GRADY CONSULTING, L.L.C.
Registered Professional Civil Engineers & Land Surveyors

STORMWATER MANAGEMENT DESIGN CALCULATIONS

345 Oak Street
Assessors Map F15-38
Pembroke, Massachusetts

COMMONWEALTH OF MASSACHUSETTS
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Prepared for

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SUMMARY

The project is the redevelopment of an existing building at 345 Oak Street, Pembroke. The new development will include the construction of a 2,400 square foot office building with 33 parking spaces, and a 1,560 square foot garage.

Stormwater on site is managed through the use of 7 –225' long x 36" diameter polyethylene pipes that fully store the 2, 10, and 25 year storm flow and slowly release the water into the nearby drop inlet. High groundwater and poor soils restrict the feasibility of onsite infiltration of stormwater, however an infiltration basin is proposed provide recharge for new impervious area. A 1" diameter orifice at the bottom of the weir placed inside of the proposed outlet structure controls the flow, with a 6" diameter orifice acting as the emergency overflow. Calculations show peak flow rates post construction to be lower for the 2, 10, 25, and 100 year storms.

This analysis was prepared to demonstrate Compliance with the Massachusetts Stormwater Management Regulations and the Town of Pembroke Rules and Regulations for Stormwater Management.

This analysis is divided into the following sections:

Section I Overall Site Analysis
Section II Compliance with Massachusetts Storm water Management Regulations
Section III Operation And Maintenance Plan

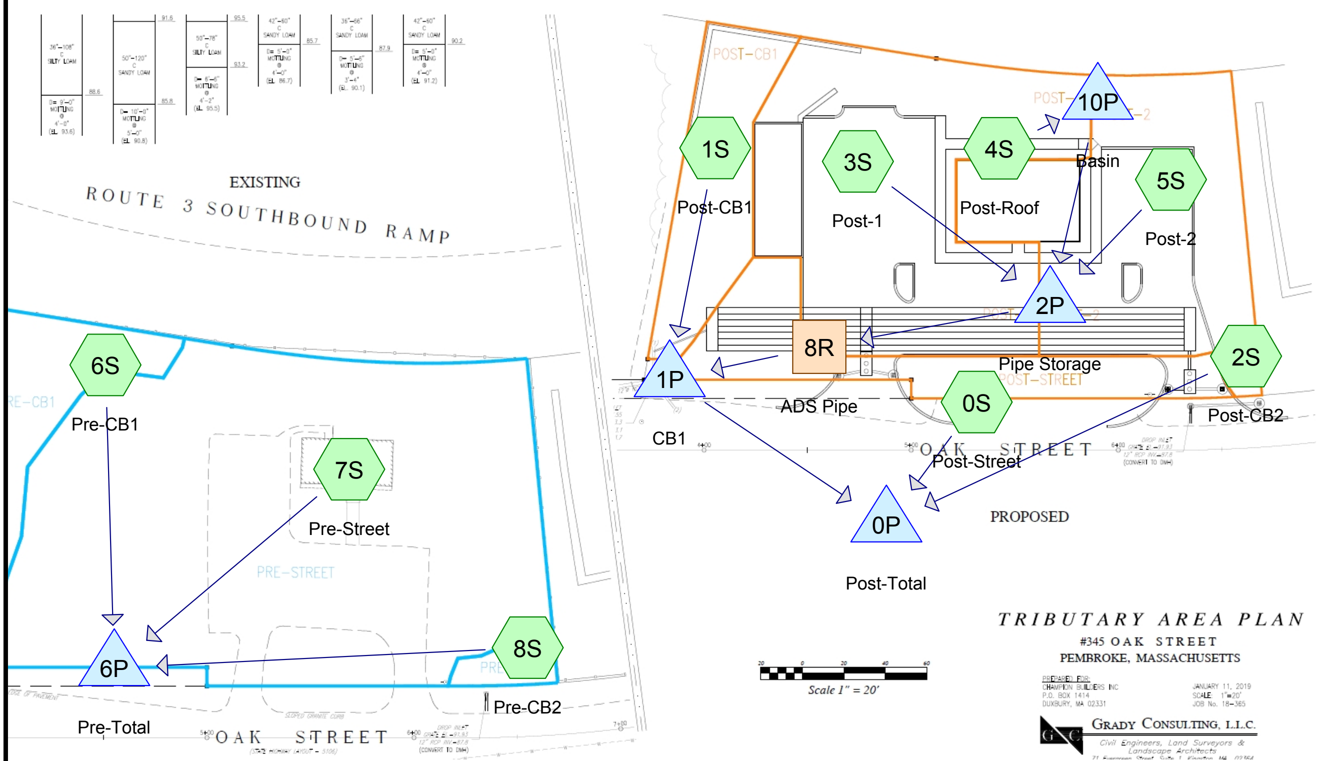
The calculations have been performed for the 2, 10, 25, 100-year 24 hour storm event, using the HydroCAD computer program. This computer program is based upon the Soils Conservation Service (SCS) TR-20 and TR-55 computer models and uses the SCS Curvilinear Unit rainfall distribution.

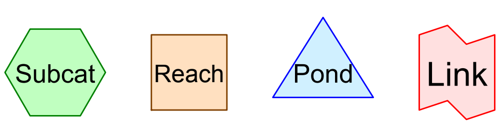
Peak Rate Summary

The following summary details a reduction in Peak Rate runoff. Values are in cubic feet per second.

	2 YEAR		10 YEAR		25 YEAR		100 YEAR	
	PRE	POST	PRE	POST	PRE	POST	PRE	POST
CB1	0.22	0.22	0.38	0.37	0.50	0.47	0.68	0.64
CB2	0.04	0.02	0.07	0.03	0.09	0.04	0.13	0.06
STREET	1.66	0.32	2.71	0.54	3.46	0.69	4.62	0.93
TOTAL	1.91	0.52	3.14	0.86	4.02	1.11	5.39	1.50

Section I
Overall Site Analysis





Routing Diagram for 345 Oak Drainage
Prepared by Grady Consulting, LLC, Printed 9/20/2019
HydroCAD® 10.00-21 s/n 09955 © 2018 HydroCAD Software Solutions LLC

Area Listing (all nodes)

Area (sq-ft)	CN	Description (subcatchment-numbers)
58,152	79	50-75% Grass cover, Fair, HSG C (0S, 1S, 2S, 3S, 4S, 5S, 6S, 7S, 8S)
24,001	98	Paved parking, HSG C (0S, 3S, 5S, 7S)
2,546	98	Roofs, HSG C (3S, 7S)
1,643	98	Unconnected pavement, HSG C (3S, 5S, 7S)
2,400	98	Unconnected roofs, HSG C (4S)
88,742	**86**	**TOTAL AREA**

Soil Listing (all nodes)

Area (sq-ft)	Soil Group	Subcatchment Numbers
0	HSG A	
0	HSG B	
88,742	HSG C	0S, 1S, 2S, 3S, 4S, 5S, 6S, 7S, 8S
0	HSG D	
0	Other	
88,742		**TOTAL AREA**

Ground Covers (all nodes)

HSG-A (sq-ft)	HSG-B (sq-ft)	HSG-C (sq-ft)	HSG-D (sq-ft)	Other (sq-ft)	Total (sq-ft)	Ground Cover	Sub Nur
0	0	58,152	0	0	58,152	50-75% Grass cover, Fair	
0	0	24,001	0	0	24,001	Paved parking	
0	0	2,546	0	0	2,546	Roofs	
0	0	1,643	0	0	1,643	Unconnected pavement	
0	0	2,400	0	0	2,400	Unconnected roofs	
0	**0**	**88,742**	**0**	**0**	**88,742**	**TOTAL AREA**	

Time span=0.00-36.00 hrs, dt=0.01 hrs, 3601 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 0S: Post-Street Runoff Area=6,350 sf 14.90% Impervious Runoff Depth=1.70"
Flow Length=64' Slope=0.1000 '/' Tc=2.9 min CN=82 Runoff=0.32 cfs 900 cf

Subcatchment 1S: Post-CB1 Runoff Area=5,213 sf 0.00% Impervious Runoff Depth=1.49"
Flow Length=165' Tc=7.5 min CN=79 Runoff=0.20 cfs 647 cf

Subcatchment 2S: Post-CB2 Runoff Area=420 sf 0.00% Impervious Runoff Depth=1.49"
Flow Length=20' Slope=0.1000 '/' Tc=1.3 min CN=79 Runoff=0.02 cfs 52 cf

Subcatchment 3S: Post-1 Runoff Area=18,392 sf 67.08% Impervious Runoff Depth=2.54"
Flow Length=171' Tc=3.7 min CN=92 Runoff=1.33 cfs 3,895 cf

Subcatchment 4S: Post-Roof Runoff Area=4,400 sf 54.55% Impervious Runoff Depth=2.26"
Flow Length=35' Tc=0.2 min CN=89 Runoff=0.32 cfs 830 cf

Subcatchment 5S: Post-2 Runoff Area=9,597 sf 66.35% Impervious Runoff Depth=2.54"
Flow Length=160' Slope=0.0200 '/' Tc=5.1 min CN=92 Runoff=0.66 cfs 2,032 cf

Subcatchment 6S: Pre-CB1 Runoff Area=6,022 sf 0.00% Impervious Runoff Depth=1.49"
Flow Length=197' Tc=8.3 min CN=79 Runoff=0.22 cfs 747 cf

Subcatchment 7S: Pre-Street Runoff Area=37,415 sf 22.82% Impervious Runoff Depth=1.77"
Flow Length=263' Slope=0.0250 '/' Tc=8.1 min CN=83 Runoff=1.66 cfs 5,534 cf

Subcatchment 8S: Pre-CB2 Runoff Area=933 sf 0.00% Impervious Runoff Depth=1.49"
Flow Length=28' Slope=0.0250 '/' Tc=3.1 min CN=79 Runoff=0.04 cfs 116 cf

Reach 8R: ADS Pipe Avg. Flow Depth=0.05' Max Vel=2.72 fps Inflow=0.03 cfs 2,561 cf
8.0" Round Pipe n=0.012 L=27.0' S=0.0519 '/' Capacity=2.98 cfs Outflow=0.03 cfs 2,560 cf

Pond 0P: Post-Total Inflow=0.52 cfs 4,159 cf
Primary=0.52 cfs 4,159 cf

Pond 1P: CB1 Inflow=0.22 cfs 3,207 cf
Primary=0.22 cfs 3,207 cf

Pond 2P: Pipe Storage Peak Elev=86.26' Storage=4,628 cf Inflow=1.97 cfs 5,927 cf
Outflow=0.03 cfs 2,561 cf

Pond 6P: Pre-Total Inflow=1.91 cfs 6,396 cf
Primary=1.91 cfs 6,396 cf

Pond 10P: Basin Peak Elev=97.42' Storage=507 cf Inflow=0.32 cfs 830 cf
Discarded=0.01 cfs 758 cf Primary=0.00 cfs 0 cf Outflow=0.01 cfs 758 cf

Total Runoff Area = 88,742 sf Runoff Volume = 14,752 cf Average Runoff Depth = 1.99"
65.53% Pervious = 58,152 sf 34.47% Impervious = 30,590 sf

Summary for Subcatchment 0S: Post-Street

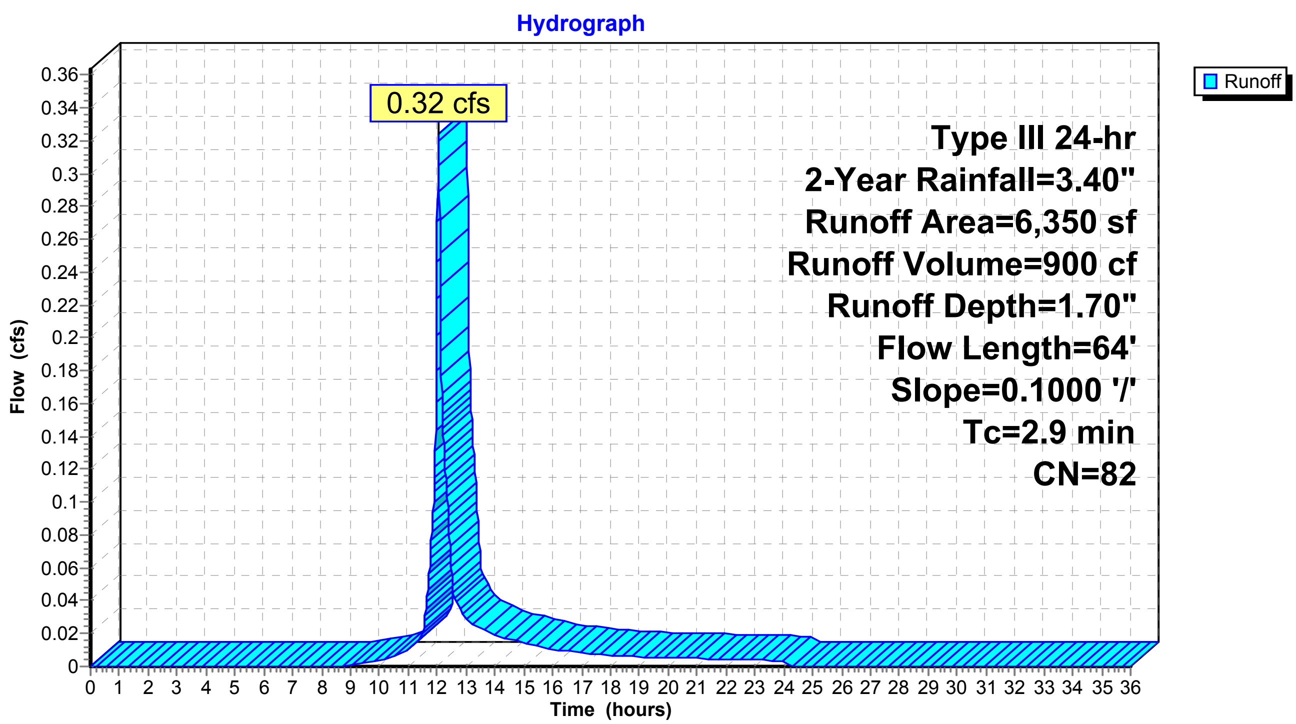
Runoff = 0.32 cfs @ 12.05 hrs, Volume= 900 cf, Depth= 1.70"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-Year Rainfall=3.40"

Area (sf)	CN	Description
0	98	Roofs, HSG C
946	98	Paved parking, HSG C
0	98	Unconnected pavement, HSG C
5,404	79	50-75% Grass cover, Fair, HSG C
0	73	Woods, Fair, HSG C
6,350	82	Weighted Average
5,404		85.10% Pervious Area
946		14.90% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.8	50	0.1000	0.30		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.60"
0.1	14	0.1000	2.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
2.9	64	Total			

Subcatchment 0S: Post-Street



Summary for Subcatchment 1S: Post-CB1

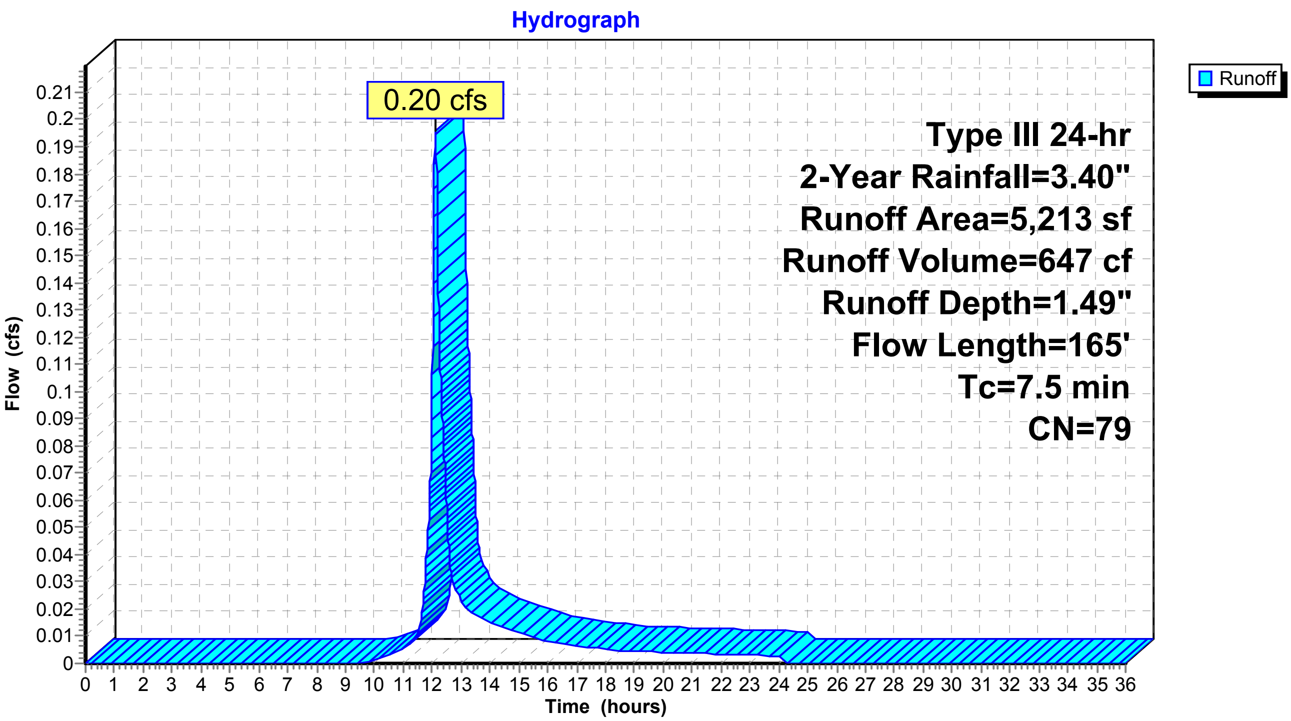
Runoff = 0.20 cfs @ 12.11 hrs, Volume= 647 cf, Depth= 1.49"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-Year Rainfall=3.40"

Area (sf)	CN	Description
0	98	Roofs, HSG C
0	98	Paved parking, HSG C
0	98	Unconnected pavement, HSG C
5,213	79	50-75% Grass cover, Fair, HSG C
0	73	Woods, Fair, HSG C
5,213	79	Weighted Average
5,213		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.5	50	0.0120	0.13		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.60"
1.0	115	0.0750	1.92		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
7.5	165	Total			

Subcatchment 1S: Post-CB1



Summary for Subcatchment 2S: Post-CB2

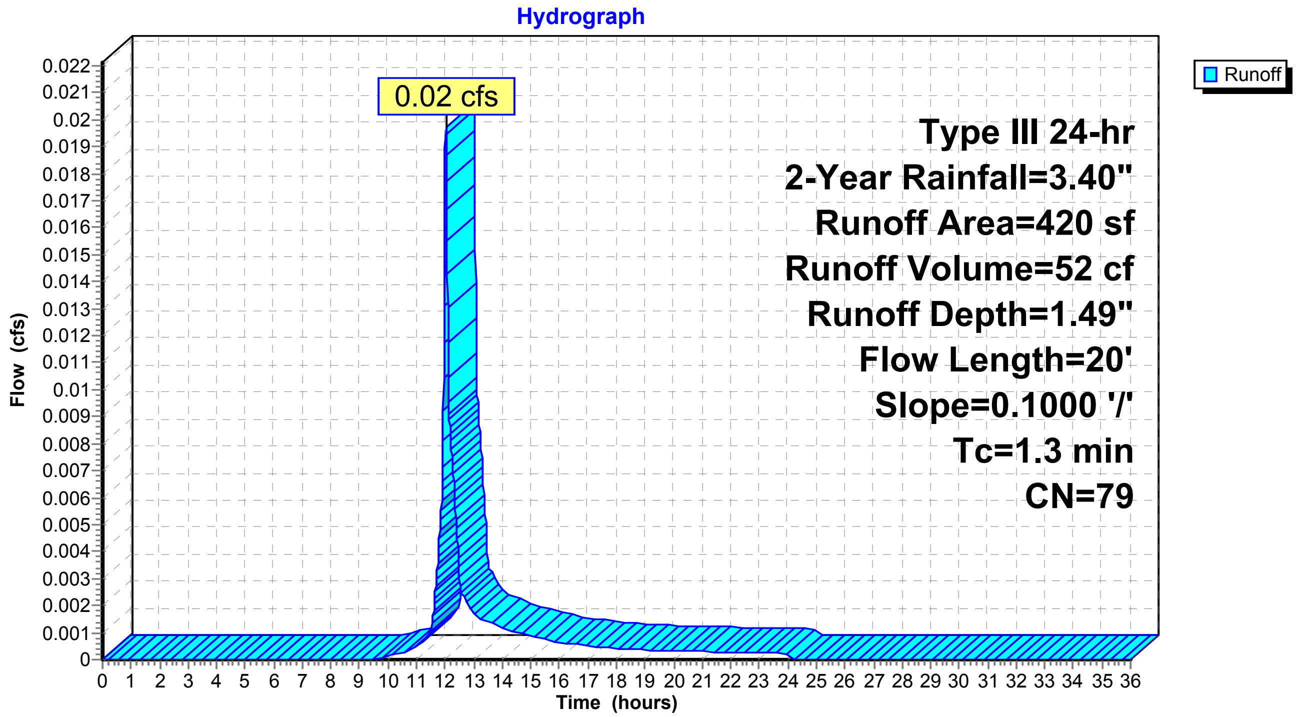
Runoff = 0.02 cfs @ 12.02 hrs, Volume= 52 cf, Depth= 1.49"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-Year Rainfall=3.40"

Area (sf)	CN	Description
0	98	Roofs, HSG C
0	98	Paved parking, HSG C
0	98	Unconnected pavement, HSG C
420	79	50-75% Grass cover, Fair, HSG C
0	73	Woods, Fair, HSG C
420	79	Weighted Average
420		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
1.3	20	0.1000	0.25		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.60"

