It is possible to enter a width while specifying routing type 3 (which by default in VCRat uses the velocity-slope-discharge data for 40' road). The effect in VCRat2.2 or 2.64 is to force the flow to stay in the road and not have the program automatically change to a pipe or a channel when the flow is large enough. This allows the modeler to simulate channel overflows that occur as street flow at road crossings such as in the Tapo Canyon channel in Simi Valley. It does not matter what the specified width value is- the resulting flow will be the same because the program uses the default 40' street velocity/flow depth info embedded in the program.

3.12.5 Pipe Diameter Not Specified But N Value Specified

VCRat2.2 ignores the n value when it is entered and uses the default value of 0.012 when pipe flow is specified for the channel type but no diameter is specified. If flow is large enough for the program to select a channel, the n value is used by the program at that point.

3.12.6 Channel Type 5 with Depth or Velocity Specified

VCRat2.2 ignores any maximum depth or velocity information associated with channel type 6 entered by the user if channel type 5 is specified. VCRat2.6 and 2.64 provide a warning message about this if the file is imported.

3.12.7 Natural Valley or Mountain Channel Routing but N Value or Width Specified

If natural valley or mountain channel routing is specified along with an n value or width, VCRat ignores this information during the run. The embedded Manning's "n" value for Mountain Channel Routing is higher than Valley Channel because it is assumed that Mountain Channels have cobble bottoms or possible vegetation in the channel. Therefore, for a given slope and flow the velocity will be higher in a Valley Channel and could lead to higher downstream peaks.

3.12.8 Pipe Routing Specified and Diameter Specified

If pipe routing is selected and a specified pipe diameter is given, this forces the program to use that pipe size for the routing. If the diameter is not adequate to carry the calculated flow, the program will force flow through the pipe under pressure, with unrealistic velocities that affect travel times and routing calculations. Pipe diameters should generally not be specified in the input file unless they have been verified to be adequate to carry the design storm flow under open channel conditions. VCRat2.6 and 2.64 provides a warning about this if a pipe diameter is specified.

3.12.9 Clearing Hydrograph Bank

Clearing of a hydrograph should occur before any other operation for that node. This needs to be done when importing a hydrograph or after performing a split and before using the lateral channel letter for a new tributary. Otherwise any hydrograph data stored in the program memory in the lateral will be added to the new subarea information and the peak flow results will be not be correct for the new subarea.

3.12.10 Importing Historic Models into VCRat2.64

VCRat2.2 and previous version models allowed more flexibility in the input data than is currently allowed. Some historic models have areas and Tc's that are outside of the currently allowed ranges of 5 to 300 ac and 5 to 30 minutes, respectively. Channel routing data is sometimes inconsistent such as specifying a Manning's "n" value for street routing. When imported into VCRat2.64, the program will identify any out-of-bounds data and routing inconsistencies and generate a list for the user.

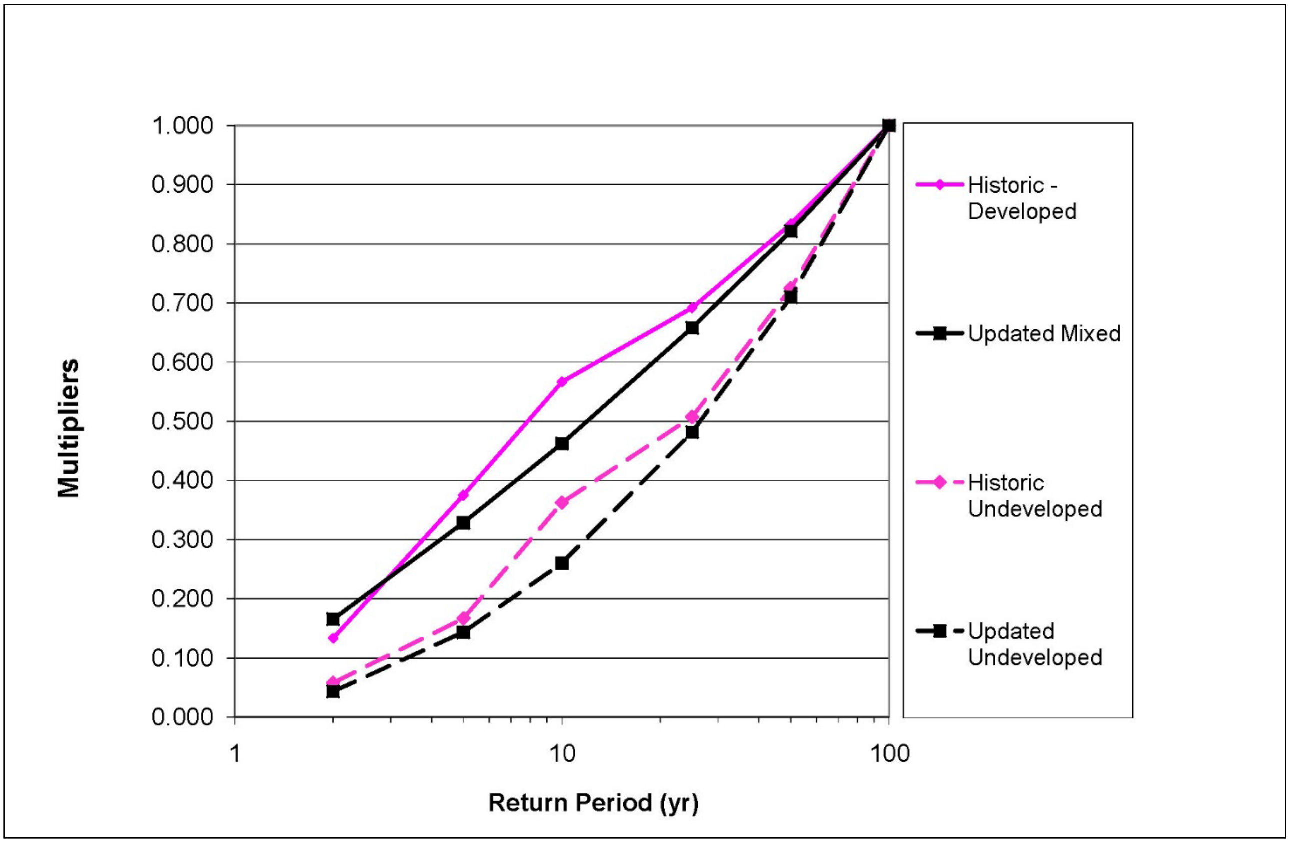
VCRat2.64 is programmed to run a 2.2 input file without importing it, and import a 2.2 input file and run the model as long as the user does not attempt to revise a subarea that contains any inconsistencies. If the subarea is selected for editing, VCRat2.64 will force the user to change the inconsistent parameters and save the changes before running the file. There are several ways to change the file back to the historic model version so that the same results can be obtained as follows:

1. If a subarea has an area that is bigger than 300 ac, another subarea can be inserted above or below and the area can be split so that both input lines have the same Tc, soil, storm type, etc, and the total area matches the historic total.
2. For areas that are too small or Tc's that are outside the limits, revise the subarea with an acceptable number, save and close VCRat2.64, and open the *.vin input file with a text editor and change the affected data back to match the historic file. Then reopen the file in the VCRat2.64 program and run the model. When doing direct editing, however, it is always a good idea to save a backup copy in case the editing process somehow results in a corrupted file that will not execute.

3.12.11 Comparision of VCRat Results to Stream Gage Flow Frequency Data

As part of the Manual update, the design storm ratios or multipliers commonly used by hydrologists to estimate the other design storm peaks from a single model run were updated using stream gage flow frequency analysis results. Gage frequency results were separated into two categories based on land use, undeveloped and mixed (partially developed). The design storm ratios calculated from the frequency results were averaged for each category. The resultant ratios relative to the 100-yr storm are plotted in the following figure.

The data show that the updated ratios are relatively similar to the historic ratios except at the 10-yr storm level. It appears that the historic 10-yr ratios were adjusted upward to match the results from VCRat modeling. This has implications for design storm work because the 10-yr storm is commonly used to set the mitigation goal for detention facilities. If the VCRat 10-yr results are too high compared to stream gage design storm ratio, that means that mitigation facilities such as detention basins may not providing as much benefit as expected. If the VCRat model and associated design storm ratios are revised to be consistent with stream gage frequency analyses, mitigation facilities may have to be bigger.



3.12.12 Multiple Areal Reduction Calculations

It is sometimes necessary to apply areal reduction more than once to a drainage line to get final AR results at a study location. This occurs often when the study site is located downstream from a detention basin where the inflow to the basin has already had AR applied so that the basin outflow peak is correctly calculated. If the study site has a tributary area downstream of the dam that is several hundred acres in size, it is necessary to apply another AR factor appropriate for the net area downstream of the basin to the peak flows. In this case the AR factor is applied even if the net area is less than 640 ac because the total watershed area is greater than 640 ac. An example of how to do this is provided in Appendix B.

Another issue is whether or not an AR curve developed for the unregulated watershed above the basin can be applied to peaks below the basin. Research by the District on this topic has indicated that if the inflow peak to the basin is significantly attenuated by the basin then an AR curve developed for the unregulated watershed is not appropriate for use in applying AR to the regulated subareas on the mainstem downstream of the basin. If the basin does not attenuate the inflow peak much then the AR curve developed for the unregulated watershed can be applied to the downstream subareas. It is relatively easy to do AR runs however, so when in doubt it is best to do additional AR runs to get the data points needed for the study.

3.12.13 Multiple Yield Adjustment Calculations

It is sometimes necessary to apply yield adjustments more than once to a drainage line to get final results at a study location. This occurs often when the study site is located downstream from one or more detention basins where the inflow to an upstream basin has already been "fattened". For the next downstream basin, the fattening factor is calculated by the following:

1. Calculate the yield of the outflow hydrograph from the upstream basin.
2. Calculate the yield of the tributary watershed downstream of the upper basin that provides flow to the downstream basin.
3. Sum the two yields, and convert that to inches by dividing the yield volume by the total tributary area upstream of the second basin. Use that as the fattening factor.

An example of how this is done is provided in Appendix B.

3.12.14 Debris and Detention Basin Modeling Policy

The District's policy is that only basins that were specifically designed to provide detention for the 100-yr storm, meeting all of the District's design standards, can be included in hydrology models. Debris basins that were primarily designed to capture sediment and result in emergency spillway flow for the 100-yr storm cannot be included in hydrology models even if they attenuate the inflow peak to some extent.

Detention basins are modeled by including stage-storage-discharge data in the model. The first discharge and storage data point must be a 0 for the interpolation routine to work correctly. More accurate results are obtained if the storage data points each represent no more than about 10% of the total basin volume up to the emergency spillway level. Points should be provided wherever the discharge and volume curves show large changes or discontinuities in slope. The design standard for detention basins are described in detail in the District's Debris and Detention Basins Manual (2005).

3.12.15 Running VCRat2.2 Models with VCRat2.64

VCRAt2.64 continues to have the capability of running VCRat2.2 format files directly first contained in VCRat2.6. Recent testing with VCRat2.64 showed that some of the legacy files with data input lines that ended with slope data in position 41 (slope information is supposed to extend to position 43) were misinterpreted by the VCRat FORTRAN program after being recompiled with the 64-bit compiler. The fix to this is to add spaces to the data input lines with this problem to position 43 or more. It turns out that importing a VCRat2.2 file into VCRat2.64 and running it, produces an output file with the VCRat2.2 input file appended to the end. This VCRat2.2 input file has the required spaces in it.

3.13 VCRAT SPREADSHEET

A spreadsheet was developed as part of this update to calculate the runoff hydrograph from a single subarea and perform flow-through basin routing. The spreadsheet also calculates the volume needed for a bypass basin if desired. An example of the spreadsheet use is shown in Appendix D-3 and the spreadsheet is provided in Appendix E.

SECTION 4 HSPF DESIGN STORM MODELING

The work done to use continuous hydrology HSPF models for design storm modeling includes results for the Santa Clara Watershed (AQUA TERRA, 2009), and the Ventura River Watershed (Tetra Tech 2009 and VCWPD, 2010). The project to obtain design storm results for the Calleguas Creek Watershed Model was completed in 2011.

Many of the catchments in these watersheds been evaluated in those regional models and the results are contained in the reports posted on the District's website in the pages for each watershed. These results can be used for design purposes. If detailed modeling results are required, the HSPF model can be refined. For urban areas, a MRM model can also be developed. The MRM and HSPF models should provide flow peaks within 5% at coincident points.

The conceptual model of flow in the HSPF model is different from the VCRat model in that runoff from a subarea is assumed to be added to the top of the channel reach in addition to any flow from an upstream subarea and routed through the channel. This provides the opportunity to calibrate the peak and shape of the outflow hydrograph by adjusting the channel routing parameters in the model. However, this conceptual model provides somewhat shorter travel times than VCRat model routing due to steeper water surface slopes from the subarea flow being added to the channel in the model before it physically reaches the channel in reality.

4.1 CONTINUOUS MODELS IN DESIGN STORM MODELING

Hypothetically, the results from a calibrated continuous HSPF model could be used to provide annual peaks to be subjected to a flow frequency analysis to produce design storm peaks. In practice, the HSPF model results on Ventura County streams have resulted in annual maxima flow frequency analysis peaks that are not sufficiently close to results obtained from stream gage data to be used for design purposes. The main problem with the HSPF results has been concluded to be the underestimation of peak flows during relatively dry years. During those years, the storm cells that produce rain leading to the peaks seem to be of limited extent and often do not pass over the rain gage network. Therefore, too little rain is applied to the watershed in the model, resulting in the underestimated peaks and skewing the frequency analysis results. Some agencies (DuPage County, Illinois) have overcome this obstacle by using partial duration flow frequency analyses to obtain the 100-yr design storm peaks for floodplain mapping but this provides 2- to 10-yr peaks that are higher than those obtained through annual maxima analyses. Another issue with partial duration results is that the methodology is not considered to be a common practice in the use of Bulletin 17b (USGS, 1982) techniques and programs and therefore may not be acceptable for submitting design storm hydrology to FEMA.

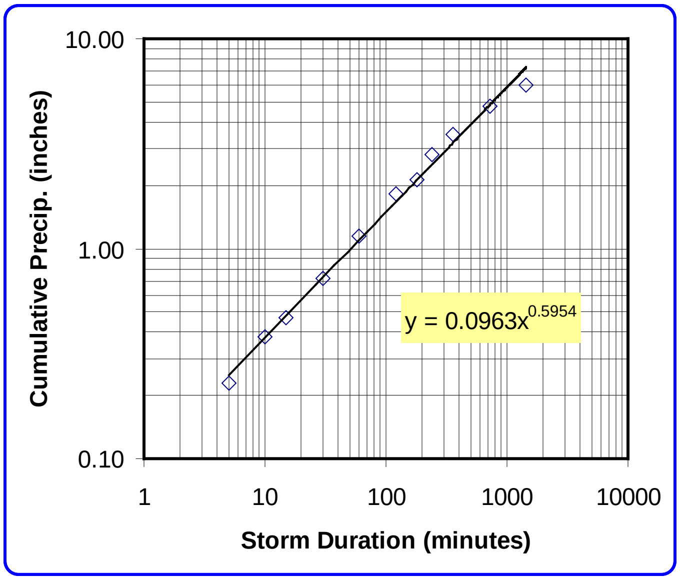
Because of this, in 2008 the HSPF model of the Santa Clara River was used to provide design storm peaks by inserting a design storm hyetograph in the model rainfall time series just after some of the highest rainfall totals observed in recent history. The resultant design storm model peaks matched the stream gage FFA results to within 10% or less. Because of this generally good calibration result, the Santa Clara model was used to provide design peaks for FEMA and USACE floodplain mapping studies in the river. The approach was subsequently used in the FEMA FIS for the Ventura River to provide design storm peaks from the HSPF model. It was also used in the Calleguas Creek HSPF model. There was good agreement with the HSPF results and the stream gage FFA design peaks for the three watersheds.

4.2 DEVELOPMENT OF DESIGN STORM HYETOGRAPHS

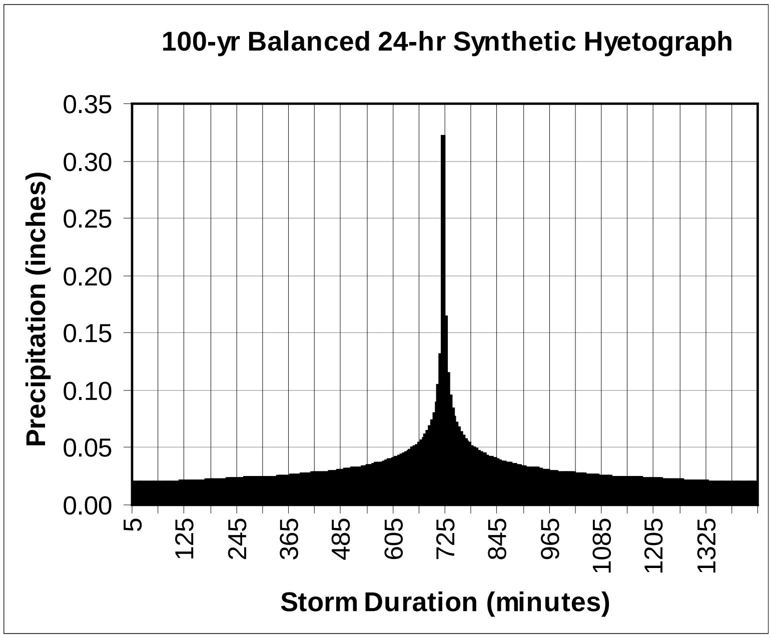
Design storm hyetographs have been developed for input to the HSPF design storm model assuming the peak rainfall occurs at 50% of the rainfall duration through the alternating block method as follows:

1. Perform a Pearson III Frequency Analysis of the rainfall data in the study area using the annual maxima data at intervals ranging from 5-minutes to 24-hours. The District makes these data available for each rain gage in their network. Alternatively, obtain the NOAA design storm depths from the rain frequency data provided in Appendix A or directly from the NOAA website.
2. Plot the depth-versus-duration data on a log-log plot and fit a power equation trendline through the results.
3. Establish the desired rainfall storm duration. For the relatively large Santa Clara River, Ventura River, and Calleguas Creek watersheds, a 24-hour duration storm was used. For smaller watersheds, a shorter design storm may be more appropriate.
4. Establish a duration interval that divides equally into an hour. For District studies, a 5-minute interval is commonly used.
5. Tabulate the duration in increasing values of the interval.
6. Use the regression equation from Step 2 to calculate the rainfall depth for each interval.
7. Calculate the incremental rainfall depth for each time period by subtracting the cumulative rainfall at the previous time step from the cumulative rainfall for the current time step.
8. If the sum of the incremental values is larger than the 24-hour depth from the frequency analysis, reduce the incremental values by a constant factor for each interval so that the sum matches the 24-hour depth.
9. Distribute the incremental depth values. Use time blocks that correlate with the duration intervals. Assign the highest incremental depth to the central time block, and arrange the remaining incremental depth blocks in descending order, alternating between the upper and lower time blocks away from the central time block.

The resulting rain gage hyetograph ordinates are then used as input to the HSPF Model. For rain gages that only have daily records, the 24-hour value (resulting from a frequency analysis of the daily gage data) can be applied to the dimensionless distribution of an adjacent gage concluded to be a good surrogate for the gage of interest. The following figures shows the depth-versus-duration data and trendline for a District rain gage and the resultant hyetograph for gage 165 (Stewart Canyon) used in the Ventura River design storm modeling. A detailed example is shown in Appendix C. A spreadsheet that can be used to provide the hyetograph is provided in Appendix E.



Gage 165 (Stewart Canyon) Depth Versus Duration Data

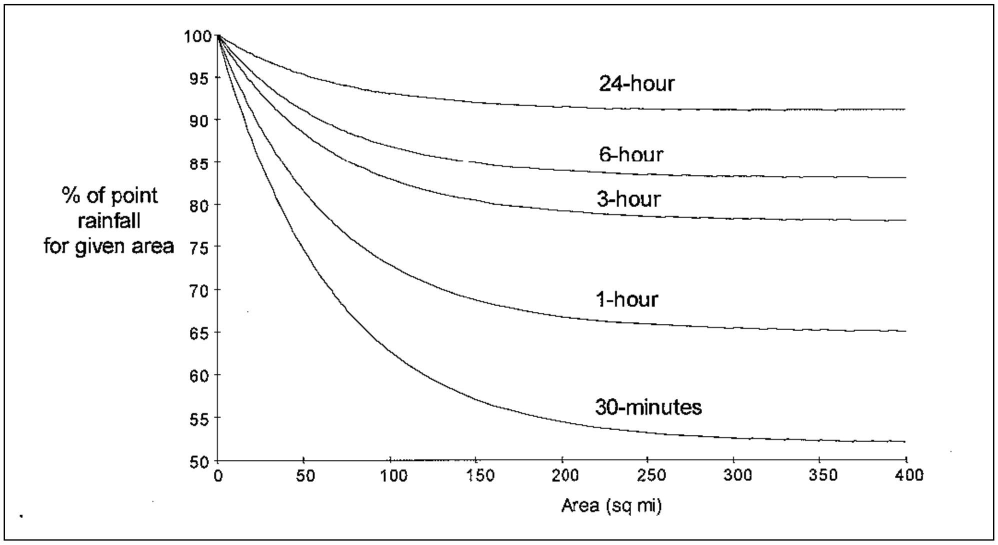


Gage 165 Design Storm Hyetograph

4.3 RAINFALL AREAL REDUCTION FACTORS

Areal reduction rainfall factors are used in the HSPF modeling to account for the limited spatial extent of the storm cells providing design storm intensities, similar to the VCRat approach. The factors are applied in the model run similar to the VCRat approach. The areal reduction factors are obtained from the HEC-

HMS model documentation or from a HEC-HMS model run using the AR option in the meteorological module.



HEC-HMS Areal Reduction Curves for Design Storms

4.4 DESIGN STORM PERIOD SELECTION

The design storm rainfall hyetographs should be applied to the model in the period immediately after a storm that provides saturation levels appropriate for the recurrence level of interest. For the 50-yr and greater recurrence interval storms in Ventura County watersheds, the period after the intense rains preceding January 10, 2005, was concluded to be an appropriate period to provide peaks for those design storms. For a 10-yr storm, the design storm rain should be applied to a historic period that provided an approximate 10-yr peak. One thing to consider in the preparation of an HSPF model for detention basin design is how much volume is contained in the channels at the start of the design storm.

4.5 MODEL PROCEDURE AND CALIBRATION

The steps in preparing and running a design storm HSPF model are as follows:

1. Run the calibration HSPF User Control Input (UCI) file for the entire watershed to get an initial state of the system at the beginning of the analysis period for the design storm (end of day January 9, 2005). Extract initial state data from model output for all subareas and reaches to set initial conditions to simulate runoff from January 10 through 31, 2005.
2. Modify calibration UCI for storm simulation, including changing to a 5-minute time step, and revising initial storages, the start time, rain data sets, and adjusted rainfall factors. The adjusted rain factors (MFACTs) will incorporate the calibrated continuous model MFACTs, areal reduction (AR) factors, and any adjustments with a calibration factor required to match design storm peaks from stream gage

frequency analyses. Therefore, the applied HSPF Rain Factor= Calibrated MFACT from continuous model * AR Factor * Calibration Factor.

3. Run the modified UCI. Multiple runs were needed to implement the appropriate AR factors for each site; AR factors for all sites upstream of a location of interest must be identical. For calibration sites, adjust calibration factor to calibrate/match 100-year peak flow within several percent.
4. For ungaged sites, evaluate results from gaged watersheds with similar land uses and hydrological conditions and apply calibration factors accordingly. Compare to previous modeling results for consistency if available.
5. Extract results for plotting and summary tables using WDMUtil or GenScn.

4.6 DESIGN STORM RATIOS AND HSPF RESULTS

Little work has been done to evaluate and calibrate the HSPF model design storm peaks for storms with recurrence intervals shorter than the 100-yr storm. For these storms, the soil saturation levels can vary and it is more difficult to select a historic period with saturation levels that will reliably provide the design storm peaks. Therefore, it is acceptable to use the District Design Storm Ratios provided in Appendix A to provide the peaks and hydrographs for design work from the HSPF model results.

4.7 INTERMEDIATE DISCHARGES

Because the HSPF models prepared by the District have been regional models, sometimes the subareas can be relatively large with relatively long channel reaches. It is often necessary to provide flow at intermediate points along the reach for hydraulic modeling purposes. When this occurs in the most upstream subarea of a stream where the variation in flow along the reach is not known, the District recommends the use of the USGS 94-4002 report equations (USGS, 1993). In that report, the equations recommended for estimating the design storm peaks for the 2-, 5-, 10-, 25-, 50-, and 100-yr storms are as follows:

$$Q2 = 0.14\ A^{0.72}\ p^{1.62}$$

$$Q5 = 0.40\ A^{0.77}\ p^{1.69}$$

$$Q10 = 0.63\ A^{0.79}\ p^{1.75}$$

$$Q25 = 1.10\ A^{0.81}\ p^{1.81}$$

$$Q50 = 1.50\ A^{0.82}\ p^{1.85}$$

$$Q100 = 1.95\ A^{0.83}\ p^{1.87}$$

Where A is the area of the tributary watershed in sq mi, and p is the mean annual rain in inches using a regional map referenced in the report.

If the Q100 is provided by an HSPF model for a subarea, the equation constant can be calculated and compared to the suggested 1.95 value. For most HSPF model subareas under evaluation, p is relatively constant from the regional map. With that assumption, the 100-yr peak discharge at an upstream location in an HSPF model subarea can be calculated as:

$$Q100_{us} = Q100_{ds}\ (A_{us} / A_{ds})^{0.83}$$

The 0.83 exponent on the equation implies that the cfs/area ratio increases in the upstream direction consistent with the concept of areal reduction. This approach can be used on other model results if necessary. If the subarea is downstream from another subarea, the intermediate discharges can be estimated by interpolating between the two HSPF model peaks using the peaks and the tributary areas.

Because the modified rational method model tends to have a higher degree of spatial resolution than the other models in use, a historic VCRat model can be used to provide intermediate flow results within a watershed if it follows all of the design criteria listed in the Hydrology Manual. This is done by calculating the ratio of the peak at the point of interest to the peak at the subarea outlet and applying that ratio to the HSPF subarea peak. The results are concluded to reflect timing differences within a watershed better than use of the USGS regression equations.

4.8 Channel Routing and Timestep Issues

HSPF uses the Modified Puls method to do channel routing. This treats a channel reach like a linear reservoir and requires the generation of a stage-storage-discharge table (ftable) for each reach. The ftable is relatively easy to generate if there is a HEC-RAS model of the channel as it currently is an option in the RAS model version 4.0 to provide it. However, the District’s experience with the Santa Clara and Ventura River design storm models has shown that there are a number of issues associated with this routing method as follows:

1. In order for this simplified channel routing method to work correctly, the model timestep must be longer than the travel time through the channel reach based on wave velocity. Otherwise there is not enough time for the translatory floodwave to travel through the reach in the duration of one timestep and the assumption that outflow is a function of storage inherent in the method is not valid. An approximation of the wave velocity in a natural channel is 1.5 times the main channel velocity. For the continuous HSPF model with 15-min (Ventura River model) or 1-hr (Santa Clara model) timesteps, the Modified Puls routing method was acceptable. However, for the 5-min timestep used in the design storm model, some of the model reaches were too long for the Modified Puls method to work as intended.
2. The long reaches relative to the 5-min timestep, and combined in some cases with significant areas of overbank storage reflected in the ftables used in the HSPF models, resulted in attenuation of the peaks for some reaches of greater than 15% in the design storm model. This is undesirable for a number of reasons, including: 1) the routing scheme in HSPF is probably not complex enough to adequately resolve peak attenuation for design and floodplain mapping purposes, especially if the timestep length affects the attenuation; and 2) the hydraulic engineer using the hydrology results often prefers flows that do not reflect hydraulic constrictions so that they can adjust the hydrographs as necessary based on their own engineering judgment or by inserting the hydrographs in an unsteady flow model.
3. In steep reaches the HEC-RAS model will often show the flow to be in the supercritical regime. However, it is known that in natural streams the channel conditions will be affected by high velocity supercritical flow to create scour holes or meanders to dissipate that energy and restore the stream to a more equilibrium situation.

Our analysis of the above factors has led to the following approaches in developing ftables for HSPF channel routing:

1. HEC-RAS runs to generate ftables should be done at subcritical conditions to reflect typical stream behavior in returning to equilibrium conditions.
2. HSPF model results should be evaluated to make sure peak flow attenuation in any reach is not excessive. Attenuation levels greater than 10% should be re-evaluated based on aerial photos and topography to ensure that the overbank flow conditions actually occur in the reach. If not, the ftable should be adjusted accordingly.
3. The recent option of performing unsteady state flow simulations with HEC-RAS makes it possible to transfer the unattenuated peak flow results from HSPF to the HEC-RAS model to more accurately model the attenuation and overbank storage. If this option is done, the HEC-RAS model used to create ftables for the HSPF model should be adjusted to limit the amount of overbank storage represented in the resultant ftables.
4. If a reduction in the timestep appears to affect the peak flow results for long reaches in the model, the modeler should consider subdividing that reach in the HSPF model.

4.9 URBAN RUNOFF PEAK REDUCTION FACTOR

The representation of storage within the urbanized watershed and its effect on design storm peaks has not been evaluated in detail in the District's models. Most cities in the County design their curb inlets to accept only 10-yr inflow, and runoff above that level is expected to be stored in the streets until it can be discharged into one of the District's jurisdictional channels. Some cities have required the building of detention facilities for new development to mitigate existing flooding problems and have developed storage in that manner.

The Ventura River HSPF model has two urbanized subareas with stream gages to use in calibrating the model. Most of the development in the watersheds occurred before detention basin requirements were implemented in the County so that storage in the subareas is mostly due to urban inlet constrictions and undersized drainage facilities. In order to calibrate the HSPF model peaks to match the FFA results, the 100-yr rain intensities from each watershed had to be reduced by a factor of 0.7.

Upon further review, it was observed that the use of the 0.7 factor applied to the rain also reduced the runoff volume from the subarea to unrealistically low levels. Therefore, an approach was developed as follows:

1. A rain factor of 0.7 was applied to match the FFA peak in the model for the developed watersheds.
2. The rain factor was reset to 1.0.
3. The ftable was adjusted to provide more storage for discharges and volumes above the 10-yr peak level based on the FFA results. For each additional foot of channel elevation above the 10-yr level, approximately 20% of an assumed extra volume was added to the existing Ftable.
4. The extra volume was adjusted up and down until the 100-yr peak matched the FFA result.
5. Then the extra volume number was checked to make sure it was in a reasonable range by converting it to a depth in inches. The additional volume for the two watersheds worked out to about 0.3 inches of storage across the watersheds, which seems reasonable based on the proportion of streets to the rest of the watershed.
6. For the Calleguas model, the extra storage volume for the highly urbanized areas was about double the volume necessary in the Ventura model due to the additional development.

4.10 HSPF HYDROGRAPH YIELDS

Because the HSPF design storm model is based on a calibrated continuous hydrology HSPF model that matches historic runoff volumes well, the hydrograph yields for the 100-yr storms have been comparable to the yields that would be calculated using the District's NRCS CN approach. Therefore, HSPF hydrographs can generally be used in other model work such as sediment transport studies or levee seepage analyses after checking their yields for consistency with NRCS results.

4.11 COMPARISON TO OTHER MODELS

It is recommended that the HSPF design storm flow results for ungaged watersheds be compared to other available model results to make sure that the numbers are consistent. Because the method is relatively new and has only been used on regional models, the comparison will help develop confidence in the use of the HSPF model results for design purposes. The District has done this comparison in all of the work they have done with HSPF design storm models.

Because the HSPF models developed so far have been regional in nature, the District's policy is to accept VCRat model results with refined subareas, flow patterns, or boundaries, for projects where they have been developed to calibrate the regional HSPF model results.

4.12 TRANSFORMING HYDROGRAPHS

If VCRat hydrographs are imported into another model, the District's approach is to extrapolate the VCRat hydrograph to 0 cfs using the last several points in the hydrograph, and then adjust the time-of-peak of the VCRat hydrograph so that it matches the other model time-of-peak at that location. The last step is to transform the VCRat hydrograph into a hydrograph with regular time-intervals to match the other model.

When using other model hydrographs in VCRat models, the regularly-spaced hydrograph time ordinates are adjusted so that the peaks occur at the same time and then the flows are interpolated to obtain the points required in the irregularly-spaced VCRat hydrograph discretization scheme. The various programs produce hydrographs with slightly different shapes but they are similar enough so that the results can be used for design purposes.

SECTION 5 HEC-HMS DESIGN STORM MODELING

5.1 HEC-HMS MODELS AND REPORTS

The biggest HEC-HMS modeling effort providing official model results for one of the District's watersheds was done by the USACE (2003) when they prepared a regional HMS model of the Calleguas watershed in support of the FEMA FIS update for that basin. This model presented results for the natural, existing, and future conditions and has been used for various studies in the watershed. The model used an S-Graph developed for Sespe Creek and design storm hyetographs using the alternating block technique. The resultant hydrographs are very peaky, similar to MRM hydrographs, and generally have yields that are less than would be expected based on NRCS Curve Number yield analyses for the watersheds. Therefore, the hydrographs should not be used for hydrology and floodplain mapping studies requiring accurate volumetric hydrographs. The model did not explicitly include urban hydraulic constraints and required the use of the standard areal reduction factors and also a runoff calibration factor to match the peaks provided by stream gage frequency analyses documented in the 2003 report.

5.2 UNDEVELOPED WATERSHED S-GRAPH

The District performed a study in 2007 that calibrated hydrologic model parameters using the Snyder Unit Hydrograph and a constant loss rate in conjunction with the USACE lag method. From the results several S-Graphs were obtained that can be used to obtain design storm peaks and hydrographs for undeveloped watersheds greater than 5 sq mi in size. Although several partially-developed watersheds were included in the study, the results were inconclusive and therefore the method should not be used on developed or mixed use watersheds. The smallest undeveloped watershed in that study was Pole Ck at about 8.5 sq mi. This method should not be applied to developed watersheds or undeveloped watersheds less than 5 sq mi in area.

The S-Graphs are used in conjunction with a lag time, a constant loss rate, the SCS Type 1 storm distribution, the 100-yr 24-hr rainfall depth, and the SCS AMC II watershed yield to produce the design storm hydrograph.

5.2.1 Lag Equation

The lag time is calculated through the use of the USACE lag equation as follows:

$$T_l = 24*n\ (LL_c/S^{1/2})^m$$

Where:

T_l = catchment lag (hr), defined as time from start of unit rainfall to 50% of total runoff volume.

L = length of the main stream from outlet to divide (mi)

L_c = length of main stream from outlet to the point closest to the watershed centroid (mi)

n = basin factor related to Manning's n for channels and overland flow, ranging from 0.015 for improved channels and uniform drainage areas to 0.200 for overland flow areas with substantial vegetation.

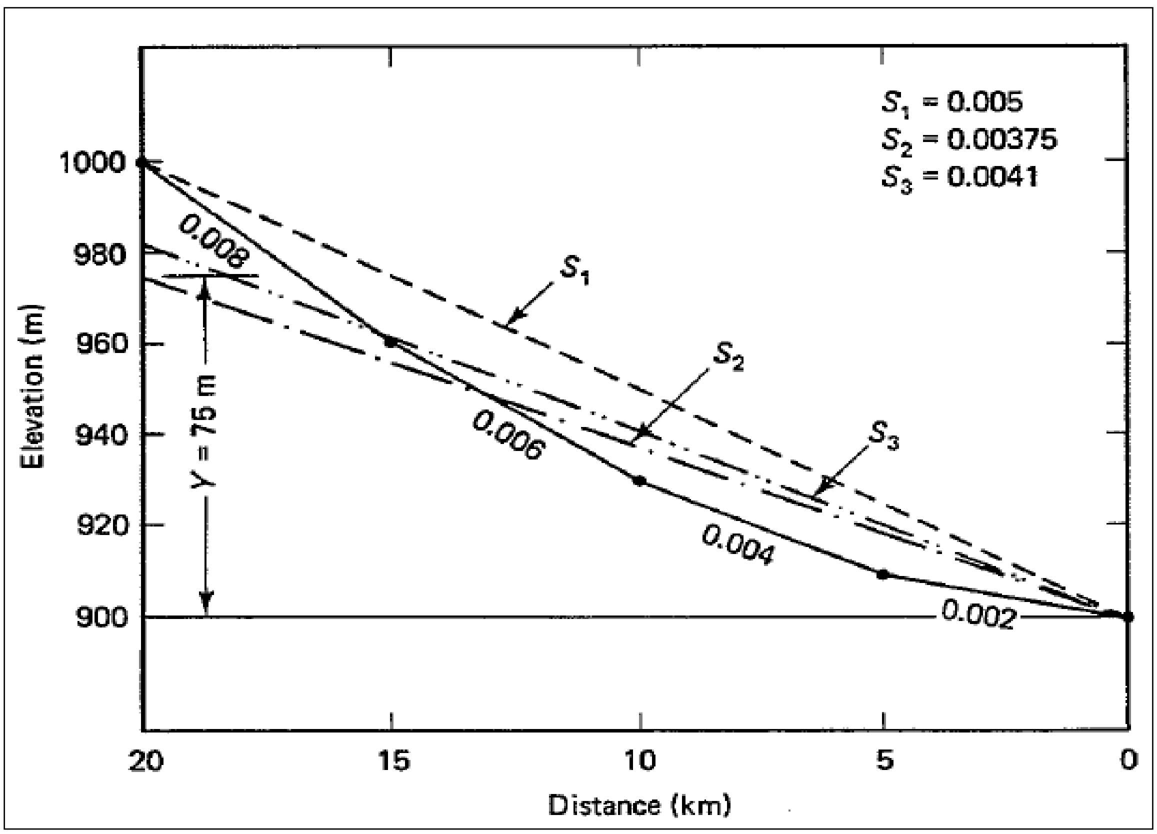
S = Overall slope between the headwaters and collection point in ft/mi

m = exponent, determined by regional flood reconstitution studies- Los Angeles District of USACE has determined the exponent for Southern California to be 0.38 based on analysis of historical storms.

This equation is commonly used to calculate lags for other unit hydrograph methodologies because it is assumed that the uncertainties associated with using the parameters to calculate the lag are greater than the uncertainties introduced by the different lag definitions.

5.2.2 Slope

There a several different definitions of catchment slope. Ponce (1989) defined the slope in the USACE lag equation as S_1. He defined an S_3 slope as a weighted average slope that that accounts for the fact that the travel time in different channel reaches does not vary linearly and therefore takes into account the basin response time. The figure below from Ponce (1989) shows the graphical representations of the slopes. The VCWPD study (2007) found that the S1 slope did not always provide a lag that matched the optimized lag. In some cases the S3 slope, yielding a slightly longer lag, matched the optimized lag better.



Catchment Slope Depictions

The equation used in order to calculate the S3 slope is:

$$S_3 = \left[\frac{\sum_{i=1}^{n} L_i}{\sum_{i=1}^{n} (L_i / S_i^{1/2})} \right]^2$$

The S3 slope is found by plotting the elevation vs. watercourse length and separating the curve into at least three reaches. The upper reach should be the steep upper portion of the stream, the middle reach should be a less steep foothill portion of the stream, and the most downstream reach is usually a flatter valley portion of the stream. The effect of using this approach for North Fork Matilija is that the S1 lag time using the COE lag equation was 1.31 hours and the S3 lag is 1.35 hours, a 3 % difference.

In some cases, the lag calculated with the S1 slope matched the optimized slope from the calibration better than lags calculated with the S3 slope. A number of shape and slope parameters were tested to find a combination that appeared to explain which slope should be used in the lag calculation. The best combination is as follows:

ER * S3 / (Lc/L)

Where ER is the elongation ratio defined as the diameter of a circle with an area equivalent to the watershed area divided by the length of the longest watercourse. As the watershed becomes longer and narrower, ER decreases. Physically the shape factor represents the ER times the change in elevation divided by the distance from the catchment outlet to a point opposite the catchment centroid. When this shape factor is less than 200, the S1 slope should be used in the lag calculation. When this shape factor is greater than or equal to 200, S3 slope should be used in the calculation.

5.2.3 Basin N Factors

The VCWPD study resulted in calibrated basin n factors as follows:

1. For undeveloped basins with S3 slopes greater than 150 ft/mi in the Santa Clara, Calleguas, and lower Ventura River watersheds, use a basin n factor of 0.045.
2. For steep S3 slope catchments of 300 ft/mi or greater in the upper Ventura River watershed, use a basin n factor of 0.055.
3. For undeveloped basins with S3 slopes less than or equal to 150 ft/mi in all watersheds, use a basin n factor of 0.035.

5.2.4 Design Storm Rainfall

The VCWPD study (2007) found that the rainfall distribution that provided reasonable calibration results is the SCS Type 1 rainfall distribution. The 24-hr 100-yr rainfall depth used with this distribution is obtained from the isohyetal maps provided in this manual. If the contour maps vary smoothly across the watershed, the value at the centroid of the watershed can be used. If the contours do not vary smoothly, a weighted average value should be calculated. This weighted average rainfall depth is applied in the meteorological module in the HMS model after specifying the SCS Type 1 rainfall distribution.

5.2.5 Design Storm Yields and Loss Rates

The VCWPD study (2007) found that the watershed yield calculated assuming Antecedent Moisture Condition II and obtaining the curve numbers and soil types for the undeveloped study watershed provides reasonable results in obtaining design storm peaks. Once the watershed yield is calculated, the constant loss rate in the HMS model is adjusted until the model yield matches the calculated 100-yr yield. No initial loss rate is necessary for the design storm.

5.2.6 S-Graph Selection.

For undeveloped watersheds, one of three S-Graphs can be selected based on the shape parameters calculated for each watershed as follows:

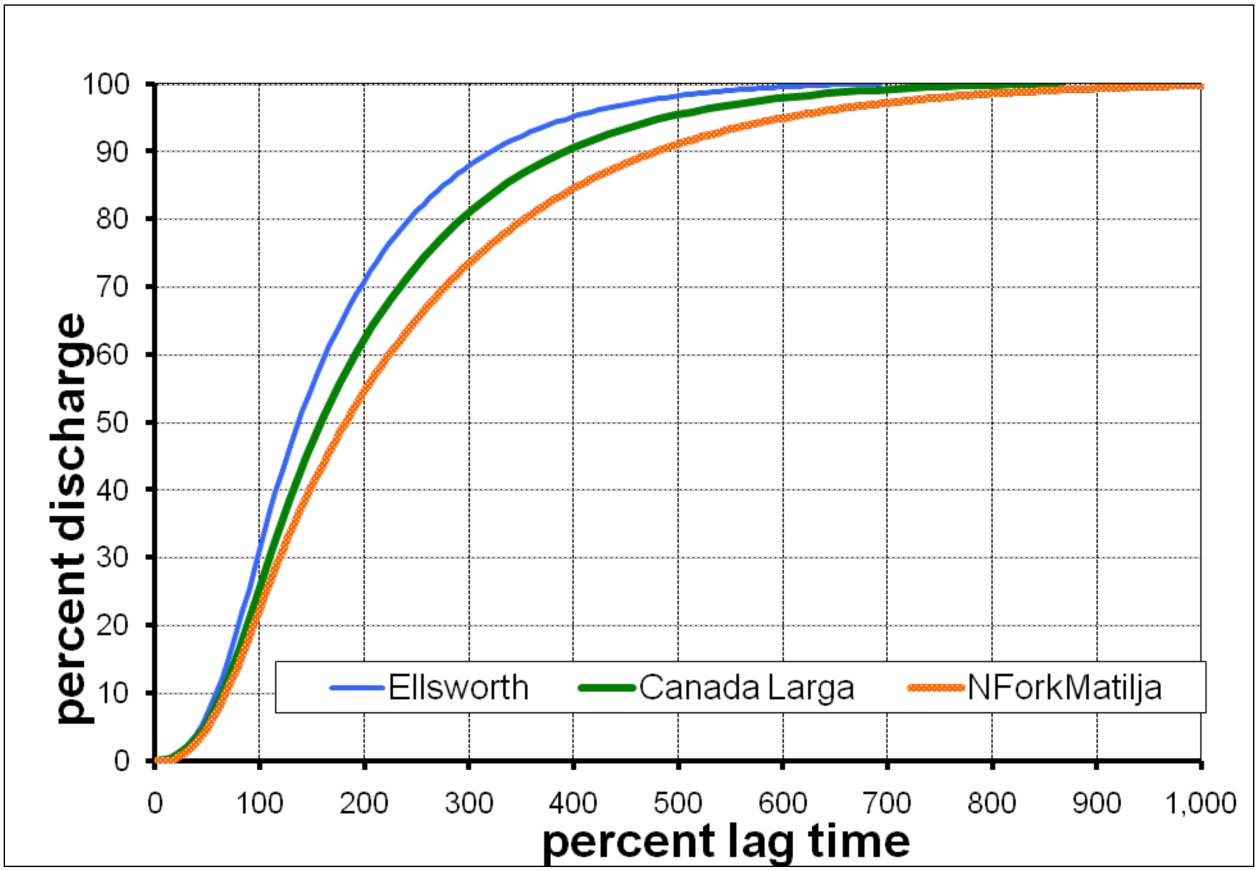
1. For long narrow watersheds with extensive headwater areas such as Ellsworth Barranca with a relatively low slope and small elongation ratio, use the Ellsworth Barranca S-Graph.
2. For round-shaped watersheds with a high elongation ratio and where there are several major tributaries with distinctly different lag times for major portions of the watershed (such as North Fork Matilija), choose the North Fork Matilija S-Graph.
3. For other watersheds, use the Canada Larga S-Graph that represents the average of the other four undeveloped watersheds included in the study. Tables of the S-Graph ordinates are provided in Appendix C. HMS model files using the three S-Graphs and other parameters to produce design storm hydrographs are provided in Appendix E.

5.3 CALIBRATION TO OTHER MODELS

The results of the HMS model design storm should be checked against other HMS runs of similar watersheds, other model results, or available stream gage flow frequency analyses for similar watersheds. The peak cfs/ac ratio for the design storm should be within the range of other model or stream gage results for nearby watersheds.

5.4 GENERATION OF SNYDER HYDROGRAPH

The HMS model has been used to develop regional hydrographs for use in VCRat2.64 modeling in limited applications. Due to the truncation of the VCRat2.64 hydrograph at the end of the one day simulation length, it is difficult to perform a yield adjustment on hydrographs from watersheds greater than about 70 to 80 sq mi in the VCRat program. For these watersheds, a lag is calculated, then the NRCS yield using soils and CN's is calculated, and a weighted average 100-yr 24-hr rainfall is obtained. These data are entered in an HMS model with a Snyder Cp factor of about 0.50. The constant loss rate is adjusted until the hydrograph yield matches the NRCS yield. Then the Cp parameter is adjusted until the hydrograph peak matches the areally-reduced VCRat2.6 peak at the location of interest. Finally, the hydrograph is translated so that the peak flow occurs at the same time as the VCRat peak, interpolated onto the VCRat variable time hydrograph spacing, and then the hydrograph is imported into the VCRat program for use in evaluating the downstream impacts on the District's facilities. An example of this is given in Appendix C and sample files are available in Appendix E.



Undeveloped Watershed S-Graphs.

SECTION 6 DESIGN PROCEDURES AND TOPICS

The following sections provide information on topics affecting the design procedures. Several examples are provided in Appendix B to demonstrate the use of the design techniques to calculate peak flows.

6.1 MODELING HYDRAULIC CONSTRAINTS

VCRat does not have the capability to easily model hydraulic constraints in the drainage system such as 10-yr storm curb inlet limitations or undersized drainage pipes detaining flow and attenuating peaks. Therefore, with limited exceptions, model results generally provide peaks assuming that all of the flow in the watershed can be discharged to the outlet in adequately sized pipes and channels. If the undersized pipes are included explicitly in the model, VCRat assumes that the flow is forced through under pressure, resulting in an unrealistic travel time and affecting the model peaks.

Providing peaks that are not attenuated by system deficiencies allows the hydraulic engineer to adjust the hydrographs as necessary to reflect constraints or show the impacts of improving the drainage system on the downstream peak. If it is important to accurately model the effect of hydraulic constrictions, there are a number of ways to use VCRat or other models to do this as follows:

1. For VCRat, a) Apply the 10-yr rain mass curves in any developed subarea with 10-yr curb inlet limits. Adjust the yield to match the 100-yr yield; b) Evaluate the topography to identify any alternate routes for the street flow to reach the channel and model those as splits in the VCRat model; or c_ Evaluate detetention due to backwater effects with stage storage curves and model those as basins in VCRat.
2. In HSPF, modify the ftables for flows above the 10-yr level to reflect the storage in the system. Add detention basins where necessary.
3. In HMS, add detention basins where necessary to reflect system storage.

6.2 VCRAT AND FLOODPLAIN ROUTING-BREAKOUT SIMULATION

Although the VCRat program has been upgraded over the years to provide limited routing capabilities, in some cases the program has been used to simulate floodplain routing and/or flow breakouts that occur as streetflow and confluence with the channel flow downstream of the breakout location. The District does not consider the VCRat program to be suitable to perform hydraulic routing where timing differences between the channel and breakout flow can reduce the channel peak flow significantly. If this occurs, the peak flows provided by the program should be transferred to a hydraulic program that provides routing methods that can adequately simulate complex flow patterns.

6.3 DISTRICT HYDROLOGY DATA AVAILABILITY

The streamflow, rainfall, evaporation, and hydrology study data available electronically at the District are available through the http://www.vcwatershed.net/hydrodata/ website. This website allows the users to download formatted or text files of daily flows and rainfall for the District’s gages. It also provides station information, and precipitation and stream frequency analysis results. The “Frequently Asked Questions” file shown on the website provides a detailed description of the available data and quality control codes. Limited hourly flows and rainfall are also available through the website.

If District data are needed for studies that are not currently available through the website, consultants can email the request to HydroData@Ventura.Org. The Hydrology Section will review the request and provide a response and/or the data in a timely fashion. If data is requested requires extensive processing in advance of the District's normal schedule or in addition to the normal workload, costs for the processing will be charged according to the policy set by the Ventura County Board of Supervisors.

6.4 DESIGN STUDY SUBMITTAL MATERIALS

Often hydrology studies are performed to demonstrate the effects of development and required mitigation strategies on the District's jurisdictional channels and the resultant drainage reports are submitted to the Permits Section for review. The required information is in a pdf document accessed through the following webpage: http://vcpublicworks.org/pwa/watercourse-permits. A WORD document showing an example format and information for the hydrology portion of the study and providing procedures for many of the topics discussed in this section are provided for consultant use as part of Appendix E.

6.5 UPDATED MPD DATA AND DESIGN

Before the District began developing official watershed models the Cities had Master Plans of Drainage (MPDs) to evaluate their local storm drain systems and plan for system upgrades. The MPDs all use the District's VCRat model except for the City of Oxnard with their Cook's method (considered to be a simplified Rational Method approach). The Oxnard MPD prepared by Hawks Associates (2003) contains a comparison of peak flow using both methods. The results of the comparison are that the Cook's method yields peaks that are about the same or bigger than VCRat peaks for developed watersheds up to several hundred acres. VCRat peaks are bigger for larger watersheds and for undeveloped areas.

The District's policy is to allow the use of MPD results for small project areas as described in Section 6.6. The Cities of Thousand Oaks and Camarillo have issued updates to their MPDs. Simi Valley has a draft MPD (as of July 2017) available to update their 1990s report. The District has commented on the Thousand Oaks MPD but has not reviewed the Camarillo MPD. Because of this, the District will accept the use of MPD results to evaluate small project areas at this time but the MPD models cannot be used to evaluate large projects or assess the downstream impacts of projects on the District's jurisdictional channels. When this is required, the District's official models should be used or if not available, the MPD should be updated to meet the District's requirements and calibrated to existing FFA data.

6.6 UNIT RUNOFF CALCULATIONS FOR SMALL PROJECTS

When development projects consist of small areas that do not meet the Hydrology Manual minimum subarea guidelines, it is possible to estimate the change in peak flows from the project area using pro-rated values based on the unit runoff. The steps are as follows:

1. Find the subarea that incorporates the project area in a city Master Drainage Plan or official District VCRat hydrology model.
2. Evaluate if the change in development for the project would affect the subarea Tc by more than 0.5 minutes (VCRat only accepts Tc's rounded to the nearest minute). Unless the project is located in the upper portion of the subarea and would affect the overland flow portion of the Tc, the Tc is not likely to change. If the Tc does not change, the intensity used in the subarea peak flow calculation does not

change. If the Tc does change, recalculate it to obtain the correct design storm intensity for use in peak flow calculations (Exhibits 2 or 3).

3. Find the C coefficient for the pre- and post-development conditions (Exhibits 5 or 6), and recalculate the peak flows from the project area only.
4. If the pre-or post-developed condition percent imperviousness matches that used in the model subarea, the peak can be obtained from the model result through pro-rating based on area.
5. Sometimes the increase is runoff is very small but the District has been concerned about the cumulative increase in flow due to numerous small projects and so has been asking for mitigation for any new project with very limited exceptions. Even when the increase in peak is small, the increase in runoff volume can be significant.
6. If a detention basin is selected to provide mitigation, the VCRat model can be used for its design. Simplified methods for designing detention areas for very small projects are provided in following sections.

An example of this method is provided in Appendix B.

For this iteration of the Hydrology Manual, the District has developed several spreadsheets to assist consultants with small projects. The spreadsheets include the following:

1. Spreadsheet that calculates the time of concentration for one subarea after the user enters in the required subarea and flowpath information.

2. Spreadsheet that calculates the flow hydrograph for one subarea, adjusts the yield, and routes it through one flow-through detention basin using the provided stage-storage-discharge data. The spreadsheet also calculates the required bypass detention basin volume to store the runoff volume occurring above the required mitigation peak level.

These spreadsheets are provided in Appendix E. The user interface portions of the spreadsheets are shown in Appendix A.

6.7 HYDROLOGIC MULTIPLIERS

Time of Concentration (Tc) values required for each subarea in the VCRat model are a function of rainfall intensity and therefore design storm recurrence interval. Because of this, they have to be recalculated for each design storm. Because hand Tc calculations are time-intensive, in the past the District developed a table of hydrologic design storm ratios or “multipliers” based on stream gage frequency analyses. The multipliers were used to estimate other design storm flows once the results from one design storm were available. Additionally, the 1992 Hydrology Manual only provided the 50-yr 24-hr rainfall design storm depths for use in yield calculations, and there was a need to estimate other design storm values using average design storm rainfall ratio multipliers.

Currently, the Tc calculator has been automated so that it is relatively easy to calculate Tc’s for all design storms of interest once the subarea Tc physical data have been entered into the calculator. The current Hydrology Manual now provides the 24-hr rainfall depths for the 10-, 25-, 50-, and 100-yr storms.

Therefore, there is no longer a need to use the Hydrology Multipliers in design calculations using the VCRat model except in limited special cases. However, the HSPF and HEC-HMS model results still require the use of the multipliers. Exhibit A-21 provides the updated multipliers developed by the District in a summary table.

If a VCRat model has been run for more than one design storm, the results should be used to calculate the design storm peak ratio and compared to the updated multipliers to make sure they are applicable. If the standard multipliers do not appear applicable, they should be adjusted for use in that study using reasonable assumptions.

6.8 TIME OF CONCENTRATION CALCULATIONS AND DESIGN EXAMPLES

Because hand calculations of the Time of Concentration (Tc) values required for each subarea in the VCRat model were time-intensive, previously the hydrologist was only required to calculate Tc's for 20 percent of the subareas. The hydrologist could then use those results to estimate Tc's for the other subareas if they were hydrologically-similar. In addition, Tc's for other design storms were often assumed based on engineering judgment instead of recalculating them. The current Tc calculator program automatically does the iterations necessary for the calculation and therefore greatly decreases the time necessary for a single Tc. Also, the program makes it easy calculate Tc's for all design storm levels once the Tc input data file is generated. Because of these factors, currently the hydrologist is required to calculate Tc's for 75 percent of the developed subareas and 25 percent of the undeveloped subareas included in the hydrologic model. Engineering judgment can be used to estimate Tc's for the other subareas as long as they are hydrologically similar in slope and development type to the subareas where Tc's have been calculated directly. It is also possible to develop regression equations based on the calculated Tc's to estimate the other Tc's.

To illustrate use of the MRM for computing design flow rates, two detailed examples are presented in Appendix B. The first example describes the recommended procedure for computing both a peak flow rate and runoff hydrograph considering the entire tributary drainage area as a single unit. This is appropriate only when channel routing is not necessary and only for watershed areas with a time of concentration between 5 and 30 minutes. The first example also demonstrates a technique for adjusting the volume of runoff associated with a storm hydrograph. Reasonable storm volumes are important for the design of pumping stations and detention basins.

Complete drainage areas with total times of concentration greater than 30 minutes must be subdivided into smaller subareas and a time of concentration computed for each. Runoff hydrographs are then computed for each subarea, routed, and combined with other subarea hydrographs to establish design flow rates. Because of the complex calculations required for the hydrograph routing, it is necessary to use the VCRat program to model multiple subareas with channel routing. Example Two in Appendix B describes the necessary procedures for use in subarea definition and model development using VCRat. The Exhibits for the examples are provided in Appendix A.

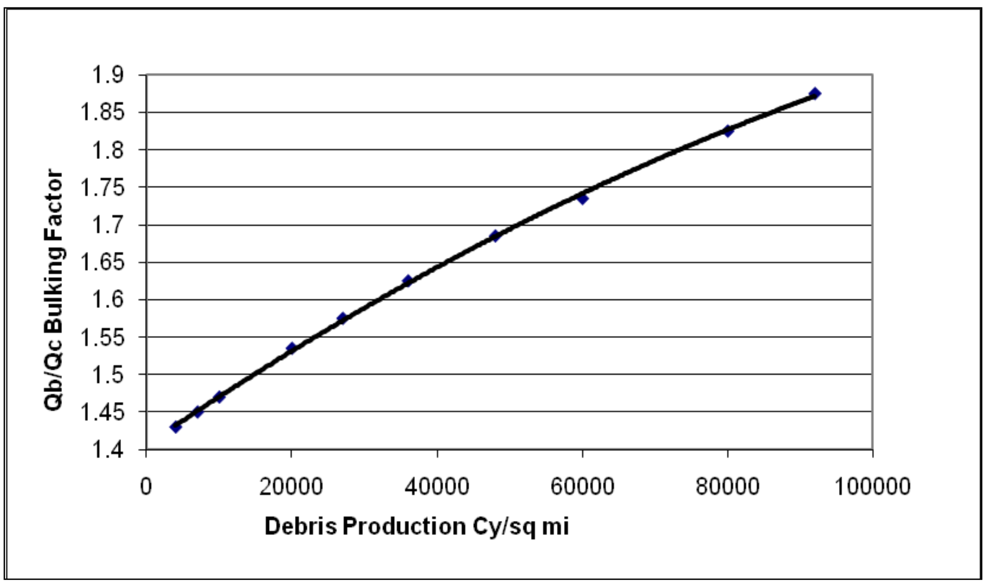
6.9 BULKING FACTORS

The hydrology model results generated by the VCRat models were generally considered clear water estimates except in limited cases where the model results have been calibrated to stream gages. Stream gages generally have a limited amount of sediment in the flow, such as the gages used to calibrate the District's official model of Calleguas Creek. Because of the sediment, the Calleguas model numbers are considered to be bulked to a limited extent. Bulking has also been applied to model results for smaller watersheds with known high sediment production such as the FIS 100-yr peak for Pole Creek where the clear water hydrology model peak was increased by a bulking factor of 1.5.

Bulking factors for watersheds such as Pole Creek or subject to frequent fires can be obtained by first calculating the expected sediment yield using the Scott and Williams (1978) equation or some similar method. Then the sediment production in cy/sq mi is used to obtain a bulking factor based on a historic curve shown below. The bulking factors obtained through this approach range from about 1.42 to 1.72 for the District's watersheds.

The District hired a consultant study to make recommendations about the use of bulking factors in design storm hydrology (WEST, 2011). The conclusions are as follows:

1. The highest sediment concentrations ever measured on a mainstem was about 70,000 mg/l, which corresponds to a sediment volume of roughly four percent. Bulking factors on mainstems are generally small due to runoff from numerous watersheds, only some of which are high sediment producers due to fires or erosion-prone soils.
2. The historic bulking factors should be applied to the design of jurisdictional channels downstream of small watersheds that are known high sediment producers or subject to frequent fires. In the case of Pole Creek, the gravel-sized chunks of shale that were carried in the flow deposited and blocked the channel in 2005 after a fire in 2003. The Pole Creek watershed is less than 9 sq mi in size.
3. The historic bulking factors should also be used for emergency projects designed to protect development from recent fires in the watersheds, or for design of critical development such as hospitals and schools.



VCWPD Bulking Factors Used in Historic Studies

The method for applying bulking based on the calculated sediment yield from the undeveloped portions of a watershed follows the concepts developed by the Los Angeles Department of Public Works as described by West (2011).

To convert the estimated debris yield (i.e., debris volume) to a bulking factor requires that the clear-water hydrograph be computed using a rainfall-runoff model. To distribute the total debris volume throughout the flow hydrograph, the following equation may is used:

$$Q_S = a\, Q_W{}^{n}$$

where Q_S is the sediment discharge (cfs), Q_W is the clear-water discharge (cfs), and *a* and *n* are bulking constants (fixed throughout the hydrograph). This equation is used in the sedimentation manual (Los Angeles County, 2006) when using bulked flows in sediment transport studies.

According to Vanoni (2006), the value of *n* is between 2 and 3 for most sand-bed streams. For Ventura County, the value is assumed to be 3. The coefficient *a* is determined by numerical integration of the cubed 100-year hydrograph ordinates as follows:

$$a = \frac{V_S}{\sum\left(\Delta t * Q_W^n\right)}$$

where V_S is the total sediment yield and Δt is the computational time interval from the hydrologic model.

It should be noted that this method assumes that the peak sediment hydrograph outflow will occur at the same time as the peak storm hydrograph. The volume of the sediment is obtained from the District's ScotSed program or a spreadsheet using the Scott and Williams (1978) regression equation as described in the District's Debris and Detention Basin Manual (2005). A spreadsheet has been created to apply the sediment to yield-adjusted VCRat hydrographs. An example of using the spreadsheet is given in Appendix D. The spreadsheet is available from Appendix E.

Use of this approach in several District studies has resulted in a Bulking Factor on the order of 1.2.

6.10 CHANGE IN RUNOFF PARAMETERS DUE TO FIRE

A related issue to the increase in peak due to bulking is the increase in runoff due to reduced infiltration and vegetation cover after fires. The District does not have a policy to increase C coefficients in VCRat or reduce basin n values and soil infiltration rates in HEC-HMS to account for this. The HSPF modeling done in the Santa Clara River model did a simple analysis of the increase in peaks due to fires in the Piru Creek and Sespe watersheds and found that the mean annual runoff volumes can increase by up to 20 percent, while the 100-yr design storm peak on the Sespe increased by about five percent when about a third of the watershed was modeled with burn conditions.

Specific recommendations and procedures for changing runoff parameters due to fires are still under development at this time. Until the District's policy is finalized, fire effects will be modeled on a case-by-case basis after consultation with the District's Hydrology Section.

6.11 FLOW LIMITATION AGREEMENTS, CITY OF OXNARD

The District's Rice Rd Drain jurisdictional channel in the City of Oxnard has been subject to upstream development. Because the increase in runoff has increased the flooding potential in downstream areas, the

District and the City of Oxnard developed an agreement that limited the runoff from new development to specified limits. Agreement FC-2-87-6A limited the peaks from new development for the 100-yr storm to 1 cfs/ac north of Fifth Street and to 0.72 cfs/ac for the portion of the watershed between Fifth Street and Emerson Avenue.

In addition, the City of Oxnard has their own procedures for designing local storm drain systems. They use the Cook's Method for the drainage systems. Their method does not include detention basin design so for those facilities they accept the results from VCRat models following the District's methods. The City of Oxnard can confirm these requirements for projects in their jurisdiction.

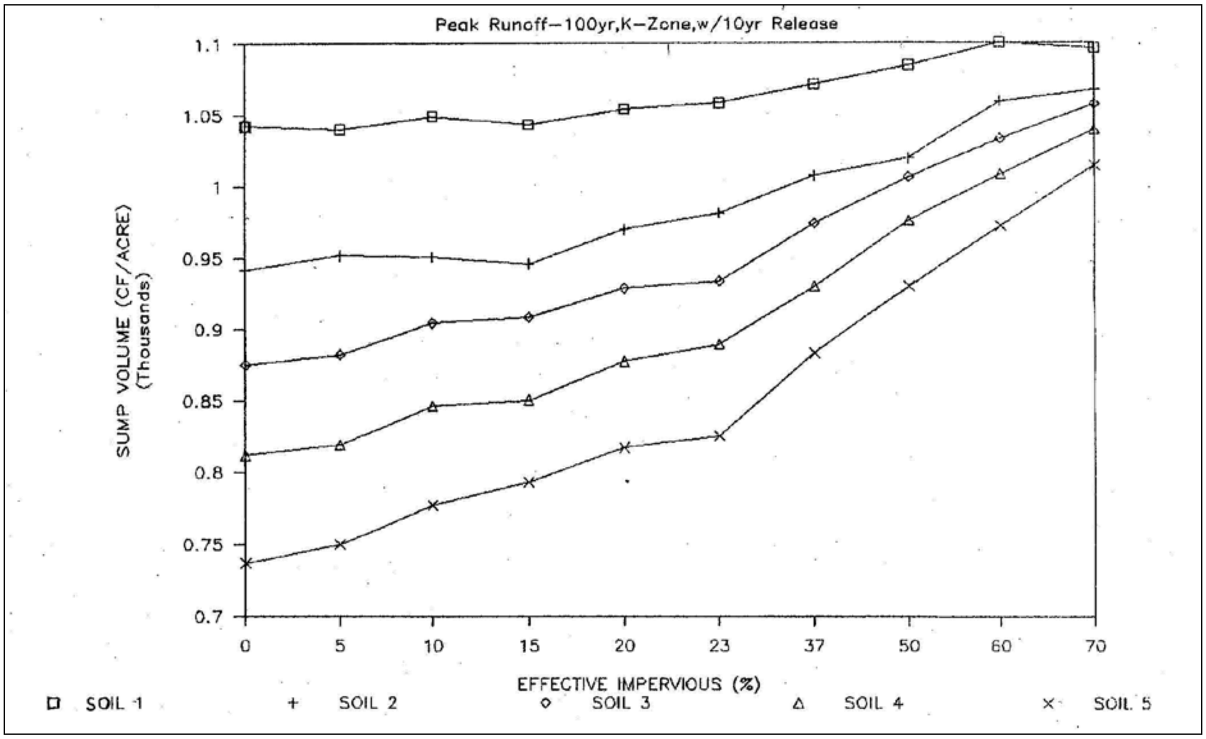
6.12 DEVELOPMENT MITIGATION CRITERIA

Information on development criteria is provided for convenience but it is suggested that the consultant verify their mitigation with the agency having jurisdiction over their proposed projects. Generally the Cities and unincorporated County direct the consultant to design local drainage to accept the 10-yr developed condition peak and to check to see that the flow above that level up to the 100-yr peak could be conveyed in the street without flooding adjacent structures. One exception is the City of Moorpark that allows consultants to design the local drainage to convey the 50-yr peak.

To minimize the impacts of development on the existing drainage system, and in some cases to remedy existing drainage deficiencies, most Cities require that the consultant use detention to attenuate the 100-yr developed condition peak back to the 10-yr developed condition peak. For some watersheds with severe channel deficiencies, the mitigation goal has been the 10-yr undeveloped condition peak. For the unincorporated County, the mitigation is normally no increase in flow for any design storm from the 10-, 25-, 50-, or 100-yr frequency. However, these criteria should be confirmed with the agency having jurisdiction prior to any work on project design.

6.13 BYPASS BASIN DESIGN

In 1988 the District provided training to consultants and City engineers about detention basin design. As part of the training a Truncated Sump figure was provided that provided design basin volume criteria for bypass basins located in the City of Oxnard. The figure indicated that the required basin volume to attenuate the developed 100-yr peak back to the 10-yr developed peak level was a maximum of about 1,000 cf/ac for most development and soil combinations. This mitigation volume was then adopted by a number of cities in Ventura County including Simi Valley, Thousand Oaks, Camarillo, and Oxnard. Historical studies submitted to the District for review were commonly designed by providing a basin with this volume, with outflow from the basin controlled by an orifice plate sized to limit the discharge to the 10-yr peak based on the assumed depth of the basin.



Truncated Sump Volume Figure, 1988

The Truncated Sump Figure discussed above presented results that were simplified because it did not show how the mitigation volume varied with Tc and watershed yield. The figure was only intended to be used for bypass basin design in the City of Oxnard where the VCRat hydrograph yield is generally very similar to the watershed yield calculated through the NRCS CN approach.

The use of the NOAA rainfall and revisions to the C coefficients used in design storm modeling for VCRat2.64 made it difficult to establish standard sump volumes for the various soil types. The hydrograph yield adjustment using the updated rain and C coefficient data leads to a wide range of sump volume results. The volume for bypass basins can be obtained through analyses using the updated VCRat2.64 program or the VCRat one-subarea spreadsheet that also calculates the bypass basin volume based on the user-specified mitigation level. The spreadsheet interface is shown in Appendix D and the Excel file is provided in Appendix E.

6.14 FLOW-THROUGH BASIN DESIGN

The District has not attempted to produce a nomograph that could be used for flow-through basin design by consultants because there are so many parameters associated with routing of flow through a basin, including hydrograph shape, operating spillway design, low flow outlet design, 100-yr 24-hr rain depth, subarea % imperviousness, and Tc's and C coefficients for the VCRat program. However, in an attempt to make the design process simpler and more straightforward for basin designers, a study was completed that developed a method to design and evaluate basins using VCRat in conjunction with HEC-HMS.

The design parameters selected for use in the study were the following:

1. Use as many criteria as possible from the County NDPES Technical Guidance Manual to design basin detention for stormwater quality purposes such as basin sideslope criteria (3H:1V), basin length to width ratio (2L:1W), and the low flow outlet orifice sizing equation.
2. To minimize the downstream impacts on natural channels due to erosion from the increase in runoff volume, the basin was provided with a low level outlet sized to detain flow until 20-24 hrs after the peak rainfall had occurred.
3. Assume the 100-yr developed condition was being mitigated back to the 10-yr developed condition in the study. This is the most common mitigation condition used in the County.
4. Evaluate the range of 100-yr 1-day rainfall values commonly found in developed areas.
5. Minimize the depth of the basin because it is assumed that this is desirable for most projects because areas with flat slopes will require more grading if deeper basins are built. Most of the basins were assumed to be 5 ft deep for a subarea of 100 ac.
6. Because VCRat simulations only extend to 24 hrs, and one of the goals was to design a basin that would not outlet all of the flow until 24 hrs after the peak rainfall had occurred, it was necessary to export the VCRat hydrograph to HMS to do a multiple day run.
7. Each basin was assumed to be designed with a vertical standpipe with the top at ½ the basin depth and sized to outlet the 10-yr developed condition peak with basin full. Each standpipe was assumed to have a low level outlet sized to empty the basin 20-24 hrs after the end of rainfall and sized using NPDES Technical Guidance Manual equations.

A detailed procedure and example is provided in Appendix D. The study results showed that the most conservative basin design is required for long Tc-small % impervious development combinations because the broader hydrograph shape contains more volume above the mitigation level. An evaluation of the regional detention basins contained in the District's official Calleguas Creek model showed that the average ratio of the operating volume at the time of peak outflow from the basins to the inflow hydrograph volume was about 0.15. In this study, the same ratio ranged from about 0.16 to 0.18.

The use of the NOAA rainfall and revisions to the C coefficients used in design storm modeling for VCRat2.64 made it difficult to establish standard basin volumes for the various soil types. The hydrograph yield adjustment using the updated rain and C coefficient data leads to a wide range of basin volume results. The volume for basins can be obtained through analyses using the updated VCRat2.64 program or the VCRat one-subarea spreadsheet that also calculates the flow-through basin volume based on the user-specified mitigation level. Appendix D provides an example of the design process. Appendix E provides copies of the files used in the examples.

6.15 SIMPLIFIED BASIN DESIGN PROCEDURES FOR SMALL PROJECTS

For consultants or permit applicants that are only developing or modifying a small project area, the District has developed a set of simplified procedures to size detention facilities. The results of the procedures are relatively conservative when compared to designs using full basin routing analyses. Therefore, they are only used when the small size of the project does not warrant a more sophisticated analysis. Projects of 5 ac or more can be evaluated with the VCRat program, therefore, this method should be limited to projects that are less than 5 ac in size.

6.15.1 100-Yr Undeveloped Condition Peak Mitigation

Estimates of the detention volume required for projects to mitigate from the 100-yr developed to the 100-yr undeveloped condition can be obtained with a NRCS Curve Number evaluation of the additional impervious project area as follows:

1. Find 100-yr 1-day rainfall for project area from Appendix E maps or GIS shapefiles provided with Hydrology Manual.
2. Find CNs associated with undeveloped and impervious project conditions from Exhibit 14,
3. Find runoff depths in inches from Exhibit 13 or use equation provided on Exhibit 13.
4. To find net yield, subtract additional 0.5 inch for additional depression storage and abstractions so that result is more consistent with the District's detention basin routing results.
5. Multiply runoff depths in feet by impervious area of project in square feet to obtain the undeveloped and developed runoff volumes.
6. This volume will generally be larger than that obtained through a routing and design analysis of the basin using a yield-adjusted VCRat hydrograph because the routing effects generally reduce the required basin size. The volume may also be larger than that required by reducing the peak back to the 10-yr developed level below due to the CNs used.

An example calculation is provided in the following table, and the spreadsheet is provided in Appendix E.

Watershed Data	Undeveloped	Impervious
100-yr 1-d Rain (inch)	7.6	7.6
Soil Type	3	3
Land Use	Open Space	Imperv area
CN Exhibit 14	73	98
S = 1000/CN-10	3.70	0.20
Yield (inch) from Exhibit 13	4.46	7.36
Volume Calculation		
Yield Difference in		2.90
Additional Assumed Depression Storage Impervious Surfaces (inch)		0.50
Net Yield (inch)		2.40
Impervious Area (ac)		0.0500
Vol Increase - Max. Basin Size Req'd (cf)		436

6.15.2 10-Yr Developed Peak Mitigation Criteria

For small project areas with mitigation requirements that the 100-yr developed peak should be reduced to the 10-yr developed peak, the following approach has also been used:

1. Find the 100-yr 1-day rain depth for project site.
2. Find the 10-yr 1-day rain depth for project site
3. Subtract the two plus an additional 0.5 in for depression storage
4. Multiply by impervious area with units in cubic feet

The following table shows an example of the approach.

Volume Calculation	100-yr 24-Hr Depth	10-yr 24-Hr Depth
Rainfall (inch)	7.6	5
Yield (inch)		2.6
Depression Storage Impervious Surfaces (inch)		0.50
Net Yield (inch)		2.10
Impervious Area (ac)		0.0500
Vol Increase - Max. Basin Size Req'd (cf)		381.2

6.15.3 VCRat Hydrographs for Small Projects

The minimum subarea size in VCRat2.6 and 2.64 is 5 ac to decrease the chances of the program being used to produce design flows for numerous tiny subareas such as is commonly required for drainage design. However, for small developments where peak mitigation is required through basin design, it is possible to use the program to get a hydrograph. The procedure takes advantage of the fact that the VCRat results are linear with area, so that the hydrograph of a 10-ac subarea is identical to the hydrograph of a 100-ac subarea divided by 10 as long as the other model input parameters (Tc, % impervious, soil type) are identical. The procedure to get a hydrograph for a 1.3 ac site is as follows:

1. Per the previous MPD discussion, find the subarea Tc applicable to the project area from an existing model or calculate one. Set up a model using the desired model rain zone and Tc and project area soil type and % imperviousness. For subarea size in the model, use the project area times a factor from 10 to 100. For this example, use a factor of 10 so the subarea size will be 1.3 x 10 = 13 ac.
2. "Fatten" the project area hydrograph using the yield adjustment procedure described in this manual.
3. Export the project area hydrograph in csv format so it can be imported into Excel. Divide the hydrograph ordinates by 10. The resultant hydrograph can be used in another program to do basin design for the project area.
4. Alternatively, use the flow split option in VCRat to split off 90% of the flow into a lateral, leaving 10% or $1/10^{th}$ of the hydrograph in the main line for use in designing a basin.

An example of this technique is shown in Appendix B-12.

6.16 Areally Reduced Flow Results in Junction Analyses

If confluence information is requested in the VCRat model, the model will print out the flows at a confluence at the time the main line upstream of the junction is peaking, at the time the tributary is peaking, and at the time that the main line downstream of the junction is peaking. The flows provided in the model results fulfill mass balance requirements. However, if AR is required for the main line and perhaps the tributary (if area is greater than 600 ac), because the AR curves are nonlinear with area, the resultant flows will not be balanced. To preserve mass balance requirements for hydraulic junction analyses, use the following steps:

1. From main line point-of-view: Find the time of peak of the main line downstream of the junction, apply AR to that peak. Find the tributary flow at the main line time-of-peak, and apply tributary AR factor to that flow if required. Upstream net main line flow is equal to the downstream main line AR flow minus tributary AR flow at the main line time of peak.
2. From the tributary point-of-view: Find the time of tributary peak, apply AR to that peak. Find the main line flow downstream of the junction at the tributary time-of-peak, and apply main line AR factor to that flow. Upstream Net Main Line Flow is equal to the Downstream Main Line AR flow minus tributary AR peak.

The results are generally used in hydraulic analyses of junctions using VCRat model results and the most conservative case (generally when the tributary is peaking) governs the design. For HMS and HSPF models, because AR is applied in the model to the input rainfall, two model runs are required to provide the flow results for the two points-of-view, one for the junction and one for the main line.

6.17 Converting VCRat2.2 Models to VCRat2.64 Models

The changes in hydrology rainfall mass curves and C coefficients for the 2017 Manual will lead to revised design storm peaks, especially in undeveloped areas. Extensive work is required to convert a VCRat2.2 model to a VCRat2.64 model as follows:

1) Apply the appropriate NOAA mass curve to the VCRat2.64 model.

2) Use the revised C coefficients.

3) Confirm the development type and update the percent imperviousness used in the subareas from effective to actual values.

4) Recalculate the Tc’s for 25 percent of the undeveloped subareas and 75 percent of the developed subareas using the revised rainfall, C coefficients, and percent imperviousness information. Use engineering judgment to assign Tc’s to the remaining subareas. Update the Tc’s in the model.

The VCRat2.64 model results are very similar to the VCRat2.2 results in developed areas but have smaller peaks in undeveloped watersheds. This is consistent with the results from other models such as the HSPF and HEC-HMS models that the District has developed.

To provide official results to the District for review, the Tc's must be recalculated using the revised data as described in step 4 above. However, to do a quick estimate of the change in peak due to the Tc changes, the revised data used in the Tc calculations usually causes the following:

1) VCRat2.2 and 2.6 Tc's from 5-9 min usually increase by 1 min.

2) VCRat2.2 and 2.6 Tc's from 10-19 min usually increase by 2 mins.

3) VCRat2.2 and 2.6 Tc's from 20-27 mins usually increase by 3 mins.

4) VCRat2.2 and 2.6 Tc's from 28-30 mins are revised to be 30 mins.

This information can be used to obtain a quick estimate of the change in design storm peak for a VCRat2.64 model.

