Surface Storage Volume Tables for Bioretention, Bioswales, Rain Gardens, and Landscape Infiltration

Tables to be used with State Highway Administration (SHA) Bioretention Soil Mix (BSM)

Limitations and Guidance:

1) These tables are used for determining the amount of surface storage required above the media. The tables can only be used with State Highway Administration (SHA) Bioretention Soil Mix (BSM) with an infiltration rate of 1 inch/hour. The tables are not valid for media with an infiltration rate different than 1 inch/hour. If SHA BSM is not used, then 75% of the ESD volume (minimum) must be stored above the surface of the media. If SHA BSM is used but the designer elects to not use the tables, then 60% of the ESD volume (minimum) must be stored above the surface of the media.
2) The Pe correlates to the drainage area of the ESD facility.
3) The vertical column is selected based on the ratio of the surface area of the ESD facility (Af) to the impervious surface in the drainage area (Ai).
4) The horizontal row is selected based on the percentage of impervious area (% Imp) in the contributing drainage area to the ESD facility.
5) The resulting percentage is the required percentage of 100% of the ESDv that must be stored as temporary ponding above the surface of the ESD facility.
6) If the design satisfies these tables, and the minimum media depths are used from the Chapter 5 guidance, then the requirement to store 75% of the ESDv will be met.

Storage Volume (% of ESDv) required above surface for Pe =								0.1	inch		
	Af/Ai										
% Imp	2%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
5%	21%	10%	3%	0%	0%	0%	0%	0%	0%	0%	0%
10%	23%	12%	3%	0%	0%	0%	0%	0%	0%	0%	0%
15%	26%	14%	5%	0%	0%	0%	0%	0%	0%	0%	0%
20%	29%	17%	6%	0%	0%	0%	0%	0%	0%	0%	0%
25%	30%	17%	6%	0%	0%	0%	0%	0%	0%	0%	0%
30%	31%	17%	6%	0%	0%	0%	0%	0%	0%	0%	0%
35%	31%	18%	6%	0%	0%	0%	0%	0%	0%	0%	0%
40%	32%	18%	6%	0%	0%	0%	0%	0%	0%	0%	0%
45%	33%	18%	6%	0%	0%	0%	0%	0%	0%	0%	0%
50%	34%	19%	6%	0%	0%	0%	0%	0%	0%	0%	0%
55%	34%	19%	6%	0%	0%	0%	0%	0%	0%	0%	0%
60%	35%	19%	6%	0%	0%	0%	0%	0%	0%	0%	0%
65%	35%	19%	6%	0%	0%	0%	0%	0%	0%	0%	0%
70%	35%	19%	6%	0%	0%	0%	0%	0%	0%	0%	0%
75%	35%	19%	6%	0%	0%	0%	0%	0%	0%	0%	0%
80%	35%	19%	6%	0%	0%	0%	0%	0%	0%	0%	0%
85%	35%	19%	6%	0%	0%	0%	0%	0%	0%	0%	0%
90%	35%	19%	6%	0%	0%	0%	0%	0%	0%	0%	0%
95%	35%	19%	6%	0%	0%	0%	0%	0%	0%	0%	0%

Storage Volume (% of ESDv) required above surface for Pe =								0.2	inch		
	Af/Ai										
% Imp	2%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
5%	32%	18%	10%	6%	3%	1%	0%	0%	0%	0%	0%
10%	32%	20%	12%	7%	3%	1%	0%	0%	0%	0%	0%
15%	35%	24%	14%	9%	5%	1%	0%	0%	0%	0%	0%
20%	38%	26%	17%	10%	6%	1%	0%	0%	0%	0%	0%
25%	39%	27%	17%	10%	6%	1%	0%	0%	0%	0%	0%
30%	39%	28%	17%	10%	6%	1%	0%	0%	0%	0%	0%
35%	40%	28%	18%	10%	6%	1%	0%	0%	0%	0%	0%
40%	41%	29%	18%	10%	6%	1%	0%	0%	0%	0%	0%
45%	42%	30%	18%	10%	6%	1%	0%	0%	0%	0%	0%
50%	42%	30%	19%	10%	6%	1%	0%	0%	0%	0%	0%
55%	43%	31%	19%	10%	6%	1%	0%	0%	0%	0%	0%
60%	44%	31%	19%	10%	6%	1%	0%	0%	0%	0%	0%
65%	44%	31%	19%	10%	6%	1%	0%	0%	0%	0%	0%
70%	44%	31%	19%	10%	6%	1%	0%	0%	0%	0%	0%
75%	44%	31%	19%	10%	6%	1%	0%	0%	0%	0%	0%
80%	44%	31%	19%	10%	6%	1%	0%	0%	0%	0%	0%
85%	44%	31%	19%	10%	6%	1%	0%	0%	0%	0%	0%
90%	44%	31%	19%	10%	6%	1%	0%	0%	0%	0%	0%
95%	44%	31%	19%	10%	6%	1%	0%	0%	0%	0%	0%

Storage Volume (% of ESDv) required above surface for Pe =								0.3	inch		
	Af/Ai										
% Imp	2%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
5%	37%	24%	14%	10%	7%	5%	3%	1%	1%	0%	0%
10%	38%	25%	16%	12%	8%	6%	3%	1%	1%	0%	0%
15%	40%	29%	20%	14%	10%	7%	5%	2%	1%	0%	0%
20%	43%	32%	23%	17%	11%	9%	6%	3%	1%	0%	0%
25%	43%	32%	23%	17%	11%	8%	6%	3%	1%	0%	0%
30%	44%	33%	24%	17%	12%	8%	6%	3%	1%	0%	0%
35%	44%	34%	24%	18%	12%	8%	6%	3%	1%	0%	0%
40%	45%	35%	25%	18%	12%	8%	6%	3%	1%	0%	0%
45%	46%	36%	25%	18%	12%	8%	6%	3%	1%	0%	0%
50%	46%	36%	26%	19%	12%	8%	6%	3%	1%	0%	0%
55%	47%	37%	26%	19%	13%	9%	6%	3%	1%	0%	0%
60%	47%	37%	27%	19%	13%	9%	6%	3%	1%	0%	0%
65%	47%	37%	27%	19%	13%	9%	6%	3%	1%	0%	0%
70%	47%	37%	27%	19%	13%	9%	6%	3%	1%	0%	0%
75%	47%	37%	27%	19%	13%	9%	6%	3%	1%	0%	0%
80%	47%	37%	27%	19%	13%	9%	6%	3%	1%	0%	0%
85%	47%	37%	27%	19%	13%	9%	6%	3%	1%	0%	0%
90%	47%	37%	27%	19%	13%	9%	6%	3%	1%	0%	0%
95%	47%	37%	27%	19%	13%	9%	6%	3%	1%	0%	0%

