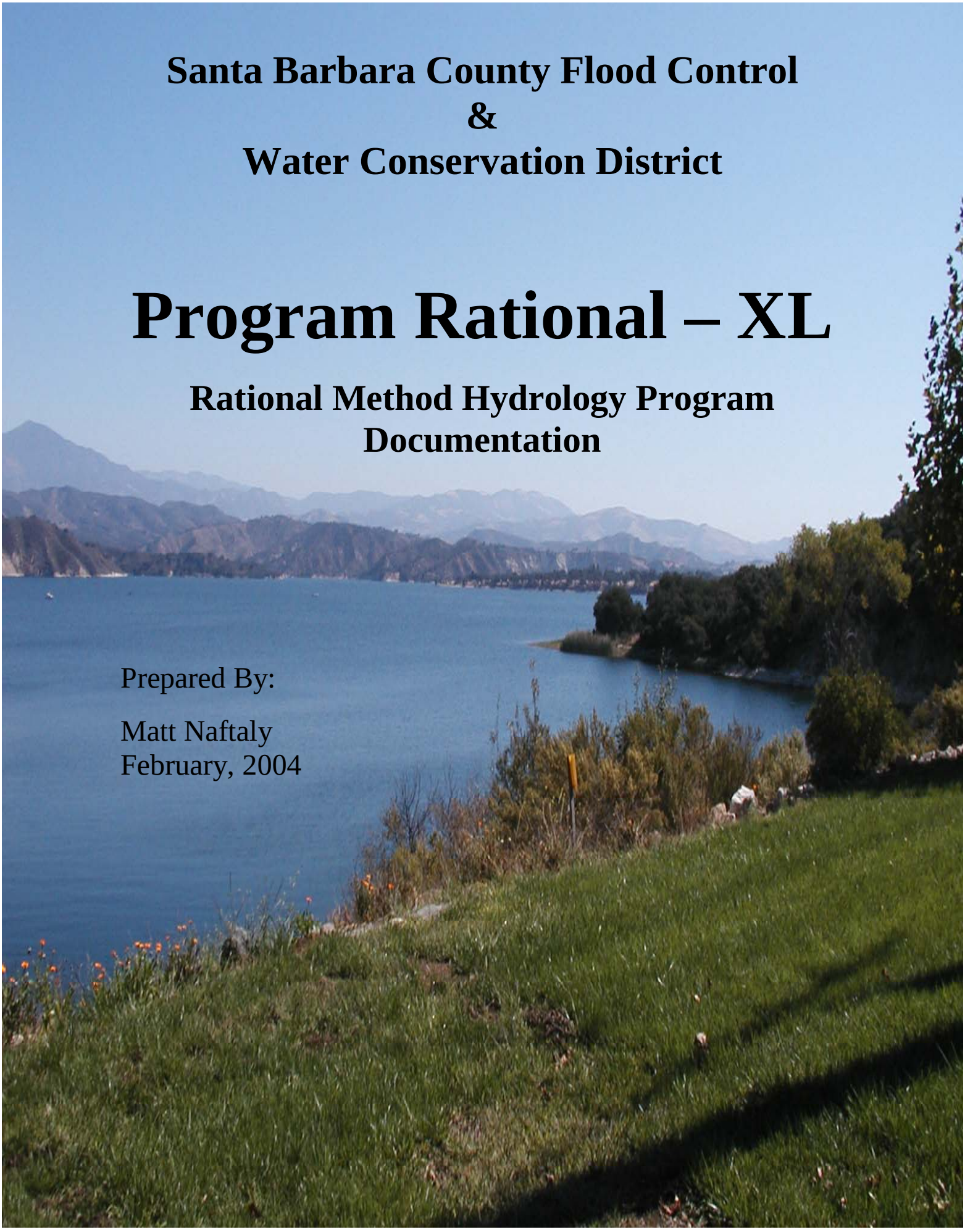

Santa Barbara County Flood Control
&
Water Conservation District

Program Rational – XL

Rational Method Hydrology Program Documentation

Prepared By:

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February, 2004

INTRODUCTION

The Rational Method is widely used for estimation of runoff from small watersheds. It provides determination of peak discharge and has particular application in the design of drainage improvements. The Santa Barbara County Flood Control District developed Rainfall Intensity and Runoff Coefficient curves in the mid 1960's in order to customize the Rational Method for local conditions. Since then, the District has used the customized method to determine peak discharges for certain applications.

In the late 1980's, the District developed Program Rational, a computer program written in Basic code to automate the Rational Method including the customized curves. Program Rational – XL, the version documented herein, modifies that program to run in Excel and is coded in Visual Basic for Applications. In addition, Program Rational – XL incorporates rainfall intensity data collected since the development of the original curves and divides the County into additional, more specific areas for calculation.

Note that Program Rational – XL is not valid for use in watersheds outside of Santa Barbara County.

THE RATIONAL METHOD

The Rational method is based on the equation:

$$\mathbf{Q = C*i*A}$$

Q is the peak discharge for a given rainfall intensity in cubic feet per second (cfs). **C** is the runoff coefficient, a dimensionless factor between 0 and 1. **i** is the rainfall intensity in inches per hour, and **A** is the watershed area in acres.

The Rational Method assumes that rainfall intensity is uniform over the watershed and that it continues for the time of concentration of the watershed. The time of concentration is the time required for rain falling on the most remote part of the basin to reach the basin outlet. A constant rainfall intensity continuing for the time of concentration results in simultaneous runoff from every part of the watershed.

Of particular importance to the Rational Method is estimation of the Runoff Coefficient (**C**). **C** is defined as the ratio of runoff to rainfall. It indirectly accounts for infiltration and other losses and may be affected by several factors including soil type, vegetation and impervious area. It is essential for the analyst to exercise sound engineering judgment in selecting runoff coefficients for specific applications. Runoff Coefficient curves for Santa Barbara County have been developed and are viewable within the program (See Appendix B: Runoff Coefficient Curves).

Program Rational – XL requires as input the time of concentration, which is used to determine the critical rainfall intensity for a given return period (Appendix A: Rainfall Intensity Curves). Several methods of empirical formulae as well as direct measurement are used for the determination of the time of concentration for urban and rural drainages.

USING PROGRAM RATIONAL - XL

Program Rational – XL incorporates macros and VBA scripting. Therefore, to run the program it is necessary for the Excel security level to be either medium or low. To set Excel security, open Excel and click **Tools** on the menu bar. Select **Macro** from the drop down menu, then select **Security**. Check the box for either medium or low (medium is recommended as it provides greater protection).

Run Program Rational – XL and select the **Enable Macros** button. The introductory screen provides information regarding the program. Click the **Continue** button. The form presented is used both for inputting data and displaying results (Figure 1). The screen is divided into four sections entitled **User Data, Input Data, For Large Lot Subdivisions, and Results**.

The project name and other project-specific information may be entered in the **User Data** section. In the section entitled **Input Data**, select the project location from the drop-down menu. The available areas have been expanded to include Buellton – Santa Ynez, Lompoc, Los Alamos, Santa Maria - Orcutt, Sisquoc, and the South Coast (Appendix A: Rainfall Intensity Curves). Enter the project area and time of concentration in the appropriate spaces. Note that the program is designed for times of concentration that are between 11 and 151 minutes. Times entered that are not within this range will produce an error message. Select land use types from the drop-down menu. The options for land use are Commercial, Single Family Residence (<10,000 square feet lot size), Agriculture, Condominium – Apartments, and Large Lot Subdivisions (>10,000 square feet lot size).

With the exception of Large Lot Subdivision (see below), pressing the **Calculate** button will fill the boxes in the **Results** Section. The rainfall intensity, runoff coefficient and design discharges are displayed for 10, 25, 50 and 100 year frequencies. In some cases, the user may want to use a runoff coefficient other than that produced by the curves included in the program. Entering values in the **Input Data** section next to "User Selected Runoff Coefficient (Optional)," causes the program to use the user-selected values, which also appear in the **Results** Section. The boxes entitled "Calculated Runoff Coefficient" display the coefficient values based on the program curves for comparison to the user selected values.

