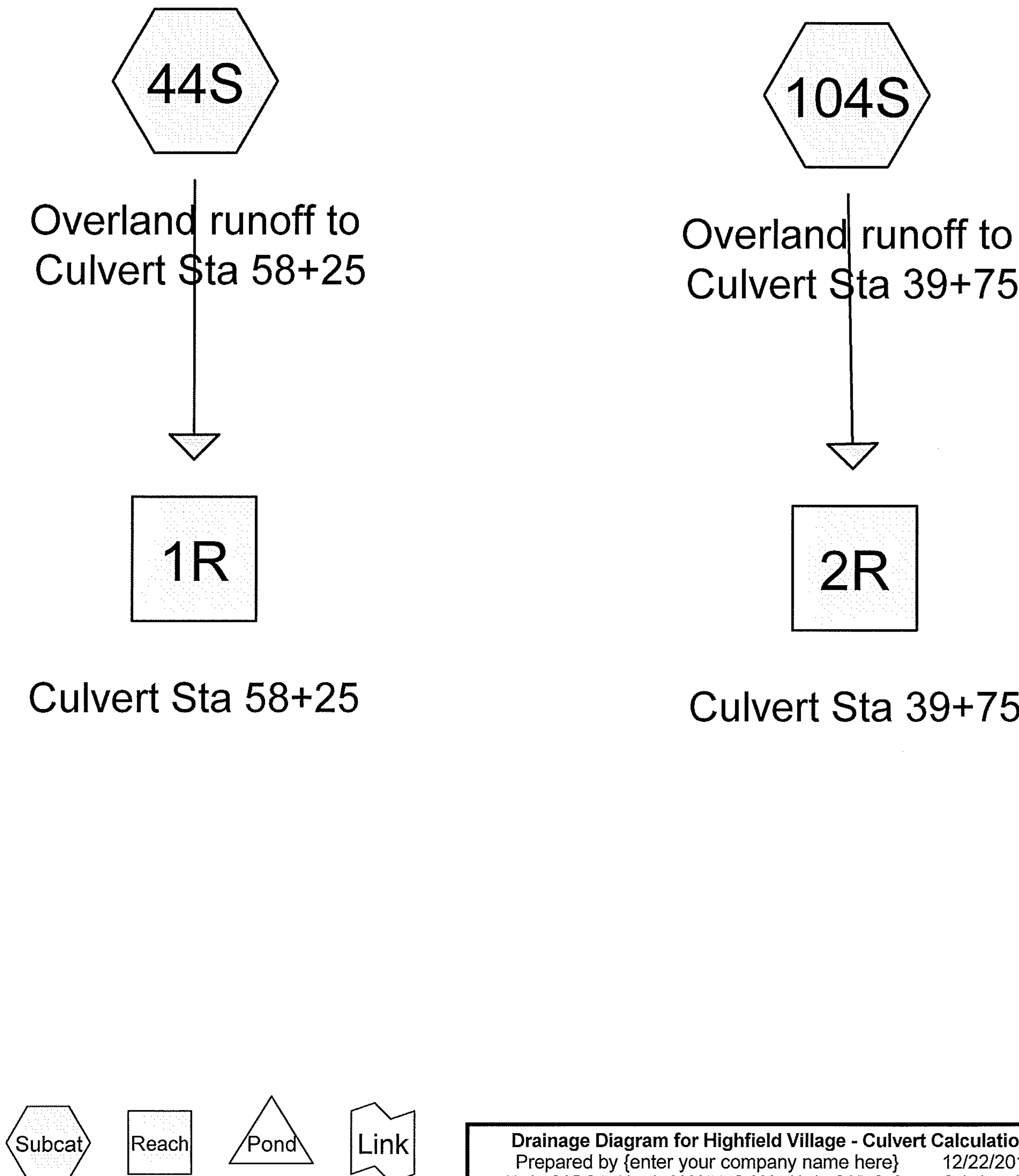
CULVERT CROSSING CALCULATIONS



Drainage Diagram for Highfield Village - Culvert Calculations
Prepared by {enter your company name here} 12/22/2015

Time span=5.00-20.00 hrs, dt=0.05 hrs, 301 points
Runoff by SCS TR-20 method, UH=SCS
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 44S: Overland runoff to Culvert Sta 58+25 Runoff Area=2.720 ac Runoff Depth>3.44"
Flow Length=505' Tc=10.2 min CN=74 Runoff=10.12 cfs 0.780 af

Subcatchment 104S: Overland runoff to Culvert Sta 39+75 Runoff Area=0.950 ac Runoff Depth>3.33"
Flow Length=170' Tc=25.2 min CN=73 Runoff=2.44 cfs 0.263 af

Reach 1R: Culvert Sta 58+25 Peak Depth=0.09' Max Vel=3.9 fps Inflow=10.12 cfs 0.780 af
n=0.022 L=58.0' S=0.0862 '/' Capacity=3,287.78 cfs Outflow=10.06 cfs 0.780 af

Reach 2R: Culvert Sta 39+75 Peak Depth=0.05' Max Vel=1.8 fps Inflow=2.44 cfs 0.263 af
n=0.022 L=55.0' S=0.0364 '/' Capacity=2,135.33 cfs Outflow=2.43 cfs 0.263 af

Total Runoff Area = 3.670 ac Runoff Volume = 1.044 af Average Runoff Depth = 3.41"

Subcatchment 44S: Overland runoff to Culvert Sta 58+25

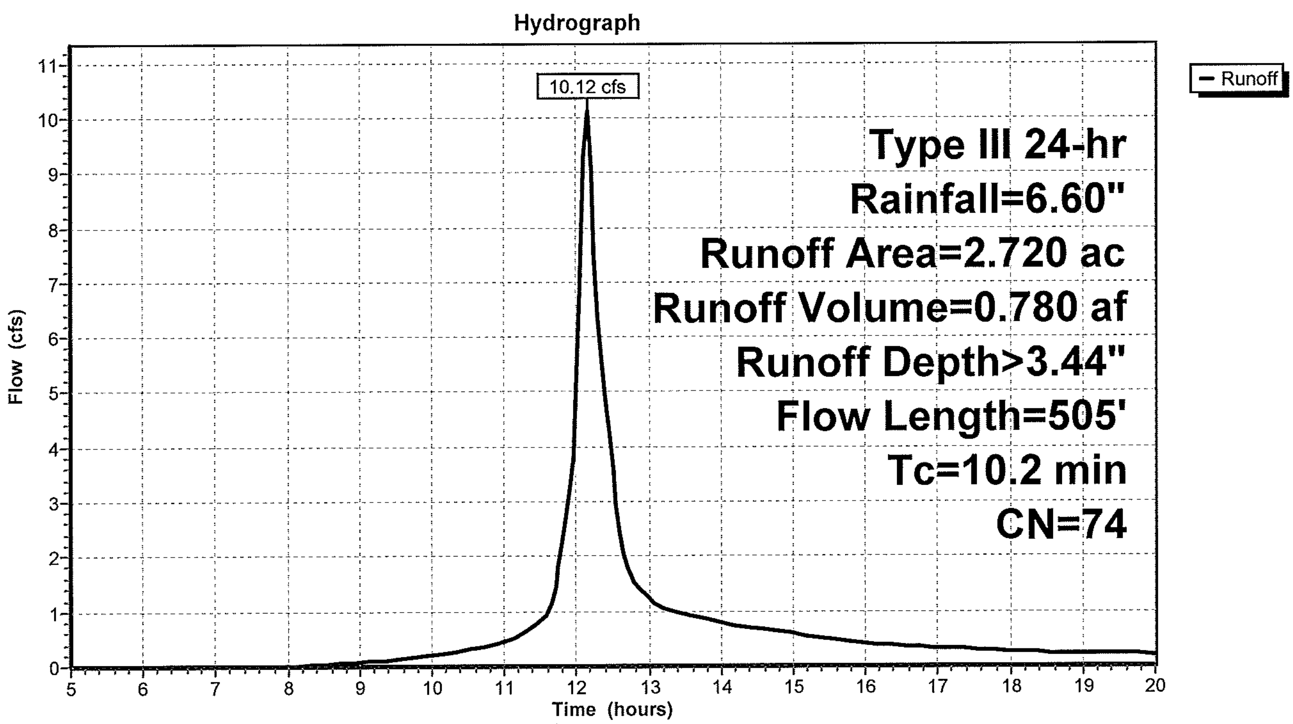
Runoff = 10.12 cfs @ 12.15 hrs, Volume= 0.780 af, Depth> 3.44"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr Rainfall=6.60"

Area (ac)	CN	Description
0.220	98	Paved parking & roofs
1.140	74	>75% Grass cover, Good, HSG C
1.360	70	Woods, Good, HSG C
2.720	74	Weighted Average

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.3	50	0.0400	0.2		**Sheet Flow, Path 1** Grass: Short n= 0.150 P2= 3.20"
5.9	455	0.0659	1.3		**Shallow Concentrated Flow, Path 2** Woodland Kv= 5.0 fps
10.2	505	Total			

Subcatchment 44S: Overland runoff to Culvert Sta 58+25



Hydrograph for Subcatchment 44S: Overland runoff to Culvert Sta 58+25

Time (hours)	Precip. (inches)	Excess (inches)	Runoff (cfs)
5.00	0.37	0.00	0.00
5.25	0.40	0.00	0.00
5.50	0.42	0.00	0.00
5.75	0.45	0.00	0.00
6.00	0.48	0.00	0.00
6.25	0.50	0.00	0.00
6.50	0.53	0.00	0.00
6.75	0.56	0.00	0.00
7.00	0.60	0.00	0.00
7.25	0.63	0.00	0.00
7.50	0.67	0.00	0.00
7.75	0.71	0.00	0.00
8.00	0.75	0.00	0.01
8.25	0.80	0.00	0.02
8.50	0.85	0.01	0.03
8.75	0.90	0.01	0.05
9.00	0.96	0.02	0.07
9.25	1.03	0.03	0.10
9.50	1.10	0.04	0.13
9.75	1.17	0.05	0.16
10.00	1.25	0.07	0.20
10.25	1.33	0.10	0.24
10.50	1.43	0.12	0.30
10.75	1.53	0.16	0.37
11.00	1.65	0.20	0.45
11.25	1.79	0.26	0.58
11.50	1.97	0.33	0.82
11.75	2.34	0.52	1.82
12.00	3.30	1.10	**4.87**
12.25	4.26	1.79	**7.52**
12.50	4.63	2.08	3.59
12.75	4.81	2.21	1.64
13.00	4.95	2.32	1.25
13.25	5.07	2.42	1.03
13.50	5.17	2.50	0.94
13.75	5.27	2.58	0.86
14.00	5.35	2.65	0.78
14.25	5.43	2.71	0.71
14.50	5.50	2.77	0.67
14.75	5.57	2.83	0.63
15.00	5.64	2.88	0.59
15.25	5.70	2.93	0.55
15.50	5.75	2.98	0.50
15.75	5.80	3.02	0.46
16.00	5.85	3.06	0.42
16.25	5.89	3.09	0.39
16.50	5.93	3.13	0.37
16.75	5.97	3.16	0.35
17.00	6.00	3.19	0.33
17.25	6.04	3.22	0.31
17.50	6.07	3.24	0.29
17.75	6.10	3.27	0.28
18.00	6.12	3.29	0.26
18.25	6.15	3.31	0.24
18.50	6.18	3.33	0.24
18.75	6.20	3.35	0.23
19.00	6.23	3.38	0.23
19.25	6.25	3.40	0.22
19.50	6.27	3.41	0.22
19.75	6.29	3.43	0.21
20.00	**6.32**	**3.45**	0.20

Subcatchment 104S: Overland runoff to Culvert Sta 39+75

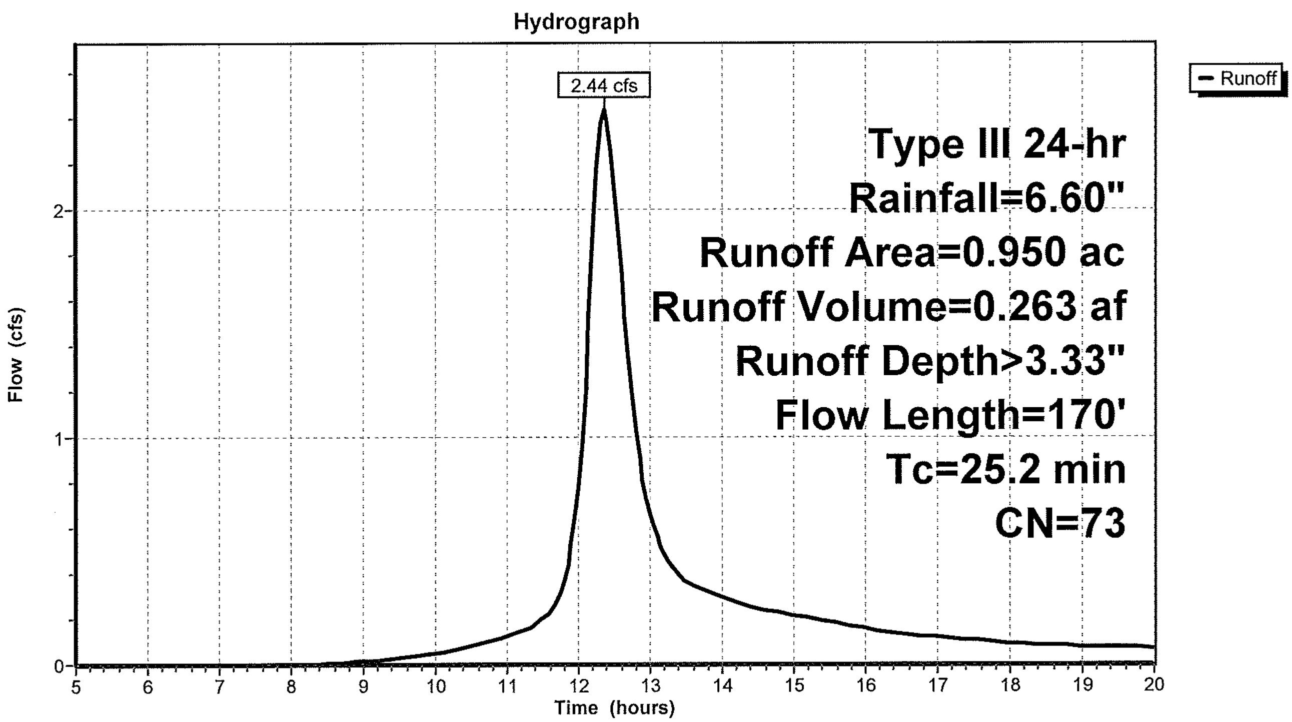
Runoff = 2.44 cfs @ 12.35 hrs, Volume= 0.263 af, Depth> 3.33"

Runoff by SCS TR-20 method, UH=SCS, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Type III 24-hr Rainfall=6.60"

Area (ac)	CN	Description
0.060	98	Paved parking & roofs
0.300	74	>75% Grass cover, Good, HSG C
0.590	70	Woods, Good, HSG C
0.950	73	Weighted Average

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
20.0	50	0.0060	0.0		**Sheet Flow, Path 1** Woods: Light underbrush n= 0.400 P2= 3.20"
5.2	120	0.0060	0.4		**Shallow Concentrated Flow, Path 2** Woodland Kv= 5.0 fps
25.2	170	Total			

Subcatchment 104S: Overland runoff to Culvert Sta 39+75



Hydrograph for Subcatchment 104S: Overland runoff to Culvert Sta 39+75

Time (hours)	Precip. (inches)	Excess (inches)	Runoff (cfs)
5.00	0.37	0.00	0.00
5.25	0.40	0.00	0.00
5.50	0.42	0.00	0.00
5.75	0.45	0.00	0.00
6.00	0.48	0.00	0.00
6.25	0.50	0.00	0.00
6.50	0.53	0.00	0.00
6.75	0.56	0.00	0.00
7.00	0.60	0.00	0.00
7.25	0.63	0.00	0.00
7.50	0.67	0.00	0.00
7.75	0.71	0.00	0.00
8.00	0.75	0.00	0.00
8.25	0.80	0.00	0.00
8.50	0.85	0.00	0.00
8.75	0.90	0.01	0.01
9.00	0.96	0.01	0.01
9.25	1.03	0.02	0.02
9.50	1.10	0.03	0.03
9.75	1.17	0.04	0.04
10.00	1.25	0.06	0.05
10.25	1.33	0.08	0.06
10.50	1.43	0.11	0.08
10.75	1.53	0.14	0.10
11.00	1.65	0.18	0.12
11.25	1.79	0.23	0.15
11.50	1.97	0.31	0.20
11.75	2.34	0.49	0.31
12.00	3.30	1.05	0.78
12.25	4.26	1.71	**2.19**
12.50	4.63	2.00	**2.09**
12.75	4.81	2.13	1.18
13.00	4.95	2.24	0.66
13.25	5.07	2.33	0.46
13.50	5.17	2.42	0.37
13.75	5.27	2.49	0.32
14.00	5.35	2.56	0.29
14.25	5.43	2.62	0.27
14.50	5.50	2.68	0.24
14.75	5.57	2.74	0.23
15.00	5.64	2.79	0.22
15.25	5.70	2.84	0.20
15.50	5.75	2.88	0.19
15.75	5.80	2.93	0.17
16.00	5.85	2.96	0.16
16.25	5.89	3.00	0.14
16.50	5.93	3.03	0.13
16.75	5.97	3.06	0.13
17.00	6.00	3.09	0.12
17.25	6.04	3.12	0.11
17.50	6.07	3.14	0.11
17.75	6.10	3.17	0.10
18.00	6.12	3.19	0.09
18.25	6.15	3.21	0.09
18.50	6.18	3.24	0.08
18.75	6.20	3.26	0.08
19.00	6.23	3.28	0.08
19.25	6.25	3.30	0.08
19.50	6.27	3.32	0.08
19.75	6.29	3.33	0.07
20.00	**6.32**	**3.35**	0.07

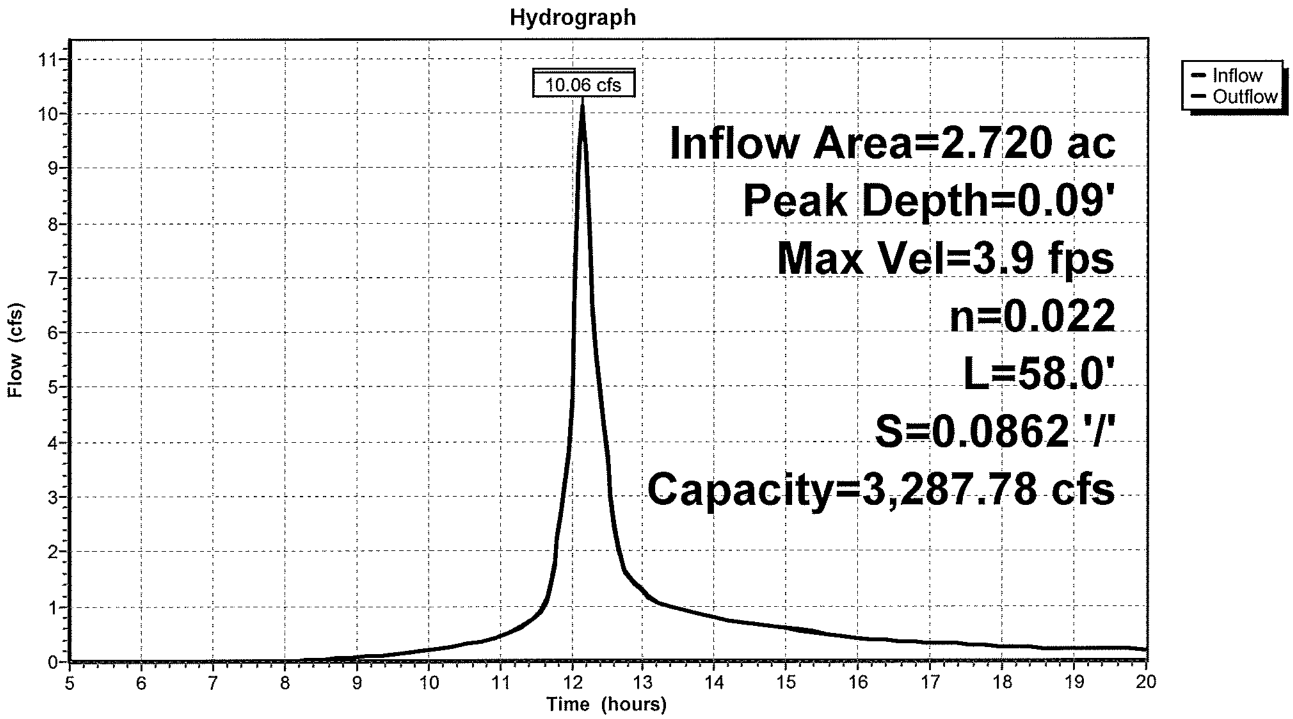
Reach 1R: Culvert Sta 58+25

Inflow Area =	2.720 ac,	Inflow Depth > 3.44"	
Inflow =	10.12 cfs @	12.15 hrs, Volume=	0.780 af
Outflow =	10.06 cfs @	12.15 hrs, Volume=	0.780 af, Atten= 1%, Lag= 0.4 min

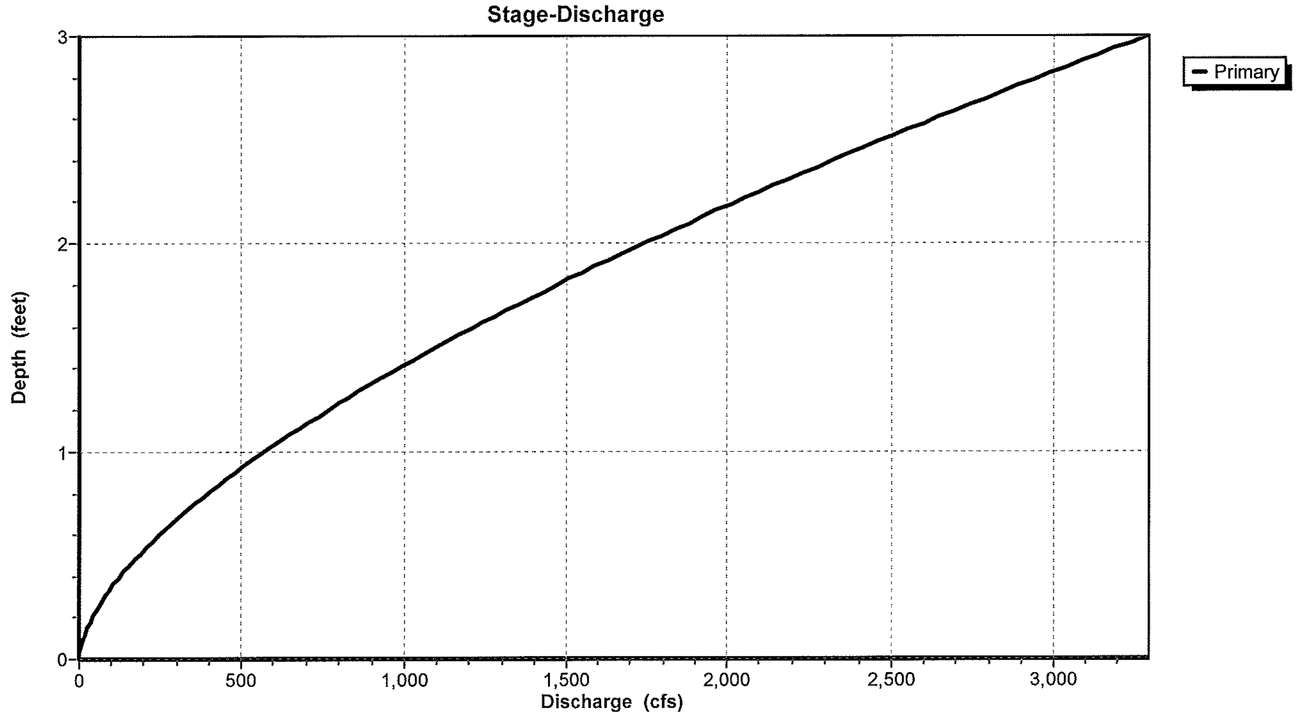
Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Max. Velocity= 3.9 fps, Min. Travel Time= 0.2 min
Avg. Velocity = 2.0 fps, Avg. Travel Time= 0.5 min

