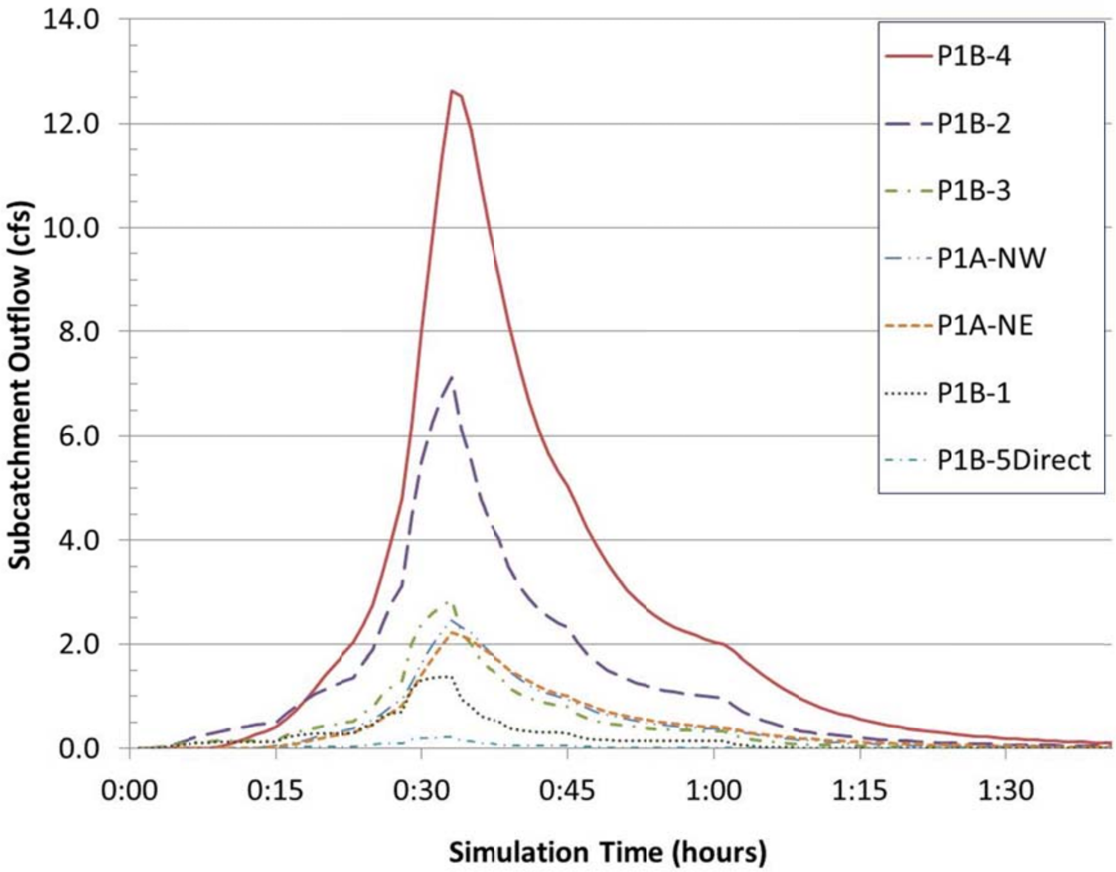

Figure 6. Baseline Outflow Hydrographs from the Commercial Site SWMM Model Subcatchments for the 100-Year Storm (No Stormwater Harvesting Modeled).

Reduction in Peak Discharge Due to Stormwater Harvesting

a) La Terraza SWMM Model Results

The modeled reduction in peak discharge for the 54 configurations of stormwater harvesting volume at the La Terraza subdivision are shown in Figure 7 (Appendix D-3). When the reduction in peak discharge is plotted versus the retention volume as a percent of the runoff volume, a similar pattern is found for all three return period storms. At each percent of volume retained, differences were found in peak discharge reduction due to the distribution of stormwater harvesting volume within the study area, and the additional six simulations for the two watershed shapes modeled in the case of the 100-yr event. The distribution of stormwater harvesting volume within the study area did not indicate a reliable trend in peak reduction in the La Terraza study results and the total retention volume was selected as the indicator of pea discharge reduction from this initial study.

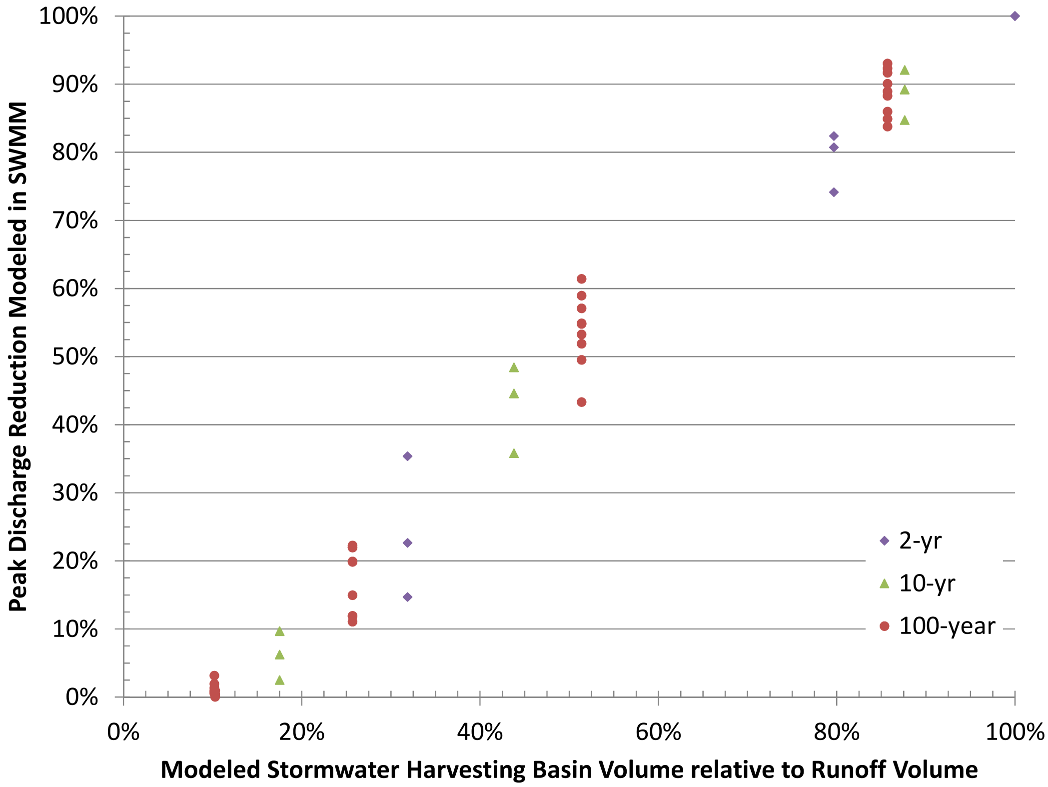

Figure 7. Modeled Reduction in Peak Discharge due to Stormwater Harvesting Volume for the La Terraza subdivision.

b) Commercial Site SWMM Model Results

The Commercial Site SWMM model results from the 36 configurations with about 99 percent of the watershed draining to some stormwater harvesting ("W_A = 99 percent") showed that the area-weighted distribution of volume among three basins ("Basin 1, Basin 2, and Basin 3 Area-Weighted") and the distribution of one large basin at the outlet ("Basin 1") reduced peak discharge the most in the model (with the area-weighted, three-basin distribution performing slightly better in all cases). The equal distribution of volume among three basins ("Basin 1, Basin 2, and Basin 3 Equal Distribution") showed less efficiency in reducing peak discharge at higher volumes of stormwater harvesting (although slightly better at lower volumes) (Figure 8, Appendix D-4).

The lower reduction in peak discharge for the equal distribution of volume is attributed to stormwater harvesting basins at the top of the watershed being oversized and not filling up with runoff during smaller storm events (i.e. the 2-year event), which results in non-utilized stormwater harvesting volume. The equal distribution of stormwater volume is considered to be a less-than-ideal design in this case, but the modeling results are used to measure the reduction in peak discharge and calibrate stormwater harvesting factors in case of a less-than-ideal design.

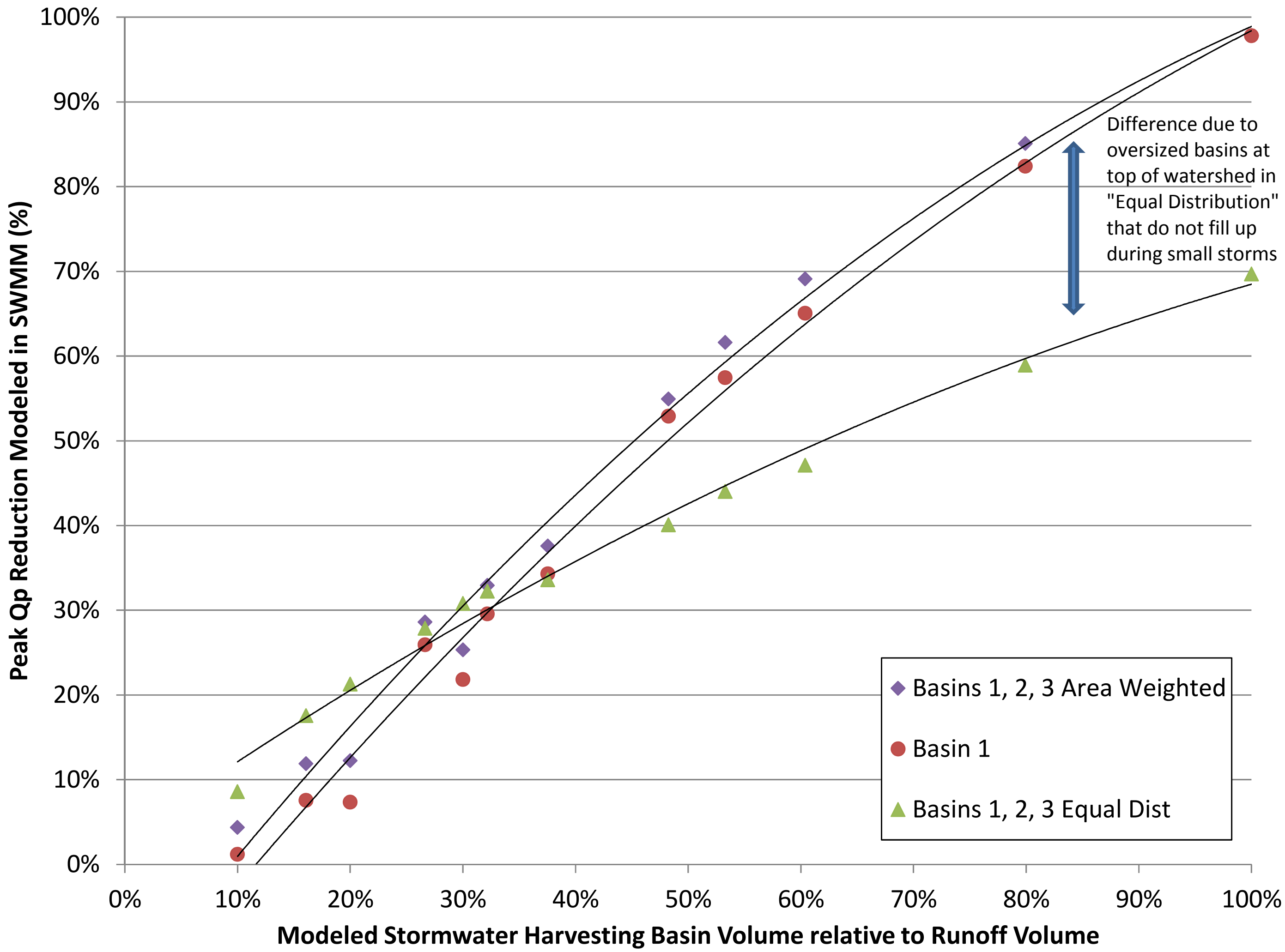

Figure 8. Modeled Reduction in Peak Discharge due to Stormwater Harvesting Volume by Distribution of Volume between Basins using the Commercial Site SWMM Model.

c) Validation Analysis of Initial Stormwater Harvesting Factors using the Commercial Site SWMM Model

The ability of an initial set of stormwater harvesting factors which were obtained from a regression of the La Terraza study results to predict the reduction in peak discharge was measured using the Commercial Site SWMM Model. The explanation of variance (R^2) in peak reduction of the initial factors was found to be 82.2% by comparing the estimated reduction in peak discharge using the initial factors to the modeled peak discharge reduction from the SWMM model.

When the prediction ability of the initial factors was grouped by the distribution of retention volume within the study area, the initial stormwater harvesting factors provided a very good ability to predict reduction in peak discharge for the one large basin at the outfall ("Basin 1", R^2 = 98.5 percent) as well as the three basins with volumes weighted by contributing drainage area ("Basin 1, Basin 2, and Basin 3 Area-Weighted", R^2 = 93.4 percent). However, the initial factors showed a poor ability to predict peak discharge reduction for the three basins of equal size distribution ("Basin 1, Basin 2, and Basin 3 Equal Distribution", R^2 = 21.0 percent) due to the larger basin volumes at the top of the watershed that were not utilized during the smaller 2-year and 10-year storms and therefore did not provide additional reduction in peak discharge. All of the Commercial Site SWMM modeling results were included in the final regression after the validation analysis to improve the accuracy of the stormwater harvesting factors, and the results from these "less-than-ideal" configurations brought the regression line lower to provide a factor of safety for estimating peak discharge reduction when using the stormwater harvesting factors.

Regression Analysis of Peak Discharge Reduction and Retention Volume

Sixty-four modeled data points were used in the regression, with 28 data points from the 31-acre La Terraza subdivision result set, and 36 data points from the 1.6-acre commercial site SWMM modeling results. The least-squares polynomial equation applied to the total modeled points has a correlation coefficient (R^2) of 0.946 (Figure 9) and a Root Mean Squared Error (RMSE) of 6.9%. The regression shows that reduction in peak discharge is approximately zero when the volume retained is less than or equal to 10% of the runoff volume. The results used in the regression analysis include several "less-than-ideal" designs which displayed significantly less reduction in peak discharge, particularly during smaller storms which were likely to have the retention volume equal to 60% or more of the runoff volume. These points provide a factor of safety by weighting the regression line towards lower reduction factors. For example, although stormwater harvesting volumes may be designed to capture 100% of the runoff volume, the maximum amount of peak discharge reduction found is 94.5% from the regression analysis, which indicates that some flow is not expected to be captured by the basins.