6.18 SEDIMENT YIELD CALCULATION UPDATES FOR BASIN DESIGN

The District's Debris and Detention Basin Manual updated in 2005 describes the requirements for basin design for facilities to be maintained by the District. If a detention basin is located downstream of an undeveloped area that can produce sediment, it is generally required to have enough volume for 125% of the 100-yr storm sediment yield in addition to the volume that is required for flood storage and peak attenuation.

The regression equation used by the District to estimate design storm sediment yield volumes for basin design was developed by Scott and Williams (1978). Recently the District's basin sediment removal volume was used to evaluate and update the regression equation and develop equations with other parameters. The results show that the 1-day and 10-day rainfall that were important parameters in the Scott and Williams equation do not correlate as highly now. For basins with small watersheds of 1.6 sq mi or less, the maximum hourly intensity during a storm is a better predictor of yield. For large watershed basins, other studies have found that peak inflow is a better predictor. Because peak inflow is not measured at any of the District basins except for the new Pole Creek basin, 1-day rain is still used as a predictor of sediment yield in the updated equation for medium to large watersheds. The District has a draft report presenting the results of the analysis (2009). The results cannot be used for basin design but instead can be used for comparison purposes.

6.19 NPDES REQUIREMENTS

NPDES requirements for projects are outlined in the Technical Guidance Manual available through the District's website. Those requirements have been developed through the use of national methodologies applied to Ventura County and also evaluations of local data. Some of the methodologies involve using a rational method approach to estimating runoff volumes based on design rainfall intensity data. The one flow-based peak method provided in the Technical Guidance Manual (TGM) allows the user to calculate the Stormwater Quality Design Flow (SQDF) peak from a model run that provides the 50-yr peak for the developed area by multiplying the peak times 0.10. The resultant peak that has to be treated by the NPDES system is close to the peak that would be expected from a 2-yr storm for an undeveloped subarea using the District's standard multipliers. The other methods provided in the Technical Guidance Manual result in

Stormwater Quality Design Volumes (SQDV) that need to be treated to meet the NPDES requirements. The design numbers should be obtained from the TGM.

Several NPDES Best Management Practices included detention basins. To minimize space requirements for basins, it is common to see developments with one basin providing mitigation for NPDES and design storms. The lower portion of the basin is designed to meet the volume and drainage time requirements for NPDES, and the upper portion of the basin is designed to mitigate the 100-yr developed condition peak back to the desired design storm mitigation level. As the design storm volume has to be drained in 24-hrs after the end of design storm rainfall, unless the NPDES portion of the basin is also drained in that time it cannot be used as part of the design storm mitigation volume.

SECTION 7 REFERENCES

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APPENDIX A: EXHIBITS

EXHIBIT 1A. LEGACY DESIGN STORM RAINFALL CONTOURS- 100-YR STORM

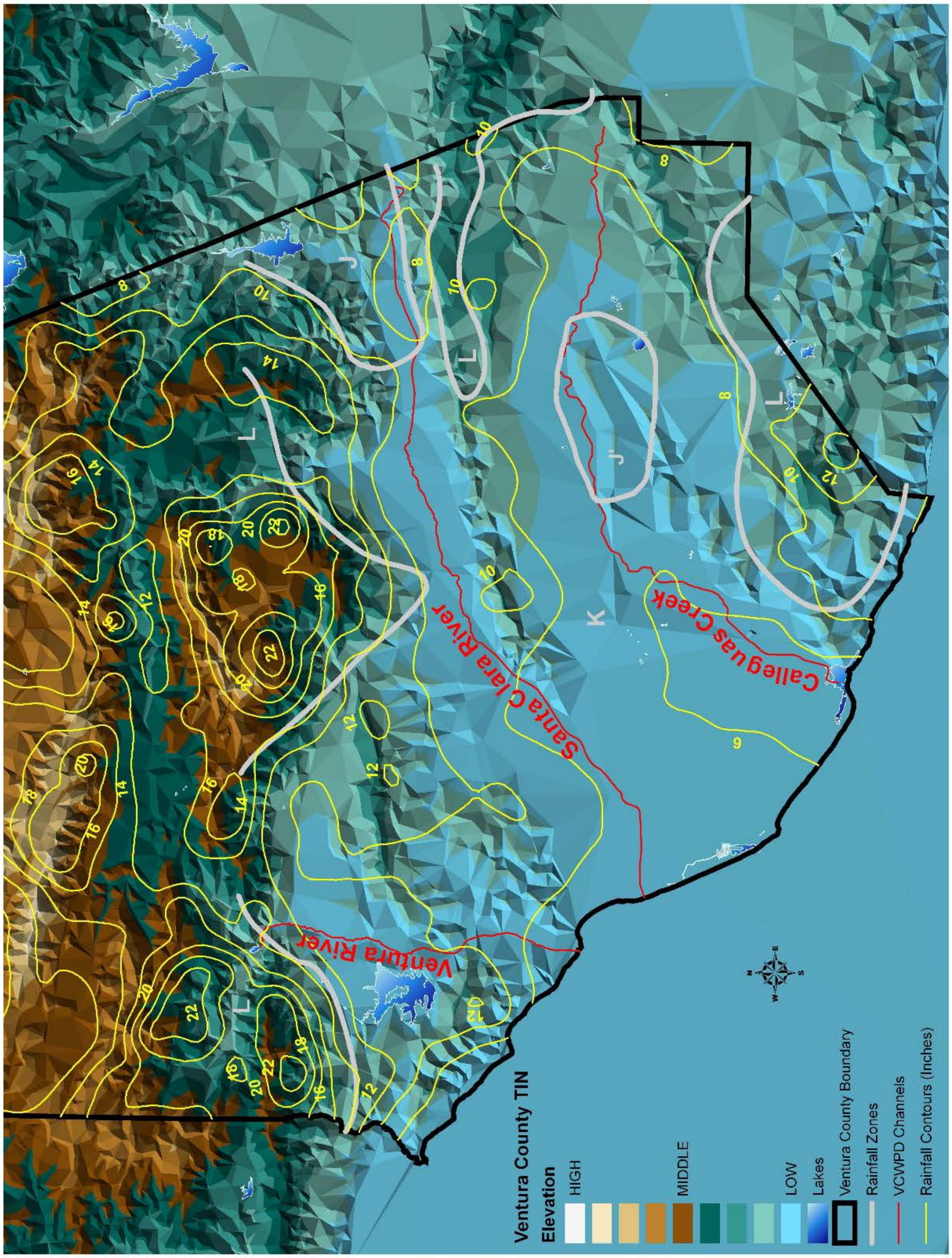


EXHIBIT 1B. LEGACY DESIGN STORM RAINFALL CONTOURS- 50-YR STORM

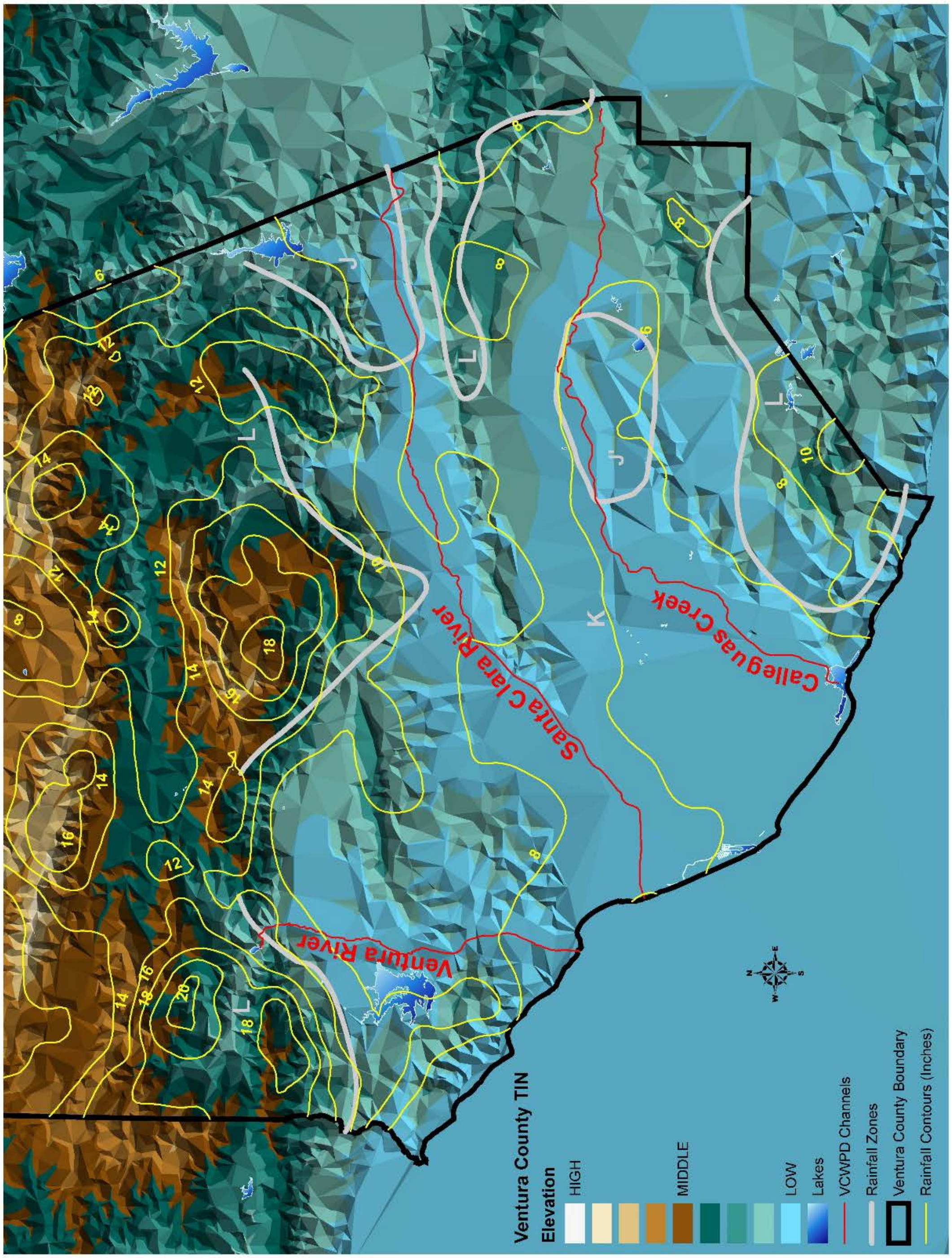


EXHIBIT 1C. LEGACY DESIGN STORM RAINFALL CONTOURS- 25-YR STORM

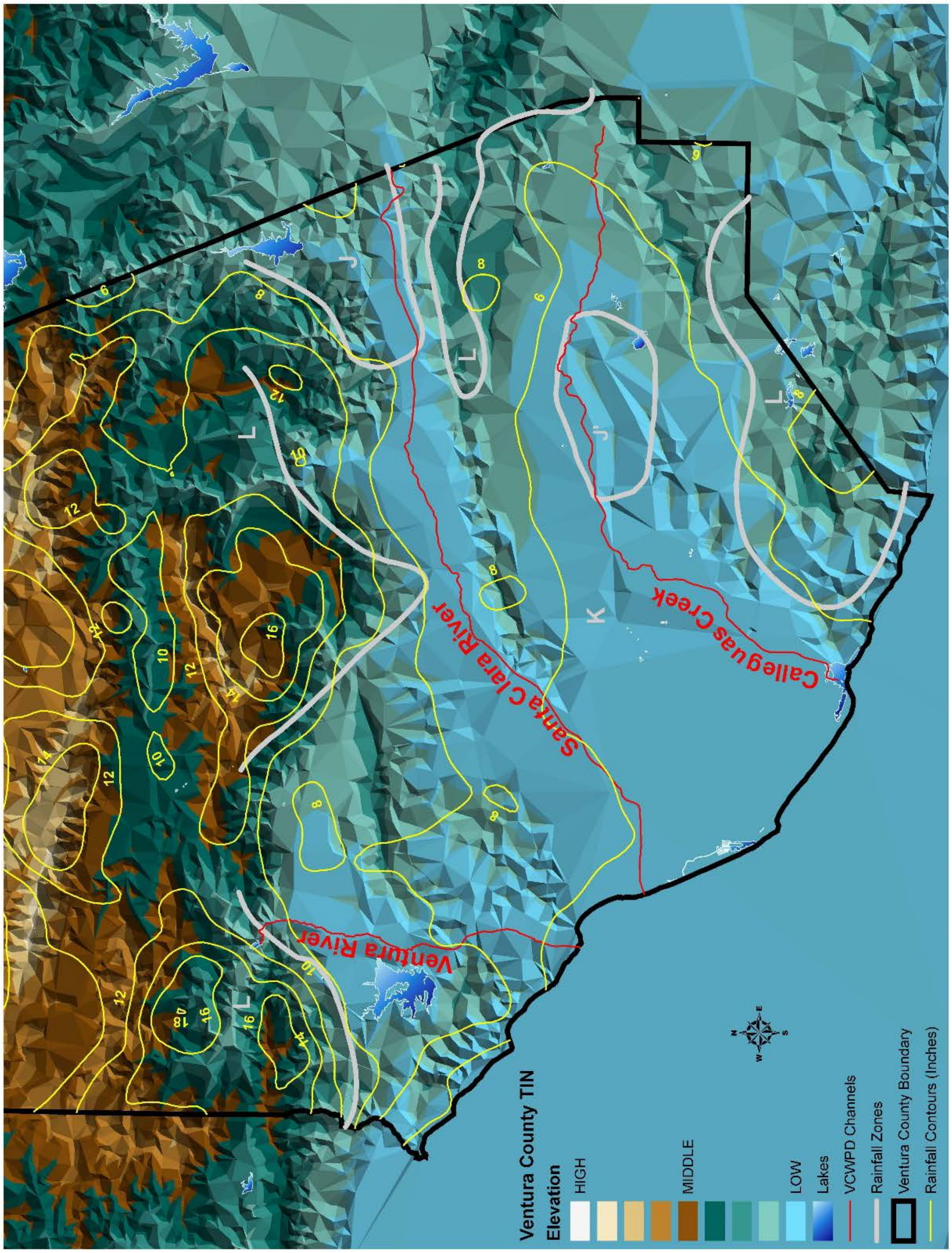


EXHIBIT 1D. LEGACY DESIGN STORM RAINFALL CONTOURS- 10-YR STORM

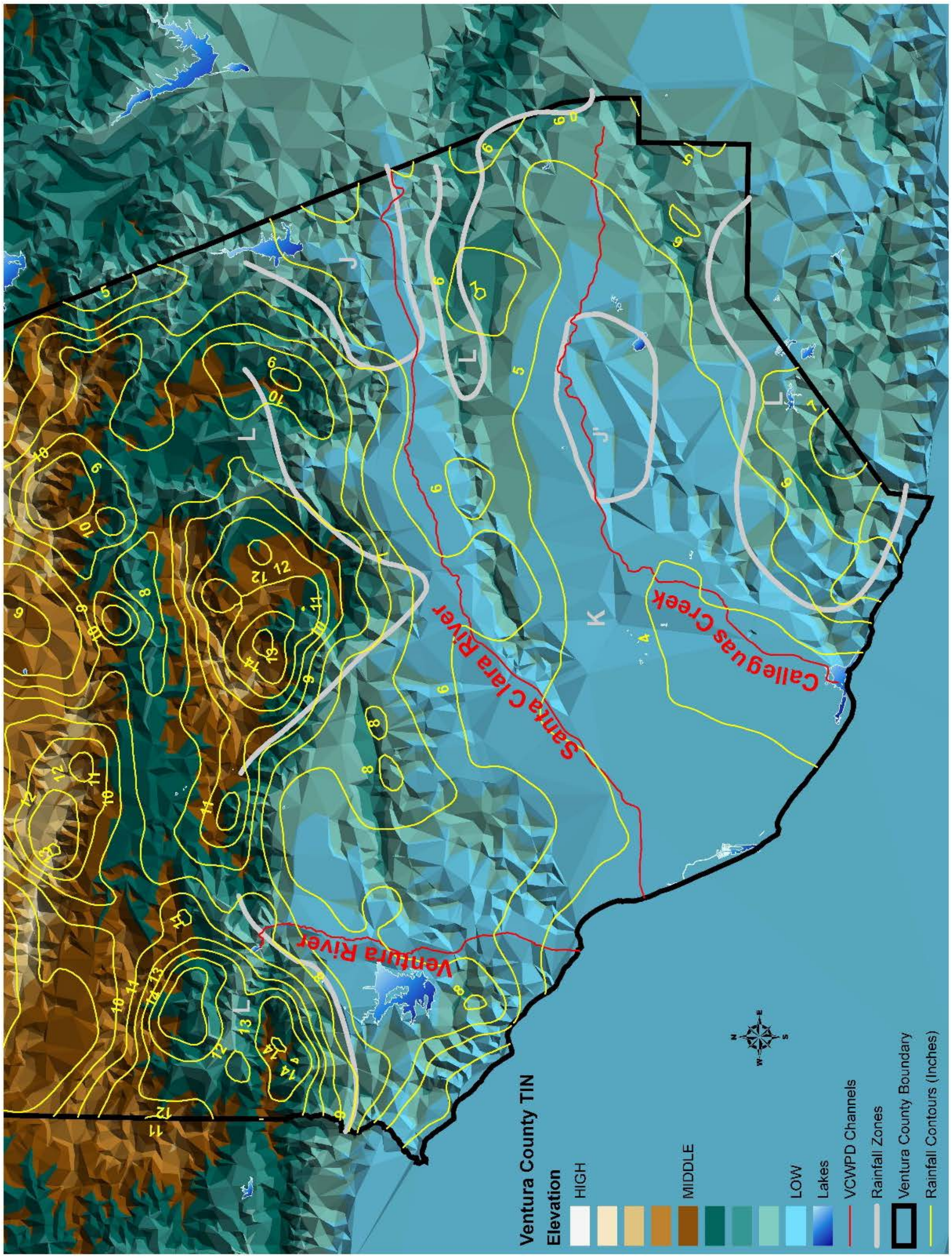


EXHIBIT 2A. NOAA DESIGN STORM RAINFALL CONTOURS- 100-YR STORM

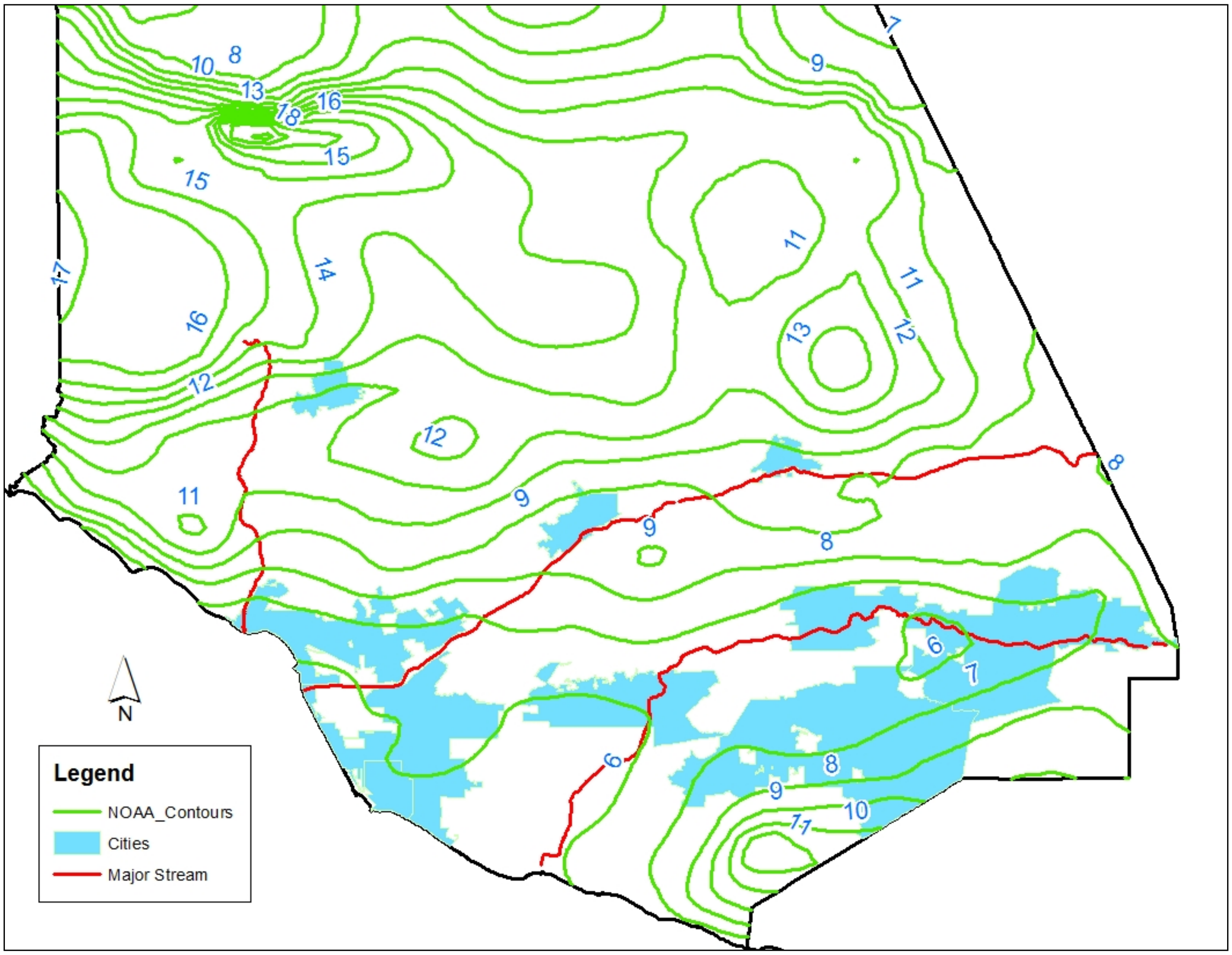


EXHIBIT 2B. NOAA DESIGN STORM RAINFALL CONTOURS- 50-YR STORM

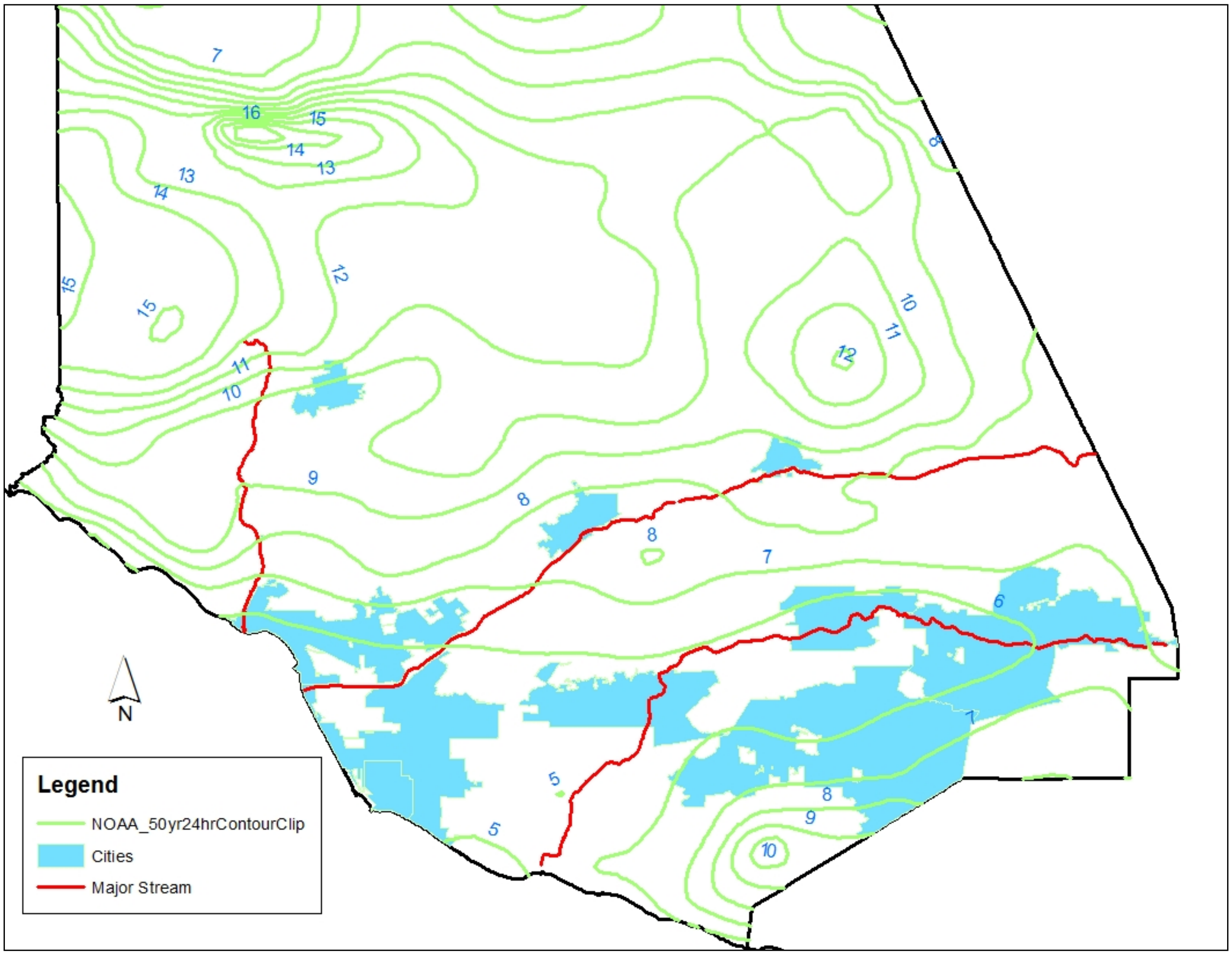


EXHIBIT 2C. NOAA DESIGN STORM RAINFALL CONTOURS- 25-YR STORM

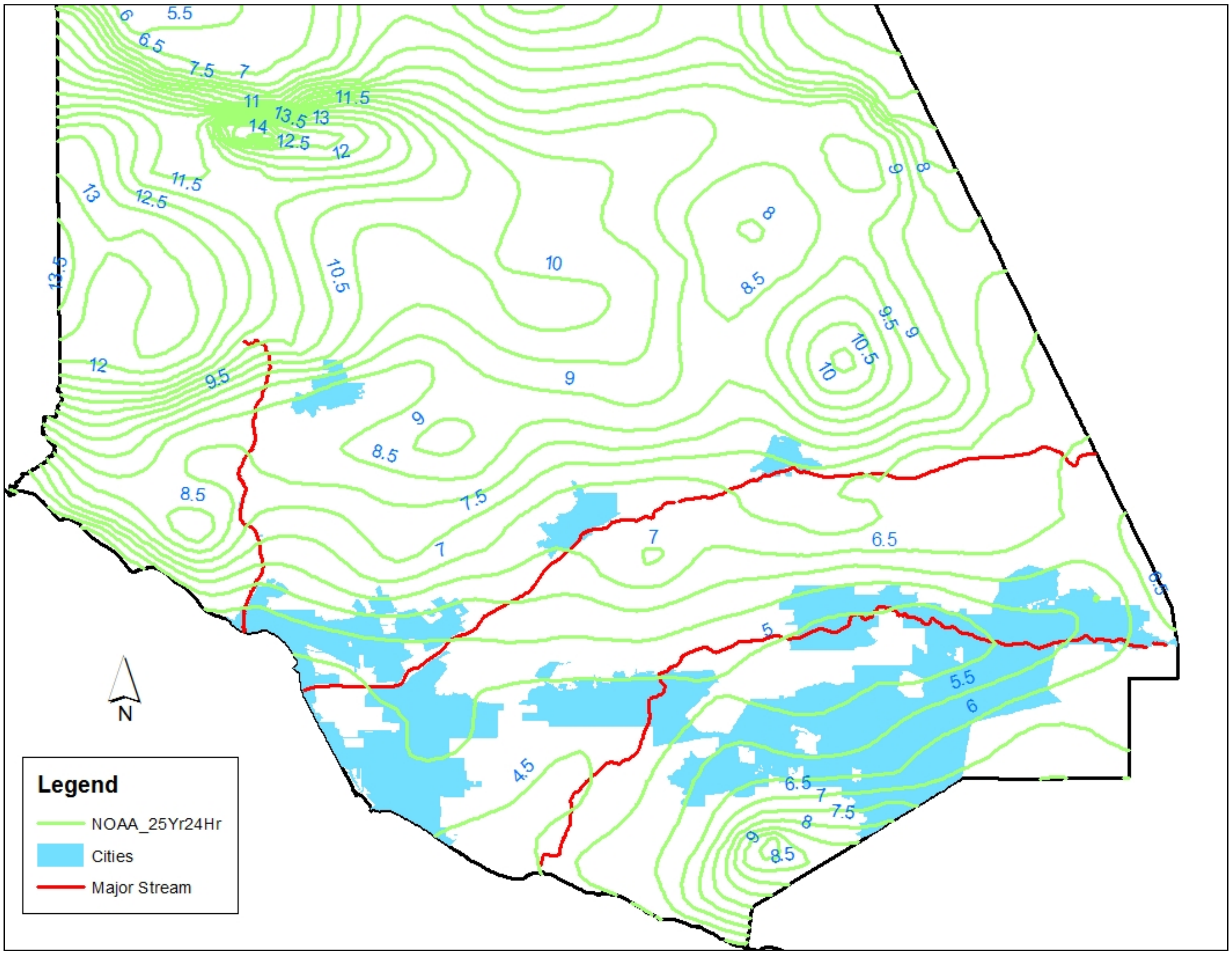


EXHIBIT 2D. NOAA DESIGN STORM RAINFALL CONTOURS- 10-YR STORM

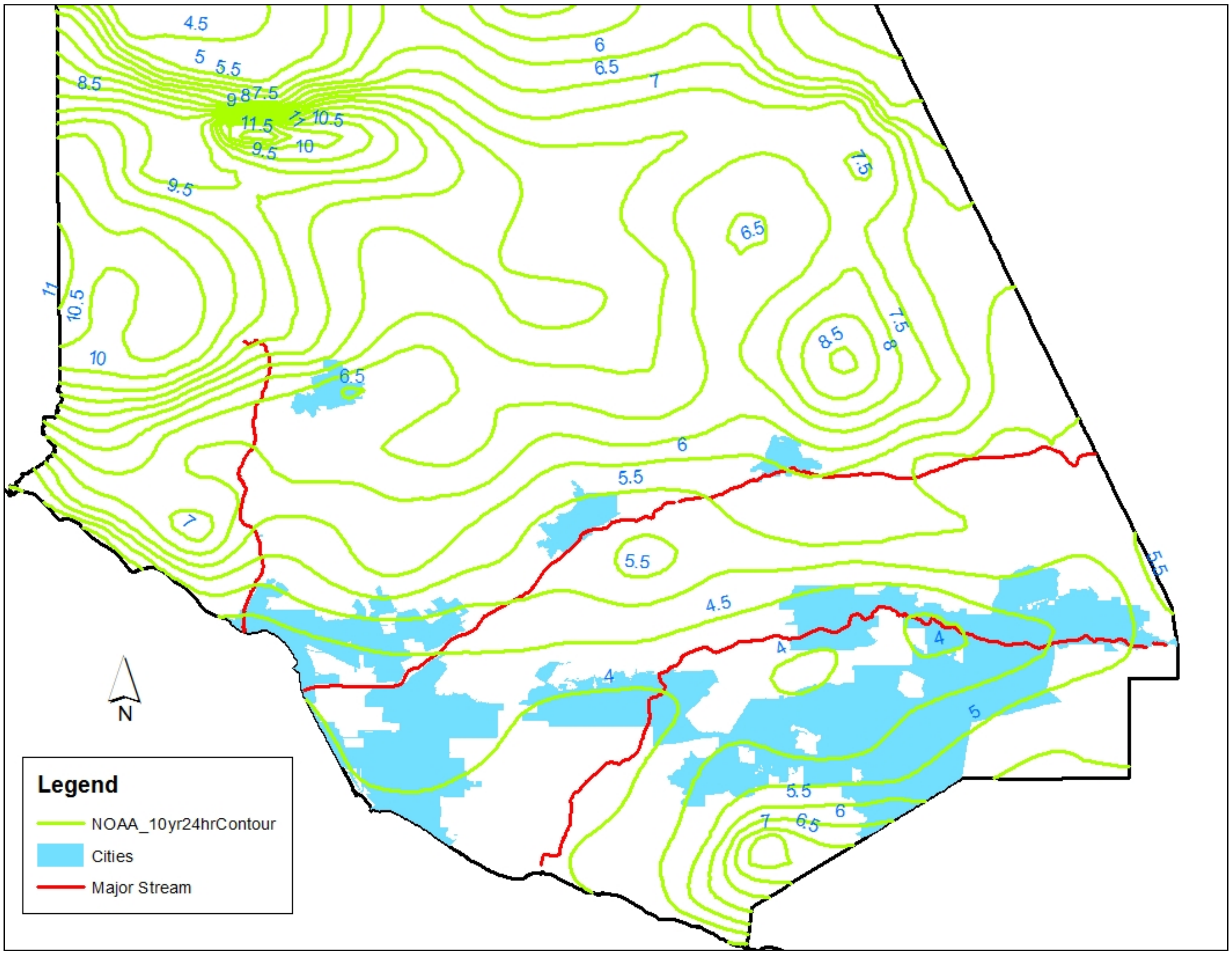


EXHIBIT 3. LEGACY TC RAINFALL INTENSITIES

Zone	J	Jp	K	L	J	Jp	K	L	J	Jp	K	L	J	Jp	K	L
Year	**10**	**10**	**10**	**10**	**25**	**25**	**25**	**25**	**50**	**50**	**50**	**50**	**100**	**100**	**100**	**100**
Cum. Rain (in.)	**3.17**	**4.38**	**5.53**	**7.21**	**3.91**	**5.28**	**6.41**	**8.81**	**5.0**	**6.0**	**8.0**	**11.0**	**7.0**	**6.66**	**10.6**	**15.0**
Tc (min)	**Rainfall Intensity (in/hr)**															
5	2.16	2.16	3.72	4.31	2.64	3.34	4.27	4.94	2.94	3.79	4.55	5.58	3.23	4.06	5.10	6.11
6	2.02	2.01	3.40	3.90	2.52	2.94	3.80	4.39	2.80	3.34	4.10	5.05	2.90	3.55	4.59	5.43
7	1.86	1.90	3.09	3.56	2.30	2.65	3.45	3.99	2.55	3.01	3.77	4.63	2.67	3.19	4.23	4.95
8	1.74	1.82	2.86	3.30	2.14	2.58	3.19	3.69	2.36	2.93	3.52	4.28	2.50	2.99	3.95	4.58
9	1.63	1.76	2.68	3.07	1.99	2.44	2.99	3.45	2.21	2.77	3.33	4.00	2.36	2.87	3.74	4.30
10	1.53	1.70	2.52	2.86	1.87	2.29	2.81	3.24	2.08	2.60	3.16	3.76	2.25	2.78	3.57	4.07
11	1.45	1.64	2.40	2.70	1.76	2.17	2.66	3.07	1.95	2.46	3.02	3.56	2.13	2.67	3.39	3.88
12	1.38	1.59	2.29	2.56	1.66	2.07	2.53	2.92	1.85	2.35	2.90	3.39	2.02	2.58	3.23	3.72
13	1.33	1.55	2.20	2.44	1.58	1.98	2.43	2.80	1.76	2.25	2.80	3.25	1.94	2.49	3.10	3.59
14	1.28	1.51	2.12	2.34	1.52	1.90	2.34	2.70	1.68	2.16	2.72	3.13	1.86	2.42	2.99	3.47
15	1.23	1.47	2.04	2.25	1.46	1.84	2.26	2.60	1.62	2.09	2.62	3.02	1.80	2.36	2.89	3.37
16	1.18	1.43	1.98	2.18	1.40	1.78	2.18	2.50	1.56	2.02	2.54	2.92	1.73	2.29	2.79	3.25
17	1.14	1.39	1.92	2.11	1.36	1.73	2.12	2.42	1.50	1.96	2.47	2.83	1.67	2.22	2.70	3.14
18	1.11	1.35	1.86	2.04	1.31	1.68	2.06	2.34	1.45	1.90	2.41	2.75	1.61	2.16	2.62	3.05
19	1.07	1.32	1.82	1.99	1.27	1.63	2.01	2.28	1.41	1.86	2.35	2.68	1.56	2.11	2.55	2.96
20	1.04	1.29	1.77	1.94	1.24	1.60	1.96	2.22	1.37	1.81	2.29	2.62	1.52	2.07	2.49	2.88
21	1.02	1.26	1.73	1.90	1.20	1.55	1.91	2.17	1.33	1.76	2.23	2.55	1.48	2.03	2.43	2.82
22	0.99	1.23	1.68	1.85	1.17	1.51	1.87	2.12	1.30	1.72	2.17	2.49	1.44	1.99	2.36	2.76
23	0.97	1.21	1.65	1.82	1.14	1.48	1.83	2.07	1.27	1.68	2.12	2.44	1.41	1.95	2.31	2.70
24	0.95	1.19	1.62	1.78	1.12	1.44	1.79	2.03	1.24	1.64	2.07	2.39	1.38	1.92	2.26	2.65
25	0.93	1.16	1.58	1.75	1.09	1.41	1.76	1.99	1.21	1.61	2.03	2.34	1.35	1.89	2.22	2.60
26	0.90	1.14	1.56	1.72	1.07	1.39	1.73	1.96	1.18	1.57	1.98	2.29	1.32	1.86	2.17	2.56
27	0.88	1.13	1.53	1.68	1.05	1.36	1.70	1.92	1.16	1.54	1.94	2.25	1.29	1.83	2.13	2.51
28	0.87	1.11	1.50	1.66	1.03	1.34	1.67	1.89	1.14	1.52	1.90	2.21	1.27	1.80	2.09	2.46
29	0.85	1.09	1.48	1.63	1.01	1.31	1.64	1.87	1.12	1.49	1.87	2.17	1.24	1.77	2.05	2.42
30	0.83	1.08	1.46	1.61	0.99	1.29	1.61	1.84	1.10	1.47	1.84	2.13	1.22	1.74	2.02	2.38

EXHIBIT 4A. NOAA TC RAINFALL INTENSITIES- 100-YR

NOAA Zone Name	ID	Tc (min) / Intensities (in/hr)																									
		5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
N&S Br. Arroyo Conejo-ASR	Con2	4.524	4.096	3.790	3.561	3.383	3.240	3.069	2.926	2.805	2.702	2.612	2.518	2.435	2.361	2.295	2.236	2.182	2.133	2.089	2.048	2.010	1.976	1.944	1.914	1.885	1.859
Arroyo Las Posas	ALP1	4.404	3.988	3.691	3.468	3.295	3.156	2.989	2.850	2.732	2.631	2.544	2.451	2.368	2.295	2.229	2.170	2.117	2.068	2.024	1.983	1.946	1.911	1.879	1.849	1.821	1.795
Carpenteria Coast	Carp1	6.228	5.640	5.220	4.905	4.660	4.464	4.228	4.032	3.866	3.723	3.600	3.472	3.359	3.259	3.169	3.088	3.015	2.948	2.888	2.832	2.781	2.734	2.690	2.649	2.608	2.569
Conejo Creek	Con3	4.176	3.780	3.497	3.285	3.120	2.988	2.830	2.698	2.586	2.491	2.408	2.325	2.252	2.187	2.129	2.077	2.029	1.987	1.947	1.911	1.878	1.848	1.819	1.793	1.768	1.745
Cuyama	Cuy1	5.556	5.032	4.658	4.377	4.159	3.984	3.773	3.598	3.450	3.322	3.212	3.102	3.004	2.918	2.841	2.771	2.708	2.651	2.598	2.551	2.506	2.466	2.428	2.393	2.356	2.322
Hopper	Hop1	5.580	5.052	4.675	4.392	4.172	3.996	3.785	3.614	3.468	3.344	3.233	3.136	3.050	2.976	2.911	2.851	2.798	2.749	2.704	2.663	2.624	2.589	2.557	2.528	2.496	2.467
Lake Casitas	Vta4	7.140	6.464	5.981	5.619	5.337	5.112	4.843	4.618	4.428	4.265	4.124	3.984	3.860	3.750	3.652	3.563	3.483	3.410	3.343	3.283	3.226	3.175	3.127	3.082	3.038	2.998
Lower Sespe Pole	Sespe4	5.856	5.302	4.906	4.610	4.379	4.194	3.972	3.790	3.635	3.503	3.386	3.284	3.194	3.116	3.046	2.983	2.926	2.874	2.826	2.783	2.742	2.705	2.671	2.639	2.608	2.580
Lower Ventura	Vta6	5.448	4.932	4.563	4.287	4.072	3.900	3.694	3.522	3.377	3.252	3.144	3.039	2.947	2.865	2.792	2.726	2.666	2.612	2.562	2.517	2.475	2.437	2.401	2.368	2.335	2.304
Malibu Coastal	Malbu1	5.136	4.652	4.306	4.047	3.845	3.684	3.489	3.326	3.188	3.070	2.968	2.862	2.769	2.687	2.613	2.546	2.486	2.431	2.381	2.335	2.293	2.254	2.218	2.184	2.151	2.121
N Fk Matilija	Vta2	7.212	6.530	6.043	5.678	5.393	5.166	4.893	4.665	4.472	4.307	4.164	4.038	3.926	3.827	3.738	3.658	3.586	3.520	3.460	3.405	3.354	3.308	3.264	3.224	3.185	3.148
Arroyo Conejo	Con1	4.932	4.468	4.137	3.888	3.695	3.540	3.352	3.196	3.064	2.950	2.852	2.749	2.658	2.577	2.504	2.439	2.380	2.326	2.277	2.233	2.191	2.153	2.118	2.085	2.053	2.024
Ojai	Vta3	6.612	5.988	5.542	5.208	4.948	4.740	4.490	4.282	4.106	3.955	3.824	3.703	3.597	3.502	3.421	3.347	3.281	3.221	3.165	3.115	3.066	3.021	2.979	2.940	2.904	2.870
Oxnard-Nyeland	Rev2	4.104	3.716	3.439	3.231	3.069	2.940	2.785	2.656	2.547	2.453	2.372	2.293	2.223	2.161	2.106	2.056	2.011	1.970	1.932	1.898	1.866	1.837	1.810	1.785	1.758	1.733
Prince-Arundell	Prin1	4.932	4.466	4.133	3.884	3.689	3.534	3.347	3.191	3.059	2.946	2.848	2.755	2.672	2.599	2.533	2.474	2.421	2.372	2.328	2.287	2.250	2.215	2.183	2.153	2.124	2.096
Revolon-Calleguas	Rev3	3.816	3.454	3.195	3.001	2.851	2.730	2.587	2.467	2.366	2.279	2.204	2.129	2.063	2.005	1.952	1.905	1.862	1.823	1.788	1.756	1.726	1.698	1.672	1.649	1.625	1.603
San Anton-CLarga	Vta5	6.108	5.532	5.121	4.812	4.572	4.380	4.149	3.956	3.793	3.653	3.532	3.417	3.315	3.225	3.144	3.071	3.006	2.946	2.891	2.841	2.795	2.753	2.713	2.677	2.643	2.611
SCR abv Freeman	SCR2	5.064	4.586	4.245	3.989	3.789	3.630	3.437	3.277	3.141	3.025	2.924	2.831	2.748	2.675	2.610	2.551	2.498	2.449	2.405	2.365	2.327	2.293	2.261	2.231	2.202	2.174
SCR to Ocean	SCR3	4.416	4.000	3.703	3.480	3.307	3.168	3.000	2.860	2.742	2.640	2.552	2.469	2.396	2.331	2.273	2.221	2.174	2.131	2.091	2.056	2.022	1.992	1.964	1.937	1.908	1.881
SCR-Lower Piru	SCR1	5.340	4.836	4.476	4.206	3.996	3.828	3.625	3.456	3.313	3.190	3.084	2.985	2.898	2.820	2.751	2.688	2.631	2.580	2.533	2.490	2.450	2.414	2.380	2.349	2.317	2.287
Sespe Abv Bear	Sespe2	6.732	6.096	5.642	5.301	5.036	4.824	4.569	4.356	4.176	4.022	3.888	3.763	3.653	3.555	3.469	3.392	3.322	3.258	3.200	3.147	3.097	3.050	3.007	2.967	2.930	2.895
Sespe Abv Grand	Sespe3	6.180	5.596	5.179	4.866	4.623	4.428	4.193	3.998	3.833	3.691	3.568	3.459	3.362	3.276	3.199	3.130	3.067	3.011	2.959	2.911	2.867	2.827	2.789	2.755	2.722	2.691
Sespe Abv Wheeler	Sespe1	7.380	6.684	6.187	5.814	5.524	5.292	5.012	4.778	4.580	4.411	4.264	4.106	3.966	3.841	3.735	3.640	3.553	3.475	3.403	3.338	3.273	3.214	3.159	3.108	3.060	3.016
Simi Valley	Simi2	5.076	4.596	4.253	3.996	3.796	3.636	3.444	3.284	3.149	3.033	2.932	2.824	2.728	2.643	2.567	2.498	2.436	2.380	2.328	2.281	2.238	2.198	2.160	2.126	2.092	2.060
So Mtn to Mpk	Rev1	4.788	4.334	4.010	3.767	3.577	3.426	3.245	3.095	2.968	2.859	2.764	2.672	2.591	2.519	2.459	2.405	2.356	2.312	2.271	2.234	2.196	2.162	2.129	2.099	2.072	2.046
Todd to Timber	Todd1	6.228	5.640	5.220	4.905	4.660	4.464	4.227	4.030	3.863	3.720	3.596	3.481	3.379	3.290	3.215	3.148	3.086	3.031	2.980	2.933	2.886	2.842	2.802	2.764	2.729	2.697
Upper Arroyo Simi	Simi1	5.388	4.880	4.517	4.245	4.033	3.864	3.660	3.490	3.346	3.223	3.116	2.992	2.882	2.785	2.697	2.619	2.548	2.483	2.425	2.371	2.321	2.275	2.232	2.193	2.154	2.117
Upper Harmon	Harm1	5.340	4.836	4.476	4.206	3.996	3.828	3.626	3.458	3.316	3.194	3.088	2.988	2.900	2.821	2.751	2.688	2.631	2.579	2.531	2.488	2.448	2.411	2.377	2.345	2.315	2.287
Upper Matilija	Vta1	8.244	7.466	6.910	6.494	6.169	5.910	5.599	5.339	5.119	4.931	4.768	4.592	4.436	4.297	4.174	4.063	3.962	3.871	3.787	3.711	3.640	3.575	3.515	3.459	3.406	3.358
Upper Piru	Piru1	5.760	5.216	4.827	4.536	4.309	4.128	3.910	3.728	3.574	3.442	3.328	3.212	3.110	3.019	2.937	2.864	2.798	2.737	2.682	2.632	2.586	2.543	2.503	2.466	2.426	2.389
Upper Sta Paula	StPaul1	6.948	6.294	5.827	5.477	5.204	4.986	4.721	4.501	4.314	4.155	4.016	3.885	3.770	3.668	3.583	3.506	3.437	3.374	3.317	3.264	3.211	3.161	3.116	3.073	3.034	2.997

EXHIBIT 4B. NOAA TC RAINFALL INTENSITIES- 50-YR

NOAA Zone Name	ID	Tc (min) / Intensities (in/hr)																									
		5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
N&S Br. Arroyo Conejo-ASR	Con2	4.044	3.660	3.386	3.180	3.020	2.892	2.739	2.612	2.504	2.412	2.332	2.249	2.175	2.109	2.051	1.998	1.950	1.907	1.867	1.831	1.798	1.767	1.738	1.712	1.686	1.663
Arroyo Las Posas	ALP1	3.960	3.586	3.319	3.119	2.963	2.838	2.688	2.563	2.457	2.367	2.288	2.205	2.131	2.065	2.007	1.954	1.906	1.863	1.823	1.787	1.754	1.723	1.694	1.668	1.643	1.619
Carpenteria Coastal	Carp1	5.640	5.108	4.728	4.443	4.221	4.044	3.830	3.652	3.501	3.372	3.260	3.144	3.042	2.951	2.870	2.797	2.731	2.671	2.616	2.566	2.519	2.476	2.437	2.400	2.363	2.328
Conejo Creek	Con3	3.720	3.368	3.117	2.928	2.781	2.664	2.523	2.406	2.307	2.222	2.148	2.074	2.008	1.950	1.899	1.852	1.810	1.772	1.737	1.706	1.676	1.648	1.623	1.599	1.577	1.556
Cuyama	Cuy1	4.788	4.336	4.013	3.771	3.583	3.432	3.250	3.098	2.970	2.859	2.764	2.669	2.586	2.511	2.445	2.385	2.331	2.282	2.237	2.196	2.158	2.123	2.090	2.060	2.029	1.999
Hopper	Hop1	4.992	4.520	4.183	3.930	3.733	3.576	3.387	3.234	3.105	2.994	2.894	2.807	2.730	2.665	2.606	2.554	2.506	2.463	2.423	2.387	2.351	2.320	2.292	2.266	2.238	2.212
Lake Casitas	Vta4	6.324	5.728	5.302	4.983	4.735	4.536	4.296	4.096	3.927	3.782	3.656	3.532	3.423	3.325	3.238	3.160	3.089	3.025	2.966	2.912	2.862	2.817	2.774	2.735	2.696	2.660
Lower Sespe Pole	Sespe4	5.196	4.706	4.356	4.093	3.889	3.726	3.529	3.366	3.229	3.111	3.007	2.917	2.837	2.767	2.704	2.648	2.597	2.550	2.508	2.469	2.433	2.400	2.369	2.341	2.314	2.289
Lower Ventura	Vta6	4.824	4.368	4.042	3.798	3.608	3.456	3.274	3.122	2.994	2.883	2.788	2.695	2.613	2.540	2.475	2.416	2.363	2.315	2.270	2.230	2.193	2.158	2.127	2.097	2.068	2.040
Malibu Coastal	Malbu1	4.536	4.108	3.802	3.573	3.395	3.252	3.080	2.936	2.814	2.710	2.620	2.527	2.445	2.372	2.307	2.248	2.195	2.147	2.102	2.062	2.025	1.990	1.959	1.929	1.900	1.873
N Fk Matilija	Vta2	6.396	5.792	5.361	5.037	4.785	4.584	4.342	4.140	3.969	3.823	3.696	3.583	3.484	3.396	3.317	3.246	3.182	3.123	3.070	3.021	2.976	2.934	2.896	2.860	2.825	2.793
Arroyo Conejo	Con1	4.380	3.964	3.667	3.444	3.271	3.132	2.967	2.830	2.714	2.614	2.528	2.437	2.356	2.284	2.220	2.162	2.110	2.062	2.019	1.979	1.942	1.909	1.877	1.848	1.820	1.794
Ojai	Vta3	5.784	5.238	4.848	4.556	4.328	4.146	3.926	3.743	3.588	3.455	3.340	3.235	3.141	3.059	2.988	2.924	2.866	2.814	2.766	2.722	2.679	2.640	2.603	2.569	2.538	2.508
Oxnard Pln-Nyeland	Rev2	3.708	3.356	3.105	2.916	2.769	2.652	2.512	2.396	2.298	2.213	2.140	2.069	2.006	1.951	1.901	1.856	1.815	1.779	1.745	1.714	1.686	1.659	1.635	1.613	1.588	1.565
Prince-Arundell	Prin1	4.452	4.032	3.732	3.507	3.332	3.192	3.024	2.884	2.766	2.664	2.576	2.491	2.416	2.350	2.291	2.237	2.189	2.145	2.104	2.067	2.034	2.002	1.973	1.946	1.919	1.894
Revolon-Calleguas	Rev3	3.420	3.098	2.868	2.696	2.561	2.454	2.325	2.217	2.126	2.048	1.980	1.913	1.854	1.801	1.754	1.712	1.674	1.639	1.607	1.578	1.551	1.526	1.504	1.482	1.461	1.441
San Anton-CLarga	Vta5	5.400	4.888	4.522	4.248	4.035	3.864	3.660	3.490	3.346	3.223	3.116	3.015	2.925	2.846	2.775	2.711	2.653	2.601	2.553	2.508	2.468	2.431	2.396	2.364	2.334	2.306
SCR abv Freeman	SCR2	4.560	4.130	3.823	3.593	3.413	3.270	3.097	2.953	2.831	2.727	2.636	2.552	2.477	2.411	2.351	2.298	2.250	2.206	2.166	2.129	2.095	2.064	2.035	2.008	1.982	1.957
SCR to Ocean	SCR3	4.044	3.662	3.389	3.185	3.025	2.898	2.745	2.617	2.509	2.416	2.336	2.260	2.193	2.134	2.081	2.033	1.990	1.950	1.914	1.882	1.851	1.823	1.797	1.773	1.746	1.721
SCR-Lower Piru	SCR1	4.728	4.282	3.963	3.725	3.539	3.390	3.211	3.061	2.934	2.826	2.732	2.645	2.567	2.499	2.437	2.382	2.332	2.287	2.245	2.207	2.172	2.140	2.110	2.082	2.054	2.028
Sespe Abv Bear	Sespe2	5.880	5.326	4.930	4.634	4.403	4.218	3.995	3.809	3.652	3.517	3.400	3.291	3.194	3.109	3.034	2.966	2.905	2.850	2.799	2.753	2.708	2.668	2.630	2.595	2.563	2.532
Sespe Abv Grand	Sespe3	5.424	4.912	4.546	4.272	4.059	3.888	3.683	3.512	3.367	3.243	3.136	3.039	2.954	2.878	2.810	2.749	2.694	2.643	2.598	2.556	2.517	2.481	2.448	2.417	2.389	2.362
Sespe Abv Wheeler	Sespe1	6.588	5.966	5.522	5.189	4.929	4.722	4.473	4.265	4.089	3.939	3.808	3.666	3.541	3.430	3.335	3.250	3.173	3.103	3.039	2.981	2.923	2.870	2.820	2.775	2.732	2.692
Simi Valley	Simi2	4.548	4.118	3.811	3.581	3.401	3.258	3.085	2.941	2.819	2.715	2.624	2.527	2.442	2.366	2.298	2.237	2.182	2.131	2.086	2.044	2.005	1.969	1.936	1.905	1.875	1.847
So Mtn to Moorpark	Rev1	4.260	3.858	3.571	3.356	3.188	3.054	2.892	2.757	2.643	2.545	2.460	2.378	2.306	2.242	2.189	2.141	2.097	2.058	2.022	1.989	1.956	1.925	1.896	1.869	1.845	1.822
Todd to Timber	Todd1	5.436	4.922	4.555	4.280	4.065	3.894	3.688	3.517	3.372	3.248	3.140	3.039	2.950	2.871	2.806	2.746	2.693	2.644	2.600	2.559	2.518	2.480	2.444	2.412	2.381	2.353
Upper Arroyo Simi	Simi1	4.776	4.324	4.001	3.759	3.571	3.420	3.240	3.090	2.963	2.854	2.760	2.650	2.553	2.467	2.390	2.321	2.258	2.201	2.149	2.102	2.058	2.017	1.980	1.945	1.910	1.878
Upper Harmon	Harm1	4.824	4.370	4.046	3.803	3.613	3.462	3.279	3.127	2.998	2.888	2.792	2.702	2.622	2.551	2.487	2.430	2.378	2.331	2.288	2.249	2.213	2.179	2.148	2.120	2.093	2.068
Upper Matilija	Vta1	7.428	6.726	6.225	5.849	5.556	5.322	5.040	4.805	4.606	4.436	4.288	4.130	3.991	3.867	3.757	3.657	3.567	3.486	3.411	3.343	3.279	3.221	3.167	3.117	3.070	3.027
Upper Piru	Piru1	4.980	4.510	4.174	3.923	3.727	3.570	3.382	3.225	3.092	2.979	2.880	2.779	2.690	2.611	2.541	2.477	2.419	2.367	2.319	2.276	2.235	2.198	2.164	2.132	2.097	2.065
Upper Sta Paula Ck	StPaul1	6.048	5.476	5.067	4.761	4.523	4.332	4.103	3.912	3.750	3.612	3.492	3.378	3.278	3.189	3.115	3.048	2.987	2.933	2.882	2.837	2.790	2.747	2.707	2.670	2.636	2.604

EXHIBIT 4C. NOAA TC RAINFALL INTENSITIES- 25-YR

NOAA Zone Name	ID	Tc (min) / Intensities (in/hr)																								
		5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
N&S Br. Arroyo Conejo-ASR	Con2	3.576	3.238	2.997	2.816	2.675	2.562	2.427	2.315	2.220	2.139	2.068	1.994	1.928	1.870	1.818	1.771	1.729	1.690	1.655	1.623	1.593	1.565	1.540	1.516	1.494	1.473
Arroyo Las Posas	ALP1	3.528	3.196	2.959	2.781	2.643	2.532	2.398	2.286	2.191	2.110	2.040	1.966	1.900	1.841	1.789	1.742	1.699	1.661	1.625	1.593	1.563	1.536	1.510	1.487	1.464	1.443
Carpenteria	Carp1	5.004	4.530	4.191	3.938	3.740	3.582	3.393	3.235	3.102	2.987	2.888	2.785	2.695	2.614	2.542	2.477	2.418	2.365	2.316	2.272	2.230	2.192	2.157	2.125	2.092	2.061
Conejo Creek	Con3	3.288	2.978	2.757	2.590	2.461	2.358	2.233	2.129	2.041	1.965	1.900	1.834	1.776	1.725	1.679	1.638	1.601	1.567	1.537	1.509	1.482	1.458	1.435	1.414	1.395	1.376
Cuyama	Cuy1	4.068	3.684	3.410	3.204	3.044	2.916	2.762	2.634	2.526	2.433	2.352	2.271	2.200	2.137	2.080	2.029	1.983	1.941	1.903	1.868	1.835	1.805	1.778	1.752	1.725	1.700
Hopper	Hop1	4.368	3.956	3.662	3.441	3.269	3.132	2.966	2.832	2.719	2.622	2.534	2.458	2.390	2.333	2.282	2.236	2.194	2.156	2.121	2.090	2.058	2.032	2.007	1.984	1.959	1.937
Lake Casitas	Vta4	5.580	5.052	4.675	4.392	4.172	3.996	3.785	3.610	3.462	3.334	3.224	3.115	3.018	2.932	2.855	2.786	2.723	2.667	2.615	2.567	2.523	2.483	2.445	2.411	2.377	2.345
Lower Sespe Pole	Sespe4	4.548	4.118	3.811	3.581	3.401	3.258	3.085	2.943	2.823	2.720	2.629	2.549	2.479	2.418	2.363	2.314	2.270	2.229	2.192	2.159	2.127	2.098	2.071	2.046	2.023	2.001
Lower Ventura	Vta6	4.284	3.880	3.591	3.375	3.207	3.072	2.909	2.774	2.659	2.561	2.476	2.394	2.321	2.257	2.199	2.147	2.100	2.057	2.018	1.982	1.950	1.919	1.891	1.865	1.839	1.815
Malibu Coastal	Malbu1	3.984	3.608	3.339	3.138	2.981	2.856	2.705	2.580	2.474	2.383	2.304	2.222	2.150	2.085	2.028	1.976	1.929	1.887	1.848	1.812	1.779	1.749	1.721	1.695	1.669	1.646
N Fk Matilija	Vta2	5.616	5.084	4.704	4.419	4.197	4.020	3.808	3.632	3.483	3.355	3.244	3.145	3.058	2.981	2.911	2.849	2.793	2.741	2.694	2.652	2.612	2.576	2.542	2.510	2.480	2.451
Arroyo Conejo	Con1	3.840	3.476	3.216	3.021	2.869	2.748	2.603	2.482	2.380	2.292	2.216	2.136	2.065	2.002	1.946	1.895	1.849	1.807	1.769	1.735	1.702	1.673	1.645	1.620	1.595	1.572
Ojai	Vta3	4.992	4.520	4.183	3.930	3.733	3.576	3.387	3.230	3.097	2.983	2.884	2.793	2.712	2.641	2.579	2.524	2.475	2.429	2.388	2.350	2.313	2.279	2.247	2.218	2.190	2.165
Oxnard-Nyeland	Rev2	3.312	3.000	2.777	2.610	2.480	2.376	2.251	2.146	2.058	1.982	1.916	1.852	1.796	1.746	1.701	1.661	1.625	1.591	1.561	1.534	1.508	1.484	1.463	1.442	1.420	1.400
Prince-Arundell	Prin1	4.008	3.630	3.360	3.158	3.000	2.874	2.722	2.595	2.488	2.396	2.316	2.240	2.173	2.113	2.060	2.012	1.969	1.929	1.893	1.860	1.830	1.802	1.776	1.751	1.727	1.704
Revolon-Calleguas	Rev3	3.048	2.762	2.558	2.405	2.285	2.190	2.074	1.977	1.895	1.825	1.764	1.704	1.652	1.605	1.563	1.525	1.491	1.460	1.431	1.406	1.382	1.360	1.339	1.320	1.301	1.284
San Anton-CLarga	Vta5	4.704	4.260	3.943	3.705	3.520	3.372	3.194	3.046	2.921	2.813	2.720	2.632	2.553	2.484	2.422	2.366	2.315	2.269	2.227	2.189	2.154	2.121	2.091	2.063	2.036	2.012
SCR abv Freeman	SCR2	4.044	3.662	3.389	3.185	3.025	2.898	2.745	2.617	2.509	2.416	2.336	2.261	2.195	2.137	2.084	2.037	1.994	1.955	1.920	1.888	1.858	1.830	1.804	1.781	1.757	1.735
SCR to Ocean	SCR3	3.648	3.304	3.058	2.874	2.731	2.616	2.479	2.364	2.267	2.184	2.112	2.043	1.983	1.929	1.881	1.838	1.799	1.763	1.731	1.701	1.674	1.648	1.625	1.603	1.579	1.556
SCR-Lower Piru	SCR1	4.128	3.738	3.459	3.251	3.088	2.958	2.801	2.671	2.561	2.466	2.384	2.308	2.240	2.181	2.127	2.079	2.035	1.996	1.960	1.927	1.896	1.868	1.842	1.818	1.793	1.770
Sespe Abv Bear	Sespe2	5.088	4.608	4.265	4.008	3.808	3.648	3.455	3.294	3.158	3.041	2.940	2.846	2.762	2.688	2.623	2.565	2.512	2.464	2.421	2.380	2.342	2.307	2.275	2.244	2.216	2.190
Sespe Abv Grand	Sespe3	4.680	4.238	3.922	3.686	3.501	3.354	3.177	3.029	2.904	2.797	2.704	2.621	2.547	2.482	2.424	2.371	2.323	2.280	2.241	2.205	2.171	2.140	2.112	2.086	2.061	2.038
Sespe Abv Wheeler	Sespe1	5.796	5.248	4.857	4.563	4.335	4.152	3.933	3.750	3.595	3.463	3.348	3.224	3.114	3.016	2.933	2.858	2.790	2.729	2.673	2.621	2.570	2.524	2.480	2.440	2.403	2.368
Simi Valley	Simi2	4.020	3.640	3.369	3.165	3.007	2.880	2.728	2.602	2.495	2.403	2.324	2.238	2.163	2.095	2.035	1.981	1.932	1.887	1.847	1.810	1.775	1.744	1.714	1.687	1.660	1.635
So Mtn to Moorpark	Rev1	3.756	3.402	3.149	2.960	2.812	2.694	2.551	2.431	2.330	2.243	2.168	2.096	2.032	1.976	1.929	1.887	1.849	1.814	1.782	1.753	1.724	1.696	1.671	1.648	1.626	1.606
Todd to Timber	Todd1	4.692	4.250	3.934	3.698	3.513	3.366	3.188	3.039	2.913	2.805	2.712	2.625	2.549	2.481	2.424	2.373	2.327	2.285	2.246	2.211	2.176	2.143	2.112	2.084	2.058	2.034
Upper Arroyo Simi	Simi1	4.224	3.824	3.538	3.324	3.157	3.024	2.865	2.732	2.620	2.523	2.440	2.343	2.257	2.181	2.113	2.052	1.997	1.946	1.900	1.858	1.819	1.783	1.750	1.719	1.689	1.660
Upper Harmon	Harm1	4.320	3.912	3.621	3.402	3.232	3.096	2.933	2.798	2.683	2.585	2.500	2.419	2.348	2.284	2.227	2.176	2.130	2.088	2.049	2.014	1.982	1.952	1.924	1.898	1.874	1.852
Upper Matilija	Vta1	6.624	5.998	5.551	5.216	4.955	4.746	4.496	4.287	4.110	3.959	3.828	3.687	3.563	3.453	3.354	3.265	3.185	3.112	3.045	2.984	2.928	2.876	2.828	2.783	2.741	2.702
Upper Piru	Piru1	4.248	3.848	3.562	3.348	3.181	3.048	2.887	2.752	2.638	2.541	2.456	2.370	2.295	2.227	2.167	2.113	2.064	2.019	1.979	1.941	1.907	1.876	1.846	1.819	1.790	1.762
Upper Sta Paula	StPaul1	5.172	4.684	4.335	4.074	3.871	3.708	3.513	3.350	3.212	3.094	2.992	2.895	2.808	2.732	2.668	2.611	2.559	2.512	2.469	2.430	2.390	2.353	2.319	2.287	2.258	2.230

EXHIBIT 4D. NOAA TC RAINFALL INTENSITIES- 10-YR

NOAA Zone Name	ID	Tc (min) / Intensities (in/hr)																									
		5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
N&S Br. Arroyo Conejo-ASR	Con2	2.952	2.674	2.475	2.327	2.211	2.118	2.006	1.913	1.834	1.767	1.708	1.647	1.593	1.545	1.502	1.463	1.428	1.396	1.367	1.341	1.316	1.293	1.272	1.253	1.234	1.217
Arroyo Las Posas	ALP1	2.940	2.662	2.463	2.315	2.199	2.106	1.994	1.901	1.822	1.755	1.696	1.634	1.579	1.531	1.487	1.448	1.413	1.380	1.351	1.324	1.299	1.276	1.255	1.235	1.217	1.200
Carpenteria Coastal	Carp1	4.128	3.740	3.463	3.255	3.093	2.964	2.807	2.676	2.565	2.470	2.388	2.303	2.228	2.161	2.102	2.048	1.999	1.955	1.915	1.878	1.844	1.813	1.784	1.757	1.729	1.704
Conejo Creek	Con3	2.712	2.456	2.273	2.136	2.029	1.944	1.841	1.756	1.684	1.622	1.568	1.514	1.466	1.424	1.386	1.352	1.322	1.294	1.268	1.245	1.223	1.203	1.185	1.168	1.152	1.137
Cuyama	Cuy1	3.180	2.880	2.666	2.505	2.380	2.280	2.159	2.058	1.973	1.899	1.836	1.773	1.717	1.668	1.624	1.584	1.548	1.515	1.485	1.458	1.433	1.410	1.388	1.368	1.347	1.328
Hopper	Hop1	3.552	3.216	2.976	2.796	2.656	2.544	2.410	2.301	2.209	2.130	2.059	1.997	1.943	1.896	1.854	1.817	1.783	1.752	1.724	1.698	1.673	1.651	1.631	1.612	1.592	1.574
Lake Casitas	Vta4	4.584	4.150	3.840	3.608	3.427	3.282	3.109	2.965	2.843	2.739	2.648	2.558	2.479	2.409	2.346	2.289	2.238	2.191	2.149	2.110	2.074	2.040	2.010	1.981	1.953	1.927
Lower Sespe Pole	Sespe4	3.684	3.336	3.087	2.901	2.756	2.640	2.500	2.385	2.288	2.205	2.131	2.067	2.010	1.961	1.917	1.877	1.841	1.808	1.778	1.751	1.725	1.702	1.680	1.660	1.641	1.623
Lower Ventura	Vta6	3.564	3.226	2.985	2.804	2.663	2.550	2.416	2.305	2.211	2.130	2.060	1.991	1.931	1.877	1.828	1.785	1.746	1.710	1.677	1.648	1.620	1.595	1.571	1.549	1.528	1.507
Malibu Coastal	Malbu1	3.276	2.966	2.745	2.579	2.449	2.346	2.222	2.119	2.032	1.957	1.892	1.825	1.765	1.713	1.665	1.623	1.585	1.550	1.518	1.489	1.462	1.437	1.414	1.392	1.372	1.352
N Fk Matilija	Vta2	4.584	4.150	3.840	3.607	3.427	3.282	3.109	2.965	2.843	2.739	2.648	2.568	2.496	2.433	2.377	2.326	2.280	2.238	2.200	2.165	2.133	2.103	2.076	2.050	2.025	2.002
Arroyo Conejo	Con1	3.132	2.836	2.625	2.466	2.343	2.244	2.126	2.028	1.945	1.874	1.812	1.746	1.688	1.637	1.591	1.549	1.511	1.477	1.446	1.418	1.391	1.367	1.344	1.324	1.303	1.285
Ojai	Vta3	3.996	3.618	3.348	3.145	2.988	2.862	2.711	2.585	2.478	2.387	2.308	2.235	2.171	2.113	2.064	2.020	1.980	1.944	1.911	1.880	1.851	1.824	1.798	1.775	1.753	1.732
Oxnard Pln-Nyeland	Rev2	2.784	2.520	2.331	2.190	2.080	1.992	1.887	1.800	1.726	1.663	1.608	1.555	1.507	1.465	1.428	1.394	1.363	1.336	1.310	1.287	1.266	1.246	1.228	1.211	1.192	1.175
Prince-Arundell	Prin1	3.384	3.066	2.839	2.668	2.536	2.430	2.301	2.193	2.102	2.024	1.956	1.892	1.836	1.785	1.740	1.700	1.663	1.630	1.600	1.572	1.546	1.523	1.501	1.481	1.460	1.440
Revolon-Calleguas	Rev3	2.544	2.304	2.133	2.004	1.904	1.824	1.728	1.648	1.580	1.522	1.472	1.422	1.378	1.339	1.304	1.273	1.245	1.219	1.195	1.174	1.154	1.135	1.118	1.102	1.087	1.072
San Anton-CLarga	Vta5	3.816	3.456	3.199	3.006	2.856	2.736	2.592	2.472	2.370	2.283	2.208	2.136	2.072	2.016	1.965	1.920	1.879	1.841	1.807	1.776	1.747	1.721	1.696	1.673	1.652	1.632
SCR abv Freeman	SCR2	3.360	3.042	2.815	2.645	2.512	2.406	2.279	2.173	2.083	2.007	1.940	1.878	1.823	1.774	1.730	1.691	1.655	1.623	1.594	1.567	1.542	1.519	1.497	1.478	1.458	1.440
SCR to Ocean	SCR3	3.108	2.814	2.604	2.447	2.324	2.226	2.108	2.009	1.926	1.854	1.792	1.734	1.683	1.637	1.597	1.560	1.527	1.497	1.469	1.444	1.421	1.399	1.380	1.361	1.341	1.321
SCR-Lower Piru	SCR1	3.360	3.042	2.815	2.645	2.512	2.406	2.279	2.173	2.083	2.007	1.940	1.878	1.823	1.774	1.730	1.691	1.655	1.623	1.594	1.567	1.542	1.519	1.497	1.478	1.458	1.439
Sespe Abv Bear	Sespe2	4.080	3.696	3.422	3.216	3.056	2.928	2.773	2.644	2.535	2.441	2.360	2.284	2.217	2.157	2.105	2.059	2.016	1.978	1.943	1.911	1.880	1.852	1.825	1.801	1.778	1.757
Sespe Abv Grand	Sespe3	3.744	3.390	3.137	2.948	2.800	2.682	2.540	2.421	2.321	2.235	2.160	2.094	2.035	1.983	1.937	1.895	1.857	1.823	1.791	1.763	1.736	1.712	1.689	1.668	1.648	1.630
Sespe Abv Wheeler	Sespe1	4.740	4.292	3.972	3.732	3.545	3.396	3.216	3.066	2.939	2.830	2.736	2.635	2.545	2.465	2.397	2.336	2.281	2.230	2.184	2.142	2.101	2.063	2.028	1.995	1.964	1.936
Simi Valley	Simi2	3.324	3.010	2.786	2.618	2.487	2.382	2.256	2.151	2.062	1.986	1.920	1.849	1.786	1.731	1.681	1.636	1.595	1.559	1.525	1.494	1.466	1.439	1.415	1.393	1.370	1.350
So Mtn to Moorpark	Rev1	3.084	2.794	2.587	2.432	2.311	2.214	2.097	1.999	1.916	1.845	1.784	1.725	1.672	1.625	1.587	1.552	1.520	1.492	1.465	1.442	1.417	1.395	1.374	1.354	1.336	1.320
Todd to Timber	Todd1	3.768	3.414	3.161	2.972	2.824	2.706	2.563	2.443	2.342	2.255	2.180	2.110	2.048	1.993	1.948	1.907	1.869	1.836	1.805	1.776	1.748	1.721	1.697	1.674	1.653	1.633
Upper Arroyo Simi	Simi1	3.480	3.152	2.918	2.742	2.605	2.496	2.364	2.254	2.161	2.081	2.012	1.932	1.861	1.799	1.743	1.692	1.646	1.605	1.567	1.532	1.500	1.470	1.443	1.418	1.392	1.369
Upper Harmon	Harm1	3.636	3.292	3.046	2.862	2.719	2.604	2.467	2.352	2.255	2.172	2.100	2.032	1.972	1.919	1.871	1.828	1.789	1.754	1.722	1.692	1.665	1.640	1.616	1.595	1.575	1.556
Upper Matilija	Vta1	5.532	5.010	4.637	4.358	4.140	3.966	3.757	3.583	3.436	3.309	3.200	3.082	2.978	2.886	2.804	2.729	2.662	2.601	2.546	2.495	2.447	2.404	2.364	2.326	2.291	2.259
Upper Piru	Piru1	3.348	3.032	2.806	2.637	2.505	2.400	2.272	2.166	2.076	1.999	1.932	1.865	1.805	1.753	1.705	1.663	1.625	1.590	1.558	1.529	1.502	1.477	1.454	1.432	1.409	1.388
Upper Sta Paula Ck	StPaul1	4.104	3.716	3.439	3.231	3.069	2.940	2.785	2.656	2.547	2.453	2.372	2.295	2.227	2.166	2.116	2.070	2.029	1.992	1.958	1.926	1.895	1.866	1.839	1.814	1.790	1.768

EXHIBIT 5A. UPDATED RUNOFF COEFFICIENT CURVE- SOIL 1 (NRCS TYPE D)

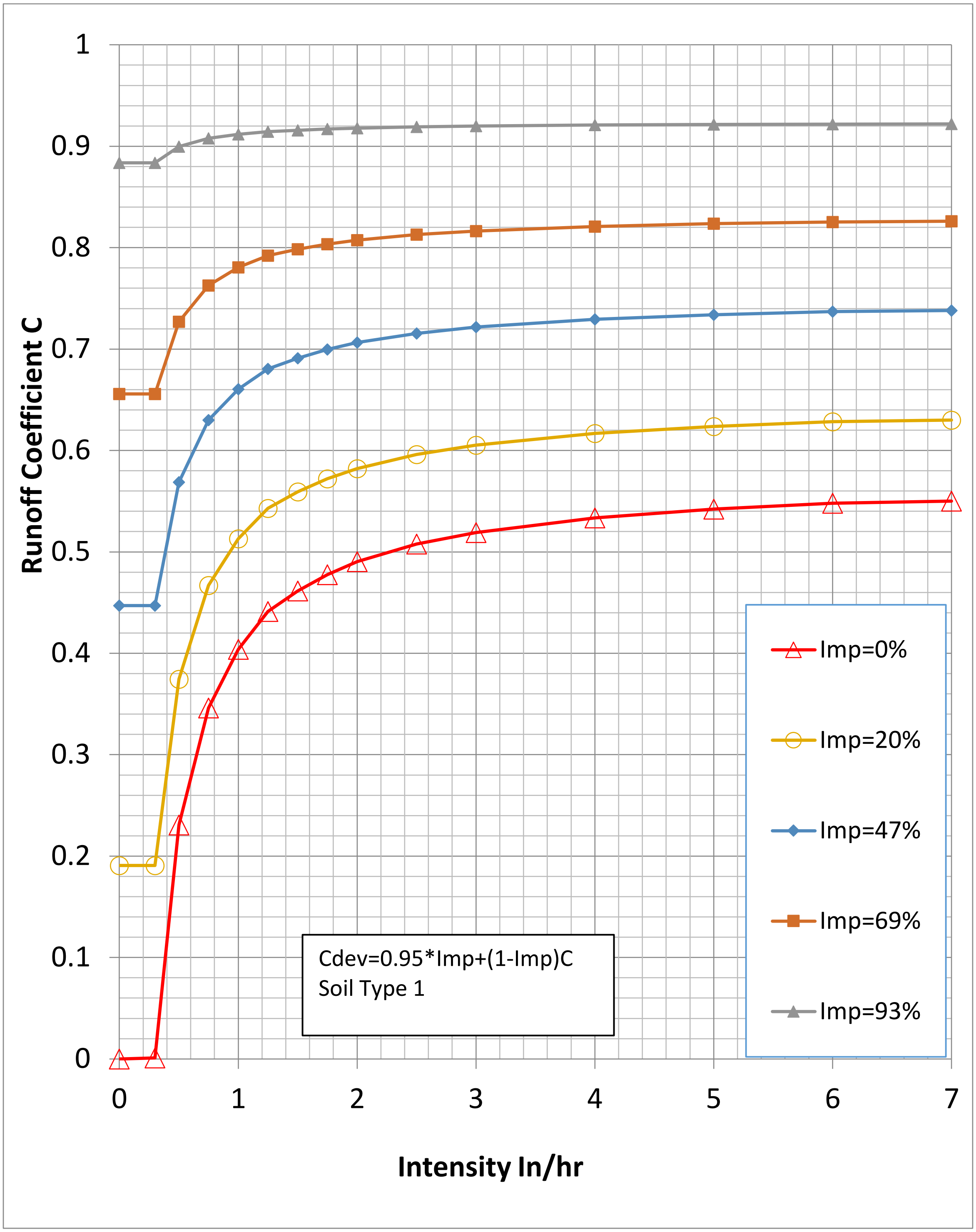


Exhibit 5b. Updated Runoff Coefficient Curve- Soil 2 (NRCS Type C)