Subcatchment 2S: Post-CB2



Summary for Subcatchment 3S: Post-1

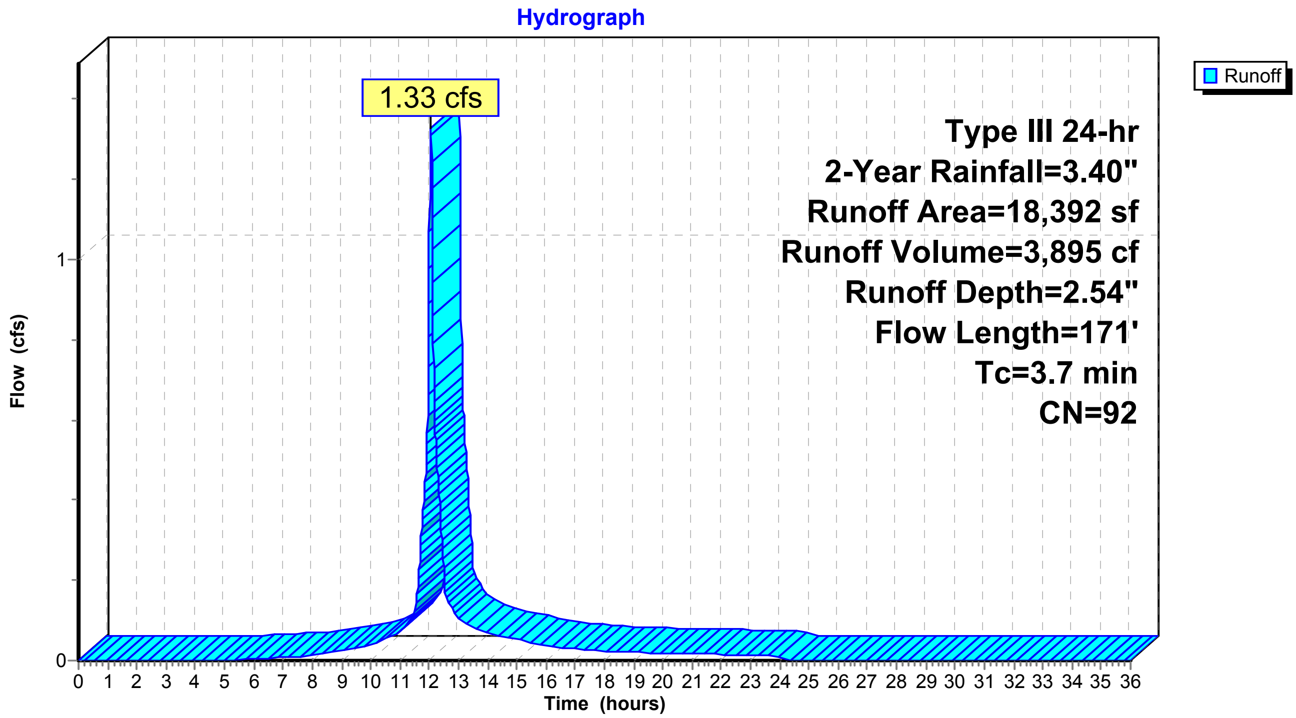
Runoff = 1.33 cfs @ 12.05 hrs, Volume= 3,895 cf, Depth= 2.54"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-Year Rainfall=3.40"

Area (sf)	CN	Description
1,560	98	Roofs, HSG C
9,716	98	Paved parking, HSG C
1,062	98	Unconnected pavement, HSG C
6,054	79	50-75% Grass cover, Fair, HSG C
0	73	Woods, Fair, HSG C
18,392	92	Weighted Average
6,054		32.92% Pervious Area
12,338		67.08% Impervious Area
1,062		8.61% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.7	41	0.0730	0.25		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.60"
0.3	15	0.0200	1.00		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 3.60"
0.7	115	0.0200	2.87		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
3.7	171	Total			

Subcatchment 3S: Post-1



Summary for Subcatchment 4S: Post-Roof

[49] Hint: Tc<2dt may require smaller dt

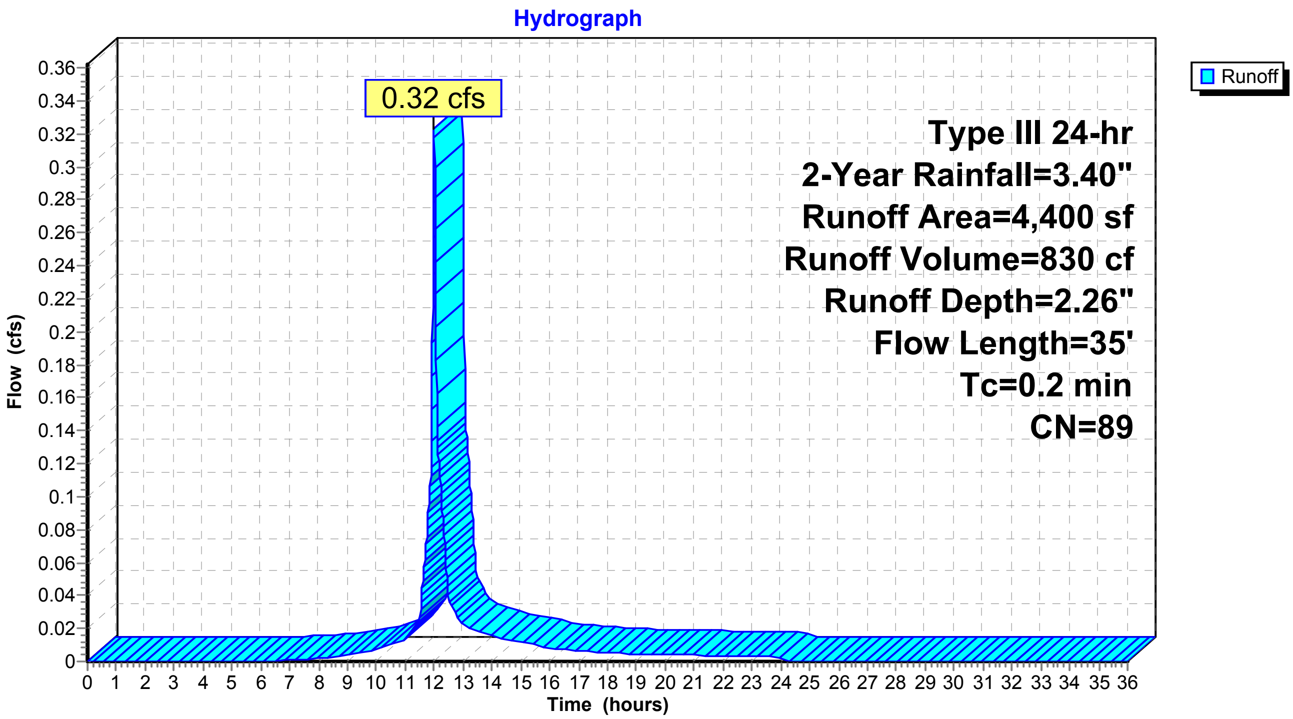
Runoff = 0.32 cfs @ 12.00 hrs, Volume= 830 cf, Depth= 2.26"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-Year Rainfall=3.40"

Area (sf)	CN	Description
2,400	98	Unconnected roofs, HSG C
2,000	79	50-75% Grass cover, Fair, HSG C
4,400	89	Weighted Average
2,000		45.45% Pervious Area
2,400		54.55% Impervious Area
2,400		100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.1	20	0.3000	3.12		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 3.60"
0.1	15	0.0200	2.12		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
0.2	35	Total			

Subcatchment 4S: Post-Roof



Summary for Subcatchment 5S: Post-2

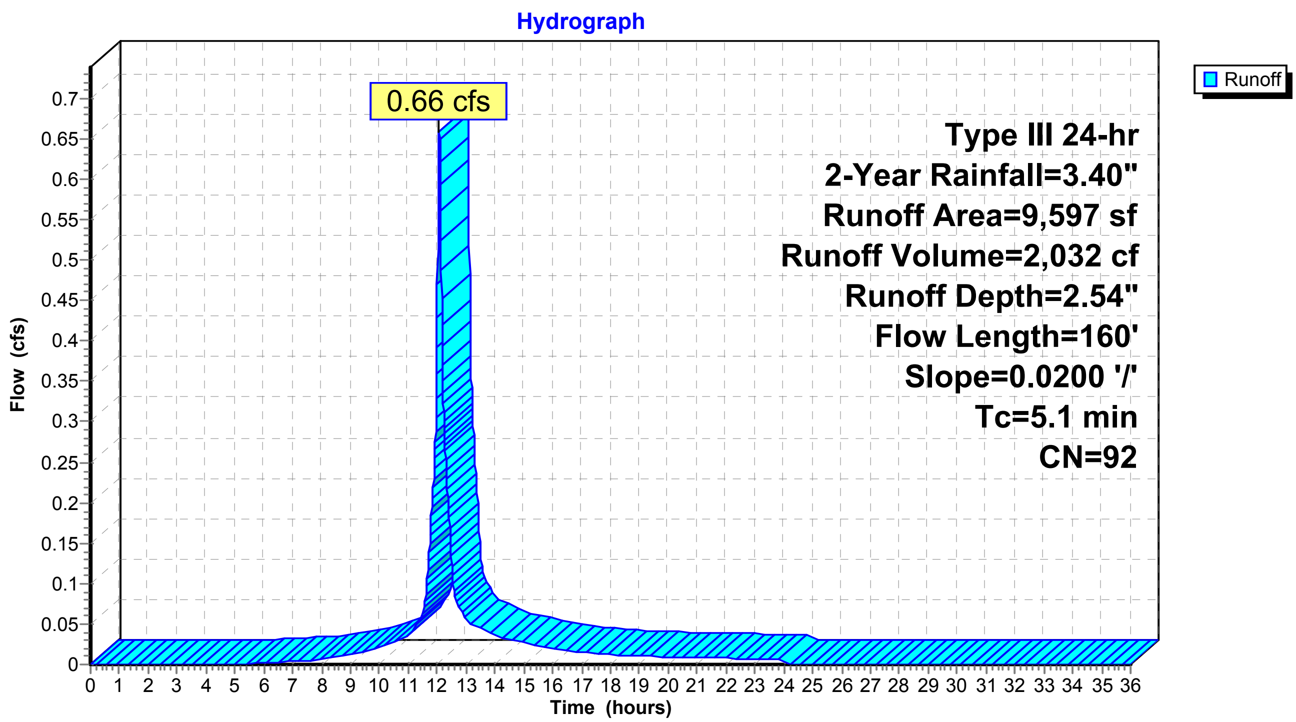
Runoff = 0.66 cfs @ 12.07 hrs, Volume= 2,032 cf, Depth= 2.54"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-Year Rainfall=3.40"

Area (sf)	CN	Description
0	98	Roofs, HSG C
5,951	98	Paved parking, HSG C
417	98	Unconnected pavement, HSG C
3,229	79	50-75% Grass cover, Fair, HSG C
0	73	Woods, Fair, HSG C
9,597	92	Weighted Average
3,229		33.65% Pervious Area
6,368		66.35% Impervious Area
417		6.55% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.4	40	0.0200	0.15		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.60"
0.7	120	0.0200	2.87		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
5.1	160	Total			

Subcatchment 5S: Post-2



Summary for Subcatchment 6S: Pre-CB1

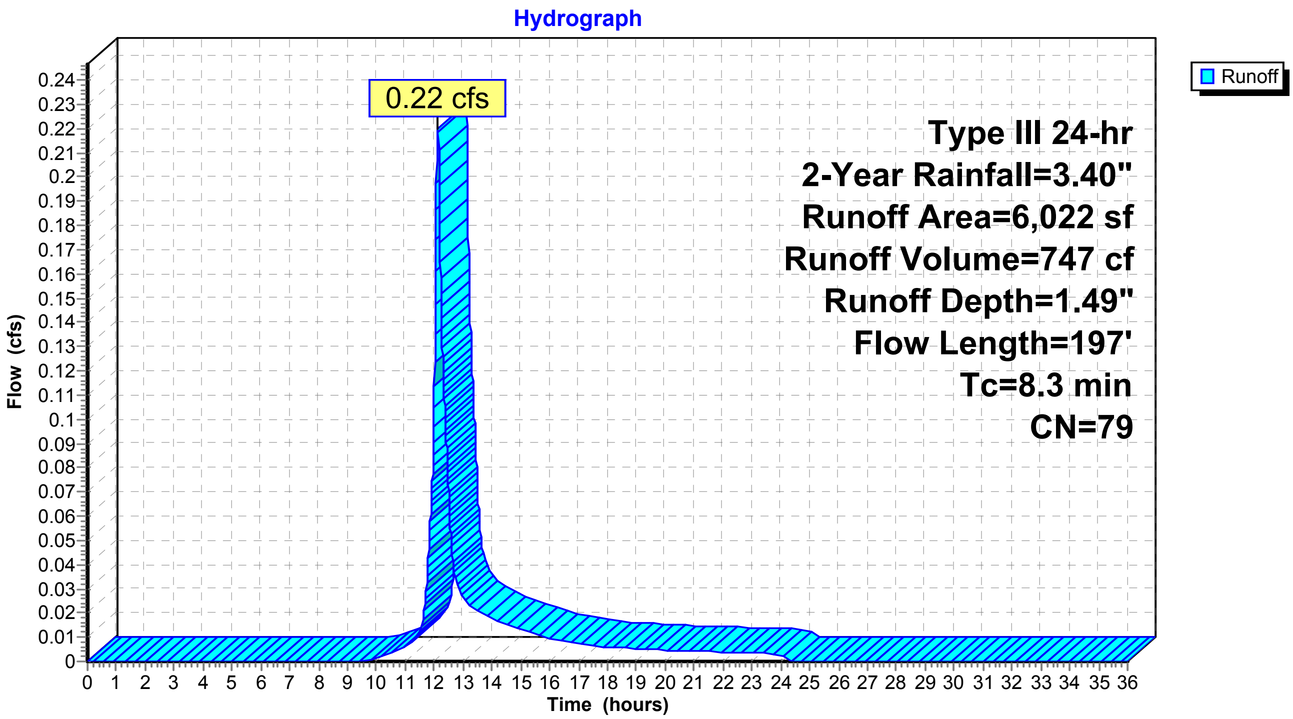
Runoff = 0.22 cfs @ 12.12 hrs, Volume= 747 cf, Depth= 1.49"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-Year Rainfall=3.40"

Area (sf)	CN	Description
0	98	Roofs, HSG C
0	98	Paved parking, HSG C
0	98	Unconnected pavement, HSG C
0	96	Gravel surface, HSG C
6,022	79	50-75% Grass cover, Fair, HSG C
0	73	Woods, Fair, HSG C
6,022	79	Weighted Average
6,022		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.1	50	0.1000	0.14		**Sheet Flow,** Woods: Light underbrush n= 0.400 P2= 3.60"
2.2	147	0.0500	1.12		**Shallow Concentrated Flow,** Woodland Kv= 5.0 fps
8.3	197	Total			

Subcatchment 6S: Pre-CB1



Summary for Subcatchment 7S: Pre-Street

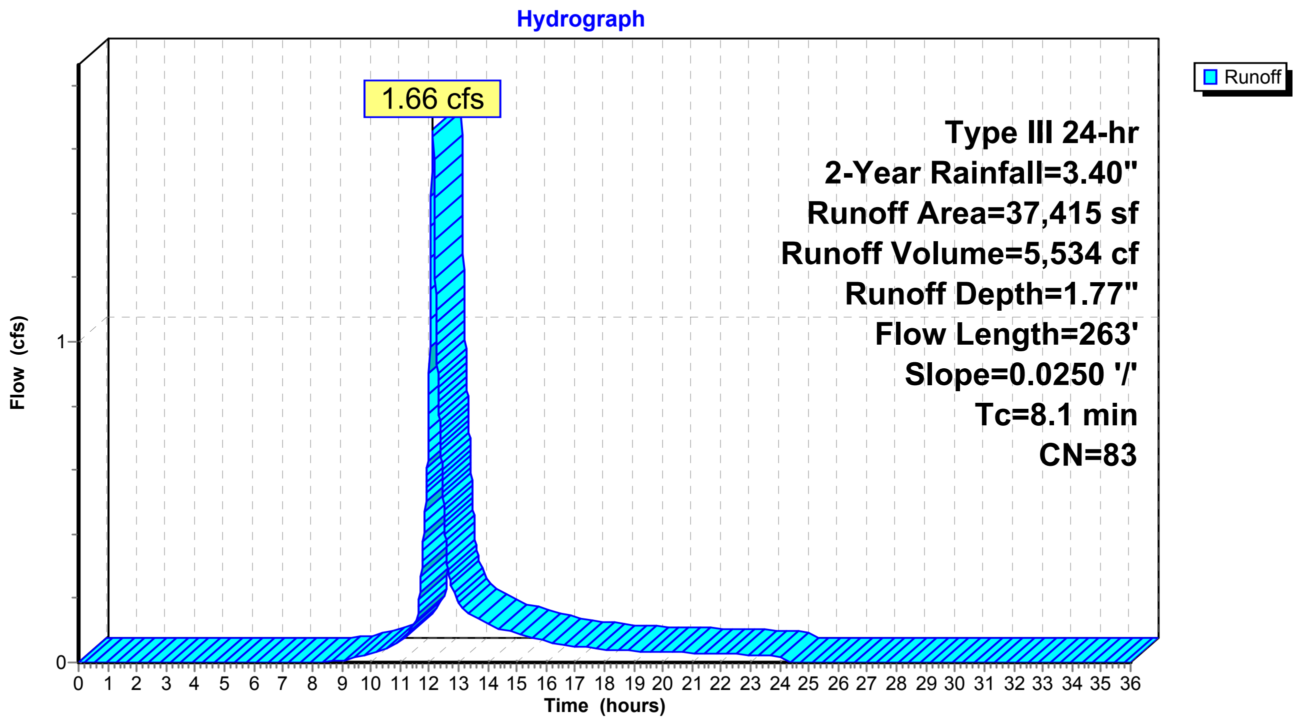
Runoff = 1.66 cfs @ 12.12 hrs, Volume= 5,534 cf, Depth= 1.77"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-Year Rainfall=3.40"

Area (sf)	CN	Description
986	98	Roofs, HSG C
7,388	98	Paved parking, HSG C
164	98	Unconnected pavement, HSG C
0	96	Gravel surface, HSG C
28,877	79	50-75% Grass cover, Fair, HSG C
0	73	Woods, Fair, HSG C
37,415	83	Weighted Average
28,877		77.18% Pervious Area
8,538		22.82% Impervious Area
164		1.92% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.9	50	0.0250	0.17		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.60"
3.2	213	0.0250	1.11		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
8.1	263	Total			

Subcatchment 7S: Pre-Street



Summary for Subcatchment 8S: Pre-CB2

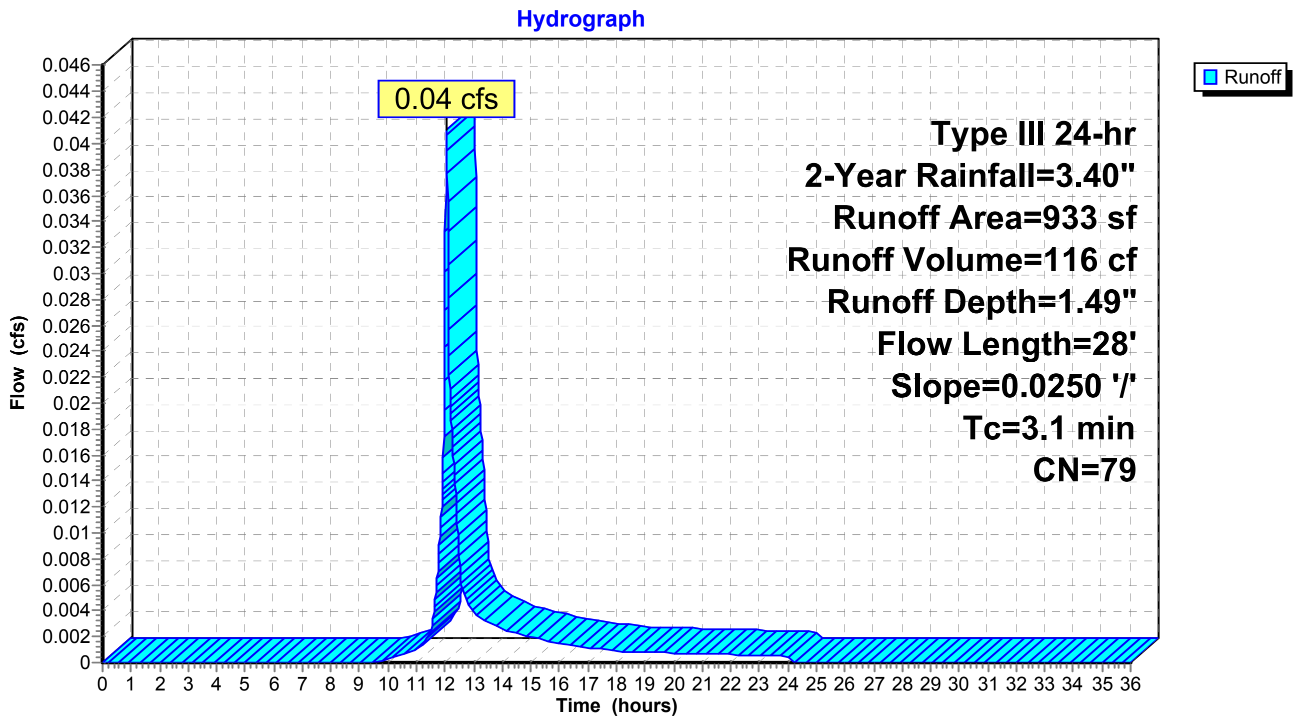
Runoff = 0.04 cfs @ 12.05 hrs, Volume= 116 cf, Depth= 1.49"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 2-Year Rainfall=3.40"

Area (sf)	CN	Description
0	98	Roofs, HSG C
0	98	Paved parking, HSG C
0	98	Unconnected pavement, HSG C
0	96	Gravel surface, HSG C
933	79	50-75% Grass cover, Fair, HSG C
0	73	Woods, Fair, HSG C
933	79	Weighted Average
933		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.1	28	0.0250	0.15		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.60"

Subcatchment 8S: Pre-CB2



Summary for Reach 8R: ADS Pipe

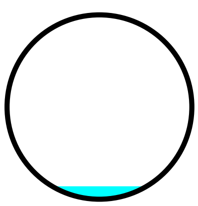
[52] Hint: Inlet/Outlet conditions not evaluated
[79] Warning: Submerged Pond 2P Primary device # 1 by 0.05'

Inflow Area = 32,389 sf, 65.16% Impervious, Inflow Depth > 0.95" for 2-Year event
Inflow = 0.03 cfs @ 19.50 hrs, Volume= 2,561 cf
Outflow = 0.03 cfs @ 19.51 hrs, Volume= 2,560 cf, Atten= 0%, Lag= 0.3 min