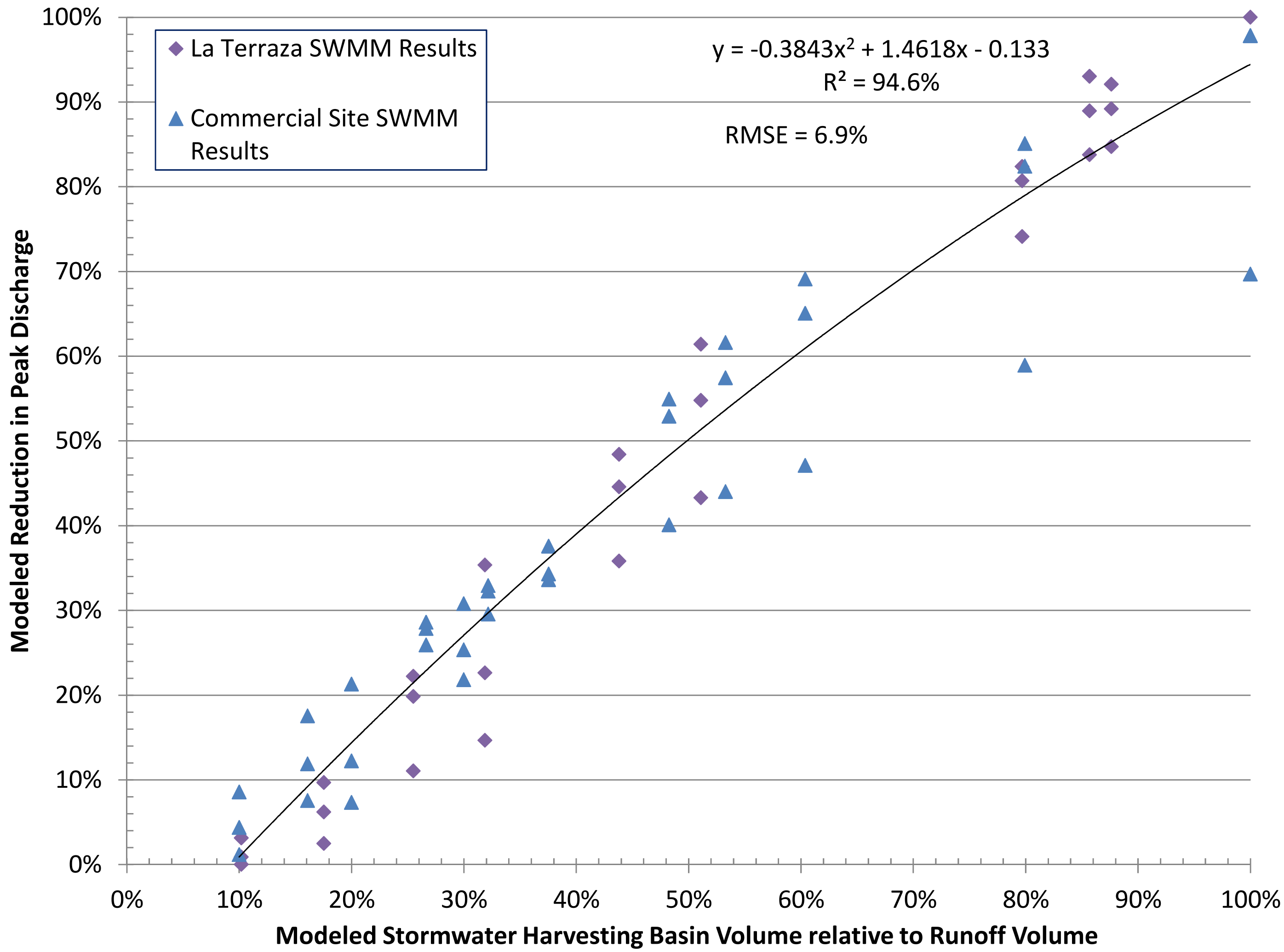

Figure 9. Modeled Peak Discharge Reduction Versus Stormwater Harvesting Volume for the Commercial Site and La Terraza Results.

The following equation from the regression analysis was used to develop a table of stormwater harvesting factors for peak discharge reduction (Table 3) based on the total retention volume in the watershed:

$$H_{rp} = -0.3843X_{rp}^2 + 1.4618X_{rp} - 0.133 \quad \text{(Equation D-2)}$$

for $0.10 \leq \boldsymbol{X_{rp}} \leq 1.00$

Table 3. Storm Water Harvesting Factors (H_{rp}) for Peak Discharge Rate Reduction Based on Total Volume Retained (X_{rp})

X_{rp}	H_{rp}
< 10%	0.0%
10%	0.9%
11%	2.3%
12%	3.7%
13%	5.1%
14%	6.4%
15%	7.8%
16%	9.1%
17%	10.4%
18%	11.8%
19%	13.1%
20%	14.4%
21%	15.7%
22%	17.0%
23%	18.3%
24%	19.6%
25%	20.8%
26%	22.1%
27%	23.4%
28%	24.6%
29%	25.9%
30%	27.1%
31%	28.3%
32%	29.5%
33%	30.8%
34%	32.0%
35%	33.2%
36%	34.3%
37%	35.5%
38%	36.7%
39%	37.9%

X_{rp}	H_{rp}
40%	39.0%
41%	40.2%
42%	41.3%
43%	42.5%
44%	43.6%
45%	44.7%
46%	45.8%
47%	46.9%
48%	48.0%
49%	49.1%
50%	50.2%
51%	51.3%
52%	52.3%
53%	53.4%
54%	54.4%
55%	55.5%
56%	56.5%
57%	57.5%
58%	58.6%
59%	59.6%
60%	60.6%
61%	61.6%
62%	62.6%
63%	63.5%
64%	64.5%
65%	65.5%
66%	66.4%
67%	67.4%
68%	68.3%
69%	69.3%
70%	70.2%

X_{rp}	H_{rp}
71%	71.1%
72%	72.0%
73%	72.9%
74%	73.8%
75%	74.7%
76%	75.6%
77%	76.5%
78%	77.3%
79%	78.2%
80%	79.0%
81%	79.9%
82%	80.7%
83%	81.6%
84%	82.4%
85%	83.2%
86%	84.0%
87%	84.8%
88%	85.6%
89%	86.4%
90%	87.1%
91%	87.9%
92%	88.7%
93%	89.4%
94%	90.2%
95%	90.9%
96%	91.6%
97%	92.3%
98%	93.0%
99%	93.8%
≥ 100%	94.5%

Using Watershed Area Draining to Stormwater Harvesting, "W_A", to Account for Limited Runoff

Eighteen of the 54 Commercial Site SWMM model configurations had smaller percent of watershed areas draining to stormwater harvesting ("W_A") than the 36 configurations used in the regression analysis. Nine of these configurations had stormwater harvesting in the NE and NW Basins at the top of the watershed (W_A = 38 percent), and 9 configurations had stormwater harvesting in only the NE Basin (W_A = 19 percent). The modeling results indicate that a stormwater harvesting basin at the top of the watershed can significantly reduce the peak discharge at the outlet by retaining runoff volume as long as the contributing drainage area to the basin is large enough that runoff will utilize the volume of the basin.

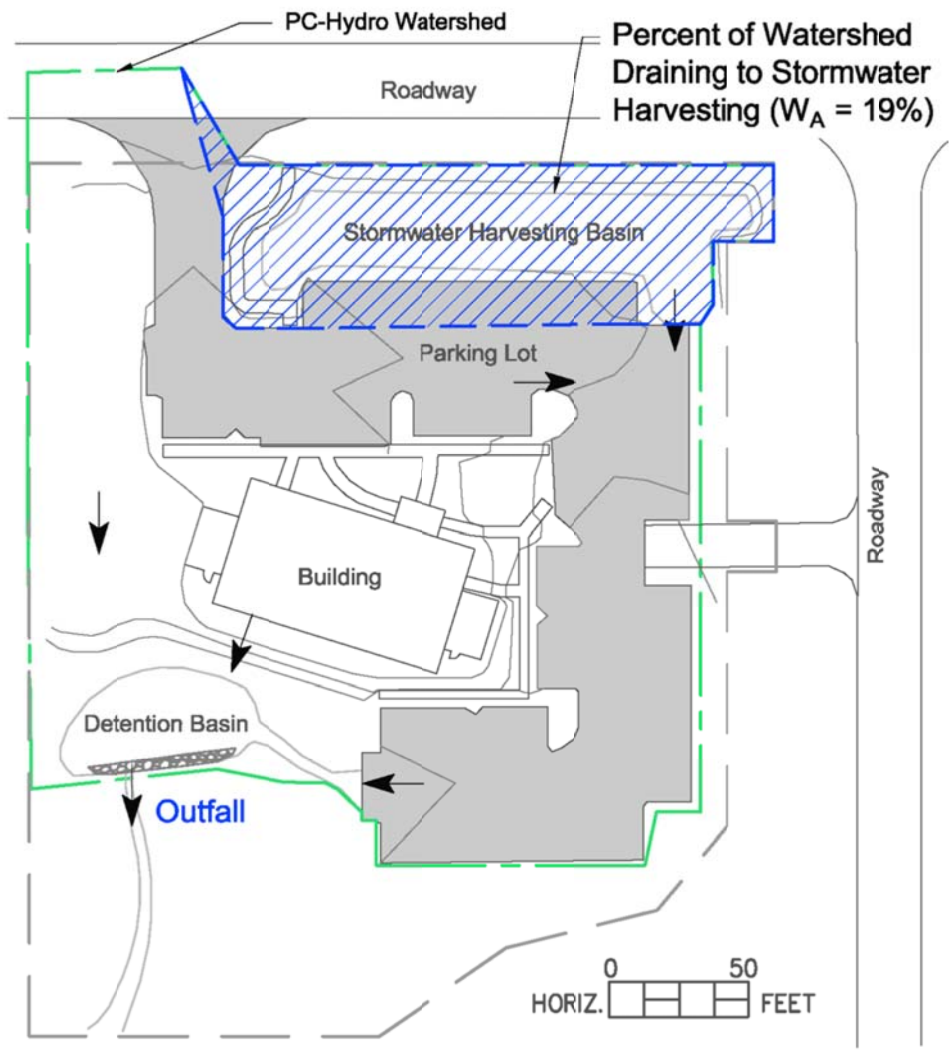

Figure 11. Example of a PC-Hydro Watershed with a Portion Draining to a Stormwater Harvesting Basin.

To account for the availability of runoff to one or more upstream stormwater harvesting basins within a watershed, an assumption can be made for simplification that the runoff volume reaching the basins will be approximately equal to the percent of the watershed area draining to the basins multiplied by the total runoff volume at the watershed outlet. This procedure can be summarized as follows:

1. Determine the area of the watershed that will flow to or through stormwater harvesting basins (A_s) and the total watershed area (A_t), and calculate the percent watershed area draining to stormwater harvesting (W_A) using the following equation:

$$W_A = \frac{A_s}{A_t} \qquad \text{(Equation D-3)}$$

2. Calculate the ratio (X_{rp}) of the sum of the stormwater harvesting basin volumes (V_{bas}) to the post-development runoff volume(V_{post}) with the following equation:

$$X_{rp} = \frac{V_{bas}}{V_{post}}$$

or $X_{rp} = W_A$, whichever is less. (Equation D-4)

3. Find the Storm Water Harvesting Factor (H_{rp}) for peak discharge reduction from the table based on the total retention volume within the watershed (X_{rp}).

This "limiting runoff volume" ($X_{rp} = W_A$) allows the full volume of stormwater harvesting within the watershed to be counted, including a basin near the top of a watershed, unless it is limited by runoff (found by W_A) without the need for additional PC-Hydro models. The runoff volume reaching the outlet of the watershed after accounting for stormwater harvesting basins can then be found as:

$$V_{swh-rp} = V_{post}(1 - X_{rp}) \qquad \text{(Equation D-5)}$$

When this "limiting volume" method is used to predict peak reduction for 27 scenarios from the Commercial Site that have varying draining watershed area (W_A) (Appendix D-4 Table 2), the explanation of variance (R^2) is 62.4% using this assumption while R^2 is -38.1% when no assumption is made to account for limited runoff reaching stormwater harvesting basins. If more detail is required, this assumption (W_A) can be avoided by calculating the discharge for the area draining to the inlet of the basins, which would find W_A = 100% in the above method.

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Appendix D-1. La Terraza SWMM Model parameters.

Appendix D-1, Table 1. Base La Terraza SWMM Model subcatchment parameters.

SUBCATCHMENTS Name	Watershed	Outlet	Total Area (ac)	Pcnt. Imperv	Width	Pcnt. Slope	N-Imperv	N-Perv	S-Imperv	S-Perv	PctZero	RouteTo	PctRouted
S1	**Urban**	J19	1.46	43	587.9	2.0	0.013	0.130	0.018	0.079	14	PERVIOUS	67.4
S2		J19	2.98	27	581.1	0.2	0.013	0.130	0.018	0.079	6	PERVIOUS	77.8
S3		J13	2.46	29	539.6	0.2	0.013	0.130	0.018	0.079	7	PERVIOUS	75.9
S4		J13	2.46	25	628.9	0.5	0.013	0.130	0.018	0.079	7	PERVIOUS	72.0
S5		J300	2.72	29	602.2	6.8	0.013	0.130	0.018	0.079	7	PERVIOUS	75.9
S6		J10	2.14	30	458.4	3.7	0.013	0.130	0.018	0.079	7	PERVIOUS	76.7
S7		J10	0.98	29	198.0	0.5	0.013	0.130	0.018	0.079	7	PERVIOUS	75.9
S8		J10	1.64	44	532.2	5.0	0.013	0.130	0.018	0.079	11	PERVIOUS	75.0
S9		J100	0.56	22	103.6	2.0	0.013	0.130	0.018	0.079	4	PERVIOUS	81.8
S10		J10	0.20	12	268.1	5.7	0.013	0.130	0.018	0.079	0	PERVIOUS	100.0
S11		J20	3.44	21	829.8	2.0	0.013	0.130	0.018	0.079	6	PERVIOUS	71.4
S12		J19	1.23	21	259.1	3.0	0.013	0.130	0.018	0.079	6	PERVIOUS	71.4
S13		J13	0.13	22	178.9	3.0	0.013	0.130	0.018	0.079	0	PERVIOUS	100.0
S14		J300	0.46	30	101.0	5.0	0.013	0.130	0.018	0.079	9	PERVIOUS	70.0
S15		J300	2.23	30	506.6	3.0	0.013	0.130	0.018	0.079	7	PERVIOUS	76.7
S16		J20	1.55	48	503.2	5.0	0.013	0.130	0.018	0.079	16	PERVIOUS	66.7
S17		S16	0.03	100	42.8	0.5	0.013	0.130	0.018	0.079	100	PERVIOUS	0.0
S19		J19	0.06	61	24.3	0.8	0.013	0.130	0.018	0.079	0	PERVIOUS	100.0
S21		J20	0.44	45	178.9	2.0	0.013	0.130	0.079	0.004	0	PERVIOUS	73.3
S22		J100	0.95	45	307.6	2.0	0.013	0.130	0.018	0.079	9	PERVIOUS	80.0
S23		J100	0.35	32	113.8	2.0	0.013	0.130	0.018	0.079	9	PERVIOUS	71.9
S24		J100	0.13	13	157.5	4.3	0.013	0.130	0.018	0.079	0	PERVIOUS	100.0
S25		J100	0.56	27	162.2	2.0	0.013	0.130	0.018	0.079	6	PERVIOUS	77.8
S34	**Grassland**	S42	14.47	0	710.6	4.1	0.013	0.130	0.018	0.079	0	PERVIOUS	0.0
S35		S44	7.28	0	452.0	3.2	0.013	0.130	0.018	0.079	0	PERVIOUS	0.0
S36		S32	8.31	0	537.3	4.3	0.013	0.130	0.018	0.079	0	PERVIOUS	0.0
S37		S36	5.78	0	344.2	4.3	0.013	0.130	0.018	0.079	0	PERVIOUS	0.0
S38		S33	5.89	0	341.4	4.1	0.013	0.130	0.018	0.079	0	PERVIOUS	0.0
S39		S38	5.21	0	303.4	4.9	0.013	0.130	0.018	0.079	0	PERVIOUS	0.0
S40		S46	14.75	0	712.3	4.9	0.013	0.130	0.018	0.079	0	PERVIOUS	0.0
S42		S41	8.77	0	436.1	3.5	0.013	0.130	0.018	0.079	0	PERVIOUS	0.0
S44		s43	6.57	0	480.9	1.7	0.013	0.130	0.018	0.079	0	PERVIOUS	0.0
S46		S45	10.35	0	515.3	3.2	0.013	0.130	0.018	0.079	0	PERVIOUS	0.0
S43		s41	0.14	0	9.8	1.7	0.013	0.130	0.018	0.079	0	PERVIOUS	0.0
S41		S45	0.07	0	9.8	1.3	0.013	0.130	0.018	0.079	0	PERVIOUS	0.0
S45		S33	0.10	0	9.8	1.0	0.013	0.130	0.018	0.079	0	PERVIOUS	0.0
S32		J18	0.12	0	9.8	2.1	0.013	0.130	0.018	0.079	0	PERVIOUS	0.0
S33		J18	0.07	0	9.8	1.5	0.013	0.130	0.018	0.079	0	PERVIOUS	0.0

Appendix D-1, Table 2. Base La Terraza SWMM Model conduit parameters.