Storage Volume (% of ESDv) required above surface for Pe =								0.4	inch		
	Af/Ai										
% Imp	2%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
5%	39%	28%	18%	13%	10%	8%	6%	4%	3%	2%	1%
10%	41%	29%	20%	15%	12%	9%	7%	5%	3%	1%	1%
15%	43%	32%	24%	18%	14%	11%	9%	7%	5%	3%	1%
20%	45%	35%	26%	21%	17%	13%	10%	8%	6%	3%	1%
25%	46%	36%	27%	22%	17%	13%	10%	8%	6%	3%	1%
30%	46%	37%	28%	22%	17%	13%	10%	8%	6%	3%	1%
35%	47%	38%	28%	22%	18%	13%	10%	8%	6%	3%	1%
40%	48%	38%	29%	23%	18%	13%	10%	8%	6%	3%	1%
45%	48%	39%	30%	23%	18%	13%	10%	8%	6%	3%	1%
50%	49%	40%	30%	24%	19%	14%	10%	8%	6%	3%	1%
55%	50%	41%	31%	24%	19%	14%	10%	8%	6%	3%	1%
60%	50%	41%	31%	25%	19%	14%	10%	8%	6%	3%	1%
65%	50%	41%	31%	25%	19%	14%	10%	8%	6%	3%	1%
70%	50%	41%	31%	25%	19%	14%	10%	8%	6%	3%	1%
75%	50%	41%	31%	25%	19%	14%	10%	8%	6%	3%	1%
80%	50%	41%	31%	25%	19%	14%	10%	8%	6%	3%	1%
85%	50%	41%	31%	25%	19%	14%	10%	8%	6%	3%	1%
90%	50%	41%	31%	25%	19%	14%	10%	8%	6%	3%	1%
95%	50%	41%	31%	25%	19%	14%	10%	8%	6%	3%	1%

Storage Volume (% of ESDv) required above surface for Pe =								0.5	inch		
	Af/Ai										
% Imp	2%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
5%	41%	32%	21%	16%	12%	10%	8%	7%	5%	4%	3%
10%	43%	32%	23%	18%	14%	12%	10%	8%	6%	5%	3%
15%	45%	35%	26%	21%	18%	14%	12%	9%	8%	6%	5%
20%	47%	38%	29%	24%	20%	17%	13%	11%	9%	7%	6%
25%	48%	39%	30%	24%	21%	17%	14%	11%	9%	7%	6%
30%	48%	39%	31%	25%	21%	17%	14%	11%	9%	7%	6%
35%	49%	40%	31%	26%	22%	18%	14%	11%	9%	7%	6%
40%	50%	41%	32%	26%	22%	18%	14%	11%	9%	7%	6%
45%	50%	42%	33%	27%	22%	18%	14%	11%	9%	7%	6%
50%	51%	42%	34%	28%	23%	19%	15%	11%	9%	7%	6%
55%	52%	43%	34%	28%	23%	19%	15%	12%	9%	7%	6%
60%	52%	44%	35%	28%	23%	19%	15%	12%	9%	7%	6%
65%	52%	44%	35%	28%	23%	19%	15%	12%	9%	7%	6%
70%	52%	44%	35%	28%	23%	19%	15%	12%	9%	7%	6%
75%	52%	44%	35%	28%	23%	19%	15%	12%	9%	7%	6%
80%	52%	44%	35%	28%	23%	19%	15%	12%	9%	7%	6%
85%	52%	44%	35%	28%	23%	19%	15%	12%	9%	7%	6%
90%	52%	44%	35%	28%	23%	19%	15%	12%	9%	7%	6%
95%	52%	44%	35%	28%	23%	19%	15%	12%	9%	7%	6%

Storage Volume (% of ESDv) required above surface for Pe =								0.6	inch		
	Af/Ai										
% Imp	2%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
5%	42%	34%	24%	18%	14%	12%	10%	9%	7%	6%	5%
10%	45%	35%	25%	20%	16%	14%	12%	10%	8%	7%	6%
15%	47%	37%	29%	24%	20%	17%	14%	12%	10%	9%	7%
20%	49%	40%	32%	26%	23%	20%	17%	14%	11%	10%	9%
25%	49%	41%	32%	27%	23%	20%	17%	14%	11%	10%	8%
30%	50%	41%	33%	28%	24%	20%	17%	14%	12%	10%	8%
35%	50%	42%	34%	28%	24%	21%	18%	15%	12%	10%	8%
40%	51%	43%	35%	29%	25%	21%	18%	15%	12%	10%	8%
45%	52%	44%	36%	30%	25%	22%	18%	15%	12%	10%	8%
50%	52%	44%	36%	30%	26%	22%	19%	15%	12%	10%	8%
55%	53%	45%	37%	31%	26%	22%	19%	16%	13%	10%	9%
60%	53%	45%	37%	31%	27%	23%	19%	16%	13%	10%	9%
65%	53%	45%	37%	31%	27%	23%	19%	16%	13%	10%	9%
70%	53%	45%	37%	31%	27%	23%	19%	16%	13%	10%	9%
75%	53%	45%	37%	31%	27%	23%	19%	16%	13%	10%	9%
80%	53%	45%	37%	31%	27%	23%	19%	16%	13%	10%	9%
85%	53%	45%	37%	31%	27%	23%	19%	16%	13%	10%	9%
90%	53%	45%	37%	31%	27%	23%	19%	16%	13%	10%	9%
95%	53%	45%	37%	31%	27%	23%	19%	16%	13%	10%	9%