Peak Depth= 0.09' @ 12.15 hrs
Capacity at bank full= 3,287.78 cfs
Inlet Invert= 593.00', Outlet Invert= 588.00'
30.00' x 3.00' deep channel, n= 0.022 Earth, clean & straight
Length= 58.0' Slope= 0.0862 '/'

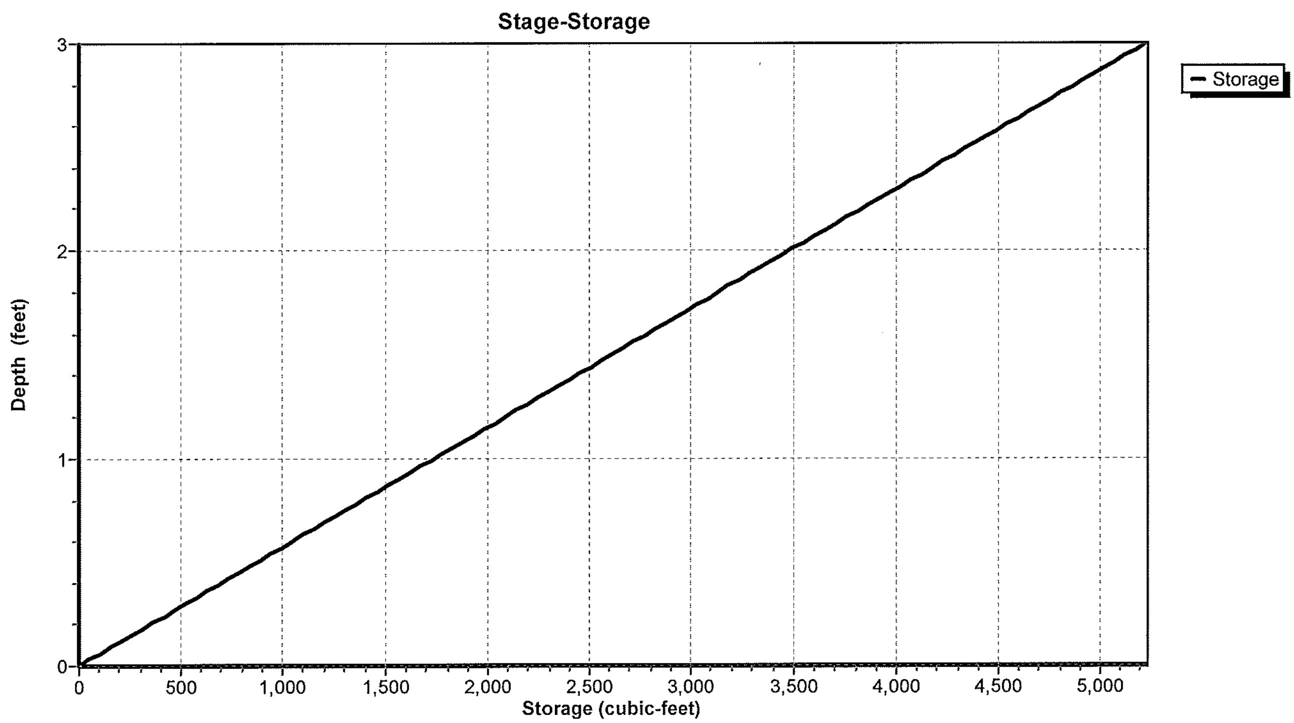
Reach 1R: Culvert Sta 58+25



Reach 1R: Culvert Sta 58+25



Reach 1R: Culvert Sta 58+25



Hydrograph for Reach 1R: Culvert Sta 58+25

Time (hours)	Inflow (cfs)	Storage (cubic-feet)	Elevation (feet)	Outflow (cfs)
5.00	0.00	0	593.00	0.00
5.50	0.00	0	593.00	0.00
6.00	0.00	0	593.00	0.00
6.50	0.00	0	593.00	0.00
7.00	0.00	0	593.00	0.00
7.50	0.00	0	593.00	0.00
8.00	0.01	0	593.00	0.01
8.50	0.03	1	593.00	0.03
9.00	0.07	2	593.00	0.07
9.50	0.13	4	593.00	0.13
10.00	0.20	6	593.00	0.20
10.50	0.30	9	593.01	0.30
11.00	0.45	14	593.01	0.45
11.50	0.82	25	593.01	0.81
12.00	**4.87**	**95**	**593.05**	**4.69**
12.50	**3.59**	**79**	**593.05**	**3.69**
13.00	1.25	38	593.02	1.27
13.50	0.94	29	593.02	0.95
14.00	0.78	24	593.01	0.78
14.50	0.67	20	593.01	0.67
15.00	0.59	18	593.01	0.59
15.50	0.50	15	593.01	0.51
16.00	0.42	13	593.01	0.42
16.50	0.37	11	593.01	0.37
17.00	0.33	10	593.01	0.33
17.50	0.29	9	593.01	0.30
18.00	0.26	8	593.00	0.26
18.50	0.24	7	593.00	0.24
19.00	0.23	7	593.00	0.23
19.50	0.22	7	593.00	0.22
20.00	0.20	6	593.00	0.20

Stage-Discharge for Reach 1R: Culvert Sta 58+25

Elevation (feet)	Velocity (ft/sec)	Discharge (cfs)	Elevation (feet)	Velocity (ft/sec)	Discharge (cfs)	Elevation (feet)	Velocity (ft/sec)	Discharge (cfs)
593.00	0.0	0.00	594.02	19.2	588.54	595.04	29.3	1,793.16
593.02	1.5	0.88	594.04	19.5	607.39	595.06	29.5	1,821.13
593.04	2.3	2.78	594.06	19.7	626.46	595.08	29.6	1,849.25
593.06	3.0	5.46	594.08	19.9	645.75	595.10	29.8	1,877.52
593.08	3.7	8.81	594.10	20.2	665.25	595.12	30.0	1,905.93
593.10	4.3	12.76	594.12	20.4	684.97	595.14	30.1	1,934.48
593.12	4.8	17.28	594.14	20.6	704.89	595.16	30.3	1,963.18
593.14	5.3	22.32	594.16	20.8	725.02	595.18	30.5	1,992.02
593.16	5.8	27.86	594.18	21.1	745.36	595.20	30.6	2,021.01
593.18	6.3	33.87	594.20	21.3	765.90	595.22	30.8	2,050.13
593.20	6.7	40.34	594.22	21.5	786.65	595.24	30.9	2,079.40
593.22	7.2	47.24	594.24	21.7	807.60	595.26	31.1	2,108.80
593.24	7.6	54.56	594.26	21.9	828.74	595.28	31.3	2,138.35
593.26	8.0	62.30	594.28	22.1	850.09	595.30	31.4	2,168.03
593.28	8.4	70.43	594.30	22.3	871.63	595.32	31.6	2,197.85
593.30	8.8	78.94	594.32	22.6	893.36	595.34	31.7	2,227.80
593.32	9.1	87.83	594.34	22.8	915.28	595.36	31.9	2,257.89
593.34	9.5	97.08	594.36	23.0	937.40	595.38	32.0	2,288.11
593.36	9.9	106.69	594.38	23.2	959.71	595.40	32.2	2,318.47
593.38	10.2	116.65	594.40	23.4	982.20	595.42	32.4	2,348.96
593.40	10.6	126.95	594.42	23.6	1,004.88	595.44	32.5	2,379.59
593.42	10.9	137.59	594.44	23.8	1,027.75	595.46	32.7	2,410.34
593.44	11.3	148.55	594.46	24.0	1,050.79	595.48	32.8	2,441.22
593.46	11.6	159.84	594.48	24.2	1,074.02	595.50	33.0	2,472.24
593.48	11.9	171.44	594.50	24.4	1,097.43	595.52	33.1	2,503.38
593.50	12.2	183.35	594.52	24.6	1,121.02	595.54	33.3	2,534.66
593.52	12.5	195.57	594.54	24.8	1,144.79	595.56	33.4	2,566.06
593.54	12.8	208.08	594.56	25.0	1,168.74	595.58	33.6	2,597.58
593.56	13.1	220.90	594.58	25.2	1,192.86	595.60	33.7	2,629.24
593.58	13.4	234.00	594.60	25.4	1,217.15	595.62	33.9	2,661.02
593.60	13.7	247.39	594.62	25.5	1,241.61	595.64	34.0	2,692.92
593.62	14.0	261.06	594.64	25.7	1,266.25	595.66	34.1	2,724.95
593.64	14.3	275.02	594.66	25.9	1,291.06	595.68	34.3	2,757.10
593.66	14.6	289.24	594.68	26.1	1,316.03	595.70	34.4	2,789.37
593.68	14.9	303.74	594.70	26.3	1,341.18	595.72	34.6	2,821.77
593.70	15.2	318.50	594.72	26.5	1,366.49	595.74	34.7	2,854.29
593.72	15.4	333.53	594.74	26.7	1,391.96	595.76	34.9	2,886.93
593.74	15.7	348.82	594.76	26.8	1,417.60	595.78	35.0	2,919.69
593.76	16.0	364.36	594.78	27.0	1,443.40	595.80	35.1	2,952.56
593.78	16.2	380.16	594.80	27.2	1,469.37	595.82	35.3	2,985.56
593.80	16.5	396.21	594.82	27.4	1,495.49	595.84	35.4	3,018.68
593.82	16.8	412.51	594.84	27.6	1,521.78	595.86	35.6	3,051.91
593.84	17.0	429.05	594.86	27.7	1,548.22	595.88	35.7	3,085.26
593.86	17.3	445.84	594.88	27.9	1,574.82	595.90	35.8	3,118.73
593.88	17.5	462.86	594.90	28.1	1,601.58	595.92	36.0	3,152.31
593.90	17.8	480.13	594.92	28.3	1,628.49	595.94	36.1	3,186.01
593.92	18.0	497.62	594.94	28.4	1,655.55	595.96	36.3	3,219.82
593.94	18.3	515.35	594.96	28.6	1,682.77	595.98	36.4	3,253.74
593.96	18.5	533.31	594.98	28.8	1,710.14	596.00	**36.5**	**3,287.78**
593.98	18.8	551.49	595.00	29.0	1,737.67			
594.00	19.0	569.91	595.02	29.1	1,765.34			

Stage-Area-Storage for Reach 1R: Culvert Sta 58+25

Elevation (feet)	Storage (cubic-feet)	Elevation (feet)	Storage (cubic-feet)	Elevation (feet)	Storage (cubic-feet)
593.00	0	594.02	1,775	595.04	3,550
593.02	35	594.04	1,810	595.06	3,584
593.04	70	594.06	1,844	595.08	3,619
593.06	104	594.08	1,879	595.10	3,654
593.08	139	594.10	1,914	595.12	3,689
593.10	174	594.12	1,949	595.14	3,724
593.12	209	594.14	1,984	595.16	3,758
593.14	244	594.16	2,018	595.18	3,793
593.16	278	594.18	2,053	595.20	3,828
593.18	313	594.20	2,088	595.22	3,863
593.20	348	594.22	2,123	595.24	3,898
593.22	383	594.24	2,158	595.26	3,932
593.24	418	594.26	2,192	595.28	3,967
593.26	452	594.28	2,227	595.30	4,002
593.28	487	594.30	2,262	595.32	4,037
593.30	522	594.32	2,297	595.34	4,072
593.32	557	594.34	2,332	595.36	4,106
593.34	592	594.36	2,366	595.38	4,141
593.36	626	594.38	2,401	595.40	4,176
593.38	661	594.40	2,436	595.42	4,211
593.40	696	594.42	2,471	595.44	4,246
593.42	731	594.44	2,506	595.46	4,280
593.44	766	594.46	2,540	595.48	4,315
593.46	800	594.48	2,575	595.50	4,350
593.48	835	594.50	2,610	595.52	4,385
593.50	870	594.52	2,645	595.54	4,420
593.52	905	594.54	2,680	595.56	4,454
593.54	940	594.56	2,714	595.58	4,489
593.56	974	594.58	2,749	595.60	4,524
593.58	1,009	594.60	2,784	595.62	4,559
593.60	1,044	594.62	2,819	595.64	4,594
593.62	1,079	594.64	2,854	595.66	4,628
593.64	1,114	594.66	2,888	595.68	4,663
593.66	1,148	594.68	2,923	595.70	4,698
593.68	1,183	594.70	2,958	595.72	4,733
593.70	1,218	594.72	2,993	595.74	4,768
593.72	1,253	594.74	3,028	595.76	4,802
593.74	1,288	594.76	3,062	595.78	4,837
593.76	1,322	594.78	3,097	595.80	4,872
593.78	1,357	594.80	3,132	595.82	4,907
593.80	1,392	594.82	3,167	595.84	4,942
593.82	1,427	594.84	3,202	595.86	4,976
593.84	1,462	594.86	3,236	595.88	5,011
593.86	1,496	594.88	3,271	595.90	5,046
593.88	1,531	594.90	3,306	595.92	5,081
593.90	1,566	594.92	3,341	595.94	5,116
593.92	1,601	594.94	3,376	595.96	5,150
593.94	1,636	594.96	3,410	595.98	5,185
593.96	1,670	594.98	3,445	596.00	**5,220**
593.98	1,705	595.00	3,480		
594.00	1,740	595.02	3,515		

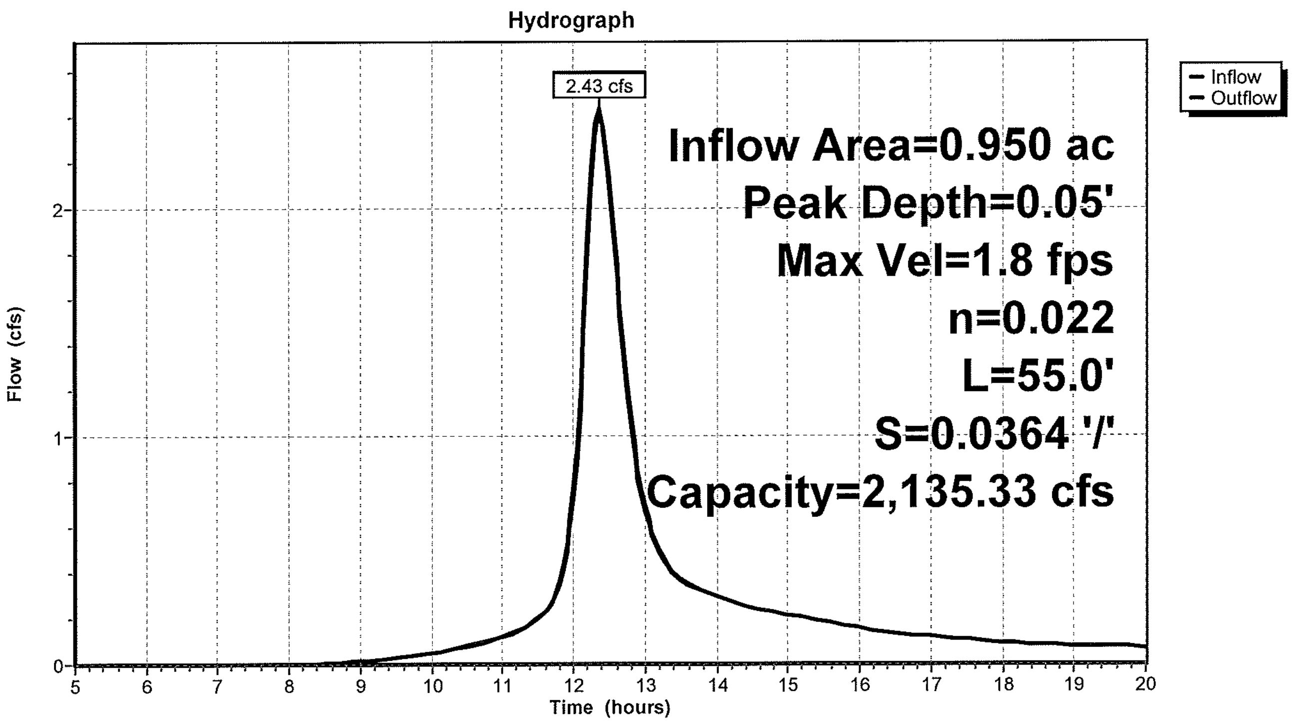
Reach 2R: Culvert Sta 39+75

Inflow Area = 0.950 ac, Inflow Depth > 3.33"
Inflow = 2.44 cfs @ 12.35 hrs, Volume= 0.263 af
Outflow = 2.43 cfs @ 12.37 hrs, Volume= 0.263 af, Atten= 0%, Lag= 0.8 min

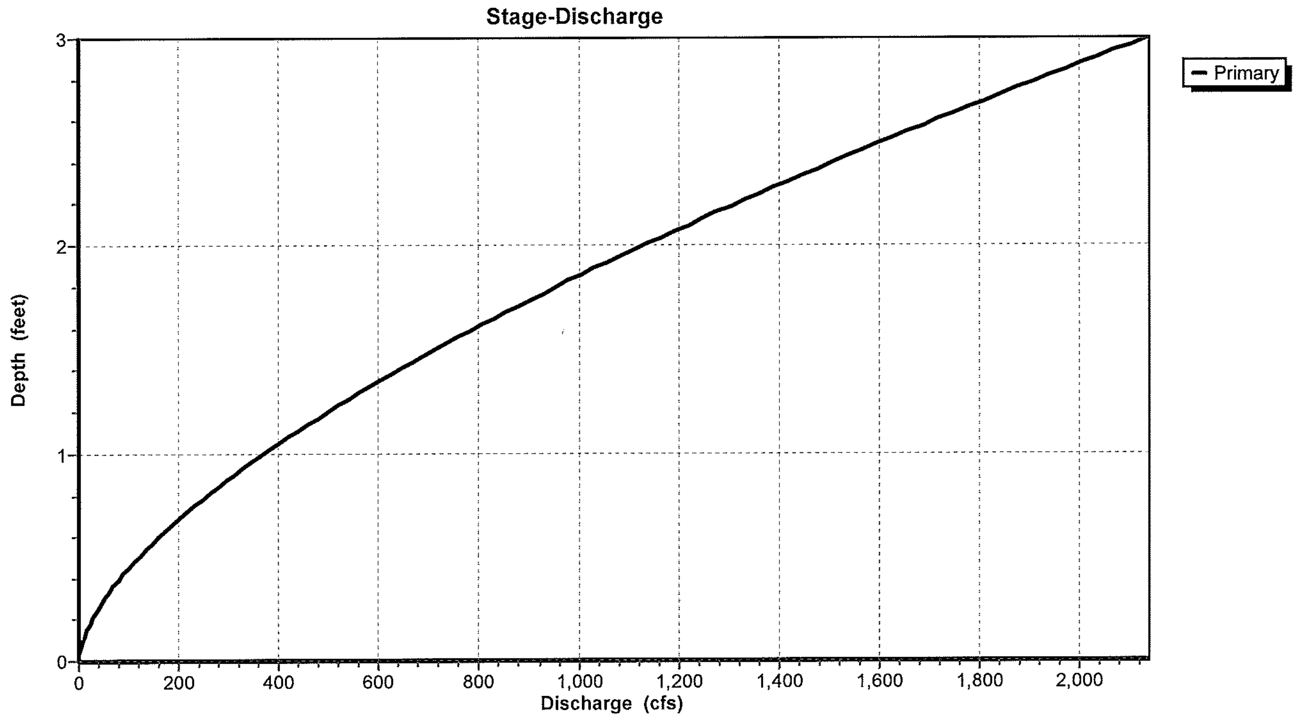
Routing by Stor-Ind+Trans method, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Max. Velocity= 1.8 fps, Min. Travel Time= 0.5 min
Avg. Velocity = 1.3 fps, Avg. Travel Time= 0.7 min

Peak Depth= 0.05' @ 12.36 hrs
Capacity at bank full= 2,135.33 cfs
Inlet Invert= 627.00', Outlet Invert= 625.00'
30.00' x 3.00' deep channel, n= 0.022 Earth, clean & straight
Length= 55.0' Slope= 0.0364 '/'

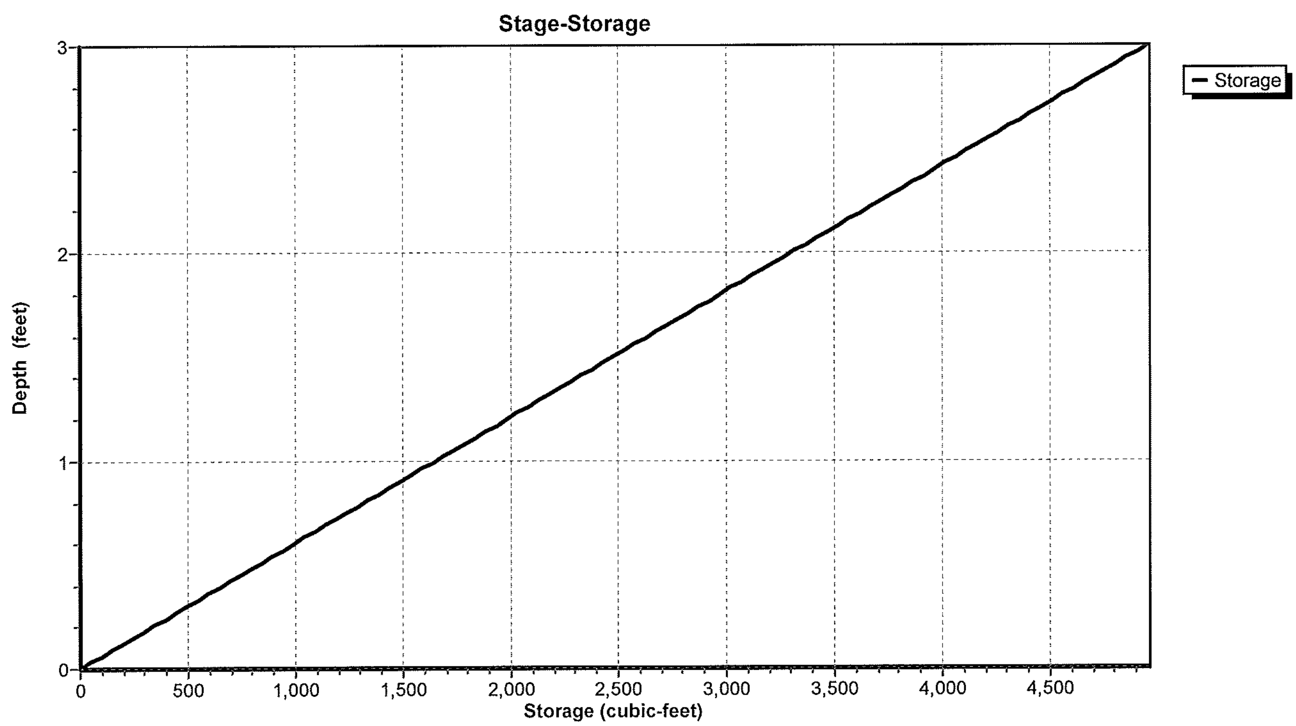
Reach 2R: Culvert Sta 39+75



Reach 2R: Culvert Sta 39+75



Reach 2R: Culvert Sta 39+75



Hydrograph for Reach 2R: Culvert Sta 39+75

Time (hours)	Inflow (cfs)	Storage (cubic-feet)	Elevation (feet)	Outflow (cfs)
5.00	0.00	0	627.00	0.00
5.50	0.00	0	627.00	0.00
6.00	0.00	0	627.00	0.00
6.50	0.00	0	627.00	0.00
7.00	0.00	0	627.00	0.00
7.50	0.00	0	627.00	0.00
8.00	0.00	0	627.00	0.00
8.50	0.00	0	627.00	0.00
9.00	0.01	1	627.00	0.01
9.50	0.03	1	627.00	0.03
10.00	0.05	2	627.00	0.05
10.50	0.08	3	627.00	0.08
11.00	0.12	5	627.00	0.12
11.50	0.20	9	627.01	0.20
12.00	**0.78**	**33**	**627.02**	**0.72**
12.50	**2.09**	**70**	**627.04**	**2.14**
13.00	0.66	30	627.02	0.69
13.50	0.37	16	627.01	0.37
14.00	0.29	13	627.01	0.30
14.50	0.24	11	627.01	0.25
15.00	0.22	10	627.01	0.22
15.50	0.19	8	627.01	0.19
16.00	0.16	7	627.00	0.16
16.50	0.13	6	627.00	0.13
17.00	0.12	5	627.00	0.12
17.50	0.11	5	627.00	0.11
18.00	0.09	4	627.00	0.10
18.50	0.08	4	627.00	0.08
19.00	0.08	4	627.00	0.08
19.50	0.08	3	627.00	0.08
20.00	0.07	3	627.00	0.07