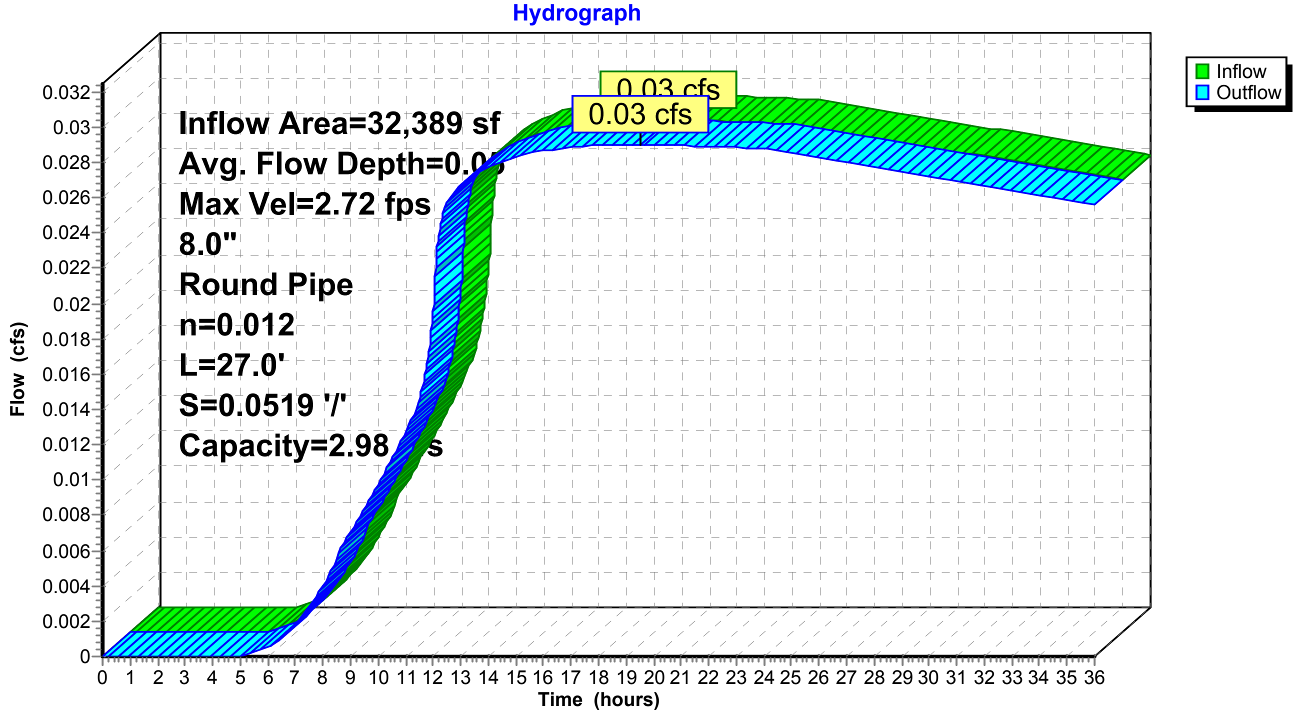
Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Max. Velocity= 2.72 fps, Min. Travel Time= 0.2 min
Avg. Velocity = 2.44 fps, Avg. Travel Time= 0.2 min

Peak Storage= 0 cf @ 19.51 hrs
Average Depth at Peak Storage= 0.05'
Bank-Full Depth= 0.67' Flow Area= 0.3 sf, Capacity= 2.98 cfs

8.0" Round Pipe
n= 0.012 Corrugated PP, smooth interior
Length= 27.0' Slope= 0.0519 '/'
Inlet Invert= 85.00', Outlet Invert= 83.60'



Reach 8R: ADS Pipe

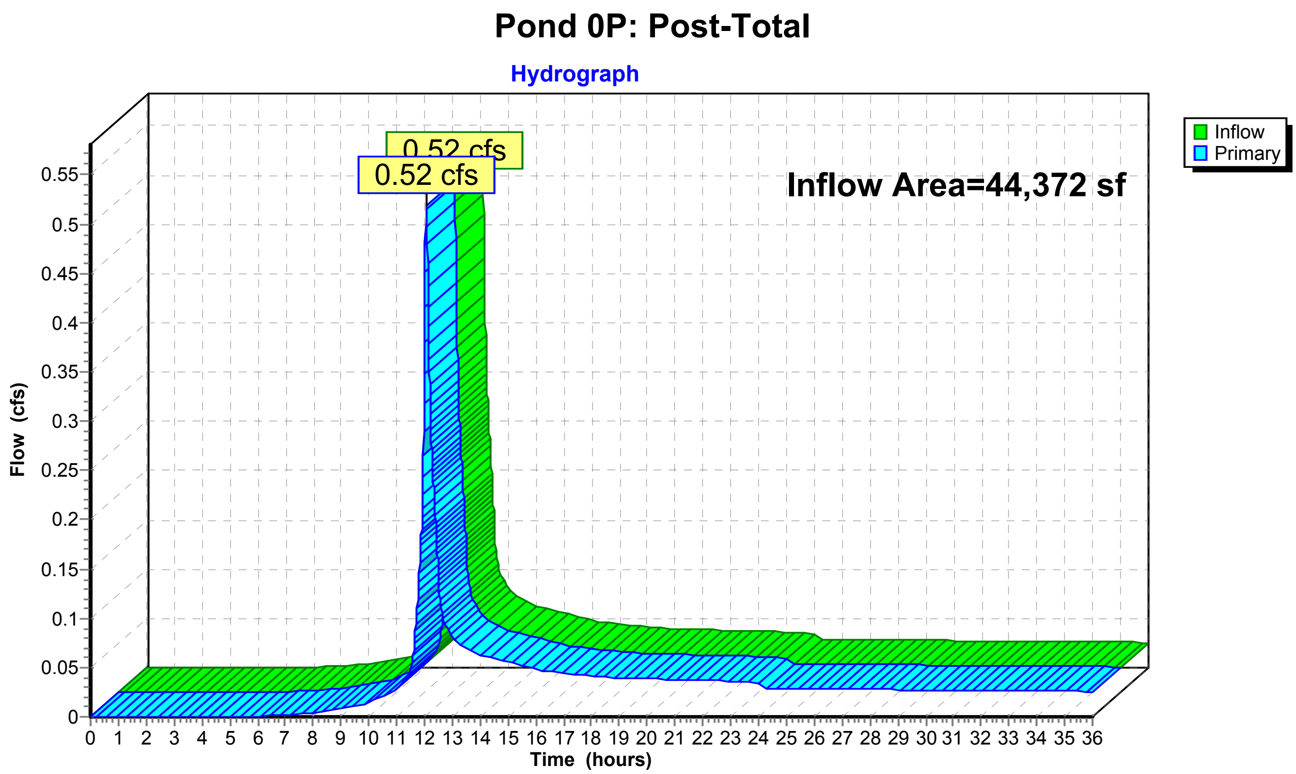


Summary for Pond 0P: Post-Total

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area =	44,372 sf,	49.70% Impervious,	Inflow Depth > 1.12"	for 2-Year event
Inflow =	0.52 cfs @	12.06 hrs, Volume=	4,159 cf	
Primary =	0.52 cfs @	12.06 hrs, Volume=	4,159 cf,	Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs

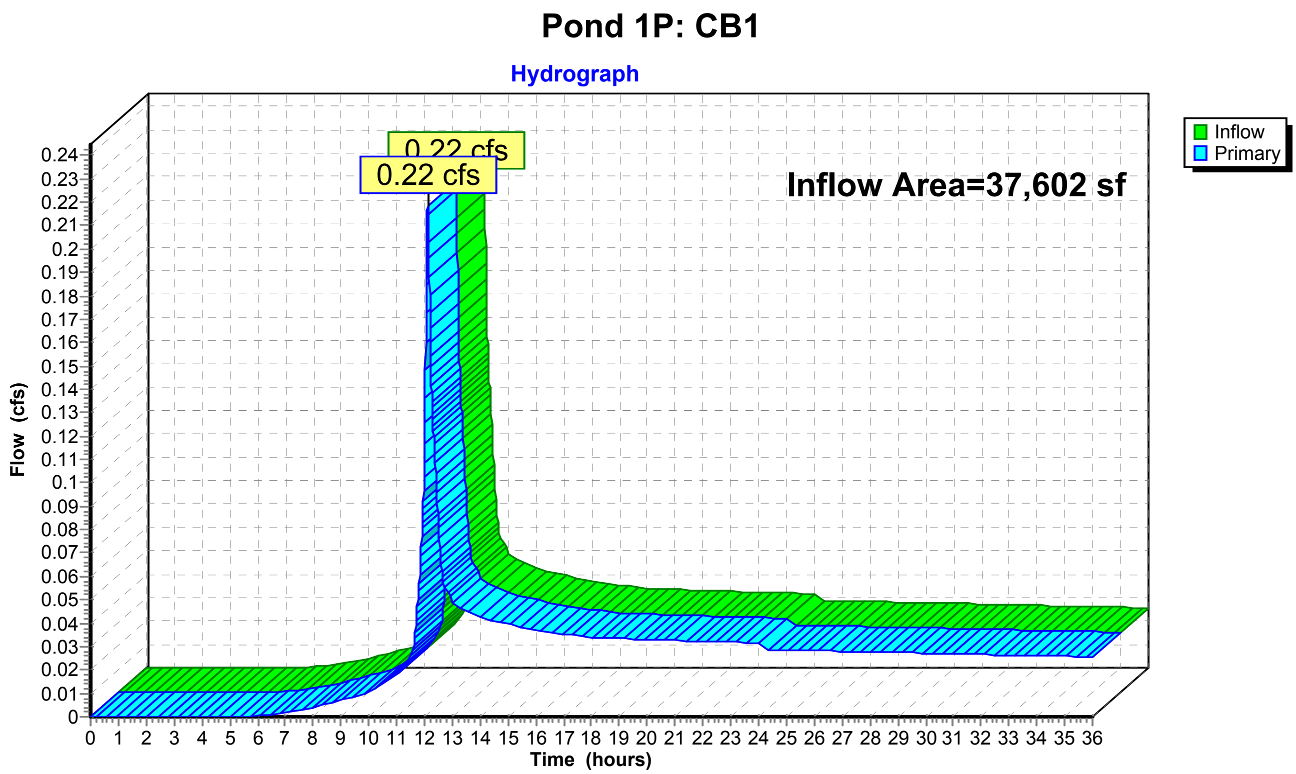


Summary for Pond 1P: CB1

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 37,602 sf, 56.13% Impervious, Inflow Depth > 1.02" for 2-Year event
Inflow = 0.22 cfs @ 12.11 hrs, Volume= 3,207 cf
Primary = 0.22 cfs @ 12.11 hrs, Volume= 3,207 cf, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs



Summary for Pond 2P: Pipe Storage

Inflow Area = 32,389 sf, 65.16% Impervious, Inflow Depth = 2.20" for 2-Year event
Inflow = 1.97 cfs @ 12.06 hrs, Volume= 5,927 cf
Outflow = 0.03 cfs @ 19.50 hrs, Volume= 2,561 cf, Atten= 99%, Lag= 446.7 min
Primary = 0.03 cfs @ 19.50 hrs, Volume= 2,561 cf

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 86.26' @ 19.50 hrs Surf.Area= 4,814 sf Storage= 4,628 cf

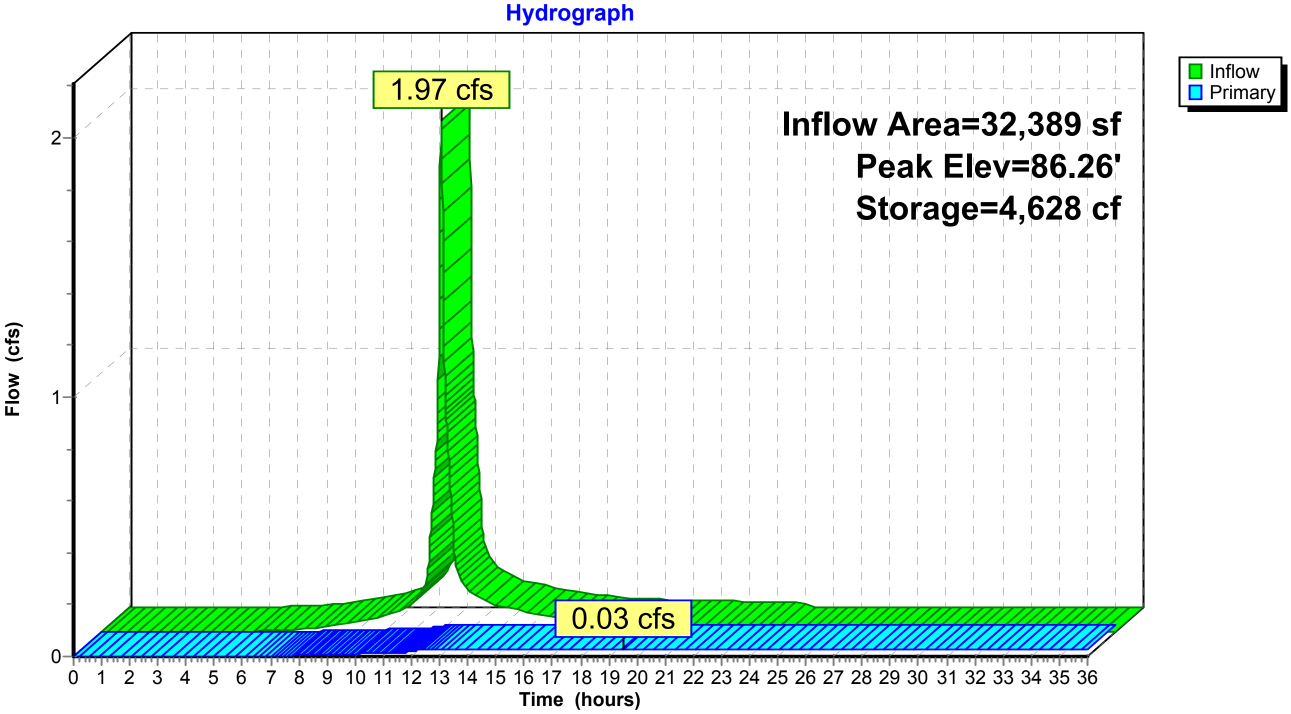
Plug-Flow detention time= 706.9 min calculated for 2,560 cf (43% of inflow)
Center-of-Mass det. time= 586.7 min (1,380.6 - 793.9)

Volume	Invert	Avail.Storage	Storage Description
#1	85.00'	11,133 cf	**36.0" Round RCP_Round 36"** x 7 L= 225.0'
#2	85.00'	250 cf	**5.00'W x 10.00'L x 5.00'H Tank Housing**
#3	85.00'	250 cf	**5.00'W x 10.00'L x 5.00'H Tank Housing**
#4	85.00'	250 cf	**5.00'W x 10.00'L x 5.00'H Tank Housing**
		11,883 cf	Total Available Storage

Device	Routing	Invert	Outlet Devices
#1	Primary	85.00'	**1.0" Vert. Orifice/Grate** C= 0.600
#2	Primary	87.50'	**6.0" Vert. Orifice/Grate** C= 0.600

Primary OutFlow Max=0.03 cfs @ 19.50 hrs HW=86.26' (Free Discharge)
├─**1=Orifice/Grate** (Orifice Controls 0.03 cfs @ 5.32 fps)
└─**2=Orifice/Grate** (Controls 0.00 cfs)

Pond 2P: Pipe Storage

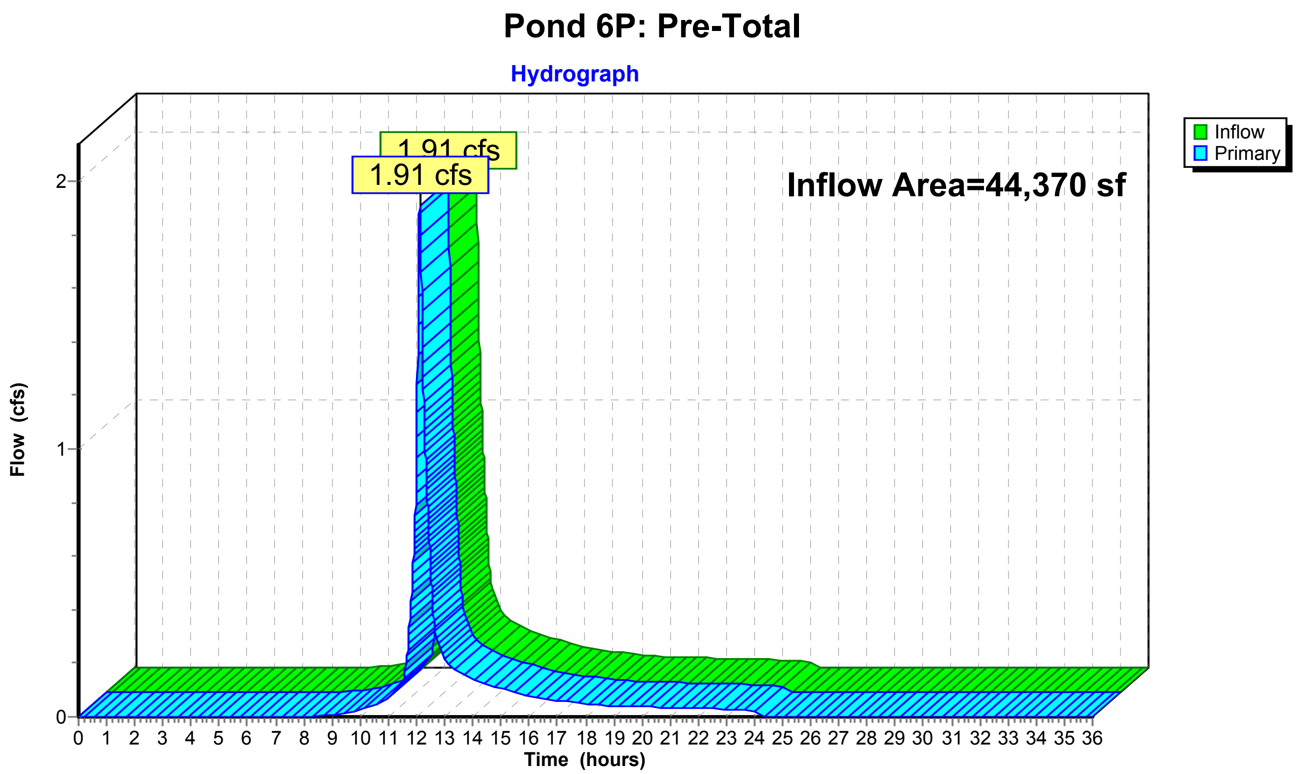


Summary for Pond 6P: Pre-Total

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 44,370 sf, 19.24% Impervious, Inflow Depth = 1.73" for 2-Year event
Inflow = 1.91 cfs @ 12.12 hrs, Volume= 6,396 cf
Primary = 1.91 cfs @ 12.12 hrs, Volume= 6,396 cf, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs



Summary for Pond 10P: Basin

Inflow Area =	4,400 sf,	54.55% Impervious,	Inflow Depth = 2.26"	for 2-Year event	
Inflow =	0.32 cfs @	12.00 hrs,	Volume=	830 cf	
Outflow =	0.01 cfs @	15.96 hrs,	Volume=	758 cf,	Atten= 97%, Lag= 237.3 min
Discarded =	0.01 cfs @	15.96 hrs,	Volume=	758 cf	
Primary =	0.00 cfs @	0.00 hrs,	Volume=	0 cf	

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Peak Elev= 97.42' @ 15.96 hrs Surf.Area= 1,329 sf Storage= 507 cf

Plug-Flow detention time= 582.8 min calculated for 758 cf (91% of inflow)
Center-of-Mass det. time= 539.1 min (1,342.5 - 803.3)

Volume	Invert	Avail.Storage	Storage Description
#1	97.00'	1,373 cf	**Custom Stage Data (Prismatic)**Listed below (Recalc)

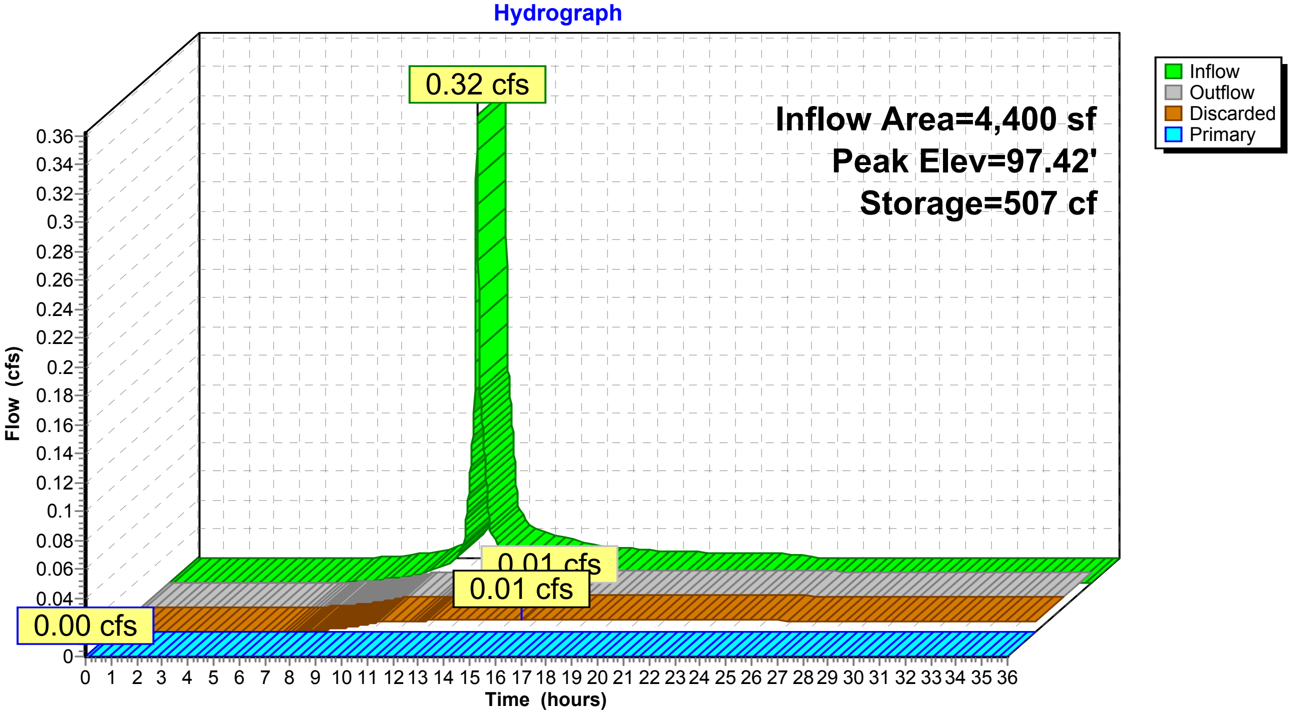
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
97.00	1,111	0	0
98.00	1,635	1,373	1,373

Device	Routing	Invert	Outlet Devices
#1	Discarded	97.00'	**0.270 in/hr Exfiltration over Surface area**
#2	Primary	97.60'	**8.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Discarded OutFlow Max=0.01 cfs @ 15.96 hrs HW=97.42' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.01 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=97.00' (Free Discharge)
└─**2=Orifice/Grate** (Controls 0.00 cfs)