CONDUITS Name	Inlet Node	Outlet Node	Length	Manning N
C10	J10	J20	846.2	0.025
C19	J13	J19	315.0	0.025
C21	J19	J20	223.6	0.025
Chan18	J18	J300	210.0	0.030
Chan20	J20	Outfall1	203.4	0.014
Chan300	J300	J13	304.5	0.025
Pipe100	J100	J20	700.0	0.020

Appendix D-1, Table 3. La Terraza SWMM Model cross section variables.

XSECTIONS Link	Shape	Geom1	Geom2	Geom3	Geom4	Barrels
Chan20	TRAPEZOIDAL	6	10	0.5	0.5	1
Pipe100	CIRCULAR	2	0	0	0	1
Chan300	RECT_OPEN	3	24	0	0	1
Chan18	TRAPEZOIDAL	5	5	0.25	0.25	1
C19	RECT_OPEN	3	24	0	0	1
C21	RECT_OPEN	3	24	0	0	1
C10	RECT_OPEN	3	24	0	0	1

Appendix D-1, Table 4. La Terraza SWMM Model junction variables.

JUNCTIONS Name	Invert Elev.	Max. Depth
J20	4683	5
J100	4684	6
J300	4697	5
J18	4700	5
J13	4692	5
J19	4686	5
J10	4688	5

Appendix D-2, Table 1. Commercial Site SWMM Model Parameters.

Subcatchments							
Name	Raingage	Outlet	Total Area	Pcnt. Impervious (%)	Length	Width	Percent Slope (%)
P1A-NW	1-hr 100-yr, 10-yr or 2-yr	P1B-4	0.3	36	160	82	1.1
P1A-NE	1-hr 100-yr, 10-yr or 2-yr	P1B-2	0.3	34	175	75	0.8
P1B-1	1-hr 100-yr, 10-yr or 2-yr	P1B-2	0.13	93	115	49	2.4
P1B-2	1-hr 100-yr, 10-yr or 2-yr	P1B-4	0.37	97	254	64	1.6
P1B-3	1-hr 100-yr, 10-yr or 2-yr	P1B-4	0.30	45	116	110	1.0
P1B-4	1-hr 100-yr, 10-yr or 2-yr	Outfall1	0.18	2	74	104	1.0
P1B-5 Direct	1-hr 100-yr, 10-yr or 2-yr	Outfall 1	0.02	0	10	97	1.0

Subcatchments							
Name	N-Imperv	N-Pervious	S-Imperv	S-Perv	PctZero	RouteTo	PctRouted
P1A-NW	0.013	0.13	0.018	0.079	0	Pervious	100
P1A-NE	0.013	0.13	0.018	0.079	0	Pervious	100
P1B-1	0.013	0.13	0.018	0.079	0	Outlet	100
P1B-2	0.013	0.13	0.018	0.079	0	Outlet	100
P1B-3	0.013	0.13	0.018	0.079	0	Outlet	100
P1B-4	0.013	0.13	0.018	0.079	0	Outlet	100
P1B-5 Direct	0.013	0.13	0.018	0.079	0	Outlet	100

Infiltration	Green-Ampt		
Subcatchment	Suction	HydrCon	Initial Moisture Deficit
P1A-NW	6.4	0.1	0.15
P1A-NE	6.4	0.1	0.15
P1B-1	6.4	0.1	0.15
P1B-2	6.4	0.1	0.15
P1B-3	6.4	0.1	0.15
P1B-4	6.4	0.1	0.15
P1B-5 Direct	6.4	0.1	0.15

Appendix D-2, Table 2. The volume of stormwater harvesting basins used in the Commercial Site SWMM model for W_A = 99%.

Model	Basin Volume as Percent of Post-Developed Runoff Volume (%)	Location of Retention	Basin 1 (P1B-4) Volume (ac-ft)	Basin 2 (P1A-NW) Volume (ac-ft)	Basin 3 (P1A-NE) Volume (ac-ft)	Watershed D-Storage Basin 1 (in)	Watershed D-Storage Basin 2 (in)	Watershed D-Storage Basin 3 (in)	Basin 1 Area required for 9 in depth	Basin 2 Area required for 9 in depth	Basin 3 Area required for 9 in depth	Basin 1 Area as % of Pervious P1B-4 Subcatch-ment Area	Basin 2 Area as % of Pervious P1A-NW Subcatch-ment Area	Basin 3 Area as % of Pervious P1A-NE Subcatch-ment Area
SWH100yr_Vol2yr_Dist0	38%	Basin 1	0.128	0.000	0.000	8.612	0.079	0.079	7434	0	0	95%	0%	0%
SWH100yr_Vol2yr_Dist100	38%	Basins 1, 2, 3	0.043	0.043	0.043	2.923	2.746	2.665	2478	2478	2478	32%	30%	29%
SWH100yr_Vol2yr_DistAreaWght	38%	Basins 1, 2, 3 Area Weighted	0.080	0.024	0.024	5.412	1.579	1.534	4646	1394	1394	59%	17%	16%
SWH100yr_Vol30_Dist0	30%	Basin 1	0.102	0.000	0.000	6.899	0.079	0.079	5942	0	0	76%	0%	0%
SWH100yr_Vol30_Dist100	30%	Basins 1, 2, 3	0.034	0.034	0.034	2.352	2.210	2.146	1981	1981	1981	25%	24%	23%
SWH100yr_Vol30_DistAreaWght	30%	Basins 1, 2, 3 Area Weighted	0.064	0.019	0.019	4.342	1.278	1.242	3713	1114	1114	47%	13%	13%
SWH100yr_Vol20_Dist0	20%	Basin 1	0.068	0.000	0.000	4.626	0.079	0.079	3961	0	0	51%	0%	0%
SWH100yr_Vol20_Dist100	20%	Basins 1, 2, 3	0.023	0.023	0.023	1.595	1.500	1.457	1320	1320	1320	17%	16%	15%
SWH100yr_Vol20_DistAreaWght	20%	Basins 1, 2, 3 Area Weighted	0.043	0.013	0.013	2.921	0.878	0.854	2476	743	743	32%	9%	9%
SWH100yr_Vol10_Dist0	10%	Basin 1	0.034	0.000	0.000	2.352	0.079	0.079	1981	0	0	25%	0%	0%
SWH100yr_Vol10_Dist100	10%	Basins 1, 2, 3	0.011	0.011	0.011	0.837	0.789	0.768	660	660	660	8%	8%	8%
SWH100yr_Vol10_DistAreaWght	10%	Basins 1, 2, 3 Area Weighted	0.021	0.006	0.006	1.500	0.479	0.467	1238	371	371	16%	4%	4%
SWH10yr_Vol2yr_Dist0	60%	Basin 1	0.128	0.000	0.000	8.612	0.079	0.079	7434	0	0	95%	0%	0%
SWH10yr_Vol2yr_Dist100	60%	Basins 1, 2, 3	0.043	0.043	0.043	2.923	2.746	2.665	2478	2478	2478	32%	30%	29%
SWH10yr_Vol2yr_DistAreaWght	60%	Basins 1, 2, 3 Area Weighted	0.080	0.024	0.024	5.412	1.579	1.534	4646	1394	1394	59%	17%	16%
SWH10yr_Vol30_Dist0	48%	Basin 1	0.102	0.000	0.000	6.899	0.079	0.079	5942	0	0	76%	0%	0%
SWH10yr_Vol30_Dist100	48%	Basins 1, 2, 3	0.034	0.034	0.034	2.352	2.210	2.146	1981	1981	1981	25%	24%	23%
SWH10yr_Vol30_DistAreaWght	48%	Basins 1, 2, 3 Area Weighted	0.064	0.019	0.019	4.342	1.278	1.242	3713	1114	1114	47%	13%	13%
SWH10yr_Vol20_Dist0	32%	Basin 1	0.068	0.000	0.000	4.626	0.079	0.079	3961	0	0	51%	0%	0%
SWH10yr_Vol20_Dist100	32%	Basins 1, 2, 3	0.023	0.023	0.023	1.595	1.500	1.457	1320	1320	1320	17%	16%	15%
SWH10yr_Vol20_DistAreaWght	32%	Basins 1, 2, 3 Area Weighted	0.043	0.013	0.013	2.921	0.878	0.854	2476	743	743	32%	9%	9%
SWH10yr_Vol10_Dist0	16%	Basin 1	0.034	0.000	0.000	2.352	0.079	0.079	1981	0	0	25%	0%	0%
SWH10yr_Vol10_Dist100	16%	Basins 1, 2, 3	0.011	0.011	0.011	0.837	0.789	0.768	660	660	660	8%	8%	8%
SWH10yr_Vol10_DistAreaWght	16%	Basins 1, 2, 3 Area Weighted	0.021	0.006	0.006	1.500	0.479	0.467	1238	371	371	16%	4%	4%
SWH2yr_Vol2yr_Dist0	100%	Basin 1	0.128	0.000	0.000	8.612	0.079	0.079	7434	0	0	95%	0%	0%
SWH2yr_Vol2yr_Dist100	100%	Basins 1, 2, 3	0.043	0.043	0.043	2.923	2.746	2.665	2478	2478	2478	32%	30%	29%
SWH2yr_Vol2yr_DistAreaWght	100%	Basins 1, 2, 3 Area Weighted	0.080	0.024	0.024	5.412	1.579	1.534	4646	1394	1394	59%	17%	16%
SWH2yr_Vol30_Dist0	80%	Basin 1	0.102	0.000	0.000	6.899	0.079	0.079	5942	0	0	76%	0%	0%
SWH2yr_Vol30_Dist100	80%	Basins 1, 2, 3	0.034	0.034	0.034	2.352	2.210	2.146	1981	1981	1981	25%	24%	23%
SWH2yr_Vol30_DistAreaWght	80%	Basins 1, 2, 3 Area Weighted	0.064	0.019	0.019	4.342	1.278	1.242	3713	1114	1114	47%	13%	13%
SWH2yr_Vol20_Dist0	53%	Basin 1	0.068	0.000	0.000	4.626	0.079	0.079	3961	0	0	51%	0%	0%
SWH2yr_Vol20_Dist100	53%	Basins 1, 2, 3	0.023	0.023	0.023	1.595	1.500	1.457	1320	1320	1320	17%	16%	15%
SWH2yr_Vol20_DistAreaWght	53%	Basins 1, 2, 3 Area Weighted	0.043	0.013	0.013	2.921	0.878	0.854	2476	743	743	32%	9%	9%
SWH2yr_Vol10_Dist0	27%	Basin 1	0.034	0.000	0.000	2.352	0.079	0.079	1981	0	0	25%	0%	0%
SWH2yr_Vol10_Dist100	27%	Basins 1, 2, 3	0.011	0.011	0.011	0.837	0.789	0.768	660	660	660	8%	8%	8%
SWH2yr_Vol10_DistAreaWght	27%	Basins 1, 2, 3 Area Weighted	0.021	0.006	0.006	1.500	0.479	0.467	1238	371	371	16%	4%	4%

Appendix D-2, Table 3. The volume of stormwater harvesting basins used in the Commercial Site SWMM model for the W_A = 19%, 39%, and 99% scenarios.

Model	Basin Volume as Percent of Post-Developed Runoff Volume (%)	Location of Retention	Basin 1 (P1B-4) Volume (ac-ft)	Basin 2 (P1A-NW) Volume (ac-ft)	Basin 3 (P1A-NE) Volume (ac-ft)	Watershed D-Storage Basin 1 (in)	Watershed D-Storage Basin 2 (in)	Watershed D-Storage Basin 3 (in)	Basin 1 Area required for 9 in depth	Basin 2 Area required for 9 in depth	Basin 3 Area required for 9 in depth	Basin 1 Area as % of Pervious P1B-4 Subcatch-ment Area	Basin 2 Area as % of Pervious P1A-NW Subcatch-ment Area	Basin 3 Area as % of Pervious P1A-NE Subcatch-ment Area
SWH100yr_Vol10_Dist38%	10%	Basins 2, 3	0.000	0.017	0.017	0.079	1.145	1.112	0	990	990	0%	12%	11%
SWH10yr_Vol10_Dist38%	16%	Basins 2, 3	0.000	0.017	0.017	0.079	1.145	1.112	0	990	990	0%	12%	11%
SWH2yr_Vol10_Dist38%	27%	Basins 2, 3	0.000	0.017	0.017	0.079	1.145	1.112	0	990	990	0%	12%	11%
SWH100yr_Vol20_Dist38%	20%	Basins 2, 3	0.000	0.034	0.034	0.079	2.210	2.146	0	1981	1981	0%	24%	23%
SWH10yr_Vol20_Dist38%	32%	Basins 2, 3	0.000	0.034	0.034	0.079	2.210	2.146	0	1981	1981	0%	24%	23%
SWH2yr_Vol20_Dist38%	53%	Basins 2, 3	0.000	0.034	0.034	0.079	2.210	2.146	0	1981	1981	0%	24%	23%
SWH100yr_Vol30_Dist38%	30%	Basins 2, 3	0.000	0.051	0.051	0.079	3.276	3.179	0	2971	2971	0%	36%	34%
SWH10yr_Vol30_Dist38%	48%	Basins 2, 3	0.000	0.051	0.051	0.079	3.276	3.179	0	2971	2971	0%	36%	34%
SWH2yr_Vol30_Dist38%	80%	Basins 2, 3	0.000	0.051	0.051	0.079	3.276	3.179	0	2971	2971	0%	36%	34%
SWH100yr_Vol10_Dist19%	10%	Basin 3	0.000	0.000	0.034	0.079	0.079	2.146	0	0	1981	0%	0%	23%
SWH10yr_Vol10_Dist19%	16%	Basin 3	0.000	0.000	0.034	0.079	0.079	2.146	0	0	1981	0%	0%	23%
SWH2yr_Vol10_Dist19%	27%	Basin 3	0.000	0.000	0.034	0.079	0.079	2.146	0	0	1981	0%	0%	23%
SWH100yr_Vol20_Dist19%	20%	Basin 3	0.000	0.000	0.068	0.079	0.079	4.212	0	0	3961	0%	0%	46%
SWH10yr_Vol20_Dist19%	32%	Basin 3	0.000	0.000	0.068	0.079	0.079	4.212	0	0	3961	0%	0%	46%
SWH2yr_Vol20_Dist19%	53%	Basin 3	0.000	0.000	0.068	0.079	0.079	4.212	0	0	3961	0%	0%	46%
SWH100yr_Vol30_Dist19%	30%	Basin 3	0.000	0.000	0.102	0.079	0.079	6.279	0	0	5942	0%	0%	69%
SWH10yr_Vol30_Dist19%	48%	Basin 3	0.000	0.000	0.102	0.079	0.079	6.279	0	0	5942	0%	0%	69%
SWH2yr_Vol30_Dist19%	80%	Basin 3	0.000	0.000	0.102	0.079	0.079	6.279	0	0	5942	0%	0%	69%
SWH100yr_Vol30_DistAreaWght	30%	Basins 1, 2, 3	0.064	0.019	0.019	4.342	1.278	1.242	3713	1114	1114	47%	13%	13%
SWH100yr_Vol20_DistAreaWght	20%	Basins 1, 2, 3	0.043	0.013	0.013	2.921	0.878	0.854	2476	743	743	32%	9%	9%
SWH100yr_Vol10_DistAreaWght	10%	Basins 1, 2, 3	0.021	0.006	0.006	1.500	0.479	0.467	1238	371	371	16%	4%	4%
SWH10yr_Vol30_DistAreaWght	48%	Basins 1, 2, 3	0.064	0.019	0.019	4.342	1.278	1.242	3713	1114	1114	47%	13%	13%
SWH10yr_Vol20_DistAreaWght	32%	Basins 1, 2, 3	0.043	0.013	0.013	2.921	0.878	0.854	2476	743	743	32%	9%	9%
SWH10yr_Vol10_DistAreaWght	16%	Basins 1, 2, 3	0.021	0.006	0.006	1.500	0.479	0.467	1238	371	371	16%	4%	4%
SWH2yr_Vol30_DistAreaWght	80%	Basins 1, 2, 3	0.064	0.019	0.019	4.342	1.278	1.242	3713	1114	1114	47%	13%	13%
SWH2yr_Vol20_DistAreaWght	53%	Basins 1, 2, 3	0.043	0.013	0.013	2.921	0.878	0.854	2476	743	743	32%	9%	9%
SWH2yr_Vol10_DistAreaWght	27%	Basins 1, 2, 3	0.021	0.006	0.006	1.500	0.479	0.467	1238	371	371	16%	4%	4%

Appendix D-3, Table 1. La Terraza SWMM Modeling Base Peak Discharge results.