Stage-Discharge for Reach 2R: Culvert Sta 39+75

Elevation (feet)	Velocity (ft/sec)	Discharge (cfs)
627.00	0.0	0.00
627.02	0.9	0.57
627.04	1.5	1.80
627.06	2.0	3.54
627.08	2.4	5.72
627.10	2.8	8.29
627.12	3.1	11.22
627.14	3.5	14.50
627.16	3.8	18.09
627.18	4.1	22.00
627.20	4.4	26.20
627.22	4.6	30.68
627.24	4.9	35.44
627.26	5.2	40.46
627.28	5.4	45.74
627.30	5.7	51.27
627.32	5.9	57.04
627.34	6.2	63.05
627.36	6.4	69.29
627.38	6.6	75.76
627.40	6.9	82.45
627.42	7.1	89.36
627.44	7.3	96.48
627.46	7.5	103.81
627.48	7.7	111.34
627.50	7.9	119.08
627.52	8.1	127.02
627.54	8.3	135.15
627.56	8.5	143.47
627.58	8.7	151.98
627.60	8.9	160.67
627.62	9.1	169.56
627.64	9.3	178.62
627.66	9.5	187.86
627.68	9.7	197.27
627.70	9.9	206.86
627.72	10.0	216.62
627.74	10.2	226.55
627.76	10.4	236.64
627.78	10.6	246.91
627.80	10.7	257.33
627.82	10.9	267.92
627.84	11.1	278.66
627.86	11.2	289.56
627.88	11.4	300.62
627.90	11.5	311.83
627.92	11.7	323.19
627.94	11.9	334.71
627.96	12.0	346.37
627.98	12.2	358.18
628.00	12.3	370.14
628.02	12.5	382.24
628.04	12.6	394.49
628.06	12.8	406.87
628.08	12.9	419.40
628.10	13.1	432.07
628.12	13.2	444.87
628.14	13.4	457.81
628.16	13.5	470.88
628.18	13.7	484.09
628.20	13.8	497.44
628.22	14.0	510.91
628.24	14.1	524.51
628.26	14.2	538.25
628.28	14.4	552.11
628.30	14.5	566.10
628.32	14.7	580.21
628.34	14.8	594.45
628.36	14.9	608.82
628.38	15.1	623.31
628.40	15.2	637.91
628.42	15.3	652.64
628.44	15.5	667.50
628.46	15.6	682.46
628.48	15.7	697.55
628.50	15.8	712.76
628.52	16.0	728.08
628.54	16.1	743.51
628.56	16.2	759.07
628.58	16.3	774.73
628.60	16.5	790.51
628.62	16.6	806.40
628.64	16.7	822.40
628.66	16.8	838.51
628.68	17.0	854.73
628.70	17.1	871.06
628.72	17.2	887.50
628.74	17.3	904.05
628.76	17.4	920.70
628.78	17.6	937.46
628.80	17.7	954.32
628.82	17.8	971.29
628.84	17.9	988.36
628.86	18.0	1,005.53
628.88	18.1	1,022.81
628.90	18.2	1,040.18
628.92	18.4	1,057.66
628.94	18.5	1,075.24
628.96	18.6	1,092.92
628.98	18.7	1,110.70
629.00	18.8	1,128.57
629.02	18.9	1,146.55
629.04	19.0	1,164.62
629.06	19.1	1,182.78
629.08	19.2	1,201.04
629.10	19.4	1,219.40
629.12	19.5	1,237.85
629.14	19.6	1,256.40
629.16	19.7	1,275.04
629.18	19.8	1,293.77
629.20	19.9	1,312.59
629.22	20.0	1,331.51
629.24	20.1	1,350.52
629.26	20.2	1,369.62
629.28	20.3	1,388.80
629.30	20.4	1,408.08
629.32	20.5	1,427.45
629.34	20.6	1,446.90
629.36	20.7	1,466.44
629.38	20.8	1,486.07
629.40	20.9	1,505.79
629.42	21.0	1,525.59
629.44	21.1	1,545.48
629.46	21.2	1,565.46
629.48	21.3	1,585.52
629.50	21.4	1,605.66
629.52	21.5	1,625.89
629.54	21.6	1,646.20
629.56	21.7	1,666.59
629.58	21.8	1,687.07
629.60	21.9	1,707.62
629.62	22.0	1,728.26
629.64	22.1	1,748.98
629.66	22.2	1,769.79
629.68	22.3	1,790.67
629.70	22.4	1,811.63
629.72	22.5	1,832.67
629.74	22.6	1,853.79
629.76	22.6	1,874.99
629.78	22.7	1,896.26
629.80	22.8	1,917.62
629.82	22.9	1,939.05
629.84	23.0	1,960.56
629.86	23.1	1,982.14
629.88	23.2	2,003.80
629.90	23.3	2,025.54
629.92	23.4	2,047.35
629.94	23.5	2,069.23
629.96	23.5	2,091.19
629.98	23.6	2,113.23
630.00	**23.7**	**2,135.33**

Stage-Area-Storage for Reach 2R: Culvert Sta 39+75

Elevation (feet)	Storage (cubic-feet)	Elevation (feet)	Storage (cubic-feet)	Elevation (feet)	Storage (cubic-feet)
627.00	0	628.02	1,683	629.04	3,366
627.02	33	628.04	1,716	629.06	3,399
627.04	66	628.06	1,749	629.08	3,432
627.06	99	628.08	1,782	629.10	3,465
627.08	132	628.10	1,815	629.12	3,498
627.10	165	628.12	1,848	629.14	3,531
627.12	198	628.14	1,881	629.16	3,564
627.14	231	628.16	1,914	629.18	3,597
627.16	264	628.18	1,947	629.20	3,630
627.18	297	628.20	1,980	629.22	3,663
627.20	330	628.22	2,013	629.24	3,696
627.22	363	628.24	2,046	629.26	3,729
627.24	396	628.26	2,079	629.28	3,762
627.26	429	628.28	2,112	629.30	3,795
627.28	462	628.30	2,145	629.32	3,828
627.30	495	628.32	2,178	629.34	3,861
627.32	528	628.34	2,211	629.36	3,894
627.34	561	628.36	2,244	629.38	3,927
627.36	594	628.38	2,277	629.40	3,960
627.38	627	628.40	2,310	629.42	3,993
627.40	660	628.42	2,343	629.44	4,026
627.42	693	628.44	2,376	629.46	4,059
627.44	726	628.46	2,409	629.48	4,092
627.46	759	628.48	2,442	629.50	4,125
627.48	792	628.50	2,475	629.52	4,158
627.50	825	628.52	2,508	629.54	4,191
627.52	858	628.54	2,541	629.56	4,224
627.54	891	628.56	2,574	629.58	4,257
627.56	924	628.58	2,607	629.60	4,290
627.58	957	628.60	2,640	629.62	4,323
627.60	990	628.62	2,673	629.64	4,356
627.62	1,023	628.64	2,706	629.66	4,389
627.64	1,056	628.66	2,739	629.68	4,422
627.66	1,089	628.68	2,772	629.70	4,455
627.68	1,122	628.70	2,805	629.72	4,488
627.70	1,155	628.72	2,838	629.74	4,521
627.72	1,188	628.74	2,871	629.76	4,554
627.74	1,221	628.76	2,904	629.78	4,587
627.76	1,254	628.78	2,937	629.80	4,620
627.78	1,287	628.80	2,970	629.82	4,653
627.80	1,320	628.82	3,003	629.84	4,686
627.82	1,353	628.84	3,036	629.86	4,719
627.84	1,386	628.86	3,069	629.88	4,752
627.86	1,419	628.88	3,102	629.90	4,785
627.88	1,452	628.90	3,135	629.92	4,818
627.90	1,485	628.92	3,168	629.94	4,851
627.92	1,518	628.94	3,201	629.96	4,884
627.94	1,551	628.96	3,234	629.98	4,917
627.96	1,584	628.98	3,267	630.00	**4,950**
627.98	1,617	629.00	3,300		
628.00	1,650	629.02	3,333		

CLOSED DRAINAGE SYSTEM

CALCULATIONS

WHITMAN & BINGHAM ASSOCIATES

DESIGN OF STORM SEWERS

PROJECT NAME: HIGHFIELD VILLAGE
PROJECT NO.: 13510
SHEET 1 OF 8
CALCULATED BY: MFP
DATE: 9-18-15

A		B		C	D	E	F	G	H	I	J	K	L	M	N	O	P	
FLOW PATH		AREA (Ac)		COEFF. OF RUNOFF (c)	TIME TO INLET (min.)	DESIGN STORM (year)	INTENSITY (i)	DESIGN FLOW (Q) (cfs) (CxFxB)	PIPE SIZE (in.)	PIPE SLOPE (ft./ft.)	ROUGH. COEFF. (n)	FULL CAPACITY (cfs)	FULL VELOCITY (fps)	DESIGN VELOCITY (fps)	LENGTH OF PIPE (ft.)	TIME IN CHANNEL (min.) (N/M)	TIME TO NEXT NODE (min.) (D+O)	REMARKS
FROM	TO	SUB-AREA	TOTAL															
NCB 2	NDMH 6	0.17	0.17	0.69	10	100	8	0.94	12	0.024	0.012	5.8	7.8	5.5	10	0.10	10.1	
NCB 4	NDMH 6	0.68	0.68	0.42	10	100	8	2.28	12	0.020	0.012	5.2	6.9	6.8	12	0.10	10.1	USE DOUBLE GRATE
NDMH 6	NDMH 8	—	0.85	0.48	10.1	100	8	3.26	12	0.030	0.012	6.5	8.4	8.4	82	0.20	10.3	
NDMH 8	NDMH 14	—	0.85	0.48	10.3	100	8	3.26	12	0.016	0.012	4.8	6.2	6.8	90	0.20	10.5	
NCB 10	NDMH 14	0.10	0.10	0.65	10	100	8	0.52	12	0.024	0.012	5.8	7.8	4.7	10	0.10	10.1	
NCB 12	NDMH 14	0.63	0.63	0.48	10	100	8	2.42	12	0.020	0.012	5.2	6.9	6.6	12	0.10	10.1	USE DOUBLE GRATE
NDMH 14	NDMH 22	—	1.58	0.49	10.5	100	8	6.19	15	0.010	0.012	7.1	5.8	6.5	256	0.70	11.2	
NCB 18	NDMH 22	0.22	0.22	0.65	10	100	8	1.14	12	0.024	0.012	5.8	7.8	6.1	10	0.10	10.1	
NCB 20	NDMH 22	1.24	1.24	0.36	10	100	8	3.57	12	0.020	0.012	5.2	6.9	7.5	12	0.10	10.1	USE DOUBLE GRATE
NDMH 22	NDMH 28	—	3.04	0.45	11.2	100	8	10.95	18	0.010	0.012	11.0	6.5	7.2	236	0.60	11.8	
NCB 24	NDMH 28	0.23	0.23	0.68	10	100	8	1.25	12	0.024	0.012	5.8	7.8	6.3	10	0.10	10.1	
NCB 26	NDMH 28	1.35	1.35	0.42	10	100	8	4.54	12	0.020	0.012	5.2	6.9	7.7	12	0.10	10.1	USE DOUBLE GRATE
NDMH 28	NDMH 36	—	4.62	0.45	11.8	100	8	16.63	24	0.010	0.012	25.0	8.2	8.9	69	0.10	11.9	
NCB 30	NDMH 34	0.23	0.23	0.68	10	100	8	1.25	12	0.024	0.012	5.8	7.8	6.4	10	0.10	10.1	
NCB 32	NDMH 34	0.66	0.66	0.37	10	100	8	1.95	12	0.020	0.012	5.2	6.9	6.4	12	0.10	10.1	
NDMH 34	NDMH 36	—	0.89	0.45	10.1	100	8	3.20	12	0.010	0.012	4.2	5.3	5.7	149	0.40	10.5	
NDMH 36	NFE	—	5.51	0.45	11.9	100	8	19.84	24	0.010	0.012	25.0	8.2	9.0	122	0.20	12.1	

WHITMAN & BINGHAM
A S S O C I A T E S

DESIGN OF STORM SEWERS

PROJECT NAME Highfield Village
PROJECT NO. 13510 SHEET 7 OF 8
CALCULATED BY MFP DATE 9-18-15

A		B		C	D	E	F	G	H	I	J	K	L	M	N	O	P	
FLOW PATH		AREA (Ac)		COEFF. OF RUNOFF (c)	TIME TO INLET (min.)	DESIGN STORM (year)	INTENSITY (i)	DESIGN FLOW (Q) (cfs) (CxFxB)	PIPE SIZE (in.)	PIPE SLOPE (ft./ft.)	ROUGH. COEFF. (n)	FULL CAPACITY (cfs)	FULL VELOCITY (fps)	DESIGN VELOCITY (fps)	LENGTH OF PIPE (ft.)	TIME IN CHANNEL (min.) (N/M)	TIME TO NEXT NODE (min.) (D+O)	REMARKS
FROM	TO	SUB-AREA	TOTAL															
NCB 38	NDMH 42	0.10	0.10	0.70	10	100	8	0.56	12	0.024	0.012	5.8	7.8	5.1	10	0.10	10.1	
NCB 40	NDMH 42	0.35	0.35	0.51	10	100	8	1.43	12	0.020	0.012	5.2	6.9	6.1	12	0.10	10.1	
NDMH 42	NDMH 44	—	0.45	0.55	10.1	100	8	1.98	12	0.023	0.012	5.6	7.3	6.7	81	0.20	10.3	
NDMH 44	NDMH 50	—	0.45	0.55	10.3	100	8	1.98	12	0.015	0.012	4.6	6.1	5.9	77	0.20	10.5	
NCB 46	NDMH 50	0.28	0.28	0.63	10	100	8	1.41	12	0.030	0.012	6.5	8.4	6.7	12	0.10	10.1	
NCB 48	NDMH 50	2.10	2.10	0.37	10	100	8	6.22	12	0.030	0.012	6.5	8.4	9.4	12	0.10	10.1	USE DOUBLE GRATE AND SINGLE GRATE
NDMH 50	NDMH 52	—	2.83	0.42	10.5	100	8	9.51	15	0.018	0.012	9.6	8.0	9.0	59	0.10	10.6	
NDMH 52	NFE	—	2.83	0.42	10.6	100	8	9.51	15	0.020	0.012	9.6	8.0	9.0	84	0.20	10.8	
NCB 54	NDMH 58	0.35	0.35	0.57	10	100	8	1.60	12	0.024	0.012	5.8	7.8	6.9	10	0.10	10.1	
NCB 56	NDMH 58	0.98	0.98	0.46	10	100	8	3.60	12	0.020	0.012	5.2	6.9	7.5	12	0.10	10.1	USE DOUBLE GRATE
NDMH 58	NDMH 64	—	1.33	0.49	10.1	100	8	5.21	12	0.032	0.012	6.6	8.7	9.6	172	0.30	10.4	
NCB 60	NDMH 64	0.35	0.35	0.42	10	100	8	1.18	12	0.020	0.012	5.2	6.9	5.5	12	0.10	10.1	
NCB 62	NDMH 64	1.57	1.57	0.42	10	100	8	5.28	12	0.024	0.012	5.8	7.8	8.7	12	0.10	10.1	USE DOUBLE GRATE 25 YEAR RATE = 3.30 cfs
NDMH 64	NDMH 66	—	3.25	0.45	10.4	100	8	11.70	18	0.020	0.012	16.0	9.2	9.9	41	0.10	10.5	
NDMH 66	NDMH 72		3.25	0.45	10.5	100	8	11.70	18	0.020	0.012	16.0	9.2	9.9	98	0.20	10.7	

WHITMAN & BINGHAM ASSOCIATES

DESIGN OF STORM SEWERS

PROJECT NAME Highfield Village
PROJECT NO. 13510' SHEET 3 OF 8
CALCULATED BY MFP DATE 9-18-15

A		B		C	D	E	F	G	H	I	J	K	L	M	N	O	P	
FLOW PATH		AREA (Ac)		COEFF. OF RUNOFF (c)	TIME TO INLET (min.)	DESIGN STORM (year)	INTENSITY (i)	DESIGN FLOW (Q) (cfs) (CxFxB)	PIPE SIZE (in.)	PIPE SLOPE (ft./ft.)	ROUGH. COEFF. (n)	FULL CAPACITY (cfs)	FULL VELOCITY (fps)	DESIGN VELOCITY (fps)	LENGTH OF PIPE (ft.)	TIME IN CHANNEL (min.) (N/M)	TIME TO NEXT NODE (min.) (D+O)	REMARKS
FROM	TO	SUB-AREA	TOTAL															
NCB 68	NDMH 72	0.46	0.46	0.45	10	100	8	1.66	12	0.020	0.012	5.2	6.9	6.2	12	0.10	10.1	
NDMH 72	NDMH 74	—	3.71	0.45	10.7	100	8	13.36	24	0.010	0.012	25.0	8.2	8.4	112	0.20	10.9	
NDMH 74	NDMH 80	—	3.71	0.45	10.9	100	8	13.36	24	0.010	0.012	25.0	8.2	8.4	82	0.20	11.1	
NCB 76	NDMH 80	2.51	2.51	0.33	10	100	8	6.63	12	0.031	0.012	6.8	8.6	9.6	12	0.10	10.1	USE DOUBLE GRATE AND SINGLE GRATE
NCB 78	NDMH 80	0.30	0.30	0.58	10	100	8	1.39	12	0.024	0.012	5.8	7.8	6.5	10	0.10	10.1	
NDMH 80	NDMH 108	—	6.52	0.41	11.1	100	8	21.39	24	0.010	0.012	25.0	8.2	9.0	248	0.50	11.6	
NCB 110	NDMH 114	0.19	0.19	0.53	10	100	8	0.81	12	0.017	0.012	5.0	6.4	4.6	14	0.10	10.1	
NCB 112	NDMH 114	0.15	0.15	0.70	10	100	8	0.84	12	0.017	0.012	5.0	6.4	5.0	14	0.10	10.1	
NDMH 114	NDMH 108	—	0.34	0.61	10.1	100	8	1.66	12	0.024	0.012	5.8	7.8	6.9	116	0.30	10.4	
NCB 82	NDMH 86	0.45	0.45	0.47	10	100	8	1.69	12	0.020	0.012	5.2	6.9	6.2	12	0.10	10.1	
NCB 84	NDMH 86	0.15	0.15	0.44	10	100	8	0.53	12	0.024	0.012	5.8	7.8	5.3	10	0.10	10.1	
NDMH 86	NDMH 94	—	0.60	0.46	10.1	100	8	2.21	12	0.034	0.012	6.6	9.2	8.3	165	0.30	10.4	
NCB 88	NDMH 92	1.57	1.57	0.45	10	100	8	5.65	12	0.030	0.012	6.8	8.6	9.5	10	0.10	10.1	USE DOUBLE GRATE 15 YR RATE = 3.53 cfs
NCB 90	NDMH 92	0.23	0.23	0.73	10	100	8	1.34	12	0.030	0.012	6.8	8.6	6.9	10	0.10	10.1	
NDMH 92	NDMH 94	—	1.80	0.49	10.1	100	8	7.06	15	0.010	0.012	7.1	5.8	6.5	60	0.20	10.3	
NDMH 94	NDMH 96	—	2.40	0.48	10.3	100	8	9.22	18	0.010	0.012	11.0	6.5	7.2	55	0.10	10.4	

WHITMAN & BINGHAM ASSOCIATES

DESIGN OF STORM SEWERS

PROJECT NAME: HIGHFIELD VILLAGE
PROJECT NO.: 13510
SHEET 4 OF 8
CALCULATED BY: MFP
DATE: 9-18-15

A		B		C	D	E	F	G	H	I	J	K	L	M	N	O	P	
FLOW PATH		AREA (Ac)		COEFF. OF RUNOFF (c)	TIME TO INLET (min.)	DESIGN STORM (year)	INTENSITY (i)	DESIGN FLOW (Q) (cfs) (CxFxB)	PIPE SIZE (in.)	PIPE SLOPE (ft./ft.)	ROUGH. COEFF. (n)	FULL CAPACITY (cfs)	FULL VELOCITY (fps)	DESIGN VELOCITY (fps)	LENGTH OF PIPE (ft.)	TIME IN CHANNEL (min.) (N/M)	TIME TO NEXT NODE (min.) (D+O)	REMARKS
FROM	TO	SUB-AREA	TOTAL															
NDMH 96	NDMH 98	—	2.40	0.48	10.4	100	8	9.22	18	0.010	0.012	11.0	6.5	7.2	44	0.10	10.5	
NDMH 98	NDMH 100	—	2.40	0.48	10.5	100	8	9.22	18	0.020	0.012	16.0	9.2	9.5	59	0.10	10.6	
NDMH 100	NDMH 102	—	2.40	0.48	10.6	100	8	9.22	18	0.020	0.012	16.0	9.2	9.5	169	0.30	10.9	
NDMH 102	NDMH 104	—	2.40	0.48	10.9	100	8	9.22	18	0.020	0.012	16.0	9.2	9.5	70	0.10	11.0	
NDMH 104	NDMH 108	—	2.40	0.48	11.0	100	8	9.22	18	0.020	0.012	16.0	9.2	9.5	56	0.10	11.1	
NCB 106	NDMH 108	1.87	1.87	0.40	10	100	8	5.98	15	0.010	0.012	7.1	5.8	6.5	25	0.10	10.1	USE DOUBLE GRATE
																		25 YR RATE = 3.74 CFS
NCB 107	NDMH 108	1.87	1.87	0.40	10	100	8	5.98	15	0.020	0.012	9.6	8.0	9.0	12	0.10	10.1	USE DOUBLE GRATE
																		25 YR RATE = 3.74 CFS
NDMH 108	NDMH 118	—	13.00	0.43	11.6	100	8	44.72	36	0.005	0.012	50.0	7.3	8.2	20	0.10	11.7	
NCB 117	NDMH 119	0.33	0.33	0.66	10	100	8	1.74	12	0.010	0.012	4.2	5.3	5.1	26	0.10	10.1	
NDMH 119	NFE	—	13.33	0.44	11.7	100	8	46.92	36	0.005	0.012	50.0	7.3	8.2	85	0.20	11.9	
NCB 130	NDMH 134	0.29	0.29	0.61	10	100	8	1.42	12	0.024	0.012	5.8	7.8	6.7	10	0.10	10.1	
NCB 132	NDMH 134	0.26	0.26	0.54	10	100	8	1.12	12	0.020	0.012	5.2	6.9	5.5	12	0.10	10.1	
NDMH 134	NDMH 136	—	0.55	0.58	10.1	100	8	2.55	12	0.039	0.012	6.8	8.9	8.2	100	0.20	10.3	
NDMH 136	NDMH 140	—	0.55	0.58	10.3	100	8	2.55	12	0.039	0.012	6.8	8.9	8.0	108	0.20	10.5	
NCB 138	NDMH 140	0.37	0.37	0.40	10	100	8	1.18	12	0.024	0.012	5.8	7.8	6.2	10	0.10	10.1	
NDMH 140	NDMH 144	—	0.92	0.51	10.5	100	8	3.75	15	0.010	0.012	7.1	5.8	6.0	35	0.10	10.6	
NCB 142	NDMH 144	0.35	0.35	0.58	10	100	8	1.62	12	0.010	0.012	4.2	5.3	4.9	28	0.10	10.1	
NDMH 144	NFE	—	1.27	0.53	10.6	100	8	5.38	15	0.010	0.012	7.1	5.8	6.4	110	0.30	10.9	