Storage Volume (% of ESDv) required above surface for Pe =								0.7	inch		
	Af/Ai										
% Imp	2%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
5%	43%	36%	26%	20%	16%	14%	12%	10%	9%	8%	6%
10%	46%	37%	27%	22%	18%	16%	13%	12%	10%	9%	7%
15%	48%	39%	30%	25%	22%	19%	17%	14%	12%	10%	9%
20%	50%	42%	33%	28%	25%	22%	19%	17%	14%	12%	11%
25%	50%	42%	34%	29%	25%	22%	20%	17%	15%	12%	11%
30%	51%	43%	35%	30%	26%	23%	20%	17%	15%	12%	11%
35%	51%	44%	36%	30%	26%	23%	20%	18%	15%	12%	11%
40%	52%	44%	37%	31%	27%	24%	21%	18%	15%	13%	11%
45%	53%	45%	38%	32%	28%	24%	21%	18%	16%	13%	11%
50%	53%	46%	38%	33%	28%	25%	21%	19%	16%	13%	11%
55%	54%	46%	39%	33%	29%	25%	22%	19%	16%	13%	11%
60%	55%	47%	39%	34%	29%	26%	22%	19%	16%	13%	11%
65%	55%	47%	39%	34%	29%	26%	22%	19%	16%	13%	11%
70%	55%	47%	39%	34%	29%	26%	22%	19%	16%	13%	11%
75%	55%	47%	39%	34%	29%	26%	22%	19%	16%	13%	11%
80%	55%	47%	39%	34%	29%	26%	22%	19%	16%	13%	11%
85%	55%	47%	39%	34%	29%	26%	22%	19%	16%	13%	11%
90%	55%	47%	39%	34%	29%	26%	22%	19%	16%	13%	11%
95%	55%	47%	39%	34%	29%	26%	22%	19%	16%	13%	11%

Storage Volume (% of ESDv) required above surface for Pe =								0.8	inch		
	Af/Ai										
% Imp	2%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
5%	43%	38%	28%	22%	18%	15%	13%	11%	10%	9%	8%
10%	46%	38%	29%	24%	20%	17%	15%	13%	12%	10%	9%
15%	49%	41%	32%	27%	24%	21%	18%	16%	14%	12%	11%
20%	51%	43%	35%	30%	26%	23%	21%	19%	17%	15%	13%
25%	51%	44%	36%	31%	27%	24%	22%	19%	17%	15%	13%
30%	52%	44%	37%	32%	28%	24%	22%	20%	17%	15%	13%
35%	52%	45%	38%	32%	28%	25%	22%	20%	18%	15%	13%
40%	53%	46%	38%	33%	29%	26%	23%	20%	18%	16%	13%
45%	54%	46%	39%	34%	30%	26%	23%	21%	18%	16%	13%
50%	54%	47%	40%	35%	30%	27%	24%	21%	19%	16%	14%
55%	55%	48%	41%	35%	31%	28%	24%	21%	19%	16%	14%
60%	55%	48%	41%	36%	31%	28%	25%	22%	19%	17%	14%
65%	55%	48%	41%	36%	31%	28%	25%	22%	19%	17%	14%
70%	55%	48%	41%	36%	31%	28%	25%	22%	19%	17%	14%
75%	55%	48%	41%	36%	31%	28%	25%	22%	19%	17%	14%
80%	55%	48%	41%	36%	31%	28%	25%	22%	19%	17%	14%
85%	55%	48%	41%	36%	31%	28%	25%	22%	19%	17%	14%
90%	55%	48%	41%	36%	31%	28%	25%	22%	19%	17%	14%
95%	55%	48%	41%	36%	31%	28%	25%	22%	19%	17%	14%

Storage Volume (% of ESDv) required above surface for Pe =								0.9	inch		
	Af/Ai										
% Imp	2%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
5%	44%	39%	30%	24%	20%	17%	14%	13%	11%	10%	9%
10%	47%	40%	31%	25%	22%	19%	16%	15%	13%	12%	11%
15%	50%	42%	34%	29%	25%	22%	20%	18%	16%	14%	13%
20%	52%	44%	37%	32%	28%	25%	23%	21%	19%	17%	15%
25%	52%	45%	37%	32%	28%	25%	23%	21%	19%	17%	15%
30%	52%	45%	38%	33%	29%	26%	24%	22%	19%	17%	15%
35%	53%	46%	39%	34%	30%	27%	24%	22%	20%	18%	16%
40%	54%	47%	40%	35%	31%	27%	25%	22%	20%	18%	16%
45%	54%	47%	41%	36%	32%	28%	25%	23%	21%	18%	16%
50%	55%	48%	41%	36%	32%	29%	26%	23%	21%	19%	16%
55%	56%	49%	42%	37%	33%	29%	26%	24%	21%	19%	17%
60%	56%	49%	42%	37%	33%	30%	27%	24%	21%	19%	17%
65%	56%	49%	42%	37%	33%	30%	27%	24%	21%	19%	17%
70%	56%	49%	42%	37%	33%	30%	27%	24%	21%	19%	17%
75%	56%	49%	42%	37%	33%	30%	27%	24%	21%	19%	17%
80%	56%	49%	42%	37%	33%	30%	27%	24%	21%	19%	17%
85%	56%	49%	42%	37%	33%	30%	27%	24%	21%	19%	17%
90%	56%	49%	42%	37%	33%	30%	27%	24%	21%	19%	17%
95%	56%	49%	42%	37%	33%	30%	27%	24%	21%	19%	17%