Watershed	RP	V (ac-ft)	Qp (cfs)
La Terraza (Base)	2-yr	1.83	59.2
La Terraza (Base)	10-yr	3.33	115.0
La Terraza (Base)	100-yr	5.57	197.2
Shorter La Terraza	100-yr	5.65	225.1
Longer La Terraza	100-yr	5.60	159.7

Appendix D-3, Table 2. La Terraza SWMM Modeling Stormwater Harvesting Peak Discharge results.

Watershed	Return Period	Distribution	SWH Volume / Runoff Volume	Qp (cfs)	Qp Reduction (%)
La Terraza (Base)	2-yr	0%	31.9%	45.8	22.6%
La Terraza (Base)	2-yr	50%	31.9%	50.5	14.7%
La Terraza (Base)	2-yr	100%	31.9%	38.3	35.4%
La Terraza (Base)	2-yr	0%	79.7%	11.4	80.7%
La Terraza (Base)	2-yr	50%	79.7%	15.3	74.1%
La Terraza (Base)	2-yr	100%	79.7%	10.4	82.4%
La Terraza (Base)	2-yr	0%	>100%	0.0	100.0%
La Terraza (Base)	2-yr	50%	>100%	0.0	100.0%
La Terraza (Base)	2-yr	100%	>100%	0.0	100.0%
La Terraza (Base)	10-yr	0%	17.5%	107.9	6.2%
La Terraza (Base)	10-yr	50%	17.5%	112.2	2.5%
La Terraza (Base)	10-yr	100%	17.5%	103.9	9.7%
La Terraza (Base)	10-yr	0%	43.8%	63.7	44.6%
La Terraza (Base)	10-yr	50%	43.8%	73.8	35.8%
La Terraza (Base)	10-yr	100%	43.8%	59.4	48.4%
La Terraza (Base)	10-yr	0%	87.6%	9.1	92.1%
La Terraza (Base)	10-yr	50%	87.6%	17.6	84.7%
La Terraza (Base)	10-yr	100%	87.6%	12.4	89.2%
La Terraza (Base)	100-yr	0%	10.3%	195.3	0.9%
La Terraza (Base)	100-yr	50%	10.3%	197.1	0.0%
La Terraza (Base)	100-yr	100%	10.3%	196.3	0.4%
La Terraza (Base)	100-yr	0%	25.7%	153.9	21.9%
La Terraza (Base)	100-yr	50%	25.7%	173.7	11.9%
La Terraza (Base)	100-yr	100%	25.7%	153.4	22.2%
La Terraza (Base)	100-yr	0%	51.4%	81.0	58.9%
La Terraza (Base)	100-yr	50%	51.4%	99.5	49.5%
La Terraza (Base)	100-yr	100%	51.4%	89.2	54.8%
La Terraza (Base)	100-yr	0%	85.7%	13.7	93.0%

Appendix D-3, Table 2 (continued). La Terraza SWMM Modeling Stormwater Harvesting Peak Discharge results.

Watershed	Return Period	Distribution	SWH Volume / Runoff Volume	Qp (cfs)	Qp Reduction (%)
La Terraza (Base)	100-yr	50%	85.7%	29.8	84.9%
La Terraza (Base)	100-yr	100%	85.7%	21.8	88.9%
Shorter La Terraza	100-yr	0%	10.2%	218.0	3.1%
Shorter La Terraza	100-yr	50%	10.2%	223.1	0.9%
Shorter La Terraza	100-yr	100%	10.2%	222.1	1.3%
Shorter La Terraza	100-yr	0%	25.7%	175.6	22.0%
Shorter La Terraza	100-yr	50%	25.7%	198.4	11.9%
Shorter La Terraza	100-yr	100%	25.7%	180.3	19.9%
Shorter La Terraza	100-yr	0%	51.4%	86.9	61.4%
Shorter La Terraza	100-yr	50%	51.4%	105.3	53.2%
Shorter La Terraza	100-yr	100%	51.4%	96.7	57.1%
Shorter La Terraza	100-yr	0%	85.7%	18.8	91.7%
Shorter La Terraza	100-yr	50%	85.7%	31.6	86.0%
Shorter La Terraza	100-yr	100%	85.7%	22.4	90.0%
Longer La Terraza	100-yr	0%	10.2%	158.5	0.7%
Longer La Terraza	100-yr	50%	10.2%	158.9	0.5%
Longer La Terraza	100-yr	100%	10.2%	156.6	1.9%
Longer La Terraza	100-yr	0%	25.7%	128.0	19.8%
Longer La Terraza	100-yr	50%	25.7%	142.0	11.0%
Longer La Terraza	100-yr	100%	25.7%	135.8	14.9%
Longer La Terraza	100-yr	0%	51.4%	72.1	54.9%
Longer La Terraza	100-yr	50%	51.4%	90.5	43.3%
Longer La Terraza	100-yr	100%	51.4%	76.8	51.9%
Longer La Terraza	100-yr	0%	85.7%	12.3	92.3%
Longer La Terraza	100-yr	50%	85.7%	25.9	83.8%
Longer La Terraza	100-yr	100%	85.7%	18.7	88.3%

Appendix D-4, Table 1. Commercial Site SWMM Modeling peak discharge results for W_A = 99%.

Model	Return Period	Qp (cfs)	Outflow Runoff Volume (ac-ft)	Total Volume of Basins (ac-ft)	Basin Volume as Percent of Post-Developed Runoff Volume (%)	Location of Retention	W_A	Qp Reduction (cfs)	Qp Reduction (%)
SWH100yr_Vol2yr_Dist0	100	8.43	0.211	0.128	38%	Basin 1	99%	4.40	34%
SWH100yr_Vol2yr_Dist100	100	8.52	0.212	0.128	38%	Basins 1, 2, 3 Equal	99%	4.31	34%
SWH100yr_Vol2yr_DistAreaWght	100	8.01	0.211	0.128	38%	Basins 1, 2, 3 Area Weighted	99%	4.82	38%
SWH100yr_Vol30_Dist0	100	10.03	0.237	0.102	30%	Basin 1	99%	2.80	22%
SWH100yr_Vol30_Dist100	100	8.88	0.238	0.102	30%	Basins 1, 2, 3	99%	3.95	31%
SWH100yr_Vol30_DistAreaWght	100	9.58	0.237	0.102	30%	Basins 1, 2, 3 Area Weighted	99%	3.25	25%
SWH100yr_Vol20_Dist0	100	11.89	0.271	0.068	20%	Basin 1	99%	0.94	7%
SWH100yr_Vol20_Dist100	100	10.1	0.272	0.068	20%	Basins 1, 2, 3	99%	2.73	21%
SWH100yr_Vol20_DistAreaWght	100	11.26	0.272	0.068	20%	Basins 1, 2, 3 Area Weighted	99%	1.57	12%
SWH100yr_Vol10_Dist0	100	12.68	0.306	0.034	10%	Basin 1	99%	0.15	1%
SWH100yr_Vol10_Dist100	100	11.73	0.307	0.034	10%	Basins 1, 2, 3	99%	1.10	9%
SWH100yr_Vol10_DistAreaWght	100	12.27	0.306	0.034	10%	Basins 1, 2, 3 Area Weighted	99%	0.56	4%
SWH10yr_Vol2yr_Dist0	10	2.59	0.082	0.128	60%	Basin 1	99%	4.82	65%
SWH10yr_Vol2yr_Dist100	10	3.92	0.093	0.128	60%	Basins 1, 2, 3	99%	3.49	47%
SWH10yr_Vol2yr_DistAreaWght	10	2.29	0.083	0.128	60%	Basins 1, 2, 3 Area Weighted	99%	5.12	69%
SWH10yr_Vol30_Dist0	10	3.49	0.107	0.102	48%	Basin 1	99%	3.92	53%
SWH10yr_Vol30_Dist100	10	4.44	0.11	0.102	48%	Basins 1, 2, 3	99%	2.97	40%
SWH10yr_Vol30_DistAreaWght	10	3.34	0.109	0.102	48%	Basins 1, 2, 3 Area Weighted	99%	4.07	55%
SWH10yr_Vol20_Dist0	10	5.22	0.143	0.068	32%	Basin 1	99%	2.19	30%
SWH10yr_Vol20_Dist100	10	5.02	0.143	0.068	32%	Basins 1, 2, 3	99%	2.39	32%
SWH10yr_Vol20_DistAreaWght	10	4.97	0.143	0.068	32%	Basins 1, 2, 3 Area Weighted	99%	2.44	33%
SWH10yr_Vol10_Dist0	10	6.85	0.177	0.034	16%	Basin 1	99%	0.56	8%
SWH10yr_Vol10_Dist100	10	6.11	0.178	0.034	16%	Basins 1, 2, 3	99%	1.30	18%
SWH10yr_Vol10_DistAreaWght	10	6.53	0.177	0.034	16%	Basins 1, 2, 3 Area Weighted	99%	0.88	12%
SWH2yr_Vol2yr_Dist0	2	0.09	0.001	0.128	100%	Basin 1	99%	4.00	98%
SWH2yr_Vol2yr_Dist100	2	1.24	0.039	0.128	100%	Basins 1, 2, 3	99%	2.85	70%
SWH2yr_Vol2yr_DistAreaWght	2	0.09	0.003	0.128	100%	Basins 1, 2, 3 Area Weighted	99%	4.00	98%
SWH2yr_Vol30_Dist0	2	0.72	0.024	0.102	80%	Basin 1	99%	3.37	82%
SWH2yr_Vol30_Dist100	2	1.68	0.049	0.102	80%	Basins 1, 2, 3	99%	2.41	59%
SWH2yr_Vol30_DistAreaWght	2	0.61	0.026	0.102	80%	Basins 1, 2, 3 Area Weighted	99%	3.48	85%
SWH2yr_Vol20_Dist0	2	1.74	0.059	0.068	53%	Basin 1	99%	2.35	57%
SWH2yr_Vol20_Dist100	2	2.29	0.061	0.068	53%	Basins 1, 2, 3	99%	1.80	44%
SWH2yr_Vol20_DistAreaWght	2	1.57	0.059	0.068	53%	Basins 1, 2, 3 Area Weighted	99%	2.52	62%
SWH2yr_Vol10_Dist0	2	3.03	0.093	0.034	27%	Basin 1	99%	1.06	26%
SWH2yr_Vol10_Dist100	2	2.95	0.093	0.034	27%	Basins 1, 2, 3	99%	1.14	28%
SWH2yr_Vol10_DistAreaWght	2	2.92	0.094	0.034	27%	Basins 1, 2, 3 Area Weighted	99%	1.17	29%

Appendix D-4, Table 2. Commercial Site SWMM Modeling results for W_A = 19%, 39%, and 99% that show modeled peak reduction and predicted peak reduction for the proposed stormwater harvesting factors.

Model	Return Period	Qp (cfs)	Outflow Runoff Volume (ac-ft)	Total Volume of Basins (ac-ft)	Percent of Post-Developed Runoff Volume (%)	Location of Retention	W_A	Qp Reduction (cfs)	Qp Reduction (%)	X_{rp} (V_{bas}/V_{post} or W_A)	H_{rp}	Predicted Qp Reduction (Base Qp * H_{rp}) (cfs)	Error (Predicted - Simulated Qp Reduction) (cfs)
SWH100yr_Vol10_Dist38%	100	10.97	0.307	0.034	10%	Basins 2, 3	38%	1.86	14%	10%	0.9%	0.12	-1.74
SWH10yr_Vol10_Dist38%	10	5.63	0.178	0.034	16%	Basins 2, 3	38%	1.78	24%	16%	9.1%	0.64	-1.14
SWH2yr_Vol10_Dist38%	2	3.1	0.094	0.034	27%	Basins 2, 3	38%	0.99	24%	27%	23.4%	0.84	-0.15
SWH100yr_Vol20_Dist38%	100	9.17	0.273	0.068	20%	Basins 2, 3	38%	3.66	29%	20%	14.4%	1.87	-1.79
SWH10yr_Vol20_Dist38%	10	5.37	0.144	0.068	32%	Basins 2, 3	38%	2.04	28%	32%	29.5%	2.07	0.02
SWH2yr_Vol20_Dist38%	2	3.1	0.084	0.068	53%	Basins 2, 3	38%	0.99	24%	38%	36.7%	1.32	0.33
SWH100yr_Vol30_Dist38%	100	9.1	0.239	0.102	30%	Basins 2, 3	38%	3.73	29%	30%	27.1%	3.52	-0.21
SWH10yr_Vol30_Dist38%	10	5.37	0.136	0.102	48%	Basins 2, 3	38%	2.04	28%	38%	36.7%	2.57	0.53
SWH2yr_Vol30_Dist38%	2	3.1	0.084	0.102	80%	Basins 2, 3	38%	0.99	24%	38%	36.7%	1.32	0.33
SWH100yr_Vol10_Dist19%	100	11.23	0.307	0.034	10%	Basin 3	19%	1.6	12%	10%	0.9%	0.12	-1.48
SWH10yr_Vol10_Dist19%	10	6.54	0.178	0.034	16%	Basin 3	19%	0.87	12%	16%	9.1%	0.64	-0.23
SWH2yr_Vol10_Dist19%	2	3.69	0.106	0.034	27%	Basin 3	19%	0.4	10%	19%	13.1%	0.47	0.07
SWH100yr_Vol20_Dist19%	100	11.23	0.279	0.068	20%	Basin 3	19%	1.6	12%	19%	13.1%	1.70	0.10
SWH10yr_Vol20_Dist19%	10	6.54	0.174	0.068	32%	Basin 3	19%	0.87	12%	19%	13.1%	0.92	0.05
SWH2yr_Vol20_Dist19%	2	3.69	0.106	0.068	53%	Basin 3	19%	0.4	10%	19%	13.1%	0.47	0.07
SWH100yr_Vol30_Dist19%	100	11.23	0.279	0.102	30%	Basin 3	19%	1.6	12%	19%	13.1%	1.70	0.10
SWH10yr_Vol30_Dist19%	10	6.54	0.174	0.102	48%	Basin 3	19%	0.87	12%	19%	13.1%	0.92	0.05
SWH2yr_Vol30_Dist19%	2	3.69	0.106	0.102	80%	Basin 3	19%	0.4	10%	19%	13.1%	0.47	0.07
SWH100yr_Vol30_DistAreaWght	100	9.58	0.237	0.102	30%	Basins 1, 2, 3	99%	3.25	25%	30%	27.1%	3.52	0.27
SWH100yr_Vol20_DistAreaWght	100	11.26	0.272	0.068	20%	Basins 1, 2, 3	99%	1.57	12%	20%	14.4%	1.87	0.30
SWH100yr_Vol10_DistAreaWght	100	12.27	0.306	0.034	10%	Basins 1, 2, 3	99%	0.56	4%	10%	0.9%	0.12	-0.44
SWH10yr_Vol30_DistAreaWght	10	3.34	0.109	0.102	48%	Basins 1, 2, 3	99%	4.07	55%	48%	48.0%	3.36	-0.71
SWH10yr_Vol20_DistAreaWght	10	4.97	0.143	0.068	32%	Basins 1, 2, 3	99%	2.44	33%	32%	29.5%	2.07	-0.38
SWH10yr_Vol10_DistAreaWght	10	6.53	0.177	0.034	16%	Basins 1, 2, 3	0.99	0.88	12%	16%	9.1%	0.64	-0.24
SWH2yr_Vol30_DistAreaWght	2	0.61	0.026	0.102	80%	Basins 1, 2, 3	99%	3.48	85%	80%	79.0%	2.84	-0.64
SWH2yr_Vol20_DistAreaWght	2	1.57	0.059	0.068	53%	Basins 1, 2, 3	99%	2.52	62%	53%	53.4%	1.92	-0.60
SWH2yr_Vol10_DistAreaWght	2	2.92	0.094	0.034	27%	Basins 1, 2, 3	99%	1.17	29%	27%	23.4%	0.84	-0.33

APPENDIX D: THE METHOD USED BY THE STORMWATER HARVESTING SPREADSHEET TO MODIFY A PC-HYDRO HYDROGRAPH TO ACCOUNT FOR STORMWATER HARVESTING

APPENDIX D: THE METHOD USED BY THE STORMWATER HARVESTING SPREADSHEET TO MODIFY A PC-HYDRO HYDROGRAPH TO ACCOUNT FOR STORMWATER HARVESTING

This section presents a method to modify a PC-Hydro hydrograph to account for stormwater harvesting based on the peak reduction factors and volume from Section 3.3.