WHITMAN & BINGHAM
ASSOCIATES

DESIGN OF STORM SEWERS

PROJECT NAME: HIGHFIELD VILLAGE
PROJECT NO.: 13510
SHEET 5 OF 8
CALCULATED BY: MFP
DATE: 9-18-15

A		B		C	D	E	F	G	H	I	J	K	L	M	N	O	P	
FLOW PATH		AREA (Ac)		COEFF. OF RUNOFF (c)	TIME TO INLET (min.)	DESIGN STORM (year)	INTENSITY (i)	DESIGN FLOW (Q) (cfs) (CxFxB)	PIPE SIZE (in.)	PIPE SLOPE (ft./ft.)	ROUGH. COEFF. (n)	FULL CAPACITY (cfs)	FULL VELOCITY (fps)	DESIGN VELOCITY (fps)	LENGTH OF PIPE (ft.)	TIME IN CHANNEL (min.) (N/M)	TIME TO NEXT NODE (min.) (D+O)	REMARKS
FROM	TO	SUB-AREA	TOTAL															
NCB 116	NDMH 120	0.57	0.57	0.45	10	100	8	2.05	12	0.024	0.012	5.8	7.8	7.0	10	0.10	10.1	
NCB 118	NDMH 120	0.19	0.19	0.69	10	100	8	1.05	12	0.020	0.012	5.2	6.9	5.5	12	0.10	10.1	
NDMH 120	NDMH 124	—	0.76	0.51	10.1	100	8	3.10	12	0.017	0.012	4.6	6.1	6.6	180	0.50	10.6	
NCB 122	NDMH 124	0.71	0.71	0.42	10	100	8	2.39	12	0.016	0.012	4.2	5.3	5.4	16	0.10	10.1	USE DOUBLE GRATE
NCB 123	NDMH 124	0.09	0.09	0.73	10	100	8	0.53	12	0.010	0.012	4.2	5.3	3.5	16	0.10	10.1	
																		CONT. ON SHEET 8.
NCB 162	NDMH 166	0.19	0.19	0.82	10	100	8	1.25	12	0.010	0.012	4.2	5.3	4.8	20	0.10	10.1	
NCB 164	NDMH 166	0.18	0.18	0.57	10	100	8	0.82	12	0.020	0.012	5.2	6.9	4.8	10	0.10	10.1	
NDMH 166	NDMH 168	—	0.37	0.70	10.1	100	8	2.07	12	0.010	0.012	4.2	5.3	5.3	20	0.10	10.2	
NDMH 168	NDMH 170	—	0.37	0.70	10.2	100	8	2.07	12	0.017	0.012	4.6	6.1	6.0	230	0.60	10.8	
NDMH 170	NDMH 172	—	0.37	0.70	10.8	100	8	2.07	12	0.040	0.012	6.8	8.9	7.9	65	0.10	10.9	
NDMH 172	NFE	—	0.37	0.70	10.9	100	8	2.07	12	0.040	0.012	6.8	8.9	7.9	41	0.10	11.0	
NCB 146	NDMH 150	0.35	0.35	0.57	10	100	8	1.60	12	0.020	0.012	5.2	6.9	6.1	12	0.10	10.1	
NCB 148	NDMH 150	0.80	0.80	0.45	10	100	8	2.88	12	0.020	0.012	5.2	6.9	7.2	12	0.10	10.1	USE DOUBLE GRATE
NDMH 150	NDMH 154	—	1.15	0.49	10.1	100	8	4.51	12	0.014	0.012	5.0	6.4	7.2	197	0.50	10.6	
NCB 152	NDMH 154	0.32	0.32	0.63	10	100	8	1.61	12	0.020	0.012	5.2	6.9	6.1	11	0.10	10.1	
NDMH 154	NDMH 158	—	1.47	0.52	10.6	100	8	6.11	15	0.010	0.012	7.1	5.8	6.5	18	0.10	10.7	
NCB 156	NDMH 158	0.62	0.62	0.55	10	100	8	2.73	12	0.020	0.012	5.2	6.9	7.1	18	0.10	10.2	25 YEAR RATE = 1.71
NDMH 158	NDMH 160	—	2.09	0.53	10.7	100	8	8.86	15	0.020	0.012	9.6	8.0	9.0	67	0.10	10.8	
NDMH 160	NFE	—	2.09	0.53	10.8	100	8	8.86	15	0.020	0.012	9.6	8.0	9.0	35	0.10	10.9	

WHITMAN & BINGHAM
ASSOCIATES

DESIGN OF STORM SEWERS

PROJECT NAME: HIGHFIELD VILLAGE
PROJECT NO.: 13510 SHEET 6 OF 8
CALCULATED BY: MFP DATE: 9-18-15

A FLOW PATH FROM	A FLOW PATH TO	B AREA (Ac) SUB-AREA	B AREA (Ac) TOTAL	C COEFF. OF RUNOFF (c)	D TIME TO INLET (min.)	E DESIGN STORM (year)	F INTENSITY (i)	G DESIGN FLOW (Q) (cfs) (CxFxB)	H PIPE SIZE (in.)	I PIPE SLOPE (ft./ft.)	J ROUGH. COEFF. (n)	K FULL CAPACITY (cfs)	L FULL VELOCITY (fps)	M DESIGN VELOCITY (fps)	N LENGTH OF PIPE (ft.)	O TIME IN CHANNEL (min.) (N/M)	P TIME TO NEXT NODE (min.) (D+O)	REMARKS
NCB 174	NDMH 178	0.16	0.16	0.68	10	100	8	0.87	12	0.020	0.012	5.2	6.9	5.4	12	0.10	10.1	
NCB 176	NDMH 178	0.15	0.15	0.63	10	100	8	0.76	12	0.024	0.012	5.8	7.8	5.2	10	0.10	10.1	
NDMH 178	NDMH 184	—	0.31	0.66	10.1	100	8	1.64	12	0.014	0.012	5.0	6.4	5.8	250	0.70	10.8	
NCB 180	NDMH 184	0.14	0.14	0.72	10	100	8	0.81	12	0.020	0.012	5.2	6.9	5.1	12	0.10	10.1	
NCB 182	NDMH 184	0.22	0.22	0.67	10	100	8	1.18	12	0.024	0.012	5.8	7.8	6.2	10	0.10	10.1	
NDMH 184	NDMH 186	—	0.67	0.68	10.8	100	8	3.64	12	0.017	0.012	4.6	6.1	6.7	63	0.20	11.0	
NDMH 186	NDMH 188	—	0.67	0.68	11.0	100	8	3.64	12	0.038	0.012	6.8	8.9	9.1	90	0.20	11.2	
NDMH 188	NDMH 194	—	0.67	0.68	11.2	100	8	3.64	12	0.040	0.012	6.8	8.9	9.1	93	0.20	11.4	
NCB 190	NDMH 194	0.31	0.31	0.61	10	100	8	1.51	12	0.015	0.012	4.8	6.2	5.5	16	0.10	10.1	
NCB 192	NDMH 194	0.44	0.44	0.59	10	100	8	2.08	12	0.020	0.012	5.2	6.9	6.6	12	0.10	10.1	
NDMH 194	NDMH 196	—	1.42	0.64	11.4	100	8	7.27	15	0.020	0.012	9.6	8.0	8.8	90	0.20	11.6	
NDMH 196	NDMH 202	—	1.42	0.64	11.6	100	8	7.27	15	0.020	0.012	9.6	8.0	8.8	69	0.10	11.7	
NCB 198	NDMH 202	0.18	0.18	0.62	10	100	8	0.89	12	0.015	0.012	4.8	6.2	4.9	16	0.10	10.1	
NCB 200	NDMH 202	0.24	0.24	0.63	10	100	8	1.21	12	0.020	0.012	5.2	6.9	5.7	12	0.10	10.1	
NDMH 202	NDMH 204	—	1.84	0.64	11.7	100	8	9.42	18	0.020	0.012	16.0	9.2	9.6	61	0.10	11.8	
NDMH 204	NDMH 210	—	1.84	0.64	11.8	100	8	9.42	18	0.020	0.012	16.0	9.2	9.6	159	0.30	12.1	
NCB 206	NDMH 210	0.13	0.13	0.59	10	100	8	0.61	12	0.024	0.012	5.8	7.8	5.1	10	0.10	10.1	
NCB 208	NDMH 210	1.48	1.48	0.46	10	100	8	5.44	12	0.024	0.012	5.8	7.8	8.7	12	0.10	10.1	USE DOUBLE GRATE
NDMH 210	NDMH 214	—	3.45	0.56	12.1	100	8	15.46	24	0.017	0.012	30.0	9.8	9.8	242	0.40	12.5	
NCB 212	NDMH 214	2.05	2.05	0.45	10	100	8	7.38	15	0.015	0.012	9.0	7.5	8.3	15	0.10	10.1	USE DOUBLE GRATE
NDMH 214	NDMH 218	—	5.50	0.52	12.5	100	8	22.88	24	0.010	0.012	25.0	8.2	9.2	20	0.10	12.6	AND SINGLE GRATE
NCB 216	NDMH 218	0.26	0.26	0.69	10	100	8	1.44	12	0.020	0.012	5.2	6.9	6.1	15	0.10	10.1	
NDMH 218	NDMH 220	—	5.76	0.53	12.6	100	8	24.42	24	0.010	0.012	25.0	8.2	9.2	62	0.10	12.7	
NDMH 220	NFE	—	5.76	0.53	12.7	100	8	24.42	24	0.010	0.012	25.0	8.2	9.2	48	0.10	12.8	
NCB 213	NDMH 214	—	—						12	0.010	0.012	4.2	5.3		10			ADDED CATCH BASIN TO
																		COLLECT RUNOFF AT NCB 212

WHITMAN & BINGHAM ASSOCIATES — DESIGN OF STORM SEWERS

PROJECT NAME: HIGHFIELD VILLAGE
PROJECT NO.: 13510
CALCULATED BY: MFP
SHEET 7 OF 8
DATE: 9-22-15

A: FLOW PATH FROM	A: FLOW PATH TO	B: AREA (Ac) SUB-AREA	B: AREA (Ac) TOTAL	C: COEFF. OF RUNOFF (c)	D: TIME TO INLET (min.)	E: DESIGN STORM (year)	F: INTENSITY (i)	G: DESIGN FLOW (Q) (cfs) (CxFxB)	H: PIPE SIZE (in.)	I: PIPE SLOPE (ft./ft.)	J: ROUGH. COEFF. (n)	K: FULL CAPACITY (cfs)	L: FULL VELOCITY (fps)	M: DESIGN VELOCITY (fps)	N: LENGTH OF PIPE (ft.)	O: TIME IN CHANNEL (min.) (N/M)	P: TIME TO NEXT NODE (min.) (D+O)	REMARKS
NCB 227	NDMH 231	2.34	2.34	0.38	10	100	8	7.11	15	0.020	0.012	9.6	8.0	8.7	12	0.10	10.1	25 YEAR RATE = 4.45
NCB 229	NDMH 231	—	—						15	0.020	0.012	9.6	8.0	8.7	10	0.10	10.1	ADD CATCH BASIN TO
																		collect RUNOFF AT NCB 228
NDMH 231	NDMH 230	—	2.34	0.38	10.1	100	8	7.11	15	0.013	0.012	8.1	6.7	7.5	68	0.20	10.3	
NCB 222	NDMH 226	0.10	0.10	0.70	10	100	8	0.56	12	0.010	0.012	4.2	5.3	3.6	14	0.10	10.1	
NCB 224	NDMH 226	2.10	2.10	0.45	10	100	8	7.56	15	0.015	0.012	9.0	7.5	8.3	14	0.10	10.1	25 YEAR RATE = 4.73
NCB 223	NDMH 226	—	—						15	0.015	0.012	9.0	7.5	8.3	10	0.10	10.1	ADD CATCH BASIN TO
																		collect RUNOFF AT NCB 224
NDMH 226	NDMH 230	—	2.20	0.46	10.1	100	8	8.10	15	0.015	0.012	9.0	7.5	8.4	136	0.30	10.4	
NCB 228	NDMH 230	2.95	2.95	0.34	10	100	8	8.02	15	0.015	0.012	9.0	7.5	8.3	14	0.10	10.1	25 YEAR RATE = 5.02
NCB 233	NDMH 230	—	—						15	0.015	0.012	9.0	7.5	8.3	14	0.10	10.1	ADD CATCH BASIN TO
																		collect RUNOFF AT NCB 228
NDMH 230	NDMH 234	—	7.49	0.39	10.4	100	8	23.37	24	0.010	0.012	25.0	8.2	9.2	12	0.10	10.5	
NCB 232	NDMH 234	0.48	0.48	0.66	10	100	8	2.53	12	0.020	0.012	5.2	6.9	6.8	12	0.10	10.1	USE DOUBLE GRATE
NDMH 234	NDMH 236	—	7.97	0.41	10.5	100	8	26.14	30	0.005	0.012	30.0	6.4	7.2	80	0.20	10.7	
NDMH 236	NFE	—	7.97	0.41	10.7	100	8	26.14	30	0.005	0.012	30.0	6.4	7.2	60	0.10	10.8	

WHITMAN & BINGHAM
ASSOCIATES

DESIGN OF STORM SEWERS

PROJECT NAME HIGHFIELD VILLAGE
PROJECT NO. 13510 SHEET 8 OF 8
CALCULATED BY MFP DATE 12-21-15

A		B		C	D	E	F	G	H	I	J	K	L	M	N	O	P	
FLOW PATH		AREA (Ac)		COEFF. OF RUNOFF (c)	TIME TO INLET (min.)	DESIGN STORM (year)	INTENSITY (i)	DESIGN FLOW (Q) (cfs) (CxFxB)	PIPE SIZE (in.)	PIPE SLOPE (ft./ft.)	ROUGH. COEFF. (n)	FULL CAPACITY (cfs)	FULL VELOCITY (fps)	DESIGN VELOCITY (fps)	LENGTH OF PIPE (ft.)	TIME IN CHANNEL (min.) (N/M)	TIME TO NEXT NODE (min.) (D+O)	REMARKS
FROM	TO	SUB-AREA	TOTAL															
NCB 250	NDMH 252	—	0.04	0.78	10	100	8	0.25	12	0.010	0.012	4.2	5.3	3.0	10	0.10	10.1	
NCB 251	NDMH 252	—	0.17	0.51	10	100	8	0.69	12	0.005	0.012	2.8	3.5	3.0	20	0.10	10.1	
NDMH 252	SWM 900	—	0.21	0.56	10.1	100	8	0.94	12	0.005	0.012	2.8	3.5	3.2	20	0.10	10.2	
SWM 900	NFE	—	0.21	0.56	10.2	100	8	0.94	12	0.005	0.012	2.8	3.5	3.2	80	0.40	10.6	
NCB 240	NDMH 242	—	0.29	0.73	10	100	8	1.69	12	0.010	0.012	4.2	5.3	5.0	16	0.10	10.1	
NCB 241	NDMH 242	—	0.33	0.54	10	100	8	1.43	12	0.010	0.012	4.2	5.3	4.9	16	0.10	10.1	
NDMH 242	NDMH 243	—	0.62	0.63	10.1	100	8	3.12	12	0.010	0.012	4.2	5.3	5.8	60	0.20	10.3	
NDMH 243	NDMH 244	—	0.62	0.63	10.3	100	8	3.12	12	0.010	0.012	4.2	5.3	5.8	142	0.40	10.7	
NDMH 244	NFE	—	0.62	0.63	10.7	100	8	3.12	12	0.010	0.012	4.2	5.3	5.8	15	0.10	10.8	
NDMH 124	NDMH 127	—	1.56	0.48	10.6	100	8	5.99	15	0.008	0.012	6.5	5.6	6.3	140	0.40	11.0	
NCB 125	NDMH 127	—	0.69	0.38	10	100	8	2.10	12	0.005	0.012	2.8	3.5	3.8	16	0.10	10.1	USE DOUBLE GRATE
NCB 126	NDMH 127	—	0.20	0.73	10	100	8	1.17	12	0.005	0.012	2.8	3.5	3.3	16	0.10	10.1	
NDMH 127	NDMH 128	—	2.45	0.47	11.0	100	8	9.21	18	0.006	0.012	9.3	5.4	6.1	40	0.10	11.1	
NDMH 128	NDMH 129	—	2.45	0.47	11.1	100	8	9.21	18	0.006	0.012	9.3	5.4	6.1	144	0.40	11.5	
NDMH 129	NFE	—	2.45	0.47	11.5	100	8	9.21	18	0.006	0.012	9.3	5.4	6.1	20	0.10	11.6	

RECHARGE VOLUME CALCULATIONS

<u>RECHARGE VOLUME CALCULATION</u> September 17, 2015

Calculate recharge volume lost to newly developed impervious areas.

- Refer to Drainage Data for the Soil Types on site –

  Impervious area = building roofs, driveways, sidewalks and roadways.

  Total of 10.47 acres of impervious area in C soils group and 1.10 acres of impervious area in the B soils group.

  Approximately 10.50 acres of impervious area going to recharge facilities.

  Ratio of total impervious area to impervious area draining to recharge facilities.

  11.57 acres/10.50 acres = 1.11

  Recharge volume =

  (10.47 AC)(0.25"/12"/ft)(43,560 SF/AC) = 9,502 *Cubic Feet (CF)*
  (1.10 AC)(0.35"/12"/ft)(43,560 SF/AC) = 1,398 CF

  Total Recharge Volume = 10,900 CF

  Adjusted minimum required recharge volume =

  1.11 x (10,900 CF) = 12,100 CF

  <u>TOTAL RECHARGE VOLUME REQUIRED</u> = <u>12,100 CF</u>

Calculate the recharge volume provided.

Calculate Retention Basin volumes below outlet:

Volume from HydroCAD Storage-Area Graphs = 22,680 CF

<u>TOTAL RECHARGE VOLUME PROVIDED</u> = <u>22,680 CF</u>

DRAWDOWN CALCULATION (For each basin)

Time (drawdown) = Rv (storage volume) / [K x(Bottom Area)]

K - Saturated Hydraulic Conductivity 0.27 Inches / Hour = 0.0225 Feet / Hour

Retention Basin 10

Time = 1,501 C.F. / [(0.0225 Feet / Hour) x 1,947 S.F.]

Time = 34.26 Hours

Retention Basin 20

Time = 8,169 C.F. / [(0.0225 Feet / Hour) x 12,047 S.F.]

Time = 30.14 Hours

Retention Basin 30

Time = 3,043 C.F. / [(0.0225 Feet / Hour) x 3,528 S.F.]

Time = 38.33 Hours

Retention Basin 40

Time = 2,219 C.F. / [(0.0225 Feet / Hour) x 5,350 S.F.]

Time = 18.43 Hours

Retention Basin 50

Time = 2,780 C.F. / [(0.0225 Feet / Hour) x 6,517 S.F.]

Time = 18.96 Hours

Retention Basin 60

Time = 1,307 C.F. / [(0.0225 Feet / Hour) x 1,934 S.F.]

Time = 30.04 Hours

Retention Basin 70

Time = 1,982 C.F. / [(0.0225 Feet / Hour) x 5,160 S.F.]

Time = 17.07 Hours

Retention Basin 80

Time = 454 C.F. / [(0.0225 Feet / Hour) x 1,336 S.F.]

Time = 15.10 Hours

Retention Basin 90

Time = 1,389 C.F. / [(0.0225 Feet / Hour) x 1,964 S.F.]

Time = 31.43 Hours

Retention Basin 100

Time = 1,337 C.F. / [(0.0225 Feet / Hour) x 1,773 S.F.]

Time = 33.52 Hours

SEDIMENT FOREBAY CALCULATIONS

SEDIMENT FOREBAY VOLUME CALCULATIONS September 17, 2015

Calculate the volume of the sediment forebays for the minimum 0.1 inch per impervious acre as stated in the Department of Environmental Protection Stormwater Management Standards

Sediment Forebay at Roadway Entrance

(0.10"/12") X (43,560 x 0.15 Ac) = 55 Cubic Feet (C.F.) Required

Volume Provided = 1,500 C.F.

Forebay at Retention Basin 20

(0.10"/12") X (43,560 x 1.34 Ac) = 486 Cubic Feet (C.F.) Required

Volume Provided = 2,610 C.F.

Forebay at Retention Basin 30

(0.10"/12") X (43,560 x 0.53 Ac) = 193 Cubic Feet (C.F.) Required

Volume Provided = 300 C.F.

Forebay at Retention Basin 40

(0.10"/12") X (43,560 x 2.60 Ac) = 945 Cubic Feet (C.F.) Required

Volume Provided = 1,475 C.F.

Forebay at Retention Basin 50

(0.10"/12") X (43,560 x 1.55 Ac) = 563 Cubic Feet (C.F.) Required

Volume Provided = 927 C.F.

Forebay at Retention Basin 60

(0.10"/12") X (43,560 x 1.63 Ac) = 592 Cubic Feet (C.F.) Required

Volume Provided = 710 C.F.

Forebay at Retention Basin 80

(0.10"/12") X (43,560 x 0.55 Ac) = 200 Cubic Feet (C.F.) Required

Volume Provided = 819 C.F.

Forebay at Retention Basin 90

(0.10"/12") X (43,560 x 0.73 Ac) = 265 Cubic Feet (C.F.) Required

Volume Provided = 740 C.F.

OPERATION AND MAINTENANCE PLAN

WHITMAN & BINGHAM
ASSOCIATES

510 Mechanic Street
Leominster, Massachusetts 01453
(978) 537-5296
FAX (978) 537-1423

STORMWATER MANAGEMENT SYSTEM
INSPECTION AND MAINTENANCE PLAN

Highfield Village Definitive Subdivision
Off Northfield Road
Lunenburg, Massachusetts

Prepared for:

JEG Holdings, LLC
P.O. Box 5515
Beverly, MA 01915

Date: September 17, 2015
Revised: December 21, 2015

The proposed Highfield Village Definitive Subdivision has been designed to function properly provided that routine maintenance is performed. Maintenance of the roadways, catch basins, stormwater treatment unit, grass channels and retention basins are required to ensure that sedimentation and pollution is controlled and storm water retention capacity is sustained. To ensure the proper functioning of these facilities the following maintenance practices will be used:

Owner and Party Responsible for Maintenance:

JEG Holdings LLC
P.O. Box 5515
Beverly, MA 01915

The owner shall develop a chart with a list of the following Best Management Practices (BMP's) with the chart listing the maintenance requirement, frequency of maintenance and the date the maintenance was performed.

PART 1 - INSPECTION AND MAINTENANCE (DURING CONSTRUCTION)

A. It shall be the responsibility of the General Contractor to ensure that the inspection, maintenance and protection of the stormwater management system (defined in Section 2a below) is performed during the construction phase of the project and up to final stabilization of the site (refer to attached plan).

B. The on-site stormwater management system shall be protected from the introduction of sediments and debris both during installation and throughout the duration of site construction in order to provide a fully functioning and long lasting system upon completion of construction.

C. The following steps shall be implemented, at a minimum, to protect the stormwater management system during construction:

1. During construction of the grass channels, forebays and retention basins, the open excavation shall be protected from on-site sediments from storm runoff and snow melt by providing a line of erosion controls consisting of haybales or silt fence or a combination of both. In the event that the excavation is compromised by sediment, the sediments shall be removed and the bottom of the excavation restored.

2. An inspection of the stormwater management system shall be conducted by the General Contractor weekly as well as during and after all rainstorms until the completion of construction. In case of any noted introduction of sediments into the system, the General Contractor shall immediately remove said sediments and take any necessary steps to limit further introduction of sediments and notify the engineer of any problems involving storm water management systems.

   a) The stormwater management system shall be defined as the catch basins, drain manholes, grass channels, forebays and retention basins.

   b) A rainstorm shall be defined by all or one of the following thresholds:

      i. Any storm in which rain is predicted to last for twelve consecutive hours or more.

      ii. Any storm for which a flash flood watch or warning is issued.

      iii. Any single storm predicted to have a cumulative rainfall of greater than one-half inch.

      iv. Any storm not meeting the previous three thresholds but which would mark a third consecutive day of measurable rainfall.

3. The General Contractor shall also inspect the stormwater management systems at times of significant increase in surface water runoff due to rapid thawing when the risk of sediment migration is significant.

4. All collected/removed sediments shall be removed from the site and disposed of in a legal manner.

PART 2 - INSPECTION AND MAINTENANCE (POST-CONSTRUCTION)

A. It shall be the responsibility of the Owner to ensure that the long-term inspection and maintenance of the stormwater management system on-site is performed. The on-site system shall include the following individual components of the stormwater management system: catch basins, drain manholes, grass channels, forebays and retention basins as shown on the approved plans. The Owner shall obtain the services of a qualified Contractor to perform the required inspections and maintenance of the individual components of the stormwater management system on-site, as listed above. All inspections and maintenance of the components of the stormwater management system.

B. It shall be the responsibility of the Owner to maintain adequate records to demonstrate conformance with this inspection and maintenance plan.

C. The inspection and maintenance plan for the on-site stormwater management system (as listed in Section A above) shall be carried out by the current owner (project applicant) and by any and all future owners of the site in perpetuity.