Pond 10P: Basin



Time span=0.00-36.00 hrs, dt=0.01 hrs, 3601 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 0S: Post-Street Runoff Area=6,350 sf 14.90% Impervious Runoff Depth=2.81"
Flow Length=64' Slope=0.1000 '/' Tc=2.9 min CN=82 Runoff=0.54 cfs 1,488 cf

Subcatchment 1S: Post-CB1 Runoff Area=5,213 sf 0.00% Impervious Runoff Depth=2.55"
Flow Length=165' Tc=7.5 min CN=79 Runoff=0.34 cfs 1,106 cf

Subcatchment 2S: Post-CB2 Runoff Area=420 sf 0.00% Impervious Runoff Depth=2.55"
Flow Length=20' Slope=0.1000 '/' Tc=1.3 min CN=79 Runoff=0.03 cfs 89 cf

Subcatchment 3S: Post-1 Runoff Area=18,392 sf 67.08% Impervious Runoff Depth=3.80"
Flow Length=171' Tc=3.7 min CN=92 Runoff=1.95 cfs 5,819 cf

Subcatchment 4S: Post-Roof Runoff Area=4,400 sf 54.55% Impervious Runoff Depth=3.49"
Flow Length=35' Tc=0.2 min CN=89 Runoff=0.49 cfs 1,278 cf

Subcatchment 5S: Post-2 Runoff Area=9,597 sf 66.35% Impervious Runoff Depth=3.80"
Flow Length=160' Slope=0.0200 '/' Tc=5.1 min CN=92 Runoff=0.96 cfs 3,036 cf

Subcatchment 6S: Pre-CB1 Runoff Area=6,022 sf 0.00% Impervious Runoff Depth=2.55"
Flow Length=197' Tc=8.3 min CN=79 Runoff=0.38 cfs 1,277 cf

Subcatchment 7S: Pre-Street Runoff Area=37,415 sf 22.82% Impervious Runoff Depth=2.90"
Flow Length=263' Slope=0.0250 '/' Tc=8.1 min CN=83 Runoff=2.71 cfs 9,054 cf

Subcatchment 8S: Pre-CB2 Runoff Area=933 sf 0.00% Impervious Runoff Depth=2.55"
Flow Length=28' Slope=0.0250 '/' Tc=3.1 min CN=79 Runoff=0.07 cfs 198 cf

Reach 8R: ADS Pipe Avg. Flow Depth=0.05' Max Vel=2.88 fps Inflow=0.03 cfs 3,149 cf
8.0" Round Pipe n=0.012 L=27.0' S=0.0519 '/' Capacity=2.98 cfs Outflow=0.03 cfs 3,148 cf

Pond 0P: Post-Total Inflow=0.86 cfs 5,831 cf
Primary=0.86 cfs 5,831 cf

Pond 1P: CB1 Inflow=0.37 cfs 4,254 cf
Primary=0.37 cfs 4,254 cf

Pond 2P: Pipe Storage Peak Elev=86.81' Storage=7,287 cf Inflow=2.89 cfs 8,955 cf
Outflow=0.03 cfs 3,149 cf

Pond 6P: Pre-Total Inflow=3.14 cfs 10,530 cf
Primary=3.14 cfs 10,530 cf

Pond 10P: Basin Peak Elev=97.61' Storage=781 cf Inflow=0.49 cfs 1,278 cf
Discarded=0.01 cfs 850 cf Primary=0.01 cfs 100 cf Outflow=0.02 cfs 949 cf

Total Runoff Area = 88,742 sf Runoff Volume = 23,346 cf Average Runoff Depth = 3.16"
65.53% Pervious = 58,152 sf 34.47% Impervious = 30,590 sf

Summary for Subcatchment 0S: Post-Street

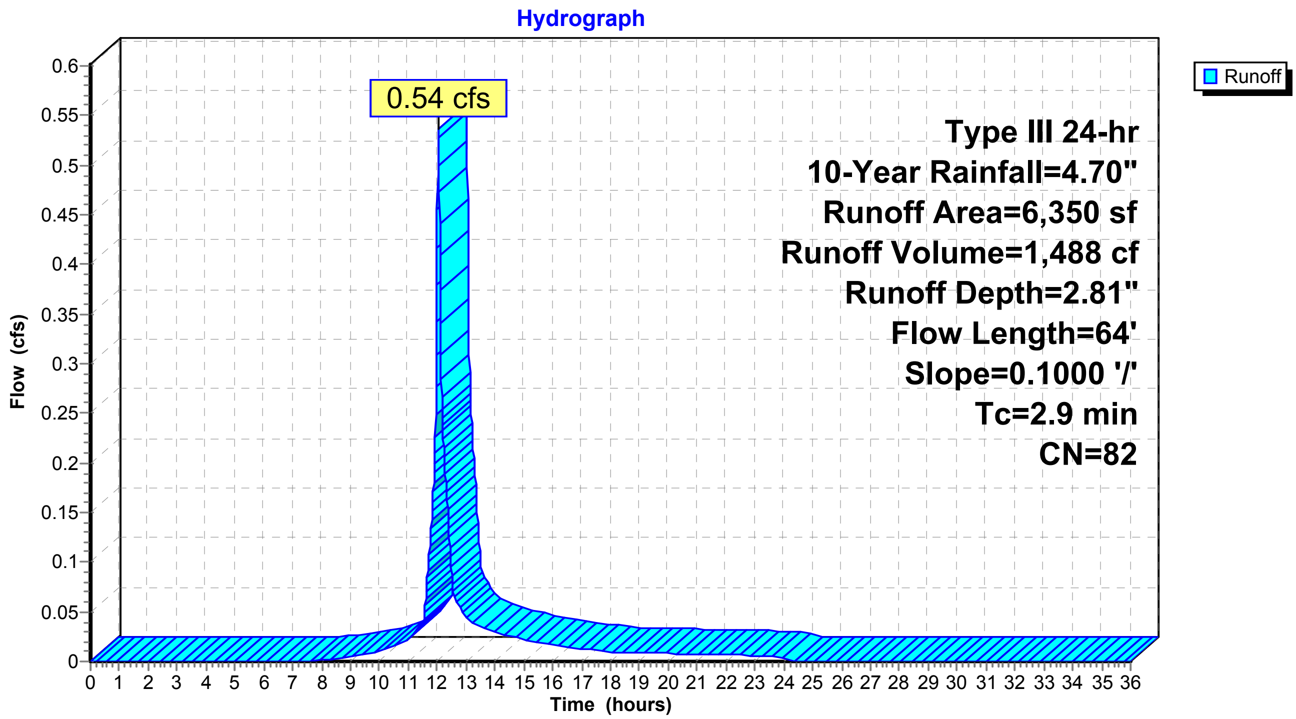
Runoff = 0.54 cfs @ 12.04 hrs, Volume= 1,488 cf, Depth= 2.81"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-Year Rainfall=4.70"

Area (sf)	CN	Description
0	98	Roofs, HSG C
946	98	Paved parking, HSG C
0	98	Unconnected pavement, HSG C
5,404	79	50-75% Grass cover, Fair, HSG C
0	73	Woods, Fair, HSG C
6,350	82	Weighted Average
5,404		85.10% Pervious Area
946		14.90% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.8	50	0.1000	0.30		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.60"
0.1	14	0.1000	2.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
2.9	64	Total			

Subcatchment 0S: Post-Street



Summary for Subcatchment 1S: Post-CB1

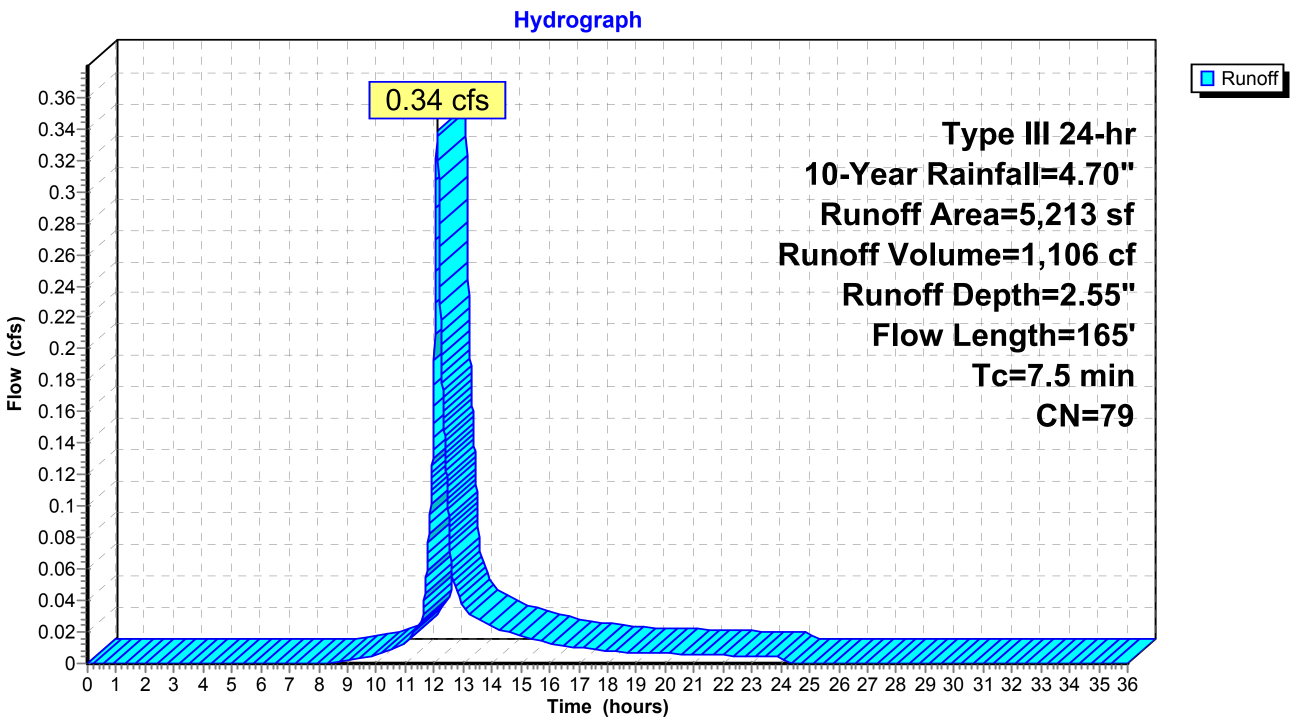
Runoff = 0.34 cfs @ 12.11 hrs, Volume= 1,106 cf, Depth= 2.55"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-Year Rainfall=4.70"

Area (sf)	CN	Description
0	98	Roofs, HSG C
0	98	Paved parking, HSG C
0	98	Unconnected pavement, HSG C
5,213	79	50-75% Grass cover, Fair, HSG C
0	73	Woods, Fair, HSG C
5,213	79	Weighted Average
5,213		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.5	50	0.0120	0.13		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.60"
1.0	115	0.0750	1.92		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
7.5	165	Total			

Subcatchment 1S: Post-CB1



Summary for Subcatchment 2S: Post-CB2

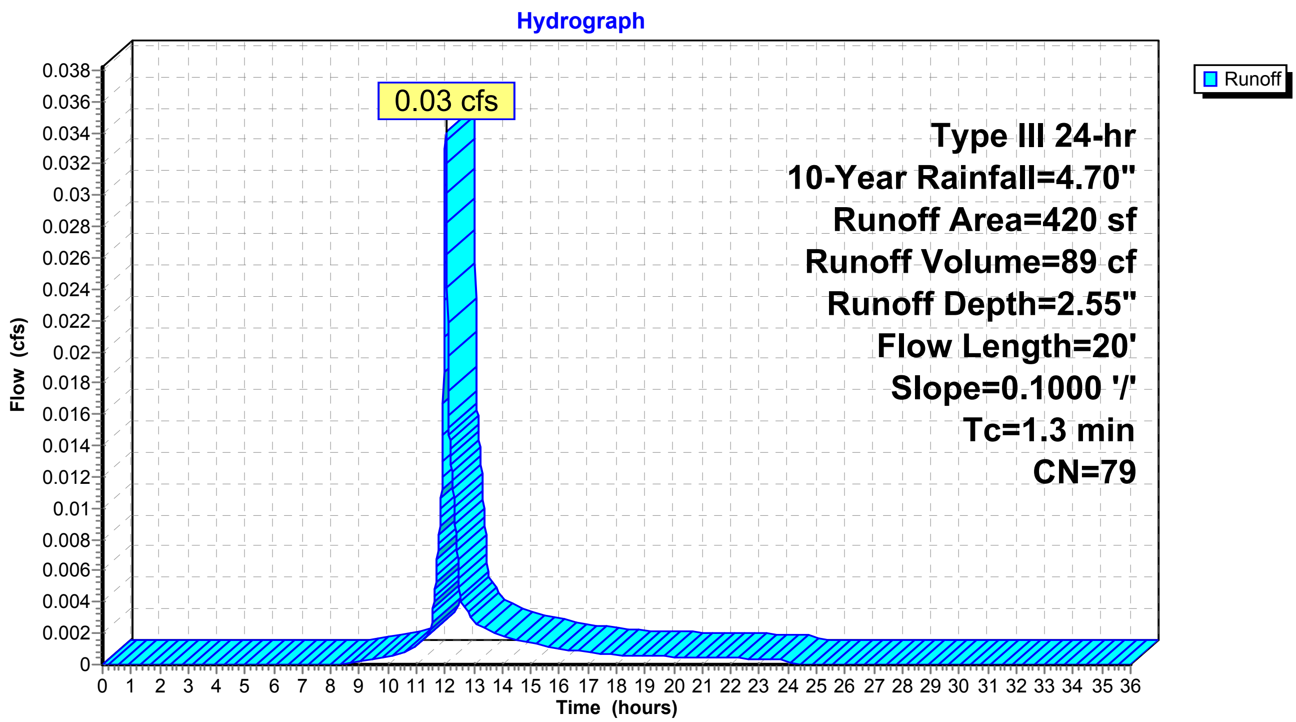
Runoff = 0.03 cfs @ 12.02 hrs, Volume= 89 cf, Depth= 2.55"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-Year Rainfall=4.70"

Area (sf)	CN	Description
0	98	Roofs, HSG C
0	98	Paved parking, HSG C
0	98	Unconnected pavement, HSG C
420	79	50-75% Grass cover, Fair, HSG C
0	73	Woods, Fair, HSG C
420	79	Weighted Average
420		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
1.3	20	0.1000	0.25		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.60"

Subcatchment 2S: Post-CB2



Summary for Subcatchment 3S: Post-1

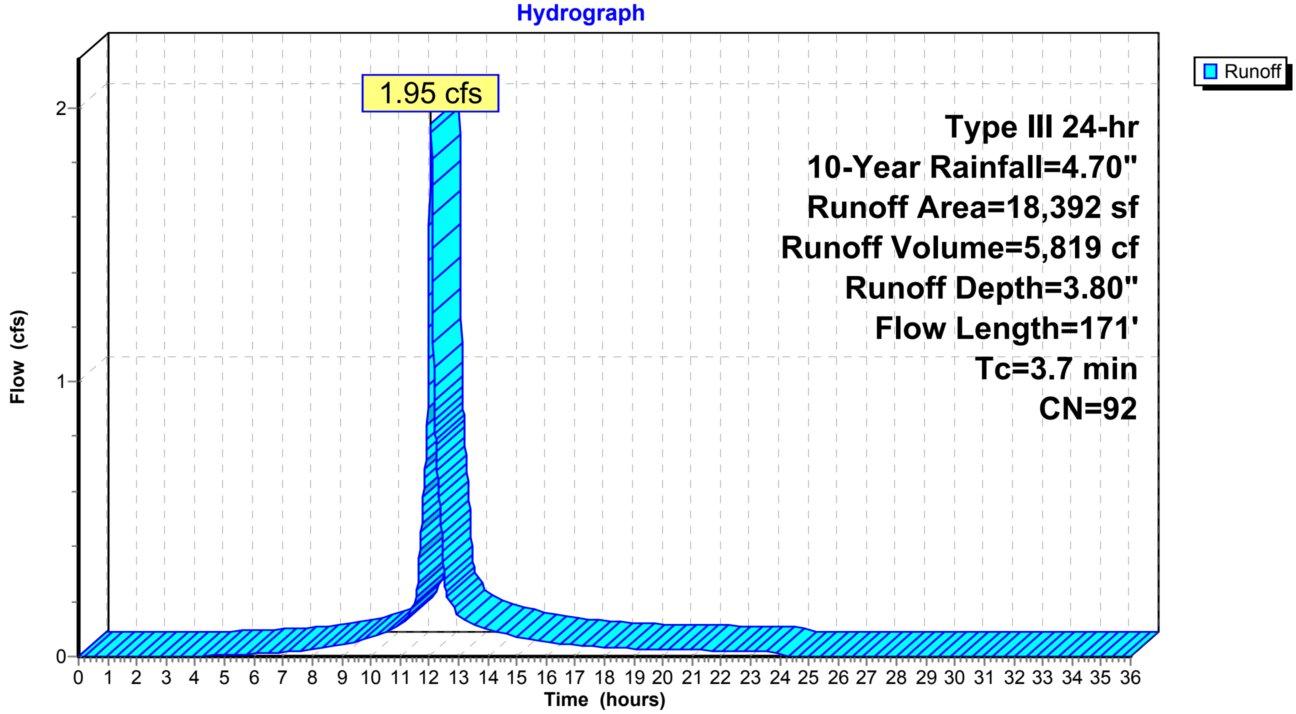
Runoff = 1.95 cfs @ 12.05 hrs, Volume= 5,819 cf, Depth= 3.80"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-Year Rainfall=4.70"

Area (sf)	CN	Description
1,560	98	Roofs, HSG C
9,716	98	Paved parking, HSG C
1,062	98	Unconnected pavement, HSG C
6,054	79	50-75% Grass cover, Fair, HSG C
0	73	Woods, Fair, HSG C
18,392	92	Weighted Average
6,054		32.92% Pervious Area
12,338		67.08% Impervious Area
1,062		8.61% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.7	41	0.0730	0.25		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.60"
0.3	15	0.0200	1.00		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 3.60"
0.7	115	0.0200	2.87		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
3.7	171	Total			

Subcatchment 3S: Post-1



Summary for Subcatchment 4S: Post-Roof

[49] Hint: Tc<2dt may require smaller dt

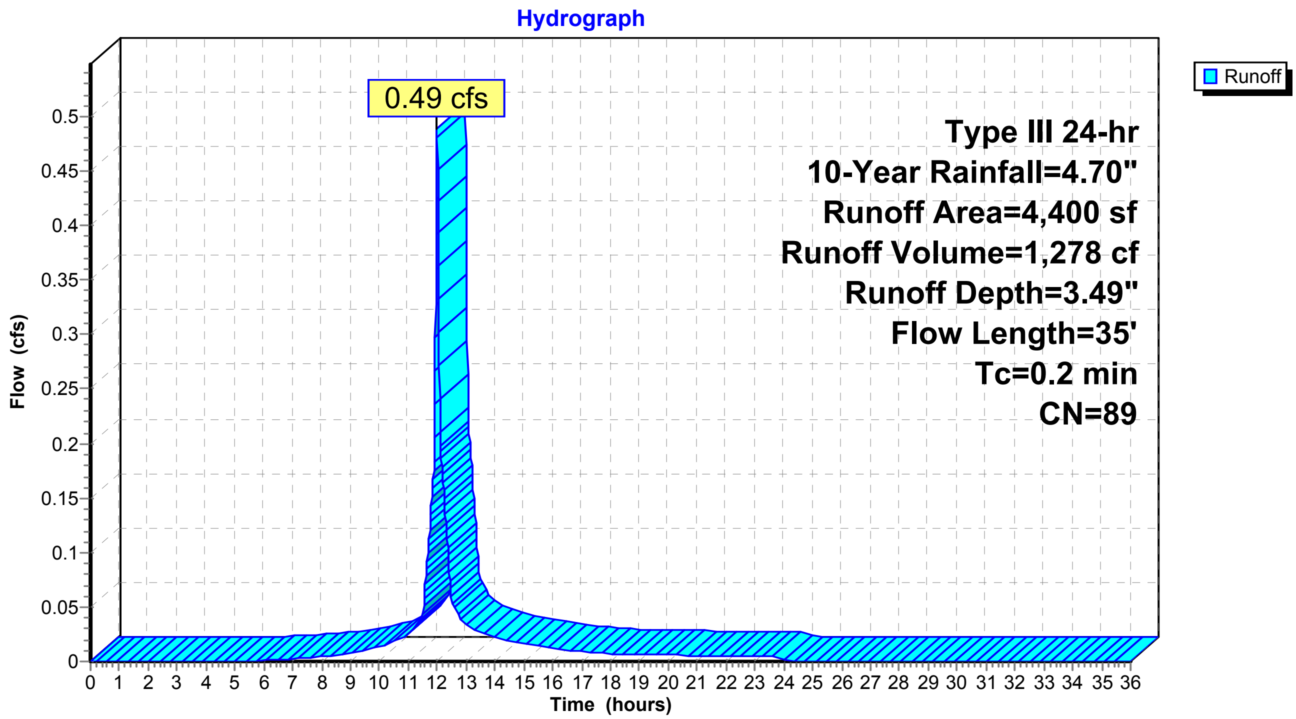
Runoff = 0.49 cfs @ 12.00 hrs, Volume= 1,278 cf, Depth= 3.49"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-Year Rainfall=4.70"

Area (sf)	CN	Description
2,400	98	Unconnected roofs, HSG C
2,000	79	50-75% Grass cover, Fair, HSG C
4,400	89	Weighted Average
2,000		45.45% Pervious Area
2,400		54.55% Impervious Area
2,400		100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.1	20	0.3000	3.12		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 3.60"
0.1	15	0.0200	2.12		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
0.2	35	Total			