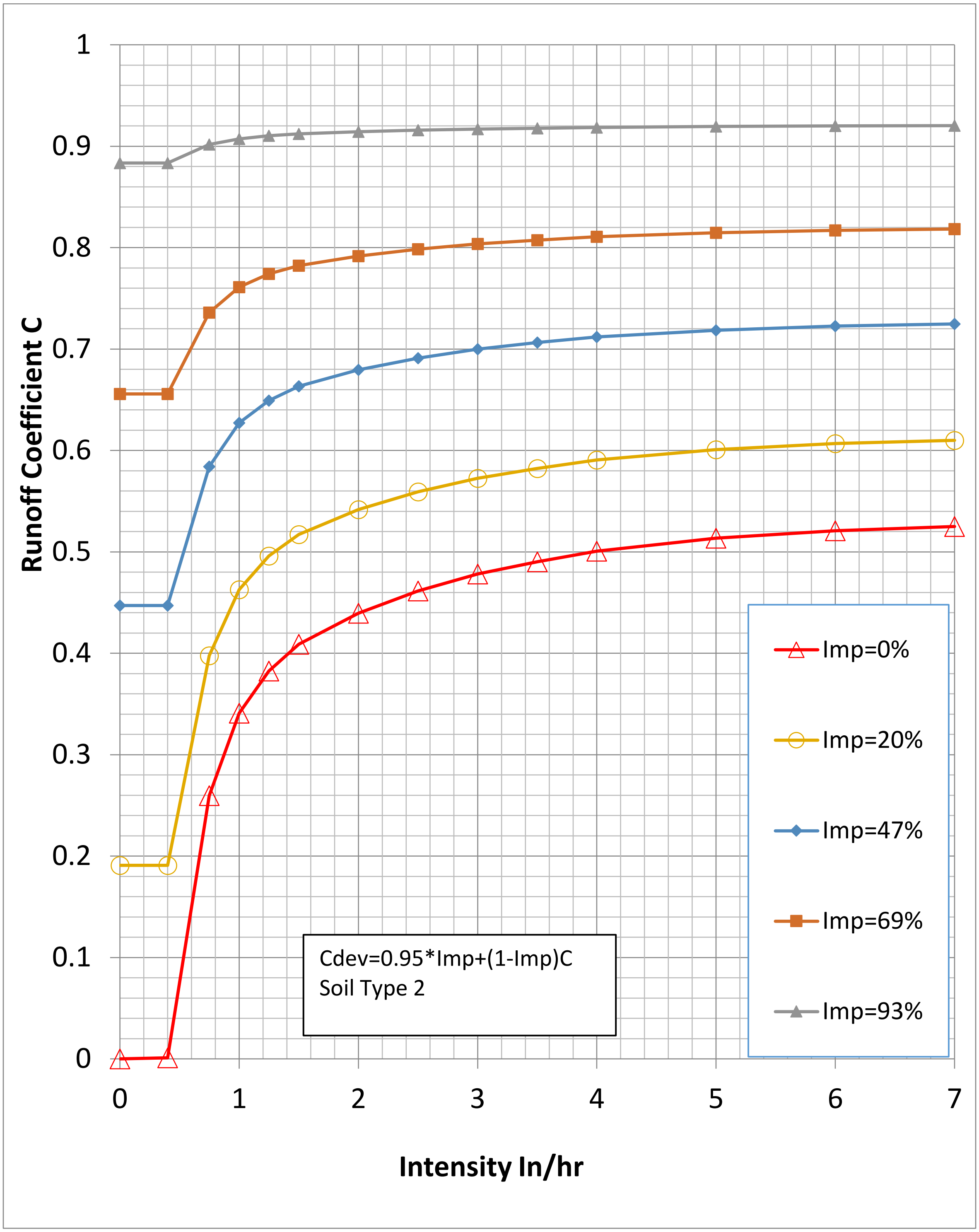


EXHIBIT 5C. UPDATED RUNOFF COEFFICIENT CURVE- SOIL 3 (NRCS TYPE C)

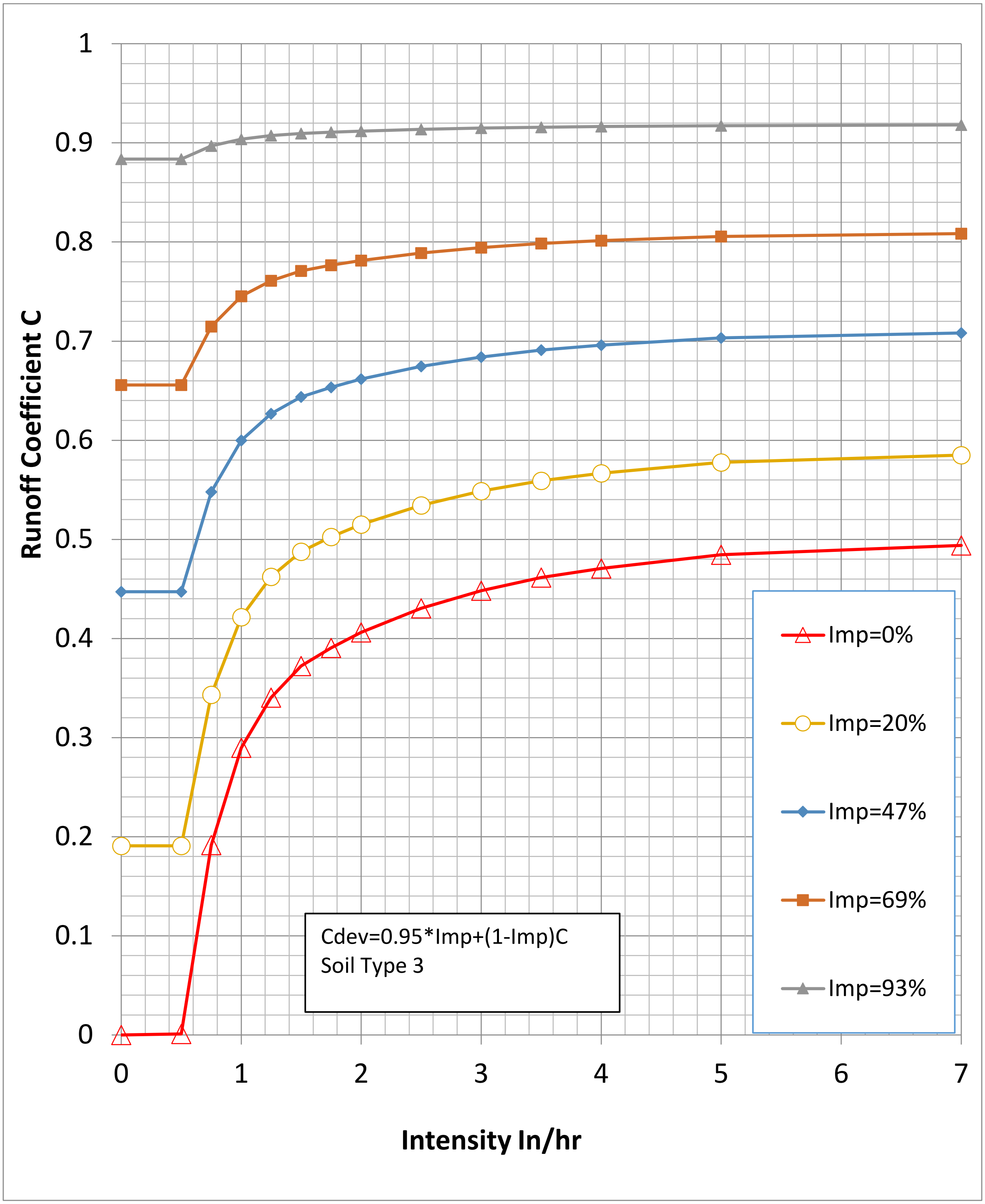


EXHIBIT 5D. UPDATED RUNOFF COEFFICIENT CURVE- SOIL 4 (NRCS TYPE B)

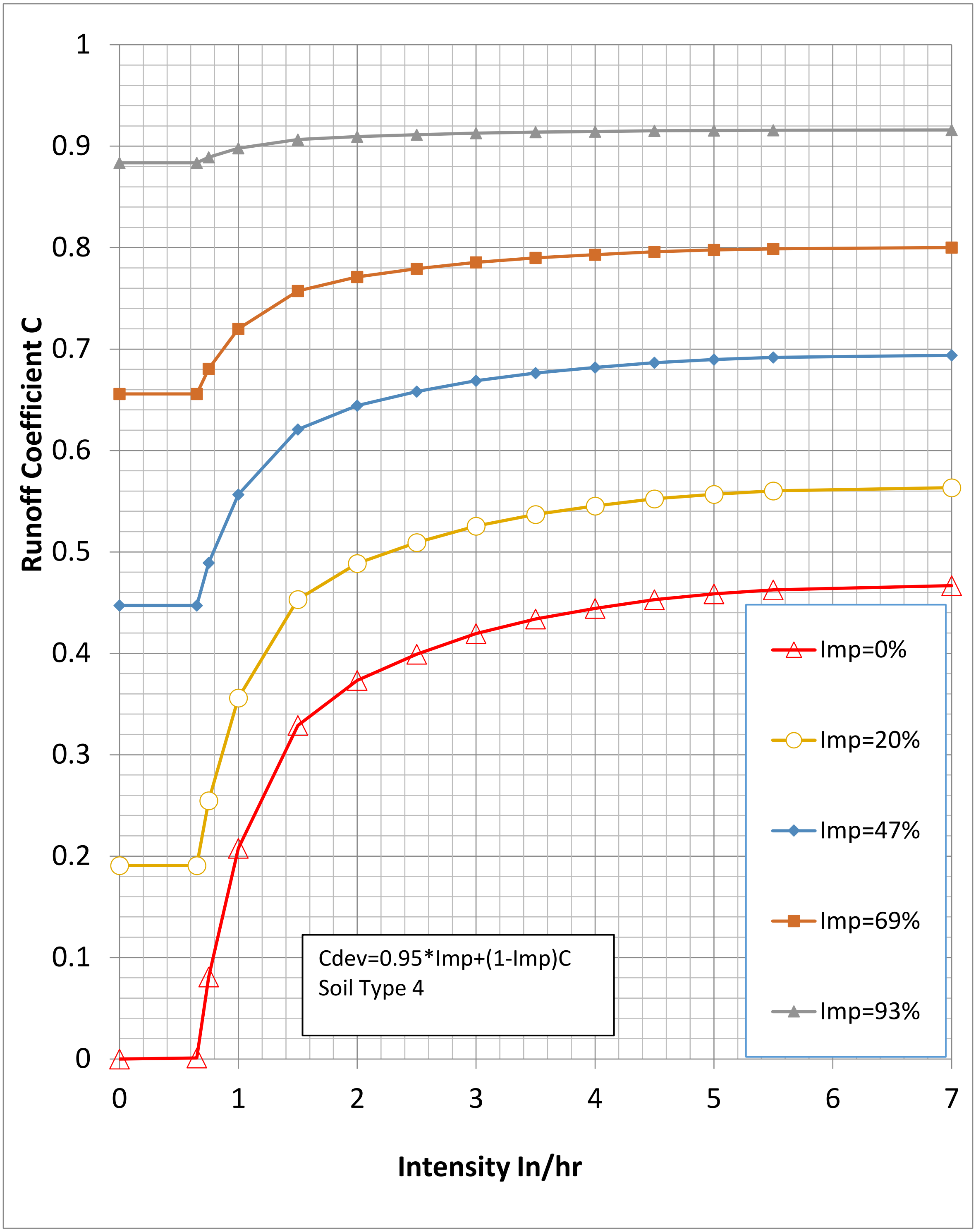


EXHIBIT 5E. UPDATED RUNOFF COEFFICIENT CURVE- SOIL 5 (NRCS TYPE B)

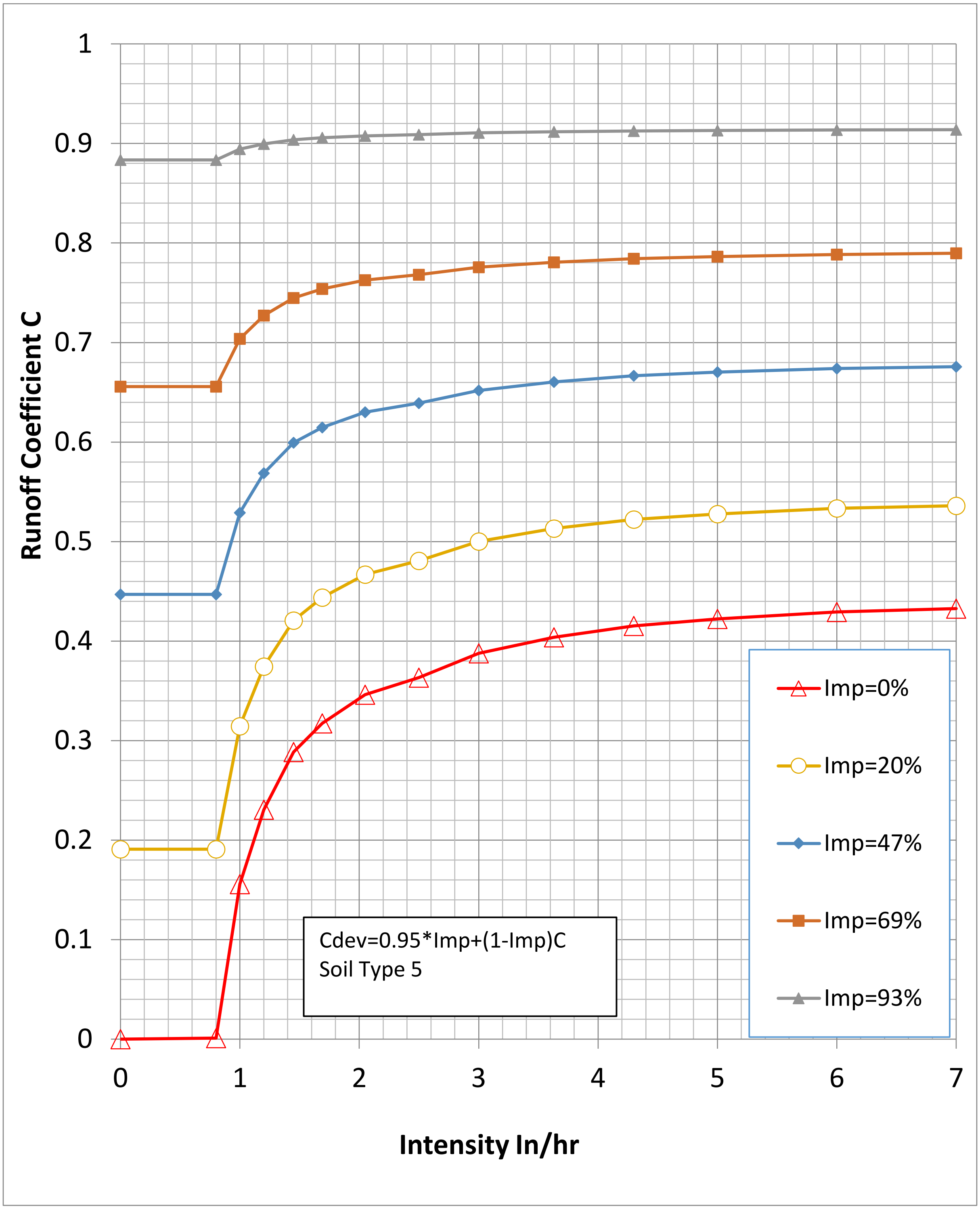


EXHIBIT 5F. UPDATED RUNOFF COEFFICIENT CURVE- SOIL 6 (NRCS TYPE A)

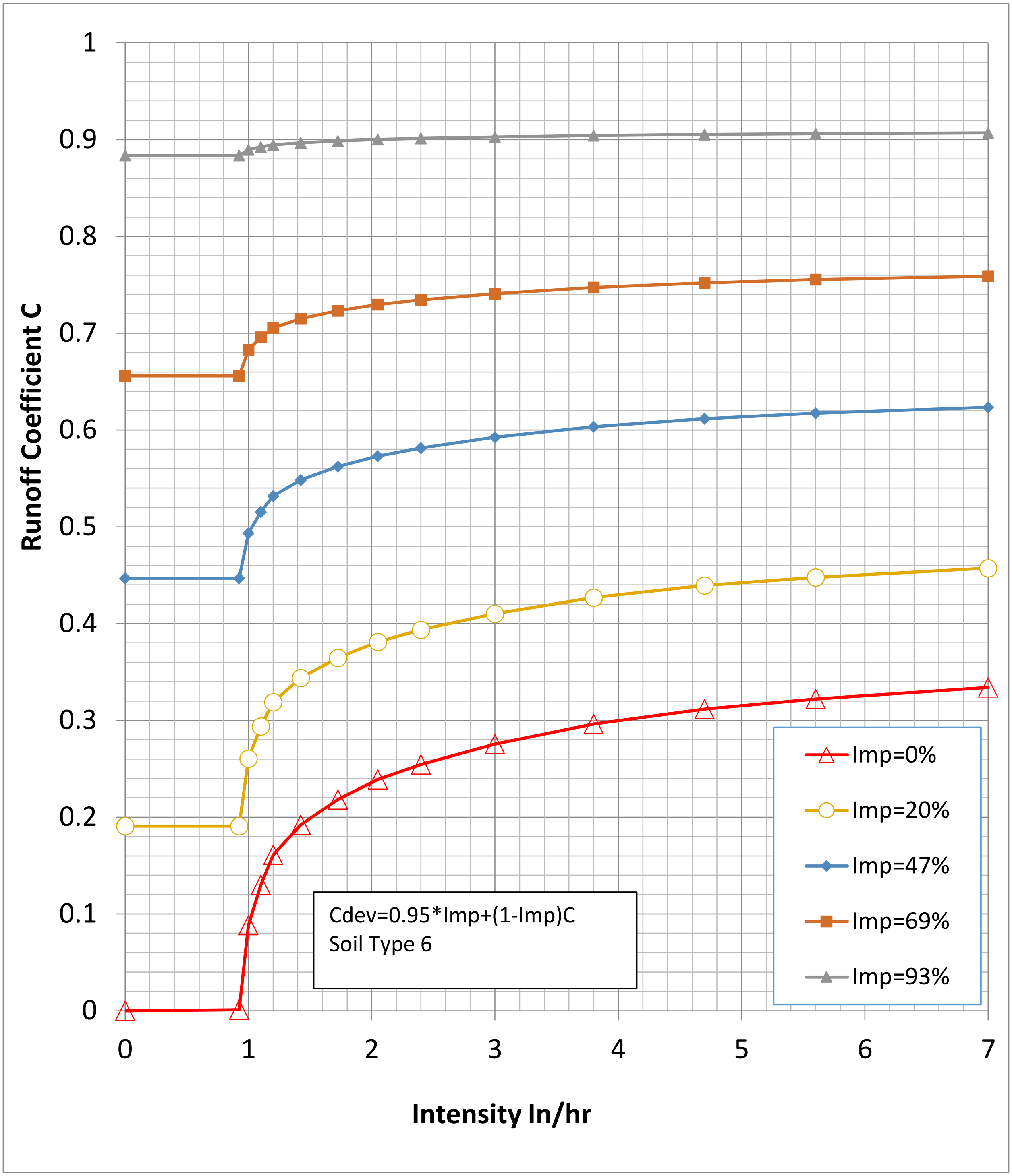


EXHIBIT 5G. UPDATED RUNOFF COEFFICIENT CURVE- SOIL 7 (NRCS TYPE A)

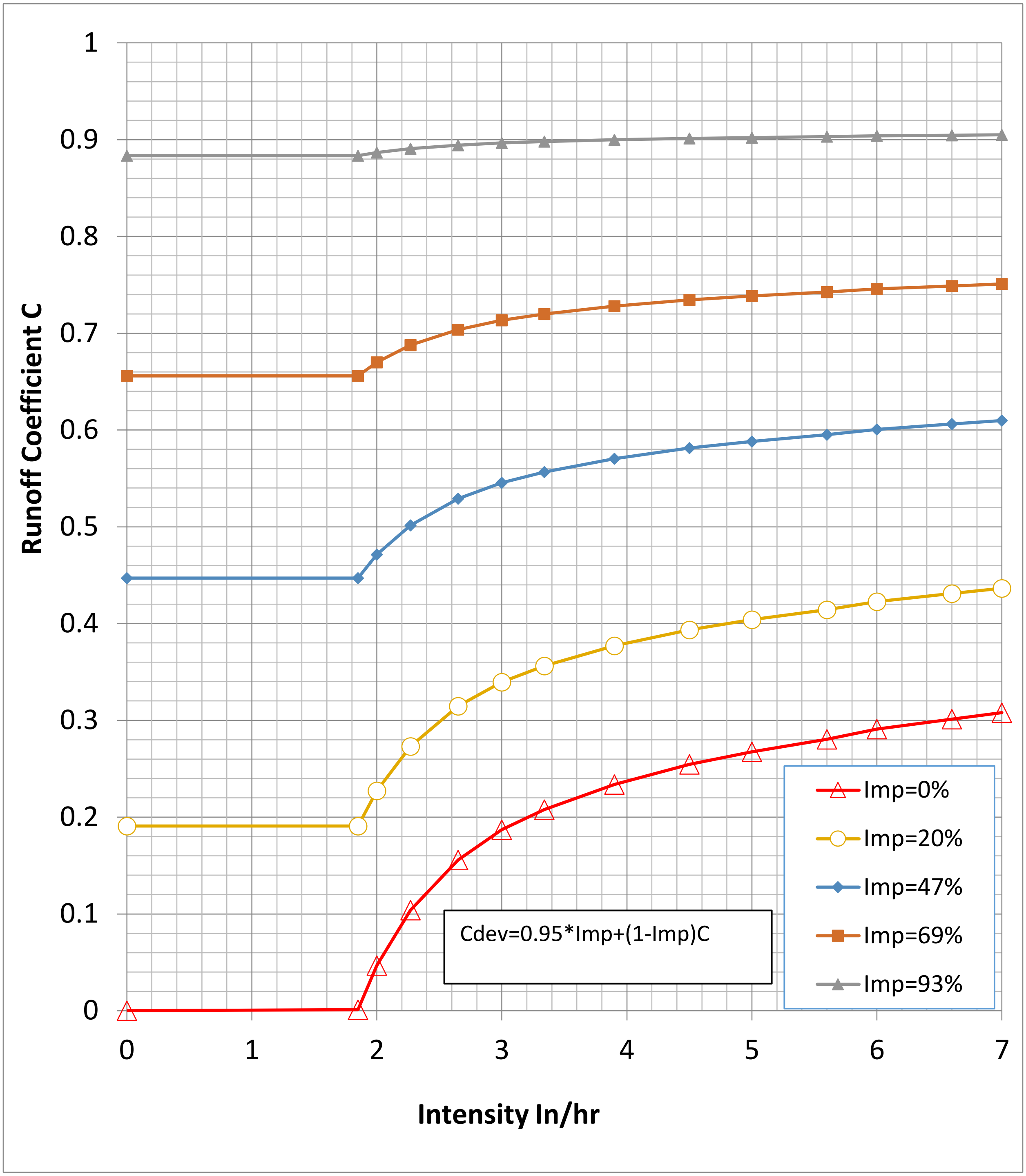


EXHIBIT 6A. LEGACY RUNOFF COEFFICIENT CURVE- SOIL 1 (NRCS TYPE D)

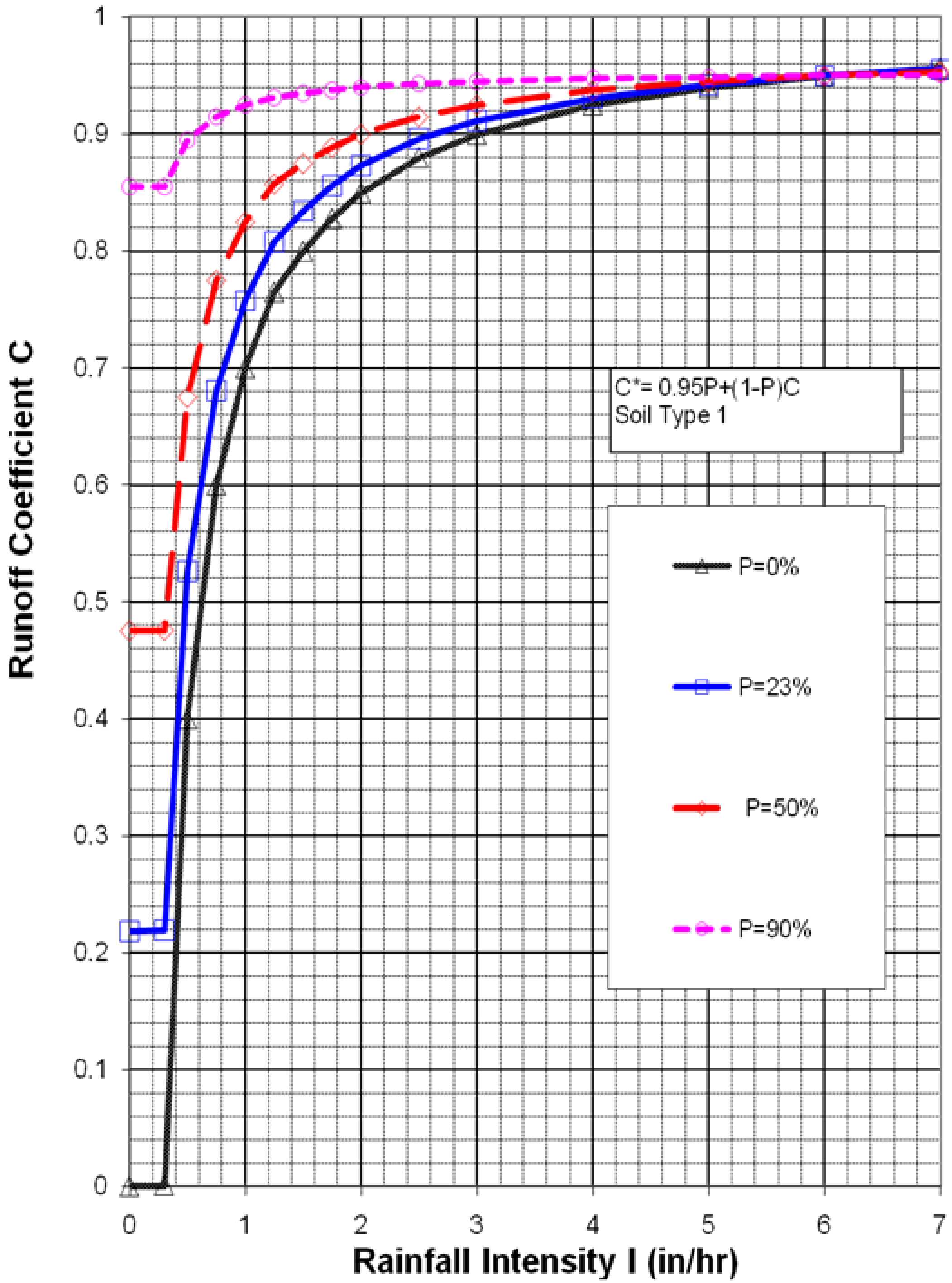


EXHIBIT 6B. LEGACY RUNOFF COEFFICIENT CURVE- SOIL 2 (NRCS TYPE C)

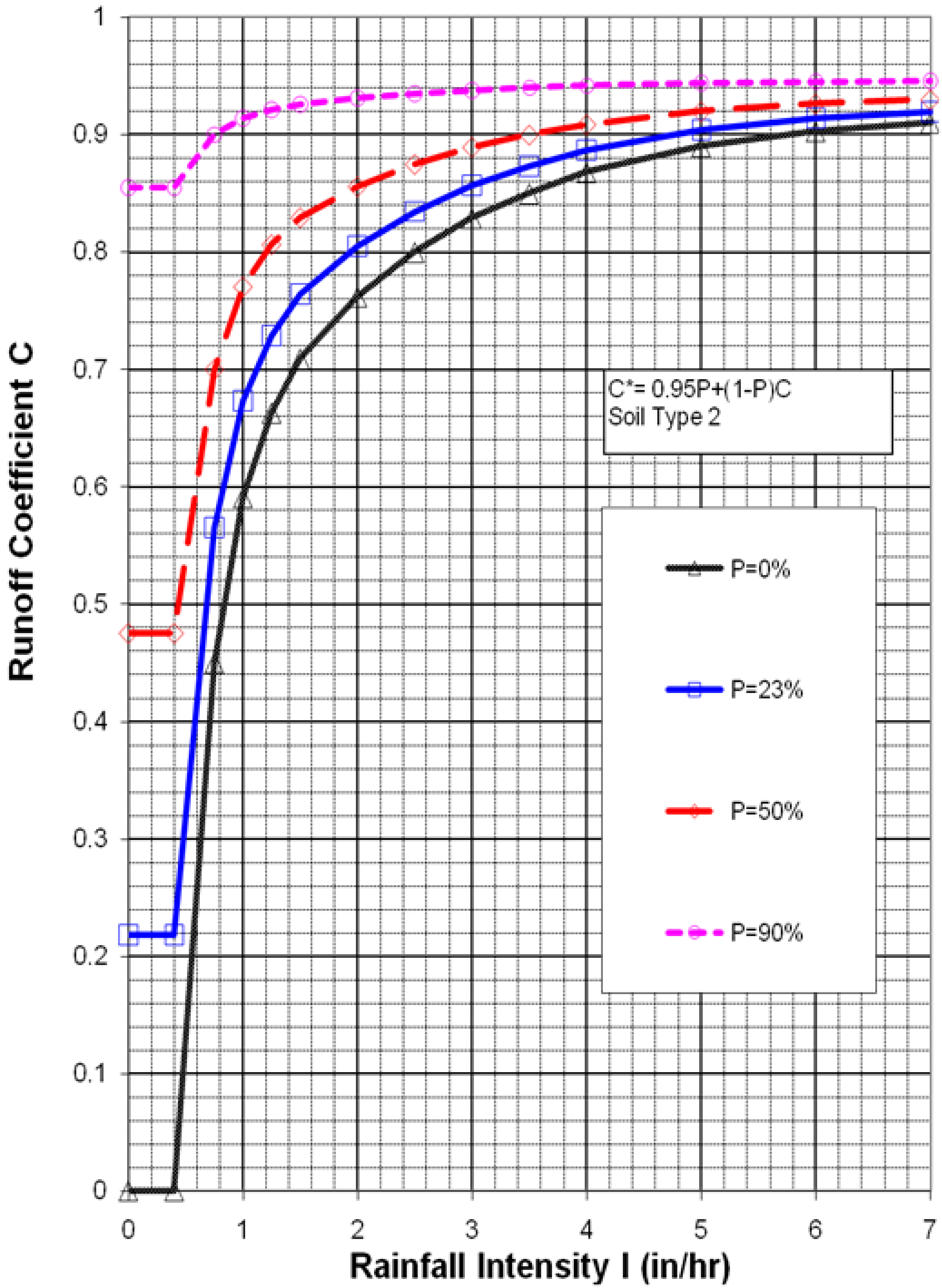


EXHIBIT 6C. LEGACY RUNOFF COEFFICIENT CURVE- SOIL 3 (NRCS TYPE C)

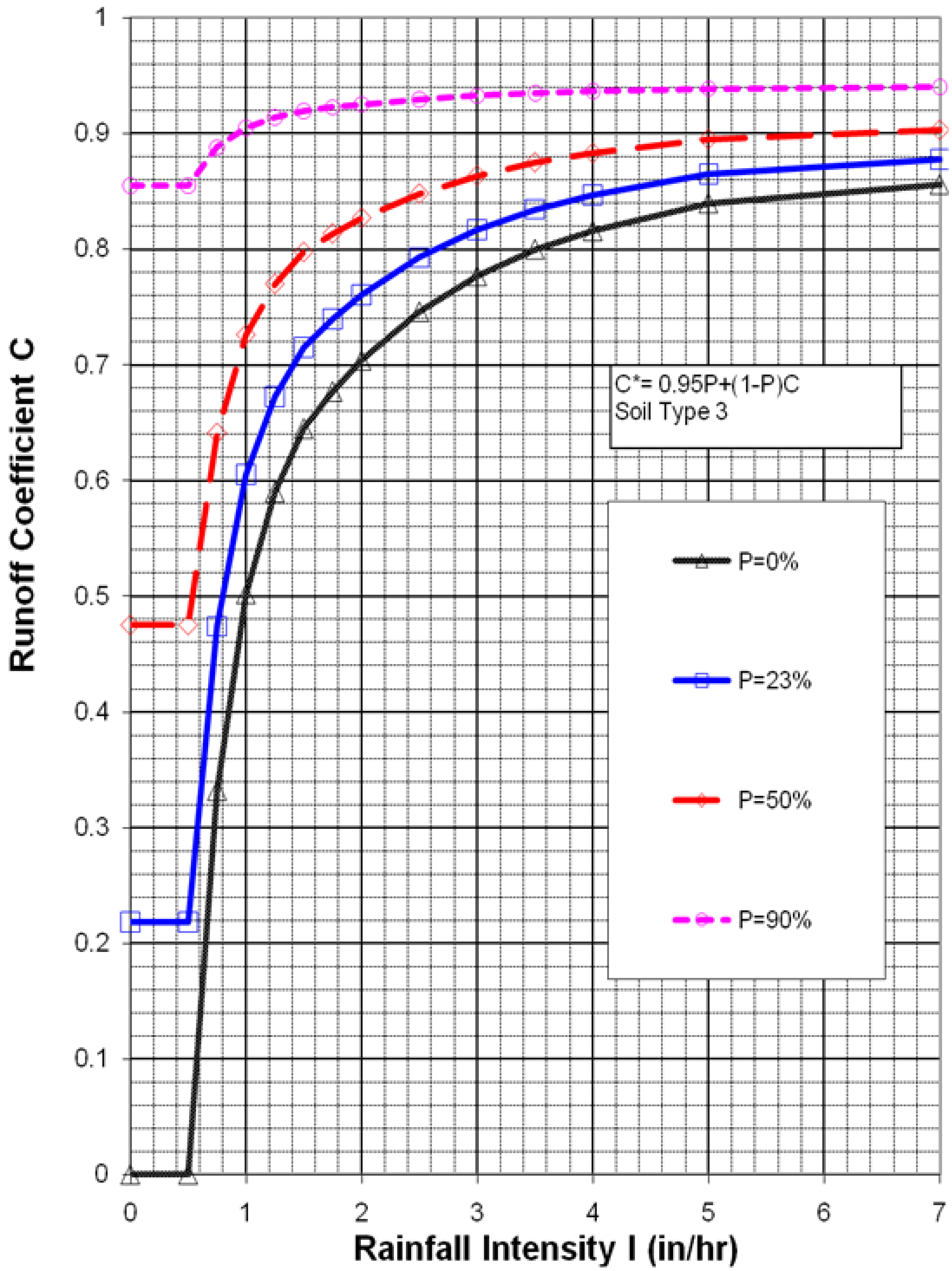


EXHIBIT 6D. LEGACY RUNOFF COEFFICIENT CURVE- SOIL 4 (NRCS TYPE B)

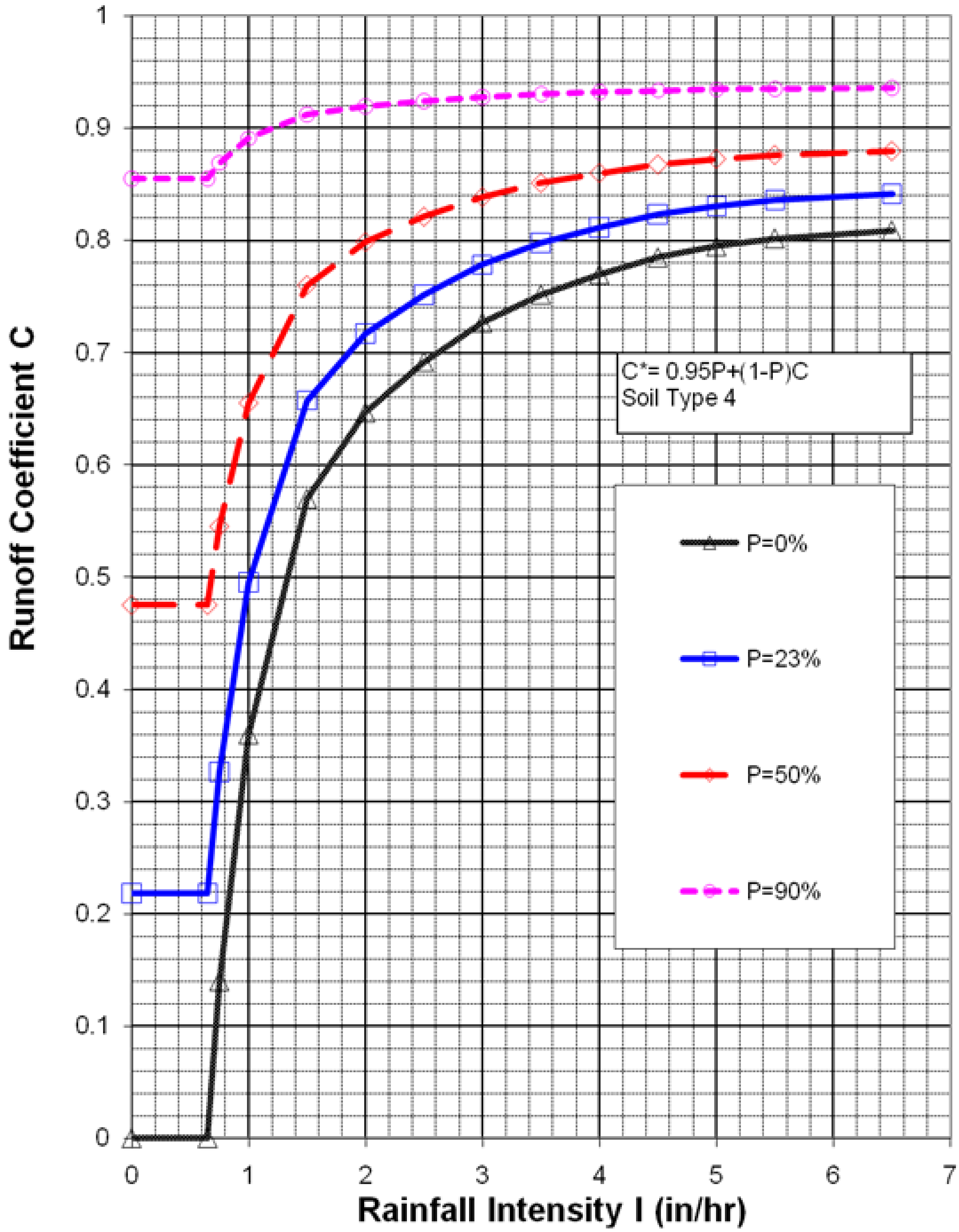


EXHIBIT 6E. LEGACY RUNOFF COEFFICIENT CURVE- SOIL 5 (NRCS TYPE B)

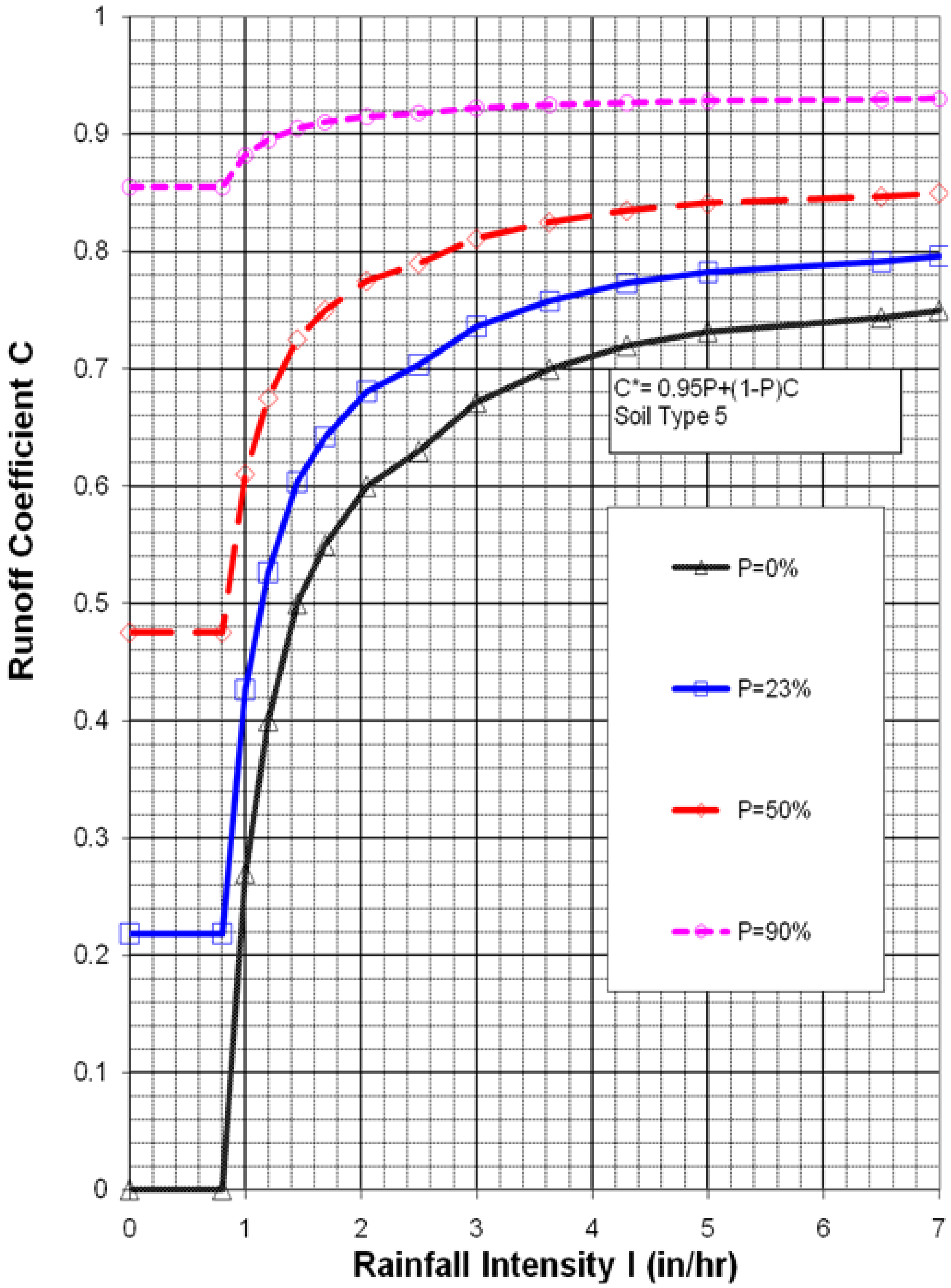


EXHIBIT 6F. LEGACY RUNOFF COEFFICIENT CURVE- SOIL 6 (NRCS TYPE A)

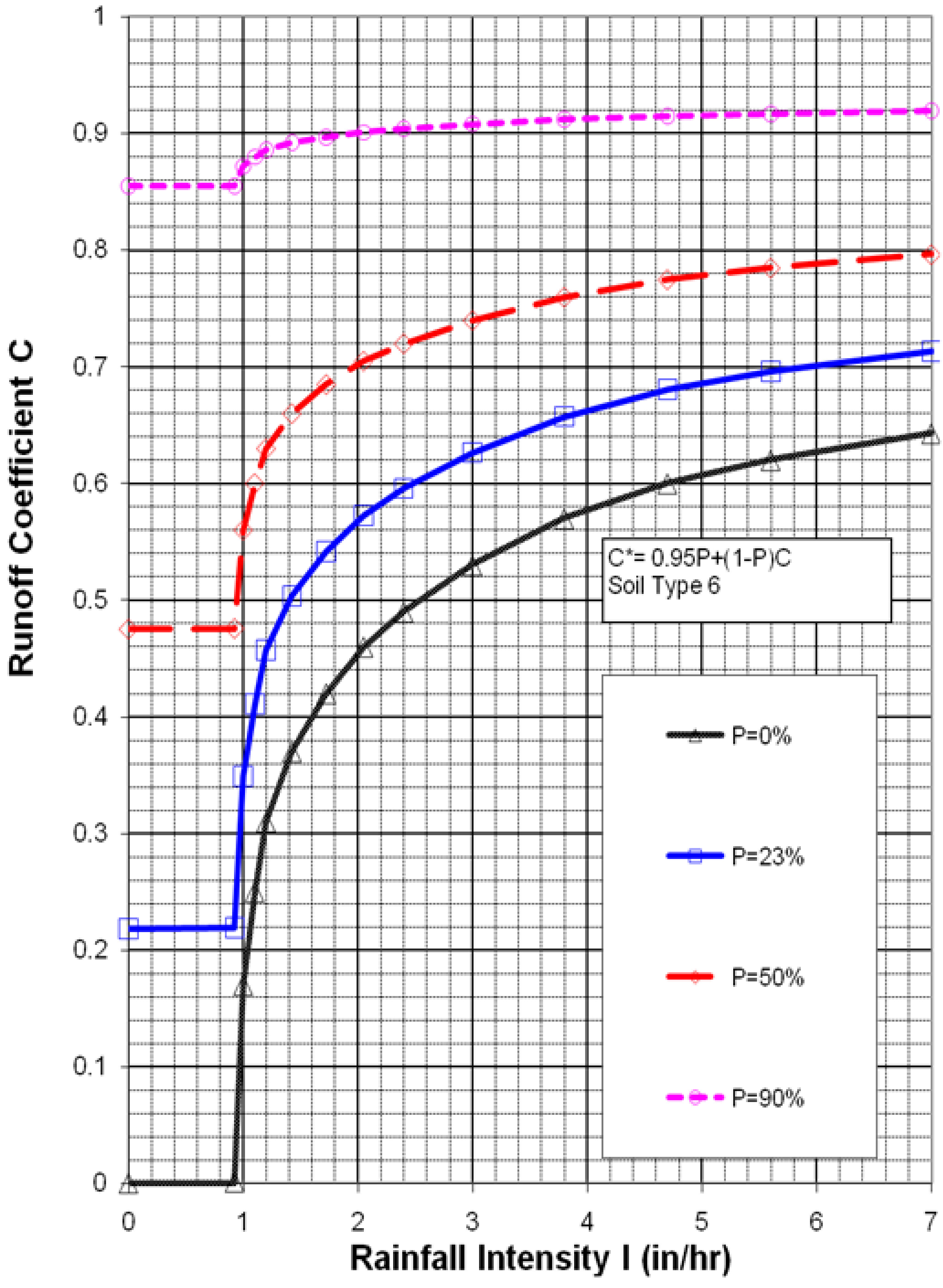


EXHIBIT 6G. LEGACY RUNOFF COEFFICIENT CURVE- SOIL 7 (NRCS TYPE A)

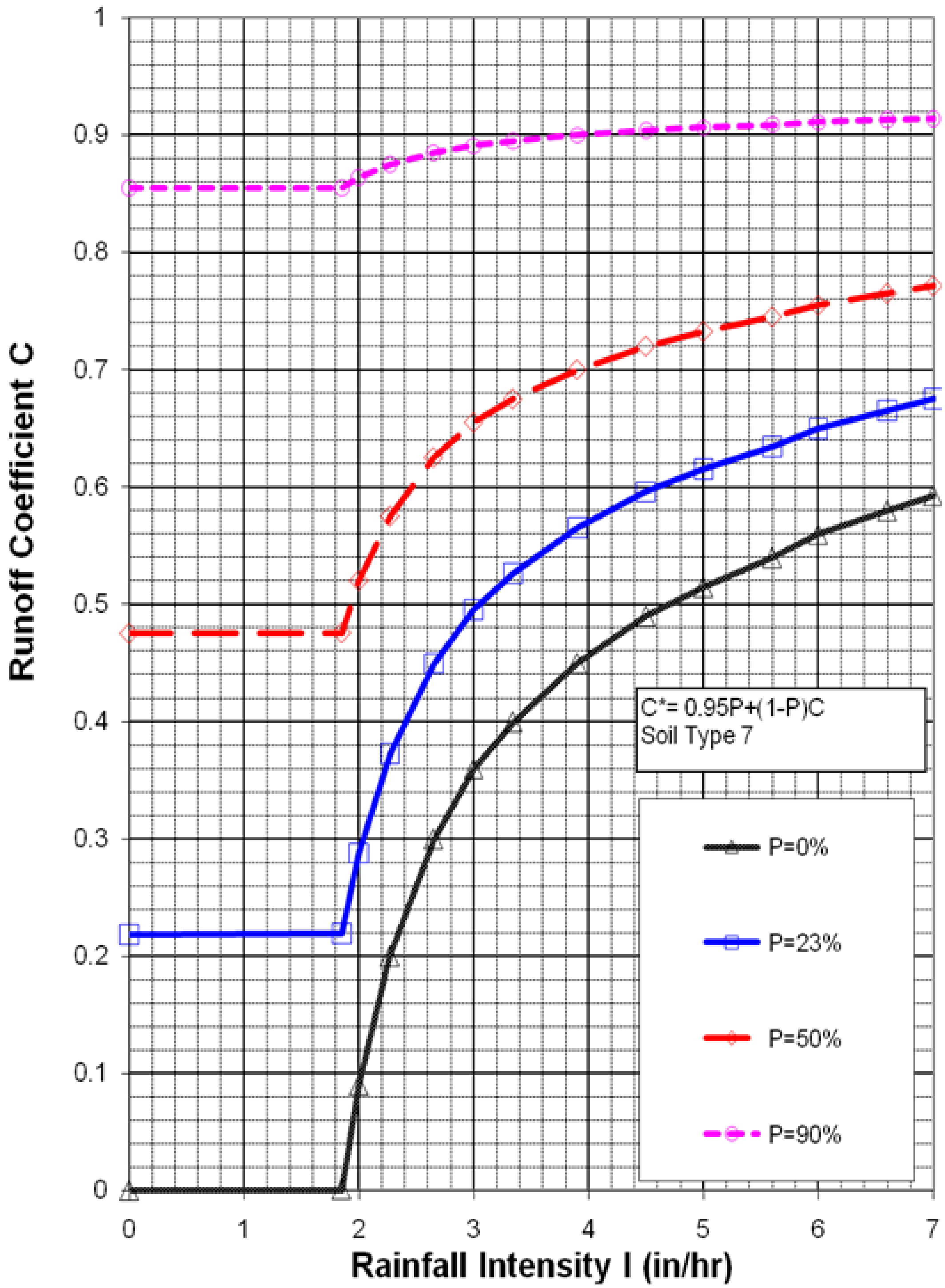


EXHIBIT 6H. INTENSITIES VS UPDATED PERVIOUS AREA C COEFFICIENTS

Intensity	VCWPD Soil Type / C Coefficient						
(in/hr)	1	2	3	4	5	6	7
0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.01	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.02	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.03	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.04	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.05	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.06	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.07	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.08	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.09	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.10	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.11	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.12	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.13	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.14	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.15	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.16	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.17	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.18	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.19	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.20	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.21	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.22	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.23	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.24	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.25	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.26	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.27	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.28	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.29	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.30	0.001	0.000	0.000	0.000	0.000	0.000	0.000
0.31	0.012	0.000	0.000	0.000	0.000	0.000	0.000
0.32	0.024	0.000	0.000	0.000	0.000	0.000	0.000
0.33	0.035	0.000	0.000	0.000	0.000	0.000	0.000
0.34	0.047	0.000	0.000	0.000	0.000	0.000	0.000
0.35	0.058	0.000	0.000	0.000	0.000	0.000	0.000
0.36	0.070	0.000	0.000	0.000	0.000	0.000	0.000
0.37	0.081	0.000	0.000	0.000	0.000	0.000	0.000
0.38	0.093	0.000	0.000	0.000	0.000	0.000	0.000
0.39	0.104	0.000	0.000	0.000	0.000	0.000	0.000
0.40	0.116	0.001	0.000	0.000	0.001	0.000	0.000
0.41	0.127	0.008	0.000	0.000	0.001	0.000	0.000
0.42	0.139	0.016	0.000	0.000	0.001	0.000	0.000

Intensity	VCWPD Soil Type / C Coefficient						
(in/hr)	1	2	3	4	5	6	7
0.43	0.150	0.023	0.000	0.000	0.001	0.000	0.000
0.44	0.162	0.031	0.000	0.000	0.001	0.000	0.000
0.45	0.173	0.038	0.000	0.000	0.001	0.000	0.000
0.46	0.185	0.045	0.000	0.000	0.001	0.000	0.000
0.47	0.196	0.053	0.000	0.000	0.001	0.000	0.000
0.48	0.208	0.060	0.000	0.000	0.001	0.000	0.000
0.49	0.219	0.067	0.000	0.000	0.001	0.000	0.000
0.50	0.231	0.075	0.001	0.000	0.001	0.000	0.000
0.51	0.235	0.082	0.009	0.000	0.001	0.000	0.000
0.52	0.240	0.090	0.016	0.000	0.001	0.000	0.000
0.53	0.245	0.097	0.024	0.000	0.001	0.000	0.000
0.54	0.249	0.104	0.031	0.000	0.001	0.000	0.000
0.55	0.254	0.112	0.039	0.000	0.001	0.000	0.000
0.56	0.258	0.119	0.047	0.000	0.001	0.000	0.000
0.57	0.263	0.127	0.054	0.000	0.001	0.000	0.000
0.58	0.268	0.134	0.062	0.000	0.001	0.000	0.000
0.59	0.272	0.141	0.070	0.000	0.001	0.000	0.000
0.60	0.277	0.149	0.077	0.000	0.001	0.000	0.000
0.61	0.282	0.156	0.085	0.000	0.001	0.000	0.000
0.62	0.286	0.164	0.092	0.000	0.001	0.000	0.000
0.63	0.291	0.171	0.100	0.000	0.001	0.000	0.000
0.64	0.295	0.178	0.108	0.000	0.001	0.000	0.000
0.65	0.300	0.186	0.115	0.001	0.001	0.000	0.000
0.66	0.305	0.193	0.123	0.009	0.001	0.000	0.000
0.67	0.309	0.200	0.131	0.017	0.001	0.000	0.000
0.68	0.314	0.208	0.138	0.025	0.001	0.000	0.000
0.69	0.318	0.215	0.146	0.033	0.001	0.000	0.000
0.70	0.323	0.223	0.153	0.041	0.001	0.000	0.000
0.71	0.328	0.230	0.161	0.049	0.001	0.000	0.000
0.72	0.332	0.237	0.169	0.057	0.001	0.000	0.000
0.73	0.337	0.245	0.176	0.065	0.001	0.000	0.000
0.74	0.341	0.252	0.184	0.073	0.001	0.000	0.000
0.75	0.346	0.260	0.192	0.081	0.001	0.000	0.000
0.76	0.348	0.263	0.195	0.086	0.001	0.000	0.000
0.77	0.351	0.266	0.199	0.091	0.001	0.000	0.000
0.78	0.353	0.269	0.203	0.096	0.001	0.000	0.000
0.79	0.355	0.273	0.207	0.101	0.001	0.000	0.000
0.80	0.358	0.276	0.211	0.106	0.001	0.000	0.000
0.81	0.360	0.279	0.215	0.111	0.009	0.000	0.000
0.82	0.362	0.282	0.219	0.116	0.016	0.000	0.000
0.83	0.365	0.286	0.223	0.121	0.024	0.000	0.000
0.84	0.367	0.289	0.227	0.126	0.032	0.000	0.000
0.85	0.369	0.292	0.231	0.132	0.040	0.000	0.000
0.86	0.371	0.295	0.235	0.137	0.047	0.000	0.000
0.87	0.374	0.299	0.239	0.142	0.055	0.000	0.000

Intensity	VCWPD Soil Type / C Coefficient						
(in/hr)	1	2	3	4	5	6	7
0.88	0.376	0.302	0.243	0.147	0.063	0.000	0.000
0.89	0.378	0.305	0.246	0.152	0.071	0.000	0.000
0.90	0.381	0.308	0.250	0.157	0.078	0.000	0.000
0.91	0.383	0.312	0.254	0.162	0.086	0.000	0.000
0.92	0.385	0.315	0.258	0.167	0.094	0.001	0.000
0.93	0.388	0.318	0.262	0.172	0.102	0.007	0.000
0.94	0.390	0.321	0.266	0.177	0.109	0.018	0.000
0.95	0.392	0.325	0.270	0.182	0.117	0.030	0.000
0.96	0.395	0.328	0.274	0.187	0.125	0.042	0.000
0.97	0.397	0.331	0.278	0.192	0.133	0.053	0.000
0.98	0.399	0.334	0.282	0.198	0.140	0.065	0.000
0.99	0.401	0.338	0.286	0.203	0.148	0.077	0.000
1.00	0.404	0.341	0.290	0.208	0.156	0.088	0.000
1.01	0.405	0.343	0.292	0.210	0.160	0.092	0.000
1.02	0.407	0.344	0.294	0.213	0.163	0.097	0.000
1.03	0.408	0.346	0.296	0.215	0.167	0.101	0.000
1.04	0.410	0.348	0.298	0.217	0.171	0.105	0.000
1.05	0.411	0.349	0.300	0.220	0.175	0.109	0.000
1.06	0.413	0.351	0.302	0.222	0.178	0.113	0.000
1.07	0.414	0.353	0.304	0.225	0.182	0.117	0.000
1.08	0.416	0.354	0.306	0.227	0.186	0.122	0.000
1.09	0.417	0.356	0.308	0.229	0.190	0.126	0.000
1.10	0.419	0.358	0.310	0.232	0.193	0.130	0.000
1.11	0.420	0.359	0.312	0.234	0.197	0.133	0.000
1.12	0.422	0.361	0.314	0.237	0.201	0.136	0.000
1.13	0.423	0.363	0.316	0.239	0.205	0.139	0.000
1.14	0.425	0.364	0.318	0.242	0.208	0.142	0.000
1.15	0.426	0.366	0.320	0.244	0.212	0.146	0.000
1.16	0.428	0.368	0.322	0.246	0.216	0.149	0.000
1.17	0.429	0.369	0.324	0.249	0.220	0.152	0.000
1.18	0.431	0.371	0.326	0.251	0.223	0.155	0.000
1.19	0.432	0.373	0.328	0.254	0.227	0.158	0.000
1.20	0.434	0.374	0.330	0.256	0.231	0.161	0.000
1.21	0.435	0.376	0.332	0.259	0.233	0.162	0.000
1.22	0.437	0.378	0.334	0.261	0.235	0.164	0.000
1.23	0.438	0.379	0.336	0.263	0.238	0.165	0.000
1.24	0.440	0.381	0.338	0.266	0.240	0.167	0.000
1.25	0.441	0.383	0.340	0.268	0.242	0.168	0.000
1.26	0.442	0.384	0.342	0.271	0.245	0.169	0.000
1.27	0.443	0.385	0.343	0.273	0.247	0.171	0.000
1.28	0.444	0.386	0.344	0.276	0.249	0.172	0.000
1.29	0.445	0.387	0.345	0.278	0.252	0.174	0.000
1.30	0.445	0.388	0.347	0.280	0.254	0.175	0.000
1.31	0.446	0.389	0.348	0.283	0.256	0.176	0.000
1.32	0.447	0.390	0.349	0.285	0.258	0.178	0.000

Intensity	VCWPD Soil Type / C Coefficient						
(in/hr)	1	2	3	4	5	6	7
1.33	0.448	0.391	0.351	0.288	0.261	0.179	0.000
1.34	0.449	0.392	0.352	0.290	0.263	0.180	0.000
1.35	0.449	0.393	0.353	0.292	0.265	0.182	0.000
1.36	0.450	0.394	0.354	0.295	0.268	0.183	0.000
1.37	0.451	0.395	0.356	0.297	0.270	0.185	0.000
1.38	0.452	0.396	0.357	0.300	0.272	0.186	0.000
1.39	0.453	0.397	0.358	0.302	0.275	0.187	0.000
1.40	0.453	0.398	0.359	0.305	0.277	0.189	0.000
1.41	0.454	0.399	0.361	0.307	0.279	0.190	0.000
1.42	0.455	0.401	0.362	0.309	0.281	0.192	0.000
1.43	0.456	0.402	0.363	0.312	0.284	0.193	0.000
1.44	0.457	0.403	0.364	0.314	0.286	0.194	0.000
1.45	0.457	0.404	0.366	0.317	0.288	0.194	0.000
1.46	0.458	0.405	0.367	0.319	0.290	0.195	0.000
1.47	0.459	0.406	0.368	0.322	0.291	0.196	0.000
1.48	0.460	0.407	0.370	0.324	0.292	0.197	0.000
1.49	0.461	0.408	0.371	0.326	0.293	0.198	0.000
1.50	0.462	0.409	0.372	0.329	0.294	0.199	0.000
1.51	0.462	0.410	0.373	0.330	0.296	0.200	0.000
1.52	0.463	0.410	0.374	0.331	0.297	0.200	0.000
1.53	0.463	0.411	0.374	0.331	0.298	0.201	0.000
1.54	0.464	0.411	0.375	0.332	0.299	0.202	0.000
1.55	0.465	0.412	0.376	0.333	0.300	0.203	0.000
1.56	0.465	0.413	0.377	0.334	0.302	0.204	0.000
1.57	0.466	0.413	0.377	0.335	0.303	0.205	0.000
1.58	0.467	0.414	0.378	0.336	0.304	0.206	0.000
1.59	0.467	0.415	0.379	0.337	0.305	0.207	0.000
1.60	0.468	0.415	0.379	0.338	0.306	0.207	0.000
1.61	0.469	0.416	0.380	0.339	0.308	0.208	0.000
1.62	0.469	0.416	0.381	0.339	0.309	0.209	0.000
1.63	0.470	0.417	0.382	0.340	0.310	0.210	0.000
1.64	0.471	0.418	0.382	0.341	0.311	0.211	0.000
1.65	0.471	0.418	0.383	0.342	0.312	0.212	0.000
1.66	0.472	0.419	0.384	0.343	0.314	0.213	0.000
1.67	0.473	0.419	0.385	0.344	0.315	0.213	0.000
1.68	0.473	0.420	0.385	0.345	0.316	0.214	0.000
1.69	0.474	0.421	0.386	0.346	0.317	0.215	0.000
1.70	0.474	0.421	0.387	0.347	0.318	0.216	0.000
1.71	0.475	0.422	0.388	0.347	0.319	0.217	0.000
1.72	0.476	0.422	0.388	0.348	0.320	0.218	0.000
1.73	0.476	0.423	0.389	0.349	0.321	0.219	0.000
1.74	0.477	0.424	0.390	0.350	0.321	0.219	0.000
1.75	0.478	0.424	0.391	0.351	0.322	0.220	0.000
1.76	0.478	0.425	0.391	0.352	0.323	0.220	0.000
1.77	0.479	0.426	0.392	0.353	0.324	0.221	0.000

Intensity	VCWPD Soil Type / C Coefficient						
(in/hr)	1	2	3	4	5	6	7
1.78	0.479	0.426	0.392	0.354	0.325	0.222	0.000
1.79	0.480	0.427	0.393	0.355	0.325	0.222	0.000
1.80	0.480	0.427	0.394	0.355	0.326	0.223	0.000
1.81	0.481	0.428	0.394	0.356	0.327	0.224	0.000
1.82	0.481	0.429	0.395	0.357	0.328	0.224	0.000
1.83	0.482	0.429	0.395	0.358	0.329	0.225	0.000
1.84	0.482	0.430	0.396	0.359	0.329	0.226	0.000
1.85	0.483	0.430	0.397	0.360	0.330	0.226	0.001
1.86	0.483	0.431	0.397	0.361	0.331	0.227	0.004
1.87	0.484	0.432	0.398	0.362	0.332	0.227	0.007
1.88	0.484	0.432	0.399	0.363	0.333	0.228	0.010
1.89	0.485	0.433	0.399	0.363	0.333	0.229	0.013
1.90	0.485	0.433	0.400	0.364	0.334	0.229	0.016
1.91	0.486	0.434	0.400	0.365	0.335	0.230	0.019
1.92	0.486	0.435	0.401	0.366	0.336	0.231	0.022
1.93	0.487	0.435	0.402	0.367	0.337	0.231	0.025
1.94	0.487	0.436	0.402	0.368	0.337	0.232	0.028
1.95	0.488	0.437	0.403	0.369	0.338	0.233	0.032
1.96	0.488	0.437	0.404	0.370	0.339	0.233	0.035
1.97	0.489	0.438	0.404	0.371	0.340	0.234	0.038
1.98	0.489	0.438	0.405	0.371	0.341	0.235	0.041
1.99	0.490	0.439	0.405	0.372	0.341	0.235	0.044
2.00	0.490	0.440	0.406	0.373	0.342	0.236	0.047
2.01	0.491	0.440	0.407	0.374	0.343	0.236	0.049
2.02	0.491	0.440	0.407	0.374	0.344	0.237	0.051
2.03	0.491	0.441	0.408	0.375	0.345	0.238	0.053
2.04	0.492	0.441	0.408	0.375	0.345	0.238	0.055
2.05	0.492	0.442	0.409	0.376	0.346	0.239	0.057
2.06	0.492	0.442	0.409	0.376	0.346	0.239	0.059
2.07	0.493	0.443	0.410	0.377	0.347	0.240	0.062
2.08	0.493	0.443	0.410	0.377	0.347	0.240	0.064
2.09	0.494	0.444	0.410	0.378	0.348	0.241	0.066
2.10	0.494	0.444	0.411	0.378	0.348	0.241	0.068
2.11	0.494	0.444	0.411	0.379	0.348	0.242	0.070
2.12	0.495	0.445	0.412	0.379	0.349	0.242	0.072
2.13	0.495	0.445	0.412	0.380	0.349	0.243	0.074
2.14	0.495	0.446	0.413	0.380	0.350	0.243	0.076
2.15	0.496	0.446	0.413	0.381	0.350	0.243	0.079
2.16	0.496	0.447	0.414	0.382	0.350	0.244	0.081
2.17	0.496	0.447	0.414	0.382	0.351	0.244	0.083
2.18	0.497	0.447	0.415	0.383	0.351	0.245	0.085
2.19	0.497	0.448	0.415	0.383	0.351	0.245	0.087
2.20	0.497	0.448	0.416	0.384	0.352	0.246	0.089
2.21	0.498	0.449	0.416	0.384	0.352	0.246	0.091
2.22	0.498	0.449	0.417	0.385	0.353	0.247	0.093

Intensity	VCWPD Soil Type / C Coefficient						
(in/hr)	1	2	3	4	5	6	7
2.23	0.498	0.450	0.417	0.385	0.353	0.247	0.095
2.24	0.499	0.450	0.418	0.386	0.353	0.247	0.098
2.25	0.499	0.451	0.418	0.386	0.354	0.248	0.100
2.26	0.499	0.451	0.419	0.387	0.354	0.248	0.102
2.27	0.500	0.451	0.419	0.387	0.355	0.249	0.104
2.28	0.500	0.452	0.420	0.388	0.355	0.249	0.105
2.29	0.500	0.452	0.420	0.388	0.355	0.250	0.107
2.30	0.501	0.453	0.421	0.389	0.356	0.250	0.108
2.31	0.501	0.453	0.421	0.389	0.356	0.251	0.109
2.32	0.501	0.454	0.422	0.390	0.356	0.251	0.111
2.33	0.502	0.454	0.422	0.390	0.357	0.251	0.112
2.34	0.502	0.454	0.423	0.391	0.357	0.252	0.113
2.35	0.503	0.455	0.423	0.391	0.358	0.252	0.115
2.36	0.503	0.455	0.424	0.392	0.358	0.253	0.116
2.37	0.503	0.456	0.424	0.392	0.358	0.253	0.118
2.38	0.504	0.456	0.425	0.393	0.359	0.254	0.119
2.39	0.504	0.457	0.425	0.393	0.359	0.254	0.120
2.40	0.504	0.457	0.426	0.394	0.360	0.255	0.122
2.41	0.505	0.458	0.426	0.395	0.360	0.255	0.123
2.42	0.505	0.458	0.427	0.395	0.360	0.255	0.124
2.43	0.505	0.458	0.427	0.396	0.361	0.256	0.126
2.44	0.506	0.459	0.427	0.396	0.361	0.256	0.127
2.45	0.506	0.459	0.428	0.397	0.361	0.256	0.129
2.46	0.506	0.460	0.428	0.397	0.362	0.257	0.130
2.47	0.507	0.460	0.429	0.398	0.362	0.257	0.131
2.48	0.507	0.461	0.429	0.398	0.363	0.257	0.133
2.49	0.507	0.461	0.430	0.399	0.363	0.258	0.134
2.50	0.508	0.462	0.430	0.399	0.363	0.258	0.135
2.51	0.508	0.462	0.431	0.400	0.364	0.258	0.137
2.52	0.508	0.462	0.431	0.400	0.364	0.259	0.138
2.53	0.508	0.463	0.431	0.400	0.365	0.259	0.139
2.54	0.509	0.463	0.432	0.401	0.365	0.259	0.141
2.55	0.509	0.463	0.432	0.401	0.366	0.260	0.142
2.56	0.509	0.464	0.433	0.402	0.366	0.260	0.144
2.57	0.509	0.464	0.433	0.402	0.367	0.260	0.145
2.58	0.510	0.464	0.433	0.402	0.367	0.261	0.146
2.59	0.510	0.465	0.434	0.403	0.368	0.261	0.148
2.60	0.510	0.465	0.434	0.403	0.368	0.262	0.149
2.61	0.510	0.465	0.434	0.404	0.369	0.262	0.150
2.62	0.510	0.466	0.435	0.404	0.369	0.262	0.152
2.63	0.511	0.466	0.435	0.404	0.370	0.263	0.153
2.64	0.511	0.466	0.435	0.405	0.370	0.263	0.155
2.65	0.511	0.467	0.436	0.405	0.371	0.263	0.156
2.66	0.511	0.467	0.436	0.406	0.371	0.264	0.157
2.67	0.512	0.467	0.436	0.406	0.372	0.264	0.158

Intensity	VCWPD Soil Type / C Coefficient						
(in/hr)	1	2	3	4	5	6	7
2.68	0.512	0.468	0.437	0.406	0.372	0.264	0.159
2.69	0.512	0.468	0.437	0.407	0.373	0.265	0.159
2.70	0.512	0.468	0.438	0.407	0.373	0.265	0.160
2.71	0.513	0.469	0.438	0.408	0.374	0.265	0.161
2.72	0.513	0.469	0.438	0.408	0.374	0.266	0.162
2.73	0.513	0.469	0.439	0.408	0.375	0.266	0.163
2.74	0.513	0.470	0.439	0.409	0.375	0.266	0.164
2.75	0.513	0.470	0.439	0.409	0.376	0.267	0.165
2.76	0.514	0.470	0.440	0.410	0.376	0.267	0.166
2.77	0.514	0.471	0.440	0.410	0.377	0.267	0.167
2.78	0.514	0.471	0.440	0.411	0.377	0.268	0.167
2.79	0.514	0.471	0.441	0.411	0.377	0.268	0.168
2.80	0.515	0.472	0.441	0.411	0.378	0.268	0.169
2.81	0.515	0.472	0.441	0.412	0.378	0.269	0.170
2.82	0.515	0.472	0.442	0.412	0.379	0.269	0.171
2.83	0.515	0.473	0.442	0.413	0.379	0.270	0.172
2.84	0.516	0.473	0.443	0.413	0.380	0.270	0.173
2.85	0.516	0.473	0.443	0.413	0.380	0.270	0.174
2.86	0.516	0.474	0.443	0.414	0.381	0.271	0.175
2.87	0.516	0.474	0.444	0.414	0.381	0.271	0.175
2.88	0.516	0.474	0.444	0.415	0.382	0.271	0.176
2.89	0.517	0.475	0.444	0.415	0.382	0.272	0.177
2.90	0.517	0.475	0.445	0.415	0.383	0.272	0.178
2.91	0.517	0.475	0.445	0.416	0.383	0.272	0.179
2.92	0.517	0.476	0.445	0.416	0.384	0.273	0.180
2.93	0.518	0.476	0.446	0.417	0.384	0.273	0.181
2.94	0.518	0.476	0.446	0.417	0.385	0.273	0.182
2.95	0.518	0.477	0.446	0.417	0.385	0.274	0.183
2.96	0.518	0.477	0.447	0.418	0.386	0.274	0.183
2.97	0.519	0.477	0.447	0.418	0.386	0.274	0.184
2.98	0.519	0.478	0.447	0.419	0.387	0.275	0.185
2.99	0.519	0.478	0.448	0.419	0.387	0.275	0.186
3.00	0.519	0.478	0.448	0.419	0.388	0.275	0.187
3.01	0.519	0.478	0.448	0.420	0.388	0.276	0.188
3.02	0.519	0.479	0.449	0.420	0.388	0.276	0.188
3.03	0.520	0.479	0.449	0.420	0.388	0.276	0.189
3.04	0.520	0.479	0.449	0.421	0.389	0.276	0.189
3.05	0.520	0.479	0.450	0.421	0.389	0.277	0.190
3.06	0.520	0.480	0.450	0.421	0.389	0.277	0.191
3.07	0.520	0.480	0.450	0.421	0.389	0.277	0.191
3.08	0.520	0.480	0.450	0.422	0.390	0.277	0.192
3.09	0.520	0.480	0.451	0.422	0.390	0.278	0.193
3.10	0.521	0.481	0.451	0.422	0.390	0.278	0.193
3.11	0.521	0.481	0.451	0.423	0.391	0.278	0.194
3.12	0.521	0.481	0.451	0.423	0.391	0.279	0.194

Intensity	VCWPD Soil Type / C Coefficient						
(in/hr)	1	2	3	4	5	6	7
3.13	0.521	0.481	0.452	0.423	0.391	0.279	0.195
3.14	0.521	0.482	0.452	0.423	0.391	0.279	0.196
3.15	0.521	0.482	0.452	0.424	0.392	0.279	0.196
3.16	0.522	0.482	0.452	0.424	0.392	0.280	0.197
3.17	0.522	0.482	0.453	0.424	0.392	0.280	0.197
3.18	0.522	0.483	0.453	0.425	0.392	0.280	0.198
3.19	0.522	0.483	0.453	0.425	0.393	0.280	0.199
3.20	0.522	0.483	0.454	0.425	0.393	0.281	0.199
3.21	0.522	0.483	0.454	0.425	0.393	0.281	0.200
3.22	0.522	0.484	0.454	0.426	0.393	0.281	0.200
3.23	0.523	0.484	0.454	0.426	0.394	0.281	0.201
3.24	0.523	0.484	0.455	0.426	0.394	0.282	0.202
3.25	0.523	0.484	0.455	0.427	0.394	0.282	0.202
3.26	0.523	0.485	0.455	0.427	0.394	0.282	0.203
3.27	0.523	0.485	0.455	0.427	0.395	0.282	0.204
3.28	0.523	0.485	0.456	0.427	0.395	0.283	0.204
3.29	0.523	0.485	0.456	0.428	0.395	0.283	0.205
3.30	0.524	0.486	0.456	0.428	0.395	0.283	0.205
3.31	0.524	0.486	0.456	0.428	0.396	0.283	0.206
3.32	0.524	0.486	0.457	0.429	0.396	0.284	0.207
3.33	0.524	0.486	0.457	0.429	0.396	0.284	0.207
3.34	0.524	0.486	0.457	0.429	0.396	0.284	0.208
3.35	0.524	0.487	0.458	0.429	0.397	0.284	0.208
3.36	0.524	0.487	0.458	0.430	0.397	0.285	0.209
3.37	0.525	0.487	0.458	0.430	0.397	0.285	0.209
3.38	0.525	0.487	0.458	0.430	0.397	0.285	0.210
3.39	0.525	0.488	0.459	0.431	0.398	0.285	0.210
3.40	0.525	0.488	0.459	0.431	0.398	0.286	0.211
3.41	0.525	0.488	0.459	0.431	0.398	0.286	0.211
3.42	0.525	0.488	0.459	0.431	0.398	0.286	0.212
3.43	0.525	0.489	0.460	0.432	0.399	0.287	0.212
3.44	0.526	0.489	0.460	0.432	0.399	0.287	0.212
3.45	0.526	0.489	0.460	0.432	0.399	0.287	0.213
3.46	0.526	0.489	0.460	0.433	0.399	0.287	0.213
3.47	0.526	0.490	0.461	0.433	0.400	0.288	0.214
3.48	0.526	0.490	0.461	0.433	0.400	0.288	0.214
3.49	0.526	0.490	0.461	0.434	0.400	0.288	0.215
3.50	0.526	0.490	0.461	0.434	0.400	0.288	0.215
3.51	0.527	0.491	0.462	0.434	0.401	0.289	0.216
3.52	0.527	0.491	0.462	0.434	0.401	0.289	0.216
3.53	0.527	0.491	0.462	0.434	0.401	0.289	0.217
3.54	0.527	0.491	0.462	0.435	0.401	0.289	0.217
3.55	0.527	0.491	0.462	0.435	0.402	0.290	0.218
3.56	0.527	0.492	0.463	0.435	0.402	0.290	0.218
3.57	0.527	0.492	0.463	0.435	0.402	0.290	0.218

Intensity	VCWPD Soil Type / C Coefficient						
(in/hr)	1	2	3	4	5	6	7
3.58	0.528	0.492	0.463	0.435	0.403	0.290	0.219
3.59	0.528	0.492	0.463	0.436	0.403	0.291	0.219
3.60	0.528	0.492	0.463	0.436	0.403	0.291	0.220
3.61	0.528	0.493	0.464	0.436	0.403	0.291	0.220
3.62	0.528	0.493	0.464	0.436	0.404	0.291	0.221
3.63	0.528	0.493	0.464	0.437	0.404	0.292	0.221
3.64	0.528	0.493	0.464	0.437	0.404	0.292	0.222
3.65	0.529	0.493	0.464	0.437	0.404	0.292	0.222
3.66	0.529	0.494	0.464	0.437	0.404	0.292	0.223
3.67	0.529	0.494	0.465	0.437	0.404	0.293	0.223
3.68	0.529	0.494	0.465	0.438	0.405	0.293	0.224
3.69	0.529	0.494	0.465	0.438	0.405	0.293	0.224
3.70	0.529	0.495	0.465	0.438	0.405	0.294	0.225
3.71	0.529	0.495	0.465	0.438	0.405	0.294	0.225
3.72	0.530	0.495	0.466	0.438	0.405	0.294	0.225
3.73	0.530	0.495	0.466	0.439	0.406	0.294	0.226
3.74	0.530	0.495	0.466	0.439	0.406	0.295	0.226
3.75	0.530	0.496	0.466	0.439	0.406	0.295	0.227
3.76	0.530	0.496	0.466	0.439	0.406	0.295	0.227
3.77	0.530	0.496	0.466	0.439	0.406	0.295	0.228
3.78	0.530	0.496	0.467	0.440	0.406	0.296	0.228
3.79	0.531	0.496	0.467	0.440	0.407	0.296	0.229
3.80	0.531	0.497	0.467	0.440	0.407	0.296	0.229
3.81	0.531	0.497	0.467	0.440	0.407	0.296	0.230
3.82	0.531	0.497	0.467	0.440	0.407	0.296	0.230
3.83	0.531	0.497	0.468	0.441	0.407	0.297	0.231
3.84	0.531	0.497	0.468	0.441	0.407	0.297	0.231
3.85	0.531	0.498	0.468	0.441	0.408	0.297	0.231
3.86	0.532	0.498	0.468	0.441	0.408	0.297	0.232
3.87	0.532	0.498	0.468	0.441	0.408	0.297	0.232
3.88	0.532	0.498	0.468	0.442	0.408	0.297	0.233
3.89	0.532	0.498	0.469	0.442	0.408	0.298	0.233
3.90	0.532	0.499	0.469	0.442	0.408	0.298	0.234
3.91	0.532	0.499	0.469	0.442	0.409	0.298	0.234
3.92	0.532	0.499	0.469	0.443	0.409	0.298	0.234
3.93	0.533	0.499	0.469	0.443	0.409	0.298	0.235
3.94	0.533	0.499	0.470	0.443	0.409	0.299	0.235
3.95	0.533	0.500	0.470	0.443	0.409	0.299	0.236
3.96	0.533	0.500	0.470	0.443	0.410	0.299	0.236
3.97	0.533	0.500	0.470	0.444	0.410	0.299	0.236
3.98	0.533	0.500	0.470	0.444	0.410	0.299	0.237
3.99	0.533	0.500	0.471	0.444	0.410	0.299	0.237
4.00	0.534	0.501	0.471	0.444	0.410	0.300	0.237
4.01	0.534	0.501	0.471	0.444	0.410	0.300	0.238
4.02	0.534	0.501	0.471	0.445	0.411	0.300	0.238