Storage Volume (% of ESDv) required above surface for Pe =								1	inch		
	Af/Ai										
% Imp	2%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
5%	44%	39%	32%	26%	21%	18%	16%	14%	12%	11%	10%
10%	47%	41%	32%	27%	23%	20%	18%	16%	14%	13%	12%
15%	50%	43%	35%	30%	26%	24%	21%	19%	18%	16%	14%
20%	52%	45%	38%	33%	29%	26%	24%	22%	20%	19%	17%
25%	52%	46%	39%	34%	30%	27%	24%	23%	21%	19%	17%
30%	53%	46%	39%	35%	31%	28%	25%	23%	21%	19%	17%
35%	53%	47%	40%	35%	31%	28%	26%	23%	22%	20%	18%
40%	54%	48%	41%	36%	32%	29%	26%	24%	22%	20%	18%
45%	55%	48%	42%	37%	33%	30%	27%	25%	22%	20%	18%
50%	56%	49%	42%	38%	34%	30%	28%	25%	23%	21%	19%
55%	56%	50%	43%	38%	34%	31%	28%	26%	23%	21%	19%
60%	57%	50%	44%	39%	35%	31%	28%	26%	23%	21%	19%
65%	57%	50%	44%	39%	35%	31%	28%	26%	23%	21%	19%
70%	57%	50%	44%	39%	35%	31%	28%	26%	23%	21%	19%
75%	57%	50%	44%	39%	35%	31%	28%	26%	23%	21%	19%
80%	57%	50%	44%	39%	35%	31%	28%	26%	23%	21%	19%
85%	57%	50%	44%	39%	35%	31%	28%	26%	23%	21%	19%
90%	57%	50%	44%	39%	35%	31%	28%	26%	23%	21%	19%
95%	57%	50%	44%	39%	35%	31%	28%	26%	23%	21%	19%

Storage Volume (% of ESDv) required above surface for Pe =								1.1	inch		
	Af/Ai										
% Imp	2%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
5%	44%	40%	33%	27%	23%	19%	17%	15%	13%	12%	11%
10%	48%	42%	33%	28%	24%	21%	19%	17%	15%	14%	13%
15%	51%	44%	36%	31%	27%	25%	22%	21%	19%	17%	16%
20%	53%	46%	39%	34%	30%	27%	25%	23%	22%	20%	18%
25%	53%	47%	40%	35%	31%	28%	26%	24%	22%	20%	19%
30%	53%	47%	40%	36%	32%	29%	26%	24%	22%	21%	19%
35%	54%	48%	41%	37%	33%	30%	27%	25%	23%	21%	19%
40%	55%	48%	42%	37%	34%	30%	28%	26%	23%	22%	20%
45%	55%	49%	43%	38%	34%	31%	28%	26%	24%	22%	20%
50%	56%	50%	43%	39%	35%	32%	29%	27%	24%	22%	20%
55%	57%	50%	44%	39%	36%	33%	30%	27%	25%	23%	21%
60%	57%	51%	45%	40%	36%	33%	30%	28%	25%	23%	21%
65%	57%	51%	45%	40%	36%	33%	30%	28%	25%	23%	21%
70%	57%	51%	45%	40%	36%	33%	30%	28%	25%	23%	21%
75%	57%	51%	45%	40%	36%	33%	30%	28%	25%	23%	21%
80%	57%	51%	45%	40%	36%	33%	30%	28%	25%	23%	21%
85%	57%	51%	45%	40%	36%	33%	30%	28%	25%	23%	21%
90%	57%	51%	45%	40%	36%	33%	30%	28%	25%	23%	21%
95%	57%	51%	45%	40%	36%	33%	30%	28%	25%	23%	21%

Storage Volume (% of ESDv) required above surface for Pe =								1.2	inch		
	Af/Ai										
% Imp	2%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
5%	45%	41%	34%	28%	24%	21%	18%	16%	14%	13%	12%
10%	48%	43%	35%	29%	25%	22%	20%	18%	16%	15%	14%
15%	51%	45%	37%	32%	29%	26%	24%	22%	20%	18%	17%
20%	53%	47%	40%	35%	32%	29%	26%	24%	23%	21%	20%
25%	53%	47%	41%	36%	32%	29%	27%	25%	23%	22%	20%
30%	54%	48%	41%	37%	33%	30%	28%	25%	24%	22%	20%
35%	54%	49%	42%	38%	34%	31%	28%	26%	24%	22%	21%
40%	55%	49%	43%	38%	35%	32%	29%	27%	25%	23%	21%
45%	56%	50%	44%	39%	36%	33%	30%	27%	25%	23%	22%
50%	56%	51%	44%	40%	36%	33%	30%	28%	26%	24%	22%
55%	57%	51%	45%	41%	37%	34%	31%	29%	26%	24%	22%
60%	57%	52%	45%	41%	37%	34%	31%	29%	27%	25%	23%
65%	57%	52%	45%	41%	37%	34%	31%	29%	27%	25%	23%
70%	57%	52%	45%	41%	37%	34%	31%	29%	27%	25%	23%
75%	57%	52%	45%	41%	37%	34%	31%	29%	27%	25%	23%
80%	57%	52%	45%	41%	37%	34%	31%	29%	27%	25%	23%
85%	57%	52%	45%	41%	37%	34%	31%	29%	27%	25%	23%
90%	57%	52%	45%	41%	37%	34%	31%	29%	27%	25%	23%
95%	57%	52%	45%	41%	37%	34%	31%	29%	27%	25%	23%

Storage Volume (% of ESDv) required above surface for Pe =								1.3	inch		
	Af/Ai										
% Imp	2%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
5%	45%	41%	35%	30%	25%	22%	19%	17%	15%	14%	13%
10%	48%	43%	36%	30%	26%	23%	21%	19%	18%	16%	15%
15%	51%	46%	38%	33%	30%	27%	24%	23%	21%	19%	18%
20%	53%	48%	41%	36%	32%	30%	27%	25%	24%	22%	21%
25%	54%	48%	41%	37%	33%	30%	28%	26%	24%	23%	21%
30%	54%	49%	42%	38%	34%	31%	29%	27%	25%	23%	22%
35%	55%	49%	43%	38%	35%	32%	29%	27%	25%	24%	22%
40%	55%	50%	44%	39%	36%	33%	30%	28%	26%	24%	22%
45%	56%	50%	44%	40%	37%	34%	31%	29%	27%	25%	23%
50%	57%	51%	45%	41%	37%	34%	32%	29%	27%	25%	23%
55%	57%	52%	46%	41%	38%	35%	32%	30%	28%	26%	24%
60%	58%	52%	46%	42%	38%	35%	33%	30%	28%	26%	24%
65%	58%	52%	46%	42%	38%	35%	33%	30%	28%	26%	24%
70%	58%	52%	46%	42%	38%	35%	33%	30%	28%	26%	24%
75%	58%	52%	46%	42%	38%	35%	33%	30%	28%	26%	24%
80%	58%	52%	46%	42%	38%	35%	33%	30%	28%	26%	24%
85%	58%	52%	46%	42%	38%	35%	33%	30%	28%	26%	24%
90%	58%	52%	46%	42%	38%	35%	33%	30%	28%	26%	24%
95%	58%	52%	46%	42%	38%	35%	33%	30%	28%	26%	24%