The "Stormwater Harvesting" spreadsheet is available that performs all of the following modifications to a PC-Hydro hydrograph and provides a hydrograph to represent outflow from a watershed with one or more stormwater harvesting basins that may be distributed within the watershed.

Method:

Generate PC Hydro hydrographs that model the post-development discharge without stormwater harvesting basins for each return period. A PC-Hydro calculation is needed to determine the peak discharge ($Qp_{post\text{-}rp}$), runoff volume ($V_{post\text{-}rp}$), and a hydrograph that approximates this runoff volume for the post-developed condition without stormwater harvesting basins.

1. Use the methods in Sections 3.3 to calculate the stormwater harvesting factor (H_{rp}) and the peak of the post-development hydrograph with stormwater harvesting basins ($Q_{swh\text{-}rp}$) from the volume of the proposed stormwater harvesting basins (V_{bas}), post-developed runoff volume ($V_{post\text{-}rp}$), and the percent of the watershed area flowing to stormwater harvesting (W_A). The spreadsheet will perform the peak discharge reduction calculation when provided with the PC-Hydro peak discharges, runoff volumes, and stormwater harvesting basin volumes.

2. The spreadsheet creates an intermediate hydrograph using the Pima County dimensionless hydrograph (Table G.1) with the reduced peak discharge due to stormwater harvesting ($Q_{swh\text{-}rp}$) and the time to rise from the original PC-Hydro hydrograph (Tr). Stormwater harvesting basins may cause a slight lag in the hydrograph peak depending on the distribution of the basins within the watershed, but quantifying the detention effects of stormwater harvesting would require detailed modeling on a case-by-case basis and the time to rise of the intermediate hydrograph is assumed to remain the same as the original hydrograph for simplification and to reduce analysis time.

   The intermediate hydrograph is created by calculating time (t) and outflow (q) for each point on the hydrograph using the table below based on Table 3.3 from PCDOT&FCD (1987):

Table G.1. Pima County dimensionless hydrograph ordinates.

t/T_r	q/Q_{swh-rp}	t/T_r	q/Q_{swh-rp}
0.00	0.000	1.60	0.545
0.10	0.025	1.70	0.482
0.20	0.087	1.80	0.424
0.30	0.160	1.90	0.372
0.40	0.243	2.00	0.323
0.50	0.346	2.20	0.241
0.60	0.451	2.40	0.179
0.70	0.576	2.60	0.136
0.80	0.738	2.80	0.102
0.90	0.887	3.00	0.078
1.00	1.000	3.40	0.049
1.10	0.924	3.80	0.030
1.20	0.839	4.20	0.020
1.30	0.756	4.60	0.012
1.40	0.678	5.00	0.008
1.50	0.604	7.00	0.000

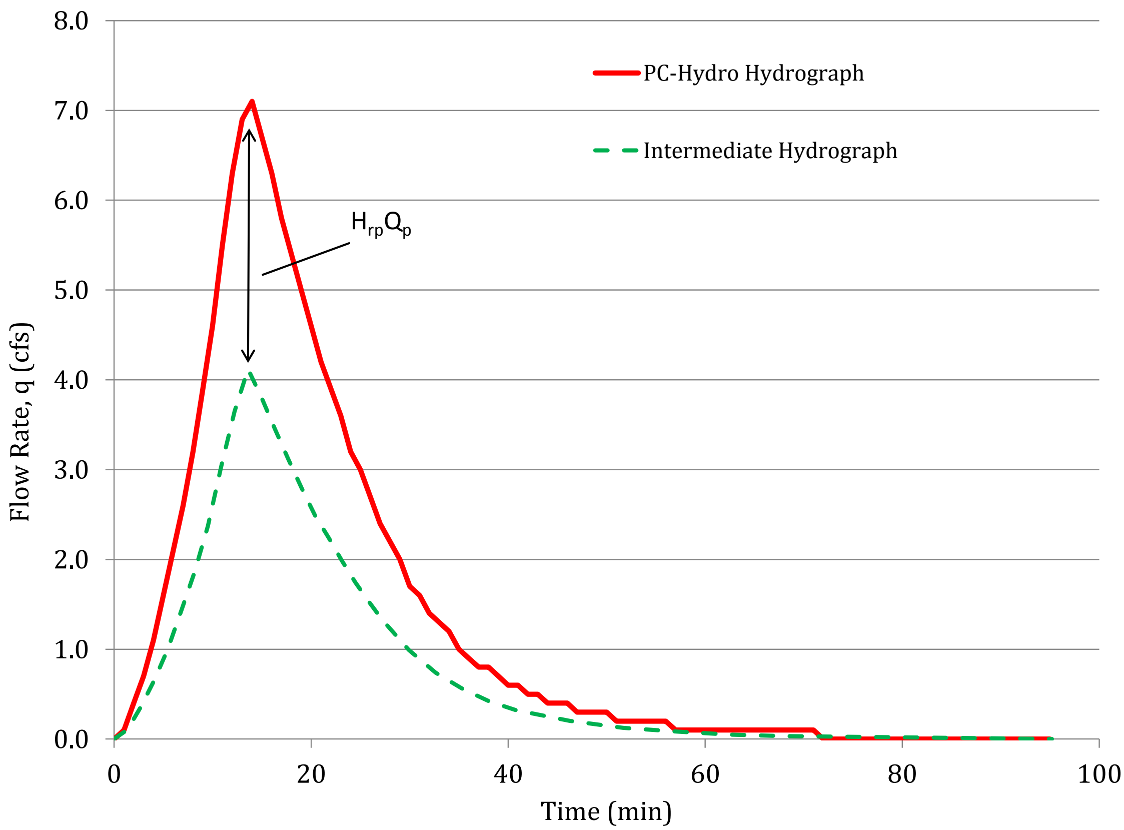


Figure G1. Intermediate hydrograph with peak equal to the reduced peak discharge calculated from Section 3.3.

3. The spreadsheet calculates the ratio of the reduced runoff volume due to stormwater harvesting ($V_{swh\text{-}rp}$ from Section 3.3) by the volume of the intermediate hydrograph calculated in step 4 (V_{int}). This ratio is defined here as the "volume factor", which is equal to $V_{swh\text{-}rp}$ /V_{int}. The spreadsheet uses the "volume factor" to match the reduced runoff volume when enough of the watershed is diverted to stormwater harvesting basins to utilize the storage capacity of the basins:

   a. If the "volume factor" is less than one (this typically occurs when the percent reduction in peak discharge is less than the percent reduction in volume), volume is removed from the intermediate hydrograph in the spreadsheet using the following method:

      i. The excess volume of the intermediate hydrograph is calculated by subtracting the reduced runoff volume ($V_{swh\text{-}rp}$) from the intermediate volume (V_{int}).

      ii. The front of the intermediate hydrograph is reduced by a volume equal to the amount from step (i) (the capacity of the stormwater harvesting basins) or the volume up to the time step before the reduced peak discharge, whichever is less.

      When volume is removed from the front of the hydrograph, the volume of retention is calculated by multiplying the flow rates (q) by the percent of watershed area directed to stormwater harvesting (W_A) and the time step (Figure G.2). The outflow rate at the front of the hydrograph is determined as the percent of directly-connected watershed area ($1 – W_A$) multiplied by the intermediate hydrograph flow rate (q).

      The time to peak of this stormwater harvesting hydrograph matches the time to peak of the original PC-Hydro hydrograph because the stormwater harvesting basins are treated as "depression storage" and additional detention effects will vary depending on the distribution of the basins and are not included for simplification.

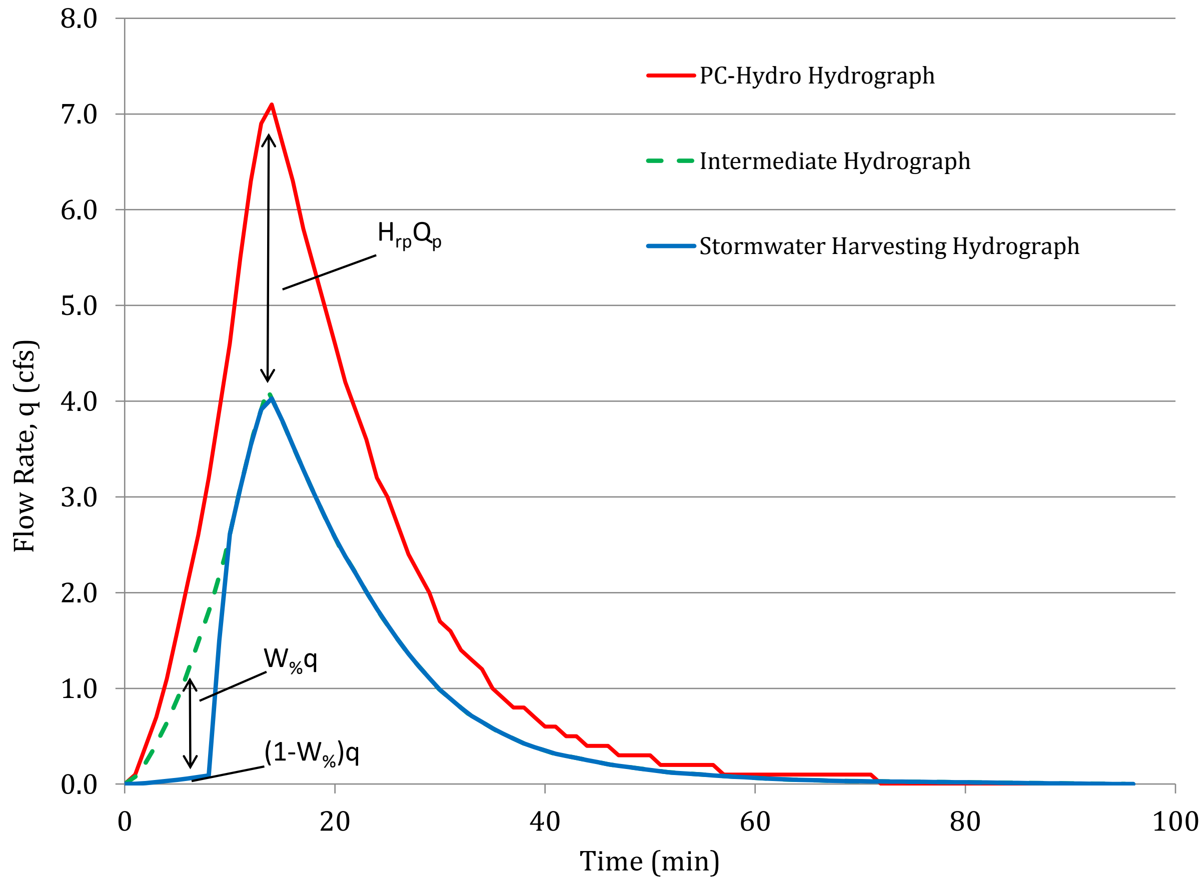


Figure G.2. Stormwater harvesting hydrograph with H_{rp} = 0.436 and W_A = 0.95.

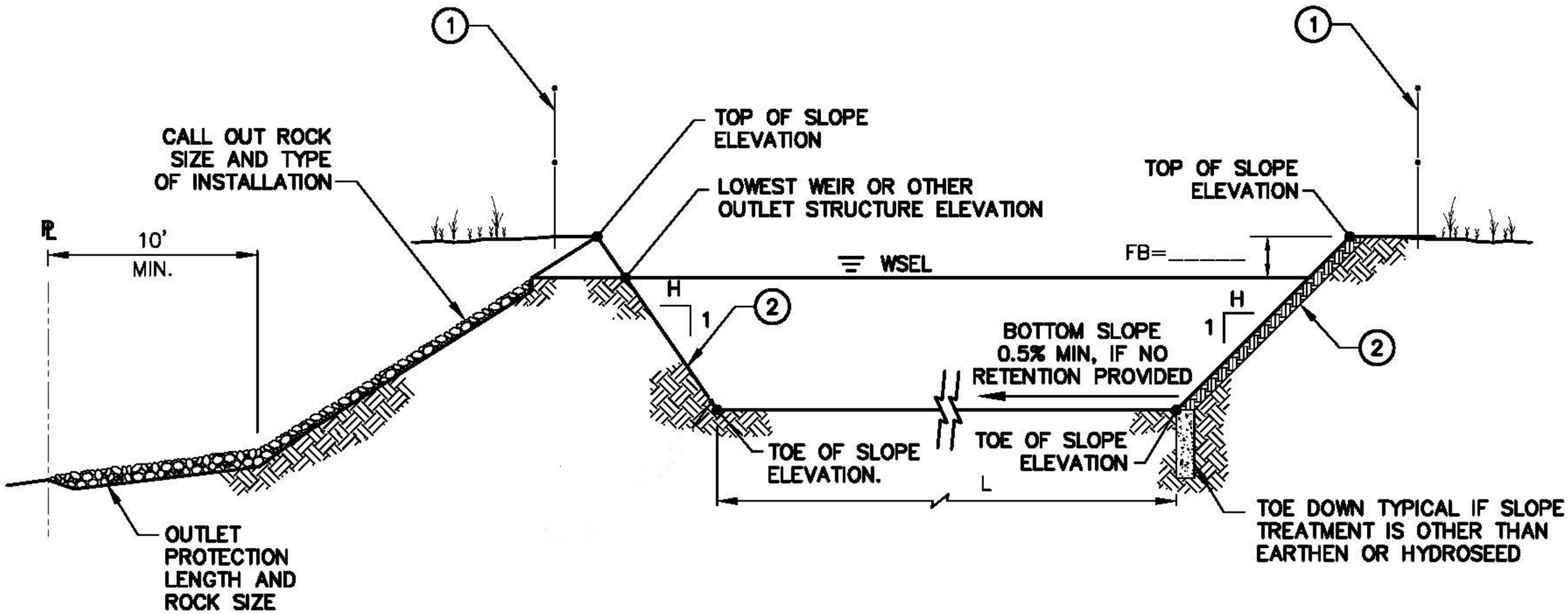
b. If the “volume factor” is slightly greater than one (this may occur in a few cases where the percent reduction in peak discharge is slightly greater than the percent reduction in volume), each time step in the hydrograph (i.e. each ‘t’ in Table G.1 above) is multiplied by the volume factor, and all flow rates from the intermediate hydrograph are left unchanged, so that the hydrograph volume matches the runoff volume after stormwater harvesting ($V_{swh\text{-}rp}$).