D. The inspection and maintenance plan shall be carried out as outlined below upon completion and final stabilization of the project site:

E. During the first six months of operation of the facility the stormwater management system shall be inspected a minimum of once per month and after every rainstorm (defined in Part 1 above). A portion of this time period must be in the growing season. As warranted by these inspections maintenance of the system shall be performed including, but not limited to the following:

   1. Visual inspection of the catch basins, stormwater treatment unit, grass channels, forebays and retention basins to ensure that the system is not backed up and is emptying properly.

F. After the six month time period above has elapsed, thorough investigations shall be conducted four times a year. Maintenance requirements may be adjusted based upon the results obtained from the first year of operation. As warranted by these inspections maintenance of the system shall be performed including, but not limited to the following:

   1. The catch basins, stormwater treatment unit, grass channels, forebays and retention basins requires an annual inspection for necessary maintenance (refer to attached plan). This consists of visually inspecting for the accumulation of sediment; obstructions within the channels, forebays and basins. Remove sediments from the catch basins, grass channels, forebays and retention basins. Sediment, which is removed, shall be legally disposed of. The retention basins shall be monitored at several intervals during and after a small and large rainfall event to ensure the basin is functional.

MAINTENANCE LOGS

Maintain a log of all operation and maintenance activities including without limitation inspections, repairs, replacement and disposal (for disposal, the log shall indicate the type of material and disposal location). A copy of the yearly maintenance logs shall be made accessible to the following agencies:

Conservation Commission
Ritter Memorial Building
960 Massachusetts Avenue
Lunenburg, MA 01462

Department of Environmental Protection
Central Regional Office
8 New Bond Street
Worcester, MA 01606

CATCH BASIN INSPECTION FORM

JEG Holdings, LLC
P.O. Box 5515
Beverly, MA 01915

Owner:__________________________

Property Manager:_______________________

Inspected By:_____________________

Date of Inspection:______________________

Catch Basins Inspected (indicate Street name and Station number of Basin):

Acceptable ☐ Needs Work ☐

Add notes below if structures need work:

Date of cleaning:__________________ By Whom:_________________

Date of repair: ____________________ By Whom:_________________

Below note any further actions that need to be taken as necessary:

DRAIN MANHOLE INSPECTION FORM

JEG Holdings, LLC
P.O. Box 5515
Beverly, MA 01915

Owner:________________________

Property Manager:_____________________

Inspected By:___________________

Date of Inspection:_____________________

Drain Manhole Inspected (indicate Street name and Station number of Manhole):

Acceptable ☐ Needs Work ☐

Add notes below if structures need work:

Date of cleaning:__________________ By Whom:_______________

Date of repair: __________________ By Whom:_______________

Below note any further actions that need to be taken as necessary:

GRASS CHANNEL INSPECTION FORM

JEG Holdings, LLC
P.O. Box 5515
Beverly, MA 01915

Owner:__________________________

Property Manager:_______________________

Inspected By:_____________________

Date of Inspection:______________________

Grass Channel Inspected (Describe location of channel):

Acceptable ☐ Needs Work ☐

Add notes below if structures need work:

Date of cleaning:__________________ By Whom:________________

Date of repair: ____________________ By Whom:________________

Below note any further actions that need to be taken as necessary:

RETENTION BASIN INSPECTION FORM

JEG Holdings, LLC
P.O. Box 5515
Beverly, MA 01915

Owner:________________________

Property Manager:______________________

Inspected By:___________________

Date of Inspection:______________________

Retention Basins Inspected (Describe location of Basin):

Acceptable ☐ Needs Work ☐

Add notes below if structure needs work:

Date of cleaning:_________________ By Whom:________________

Date of repair: ___________________ By Whom:________________

Below note any further actions that need to be taken as necessary:

STORMWATER TREATMENT UNIT INSPECTION FORM

JEG Holdings, LLC
P.O. Box 5515
Beverly, MA 01915

Owner:________________________

Property Manager:_____________________

Inspected By:___________________

Date of Inspection:_____________________

Stormwater Treatment Unit Inspected:

Acceptable ☐ Needs Work ☐

Add notes below if structures need work:

Date of cleaning:__________________ By Whom:_______________

Date of repair: __________________ By Whom:_______________

Below note any further actions that need to be taken as necessary:

TSS REMOVAL CALCULATIONS

TSS Removal Calculation Worksheet

Location: **LUNENBURG, MA**

A BMP	B TSS Removal Rate	C Starting TSS Load *	D Amount Removed (BxC)	E Remaining Load (C-D)
Catch Basin w/Deep Sump	0.25	1.00	0.250	0.75
Stormceptor	0.80	0.75	0.600	0.15
		Total TSS Removal =	0.850	= ***85.0%***

Project: **Highfield Village**
Prepared By: **MFP**
Date: **12/21/2015**

* Equals remaining load from previous BMP (E) which enters the BMP

TSS Removal Calculation Worksheet

Location: **LUNENBURG, MA**

A BMP	B TSS Removal Rate	C Starting TSS Load *	D Amount Removed (BxC)	E Remaining Load (C-D)
Catch Basin w/ Deep Sump	0.25	1.00	0.250	0.75
Basin w/ pre-treatment	0.80	0.75	0.600	0.15
		Total TSS Removal =	0.850 =	***85.0%***

Project: **Highfield Village**
Prepared By: **MFP**
Date: **12/21/2015**

* Equals remaining load from previous BMP (E) which enters the BMP

TSS Removal Calculation Worksheet

Location: **LUNENBURG, MA**

A BMP	B TSS Removal Rate	C Starting TSS Load *	D Amount Removed (BxC)	E Remaining Load (C-D)
Catch Basin w/ Deep Sump	0.25	1.00	0.250	0.75
Grassed Channel	0.50	0.75	0.375	0.38
Basin w/pre-treatment	0.80	0.38	0.300	0.08
		Total TSS Removal =	0.925	= ***92.5%***

Project: **Highfield Village**
Prepared By: **MFP**
Date: **12/21/2015**

* Equals remaining load from previous BMP (E) which enters the BMP

Technology Assessment Report

Storm*ceptor*®

CSR™ New England Pipe

Prepared for
The Massachusetts Strategic
Envirotechnology Partnership
STEP

December, 1997

Prepared by

Dr. Eric Winkler
Center for Energy Efficiency and Renewable Energy
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CEERE

Center for Energy Efficiency and Renewable Energy

University of Massachusetts
UMASS Amherst

PROJECT FUNDING

The Step Technology Assessment Project was Funded by
The University Of Massachusetts and The Massachusetts Division of Energy Resources

PREFACE

The STEP technology assessment process is designed to identify those technologies that will support the economic and environmental/energy goals of the Commonwealth of Massachusetts and may benefit from STEP assistance. The process is meant to be one of screening, in which technologies are evaluated by independent technical specialists. Recommendation from this process does not constitute an endorsement of the technology or of the absolute validity of the technology. Rather, STEP technical assessments attest only that, through the screening process, the reviewers feel there may be benefit to the Commonwealth of Massachusetts.

EXECUTIVE SUMMARY

The technology described in this review is Storm*ceptor*® and is currently owned by Storm*ceptor*® Corporation and licensed to CSR/New England Pipe (CSR/NEP) of Wauregan, CT, for distribution in Massachusetts, among other states. The system is being commercialized by CSR/NEP. The Storm*ceptor* technology addresses treatment of stormwater runoff. It is proposed as an effective spill control and stormwater quality enhancement system, capable of retaining grit, suspended solids, oils and grease during periods of both low and high flows. It is proposed as a replacement for conventional manholes within a storm drain system. It is not designed as a catch basin or detention system. It can be used within any new or existing lateral piped conveyance system and comes in several sizes with outlets up to 60". The system is claimed as capable of removing 50 - 80% of TSS when properly sized. The Storm*ceptor* system is recommended as a stand alone or as a component to a system or in combination with different BMPs. An example configuration may include the following components: catch basin or water quality inlet, Storm*ceptor*, detention basin or infiltration system.

The system is a prefabricated well type structure which provides sedimentation, oil, and grease separation. It is manufactured in both concrete or fiberglass. Current sizes range from 900 to 7200 gallons, with diameters between 6 and 12 feet. The design of the system provides two sections, a treatment chamber and bypass chamber. The structural components of the system are separated by an insert which has a weir, inflow drop pipe, and outflow riser. Operation of the system is passive with respect to flow control and treatment. During low flows or frequent storm events, stormwater from the inlet is directed down the inflow drop pipe located adjacent to the inlet of the treatment chamber. Flow in excess of the inflow drop pipe capacity is directed into the bypass chamber to the outlet of the system. The effective treatment capacity is set by a weir which surrounds the inflow drop pipe at the inlet and the volume of the treatment chamber. Effluent from the treatment chamber exits via the outflow riser which extends below the water surface in the treatment chamber up to the overflow chamber and to the system outlet. Sediment is retained in the bottom of the treatment chamber and oils and grease are retained at the top of the treatment chamber in a quiescent area.

The Storm*ceptor* system is stormwater treatment structure providing event based solids separation. The value added in the Storm*ceptor* system is the ability to reduce turbulence in the treatment chamber, which makes it better at removing TSS and TPH than conventional BMPs of the same category. The Storm*ceptor* system has been demonstrated to provide at least 52% removal of TSS when sized according to Storm*ceptor's* "Treatment Train" criteria and 77% when sized according to Storm*ceptor's* "Sensitive Area" criteria. It is likely that a higher removal efficiency, greater than 80%, could be expected if the contributing drainage area is smaller than the sizing recommended. The system is likely to remove grease and oils with its inflow and outflow pipe configurations. The Storm*ceptor* system appears to be a good control technology in areas of higher pollution potential, Standard 5 described in the Stormwater Management Handbooks (DEP and CZM, 1997). Storm*ceptor* system may be used as a component in combination with different BMPs or may be used as a stand alone installation provided it is sized for 80% TSS removal. STEP recommends collection of additional data representing a varied set of operating conditions over a realistic maintenance cycle to verify TSS removal rates greater than 80%.

HIGHLIGHTS

- Performance data available demonstrates that the Storm*ceptor* system can provide TSS removal rates of 77% when sized according to the "Sensitive Area" criteria. Evidence suggests that the Storm*ceptor* system may be capable of achieving TSS removal rates between 89% and 99% when sized accordingly, under conditions similar to those reported in the Westwood Massachusetts site, including: climate and land use intensity.
- Performance data available to this reviewer suggest that the Storm*ceptor* system can provide TSS removal rates of 52% when sized according to the "Treatment Train" criteria.
- Use of the Storm*ceptor* system as a pretreatment component in combination with different BMPs, when sized according to the "Treatment Train" criteria, will likely meet standards 4 and 6 of the Stormwater Management Handbooks (DEP and CZM,1997). Use as a stand alone device may be justified when sized according to the "Sensitive Area" criteria.
- The Storm*ceptor* system is likely to perform in areas with higher potential pollutant levels in Standard 5 of the Stormwater Management Handbooks (DEP and CZM,1997).
- The Storm*ceptor* system is useful for new and retrofit installations in Standard 7 of the Stormwater Management Handbooks (DEP and CZM,1997), especially where space is limited.
- The Storm*ceptor* system is also suited for secondary sediment control from construction related sediment loads specified in Standard 8 (DEP and CZM,1997).

TABLE OF CONTENTS

TECHNOLOGY PROPONENT

The technology described in this review is Storm*ceptor*® and is currently owned by Storm*ceptor*® Corporation and licensed to CSR/New England Pipe (CSR/NEP) of Wauregan, CT, for distribution in Massachusetts, among other states. The system is being commercialized by CSR/NEP. CSR/NEP is a subsidiary of CSR Hydro Conduit Corporation which manufactures Storm*ceptor* in the most of the United States.

TECHNOLOGY DESCRIPTION

The Storm*ceptor* technology addresses treatment of stormwater runoff. It is proposed as an effective spill control and stormwater quality enhancement system, capable of retaining grit, suspended solids, oils and grease during periods of both low and high flows. It is proposed as a replacement for conventional manholes within a storm drain system. It is not designed as an inlet or detention system. It can be used within any lateral piped conveyance system and comes in several sizes with outlets up to 60". The system is claimed as capable of removing 50 to 80% of TSS when properly sized. The Storm*ceptor* system may be used as a stand alone BMP or as a component within a combination of different BMPs. An example of a combination of different BMPs is a catch basin, Storm*ceptor,* and detention pond. It is compatible with any existing conveyance system. It is proposed that the system has an added value in its small size and its added removal capability over similar conventional BMPs such as catch basins and deep sumps. The system is currently protected by a United States Patent No. 4,985,148.

The system is a prefabricated well type structure which provides sedimentation, oil, and grease separation (Figure 1). It is manufactured in both concrete or fiberglass. Current sizes range from 900 to 7200 gallons, with diameters between 6 and 12 feet. The design of the system provides two sections, a treatment chamber and bypass chamber. The structural components of the system are separated by an insert which has a weir, inflow drop pipe, and outflow riser (Figure 2). The size of the insert and its associated components depends on the overall size of the treatment chamber and bypass chamber.

Operation of the system is passive with respect to flow control and treatment. During low flows or frequent storm events, stormwater from the inlet is directed down the inflow drop pipe located adjacent to the inlet of the treatment chamber. Flow in excess of the inflow drop pipe capacity is directed into the bypass chamber to the outlet of the system. The effective treatment capacity is set by a weir which surrounds the inflow drop pipe at the inlet and the volume of the treatment chamber. Effluent from the treatment chamber exits via the outflow riser which extends below the water surface in the treatment chamber, up to the overflow chamber, and to the system outlet. Sediment is retained in the bottom of the treatment chamber and oils and grease are retained at the top of the treatment chamber in a quiescent area. Oil and grease are prevented from leaving the chamber by the outflow riser.

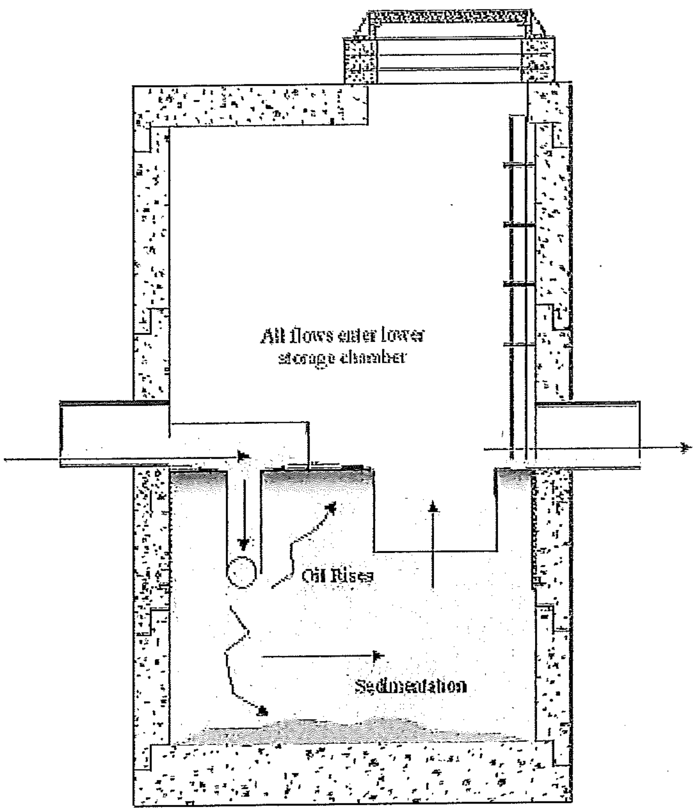

Figure 2. Storm*ceptor* operation during average flow conditions.

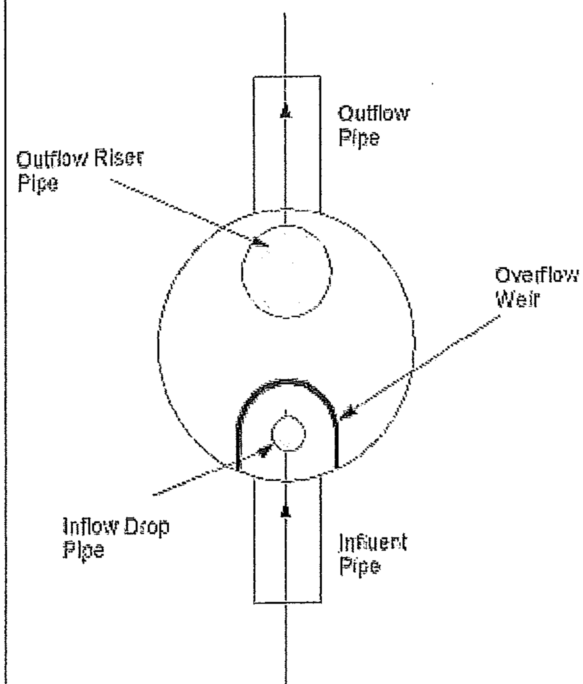

Figure 1. Top view of Storm*ceptor* insert.

The inlet and outlet elevations of the system are kept at a minimum with 1" difference in the concrete and fiberglass units. The multiple inlet units have a 3" difference between the inlet and outlet. Approximately 9 inches of hydrostatic head is developed from the influent elevation in the weir. A low head system is designed to reduce the potential for scouring from higher velocities in the treatment chamber. During storm events exceeding the treatment capacity of the chamber the head on the system is kept constant because stormwater elevation over the drop pipe is nearly equivalent to the head over the outflow riser. Studies prepared by Storm*ceptor* Corporation (Marsalek et al., 1994) demonstrated when total flow to the system was increased, in excess of the treatment chamber capacity, flow through the treatment chamber increased initially and then decreased slightly. This implies that treatment performance would not be lowered during high flow events and scouring and resuspension of previously settled solids is prevented.

The system is suited for local or lateral lines within any conveyance system. The system is not recommended for large storm drain trunk lines. The system is not designed to be used as an inlet catch basin. Storm*ceptor* Corporation produces 8 models with different sediment and oil capacities illustrated in Table A1 in the Appendix. Preliminary sizing recommendations are presented in Technical Design Manual (Storm*ceptor* Corporation, 1997) and in Table A2 in the Appendix. The preliminary recommended sizing table specifies units per impervious drainage area based on percentages of treatment.

TECHNICAL FEASIBILITY

The Storm*ceptor* system is stormwater treatment structure providing event based solids separation. The Storm*ceptor* has a greater TSS removal efficiency than water quality inlets. The value added in the Storm*ceptor* system is the ability to reduce turbulence in the treatment chamber, which makes it better at removing TSS and TPH than conventional BMPs of the same category. A significant amount of design engineering has gone into the Storm*ceptor*. In particular, the flow control device developed for the insert is capable of reducing turbulence in the treatment chamber to quiescent levels. This directly increases removal efficiencies for TSS and grease and oils. The system appears to be capable of limiting resuspension of settled particles, a common problem in catch basins.

The basic principle of operation is sedimentation. In addition, some minimal treatment to pollutant parameters associated with the settled solids is likely to occur. In particular, BOD_5, COD, particulate N, P, and pathogens may be associated with the finer fractions of sediments and removed from the stormwater. Oil and grease are less dense than water so they float to the top of the treatment chamber. Since the outflow riser extends below the surface of the water in the treatment chamber, oil and grease will be trapped in the treatment chamber.

COMPETING TECHNOLOGIES

Several direct competing technologies exist for Storm*ceptor*, including other sedimentation chamber technologies like oil and grit separators. Information submitted by a competing technology suggests that Storm*ceptor* is a cost competitive product. However, no comparative data on oil and grit separators was submitted by CSR/NEP on these technologies. Typical oil and grit separators are not likely to achieve the same level of treatment as the Stormceptor system. The Storm*ceptor* system should be competitive with other technologies that produce comparable removal efficiencies. The Storm*ceptor* system has spatial requirement advantages over detention ponds and artificial wetlands which have large area requirements. The Storm*ceptor* system is not a recharging system and therefore not comparable to recharging systems such as infiltration basins and trenches. It may produce equivalent treatment levels as recharging systems, when sized properly. The Stormceptor system is not suitable for meeting recharge Standard 3 as a singular treatment system (DEP and CZM, 1997), but may be well suited for pretreatment in a mixed component system with recharge. The system should be competitive with the other BMPs in the deep sump catch basin category.

DATA SUPPORTING CLAIMS

Prior to considering performance data from any treatment technology, the following notation is advised. Data collected from isolated stormwater treatment systems may be variable. Some of this variability may be due to differences in land use, climate, and soil type. Additionally, it is possible that storm events may have variable pollutant loads, resulting in varied treatment system performance at an individual site. The combination of these two sources of variability, inherent in all BMP performance verification, presents an unknown level of uncertainty. In order to overcome this uncertainty a larger set of data would be required to predict the performance of the technology under a variety of conditions. The Storm*ceptor* system has a limited set of performance data.

The data submitted by CSR/NEP are intended to demonstrate performance capable of achieving Standards 4, 5, 6 and 7 of the Department of Environmental Protection (DEP) Stormwater Management Handbooks (DEP and CZM,1997). In this Technical Assessment, performance is based on available data in the proponent's submission from installations in Toronto and Edmonton Canada. Bench scale testing and modeling data were used as predictors of performance but not for sizing. A third installation, in Westwood, Massachusetts, supports performance claims at Storm*ceptor's* "Sensitive Area" criteria of 80%. Storm*ceptor* has more than 1600 units installed in the U.S. and Canada. Additional data from other installations may become available for future performance verifications.

Analytical Modeling and Bench Scale Studies

Storm*ceptor* Corporation has committed resources to study the Storm*ceptor* system using analytical models with bench and pilot scale validation. Several modeling scenarios were developed for Storm*ceptor* by Marshall Macklin Monaghan, LTD. (1994) to evaluate the removal of TSS under a variety of storm event conditions using the Stormwater Management Model (SWMM). Some of the parameters for the model include: rainfall data, temperature, and runoff. The analytical model results are based on non-ideal settling and do not account for flocculation effects due to its considerable complexity. Predicted long term TSS removal rates were calculated as a function of drainage area per unit for 4 different Storm*ceptor* models. Results from this modeling study suggest that in small drainage areas the Storm*ceptor* units had higher removal rates. The long term TSS removal rates for a 1.2 acre/unit drainage area were calculated at 53%, 46%, 39%, and 30% for systems sized at 6800 gal., 4850 gal., 2800 gal., and 1820 gal., respectively. Removal rates decreased proportionately by 25% of the highest rate when the drainage area was doubled. Removal rates were less than 20% at 4.25 acres/unit.

Another laboratory study performed by Marcalek et al. (1994) suggests a much larger variation for TSS removal rates, ranging from 6% to 95%. In these studies flow rate was manipulated along with configurations of the inflow drop pipe and outflow riser. Systems used in these tests were 1/4 size and the sediment used was an ABS polymer used to control particle size more effectively. A scaling factor of 32 was used to estimate the actual prototype design flows based on equivalent Froude number under the special case where no free fluid surface exists with incompressible fluid. The removal rates for fine to medium sands were 95% at 95 gal/min, 77% at 206 gal/min, 68% at 285 gal/min, and 6% at 634 gal/min.

A study from the University of Conventry (Pratt, 1996) tested the equivalent to the STC 900 system at 144 gal/min in a 20 minute event. Sand and crankcase oil were loaded at 4100 mg/l and 90 mg/l, respectively to the influent water. Removal efficiencies were reported at 83% for sand and 98% for oil. While this was a full scale study, the conditions of the test may not accurately reflect field conditions under all circumstances. In particular, the flow rates do not fall within the recommended ranges specified in the Storm*ceptor* Design Manual (Storm*ceptor* Corporation, 1997). Additionally, the use of model sands do not always reflect the behavior of sediments under field conditions. Lastly, the number of replicates do not warrant statistical significance due to limited replications.

Storm*ceptor* Corporation and CSR/NEP have indicated that the preliminary sizing recommendations are based on their field installations and not the laboratory data or modeling data. Review of these data indicate that the laboratory data and modeling data do not give a definitive picture of system performance under field conditions. It is suggested that additional performance data be gathered from field installations and return to the modeling data for model calibration. Analysis of model sensitivity would be appropriate once additional field data has been collected.