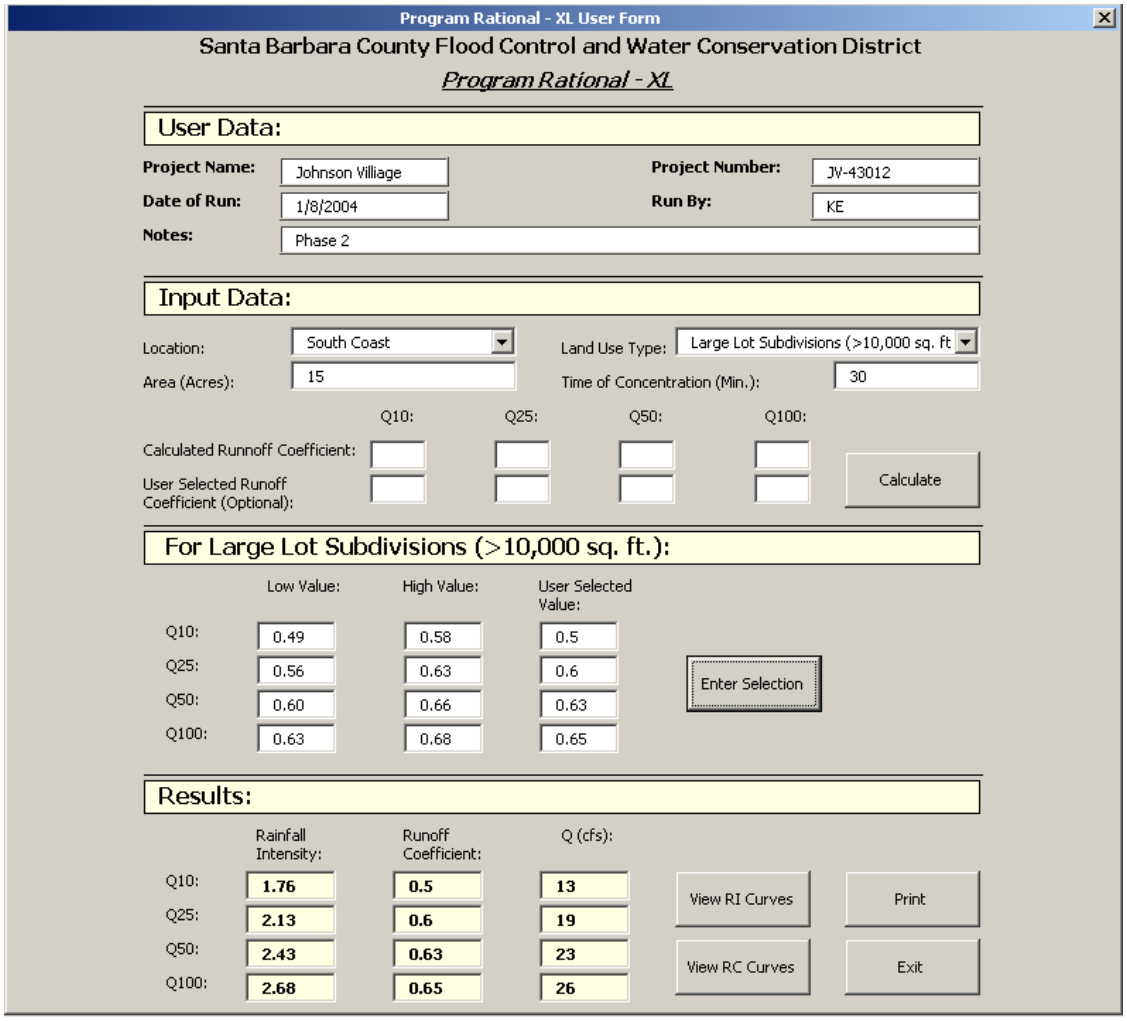


Figure 1: User Form

If Large Lot Subdivisions is selected for land use type in the **Input Data** Section, the user will be prompted to interpolate between runoff coefficient values for single-family lots and agriculture. After pressing the **Calculate** button, these values will be displayed in the **Large Lot Subdivisions** section. The value input by the user should be based on the character of the proposed development. Inputting a value outside of the range provided by the program produces an error message. After inputting the appropriate values press the **Enter Selection** button. This will cause the results and selected runoff coefficients to be displayed (Figure 1).

There are four additional buttons in the **Results** section. The **Print** button causes the form to be printed including input data and results. The **View RI Curves** and **View RC Curves** buttons display graphs of some of the Rainfall Intensity and Runoff Coefficient curves used by the program. To return to the form from the graphs, press the **Return** button at the top. For further discussion of these curves, see Appendices A and B. The **Exit** button closes Program Rational – XL.

APPENDIX A:

RAINFALL INTENSITY - DURATION CURVES

Rainfall Intensity/Duration Curve Development

The original Rainfall Intensity-Duration curves for Santa Barbara County were produced in 1964 based on data from The California Division of Highway's, "California Culvert Practice Manual", October 1960 and The United States Weather Bureau's, "Rainfall Intensities for Local Drainage Design in the Western United States for Durations of 20 Minutes to 24 hours and 1 to 100 Year Return Periods," Technical Paper No. 28, 1956. At the time that the curves were produced, rainfall intensity data was limited both by the number of gages available and by the years of record available from each gage. Therefore, both publications employed statistical methods to extrapolate data to time periods sufficient for the development of rainfall intensity curves. For similar reasons, curves were developed for only three areas of the County and some curves combined areas of significant lateral and vertical separation.

With the addition of many recording rainfall gages and access to an additional 40 years of data, it is now possible to further divide the areas for which data is available and to develop curves based on actual intensity with less statistical extrapolation. In developing Program Rational - XL, gages having significant lengths of record were selected for areas of interest. Depth/duration data from these gages was used to produce intensity/duration curves for 10, 25, 50 and 100 year frequencies. Equations approximating the curves were developed for use in the program.

Details regarding each gage and the development of the equations used in the program are contained on the following pages along with graphical representation of the actual and synthetic curves. Note that the Stanwood Fire Station gage (#228) was selected as a suitable approximation of the varying elevations and microclimates along the south coast of Santa Barbara County.

Curve Construction for Buelton/Santa Ynez

SBCFCD August, 2003

Area:	Buellton/Santa Ynez
Gage #:	233
Elevation:	360 ft.
Years of Record:	37

Depth/Duration

Duration (Mins.):	15	30	45	60	75	90	105	120	135	150	165	180
Frequency (yrs):												
10	0.54	0.76	0.964741	1.13	1.275	1.431	1.575	1.68	1.786864	1.900526	2.021418	2.15
25	0.66	0.92	1.155289	1.37	1.525	1.698	1.846727	2.04	2.167534	2.303041	2.44702	2.6
50	0.74	1.04	1.301575	1.54	1.76	1.95	2.1385	2.29	2.433449	2.585885	2.747869	2.92
100	0.82	1.15	1.445611	1.71	1.9225	2.124	2.33625	2.54	2.699365	2.868728	3.048718	3.24

Intensity/Duration

Duration (Mins.):	15	30	45	60	75	90	105	120	135	150	165	180
Frequency (yrs):												
10	2.16	1.52	1.286	1.13	1.02	0.954	0.9	0.84	0.794162	0.76021	0.735061	0.716667
25	2.64	1.84	1.54	1.37	1.22	1.132	1.055273	1.02	0.963349	0.921217	0.889826	0.866667
50	2.96	2.08	1.735	1.54	1.408	1.3	1.222	1.145	1.081533	1.034354	0.999225	0.973333
100	3.28	2.3	1.927	1.71	1.538	1.416	1.335	1.27	1.199718	1.147491	1.108625	1.08