Intensity	VCWPD Soil Type / C Coefficient						
(in/hr)	1	2	3	4	5	6	7
4.03	0.534	0.501	0.471	0.445	0.411	0.300	0.238
4.04	0.534	0.501	0.471	0.445	0.411	0.300	0.239
4.05	0.534	0.501	0.471	0.445	0.411	0.300	0.239
4.06	0.534	0.501	0.472	0.445	0.411	0.301	0.239
4.07	0.534	0.502	0.472	0.445	0.411	0.301	0.240
4.08	0.534	0.502	0.472	0.446	0.412	0.301	0.240
4.09	0.534	0.502	0.472	0.446	0.412	0.301	0.240
4.10	0.534	0.502	0.472	0.446	0.412	0.301	0.241
4.11	0.535	0.502	0.472	0.446	0.412	0.301	0.241
4.12	0.535	0.502	0.472	0.446	0.412	0.302	0.241
4.13	0.535	0.502	0.473	0.446	0.412	0.302	0.242
4.14	0.535	0.502	0.473	0.447	0.413	0.302	0.242
4.15	0.535	0.503	0.473	0.447	0.413	0.302	0.242
4.16	0.535	0.503	0.473	0.447	0.413	0.302	0.243
4.17	0.535	0.503	0.473	0.447	0.413	0.303	0.243
4.18	0.535	0.503	0.473	0.447	0.413	0.303	0.244
4.19	0.535	0.503	0.473	0.448	0.413	0.303	0.244
4.20	0.535	0.503	0.473	0.448	0.414	0.303	0.244
4.21	0.535	0.503	0.474	0.448	0.414	0.303	0.245
4.22	0.536	0.503	0.474	0.448	0.414	0.303	0.245
4.23	0.536	0.504	0.474	0.448	0.414	0.304	0.245
4.24	0.536	0.504	0.474	0.448	0.414	0.304	0.246
4.25	0.536	0.504	0.474	0.449	0.415	0.304	0.246
4.26	0.536	0.504	0.474	0.449	0.415	0.304	0.246
4.27	0.536	0.504	0.474	0.449	0.415	0.304	0.247
4.28	0.536	0.504	0.475	0.449	0.415	0.304	0.247
4.29	0.536	0.504	0.475	0.449	0.415	0.305	0.247
4.30	0.536	0.505	0.475	0.449	0.415	0.305	0.248
4.31	0.536	0.505	0.475	0.450	0.415	0.305	0.248
4.32	0.536	0.505	0.475	0.450	0.416	0.305	0.248
4.33	0.536	0.505	0.475	0.450	0.416	0.305	0.249
4.34	0.537	0.505	0.475	0.450	0.416	0.305	0.249
4.35	0.537	0.505	0.476	0.450	0.416	0.306	0.249
4.36	0.537	0.505	0.476	0.450	0.416	0.306	0.250
4.37	0.537	0.505	0.476	0.451	0.416	0.306	0.250
4.38	0.537	0.506	0.476	0.451	0.416	0.306	0.250
4.39	0.537	0.506	0.476	0.451	0.416	0.306	0.251
4.40	0.537	0.506	0.476	0.451	0.416	0.306	0.251
4.41	0.537	0.506	0.476	0.451	0.416	0.307	0.251
4.42	0.537	0.506	0.477	0.452	0.417	0.307	0.252
4.43	0.537	0.506	0.477	0.452	0.417	0.307	0.252
4.44	0.537	0.506	0.477	0.452	0.417	0.307	0.253
4.45	0.538	0.506	0.477	0.452	0.417	0.307	0.253
4.46	0.538	0.507	0.477	0.452	0.417	0.308	0.253
4.47	0.538	0.507	0.477	0.452	0.417	0.308	0.254

Intensity	VCWPD Soil Type / C Coefficient						
(in/hr)	1	2	3	4	5	6	7
4.48	0.538	0.507	0.477	0.453	0.417	0.308	0.254
4.49	0.538	0.507	0.478	0.453	0.417	0.308	0.254
4.50	0.538	0.507	0.478	0.453	0.417	0.308	0.255
4.51	0.538	0.507	0.478	0.453	0.417	0.308	0.255
4.52	0.538	0.507	0.478	0.453	0.418	0.309	0.255
4.53	0.538	0.507	0.478	0.453	0.418	0.309	0.255
4.54	0.538	0.508	0.478	0.453	0.418	0.309	0.256
4.55	0.538	0.508	0.478	0.453	0.418	0.309	0.256
4.56	0.538	0.508	0.478	0.454	0.418	0.309	0.256
4.57	0.539	0.508	0.479	0.454	0.418	0.309	0.256
4.58	0.539	0.508	0.479	0.454	0.418	0.310	0.257
4.59	0.539	0.508	0.479	0.454	0.418	0.310	0.257
4.60	0.539	0.508	0.479	0.454	0.418	0.310	0.257
4.61	0.539	0.508	0.479	0.454	0.418	0.310	0.257
4.62	0.539	0.509	0.479	0.454	0.419	0.310	0.258
4.63	0.539	0.509	0.479	0.454	0.419	0.310	0.258
4.64	0.539	0.509	0.480	0.454	0.419	0.311	0.258
4.65	0.539	0.509	0.480	0.455	0.419	0.311	0.258
4.66	0.539	0.509	0.480	0.455	0.419	0.311	0.259
4.67	0.539	0.509	0.480	0.455	0.419	0.311	0.259
4.68	0.540	0.509	0.480	0.455	0.419	0.311	0.259
4.69	0.540	0.509	0.480	0.455	0.419	0.312	0.260
4.70	0.540	0.510	0.480	0.455	0.419	0.312	0.260
4.71	0.540	0.510	0.481	0.455	0.419	0.312	0.260
4.72	0.540	0.510	0.481	0.455	0.420	0.312	0.260
4.73	0.540	0.510	0.481	0.456	0.420	0.312	0.261
4.74	0.540	0.510	0.481	0.456	0.420	0.312	0.261
4.75	0.540	0.510	0.481	0.456	0.420	0.312	0.261
4.76	0.540	0.510	0.481	0.456	0.420	0.312	0.261
4.77	0.540	0.510	0.481	0.456	0.420	0.313	0.262
4.78	0.540	0.511	0.482	0.456	0.420	0.313	0.262
4.79	0.540	0.511	0.482	0.456	0.420	0.313	0.262
4.80	0.541	0.511	0.482	0.456	0.420	0.313	0.262
4.81	0.541	0.511	0.482	0.456	0.420	0.313	0.263
4.82	0.541	0.511	0.482	0.457	0.421	0.313	0.263
4.83	0.541	0.511	0.482	0.457	0.421	0.313	0.263
4.84	0.541	0.511	0.482	0.457	0.421	0.313	0.263
4.85	0.541	0.511	0.483	0.457	0.421	0.313	0.264
4.86	0.541	0.512	0.483	0.457	0.421	0.314	0.264
4.87	0.541	0.512	0.483	0.457	0.421	0.314	0.264
4.88	0.541	0.512	0.483	0.457	0.421	0.314	0.264
4.89	0.541	0.512	0.483	0.457	0.421	0.314	0.265
4.90	0.541	0.512	0.483	0.457	0.421	0.314	0.265
4.91	0.542	0.512	0.483	0.458	0.421	0.314	0.265
4.92	0.542	0.512	0.483	0.458	0.422	0.314	0.266

Intensity	VCWPD Soil Type / C Coefficient						
(in/hr)	1	2	3	4	5	6	7
4.93	0.542	0.513	0.484	0.458	0.422	0.314	0.266
4.94	0.542	0.513	0.484	0.458	0.422	0.314	0.266
4.95	0.542	0.513	0.484	0.458	0.422	0.315	0.266
4.96	0.542	0.513	0.484	0.458	0.422	0.315	0.267
4.97	0.542	0.513	0.484	0.458	0.422	0.315	0.267
4.98	0.542	0.513	0.484	0.458	0.422	0.315	0.267
4.99	0.542	0.513	0.484	0.458	0.422	0.315	0.267
5.00	0.542	0.513	0.485	0.459	0.422	0.315	0.268
5.01	0.542	0.513	0.485	0.459	0.422	0.315	0.268
5.02	0.542	0.514	0.485	0.459	0.422	0.315	0.268
5.03	0.542	0.514	0.485	0.459	0.423	0.316	0.268
5.04	0.542	0.514	0.485	0.459	0.423	0.316	0.268
5.05	0.542	0.514	0.485	0.459	0.423	0.316	0.269
5.06	0.543	0.514	0.485	0.459	0.423	0.316	0.269
5.07	0.543	0.514	0.485	0.459	0.423	0.316	0.269
5.08	0.543	0.514	0.485	0.459	0.423	0.316	0.269
5.09	0.543	0.514	0.485	0.459	0.423	0.316	0.270
5.10	0.543	0.514	0.485	0.459	0.423	0.316	0.270
5.11	0.543	0.514	0.485	0.460	0.423	0.316	0.270
5.12	0.543	0.514	0.485	0.460	0.423	0.317	0.270
5.13	0.543	0.514	0.485	0.460	0.423	0.317	0.270
5.14	0.543	0.514	0.485	0.460	0.423	0.317	0.271
5.15	0.543	0.515	0.485	0.460	0.423	0.317	0.271
5.16	0.543	0.515	0.485	0.460	0.423	0.317	0.271
5.17	0.543	0.515	0.485	0.460	0.423	0.317	0.271
5.18	0.543	0.515	0.485	0.460	0.424	0.317	0.271
5.19	0.543	0.515	0.485	0.460	0.424	0.317	0.272
5.20	0.543	0.515	0.486	0.460	0.424	0.317	0.272
5.21	0.543	0.515	0.486	0.460	0.424	0.318	0.272
5.22	0.543	0.515	0.486	0.460	0.424	0.318	0.272
5.23	0.543	0.515	0.486	0.460	0.424	0.318	0.273
5.24	0.543	0.515	0.486	0.461	0.424	0.318	0.273
5.25	0.543	0.515	0.486	0.461	0.424	0.318	0.273
5.26	0.543	0.515	0.486	0.461	0.424	0.318	0.273
5.27	0.543	0.515	0.486	0.461	0.424	0.318	0.273
5.28	0.543	0.516	0.486	0.461	0.424	0.318	0.274
5.29	0.543	0.516	0.486	0.461	0.424	0.319	0.274
5.30	0.543	0.516	0.486	0.461	0.424	0.319	0.274
5.31	0.543	0.516	0.486	0.461	0.424	0.319	0.274
5.32	0.544	0.516	0.486	0.461	0.425	0.319	0.275
5.33	0.544	0.516	0.486	0.461	0.425	0.319	0.275
5.34	0.544	0.516	0.486	0.461	0.425	0.319	0.275
5.35	0.544	0.516	0.486	0.461	0.425	0.319	0.275
5.36	0.544	0.516	0.486	0.462	0.425	0.319	0.275
5.37	0.544	0.516	0.486	0.462	0.425	0.319	0.276

Intensity	VCWPD Soil Type / C Coefficient						
(in/hr)	1	2	3	4	5	6	7
5.38	0.544	0.516	0.486	0.462	0.425	0.320	0.276
5.39	0.544	0.516	0.486	0.462	0.425	0.320	0.276
5.40	0.544	0.516	0.486	0.462	0.425	0.320	0.276
5.41	0.544	0.516	0.486	0.462	0.425	0.320	0.276
5.42	0.544	0.517	0.487	0.462	0.425	0.320	0.277
5.43	0.544	0.517	0.487	0.462	0.425	0.320	0.277
5.44	0.544	0.517	0.487	0.462	0.425	0.320	0.277
5.45	0.544	0.517	0.487	0.462	0.425	0.320	0.277
5.46	0.544	0.517	0.487	0.462	0.425	0.320	0.278
5.47	0.544	0.517	0.487	0.462	0.426	0.321	0.278
5.48	0.544	0.517	0.487	0.463	0.426	0.321	0.278
5.49	0.544	0.517	0.487	0.463	0.426	0.321	0.278
5.50	0.544	0.517	0.487	0.463	0.426	0.321	0.278
5.51	0.544	0.517	0.487	0.463	0.426	0.321	0.279
5.52	0.544	0.517	0.487	0.463	0.426	0.321	0.279
5.53	0.544	0.517	0.487	0.463	0.426	0.321	0.279
5.54	0.544	0.517	0.487	0.463	0.426	0.321	0.279
5.55	0.544	0.518	0.487	0.463	0.426	0.322	0.280
5.56	0.544	0.518	0.487	0.463	0.426	0.322	0.280
5.57	0.544	0.518	0.487	0.463	0.426	0.322	0.280
5.58	0.545	0.518	0.487	0.463	0.426	0.322	0.280
5.59	0.545	0.518	0.487	0.463	0.426	0.322	0.280
5.60	0.545	0.518	0.487	0.463	0.426	0.322	0.281
5.61	0.545	0.518	0.487	0.463	0.427	0.322	0.281
5.62	0.545	0.518	0.487	0.463	0.427	0.322	0.281
5.63	0.545	0.518	0.487	0.463	0.427	0.322	0.281
5.64	0.545	0.518	0.488	0.463	0.427	0.322	0.282
5.65	0.545	0.518	0.488	0.463	0.427	0.323	0.282
5.66	0.545	0.518	0.488	0.463	0.427	0.323	0.282
5.67	0.545	0.518	0.488	0.463	0.427	0.323	0.282
5.68	0.545	0.518	0.488	0.463	0.427	0.323	0.283
5.69	0.545	0.519	0.488	0.463	0.427	0.323	0.283
5.70	0.545	0.519	0.488	0.463	0.427	0.323	0.283
5.71	0.545	0.519	0.488	0.463	0.427	0.323	0.283
5.72	0.545	0.519	0.488	0.463	0.427	0.323	0.284
5.73	0.545	0.519	0.488	0.463	0.427	0.323	0.284
5.74	0.545	0.519	0.488	0.463	0.427	0.323	0.284
5.75	0.545	0.519	0.488	0.463	0.427	0.323	0.284
5.76	0.545	0.519	0.488	0.463	0.428	0.323	0.285
5.77	0.545	0.519	0.488	0.463	0.428	0.324	0.285
5.78	0.545	0.519	0.488	0.463	0.428	0.324	0.285
5.79	0.545	0.519	0.488	0.463	0.428	0.324	0.285
5.80	0.545	0.519	0.488	0.464	0.428	0.324	0.286
5.81	0.545	0.519	0.488	0.464	0.428	0.324	0.286
5.82	0.545	0.520	0.488	0.464	0.428	0.324	0.286

Intensity	VCWPD Soil Type / C Coefficient						
(in/hr)	1	2	3	4	5	6	7
5.83	0.545	0.520	0.488	0.464	0.428	0.324	0.287
5.84	0.546	0.520	0.488	0.464	0.428	0.324	0.287
5.85	0.546	0.520	0.489	0.464	0.428	0.324	0.287
5.86	0.546	0.520	0.489	0.464	0.428	0.324	0.287
5.87	0.546	0.520	0.489	0.464	0.428	0.324	0.288
5.88	0.546	0.520	0.489	0.464	0.428	0.324	0.288
5.89	0.546	0.520	0.489	0.464	0.428	0.325	0.288
5.90	0.546	0.520	0.489	0.464	0.429	0.325	0.288
5.91	0.546	0.520	0.489	0.464	0.429	0.325	0.289
5.92	0.546	0.520	0.489	0.464	0.429	0.325	0.289
5.93	0.546	0.520	0.489	0.464	0.429	0.325	0.289
5.94	0.546	0.520	0.489	0.464	0.429	0.325	0.289
5.95	0.546	0.521	0.489	0.464	0.429	0.325	0.290
5.96	0.546	0.521	0.489	0.464	0.429	0.325	0.290
5.97	0.546	0.521	0.489	0.464	0.429	0.325	0.290
5.98	0.546	0.521	0.489	0.464	0.429	0.325	0.290
5.99	0.546	0.521	0.489	0.464	0.429	0.325	0.291
6.00	0.546	0.521	0.489	0.464	0.429	0.326	0.291
6.01	0.546	0.521	0.489	0.464	0.429	0.326	0.291
6.02	0.546	0.521	0.489	0.464	0.429	0.326	0.291
6.03	0.546	0.521	0.489	0.464	0.429	0.326	0.291
6.04	0.546	0.521	0.489	0.464	0.429	0.326	0.292
6.05	0.546	0.521	0.489	0.464	0.429	0.326	0.292
6.06	0.546	0.521	0.489	0.464	0.429	0.326	0.292
6.07	0.546	0.521	0.490	0.464	0.429	0.326	0.292
6.08	0.546	0.521	0.490	0.464	0.429	0.326	0.292
6.09	0.546	0.521	0.490	0.464	0.430	0.326	0.292
6.10	0.547	0.521	0.490	0.464	0.430	0.326	0.293
6.11	0.547	0.521	0.490	0.464	0.430	0.326	0.293
6.12	0.547	0.521	0.490	0.464	0.430	0.327	0.293
6.13	0.547	0.521	0.490	0.464	0.430	0.327	0.293
6.14	0.547	0.521	0.490	0.464	0.430	0.327	0.293
6.15	0.547	0.522	0.490	0.464	0.430	0.327	0.293
6.16	0.547	0.522	0.490	0.465	0.430	0.327	0.294
6.17	0.547	0.522	0.490	0.465	0.430	0.327	0.294
6.18	0.547	0.522	0.490	0.465	0.430	0.327	0.294
6.19	0.547	0.522	0.490	0.465	0.430	0.327	0.294
6.20	0.547	0.522	0.490	0.465	0.430	0.327	0.294
6.21	0.547	0.522	0.490	0.465	0.430	0.327	0.295
6.22	0.547	0.522	0.490	0.465	0.430	0.327	0.295
6.23	0.547	0.522	0.490	0.465	0.430	0.327	0.295
6.24	0.547	0.522	0.490	0.465	0.430	0.328	0.295
6.25	0.547	0.522	0.490	0.465	0.430	0.328	0.295
6.26	0.547	0.522	0.490	0.465	0.430	0.328	0.295
6.27	0.547	0.522	0.490	0.465	0.430	0.328	0.296

Intensity	VCWPD Soil Type / C Coefficient						
(in/hr)	1	2	3	4	5	6	7
6.28	0.547	0.522	0.490	0.465	0.430	0.328	0.296
6.29	0.547	0.522	0.491	0.465	0.430	0.328	0.296
6.30	0.547	0.522	0.491	0.465	0.430	0.328	0.296
6.31	0.547	0.522	0.491	0.465	0.430	0.328	0.296
6.32	0.547	0.522	0.491	0.465	0.430	0.328	0.296
6.33	0.547	0.522	0.491	0.465	0.430	0.328	0.297
6.34	0.547	0.522	0.491	0.465	0.430	0.328	0.297
6.35	0.547	0.522	0.491	0.465	0.430	0.329	0.297
6.36	0.548	0.522	0.491	0.465	0.430	0.329	0.297
6.37	0.548	0.522	0.491	0.465	0.430	0.329	0.297
6.38	0.548	0.522	0.491	0.465	0.431	0.329	0.297
6.39	0.548	0.522	0.491	0.465	0.431	0.329	0.298
6.40	0.548	0.523	0.491	0.465	0.431	0.329	0.298
6.41	0.548	0.523	0.491	0.465	0.431	0.329	0.298
6.42	0.548	0.523	0.491	0.465	0.431	0.329	0.298
6.43	0.548	0.523	0.491	0.465	0.431	0.329	0.298
6.44	0.548	0.523	0.491	0.465	0.431	0.329	0.299
6.45	0.548	0.523	0.491	0.465	0.431	0.329	0.299
6.46	0.548	0.523	0.491	0.465	0.431	0.329	0.299
6.47	0.548	0.523	0.491	0.465	0.431	0.330	0.299
6.48	0.548	0.523	0.491	0.465	0.431	0.330	0.299
6.49	0.548	0.523	0.491	0.465	0.431	0.330	0.299
6.50	0.548	0.523	0.492	0.465	0.431	0.330	0.300
6.51	0.548	0.523	0.492	0.465	0.431	0.330	0.300
6.52	0.548	0.523	0.492	0.465	0.431	0.330	0.300
6.53	0.548	0.523	0.492	0.466	0.431	0.330	0.300
6.54	0.548	0.523	0.492	0.466	0.431	0.330	0.300
6.55	0.548	0.523	0.492	0.466	0.431	0.330	0.300
6.56	0.548	0.523	0.492	0.466	0.431	0.330	0.301
6.57	0.548	0.523	0.492	0.466	0.431	0.330	0.301
6.58	0.548	0.523	0.492	0.466	0.431	0.330	0.301
6.59	0.548	0.523	0.492	0.466	0.431	0.331	0.301
6.60	0.548	0.523	0.492	0.466	0.431	0.331	0.301
6.61	0.548	0.523	0.492	0.466	0.431	0.331	0.301
6.62	0.549	0.523	0.492	0.466	0.431	0.331	0.302
6.63	0.549	0.523	0.492	0.466	0.431	0.331	0.302
6.64	0.549	0.524	0.492	0.466	0.431	0.331	0.302
6.65	0.549	0.524	0.492	0.466	0.431	0.331	0.302
6.66	0.549	0.524	0.492	0.466	0.432	0.331	0.302
6.67	0.549	0.524	0.492	0.466	0.432	0.331	0.302
6.68	0.549	0.524	0.492	0.466	0.432	0.331	0.303
6.69	0.549	0.524	0.492	0.466	0.432	0.331	0.303
6.70	0.549	0.524	0.492	0.466	0.432	0.332	0.303
6.71	0.549	0.524	0.492	0.466	0.432	0.332	0.303
6.72	0.549	0.524	0.493	0.466	0.432	0.332	0.303

Intensity	VCWPD Soil Type / C Coefficient						
(in/hr)	1	2	3	4	5	6	7
6.73	0.549	0.524	0.493	0.466	0.432	0.332	0.304
6.74	0.549	0.524	0.493	0.466	0.432	0.332	0.304
6.75	0.549	0.524	0.493	0.466	0.432	0.332	0.304
6.76	0.549	0.524	0.493	0.466	0.432	0.332	0.304
6.77	0.549	0.524	0.493	0.466	0.432	0.332	0.304
6.78	0.549	0.524	0.493	0.466	0.432	0.332	0.304
6.79	0.549	0.524	0.493	0.466	0.432	0.332	0.305
6.80	0.549	0.524	0.493	0.466	0.432	0.332	0.305
6.81	0.549	0.524	0.493	0.466	0.432	0.332	0.305
6.82	0.549	0.524	0.493	0.466	0.432	0.333	0.305
6.83	0.549	0.524	0.493	0.466	0.432	0.333	0.305
6.84	0.549	0.524	0.493	0.466	0.432	0.333	0.305
6.85	0.549	0.524	0.493	0.466	0.432	0.333	0.306
6.86	0.549	0.524	0.493	0.466	0.432	0.333	0.306
6.87	0.549	0.524	0.493	0.466	0.432	0.333	0.306
6.88	0.550	0.525	0.493	0.466	0.432	0.333	0.306
6.89	0.550	0.525	0.493	0.466	0.432	0.333	0.306
6.90	0.550	0.525	0.493	0.467	0.432	0.333	0.306
6.91	0.550	0.525	0.493	0.467	0.432	0.333	0.307
6.92	0.550	0.525	0.493	0.467	0.432	0.333	0.307
6.93	0.550	0.525	0.493	0.467	0.432	0.333	0.307
6.94	0.550	0.525	0.494	0.467	0.432	0.334	0.307
6.95	0.550	0.525	0.494	0.467	0.433	0.334	0.307
6.96	0.550	0.525	0.494	0.467	0.433	0.334	0.307
6.97	0.550	0.525	0.494	0.467	0.433	0.334	0.308
6.98	0.550	0.525	0.494	0.467	0.433	0.334	0.308
6.99	0.550	0.525	0.494	0.467	0.433	0.334	0.308
7.00	0.550	0.525	0.494	0.467	0.433	0.334	0.308

EXHIBIT 7. SLOPE CORRECTION CURVE FOR MOUNTAIN CHANNEL SCOUR VELOCITY CHECK

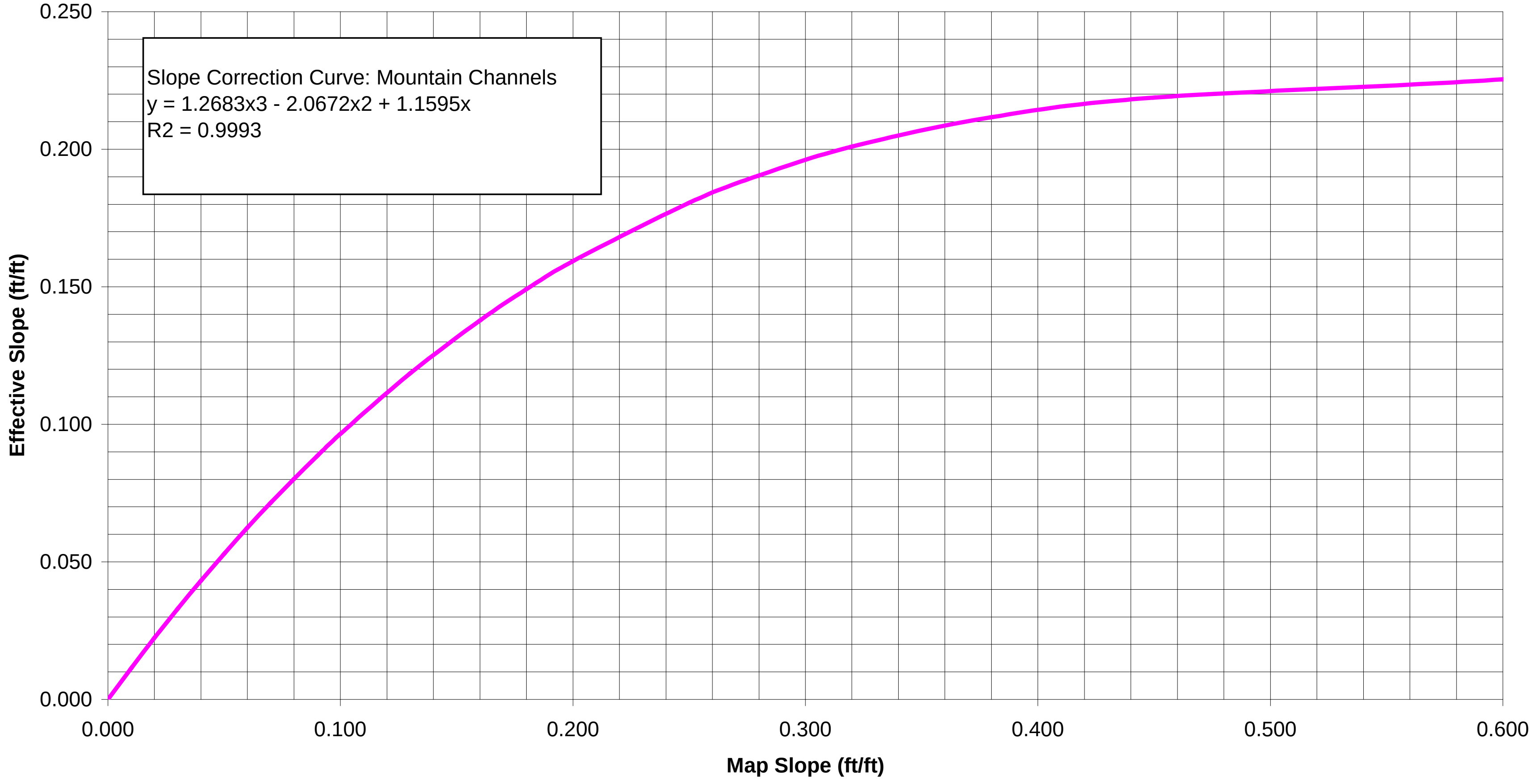
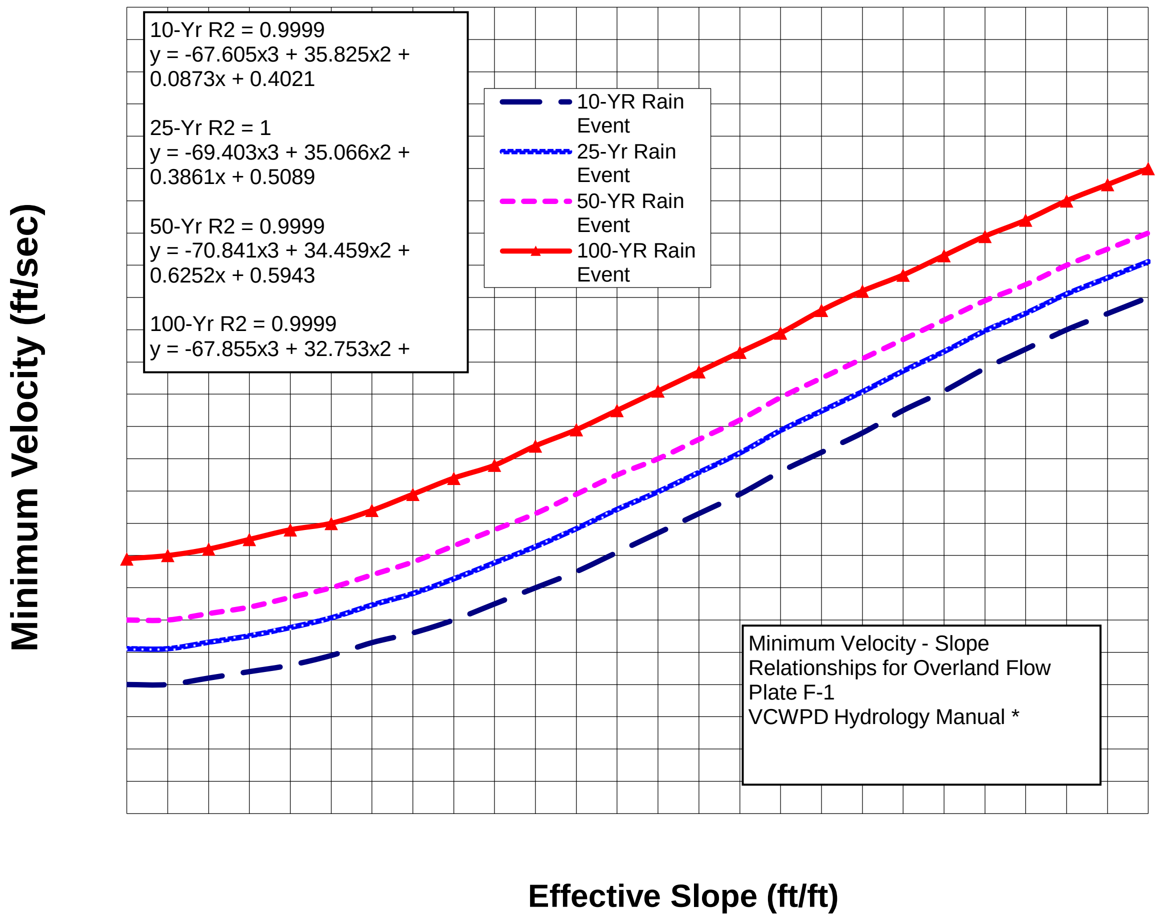


EXHIBIT 8. MINIMUM VELOCITY-SLOPE RELATIONSHIPS, OVERLAND FLOW



Note: Commercial and Industrial Areas: For 100- and 50-Yr storms, minimum velocity is 1.0 fps; for 25- and 10-Yr storms, minimum velocity is 0.5 fps except in areas with very low slopes. .

EXHIBIT 9. VELOCITY- DISCHARGE- SLOPE RELATIONSHIPS, NATURAL MOUNTAIN CHANNELS

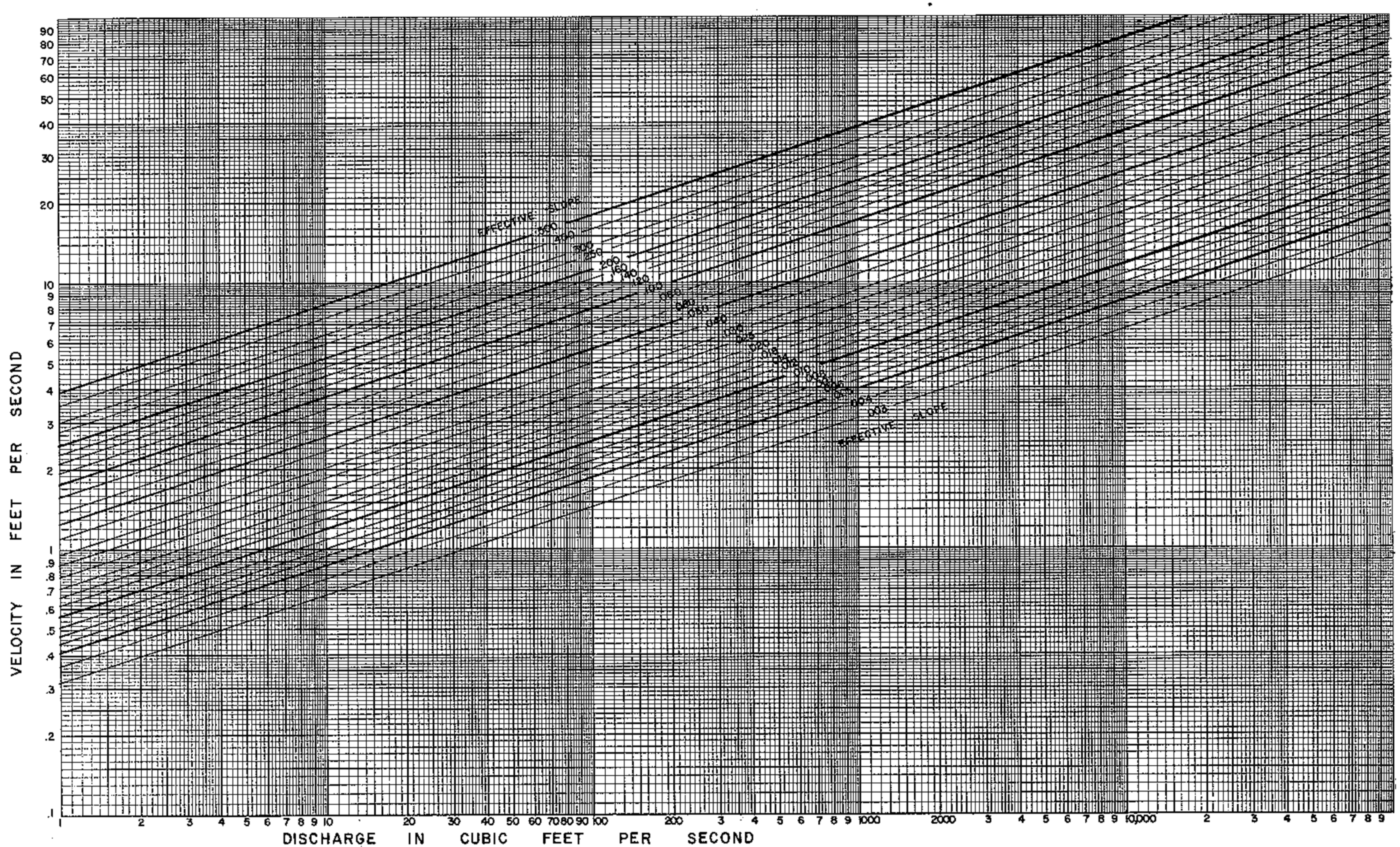


EXHIBIT 10. VELOCITY- DISCHARGE- SLOPE RELATIONSHIPS, NATURAL VALLEY CHANNELS

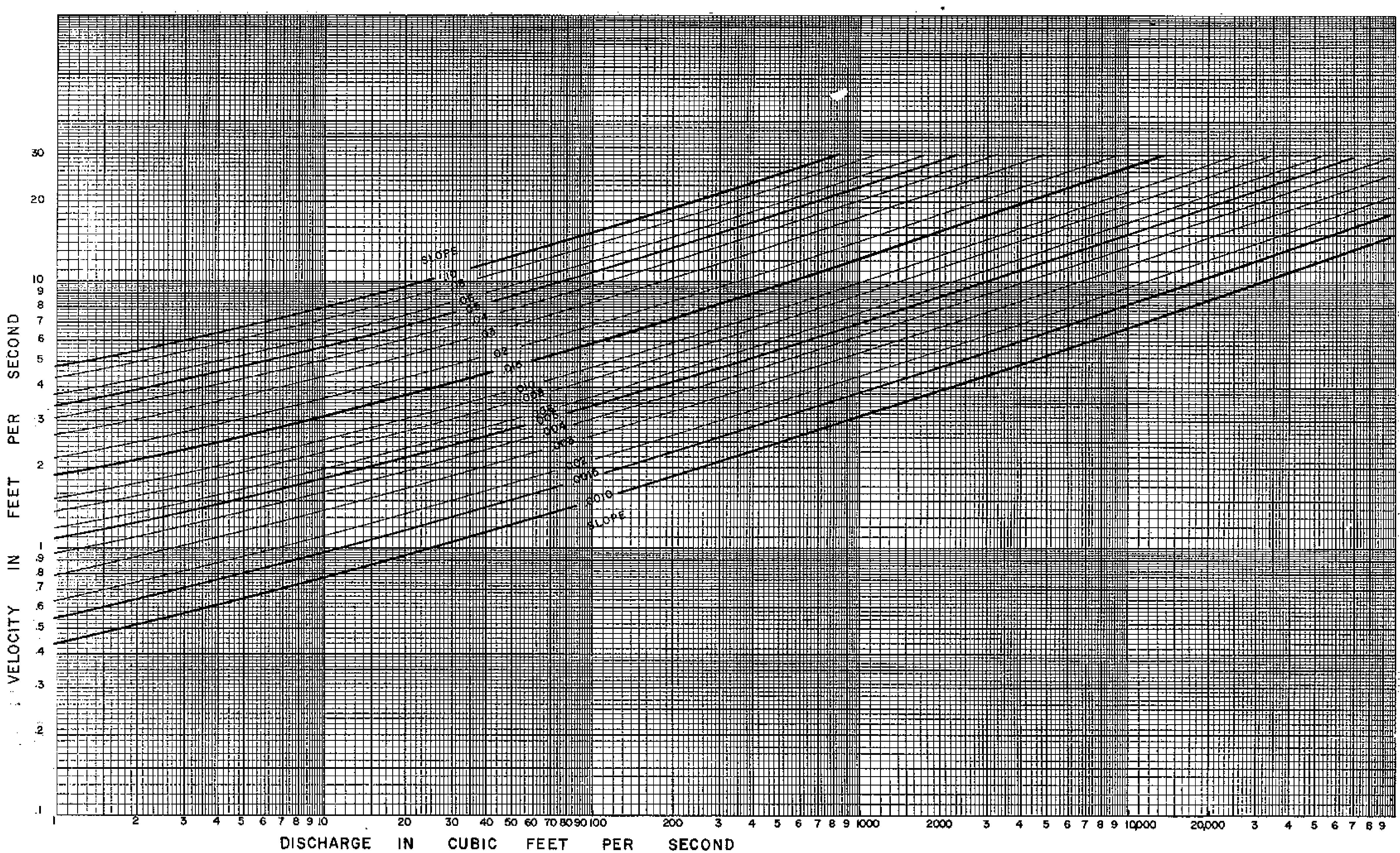


EXHIBIT 11A. VELOCITY- DISCHARGE- SLOPE RELATIONSHIPS, 32' ROAD WIDTH – 6" CURB

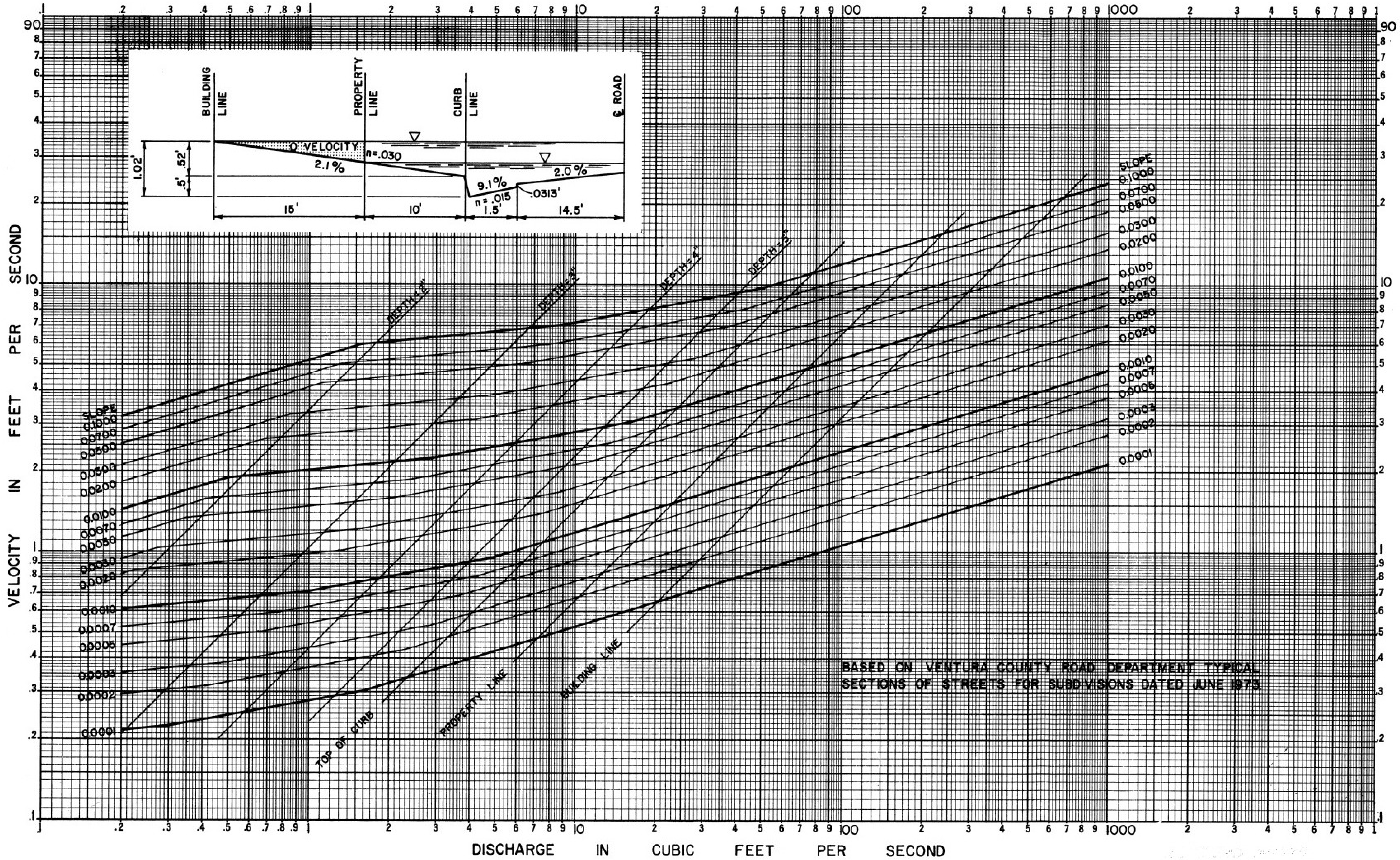


EXHIBIT 11B. VELOCITY- DISCHARGE- SLOPE RELATIONSHIPS, 32' ROAD WIDTH – 8" CURB

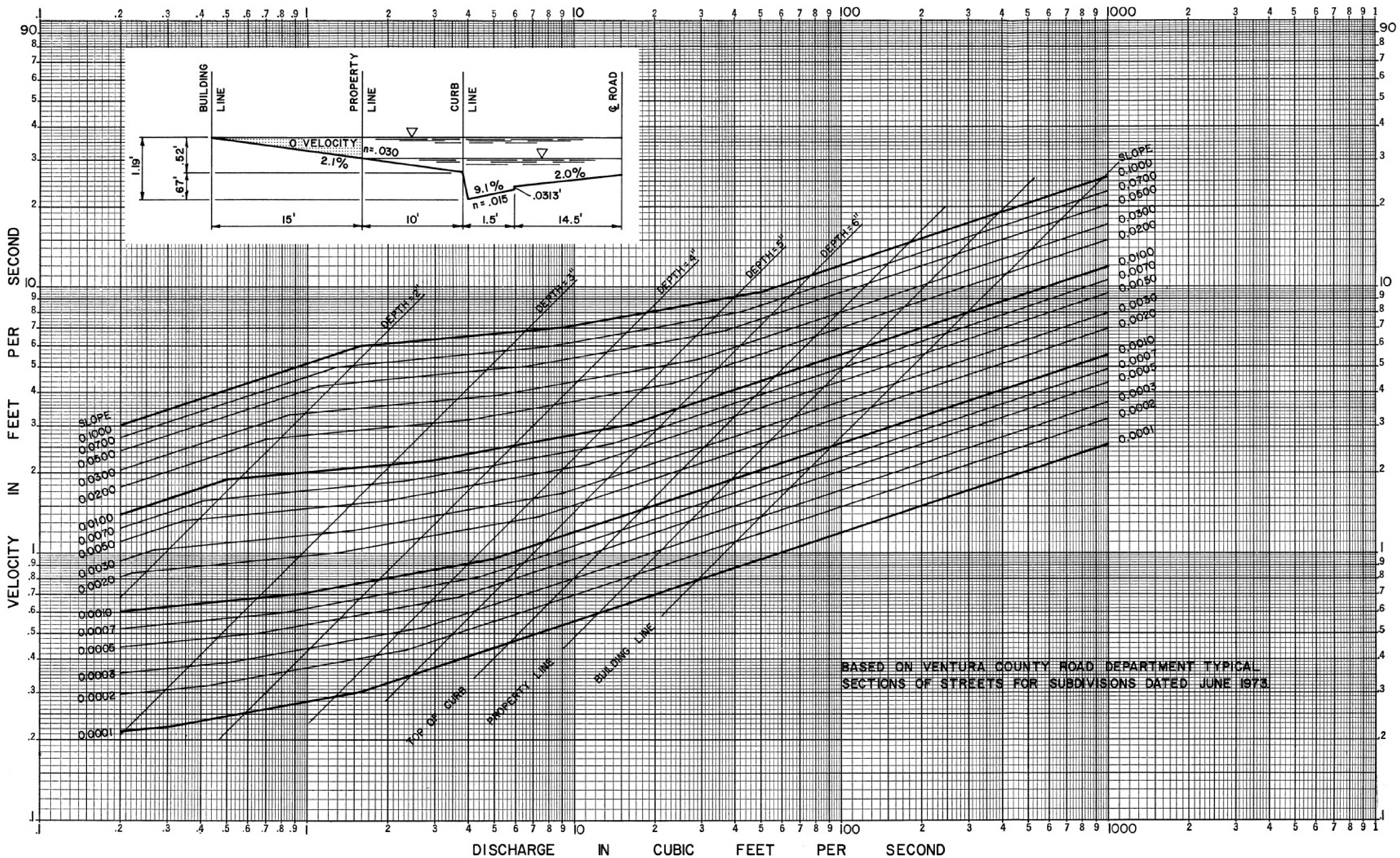


EXHIBIT 11C. VELOCITY- DISCHARGE- SLOPE RELATIONSHIPS, 40' ROAD WIDTH – 6" CURB

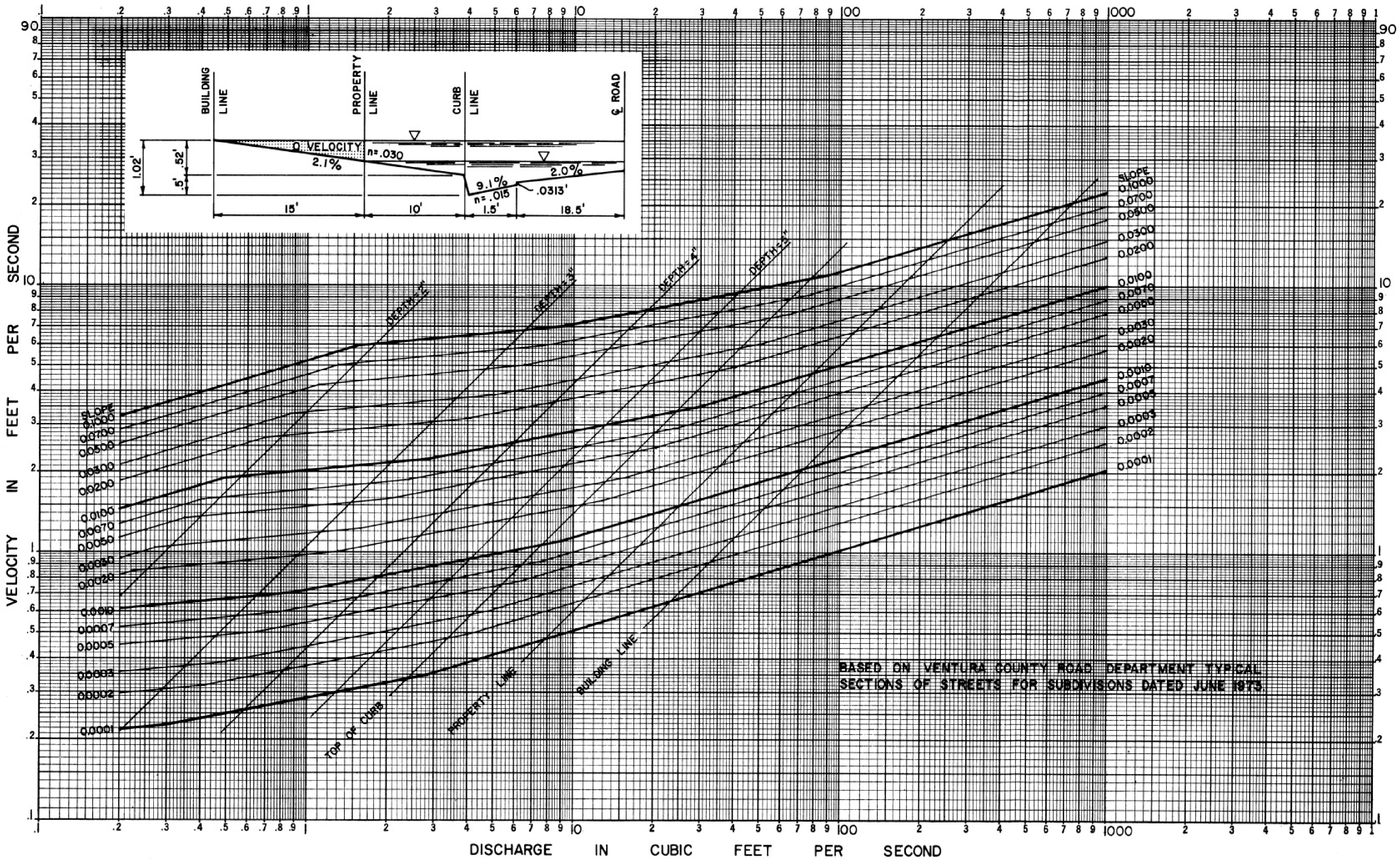


EXHIBIT 11D. VELOCITY- DISCHARGE- SLOPE RELATIONSHIPS, 40' ROAD WIDTH – 8" CURB

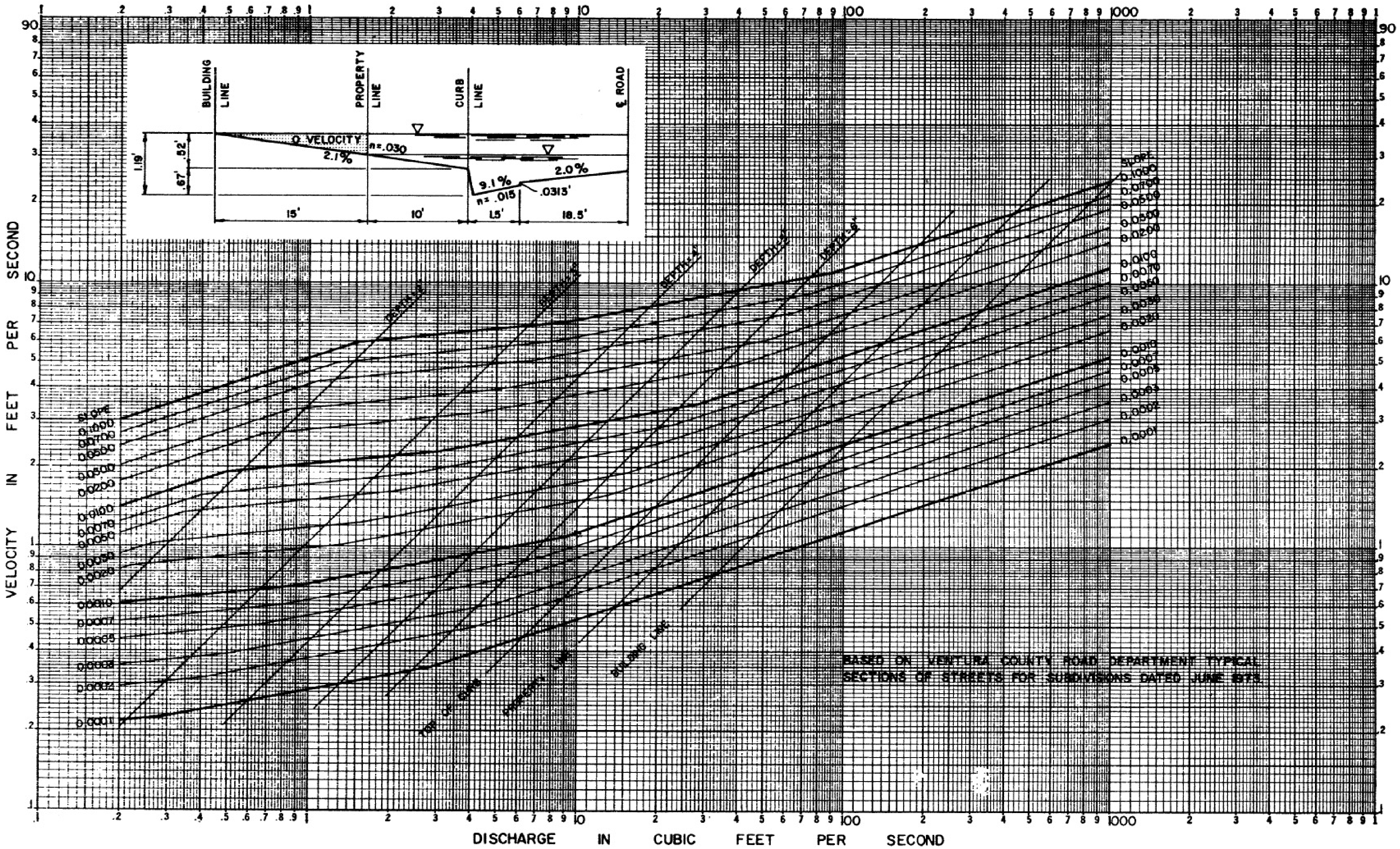


EXHIBIT 12A. WAVE VELOCITY- RECTANGULAR CHANNEL

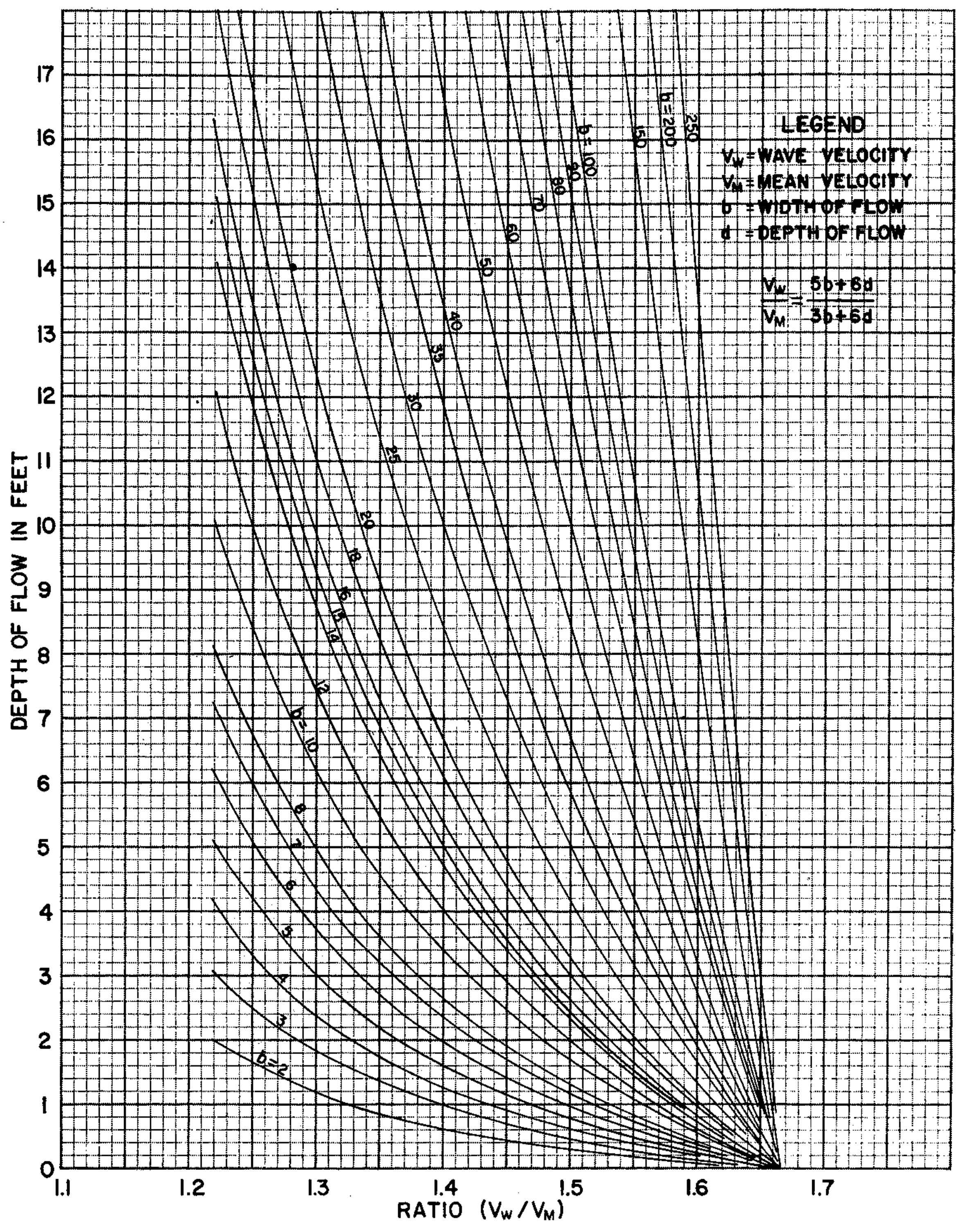
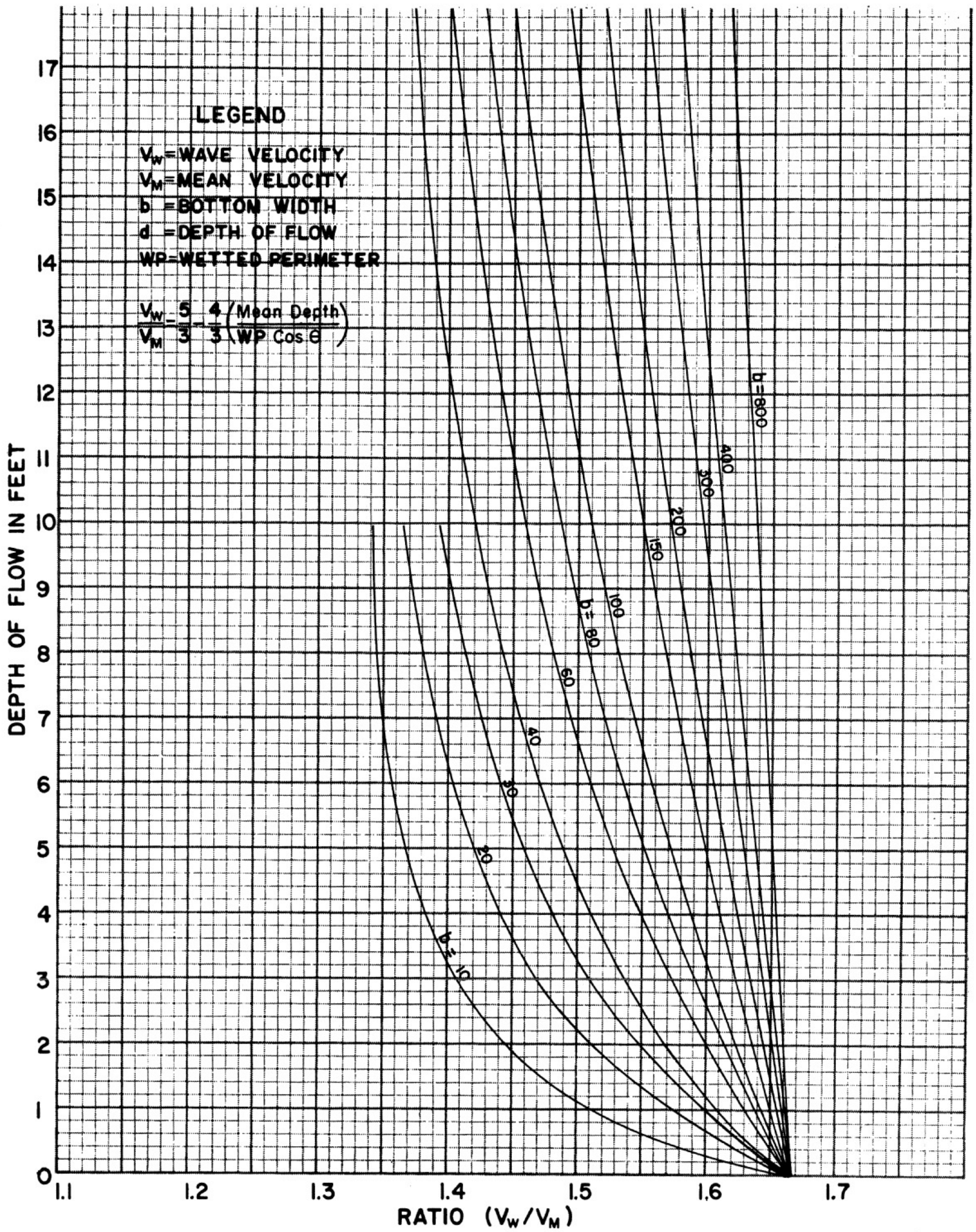


EXHIBIT 12B. WAVE VELOCITY- TRAPEZOIDAL CHANNEL 1.5:1 SIDESLOPE



%Q	%V	%Vw	%Q	%V	%Vw	%Q	%V	%Vw	%Q	%V	%Vw	%Q	%V	%Vw
0	0	--												
1	30	43	21	78	110	41	95	129	61	105	137	81	111	137
2	37	53	22	79	111	42	96	130	62	105	137	82	112	137
3	42	61	23	81	112	43	96	130	63	106	137	83	112	137
4	46	66	24	82	113	44	97	131	64	106	137	84	112	137
5	50	70	25	83	115	45	97	131	65	106	137	85	112	137
6	53	74	26	84	116	46	98	132	66	107	137	86	112	137
7	55	78	27	85	117	47	98	132	67	107	137	87	113	137
8	57	81	28	86	118	48	99	133	68	107	137	88	113	137
9	59	84	29	86	119	49	100	133	69	108	137	89	113	137
10	62	88	30	87	120	50	100	133	70	108	137	90	113	137
11	64	91	31	88	121	51	101	134	71	108	137	91	113	137
12	66	93	32	89	122	52	101	134	72	109	137	92	113	137
13	68	95	33	90	123	53	101	135	73	109	137	93	113	137
14	69	97	34	90	124	54	102	135	74	109	137	94	114	137
15	71	99	35	91	125	55	102	136	75	110	137	95	114	137
16	72	101	36	92	126	56	103	136	76	110	137	96	114	137
17	74	103	37	93	126	57	103	136	77	110	137	97	114	137
18	75	105	38	93	127	58	104	136	78	111	137	98	114	137
19	76	107	39	94	128	59	104	136	79	111	137	99	114	137
20	77	108	40	95	128	60	105	137	80	111	137	100	114	137

EXHIBIT 12C. WAVE VELOCITY- CIRCULAR PIPE

Note:

1. In %Q column find %Q based on pipe-full Q
2. On same line as %Q, find %V and %VW; These are percentages of mean velocity in pipe flowing full
3. Because pipe-full Q is not maximum Q due to boundary resistance, appears table only goes up to depth/diameter = 0.82

EXHIBIT 13. DIRECT RUNOFF FOR VARIOUS CURVE NUMBERS- NRCS

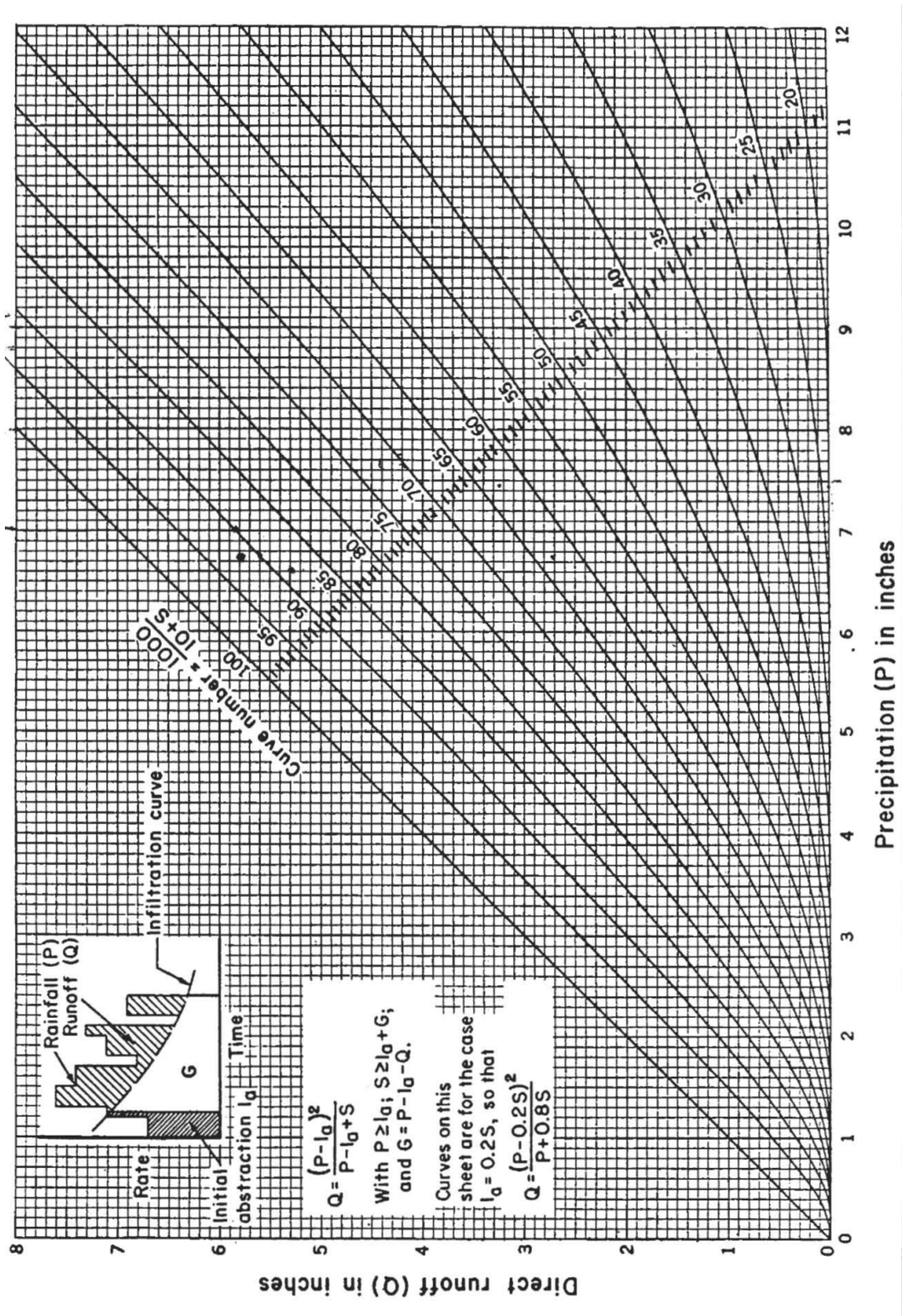


EXHIBIT 14A. AMC II NRCS CURVE NUMBERS FOR UNDEVELOPED LAND

UNDEVELOPED LAND USE AND CONDITION		% Impervious		HYDROLOGIC SOIL GROUP AND VCWPD NUMBERS						
Poor: Less than 50% Cover Fair: From 50% to 75% Cover Good: More Than 75% Cover				A (1), (2)		B		C		D (3)
		Effective	Average	7	6	5	4	3	2	1
Grassland (Annual Grass)	Poor	0	0	46	57	60	63	68	72	76
"	Fair	0	0	21	42	47	53	60	66	70
"	Good	0	0	-	-	41	47	54	59	64
Open Brush (Sagebrush, Flattop Buckwheat)	Poor	0	0	31	51	55	60	66	70	75
"	Fair	0	0	22	40	44	49	54	58	61
"	Good	0	0	-	-	33	39	46	51	56
Big Brush (Scrub Oak, Manzanita, Ceanothis)	Fair	0	0	23	39	42	46	51	54	59
"	Good	0	0	-	-	29	34	41	46	51
Chamise (Narrow Leaf Chaparral)	Fair	0	0	21	43	48	55	63	68	75
"	Good	0	0	-	-	44	49	55	60	64
Oak Savannah (Sparse Oaks & Annual Grass)	Poor	0	0	34	53	57	62	67	71	-
"	Fair	0	0	22	41	45	51	57	61	-
Orchard	Poor	0	0	42	56	59	62	65	67	71
Woodland	Fair	0	0	-	-	35	39	43	47	-
Pinon & Juniper	Fair	0	0	-	-	43	48	54	58	62
Forest	Fair	0	0	22	41	45	50	56	60	64
Pasture or Range	Poor	0	0	61	76	78	81	84	87	89
"	Fair	0	0	40	61	65	71	77	81	84
"	Good	0	0	29	52	57	64	71	76	80

NOTE: WPD MODIFIED RATIONAL METHOD USES SOIL TYPES 1-7 AND EFFECTIVE IMPERVIOUS PERCENTAGE IN VCRat MODEL

Note (1)	Curve numbers for soil types 6 and 7 not all available
Note (2)	For CNs<30, ensure that P-0.2*S > 0
Note (3)	Curve numbers for soil type 1 not all available
Reference:	Boyle, 1967. Revised Hydrologic Analysis, Zone II except Pasture from NRCS TR-55 Table 2-2c. For other land use types see TR-55

EXHIBIT 14B. AMC II NRCS CURVE NUMBERS FOR DEVELOPED LAND

DEVELOPED LAND USE	Condition (1)	% IMPERVIOUS EFFEC-TIVE	% IMPERVIOUS AVER-AGE	HYDROLOGIC SOIL GROUP (5) A 7	A 6	B 5	B 4	C 3	C 2	D 1
Open Spaces, Lawns, Parks, Golf Courses, Cemeteries, etc.	Good	0	0	29	52	57	64	71	76	80
"	Fair	0	0	42	61	65	71	77	81	84
Residential 1 ac. Lot	-	10	20	45	62	66	71	76	80	84
Residential 1/2 ac. Lot	-	13	25	45	65	68	73	78	81	85
Residential 1/3 ac. Lot	-	15	30	48	67	70	75	79	82	86
Residential 1/4 ac. Lot	-	19	38	53	70	73	77	81	84	87
Residential 1/5 ac. Lot	-	23	47	59	74	77	80	84	86	89
Residential 1/6 ac. Lot	-	28	56	66	79	81	84	86	88	90
Residential 1/8 ac. Lot	-	32	65	72	83	84	87	89	90	92
Residential - Condos	-	37	69	74	84	86	88	90	92	93
Industrial Unpaved Yards, etc.	-	36	72	77	86	87	89	91	92	93
Commercial & Business	-	50	85	88	90	91	93	93	95	95
Industrial Parks, Paved Parking, etc.	-	70	93	93	94	95	96	96	97	97
Parking Lots, Roofs, Driveways, Paved Streets with Curbs & Drains	-	90	100	98	98	98	98	98	98	98
Public Facilities & Institutions; Includes Schools, Government CenterS, Military Bases, etc. (2)	-	23	47	59	74	77	80	84	86	89
Transportation and utilities (3)	-	70	93	79	87	88	90	91	92	93
Newly graded/under construction - No veg.	-	0	0	71	83	85	88	90	92	94
Paved Streets with open ditches including right-of-way (3)	-	70	93	79	87	88	90	91	92	93
Gravel streets including right-of-way	-	0	0	71	82	84	86	88	90	91
Dirt street including right-of-way	-	0	0	66	79	81	83	86	88	89
Natural desert landscaping- native vegetation	-	0	0	55	72	75	79	83	86	88
Farmsteads- buildings, lanes, driveways, and surrounding lots (2)	-	23	47	51	69	72	76	80	83	86
Agriculture- Straight Row + Crop Residue Cover on >5% of surface	Good	0	0	57	72	74	77	80	83	85
Agriculture- Straight Row + Crop Residue Cover on <5% of surface	Poor	0	0	64	78	80	83	86	88	90

DEVELOPED LAND USE	Condition (1)	% IMPERVIOUS		HYDROLOGIC SOIL GROUP (5)						
		EFFEC-TIVE	AVER-AGE	A		B		C		D
				7	6	5	4	3	2	1
Agriculture- Straight Row Good	Good	0	0	60	75	77	80	84	86	89
Agriculture- Straight Row Poor	Good	0	0	65	79	81	84	87	89	91
Strawberries, 36" beds on 48" centers, beds covered with plastic (4)	-	72	72	90	94	94	95	96	96	97
Fallow - Bare Soil or Newly Graded Lands	-	0	0	71	83	85	88	90	92	94
Fallow - with crop residue cover on >5% of surface	Good	0	0	68	80	82	84	87	88	90
Orchard or Tree Farm, 50/50 woods-grass	Poor	0	0	39	60	64	69	75	79	83
Orchard or Tree Farm, 50/50 woods-grass	Fair	0	0	26	48	53	59	67	72	77
Orchard or Tree Farm, 50/50 woods-grass	Good	0	0	21	42	47	54	61	66	72

	NOTE: WPD MODIFIED RATIONAL METHOD USES SOIL TYPES 1-7 AND IMPERVIOUS PERCENTAGE IN VCRat2.64 MODEL
Note (1)	Poor is < 50% cover; Fair is from 50 to 75% cover; Good is >75% cover; also consider density of canopy and vegetative cover and degree of surface roughness
Note (2)	% Impervious and CNs assumed same as residential 1/5 ac lots
Note (3)	Assumed same as industrial parks
Note (4)	Calculated assuming planted on 200'x208' parcel with 8' road along one boundary.
Note (5)	TR-55 Notes: CNs developed using average % imperviousness with CN=98, pervious areas equivalent to open space in good condition. Greater than 30% impervious area considered directly connected.
Reference:	TR-55 Manual Table 2-2. For other land use types, see TR-55 Manual.

EXHIBIT 15. LEGACY ZONE FOURTH DAY STORM TOTALS AND MASS CURVE IDS

Rainfall Zone	100-Year Storm	50-Year Storm	25-Year Storm	10-Year Storm
J	7.00	5.0	3.91	3.17
J' (J prime)	6.66	6.0	5.28	4.38
K	10.60	8.0	6.41	5.53
L	15.00	11.0	8.81	7.21
	VCRat 2.5 Model Mass Curve IDs			
J	D96 (Note 1)	I50	I25	I10
J' (J prime)	A97	J50	J25	J10
K	B98	K50	K25	K10
L	C99	L50	L25	L10

Note 1: For VCRat2.2, the J and J prime distributions use the same mass curve Ids of A97, J50, J25, and J10 in the VCRain.dat file and the modeler is required to insert the correct mass curve data required for the run in the appropriate location. This is not necessary in VCRat2.6 and 2.64.

EXHIBIT 16. VCRATP.FOR AREAL REDUCTION DATA FROM FORTRAN PROGRAM

Area (ac)	Area (sq mi)	Factor	Area (ac)	Area (sq mi)	Factor
0	0	1.0000	19,200	30	0.7850
800	1.25	0.9450	22,400	35	0.7730
1,600	2.5	0.9250	25,600	40	0.7625
3,200	5	0.8950	28,800	45	0.7520
6,400	10	0.8600	32,000	50	0.7420
9,600	15	0.8350	48,000	75	0.7020
12,800	20	0.8150	64,000	100	0.6700
16,000	25	0.8000			

EXHIBIT 17. 100-YR HYDROGRAPH DISCRETIZATION

Time Period Minutes	Point Spacing Minutes	Number of Points
0 - 1000	100	11
1000 - 1100	50	2
1100 - 1130	10	3
1130 - 1300	1	170
1300 - 1400	10	10
1400 - 1460	20	3
1460 - 1500	40	1
		Total 200

EXHIBIT 18. VCRAIN.DAT FILE FOR VCRAT2.2

C coefficients and mass curves for J'10, 50, 100, J25, K10, 25, 50, 100, L10, 25, 50, and 100. For VCRat 2.2, the J and J prime distributions use the same mass curve Ids of A97, J50, J25, and J10 in the VCRain.dat file and the modeler is required to insert the correct mass curve data required for the run in the appropriate location.

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EXHIBIT 19. VCRAIN.DAT FILE FOR VCRAT2.6

Same info as VCRat2.2 VCRAIN.DAT file but more legible format.