Subcatchment 4S: Post-Roof



Summary for Subcatchment 5S: Post-2

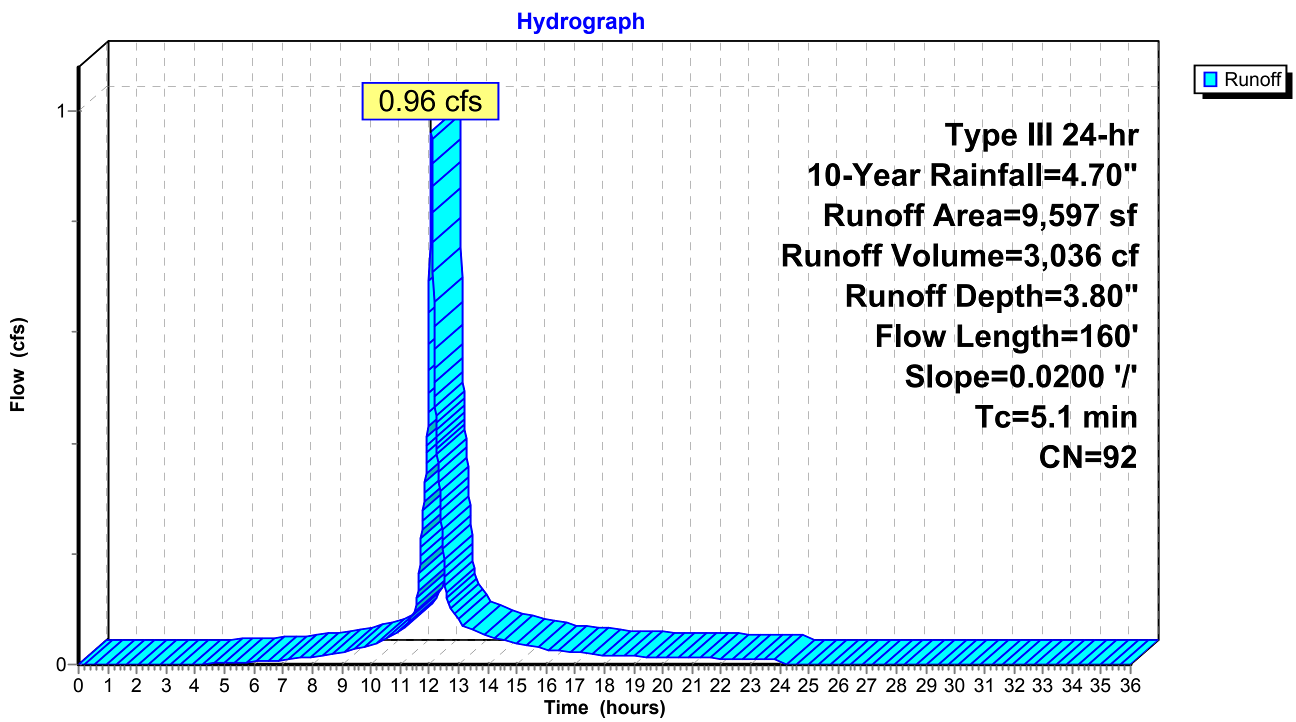
Runoff = 0.96 cfs @ 12.07 hrs, Volume= 3,036 cf, Depth= 3.80"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-Year Rainfall=4.70"

Area (sf)	CN	Description
0	98	Roofs, HSG C
5,951	98	Paved parking, HSG C
417	98	Unconnected pavement, HSG C
3,229	79	50-75% Grass cover, Fair, HSG C
0	73	Woods, Fair, HSG C
9,597	92	Weighted Average
3,229		33.65% Pervious Area
6,368		66.35% Impervious Area
417		6.55% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.4	40	0.0200	0.15		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.60"
0.7	120	0.0200	2.87		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
5.1	160	Total			

Subcatchment 5S: Post-2



Summary for Subcatchment 6S: Pre-CB1

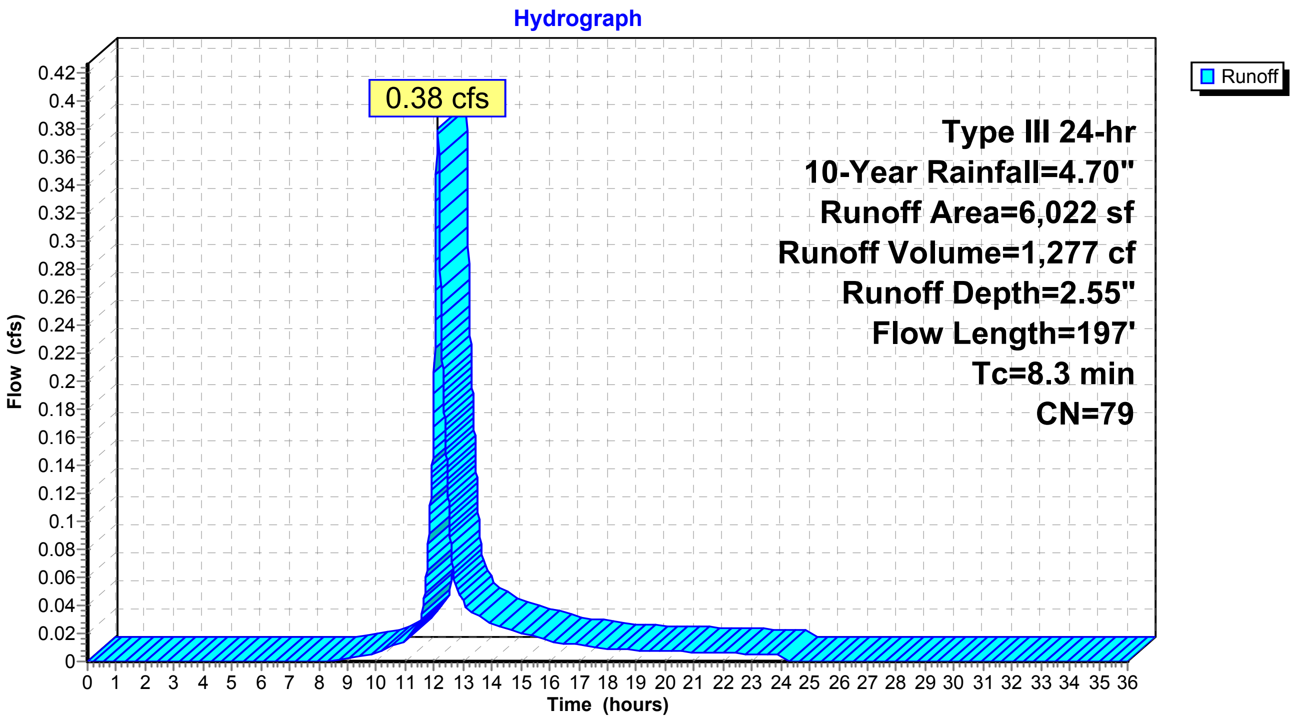
Runoff = 0.38 cfs @ 12.12 hrs, Volume= 1,277 cf, Depth= 2.55"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-Year Rainfall=4.70"

Area (sf)	CN	Description
0	98	Roofs, HSG C
0	98	Paved parking, HSG C
0	98	Unconnected pavement, HSG C
0	96	Gravel surface, HSG C
6,022	79	50-75% Grass cover, Fair, HSG C
0	73	Woods, Fair, HSG C
6,022	79	Weighted Average
6,022		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.1	50	0.1000	0.14		**Sheet Flow,** Woods: Light underbrush n= 0.400 P2= 3.60"
2.2	147	0.0500	1.12		**Shallow Concentrated Flow,** Woodland Kv= 5.0 fps
8.3	197	Total			

Subcatchment 6S: Pre-CB1



Summary for Subcatchment 7S: Pre-Street

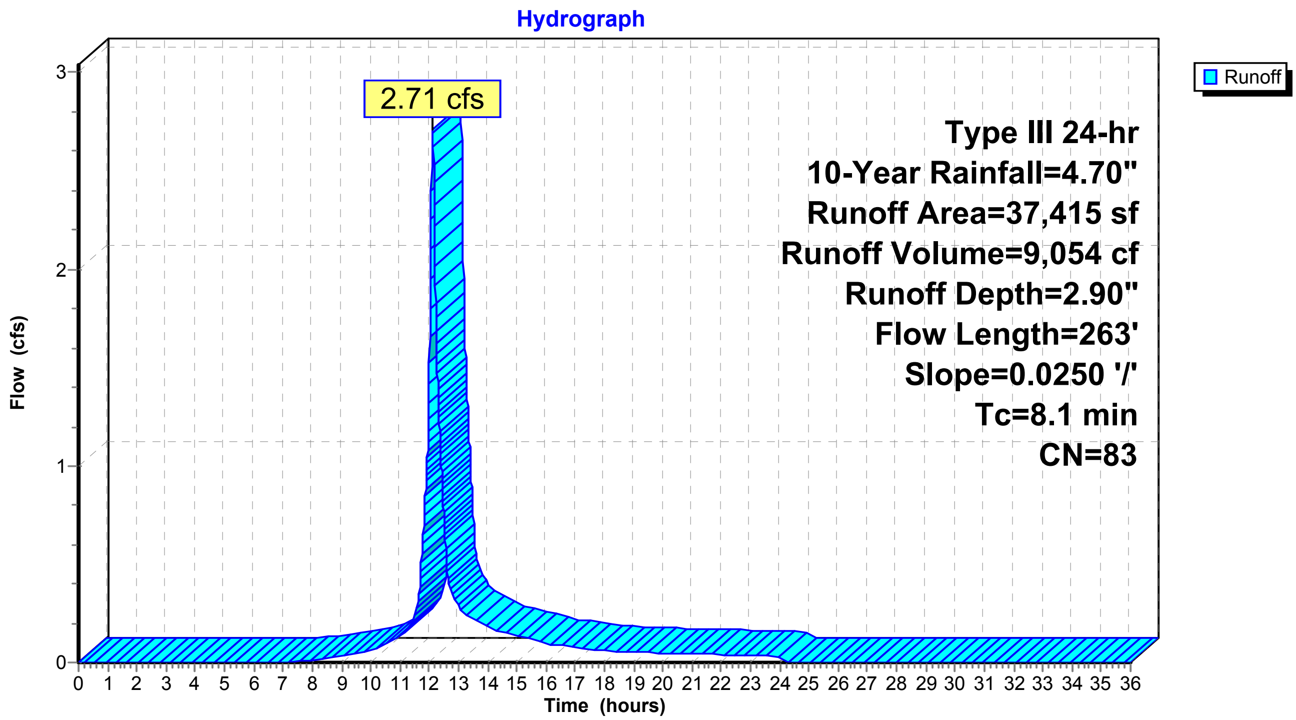
Runoff = 2.71 cfs @ 12.11 hrs, Volume= 9,054 cf, Depth= 2.90"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-Year Rainfall=4.70"

Area (sf)	CN	Description
986	98	Roofs, HSG C
7,388	98	Paved parking, HSG C
164	98	Unconnected pavement, HSG C
0	96	Gravel surface, HSG C
28,877	79	50-75% Grass cover, Fair, HSG C
0	73	Woods, Fair, HSG C
37,415	83	Weighted Average
28,877		77.18% Pervious Area
8,538		22.82% Impervious Area
164		1.92% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.9	50	0.0250	0.17		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.60"
3.2	213	0.0250	1.11		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
8.1	263	Total			

Subcatchment 7S: Pre-Street



Summary for Subcatchment 8S: Pre-CB2

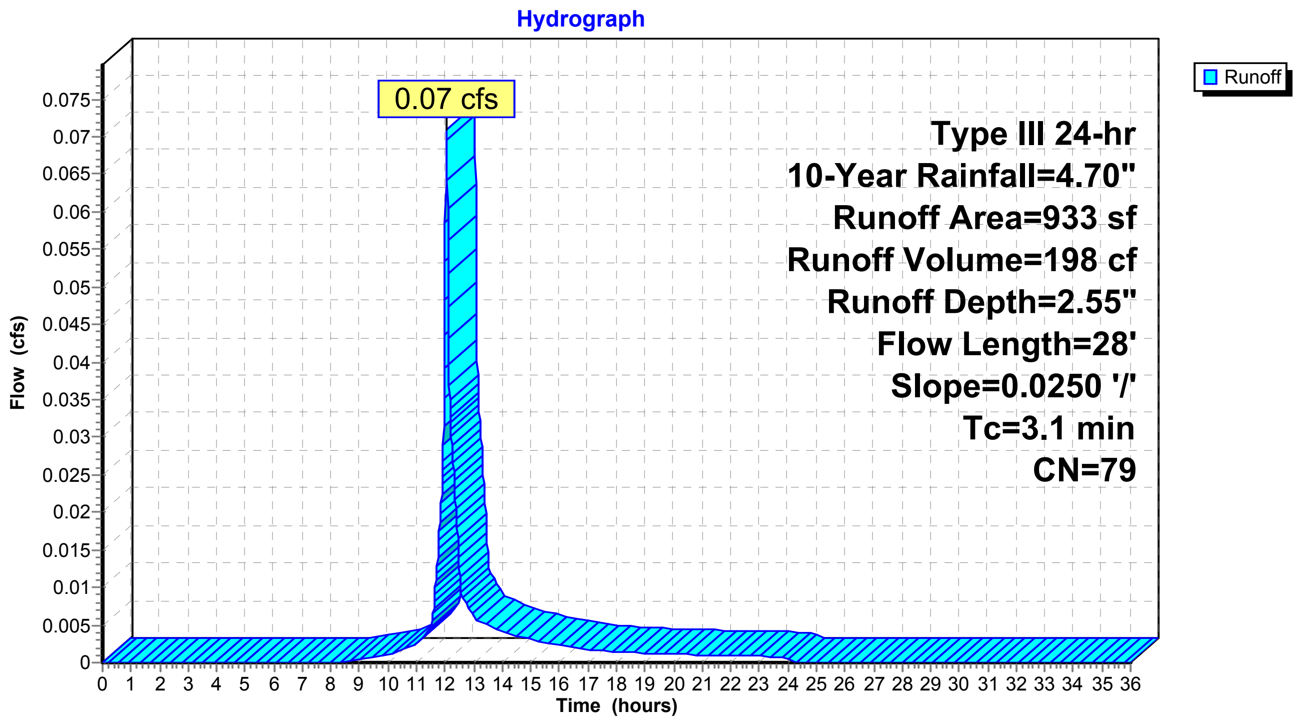
Runoff = 0.07 cfs @ 12.05 hrs, Volume= 198 cf, Depth= 2.55"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 10-Year Rainfall=4.70"

Area (sf)	CN	Description
0	98	Roofs, HSG C
0	98	Paved parking, HSG C
0	98	Unconnected pavement, HSG C
0	96	Gravel surface, HSG C
933	79	50-75% Grass cover, Fair, HSG C
0	73	Woods, Fair, HSG C
933	79	Weighted Average
933		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.1	28	0.0250	0.15		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.60"

Subcatchment 8S: Pre-CB2



Summary for Reach 8R: ADS Pipe

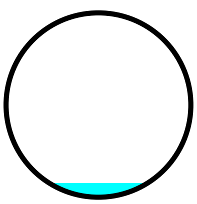
[52] Hint: Inlet/Outlet conditions not evaluated
[79] Warning: Submerged Pond 2P Primary device # 1 by 0.05'

Inflow Area = 32,389 sf, 65.16% Impervious, Inflow Depth > 1.17" for 10-Year event
Inflow = 0.03 cfs @ 21.14 hrs, Volume= 3,149 cf
Outflow = 0.03 cfs @ 21.15 hrs, Volume= 3,148 cf, Atten= 0%, Lag= 0.3 min

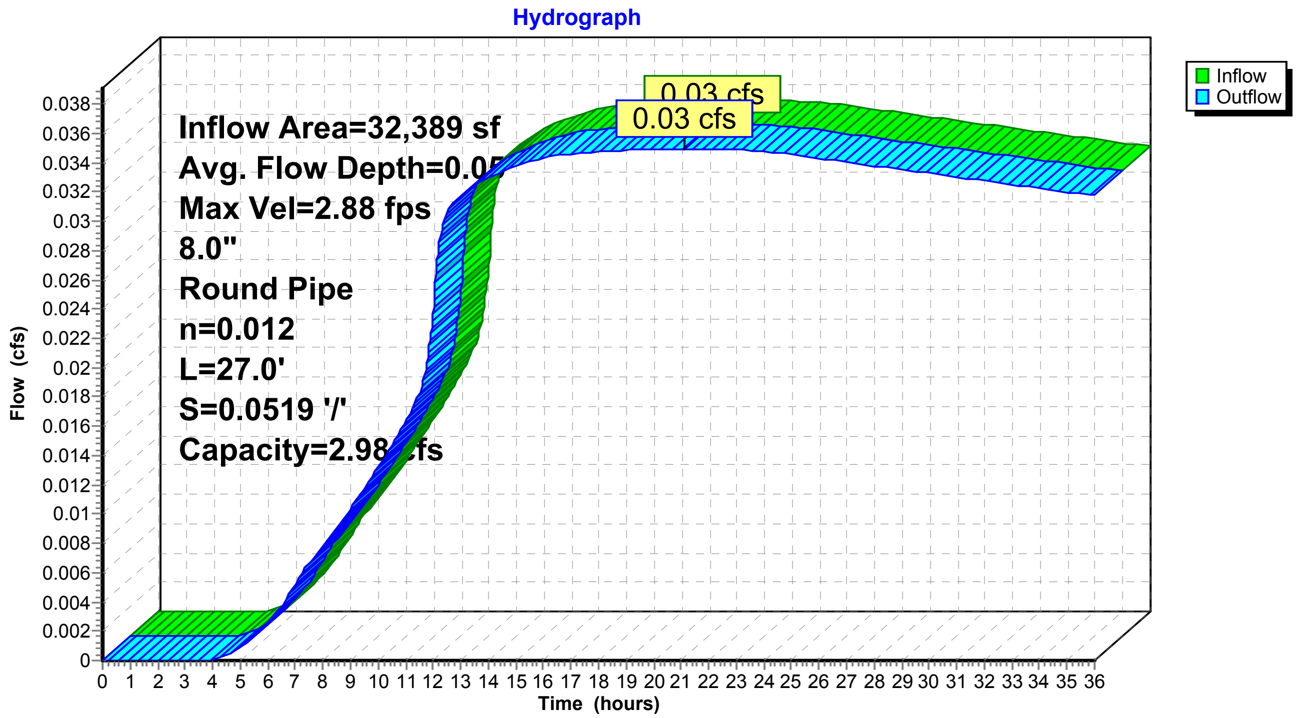
Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Max. Velocity= 2.88 fps, Min. Travel Time= 0.2 min
Avg. Velocity = 2.57 fps, Avg. Travel Time= 0.2 min

Peak Storage= 0 cf @ 21.14 hrs
Average Depth at Peak Storage= 0.05'
Bank-Full Depth= 0.67' Flow Area= 0.3 sf, Capacity= 2.98 cfs

8.0" Round Pipe
n= 0.012 Corrugated PP, smooth interior
Length= 27.0' Slope= 0.0519 '/'
Inlet Invert= 85.00', Outlet Invert= 83.60'



Reach 8R: ADS Pipe

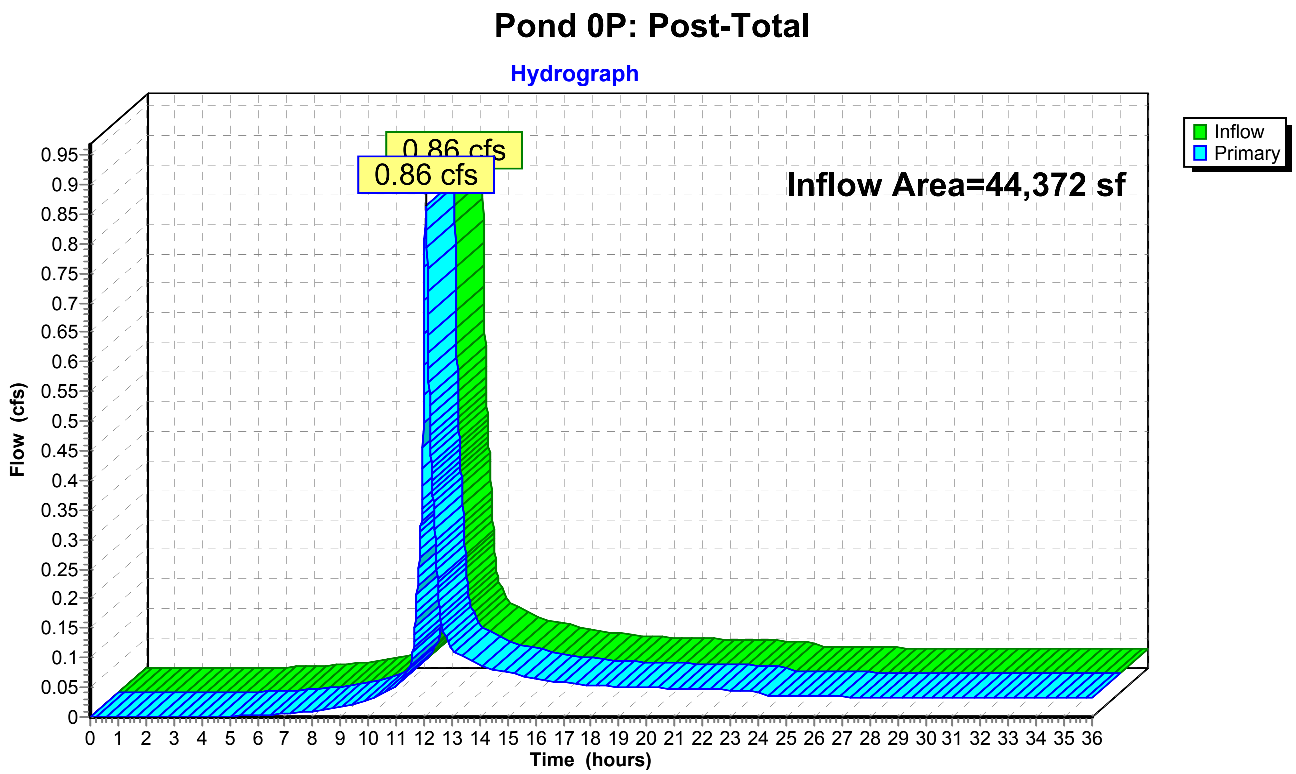


Summary for Pond 0P: Post-Total

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area =	44,372 sf,	49.70% Impervious,	Inflow Depth > 1.58"	for 10-Year event
Inflow =	0.86 cfs @	12.06 hrs, Volume=	5,831 cf	
Primary =	0.86 cfs @	12.06 hrs, Volume=	5,831 cf,	Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs



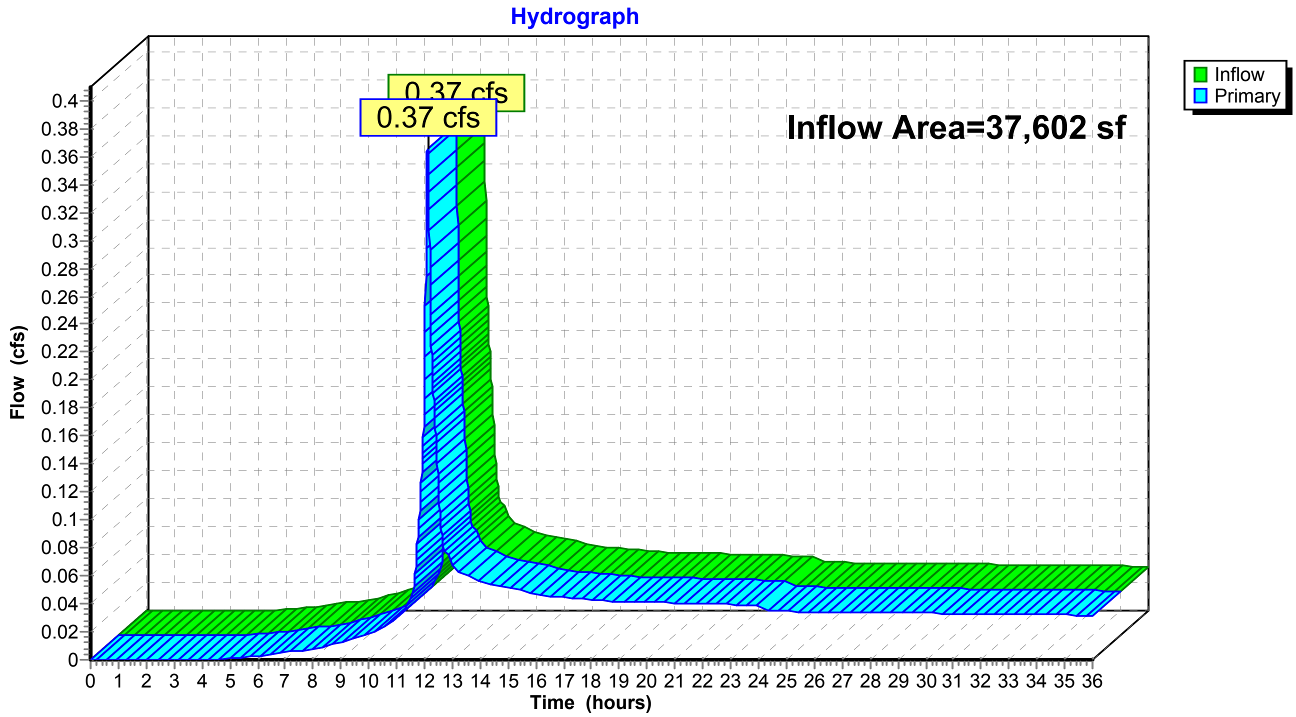
Summary for Pond 1P: CB1

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 37,602 sf, 56.13% Impervious, Inflow Depth > 1.36" for 10-Year event
Inflow = 0.37 cfs @ 12.11 hrs, Volume= 4,254 cf
Primary = 0.37 cfs @ 12.11 hrs, Volume= 4,254 cf, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs

Pond 1P: CB1



Summary for Pond 2P: Pipe Storage

Inflow Area = 32,389 sf, 65.16% Impervious, Inflow Depth = 3.32" for 10-Year event
Inflow = 2.89 cfs @ 12.06 hrs, Volume= 8,955 cf
Outflow = 0.03 cfs @ 21.14 hrs, Volume= 3,149 cf, Atten= 99%, Lag= 545.0 min
Primary = 0.03 cfs @ 21.14 hrs, Volume= 3,149 cf

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 86.81' @ 21.14 hrs Surf.Area= 4,774 sf Storage= 7,287 cf

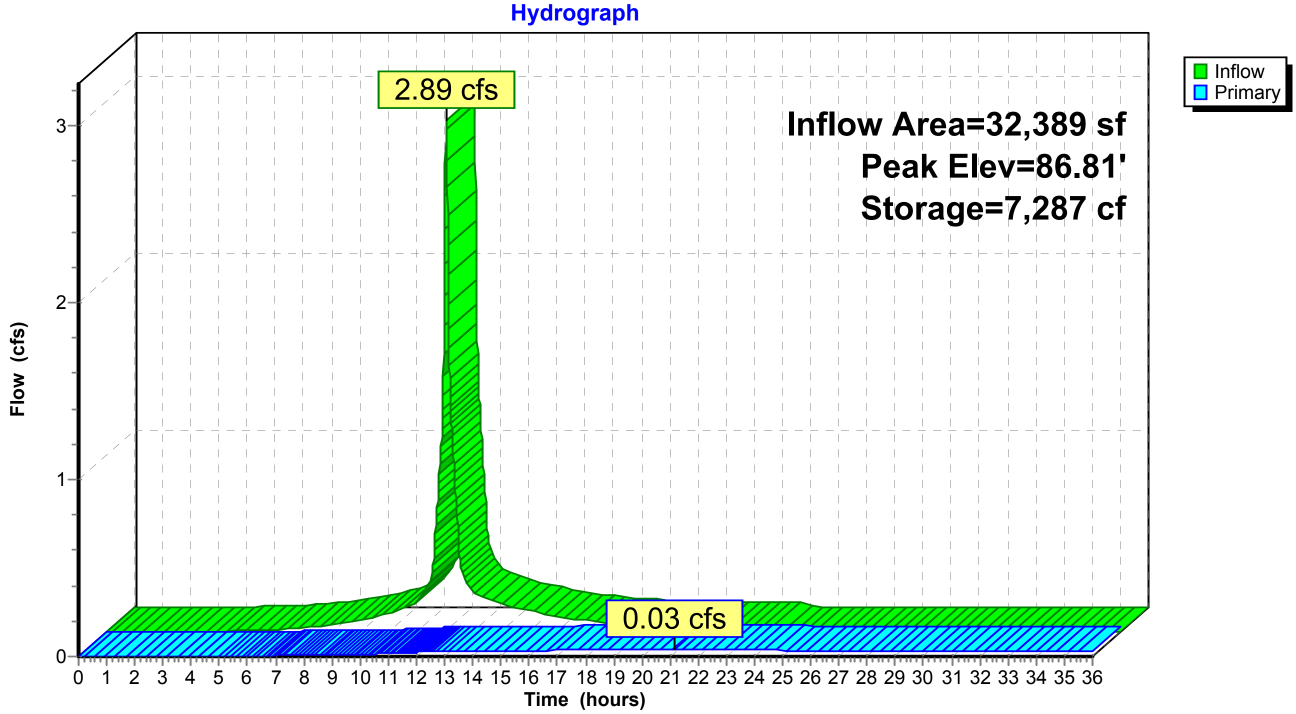
Plug-Flow detention time= 725.7 min calculated for 3,149 cf (35% of inflow)
Center-of-Mass det. time= 587.1 min (1,371.3 - 784.3)

Volume	Invert	Avail.Storage	Storage Description
#1	85.00'	11,133 cf	**36.0" Round RCP_Round 36"** x 7 L= 225.0'
#2	85.00'	250 cf	**5.00'W x 10.00'L x 5.00'H Tank Housing**
#3	85.00'	250 cf	**5.00'W x 10.00'L x 5.00'H Tank Housing**
#4	85.00'	250 cf	**5.00'W x 10.00'L x 5.00'H Tank Housing**
		11,883 cf	Total Available Storage

Device	Routing	Invert	Outlet Devices
#1	Primary	85.00'	**1.0" Vert. Orifice/Grate** C= 0.600
#2	Primary	87.50'	**6.0" Vert. Orifice/Grate** C= 0.600

Primary OutFlow Max=0.03 cfs @ 21.14 hrs HW=86.81' (Free Discharge)
├─**1=Orifice/Grate** (Orifice Controls 0.03 cfs @ 6.40 fps)
└─**2=Orifice/Grate** (Controls 0.00 cfs)

Pond 2P: Pipe Storage

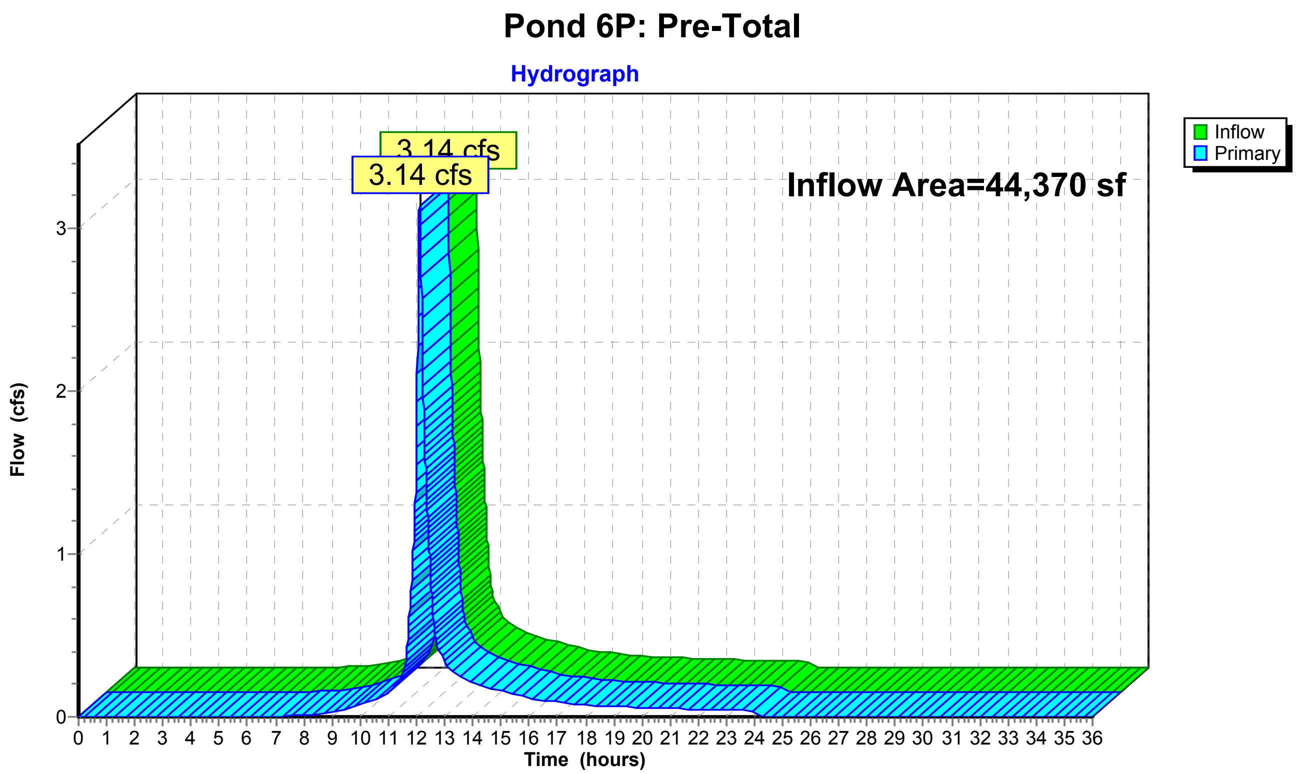


Summary for Pond 6P: Pre-Total

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area =	44,370 sf,	19.24% Impervious,	Inflow Depth = 2.85"	for 10-Year event
Inflow =	3.14 cfs @	12.11 hrs, Volume=	10,530 cf	
Primary =	3.14 cfs @	12.11 hrs, Volume=	10,530 cf,	Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs



Summary for Pond 10P: Basin

Inflow Area =	4,400 sf,	54.55% Impervious,	Inflow Depth = 3.49"	for 10-Year event	
Inflow =	0.49 cfs @	12.00 hrs,	Volume=	1,278 cf	
Outflow =	0.02 cfs @	14.14 hrs,	Volume=	949 cf,	Atten= 96%, Lag= 128.0 min
Discarded =	0.01 cfs @	14.14 hrs,	Volume=	850 cf	
Primary =	0.01 cfs @	14.14 hrs,	Volume=	100 cf	

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Peak Elev= 97.61' @ 14.14 hrs Surf.Area= 1,433 sf Storage= 781 cf

Plug-Flow detention time= 568.7 min calculated for 949 cf (74% of inflow)
Center-of-Mass det. time= 482.5 min (1,273.7 - 791.2)

Volume	Invert	Avail.Storage	Storage Description
#1	97.00'	1,373 cf	**Custom Stage Data (Prismatic)**Listed below (Recalc)

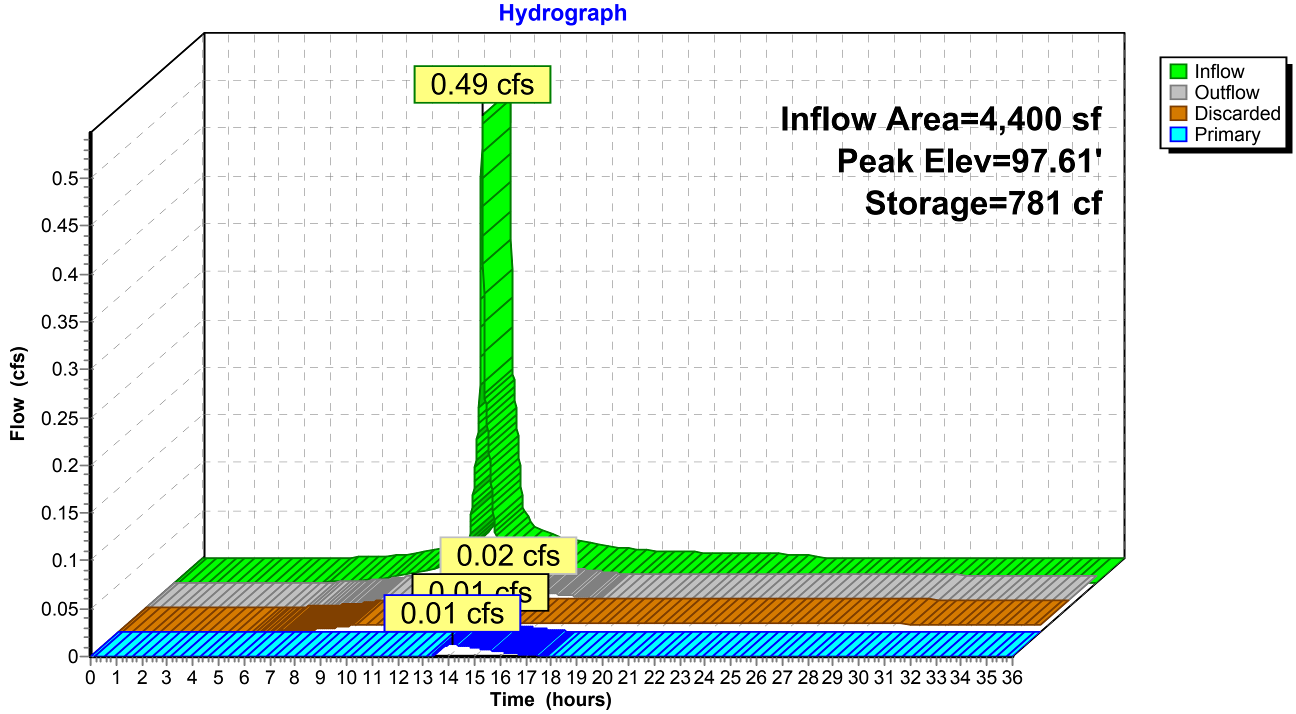
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
97.00	1,111	0	0
98.00	1,635	1,373	1,373

Device	Routing	Invert	Outlet Devices
#1	Discarded	97.00'	**0.270 in/hr Exfiltration over Surface area**
#2	Primary	97.60'	**8.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Discarded OutFlow Max=0.01 cfs @ 14.14 hrs HW=97.61' (Free Discharge)
↑—**1=Exfiltration** (Exfiltration Controls 0.01 cfs)

Primary OutFlow Max=0.01 cfs @ 14.14 hrs HW=97.61' (Free Discharge)
↑—**2=Orifice/Grate** (Weir Controls 0.01 cfs @ 0.39 fps)

Pond 10P: Basin



Time span=0.00-36.00 hrs, dt=0.01 hrs, 3601 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 0S: Post-Street Runoff Area=6,350 sf 14.90% Impervious Runoff Depth=3.62"
Flow Length=64' Slope=0.1000 '/' Tc=2.9 min CN=82 Runoff=0.69 cfs 1,916 cf

Subcatchment 1S: Post-CB1 Runoff Area=5,213 sf 0.00% Impervious Runoff Depth=3.32"
Flow Length=165' Tc=7.5 min CN=79 Runoff=0.44 cfs 1,444 cf

Subcatchment 2S: Post-CB2 Runoff Area=420 sf 0.00% Impervious Runoff Depth=3.32"
Flow Length=20' Slope=0.1000 '/' Tc=1.3 min CN=79 Runoff=0.04 cfs 116 cf

Subcatchment 3S: Post-1 Runoff Area=18,392 sf 67.08% Impervious Runoff Depth=4.68"
Flow Length=171' Tc=3.7 min CN=92 Runoff=2.37 cfs 7,168 cf

Subcatchment 4S: Post-Roof Runoff Area=4,400 sf 54.55% Impervious Runoff Depth=4.35"
Flow Length=35' Tc=0.2 min CN=89 Runoff=0.60 cfs 1,595 cf

Subcatchment 5S: Post-2 Runoff Area=9,597 sf 66.35% Impervious Runoff Depth=4.68"
Flow Length=160' Slope=0.0200 '/' Tc=5.1 min CN=92 Runoff=1.17 cfs 3,740 cf

Subcatchment 6S: Pre-CB1 Runoff Area=6,022 sf 0.00% Impervious Runoff Depth=3.32"
Flow Length=197' Tc=8.3 min CN=79 Runoff=0.50 cfs 1,668 cf

Subcatchment 7S: Pre-Street Runoff Area=37,415 sf 22.82% Impervious Runoff Depth=3.72"
Flow Length=263' Slope=0.0250 '/' Tc=8.1 min CN=83 Runoff=3.46 cfs 11,604 cf

Subcatchment 8S: Pre-CB2 Runoff Area=933 sf 0.00% Impervious Runoff Depth=3.32"
Flow Length=28' Slope=0.0250 '/' Tc=3.1 min CN=79 Runoff=0.09 cfs 258 cf

Reach 8R: ADS Pipe Avg. Flow Depth=0.05' Max Vel=2.98 fps Inflow=0.04 cfs 3,553 cf
8.0" Round Pipe n=0.012 L=27.0' S=0.0519 '/' Capacity=2.98 cfs Outflow=0.04 cfs 3,552 cf

Pond 0P: Post-Total Inflow=1.11 cfs 7,029 cf
Primary=1.11 cfs 7,029 cf

Pond 1P: CB1 Inflow=0.47 cfs 4,997 cf
Primary=0.47 cfs 4,997 cf

Pond 2P: Pipe Storage Peak Elev=87.27' Storage=9,369 cf Inflow=3.51 cfs 11,277 cf
Outflow=0.04 cfs 3,553 cf

Pond 6P: Pre-Total Inflow=4.02 cfs 13,531 cf
Primary=4.02 cfs 13,531 cf

Pond 10P: Basin Peak Elev=97.65' Storage=827 cf Inflow=0.60 cfs 1,595 cf
Discarded=0.01 cfs 874 cf Primary=0.07 cfs 369 cf Outflow=0.08 cfs 1,243 cf

Total Runoff Area = 88,742 sf Runoff Volume = 29,510 cf Average Runoff Depth = 3.99"
65.53% Pervious = 58,152 sf 34.47% Impervious = 30,590 sf

Summary for Subcatchment 0S: Post-Street

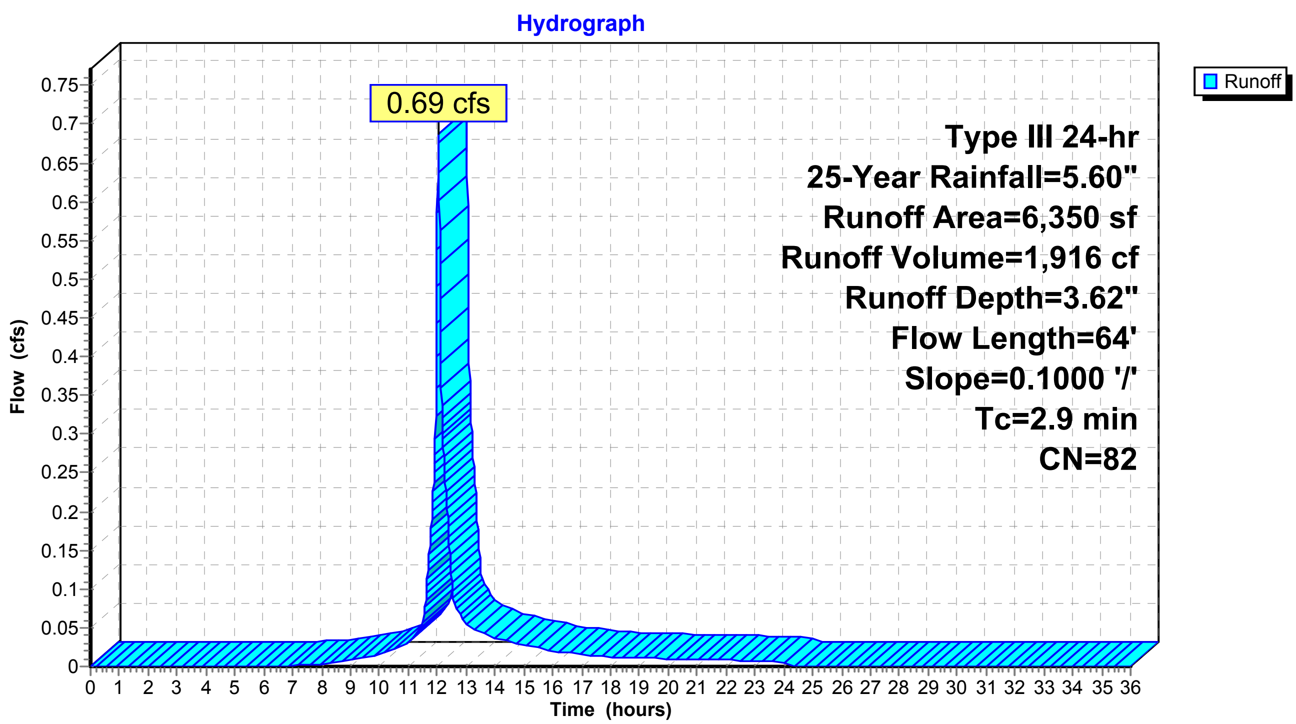
Runoff = 0.69 cfs @ 12.04 hrs, Volume= 1,916 cf, Depth= 3.62"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-Year Rainfall=5.60"

Area (sf)	CN	Description
0	98	Roofs, HSG C
946	98	Paved parking, HSG C
0	98	Unconnected pavement, HSG C
5,404	79	50-75% Grass cover, Fair, HSG C
0	73	Woods, Fair, HSG C
6,350	82	Weighted Average
5,404		85.10% Pervious Area
946		14.90% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.8	50	0.1000	0.30		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.60"
0.1	14	0.1000	2.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
2.9	64	Total			