4. The stormwater harvesting hydrograph obtained from completing Step 5 using the spreadsheet may be used as the inflow hydrograph to a detention basin or another concentration point.

Appendix G References

PCDOT&FCD, 1987. Stormwater Detention/Retention Manual. Pima County Department of Transportation and Flood Control District, and the City of Tucson Department of Transportation, Tucson, Arizona.

APPENDIX E: DETAILS



① SECURITY BARRIER PER PCCOT STD/DTL. #105 OR FUNCTIONAL SUBSTITUTE, IF 100-YEAR DEPTH > 2' AND SIDE SLOPES STEEPER THAN 4:1.

② SLOPE TREATMENT PER SECTION 4.7.1 PIMA COUNTY DESIGN STANDARDS FOR STORMWATER DETENTION.

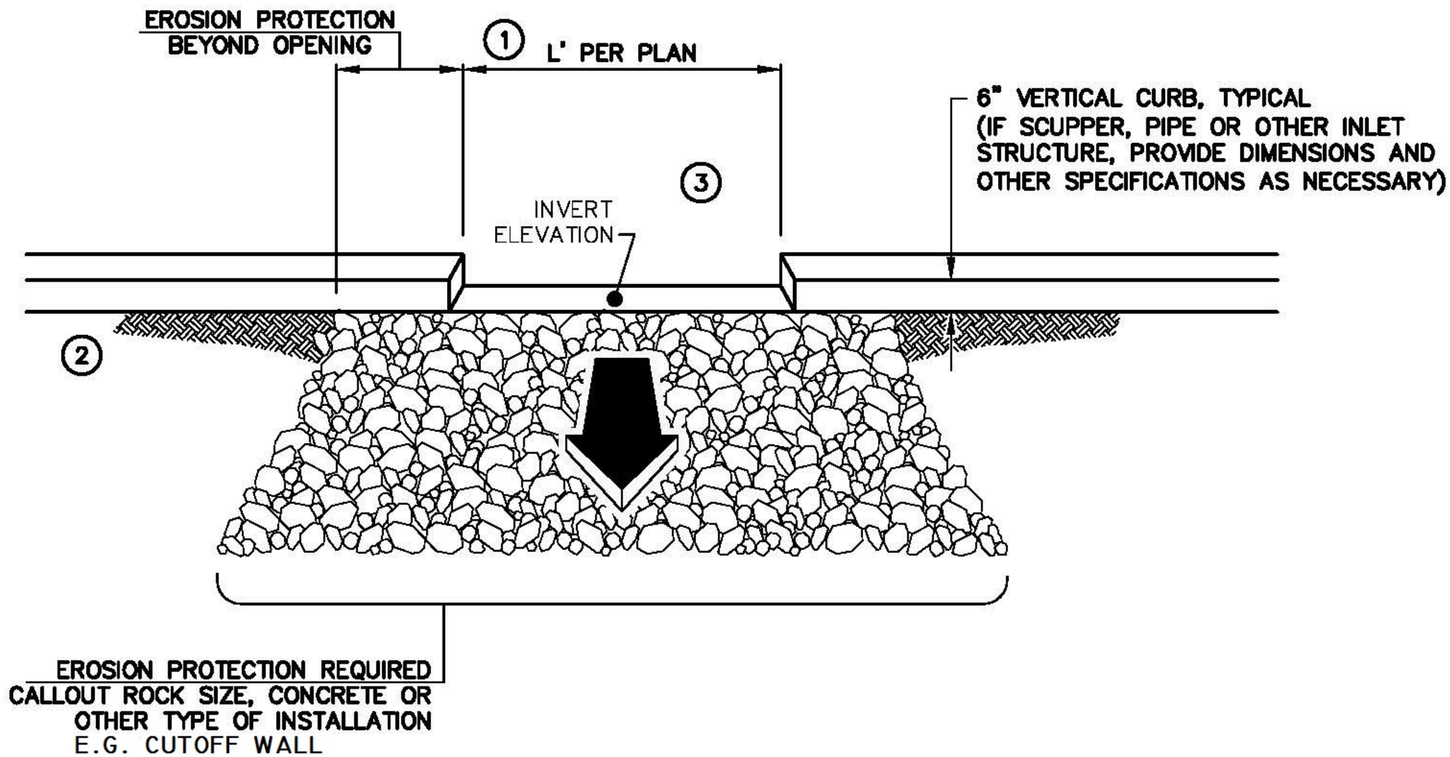
Pima County Regional FLOOD CONTROL DISTRICT

DETAIL B.1

TYPICAL CROSS-SECTION FOR EXCAVATED BASIN
PRIVATE DETENTION BASIN

SCALE: NONE DRAWN BY: sak DATE: July 2012

THE SEAL of PIMA COUNTY ARIZONA



VIEW FROM BASIN INTERIOR

① INLET DIMENSIONS TO MATCH DRAINAGE REPORT ANALYSIS AND TO BE PLACED ON PLAN VIEW.

② SLOPE TREATMENT PER SECTION 3.8.1 PIMA COUNTY DESIGN STANDARDS FOR STORMWATER DETENTION.

③ DESIGN Q_{100} AT THE INLET.

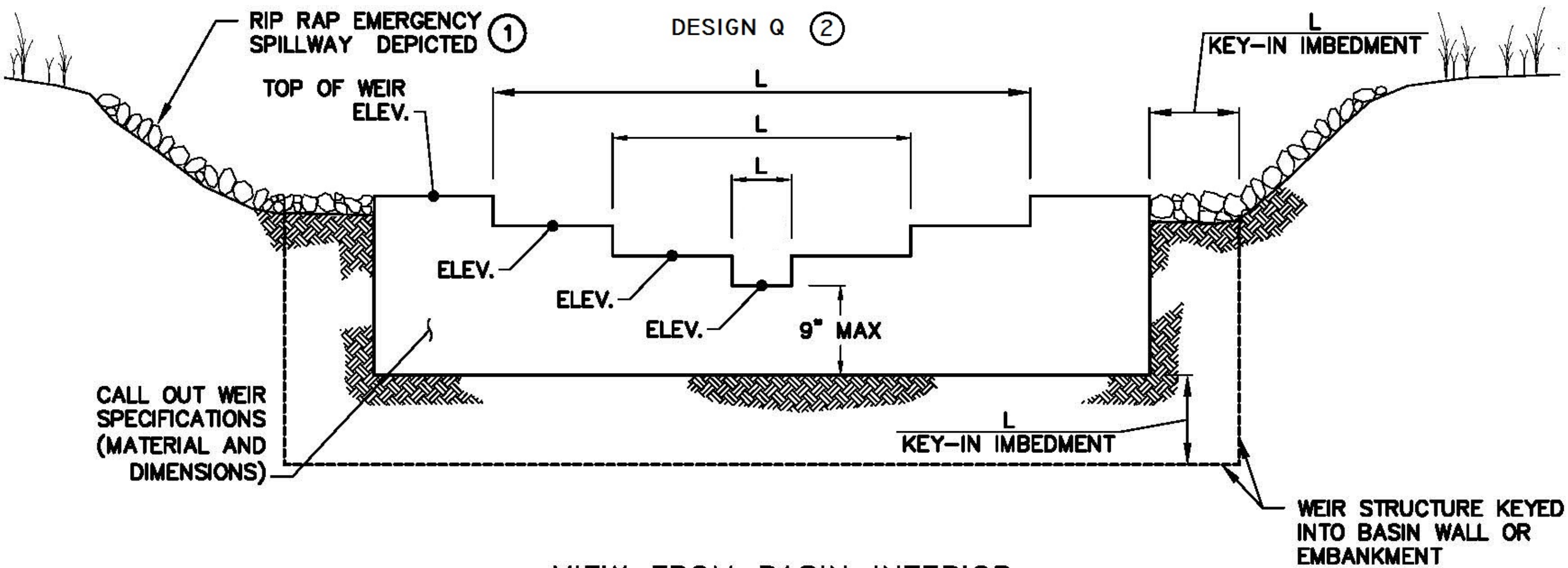
Pima County Regional FLOOD CONTROL DISTRICT

DETAIL B.2

TYPICAL BASIN INLET
PERPENDICULAR TO FLOW

SCALE: NONE | DRAWN BY: sak | DATE: JUNE 2012

THE SEAL of PIMA COUNTY ARIZONA



VIEW FROM BASIN INTERIOR

① IF EMBANKMENT, PROVIDE LENGTH AND ELEVATION OF EMERGENCY SPILLWAY.

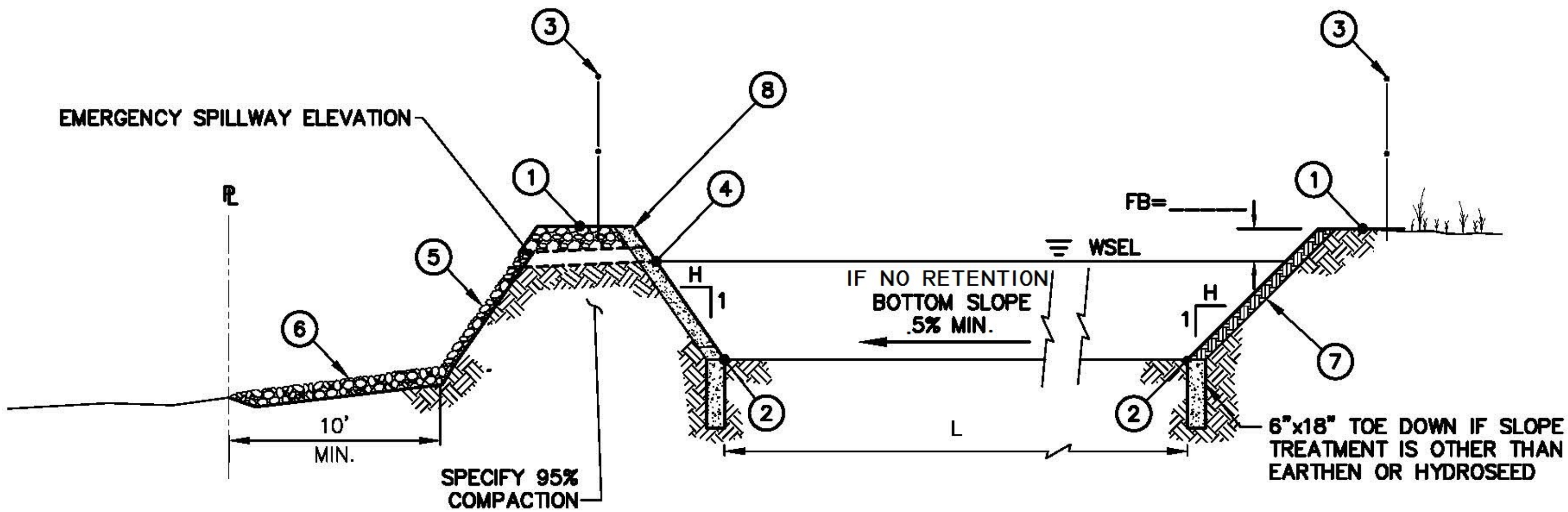
② DESIGN Q_{100}, Q_{10}, Q_2

Pima County Regional FLOOD CONTROL DISTRICT

DETAIL B.3

TYPICAL BASIN OUTLET
PERPENDICULAR TO FLOW

SCALE: NONE | DRAWN BY: sak | DATE: June 2012



(#) NOTES:

1. TOP OF SLOPE ELEVATION
2. TOE OF SLOPE ELEVATION
3. SECURITY BARRIER PER PCCOT STD/DTL. #105 OR FUNCTIONAL SUBSTITUTE, IF 100-YEAR DEPTH > 2' AND SIDE SLOPES STEEPER THAN 4:1.
4. LOWEST WEIR OR OTHER OUTLET STRUCTURE ELEVATION
5. CALL OUT ROCK SIZE AND TYPE OF INSTALLATION.
6. OUTLET PROTECTION LENGTH AND ROCK SIZE
7. SLOPE TREATMENT PER SECTION 4.7.1 PIMA COUNTY DESIGN STANDARDS FOR STORMWATER DETENTION.
8. EMBANKMENT SLOPE TREATMENT PER SECTION 4.10.1 PIMA COUNTY DESIGN STANDARDS FOR STORMWATER DETENTION.

Pima County Regional FLOOD CONTROL DISTRICT

DETAIL B.4

TYPICAL CROSS-SECTION FOR BASIN WITH EMBANKMENT CONDITIONS

PRIVATE DETENTION BASIN

SCALE: NONE | DRAWN BY: sak | DATE: June 2012

THE SEAL of PIMA COUNTY ARIZONA

APPENDIX F: MAINTENANCE CHECKLIST

Detention Basin Inspection and Maintenance Checklist

Date:	Basin Name/Location:	
Inspector:	Title:	Affiliation:
Type of Inspection: ☐ Annual ☐ After a Significant Storm Event		

General Requirements

- Basins shall be maintained to perform as designed for the life of the project and shall not be converted to a different use without a Floodplain Use Permit. A Floodplain Use Permit is not required for maintenance activities.
- Basins shall be inspected annually and after significant storm events.
- The purpose of the inspection is to evaluate whether as-built characteristics are maintained.

Basin Component	Inspection Item	Requires Maintenance	If maintenance is required, describe corrective action
Inlet	As-built grades and elevations	☐	
	Presence of obstructions	☐	
	Evidence of material damage	☐	
Outlet	As-built grades and elevations	☐	
	Presence of obstructions	☐	
	Evidence of material damage	☐	
Slopes	As-built grades and elevations	☐	
	Invasive non-native plants	☐	
	Slope treatment	☐	
Retaining walls	As-built grades and elevations	☐	
	Presence of damage or instability	☐	
	Drainage function	☐	
Depth	As-built grades and elevations	☐	
	Sediment accumulation >10% of design volume	☐	
Floor	As-built grades and elevations	☐	
	Presence of ponding	☐	
	Evidence of oil, grease, chemicals or trash	☐	
	Presence of invasive non-native plants	☐	

Detention Basin Inspection and Maintenance Checklist (Continued)

Date:	Basin Name/Location:

Basin Component	Inspection Item	Requires Maintenance	If maintenance is required, describe corrective action
Perimeter Wall	As-built grades and elevations	☐	
	Presence of damage or instability	☐	
	Drainage function	☐	
Security Barrier	Presence of damage or instability	☐	
Access	Presence of obstruction	☐	
Landscaping	Presence of overgrown vegetation	☐	
	Presence of invasive non-native plants	☐	
	Damage to basin due to landscape elements	☐	
Pump	Alarm System	☐	
	Presence of obstruction	☐	
	As-built specifications	☐	
Other			

APPENDIX G: COVENANTS

PIMA COUNTY REGIONAL FLOOD CONTROL DISTRICT
COVENANTS RUNNING WITH THE LAND

The undersigned hereby warrant to be the Owner(s) of record of the real property described in Exhibit A and hereby covenant and warrant that the Property shall be used, improved, occupied, held, sold and conveyed subject to the following conditions, covenants and restrictions running with the land.

General Conditions, Covenants and Restrictions:

1. Regional Flood Control District approval of the (Development Plan, Tentative Plat) to be recorded in the records of Pima County, Arizona, is issued in direct reliance upon representations by the Owner(s) or their agents that any development of the property shall not create a drainage or erosion danger or hazard, either on the property or on any other properties, **and that engineered, site-specific flood/erosion control improvements and (Low Impact Development Practice(s) including stormwater harvesting basins, retention swales, permeable pavement) shall be maintained as shown on the (Development Plan Tentative Plat), by all present and future Owners unless a subsequent (Development Plan, Tentative Plat) is approved that supersedes a previously approved design.**

2. The Owner(s) specify that the Low Impact Development Practice(s) shown on the (Development Plan, Tentative Plat) and on Exhibit B shall be inspected annually and after storm events. Based on these inspections the Owner(s) shall undertake maintenance, including but not limited to, removal and proper disposal of all debris, sediments, oils, weeds, overgrown landscape plants or other elements within the Low Impact Development Practice(s) areas which reduce volume or proper functioning or conveyance. The Owner shall undertake appropriate cleaning, maintenance or repairs if inspections reveal damage or deterioration to the design conditions shown on the (Development Plan, Tentative Plat).