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VCRAIN.DAT v2.5
VERSION 200604
SOILCRV 010
INTENSI 1 0.000 0.300 0.500 0.750 1.000 1.250 1.500 1.750 2.000 2.500 3.000 4.000 5.000 6.000
RUNOFF  1 0.000 0.001 0.400 0.600 0.700 0.765 0.800 0.828 0.850 0.880 0.900 0.925 0.940 0.950
SOILCRV 020
INTENSI 1 0.000 0.400 0.750 1.000 1.250 1.500 2.000 2.500 3.000 3.500 4.000 5.000 6.000 7.000
RUNOFF  1 0.000 0.000 0.450 0.591 0.663 0.709 0.762 0.800 0.829 0.850 0.868 0.890 0.903 0.910
SOILCRV 030
INTENSI 1 0.000 0.500 0.750 1.000 1.250 1.500 1.750 2.000 2.500 3.000 3.500 4.000 5.000 7.000
RUNOFF  1 0.000 0.000 0.332 0.502 0.590 0.645 0.677 0.704 0.746 0.777 0.800 0.816 0.840 0.856
SOILCRV 040
INTENSI 1 0.000 0.650 0.750 1.000 1.500 2.000 2.500 3.000 3.500 4.000 4.500 5.000 5.500 6.500
RUNOFF  1 0.000 0.000 0.140 0.360 0.570 0.647 0.692 0.727 0.752 0.770 0.785 0.795 0.802 0.809
SOILCRV 050
INTENSI 1 0.000 0.800 1.000 1.200 1.450 1.690 2.050 2.500 3.000 3.630 4.300 5.000 6.000 7.000
RUNOFF  1 0.000 0.000 0.270 0.400 0.500 0.550 0.600 0.630 0.672 0.700 0.720 0.732 0.744 0.750
SOILCRV 060
INTENSI 1 0.000 0.925 1.000 1.100 1.200 1.425 1.725 2.050 2.400 3.000 3.800 4.700 5.600 7.000
RUNOFF  1 0.000 0.001 0.170 0.250 0.310 0.370 0.420 0.460 0.490 0.530 0.570 0.600 0.620 0.643
SOILCRV 070
INTENSI 1 0.000 1.850 2.000 2.270 2.650 3.000 3.340 3.900 4.500 5.000 5.600 6.000 6.600 7.000
RUNOFF  1 0.000 0.001 0.090 0.200 0.300 0.360 0.400 0.450 0.490 0.515 0.540 0.560 0.580 0.593
MASSCRV J 10 I10 3.17
TIME    1     0   100   200   300   400   500   600   700   800   900  1000  1050  1100  1110
RAIN    1     0 0.017 0.069 0.156 0.278 0.433 0.632 0.848 1.105 1.398 1.726 1.903 2.089 2.127
TIME   15  1120  1130  1135  1140  1145  1147  1148  1149  1150  1151  1152  1153  1154  1155
RAIN   15 2.168 2.216 2.246 2.286 2.340 2.370 2.392 2.428 2.464 2.500 2.536 2.572 2.584 2.594
TIME   29  1160  1170  1180  1190  1210  1230  1260  1300  1340  1400  1440  1500
RAIN   29 2.632 2.684 2.719 2.753 2.817 2.876 2.954 3.039 3.103 3.159 3.170 3.170
MASSCRV J 25 I25 3.91
TIME    1     0   100   200   300   400   500   600   700   800   900  1000  1050  1100  1110
RAIN    1 0.000 0.022 0.085 0.192 0.340 0.532 0.765 1.042 1.360 1.722 2.125 2.343 2.572 2.620
TIME   15  1120  1130  1135  1140  1145  1147  1148  1149  1150  1151  1152  1153  1154  1155
RAIN   15 2.677 2.745 2.786 2.833 2.887 2.920 2.952 2.996 3.040 3.084 3.128 3.172 3.186 3.198
TIME   29  1160  1170  1180  1190  1210  1230  1260  1300  1340  1400  1440  1500
RAIN   29 3.241 3.300 3.347 3.389 3.469 3.542 3.640 3.747 3.827 3.897 3.910 3.910
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MASSCRV J 50 I50 5.00
TIME    1     0   100   200   300   400   500   600   700   800   900  1000  1050  1100  1110
RAIN    1     0 0.028 0.111 0.251 0.446 0.698 1.005 1.368 1.786 2.261 2.791 3.077 3.377 3.439
TIME   15  1120  1130  1135  1140  1145  1147  1148  1149  1150  1151  1152  1153  1154  1155
RAIN   15 3.508 3.585 3.628 3.676 3.735 3.769 3.804 3.853 3.902 3.951 4.000 4.049 4.066 4.081
TIME   29  1160  1170  1180  1190  1210  1230  1260  1300  1340  1400  1440  1500
RAIN   29 4.133 4.199 4.257 4.313 4.419 4.516 4.645 4.786 4.891 4.983 5.000 5.000
MASSCRV J 100 D96 7.00
TIME    1     0   100   200   300   400   500   600   700   800   900  1000  1050  1100  1110
RAIN    1 0.000 0.210 0.420 0.641 0.883 1.167 1.482 1.841 2.302 2.859 3.542 3.952 4.463 4.593
TIME   15  1120  1130  1131  1132  1133  1134  1135  1136  1137  1138  1139  1140  1141  1142
RAIN   15 4.751 4.887 4.908 4.929 4.949 4.970 4.991 5.012 5.033 5.053 5.074 5.095 5.122 5.148
TIME   29  1143  1144  1145  1146  1147  1148  1149  1150  1151  1152  1153  1154  1155  1156
RAIN   29 5.174 5.202 5.236 5.270 5.305 5.339 5.350 5.360 5.424 5.592 5.655 5.689 5.716 5.733
TIME   43  1157  1158  1159  1160  1161  1162  1163  1164  1165  1166  1167  1168  1169  1170
RAIN   43 5.751 5.772 5.785 5.802 5.817 5.833 5.846 5.861 5.874 5.886 5.896 5.908 5.910 5.932
TIME   57  1171  1172  1173  1174  1175  1176  1177  1178  1179  1180  1181  1182  1183  1184
RAIN   57 5.943 5.952 5.962 5.972 5.982 5.991 6.000 6.011 6.018 6.028 6.035 6.041 6.049 6.056
TIME   71  1185  1186  1187  1188  1189  1190  1191  1192  1193  1194  1195  1196  1197  1198
RAIN   71 6.062 6.070 6.076 6.083 6.092 6.099 6.108 6.116 6.123 6.132 6.140 6.148 6.156 6.164
TIME   85  1199  1200  1201  1202  1203  1204  1205  1206  1207  1208  1209  1210  1211  1212
RAIN   85 6.172 6.180 6.190 6.199 6.209 6.218 6.227 6.237 6.246 6.256 6.265 6.275 6.281 6.287
TIME   99  1213  1214  1215  1216  1217  1218  1219  1220  1221  1222  1223  1224  1225  1226
RAIN   99 6.294 6.300 6.306 6.313 6.319 6.325 6.332 6.338 6.344 6.350 6.357 6.363 6.369 6.376
TIME  113  1227  1228  1229  1230  1231  1232  1233  1234  1235  1236  1237  1238  1239  1240
RAIN  113 6.382 6.388 6.395 6.401 6.407 6.414 6.420 6.426 6.432 6.439 6.445 6.451 6.458 6.464
TIME  127  1241  1242  1243  1244  1245  1246  1247  1248  1249  1250  1251  1252  1253  1254
RAIN  127 6.469 6.474 6.480 6.485 6.490 6.495 6.501 6.506 6.511 6.517 6.522 6.527 6.532 6.538
TIME  141  1255  1256  1257  1258  1259  1260  1261  1262  1263  1264  1265  1266  1267  1268
RAIN  141 6.543 6.548 6.553 6.559 6.564 6.569 6.574 6.580 6.585 6.590 6.595 6.601 6.606 6.611
TIME  155  1269  1270  1271  1272  1273  1274  1275  1276  1277  1278  1279  1280  1281  1282
RAIN  155 6.616 6.622 6.626 6.630 6.634 6.638 6.643 6.647 6.651 6.655 6.659 6.664 6.668 6.672
TIME  169  1283  1284  1285  1286  1287  1288  1289  1290  1291  1292  1293  1294  1295  1296
RAIN  169 6.676 6.680 6.685 6.689 6.693 6.697 6.702 6.706 6.710 6.714 6.718 6.723 6.727 6.731
TIME  183  1297  1298  1299  1300  1310  1320  1330  1340  1350  1360  1370  1380  1390  1400
RAIN  183 6.735 6.739 6.744 6.748 6.779 6.811 6.832 6.853 6.884 6.905 6.926 6.947 6.968 6.979
TIME  197  1420  1440  1460  1500
RAIN  197 6.989 6.998 6.999 7.000
MASSCRV J' 10 J10 4.38
TIME    1     0   276   512   768   926  1072  1084  1088  1092  1104  1108  1112  1116  1120
RAIN    1 0.000 0.140 0.340 1.160 1.760 2.584 2.677 2.718 2.754 2.856 2.888 2.931 2.970 3.003
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TIME   15  1128  1136  1140  1144  1148  1152  1153  1154  1156  1158  1160  1163  1165  1167
RAIN   15 3.072 3.160 3.208 3.277 3.360 3.504 3.540 3.561 3.590 3.612 3.621 3.658 3.676 3.692
TIME   29  1170  1180  1200  1215  1236  1254  1276  1305  1340  1375  1430  1500
RAIN   29 3.714 3.784 3.896 3.940 4.020 4.080 4.140 4.200 4.260 4.340 4.360 4.380
MASSCRV J' 25 J25 5.28
TIME    1     0   100   200   300   400   500   600   700   800   900  1000  1050  1100  1110
RAIN    1 0.000 0.044 0.088 0.176 0.290 0.502 0.836 1.250 1.707 2.200 2.746 3.080 3.476 3.546
TIME   15  1120  1130  1135  1140  1145  1147  1148  1149  1150  1151  1152  1153  1154  1155
RAIN   15 3.628 3.727 3.784 3.856 3.934 4.004 4.007 4.022 4.050 4.066 4.224 4.278 4.300 4.316
TIME   29  1160  1170  1180  1190  1210  1230  1260  1300  1340  1400  1440  1500
RAIN   29 4.373 4.443 4.532 4.594 4.726 4.840 4.998 5.166 5.192 5.271 5.280 5.280
MASSCRV J' 50 J50 6.00
TIME    1     0   100   200   300   400   500   600   700   800   900  1000  1050  1100  1110
RAIN    1 0.000 0.050 0.100 0.200 0.330 0.570 0.950 1.420 1.940 2.500 3.120 3.500 3.950 4.030
TIME   15  1120  1130  1135  1140  1145  1147  1148  1149  1150  1151  1152  1153  1154  1155
RAIN   15 4.123 4.235 4.300 4.382 4.470 4.550 4.553 4.570 4.602 4.620 4.800 4.861 4.886 4.904
TIME   29  1160  1170  1180  1190  1210  1230  1260  1300  1340  1400  1440  1500
RAIN   29 4.969 5.049 5.150 5.220 5.370 5.500 5.680 5.870 5.900 5.990 6.000 6.000
MASSCRV J' 100 A97 6.66
TIME    1     0   100   200   300   400   500   600   700   800   900  1000  1050  1100  1110
RAIN    1 0.000 0.200 0.400 0.610 0.840 1.110 1.410 1.752 2.190 2.720 3.370 3.760 4.246 4.370
TIME   15  1120  1130  1131  1132  1133  1134  1135  1136  1137  1138  1139  1140  1141  1142
RAIN   15 4.520 4.650 4.670 4.690 4.709 4.729 4.749 4.769 4.789 4.808 4.828 4.848 4.873 4.898
TIME   29  1143  1144  1145  1146  1147  1148  1149  1150  1151  1152  1153  1154  1155  1156
RAIN   29 4.923 4.949 4.982 5.014 5.047 5.080 5.090 5.100 5.161 5.320 5.380 5.413 5.438 5.455
TIME   43  1157  1158  1159  1160  1161  1162  1163  1164  1165  1166  1167  1168  1169  1170
RAIN   43 5.472 5.492 5.504 5.520 5.534 5.550 5.562 5.576 5.589 5.600 5.610 5.621 5.623 5.644
TIME   57  1171  1172  1173  1174  1175  1176  1177  1178  1179  1180  1181  1182  1183  1184
RAIN   57 5.654 5.663 5.672 5.682 5.691 5.700 5.709 5.719 5.726 5.735 5.742 5.748 5.755 5.762
TIME   71  1185  1186  1187  1188  1189  1190  1191  1192  1193  1194  1195  1196  1197  1198
RAIN   71 5.768 5.775 5.781 5.788 5.796 5.803 5.811 5.819 5.826 5.834 5.842 5.849 5.857 5.865
TIME   85  1199  1200  1201  1202  1203  1204  1205  1206  1207  1208  1209  1210  1211  1212
RAIN   85 5.872 5.880 5.889 5.898 5.907 5.916 5.925 5.934 5.943 5.952 5.961 5.970 5.976 5.982
TIME   99  1213  1214  1215  1216  1217  1218  1219  1220  1221  1222  1223  1224  1225  1226
RAIN   99 5.988 5.994 6.000 6.006 6.012 6.018 6.024 6.030 6.036 6.042 6.048 6.054 6.060 6.066
TIME  113  1227  1228  1229  1230  1231  1232  1233  1234  1235  1236  1237  1238  1239  1240
RAIN  113 6.072 6.078 6.084 6.090 6.096 6.102 6.108 6.114 6.120 6.126 6.132 6.138 6.144 6.150
TIME  127  1241  1242  1243  1244  1245  1246  1247  1248  1249  1250  1251  1252  1253  1254
RAIN  127 6.155 6.160 6.165 6.170 6.175 6.180 6.185 6.190 6.195 6.200 6.205 6.210 6.215 6.220
TIME  141  1255  1256  1257  1258  1259  1260  1261  1262  1263  1264  1265  1266  1267  1268
RAIN  141 6.225 6.230 6.235 6.240 6.245 6.250 6.255 6.260 6.265 6.270 6.275 6.280 6.285 6.290
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TIME  155  1269  1270  1271  1272  1273  1274  1275  1276  1277  1278  1279  1280  1281  1282
RAIN  155 6.295 6.300 6.304 6.308 6.312 6.316 6.320 6.324 6.328 6.332 6.336 6.340 6.344 6.348
TIME  169  1283  1284  1285  1286  1287  1288  1289  1290  1291  1292  1293  1294  1295  1296
RAIN  169 6.352 6.356 6.360 6.364 6.368 6.372 6.376 6.380 6.384 6.388 6.392 6.396 6.400 6.404
TIME  183  1297  1298  1299  1300  1310  1320  1330  1340  1350  1360  1370  1380  1390  1400
RAIN  183 6.408 6.412 6.416 6.420 6.450 6.480 6.500 6.520 6.550 6.570 6.590 6.610 6.630 6.640
TIME  197  1420  1440  1460  1500
RAIN  197 6.650 6.658 6.659 6.660
MASSCRV K 10 K10 5.53
TIME    1     0   100   200   300   400   500   600   700   800   900  1000  1050  1100  1110
RAIN    1 0.000 0.100 0.210 0.350 0.520 0.735 0.980 1.290 1.670 2.140 2.792 3.154 3.547 3.646
TIME   15  1120  1130  1135  1140  1145  1147  1148  1149  1150  1151  1152  1153  1154  1155
RAIN   15 3.754 3.864 3.934 4.014 4.107 4.149 4.179 4.214 4.254 4.324 4.424 4.489 4.509 4.524
TIME   29  1160  1170  1180  1190  1210  1230  1260  1300  1340  1400  1440  1500
RAIN   29 4.594 4.689 4.762 4.830 4.961 5.060 5.175 5.305 5.400 5.490 5.530 5.530
MASSCRV K 25 K25 6.408
TIME    1     0   100   200   300   400   500   600   700   800   900  1000  1050  1100  1110
RAIN    1 0.000 0.100 0.235 0.407 0.623 0.893 1.215 1.605 2.061 2.523 3.198 3.619 4.138 4.251
TIME   15  1120  1130  1135  1140  1145  1147  1148  1149  1150  1151  1152  1153  1154  1155
RAIN   15 4.367 4.508 4.588 4.678 4.776 4.821 4.844 4.915 4.986 5.057 5.128 5.200 5.224 5.241
TIME   29  1160  1170  1180  1190  1210  1230  1260  1300  1340  1400  1440  1500
RAIN   29 5.315 5.426 5.518 5.596 5.726 5.835 5.973 6.135 6.253 6.364 6.408 6.408
MASSCRV K 50 K50 8.000
TIME    1     0   100   200   300   400   500   600   700   800   900  1000  1050  1100  1110
RAIN    1 0.000 0.100 0.280 0.510 0.810 1.180 1.640 2.175 2.770 3.470 4.340 4.784 5.311 5.426
TIME   15  1120  1130  1135  1140  1145  1147  1148  1149  1150  1151  1152  1153  1154  1155
RAIN   15 5.560 5.701 5.776 5.886 6.020 6.080 6.111 6.146 6.195 6.290 6.400 6.490 6.520 6.540
TIME   29  1160  1170  1180  1190  1210  1230  1260  1300  1340  1400  1440  1500
RAIN   29 6.620 6.730 6.830 6.930 7.100 7.240 7.420 7.640 7.800 7.950 8.000 8.000
MASSCRV K 100 B98 10.600
TIME    1     0   100   200   300   400   500   600   700   800   900  1000  1050  1100  1110
RAIN    1 0.000 0.450 0.940 1.500 2.060 2.650 3.270 3.920 4.600 5.350 6.220 6.730 7.267 7.407
TIME   15  1120  1130  1131  1132  1133  1134  1135  1136  1137  1138  1139  1140  1141  1142
RAIN   15 7.536 7.706 7.723 7.740 7.760 7.781 7.801 7.816 7.838 7.859 7.880 7.902 7.928 7.953
TIME   29  1143  1144  1145  1146  1147  1148  1149  1150  1151  1152  1153  1154  1155  1156
RAIN   29 7.978 8.004 8.038 8.072 8.106 8.140 8.225 8.310 8.327 8.480 8.565 8.599 8.624 8.646
TIME   43  1157  1158  1159  1160  1161  1162  1163  1164  1165  1166  1167  1168  1169  1170
RAIN   43 8.665 8.682 8.698 8.716 8.729 8.742 8.755 8.774 8.783 8.795 8.805 8.817 8.834 8.840
TIME   57  1171  1172  1173  1174  1175  1176  1177  1178  1179  1180  1181  1182  1183  1184
RAIN   57 8.852 8.863 8.873 8.884 8.894 8.904 8.913 8.922 8.932 8.942 8.952 8.962 8.971 8.981
TIME   71  1185  1186  1187  1188  1189  1190  1191  1192  1193  1194  1195  1196  1197  1198
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RAIN   71 8.991 9.000 9.010 9.020 9.030 9.039 9.049 9.058 9.068 9.078 9.088 9.097 9.107 9.117
TIME   85  1199  1200  1201  1202  1203  1204  1205  1206  1207  1208  1209  1210  1211  1212
RAIN   85 9.126 9.136 9.144 9.153 9.161 9.170 9.178 9.186 9.195 9.203 9.212 9.220 9.228 9.237
TIME   99  1213  1214  1215  1216  1217  1218  1219  1220  1221  1222  1223  1224  1225  1226
RAIN   99 9.246 9.254 9.262 9.271 9.280 9.288 9.296 9.305 9.314 9.322 9.330 9.339 9.348 9.356
TIME  113  1227  1228  1229  1230  1231  1232  1233  1234  1235  1236  1237  1238  1239  1240
RAIN  113 9.364 9.373 9.382 9.390 9.398 9.407 9.415 9.423 9.432 9.440 9.448 9.457 9.465 9.473
TIME  127  1241  1242  1243  1244  1245  1246  1247  1248  1249  1250  1251  1252  1253  1254
RAIN  127 9.482 9.490 9.498 9.507 9.515 9.523 9.532 9.540 9.548 9.557 9.565 9.573 9.582 9.590
TIME  141  1255  1256  1257  1258  1259  1260  1261  1262  1263  1264  1265  1266  1267  1268
RAIN  141 9.598 9.607 9.615 9.623 9.632 9.640 9.648 9.655 9.662 9.670 9.678 9.685 9.692 9.700
TIME  155  1269  1270  1271  1272  1273  1274  1275  1276  1277  1278  1279  1280  1281  1282
RAIN  155 9.708 9.715 9.722 9.730 9.738 9.745 9.752 9.760 9.768 9.775 9.782 9.790 9.798 9.805
TIME  169  1283  1284  1285  1286  1287  1288  1289  1290  1291  1292  1293  1294  1295  1296
RAIN  169 9.812 9.820 9.828 9.835 9.842 9.850 9.858 9.865 9.872 9.880 9.887 9.895 9.902 9.910
TIME  183  1297  1298  1299  1300   1310   1320   1330   1340   1350   1360   1370   1380   1390   1400
RAIN  183 9.918 9.925 9.932 9.940 10.002 10.065 10.128 10.190 10.237 10.283 10.330 10.377 10.423 10.470
TIME  197   1420   1440   1460   1500
RAIN  197 10.535 10.600 10.600 10.600
MASSCRV L 10 L10 7.21
TIME    1     0   100   200   300   400   500   600   700   800   900  1000  1050  1100  1110
RAIN    1 0.000 0.100 0.220 0.390 0.600 0.875 1.240 1.700 2.240 2.890 3.700 4.162 4.698 4.821
TIME   15  1120  1130  1135  1140  1145  1147  1148  1149  1150  1151  1152  1153  1154  1155
RAIN   15 4.965 5.115 5.198 5.281 5.368 5.418 5.449 5.490 5.558 5.638 5.768 5.808 5.828 5.843
TIME   29  1160  1170  1180  1190  1210  1230  1260  1300  1340  1400  1440  1500
RAIN   29 5.905 6.023 6.123 6.220 6.390 6.520 6.710 6.900 7.040 7.160 7.210 7.210
MASSCRV L 25 L25 8.808
TIME    1     0   100   200   300   400   500   600   700   800   900  1000  1050  1100  1110
RAIN    1 0.000 0.092 0.233 0.453 0.748 1.117 1.603 2.198 2.906 3.729 4.690 5.278 5.893 6.023
TIME   15  1120  1130  1135  1140  1145  1147  1148  1149  1150  1151  1152  1153  1154  1155
RAIN   15 6.167 6.345 6.435 6.526 6.639 6.692 6.719 6.800 6.881 6.963 7.046 7.131 7.156 7.175
TIME   29  1160  1170  1180  1190  1210  1230  1260  1300  1340  1400  1440  1500
RAIN   29 7.265 7.406 7.526 7.635 7.802 7.966 8.198 8.439 8.617 8.758 8.808 8.808
MASSCRV L 50 L50 11.000
TIME    1     0   100   200   300   400   500   600   700   800   900  1000  1050  1100  1110
RAIN    1 0.000 0.080 0.250 0.540 0.950 1.450 2.100 2.880 3.820 4.880 6.090 6.765 7.507 7.657
TIME   15  1120  1130  1135  1140  1145  1147  1148  1149  1150  1151  1152  1153  1154  1155
RAIN   15 7.820 8.000 8.103 8.220 8.350 8.410 8.445 8.500 8.565 8.670 8.835 8.910 8.950 8.975
TIME   29  1160  1170  1180  1190  1210  1230   1260   1300   1340   1400   1440   1500
RAIN   29 9.066 9.228 9.364 9.498 9.740 9.950 10.240 10.550 10.780 10.950 11.000 11.000
MASSCRV L 100 C99 15.000
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TIME    1      0    100    200    300    400    500    600    700    800    900   1000   1050   1100   1110
RAIN    1  0.000  0.720  1.500  2.300  3.120  3.960  4.820  5.750  6.710  7.800  9.070  9.780 10.550 10.720
TIME   15   1120   1130   1131   1132   1133   1134   1135   1136   1137   1138   1139   1140   1141   1142
RAIN   15 10.891 11.093 11.113 11.133 11.158 11.182 11.207 11.232 11.256 11.279 11.302 11.326 11.359 11.392
TIME   29   1143   1144   1145   1146   1147   1148   1149   1150   1151   1152   1153   1154   1155   1156
RAIN   29 11.424 11.457 11.491 11.525 11.559 11.593 11.695 11.796 11.898 12.000 12.102 12.136 12.168 12.192
TIME   43   1157   1158   1159   1160   1161   1162   1163   1164   1165   1166   1167   1168   1169   1170
RAIN   43 12.217 12.241 12.260 12.277 12.296 12.313 12.330 12.348 12.364 12.380 12.396 12.413 12.428 12.444
TIME   57   1171   1172   1173   1174   1175   1176   1177   1178   1179   1180   1181   1182   1183   1184
RAIN   57 12.460 12.477 12.492 12.506 12.521 12.536 12.550 12.563 12.576 12.588 12.602 12.616 12.631 12.645
TIME   71   1185   1186   1187   1188   1189   1190   1191   1192   1193   1194   1195   1196   1197   1198
RAIN   71 12.659 12.674 12.688 12.702 12.721 12.740 12.753 12.766 12.780 12.793 12.806 12.819 12.832 12.846
TIME   85   1199   1200   1201   1202   1203   1204   1205   1206   1207   1208   1209   1210   1211   1212
RAIN   85 12.859 12.872 12.885 12.898 12.910 12.923 12.936 12.949 12.962 12.974 12.987 13.000 13.012 13.025
TIME   99   1213   1214   1215   1216   1217   1218   1219   1220   1221   1222   1223   1224   1225   1226
RAIN   99 13.038 13.050 13.062 13.075 13.088 13.100 13.112 13.125 13.138 13.150 13.162 13.175 13.188 13.200
TIME  113   1227   1228   1229   1230   1231   1232   1233   1234   1235   1236   1237   1238   1239   1240
RAIN  113 13.212 13.225 13.238 13.250 13.262 13.273 13.285 13.297 13.308 13.320 13.332 13.343 13.355 13.367
TIME  127   1241   1242   1243   1244   1245   1246   1247   1248   1249   1250   1251   1252   1253   1254
RAIN  127 13.378 13.390 13.402 13.413 13.425 13.437 13.448 13.460 13.472 13.483 13.495 13.507 13.518 13.530
TIME  141   1255   1256   1257   1258   1259   1260   1261   1262   1263   1264   1265   1266   1267   1268
RAIN  141 13.542 13.553 13.565 13.577 13.588 13.600 13.610 13.621 13.632 13.642 13.652 13.663 13.674 13.684
TIME  155   1269   1270   1271   1272   1273   1274   1275   1276   1277   1278   1279   1280   1281   1282
RAIN  155 13.694 13.705 13.716 13.726 13.736 13.747 13.758 13.768 13.778 13.789 13.800 13.810 13.820 13.831
TIME  169   1283   1284   1285   1286   1287   1288   1289   1290   1291   1292   1293   1294   1295   1296
RAIN  169 13.842 13.852 13.862 13.873 13.884 13.894 13.904 13.915 13.926 13.936 13.946 13.957 13.968 13.978
TIME  183   1297   1298   1299   1300   1310   1320   1330   1340   1350   1360   1370   1380   1390   1400
RAIN  183 13.988 13.999 14.010 14.020 14.110 14.200 14.290 14.380 14.450 14.520 14.590 14.660 14.730 14.800
TIME  197   1420   1440   1460   1500
RAIN  197 14.900 15.000 15.000 15.000
MASSCRV T 01 T01 8.00
TIME    1      0    100    200    300    400    500    600    700    800    900   1000   1050   1100   1110
RAIN    1  0.000  0.100  0.280  0.510  0.810  1.180  1.640  2.175  2.770  3.470  4.340  4.784  5.311  5.426
TIME   15   1120   1130   1131   1132   1133   1134   1135   1136   1137   1138   1139   1140   1141   1142
RAIN   15  5.560  5.701  5.716  5.731  5.746  5.761  5.776  5.798  5.820  5.842  5.864  5.886  5.913  5.940
TIME   29   1143   1144   1145   1146   1147   1148   1149   1150   1151   1152   1153   1154   1155   1156
RAIN   29  5.966  5.993  6.020  6.050  6.080  6.111  6.146  6.195  6.290  6.400  6.490  6.520  6.540  6.556
TIME   43   1157   1158   1159   1160   1161   1162   1163   1164   1165   1166   1167   1168   1169   1170
RAIN   43  6.572  6.588  6.604  6.620  6.631  6.642  6.653  6.664  6.675  6.686  6.697  6.708  6.719  6.730
TIME   57   1171   1172   1173   1174   1175   1176   1177   1178   1179   1180   1181   1182   1183   1184
RAIN   57  6.740  6.750  6.760  6.770  6.780  6.790  6.800  6.810  6.820  6.830  6.840  6.850  6.860  6.870
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TIME	71	1185	1186	1187	1188	1189	1190	1191	1192	1193	1194	1195	1196	1197	1198
RAIN	71	6.880	6.890	6.900	6.910	6.920	6.930	6.938	6.947	6.956	6.964	6.972	6.981	6.990	6.998
TIME	85	1199	1200	1201	1202	1203	1204	1205	1206	1207	1208	1209	1210	1211	1212
RAIN	85	7.006	7.015	7.024	7.032	7.040	7.049	7.058	7.066	7.074	7.083	7.092	7.100	7.107	7.114
TIME	99	1213	1214	1215	1216	1217	1218	1219	1220	1221	1222	1223	1224	1225	1226
RAIN	99	7.121	7.128	7.135	7.142	7.149	7.156	7.163	7.170	7.177	7.184	7.191	7.198	7.205	7.212
TIME	113	1227	1228	1229	1230	1231	1232	1233	1234	1235	1236	1237	1238	1239	1240
RAIN	113	7.219	7.226	7.233	7.240	7.246	7.252	7.258	7.264	7.270	7.276	7.282	7.288	7.294	7.300
TIME	127	1241	1242	1243	1244	1245	1246	1247	1248	1249	1250	1251	1252	1253	1254
RAIN	127	7.306	7.312	7.318	7.324	7.330	7.336	7.342	7.348	7.354	7.360	7.366	7.372	7.378	7.384
TIME	141	1255	1256	1257	1258	1259	1260	1261	1262	1263	1264	1265	1266	1267	1268
RAIN	141	7.390	7.396	7.402	7.408	7.414	7.420	7.426	7.431	7.436	7.442	7.448	7.453	7.458	7.464
TIME	155	1269	1270	1271	1272	1273	1274	1275	1276	1277	1278	1279	1280	1281	1282
RAIN	155	7.470	7.475	7.480	7.486	7.492	7.497	7.502	7.508	7.514	7.519	7.524	7.530	7.536	7.541
TIME	169	1283	1284	1285	1286	1287	1288	1289	1290	1291	1292	1293	1294	1295	1296
RAIN	169	7.546	7.552	7.557	7.563	7.568	7.574	7.580	7.585	7.590	7.596	7.602	7.607	7.612	7.618
TIME	183	1297	1298	1299	1300	1310	1320	1330	1340	1350	1360	1370	1380	1390	1400
RAIN	183	7.624	7.629	7.634	7.640	7.680	7.720	7.760	7.800	7.825	7.850	7.875	7.900	7.925	7.950
TIME	197	1420	1440	1460	1500										

EXHIBIT 20A. TC CALCULATION FORM FOR HAND CALCULATIONS- PART 1

VENTURA COUNTY WATERSHED PROTECTION DISTRICT
TIME OF CONCENTRATION CALCULATION FORM

PROJECT ______ PROJECT NO. ______ RAINFALL ZONE ______
COMPUTED ______ DATE ______
SUBAREA ______ SOIL No. ______ RAINFALL FREQUENCY ______
Infil. Rate ______ in/hr
TOTAL AREA ______ ac % IMPERVIOUS ______ TYPE DEVELOPMENT ______ SHEET ____ OF ____

ASSUMPTION NO.	T_c (min.)	INTENSITY (in./hr.)	C-coeff	AREA (acres)	Q (cfs)
1					
2					

FINAL T_C =		min.

IDENT. NO.	AREA PLAN.		AREA ACRES	% OF AREA	Q-Trial 1 (cfs)	Q-Trial 2 (cfs)
a					0.0	0.0
b					0.0	0.0
c					0.0	0.0
d					0.0	0.0
e					0.0	0.0
TOTAL			0.0	0%	0.0	0.0

TRIAL NO.	Length ft	Elev Top	Elev Bott	SLOPE	EFFEC. SLOPE	VELOCITY	LENGTH (ft.)	TIME (min.)
1								
2								

CONVEYANCE	TRIALS 1	TRIALS 2	TRIALS 3
LOT/OVERLAND	0.00	0.00	
NATURAL CHAN.			
STREET	0.00	0.00	
PIPE			
RECT CHANNEL			
TRAP CHANNEL			
TOTAL	0.0	0.0	

MOUNTAIN OVERLAND FLOW VELOCITY CHECK

VEL. CHECK	SLOPE THRU REACH	EFFEC. SLOPE	VELOCITY<6.0 fps

LENGTH (ft.)	ELEVATION TOP	ELEVATION BOT.	Δ

MOUNTAIN OR VALLEY CHANNEL ROUTING

REACH	LENGTH (ft.)	ELEVATION TOP	ELEVATION BOT.	Δ	SLOPE MAP	SLOPE EFFEC.	Q (cfs) TOP	Q (cfs) BOT.	VELOCITY TOP	VELOCITY BOT.	VELOCITY AVE.	VELOCITY WAVE	TIME (min.)
Trial 1													
Trial 2													

STREET TRIAL 1 WIDTH ______ CURB HEIGHT ______

REACH	LENGTH (ft.)	ELEVATION TOP	ELEVATION BOT.	Δ	SLOPE MAP	SLOPE EFFEC.	Q (cfs) TOP	Q (cfs) BOT.	VELOCITY TOP	VELOCITY BOT.	VELOCITY AVE.	VELOCITY WAVE	TIME (min.)
1													
2													
3													
												Sum	

STREET TRIAL 2 WIDTH ______ CURB HEIGHT ______

REACH	LENGTH (ft.)	ELEVATION TOP	ELEVATION BOT.	Δ	SLOPE MAP	SLOPE EFFEC.	Q (cfs) TOP	Q (cfs) BOT.	VELOCITY TOP	VELOCITY BOT.	VELOCITY AVE.	VELOCITY WAVE	TIME (min.)
1													
2													
3													

PIPE

$d^{8/3} = \frac{Qn}{S^{1/2} \times 0.463} =$ ______ = ______ d = ______ ft USE D = ______ ft

$Q_{full} = \frac{Kd^{8/3} \times S^{1/2}}{n} = \frac{0.463 \times d^{8/3} \times S^{1/2}}{0.012} =$ ______ = ______ c.f.s.

$AREA = \frac{\Pi d^2}{4} =$ ______ = ______ ft.^{2} $V_n = \frac{Q_{full}}{AREA} =$ ______ = ______ ft./sec.

REACH	LENGTH (ft.)	ELEVATION TOP	ELEVATION BOT.	SLOPE	Q (cfs) TOP	Q (cfs) BOT.	Qave cfs	DIA. (ft)	Nom DIA.	n	FULL PIPE K	FULL PIPE Q	FULL PIPE V	%Q	$\%V_W$	V_W	TIME (min.)
1																	
2																	

RECTANGULAR-TRAPEZOIDAL CHANNEL

Type ______ Width 2 ft Sideslope 0 H: 1V N Value 0.015

REACH	LENGTH (ft.)	ELEVATION TOP	ELEVATION BOT.	Δ	SLOPE MAP	SLOPE EFFEC.	Q (cfs) TOP	Q (cfs) BOT.	Calc. Q Top	Calc. Q Bott.
Trial 1										
Trial 2										

Normal Depth (ft)	Mean Depth	VELOCITY	TIME

EXHIBIT 20B. TC CALCULATION FORM FOR HAND CALCULATIONS- PART 2

VENTURA COUNTY WATERSHED PROTECTION DISTRICT

TIME OF CONCENTRATION CALCULATION FORM

PROJECT ______________________ PROJECT NO. ____________ RAINFALL ZONE ______

COMPUTED ____________ DATE ____________

SUBAREA ____________ SOIL No. ________ RAINFALL FREQUENCY ________

Infil. Rate ________ in/hr

TOTAL AREA ________ ac % IMPERVIOUS ________ TYPE DEVELOPMENT ________ SHEET ____ OF ____

Subarea Figure showing:

1. Subarea boundary
2. Scale
3. North Arrow
4. Topography or elevations used for slope calculations
5. Development
6. Flowpaths and associated subarea portions with labels

EXHIBIT 21. DESIGN STORM RATIOS

Category (1)	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
Precipitation	0.43	0.61	0.73	0.88	1.00	1.11	Not Analyzed	Not Analyzed
Undeveloped- HMS & HSPF, Updated VCRat	0.043	0.144	0.262	0.484	0.711	1.000	1.345	1.952
Developed HMS & HSPF, Updated VCRat	0.166	0.330	0.464	0.660	0.882	1.000	1.191	1.502
Undeveloped- Legacy VCRat (2)	0.043	0.144	0.362	0.484	0.711	1.000	1.345	1.952
Developed Legacy VCRat (2)	0.166	0.330	0.567	0.660	0.882	1.000	1.191	1.502
Casitas Dam Outflow	0.005	0.030	0.048	0.110	0.143	1.000	1.191	1.448
Coyote Ck below Dam	0.005	0.100	0.200	0.400	0.580	1.000	1.191	1.416
Piru Ck Below Dam	0.031	0.042	0.061	0.136	0.805	1.000	1.183	1.463

Note (1): Ratios cannot be used for watersheds with detention basins or water storage dams affecting more than 10% of the area except for those developed specifically for dam outflow (Casitas and Piru).

Note (2): VCRat ratios provided for reference only as current practice is to run the model using the correct Tc's and rainfall for all storms required for design studies. In rare cases it may be necessary to use the multipliers in VCRat studies such as estimating 10-yr peaks from Soil Type 7 in the J' zone.

Note (3): Calleguas Watershed VCRat models have specific ratios that can be provided on request.

APPENDIX B – VCRAT METHODS AND EXAMPLES

B-1. VCRAT EXAMPLE 1- LAS POSAS-FORTUNA TRACT

1. Subarea Boundaries- Carefully outline the drainage boundary on a topographic map. With reference to other larger scale maps, known improvement plans, and planned improvements, decisions governed by topography alone must be adjusted to reflect an ultimate drainage boundary. The study watershed used in this example is shown in Exhibit B-1.1

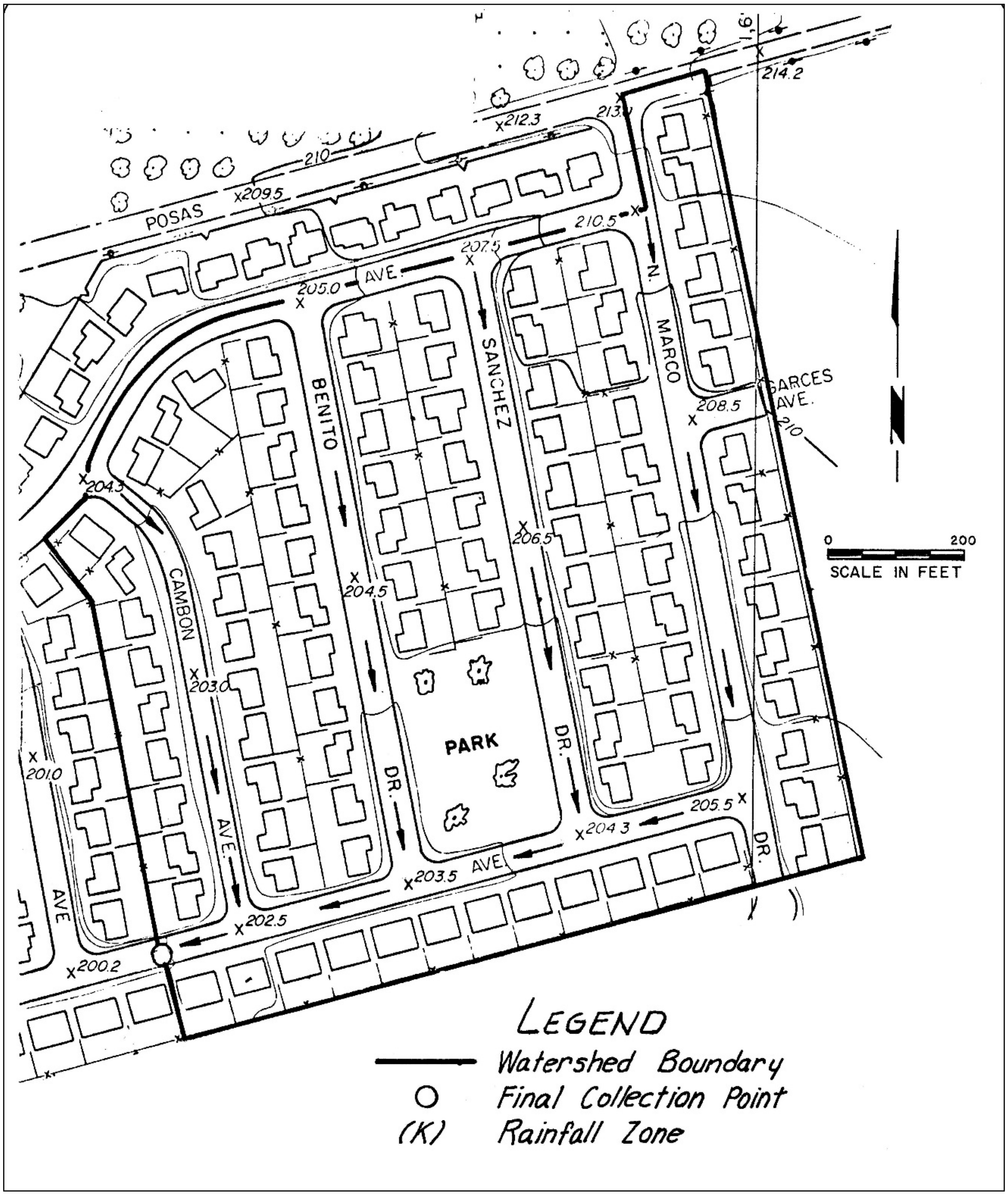
2. Field Verification- Verify boundary correctness by a field trip to the area and incorporate any changes on the map.

3. Rainfall and Soil Zones- From the hydrologic maps and GIS files in Appendix E, determine the dominant rainfall intensity zones for the study watershed. Indicate this zone on the watershed map. From the same hydrologic map, evaluate the soil types of the project watershed using an overlay or the provided GIS shapefile.

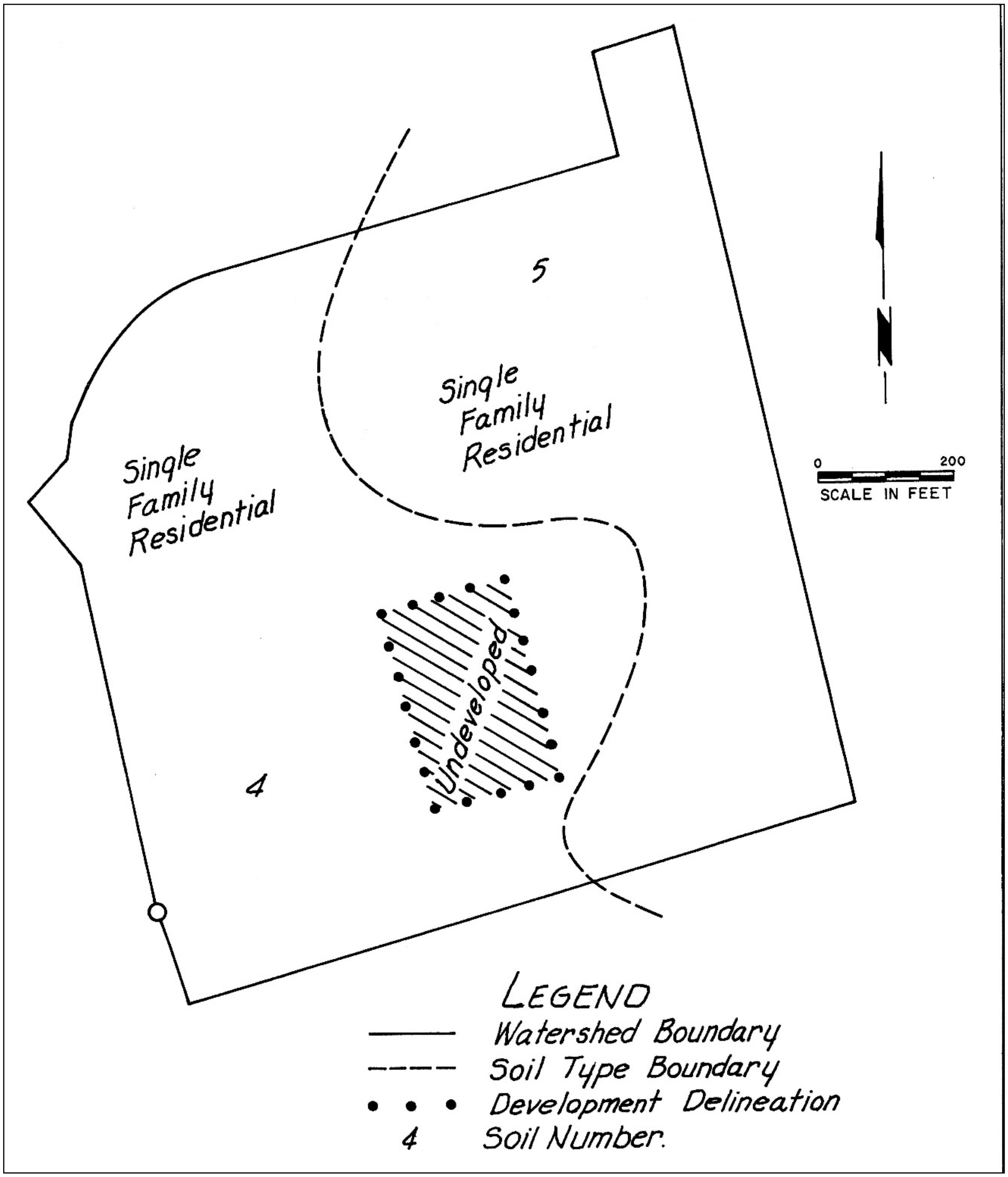
4. Future Land Use- Determine anticipated ultimate development from best sources available (current zoning, Planning Department master plans, development trends in surrounding area). Undeveloped, single family residential, and commercial development types describe most areas with occasional classifications of heavy industrial or large estate lots.

5. Percent Imperviousness- Calculate percent impervious values for the development. Assign imperviousness percentages to each development type using the values in Exhibit 14a&b.

B-1.1 Example 1- Las Posas-Fortuna Tract Watershed Map



B-1.2 Soils and Development Map



6. Watershed Area- Planimeter or use GIS or AutoCAD to calculate the area associated with each soil and development type combination and indicate as shown in Appendix B-1.3.

7. Composite Runoff Coefficient- Calculate composite runoff coefficient curve as shown in Appendix B-1.3, by first listing the appropriate runoff coefficients for selected rainfall intensities from Exhibits 6a-g. The composite runoff coefficient is weighted according to the drainage area of each soil and development classification. Plot composite runoff coefficient curve as shown in Appendix B-1.4.

8. Compute the time of concentration for the watershed using the form for hand calculations shown in Exhibit 20 or use the Tc Calculator Program as described in Section B-3. This trial-and-error hand computation includes the following general procedures:

a. Using engineering judgment, select a time of concentration for the project watershed. From the appropriate rainfall intensity-duration table in the 2006 Manual Exhibits 2a-5d, select the peak period intensity for the duration equal to the assumed time of concentration. Using the selected rainfall intensity, find an appropriate runoff coefficient “C” from the composite runoff coefficient curve from Exhibits 6a-g. Solve Q=CIA for an initial peak flow estimate.

b. Divide the project watershed into several contributing parts by streets, topographic barriers, or fence lines, and proportion the initial flow rate to the various parts by area.

c. Start at most remote point in the project watershed, select an appropriate parcel, and assign an overland flow velocity (Exhibit 8). Using street velocity-discharge-slope graphs (Exhibits 11a-d), pipe or channel hydraulic tables (not provided- use Manning’s Equation), compute flow velocities from collection point to collection point gathering discharge on the selected path to the point of concentration. Average velocity is increased to wave velocity in streets and natural channels by a factor of 1.5. Pipe and trapezoid channel wave velocities are provided in Exhibits 12a-c.

d. Compute and sum travel times associated with lot, street, and pipe or channel flow. Compare to assumed.time of concentration. If original assumption was incorrect, select a revised time of concentration, compute a new peak flow rate, distribute as before, and determine revised travel time.

e. When the computed travel time equals the estimated time of concentration within 0. 5 minutes, the associated discharge represents the desired peak flow rate.

A detailed discussion of the Tc calculation procedures is provided in the Tc Calculator Manual provided with the program.

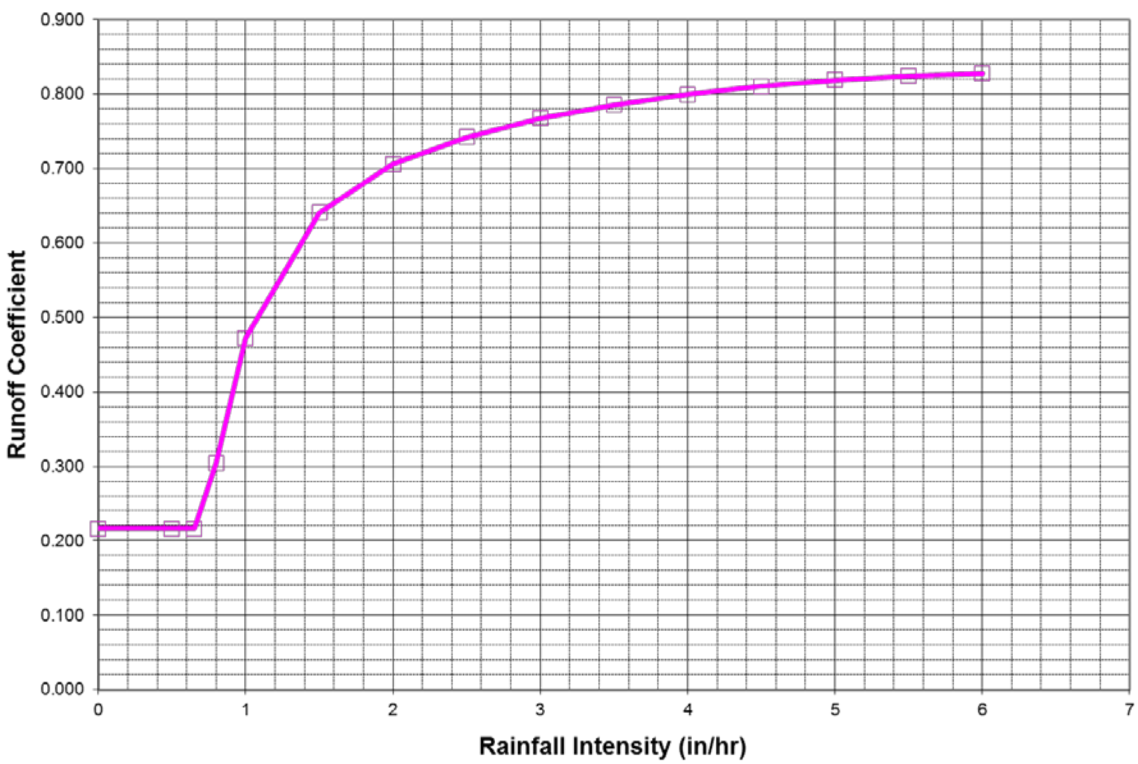
B-1.3 Composite Runoff Coefficient Curve Data

	Soil Number						
	Soil 4			Soil 5			
	Undeveloped	Single Family 1/4 ac. lots	Commercial	Undeveloped	Single Family 1/4 ac. lots	Commercial	
	Effective Imperviousness (%)						
	0	23	-	-	23	-	
	Land Use Area (ac)						Total Area
	1.3	12.2	-	-	10.5	-	24.0
	Percent of Total Area (%)						Total Percent
	5.4	50.8	-	-	43.8	-	100.0
	Pervious Area Infiltration Rate (in/hr)						
	0.65			0.80			
Int. (in/hr)	Runoff Coefficients						Comp Coeff. C
0	0.000	0.229			0.229		0.217
0.5	0.000	0.229			0.229		0.217
0.65	0.000	0.229			0.229		0.217
0.8	0.200	0.379			0.229		0.304
1	0.370	0.511			0.440		0.472
1.5	0.567	0.667			0.620		0.641
2	0.647	0.728			0.688		0.706
2.5	0.692	0.764			0.723		0.742
3	0.727	0.790			0.747		0.768
3.5	0.752	0.808			0.763		0.785
4	0.772	0.822			0.777		0.800
4.5	0.784	0.834			0.787		0.811
5	0.794	0.843			0.794		0.819
5.5	0.802	0.848			0.800		0.824
6	0.808	0.851			0.803		0.828

Sample Calculation for Intensity = 2.0 in/hr:

Composite C=(0.675*5.4/100)+(0.738*50.8/100)+(0.681*43.8/100) = 0.710

B-1.4 Composite Runoff Coefficient Curve



B-2 EXAMPLE 1 (CONT.) - CALCULATING A RUNOFF HYDROGRAPH

If only an instantaneous peak flow rate is desired at the reference point, the peak flow can be computed with A=CIA using the appropriate intensity and runoff coefficient. However, if flood routing is necessary, or a flood-detention basin is to be sized for a small development, a runoff hydrograph will need to be computed. The procedure continues as follows.

1. Using an appropriate tabulation of rainfall intensities selected from 2006 Hydrology Manual Exhibits 2a-5d, tabulate intensity for selected storm times as shown in Exhibit B-2.1.

2. Using the composite runoff coefficient curve for the watershed, tabulate as shown in Exhibit B-2.1 the runoff coefficient for each intensity value.

3. Compute the flow rate for each storm time using the rational equation and plot the resulting runoff hydrograph as shown in Exhibit B-2.3.

4. Calculate the area under the hydrograph and convert to runoff volume in inches as shown in Exhibit B-2.2, and compare with the 24-hour rainfall amount at the centroid of the watershed as shown in the isohyetal maps in Appendix E. Expected runoff volume can be estimated from nearby raingage and streamflow records if available. Expected volume can also be estimated from synthetic rainfall-runoff relationships such as the Soil Conservation Service method for computing runoff using 24-hour rainfall and an appropriate runoff curve number as described in Section 4.

5. If the percentage of runoff is less than the expected volume from that watershed, the hydrograph should be adjusted using a technique similar to that shown in Exhibit B-2.2. The adjustment procedure is as follows:

    a. Compute a runoff coefficient curve adjustment factor by determining the ratio of desired yield to actual yield.

    b. Adjust the runoff coefficient curve using the adjustment factor, and plot a new curve as shown in Exhibit B-2.1.

    c. Using the peak flow determined above, compute C*I in cfs/acre.

    d. From the adjusted runoff coefficient curve, find a combination of C and I such that their product equals the value determined in c., above.

    e. From the appropriate intensity-duration curve, select a revised duration corresponding to the average rainfall intensity determined in d. and use as a revised time of concentration for the watershed.

    f. As shown in Exhibit B-2.1, tabulate adjusted rainfall intensities, adjusted runoff coefficients, and compute an adjusted runoff hydrograph.

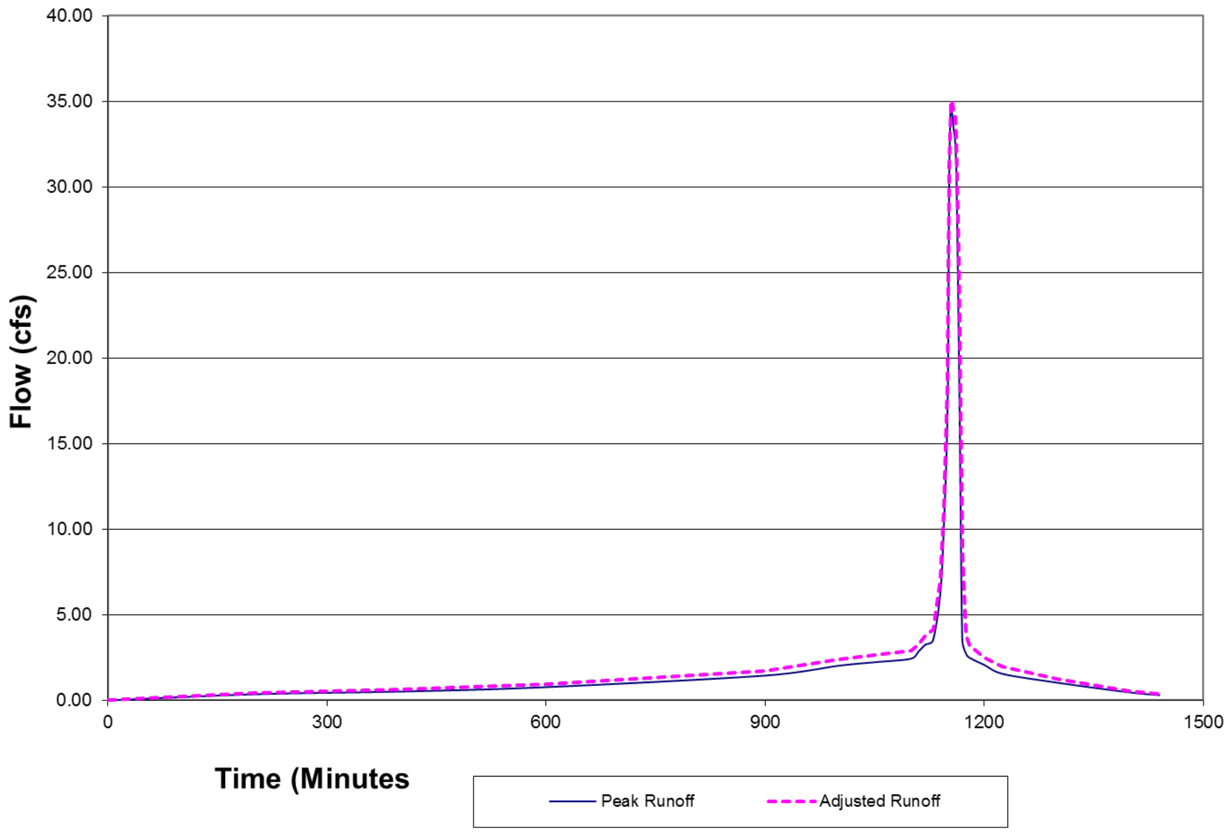
6. Plot the adjusted hydrograph and check its runoff volume as shown in Exhibit B-2.3

B-2.1 Hydrograph and Hydrograph Adjustment Calculations

K Zone 10-Year Recurrence Storm								
Storm Time (min)	Rainfall Intensity (in/hr) Tc=15 min	Runoff Coefficient C	Q=CIA (cfs) A=24 ac	Incremental Hydrograph Volume (ac-ft)	Rainfall Intensity (in/hr) Tc=21 min	Adjusted Runoff Coeff C(P)	Qadj = Cadj I A (cfs) A=24 ac	Incremental Hydrograph Volume (ac-ft)
0	0.00	0.217	0.00		0	0.258	0.00	
200	0.07	0.217	0.36	0.05	0.07	0.258	0.43	0.06
400	0.10	0.217	0.52	0.12	0.10	0.258	0.62	0.15
600	0.15	0.217	0.78	0.18	0.15	0.258	0.93	0.21
900	0.28	0.217	1.46	0.46	0.28	0.258	1.74	0.55
1000	0.39	0.217	2.03	0.24	0.39	0.258	2.42	0.29
1050	0.43	0.217	2.24	0.15	0.43	0.258	2.67	0.18
1100	0.47	0.217	2.44	0.16	0.47	0.258	2.91	0.19
1110	0.55	0.217	2.86	0.04	0.53	0.258	3.29	0.04
1120	0.63	0.217	3.27	0.04	0.61	0.258	3.78	0.05
1130	0.66	0.222	3.52	0.05	0.65	0.265	4.14	0.05
1140	0.82	0.321	6.31	0.07	0.77	0.382	7.07	0.08
1145	0.97	0.447	10.41	0.06	0.88	0.533	11.26	0.06
1150	1.28	0.567	17.41	0.10	1.15	0.676	18.66	0.10
1152	1.83	0.684	30.04	0.07	1.60	0.816	31.33	0.07
1154	2.04	0.709	34.71	0.09	1.72	0.846	34.92	0.09
1156	2.02	0.708	34.30	0.10	1.73	0.844	35.05	0.10
1158	1.98	0.704	33.43	0.09	1.71	0.839	34.44	0.10
1160	1.95	0.700	32.74	0.09	1.70	0.835	34.05	0.09
1162	1.86	0.688	30.71	0.09	1.66	0.821	32.69	0.09
1166	1.31	0.577	18.14	0.13	1.55	0.688	25.60	0.16
1170	0.66	0.222	3.52	0.06	1.36	0.265	8.66	0.09
1175	0.53	0.217	2.76	0.02	0.62	0.258	3.84	0.04
1180	0.48	0.217	2.50	0.02	0.52	0.258	3.22	0.02
1200	0.40	0.217	2.08	0.06	0.40	0.258	2.48	0.08
1225	0.30	0.217	1.56	0.06	0.32	0.258	1.98	0.08
1300	0.20	0.217	1.04	0.13	0.20	0.258	1.24	0.17
1400	0.09	0.217	0.47	0.10	0.09	0.258	0.56	0.12
1440	0.06	0.217	0.31	0.02	0.06	0.258	0.37	0.03
			Total				Total	
			Vol (ac-ft)	2.85			Vol (ac-ft)	3.34

B-2.2 Hydrograph Volume Adjustment Steps

Hydrograph Volume Adjustment					
1. Watershed Yield					
Areally Weighted CN=73.5					
From Contour Map, 10Yr Rainfall= 4.3 inches					
From SCS Direct Runoff Figure, Runoff = 1.7 inches					
Watershed Yield = 1.7/4.3=0.395 or 0.40					
2. Hydrograph Volume, Tc=15 min= 2.85 ac-ft					
Yield (24 ac) =		1.425	inches		
3. Desired Yield Adjustment Factor					
P=Desired Yield/Actual Yield = 1.7/1.425 =				1.19	
4. Calculate (CI) for Peak Q					
CI= Q/A= 2.04 in/hr * 0.709 =			1.45	cfs/ac	
5. Increase C Coefficients By Adjustment Factor					
6. Find intensity with increased C that gives same CI					
	Max C=	0.846			
	I= C*I/C=1.45/0.846=		1.71	in/hr	
7. Find Tc on K Zone 10-Yr Intensity Table with peak intensity					
	Tc= 21 min				
8. Recalculate Q's Using					
	C from adjusted runoff coefficient curve				
	I for Tc= 21 min				
	Area as above (24 ac)				



B-2.3 Runoff Hydrograph with Adjustment

B-3 VCRAT PROGRAM USE FOR MULTIPLE SUBAREAS

1. Watershed Delineation- Carefully outline the drainage boundary on a topographic map. With reference to other larger scale maps, known improvement plans, and planned improvements, decisions governed by topography alone must be adjusted to reflect an ultimate drainage boundary.

2. Field Verification- Verify drainage boundary map with a field trip to the area and incorporate any changes on the map.

3. Subarea Delineation- Divide the watershed into subareas ranging from 40 to 80 acres in size. Where areas tributary to the main collector channel exceed the maximum size, a separate lateral channel is delineated and the contributing area is also subdivided.

4. Beginning with the point of concentration of the hydraulically most remote subarea, assign a number representing each point in the drainage system where a Q is to be determined. The main channel is designated the “A”-line and subareas are numbered sequentially in VCRat2.2 (i. e., lA, 2A, 3A, etc.).

5. Laterals are assigned a letter from B to F preceded by the next number in sequence (i.e., llB, 12B, 14C, etc.).

6. At a lateral-main line confluence, the next number in sequence is followed by letters representing both lines, with the primary channel listed first (i. e. l6AB).

7. Using the hydrologic maps or GIS files in Appendix E, prepare a soils overlay of the watershed. Place the soils map over the watershed and determine which soil type is dominant in each subarea.

8. For future land use conditions, determine anticipated ultimate development from best sources available (current zoning, Planning Department master plans, development trends in surrounding area). Undeveloped, single family residential and commercial development should encompass most areas, with occasional classifications of heavy industrial or large estate lots. Prepare land-use map of watershed.

9. Assign an impervious percentage to each development using the general classifications in Exhibit 15. When a subarea has more than one development type, a weighted average imperviousness should be determined.

10. Planimeter or use GIS to calculate the area of each subarea and check by totaling all subareas and comparing with the total watershed area.

11. From provided maps or shapefiles, determine the appropriate rainfall intensity zone.

12. Using the form and the hand-calculation procedures described above or Tc calculator program, compute time of concentration for all subareas.

13. Determine the length and average slope of conveyance channels between collection points.

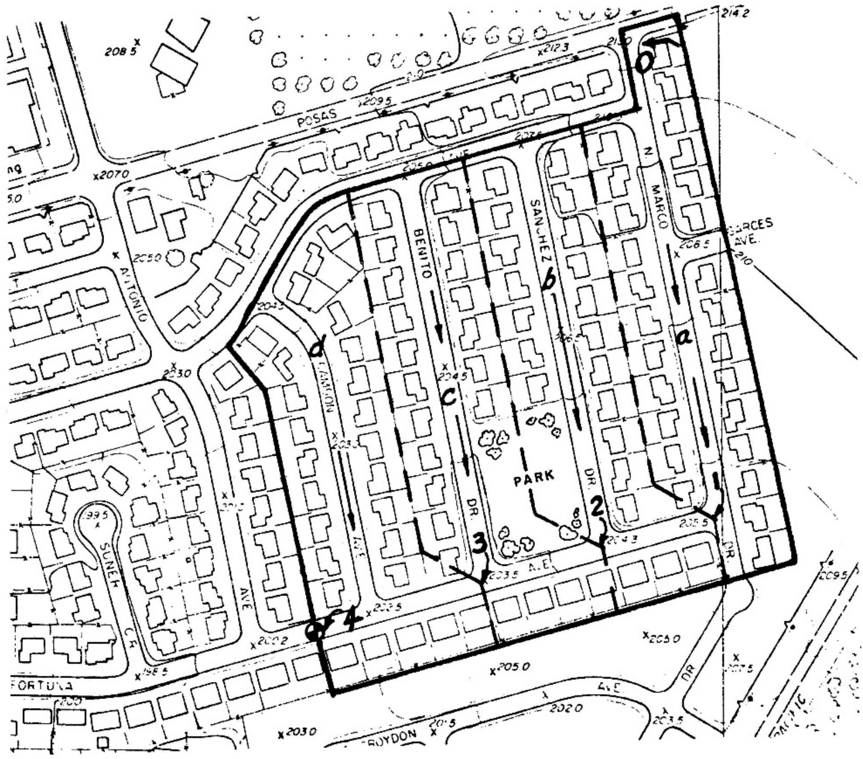
14. Sufficient watershed data is now available to code the input for VCRat2.2 or VCRat 2.6. A detailed description of input data for each column is included in below. An input data line is needed for each subarea and confluence with sufficient data listed for the computation of a runoff hydrograph and flood routing of each hydrograph through the indicated conveyance channel. To clear the hydrograph memory at the start of a run, a letter G should be placed in Column 64, Row 1, in the first 006 data line for each VCRat2.2 job. Place a number 1 in Column 63 in each row where confluence flow and timing data are required, and in Column 62 in each row where a printed hydrograph is desired. A page heading data line, is needed for each job that will clearly identify the job, and for each point at which a hydrograph has been specified.

15. Data input for the seven runoff coefficient curves are included as input for the program in the default file VCRAIN.DAT. If composite runoff coefficient curves are needed for a watershed, they should be calculated and entered in the VCRAIN.DAT file.

Computer input and output for an example watershed are provided below.

NOTE: The VCRat programs perform complex channel routing calculations with wave velocity so that it is not possible to reproduce the results of the VCRat model by hand at this time. If several subareas are modeled and require channel routing, the hydrologist must obtain the VCRat program from the District in order to perform the design study correctly.

B-3.1 Tc Program Example- Las Posas



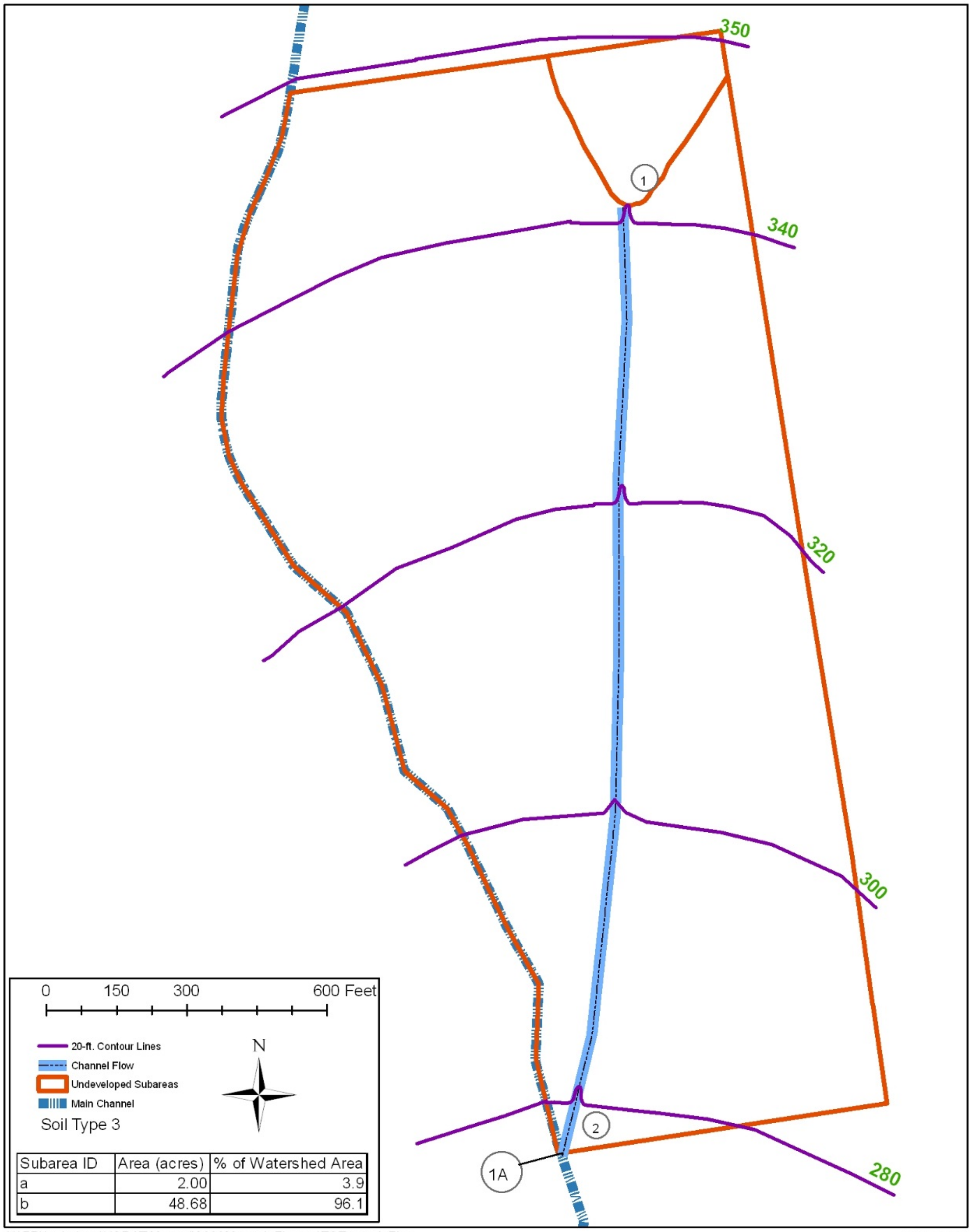

```
VENTURA COUNTY WATERSHED PROTECTION DISTRICT
TIME OF CONCENTRATION
TC Program Version: 2.6.2008.11
Project: Las Posas Manual Example
Date: 5/27/2010 1:52:09 PM
Engineer: TMB
Consultant: VCWPD
------------------------------------------------------------------------
           S U M M A R Y   O F   C O M P U T A T I O N S
------------------------------------------------------------------------
Watershed Name: Las Posas
------------------------------------------------------------------------
Name                  Zone   Storm   Soil   Area (acres)       TC (min)
------------------------------------------------------------------------
Single Family and Par  K        10   4.00    24.0 /  24     15.003 / 15
------------------------------------------------------------------------
------------------------------------------------------------------------
Watershed Name: Las Posas
------------------------------------------------------------------------
Sub-Area Name: Single Family and Park
Tc: 15.003 Minutes
DATA FOR SUB AREA 1
------------------------------------------------------------------------
SUB AREA TIME OF CONCENTRATION: 15.003 min. = 15 min.
------------------------------------------------------------------------
SUB AREA INPUT DATA
```

```
----------------------------------------------------------------------
Sub Area Name: Single Family and Park
Total Area (ac): 24
Flood Zone: 3
Rainfall Zone: K
Storm Frequency (years): 10
Development Type: Residential
Soil Type: 4.00
Percent Impervious: 23
SUB AREA OUTPUT
----------------------------------------------------------------------
Intensity (in/hr): 2.044
C Total: 0.720
Sum Q Segments (cfs): 35.31
Q Total (cfs): 35.31
Sum Percent Area (%): 100.0
Sum of Flow Path Travel Times (sec): 900.17
Time of Concentration (min): 15.003
----------------------------------------------------------------------
DATA FOR FLOW PATH 1
----------------------------------------------------------------------
Flow Path Name: Overland
FLOW PATH TRAVEL TIME (min): 5.7681
Flow Type: Overland
Length (ft): 140
Top Elevation (ft): 214
Bottom Elevation (ft): 213
Contributing Area (acres): 1.2
Percent of Sub-Area (%): 5.0
Overland Type: Valley
Development Type: Residential
Map Slope: 0.0071
Effective Slope: 0.0071
Q for Flow Path (cfs): 1.77
Avg Velocity (ft/s): 0.40
Passed Scour Check: N/A
----------------------------------------------------------------------
DATA FOR FLOW PATH 2
----------------------------------------------------------------------
Flow Path Name: Subarea A
FLOW PATH TRAVEL TIME (min): 5.5823
Flow Type: Street
Length (ft): 1040
Top Elevation (ft): 213
Bottom Elevation (ft): 205.5
Contributing Area (acres): 4.32
Percent of Sub-Area (%): 18.0
Street Width (ft): 32
Curb Height (in): 6
Map Slope: 0.0072
Q for Flow Path (cfs): 6.36
Q Top (cfs): 1.77
Q Bottom (cfs): 8.12
Velocity Top (ft/s): 1.68
Velocity Bottom (ft/s): 2.46
Avg Velocity (ft/s): 2.07
Wave Velocity (ft/s): 3.11
----------------------------------------------------------------------
DATA FOR FLOW PATH 3
----------------------------------------------------------------------
Flow Path Name: Subarea B
FLOW PATH TRAVEL TIME (min): 1.1873
Flow Type: Street
```

```
Length (ft): 250
Top Elevation (ft): 205.5
Bottom Elevation (ft): 204.3
Contributing Area (acres): 6.48
Percent of Sub-Area (%): 27.0
Street Width (ft): 32
Curb Height (in): 6
Map Slope: 0.0048
Q for Flow Path (cfs): 9.53
Q Top (cfs): 8.12
Q Bottom (cfs): 17.65
Velocity Top (ft/s): 2.11
Velocity Bottom (ft/s): 2.57
Avg Velocity (ft/s): 2.34
Wave Velocity (ft/s): 3.51
------------------------------------------------------------------------
DATA FOR FLOW PATH 4
------------------------------------------------------------------------
Flow Path Name: Subarea C
FLOW PATH TRAVEL TIME (min): 1.1988
Flow Type: Street
Length (ft): 250
Top Elevation (ft): 204.3
Bottom Elevation (ft): 203.5
Contributing Area (acres): 5.76
Percent of Sub-Area (%): 24.0
Street Width (ft): 32
Curb Height (in): 6
Map Slope: 0.0032
Q for Flow Path (cfs): 8.47
Q Top (cfs): 17.65
Q Bottom (cfs): 26.13
Velocity Top (ft/s): 2.20
Velocity Bottom (ft/s): 2.43
Avg Velocity (ft/s): 2.32
Wave Velocity (ft/s): 3.48
------------------------------------------------------------------------
DATA FOR FLOW PATH 5
------------------------------------------------------------------------
Flow Path Name: Subarea D
FLOW PATH TRAVEL TIME (min): 1.2663
Flow Type: Street
Length (ft): 370
Top Elevation (ft): 203.5
Bottom Elevation (ft): 201.2
Contributing Area (acres): 6.24
Percent of Sub-Area (%): 26.0
Street Width (ft): 32
Curb Height (in): 6
Map Slope: 0.0062
Q for Flow Path (cfs): 9.18
Q Top (cfs): 26.13
Q Bottom (cfs): 35.31
Velocity Top (ft/s): 3.12
Velocity Bottom (ft/s): 3.37
Avg Velocity (ft/s): 3.25
Wave Velocity (ft/s): 4.87
```

B-4 TC PROGRAM EXAMPLE UNDEVELOPED WATERSHED- CLARKE BARRANCA

B-4.1 Watershed Map



K:\PR\hydrology\VCRATManual\2006Manual_Figures\TCExampleFigs 01/09/2006

B-4.2 Tc Calculator Results

```
VENTURA COUNTY WATERSHED PROTECTION DISTRICT
TIME OF CONCENTRATION
TC Program Version: 2.6.2008.11
Project: Clark Barranca - Tc Example 3
Date: 5/27/2010 1:52:09 PM
Engineer:
Consultant: VCWPD
------------------------------------------------------------------------
           S U M M A R Y   O F   C O M P U T A T I O N S
------------------------------------------------------------------------
Watershed Name: Watershed
------------------------------------------------------------------------
Name                  Zone   Storm   Soil   Area (acres)        TC (min)
------------------------------------------------------------------------
Clark Barranca         K       100   3.00    50.6 /  51     12.186 / 12
------------------------------------------------------------------------


------------------------------------------------------------------------
Watershed Name: Watershed
------------------------------------------------------------------------
Sub-Area Name: Clark Barranca
Tc: 12.186 Minutes
DATA FOR SUB AREA 1
------------------------------------------------------------------------
SUB AREA TIME OF CONCENTRATION: 12.186 min. = 12 min.
------------------------------------------------------------------------
SUB AREA INPUT DATA
------------------------------------------------------------------------
Sub Area Name: Clark Barranca
Total Area (ac): 50.6
Flood Zone: 2
Rainfall Zone: K
Storm Frequency (years): 100
Development Type: Undeveloped
Soil Type: 3.00
Percent Impervious: 0
SUB AREA OUTPUT
------------------------------------------------------------------------
Intensity (in/hr): 3.230
C Total: 0.788
Sum Q Segments (cfs): 128.72
Q Total (cfs): 128.72
Sum Percent Area (%): 100.0
Sum of Flow Path Travel Times (sec): 731.17
Time of Concentration (min): 12.186
------------------------------------------------------------------------
DATA FOR FLOW PATH 1
------------------------------------------------------------------------
Flow Path Name: Overland Area A
FLOW PATH TRAVEL TIME (min): 8.5319
Flow Type: Overland
Length (ft): 424
Top Elevation (ft): 350
Bottom Elevation (ft): 340
Contributing Area (acres): 1.97
Percent of Sub-Area (%): 3.9
Overland Type: Valley
Development Type: Undeveloped
Map Slope: 0.0236
Effective Slope: 0.0236
```

```
Q for Flow Path (cfs): 5.01
Avg Velocity (ft/s): 0.83
Passed Scour Check: YES
Scour Velocity (ft/sec): 3.20
----------------------------------------------------------------------
DATA FOR FLOW PATH 2
----------------------------------------------------------------------
Flow Path Name: Valley Channel
FLOW PATH TRAVEL TIME (min): 3.6543
Flow Type: Natural Channel
Length (ft): 2040
Top Elevation (ft): 340
Bottom Elevation (ft): 280
Contributing Area (acres): 48.63
Percent of Sub-Area (%): 96.1
Overland Type: Valley
Map Slope: 0.0294
Effective Slope: 0.0294
Q for Flow Path (cfs): 123.71
Q Top (cfs): 5.01
Q Bottom (cfs): 128.72
Velocity Top (ft/s): 3.62
Velocity Bottom (ft/s): 8.79
Avg Velocity (ft/s): 6.20
Wave Velocity (ft/s): 9.30
```

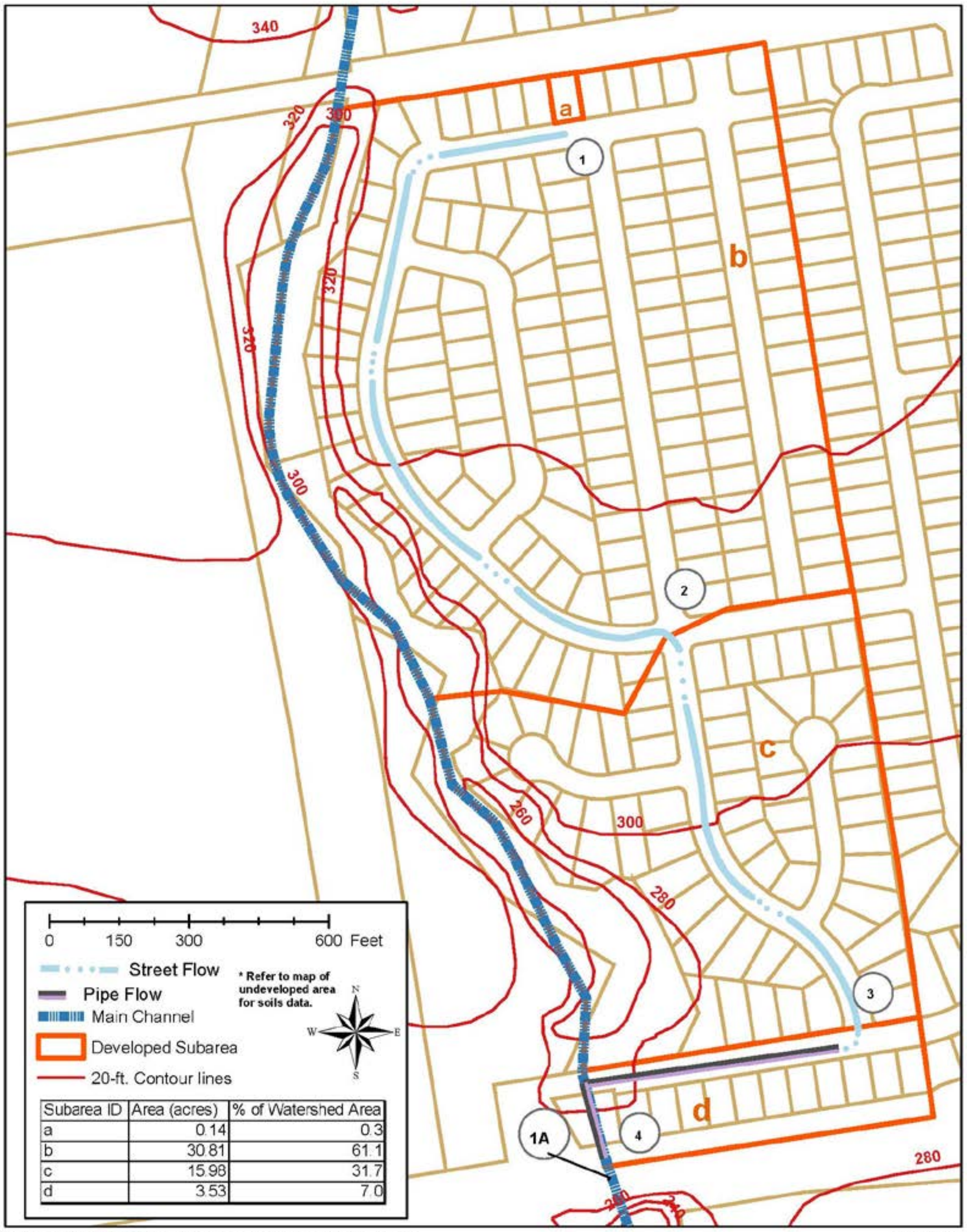
B-5 EXAMPLE 4 DEVELOPED WATERSHED- CLARKE BARRANCA

B-5.1 Aerial Map

Subarea ID	Area (acres)	% of Watershed Area
a	0.14	0.3
b	30.81	61.1
c	15.98	31.7
d	3.53	7.0

K:\PR\hydrology\VCRAT\Manual\2006Manual_Figures\TCExampleFigs 01/09/2007

B-5.2 Parcel Map



Subarea ID	Area (acres)	% of Watershed Area
a	0.14	0.3
b	30.81	61.1
c	15.98	31.7
d	3.53	7.0

K:\PR\hydrology\VCRAT\Manual\2006Manual_Figures\TCExampleFigs 01/09/2007

B-5.3 Tc Calculator Results

```
VENTURA COUNTY WATERSHED PROTECTION DISTRICT
TIME OF CONCENTRATION
TC Program Version: 2.6.2008.11
Project: Clark Barranca - Tc Example 4
Date: 5/27/2010 1:52:09 PM
Engineer: TMB
Consultant: VCWPD
------------------------------------------------------------------------
           S U M M A R Y   O F   C O M P U T A T I O N S
------------------------------------------------------------------------
Watershed Name: Clark Barranca
------------------------------------------------------------------------
Name                  Zone   Storm   Soil   Area (acres)        TC (min)
------------------------------------------------------------------------
Clark Barranca         K       100   3.00    50.7 /  51      8.291 /  8
------------------------------------------------------------------------


------------------------------------------------------------------------
Watershed Name: Clark Barranca
------------------------------------------------------------------------
Sub-Area Name: Clark Barranca
Tc: 8.291 Minutes
DATA FOR SUB AREA 1
------------------------------------------------------------------------
SUB AREA TIME OF CONCENTRATION: 8.291 min. = 8 min.
------------------------------------------------------------------------
SUB AREA INPUT DATA
------------------------------------------------------------------------
Sub Area Name: Clark Barranca
Total Area (ac): 50.65
Flood Zone: 2
Rainfall Zone: K
Storm Frequency (years): 100
Development Type: Residential
Soil Type: 3.00
Percent Impervious: 50
SUB AREA OUTPUT
------------------------------------------------------------------------
Intensity (in/hr): 3.953
C Total: 0.882
Sum Q Segments (cfs): 176.62
Q Total (cfs): 176.62
Sum Percent Area (%): 100.0
Sum of Flow Path Travel Times (sec): 497.44
Time of Concentration (min): 8.291
------------------------------------------------------------------------
DATA FOR FLOW PATH 1
------------------------------------------------------------------------
Flow Path Name: Overland Area A
FLOW PATH TRAVEL TIME (min): 2.0317
Flow Type: Overland
Length (ft): 100
Top Elevation (ft): 347
Bottom Elevation (ft): 345
Contributing Area (acres): 0.15
Percent of Sub-Area (%): 0.3
Overland Type: Valley
Development Type: Residential
Map Slope: 0.0200
Effective Slope: 0.0200
```

```
Q for Flow Path (cfs): 0.52
Avg Velocity (ft/s): 0.82
Passed Scour Check: N/A
-----------------------------------------------------------------------
DATA FOR FLOW PATH 2
-----------------------------------------------------------------------
Flow Path Name: Street Area B
FLOW PATH TRAVEL TIME (min): 4.4400
Flow Type: Street
Length (ft): 1750
Top Elevation (ft): 345
Bottom Elevation (ft): 310
Contributing Area (acres): 30.92
Percent of Sub-Area (%): 61.0
Street Width (ft): 32
Curb Height (in): 6
Map Slope: 0.0200
Q for Flow Path (cfs): 107.82
Q Top (cfs): 0.52
Q Bottom (cfs): 108.34
Velocity Top (ft/s): 1.82
Velocity Bottom (ft/s): 6.94
Avg Velocity (ft/s): 4.38
Wave Velocity (ft/s): 6.57
-----------------------------------------------------------------------
DATA FOR FLOW PATH 3
-----------------------------------------------------------------------
Flow Path Name: Street Area C
FLOW PATH TRAVEL TIME (min): 1.3622
Flow Type: Street
Length (ft): 925
Top Elevation (ft): 310
Bottom Elevation (ft): 290
Contributing Area (acres): 16.04
Percent of Sub-Area (%): 31.7
Street Width (ft): 32
Curb Height (in): 6
Map Slope: 0.0216
Q for Flow Path (cfs): 55.93
Q Top (cfs): 108.34
Q Bottom (cfs): 164.28
Velocity Top (ft/s): 7.15
Velocity Bottom (ft/s): 7.94
Avg Velocity (ft/s): 7.55
Wave Velocity (ft/s): 11.32
-----------------------------------------------------------------------
DATA FOR FLOW PATH 4
-----------------------------------------------------------------------
Flow Path Name: Pipe Area D
FLOW PATH TRAVEL TIME (min): 0.4567
Flow Type: Pipe
Length (ft): 600
Top Elevation (ft): 290
Bottom Elevation (ft): 280
Contributing Area (acres): 3.54
Percent of Sub-Area (%): 7.0
Initial Pipe Diameter (in): 48
Calculated Pipe Diameter (in): 48
Used Pipe Diameter (in): 48
Manning's N: 0.012
Map Slope: 0.0167
Q for Flow Path (cfs): 12.34
Q Top (cfs): 164.28
```

```
Q Bottom (cfs): 176.62
Avg Velocity (ft/s): 17.90
Wave Velocity (ft/s): 21.89
-
```

B-6 VCRAT2.2 PROGRAM INPUT DATA

VCRat2.2 program input data must be included in the order shown except for the data marked as optional in the following list:

a. System Data.

b. Page Heading Data.

c. System Data.

d. Hydrograph Header Data. (Optional)

e. Hydrograph Data (Optional)

f. System Data.

g. Location Data.

h. Reservoir Routing and Yield Adjustment Data

i. System Data.

j. Runoff Coefficient Curve Data.

k. Rainfall Mass Curve Header Data.

l. Rainfall Mass Curve Data.

m. System Data.