Storage Volume (% of ESDv) required above surface for Pe =								1.4	inch		
	Af/Ai										
% Imp	2%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
5%	45%	42%	36%	31%	26%	23%	20%	18%	16%	15%	14%
10%	49%	44%	37%	31%	27%	24%	22%	20%	18%	17%	16%
15%	52%	46%	39%	34%	30%	28%	25%	24%	22%	20%	19%
20%	54%	48%	42%	37%	33%	31%	28%	26%	25%	23%	22%
25%	54%	49%	42%	38%	34%	31%	29%	27%	25%	24%	22%
30%	55%	49%	43%	39%	35%	32%	30%	28%	26%	24%	23%
35%	55%	50%	44%	39%	36%	33%	30%	28%	26%	25%	23%
40%	56%	50%	44%	40%	37%	34%	31%	29%	27%	25%	24%
45%	56%	51%	45%	41%	38%	35%	32%	30%	28%	26%	24%
50%	57%	52%	46%	42%	38%	35%	33%	30%	28%	27%	25%
55%	58%	52%	46%	42%	39%	36%	33%	31%	29%	27%	25%
60%	58%	53%	47%	43%	39%	36%	34%	31%	29%	27%	26%
65%	58%	53%	47%	43%	39%	36%	34%	31%	29%	27%	26%
70%	58%	53%	47%	43%	39%	36%	34%	31%	29%	27%	26%
75%	58%	53%	47%	43%	39%	36%	34%	31%	29%	27%	26%
80%	58%	53%	47%	43%	39%	36%	34%	31%	29%	27%	26%
85%	58%	53%	47%	43%	39%	36%	34%	31%	29%	27%	26%
90%	58%	53%	47%	43%	39%	36%	34%	31%	29%	27%	26%
95%	58%	53%	47%	43%	39%	36%	34%	31%	29%	27%	26%

Storage Volume (% of ESDv) required above surface for Pe =								1.5	inch		
	Af/Ai										
% Imp	2%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
5%	45%	42%	37%	32%	27%	24%	21%	19%	17%	16%	14%
10%	49%	45%	38%	32%	28%	25%	23%	21%	19%	18%	16%
15%	52%	47%	40%	35%	31%	29%	26%	24%	23%	21%	20%
20%	54%	49%	43%	38%	34%	32%	29%	27%	25%	24%	23%
25%	54%	49%	43%	39%	35%	32%	30%	28%	26%	24%	23%
30%	55%	50%	44%	39%	36%	33%	31%	29%	27%	25%	24%
35%	55%	50%	44%	40%	37%	34%	31%	29%	27%	26%	24%
40%	56%	51%	45%	41%	38%	35%	32%	30%	28%	26%	25%
45%	57%	52%	46%	42%	38%	36%	33%	31%	29%	27%	25%
50%	57%	52%	46%	42%	39%	36%	34%	32%	29%	28%	26%
55%	58%	53%	47%	43%	40%	37%	34%	32%	30%	28%	26%
60%	58%	53%	47%	44%	40%	37%	35%	33%	30%	28%	27%
65%	58%	53%	47%	44%	40%	37%	35%	32%	30%	28%	27%
70%	58%	53%	47%	44%	40%	37%	35%	32%	30%	28%	27%
75%	58%	53%	47%	44%	40%	37%	35%	32%	30%	28%	27%
80%	58%	53%	47%	44%	40%	37%	35%	32%	30%	28%	27%
85%	58%	53%	47%	44%	40%	37%	35%	32%	30%	28%	27%
90%	58%	53%	47%	44%	40%	37%	35%	32%	30%	28%	27%
95%	58%	53%	47%	44%	40%	37%	35%	32%	30%	28%	27%

Storage Volume (% of ESDv) required above surface for Pe =								1.6	inch		
	Af/Ai										
% Imp	2%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
5%	45%	42%	38%	33%	28%	25%	22%	20%	18%	16%	15%
10%	49%	45%	38%	33%	29%	26%	24%	22%	20%	19%	17%
15%	52%	47%	41%	36%	32%	29%	27%	25%	24%	22%	21%
20%	54%	49%	43%	39%	35%	32%	30%	28%	26%	25%	23%
25%	55%	50%	44%	39%	36%	33%	31%	29%	27%	25%	24%
30%	55%	50%	44%	40%	37%	34%	32%	29%	28%	26%	24%
35%	56%	51%	45%	41%	38%	35%	32%	30%	28%	27%	25%
40%	56%	51%	46%	42%	38%	36%	33%	31%	29%	27%	26%
45%	57%	52%	46%	42%	39%	36%	34%	32%	30%	28%	26%
50%	58%	53%	47%	43%	40%	37%	35%	33%	30%	29%	27%
55%	58%	53%	48%	44%	41%	38%	35%	33%	31%	29%	28%
60%	59%	54%	48%	44%	41%	38%	36%	34%	31%	30%	28%
65%	59%	54%	48%	44%	41%	38%	36%	34%	31%	30%	28%
70%	58%	54%	48%	44%	41%	38%	36%	34%	31%	30%	28%
75%	58%	54%	48%	44%	41%	38%	36%	34%	31%	30%	28%
80%	58%	54%	48%	44%	41%	38%	36%	34%	31%	30%	28%
85%	58%	54%	48%	44%	41%	38%	36%	34%	31%	30%	28%
90%	58%	54%	48%	44%	41%	38%	36%	34%	31%	30%	28%
95%	58%	54%	48%	44%	41%	38%	36%	34%	31%	30%	28%