Field Installations

A field test of the Storm*ceptor* system was carried out in The City of Edmonton Canada at a parking lot located in the Westmount Shopping center on Fountain Lake. A single Storm*ceptor* unit (Model STC2000, which is equivalent to an STC2400) was installed to treat an approximate impervious drainage area of 9.8 acres. This installation had a unit undersized by a factor of 3. The unit was fitted with automated samplers on inflow and outflow pipes. Water quality was measured on 4 storm events, and included TSS, metals, oil and grease. Average removal efficiencies were 51.5%, 39 to 53%, and 43%, respectively (Table 1). No additional data on the variability of these data were available. Precipitation data for the storm events were not made available to this reviewer at the time of this assessment. Therefore, it is unclear whether these events were 0.5 inch or more. The Storm*ceptor* Corporation's recommended impervious drainage area for the STC 2000 (equivalent to the STC 2400) is 3.35 acres, therefore the system was largely under-sized. The performance of this system exceeded the predicted performance based on the sizing guidelines set by Storm*ceptor*. Under similar environmental conditions, including climate, land use intensity, and soil conditions as that at the Edmonton installation, it is possible that the undersized Storm*ceptor* system will provide at least 52% removal of TSS, sized under Storm*ceptor's* "Treatment Train" criteria (50% TSS removal).

Table 1. Water Quality Tests at Westmount Shopping Center, Edmonton Canada, 1996

Water Quality Parameter	**Average Percent Removal Efficiency**
TSS	52%
Metals (Fe, Pb, Zn, Cr, and Cu)	39 - 53%
Oil and Grease	43%

Storm*ceptor* conducted a survey of sediment loads to 23 Storm*ceptor* units installed in the City of Toronto, Canada (Bryant et al., 1995). Analysis of the sediment accumulations and estimates of TSS removal efficiency were calculated based on predicted flow and loadings. In this study, a mass balance was not utilized to measure removal efficiency. Rather, estimates based on regional precipitation data and estimated mean concentration (EMC) (Novotny, 1992) were used to determine loadings. The removal efficiency was calculated from the ratio of sediment collected in the unit and corrected for water content, and estimated loading. Solids removal efficiency increased with greater storage capacity (r^2=0.60) (Figure 3). The range of removal efficiencies was 18 to 95%. The authors did not verify whether there were significant losses of sediment out of the units (Bryant et al., 1995). These data indicate a relatively high potential for removal, especially where sediment storage capacity is high. Data from this study were used to calculate preliminary sizing recommendations, detailed later in this review (Appendix, Table A1). The approach used to estimate performance and the subsequent sizing recommendations is based on rational assumptions. Actual performance under conditions other than those tested may require verification to compare with these results.

In Westwood Massachusetts, an ongoing study of a Storm*ceptor* STC 2600, sized according to the "Sensitive Area" criteria, demonstrated 77% TSS removal efficiencies from six storm events. Two events produced no appreciable sediment load over the composite sampling period. The first three events had a mean of 90% TSS removal based on first flush grab samples. Three of the six events had removal rates in excess of 89% and as high as 99%. One event produced a low removal rate of 28% and may have been an artifact of the sampling procedure. Overall the removal efficiency for TSS is near 80%. Removal of TPH averaged 93%, based on first flush grab samples of the first three storm events. Overall TPH removal, based on composite sampling over 5 events, was 80% with 3 events contributing no data to the mean. The mean precipitation and duration of these events were 0.4 inches and 13 hours, respectively.

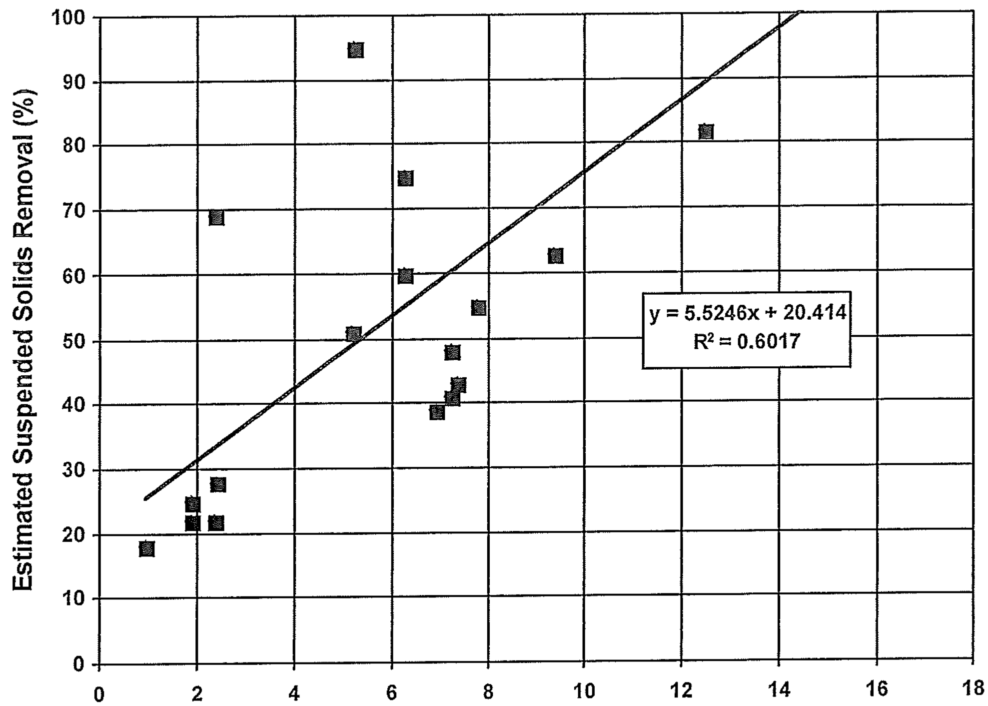

Figure 3: Storm*ceptor*® Sizing Guideline - Removal efficiency as a function of storage capacity from 23 Storm*ceptor* units in Toronto Canada.

Performance Summary

The Storm*ceptor* system has been demonstrated to provide at least 77% removal of TSS when sized under Storm*ceptor*'s "Sensitive Area" criteria and 52% TSS removal when sized under Storm*ceptor*'s "Treatment Train" criteria. Based on these data, the Storm*ceptor* systems receiving stormwater from a drainage area sized according to the "Sensitive Area" criteria are likely to provide a removal efficiency of 80%, on the annual stormwater runoff. While the set of data useful for predicting the relationship between treatment efficiency and loading rates is limited, it is likely that the STC 2400 is capable of meeting standards 4 and 6, for 80% removal of TSS in the first 0.5 or 1.0 inch of a storm event, if sized appropriately. STC 2400 Furthermore, performance of larger and smaller sized units may be capable of achieving removal rates that meet Standards 4 and 6. However, data to support this claim are not currently available.

SITE SUITABILITY RECOMMENDATIONS

The applicability of this technology with respect to TSS removal is similar to that of several other BMPs, including: sand and organic filters, catch basins, and water quality inlets, all described in the Stormwater Management Handbooks (DEP and CZM, 1997). The use of this technology can be made to Standards 4, 5, 6, and 7 in the Stormwater Management Handbooks (DEP and CZM, 1997).

The system is suitable for new and retrofit situations. The Storm*ceptor* system is particularly well suited for constricted areas, areas that require pretreatment for a multi-component treatment system, and redevelopment and retrofits described under Standard 7 in the Stormwater Management Handbook (DEP and CZM, 1997). The Storm*ceptor* system appears to have the ability to trap spills of hydrocarbons, oils, and grease. This makes the system suitable for use on areas with higher potential pollutant loads, specified under Standard 5 in the Stormwater Management Handbooks (DEP and CZM, 1997).

The system can be used on sites with a wide range of drainage areas provided it is sized correctly. On larger drainage area installations, units can be located throughout the drainage area rather than in a central location and provide treatment of runoff closer to its source. The system is suitable on small drainage areas or on individual inlets. The system is generally associated with a conveyance system and is recommended as part of a combination of different BMPs. The system is not designed as a recharge system and is not applicable to Standard 3 (DEP and CZM, 1997) unless combined with an approved recharge system. The system may be used as a pretreatment device for recharging systems. In this application, the life of the recharging system should be extended due to reduced clogging of the infiltrative surface. In high groundwater conditions the system is likely to withstand the hydrostatic pressures created by the saturated soil conditions around the unit. Care must be taken to assure the seam in the concrete unit does not leak. Buoyancy of the unit should be considered in the engineering plan. Storm*ceptor* Corporation recommends use of fiberglass tanks where there is potential for spills of hazardous materials. The precast concrete units are applicable to other installations including roads, highways, and parking lots.

Sizing

The recommended sizing, presented in the Appendix Table A1, was developed by Storm*ceptor* Corporation based on calculated loadings from the Toronto survey of system performance (Bryant et al., 1995). Based on the Edmonton Study, removal efficiencies determined for the STC 2000 (equivalent to the STC 2400) fall within the range of removal rates specified in the sizing guidlines. The performance ratings for the STC 2400, listed in Table A1 under "Treatment Train" criteria, may be conservative estimates, since that system was grossly undersized. When sized appropriately, the system is likely to perform as claimed under similar environmental and operating conditions including: climate, land use intensity, and soil conditions. The larger sized units listed in Table A1 have not been verified. The performance characteristics of these systems may vary as a function of scale. Performance of other sized units may have comparable removal efficiencies and are likely to meet Standards 4 and 6, requiring 80% TSS removal of the first 0.5 and 1 inch of rainfall respectively. The Storm*ceptor* system may be used as a stand alone BMP or as a component within a combination of different BMPs.. It is possible that sizing which corresponds to the "Sensitive Area" category in Table A1 may meet Standard 4 and 6, requiring 80% TSS removal of the first 0.5 and 1.0 inch of rainfall, respectively.

Maintenance

All BMPs require periodic maintenance. Inspection of the sediment load and oil and grease volumes is easily made from the surface with a tube dipstick inserted through a 6" vent tube. Depths of sediment indicating maintenance are presented the Appendix, under maintenance. Inspection of the internal structure should be part of the routine inspection plan. The unit is designed to accept 15% of its capacity in solids annually based on maximum drainage area loading listed in Table 4 of the Technical Design Manual (Storm*ceptor* Corporation, 1997). Removal of sediment, oils, and grease from the system will depend on rates of accumulation. Sediment removal is recommended annually but is likely to vary widely based on site conditions and loadings. The Stormwater Management Handbook (DEP and CZM, 1997) recommends quarterly maintenance. Reduced or more frequent maintenance frequency can be determined after experience with the system increases. Typical maintenance cleaning can be done with a vacuum truck. Maintenance costs are not expected to be in excess of normal costs for maintaining deep sump catch basins. Costs for cleaning, not adjusted for economies of scale, range from $250 to $500 depending on the size of the system and disposal fees.

REGULATORY ISSUES

The performance requirements for stormwater treatment systems are established by the DEP Stormwater Management Standards listed in the Stormwater Management Handbook (DEP and CZM, 1997). Projects subject to the standards may be required to file a Notice of Intent when they are sited in wetlands jurisdictional areas. Under the Wetlands Protection Act, conservation commissions, must apply the standards to new or modified discharges. Permits for surface water discharges under the National Pollutant Discharge Elimination System (NPDES), issued by the Massachusetts DEP Bureau of Resource Protection Division of Watershed Management, are not required if the discharge is tied to a conveyance or system of conveyances operated primarily for the purpose of collecting and conveying uncontaminated stormwater runoff.

CROSS MEDIA IMPACTS

Disposal of sediment from stormwater treatment systems is permitted in lined or unlined permitted solid waste landfills. In the absence of written approval from DEP, sediments are considered non-hazardous solid waste and may be treated in accordance with all DEP regulations policies and guidelines. Typical removal of sediment and biofilter material can be performed with a vacuum truck and disposed of. Grease and oils may accumulate in the sedimentation chambers and can be removed and disposed as non-hazardous solid waste. If the system has received influent from a hazardous materials spill, the system should be managed in accordance with an approved emergency response plan and appropriate state requirements. The Storm*ceptor* system does not present more restrictions for removal of wastes than would be associated with any other BMP.

ENERGY ISSUES{TC "ENERGY ISSUES"}

There are no specific energy issues related to this technology as it is not an energy consumer. There may be energy benefits when this "passive" system is compared to other technologies that may consume energy resources.

NEED FOR ADDITIONAL RESEARCH, DEMONSTRATION, AND STEP SUPPORT

The Storm*ceptor* technology is a unique approach for stormwater pretreatment and appears to be technically feasible based on a preliminary analysis of the available data. Further research on the Storm*ceptor* system should include studies to assess actual sediment loading under a variety of environmental conditions. To establish removal rates in excess of those reported herein, further research on the Storm*ceptor* system should include: i) evaluation of seasonal variation in performance, ii) performance as a function of flow rate, iii) efficiency with dual or multiple inlets, and iv) bacteria and pathogen removal efficiency in dry weather periods. The STEP program will be able to assist in performance verification on an as needed basis. Installations already being monitored by CSR and Storm*ceptor* will continue to provide performance data in a variety of environmental conditions. Existing monitoring programs may be augmented with STEP support through STEP oversight and reporting. STEP support may include development of experimental plans and review of data. Additional data would be useful for confirming field performance claims greater than 80% TSS removal efficiency.

SUMMARY RECOMMENDATION

The Storm*ceptor* system is based on reasonable and accepted principles applied to water treatment and conveyance systems. Review of available data suggests that the Storm*ceptor* system should be capable of providing an effective solution for treatment of stormwater runoff. At present, it is not possible to verify the performance of all the Storm*ceptor* models under the recommended sizing guidelines. The system is likely to be capable of TSS removal for Standards 4 and 6 when sized according to the "Sensitive Area" criteria. Other sized Storm*ceptor* models may provide similar TSS removal rates when sized accordingly under similar climatic conditions, land use intensities, and soil conditions. The Storm*ceptor* system is uniquely designed to trap hydrocarbons and is well suited for areas of higher pollutant potential, Standard 5 in the Stormwater Management Handbook (DEP and CZM, 1997). The system is also likely to remove grease and oils.

Based on available data, the Storm*ceptor* technology may be capable of meeting Standards 4, 5, 6, and 7 in the Stormwater Management Handbook (DEP and CZM, 1997) if installed, designed, and operated according to manufacturer's instructions. Additional data representing a varied set of operating conditions over a realistic maintenance cycle on other Storm*ceptor* models will assist in further clarification of TSS removal rates. Performance claims can be further verified as data is generated on systems currently being monitored. The Storm*ceptor* system compares favorably to other conventional BMP technologies with similar TSS removal rates, offering enhanced treatment and application.

Highlights

- Performance data available demonstrates that the Storm*ceptor* system can provide TSS removal rates of 77% when sized according to the "Sensitive Area" criteria. Evidence suggests that the Storm*ceptor* system may be capable of achieving TSS removal rates between 89% and 99% when sized accordingly, under conditions similar to those reported in the Westwood Massachusetts site, including: climate and land use intensity.
- Performance data available to this reviewer suggest that the Storm*ceptor* system can provide TSS removal rates of 52% when sized according to the "Treatment Train" criteria.
- Use of the Storm*ceptor* system as a pretreatment component in combination with different BMPs, when sized according to the "Treatment Train" criteria, will likely meet standards 4 and 6 of the Stormwater Management Handbooks (DEP and CZM,1997). Use as a stand alone device may be justified when sized according to the "Sensitive Area" criteria.
- The Storm*ceptor* system is likely to perform in areas with higher potential pollutant levels in Standard 5 of the Stormwater Management Handbooks (DEP and CZM,1997).
- The Storm*ceptor* system is useful for new and retrofit installations in Standard 7 of the Stormwater Management Handbooks (DEP and CZM,1997), especially where space is limited.
- The Storm*ceptor* system is also suited for secondary sediment control from construction related sediment loads specified in Standard 8 (DEP and CZM,1997).

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Bryant, G., F. Misa, D. Weatherbe, and W . Snodgrass. 1995. Field monitoring of Storm*ceptor* performance. *In* Storm*ceptor* Study Manual. Storm*ceptor* Corp. Rockville, MD.

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Marsalek, J., R. Long, and D. Doede. 1994. Laboratory development of Storm*ceptor* II. National Water Research Institute (Environment Cananda), *In* Stormceptor Study Manual. Stormceptor Corp. Rockville, MD.

Marshall Macklin Monaghan, LTD. 1994. Storm*ceptor* Modelling Study. *In* Storm*ceptor* Study Manual. Storm*ceptor* Corp. Rockville, MD.

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APPENDIX

Table A1. Storm*ceptor*® Capacities*					
Model	Maximum Treatment Flowrate (gal/min.)**	Down Riser Pipe / Orifice Diameter (in.)	Sediment Capacity (ft^3)	Oil Capacity (gal)	Total Holding Capacity (gal)
STA/STC 900	285	6	75	280	950
STA/STC 1200	285	6	110	280	1230
STA/STC 1800	285	6	195	280	1830
STA/STC 2400	475	8	180	880	2495
STA/STC 3600	475	8	345	880	3750
STA/STC 4800	800	10	465	1025	5020
STA/STC 6000	800	10	610	1025	6095
STA/STC 7200	1110	12	725	1100	7415

* approximate, ** without by-passing

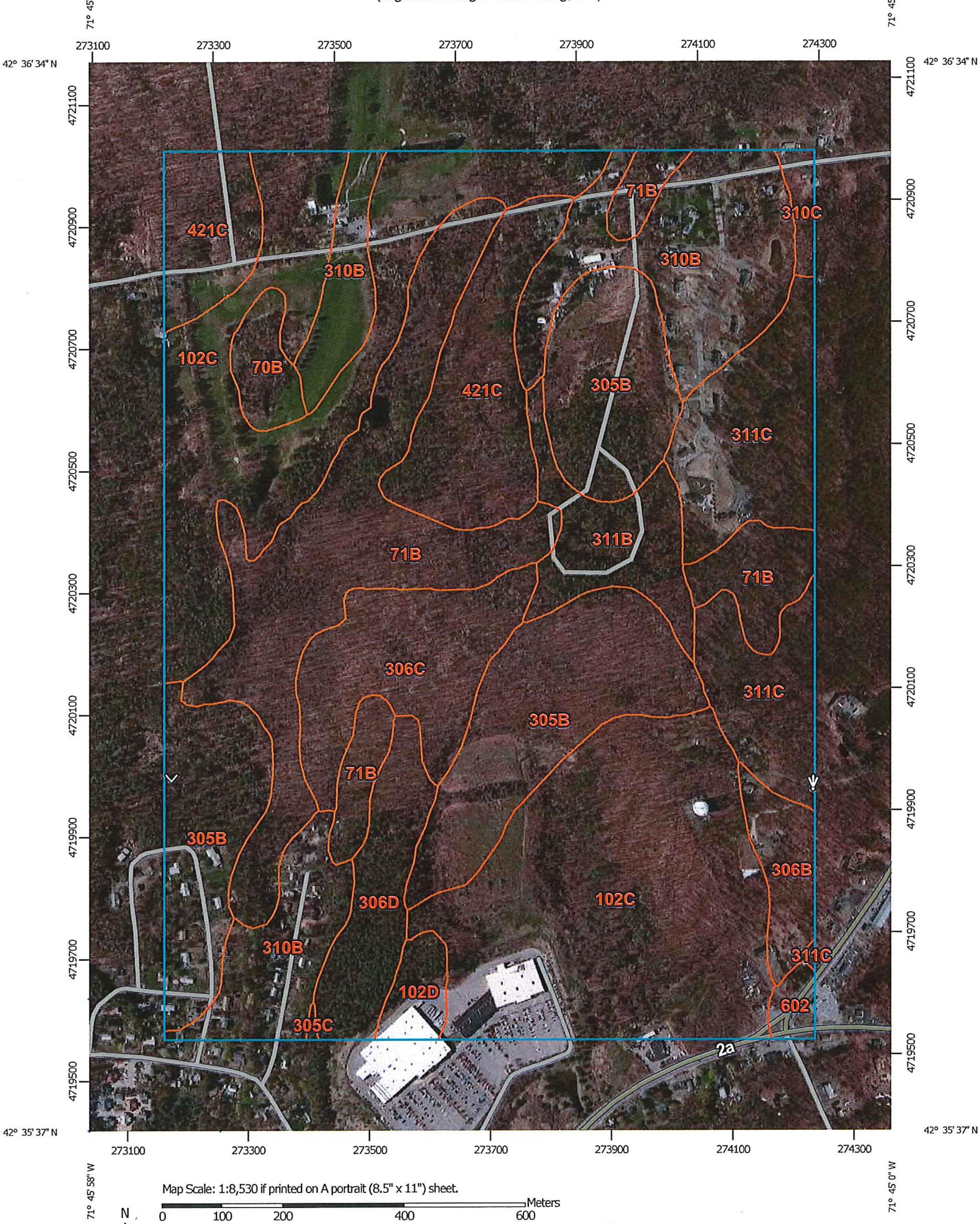
Table A2. Maximum Impervious Drainage Area Guidelines (acres)				
Storm*ceptor*® Model (STA / STC)	Sensitive Area (80% TSS removal)	Standard Area (70% TSS removal)	Degraded Area (60% TSS removal)	Treatment Train (50% TSS removal)
900	0.45	0.55	0.70	0.90
1200	0.70	0.85	1.05	1.45
1800	1.25	1.50	1.90	2.55
2400	1.65	2.00	2.50	3.35
3600	2.60	3.15	3.95	5.30
4800	3.60	4.30	5.40	7.25
6000	4.60	5.55	6.95	9.25
7200	5.55	6.70	8.40	11.25

Table 6. Sediment Depths Indicating Required Maintenance*{tc "Table 6. Sediment Depths Indicating Required Maintenance*"}**Table A3. Sediment Depths Indicating Required Maintenance***	
Model	**Sediment Depth (feet)**
900	0.50
1200	0.75
1800	1.00
2400	1.00
3600	1.25
4800	1.00
6000	1.50
7200	1.25

* based on 15% of the interceptor's sediment storage

NRCS SOILS MAP

Soil Map—Worcester County, Massachusetts, Northeastern Part
(Highfield Village - Lunenburg, MA)



Map Scale: 1:8,530 if printed on A portrait (8.5" x 11") sheet.