VCRat2.6 and 2.64 require the same data but the Windows interface formats the input file for the modeler. The VCRat2.2 input file does not use decimals as it was critical to reduce memory requirements when the program was written in the 1970s.

B-6.1 Input Data Preparation

Page Heading Input Data (Code 005)- Required

Column	Entry	Description
1-3	005	Input code number.
4-9	integer	Job number to identify watershed or drain. For VCWPD models, this is the 5-digit project number associated with each jurisdictional channel.
10-14	integer	Identification point which must be identical to the most upstream point on the location layout sheet.
15-16	alphabetic	Drain label which must be identical to those indicated on location layout sheet Column.
17-80	alphanumeric	Description to be printed.

The end of the 005 input data is specified by entering 999 in the first three columns of the line after the last 005 data.

Hydrograph Data Header (Code 007) - Required

This line is required for all locations where the user wants import a hydrograph into the model.

Column	Entry	Description
1-3	007	Input code number.
4-9	integer	Job number to identify watershed or drain. For VCWPD, this is the 5-digit project number associated with each redline channel.
10-15	alphanumeric	Location number of point where hydrograph to be read in.
16-23	integer	Drainage area tributary to location in acres. If omitted the total watershed area of the model will be incorrect.
24-26	integer	Number of points used to define rising limb of hydrograph (point number of peak Q).
27-30	integer	Time of peak flow in minutes.
31-38	integer	Peak flow rate in cubic feet per second.
39-41	integer	Total number of points used to define hydrograph.
42-44	1	If first day of four-day design storm.
	2	If second day of four-day design storm.
	3	If third day of four-day design storm.
	4	If fourth day of four-day design storm.

Hydrograph Data (Code 008) Input

This input is required after 007 input data are provided.

Column	Entry	Description
1-3	008	Input code number.
4-6	integer	Maximum cumulative point number on each input line.
7-11	integer	Selected storm time in minutes.

12-20	integer	Instantaneous flow rate in cubic feet per second corresponding to storm time listed in Column 7-11.
20-24	integer	Selected storm time.
25-32	integer	Instantaneous flow rate corresponding to storm time listed in Column 20-24.
33-37	integer	Selected storm time.
38-45	integer	Instantaneous flow rate corresponding to storm time listed in Column 33-37.
46-50	integer	Selected storm time.
51-58	integer	Instantaneous flow rate corresponding to storm time listed in Column 46-50.
59-63	integer	Selected storm time.
64-71	integer	Instantaneous flow rate corresponding to storm time listed in Column 59-63.
Selected storm times may vary between 0 and 1500 minutes up to a maximum 200 points and must be listed chronologically. If default J through L zone rainfall mass curves are used, all hydrograph points for times described in the Exhibit 17 must be used. If A through I or T storm patterns are used, times to define a hydrograph must be the same times used to define the cumulative storm rainfall curve.		

The end of the 007 and 008 input is specified by entering 999 in the first three columns of the last 008 data line.

Location Data (Code 006) - Required

This data input line generally follows 005 input data, or 007 and 008 input lines if a hydrograph has been imported for use in the simulation. A line with 999 in the first three columns precedes the first 006 line signifying the end of the header data lines or hydrograph import section.

Column	**Entry**	**Description**
1-3	006	Input code number.
4-9	integer	Job number to identify watershed or drain.
10-14	integer	Location number or model ID of point in the watershed where a calculation is to be made. Location numbers must be listed in the sequence calculations are to be made and numbered sequentially from upstream to downstream without gaps.

Column	Entry	Description
15	A	If hydrograph in main line of the drainage system located in primary storage.
	B	If hydrograph in main line of the drainage system located in primary storage.
	C	If hydrograph in Lateral C located in primary storage.
	D	If hydrograph in Lateral D located in primary storage.
	E	If hydrograph in Lateral E located in primary storage.
	F	If hydrograph in Lateral F located in primary storage.
		The alphabetic code identifies the drain where flow rate is to be modified by: (1) addition of a hydrograph from a lateral or subarea; (2) separation of flow by junction with a relief drain; (3) flood routing and channel storage effects. A letter must be listed on each location data input line.
16	B	If hydrograph in principal Lateral B to be combined with hydrograph in the main line.
	C	If hydrograph in Lateral C to be combined with hydrograph in Line A or B.
	D	If hydrograph in Lateral D to be combined with hydrograph in Lines A, B or C.
	E	If hydrograph in Lateral E to be combined with hydrograph in Lines A, B, C, or D.
	F	If hydrograph in Lateral F to be combined with hydrograph in Lines A, B, C, D, or E.
		For relief drains (See Column 53-59.) the alphanumeric code indicates the lateral receiving flow separated from the primary drain.
17	integer	Place 0 in this column when one of seven standard runoff coefficient curves is used.
18	integer	When one of the seven standard runoff coefficient curves are used, place a number from 1 through 7 in this column.
19	integer	Place 0 in this column when one of seven standard runoff coefficient curves is used.
		When a composite runoff coefficient curve is used, any integer designation between 002 through 199 may be used in columns 17-19.
20-22	integer	Effective imperviousness of subarea in percent.
23-26	integer	Subarea tributary drainage in acres.

Column	Entry	Description
27-28	integer	Time of concentration in minutes. An arbitrary time for a zero acre subarea in Column 23-26 must be shown if flood routing through a reach with no tributary area is desired- 99 is typically used.
29	alphabetic	If storm pattern D through I for other than design storm rainfall to be used.
	J (or A)	If J or J’ zone design storm rainfall pattern to be used. (For 100-year frequency rainfall use A; also for areal reduction runs.)
	K (or B)	If K zone design storm rainfall pattern to be used. (For 100-year frequency rainfall use B.)
	L (or C)	If L zone design storm rainfall pattern to be used. (For 100-year frequency rainfall use C, also for areal reduction runs.)
	T	If design thunderstorm rainfall pattern to be used. Also used for simulations to evaluate areal reduction for K Zone 50-yr storms
30-31	integer	If A through I storm pattern to be used, an identification number between 1 and 99 must also be used.
	01	If thunderstorm (convective storm) design rainfall pattern to be used. Also used for simulations to evaluate areal reduction for K zone 50-yr storms.
	10	If 10 - year frequency rainfall for J, K, L zone rainfall to be used.
	25	If 25 - year frequency rainfall for J, K, L zone rainfall to be used.
	50	If 50 - year frequency rainfall for J, K, L zone rainfall to be used.
	96	If 100-year frequency rainfall for D zone rainfall to be used.
	97	If 100-year frequency rainfall for A zone rainfall to be used.
	98	If 100-year frequency rainfall for B zone rainfall to be used.
	99	If 100-year frequency rainfall for C zone rainfall to be used.
32	integer	Specify the type of channel to use for routing to next confluence point
	1	If mountain channel reach to be used. (See Exhibit 9.)
	2	If natural valley channel reach to be used. (SeeExhibit 10)
	3	If typical 40-foot road width, 8-inch curb street to be used. (SeeExhibit 11d)
	4	If circular pipe to be used, or if street flow is undesirable.
	5	If rectangular or trapezoidal channel base width or depth to be specified. (Trapezoidal section side slope can be specified as well as Manning's n values.)

Column	Entry	Description
	6	If trapezoidal channel side slope, maximum peak velocity, and either width or depth to be specified. The trapezoidal channel (6) may involve composite lining with unlined bottom to facilitate channel percolation, or for economic or other design considerations. In steeper areas where scour of the channel bottom could occur, the system routes flow by adjusting channel slope as necessary (drop structures assumed) to not exceed the specified maximum velocity at peak flow rate in Cols 76-77. Specified values would be: (1) maximum velocity and maximum depth; or (2) maximum velocity and base width.
	blank	If the system is to begin flood routing in a street section and change from street to pipe section when flow depth reaches the property line, from pipe to rectangular channel when pipe diameter of 8 feet is exceeded, and from the hydraulically most efficient rectangular section to a maximum depth of 13 feet when that depth is reached. [This change in conveyance is also automatic if either street (3) or pipe (4, with no size listed) is specified].
33-37	integer	Length of channel reach between subarea collection points in feet.
38-43	numeric	Slope of drain in feet per foot. Decimal is not used but is assumed to be between columns 37 and 38. If the field does not have spaces to column 43, VCRat2.64 may not read the slope data correctly.
44-46	numeric	If trapezoidal channel (5 or 6 in Column 32). Computed as horizontal projection of channel wall divided by depth in feet per foot. Decimal is not used but is assumed to be between columns 44 and 45.
	blank	If rectangular section.
47-52	numeric	If specified circular pipe diameter in feet is to be used (4 in Column 32). Decimal is not used but is assumed to be between columns 50 and 51. If 3 is specified in Column 32, then any width in these fields will force the flow to stay in the street no matter how large the flow is.
	numeric	If specified bottom width of rectangular channel in feet is to be used (5 in Column 32).
	numeric	If specified bottom width of trapezoidal channel in feet is to be used (6 in Column32).
	blank	For channel types 1, 2, and 3, or if the user wishes the program to size the appropriate channel for types 4, 5, or 6.
53-59	integer	Peak flow rate in cubic feet per second (no decimal) to remain in main line or lateral listed in Column 15 at junction with relief drain specified (3 or 4 in Column 60).

Column	Entry	Description
	integer	Flow rate to be used to as the basis to calculate a percent used to proportion hydrograph and transfer excess to relief drain (1 in Column 60).
	integer	Percent (no decimal) to be applied to hydrograph ordinate to proportion the hydrograph and transfer excess to relief drain (2 in Column 60).
60	1	Hydrograph in drain listed in Column 15 to be proportioned on percentage basis with residual flow transferred to relief drain listed in Column 16. Percentage is calculated by dividing flow number in Columns 53-59 by peak flow calculated by program. Hydrograph remaining in drain will have peak flow listed in Column 53-59. Output will show percent under Control Q column, not input flow number.
	2	Hydrograph in drain listed in Column 15 to be proportioned on percentage basis such that hydrograph remaining in drain has percentage of total flow specified in Column 53-59 with excess flow transferred to relief drain listed in Column 16.
	3	Hydrograph in drain listed in Column 15 to be separated such that all flow up to peak flow rate listed in Column 53-59 remains in the drain with excess flow transferred to relief drain listed in Column 16.
	4	Hydrograph in drain listed in Column 15 to be separated such that only flow above base value (equal to peak minus specified value in Columns 53-59) remains in the drain with all other flow transferred to relief drain listed in Column 16.
61	1	If hydrograph for all four days of a four-day design storm to be computed.
	2	If hydrograph for second, third, and fourth days of four-day design storm to be computed.
	3	If hydrograph for third and fourth days of four-day design storm to be computed.
	blank	If hydrograph for only fourth day (maximum day rainfall) of four-day design storm to be computed, or hydrograph for thunderstorm, or other selected storm rainfall to be computed.
62	1	If hydrograph printout only desired. Requires 005 input data containing location for hydrograph
	2	If hydrograph printout plus output hydrograph file desired.
63	1	Confluence Q printout listing peak flow and time for primary drain and lateral and combined peak and time at downstream end of confluence.
64	A	If hydrograph stored in Line A to be erased.
	B	If hydrograph stored in Line B to be erased.

Column	Entry	Description
	C	If hydrograph stored in Line C to be erased.
	D	If hydrograph stored in Line D to be erased.
	E	If hydrograph stored in Line E to be erased.
	F	If hydrograph stored in Line F to be erased.
	G	If all hydrographs stored in system to be erased (beginning of model).
65	1	If project description heading at beginning of printout and heading for hydrograph printout sheets desired.
	2	If end of job- last data input line.
66	A,B,C,D,E,F	Causes hydrograph data input from Column 15 to be read into main line or lateral listed here.
67	blank	If area reduction not to be computed.
	1	If main line flow to be recomputed using area reduction factor for total drainage area and initially computed drain sizes.
	2	If Lateral B flow to be recomputed using area reduction factor for total drainage area and initially computed drain sizes.
	3	If Lateral C flow to be recomputed using area reduction factor for total drainage area and initially computed drain sizes.
	4	If Lateral D flow to be recomputed using area reduction factor for total drainage area and initially computed drain sizes.
	5	If Lateral E flow to be recomputed using area reduction factor for total drainage area and initially computed drain sizes.
	7	If area reduction to be set at 1.0.
68-70	blank	If minimum n of .014 to be used for channel bottom- channel type 5 or 6.
	numeric	If higher n value for rougher channel bottom to be used for channel type 5 or 6. Decimal is not used but is assumed to be between columns 67 and 68.
71-73	blank	If minimum n of .014 to be used for channel side walls- types 5 and 6.
	numeric	If higher n value for rougher surface to be used for types 5 and 6. Decimal is not used but is assumed to be between columns 37 and 38.
74-75	blank	If rectangular or trapezoidal channel maximum depth 13 feet to be used.
	integer	If rectangular or trapezoidal channel, maximum channel depth in whole feet other than 13 feet to be used.
76-77	integer	Maximum velocity in whole feet per second when trapezoidal channel (6) specified in Column 32.

B-6.2 Rainfall and Runoff Coefficient File Data Input

Runoff Coefficient Curve Data (Code 009) – Required

These data are entered in a separate rainfall and runoff coefficient data file. Currently the default filename used in VCRat2.2 is vcrain.dat.

Column	Entry	Description
1-3	009	Code number.
4-6	integer	Soil type number specified by Code 010 through 070.If composite runoff coefficient curve is available, use numbers between 002 and 199.
7	1	If runoff coefficient curve is used.
	2	If infiltration rate (loss rate) curve is used.
8-10	integer	Total number of points (maximum of 14) used to define runoff coefficient curve. This number must appear on all input lines.
11-13	integer	Maximum cumulative point number appearing on each input line.
14-17	numeric	Runoff coefficient as decimal corresponding to rainfall intensity listed in Column 18-22. The initial point on first input line must be 0.000. If decimal is not included it is assumed to be between the first and second columns.
18-22	numeric	Rainfall intensity in inches per hour corresponding to point value listed in Column 14-17. The initial point on first input line must be 00.000. If decimal is not included it is assumed to be betweenincluded the second and third columns
23-26	numeric	Runoff coefficient corresponding to rainfall intensity listed in Column 27-31. If decimal is not included it is assumed to be between the first and second columns
27-31	numeric	Rainfall intensity corresponding to point value listed in column 23-26. If decimal is not included it is assumed to be between the second and third columns
32-35	numeric	Runoff coefficient corresponding to rainfall intensity listed in Column 36-40.
36-40	numeric	Rainfall intensity corresponding to point value listed in Column 32-35. If decimal is not included it is assumed to be between the second and third columns

Column	Entry	Description
41-44	numeric	Runoff coefficient corresponding to rainfall intensity listed in Column 45-49. If decimal is not be included it is assumed to be between the first and second columns
45-49	numeric	Rainfall intensity corresponding to point value listed in Column 41-44. If decimal is not included it is assumed to be between the second and third columns
50-53	numeric	Runoff coefficient corresponding to rainfall intensity listed in Column 54-58. If decimal is not be included it is assumed to be between the first and second columns
54-58	numeric	Rainfall intensity corresponding to point value listed in Column 50-53. If decimal is not included it is assumed to be between the second and third columns
59-76	numeric	Repeat procedure described above for Columns14-58.

These data are currently included in the VCRAIN.DAT file that is the default runoff coefficient and rainfall mass curve file for VCRat2.2. VCRat2.2 and 2.5 use this file to generate a model and rainfall combined input file that is used by the FORTRAN VCRat calculation engine.

Rainfall Mass Curve Header Data (Code 010) – Required

These data currently follow the 009 data entered in a rainfall and runoff coefficient file. Currently the default file used in VCRat2.2 is vcrain.dat.

Column	Entry	Description
1-3	010	Code number for first line of rainfall hydrograph data line.
4	alphabetic	If storm pattern D through I for other than design storm rainfall to be used.
	J (or A)	If J zone design storm rainfall pattern to be used. (For 100-year frequency rainfall only use A.)
	K (or B)	If K zone design storm rainfall pattern to be used. (For 100-year frequency rainfall only use B.)
	L (or C)	If L zone design storm rainfall pattern to be used. (For 100-year frequency rainfall only use C.)
	T	If design thunderstorm rainfall pattern to be used. Also used for simulations to evaluate areal reduction
5-6	integer	If A through I storm pattern to be used, an identification number between 1 and 99 must also be used.

Column	Entry	Description
	01	If thunderstorm (convective storm) design rainfall pattern to be used. Also used for simulations to evaluate areal reduction
	10	If 10 - year frequency rainfall for J, K, L zone rainfall to be used.
	25	If 25 - year frequency rainfall for J, K, L zone rainfall to be used.
	50	If 50 - year frequency rainfall for J, K, L zone rainfall to be used.
	97	If 100-year frequency rainfall for A zone rainfall to be used.
	98	If 100-year frequency rainfall for B zone rainfall to be used.
	99	If 100-year frequency rainfall for C zone rainfall to be used.
7-9	Integer	Number of points in the hydrograph contained in the following 011 data lines

In VCRat2.2, J and J' zones use the same zone designations in the VCRAIN.DAT file and the modeler has to use the correct rain mass curve data to get the right results.

Rainfall Mass Curve Data (Code 011)– Required

These data currently follow the 010 data entered in a rainfall and runoff coefficient file. Currently the default file used in VCRat2.2 is vcrain.dat.

Column	Entry	Description
1-3	011	Code number for lines following 010 line of rainfall mass curve data.
4	J, K, L, A, B, C or D	Must match zone description on 010 line preceding 011 line
5-6	integer	Design frequency of storm, must match frequency entered on 010 line preceding 011 line.
7-9	Integer	Total number of points in the rainfall mass curve contained in the 011 data lines
10-12	Integer	Subtotal of mass curve ordinates contained in this and preceding 011 lines – generally 7 points per line.
13-17	Integer	Time in minutes of first mass curve point. First point must be 0000
18-22	Numeric	Cumulative rainfall corresponding to preceding time entry. If decimal is not entered it is assumed to occur between columns 19 and 20.
23-26	Integer	Time in minutes of next mass curve point

27-31	Numeric	Cumulative rainfall corresponding to preceding time entry. If decimal is not entered it is assumed to occur between columns 19 and 20.
32-72	Numeric	Remaining hydrograph times and cumulative rainfall pairs until the total number of pairs matches the entry in columns 10-12.

More than one rainfall mass curve can be included in a rainfall and runoff coefficient file. When all desired rainfall mass curves are included, the last line of the file should have 999 entered in the first three columns.

B-6.3 Reservoir Routing Information

The data input lines can follow any 006 in a VCRat2.2 input file except the last one. Decimal points must be included with all numbers on any of the these data lines. A dummy node must be used in a regular reservoir routing. A dummy node must be used after fattening. A confluence must be used in a split flow or bypass reservoir. The possible data input lines for reservoir routing include the following:

a. 110 (required for areal reduction, fattening and/or reservoir routing)
b. 111 (required for areal reduction, fattening and/or reservoir routing)
c. 112 (required for reservoir routing)
d. 113 (required for reservoir routing)
e. 114 (required for reservoir routing)
f. 115 (required for channel routing directly below the reservoir)
g. 116 (required for channel routing directly below the reservoir)
h. 110 (required for fattening and/or reservoir routing)

Start of Reservoir Routing, Areal Reduction, and Fattening Data Input Line (110)

Required to signify beginning and ending of reservoir routing and/or fattening. Can be preceded by a 006, 114, or 116 data line.

Column	Entry	Description
1-3	110	Code number for lines following 006 subarea line with dummy information.

Reservoir Routing, Areal Reduction, and Fattening Data Input Line (111)

Required after a 110 data input line. The numeric entries MUST contain a decimal point.

Column	Entry	Description
1-3	111	Code number for reservoir and hydrograph information.
4-11	numeric	Spillage elevation- usually corresponds to emergency spillway invert elevation. (elevation in feet) Used in reservoir routing only. This numeric entry MUST be in the form #####.##
	blank	No reservoir routing.
12-22	numeric	Hydrograph adjustment or areal reduction factor. Each point on the hydrograph will be multiplied by this adjustment factor. This numeric entry MUST be in the form #####.##### with at most 5 decimal places.
	blank	Hydrograph will not be adjusted.
23-30	numeric	Runoff factor. (inches) Used in fattening only. This numeric entry MUST be in the form #####.##. For 2.64, ####.###
31-38	numeric	Drainage area tributary to location. (acres) Overrides drainage area in node directly below the reservoir. This entry is the same as column16-23 on a 007 card for a read in hydrograph. This numeric entry MUST be in the form #####.##
	blank	No drainage area change.

Reservoir Routing Data- Stage Information (112)

Required if reservoir routing is performed. The reservoir stage (elevation in feet) information is entered on this data line. Up to 10 numeric entries can be placed on each 112 line, and up to five 112 lines are allowed. Elevation values must be larger than zero. The numeric entries for 2.2 and 2.6 MUST contain a decimal point and be in the form #####.##. VCRat2.64 numeric entries are in the form of ####.###. VCRat2.2 does not check to make sure the values are entered in ascending order.

Column	Entry	Description
1-3	112	Card code number.
4-11	numeric	The reservoir stage. (elevation in feet)
12-19	numeric	The reservoir stage. (elevation in feet)
20-27	numeric	The reservoir stage. (elevation in feet)
28-35	numeric	The reservoir stage. (elevation in feet)
36-43	numeric	The reservoir stage. (elevation in feet)
44-51	numeric	The reservoir stage. (elevation in feet)
52-59	numeric	The reservoir stage. (elevation in feet)
60-67	numeric	The reservoir stage. (elevation in feet)

68-75	numeric	The reservoir stage. (elevation in feet)
76-83	numeric	The reservoir stage. (elevation in feet)

Reservoir Routing Data- Storage Information (113)

Required after a 112 line. The reservoir storage (volume in acre-feet) information is entered in this line corresponding to the elevations entered on the 112 data lines. Up to 10 numeric entries can be placed on each 113 line, and up to five 113 lines are allowed. The numeric entries for 2.2 and 2.6 MUST contain a decimal point and be in the form *#####.##*. VCRat2.64 numeric entries are in the form of ####.###. VCRat2.2 does not check to make sure the values are entered in ascending order.

Column	Entry	Description
1-3	113	Card code number.
4-11	numeric	The reservoir storage (acre-feet)
12-19	numeric	The reservoir storage (acre-feet)
20-27	numeric	The reservoir storage (acre-feet)
28-35	numeric	The reservoir storage (acre-feet)
36-43	numeric	The reservoir storage (acre-feet)
44-51	numeric	The reservoir storage (acre-feet)
52-59	numeric	The reservoir storage (acre-feet)
60-67	numeric	The reservoir storage (acre-feet)
68-75	numeric	The reservoir storage (acre-feet)
76-83	numeric	The reservoir storage (acre-feet)

Reservoir Routing Data- Discharge Information (114)

Required after a 113 line. The reservoir discharge (cfs) information is entered in this line corresponding to the elevations entered on the 112 lines. Up to 10 numeric entries can be placed on each 114 line, and up to five *114* lines are allowed. The numeric entries for 2.2 and 2.6 MUST contain a decimal point and be in the form *#####.##*. VCRat2.64 numeric entries are in the form of ####.###. VCRat2.2 does not check to make sure the values are entered in ascending order.

Column	Entry	Description
1-3	114	Card code number.
4-11	numeric	The reservoir discharge (cfs)
12-19	numeric	The reservoir discharge (cfs)

20-27	numeric	The reservoir discharge (cfs)
28-35	numeric	The reservoir discharge (cfs)
36-43	numeric	The reservoir discharge (cfs)
44-51	numeric	The reservoir discharge (cfs)
52-59	numeric	The reservoir discharge (cfs)
60-67	numeric	The reservoir discharge (cfs)
68-75	numeric	The reservoir discharge (cfs)
76-83	numeric	The reservoir discharge (cfs)

Start of Channel Routing, Areal Reduction, and Fattening Data Input Line (115)

Required after a 114 data line at the end of reservoir routing or a 111 data line after areal reduction and fattening to signify that channel routing below the reservoir or upstream subarea will be performed next.

Column	**Entry**	**Description**
1-3	115	Code number for line following 114 end of reservoir routing or 111 end of areal reduction/fattening data input.

Channel Routing Below Reservoir Data Input Line (116)

Required after a 115 data line to provide channel routing information. Dummy information for a subarea should be provided on this line along with the routing information. Please see the explanation for the routing data required for a 006 data line for the required parameters.

End of Channel Routing, Areal Reduction, and Fattening Data Input Line (110)

Required after a 111, 114, or 116 line to signify the end of reservoir and/or channel routing and/or areal reduction and fattening information.

Column	**Entry**	**Description**
1-3	110	Code number for line following 111, 114 or 116 data input.

Example data input lines with added column numbers (not used in model input file)

```
Column Numbering
0        10        20        30        40        50        60        70
```

```
12345678901234567890123456789012345678901234567890123456789012345678901234567890
********************************************************************************
006 15031  056B 020      099B98                         1
110
111 1130.5     1.00000    4.50
112 1110.   1112.   1114.   1116.   1118.   1119.   1120.   1121.   1122.   1123.
112 1124.   1125.   1126.   1127.   1128.   1129.   1130.   1131.   1132.   1133.
113    0.0     2.5     5.4     8.9    12.0    15.1    17.4    19.9    22.5    25.2
113   28.0    31.0    34.1    37.4    40.9    44.5    48.3    52.4    56.6    60.5
114    0.0    30.0   100.0   195.0   310.0   360.0   400.    430.    463.    492.
114  520.    545.    570.    594.    616.    639.    660.    713.    871.   1088.
115
116 15031  056B 020      099B982 1100002277
110
```

B-6.4 Running VCRat2.2

Copy the input files (model input and rainfall and runoff coefficient input) to a directory containing the VCRat2.2 programs on a 32-bit computer or on a 64-bit computer running Virtual XP mode. Run program VCRat2.exe and enter the following data:

1. Model input data filename
2. Rainfall and runoff coefficient mass curve data file
3. Output model data filename.

If the program does not run, the following sections discuss some common error messages that occur.

B-6.5 VCRat2.2 Error Checking

VCRat2.2 is designed to edit runoff coefficient curves, rainfall mass curves, and hydrograph data input, and to verify the consistency of subarea data and various computation instructions. It checks input data prior to hydrologic computations. When errors are encountered, further processing is terminated and error messages are produced.

Runoff Coefficient Curve and Rainfall Data Mass Curve Editor (PROGRAM F0601M)

Error messages produced by this program are of the following form:

CURVE NAME ERROR NO.

Error Number	Description
1	The code (Column 1-3) on first line of a mass curve not 009 (runoff coefficient curve) or 010 (rainfall mass curve).
2	Number in Column 7 on the first line outside the range 1-5.
3	Total number of points indicated for the curve exceeds 14 (runoff coefficient curve) or 199 (rainfall mass curve).
4	On lines following the first input line of a curve either (a) The input line code (Column 1-3) not equal to 009 (runoff coefficient curve) or 011 (rainfall mass curve), (b) The curve number in Column 4-6 does not match or (c) The curve number in Column 7 does not match.
5	The number of points in a line exceeds the total number indicated on the header line.
6	The data input lines are out of sequence.
7	Initial data point not zero, negative runoff coefficient curve number, or points on rainfall mass curve not in chronological or cumulative sequence.
8	The curve number (Column 4-6) listed in the first header line, not (a) 002 through 199 for runoff coefficient curve, (b) A through I in Column 4 and 01 through 99 in Column 5-6, for selected storm rainfall mass curve, (c) J through L in Column 4 and 10, 25 or 50 in Column 5-6 for standard design storm rainfall curve, or (d) T in Column 4 and 01 in Column 5-6 for thunderstorm (convective storm) rainfall mass curve.

Subarea and Hydrograph Data Editor (PROGRAM F06010)

Error messages produced by this program are of the following form:

LOCATION NAME ERROR NO.

Error Number	Description
1	The line code (Column 1-3) of a subarea data input line not 006.
2	Subarea data not in ascending sequence (hydrograph input may be specified on the same line, and hydrograph modification may be specified on the preceding line) or a thunderstorm specified in Column 67 and Line A not specified in Column 15.
3	Column 15 (primary storage location), Column 17-19 (runoff coefficient curve) or Column 29-31 (rainfall mass curve) contains all blanks or an invalid value.
4	Secondary hydrograph is specified and (a) alphanumeric character other than A through F listed in Column 16, (b) hydrograph computation is also specified, (c) read hydrograph also specified, (d) number in Column 60 outside the range 0-4, (e) number in Column 63 outside range 0-1, or (f) negative number in Column 53-59.

Error Number	Description
5	Hydrograph input and hydrograph computation both indicated.
6	Hydrograph computation specified and (a) time of concentration not listed in Column 27-28 or hydrograph input, (b) confluence output also specified, (c) hydrograph modification also specified, (d) control Q also specified, or (e) negative number in Column 20-28. Read hydrograph specified with confluence output, hydrograph modification or control Q specified also results in error 6 printout.
7	Routing errors with (a) number in Column 32 outside range 0-6, (b) 1-6 specified in Column 32 with slope and channel length not specified in Column 33-43 or, (c) 6 specified in Column 32 and combination of Column 47-52, and Column 74-75, Column 47-52 and Column 76-77, or Column 74-75 and Column 76-77 not specified, (d) number specified in Column 74-75 outside range 0-29, or (e) negative number in Column 33-52 or Column 68-77.
8	Location input line instruction errors with (a) number in Column 61 inconsistent or outside range 0-3, (b) number in both Column 61 and Column 67 other than 0, 1, 2, 3, 5, 7 specified in Column 67, (c) other than alphabetic code A through G specified in Column 64, or (d) negative number in Column 65.
9	Hydrograph header input line errors with (a) input line code (column 1-3) not 007, (b) missing job or location number in Column 4-14, (c) drain A through F not specified in Column 15, (d) number in Column 24-26 outside range 1-200, (e) number in Column 27-30 outside range 1-1500, (f) negative number in Column 16-23 or Column 31-38, (g) number in Column 39-41 outside range 1-200, or (h) number in Column 42-44 outside range 1-4.
10	Hydrograph data input line errors with (a) input line code (Column 1-3) not 008, (b) number of points on input line less or greater than total number indicated on header input line, or (c) data input lines not in sequence.
11	Hydrograph error affecting the associated subarea data set.
12	Initial hydrograph data point not zero, or points on hydrograph not in chronological sequence.
13	Total hydrograph data points not equal to number of points specified in header line.
14	The line code (Column 1-3) not 005 on first page heading input line.
15	Hydrograph output specified and (a) the associated page heading line is missing, (b) the line code (Column 1-3) not 005 on associated page heading line, or (c) the location name on the associated page heading line and location point line not identical.
16	More than 1000 lines of input data submitted for job. (This limitation applies to VCRat 1.0. VCRat2.2 has been recompiled to allow up to 5,000 subareas.)
18	End of job not specified by number 2 in Column 65.

Hydrologic Computation (PROGRAM F0601A)

Error messages produced by this program are of the following form:

PAGE HEADING

PROCESSING DISCONTINUED AT LOCATION NAME ERROR NO.

Error Number	Description
2	Device failure has occurred while reading from file. Program should be restarted.
3	The name on a runoff coefficient curve or rainfall mass curve does not match the one called for on a location point line or the number of points exceeds the maximum allowable points.
4	Failure in search of table for partially full pipe sections when computing wave velocities.
5	Hydrograph input indicated and the referenced hydrograph not in the input stream.
6	The number or time of points for an input hydrograph not identical with points used in rainfall mass curve.
7	The specified time of concentration is greater than the interval between zero time and the first time specified on the rainfall mass curve.
8	Failure in search for bottom width of trapezoidal channel.
9	Failure in search for depth while computing wave velocities in trapezoidal channel.
10	Failure in search for area reduction factor during computation of subarea hydrograph.
11	Failure in search for runoff rate during computation of subarea hydrograph.
12	Failure in hydrograph routing due to magnitude of channel flow rate.
99	Recycle past the beginning of the job during thunderstorm computations attempted, or more than 1,000 location point and page heading input lines were submitted. (This limitation applies to VCRat 1.0. VCRat2.2 has been recompiled to allow up to 5,000 subareas.)

B-6.6 Computation Procedures

Storm Rainfall Relationships

The system interpolates rainfall mass curve data entered as data input and constructs a system storage table of accumulated total rainfall by one minute increments from zero rainfall to the time of the last point indicated by input data.

Legacy design storm rainfall mass curve data included in vcrain.dat are:

Fourth Day Total, Inches

Rainfall Zone	100-Year Storm	50-Year Storm	25-Year Storm	10-Year Storm
J	7.00	5.0	3.91	3.17
J’ (J prime)	6.66	6.0	5.28	4.38
K	10.60	8.0	6.41	5.53
L	15.00	11.0	8.81	7.21

The average rainfall intensity for any specified duration at a specified storm time is calculated by subtracting from the cumulative storm rainfall at the specified storm time from the cumulative storm rainfall at the earlier storm time or determined by the specified duration. Rainfall intensity in inches per hour is calculated as the incremental cumulative storm total, times 60 (minutes in an hour) divided by the specified duration (time of concentration in minutes).

VCRat2.64 also contains 31 NOAA rainfall mass curves for each design storm level (10-, 25-, 50-, and 100-yr storms).

For the design storm, rainfall intensities are reduced if computations for other than the fourth day (maximum day) rainfall are specified. The reduction factor is 0.10, 0.40, 0.35, and 1.00 for first through fourth day, respectively. Thunderstorm rainfall intensities are reduced by an areal reduction curve coded into the program by to decrease rainfall intensity with increasing watershed size.

VCRatP.for data from FORTRAN PROGRAM

ac	sq mi	Factor	ac	sq mi	Factor
0	0	1.0000	19,200	30	0.7850
800	1.25	0.9450	22,400	35	0.7730
1,600	2.5	0.9250	25,600	40	0.7625
3,200	5	0.8950	28,800	45	0.7520
6,400	10	0.8600	32,000	50	0.7420
9,600	15	0.8350	48,000	75	0.7020
12,800	20	0.8150	64,000	100	0.6700
16,000	25	0.8000			

B-7 AREAL REDUCTION EXAMPLE

B-7.1 VCRat2.2 AR Input File

As of July 2017, Areal Reduction runs can only be done using legacy 100-yr mass curves for the J', K, and L zones. The VCRat2.2 input file format for an Areal Reduction run is as follows with AR input in shaded yellow lines:

```
005  8822    1A SUDDEN BARRANCA UPDATE TO 1982 STUDY Q100F DL/JL 3/03; AREALLY REDUCED
005  8822    8ABSUDDEN BARRANCA AT FOOTHILL RD Q100F
005  8822   13ABSUDDEN BARRANCA AT TELEGRAPH RD Q100F
005  8822   18ACSUDDEN BARRANCA AT SANTA PAULA FREEWAY Q100F
005  8822   23ABSUDDEN BARRANCA AFTER JCT W/ PIPE IN JASPER AND EAST TELE.Q100F
005  8822   30ABSUDDEN BARRANCA AFTER JCT. W/ TR 3198 Q100F
999
999
006  8822    1A 040  0  7612B981 1550005940                    G1 7
006  8822    2A 030  0  5810B981 1730004040
006  8822    3A 020     2908B981 1250003200
006  8822    4A 020     8211B981  600003330
006  8822    5A 020      099B98
006  8822    6B 020 10  7215B984  650000170
006  8822    7B 030 10  4014B98
006  8822    8AB030         B985 1300002750                  11
006  8822    9A 040 23  4108B985 0950002750
006  8822   10A 040 23  31 8B985  950001700
006  8822   11A 040 00  0706B98
006  8822   12B 040 23  3713B984  150000800
006  8822   13AB040         B984 2500002500                  11
006  8822   14A 040 10  2107B98
006  8822   15C 040 23  5010B984 2500002000
006  8822   16C 030 35  5312B98
006  8822   17C 010 23  4108B984 1200001200
006  8822   18AC010         B985 1580002200                  11
006  8822   19A 030 20  2211B985 1975001500
006  8822   20A 030 23  3211B98
006  8822   21B 030 23  5511B984 1500001400
006  8822   22B 030 23  4912B98
006  8822   23AB030         B985 1200001330                  11
006  8822   24C 030      099B98
006  8822   25A 030      099B98
006  8822   26A 030 23  0813B985  337003233
006  8822   27A 030 23  0513B985  472001688
006  8822   28A 030 23  0613B985  165001688
006  8822   29B 030 23  3613B98
1234567890123456789012345678901234567890123456789012345678901234567890(Not used in run)
006  8822   30AB030         B985 1050002630200   800         11   1035035
006  8822   31A 030 23  1608B98                                 2
```

Where "1" in column 65 prints the heading at the beginning of the printout and headings where hydrograph printout sheets are desired. In column 67 at node 1A (first 006 line , beginning of 006 lines), any number from 1 to 7 is necessary to perform Areal Reduction. In column 64, "G" clears the all the hydrographs stored in the system. Areal reduction runs with or without the column 64 command.

By putting a “1” on column 67 on any node, including placeholders and confluences, the program recognizes that areal reduction is needed therefore it will re-run to re-calculate the peak flow. The program then uses the embedded rainfall reduction factors in the VCRATP.for program to obtain an Areal Reduction Factor for Rain (ARr) and applies that to the Zonal rainfall mass curve to reduce the intensities at that location. For this example, areal reduction was set for node 30AB. The program ran regularly until it reaches node 30AB and recognized a command for areal reduction. Therefore, VCRat2.2 ran again to accommodate for areal reduction. The output should repeat, like the example below. The highlighted section in the input above shows where areal reduction is calculated. The highlighted section in the output below shows how the program runs regularly until 30AB where the areal reduction command was set, which re-calculate to accommodate for areal reduction. The AR factor for flow (ARq) is calculated as the areally-reduced flow/unareally-reduced flow or in this case 1,467/1,583=0.9267.

3) Another characteristic of an AR run is that the flow values up to the point where AR has been specified (1 in col 67) cannot be used to calculate ARq values because the ARr value is only good at the node point specified. Also, the flow values below where AR was specified are not valid model results and cannot be used for design or in ARq calculations.

4) If a hydrograph is printed at the node where AR is requested, the reduction factor printed at the top of the hydrograph is the ARr value for the node location, not the ARq value. The ARq value has to be hand calculated.

5) VCRat2.2 AR runs used to provide two sets of output, one with the AR flows and one with the non-AR flows. VCRat2.64 only provides the AR flows in the output and the non-AR flows have to be calculated in a different run.

B-7.2 VCRat2.2 AR Output File

```
                                 VENTURA COUNTY FLOOD CONTROL DISTRICT
                            MODIFIED RATIONAL METHOD HYDROLOGY / PC 2.21-950
    SUDDEN BARRANCA UPDATE TO 1982 STUDY Q100F DL/JL 3/03                                            STORM DAY 4
                SUBAREA  SUBAREA     TOTAL     TOTAL  CONV   CONV     CONV     CONV   CONV   CONTROL SOIL      RAIN  PCT
    LOCATION      AREA      Q        AREA        Q    TYPE   LNGTH    SLOPE    SIZE     Z       Q    NAME  TC  ZONE  IMPV
    8822    1A     76.       182.       76.       182.   1    1550.  0.05940    0.00  0.00        0.   40  12   B98  0.00
    8822    2A     58.       166.      134.       309.   1    1730.  0.04040    0.00  0.00        0.   30  10   B98  0.00
    8822    3A     29.        99.      163.       299.   1    1250.  0.03200    0.00  0.00        0.   20   8   B98  0.00
    8822    4A     82.       235.      245.       423.   1     600.  0.03330    0.00  0.00        0.   20  11   B98  0.00
    8822    5A      0.         0.      245.       415.   0       0.  0.00000    0.00  0.00        0.   20  99   B98  0.00
    8822    6B     72.       174.       72.       174.   4     650.  0.00170    6.00  0.00        0.   20  15   B98  0.10
    8822    7B     40.        95.      112.       262.   0       0.  0.00000    0.00  0.00        0.   30  14   B98  0.10
****************************************************************************************************************************
*                                                      CONFLUENCE Q'S                                                     *
*   8822    8A  TA 1161 QA     415. QAB     666. QB     250.    8822    8B  TB 1158 QB     262. QBA     649. QA     386.   *
*                           8822    8AB TAB 1160 QAB     668. QA     412. QB     256.                                     *
****************************************************************************************************************************
                SUBAREA  SUBAREA     TOTAL     TOTAL  CONV   CONV     CONV     CONV   CONV   CONTROL SOIL      RAIN  PCT
    LOCATION      AREA      Q        AREA        Q    TYPE   LNGTH    SLOPE    SIZE     Z       Q    NAME  TC  ZONE  IMPV
    8822    8AB   112.       262.      357.       668.   5    1300.  0.02750    8.00  0.00        0.   30   0   B98  0.00
    8822    9A     41.       131.      398.       733.   5     950.  0.02750    8.00  0.00        0.   40   8   B98  0.23
    8822   10A     31.        99.      429.       786.   5     950.  0.01700    8.00  0.00        0.   40   8   B98  0.23
    8822   11A      7.        25.      436.       780.   0       0.  0.00000    0.00  0.00        0.   40   6   B98  0.00
    8822   12B     37.        90.       37.        90.   4     150.  0.00800    3.50  0.00        0.   40  13   B98  0.23
****************************************************************************************************************************
*                                                      CONFLUENCE Q'S                                                     *
*   8822   13A  TA 1159 QA     780. QAB     864. QB      84.    8822   13B  TB 1155 QB      90. QBA     734. QA     645.   *
*                           8822   13AB TAB 1159 QAB     864. QA     780. QB      84.                                     *
****************************************************************************************************************************
                SUBAREA  SUBAREA     TOTAL     TOTAL  CONV   CONV     CONV     CONV   CONV   CONTROL SOIL      RAIN  PCT
    LOCATION      AREA      Q        AREA        Q    TYPE   LNGTH    SLOPE    SIZE     Z       Q    NAME  TC  ZONE  IMPV
    8822   13AB    37.        90.      473.       864.   4    2500.  0.02500    6.50  0.00        0.   40   0   B98  0.00
    8822   14A     21.        71.      494.       859.   0       0.  0.00000    0.00  0.00        0.   40   7   B98  0.10
    8822   15C     50.       143.       50.       143.   4    2500.  0.02000    3.50  0.00        0.   40  10   B98  0.23
    8822   16C     53.       145.      103.       267.   0       0.  0.00000    0.00  0.00        0.   30  12   B98  0.35
    8822   17C     41.       151.      144.       404.   4    1200.  0.01200    5.75  0.00        0.   10   8   B98  0.23
****************************************************************************************************************************
*                                                      CONFLUENCE Q'S                                                     *
*   8822   18A  TA 1162 QA     859. QAC    1172. QC     313.    8822   18C  TC 1158 QC     395. QCA    1196. QA     800.   *
*                           8822   18AC TAC 1160 QAC    1216. QA     842. QC     373.                                     *
****************************************************************************************************************************
                SUBAREA  SUBAREA     TOTAL     TOTAL  CONV   CONV     CONV     CONV   CONV   CONTROL SOIL      RAIN  PCT
```

```
    LOCATION      AREA       Q         AREA         Q    TYPE   LNGTH   SLOPE      SIZE     Z        Q    NAME  TC  ZONE  IMPV
    8822   18AC   144.        395.       638.     1216.   5    1580.  0.02200    10.00  0.00        0.    10   0    B98  0.00
    8822   19A     22.         62.       660.     1249.   5    1975.  0.01500    10.00  0.00        0.    30  11    B98  0.20
    8822   20A     32.         90.       692.     1291.   0      0.   0.00000     0.00  0.00        0.    30  11    B98  0.23
    8822   21B     55.        155.        55.      155.   4    1500.  0.01400     4.00  0.00        0.    30  11    B98  0.23
    8822   22B     49.        131.       104.      276.   0      0.   0.00000     0.00  0.00        0.    30  12    B98  0.23
********************************************************************************************************************************
*                                                CONFLUENCE Q'S                                                                *
*   8822   23A  TA 1162 QA     1291. QAB    1499. QB     207.    8822   23B  TB 1157 QB     276. QBA    1268. QA     992.    *
*                            8822   23AB TAB 1161 QAB    1504. QA    1268. QB     236.                                         *
********************************************************************************************************************************
                  SUBAREA  SUBAREA      TOTAL      TOTAL  CONV   CONV     CONV      CONV   CONV   CONTROL SOIL      RAIN  PCT
    LOCATION      AREA       Q         AREA         Q    TYPE   LNGTH   SLOPE      SIZE     Z        Q    NAME  TC  ZONE  IMPV

                                            VENTURA COUNTY FLOOD CONTROL DISTRICT
                                       MODIFIED RATIONAL METHOD HYDROLOGY / PC 2.21-950
    SUDDEN BARRANCA UPDATE TO 1982 STUDY Q100F DL/JL 3/03                                                          STORM DAY 4
                  SUBAREA  SUBAREA      TOTAL      TOTAL  CONV   CONV     CONV      CONV   CONV   CONTROL SOIL      RAIN  PCT
    LOCATION      AREA       Q         AREA         Q    TYPE   LNGTH   SLOPE      SIZE     Z        Q    NAME  TC  ZONE  IMPV
    8822   23AB   104.        276.       796.     1504.   5    1200.  0.01330    12.00  0.00        0.    30   0    B98  0.00
    8822   24C      0.          0.         0.      395.   0      0.   0.00000     0.00  0.00        0.    30  99    B98  0.00
    8822   25A      0.          0.       796.     1497.   0      0.   0.00000     0.00  0.00        0.    30  99    B98  0.00
    8822   26A      8.         20.       804.     1512.   5     337.  0.03233    10.00  0.00        0.    30  13    B98  0.23
    8822   27A      5.         13.       809.     1518.   5     472.  0.01688    10.00  0.00        0.    30  13    B98  0.23
    8822   28A      6.         15.       815.     1526.   5     165.  0.01688    10.00  0.00        0.    30  13    B98  0.23
    8822   29B     36.         91.        36.       91.   0      0.   0.00000     0.00  0.00        0.    30  13    B98  0.23
********************************************************************************************************************************
*                                                CONFLUENCE Q'S                                                                *
*   8822   30A  TA 1163 QA     1525. QAB    1582. QB      57.    8822   30B  TB 1154 QB      91. QBA     913. QA     822.    *
*                            8822   30AB TAB 1162 QAB    1583. QA    1515. QB      68.                                         *
********************************************************************************************************************************
                  SUBAREA  SUBAREA      TOTAL      TOTAL  CONV   CONV     CONV      CONV   CONV   CONTROL SOIL      RAIN  PCT
    LOCATION      AREA       Q         AREA         Q    TYPE   LNGTH   SLOPE      SIZE     Z        Q    NAME  TC  ZONE  IMPV
    8822   30AB    36.         91.       851.     1583.   5    1050.  0.02630     8.00  2.00        0.    30   0    B98  0.00

                                            VENTURA COUNTY FLOOD CONTROL DISTRICT
                                       MODIFIED RATIONAL METHOD HYDROLOGY / PC 2.21-950
    SUDDEN BARRANCA UPDATE TO 1982 STUDY Q100F DL/JL 3/03                                                          STORM DAY 4
                  SUBAREA  SUBAREA      TOTAL      TOTAL  CONV   CONV     CONV      CONV   CONV   CONTROL SOIL      RAIN  PCT
    LOCATION      AREA       Q         AREA         Q    TYPE   LNGTH   SLOPE      SIZE     Z        Q    NAME  TC  ZONE  IMPV
    8822     1A    76.        169.        76.      169.   1    1550.  0.05940     0.00  0.00        0.    40  12    B98  0.00
    8822     2A    58.        155.       134.      286.   1    1730.  0.04040     0.00  0.00        0.    30  10    B98  0.00
    8822     3A    29.         93.       163.      272.   1    1250.  0.03200     0.00  0.00        0.    20   8    B98  0.00
    8822     4A    82.        220.       245.      385.   1     600.  0.03330     0.00  0.00        0.    20  11    B98  0.00
    8822     5A     0.          0.       245.      378.   0      0.   0.00000     0.00  0.00        0.    20  99    B98  0.00
    8822     6B    72.        162.        72.      162.   4     650.  0.00170     6.00  0.00        0.    20  15    B98  0.10
```

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    8822    7B     40.        89.      112.      245.  0       0.  0.00000     0.00  0.00        0.   30  14   B98  0.10
*****************************************************************************************************************************
*                                                  CONFLUENCE Q'S                                                           *
*   8822    8A  TA 1161 QA     378. QAB     611. QB     233.    8822    8B  TB 1158 QB     245. QBA     596. QA     350.    *
*                               8822    8AB TAB 1160 QAB     613. QA     375. QB     239.                                   *
*****************************************************************************************************************************
                SUBAREA  SUBAREA     TOTAL     TOTAL  CONV   CONV     CONV     CONV   CONV   CONTROL SOIL       RAIN  PCT
    LOCATION      AREA      Q        AREA        Q    TYPE   LNGTH   SLOPE     SIZE     Z       Q    NAME  TC  ZONE  IMPV
    8822    8AB   112.      245.      357.      613.  5    1300.  0.02750     8.00  0.00        0.   30   0   B98  0.00
    8822    9A     41.      123.      398.      673.  5     950.  0.02750     8.00  0.00        0.   40   8   B98  0.23
    8822   10A     31.       93.      429.      723.  5     950.  0.01700     8.00  0.00        0.   40   8   B98  0.23
    8822   11A      7.       24.      436.      718.  0       0.  0.00000     0.00  0.00        0.   40   6   B98  0.00
    8822   12B     37.       84.       37.       84.  4     150.  0.00800     3.50  0.00        0.   40  13   B98  0.23
*****************************************************************************************************************************
*                                                  CONFLUENCE Q'S                                                           *
*   8822   13A  TA 1159 QA     718. QAB     796. QB      78.    8822   13B  TB 1155 QB      84. QBA     672. QA     588.    *
*                               8822   13AB TAB 1159 QAB     796. QA     718. QB      78.                                   *
*****************************************************************************************************************************
                SUBAREA  SUBAREA     TOTAL     TOTAL  CONV   CONV     CONV     CONV   CONV   CONTROL SOIL       RAIN  PCT
    LOCATION      AREA      Q        AREA        Q    TYPE   LNGTH   SLOPE     SIZE     Z       Q    NAME  TC  ZONE  IMPV
    8822   13AB    37.       84.      473.      796.  4    2500.  0.02500     6.50  0.00        0.   40   0   B98  0.00
    8822   14A     21.       66.      494.      792.  0       0.  0.00000     0.00  0.00        0.   40   7   B98  0.10
    8822   15C     50.      134.       50.      134.  4    2500.  0.02000     3.50  0.00        0.   40  10   B98  0.23
    8822   16C     53.      136.      103.      250.  0       0.  0.00000     0.00  0.00        0.   30  12   B98  0.35
    8822   17C     41.      142.      144.      380.  4    1200.  0.01200     5.75  0.00        0.   10   8   B98  0.23
*****************************************************************************************************************************
*                                                  CONFLUENCE Q'S                                                           *
*   8822   18A  TA 1162 QA     792. QAC    1084. QC     292.    8822   18C  TC 1158 QC     371. QCA    1111. QA     740.    *
*                               8822   18AC TAC 1160 QAC    1129. QA     779. QC     349.                                   *
*****************************************************************************************************************************
                SUBAREA  SUBAREA     TOTAL     TOTAL  CONV   CONV     CONV     CONV   CONV   CONTROL SOIL       RAIN  PCT
    LOCATION      AREA      Q        AREA        Q    TYPE   LNGTH   SLOPE     SIZE     Z       Q    NAME  TC  ZONE  IMPV
    8822   18AC   144.      371.      638.     1129.  5    1580.  0.02200    10.00  0.00        0.   10   0   B98  0.00
    8822   19A     22.       58.      660.     1160.  5    1975.  0.01500    10.00  0.00        0.   30  11   B98  0.20
    8822   20A     32.       84.      692.     1198.  0       0.  0.00000     0.00  0.00        0.   30  11   B98  0.23
    8822   21B     55.      145.       55.      145.  4    1500.  0.01400     4.00  0.00        0.   30  11   B98  0.23
    8822   22B     49.      122.      104.      258.  0       0.  0.00000     0.00  0.00        0.   30  12   B98  0.23
*****************************************************************************************************************************
*                                                  CONFLUENCE Q'S                                                           *
*   8822   23A  TA 1162 QA    1198. QAB    1392. QB     194.    8822   23B  TB 1157 QB     258. QBA    1164. QA     906.    *
*                               8822   23AB TAB 1161 QAB    1395. QA    1175. QB     220.                                   *
*****************************************************************************************************************************
                SUBAREA  SUBAREA     TOTAL     TOTAL  CONV   CONV     CONV     CONV   CONV   CONTROL SOIL       RAIN  PCT
    LOCATION      AREA      Q        AREA        Q    TYPE   LNGTH   SLOPE     SIZE     Z       Q    NAME  TC  ZONE  IMPV

                                           VENTURA COUNTY FLOOD CONTROL DISTRICT
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MODIFIED RATIONAL METHOD HYDROLOGY / PC 2.21-950

SUDDEN BARRANCA UPDATE TO 1982 STUDY Q100F DL/JL 3/03 STORM DAY 4

LOCATION	SUBAREA AREA	SUBAREA Q	TOTAL AREA	TOTAL Q	CONV TYPE	CONV LNGTH	CONV SLOPE	CONV SIZE	CONV Z	CONTROL Q	SOIL NAME	TC	RAIN ZONE	PCT IMPV
8822 23AB	104.	258.	796.	1395.	5	1200.	0.01330	12.00	0.00	0.	30	0	B98	0.00
8822 24C	0.	0.	0.	371.	0	0.	0.00000	0.00	0.00	0.	30	99	B98	0.00
8822 25A	0.	0.	796.	1388.	0	0.	0.00000	0.00	0.00	0.	30	99	B98	0.00
8822 26A	8.	19.	804.	1402.	5	337.	0.03233	10.00	0.00	0.	30	13	B98	0.23
8822 27A	5.	12.	809.	1407.	5	472.	0.01688	10.00	0.00	0.	30	13	B98	0.23
8822 28A	6.	14.	815.	1415.	5	165.	0.01688	10.00	0.00	0.	30	13	B98	0.23
8822 29B	36.	86.	36.	86.	0	0.	0.00000	0.00	0.00	0.	30	13	B98	0.23

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*******************************************************************************************
*                                      CONFLUENCE Q'S                                     *
*  8822  30A  TA 1163 QA   1415. QAB   1467. QB     53.   8822  30B  TB 1154 QB    86. QBA   829. QA   744.  *
*                       8822  30AB TAB 1163 QAB   1467. QA   1415. QB    53.              *
*******************************************************************************************
```

LOCATION	SUBAREA AREA	SUBAREA Q	TOTAL AREA	TOTAL Q	CONV TYPE	CONV LNGTH	CONV SLOPE	CONV SIZE	CONV Z	CONTROL Q	SOIL NAME	TC	RAIN ZONE	PCT IMPV
8822 30AB	36.	86.	851.	1467.	5	1050.	0.02630	8.00	2.00	0.	30	0	B98	0.00
8822 31A	16.	50.	867.	1466.	0	0.	0.00000	0.00	0.00	0.	30	8	B98	0.23

B-8 – VCRAT2.2 AND VCRAT2.6 DATA FILES

B-8.1 VCRat2.2 Partial Input File

```
005 48651   99E  IMPORTED HYDROGRAPH FN=SAMPLE1.DAT VCRat 2 VER. 2.2
005 48651  105A  OUTFLOW HYDROGRAPH AT THIS POINT
005 48651  170AB THIS HYDROGRAPH IS ADJUSTED FOR AREAL REDUCTION & FATTENING
005 48651  171AE INFLOW HYDROGRAPH TO DETENTION BASIN
005 48651  172A  DETENTION BASIN ROUTING
005 48651  173A  DATA LINE ALWAYS NEEDED IF END OF FILE FOLLOWS
999
007 48651   99E    4220 441158    3582200  4
008  5    0       0  100      91  200     216  300     288  400     343
008 10  500     387  600     433  700     502  800     604  900     756
008 15 1000    1047 1050    1410 1100    1804 1110    2087 1120    2245
008 20 1130    2451 1131    2494 1132    2532 1133    2568 1134    2601
008 25 1135    2633 1136    2669 1137    2707 1138    2744 1139    2782
008 30 1140    2820 1141    2857 1142    2890 1143    2923 1144    2956
008 35 1145    2988 1146    3022 1147    3057 1148    3096 1149    3138
008 40 1150    3177 1151    3191 1152    3209 1153    3298 1154    3428
008 45 1155    3502 1156    3546 1157    3570 1158    3582 1159    3582
008 50 1160    3568 1161    3545 1162    3514 1163    3477 1164    3437
008 55 1165    3398 1166    3362 1167    3329 1168    3300 1169    3279
008 60 1170    3266 1171    3258 1172    3253 1173    3249 1174    3245
008 65 1175    3242 1176    3238 1177    3234 1178    3230 1179    3225
008 70 1180    3220 1181    3219 1182    3218 1183    3216 1184    3214
008 75 1185    3212 1186    3210 1187    3211 1188    3217 1189    3251
008 80 1190    3289 1191    3301 1192    3300 1193    3293 1194    3285
008 85 1195    3277 1196    3266 1197    3247 1198    3220 1199    3214
008 90 1200    3206 1201    3194 1202    3181 1203    3141 1204    3089
008 95 1205    3044 1206    3006 1207    2972 1208    2941 1209    2913
008100 1210    2888 1211    2864 1212    2839 1213    2815 1214    2790
008105 1215    2766 1216    2741 1217    2717 1218    2693 1219    2669
008110 1220    2645 1221    2625 1222    2605 1223    2585 1224    2566
008115 1225    2546 1226    2527 1227    2508 1228    2490 1229    2472
008120 1230    2455 1231    2438 1232    2422 1233    2406 1234    2390
008125 1235    2373 1236    2356 1237    2340 1238    2324 1239    2309
008130 1240    2294 1241    2279 1242    2264 1243    2250 1244    2235
008135 1245    2221 1246    2207 1247    2194 1248    2180 1249    2167
008140 1250    2154 1251    2140 1252    2128 1253    2115 1254    2102
008145 1255    2089 1256    2077 1257    2065 1258    2053 1259    2041
008150 1260    2024 1261    2010 1262    1997 1263    1985 1264    1975
008155 1265    1964 1266    1954 1267    1944 1268    1933 1269    1922
008160 1270    1911 1271    1900 1272    1889 1273    1878 1274    1867
```

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008165 1275    1856 1276    1845 1277    1833 1278    1822 1279    1810
008170 1280    1798 1281    1787 1282    1775 1283    1763 1284    1751
008175 1285    1740 1286    1728 1287    1717 1288    1706 1289    1695
008180 1290    1685 1291    1675 1292    1665 1293    1656 1294    1647
008185 1295    1638 1296    1629 1297    1621 1298    1613 1299    1605
008190 1300    1598 1310    1546 1320    1453 1330    1361 1340    1271
008195 1350    1178 1360    1080 1370     988 1380     908 1390     845
008200 1400     795 1420     736 1440     676 1460     625 1500     570
999
006 48651   99E 010         B98                                G1A
006 48651  100A 020 23  4910B983  650 0140
006 48651  101A 020 40  2310B984  400 0100
006 48651  102A 020 14  62 8B98
006 48651  103A 020      099C99
------------ADDITIONAL SUBAREAS FROM 103A TO 169B-----------
006 48651  169B 030015  2709B98
006 48651  170AB010         B98                              1
110
111            .877      6.0
110
006 48651  171AE030         B98                              1
------------RESERVOIR ROUTING SEQUENCE----------------------
006 48651  172A 030      099B98                              1
110
111  642.5
112  634.50  640.00  640.50  641.99  642.06  642.16  642.27  642.40  643.48
113    0.00  314.59  415.21  615.98  817.07 1018.61 1320.32 1522.33 1723.57
114    0.00 1905.00 2320.00 2830.00 3540.00 5550.00 5860.00 6870.00 8875.00
115
116 48651  172A 030      099B986 12000001  2    85                020022  20
110
006 48651  173A 030      099B98                              1  2
```

B-8.2 VCRat2.2 Partial Output File

```
                                         VENTURA COUNTY FLOOD CONTROL DISTRICT
                                    MODIFIED RATIONAL METHOD HYDROLOGY / PC 2.21-950
   SAMPLE CALCULATION FN=SAMPLE1.DAT VCRat 2 VER. 2.2                                                  STORM DAY 4
              SUBAREA  SUBAREA     TOTAL     TOTAL  CONV    CONV     CONV      CONV   CONV    CONTROL SOIL      RAIN  PCT
  LOCATION      AREA      Q        AREA        Q    TYPE    LNGTH    SLOPE     SIZE     Z        Q    NAME  TC  ZONE  IMPV
 48651   99E  4220.      3582.     4220.     3582.   0        0.  0.00000     0.00  0.00       0.    10   0   B98  0.00
 48651  100A    49.       153.       49.      153.   3      650.  0.01400     0.00  0.00       0.    20  10   B98  0.23
 48651  101A    23.        73.       72.      212.   4      400.  0.01000     4.75  0.00       0.    20  10   B98  0.40
 48651  102A    62.       215.      134.      406.   0        0.  0.00000     0.00  0.00       0.    20   8   B98  0.14
 48651  103A     0.         0.      134.      406.   0        0.  0.00000     0.00  0.00       0.    20  99   C99  0.00
```

```
------------------ADDITIONAL OUTPUT FOR SUBAREAS 104A THROUGH 168B--------------------
   48651  169B    27.       84.      264.      812.  0       0.  0.00000    0.00  0.00       0.   30   9   B98  0.15
   48651  170AB  264.      812.     2317.     4057.  0       0.  0.00000    0.00  0.00       0.   10   0   B98  0.00
*****************************************************************************************************************************
*                                            HYDROGRAPH FATTENED AT   170AB                                                 *
*   INCOMING HYDROGRAPH PEAK     =   4056.80                  INCOMING HYDROGRAPH VOLUME      =    898.16 AC.FT.            *
*   HYDROGRAPH ADJUSTMENT FACTOR =      0.87700               RUNOFF FACTOR                   =      6.00 IN.               *
*   ADJUSTED HYDROGRAPH PEAK     =   3557.82                  ADJUSTED HYDROGRAPH VOLUME      =    787.69 AC.FT.            *
*   ADJ/FATTENED HYDROGRAPH PEAK =   3557.82                  ADJ/FATTENED HYDROGRAPH VOLUME  =   1157.95 AC.FT.            *
*****************************************************************************************************************************
   48651  170AB    0.      812.     2317.     3558.  0       0.  0.00000    0.00  0.00       0.    0   0     0  0.00
   48651  171AE  4220.     3582.     6537.     6812.  0       0.  0.00000    0.00  0.00       0.   30   0   B98  0.00
   48651  172A      0.        0.     6537.     6812.  0       0.  0.00000    0.00  0.00       0.   30  99   B98  0.00
*****************************************************************************************************************************
*                                            RESERVOIR ROUTING AT   172A                                                    *
*   INCOMING HYDROGRAPH PEAK     =   6811.68                  INCOMING HYDROGRAPH VOLUME      =   2879.38 AC.FT.            *
*   HYDROGRAPH ADJUSTMENT FACTOR =      1.00000                                                                             *
*   RESERVOIR INFLOW  PEAK =   6811.68  TIME OF PEAK =   1171  VOLUME UNDER INFLOW  HYDROGRAPH =   2879.38 AC.FT.           *
*   MAXIMUM ELEVATION      =    642.03  TIME         =   1249  SPILLAGE ELEVATION  =    642.50  DIFFERENCE =      -0.47     *
*   NO SPILLAGE                                                                                                             *
*   RESERVOIR OUTFLOW PEAK =   3273.38  TIME OF PEAK =   1252  VOLUME UNDER OUTFLOW HYDROGRAPH =   2428.98 AC.FT.           *
*****************************************************************************************************************************
   48651  172A      0.        0.     6537.     3273.  6    1200.  0.00100   85.00  2.00       0.   30  99   B98  0.00
                                                      VENTURA COUNTY FLOOD CONTROL DISTRICT
                                                 MODIFIED RATIONAL METHOD HYDROLOGY / PC 2.21-950
     SAMPLE CALCULATION FN=SAMPLE1.DAT VCRat 2 VER. 2.2                                                        STORM DAY 4
                SUBAREA  SUBAREA     TOTAL     TOTAL  CONV    CONV     CONV     CONV   CONV   CONTROL SOIL       RAIN  PCT
    LOCATION      AREA      Q        AREA        Q    TYPE    LNGTH    SLOPE     SIZE     Z       Q    NAME  TC  ZONE  IMPV
   48651  173A      0.        0.     6537.     3273.  0       0.  0.00000    0.00  0.00       0.   30  99   B98  0.00

                                                  MODIFIED RATIONAL METHOD HYDROLOGY / PC 2.21-950
                                           OUTFLOW HYDROGRAPH AT THIS POINT
                                HYDROGRAPH AT  48651  105A         STORM DAY 4         REDUCTION FACTOR =  1.000

                                TIME      Q      TIME      Q      TIME      Q      TIME      Q      TIME      Q
                                   0        0.    100        7.    200        8.    300        9.    400        9.
                                 500       10.    600       10.    700       11.    800       12.    900       17.
                                1000       27.   1050       38.   1100       43.   1110       62.   1120       62.
                                1130       85.   1131       87.   1132       88.   1133       91.   1134       94.
                                1135       96.   1136       97.   1137      100.   1138      103.   1139      106.
                                1140      109.   1141      113.   1142      117.   1143      121.   1144      128.
                                1145      136.   1146      146.   1147      155.   1148      165.   1149      198.
                                1150      236.   1151      244.   1152      317.   1153      363.   1154      384.
                                1155      398.   1156      406.   1157      384.   1158      356.   1159      352.
                                1160      282.   1161      238.   1162      211.   1163      181.   1164      158.
                                1165      134.   1166      114.   1167       97.   1168       84.   1169       79.
```

1170	70.	1171	65.	1172	58.	1173	56.	1174	53.
1175	51.	1176	49.	1177	44.	1178	44.	1179	42.
1180	40.	1181	40.	1182	38.	1183	37.	1184	36.
1185	36.	1186	36.	1187	36.	1188	35.	1189	35.
1190	35.	1191	35.	1192	34.	1193	34.	1194	35.
1195	35.	1196	34.	1197	34.	1198	35.	1199	34.
1200	35.	1201	34.	1202	33.	1203	32.	1204	32.
1205	31.	1206	29.	1207	29.	1208	28.	1209	28.
1210	27.	1211	26.	1212	26.	1213	26.	1214	26.
1215	25.	1216	25.	1217	25.	1218	25.	1219	25.
1220	25.	1221	25.	1222	25.	1223	25.	1224	25.
1225	25.	1226	25.	1227	25.	1228	25.	1229	25.
1230	25.	1231	25.	1232	25.	1233	25.	1234	25.
1235	25.	1236	25.	1237	24.	1238	25.	1239	24.
1240	24.	1241	24.	1242	24.	1243	24.	1244	24.
1245	24.	1246	24.	1247	24.	1248	24.	1249	24.
1250	24.	1251	24.	1252	24.	1253	24.	1254	24.
1255	24.	1256	24.	1257	24.	1258	24.	1259	24.
1260	24.	1261	24.	1262	23.	1263	23.	1264	22.
1265	22.	1266	21.	1267	20.	1268	20.	1269	19.
1270	19.	1271	19.	1272	18.	1273	18.	1274	18.
1275	18.	1276	18.	1277	18.	1278	18.	1279	18.
1280	18.	1281	18.	1282	18.	1283	18.	1284	17.
1285	18.	1286	18.	1287	18.	1288	17.	1289	17.
1290	18.	1291	18.	1292	17.	1293	17.	1294	18.
1295	17.	1296	17.	1297	17.	1298	18.	1299	17.
1300	17.	1310	12.	1320	11.	1330	10.	1340	10.
1350	9.	1360	8.	1370	8.	1380	8.	1390	8.
1400	8.	1420	7.	1440	7.	1460	5.	1500	5.

```
*************************************************************************************************************
*                                          HYDROGRAPH FATTENED AT   170AB                                   *
*   HYDROGRAPH ADJUSTMENT FACTOR =      0.87700             RUNOFF FACTOR                  =      6.00 IN.  *
*   ADJUSTED HYDROGRAPH PEAK     =   3557.82                ADJUSTED HYDROGRAPH VOLUME     =   1157.95 AC.FT. *
*************************************************************************************************************
```

ADJUSTED HYDROGRAPH AFTER FATTENING

HYDROGRAPH AT 48651 170AB STORM DAY 4 ADJUSTMENT FACTOR = 0.877

TIME	Q	TIME	Q	TIME	Q	TIME	Q	TIME	Q
0	0.	100	133.	200	157.	300	193.	400	225.
500	249.	600	288.	700	341.	800	403.	900	527.
1000	773.	1050	1002.	1100	1331.	1110	1438.	1120	1556.
1130	1726.	1131	1746.	1132	1766.	1133	1786.	1134	1807.
1135	1828.	1136	1849.	1137	1872.	1138	1895.	1139	1918.
1140	1942.	1141	1967.	1142	1993.	1143	2021.	1144	2049.
1145	2082.	1146	2116.	1147	2152.	1148	2191.	1149	2246.
1150	2304.	1151	2353.	1152	2445.	1153	2533.	1154	2622.