3. **The Owner(s), their successors in interest and assigns shall assume full responsibility for their actions on the Property and shall indemnify, defend and hold harmless Pima County, and the Pima County Flood Control District**, their officers, departments, employees and agents from and against any and all suits, actions, legal or administrative proceedings, claims, demands, or damages of any kind by reason of flooding, erosion or flowage arising out of or related to the use of the property, including all injuries and damages resulting from damage to or degradation of design conditions Low Impact Development Practices.

The undersigned, referred to in this declaration as Owner(s) has executed this instrument this ________ day of

_________________________, 2014.

________________________________ ________________________________

STATE OF ARIZONA)
)ss
COUNTY OF PIMA)

This foregoing instrument was acknowledged before me this ______________ day of _________________________,

2014, by _____________________________, of ____________________________, an

___________________________________ Corporation, on behalf of the Corporation.

____
Notary Public

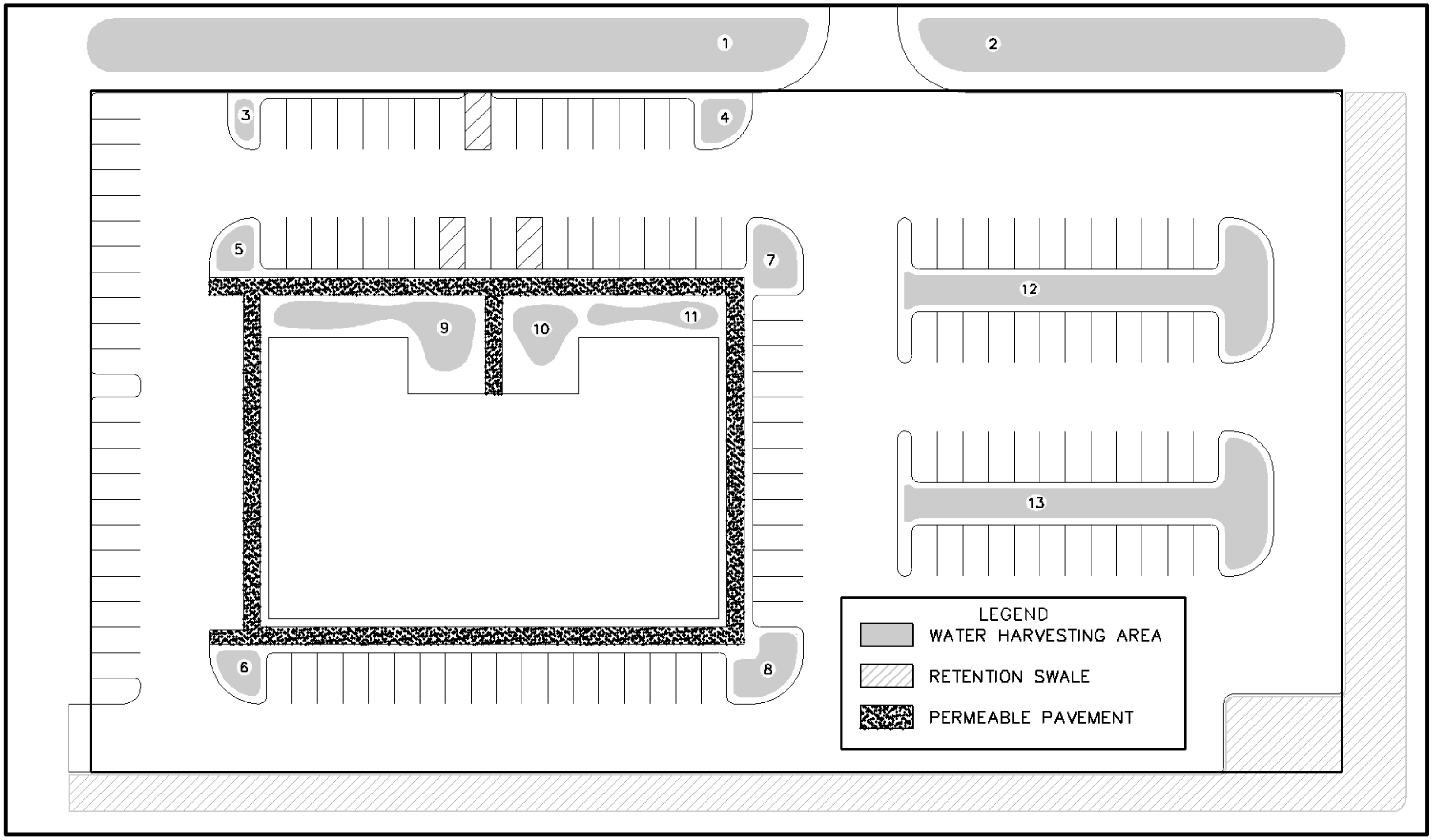
Exhibit A
(see attached)

Lot __, of ____________________________________ subdivision according to the plat of record in the office of the County Recorder of Pima County, Arizona, recorded in Book __of Maps and Plats, Page __.

Exhibit B
(see attached)

An exhibit showing the location of all Low Impact Development Practice(s) including stormwater harvesting basins, retention swales, permeable pavement to be inspected and maintained.

EXHIBIT B



WATER HARVESTING TABLE

ID #	AREA (sq.ft.)	VOL (cu.ft.)	ID #	AREA (sq.ft.)	VOL (cu.ft.)
1	?	?	8	?	?
2	?	?	9	?	?
3	?	?	10	?	?
4	?	?	11	?	?
5	?	?	12	?	?
6	?	?	13	?	?
7	?	?			

REGISTRANT SEAL

PROJECT NAME
PROJECT NUMBER

EXAMPLE: LOW IMPACT DEVELOPMENT AREAS

PIMA COUNTY REGIONAL FLOOD CONTROL DISTRICT
COVENANTS RUNNING WITH THE LAND

The undersigned hereby warrant to be the Owner(s) of record of the real property described in Exhibit A and hereby covenant and warrant that the Property shall be used, improved, occupied, held, sold and conveyed subject to the following conditions, covenants and restrictions running with the land.

General Conditions, Covenants and Restrictions:

1. Regional Flood Control District approval of the (Development Plan, Tentative Plat) to be recorded in the records of Pima County, Arizona, is issued in direct reliance upon representations by the Owner(s) or their agents that any development of the property shall not create a drainage or erosion danger or hazard, either on the property or on any other properties, **and that engineered, site-specific flood/erosion control improvements and the underground stormwater detention system(s) shall be maintained as shown on the (Development Plan, Tentative Plat), by all present and future Owners unless a subsequent (Development Plan, Tentative Plat) is approved that supercedes a previously approved design.**

2. The Owner(s) specify that the underground stormwater detention system(s) shown on the (Development Plan, Tentative Plat) and on Exhibit B shall be inspected annually and after storm events. Based on these inspections the Owner(s) shall undertake maintenance including but not limited to, removal and proper disposal of all debris and/or sediment and oils present in sumps, piping, manifolds, inlets or outlets of subsurface storage facilities, and appropriate cleaning, maintenance or repairs should conditions suggest a threat of flooding or erosion damage. The Owner(s) shall have an Arizona Registered Professional Civil Engineer prepare an annual report of inspection and maintenance performed. The Owner(s) will keep the annual reports on file at the Property.

3. **The Owner(s), their successors in interest and assigns shall assume full responsibility for their actions on the Property and shall indemnify, defend and hold harmless Pima County, and the Pima County Flood Control District,** their officers, departments, employees and agents from and against any and all suits, actions, legal or administrative proceedings, claims, demands, or damages of any kind by reason of flooding, erosion or flowage arising out of or related to the use of the property, including all injuries and damages resulting from damage to or improper functioning of underground stormwater detention systems.

The undersigned, referred to in this declaration as Owner(s) has executed this instrument this _________ day of

_________________________, 20__.

_________________________________ _________________________________

STATE OF ARIZONA)
)ss
COUNTY OF PIMA)

This forgoing instrument was acknowledged before me this ______________ day of ________________________,

20__, by ____________________________, of ___________________________, an

__________________________________ Corporation, on behalf of the Corporation.

____
Notary Public

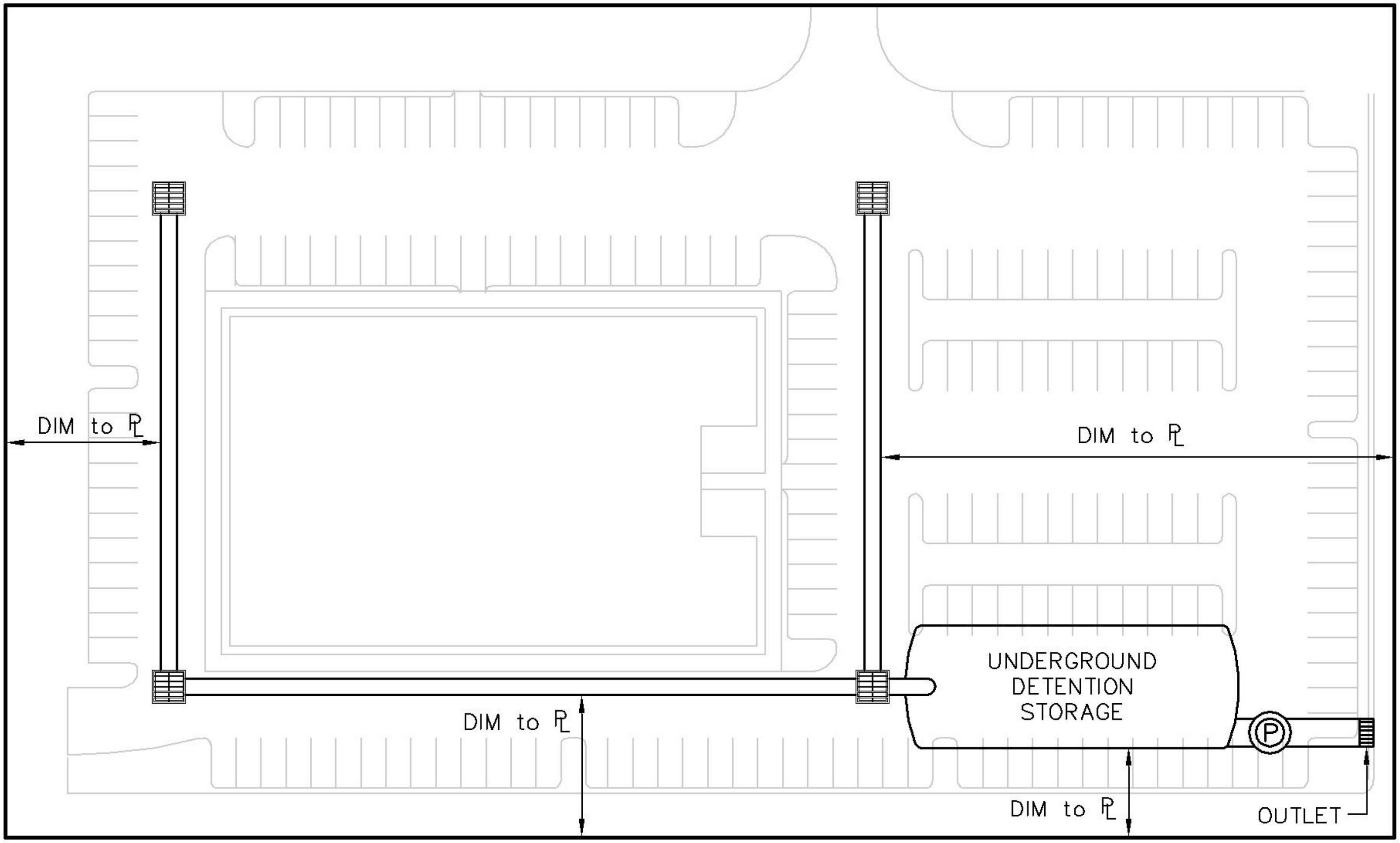
Exhibit A
(see attached)

Lot __, of ____________________________________ subdivision according to the plat of record in the office of the County Recorder of Pima County, Arizona, recorded in Book __of Maps and Plats, Page __.

Exhibit B
(see attached)

An exhibit showing the location of all underground detention systems and components to be inspected and maintained.

EXHIBIT B



DESCRIPTION OF INFRASTRUCTURE BELOW GROUND

STORAGE UNIT: (e.g. CONCRETE, VAULT)
CONVEYANCE LINES: (e.g. 300 lf. 18" RCP)
PUMP(S)*: (as per examples above) .
* IF USED

[inlet symbol]	SURFACE DRAINAGE INLETS
(P)	PUMP

EXAMPLE: UNDERGROUND DETENTION STORAGE WITH PUMP

REGISTRANT SEAL	PROJECT NAME PROJECT NUMBER

PIMA COUNTY REGIONAL FLOOD CONTROL DISTRICT
COVENANTS RUNNING WITH THE LAND

The undersigned hereby warrant to be the Owner(s) of record of the real property described in Exhibit A and hereby covenant and warrant that the Property shall be used, improved, occupied, held, sold and conveyed subject to the following conditions, covenants and restrictions running with the land.

General Conditions, Covenants and Restrictions:

1. Regional Flood Control District approval of the (Development Plan, Tentative Plat) to be recorded in the records of Pima County, Arizona, is issued in direct reliance upon representations by the Owner(s) or their agents that any development of the property shall not create a drainage or erosion danger or hazard, either on the property or on any other properties, **and that engineered, site-specific flood/erosion control improvements and storm water detention basins shall be maintained as shown on the (Development Plan, Tentative Plat), by all present and future Owners unless a subsequent (Development Plan, Tentative Plat) is approved that supersedes a previously approved design.**

2. The Owner(s) specify that the stormwater detention basin(s) shown on the (Development Plan, Tentative Plat) and on Exhibit B has(ve) been constructed with some or all of the storage volume above natural grade due to site constraints. The storage volume above natural grade is impounded behind compacted embankments which require inspection and maintenance to assure that the embankments will remain stable over the life of the project. The Owner(s) shall maintain embankments with the height, width, slope and linear extent shown on the (Development Plan, Tentative Plat). The Owners(s) or their agents shall inspect the embankments annually and after storm events to assure that the design characteristics and slope treatments have not deteriorated from the design shown on the (Development Plan, Tentative Plat). If the Owner(s) or their agents identify signs of damage, removal or instability, the Owner(s) shall undertake any necessary repairs within 90 days of the inspection which identified the need for repair.

3. **The Owner(s), their successors in interest and assigns shall assume full responsibility for their actions on the Property and shall indemnify, defend and hold harmless Pima County, and the Pima County Flood Control District**, their officers, departments, employees and agents from and against any and all suits, actions, legal or administrative proceedings, claims, demands, or damages of any kind by reason of flooding, erosion or flowage arising out of or related to the use of the property, including all injuries and damages resulting from embankment disrepair or damage.