Synthetic Curve Values:

Duration (Mins.):	15	30	45	60	75	90	105	120	135	150	165	180
Frequency (yrs):												
10	2.126267	1.567345	1.311247	1.155344	1.0473	0.966566	0.903181	0.851644	0.808632	0.772001	0.740295	0.712489
25	2.590465	1.887153	1.567954	1.37479	1.241505	1.142254	1.064555	1.001534	0.94905	0.904436	0.865887	0.832131
50	2.916611	2.127697	1.769246	1.552177	1.40232	1.290683	1.203258	1.132329	1.073243	1.023007	0.979591	0.941567
100	3.230794	2.34972	1.950382	1.708925	1.542419	1.418491	1.321512	1.242882	1.177417	1.121784	1.073726	1.031652

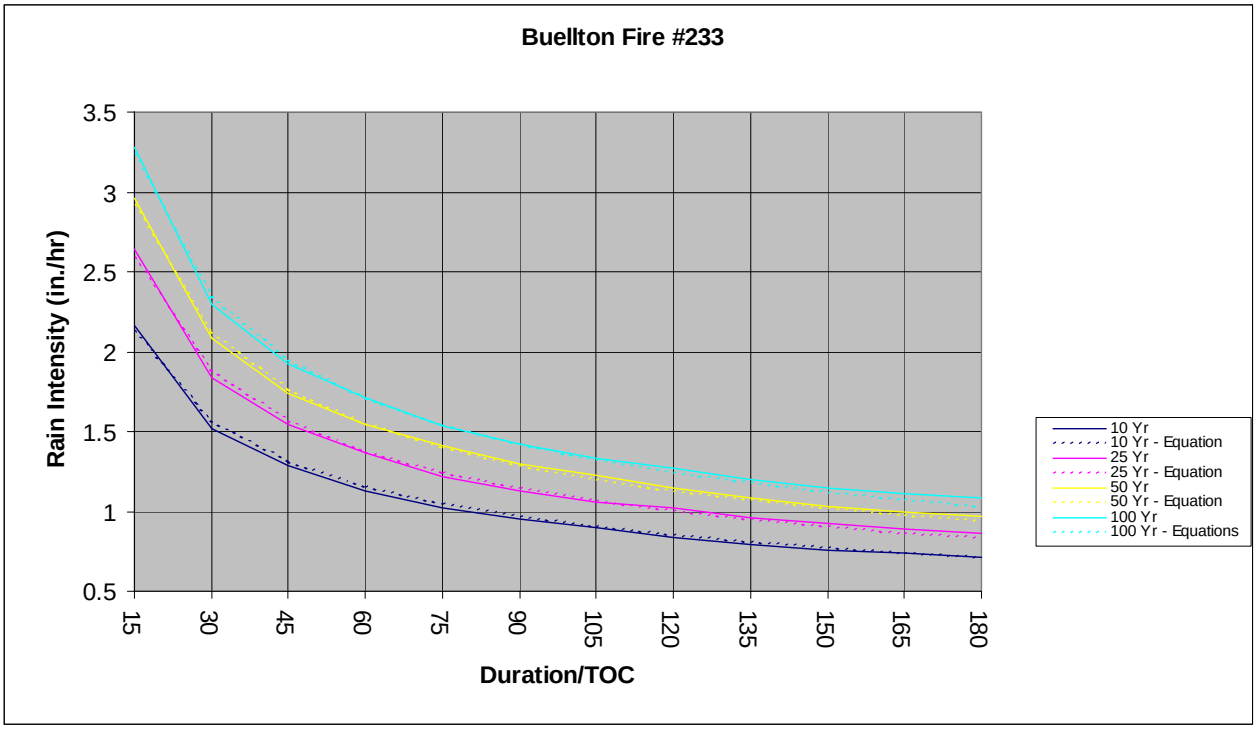
Curve Equations:

Frequency (yrs):		
10	RI = 7*(TOC)^-0.44	RI = Rainfall Intensity
25	RI = 8.93*(TOC)^-0.457	TOC = Time of Concentration/Storm Duration
50	RI = 10*(TOC)^-0.455	
100	RI = 11.21*(TOC)^-0.4594	

Variation (in.):

Duration (Mins.):	15	30	45	60	75	90	105	120	135	150	165	180
Frequency (yrs):												
10	-0.03373	0.047345	0.025247	0.025344	0.0273	0.012566	0.003181	0.011644	0.014471	0.011791	0.005234	-0.00418
25	-0.04953	0.047153	0.027954	0.00479	0.021505	0.010254	0.009282	-0.01847	-0.0143	-0.01678	-0.02394	-0.03454
50	-0.04339	0.047697	0.034246	0.012177	-0.00568	-0.00932	-0.01874	-0.01267	-0.00829	-0.01135	-0.01963	-0.03177
100	-0.04921	0.04972	0.023382	-0.00108	0.004419	0.002491	-0.01349	-0.02712	-0.0223	-0.02571	-0.0349	-0.04835

Note: "Actual" Curves taken from Santa Barbara County Flood Control District Recording Data. Data available for 15, 30, 60, 120 and 180 minutes.
Intermediate values were determined visually and by using Excel "Series" extrapolation.



Curve Construction for Lompoc

SBCFCD August, 2003

Area:	Lompoc
Gage #:	258
Elevation:	105
Years of Record:	41

Depth/Duration

Duration (Mins.):	15	30	45	60	75	90	105	120	135	150	165	180
Frequency (yrs):												
10	0.48	0.7	0.861965	0.99	1.125	1.257	1.372	1.5	1.593407	1.692631	1.798034	1.91
25	0.58	0.85	1.03901	1.2	1.35125	1.5	1.6555	1.81	1.923809	2.044774	2.173345	2.31
50	0.65	0.96	1.16054	1.35	1.52	1.692	1.869	2.04	2.169615	2.307466	2.454076	2.61
100	0.72	1.06	1.297824	1.5	1.6975	1.875	2.0685	2.26	2.4165	2.5675	2.717694	2.89

Intensity/Duration

Duration (Mins.):	15	30	45	60	75	90	105	120	135	150	165	180
Frequency (yrs):												
10	1.92	1.4	1.149	0.99	0.9	0.838	0.784	0.75	0.708181	0.677052	0.65383	0.636667
25	2.32	1.7	1.385	1.2	1.081	1	0.946	0.905	0.855026	0.81791	0.790307	0.77
50	2.6	1.92	1.547	1.35	1.216	1.128	1.068	1.02	0.964274	0.922986	0.892391	0.87
100	2.88	2.12	1.73	1.5	1.358	1.25	1.182	1.13	1.074	1.027	0.988252	0.963333

Synthetic Curve Values:

Duration (Mins.):	15	30	45	60	75	90	105	120	135	150	165	180
Frequency (yrs):												
10	1.872544	1.389918	1.167535	1.031683	0.937292	0.866617	0.811035	0.765779	0.72796	0.695716	0.66778	0.643256
25	2.272249	1.681351	1.409765	1.244116	1.129154	1.043156	0.975575	0.920584	0.874656	0.835518	0.801624	0.771883
50	2.55927	1.889143	1.581747	1.394485	1.264641	1.167578	1.091348	1.029349	0.977592	0.933504	0.895336	0.861856
100	2.84062	2.091163	1.748128	1.53944	1.394885	1.28691	1.202166	1.133281	1.075805	1.026864	0.984514	0.947377