1155	2717.	1156	2799.	1157	2871.	1158	2945.	1159	3006.
1160	3085.	1161	3152.	1162	3228.	1163	3301.	1164	3356.
1165	3400.	1166	3442.	1167	3475.	1168	3501.	1169	3524.
1170	3542.	1171	3554.	1172	3558.	1173	3551.	1174	3536.
1175	3508.	1176	3469.	1177	3420.	1178	3361.	1179	3293.
1180	3218.	1181	3138.	1182	3062.	1183	2984.	1184	2907.
1185	2829.	1186	2749.	1187	2672.	1188	2598.	1189	2530.
1190	2468.	1191	2408.	1192	2350.	1193	2293.	1194	2239.
1195	2188.	1196	2139.	1197	2093.	1198	2050.	1199	2013.
1200	1979.	1201	1945.	1202	1911.	1203	1878.	1204	1846.
1205	1815.	1206	1784.	1207	1755.	1208	1728.	1209	1701.
1210	1677.	1211	1653.	1212	1631.	1213	1610.	1214	1589.
1215	1570.	1216	1551.	1217	1534.	1218	1517.	1219	1500.
1220	1484.	1221	1469.	1222	1454.	1223	1439.	1224	1425.
1225	1412.	1226	1399.	1227	1386.	1228	1374.	1229	1363.
1230	1352.	1231	1341.	1232	1331.	1233	1320.	1234	1310.
1235	1301.	1236	1291.	1237	1282.	1238	1272.	1239	1263.
1240	1253.	1241	1244.	1242	1234.	1243	1225.	1244	1216.
1245	1206.	1246	1197.	1247	1188.	1248	1179.	1249	1171.
1250	1163.	1251	1154.	1252	1146.	1253	1138.	1254	1130.
1255	1122.	1256	1115.	1257	1107.	1258	1100.	1259	1093.
1260	1086.	1261	1080.	1262	1073.	1263	1066.	1264	1060.
1265	1053.	1266	1046.	1267	1040.	1268	1033.	1269	1027.
1270	1021.	1271	1014.	1272	1008.	1273	1002.	1274	995.
1275	989.	1276	983.	1277	978.	1278	972.	1279	966.
1280	961.	1281	956.	1282	950.	1283	944.	1284	939.
1285	934.	1286	928.	1287	923.	1288	917.	1289	912.
1290	907.	1291	901.	1292	896.	1293	891.	1294	886.
1295	881.	1296	877.	1297	872.	1298	867.	1299	863.
1300	858.	1310	804.	1320	748.	1330	699.	1340	655.
1350	606.	1360	556.	1370	514.	1380	477.	1390	445.
1400	419.	1420	372.	1440	337.	1460	309.	1500	279.

```
*****************************************************************************************************************************
*                                              RESERVOIR ROUTING AT   172A                                                  *
*   INCOMING HYDROGRAPH PEAK     =   6811.68                 INCOMING HYDROGRAPH VOLUME      =   2879.38 AC.FT.             *
*   HYDROGRAPH ADJUSTMENT FACTOR =      1.00000                                                                             *
*   RESERVOIR INFLOW  PEAK =   6811.68  TIME OF PEAK =   1171  VOLUME UNDER INFLOW  HYDROGRAPH =   2879.38 AC.FT.           *
*   MAXIMUM ELEVATION      =    642.03  TIME         =   1249  SPILLAGE ELEVATION  =    642.50  DIFFERENCE =      -0.47     *
*   NO SPILLAGE                                                                                                             *
*   RESERVOIR OUTFLOW PEAK =   3273.38  TIME OF PEAK =   1252  VOLUME UNDER OUTFLOW HYDROGRAPH =   2428.98 AC.FT.           *
*****************************************************************************************************************************
```

B-8.3 VCRat2.6 Partial Input File- VCRat2.64 File is Similar

```
PROGRAM VCRAT2.6PROJ
PROJECT 1 SAMPLE1
DESCRIP SAMPLE CALCULATION FN=SAMPLE1.DAT VCRat 2 VER. 2.2
JOB 48651 99 100
OUTPUT C:\Program Files\VCWPD Hydrology\VCRat 25\SAMPLE1.out
HYDROFILE C:\Program Files\VCWPD Hydrology\VCRat 25\SAMPLE1.hyd
TCOUTPUT C:\Program Files\VCWPD Hydrology\VCRat 25\SAMPLE1
SUBAREA 99 E 4
DESCRIP SAMPLE CALCULATION FN=SAMPLE1.DAT VCRat 2 VER. 2.2
MISCPARAMS N
IMPORT 4220 99E N
SUBAREA 100 A 0
SUBPARAMS 49 23 020 K 10
MISCPARAMS N
ROUTING 3 650 0.01400
SUBAREA 101 A 0
SUBPARAMS 23 40 020 K 10
MISCPARAMS N
ROUTING 4 400 0.01000 -1.00
SUBAREA 102 A 0
SUBPARAMS 62 14 020 K 8
MISCPARAMS N
SUBAREA 103 A 1
MISCPARAMS N
---------------------ADDITIONAL SUBAREAS BETWEEN 103A AND 169B----------------------
SUBAREA 169 B 0
SUBPARAMS 27 15 030 K 9
MISCPARAMS N
SUBAREA 170 A 2 B
DESCRIP THIS HYDROGRAPH IS ADJUSTED FOR AREAL REDUCTION & FATTENING
MISCPARAMS Y N
RESERVOIR 170 A NORES
ADJFACT 0.87700
FATRUN 6.00
SUBAREA 171 A 2 E
DESCRIP INFLOW HYDROGRAPH TO DETENTION BASIN
MISCPARAMS Y N
SUBAREA 172 A 1
DESCRIP DETENTION BASIN ROUTING
MISCPARAMS Y
RESERVOIR 172 A 642.50 643.48
ADJFACT 0.00000
STAGE   1    634.50   640.00   640.50   641.99   642.06   642.16   642.27   642.40
STORAGE 1      0.00   314.59   415.21   615.98   817.07  1018.61  1320.32  1522.33
OUTFLOW 1      0.00  1905.00  2320.00  2830.00  3540.00  5550.00  5860.00  6870.00
STAGE   9    643.48
STORAGE 9   1723.57
OUTFLOW 9   8875.00
ROUTING2 6 1200 0.00100 85
CHANLDATA2 2.00000 0.022 0.020
MAXVEL2 20 0
SUBAREA 173 A 1
DESCRIP DATA LINE ALWAYS NEEDED ONLY IF END OF FILE FOLLOWS
MISCPARAMS Y
```

B-8.4 VCRat2.6 Partial Output File- VCRat2.64 File is Similar

(Note- # next to channel type indicates program has automatically changed conveyance type to accommodate flows)

```
                                        Ventura County Watershed Protection District
                                     Modified Rational Method Hydrology Program (VCRat v2.6)


                                            Modified Rational Model Results Report


                                              Job:  48651  Project: SAMPLE1


      Project Description
      ------------------------------------------------------------------------------------------------------------------------------------
-
      SAMPLE CALCULATION FN=SAMPLE1.DAT VCRAT2 VER. 2.2


      ------------------------------------------------------------------------------------------------------------------------------------
-

      VCRat version:   2.6.2009.7
      VCRain version:  200703
      DOS EXE version: PC 2.2-200809

                                                            Job:  48651  Project: SAMPLE1
Page:     2
                                                                    Model Results
   |---------- SUBAREA DATA AND RESULTS --------|-- ACCUMULATED DATA --|------------ ROUTING AFTER ACCUMULATION ---------------------------------|
   | NODE   SOIL  RAIN   TC    %    AREA  FLOW  |  AREA    FLOW   TIME |  CHANNEL  LENGTH   SLOPE     SIZE    H:V       N VALUES      VEL  DEPTH |
   |  ID    TYPE  ZONE (MIN)  IMP   (AC)  (CFS) |  (AC)    (CFS)  (MIN)|    TYPE    (FT)   (FT/FT)    (FT)    (Z)      CHNL   SIDES  (FT/S)  (FT) |
   |--------------------------------------------|----------------------|-----------------------------------------------------------------------|
      99E :  SAMPLE CALCULATION FN=SAMPLE1.DAT VCRat 2 VER. 2.2
      99E :  Import Hydro: 99E
      99E   ---   ---    --   --   4220   3582     4220    3582   1158   -------    ----  -------    ---     ----     -----  -----    --     --
     100A   020   K100   10   23     49    153       49     153   1154   40' ROAD    650  0.01400    ---     ----     -----  -----    --     --
     101A   020   K100   10   40     23     73       72     212   1157   PIPE        400  0.01000     4.75   ----     -----  -----    --     --
     102A   020   K100    8   14     62    215      134     406   1156   -------    ----  -------    ---     ----     -----  -----    --     --
     103A   ---   ---    --   --    ---    ---      134     406   1156   -------    ----  -------    ---     ----     -----  -----    --     --
--------------ADDITIONAL OUTPUT BETWEEN 103A AND 169B----------------------------------------------------
     169B   030   K100    9   15     27     84      264     812   1160   -------    ----  -------    ---     ----     -----  -----    --     --
     170AB:  THIS HYDROGRAPH IS ADJUSTED FOR AREAL REDUCTION & FATTENING
```

```
170AB ---   ---    --   --    264    812     2317    4057   1172    -------    ---- -------    ---     ----    ----- -----     --     --
       ******************************************************************************************
       *      INCOMING HYDROGRAPH  PEAK (cfs):   4056.80         VOLUME (acre-ft):    898.16      *
       *      HYDROGRAPH ADJUSTMENT FACTOR:        0.87700                                        *
       *      ADJUSTED HYDROGRAPH  PEAK (cfs):   3557.82         VOLUME (acre-ft):    787.69      *
       *      RUNOFF FACTOR(in):   6.00                                                           *
       *      FATTENED HYDROGRAPH  PEAK (cfs):   3557.82         VOLUME (acre-ft):   1157.95      *
       ******************************************************************************************
170A  ---   ---    --   --    ---    ---     2317    3558   ----    -------    ---- -------    ---     ----    ----- -----     --     --
171AE:  INFLOW HYDROGRAPH TO DETENTION BASIN
171AE ---   ---    --   --   4220   3582     6537    6812   1171    -------    ---- -------    ---     ----    ----- -----     --     --

                                            Ventura County Watershed Protection District
                                       Modified Rational Method Hydrology Program (VCRat v2.6)

                                                   Job:  48651  Project: SAMPLE1
Page:     4
                                                           Model Results
 |---------- SUBAREA DATA AND RESULTS --------|-- ACCUMULATED DATA --|------------ ROUTING AFTER ACCUMULATION ---------------------------------|
 | NODE   SOIL  RAIN   TC    %    AREA  FLOW  |  AREA    FLOW   TIME |  CHANNEL  LENGTH   SLOPE     SIZE    H:V       N VALUES       VEL  DEPTH |
 |  ID    TYPE  ZONE (MIN)  IMP   (AC)  (CFS) |  (AC)    (CFS)  (MIN)|    TYPE    (FT)   (FT/FT)    (FT)    (Z)     CHNL   SIDES  (FT/S)  (FT) |
 |--------------------------------------------|---------------------|-----------------------------------------------------------------------|
172A :  DETENTION BASIN ROUTING
172A  ---   ---    --   --    ---    ---     6537    6812   1171    -------    ---- -------    ---     ----    ----- -----     --     --
       ******************************************************************************************
       *      INCOMING HYDROGRAPH  PEAK (cfs):   6811.68         VOLUME (acre-ft):   2879.38      *
       *      NO HYDROGRAPH ADJUSTMENT                                                            *
       *      NO HYDROGRAPH FATTENING                                                             *
       *      RESERVOIR INFLOW:    PEAK (cfs):   6811.68 @ 1171  VOLUME (acre-ft):   2879.38      *
       *      MAXIMUM ELEVATION:   STAGE (ft):    642.03 @ 1249  VOLUME (acre-ft):    730.89      *
       *      EMERGENCY SPILLWAY:   ELEV (ft):    642.50         VOLUME (acre-ft):   1540.96      *
       *          DIFFERENCE:   IN STAGE (ft):     -0.47      IN VOLUME (acre-ft):    810.07      *
       *          NO SPILL EXPECTED.       PERCNT OF VOLUME REMAINING TO SPILLWAY:     52.6%      *
       *      TOP OF DAM:           ELEV (ft):    643.48         VOLUME (acre-ft):   1723.57      *
       *          DIFFERENCE    IN STAGE (ft):     -1.45      IN VOLUME (acre-ft):    992.68      *
       *          NO OVERTOP EXPECTED.   PERCNT OF VOLUME REMAINING TO TOP OF DAM:     57.6%      *
       *      RESERVOIR OUTFLOW:   PEAK (cfs):   3273.38 @ 1252  VOLUME (acre-ft):   2428.98      *
       ******************************************************************************************
172A  ---   ---    --   --    ---    ---     6537    3273   1252    CHANNELV   1200  0.00100     85     2.00  0.020    0.022     20      0
173A :  DATA LINE ALWAYS NEEDED ONLY IF END OF FILE FOLLOWS
173A  ---   ---    --   --    ---    ---     6537    3273   1256    -------    ---- -------    ---     ----    ----- -----     --     --


                                                           Warning Messages
  TYPE      ERR NO   PROCEEDURE   LOCATION   MESSAGE
 ---------------------------------------------------------------------------------------------------------------------------------------------
```

NO MESSAGES OR WARNINGS DETECTED

Ventura County Watershed Protection District
Modified Rational Method Hydrology Program (VCRat v2.6)

Job: 48651 Project: SAMPLE1

Page: 5

Hydrograph Printouts

HYDROGRAPH PRINTOUT AT: 105A

DESCRIPTION: OUTFLOW HYDROGRAPH AT THIS POINT
TOTAL AREA TO HYDROGRAPH: 134 acres
HYDROGRAPH PEAK: 406 cfs
TIME OF PEAK: 1156 minutes
HYDROGRAPH VOLUME: 39.42 acre-ft

TIME (min)	FLOW (cfs)	TIME (min)	FLOW (cfs)	TIME (min)	FLOW (cfs)	TIME (min)	FLOW (cfs)	TIME (min)	FLOW (cfs)
0	0.	100	7.	200	8.	300	9.	400	9.
500	10.	600	10.	700	11.	800	12.	900	17.
1000	27.	1050	38.	1100	43.	1110	62.	1120	62.
1130	85.	1131	87.	1132	88.	1133	91.	1134	94.
1135	96.	1136	97.	1137	100.	1138	103.	1139	106.
1140	109.	1141	113.	1142	117.	1143	121.	1144	128.
1145	136.	1146	146.	1147	155.	1148	165.	1149	198.
1150	236.	1151	244.	1152	317.	1153	363.	1154	384.
1155	398.	1156	406.	1157	384.	1158	356.	1159	352.
1160	282.	1161	238.	1162	211.	1163	181.	1164	158.
1165	134.	1166	114.	1167	97.	1168	84.	1169	79.
1170	70.	1171	65.	1172	58.	1173	56.	1174	53.
1175	51.	1176	49.	1177	44.	1178	44.	1179	42.
1180	40.	1181	40.	1182	38.	1183	37.	1184	36.
1185	36.	1186	36.	1187	36.	1188	35.	1189	35.
1190	35.	1191	35.	1192	34.	1193	34.	1194	35.
1195	35.	1196	34.	1197	34.	1198	35.	1199	34.
1200	35.	1201	34.	1202	33.	1203	32.	1204	32.
1205	31.	1206	29.	1207	29.	1208	28.	1209	28.
1210	27.	1211	26.	1212	26.	1213	26.	1214	26.
1215	25.	1216	25.	1217	25.	1218	25.	1219	25.
1220	25.	1221	25.	1222	25.	1223	25.	1224	25.
1225	25.	1226	25.	1227	25.	1228	25.	1229	25.
1230	25.	1231	25.	1232	25.	1233	25.	1234	25.
1235	25.	1236	25.	1237	24.	1238	25.	1239	24.
1240	24.	1241	24.	1242	24.	1243	24.	1244	24.
1245	24.	1246	24.	1247	24.	1248	24.	1249	24.

1250	24.	1251	24.	1252	24.	1253	24.	1254	24.
1255	24.	1256	24.	1257	24.	1258	24.	1259	24.
1260	24.	1261	24.	1262	23.	1263	23.	1264	22.
1265	22.	1266	21.	1267	20.	1268	20.	1269	19.
1270	19.	1271	19.	1272	18.	1273	18.	1274	18.
1275	18.	1276	18.	1277	18.	1278	18.	1279	18.
1280	18.	1281	18.	1282	18.	1283	18.	1284	17.
1285	18.	1286	18.	1287	18.	1288	17.	1289	17.
1290	18.	1291	18.	1292	17.	1293	17.	1294	18.
1295	17.	1296	17.	1297	17.	1298	18.	1299	17.
1300	17.	1310	12.	1320	11.	1330	10.	1340	10.
1350	9.	1360	8.	1370	8.	1380	8.	1390	8.
1400	8.	1420	7.	1440	7.	1460	5.	1500	5.

B-9 YIELD ADJUSTMENT EXAMPLE

This section provides on example of how to do a yield adjustment in VCRat to make sure a detention basin design hydrograph has a reasonable volume. It is necessary to do this because MRM hydrographs from VCRat generally have volumes that are less than expected from an NRCS CN analysis except where the 100-yr 24-hr rainfall depth is about 6 in or less such as in the vicinity of Oxnard. The section describes the procedure using ArcMap or some similar GIS program. Other programs can also be used, or hand techniques. The procedure is the following:

1. Use VCRatX.X to produce an inflow hydrograph for the design storm and tributary watershed at the detention basin location. For this example the yield is calculated for the Mt Sinai Basin location node 55 in the official 100-yr Calleguas Model with residential and undeveloped land uses.

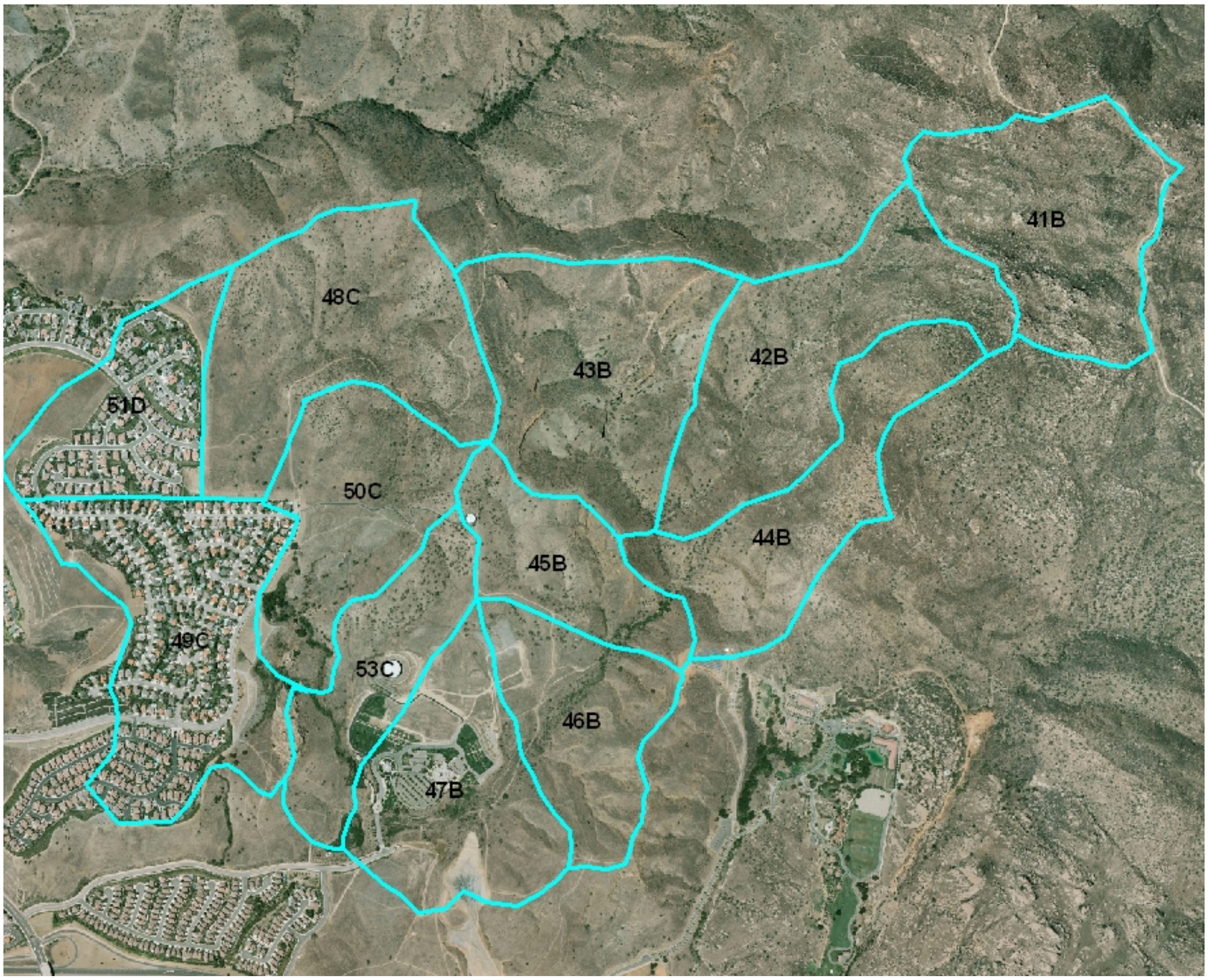


Figure B-9.1 Mt Sinai Basin Watershed Subareas

Use the shapefiles or maps in Appendix E to find the average soil type in the watershed by clipping the soils map with the watershed boundary, recalculating the clipped areas, and finding the weighted average soil type (1.45 for this example). If the rainfall contours have regularly spaced intervals across the watershed, find the total average design storm rainfall depth (N-yr 24-hour) at the watershed centroid. If the contours are irregularly spaced, use GIS techniques to assign an area to each contour and calculate the weighted average rainfall.

Soil Data Summary

SOIL NO.	AREA, AC.	WTD SOIL
1	713.8	0.785
2	19.2	0.042
2	38.5	0.085
2	39.6	0.087
3	59.3	0.196
3	9.3	0.031
3	2.3	0.008
7	27.9	0.214
Total	909.8	1.447

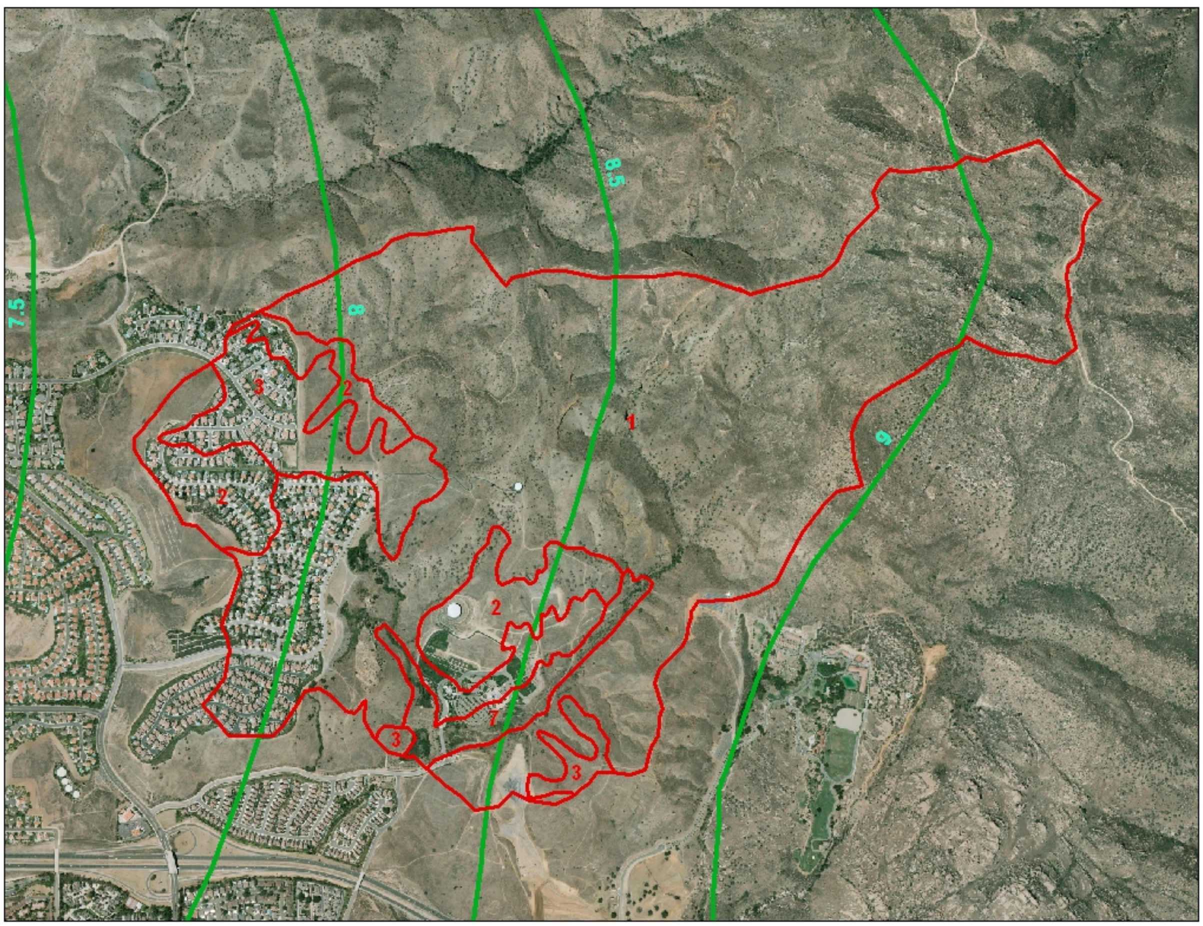


Figure B-9.2 Soils and 100-yr 24-hr Rain Map

Clip the General Plan land use shapefile with the watershed boundary to obtain a list of land uses and associated areas. Assign appropriate NRCS CNs from Exhibits 14a and b to each land use and use linear interpolation to calculate CNs for the areally weighted soil type for each land use. Calculate the areally-weighted CN for the watershed.

Land Use General	**Land Use Specific**	**Exhibit 14 Land Use**	**Area Ac.**	**CN Soil 1**	**CN Soil 2**	**CN Soil 1.45**	**Wtd CN**
OPEN SPACE AND RECREATION	Community Park	Open Space-Park	54	80	76	77.79	4.62
OPEN SPACE AND RECREATION	Undeveloped	Open Brush Fair	548	61	58	59.34	35.85
OPEN SPACE AND RECREATION	Open Space (1 du/40 ac)	Open Brush Fair	13	61	58	59.34	0.82
RESIDENTIAL 5 - 11.99 UNITS PER ACRE	Medium Density (4.5 to 15 du/ac)	Residential 1/8 ac lot	11	92	90	90.89	1.06
RESIDENTIAL 5 - 11.99 UNITS PER ACRE	Low Density (2 to 4.5 du/ac)	Residential 1/2 ac lot	282	86	82	83.79	26.05
Sum			**907**				**68.40**

Use Exhibit 13 or the NRCS equation to find the watershed yield in inches using the weighted CN from Step 3 and the total design storm rainfall depth from Step 2.

	CN AMC II Yield
100-yr 24-hr Precip. P (in)	8.4
Wtd CN:	68.40
Potential Abstraction S =(1000/CN) -10:	4.62
Initial Abstraction I_a =0.2S:	0.92
Yield =$(P-0.2S)^2/(P+0.8S)$: (in)	**4.62**

Enter this as a yield adjustment factor in the model data input file above for VCRatX.X. In 2.6 and 2.64 the user can also enter the rainfall and curve number directly and the program will calculate the resultant yield following the assumption that the initial abstraction is 0.2 times the total abstraction. The yield information is entered by editing the reservoir routing portion in the appropriate subarea editing window.

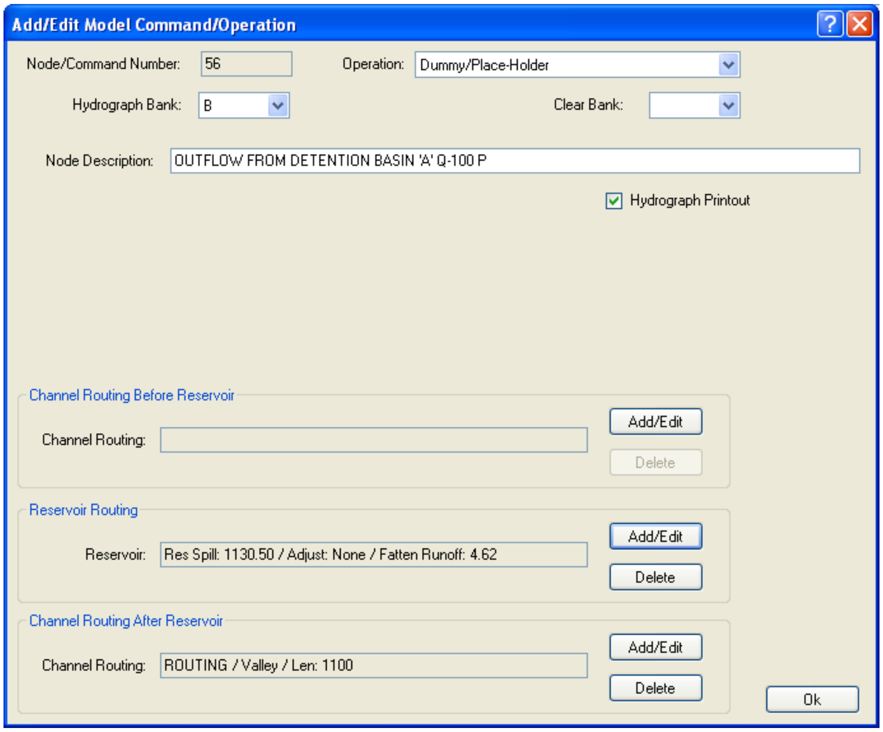


Figure B-9.3 Subarea Editing Window, VCRat2.64

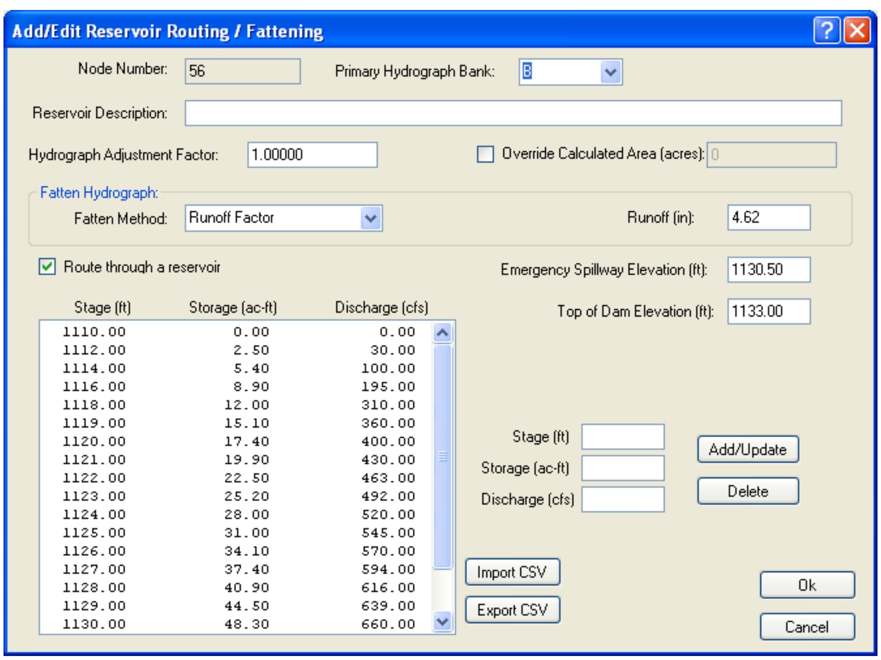


Figure B-9.4 Reservoir Routing Editing Window, VCRat2.64

As a check, the volume of the output hydrograph should equal the yield adjustment factor times the area of the tributary watershed after the units are converted. Sample input and output files for a VCRat2.2 run are shown below.

If desired, GIS techniques can be used to find each unique soil number and land use polygon, assigning CNs to the results, and calculating the average weighted CN for the watershed. Comparisons of the detailed approach and using the weighted soil number approach described above have shown relatively small differences between the two methods. It takes additional work to assign CNs to the unique combinations and therefore is not required for District studies.

B-9.1 Sample Yield Adjustment File, VCRat2.2

```
005 15031    1A CALLEGUAS CRK.Q100P YIELD ADJUSTMENT EXAMPLE 09/2010
005 15031   22A ARROYO SIMI AT KUEHNER DR.(HEADWATERS) Q100P (MDP '88)
005 15031   53C INFLOW TO DETENTION BASIN 'A' NORTH W/ AR APPLIED 100P
005 15031   56B OUTFLOW FROM DETENTION BASIN 'A' Q-100 P
005 15031   58B WHITE OAK CHL.PRIOR TO JCT.W/HUMMINGBIRD Q100P
005 15031   87BCWHITE OAK CHL.AFTER JCT.W/HUMMINGBIRD Q100P
005 15031   88B WHITE OAK PRIOR JCT.W/ARROYO SIMI Q-100P
005 15031   96ABARROYO SIMI AFTER JCT.W/WHITE OAK CHANNEL Q100P
005 15031   97A LAST POINT IN YIELD ADJUSTMENT EXAMPLE
999
007 15031   51D      55 141110      30200  4
008  5    0       0  100       3  200       3  300       4  400       4
008 10  500       4  600       4  700       4  800       5  900       8
008 15 1000      12 1050      18 1100      20 1110      30 1120      29
008 20 1130      30 1131      30 1132      30 1133      30 1134      30
008 25 1135      30 1136      30 1137      30 1138      30 1139      30
008 30 1140      30 1141      30 1142      30 1143      30 1144      30
008 35 1145      30 1146      30 1147      30 1148      30 1149      30
008 40 1150      30 1151      30 1152      30 1153      30 1154      30
008 45 1155      30 1156      30 1157      30 1158      30 1159      30
008 50 1160      30 1161      30 1162      30 1163      30 1164      30
008 55 1165      30 1166      30 1167      30 1168      30 1169      30
008 60 1170      29 1171      27 1172      26 1173      25 1174      24
008 65 1175      21 1176      21 1177      20 1178      20 1179      19
008 70 1180      17 1181      18 1182      17 1183      17 1184      17
008 75 1185      16 1186      16 1187      16 1188      16 1189      17
008 80 1190      16 1191      16 1192      16 1193      16 1194      16
008 85 1195      16 1196      16 1197      16 1198      16 1199      16
008 90 1200      14 1201      16 1202      15 1203      15 1204      15
008 95 1205      12 1206      13 1207      13 1208      13 1209      12
008100 1210      11 1211      11 1212      11 1213      11 1214      11
008105 1215      11 1216      11 1217      12 1218      11 1219      11
008110 1220      12 1221      12 1222      12 1223      11 1224      11
008115 1225      12 1226      12 1227      11 1228      11 1229      12
008120 1230      11 1231      11 1232      11 1233      11 1234      11
008125 1235      11 1236      11 1237      11 1238      11 1239      11
008130 1240      11 1241      11 1242      11 1243      11 1244      11
008135 1245      11 1246      11 1247      11 1248      11 1249      11
008140 1250      11 1251      11 1252      11 1253      11 1254      11
008145 1255      11 1256      11 1257      11 1258      11 1259      11
008150 1260      11 1261      11 1262      10 1263      10 1264      10
008155 1265      10 1266       9 1267       9 1268       9 1269       9
008160 1270       8 1271       8 1272       8 1273       8 1274       8
008165 1275       8 1276       8 1277       8 1278       8 1279       8
008170 1280       8 1281       8 1282       8 1283       8 1284       8
008175 1285       8 1286       8 1287       8 1288       8 1289       8
008180 1290       8 1291       8 1292       8 1293       8 1294       8
008185 1295       8 1296       8 1297       8 1298       8 1299       8
008190 1300       8 1310       4 1320       4 1330       4 1340       4
008195 1350       3 1360       3 1370       3 1380       3 1390       3
008200 1400       3 1420       2 1440       2 1460       0 1500       0
007 15031   54C     383 481162     706200  4
008  5    0       0  100       5  200      13  300      17  400      20
008 10  500      23  600      27  700      32  800      40  900      59
008 15 1000     100 1050     156 1100     222 1110     252 1120     282
```

```
008 20 1130     312 1131     315 1132     319 1133     323 1134     326
008 25 1135     330 1136     334 1137     338 1138     342 1139     347
008 30 1140     351 1141     355 1142     358 1143     361 1144     365
008 35 1145     369 1146     373 1147     377 1148     381 1149     386
008 40 1150     391 1151     397 1152     420 1153     455 1154     491
008 45 1155     527 1156     575 1157     617 1158     651 1159     676
008 50 1160     693 1161     703 1162     706 1163     703 1164     695
008 55 1165     682 1166     664 1167     643 1168     619 1169     596
008 60 1170     574 1171     552 1172     532 1173     519 1174     505
008 65 1175     492 1176     478 1177     465 1178     453 1179     441
008 70 1180     429 1181     418 1182     408 1183     400 1184     398
008 75 1185     396 1186     394 1187     391 1188     389 1189     387
008 80 1190     384 1191     382 1192     379 1193     377 1194     374
008 85 1195     371 1196     369 1197     366 1198     364 1199     361
008 90 1200     359 1201     356 1202     353 1203     350 1204     346
008 95 1205     343 1206     340 1207     336 1208     333 1209     329
008100 1210     326 1211     323 1212     319 1213     316 1214     313
008105 1215     309 1216     306 1217     303 1218     300 1219     296
008110 1220     291 1221     287 1222     283 1223     279 1224     275
008115 1225     271 1226     268 1227     264 1228     261 1229     257
008120 1230     254 1231     251 1232     248 1233     246 1234     243
008125 1235     240 1236     238 1237     235 1238     233 1239     229
008130 1240     222 1241     217 1242     212 1243     208 1244     204
008135 1245     201 1246     198 1247     196 1248     194 1249     192
008140 1250     190 1251     188 1252     187 1253     185 1254     184
008145 1255     182 1256     181 1257     180 1258     178 1259     177
008150 1260     176 1261     175 1262     174 1263     173 1264     172
008155 1265     171 1266     169 1267     168 1268     167 1269     165
008160 1270     164 1271     162 1272     161 1273     159 1274     158
008165 1275     156 1276     154 1277     153 1278     151 1279     150
008170 1280     149 1281     147 1282     146 1283     145 1284     143
008175 1285     142 1286     141 1287     140 1288     139 1289     138
008180 1290     137 1291     136 1292     135 1293     134 1294     133
008185 1295     132 1296     132 1297     131 1298     130 1299     130
008190 1300     129 1310     122 1320     110 1330     100 1340      93
008195 1350      87 1360      81 1370      75 1380      70 1390      66
008200 1400      63 1420      58 1440      54 1460      50 1500      46
999
006 15031  001A 010      099B98                                G1 7
006 15031  002A 010010  8313B981 115000800
006 15031  003A 010000  7611B98
006 15031  004A 010000  5113B981  40000500
006 15031  005B 010000  4512B981  50000800
006 15031  006AB010         B981 220000600                    1
006 15031  007A 010000  6011B981  30000300
006 15031  008B 010000  5914B981 205003000
006 15031  009B 010000  6410B98
006 15031  010B 010000  8113B981  60003000
006 15031  011B 010000  5212B981 170000500
006 15031  012AB010         B981  60000250                    1
006 15031  013A 010005  8212B981 110000180
006 15031  014B 010000  6314B98
006 15031  015B 010000  6312B981  90001500
006 15031  016B 010000  2710B981  90000450
006 15031  017B 010002  6913B985  76000130 000   800
006 15031  018AB010         B985  20000200 000  1000          1
006 15031  019A 050005  3809B985 100000200 000  1000
006 15031  020B 010007  7113B981  90000750
006 15031  021AB010         B985  90000100 000  1400          1
006 15031  022A 050050  6912B985  50000100 000  1400         1
006 15031  023B 010000  7512B981 280002000
006 15031  024B 010000 13117B981  70000200
006 15031  025C 010000  6814B981 110000150
006 15031  026C 010009  8412B981  45000200
006 15031  027C 010007  2411B98
```

```
006 15031  028BC010         B981 130000450                     1
006 15031  029AB010         B985 160000100 000  1800           1
006 15031  030B 010000  4708B981  47500800
006 15031  031B 010000  4208B98
006 15031  032B 010007  3009B981 195000857
006 15031  033B 010015  5610B984  15000400
006 15031  034B 010      099B985  57000157 100   200
006 15031  035B 010015  2608B985  34000356       700
006 15031  036B 030015  0507B985  27000250 200   500
006 15031  037B 030020  3710B985  70000550 150   500
006 15031  038B 050037  0908B98
006 15031  039A 050036  4910B98
006 15031  040AB010         B985 150000060 000  1800           1
006 15031  041B 010000  8517B981 4050029630
006 15031  042B 010000  9520B98
006 15031  043B 010000  9815B981  60000833
006 15031  044B 010002  7114B981  60000417
006 15031  045B 010002  4712B981 140000393
006 15031  046B 020001  5712B981 190000368
006 15031  047B 030016  7507B982  500002000
006 15031  048C 010001 10113B984 1750008170      60
006 15031  049C 020023  9813B981  30000417
006 15031  050C 020008  7612B981 110000268
006 15031  051D 020         B984 1750008170      60             D D
006 15031  052CD020         B981 155003020                     1
006 15031  053C 02000   5216B98                               1
006 15031  054C 020         B98                                 C C
006 15031  055BC020         B984  443006460      70            1
006 15031  056B 020      099B98                               1
110
111 1130.5     1.00000    4.62
112 1110.   1112.   1114.   1116.   1118.   1119.   1120.   1121.   1122.   1123.
112 1124.   1125.   1126.   1127.   1128.   1129.   1130.   1131.   1132.   1133.
113    0.0     2.5     5.4     8.9    12.0    15.1    17.4    19.9    22.5    25.2
113   28.0    31.0    34.1    37.4    40.9    44.5    48.3    52.4    56.6    60.5
114    0.0    30.0   100.0   195.0   310.0   360.0   400.    430.    463.    492.
114  520.    545.    570.    594.    616.    639.    660.    713.    871.   1088.
115
116 15031  056B 020      099B982 1100002277
110
006 15031  057B 030016  6408B985  22000175      16
006 15031  058B 030010  3410B985  90000010 20   10            1
006 15031  059C 010000  4610B981  70004300
006 15031  060C 010      099B981 105001700
006 15031  061C 010      099B981  70003200
006 15031  062C 010000  8612B981 100001600
006 15031  063D 010000  7512B981 170001900
006 15031  064D 010000  4212B98
006 15031  065D 010000  6812B981 162501200
006 15031  066CD010         B981  70001300                     1
006 15031  067C 020003  6210B981 105000700
006 15031  068C 020006  7209B981 190001000
006 15031  069D 010000  9013B98
006 15031  070D 010000  6213B981 140002100
006 15031  071D 010      099B981 175000570
006 15031  072D 010000  8910B981 130000580
006 15031  073D 010000  9611B981 110000250
006 15031  074E 010000  5712B981 150002800
006 15031  075DE010         B981  30000170
006 15031  076C 010002  5109B98
006 15031  077CD010         B981  37500050
006 15031  078C 040000  4409B98
006 15031  079C 010001  6010B985 130000050 067   500
006 15031  080D 010000  7812B984 140000070
006 15031  081D 040004  4210B98
```

```
006 15031  082CD010         B985 12000015  100  1000          1
006 15031  083D 010000  5212B984 255000200
006 15031  084D 040023  6411B98
006 15031  085CD010         B985 180000020 100  1300          1
006 15031  086C 040020  7412B98
006 15031  087BC010         B98                              11
006 15031  088B 070023  4210B985  20000060 000  1800         1
006 15031  089C 050023  2809B984  60000020
006 15031  090C 050023  8514B985  22000730 200   400               035035
006 15031  091BC010         B985  40000060 000  1800
006 15031  092B 040023  4912B985  45000060 000  1800
006 15031  093C 020011  7313B984 32000012
006 15031  094C 040023  9413B98
006 15031  095BC010         B98                               1
006 15031  096AB010         B985 22500010       2200         11
006 15031  097A 010      099B98                              1  2
```

B-9.2 Partial Sample Yield Adjustment Output File, VCRat2.2

```
                                          VENTURA COUNTY FLOOD CONTROL DISTRICT
                                       MODIFIED RATIONAL METHOD HYDROLOGY / PC 2.21-952
    CALLEGUAS CRK.Q100P YIELD ADJUSTMENT EXAMPLE 09/2010                                                      STORM DAY 4
                SUBAREA  SUBAREA     TOTAL     TOTAL  CONV   CONV     CONV     CONV   CONV   CONTROL SOIL      RAIN  PCT
    LOCATION      AREA      Q        AREA        Q    TYPE   LNGTH   SLOPE     SIZE     Z       Q    NAME  TC  ZONE  IMPV
*****************************************************************************************************************************
*                                                     CONFLUENCE Q'S                                                        *
*  15031   52C  TC 1160 QC     725. QCD     755. QD      30.   15031   52D  TD 1120 QD      30. QDC     153. QC     123.   *
*                              15031   52CD TCD 1160 QCD     755. QC     725. QD     30.                                    *
*****************************************************************************************************************************
                SUBAREA  SUBAREA     TOTAL     TOTAL  CONV   CONV     CONV     CONV   CONV   CONTROL SOIL      RAIN  PCT
    LOCATION      AREA      Q        AREA        Q    TYPE   LNGTH   SLOPE     SIZE     Z       Q    NAME  TC  ZONE  IMPV
   15031   52CD    55.        30.      330.      755.   1    1550.  0.30200    0.00  0.00       0.   20   0   B98  0.00
   15031   53C     52.       119.      382.      861.   0       0.  0.00000    0.00  0.00       0.   20  16   B98  0.00
   15031   54C    383.       706.      383.      706.   0       0.  0.00000    0.00  0.00       0.   20   0   B98  0.00
*****************************************************************************************************************************
*                                                     CONFLUENCE Q'S                                                        *
*  15031   55B  TB 1166 QB    1024. QBC    1688. QC     664.   15031   55C  TC 1162 QC     706. QCB    1637. QB     931.   *
*                              15031   55BC TBC 1165 QBC    1704. QB    1022. QC     682.                                   *
*****************************************************************************************************************************
                SUBAREA  SUBAREA     TOTAL     TOTAL  CONV   CONV     CONV     CONV   CONV   CONTROL SOIL      RAIN  PCT
    LOCATION      AREA      Q        AREA        Q    TYPE   LNGTH   SLOPE     SIZE     Z       Q    NAME  TC  ZONE  IMPV
   15031   55BC   383.       706.      911.     1704.   4     443.  0.06460    7.00  0.00       0.   20   0   B98  0.00
   15031   56B      0.         0.      911.     1704.   0       0.  0.00000    0.00  0.00       0.   20  99   B98  0.00
*****************************************************************************************************************************
*                                                 HYDROGRAPH FATTENED AT    56B                                             *
*   INCOMING HYDROGRAPH PEAK     =   1703.73                   INCOMING HYDROGRAPH VOLUME      =    302.05 AC.FT.          *
*   HYDROGRAPH ADJUSTMENT FACTOR =      1.00000                RUNOFF FACTOR                   =      4.62 IN.             *
*   ADJUSTED HYDROGRAPH PEAK     =   1703.73                   ADJUSTED HYDROGRAPH VOLUME      =    302.05 AC.FT.          *
*   ADJ/FATTENED HYDROGRAPH PEAK =   1703.73                   ADJ/FATTENED HYDROGRAPH VOLUME  =    350.58 AC.FT.          *
*****************************************************************************************************************************
*****************************************************************************************************************************
*                                                 RESERVOIR ROUTING AT    56B                                               *
*   INCOMING HYDROGRAPH PEAK     =   1703.73                   INCOMING HYDROGRAPH VOLUME      =    350.58 AC.FT.          *
*   HYDROGRAPH ADJUSTMENT FACTOR =      1.00000                                                                             *
*   RESERVOIR INFLOW  PEAK =   1703.73  TIME OF PEAK =   1165  VOLUME UNDER INFLOW  HYDROGRAPH =    350.58 AC.FT.          *
*   MAXIMUM ELEVATION      =   1132.43  TIME         =   1182  SPILLAGE ELEVATION  =   1130.50  DIFFERENCE =      +1.93    *
*   SPILLED FROM 1169 TO 1220 FOR   52 MINUTES                                                                              *
*   RESERVOIR OUTFLOW PEAK =    963.53  TIME OF PEAK =   1182  VOLUME UNDER OUTFLOW HYDROGRAPH =    331.85 AC.FT.          *
*****************************************************************************************************************************
   15031   56B      0.         0.      911.      964.   2    1100.  0.02277    0.00  0.00       0.   20  99   B98  0.00
```

B-10 MULTIPLE YIELD ADJUSTMENT EXAMPLE

It is infrequently necessary to apply yield adjustments more than once to a drainage line to get final results at a study location. This occurs most often when the study site has a series of detention basins where the inflow to an upstream basin has already been "fattened". In this example, assume that a regional basin is needed at node 95BC downstream of the Mt Sinai Basin shown in Section B-8. For the next downstream basin, the fattening factor is calculated by the following:

1. Calculate the yield of the outflow hydrograph from the upstream basin. The VCRat output file at node 56B in Section B-8.2 shows that the basin outflow yield was 331.85 af for a tributary area of 911 ac.
2. Calculate the yield of the tributary watershed downstream of the upper basin that provides flow to the downstream basin. Use the same approach described in Section B-8 for the area downstream of 56B to 95BC.

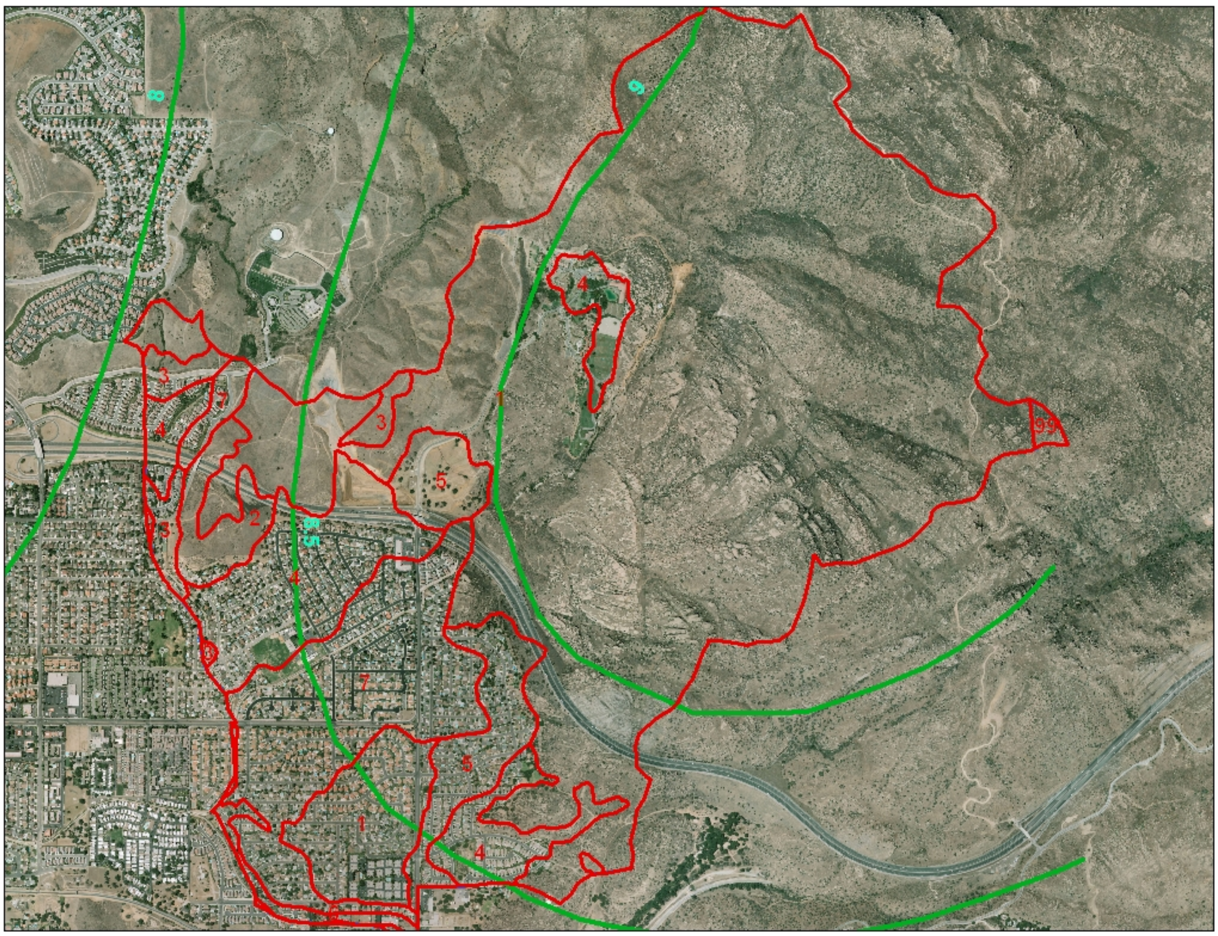


Figure B-10.1 Soil and 100-yr 24-hr Rain Map, Nodes 57 through 95, Calleguas VCRat Model

Soil Data Summary

Soil #	Area ac	Wtd Soil
1	1,248.90	0.702
2	32.87	0.037
3	32.07	0.054
4	180.22	0.405
5	85.29	0.240
6	13.74	0.046
7	187.24	0.736
Total	1,780	2.22

Calculated Weighted CN AMC II			**Wtd Soil Type**				**2.22**
Land Use General	**Land Use Specific**	**Exhibit 14 Land Use**	**Area Ac.**	**CN Soil 2**	**CN Soil 3**	**CN Soil 2.22**	**Wtd CN**
COMMERCIAL	Commercial General	Comm	3	95	93	93.44	0.170
INDUSTRIAL	Light Industrial	Industrial	5	97	96	96.22	0.267
OPEN SPACE AND RECREATION	Community Park	Park	81	76	71	72.10	3.293
OPEN SPACE AND RECREATION	Open Space (1 du/40 ac)	Open Brush Fair	1,038	58	54	54.88	32.002
PUBLIC FACILITIES AND INSTITUTIONS	Elementary School	Public	13	86	84	84.44	0.631
RESIDENTIAL <= 1 UNIT PER ACRE	None provided	Residential 1/ac	74	80	76	76.88	3.191
RESIDENTIAL >= 12 UNITS PER ACRE	High Density (15 to 30 du/ac)	Condo	19	92	90	90.44	0.950
RESIDENTIAL 1 - 4.99 UNITS PER ACRE	Medium Density Residential (4 DU/AC)	Residential 1/4 ac lot	287	84	81	81.66	13.176
RESIDENTIAL 5 - 11.99 UNITS PER ACRE	Low Density (2 to 4.5 du/ac)	Residential 1/3 ac lot	144	82	79	79.66	6.433
RESIDENTIAL 5 - 11.99 UNITS PER ACRE	Medium Density (4.5 to 15 du/ac)	Residential 1/8 ac lot	70	90	89	89.22	3.514
TRANSPORTATION AND UTILITIES	Roadway	Transpor-tation	46	92	91	91.22	2.334
		SUMS	**1,780**				**65.96**

	Yield Calculations
Precip. P (in) =	9
Wtd CN:	65.96
Potential Abstraction S =(1000/CN) -10:	5.16
Initial Abstraction I_a =0.2S:	1.03
Yield =(P-0.2S)2/(P+0.8S): (in)	**4.84**

3. Sum the two yields in af, and convert that volume in af to inches by dividing the yield volume by the total tributary area upstream of the second basin and converting the units. Use 4.68 in as the fattening factor in the VCRat simulations. You will also have to apply the correct AR factor to the hydrograph applicable for the additional 1,780 ac below the upstream basin. This topic is explored more in the next example.

Combined Yield			
Watershed	Area Ac.	Volume af	Inches
Mt Sinai Outflow	911	331.85	4.37
Below Mt Sinai	1,780	717.34	4.84
Total	2,691	1,049	4.68

B-11 MULTIPLE AREAL REDUCTION EXAMPLE

It is sometimes necessary to apply areal reduction more than once to a drainage line to get final AR results at a study location. This occurs often when the study site is located downstream from a detention basin where the inflow to the basin has already had AR applied so that the basin outflow peak is correctly calculated. As an example the AR factor will be calculated for the tributary watershed ending at node 440A below Runkle Dam in Simi Valley where an AR factor was previously applied at 424A prior to basin routing. The watershed is shown below.

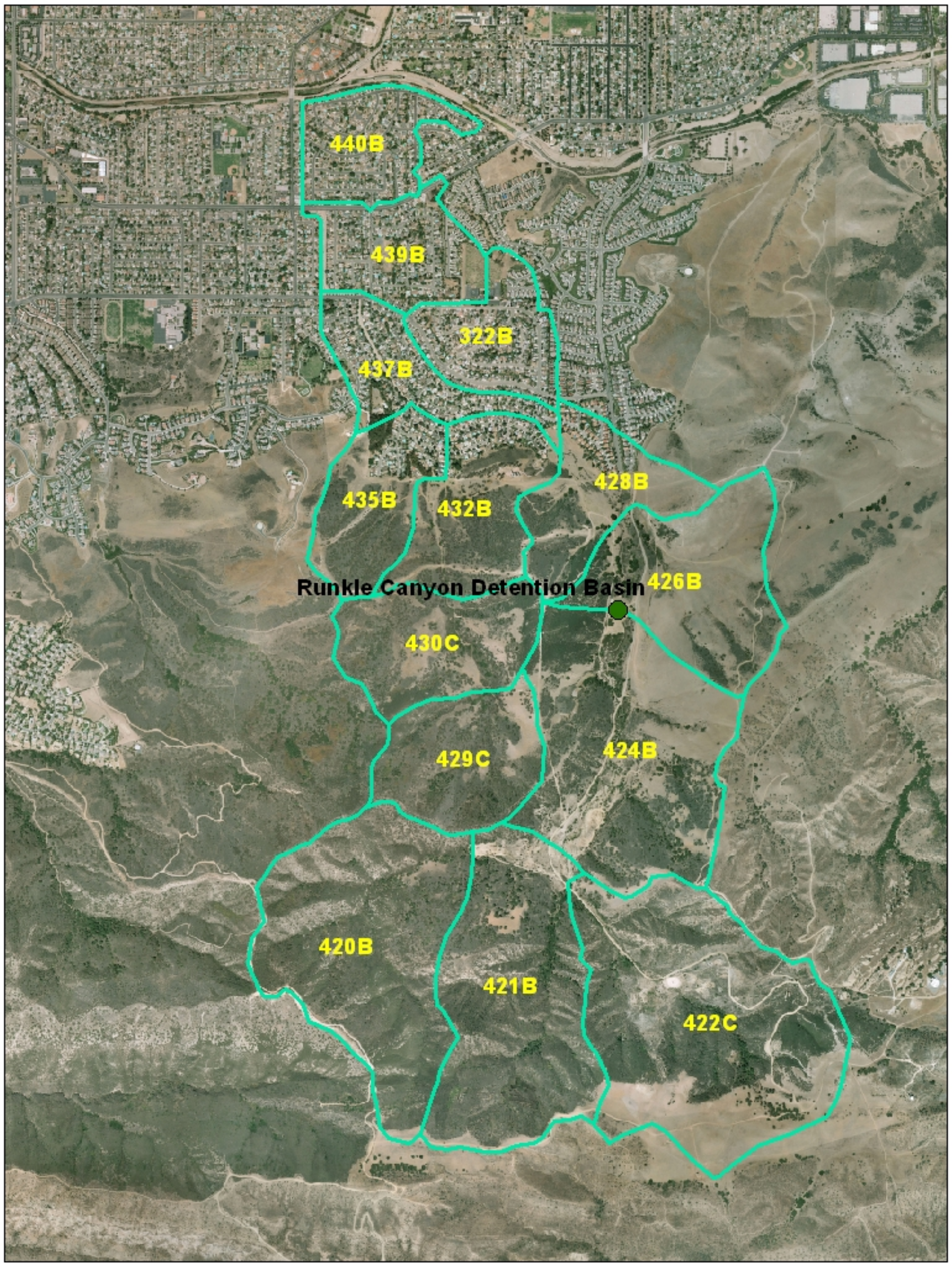


Figure B-11.1 Runkle Basin Watershed

The procedure is as follows:

1. If AR was not applied to the model at the upstream location because it was less than 600 ac in size, the AR factor should be based on the total tributary area at the location of interest below the basin. In this case it is only necessary to run the model, export the hydrograph of the basin outflow, and import the basin outflow hydrograph as the first input in a revised model. The revised model is prepared by removing the subareas above the basin and the basin routing in the input file, clear the hydrograph, and import a hydrograph of the basin outflow in the AR model including the basin tributary area in the hydrograph input. Then do an AR run for the project location.
2. If the tributary area to the basin is greater than 600 ac, do an AR run down to the basin. An example of the VCRat2.2 AR input file for the Runkle Basin is provided.

```
005 15031  419A RUNKLE AR EXAMPLE RUN424AR.99I Q100P,9/2010
005 15031  424A RUNKLE CANYON DAM INFLOW Q100,AR=0.9277,Y=3.6
005 15031  425A LAST POINT
999
999
006 15031  419A 010      099B98                           G1 7
006 15031  420A 020  0 22812B981 13000062
006 15031  421A 010  0 21011B98
006 15031  422B 020  0 28416B981  4750063
006 15031  423AB020         B981 30000037
006 15031  424A 020  0 23216B98                         1    1
006 15031  425A 010      099B98                         1  2
```

3. At node 424A corresponding to the basin, the 954 ac tributary area has a non-AR peak of 2,213 cfs and an AR peak of 2,053 cfs, with a corresponding AR factor of 2053/2213=0.9277.
4. Use this in the run for the full watershed with the following input file.

```
005 15031  419A RUNKLE AR EXAMPLE RUN440.99I Q100P,9/2010
005 15031  424A RUNKLE CANYON DAM INFLOW Q100,AR=0.92,Y=3.6,VVM/DDT/LS,6/97
005 15031  441A LAST POINT BEFORE ARROYO SIMI SUBAREAS
999
999
006 15031  419A 010      099B98                           G1 7
006 15031  420A 020  0 22812B981 13000062
006 15031  421A 010  0 21011B98
006 15031  422B 020  0 28416B981  4750063
006 15031  423AB020         B981 30000037
006 15031  424A 020  0 23216B98                         1
110
111  1086.5    0.9277     3.6
112 1071.75 1072.00 1073.00 1074.00 1075.00 1080.00 1086.00 1088.00 1090.00 1092.00
112 1094.00 1096.00
113    0.00    0.73    4.09    7.72   11.54   33.67   66.96   80.32   94.22  107.31
113  118.42  128.22
114    0.00    0.00    3.90   51.00   52.00   56.00   61.00  386.00  994.00 1805.00
114 2792.00 3942.00
110
006 15031  425A 010      099B985 130000423 300  2000               035035
006 15031  426A 020000 13814B985 140000321 300  2000               035035
006 15031  427A 010      099B98
006 15031  428A 030012  8714B985 240000205 150   750
006 15031  429B 020000  9913B981 162000545
006 15031  430B 020000 10313B981 190000316
006 15031  431B 010      099B984  70003570
006 15031  432A 030008 10014B98
006 15031  433AB010         B985  65000225 125   800          1
006 15031  434A 010      099B98
006 15031  435A 020008  8213B985 230000196 000  1000
```

```
006 15031  436A 010      099B98
006 15031  437A 040023  6912B985 165000122 200  1000
006 15031  438A 010      099B98
006 15031  439A 030021  7912B985 150000150 200  1200
006 15031  440A 040024  7110B98
006 15031  441A 010      099B98                            1  2
```

5. Create a basin outflow hydrograph that can be imported to another VCRat2.2 run. An easy way to do this is to import the VCRat2.2 input file to VCRat2.6, run the model, and then export the outflow hydrograph at 424B in VCRat2.2 format. Then replace the subarea and basin info down to 424A with the imported hydrograph. Make sure the project number and node location is added to the header of the exported hydrograph. Do not include the tributary area down to the basin because the AR factor should only apply to the net area downstream of the basin. An example input file is shown below.

```
005 15031  419A RUNKLE AR EXAMPLE RUN440AR.99I Q100P,9/2010
005 15031  441A LAST POINT BEFORE ARROYO SIMI SUBAREAS
999
007 15031  424A       0 551169    1492200  4
008  5    0       0  100       0  200       0  300       1  400       3
008 10  500      13  600      22  700      30  800      41  900      51
008 15 1000      54 1050      56 1100      59 1110      60 1120      61
008 20 1130     159 1131     177 1132     194 1133     212 1134     229
008 25 1135     246 1136     263 1137     280 1138     297 1139     314
008 30 1140     331 1141     348 1142     365 1143     382 1144     410
008 35 1145     440 1146     470 1147     500 1148     530 1149     560
008 40 1150     593 1151     626 1152     661 1153     700 1154     742
008 45 1155     786 1156     834 1157     885 1158     941 1159    1000
008 50 1160    1082 1161    1160 1162    1233 1163    1299 1164    1358
008 55 1165    1407 1166    1445 1167    1473 1168    1488 1169    1492
008 60 1170    1487 1171    1474 1172    1456 1173    1433 1174    1406
008 65 1175    1375 1176    1341 1177    1306 1178    1269 1179    1233
008 70 1180    1196 1181    1160 1182    1124 1183    1090 1184    1056
008 75 1185    1023 1186     993 1187     971 1188     950 1189     929
008 80 1190     908 1191     888 1192     869 1193     850 1194     832
008 85 1195     814 1196     797 1197     780 1198     764 1199     748
008 90 1200     733 1201     719 1202     705 1203     691 1204     678
008 95 1205     666 1206     653 1207     642 1208     630 1209     619
008100 1210     609 1211     598 1212     588 1213     578 1214     569
008105 1215     559 1216     550 1217     541 1218     533 1219     524
008110 1220     516 1221     508 1222     500 1223     492 1224     485
008115 1225     478 1226     470 1227     463 1228     457 1229     450
008120 1230     444 1231     438 1232     431 1233     426 1234     420
008125 1235     414 1236     409 1237     404 1238     399 1239     394
008130 1240     390 1241     385 1242     383 1243     380 1244     378
008135 1245     375 1246     373 1247     371 1248     368 1249     366
008140 1250     363 1251     361 1252     358 1253     356 1254     354
008145 1255     351 1256     349 1257     347 1258     344 1259     342
008150 1260     340 1261     338 1262     335 1263     333 1264     331
008155 1265     329 1266     326 1267     324 1268     322 1269     320
008160 1270     317 1271     315 1272     313 1273     311 1274     308
008165 1275     306 1276     304 1277     302 1278     299 1279     297
008170 1280     295 1281     292 1282     290 1283     288 1284     285
008175 1285     283 1286     281 1287     278 1288     276 1289     274
008180 1290     271 1291     269 1292     267 1293     265 1294     262
008185 1295     260 1296     258 1297     256 1298     253 1299     251
008190 1300     249 1310     230 1320     210 1330     192 1340     174
008195 1350     157 1360     143 1370     130 1380     118 1390     108
008200 1400      99 1420      84 1440      73 1460      65 1500      61
999
006 15031  419A 010      099B98                              G1 7
006 15031  420A 010      099B98
006 15031  421A 010      099B98
```

```
006 15031  422A 010      099B98
006 15031  423A 010      099B98
006 15031  424A 010         B98                               A A
006 15031  425A 010      099B985 130000423 300  2000              035035
006 15031  426A 020000 13814B985 140000321 300  2000              035035
006 15031  427A 010      099B98
006 15031  428A 030012  8714B985 240000205 150   750
006 15031  429B 020000  9913B981 162000545
006 15031  430B 020000 10313B981 190000316
006 15031  431B 010      099B984  70003570
006 15031  432A 030008 10014B98
006 15031  433AB010         B985  65000225 125   800          1
006 15031  434A 010      099B98
006 15031  435A 020008  8213B985 230000196 000  1000
006 15031  436A 010      099B98
006 15031  437A 040023  6912B985 165000122 200  1000
006 15031  438A 010      099B98
006 15031  439A 030021  7912B985 150000150 200  1200
006 15031  440A 040024  7110B98                                   1
006 15031  441A 010      099B98                              1  2
```

6. The tributary area for the hydrograph should be set to 0 so the 2nd AR factor is only calculated for the net area below the basin down to the proposed project location. Turn on the AR with a 1 in column 67 of the VCRat2.2 data input line for the project location, in this case subarea 440A. The results show that the non-AR peak is 2,247 cfs and the AR peak is 2,136 cfs, for an AR factor of 0.9507 for the 828 ac. watershed downstream of Runkle Basin.

B-12 UNIT RUNOFF EXAMPLE

Assume that a church in Simi Valley wishes to expand on its 2.71 ac lot as shown below. The parcel is located in node 439B of the District's official Calleguas model (2003).

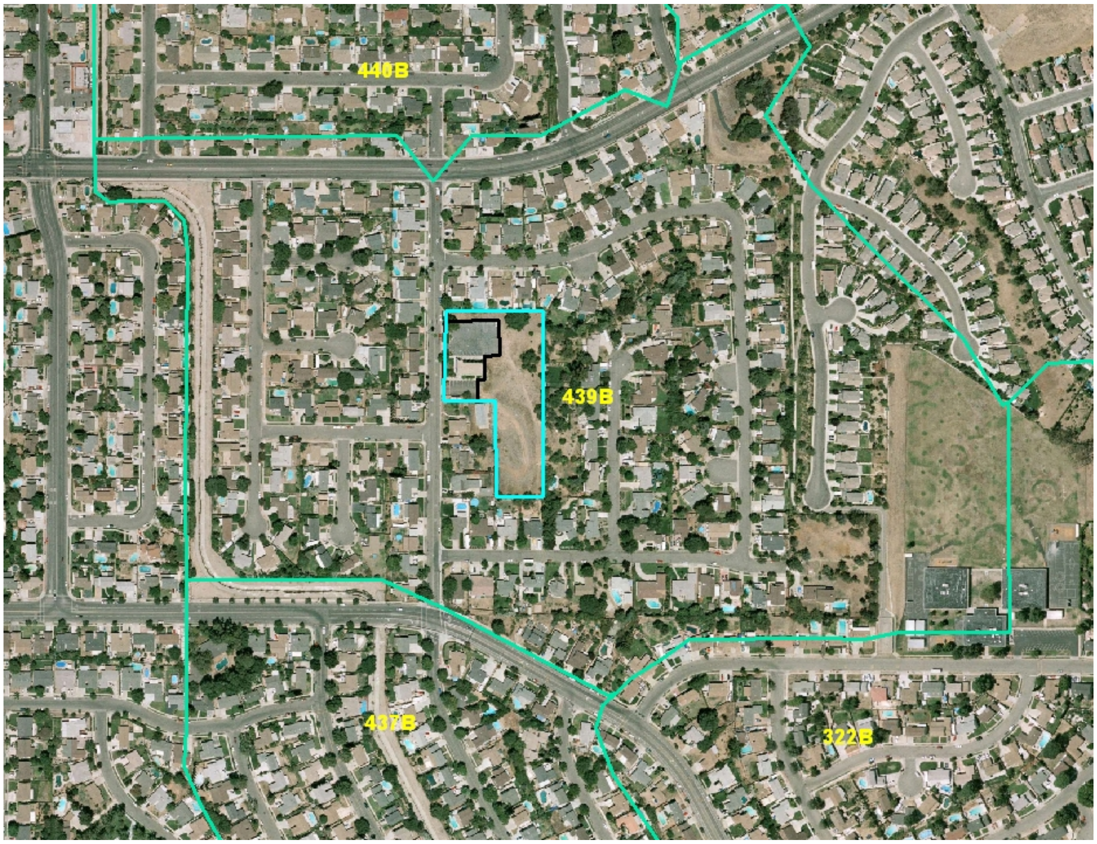


Figure B-12.1 Simi Valley Watershed

The parcel is 2.71 ac in size and approximately 0.73 ac is impervious in the existing condition. The pervious area is unirrigated grasses with some trees. The project will add a 1 ac senior center complex to the site.

The VCRat2.2 data for this subarea are as follows:

Area Ac.	Q100 cfs	Soil	Tc Min	RainZone	Eff. Imperv Frac.
79	196	3	12	B98 (K100)	0.21

As the development is located in the middle of the subarea, the Tc of the overall subarea should not be affected (usually the Tc would change only if the development affects the upstream overland flowpath or changes the imperviousness of the subarea by more than 5%).

The existing effective impervious fraction of 0.21 indicates that it was selected from Exhibit 14b for 1/5 ac lots and decreased slightly from 0.23 to reflect the open spaces in the primarily low density residential subarea. The existing development site has an impervious fraction of 0.73/2.71=0.27 which means the effective imperviousness of the parcel is likely similar to the overall subarea. Obtain the K100 rainfall intensity of 3.23 in/hr for a Tc of 12 mins from Exhibit 2. Assuming that the P=23% curve applies to the overall parcel and P=0% for the existing condition of the new complex site, the C coefficients from Exhibit 6c are 0.870 and 0.845 respectively. Calculate the existing Q100 for the overall parcel and proposed senior complex as follows:

Q100e= 2.71 ac * 3.23 in/hr * 0.870 = 7.62 cfs

Q100e = 1.0 ac * 3.23 in/hr * 0.845 = 2.73 cfs

The additional development will increase the impervious fraction of the entire parcel to 1.73/2.71=0.64. From Exhibit 14b, this is similar to high density residential development. Assuming the new project will incorporate measures to route the runoff across pervious areas and reduce the effective impervious area, the effective impervious fraction could be as low as 0.32 according to the Exhibit. The revised C coefficient for the entire parcel with the new center from Exhibit 6c is about 0.88 and for the senior complex is 0.94. The proposed condition Q100s are then:

Q100p= 2.71 ac* 3.23 in/hr* 0.88 = 7.70 cfs, an increase of about 1%.

Q100e = 1.0 ac * 3.23 in/hr * 0.94 = 3.04 cfs

While the new development does not increase the peak much, the volume of runoff from the site may increase due to the impervious area. The City of Simi Valley has historically required 1,000 cf/ac of detention for their mitigation. Using the approach outlined in Section 6.15.2, the estimated detention volume required for mitigation is a conservative volume of approximately 7,000 cf. In this case, it would probably be more cost effective to use the techniques shown in Appendix D to design a bypass or flow-through basin.

	10 yr	100-yr
100-yr 1-d Rain in	4.75	7.2
Soil Type	3	3
Land Use	Open Space	Roof
Volume Calculation		
Yield Difference in		2.45
Depression Storage on Driveways, Patios in.		0.50
Net Yield		1.95
Impervious Area ac		1.00
Vol Increase CF- Max Basin Size Req'd		7078.50

A hydrograph for the project site can be developed using VCRat even though the project size is too small following the method discussed in Section 6 as shown in Appendix B-12.

For many cities the project mitigation level is often the developed Q10 condition. If using MDPs to evaluate the site, the developed Q10 can be calculated from the info provided in the MDP 10-yr run using the approach given above. For the District's official Calleguas model, the subarea Q10 for 439B is obtained through the use of special design storm ratios developed for this study and provided on the District's

Calleguas Watershed webpage. A Q10 Tc can be back-calculated for the subarea by using VCRat and adjusting the Tc until the peak matches the official Q10. For this 79 ac subarea, the official 10-yr peak is 68.25 cfs. A 30-min Tc provides approximately this peak in VCRat2.6, which corresponds to a peak intensity of 1.46 in/hr from Exhibit 2. From Exhibit 6c, the Q10p for the new complex with a P=90% is 0.92. The proposed Q10, which is the maximum-allowed outflow level from the detention basin is then:

Q10p = 1.46 in/hr * 1 ac * 0.92 = 1.34 cfs

B-13 SMALL AREA HYDROGRAPH EXAMPLE

As discussed in Section 6, the minimum subarea size in VCRat2.64 is 5 ac to decrease the chances of the program being used to produce flows for numerous tiny subareas such as is commonly done for interior drainage design. However, for small developments where peak mitigation is required through basin design, it is possible to use the program to get a hydrograph. The procedure takes advantage of the fact that the VCRat results are linear with area, so that the hydrograph of a 10-ac subarea is identical to the hydrograph of a 100-ac subarea divided by 10 as long as the other model input parameters (Tc, % impervious, soil type) are identical. The procedure to get a hydrograph for the 1.0 ac development pad to use for detention basin design as presented in Section B-11 is as follows:

1. Set up a VCRat2.64 model using the existing model rain zone and Tc and project area soil type and % imperviousness. For subarea size in the model, use the project area times a factor from 10 to 100. For this example, use a factor of 10 so the subarea size will be 1.0 x 10 = 10 ac. Per Exhibit 14b, impervious surfaces have an effective imperviousness of 90%.

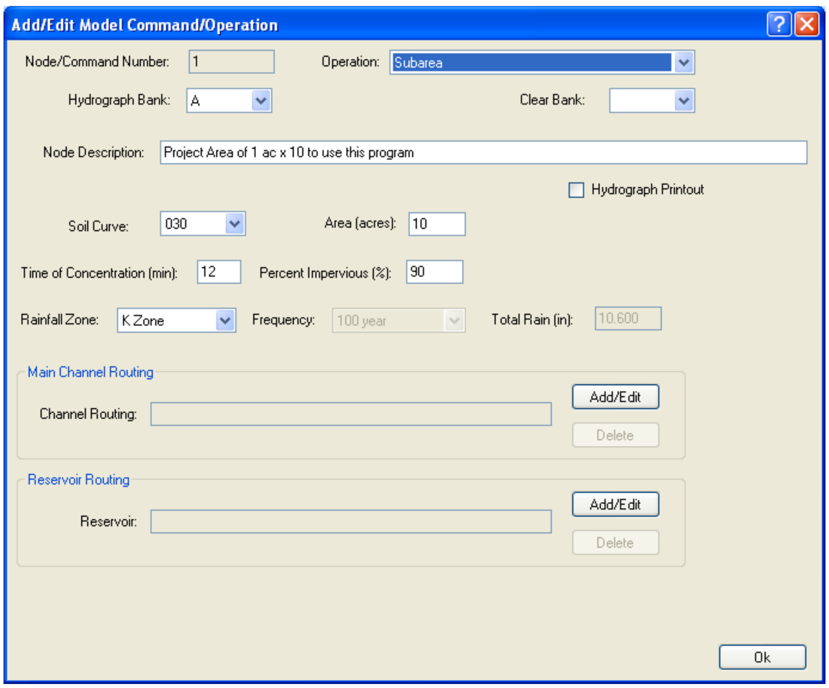


Figure B-13.1 VCRat2.64 Subarea Edit Window

2. "Fatten" the project area hydrograph in VCRat2.64 using the yield adjustment procedure described in this manual. The impervious area has a CN of 98 with a 100-yr 24-hr rain depth of 7.2 in. In this case there is so much runoff from the impervious surface in the original calculation that the yield adjustment actually results in a volume decrease as shown in the model output.

```
      2A :  Do Fattening Here, Use CN=98 and Rain=7.2 in, print out hydrograph
      2A   ---   ---    --   --    ---    ---       10      30   1154    -------    ----  ------
      2A :  Fattening for design hydrograph
*******************************************************************************************
            *      INCOMING HYDROGRAPH  PEAK (cfs):     30.16        VOLUME (acre-ft):      7.30
            *      NO HYDROGRAPH ADJUSTMENT
            *      RUNOFF FACTOR(in):   6.96      TOTAL RAIN(in):   7.20      SCS Curve: 98
            *      FATTENED HYDROGRAPH  PEAK (cfs):     30.16        VOLUME (acre-ft):      5.81
*******************************************************************************************
```

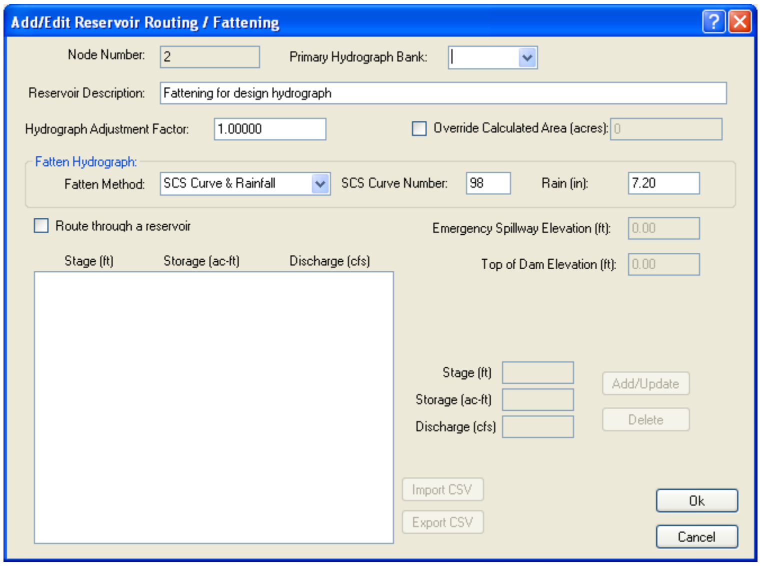


Figure B-13.2 VCRat2.64 Subarea Reservoir Routing Editing Window

3. Export the project area hydrograph in csv format so it can be imported into Excel. Divide the hydrograph ordinates by 10. The resultant hydrograph with a peak of approximately 3 cfs reduced from 30 cfs can be used in VCRat or another program to do basin design for the project area.