Subcatchment 0S: Post-Street



Summary for Subcatchment 1S: Post-CB1

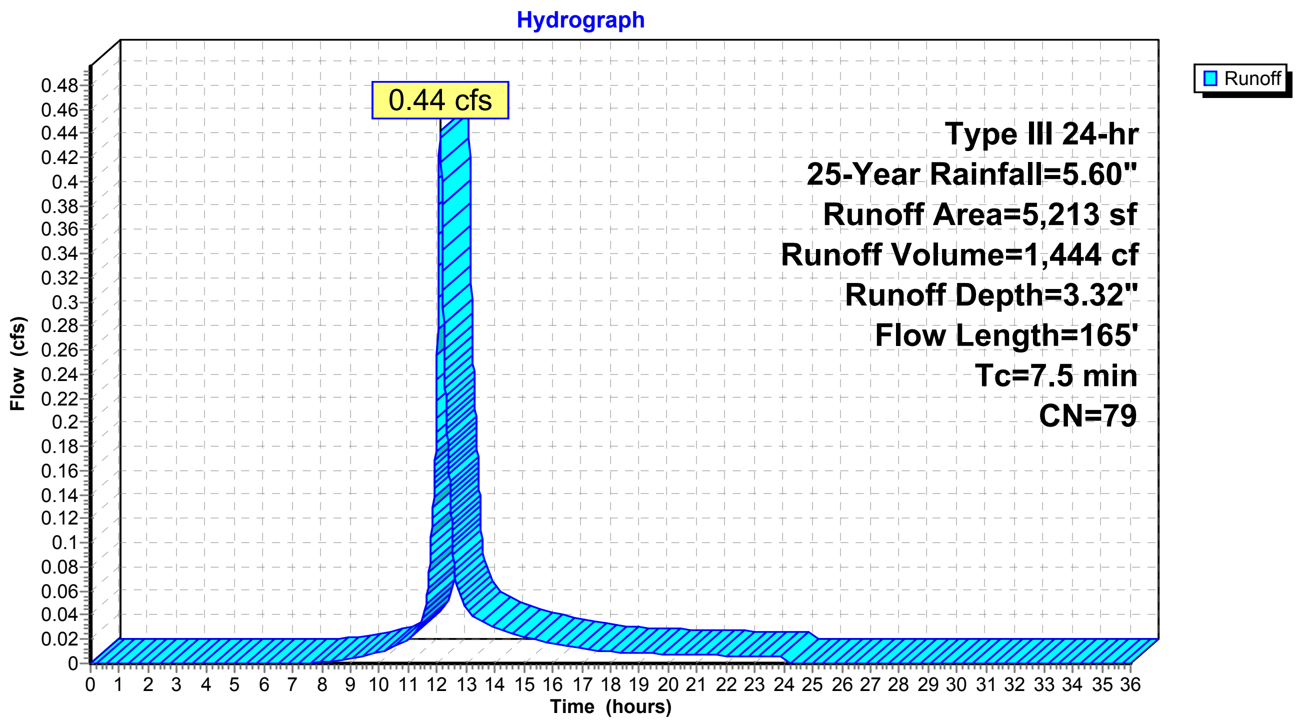
Runoff = 0.44 cfs @ 12.11 hrs, Volume= 1,444 cf, Depth= 3.32"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-Year Rainfall=5.60"

Area (sf)	CN	Description
0	98	Roofs, HSG C
0	98	Paved parking, HSG C
0	98	Unconnected pavement, HSG C
5,213	79	50-75% Grass cover, Fair, HSG C
0	73	Woods, Fair, HSG C
5,213	79	Weighted Average
5,213		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.5	50	0.0120	0.13		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.60"
1.0	115	0.0750	1.92		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
7.5	165	Total			

Subcatchment 1S: Post-CB1



Summary for Subcatchment 2S: Post-CB2

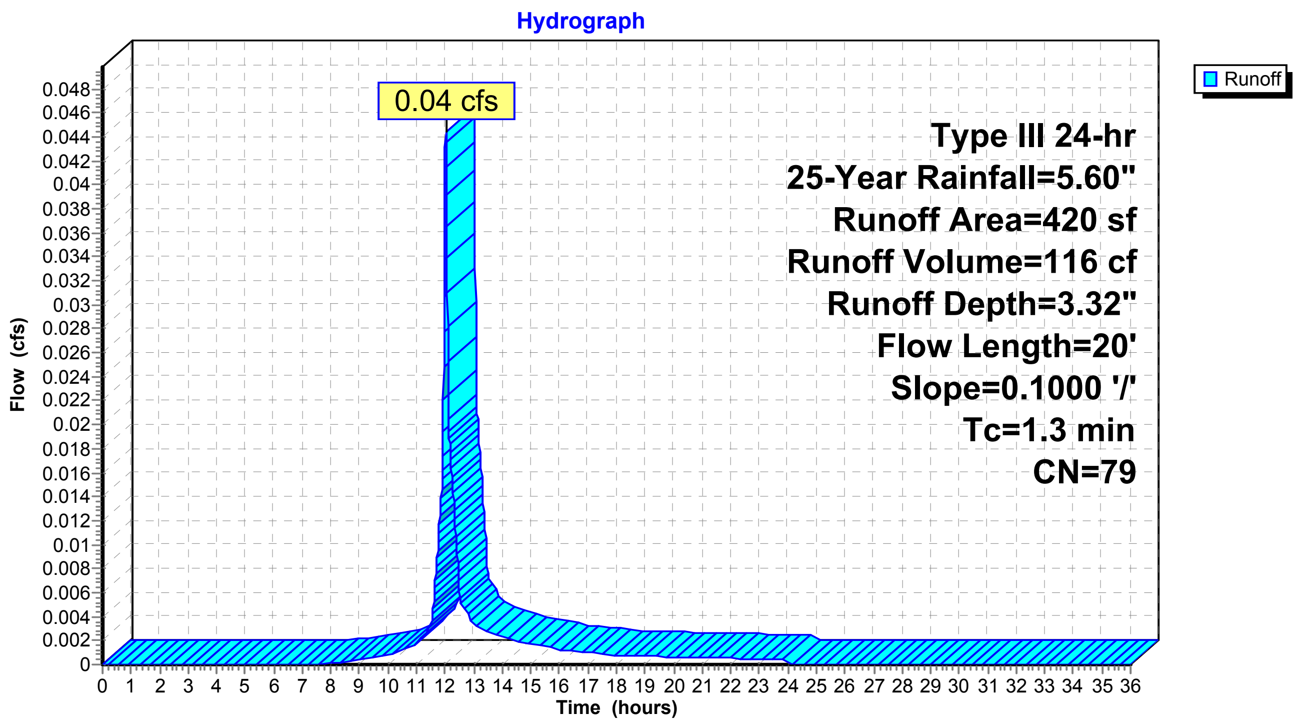
Runoff = 0.04 cfs @ 12.02 hrs, Volume= 116 cf, Depth= 3.32"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-Year Rainfall=5.60"

Area (sf)	CN	Description
0	98	Roofs, HSG C
0	98	Paved parking, HSG C
0	98	Unconnected pavement, HSG C
420	79	50-75% Grass cover, Fair, HSG C
0	73	Woods, Fair, HSG C
420	79	Weighted Average
420		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
1.3	20	0.1000	0.25		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.60"

Subcatchment 2S: Post-CB2



Summary for Subcatchment 3S: Post-1

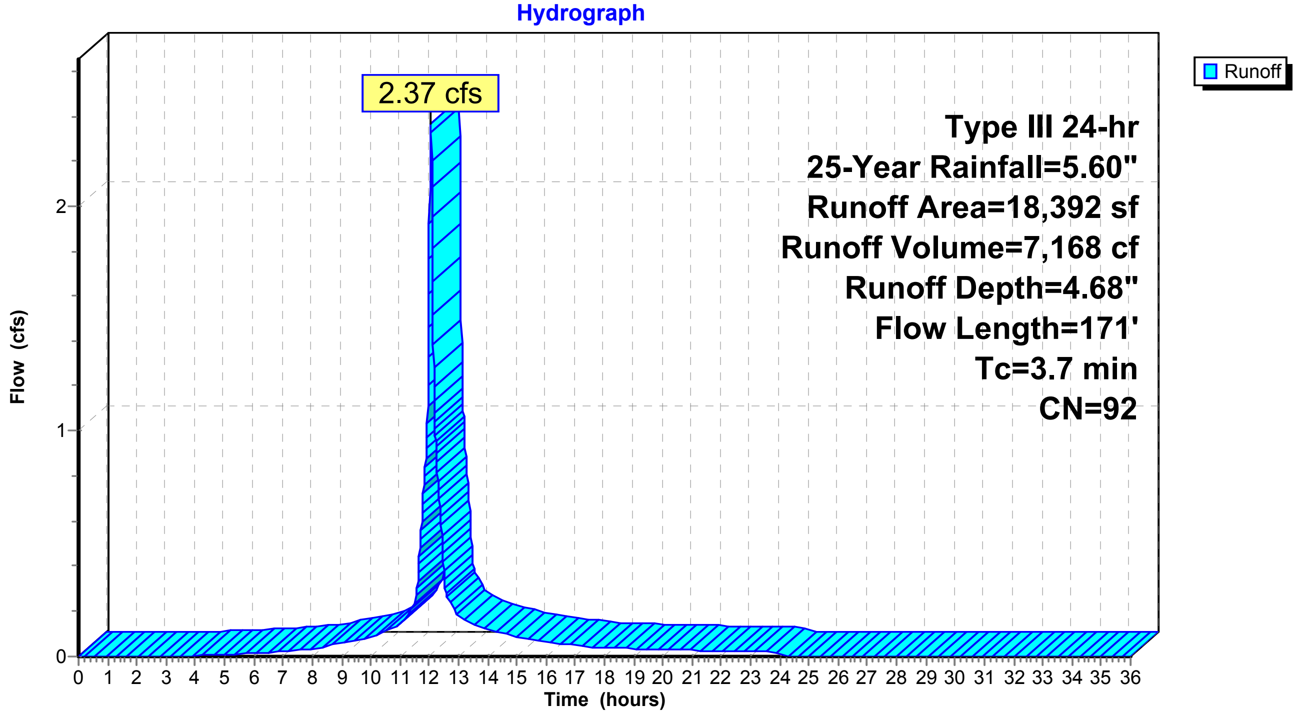
Runoff = 2.37 cfs @ 12.05 hrs, Volume= 7,168 cf, Depth= 4.68"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-Year Rainfall=5.60"

Area (sf)	CN	Description
1,560	98	Roofs, HSG C
9,716	98	Paved parking, HSG C
1,062	98	Unconnected pavement, HSG C
6,054	79	50-75% Grass cover, Fair, HSG C
0	73	Woods, Fair, HSG C
18,392	92	Weighted Average
6,054		32.92% Pervious Area
12,338		67.08% Impervious Area
1,062		8.61% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.7	41	0.0730	0.25		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.60"
0.3	15	0.0200	1.00		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 3.60"
0.7	115	0.0200	2.87		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
3.7	171	Total			

Subcatchment 3S: Post-1



Summary for Subcatchment 4S: Post-Roof

[49] Hint: Tc<2dt may require smaller dt

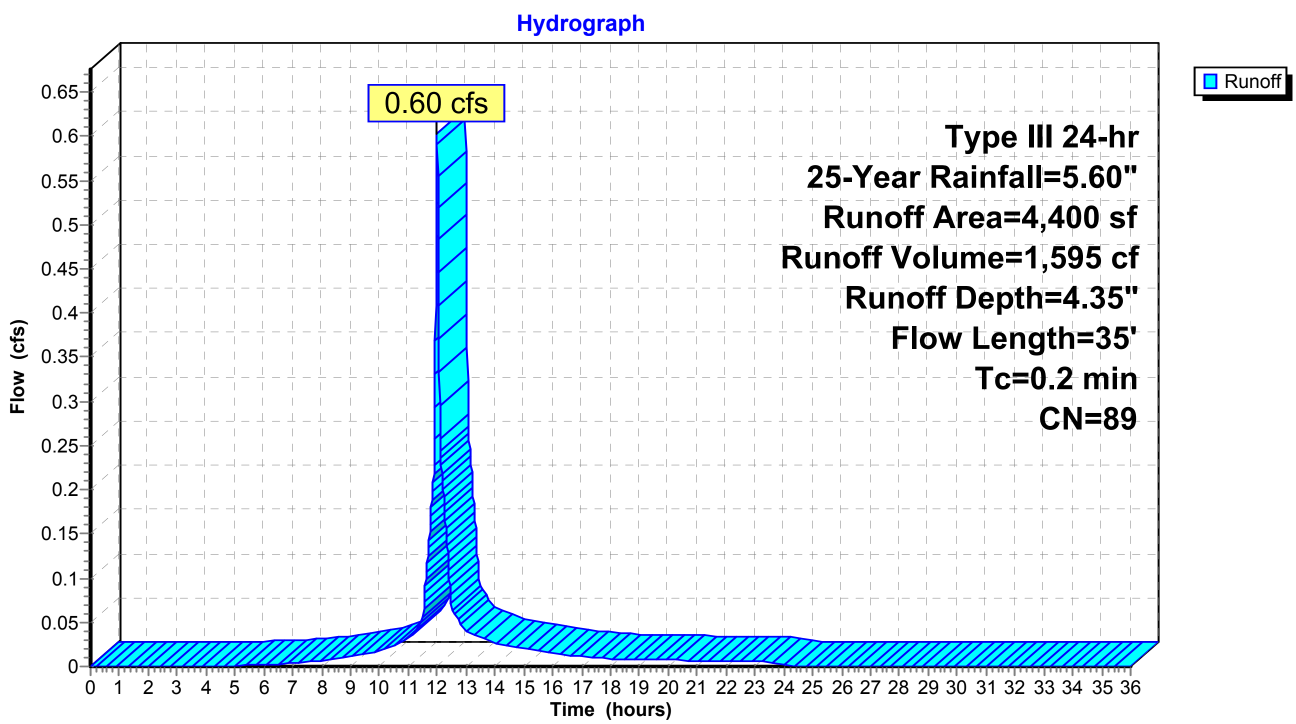
Runoff = 0.60 cfs @ 12.00 hrs, Volume= 1,595 cf, Depth= 4.35"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-Year Rainfall=5.60"

Area (sf)	CN	Description
2,400	98	Unconnected roofs, HSG C
2,000	79	50-75% Grass cover, Fair, HSG C
4,400	89	Weighted Average
2,000		45.45% Pervious Area
2,400		54.55% Impervious Area
2,400		100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.1	20	0.3000	3.12		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 3.60"
0.1	15	0.0200	2.12		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
0.2	35	Total			

Subcatchment 4S: Post-Roof



Summary for Subcatchment 5S: Post-2

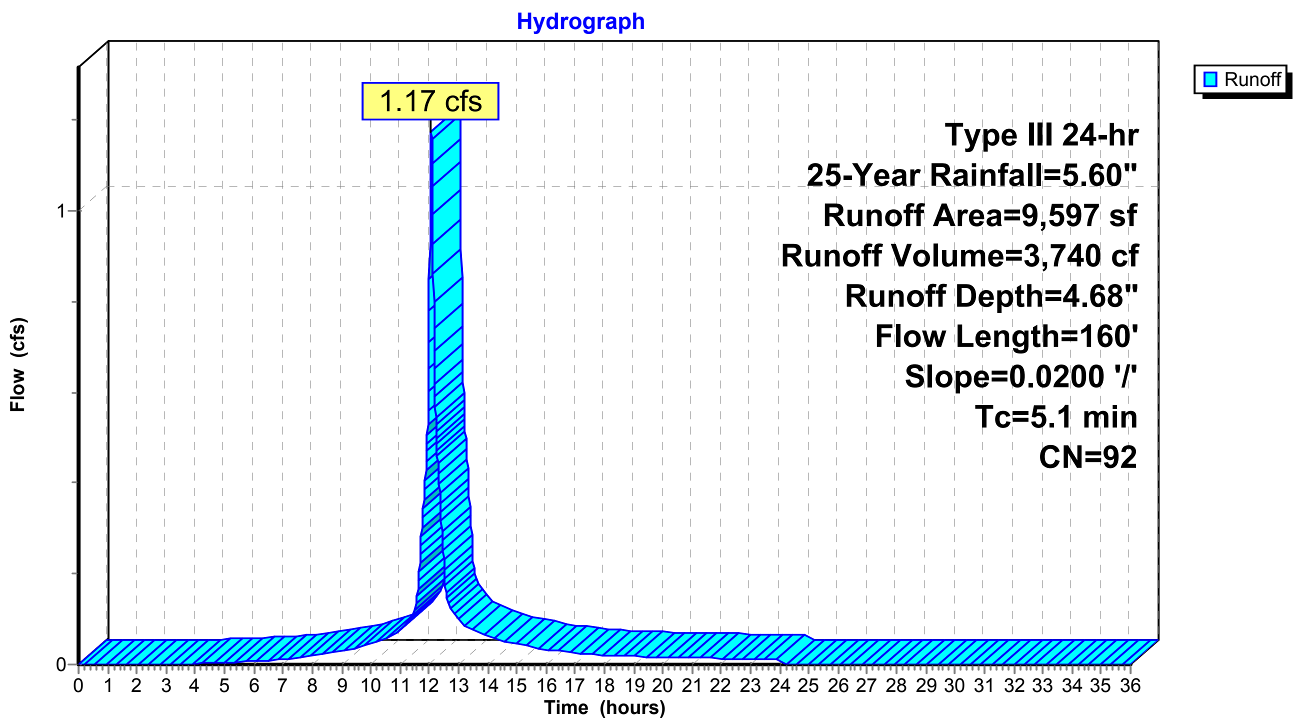
Runoff = 1.17 cfs @ 12.07 hrs, Volume= 3,740 cf, Depth= 4.68"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-Year Rainfall=5.60"

Area (sf)	CN	Description
0	98	Roofs, HSG C
5,951	98	Paved parking, HSG C
417	98	Unconnected pavement, HSG C
3,229	79	50-75% Grass cover, Fair, HSG C
0	73	Woods, Fair, HSG C
9,597	92	Weighted Average
3,229		33.65% Pervious Area
6,368		66.35% Impervious Area
417		6.55% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.4	40	0.0200	0.15		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.60"
0.7	120	0.0200	2.87		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
5.1	160	Total			

Subcatchment 5S: Post-2



Summary for Subcatchment 6S: Pre-CB1

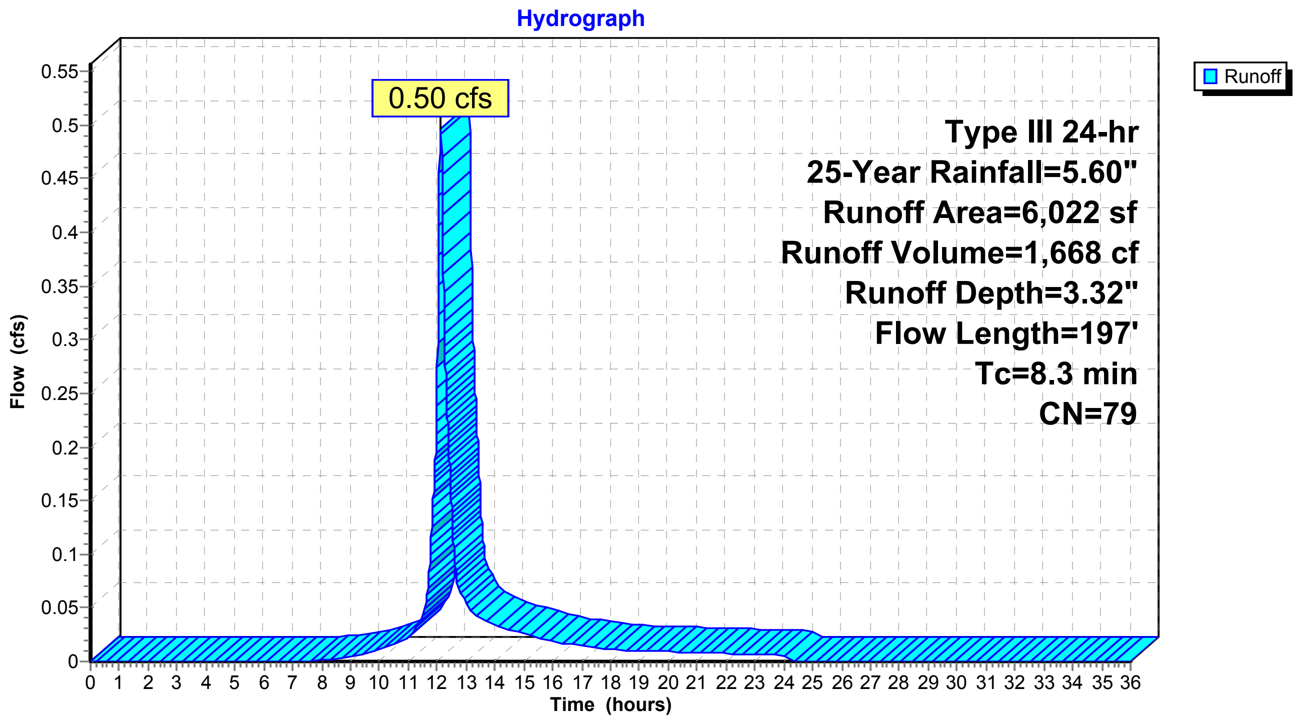
Runoff = 0.50 cfs @ 12.12 hrs, Volume= 1,668 cf, Depth= 3.32"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-Year Rainfall=5.60"

Area (sf)	CN	Description
0	98	Roofs, HSG C
0	98	Paved parking, HSG C
0	98	Unconnected pavement, HSG C
0	96	Gravel surface, HSG C
6,022	79	50-75% Grass cover, Fair, HSG C
0	73	Woods, Fair, HSG C
6,022	79	Weighted Average
6,022		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.1	50	0.1000	0.14		**Sheet Flow,** Woods: Light underbrush n= 0.400 P2= 3.60"
2.2	147	0.0500	1.12		**Shallow Concentrated Flow,** Woodland Kv= 5.0 fps
8.3	197	Total			