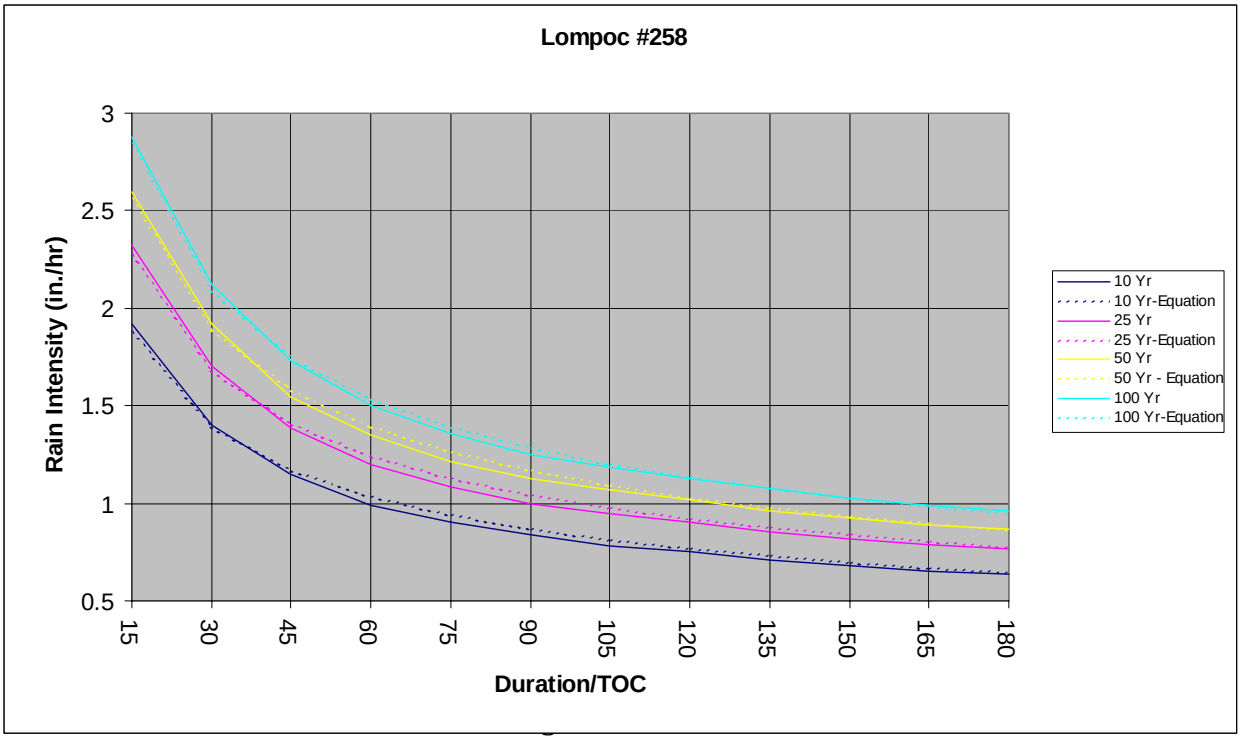
Curve Equations:

Frequency (yrs):		
10	RI = 6*(TOC)^-0.43	RI = Rainfall Intensity
25	RI = 7.37*(TOC)^-0.4345	TOC = Time of Concentration/Storm Duration
50	RI = 8.38*(TOC)^-0.438	
100	RI = 9.4*(TOC)^-0.4419	

Variation (in.):

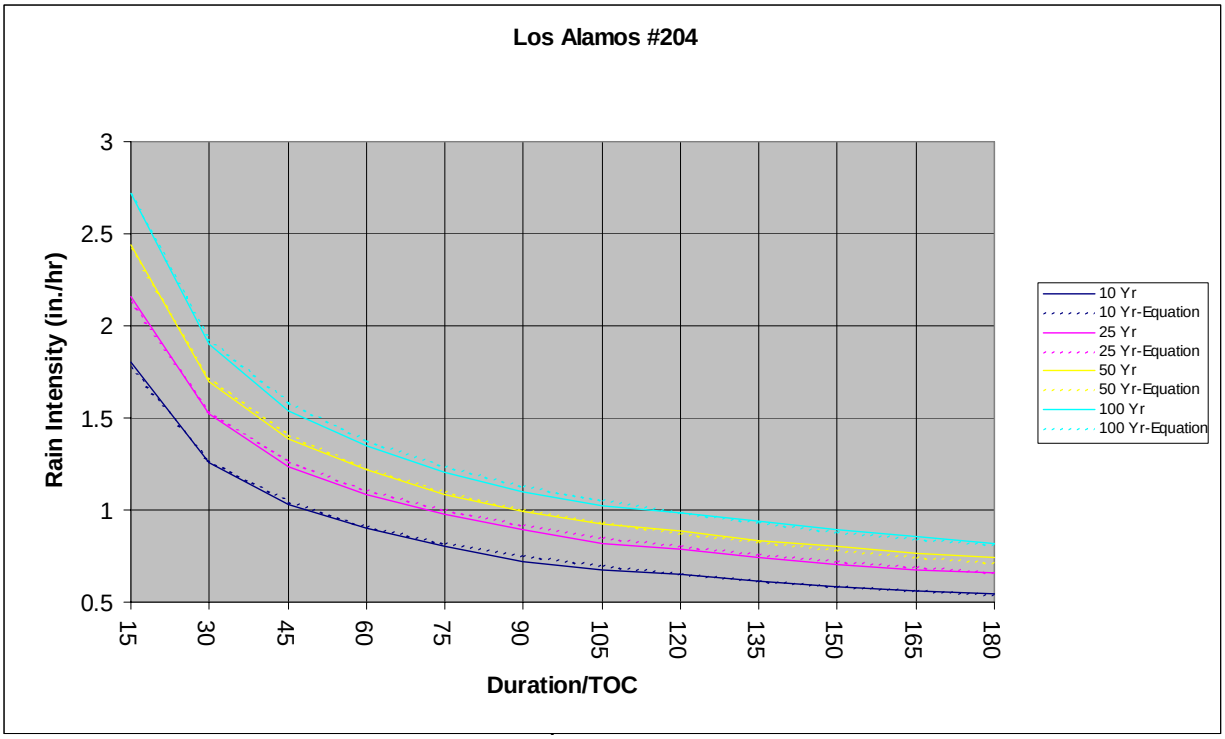
Duration (Mins.):	15	30	45	60	75	90	105	120	135	150	165	180
Frequency (yrs):												
10	-0.04746	-0.01008	0.018535	0.041683	0.037292	0.028617	0.027035	0.015779	0.019779	0.018664	0.013949	0.00659
25	-0.04775	-0.01865	0.024765	0.044116	0.048154	0.043156	0.029575	0.015584	0.01963	0.017609	0.011317	0.001883
50	-0.04073	-0.03086	0.034747	0.044485	0.048641	0.039578	0.023348	0.009349	0.013319	0.010517	0.002945	-0.00814
100	-0.03938	-0.02884	0.018128	0.03944	0.036885	0.03691	0.020166	0.003281	0.001805	-0.00014	-0.00374	-0.01596

Note: "Actual" Curves taken from Santa Barbara County Flood Control District Recording Data. Data available for 15, 30, 60, 120 and 180 minutes.
Intermediate values were determined visually and by using Excel "Series" extrapolation.