N

Meters: 0, 100, 200, 400, 600

Feet: 0, 400, 800, 1600, 2400

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 19N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils
- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

Special Point Features
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:20,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Worcester County, Massachusetts, Northeastern Part
Survey Area Data: Version 9, Sep 19, 2014

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Mar 30, 2011—May 1, 2011

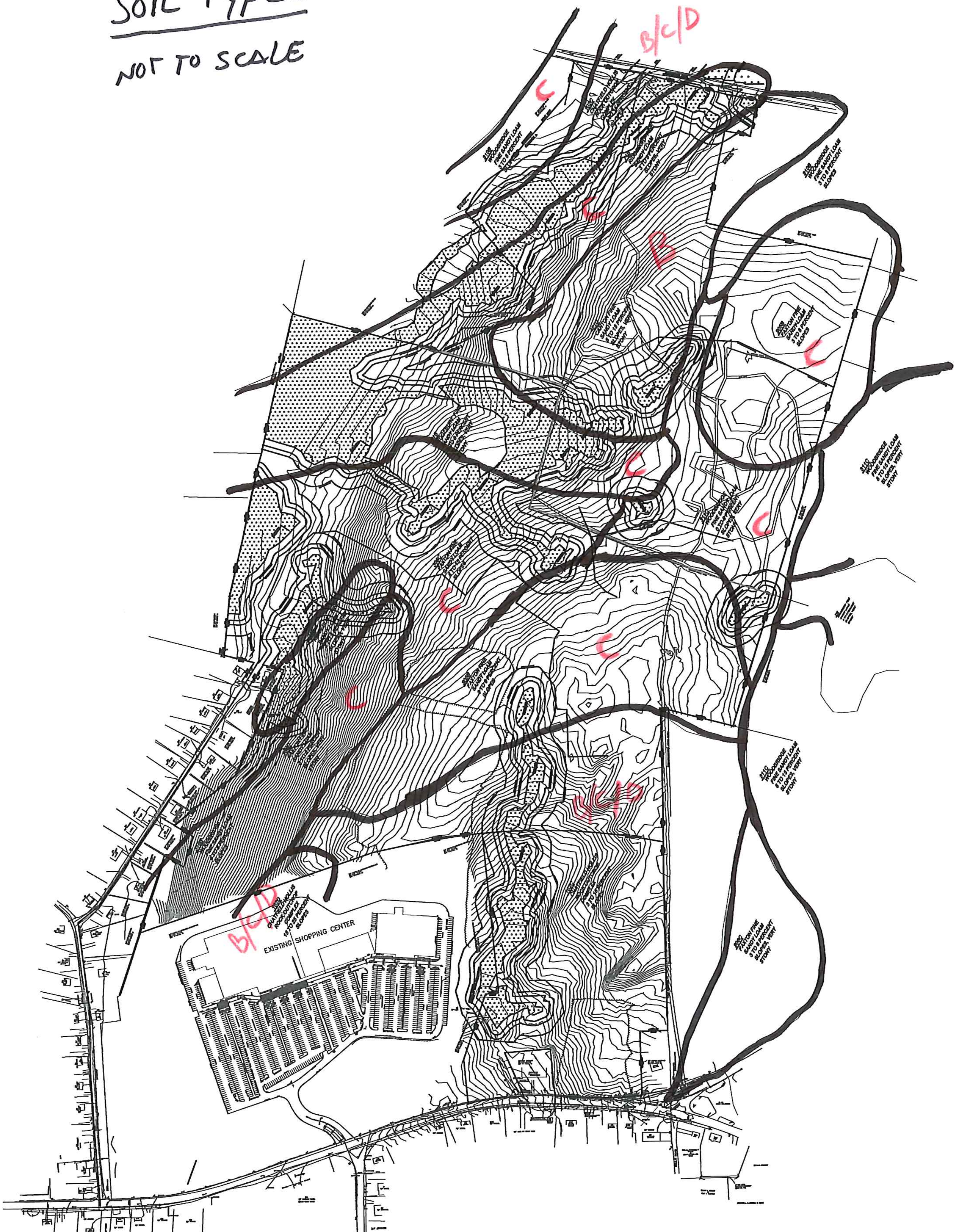
The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

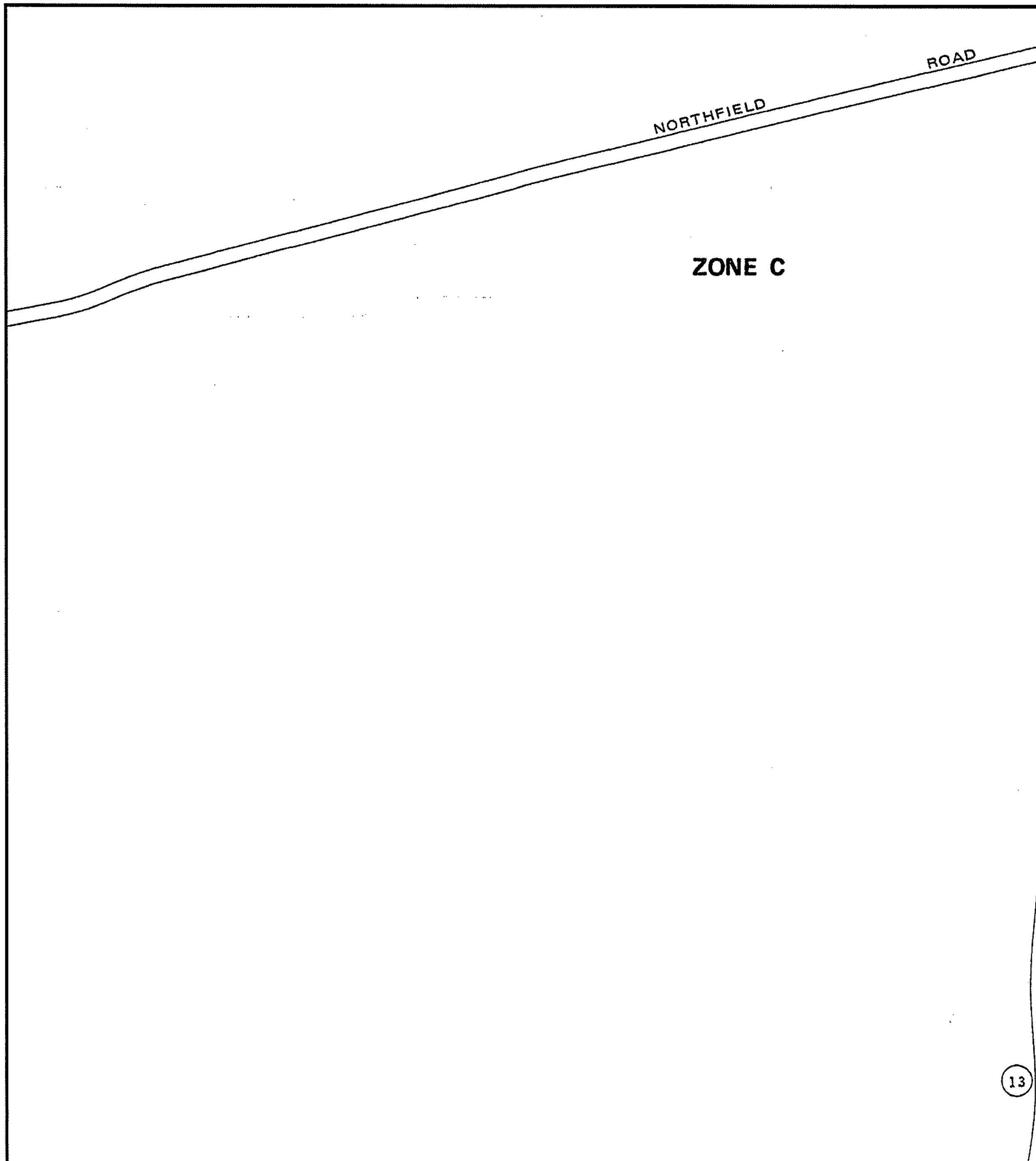
Worcester County, Massachusetts, Northeastern Part (MA613)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
70B	Ridgebury fine sandy loam, 3 to 8 percent slopes	4.7	1.2%
71B	Ridgebury fine sandy loam, 3 to 8 percent slopes, extremely stony	54.0	13.9%
102C	Chatfield-Hollis-Rock outcrop complex, 3 to 15 percent slopes	104.6	26.9%
102D	Chatfield-Hollis-Rock outcrop complex, 15 to 25 percent slopes	3.9	1.0%
305B	Paxton fine sandy loam, 3 to 8 percent slopes	60.3	15.5%
305C	Paxton fine sandy loam, 8 to 15 percent slopes	0.2	0.0%
306B	Paxton fine sandy loam, 3 to 8 percent slopes, very stony	6.5	1.7%
306C	Paxton fine sandy loam, 8 to 15 percent slopes, very stony	20.2	5.2%
306D	Paxton fine sandy loam, 15 to 25 percent slopes, very stony	12.5	3.2%
310B	Woodbridge fine sandy loam, 3 to 8 percent slopes	45.0	11.6%
310C	Woodbridge fine sandy loam, 8 to 15 percent slopes	2.1	0.5%
311B	Woodbridge fine sandy loam, 0 to 8 percent slopes, very stony	12.4	3.2%
311C	Woodbridge fine sandy loam, 8 to 15 percent slopes, very stony	30.3	7.8%
421C	Canton fine sandy loam, 8 to 15 percent slopes, very stony	29.9	7.7%
602	Urban land	2.0	0.5%
Totals for Area of Interest		**388.6**	**100.0%**

SOIL TYPES

NOT TO SCALE



FIRM MAPS



NATIONAL FLOOD INSURANCE PROGRAM

FIRM
FLOOD INSURANCE RATE MAP

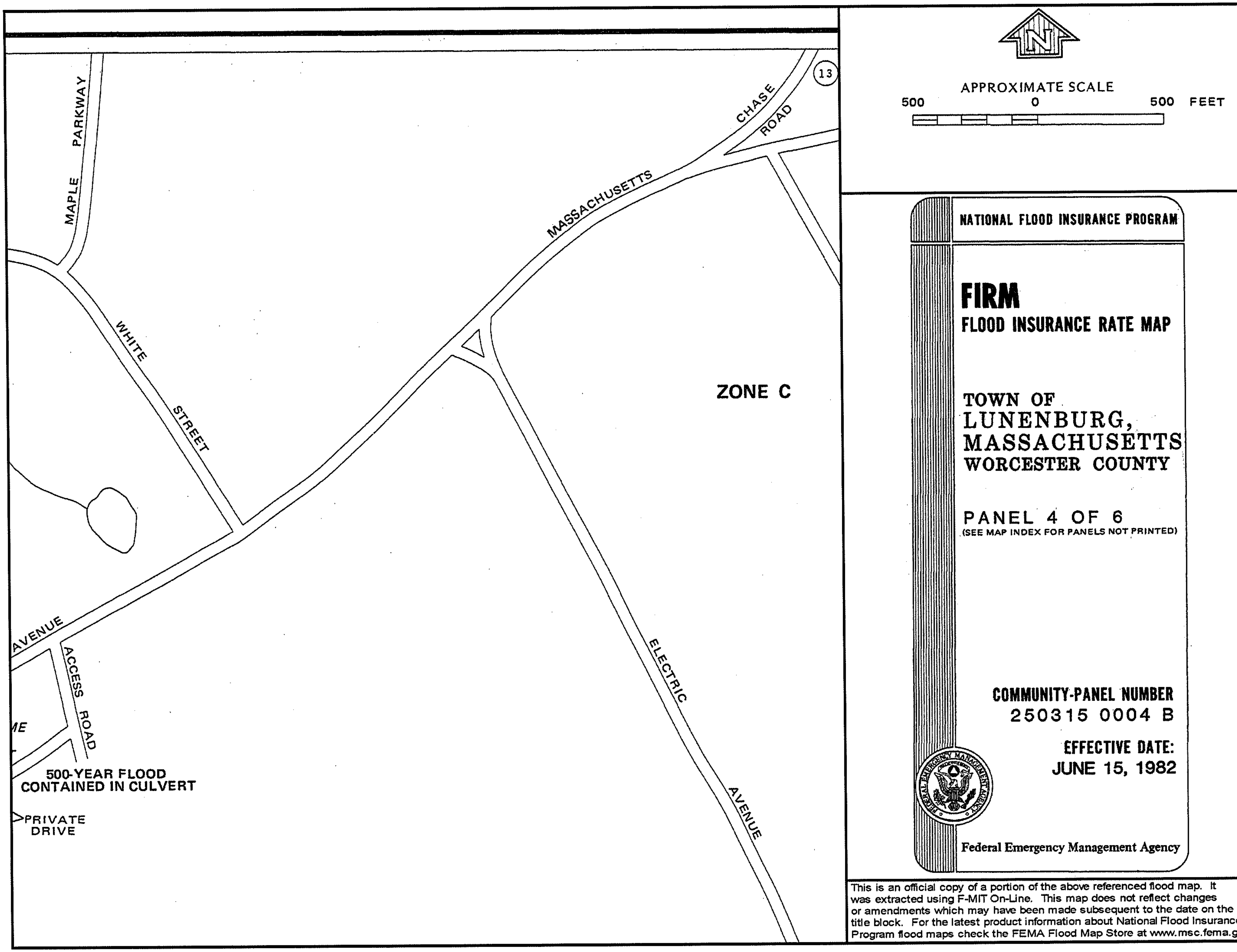
TOWN OF
LUNENBURG,
MASSACHUSETTS
WORCESTER COUNTY

PANEL 2 OF 6
(SEE MAP INDEX FOR PANELS NOT PRINTED)

COMMUNITY-PANEL NUMBER
250315 0002 B

EFFECTIVE DATE:
JUNE 15, 1982

Federal Emergency Management Agency



NATIONAL FLOOD INSURANCE PROGRAM

FIRM
FLOOD INSURANCE RATE MAP

TOWN OF
LUNENBURG,
MASSACHUSETTS
WORCESTER COUNTY

PANEL 4 OF 6
(SEE MAP INDEX FOR PANELS NOT PRINTED)

COMMUNITY-PANEL NUMBER
250315 0004 B

EFFECTIVE DATE:
JUNE 15, 1982

Federal Emergency Management Agency

TABLES AND CHARTS

Table 2-2a.—Runoff curve numbers for urban areas[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type and hydrologic condition	Average percent impervious area[2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)[3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only)[4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)[5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

[1]Average runoff condition, and $I_a = 0.2S$.
[2]The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.
[3]CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
[4]Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.
[5]Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4, based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

Table 2-2c.—Runoff curve numbers for other agricultural lands[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type	Hydrologic condition	A	B	C	D
Pasture, grassland, or range—continuous forage for grazing.[2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element.[3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	[4]30	48	65	73
Woods—grass combination (orchard or tree farm).[5]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods.[6]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	[4]30	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

[1]Average runoff condition, and $I_a = 0.2S$.

[2]*Poor:* <50% ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: >75% ground cover and lightly or only occasionally grazed.

[3]*Poor:* <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.

[4]Actual curve number is less than 30; use CN = 30 for runoff computations.

[5]CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.

[6]*Poor:* Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Sheet flow

Sheet flow is flow over plane surfaces. It usually occurs in the headwater of streams. With sheet flow, the friction value (Manning's n) is an effective roughness coefficient that includes the effect of raindrop impact; drag over the plane surface; obstacles such as litter, crop ridges, and rocks; and erosion and transportation of sediment. These n values are for very shallow flow depths of about 0.1 foot or so. Table 3-1 gives Manning's n values for sheet flow for various surface conditions.

For sheet flow of less than 300 feet, use Manning's kinematic solution (Overton and Meadows 1976) to compute T_t:

$$T_t = \frac{0.007\,(nL)^{0.8}}{(P_2)^{0.5}\,s^{0.4}} \qquad \text{[Eq. 3-3]}$$

Table 3-1.—Roughness coefficients (Manning's n) for sheet flow

Surface description	n[1]
Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover ≤20%	0.06
Residue cover >20%	0.17
Grass:	
Short grass prairie	0.15
Dense grasses[2]	0.24
Bermudagrass	0.41
Range (natural)	0.13
Woods:[3]	
Light underbrush	0.40
Dense underbrush	0.80

[1]The n values are a composite of information compiled by Engman (1986).
[2]Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.
[3]When selecting n, consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

where

T_t = travel time (hr),
n = Manning's roughness coefficient (table 3-1),
L = flow length (ft),
P_2 = 2-year, 24-hour rainfall (in), and
s = slope of hydraulic grade line (land slope, ft/ft).

This simplified form of the Manning's kinematic solution is based on the following: (1) shallow steady uniform flow, (2) constant intensity of rainfall excess (that part of a rain available for runoff), (3) rainfall duration of 24 hours, and (4) minor effect of infiltration on travel time. Rainfall depth can be obtained from appendix B.

Shallow concentrated flow

After a maximum of 300 feet, sheet flow usually becomes shallow concentrated flow. The average velocity for this flow can be determined from figure 3-1, in which average velocity is a function of watercourse slope and type of channel. For slopes less than 0.005 ft/ft, use equations given in appendix F for figure 3-1. Tillage can affect the direction of shallow concentrated flow. Flow may not always be directly down the watershed slope if tillage runs across the slope.

After determining average velocity in figure 3-1, use equation 3-1 to estimate travel time for the shallow concentrated flow segment.

Open channels

Open channels are assumed to begin where surveyed cross section information has been obtained, where channels are visible on aerial photographs, or where blue lines (indicating streams) appear on United States Geological Survey (USGS) quadrangle sheets. Manning's equation or water surface profile information can be used to estimate average flow velocity. Average flow velocity is usually determined for bank-full elevation.

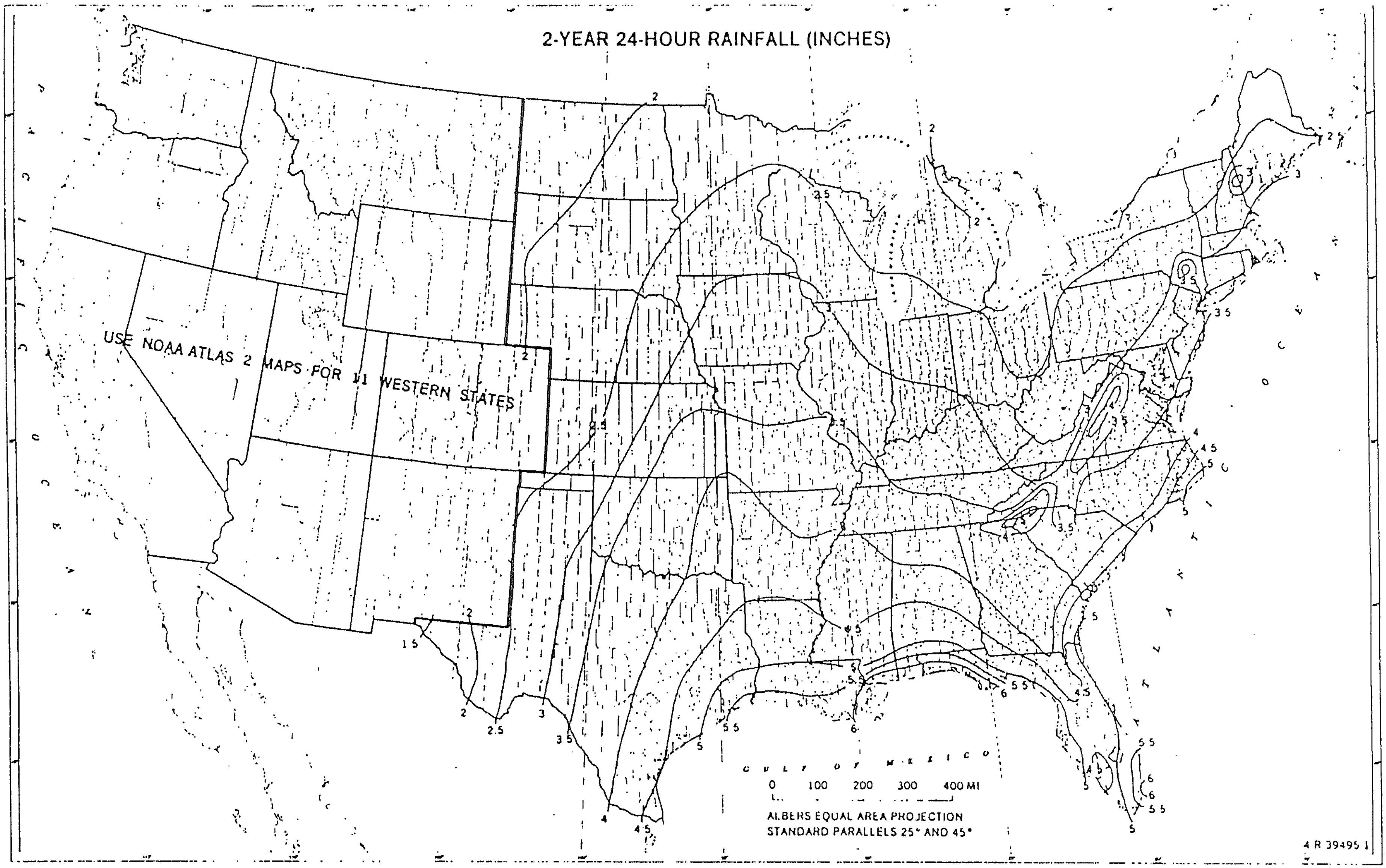


Figure B-3.—Two-year, 24-hour rainfall.

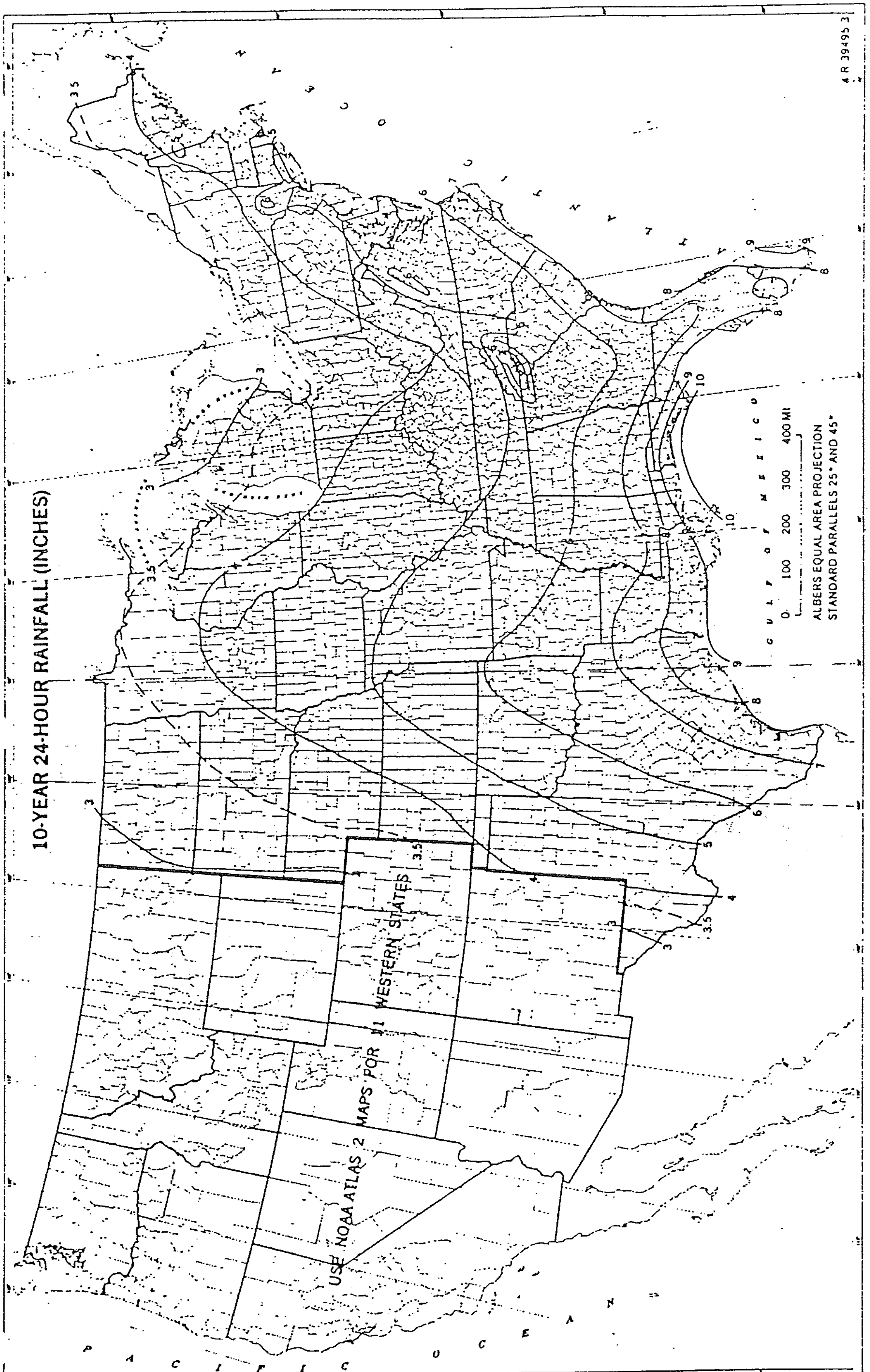


Figure B-5.—Ten-year, 24-hour rainfall.