Storage Volume (% of ESDv) required above surface for Pe =								1.7	inch		
	Af/Ai										
% Imp	2%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
5%	45%	43%	38%	34%	29%	26%	23%	21%	19%	17%	16%
10%	49%	45%	39%	34%	30%	27%	24%	23%	21%	19%	18%
15%	52%	48%	41%	37%	33%	30%	28%	26%	24%	23%	21%
20%	54%	50%	44%	39%	36%	33%	31%	29%	27%	25%	24%
25%	55%	50%	44%	40%	37%	34%	31%	29%	28%	26%	25%
30%	55%	50%	45%	41%	37%	35%	32%	30%	28%	27%	25%
35%	56%	51%	46%	41%	38%	36%	33%	31%	29%	28%	26%
40%	57%	52%	46%	42%	39%	36%	34%	32%	30%	28%	27%
45%	57%	53%	47%	43%	40%	37%	35%	33%	31%	29%	27%
50%	58%	53%	48%	44%	41%	38%	35%	33%	31%	29%	28%
55%	58%	54%	48%	44%	41%	38%	36%	34%	32%	30%	28%
60%	59%	54%	49%	45%	42%	39%	37%	34%	32%	31%	29%
65%	59%	54%	49%	45%	42%	39%	37%	34%	32%	31%	29%
70%	59%	54%	49%	45%	42%	39%	37%	34%	32%	31%	29%
75%	59%	54%	48%	45%	42%	39%	37%	34%	32%	31%	29%
80%	59%	54%	48%	45%	42%	39%	37%	34%	32%	31%	29%
85%	59%	54%	48%	45%	42%	39%	37%	34%	32%	31%	29%
90%	59%	54%	48%	45%	42%	39%	37%	34%	32%	31%	29%
95%	59%	54%	48%	45%	42%	39%	37%	34%	32%	31%	29%

Storage Volume (% of ESDv) required above surface for Pe =								1.8	inch		
	Af/Ai										
% Imp	2%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
5%	45%	43%	39%	34%	30%	27%	24%	22%	20%	18%	17%
10%	49%	46%	40%	35%	31%	28%	25%	23%	22%	20%	19%
15%	52%	48%	42%	37%	34%	31%	29%	27%	25%	24%	22%
20%	55%	50%	44%	40%	37%	34%	32%	30%	28%	26%	25%
25%	55%	50%	45%	41%	37%	35%	32%	30%	28%	27%	25%
30%	56%	51%	45%	41%	38%	36%	33%	31%	29%	28%	26%
35%	56%	51%	46%	42%	39%	36%	34%	32%	30%	28%	27%
40%	57%	52%	47%	43%	40%	37%	35%	33%	31%	29%	27%
45%	57%	53%	47%	44%	41%	38%	36%	33%	32%	30%	28%
50%	58%	54%	48%	44%	41%	39%	36%	34%	32%	30%	29%
55%	58%	54%	49%	45%	42%	39%	37%	35%	33%	31%	29%
60%	59%	55%	49%	45%	42%	40%	37%	35%	33%	31%	30%
65%	59%	55%	49%	45%	42%	40%	37%	35%	33%	31%	30%
70%	59%	55%	49%	45%	42%	40%	37%	35%	33%	31%	30%
75%	59%	55%	49%	45%	42%	40%	37%	35%	33%	31%	30%
80%	59%	55%	49%	45%	42%	40%	37%	35%	33%	31%	30%
85%	59%	55%	49%	45%	42%	40%	37%	35%	33%	31%	30%
90%	59%	55%	49%	45%	42%	40%	37%	35%	33%	31%	30%
95%	59%	55%	49%	45%	42%	40%	37%	35%	33%	31%	30%

Storage Volume (% of ESDv) required above surface for Pe =								1.9	inch		
	Af/Ai										
% Imp	2%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
5%	45%	43%	39%	35%	31%	28%	25%	22%	20%	19%	17%
10%	49%	46%	40%	35%	31%	28%	26%	24%	22%	21%	20%
15%	53%	49%	43%	38%	34%	32%	29%	27%	26%	24%	23%
20%	55%	51%	45%	41%	37%	34%	32%	30%	28%	27%	26%
25%	55%	51%	45%	41%	38%	35%	33%	31%	29%	28%	26%
30%	56%	51%	46%	42%	39%	36%	34%	32%	30%	28%	27%
35%	56%	52%	47%	43%	40%	37%	35%	33%	31%	29%	28%
40%	57%	53%	47%	43%	40%	38%	36%	33%	32%	30%	28%
45%	57%	53%	48%	44%	41%	38%	36%	34%	32%	31%	29%
50%	58%	54%	49%	45%	42%	39%	37%	35%	33%	31%	30%
55%	59%	55%	49%	45%	43%	40%	38%	36%	34%	32%	30%
60%	59%	55%	50%	46%	43%	40%	38%	36%	34%	32%	31%
65%	59%	55%	50%	46%	43%	40%	38%	36%	34%	32%	31%
70%	59%	55%	50%	46%	43%	40%	38%	36%	34%	32%	31%
75%	59%	55%	50%	46%	43%	40%	38%	36%	34%	32%	31%
80%	59%	55%	50%	46%	43%	40%	38%	36%	34%	32%	31%
85%	59%	55%	50%	46%	43%	40%	38%	36%	34%	32%	31%
90%	59%	55%	50%	46%	43%	40%	38%	36%	34%	32%	31%
95%	59%	55%	50%	46%	43%	40%	38%	36%	34%	32%	31%

Storage Volume (% of ESDv) required above surface for Pe =								2 - 2.6	inches		
	Af/Ai										
% Imp	2%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
5%	46%	43%	39%	36%	32%	28%	26%	23%	21%	19%	18%
10%	50%	46%	41%	36%	32%	29%	27%	25%	23%	21%	20%
15%	53%	49%	43%	39%	35%	32%	30%	28%	26%	25%	24%
20%	55%	51%	45%	41%	38%	35%	33%	31%	29%	28%	26%
25%	55%	51%	46%	42%	39%	36%	34%	32%	30%	28%	27%
30%	56%	52%	46%	42%	39%	37%	35%	32%	31%	29%	28%
35%	56%	52%	47%	43%	40%	38%	35%	33%	31%	30%	28%
40%	57%	53%	48%	44%	41%	38%	36%	34%	32%	31%	29%
45%	58%	54%	48%	45%	42%	39%	37%	35%	33%	31%	30%
50%	58%	54%	49%	45%	42%	40%	38%	36%	34%	32%	30%
55%	59%	55%	50%	46%	43%	41%	38%	36%	34%	33%	31%
60%	59%	55%	50%	46%	44%	41%	39%	37%	35%	33%	31%
65%	59%	55%	50%	46%	43%	41%	39%	37%	35%	33%	31%
70%	59%	55%	50%	46%	43%	41%	39%	37%	35%	33%	31%
75%	59%	55%	50%	46%	43%	41%	39%	37%	35%	33%	31%
80%	59%	55%	50%	46%	43%	41%	39%	37%	35%	33%	31%
85%	59%	55%	50%	46%	43%	41%	39%	37%	35%	33%	31%
90%	59%	55%	50%	46%	43%	41%	39%	37%	35%	33%	31%
95%	59%	55%	50%	46%	43%	41%	39%	37%	35%	33%	31%