Curve Construction for Los Alamos												
SBCFCD	August, 2003											
Area:	Los Alamos											
Gage #:	204											
Elevation:	580											
Years of Record:	37											
Depth/Duration												
Duration (Mins.):	15	30	45	60	75	90	105	120	135	150	165	180
Frequency (yrs):												
10	0.45	0.63	0.774194	0.9	1	1.081665	1.185818	1.3	1.375639	1.455679	1.540375	1.63
25	0.54	0.76	0.926482	1.08	1.2225	1.3365	1.436643	1.58	1.669588	1.764256	1.864292	1.97
50	0.61	0.85	1.037509	1.22	1.35	1.488	1.612761	1.77	1.88325	2.002094	2.097771	2.22
100	0.68	0.95	1.153788	1.35	1.51	1.65	1.792392	1.97	2.1105	2.2275	2.35675	2.46
Intensity/Duration												
Duration (Mins.):	15	30	45	60	75	90	105	120	135	150	165	180
Frequency (yrs):												
10	1.8	1.26	1.032	0.9	0.8	0.72111	0.67761	0.65	0.611395	0.582271	0.560136	0.543333
25	2.16	1.52	1.235	1.08	0.978	0.891	0.820939	0.79	0.742039	0.705702	0.677924	0.656667
50	2.44	1.7	1.383	1.22	1.08	0.992	0.921577	0.885	0.837	0.800838	0.762826	0.74
100	2.72	1.9	1.538	1.35	1.208	1.1	1.024224	0.985	0.938	0.891	0.857	0.82
Synthetic Curve Values:												
Duration (Mins.):	15	30	45	60	75	90	105	120	135	150	165	180
Frequency (yrs):												
10	1.771697	1.270267	1.045614	0.910753	0.818246	0.749682	0.696214	0.65299	0.617097	0.586664	0.56043	0.537505
25	2.125587	1.534599	1.268329	1.107926	0.997615	0.915689	0.851692	0.799883	0.756807	0.720243	0.688691	0.661095
50	2.414108	1.718905	1.409183	1.223904	1.097138	1.003373	0.930376	0.87145	0.822579	0.78119	0.745546	0.714427
100	2.71095	1.933612	1.58681	1.379168	1.237011	1.131808	1.049872	0.983706	0.928813	0.882311	0.842253	0.807273
Curve Equations:												
Frequency (yrs):												
10		RI = 6.5*(TOC)^-0.48				RI = Rainfall Intensity						
25		RI = 7.59*(TOC)^-0.47				TOC = Time of Concentration/Storm Duration						
50		RI = 9.1*(TOC)^-0.49										
100		RI = 10.15*(TOC)^-0.4875										
Variation (in.):												
Duration (Mins.):	15	30	45	60	75	90	105	120	135	150	165	180
Frequency (yrs):												
10	-0.0283	0.010267	0.013614	0.010753	0.018246	0.028572	0.018603	0.00299	0.005702	0.004393	0.000293	-0.00583
25	-0.03441	0.014599	0.033329	0.027926	0.019615	0.024689	0.030754	0.009883	0.014767	0.01454	0.010766	0.004428
50	-0.02589	0.018905	0.026183	0.003904	0.017138	0.011373	0.008799	-0.01355	-0.01442	-0.01965	-0.01728	-0.02557
100	-0.00905	0.033612	0.04881	0.029168	0.029011	0.031808	0.025648	-0.00129	-0.00919	-0.00869	-0.01475	-0.01273

Note: "Actual" Curves taken from Santa Barbara County Flood Control District Recording Data. Data available for 15, 30, 60, 120 and 180 minutes.
Intermediate values were determined visually and by using Excel "Series" extrapolation.



Curve Construction for Sisquoc

SBCFCD August, 2003

Area:	Sisquoc
Gage #:	256
Elevation:	420
Years of Record:	33

Depth/Duration (mins)

Duration (mins.):	15	30	45	60	75	90	105	120	135	150	165	180
Frequency (yrs):												
10	0.43	0.61	0.750188	0.88	0.98625	1.086	1.19875	1.28	1.338383	1.399428	1.463259	1.53
25	0.51	0.74	0.908477	1.07	1.18875	1.311	1.4385	1.55	1.6201	1.693369	1.769953	1.85
50	0.58	0.83	1.015754	1.2	1.335	1.476	1.60825	1.74	1.819398	1.90242	1.989229	2.08
100	0.64	0.92	1.125281	1.33	1.48125	1.632	1.79025	1.93	2.018696	2.111469	2.208505	2.31

Intensity/Duration

Duration (mins.):	15	30	45	60	75	90	105	120	135	150	165	180
Frequency (yrs):												
10	1.72	1.22	1	0.88	0.789	0.724	0.685	0.64	0.594837	0.559771	0.532094	0.51
25	2.04	1.48	1.211	1.07	0.951	0.874	0.822	0.775	0.720044	0.677348	0.643619	0.616667
50	2.32	1.66	1.354	1.2	1.068	0.984	0.919	0.87	0.808621	0.760968	0.723356	0.693333
100	2.56	1.84	1.5	1.33	1.185	1.088	1.023	0.965	0.897198	0.844587	0.803093	0.77

Synthetic Curve Values:

Duration (mins.):	15	30	45	60	75	90	105	120	135	150	165	180
Frequency (yrs):												
10	1.711732	1.227274	1.010224	0.87992781	0.790552	0.724308	0.672649	0.630889	0.59621	0.566808	0.541461	0.519313
25	2.027831	1.460981	1.206017	1.052585344	0.94715	0.868893	0.807793	0.758351	0.717257	0.682388	0.652308	0.626007
50	2.311384	1.65721	1.364124	1.188182775	1.067496	0.978046	0.908291	0.8519	0.805074	0.765371	0.731145	0.701237
100	2.555429	1.833456	1.509812	1.315458531	1.182108	1.083252	1.006148	0.943808	0.892035	0.848133	0.810283	0.777206

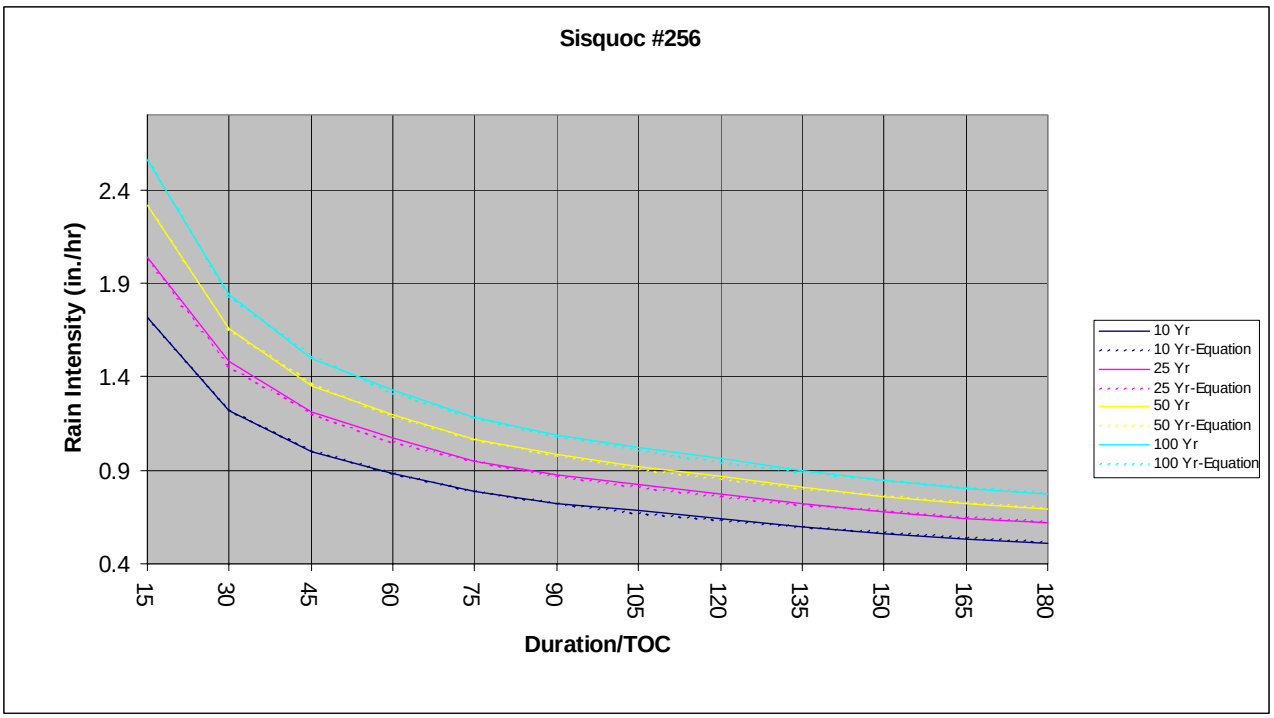
Curve Equations:

Frequency (yrs):		
10	RI = 6.28*(TOC)^-0.48	RI = Rainfall Intensity
25	RI = 7.3*(TOC)^-0.473	TOC = Time of Concentration/Storm Duration
50	RI = 8.48*(TOC)^-0.48	
100	RI = 9.35*(TOC)^-0.479	

Variation (in.):

Duration (mins.):	15	30	45	60	75	90	105	120	135	150	165	180
Frequency (yrs):												
10	-0.008268	0.007274	0.010224	-7.21904E-05	0.001552	0.000308	-0.012351	-0.009111	0.001373	0.007036	0.009367	0.009313
25	-0.012169	-0.019019	-0.004983	-0.017414656	-0.00385	-0.005107	-0.014207	-0.016649	-0.002787	0.005041	0.008689	0.00934
50	-0.008616	-0.00279	0.010124	-0.011817225	-0.000504	-0.005954	-0.010709	-0.0181	-0.003548	0.004403	0.007789	0.007904
100	-0.004571	-0.006544	0.009812	-0.014541469	-0.002892	-0.004748	-0.016852	-0.021192	-0.005164	0.003545	0.007191	0.007206

Note: "Actual" Curves taken from Santa Barbara County Flood Control District Recording Data. Data available for 15, 30, 60, 120 and 180 minutes.
Intermediate values were determined visually and by using Excel "Series" extrapolation.



Curve Construction for South Coast

SBCFCD August, 2003

Area:	South Coast
Gage #:	228
Elevation:	700
Years of Record:	45

Note: Stanwood Fire Sation used as an approximation of the average curve for all of the South Coast Gages (See Documentation).

Depth/Duration (mins)

Duration (mins.):	15	30	45	60	75	90	105	120	135	150	165	180
Frequency (yrs):												
10	0.6	0.9	1.081665	1.3	1.4525	1.602	1.736	1.89	2.000016	2.116436	2.239632	2.37
25	0.73	1.09	1.308167	1.57	1.75	1.9275	2.083778	2.29	2.422965	2.56365	2.712503	2.87
50	0.82	1.23	1.489122	1.77	1.985	2.169	2.348054	2.58	2.731184	2.891228	3.06065	3.24
100	0.91	1.36	1.645161	1.96	2.18625	2.4105	2.61275	2.86	3.027249	3.204278	3.39166	3.59

Intensity/Duration

Duration (mins.):	15	30	45	60	75	90	105	120	135	150	165	180
Frequency (yrs):												
10	2.4	1.8	1.44186	1.3	1.162	1.068	0.992	0.945	0.888896	0.846574	0.814412	0.79
25	2.92	2.18	1.743786	1.57	1.4	1.285	1.19073	1.145	1.076873	1.02546	0.986365	0.956667
50	3.28	2.46	1.985	1.77	1.588	1.446	1.341745	1.29	1.21386	1.156491	1.112964	1.08
100	3.64	2.72	2.193	1.96	1.749	1.607	1.493	1.43	1.345444	1.281711	1.233331	1.196667

Synthetic Curve Values:

Duration (mins.):	15	30	45	60	75	90	105	120	135	150	165	180
Frequency (yrs):												
10	2.371889	1.760563	1.478878	1.306798	1.187237	1.097714	1.027312	0.969986	0.922083	0.88124	0.845854	0.814791
25	2.88637	2.133551	1.787834	1.577081	1.430873	1.321533	1.235632	1.165748	1.107394	1.057675	1.014623	0.976853
50	3.324936	2.425575	2.016941	1.769482	1.598645	1.471379	1.371714	1.290855	1.223497	1.166228	1.116734	1.073386
100	3.646054	2.676478	2.233711	1.964737	1.778617	1.639712	1.530768	1.442265	1.368456	1.305639	1.251302	1.203672

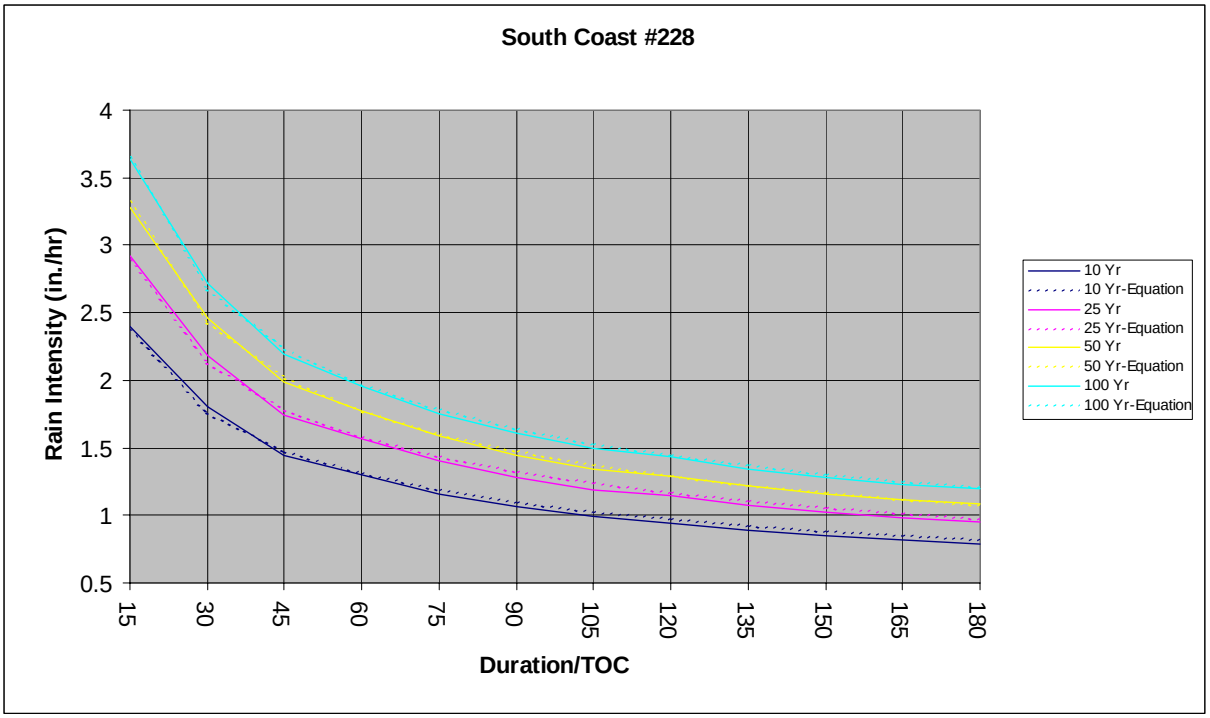
Curve Equations:

Frequency (yrs):		
10	RI = 7.6*(TOC)^-0.43	RI = Rainfall Intensity
25	RI = 9.4*(TOC)^-0.436	TOC = Time of Concentration/Storm Duration
50	RI = 11.4*(TOC)^-0.455	
100	RI = 12.2*(TOC)^-0.446	

Variation (in.):

Duration (mins.):	15	30	45	60	75	90	105	120	135	150	165	180
Frequency (yrs):	-0.02811	-0.03944	0.037018	0.006798	0.025237	0.029714	0.035312	0.024986	0.033187	0.034666	0.031442	0.024791
25	-0.03363	-0.04645	0.044048	0.007081	0.030873	0.036533	0.044902	0.020748	0.030521	0.032215	0.028258	0.020186
50	0.044936	-0.03443	0.031941	-0.00052	0.010645	0.025379	0.029969	0.000855	0.009637	0.009736	0.00377	-0.00661
100	0.006054	-0.04352	0.040711	0.004737	0.029617	0.032712	0.037768	0.012265	0.023012	0.023928	0.017971	0.007006

Note: "Actual" Curves taken from Santa Barbara County Flood Control District Recording Data. Data available for 15, 30, 60, 120 and 180 minutes.
Intermediate values were determined visually and by using Excel "Series" extrapolation.