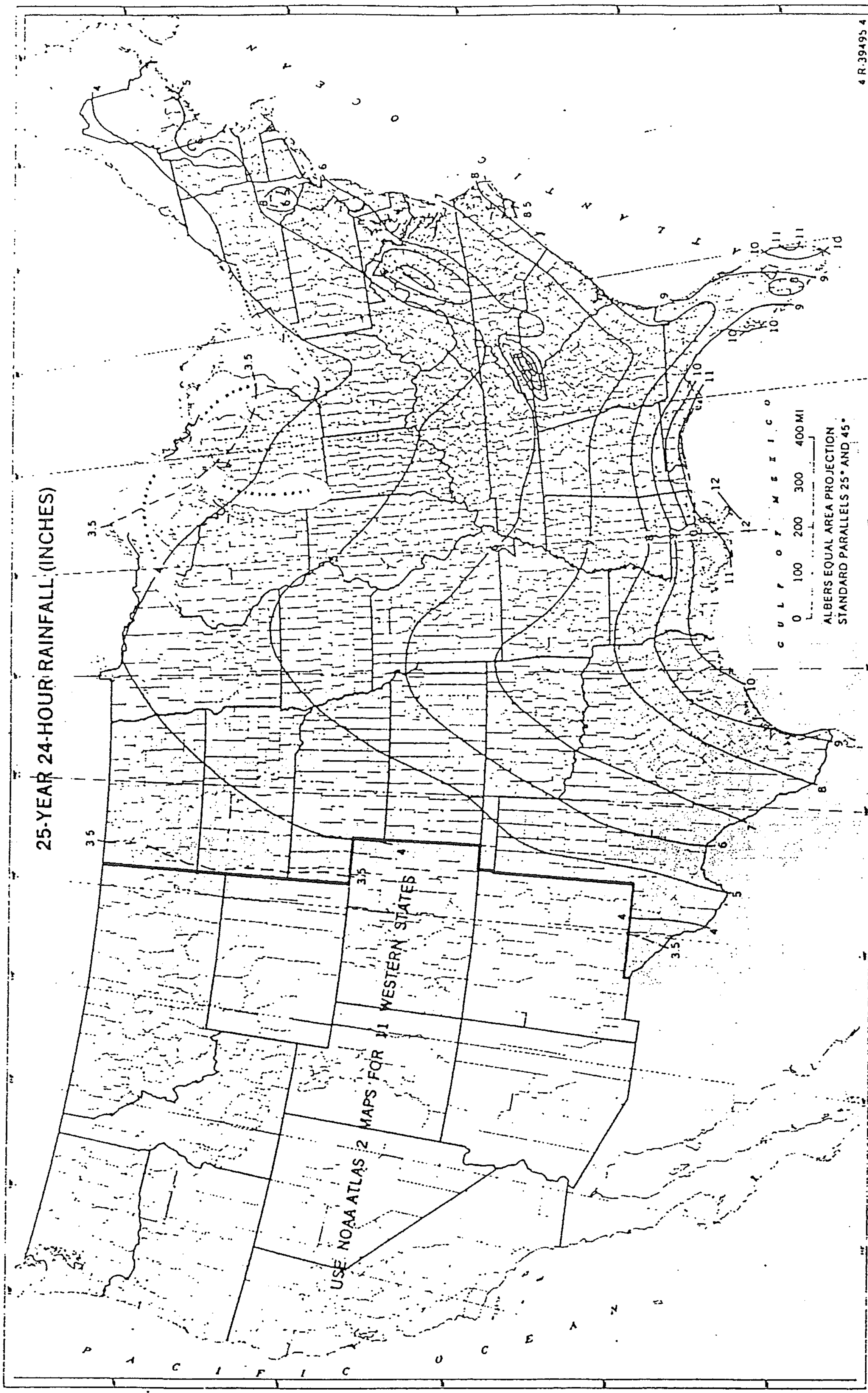


Figure B-6.—Twenty-five-year, 24-hour rainfall.

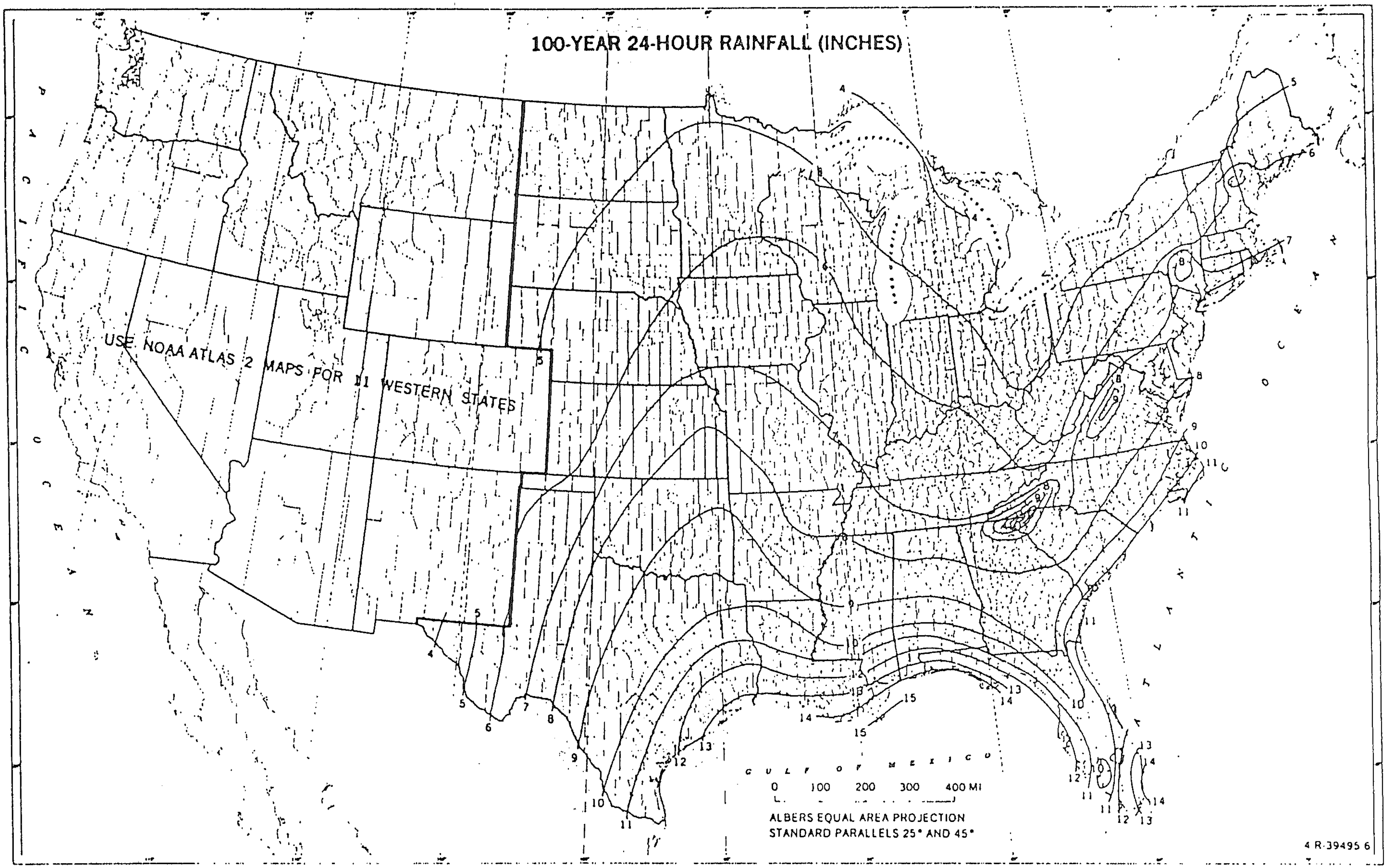


Figure B-8.—One-hundred-year, 24-hour rainfall.

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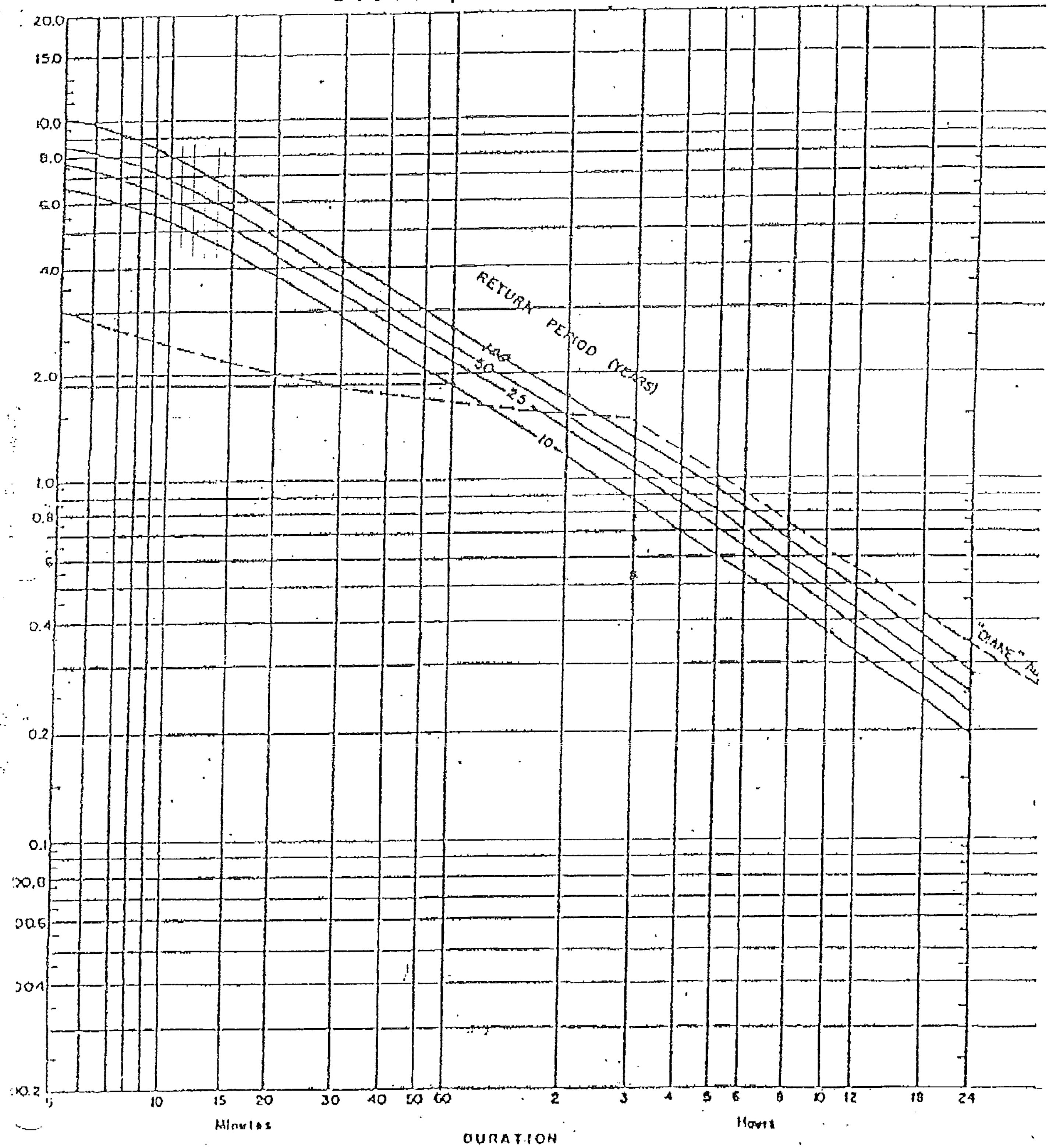


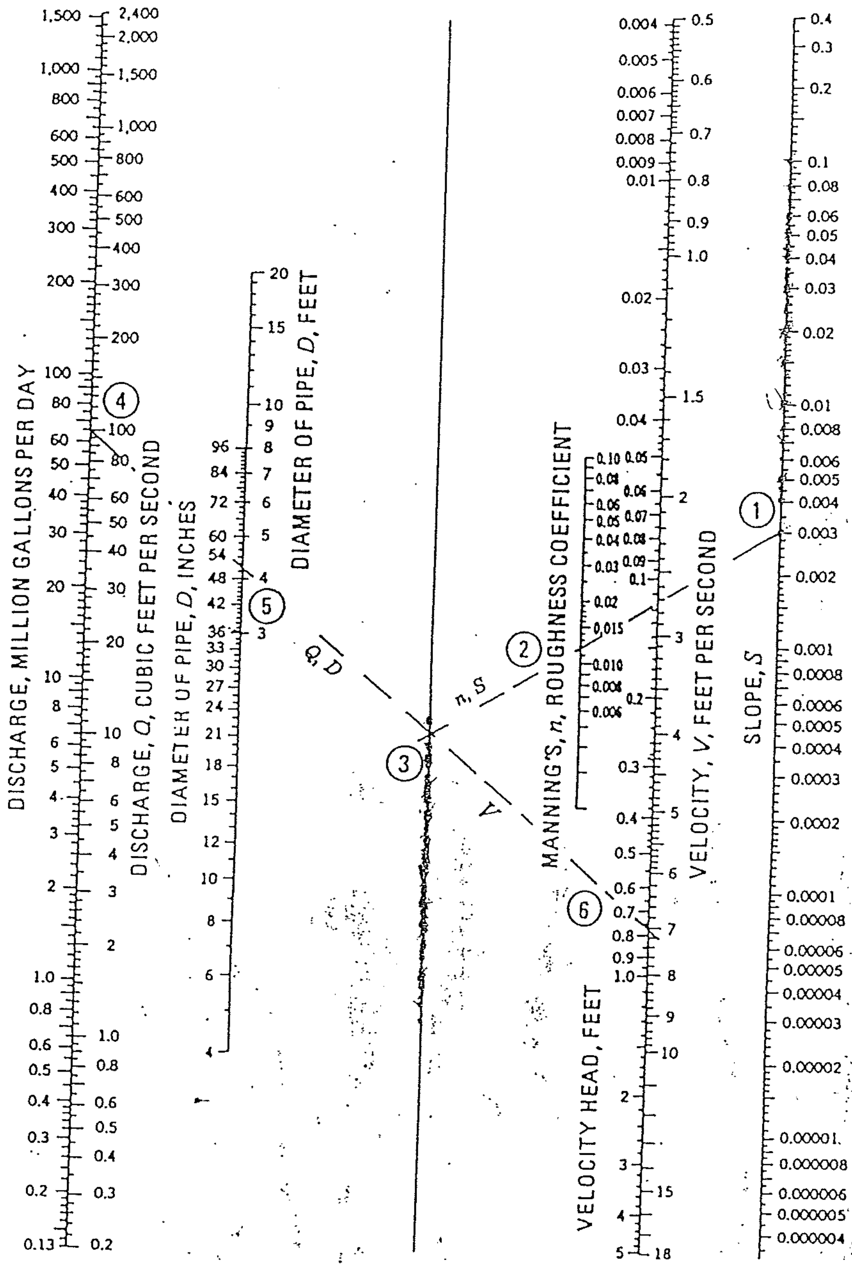
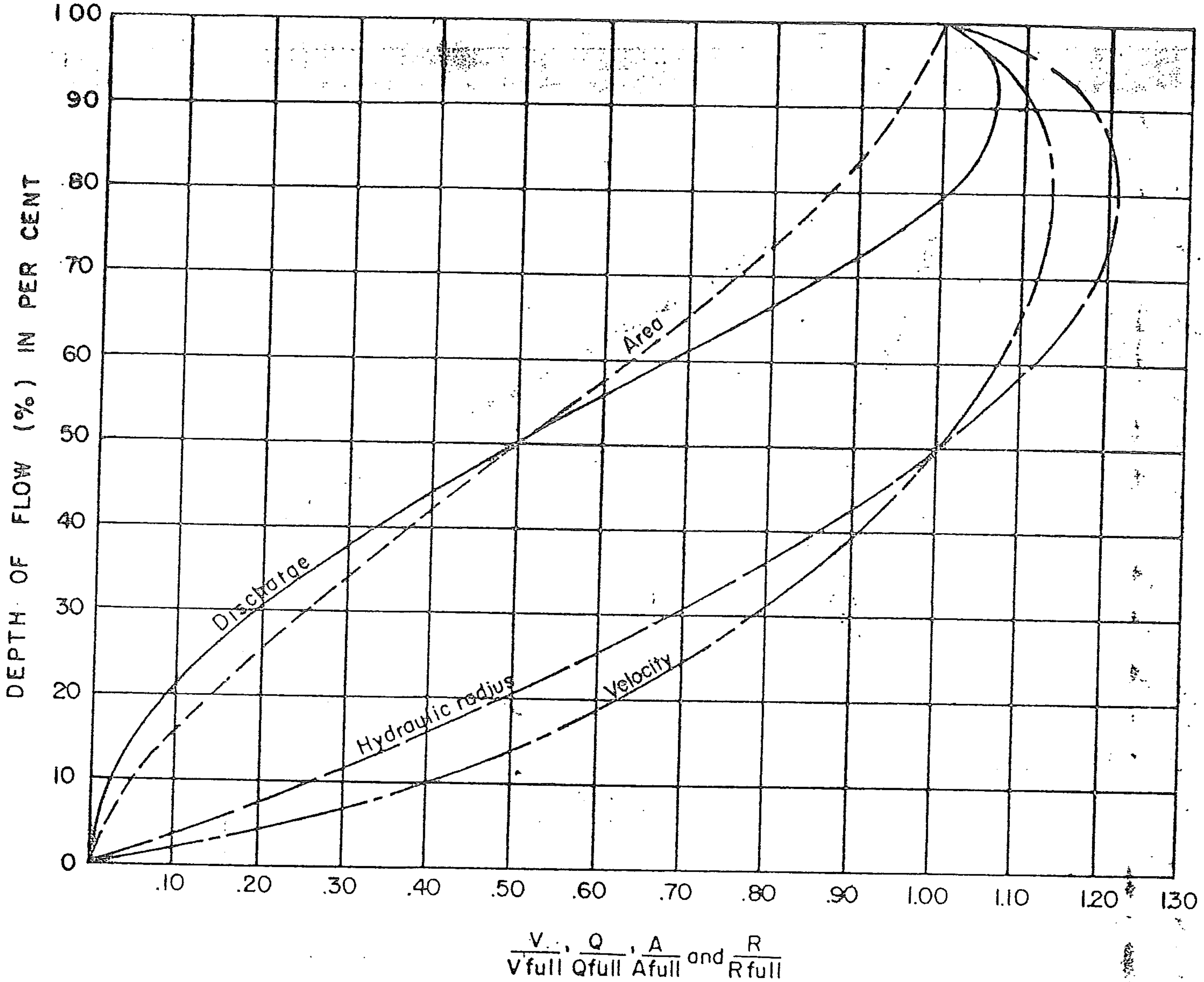


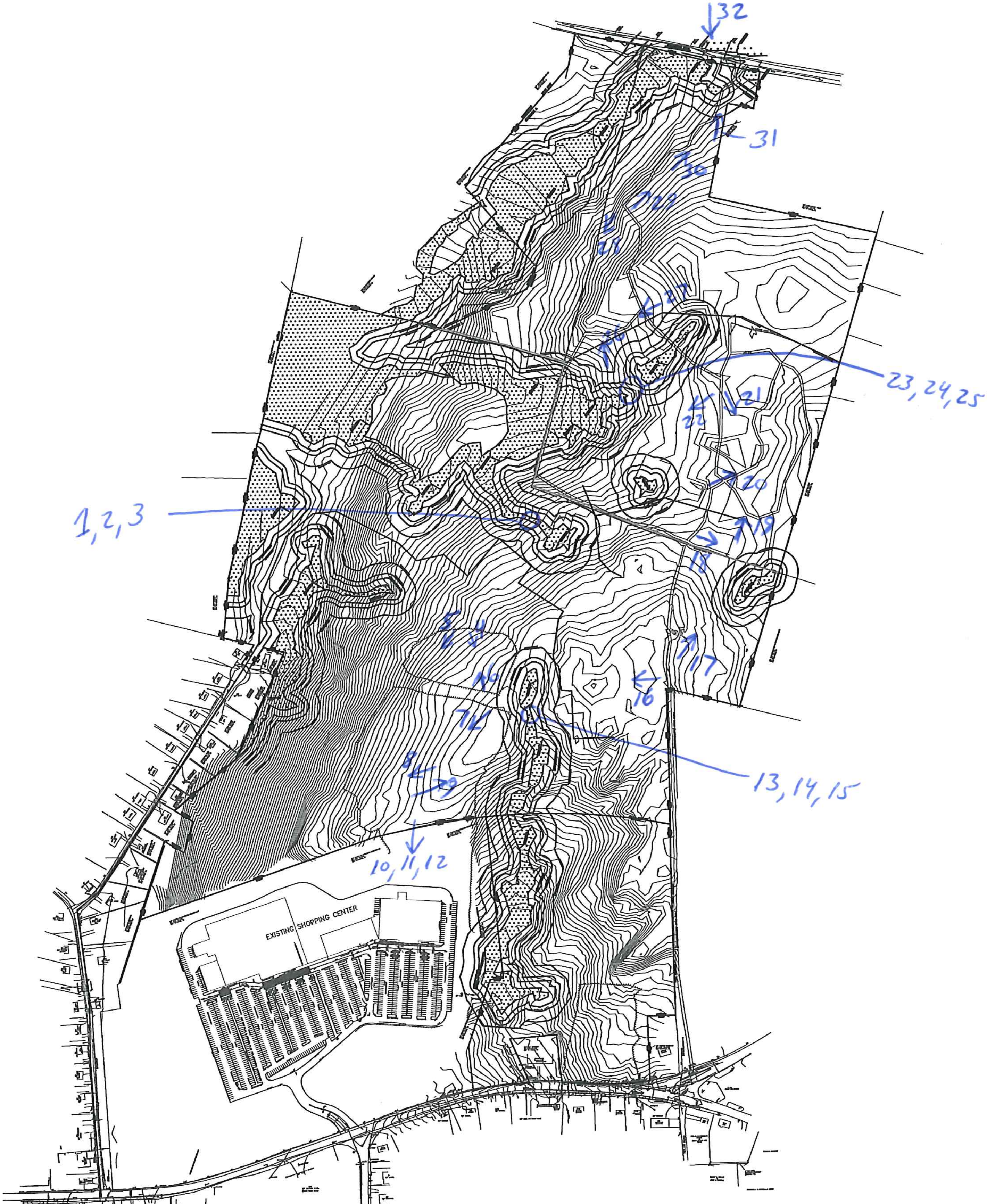
Figure 3.10. Nomograph for Manning's Equation.



HYDRAULIC ELEMENTS CHART

SITE PICTURES

SITE PICTURE LEGEND



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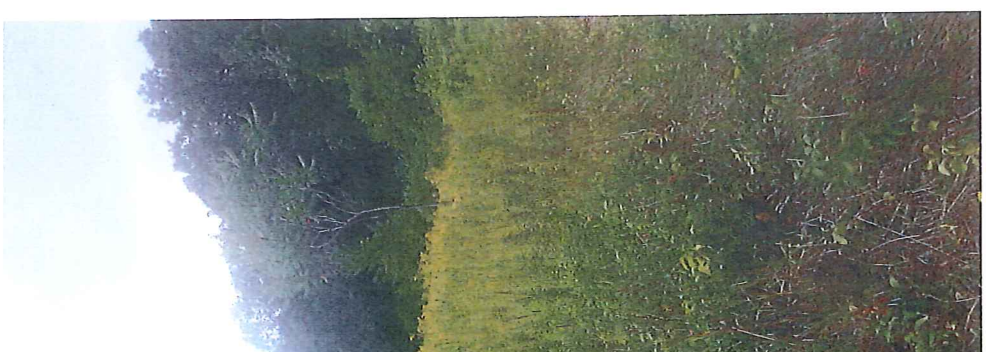

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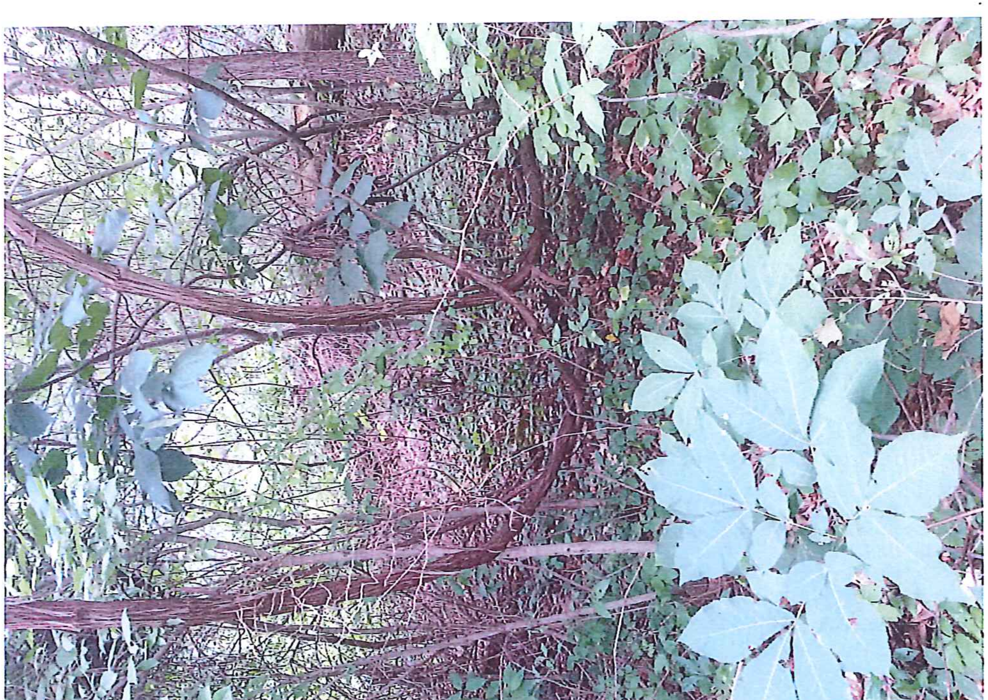

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SUBCATCHMENT MAPS