Intent

Bioretention, bioswales, rain gardens, and landscape infiltration treat runoff by allowing stormwater to filter through a layer of planting soil that is rich with micro-organisms. To be filtered effectively by the facility, stormwater must enter the soil media. If the filtering practice is located in a swale there is uncertainty about whether the flow will enter the media or runoff down the swale and bypass treatment. The same concern extends to bioretention, rain gardens, and landscape infiltration because the Environmental Site Design (ESD) volume for any facility served by an overflow device has the potential to prematurely flow out of the facility and bypass treatment. The only way to allow the ESD volume adequate opportunity to enter the filter media is by providing surface storage above the filter media to detain the runoff. But how much storage is necessary?

The Sediment and Stormwater Plan Review Division with help from the State Highway Administration (SHA) examined this question by applying hydrologic/hydraulic principals for a bioswale to a basic reservoir analysis. A "calculator" was developed that modeled the stormwater flows to the bioswale, flow rates through the media, and storage volume. (Refer to "**Bio-Swale Storage Calculator"** for more information.) The resulting output provides surface storage volumes necessary for treating ESD volume. Storage requirements vary significantly depending on the target rainfall (P_E) being treated, the surface area of the filter, and the imperviousness of the drainage area. For example, a facility with a larger surface area requires less surface storage than one with a smaller surface area. Because of the complexity of the Calculator, tables for design purposes were developed from a broad range of simulations. (Refer to "**Development of Tables**" for an explanation of how the tables were developed.)

Limitations

The Calculator assumes that the filter media is comprised of SHA bio-soil mix (BSM) with an infiltration rate of 1 inch per hour. The Surface Storage Tables are not valid for use on treatment facilities that have a different infiltration rate than SHA BSM. If a filter planting media is used that has a different infiltration rate from the SHA BSM, then 75% of the ESD volume (ESDv) should be provided above the surface of the filter. The Calculator and Surface Storage Tables also assume that the layer of planting media (SHA BSM) will be the limiting factor in determining the overall facility infiltration rate. The Surface Storage Tables will not be accurate for treatment facilities without an underdrain located on soils with an infiltration rate of less than 1 in./hr. In this situation the surface storage volume shall be at least equal to the 75% ESDv treatment requirement.

Using the Surface Storage Volume Tables

From the twenty tables provided, select the appropriate table for the respective target P_E (in), ranging from 0.1 inch to 2.6 inches. Note that the P_E correlates to the drainage area of the ESD facility. Enter the left side of the table for the imperviousness [%Imp = impervious area draining to facility (A_i)/drainage area to facility (A) = 100(A_i /A)] of the contributing drainage area to the ESD facility (negating the area occupied by the facility itself). Enter the top of the table for the ratio of the surface area of the facility (A_f) to the impervious area draining to the facility (A_i). The point where these two values intersect is the minimum required surface storage volume, expressed as a percentage of the ESDv. Multiplying this percentage by **100% of the required ESDv** gives the ponding volume that must be temporarily stored above the filter bed surface of the ESD facility in order to fully treat the respective P_E.

If the ESD facility provides the required surface storage and the minimum media depths given in MDE guidance, then the design requirements, including the 75% of the ESDv treatment requirement, will be satisfied.

Example 1 (insufficient surface storage)

Drainage area criteria

A 10,000 square foot area drains to a proposed micro biorention facility. (The drainage area includes facility.) The drainage area contains 4000 ft^2 of impervious area, and the hydrologic soil group is C.

Calculate

$I = 4000\ ft^2/10{,}000\ ft^2 = 0.4 = 40\%$

$R_v = 0.05+0.009(I) = 0.05+0.009(40) = 0.41$

The target P_E for the drainage area to the facility is 1.8 inches.

$ESDv = (P_E)(R_v)(A)/12 = (1.8\ in)(0.41)(10{,}000\ ft^2)/(12in/ft) = 615\ ft^3$

Biorention facility geometry

The surface area of the filter is 800 ft^2.

The storage provided above the surface of the media is 185 ft^3.

Quantifying the target rainfall (P_E) treated

Using the table for P_E =1.8 inches, enter at %Imp = 40% and $A_f/A_i = 800\ ft^2/4000\ ft^2 = 20\%$. Read the required surface storage as 40%.

The provided surface storage is only 185 ft^3/615 ft^3 = 30%. Therefore, the P_E of 1.8 inch is not being completely treated. At this point, the designer needs to either (1) revise the design of the facility so that the required surface storage is provided or (2) calculate the P_E treated (or achieved) based on the current design.

(1) Revising the design of the facility to treat the full target P_E can be accomplished by:
   a. Providing more surface storage;
   b. Increasing the surface area of the filter; and/or
   c. Reducing the % Impervious in the drainage area to the filter.

(2) Calculate the P_E treated
   The proposed facility does not provide enough surface storage to treat the target P_E of 1.8 inches. The P_E treated is based on providing a surface storage volume that is a certain percent of the ESDv, but that ESDv changes depending on the P_E. Therefore, determining the P_E treated is an iterative process. Continue the iterations until the actual storage and required storage are equal. This is best demonstrated in a table.