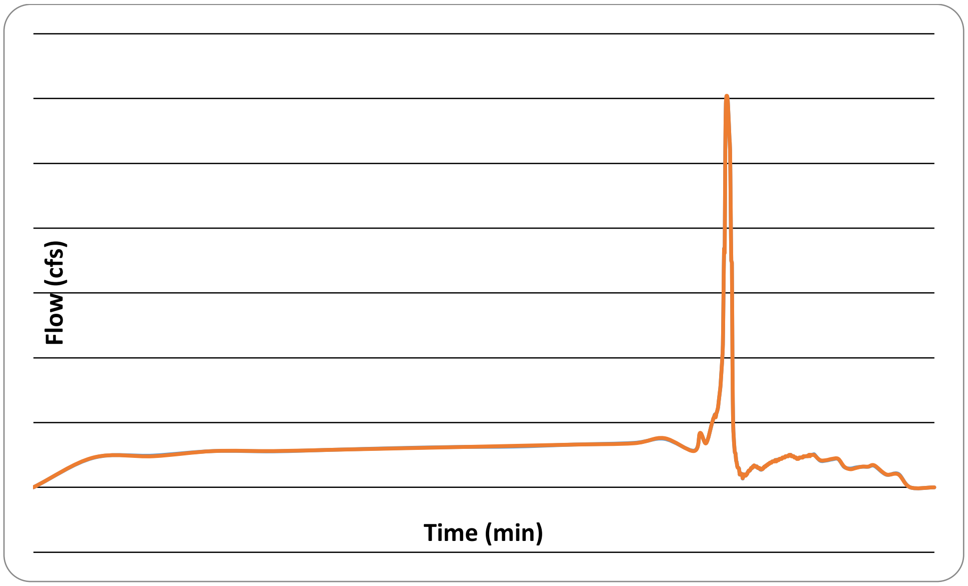


Figure B-13.3 Small Subarea Hydrograph After Export/Split

4. Another option is to use the split feature of VCRat (Figure B-13.4) and leave 10% of the flow (10% x 10ac = flow from 1 ac) in the mainline. Then export the mainline hydrograph for use in basin design. Whichever method is used, the hydrographs should be identical.

5. Comments received from consultants indicate that they are confused about why the Tc does not have to be increased when the area is increased. However, the process is only taking advantage of the linearity of the Q=CIA equation used in VCRat. Because the "apparent" effect of the increase in area is removed at the end by dividing the hydrograph by the same factor, it is not necessary to change any of the other input parameters when calculating the subarea outflow.

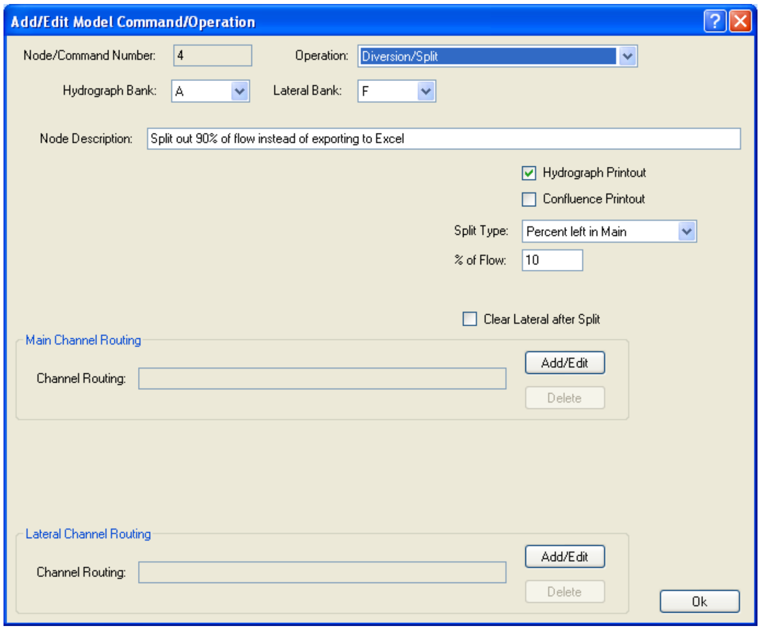


Figure B-13.4 VCRat2.64 Diversion/Split Editing Window

B-14 SPREADSHEET MODELS

For this iteration of the Hydrology Manual, the District has developed several spreadsheets to assist consultants with small projects. The spreadsheets include the following:

1. Spreadsheet that calculates the time of concentration for one subarea after the user enters in the required subarea and flowpath information.

2. Spreadsheet that calculates the flow hydrograph for one subarea, adjusts the yield, and routes it through one detention basin using the provided stage-storage-discharge data.

The user interfaces for these products are provided below.

Tc Calculator Data Sheet

Project Name and Number: Test Tc, Ventura County

USER INPUT IN BLUE FIELDS:		
Subarea Name =	1a	User Input
Watershed Area ac =	6.2	Calculated from flowpath data
% Imperviousness =	23	User Input
Land Use Description =	LowRes1/5	DropMenu
Storm Frequency	100	DropMenu
Storm Zone =	Cuyama	DropMenu
Zone ID =	Cuy1_100	Calculated
District Soil Number (1-7) =	4Rev	DropMenu- Rev for Revised C Coefficients
Tc for Intensity Calc min =	**6.00**	**Rounded, Use for Peak Flow Calc.**
Intensity in/hr =	5.032	Calculated
C_undeveloped =	0.459	Calculated
C_composite =	0.572	Calculated
Peak cfs =	17.99	Calculated
Calculated Tc=	**5.64**	**Calculated**

Instructions:

1. Set to manual calculations with File->Options->Formulas
2. Set max iterative calculations to 50
3. Enter required subarea and flowpath data in blue fields
4. Choose rain zone from map at: http://vcwatershed.net/publicMaps/data/
5. Clear any unnessary flowpath data from blue fields
6. Manually calculate with F9 or Formulas->Calculate Now
7. If error or comments appear, revise input data accordingly
8. Tc's in cells C12 and C17 should converge to the nearest minute.
9. Use result in C12 for peak flow calculation.
10. Print area is set for printing this page on one sheet.

FLOWPATH DATA- UPSTREAM TO DOWNSTREAM															Error Checking					
Flowpath Number	Type- Selected with DropMenus	Type#	Flowpath Area ac	Upper Elev. Ft	Bott. Elev. Ft	Length ft	Slope ft/ft (Calc.)	Eff Slope ft/ft (Calc.)	Diam/ Width ft	n value	Side-slope X 1V:XH	% Area	Q cfs	Cum. Q cfs	Max Length ft	Scour Check & Flowpath Length	Area-Slope	Diam/ Width ft	n value	1V:XH
1	Overland-Developed	2	1.1	202.55	200	200	0.013	0.013				17.7%	3.2	3.2	200					
2	Rectangular-Channel	10	3.9	200	193.86	375	0.016	0.016	2.0	0.015		62.9%	11.3	14.5						
3	Trapezoid-Channel	11	1.2	193.86	190.1	443	0.008	0.008	2.0	0.015	1.0	19.4%	3.5	18.0						
4	None	0		0								0.0%	-	18.0						
5	None	0		0								0.0%	-	18.0						
6	None	0		0								0.0%	-	18.0						
7	None	0		0								0.0%	-	18.0						
8	None	0		0								0.0%	-	18.0						
9	None	0		0								0.0%	-	18.0						
10	None	0		0								0.0%	-	18.0						
Sum			**6.2**									**100%**	**18.0**							

Figure B-14.1 Tc Worksheet

VCRat Single Subarea Hydrograph, Mitigation, and Detention Basin Routing Calculations

Project Information: Test Hydrograph, Ventura County

DEVELOPED CONDITION INPUT DATA		
Watershed Area ac =	3.00	User Input
Time of Concentration Tc min =	5	User Input
% Imperviousness =	51	User Input
Land Use Description =	1/5 ac Res	User Input
Storm Zone =	Arroyo Conejo	Dropdown List
Storm Frequency =	100	Dropdown List
District Soil Number =	3Rev	Dropdown List
NRCS Curve Number Yield in =	5.92	User Input
MITIGATION INPUT DATA		
Mitigation Level	10-yr Dev	User Input
Time of Concentration Tc min =	25	User Input
Storm Frequency =	10	Dropdown List
% Effective Imperviousness =	51	User Input
Land Use Description =	1/5 ac Res	User Input
CALCULATION RESULTS		
Iteration Volume Difference cf =	0.000	
Dev. Subarea Outflow Peak cfs =	10.76	
FLOW THROUGH BASIN RESULTS		
Basin Inflow Peak cfs =	10.76	Peak > Mitigation Level, Redesign Basin!
Mitigated Hydrograph Peak cfs =	2.78	
Routed Hydrograph Peak cfs =	3.14	
Max Basin Storage af =	0.1827	
Max Basin Elevation ft =	3.45	
BYPASS BASIN RESULTS		
Inflow Hydrograph Peak cfs =	10.76	
Mitigation Hydrograph Peak cfs =	2.78	
Peak Flow into Bypass Basin cfs =	7.99	
Volume into Bypass Basin cf =	5,760	
Bypass Basin Unit Volume cf/ac =	1,920	

INSTRUCTIONS

1. Under File-Options-Formulas Check Iterative Calculations 200 iterations 0.001 tolerance
2. Input data in blue fields
3. Press F9 to manually calculate the hydrology data if Volume Difference in B19 is not 0.
4. Choose rain zone at: vcwatershed.net/publicMaps/data/

Flow-Through Basin Data

Elev. ft	Storage af	Disch. cfs
0.0	0.00	0.00
0.5	0.01	0.54
1.0	0.02	1.31
1.5	0.04	1.83
2.0	0.05	2.22
2.5	0.06	2.53
3.0	0.10	2.83
3.5	0.15	3.09
4.0	1.0	5.0

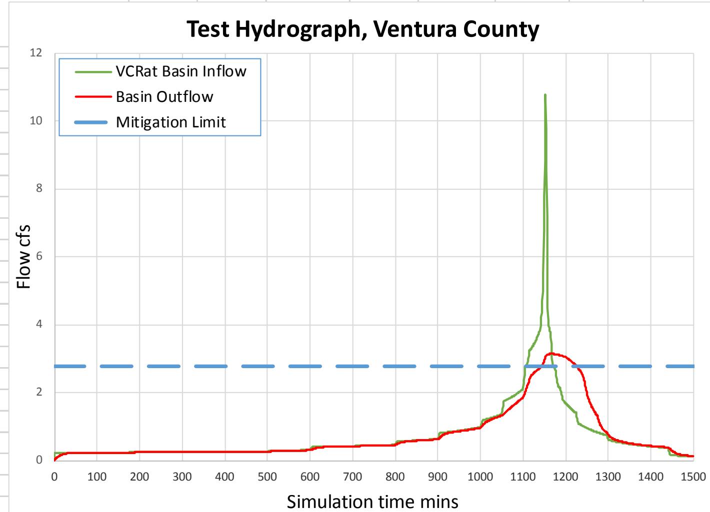


Figure B-14.2 VCRat Worksheet

B-15 Bulking Factor Spreadsheet

Sediment Hydrograph - Bulking Factor -Iterative Calculation Spreadsheet

Watershed	Fresno	Date	3/23/2017

Los Angeles Department of Public Works Method

Qsed=a*Qflow^3

Instructions

Paste VCRat Hydrograph in VCRatHydrograph worksheet

Enter user info in highlighted fields

Spreadsheet should iterate to optimize 'a' coefficient and calculate sediment hydrograph

Press F9 to recalculate if Total and Calculated Sediment Volumes don't converge

Category	Data	Source
Time of Peak min	1,169	VCRat
Volume cf	14,382,143	VCRat
Volume af	330.17	VCRat
Peak Water Flow cfs	1,148	VCRat
Watershed Area Ac	831	User
100-Yr Sed Volume cy/sq mi	22,500	Scotsed
Total Sediment Volume cy	29,215	Calc.
Calculated Sediment Vol cy	29,189	Calc.
Peak Sediment flow cfs	227.9	Calc.
Combined Peak Flow cfs	1,375.9	Calc.
Calculated Bulking Factor	1.20	Calc.
Qsed Coefficient "a" Increment	2.04E-10	Calc.
Qsed Coefficient "a"	1.51E-07	Calc.

Time(min)	Qflow(cfs)	Qs calc cfs	QS Vol cy	Qtot cfs
0	0.00	0.00	0.00	0.00
100	5.56	0.00	0.00	5.56
200	12.23	0.00	0.03	12.23
300	14.71	0.00	0.08	14.71
400	18.08	0.00	0.15	18.08
500	22.84	0.00	0.30	22.84
600	29.85	0.00	0.65	29.85
700	41.85	0.01	1.67	41.86
800	63.12	0.04	5.44	63.16

APPENDIX C HSPF AND HMS DESIGN STORM MODELING

C-1 DISTRICT RAIN GAGE FREQUENCY ANALYSIS FILE

PRECIPITATION DEPTH-DURATION (SHORT TERM) - MAXIMUM ANNUAL PRECIPITATION (IN)
VENTURA COUNTY WATERSHED PROTECTION DISTRICT

STATION #	STATION NAME	ELEV	LATITUDE	LONGITUDE	TOWNSHIP RANGE	COUNTY
VC 165	STEWART CANYON	960	34:27:38	119:14:50	T4N R23W SEC 1	VENTURA

M=MINUTES,H=HOURS,D=DAYS,W YR=WATER YEAR

WATER YR	5M	15M	30M	1H	2H	4H	6H	12H	24H
1957	0.09	0.20	0.40	0.73	1.08	1.45	1.75	2.36	2.84
1958	0.26	0.34	0.43	0.58	1.00	1.46	1.90	2.66	2.96
1959	0.27	0.47	0.71	1.09	1.35	2.00	2.70	3.40	3.45
1960	0.04	0.11	0.21	0.41	0.69	1.19	1.58	2.02	2.05
1961	0.10	0.26	0.48	0.72	1.12	1.28	1.28	1.58	2.40
1962	0.11	0.23	0.44	0.78	0.92	1.74	2.23	2.84	4.74
1963	0.24	0.46	0.56	0.88	1.29	2.44	2.76	3.20	3.94
1964	0.20	0.40	0.46	0.63	0.80	1.10	1.35	1.62	2.26
1965	0.10	0.15	0.20	0.44	0.48	0.84	1.17	2.05	3.41
1966	0.16	0.45	0.48	0.82	1.59	2.32	2.93	3.82	4.67
1967	0.18	0.25	0.42	0.53	0.90	1.53	1.86	3.50	4.25
1968	0.15	0.24	0.35	0.38	0.66	1.18	1.57	2.70	3.35
1969	0.34	0.53	0.85	1.16	1.63	2.77	3.60	4.48	7.44
1970	0.12	0.19	0.32	0.56	0.87	1.39	1.80	2.84	3.60
1971	0.09	0.21	0.31	0.58	1.11	2.01	2.98	4.25	5.06
1972	0.07	0.15	0.18	0.35	0.58	1.10	1.51	2.28	2.56
1973	0.15	0.35	0.58	1.02	1.94	2.86	3.25	3.88	4.57
1974	0.09	0.12	0.21	0.45	0.61	1.05	1.30	2.15	4.23
1975	0.10	0.25	0.47	0.87	1.59	2.54	3.14	4.59	4.81
1976	0.15	0.30	0.53	0.78	1.13	1.72	2.13	2.83	2.84
1977	0.12	0.32	0.47	0.68	1.18	1.52	1.77	2.14	2.15
1978	0.13	0.32	0.65	1.07	1.88	2.82	3.42	3.72	5.42
1979	0.08	0.16	0.30	0.57	0.97	1.55	2.00	2.76	3.01
1980	0.22	0.47	0.59	0.94	1.66	2.59	3.51	5.09	5.72
1981	0.15	0.28	0.43	0.71	1.13	1.45	1.67	2.30	2.78
1982	0.08	0.16	0.25	0.39	0.63	0.89	0.94	1.53	1.58
1983	0.35	0.57	0.77	1.15	1.50	2.30	3.03	3.46	4.28
1984	0.07	0.17	0.32	0.62	1.06	1.25	1.27	1.81	2.50
1985	0.08	0.21	0.35	0.59	1.01	1.31	1.32	1.80	2.08
1986	0.14	0.34	0.51	0.74	1.22	2.20	2.92	3.52	4.00
1987	0.12	0.35	0.59	0.85	1.06	1.27	1.38	1.54	1.61
1988	0.20	0.46	0.61	0.76	1.08	1.23	1.32	1.92	2.33
1989	0.05	0.14	0.28	0.49	0.81	1.05	1.26	1.66	2.09
1990	0.10	0.31	0.48	0.70	0.87	1.37	1.93	2.33	2.78
1991	0.11	0.18	0.27	0.42	0.81	1.35	1.86	2.92	4.24
1992	0.25	0.51	0.62	0.84	1.24	1.63	2.10	2.35	4.18
1993	0.17	0.34	0.55	0.92	1.37	1.88	2.21	3.01	5.15
1994	0.09	0.17	0.28	0.48	0.85	1.44	1.87	2.23	2.23
1995	0.19	0.48	0.72	1.19	2.18	3.85	4.35	6.92	8.68
1996	0.22	0.31	0.41	0.64	0.96	1.78	2.24	3.47	5.29
1997	0.10	0.16	0.24	0.44	0.84	1.44	2.16	2.60	2.96
1998	0.16	0.24	0.40	0.64	1.12	1.92	2.16	2.92	4.28
1999	0.16	0.24	0.32	0.44	0.56	0.80	1.12	1.76	1.96
2000	0.12	0.28	0.36	0.56	0.80	1.32	1.60	2.00	2.80
2001	0.12	0.32	0.52	0.84	1.32	2.32	2.76	3.84	4.96
2002	0.12	0.28	0.44	0.84	1.16	1.56	1.60	1.60	1.60
2003	0.12	0.24	0.40	0.72	1.24	2.16	3.04	4.20	4.64
2004	0.13	0.21	0.31	0.60	0.97	1.75	2.38	3.23	3.42
2005	0.15	0.40	0.65	1.08	1.87	2.29	2.93	3.80	7.09
2006	0.08	0.20	0.28	0.49	0.85	1.57	2.17	3.39	3.88
2007	0.10	0.24	0.34	0.43	0.65	0.76	0.98	1.25	1.63

2008	0.13	0.25	0.47	0.89	1.61	2.80	3.73	5.08	5.29

PRECIPITATION DEPTH-DURATION (SHORT TERM) - FREQUENCY TABLE AND STATISTICS
VENTURA COUNTY WATERSHED PROTECTION DISTRICT

STATION #	STATION NAME	ELEV	LATITUDE	LONGITUDE	TOWNSHIP RANGE	COUNTY
VC 165	STEWART CANYON	960	34:27:38	119:14:50	T4N R23W SEC 1	VENTURA

M=MINUTES,H=HOURS,D=DAYS,W YR=WATER YEAR

RETURN PERIOD IN YEARS	5M	15M	30M	1H	2H	4H	6H	12H	24H
2	0.13	0.26	0.40	0.64	1.01	1.56	1.95	2.64	3.35
5	0.19	0.39	0.59	0.95	1.50	2.32	2.90	3.92	4.98
10	0.23	0.47	0.72	1.15	1.82	2.81	3.52	4.76	6.04
20	0.27	0.55	0.84	1.34	2.12	3.28	4.10	5.55	7.04
25	0.28	0.57	0.87	1.40	2.21	3.42	4.28	5.79	7.36
40	0.31	0.62	0.95	1.52	2.41	3.72	4.66	6.30	8.00
50	0.32	0.65	0.98	1.58	2.50	3.86	4.83	6.54	8.30
100	0.36	0.72	1.09	1.75	2.77	4.29	5.37	7.26	9.22
200	0.39	0.79	1.20	1.92	3.04	4.71	5.89	7.96	10.11
500	0.43	0.88	1.33	2.13	3.38	5.23	6.54	8.85	11.24
1000	0.47	0.95	1.44	2.31	3.65	5.65	7.07	9.56	12.14
10000	0.58	1.16	1.77	2.84	4.50	6.96	8.70	11.76	14.94
PMP	1.16	2.34	3.56	5.70	9.03	13.97	17.47	23.63	30.01
MEAN	0.143	0.288	0.438	0.702	1.112	1.719	2.150	2.908	3.693
CLOCK HR. COR.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
CALCULATED SKEW	1.279	0.654	0.507	0.454	0.755	0.976	0.651	1.085	0.960
REGIONAL SKEW	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200
SKEW USED	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200	1.200
KURTOSIS	4.757	2.727	2.947	2.502	3.347	4.148	2.834	4.940	4.293
YEARS OF RECORD	52	52	52	52	52	52	52	52	52
LAST YEAR RECORD	2008	2008	2008	2008	2008	2008	2008	2008	2008
RECORD YEAR	1983	1983	1969	1995	1995	1995	1995	1995	1995
RECORD MAXIMUM	0.35	0.57	0.85	1.19	2.18	3.85	4.35	6.92	8.68
NORMALIZED MAX	3.083	2.420	2.638	2.154	2.765	3.332	2.715	3.573	3.222
CALC. COEF. VAR	0.471	0.405	0.357	0.323	0.348	0.372	0.377	0.386	0.419
REGN. COEF. VAR	0.475	0.475	0.475	0.475	0.475	0.475	0.475	0.475	0.475
COEF. VAR USED	0.475	0.475	0.475	0.475	0.475	0.475	0.475	0.475	0.475

PEARSON TYPE III DISTRIBUTION USED
PROBABLE MAXIMUM PRECIPITATION (PMP) ESTIMATED ON 15 STANDARD DEVIATIONS
WHERE YEARS OF RECORD IS SMALL (LESS THAN 15 YEARS) - RESULTS ARE NOT DEPENDABLE

C-2 DESIGN STORM RAINFALL HYETOGRAPH

Data from frequency analysis are used to fit a trendline using a power equation.

	Duration	Cum. Precip.
	(min)	(in)
Points	(x)	y=ax**b
1	5	**0.36**
2	10	**0.58**
3	15	**0.72**
4	30	**1.09**
5	60	**1.75**
6	120	**2.77**
7	180	**3.24**
8	240	**4.29**
9	360	**5.37**
10	720	**7.26**
11	1440	**9.22**
Note: Cells in Yellow Estimated from Trend		

The equation of the trendline is used to generate the rainfall intensities to build the hyetograph.

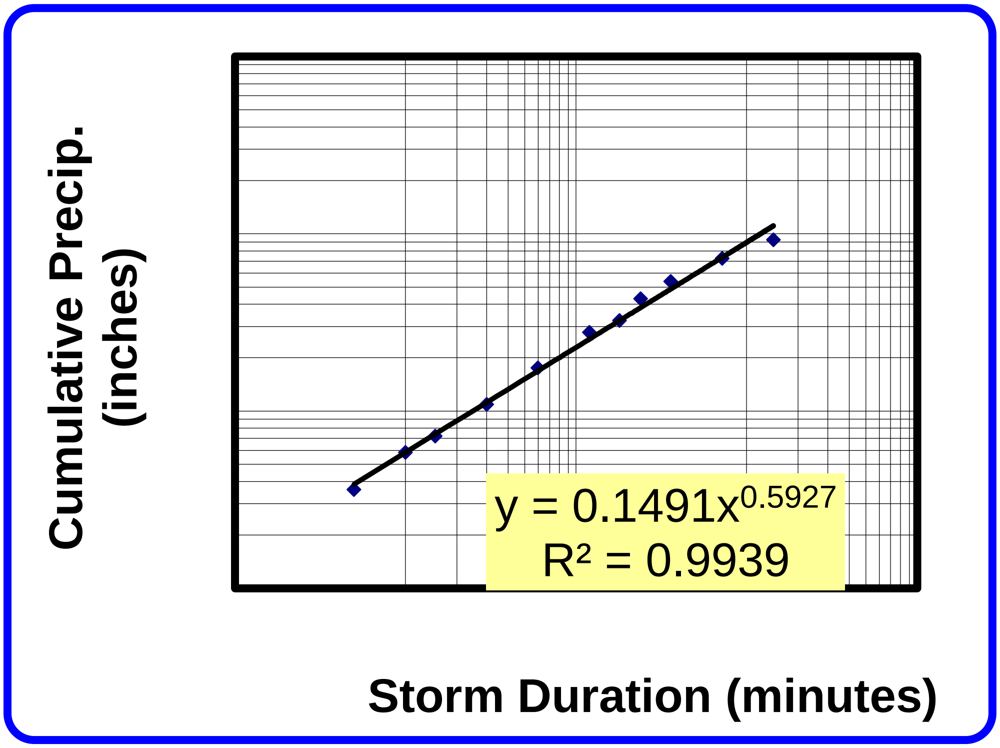


Figure C-2.1 Rain Data Regression Results

A spreadsheet with example calculations is provided in Appendix E.

C-3 UNDEVELOPED WATERSHED HEC-HMS S-GRAPH DATA

The following table provides the S-Graphs developed for three types of undeveloped watersheds- relatively long narrow ones, ones with rounded shapes, and others that do not clearly fit either category.

Ellsworth		Canada Larga		NForkMatilja			
% time	% Q	% time	% Q	% time	% Q	% time	% Q
0.00	0.00	0.00	0.00	0.00	0.00	605.56	95.14
6.41	0.06	16.04	0.41	5.56	0.03	611.11	95.30
12.82	0.26	32.07	1.96	11.11	0.13	616.67	95.45
19.23	0.69	48.11	5.09	16.67	0.33	622.22	95.59
25.64	1.38	64.14	9.97	22.22	0.67	627.78	95.74
32.05	2.37	80.18	16.38	27.78	1.16	633.33	95.87
38.46	3.67	96.22	23.77	33.33	1.81	638.89	96.01
44.87	5.31	112.25	31.36	38.89	2.63	644.44	96.14
51.28	7.30	128.29	38.44	44.44	3.64	650.00	96.26
57.69	9.64	144.32	44.81	50.00	4.84	655.56	96.39
64.10	12.32	160.36	50.51	55.56	6.24	661.11	96.51
70.51	15.29	176.40	55.64	61.11	7.82	666.67	96.62

Ellsworth		Canada Larga		NForkMatilja			
% time	% Q	% time	% Q	% time	% Q	% time	% Q
76.92	18.49	192.43	60.24	66.67	9.58	672.22	96.73
83.33	21.88	208.47	64.36	72.22	11.48	677.78	96.84
89.74	25.42	224.50	68.06	77.78	13.50	683.33	96.95
96.15	29.03	240.54	71.39	83.33	15.63	688.89	97.05
102.56	32.67	256.57	74.37	88.89	17.85	694.44	97.15
108.97	36.24	272.61	77.05	94.44	20.11	700.00	97.25
115.38	39.66	288.65	79.45	100.00	22.40	705.56	97.34
121.79	42.90	304.68	81.61	105.56	24.67	711.11	97.43
128.21	45.96	320.72	83.54	111.11	26.87	716.67	97.52
134.62	48.86	336.75	85.28	116.67	29.00	722.22	97.61
141.03	51.61	352.79	86.84	122.22	31.08	727.78	97.69
147.44	54.21	368.83	88.24	127.78	33.09	733.33	97.77
153.85	56.67	384.86	89.49	133.33	35.05	738.89	97.85
160.26	59.00	400.90	90.62	138.89	36.95	744.44	97.93
166.67	61.21	416.93	91.63	144.44	38.79	750.00	98.00
173.08	63.30	432.97	92.54	150.00	40.59	755.56	98.08
179.49	65.28	449.01	93.35	155.56	42.32	761.11	98.15
185.90	67.15	465.04	94.08	161.11	44.01	766.67	98.21
192.31	68.92	481.08	94.74	166.67	45.65	772.22	98.28
198.72	70.60	497.11	95.33	172.22	47.24	777.78	98.35
205.13	72.19	513.15	95.85	177.78	48.79	783.33	98.41
211.54	73.70	529.19	96.33	183.33	50.29	788.89	98.47
217.95	75.12	545.22	96.75	188.89	51.75	794.44	98.53
224.36	76.47	561.26	97.13	194.44	53.16	800.00	98.58
230.77	77.75	577.29	97.48	200.00	54.54	805.56	98.64
237.18	78.96	593.33	97.78	205.56	55.87	811.11	98.69
243.59	80.10	609.36	98.06	211.11	57.17	816.67	98.75
250.00	81.19	625.40	98.31	216.67	58.42	822.22	98.80
256.41	82.22	641.44	98.53	222.22	59.64	827.78	98.85
262.82	83.19	657.47	98.73	227.78	60.83	833.33	98.89
269.23	84.11	673.51	98.91	233.33	61.98	838.89	98.94
275.64	84.98	689.54	99.07	238.89	63.10	844.44	98.98
282.05	85.81	705.58	99.21	244.44	64.18	850.00	99.03
288.46	86.59	721.62	99.34	250.00	65.24	855.56	99.07
294.87	87.33	737.65	99.46	255.56	66.26	861.11	99.11
301.28	88.03	753.69	99.56	261.11	67.26	866.67	99.15
307.69	88.69	769.72	99.66	266.67	68.22	872.22	99.19

Ellsworth		Canada Larga		NForkMatilja			
% time	% Q	% time	% Q	% time	% Q	% time	% Q
314.10	89.32	785.76	99.74	272.22	69.16	877.78	99.23
320.51	89.91	801.80	99.82	277.78	70.07	883.33	99.27
326.92	90.48	817.83	99.88	283.33	70.95	888.89	99.30
333.33	91.01	833.87	99.95	288.89	71.81	894.44	99.34
339.74	91.51	849.90	100.00	294.44	72.64	900.00	99.37
346.15	91.99	865.94	100.00	300.00	73.45	905.56	99.40
352.56	92.44			305.56	74.23	911.11	99.43
358.97	92.87			311.11	75.00	916.67	99.46
365.38	93.28			316.67	75.74	922.22	99.49
371.79	93.66			322.22	76.45	927.78	99.52
378.21	94.02			327.78	77.15	933.33	99.55
384.62	94.37			333.33	77.83	938.89	99.58
391.03	94.69			338.89	78.49	944.44	99.60
397.44	95.00			344.44	79.13	950.00	99.63
403.85	95.30			350.00	79.75	955.56	99.66
410.26	95.57			355.56	80.35	961.11	99.68
416.67	95.83			361.11	80.93	966.67	99.70
423.08	96.08			366.67	81.50	972.22	99.73
429.49	96.32			372.22	82.05	977.78	99.75
435.90	96.54			377.78	82.59	983.33	99.77
442.31	96.75			383.33	83.11	988.89	99.79
448.72	96.95			388.89	83.61	994.44	99.81
455.13	97.14			394.44	84.10	1000.00	99.83
461.54	97.32			400.00	84.58	1005.56	99.85
467.95	97.48			405.56	85.04	1011.11	99.87
474.36	97.65			411.11	85.49	1016.67	99.89
480.77	97.80			416.67	85.92	1022.22	99.90
487.18	97.94			422.22	86.35	1027.78	99.92
493.59	98.08			427.78	86.76	1033.33	99.94
500.00	98.20			433.33	87.16	1038.89	99.95
506.41	98.33			438.89	87.54	1044.44	99.97
512.82	98.44			444.44	87.92	1050.00	99.99
519.23	98.55			450.00	88.28	1055.56	100.00
525.64	98.65			455.56	88.64		
532.05	98.75			461.11	88.98		
538.46	98.85			466.67	89.32		
544.87	98.93			472.22	89.64		

Ellsworth		Canada Larga		NForkMatilja			
% time	% Q	% time	% Q	% time	% Q	% time	% Q
551.28	99.02			477.78	89.96		
557.69	99.10			483.33	90.26		
564.10	99.17			488.89	90.56		
570.51	99.24			494.44	90.85		
576.92	99.31			500.00	91.13		
583.33	99.37			505.56	91.40		
589.74	99.43			511.11	91.66		
596.15	99.49			516.67	91.92		
602.56	99.54			522.22	92.17		
608.97	99.59			527.78	92.41		
615.38	99.64			533.33	92.64		
621.79	99.68			538.89	92.87		
628.21	99.73			544.44	93.09		
634.62	99.77			550.00	93.31		
641.03	99.81			555.56	93.52		
647.44	99.84			561.11	93.72		
653.85	99.88			566.67	93.92		
660.26	99.91			572.22	94.11		
666.67	99.94			577.78	94.29		
673.08	99.97			583.33	94.47		
679.49	100.00			588.89	94.65		
685.90	100.00			594.44	94.82		
692.31	100.00			600.00	94.98		

Note: Data also provided in Appendix E HEC-HMS Version 3.2 Files

C-4 HEC-HMS OR HSPF HYDROGRAPH TRANSFORMATION

The following figure shows the results of transforming an HMS hydrograph into a truncated VCRat hydrograph. The procedure is done with the spreadsheet provided in Appendix E. The process involves determining the relative peak times of the hydrographs and then adjusting the time ordinates. The adjusted file does not have to be transformed to the variable VCRat spacing because VCRat2.6 will do this after the hydrograph is imported.

The HMS or HSPF hydrograph will be truncated because the VCRat simulation length is 1,440 minutes. The yield of the transformed hydrograph will be too small once it is imported into VCRat but the volume of the leading limb of the hydrograph is most important if the hydrograph is needed for basin design. The truncated hydrograph cannot be used to evaluate the time it takes to drain the basin after the rainfall peak has occurred. Other hydrograph conversion spreadsheets are provided that convert VCRat variable timing hydrographs into 1- or 5-min intervals.

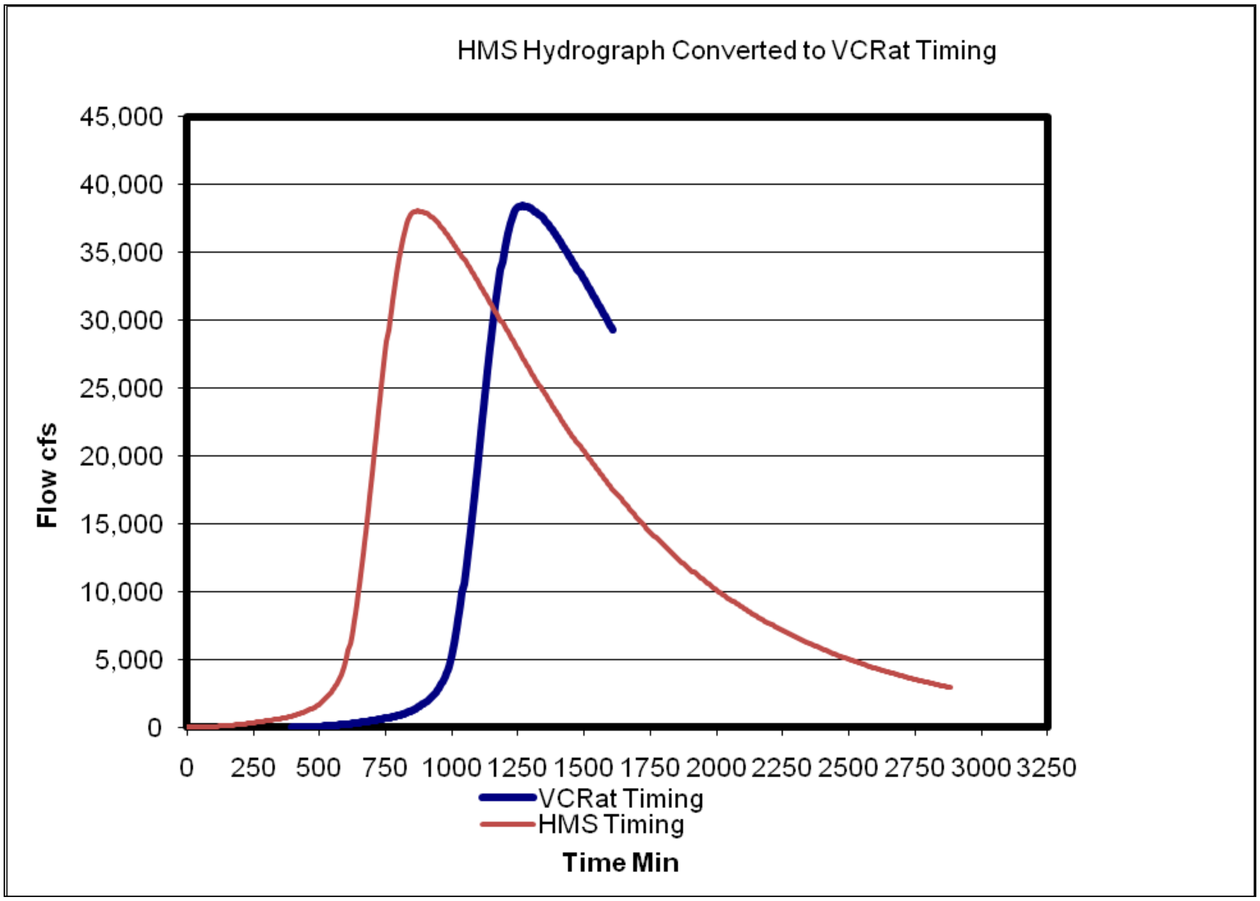


Figure C-4.1 HMS Hydrograph Converted to VCRat Timing

APPENDIX D DETENTION BASIN DESIGN

D-1 TRUNCATED SUMP UPDATE STUDY EXAMPLE FILES

The Truncated Sump or Bypass Basin analysis presented in the report showed that the required basin volume varies with development type, time of concentration, mitigation goal, and 24-hour rain depth used to fatten the design hydrograph. The procedure for performing a hydrology run to obtain the necessary bypass basin volume is as follows:

1. Establish mitigation goal, commonly the 10-yr developed condition.
2. Calculate the Tc's for the 10- and 100-yr proposed development.
3. Create a VCRat2.64 hydrology input file and enable the option to use different storm frequencies in the run.
4. Add a subarea to the input file using the 10-yr storm for rainfall.
5. In the next data input line, clear the hydrograph and add the same subarea info with the 100-yr storm. Fatten the hydrograph.
6. Run the model and obtain the 10-yr storm.
7. Add a split to the model and split all flow above the 10-yr peak level into the bypass basin.
8. The hydrograph summaries at the bottom of the output file will provide the volume of the flow diverted to the bypass basin.

For design of bypass basins, it is necessary to perform a detailed hydraulic analysis to show that the side channel weir or other diversion structure will function adequately. Appendix E provides a sample hydrology file for performing the above operations.

Also, the VCRat Excel Spreadsheet model has been designed to automatically calculate the volume required for a bypass basin to mitigate the developed condition peak.

D-2 FLOW THROUGH BASIN DESIGN

D-2.1 Basin Design Procedure

This procedure provides a method for sizing a basin and outlet works for project sites that are too small to be evaluated with standard Hydrology Section tools. In general, this procedure applies to projects that are less than 10-ac in size, although some of the techniques described here may be useful for larger projects. The variables associated with basin design include the storm interval, subarea size, Tc, soil type, % impervious value, required mitigation level, basin configuration and depth, outlet works assumptions, and n-yr 1-day rainfall used to adjust the hydrograph yield. The number of variables makes it difficult to generate nomographs or simplified relationships that can be used in design. Therefore, a simplified methodology and examples are provided here to demonstrate how basin design can be done in accordance with Hydrology Section requirements. The following sections provide information on different steps in the procedure.

D-2.1.1 Project Size

This method should be applied to projects less than 5-ac in size that cannot be evaluated with VCRat2.64 or other hydrology section tools.

D-2.1.2 Mitigation Criteria

Obtain the mitigation criteria from the jurisdiction. A common mitigation level is to reduce the developed condition Q100 peak to the developed condition Q10 peak. Other mitigation levels include the undeveloped condition Q10 or Q100.

D-2.1.3 Project Area Tc's

The project area Tc's are found through the following steps:

1. Find the subarea that incorporates the project area in a Master Drainage Plan or official hydrology study. If both sources are available, use the subarea with the longest Tc for the evaluation. The 100-yr Tc and the Tc associated with the mitigation level are needed. Once the appropriate subarea is identified, extract the subarea information such as Tc, area, % imperviousness, soil, etc.
2. Determine if the Tc will change in the developed condition and recalculate the Tc if necessary. If the project area represents the overland flow path in the Tc calculation, the Tc may decrease. Perform a Tc calculation to check this. If the project is not an overland flow path, the Tc will likely stay the same as shown in the MDP or other model and does not need to be recalculated.
3. Calculate the Tc for the mitigation condition if it is different from those provided above. If the Tc calculation from the MDP or official hydrology study is not available, the peak mitigation flow can be estimated using the Hydrology Section standard multipliers. Then VCRat can be used to find the Tc that provides that peak flow by changing the Tc until the VCRat peak matches the calculated multiplier peak.

D-2.1.4 Project Area Peak Flows and Hydrographs

The project area flow are obtained through the following:

1. Calculate the developed condition peak flow using a C coefficient that represents the developed condition effective impervious value and the rainfall intensity associated with the developed condition Tc. Calculate the mitigation condition peak flow using the C coefficient that represents the mitigation condition development type and the rainfall intensity associated with the mitigation condition Tc.
2. If the user needs a hydrograph for basin design, input the required developed condition information into a VCRat2.64 model run but multiply the subarea by a factor to get the modeled subarea into the 10-300 ac range. Because the rational method results are linearly related to area, the user can export the output VCRat hydrograph ordinates and divide by the same factor used to increase the area to get a hydrograph for use in basin design. Fatten the hydrograph in VCRat to make sure it has the right yield using the 100-yr 1-day rainfall at the project site and the appropriate Curve Number (Exhibit 14) associated with the development and soil types.
3. Alternatively, reduce the hydrograph so that it represents the actual subarea size using the split flow option in VCRat (Percent left in main). For example, if the original project area is 2 ac, this could be increased to 20 or 200 ac for the run, the Percent Left in Main would be 10 or 1%, respectively. At this time the entry into the field must be an integer so make sure the factor used allows this when converting the hydrograph back to the right volume and peak for the area.
4. Add a placeholder data input line with reservoir routing after the split flow line and enter the stage-storage-discharge information calculated from the next section. Run the model and check to see if the basin meets the mitigation requirements. Alternatively, the basin design hydrograph can be exported from VCRat and imported into HEC-HMS after interpolating it to 1-min intervals and HEC-HMS can be used for basin routing modeling.
5. Alternately, use the VCRat Excel spreadsheet model which includes basin routing capabilities to assess whether your basin design meets the required criteria.

D-2.2 Basin Design

The basin design methodology outlined in this section is obtained mainly from the NPDES dry detention basin methodology outlined in the Stormwater Technical Guidance Manual (July 2002) available on the VCWPD website. The dry detention basin guidelines include the following:

1. Basin side-slopes are minimum 3H to 1V.
2. Basin length is twice the basin width
3. Max depth of basin is calculated at 0.1*(Bottom Area)^0.5

For the purposes of this study, it is expected that basins will be designed to drain by gravity, and that a project site slope of 5% is the maximum that could be expected. Therefore, the depth of the basin is further limited so that Basin Depth/Basin Top Length ratio is less than or equal to 5% so that the basin could be designed with a minimum of above ground dam construction. For simplicity, the outlet works of the basins are assumed consist of the following:

1. One small orifice at the bottom of a circular riser that is designed discharge stored flow from the basin in 24 hours or less using the NPDES methodology or a number of small orifices in the riser to discharge stored flow in 24 hours or less
2. Weir flow into the top of a circular riser.

3. Once the height of the flow above the riser top is equal to the riser radius (submerged weir), it is assumed that the riser inflow is limited to the discharge through the culvert outlet with entrance, exit, and friction losses in the pipe. A figure given below illustrates this approach.

The design approach for the basin consists of the following steps:

1. Use the Tc and other hydrologic parameters from above to generate a VCRat run that provides the mitigation peak and developed condition peak and fattened hydrograph volume. Increase the project area by a factor to get the VCRat area in the range of 10-300 acres and then divide the results by the factor to get the project area peak, hydrograph ordinates, and hydrograph volume.
2. Find preliminary ratio of required basin volume to inflow volume from the attached summary table. As a first guess, a ratio of 0.10 is generally adequate except in high rainfall areas and for projects with long Tc's (20-30 minutes).
3. Multiply ratio times inflow volume to obtain an initial guess of the required basin volume (SQDV in subsequent calculations).
4. Calculate maximum depth of basin based on NPDES requirements: Dmax=0.1*(basin bottom area)^0.5
5. Estimate required basin depth by rounding depth to nearest foot
6. Divide basin depth by calculated basin top length to get land slope necessary to provide gravity flow at outlet. If calculated slope is greater than 5%, reduce depth and recalculate slope until slope is less than 5%.
7. Calculate diameter of orifice required to outlet flow in 24 hrs or less with the following equation:

   b. For single orifice outlet control or single row of orifices at the basin bottom surface elevation (see Figures 5-6), use the following equation based on the SQDV (ft^3) and depth of water above orifice centerline D_{BS} (ft) to determine total orifice area (in^2):

   $$\text{Total orifice area} = (SQDV) \div [(60.19)(D_{BS}^{0.5})(T)]$$

Where T= 24 hrs and SQDV = basin volume calculated above.

The DesignExample.xls spreadsheet calculates the stage-volume curve at 0.5 ft intervals. The DesignExample.xls spreadsheet calculates the stage-discharge curve at 0.5 ft intervals based on one orifice at the bottom of the basin for long-term drainage, weir flow over the riser top, and a pipe outlet that controls the outflow. The riser top elevation is assumed to be located at ½ the basin maximum depth in the preliminary design phase. These data can be entered into VCRat2.6 run to see if the basin meets the mitigation requirements. If it does not, redesign the outlet or increase the volume until the requirements are met.

Example:

A 9-ac site in Simi Valley will be converted from open space to an industrial development. The mitigation condition is assumed to be to build a detention basin that will reduce the developed condition Q100 to the developed condition Q10. The 2000 Condition Calleguas Model includes this site in a 40-ac subarea. Based on a review of topo for this subarea, the project is not part of the longest or overland flowpath used to calculate the Tc so the developed condition Tc does not need to be revised.

Model Output Evaluation

Calleguas 2000 Condition 100-yr Results

Soil Type 3; Tc 11 min; K Zone; Average Impervious = 23%.

Subarea peak flow is 113 cfs; or 2.825 cfs/ac

Calleguas 2000 Condition 10 yr Results

Q10 with Tc = 13 mins is 68 cfs, or 1.7 cfs/ac.

Use parameters from Calleguas subarea Soil Type 3; K Zone; Average Impervious = 23%

(See 2000ConditionCalleguasModelExample.vin, .out; attached output).

Using 2006 Hydrology Manual

Exhibit 14a,b show 70% effective impervious for industrial sites. CN for soil type 3 is 96.

Exhibit 2 shows K Zone rainfall intensities of:

Tc=11 min, 100-yr storm, I=3.39 in/hr

Tc=13 min, 10-yr storm, I=2.20 in/hr

Exhibit 6c shows C coefficients for Soil Type 3

If I=3.39in/hr, C(70%)= 0.90

If I=2.2in/hr, C(70%)=0.88

Project Area Developed Condition Q100= 0.90*3.39in/hr*9ac=27.5 cfs

Project Area Developed Condition Q100= 0.88*2.20in/hr*9ac=17.4 cfs

Preparation of VCRat Model for Project Area

See VCRAT2.64 files SimiValleyDesignExample.vin, .out

Since 9 ac project area is too small for VCRat run, analyze a 90 ac subarea and divide the results by factor of 10 or use split flow option in VCRat to get correct hydrograph peak and volume.

Enter subarea info for mitigation peak flow in model.

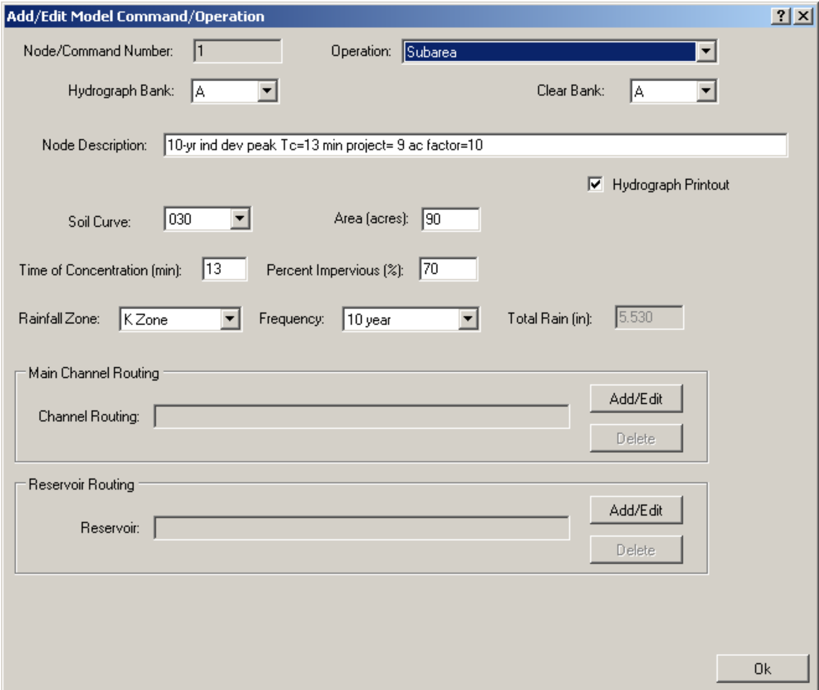


Figure D-2.1 VCRat2.64 Subarea Edit Window

Enter Developed Condition Q100 parameters in model:

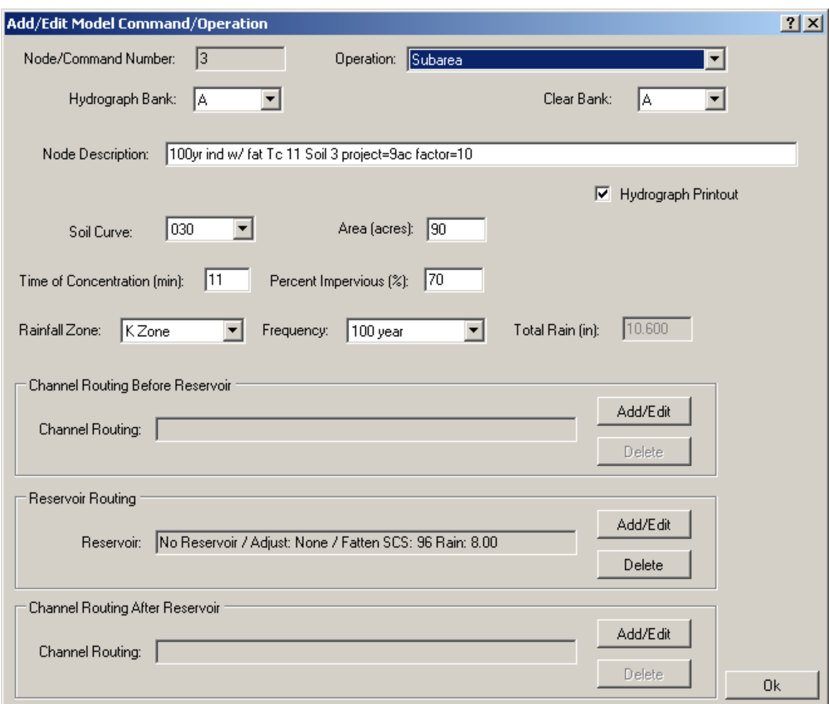


Figure D-2.2 VCRat2.64 Subarea Edit Window

Find data for yield adjustment of hydrograph (fattening).

GIS shapefile in hydrology manual shows 100-yr 1-day rainfall at project site is 8 inches. Exhibit 14a,b shows CN for soil type 3, industrial land use is 96. Enter this in reservoir routing portion of subarea:

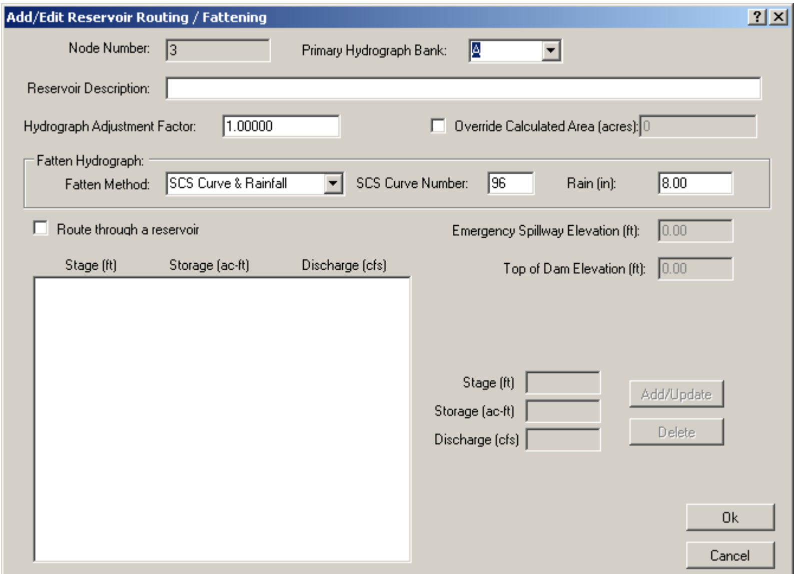


Figure D-2.3 VCRat2.64 Subarea Reservoir Routing Edit Window

Use split flow option in VCRat2.6 to reduce hydrograph peak and volume to represent project area only:

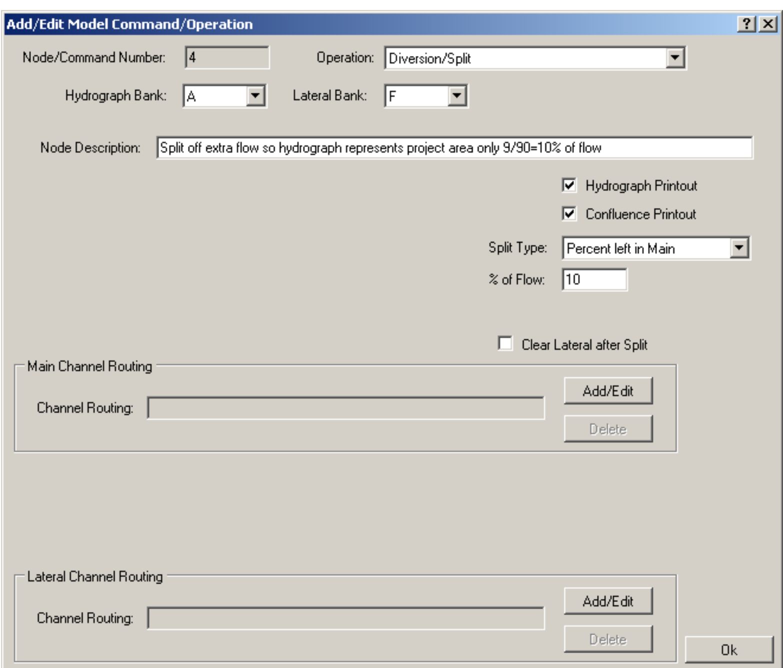


Figure D-2.4 VCRat2.64 Subarea Edit Window

VCRat Model Results (see attached)

90 Ac Subarea Results

Mitigation Q10 peak for 90 ac subarea= 175 cfs

Q100 developed condition peak for 90 ac subarea= 275 cfs

Hydrograph volume before fattening: 53.08 ac-ft

Hydrograph volume after fattening: 56.39 ac-ft

Hydrograph volume remaining in line A after splitting off 90%= 56.39/10=5.64 af

9 Ac Project Area Results

Mitigation Q10 peak for 9 ac project area = 175/10= 17.5 cfs

Q100 developed condition peak 9 ac project area= 27.5 cfs.

Hydrograph volume remaining in line A after splitting off 90%= 56.39/10=5.64 af

Calculate preliminary basin deslgn info based on results:

From 20001 VC Stormwater Quality Management Program		
Basin Design Criteria		Highlighted cells require user input
Dmax- Basin Max Depth ft	0.1*A^.5	
A= Area sf		basin bottom width x basin bottom length
L/W		length to width ratio of 2:1 or greater
Bott Width ft		Minimum Bottom width 30 ft
Z ratio, sideslopes		sideslopes 3:1 H:V desired
Basin vol af	0.56394	.10*inflow vol
Basin Vol cf	24565.23	
Vol/ac Ratio	2729.47	
Sideslopes H:V	3	

Assumed bott Width ft	40	User Input
Calc bott Length ft	80	
Calculated Basin Depth Dmax	5.657	
Assumed Depth ft	5	User Input
Calc Top Width ft	70	
Calc Top Length ft	110	
Calculated Land Slope	0.045455	Basin Assumed Depth/Basin Top Length
Calc Vol w/ Assumed Depth cf	26125	SQDV

Single Orifice Outlet to meet 24hr drawdown time at 1/2 Depth

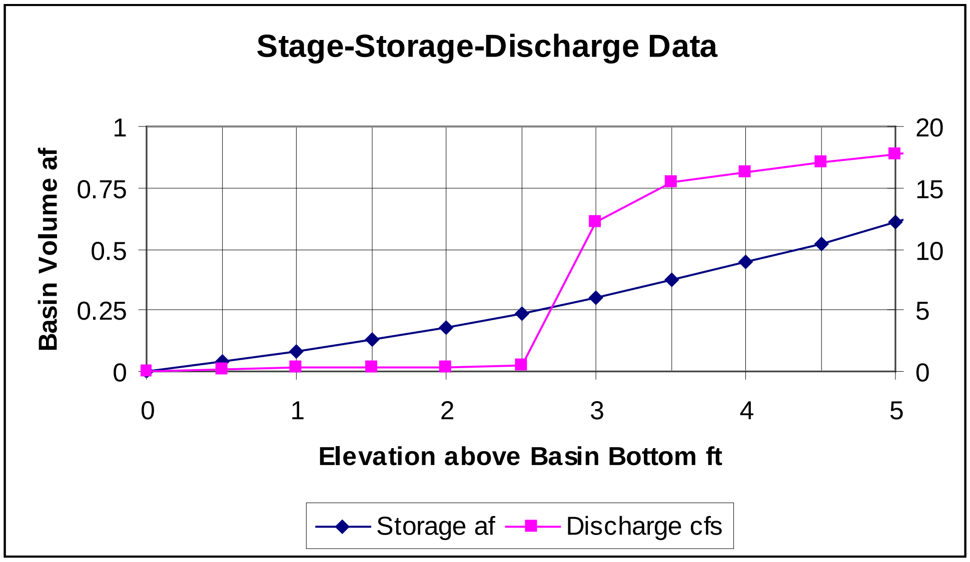
Dbs ft	4.95	Depth of water above centerline of the bottom perforation (assumed to be 0.05 ft above bottom)
c	0.6	orifice coefficient = 0.6
g ft/sec^2	32.2	gravity 32.2
T drawdown hrs	24	
Total Orifice Area sq in	8.128644	Orif Area sq in=(Basin Vol cf)/(60.19*Dbs^0.5*T)
Orifice Area sf	0.056449	
Orifice Diam ft	0.13408	D=sqrt(4*A/pi)
Max Discharge cfs full depth	0.604717	c*a*sqrt(2gh)
Discharge Time for max Q sec	43,202	Basin Volume/Orifice Discharge
Discharge Time for max Q hrs	12.0	

Stage-Storage-Discharge Calculations

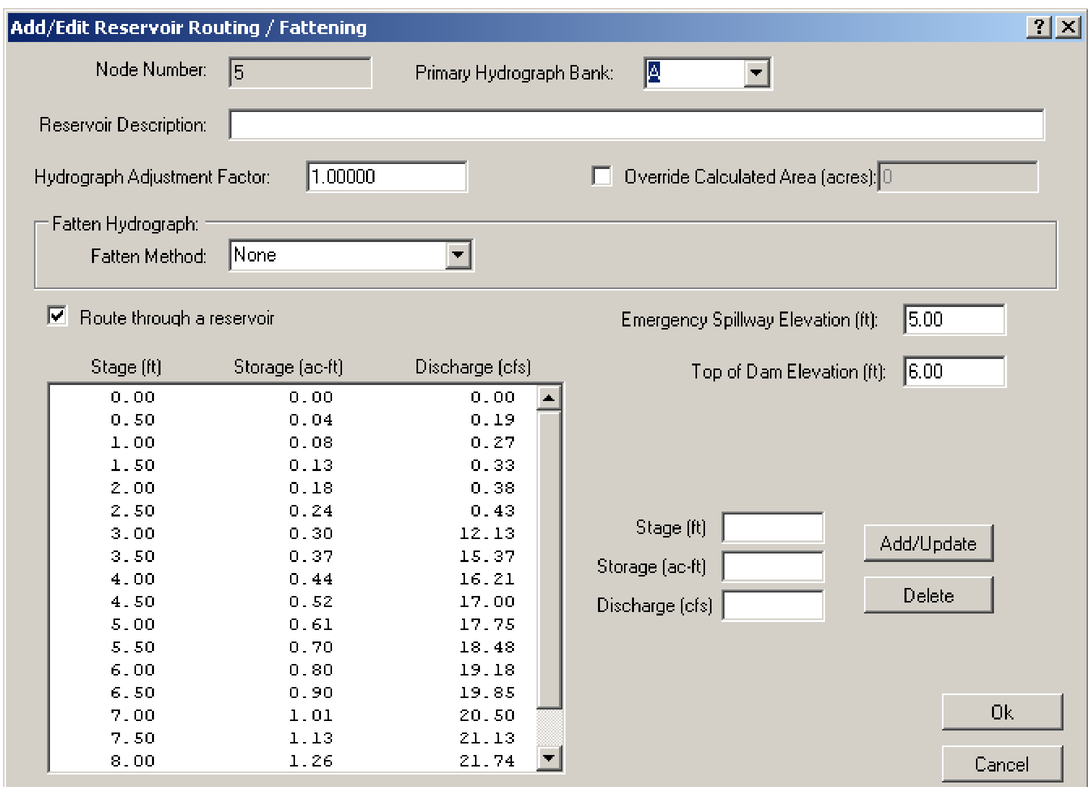
Design a basin with the following assumptions:

1. Single orifice of 0.0564 sf area at bottom of basin as above
2. Circular riser of 1.5 ft radius with top elevation of 2.5 ft above basin bottom
3. Culvert outlet 50 ft long with elevation drop of 1 ft (slope=0.02 ft/ft) with entrance, exit, and friction losses included in calcs. Outlet controls flow with radius of 0.75ft.

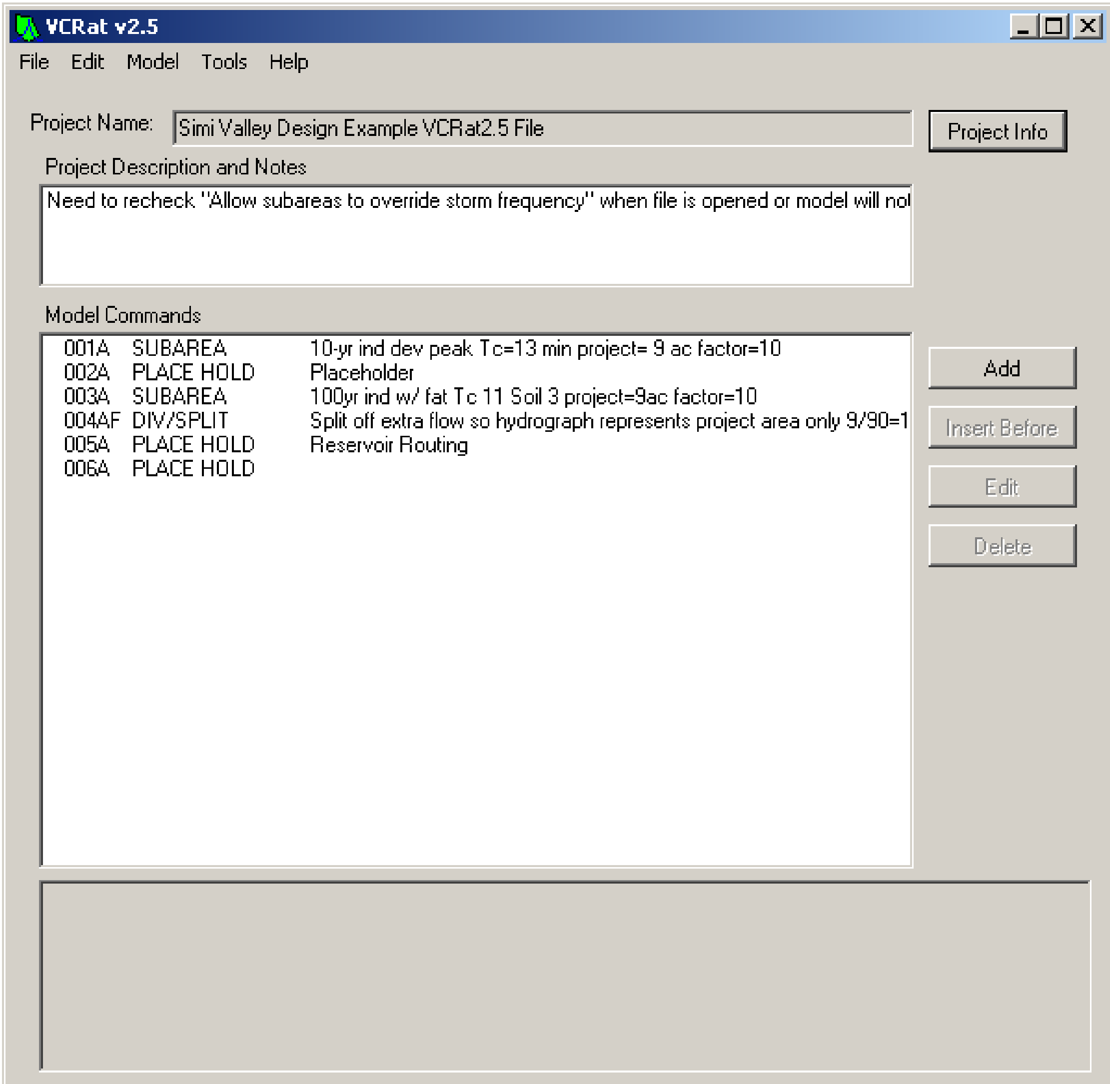
Based on these assumptions, the stage storage discharge data are:



These data are then inserted into the VCRat2.6 run as follows:



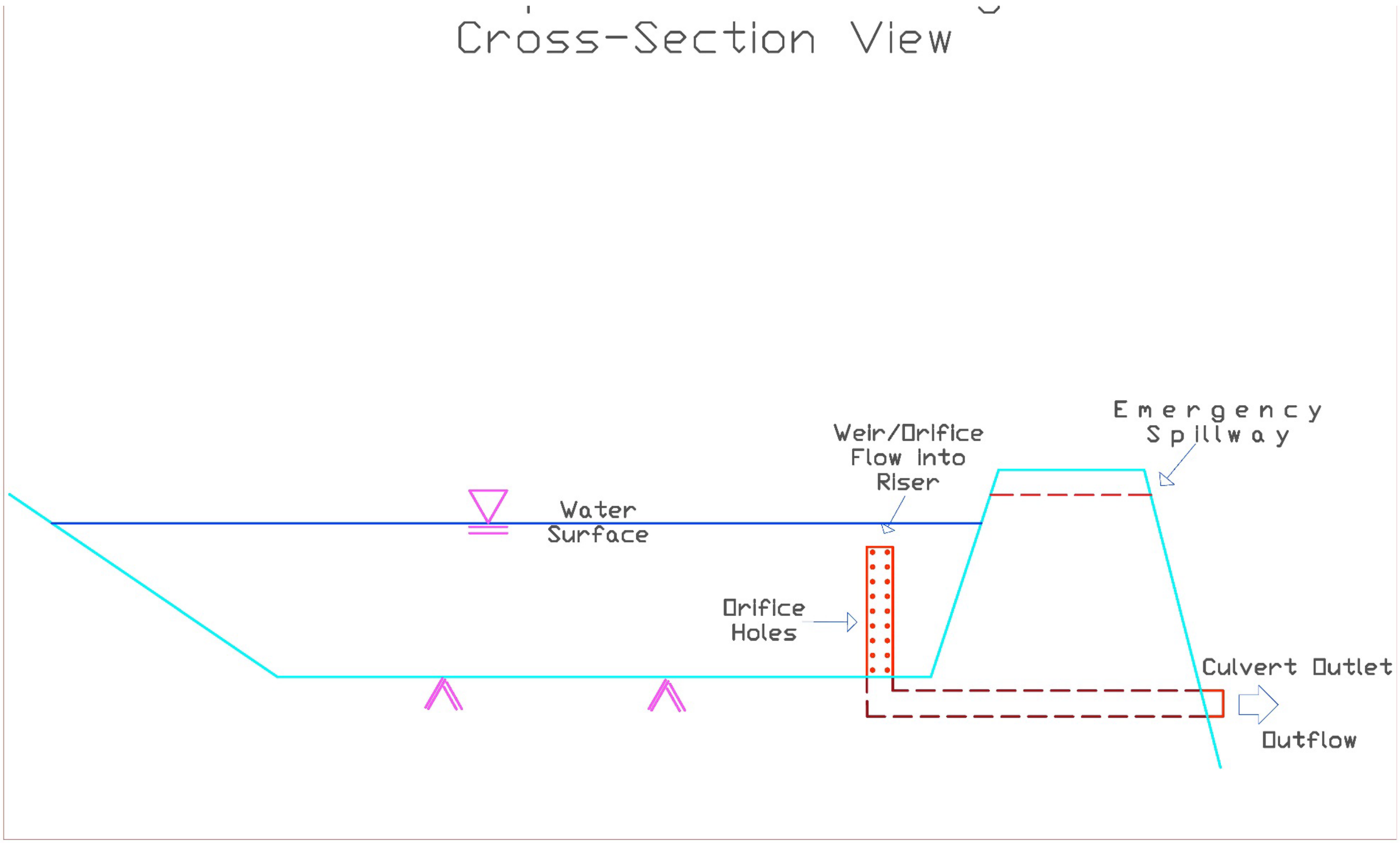
The full model input file is:



The model output file is provided in Appendix E. A summary of the results are:

```
INCOMING HYDROGRAPH  PEAK (cfs):     27.55         VOLUME (acre-ft):      5.64      *
NO HYDROGRAPH ADJUSTMENT                                                            *
NO HYDROGRAPH FATTENING                                                             *
RESERVOIR INFLOW:    PEAK (cfs):     27.55 @ 1154  VOLUME (acre-ft):      5.64      *
MAXIMUM ELEVATION:   STAGE (ft):      4.10 @ 1162  VOLUME (acre-ft):      0.46      *
EMERGENCY SPILLWAY:   ELEV (ft):      5.00         VOLUME (acre-ft):      0.61      *
    DIFFERENCE:   IN STAGE (ft):     -0.90      IN VOLUME (acre-ft):      0.15      *
NO SPILL EXPECTED.       PERCNT OF VOLUME REMAINING TO SPILLWAY:     25.2%      *
TOP OF DAM:           ELEV (ft):      6.00         VOLUME (acre-ft):      0.80      *
DIFFERENCE    IN STAGE (ft):     -1.90      IN VOLUME (acre-ft):      0.34      *
NO OVERTOP EXPECTED.   PERCNT OF VOLUME REMAINING TO TOP OF DAM:     43.0%      *
RESERVOIR OUTFLOW:   PEAK (cfs):     16.37 @ 1162  VOLUME (acre-ft):      5.16      *
```

The results show that with this design, the maximum depth in the basin is expected to be 4.1 ft with a volume of 0.46 af.


Cross-Section View
Emergency
Spillway
Weir/Orifice
Flow Into
Riser
Water
Surface
Orifice
Holes
Culvert Outlet
Outflow

```
                                            Ventura County Watershed Protection District
                                         Modified Rational Method Hydrology Program (VCRat v2.6)

      VCRat version:   2.6.2009.7
      VCRain version:  200703
      DOS EXE version: PC 2.2-200604
                                              Ventura County Watershed Protection District
                                         Modified Rational Method Hydrology Program (VCRat v2.5)

                                       Job:      1  Project: 1000 Oaks Watershed Detention Study
Page:     2
                                                                                  Model Results
   |---------- SUBAREA DATA AND RESULTS --------|-- ACCUMULATED DATA --|------------ ROUTING AFTER ACCUMULATION ---------------------------------|
   | NODE    SOIL  RAIN   TC    %    AREA  FLOW  |  AREA    FLOW   TIME |  CHANNEL  LENGTH   SLOPE     SIZE    H:V      N VALUES      VEL  DEPTH |
   |  ID     TYPE  ZONE (MIN)  IMP   (AC)  (CFS) |  (AC)    (CFS)  (MIN)|    TYPE    (FT)   (FT/FT)    (FT)    (Z)     CHNL   SIDES (FT/S)  (FT) |
   |--------------------------------------------|----------------------|-----------------------------------------------------------------------|
       1A :  Calleguas 2000 Condition 10-yr results
       1A :  Clearing Hydrograph Bank:  A
       1A   030   K10    13   23     40     68       40       68   1154   -------    ----  -------    ---     ----    -----  -----    --     --
       2A :  Placeholder
       2A   ---   ---    --   --    ---    ---       40       68   1154   -------    ----  -------    ---     ----    -----  -----    --     --
       3A :  Calleguas 2000 Condition Model incorporating project area 100-yr
       3A :  Clearing Hydrograph Bank:  A
       3A   030   K100   11   23     40    113       40      113   1154   -------    ----  -------    ---     ----    -----  -----    --     --
       4A :  Placeholder
       4A   ---   ---    --   --    ---    ---       40      113   1154   -------    ----  -------    ---     ----    -----  -----    --     --
```

Model output from VCRat2.6 run using Calleguas 2000 Condition Model data for subarea incorporating project area.

VCRat2.6 Model Output for Design Example

```
                                          Ventura County Watershed Protection District
                                     Modified Rational Method Hydrology Program (VCRat v2.6)

                                   Job:      1  Project: 1000 Oaks Watershed Detention Study
                                                         Model Results
 |---------- SUBAREA DATA AND RESULTS --------|-- ACCUMULATED DATA --|------------ ROUTING AFTER ACCUMULATION ---------------------
 | NODE   SOIL  RAIN   TC    %    AREA  FLOW  |  AREA    FLOW   TIME |  CHANNEL  LENGTH  SLOPE    SIZE   H:V      N VALUES      VEL  DEPTH |
 |  ID    TYPE  ZONE (MIN)  IMP   (AC)  (CFS) |  (AC)    (CFS)  (MIN)|   TYPE    (FT)  (FT/FT)   (FT)   (Z)     CHNL  SIDES  (FT/S)  (FT) |
 |--------------------------------------------|---------------------|-------------------------------------------------------------------|
    1A :  10-yr ind dev peak Tc=13 min project= 9 ac factor=10
    1A :  Clearing Hydrograph Bank:  A
    1A   030   K10    13   70     90    175       90     175   1154   -------    ----  -------    ---     ----    -----  -----    --     --
    2A :  Placeholder
    2A   ---   ---    --   --    ---    ---       90     175   1154   -------    ----  -------    ---     ----    -----  -----    --     --
    3A :  100yr ind w/ fat Tc 11 Soil 3 project=9ac factor=10
    3A :  Clearing Hydrograph Bank:  A
    3A   030   K100   11   70     90    275       90     275   1154   -------    ----  -------    ---     ----    -----  -----    --     --
         *******************************************************************************************
         *      INCOMING HYDROGRAPH  PEAK (cfs):    275.47         VOLUME (acre-ft):     53.08      *
         *      NO HYDROGRAPH ADJUSTMENT                                                            *
         *      RUNOFF FACTOR(in):   7.52      TOTAL RAIN(in):   8.00      SCS Curve: 96            *
         *      FATTENED HYDROGRAPH  PEAK (cfs):    275.47         VOLUME (acre-ft):     56.39      *
         *******************************************************************************************
    3A   ---   ---    --   --    ---    ---       90     275   ----   -------    ----  -------    ---     ----    -----  -----    --     --
    4AF:  Split percent
    4AF:  Control/Diversion:  10% to channel A
         ************************************************************************************
         *      Combined Peak:      275 @ 1154  Q in A:       28      Q in F:      248     *
         *          Peak in A:       28 @ 1154  Q in F:      248  Combined Q:      275     *
         *          Peak in F:      248 @ 1154  Q in A:       28  Combined Q:      275     *
         ************************************************************************************
    4AF  ---   ---    --   --    ---    ---       90      28   1154   -------    ----  -------    ---     ----    -----  -----    --     --
    5A :  Reservoir Routing
    5A   ---   ---    --   --    ---    ---       90      28   1154   -------    ----  -------    ---     ----    -----  -----    --     --
         *******************************************************************************************
         *      INCOMING HYDROGRAPH  PEAK (cfs):     27.55         VOLUME (acre-ft):      5.64      *
         *      NO HYDROGRAPH ADJUSTMENT                                                            *
         *      NO HYDROGRAPH FATTENING                                                             *
         *      RESERVOIR INFLOW:    PEAK (cfs):     27.55 @ 1154  VOLUME (acre-ft):      5.64      *
         *      MAXIMUM ELEVATION:   STAGE (ft):      4.10 @ 1162  VOLUME (acre-ft):      0.46      *
         *      EMERGENCY SPILLWAY:   ELEV (ft):      5.00         VOLUME (acre-ft):      0.61      *
         *          DIFFERENCE:   IN STAGE (ft):     -0.90      IN VOLUME (acre-ft):      0.15      *
         *          NO SPILL EXPECTED.       PERCNT OF VOLUME REMAINING TO SPILLWAY:     25.2%      *
         *      TOP OF DAM:           ELEV (ft):      9.00         VOLUME (acre-ft):      0.80      *
```

```
      *          DIFFERENCE    IN STAGE (ft):     -4.90      IN VOLUME (acre-ft):      0.34      *
      *          NO OVERTOP EXPECTED.   PERCNT OF VOLUME REMAINING TO TOP OF DAM:     43.0%      *
      *      RESERVOIR OUTFLOW:   PEAK (cfs):     16.37 @ 1162  VOLUME (acre-ft):      5.16      *
      *********************************************************************************************
 5A   ---   ---    --   --    ---    ---       90      16   1162    -------    ----  -------    ---     ----    -----  -----    --     --
 6A   ---   ---    --   --    ---    ---       90      16   1162    -------    ----  -------    ---     ----    -----  -----    --     --
```

APPENDIX E HYDROLOGY FILES

E-1 10-YR RAINFALL PDF MAP

E-2 25-YR RAINFALL PDF MAP

E-3 50-YR RAINFALL PDF MAP

E-4 100-YR RAINFALL PDF MAP

E-5 10-YR RAINFALL SHAPEFILES

E-6 25-YR RAINFALL SHAPEFILES

E-7 50-YR RAINFALL SHAPEFILES

E-8 100-YR RAINFALL SHAPEFILES

E-9 NOAA RAIN ZONES SHAPEFILES

E-10 UPDATED SOILS MAP SHAPEFILES

E-11 EXAMPLE VCRAT2.64, 2.6, AND 2.2 FILES

E-12 DESIGN RAINFALL FREQUENCY AND HYETOGRAPH FILES

E-13 HEC-HMS DESIGN STORM MODEL INPUT FILES

E-14 HYDROGRAPH TRANSFORMATION SPREADSHEETS

E-15 PERMIT REPORT SUBMITTAL EXAMPLE

E-16 TC EXAMPLE FILES

E-17 FLOW-THROUGH BASIN DESIGN SPREADSHEET

E-18 FLOW-THROUGH BASIN MODEL FILES

E-19 SMALL AREA BASIN DESIGN SPREADSHEET

E-20 EXAMPLE AR FILES- VCRAT2.2 AND 2.64

E-21 VCRAIN.DAT FILES FOR VCRAT2.2

E-22 YIELD ADJUSTMENT EXAMPLE FILES

E-23 MULTIPLE AREAL REDUCTION FACTOR FILES FOR VCRAT2.2

E-24 BYPASS BASIN VCRAT2.6 FILES

E-25 SMALL AREA HYDROGRAPH FILES

E-26 VCRAT PROGRAM

E-27 TC CALCULATOR SPREADSHEET

E-28 VCRAT AND BASIN ROUTING SPREADSHEET

E-29 BULKED FLOW SPREADSHEET

APPENDIX F ERRATA

Date	Page(s)	Description
		None reported as of July 2017