Curve Construction for Santa Maria/Orcutt

SBCFCD August, 2003

Area:	Santa Maria/Orcutt
Gage #:	198
Elevation:	280
Years of Record:	36

Depth/Duration

Duration (mins.):	15	30	45	60	75	90	105	120	135	150	165	180
Frequency (yrs):												
10	0.46	0.7	0.888222	1.02	1.098071	1.182117	1.272596	1.37	1.430828	1.494356	1.560705	1.63
25	0.56	0.85	1.050263	1.23	1.325732	1.428916	1.54013	1.66	1.732597	1.808369	1.887455	1.97
50	0.63	0.95	1.180795	1.39	1.496999	1.612234	1.736341	1.87	1.951953	2.037498	2.126793	2.22
100	0.7	1.06	1.31808	1.54	1.68875	1.824	1.94775	2.07	2.161282	2.25659	2.356101	2.46

Intensity/Duration

Duration (mins.):	15	30	45	60	75	90	105	120	135	150	165	180
Frequency (yrs):												
10	1.84	1.4	1.184	1.02	0.878456	0.788078	0.727198	0.685	0.635923	0.597742	0.567529	0.543333
25	2.24	1.7	1.4	1.23	1.060586	0.95261	0.880074	0.83	0.770043	0.723348	0.686347	0.656667
50	2.52	1.9	1.574	1.39	1.197599	1.074823	0.992195	0.935	0.867535	0.814999	0.773379	0.74
100	2.8	2.12	1.757	1.54	1.351	1.216	1.113	1.035	0.96057	0.902636	0.856764	0.82

Synthetic Curve Values:

Duration (mins.):	15	30	45	60	75	90	105	120	135	150	165	180
Frequency (yrs):												
10	1.824271	1.438487	1.173458	0.995745	0.877492	0.796432	0.735885	0.684757	0.637542	0.594319	0.560756	0.548108
25	2.223228	1.734754	1.40668	1.192762	1.054701	0.962145	0.892688	0.831867	0.773168	0.71802	0.675799	0.663826
50	2.49738	1.947586	1.580459	1.342494	1.189525	1.086724	1.008598	0.938993	0.871089	0.807406	0.7598	0.749463
100	2.776669	2.167401	1.763228	1.502496	1.334611	1.220046	1.130333	1.048071	0.966917	0.891596	0.837891	0.832653

Curve Equations:

RI = Rainfall Intensity; TOC = Time of Concentration/Storm Duration

Frequency (yrs):	
10	RI = 2.36984-0.0426578*(TOC)+0.000453186*(TOC)^2-2.34116*10^-6*(TOC)^3+4.59828*10^-9*(TOC)^4
25	RI = 2.92629-0.0553604*(TOC)+0.00061347*(TOC)^2-3.26458*10^-6*(TOC)^3+6.5396*10^-9*(TOC)^4
50	RI = 3.29268-0.0627556*(TOC)+0.000704234*(TOC)^2-3.79485*10^-6*(TOC)^3+7.68478*10^-9*(TOC)^4
100	RI = 3.66375-0.0701995*(TOC)+0.000801493*(TOC)^2-4.41048*10^-6*(TOC)^3+9.10528*10^-9*(TOC)^4

Variation (in.):

Duration (mins.):	15	30	45	60	75	90	105	120	135	150	165	180
Frequency (yrs):												
10	-0.01573	0.038487	-0.01054	-0.02426	-0.00096	0.008354	0.008688	-0.00024	0.001618	-0.00342	-0.00677	0.004774
25	-0.01677	0.034754	0.00668	-0.03724	-0.00588	0.009535	0.012614	0.001867	0.003125	-0.00533	-0.01055	0.007159
50	-0.02262	0.047586	0.006459	-0.04751	-0.00807	0.011901	0.016404	0.003993	0.003554	-0.00759	-0.01358	0.009463
100	-0.02333	0.047401	0.006228	-0.0375	-0.01639	0.004046	0.017333	0.013071	0.006347	-0.01104	-0.01887	0.012653

Note: "Actual" Curves taken from Santa Barbara County Flood Control District Recording Data. Data available for 15, 30, 60, 120 and 180 minutes.
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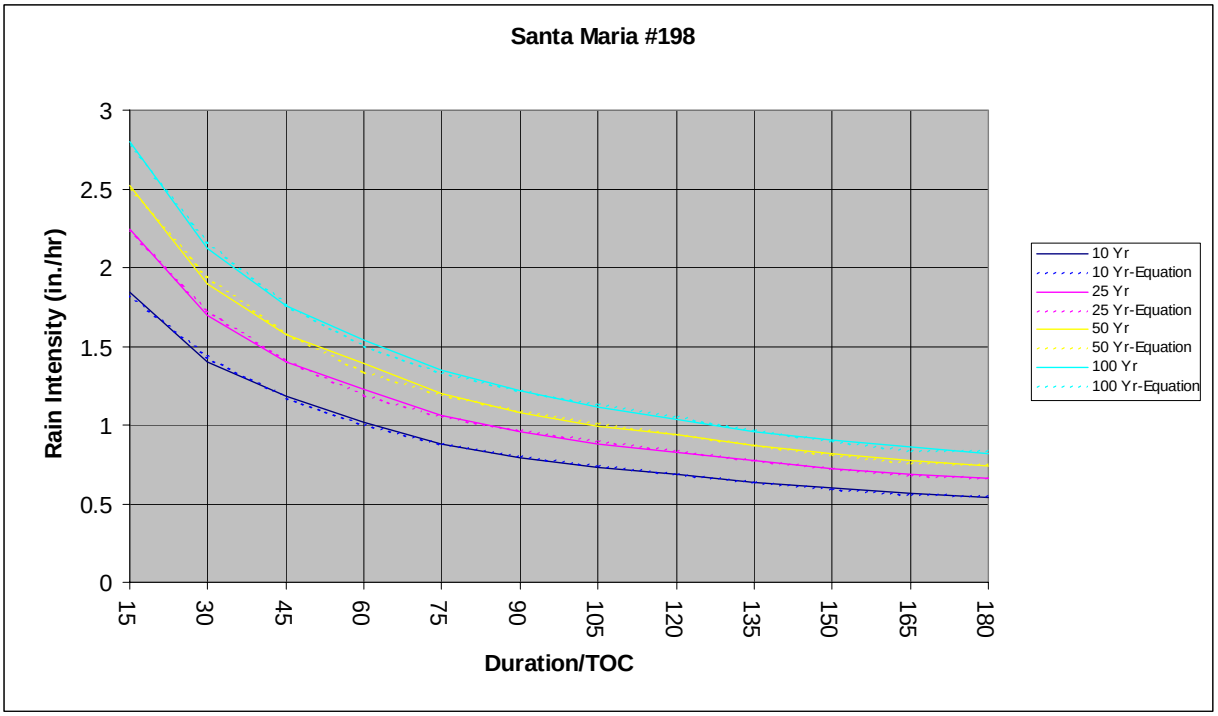


APPENDIX B:

RUNOFF COEFFICIENT – RAINFALL INTENSITY CURVES

Runoff Coefficient/Rainfall Intensity Curve Use

The Rational Method uses a runoff coefficient to account for rainfall losses. The runoff coefficient may be affected by various watershed characteristics including vegetation and soil types. Similarly, the type of land use will affect the runoff coefficient. Curves relating runoff coefficient to rainfall intensity were developed for Santa Barbara County in 1962. These curves are based on the location and type of the land use. For example, a single curve is used for commercial development in both North and South County because commercial developments are comprised primarily of impervious pavement. However, North and South County agriculture utilize two different curves due to factors that vary by region such as soils and crop types. Because both the character of the watersheds and the general nature of land use within the county have remained relatively consistent, the 1962 curves were used without alteration in Program Rational – XL.