Iteration	P_E	ESDv	required % surface storage from tables	actual % surface storage = (185 ft^3 /ESDv)
1	1.8 in	615 ft^3	40 %	30 %
2	0.9 in	308 ft^3	31 %	60 %
3	1.2 in	410 ft^3	35 %	45 %
4	1.4 in	478 ft^3	37 %	39 %
5	1.5 in	512 ft^3	38 %	36 %

The achieved P_E for this example is 1.45 inches, and the ESDv attained by the facility is 495 ft^3.

Example 2 (excess surface storage)

Drainage area criteria

A 10,000 square foot area drains to a proposed micro biorention facility. (The drainage area includes facility.) The drainage area contains 4000 ft^2 of impervious area, and the hydrologic soil group is C.

Calculate $I = 4000\ ft^2/10{,}000\ ft^2 = 0.4 = 40\%$

$R_v = 0.05+0.009(I) = 0.05+0.009(40) = 0.41$

The target P_E for the drainage area to the facility is 1.8 inches.

$ESDv = (P_E)(R_v)(A)/12 = (1.8\ in)(0.41)(10{,}000\ ft^2)/(12in/ft) = 615\ ft^3$

Biorention facility geometry

The surface area of the filter is 800 ft^2.

The storage provided above the surface of the media is 280 ft^3.

Quantifying the target rainfall (P_E) treated

Using the table for P_E =1.8 inches, enter at %Imp = 40% and $A_f/A_i = 800\ ft^2/4000\ ft^2 = 20\%$. Read the required surface storage as 40%.

The provided surface storage is 280 $ft^3/615\ ft^3$ = 46%. Therefore, more than enough surface storage is being provided. The excess storage means that the P_E being treated is larger than the target.

The P_E treated is based on providing a surface storage volume that is a certain percent of the ESDv, but that ESDv changes depending on the P_E. Therefore, determining the P_E treated is an iterative process. Continue the iterations until the actual storage and required storage are equal. This is best demonstrated in a table.

Iteration	P_E	ESDv	required % surface storage from tables	actual % surface storage = (280 ft^3 /ESDv)
1	1.8 in	615 ft^3	40 %	46 %
2	1.9 in	649 ft^3	40 %	43 %
3	2.0 in	683 ft^3	41 %	41 %

The achieved P_E for this example is 2.0 inches, and the ESDv attained by the facility is 683 ft^3.

Bio-Swale Storage Calculator

The calculator modeled stormwater flows to a facility, flow rates through the media, and storage. Runoff was computed using SCS methodologies and the Method for Computing Peak Discharge for Water Quality Storm found in Appendix D.10 of the 2000 Maryland Stormwater Design Manual. This method was used to compute the Runoff Curve Number (CN) because conventional SCS methods underestimate the volume and rate of runoff for rainfall events less than 2 inches. The Ia/P value was calculated from the user-entered site information and based on Equations 2-2 and 2-4 found in Chapter 2 of the TR-55 Manual. The Calculator used the calculated Ia/P to determine the unit peak discharge that was used for each time interval. The Tabular Hydrograph Unit Discharges (csm/in) for Type II Rainfall Distribution tables from Chapter 5 of the TR-55 Manual for drainage areas with a Tc of 0.1 and an Ia/P of 0.1, 0.3, and 0.5 were included in the Calculator. The Calculator used linear interpolation to calculate the unit discharge for any drainage area with an Ia/P value between the Ia/P values supplied by the TR-55 tables. For Ia/P values smaller than 0.1 or larger than 0.5, the unit discharges corresponding to the Ia/P of 0.1 and 0.5 were used, respectively. An Excel forecast and match function was used to interpolate between the time intervals for the TR-55 supplied unit discharges to develop a table of unit discharges starting at hour 11 of the rainfall event to hour 26 at a constant time interval of 0.1 hour. The peak discharge into the bioswale was calculated at each time interval using equation 4.1 from Chapter 4 of the TR-55 Manual.

The volume of water that infiltrated into the media at each time interval was calculated using the surface area of the filter media (A_f) and a media filtration rate of 2 feet per day (1 inch per hour). This filtration rate was approved for use with SHA BSM in 2003. The porosity of the media was 40%. The bottom width of the bioswales was held at a constant 8 feet. The length of the bioswale was adjusted to achieve the A_f required to satisfy the user entered A_f /A_i ratio. The planting media depth was a constant 2 feet.

When the stormwater runoff volume that entered the treatment facility during the 0.1 hour time interval exceeded the volume of water infiltrated into the media bed, the volume of water that did not infiltrate was added to the temporary surface storage volume. As the temporary surface storage volume increased, the Calculator used Darcy's law to increase the infiltration rate slightly as the depth of the water stored above the filter bed surface generated hydraulic head. The Calculator assumed a constant surface storage depth across the entire treatment facility (i.e. 0% longitudinal bioswale slope). The Calculator also assumed that water is only stored directly above the filter bed (i.e., no side slopes). For every time interval where the volume of stormwater runoff that entered the treatment facility was greater than the volume of water that infiltrated into the filter bed media, the excess volume was added to the surface storage volume. Once the rate of the stormwater runoff entering the treatment facility decreased below the rate at which water infiltrated into the filter bed media, the water stored above the surface of the filter bed began to drain through the filter media. The surface storage volume used to calculate the surface storage requirement is the maximum surface storage volume achieved before the stormwater runoff entering the facility subsided to the point where the water stored above the surface will begin to decrease.

Development of Tables

The Calculator was used to develop the Surface Storage Volume Tables. Simulations were repeated for rainfalls ranging from 0.1 inches to 2.6 inches at 0.1 inch intervals. Each 24 hour rainfall rate was used to generate a separate surface storage table. The surface storage tables for rainfall from 2.0 to 2.6 inches were consolidated into one table because there were negligible differences between these tables. A drainage area of 1 acre was used. However, the drainage area does not affect the results of the Surface Storage Tables because the Calculator adjusts the surface area of the treatment facility (A_f) based on a user entered filter surface area to impervious area ratio (A_f /A_i). This causes the A_f to rise to match an increase in the drainage area. Within each target rainfall table, a specific A_f /A_i ratio and site impervious percent was used to calculate a surface storage volume requirement. This surface storage volume requirement is expressed as a percent of the 100% ESDv for the drainage area to the treatment facility.