The undersigned, referred to in this declaration as Owner(s) has executed this instrument this _________ day of

_________________________, 20__.

________________________________ ________________________________

STATE OF ARIZONA)
)ss
COUNTY OF PIMA)

This foregoing instrument was acknowledged before me this ______________ day of ________________________,

20__, by ____________________________, of ___________________________, an

__________________________________ Corporation, on behalf of the Corporation.

____
Notary Public

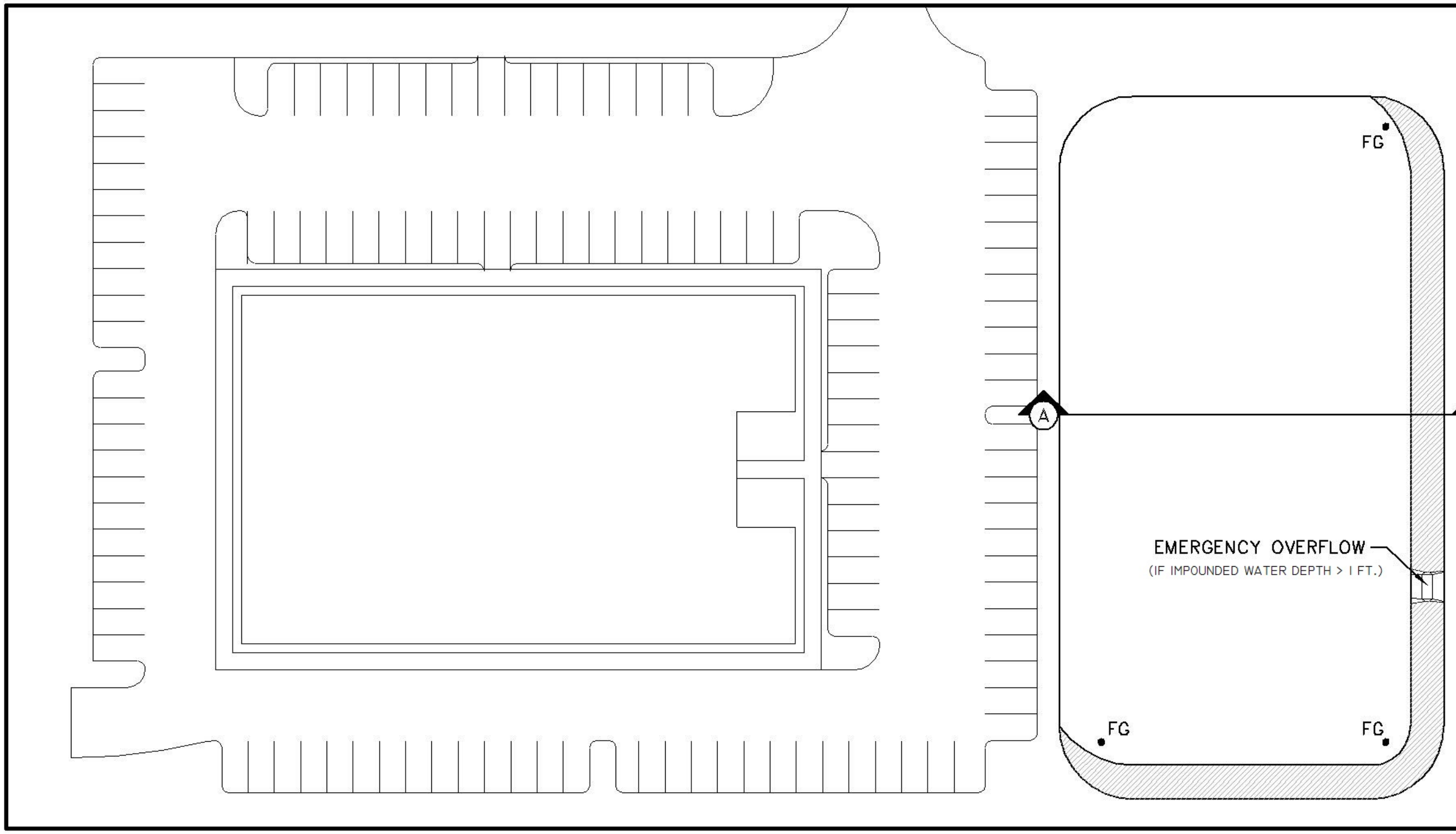
Exhibit A
(see attached)

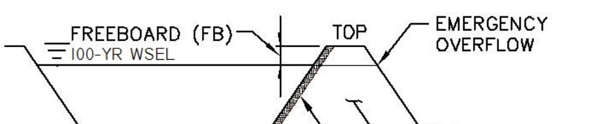
Lot __, of ____________________________________ subdivision according to the plat of record in the office of the County Recorder of Pima County, Arizona, recorded in Book __of Maps and Plats, Page __.

Exhibit B
(see attached)

An exhibit showing the location of all embankments to be inspected and maintained.

EXHIBIT B





(A) SCHEMATIC SECTION
SCALE: N.T.S.

MUST SHOW:

100-YR WSEL=____.__ft

MIN. BOTTOM ELEVATION=____.__ft

TOP ELEVATION=____.__ft

FREEBOARD=____.__ft

EMERGENCY OVERFLOW ELEVATION=____.__ft

EMBANKMENT

REGISTRANT SEAL	PROJECT NAME PROJECT NUMBER

EXAMPLE: EMBANKMENT

PIMA COUNTY REGIONAL FLOOD CONTROL DISTRICT
COVENANTS RUNNING WITH THE LAND

The undersigned hereby warrant to be the Owner(s) of record of the real property described in Exhibit A and hereby covenant and warrant that the Property shall be used, improved, occupied, held, sold and conveyed subject to the following conditions, covenants and restrictions running with the land.

General Conditions, Covenants and Restrictions:

4. Regional Flood Control District approval of the (Development Plan, Tentative Plat) to be recorded in the records of Pima County, Arizona, is issued in direct reliance upon representations by the Owner(s) or their agents that any development of the property shall not create a drainage or erosion danger or hazard, either on the property or on any other properties, **and that engineered, site-specific flood/erosion control improvements and storm water detention basins shall be maintained as shown on the (Development Plan, Tentative Plat), by all present and future Owners unless a subsequent (Development Plan, Tentative Plat) is approved that supersedes a previously approved design.**

5. The Owner(s) specify that the storm water detention basin(s) shown on the (Development Plan, Tentative Plat) and on Exhibit B has(ve) been constructed with a pump(s) to discharge some or all of the storage volume. The pump(s) and service equipment require regular and routine inspection and maintenance. The Owner(s) or their agents shall inspect the pump(s) annually and after storm events and provide required repair and maintenance to assure that the pump and service equipment continue to operate to the specifications shown on the (Development Plan, Tentative Plat). If the Owner(s) or their agents identify items requiring repair, the Owner(s) shall undertake any necessary repairs within 90 days of the inspection which identified the need for repair.

6. **The Owner(s), their successors in interest and assigns shall assume full responsibility for their actions on the Property and shall indemnify, defend and hold harmless Pima County, and the Pima County Flood Control District**, their officers, departments, employees and agents from and against any and all suits, actions, legal or administrative proceedings, claims, demands, or damages of any kind by reason of flooding, erosion or flowage arising out of or related to the use of the property, including all injuries and damages resulting from pump or service equipment disrepair or damage.

The undersigned, referred to in this declaration as Owner(s) has executed this instrument this ________ day of

_________________________, 20__.

________________________________ ________________________________

STATE OF ARIZONA)
)ss
COUNTY OF PIMA)

This foregoing instrument was acknowledged before me this ______________ day of ________________________,

20__, by ____________________________, of ___________________________, an

__________________________________ Corporation, on behalf of the Corporation.

____
Notary Public

Exhibit A
(see attached)

Lot __, of ____________________________________ subdivision according to the plat of record in the office of the County Recorder of Pima County, Arizona, recorded in Book __of Maps and Plats, Page __.

Exhibit B
(see attached)

An exhibit showing the location of all pumps to be inspected and maintained.

PIMA COUNTY REGIONAL FLOOD CONTROL DISTRICT
COVENANTS RUNNING WITH THE LAND

The undersigned hereby warrant to be the Owner(s) of record of the real property described in Exhibit A and hereby covenant and warrant that the Property shall be used, improved, occupied, held, sold and conveyed subject to the following conditions, covenants and restrictions running with the land.

General Conditions, Covenants and Restrictions:

7. Regional Flood Control District approval of the (Development Plan, Tentative Plat) to be recorded in the records of Pima County, Arizona, is issued in direct reliance upon representations by the Owner(s) or their agents that any development of the property shall not create a drainage or erosion danger or hazard, either on the property or on any other properties, **and that engineered, site-specific flood/erosion control improvements and storm water detention basins shall be maintained as shown on the (Development Plan, Tentative Plat), by all present and future Owners unless a subsequent (Development Plan, Tentative Plat) is approved that supersedes a previously approved design.**

8. The Owner(s) specify that the storm water detention basin(s) shown on the (Development Plan, Tentative Plat) and on Exhibit B has(ve) been constructed with a drywell(s) to discharge some or all of the storage volume. The drywell(s) require inspection and maintenance to assure that the drywell(s) will continue to function to the specifications shown on the (Development Plan, Tentative Plat) in perpetuity. The Owners(s) or their agents shall inspect the drywell(s) annually and after storm events. If the Owner(s) or their agents identify or are otherwise made aware of signs of damage or malfunction, the Owner(s) shall undertake any necessary repairs within 90 days of the inspection which identified the need for repair.

9. **The Owner(s), their successors in interest and assigns shall assume full responsibility for their actions on the Property and shall indemnify, defend and hold harmless Pima County, and the Pima County Flood Control District**, their officers, departments, employees and agents from and against any and all suits, actions, legal or administrative proceedings, claims, demands, or damages of any kind by reason of flooding, erosion or flowage arising out of or related to the use of the property, including all injuries and damages resulting from drywell disrepair or damage.

The undersigned, referred to in this declaration as Owner(s) has executed this instrument this _________ day of

_________________________, 20__.

_________________________________ _________________________________

STATE OF ARIZONA)
)ss
COUNTY OF PIMA)

This foregoing instrument was acknowledged before me this ______________ day of ________________________,

20__, by ____________________________, of ___________________________, an

__________________________________ Corporation, on behalf of the Corporation.

____
Notary Public

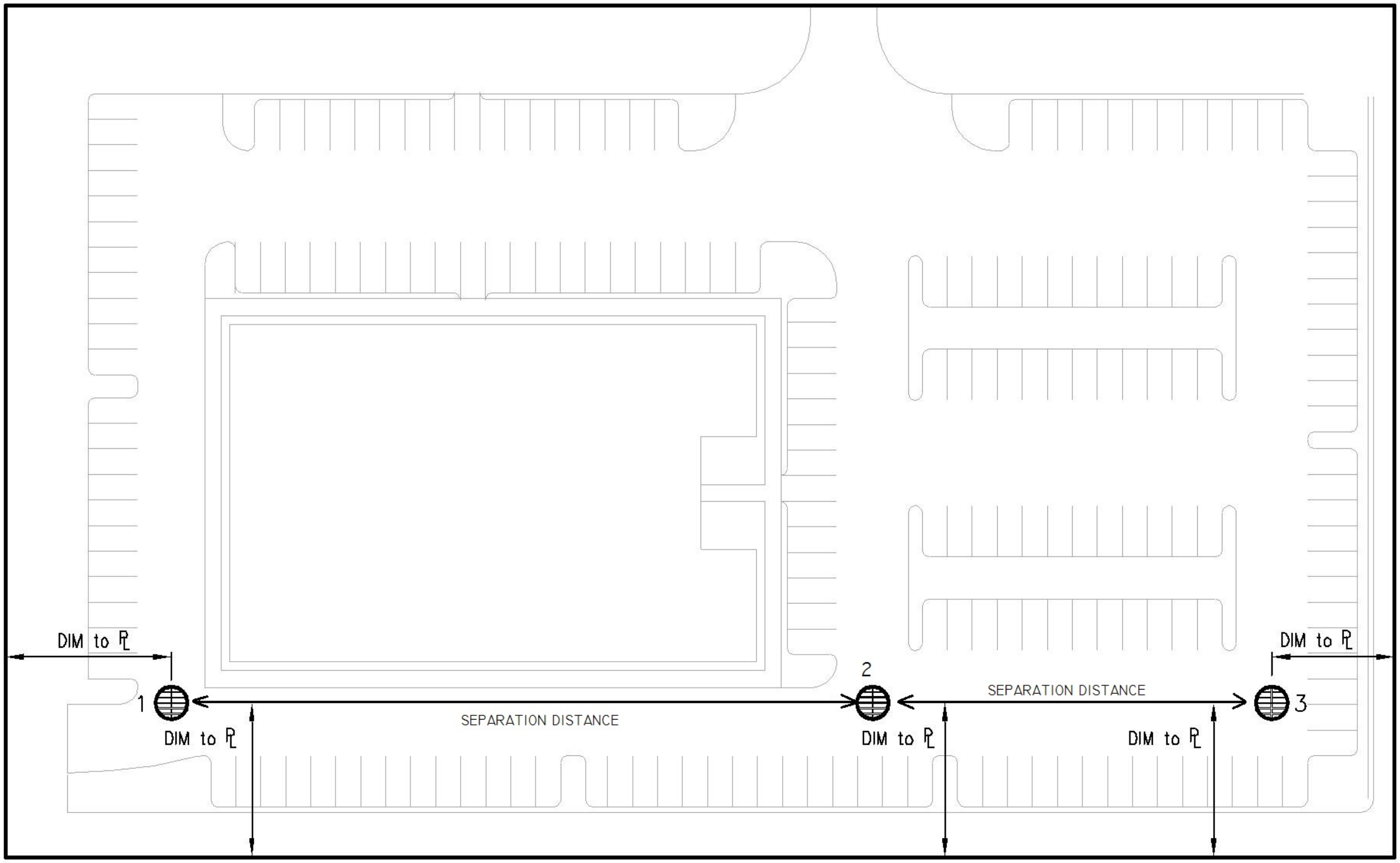
Exhibit A
(see attached)

Lot __, of ____________________________________ subdivision according to the plat of record in the office of the County Recorder of Pima County, Arizona, recorded in Book __of Maps and Plats, Page __.

Exhibit B
(see attached)

An exhibit showing the location of all drywells to be inspected and maintained.

EXHIBIT B



DRYWELL INLET

FOR EACH DRYWELL:
DESIGN FLOW RATE ____________ IN/HR
TESTED FLOW RATE ____________ IN/HR
AGED FLOW RATE ____________ IN/HR
SEPARATION DISTANCE
TO WATER WELL(S),
IF APPLICABLE ____________ FT

REGISTRANT SEAL	PROJECT NAME PROJECT NUMBER

EXAMPLE: DRYWELL INSTALLATION

APPENDIX H: HYDROGRAPH RISE TIME

The hydrograph Rise Time (T_r) is determined in the following manner:

a. For $T_c \leq 60$ minutes, read the corresponding value for T_r from Table K-1.

b. For $T_c > 60$ minutes, determine T_r from the following equation:

Equation K.1 $$T_r = \frac{0.7869\, P_n\, T_c}{P_c}$$

Where;

T_r = hydrograph rise time, in hours;
T_c = time of concentration, in hours;
P_n = *n-hour precipitation depth, in inches; and,
P_c = **precipitation depth at Tc, in inches.

*n-hour refers to the 2-, 3-, 6-, 12-, or 24-hour precipitation depths, where "n" should normally be the smallest of these values which is greater than T_c.

**P_c is calculated by linear interpolation between the calculated rainfall depths which bracket T_c. (e.g., if T_c = 2.5 hours then P_c is halfway between the 2-hour and 3-hour rainfall depths).

Hydrograph Rise Times for $T_C \leq 60$ Minutes
(T_C and T_r are in minutes)

T_C	T_r	T_C	T_r
5	13.6	33	31.9
6	14.2	34	32.3
7	15.0	35	33.0
8	15.8	36	33.5
9	16.6	37	34.2
10	17.5	38	34.7
11	18.1	39	35.2
12	18.7	40	36.0
13	19.4	41	36.6
14	19.9	42	37.2
15	20.7	43	37.8
16	21.3	44	38.4
17	21.9	45	38.7
18	22.5	46	39.3
19	23.1	47	40.0
20	23.7	48	40.4
21	24.5	49	41.1
22	25.0	50	41.8
23	25.7	51	42.2
24	26.2	52	42.9
25	27.0	53	43.3
26	27.6	54	43.7
27	28.1	55	44.5
28	28.8	56	45.0
29	29.3	57	45.4
30	29.9	58	46.3
31	30.7	59	46.7
32	31.3	60	47.2

Table K.1 Hydrograph Rise Times for $T_c \leq 60$ minutes