Program Rational – XL includes Los Alamos and Sisquoc areas, neither of which was included in the original Rational Method computations[1]. Therefore, it was necessary to determine if the existing curves are applicable to these areas. Because they are related to watershed characteristics, runoff coefficients are sometimes determined based on US Department of Agriculture, Soil Conservation Service soil survey data. Such data includes information on topography, soil type, drainage, and percolation characteristics.

"Soil Survey of Northern Santa Barbara Area, California", July 1972 was used to determine if the Los Alamos and Sisquoc areas are suitable for use with existing north county runoff coefficient curves. The report indicates that many of the same general soil types having identical characteristics exist in the Los Alamos, Sisquoc, Santa Ynez and Santa Maria areas. Therefore, the existing curves were used for Los Alamos and Sisquoc in Program Rational –XL.

Equations approximating the runoff coefficient curves were developed for use in Program Rational –XL. Details regarding the development of these equations are contained on the following pages along with graphical representation of the actual and synthetic curves.

(1) Buellton is also new but was included implicitly in the original curves by the designation "Lompoc/Santa Ynez".

Rainfall Intensity/Runoff Coefficient Equations

SBCFCD August, 2003

Curve #1 - Commercial

Equation: C = .60*(RI)^.21

Rainfall Intensity (in/hr)	Runoff Coefficient	Synthetic Value	Variation
1	0.6	0.6	0
1.5	0.66	0.653326711	0.006673289
2	0.7	0.69401291	0.00598709
2.5	0.73	0.727308482	0.002691518
3	0.76	0.755695287	0.004304713
3.5	0.78	0.780558648	-0.000558648
4	0.8	0.802756533	-0.002756533

Curve #2 - South Coast Single Family

Equation: C = -.01643+.6228(RI)-.225(RI)^2+.04115(RI)^3-.002848(RI)^4

Rainfall Intensity (in/hr)	Runoff Coefficient	Synthetic Value	Variation
1	0.42	0.419672	0.000328
1.5	0.535	0.53598325	-0.00098325
2	0.615	0.612802	0.002198
2.5	0.665	0.66603875	-0.00103875
3	0.708	0.707332	0.000668
3.5	0.745	0.74404825	0.00095175
4	0.78	0.779282	0.000718

Curve #3 - North County Single Family, South Coast Agriculture

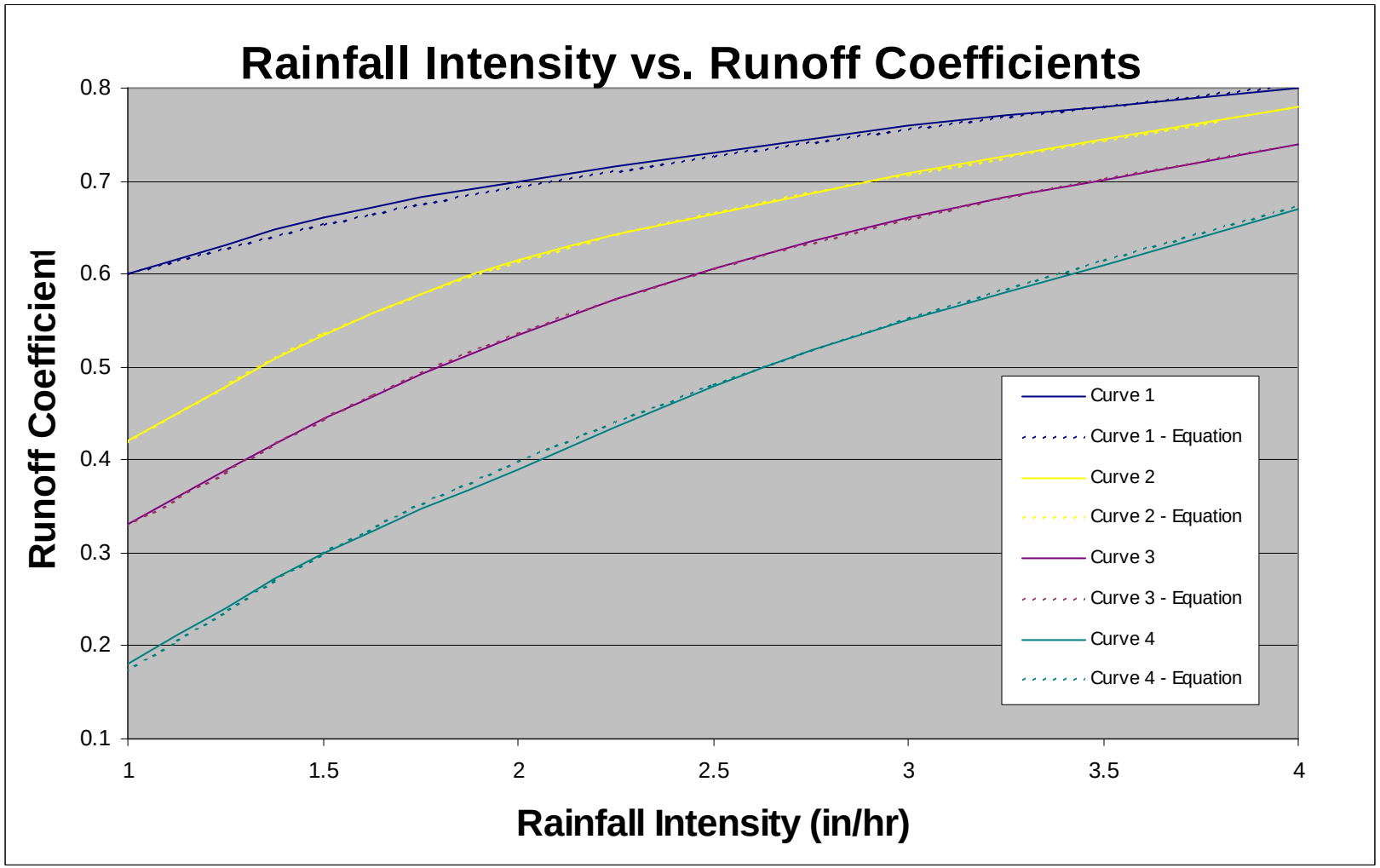
Equation: C = .004071+.3989(RI)-.07952(RI)^2+.006444(RI)^3

Rainfall Intensity (in/hr)	Runoff Coefficient	Synthetic Value	Variation
1	0.33	0.329895	0.000105
1.5	0.445	0.4452495	-0.0002495
2	0.535	0.535343	-0.000343
2.5	0.605	0.6050085	-8.5E-06
3	0.66	0.659079	0.000921
3.5	0.701	0.7023875	-0.0013875
4	0.74	0.739767	0.000233

Curve #4 - North County Agriculture

Equation: C = 1.01*(RI)^.29-.837

Rainfall Intensity (in/hr)	Runoff Coefficient	Synthetic Value	Variation
1	0.18	0.173	0.007
1.5	0.3	0.299024869	0.000975131
2	0.39	0.39786668	-0.00786668
2.5	0.48	0.480419163	-0.000419163
3	0.55	0.551949762	-0.001949762
3.5	0.61	0.615449718	-0.005449718
4	0.67	0.672797741	-0.002797741


Rainfall Intensity vs. Runoff Coefficients
Runoff Coefficient
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1
1.5
2
2.5
3
3.5
4
Rainfall Intensity (in/hr)
Curve 1
Curve 1 - Equation
Curve 2
Curve 2 - Equation
Curve 3
Curve 3 - Equation
Curve 4
Curve 4 - Equation