Subcatchment 6S: Pre-CB1



Summary for Subcatchment 7S: Pre-Street

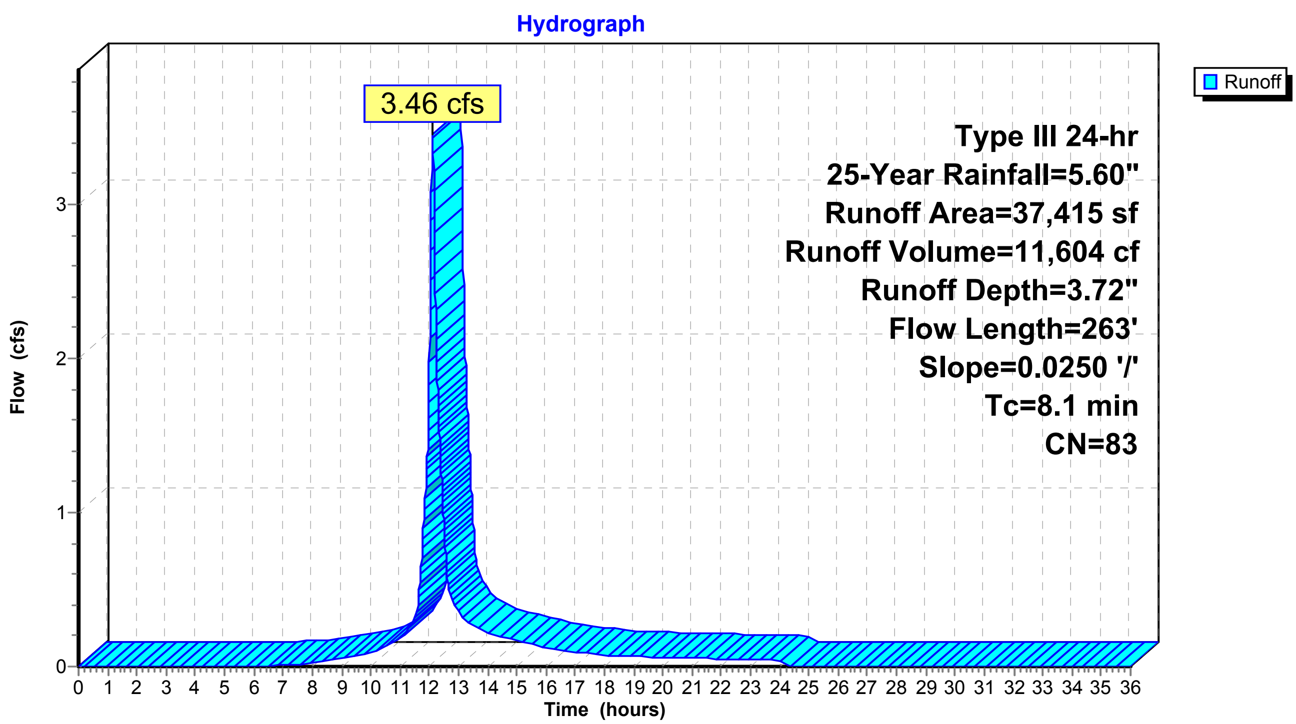
Runoff = 3.46 cfs @ 12.11 hrs, Volume= 11,604 cf, Depth= 3.72"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-Year Rainfall=5.60"

Area (sf)	CN	Description
986	98	Roofs, HSG C
7,388	98	Paved parking, HSG C
164	98	Unconnected pavement, HSG C
0	96	Gravel surface, HSG C
28,877	79	50-75% Grass cover, Fair, HSG C
0	73	Woods, Fair, HSG C
37,415	83	Weighted Average
28,877		77.18% Pervious Area
8,538		22.82% Impervious Area
164		1.92% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.9	50	0.0250	0.17		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.60"
3.2	213	0.0250	1.11		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
8.1	263	Total			

Subcatchment 7S: Pre-Street



Summary for Subcatchment 8S: Pre-CB2

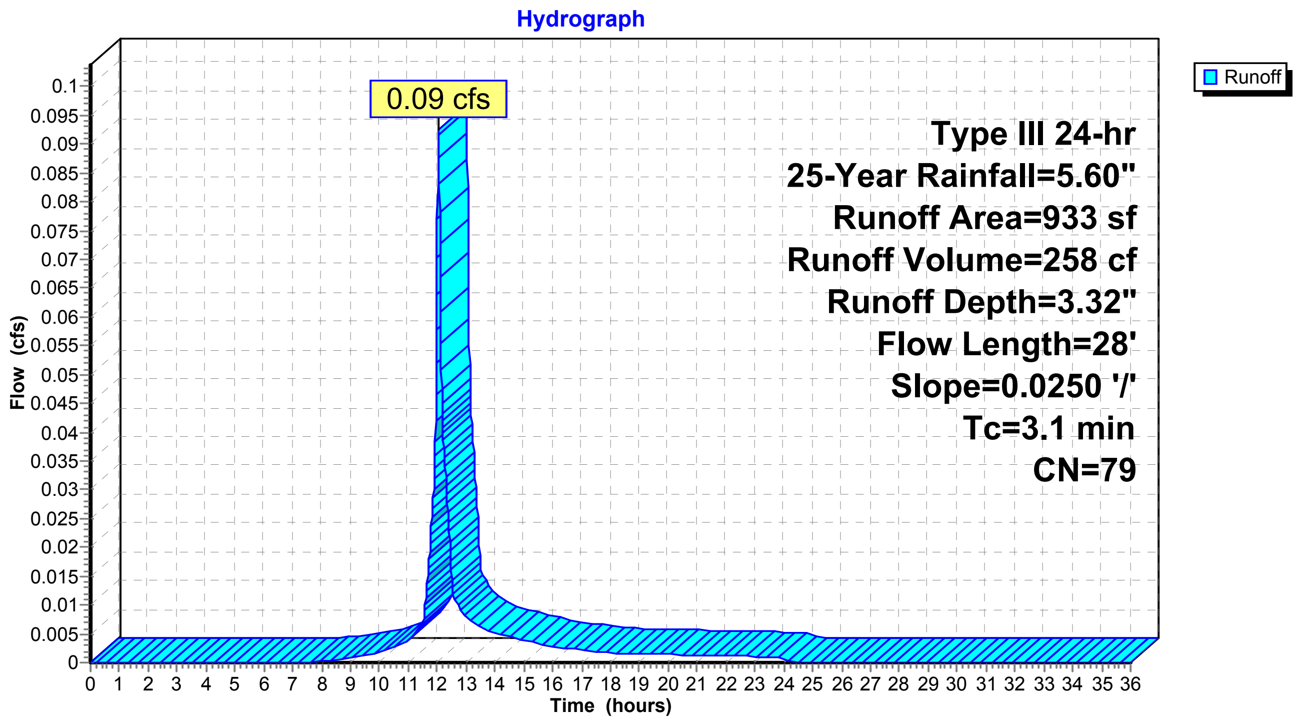
Runoff = 0.09 cfs @ 12.05 hrs, Volume= 258 cf, Depth= 3.32"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 25-Year Rainfall=5.60"

Area (sf)	CN	Description
0	98	Roofs, HSG C
0	98	Paved parking, HSG C
0	98	Unconnected pavement, HSG C
0	96	Gravel surface, HSG C
933	79	50-75% Grass cover, Fair, HSG C
0	73	Woods, Fair, HSG C
933	79	Weighted Average
933		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.1	28	0.0250	0.15		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.60"

Subcatchment 8S: Pre-CB2



Summary for Reach 8R: ADS Pipe

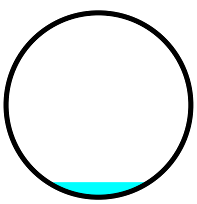
[52] Hint: Inlet/Outlet conditions not evaluated
[79] Warning: Submerged Pond 2P Primary device # 1 by 0.05'

Inflow Area = 32,389 sf, 65.16% Impervious, Inflow Depth > 1.32" for 25-Year event
Inflow = 0.04 cfs @ 21.83 hrs, Volume= 3,553 cf
Outflow = 0.04 cfs @ 21.83 hrs, Volume= 3,552 cf, Atten= 0%, Lag= 0.2 min

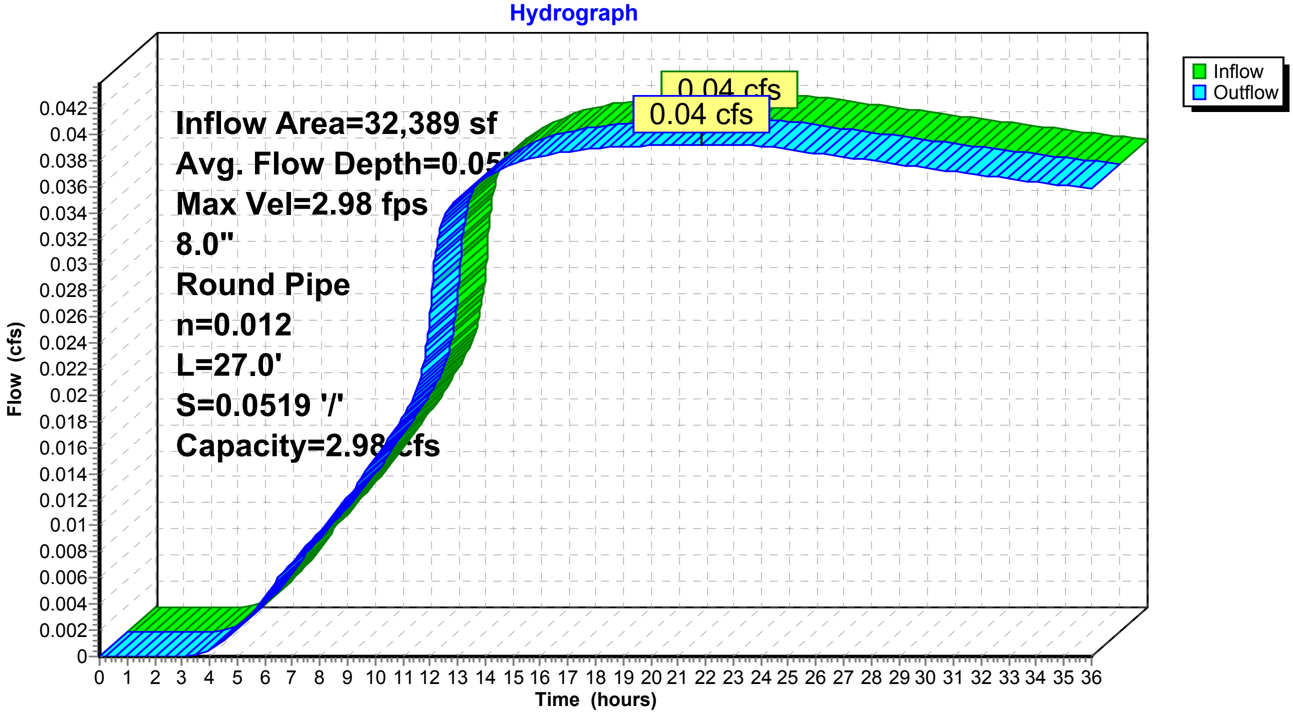
Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Max. Velocity= 2.98 fps, Min. Travel Time= 0.2 min
Avg. Velocity = 2.65 fps, Avg. Travel Time= 0.2 min

Peak Storage= 0 cf @ 21.83 hrs
Average Depth at Peak Storage= 0.05'
Bank-Full Depth= 0.67' Flow Area= 0.3 sf, Capacity= 2.98 cfs

8.0" Round Pipe
n= 0.012 Corrugated PP, smooth interior
Length= 27.0' Slope= 0.0519 '/'
Inlet Invert= 85.00', Outlet Invert= 83.60'



Reach 8R: ADS Pipe

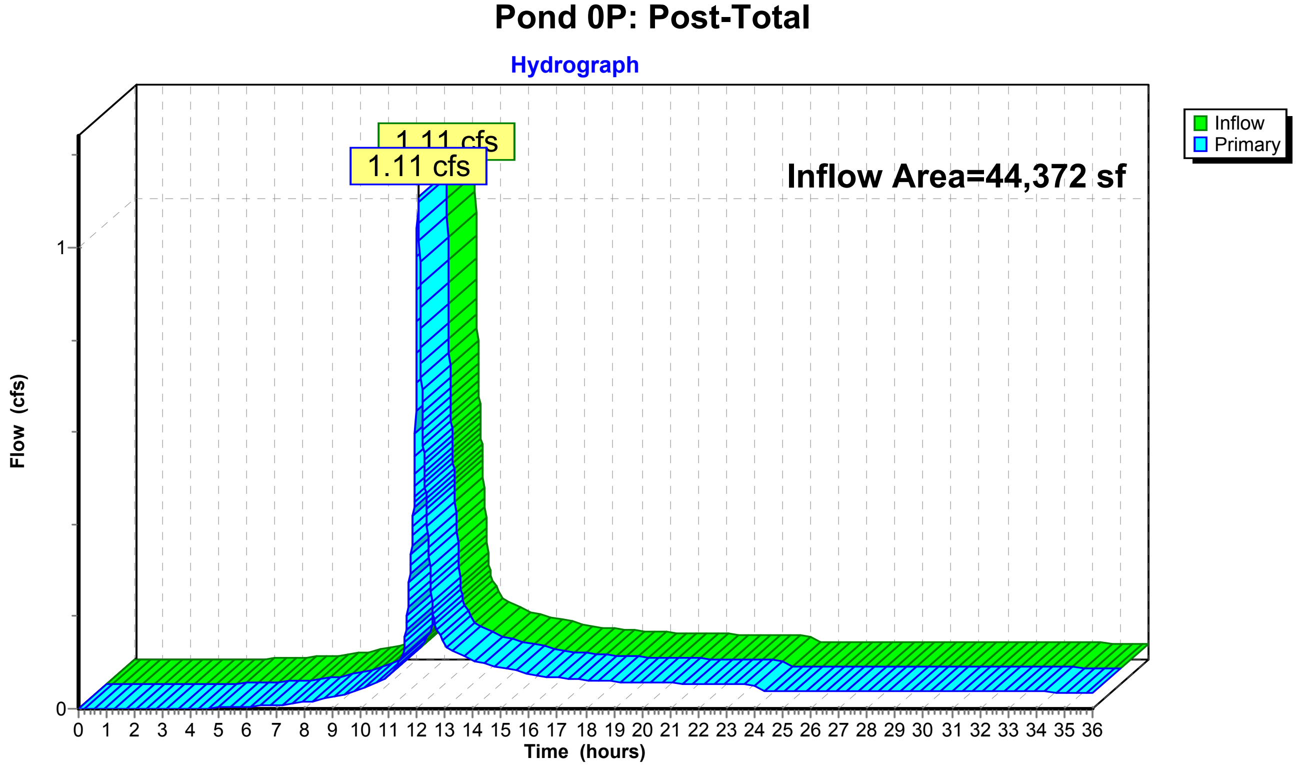


Summary for Pond 0P: Post-Total

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 44,372 sf, 49.70% Impervious, Inflow Depth > 1.90" for 25-Year event
Inflow = 1.11 cfs @ 12.06 hrs, Volume= 7,029 cf
Primary = 1.11 cfs @ 12.06 hrs, Volume= 7,029 cf, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs

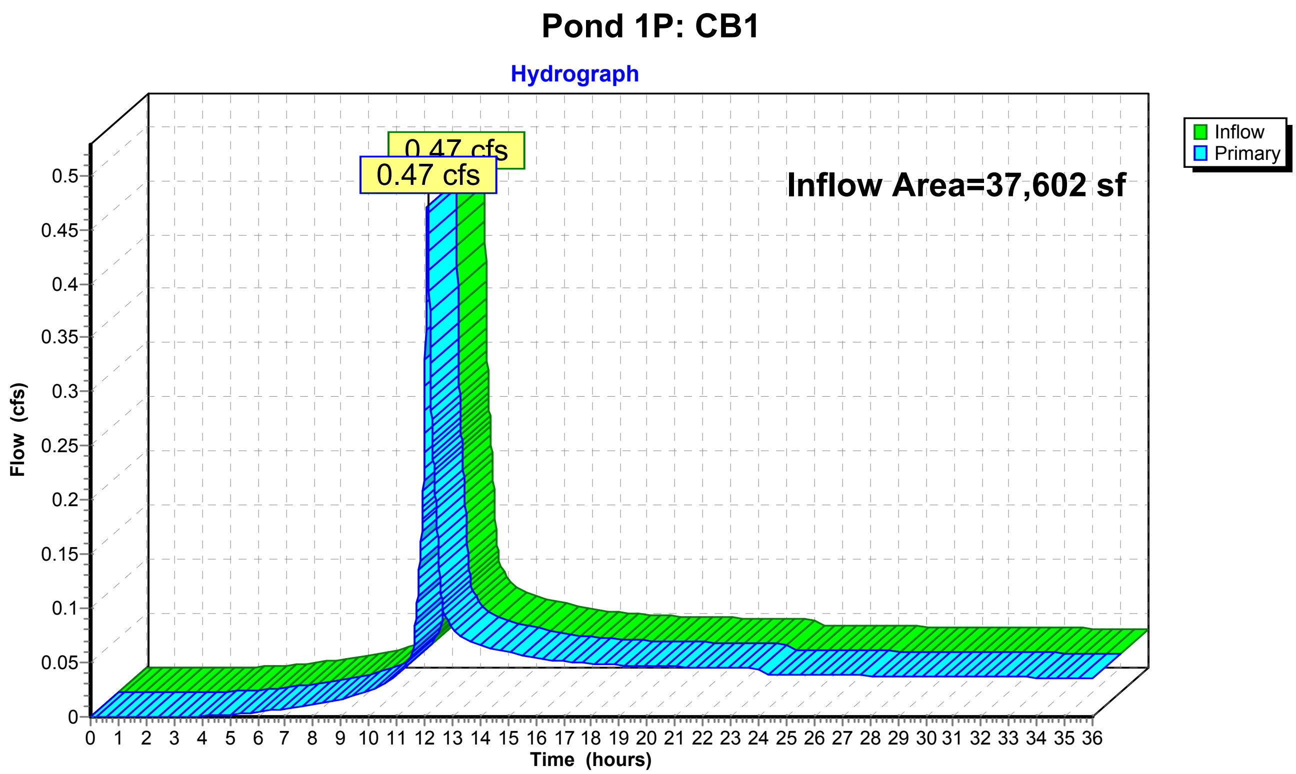


Summary for Pond 1P: CB1

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 37,602 sf, 56.13% Impervious, Inflow Depth > 1.59" for 25-Year event
Inflow = 0.47 cfs @ 12.11 hrs, Volume= 4,997 cf
Primary = 0.47 cfs @ 12.11 hrs, Volume= 4,997 cf, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs



Summary for Pond 2P: Pipe Storage

Inflow Area = 32,389 sf, 65.16% Impervious, Inflow Depth = 4.18" for 25-Year event
Inflow = 3.51 cfs @ 12.06 hrs, Volume= 11,277 cf
Outflow = 0.04 cfs @ 21.83 hrs, Volume= 3,553 cf, Atten= 99%, Lag= 586.1 min
Primary = 0.04 cfs @ 21.83 hrs, Volume= 3,553 cf

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 87.27' @ 21.83 hrs Surf.Area= 4,209 sf Storage= 9,369 cf

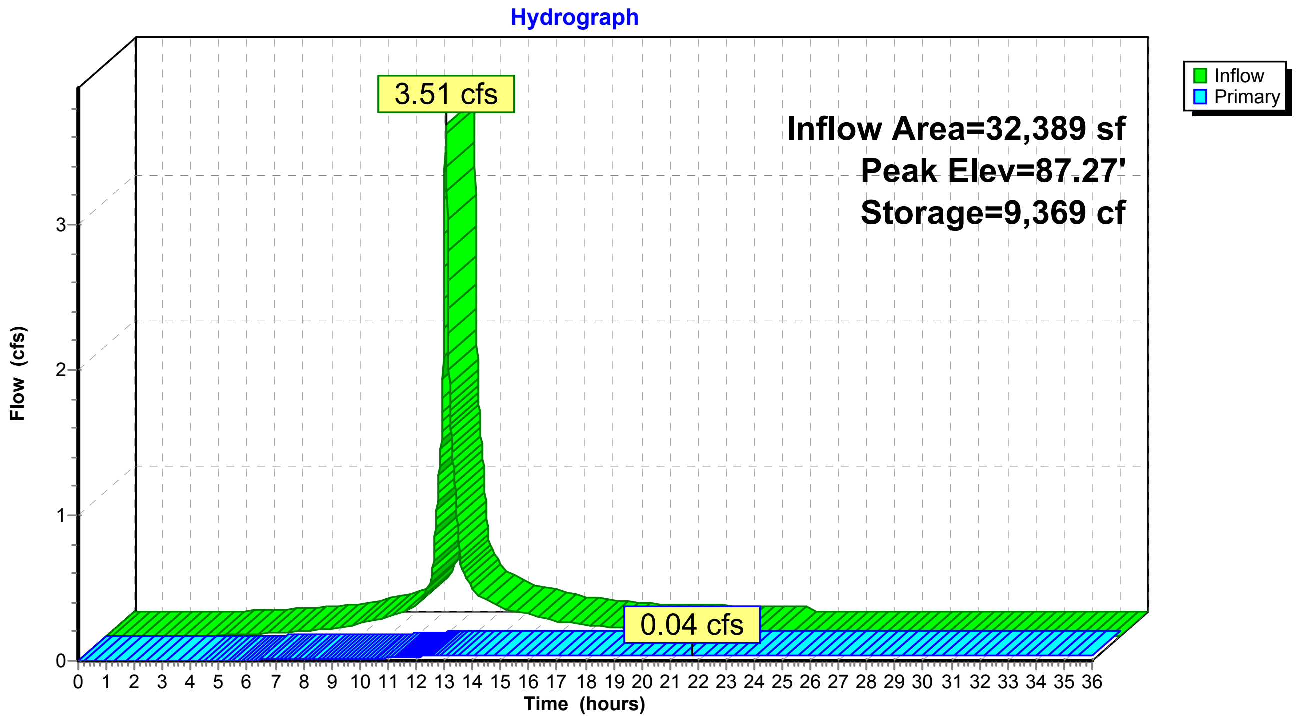
Plug-Flow detention time= 738.0 min calculated for 3,553 cf (32% of inflow)
Center-of-Mass det. time= 587.7 min (1,366.9 - 779.2)

Volume	Invert	Avail.Storage	Storage Description
#1	85.00'	11,133 cf	**36.0" Round RCP_Round 36"** x 7 L= 225.0'
#2	85.00'	250 cf	**5.00'W x 10.00'L x 5.00'H Tank Housing**
#3	85.00'	250 cf	**5.00'W x 10.00'L x 5.00'H Tank Housing**
#4	85.00'	250 cf	**5.00'W x 10.00'L x 5.00'H Tank Housing**
		11,883 cf	Total Available Storage

Device	Routing	Invert	Outlet Devices
#1	Primary	85.00'	**1.0" Vert. Orifice/Grate** C= 0.600
#2	Primary	87.50'	**6.0" Vert. Orifice/Grate** C= 0.600

Primary OutFlow Max=0.04 cfs @ 21.83 hrs HW=87.27' (Free Discharge)
↑—**1=Orifice/Grate** (Orifice Controls 0.04 cfs @ 7.18 fps)
└—**2=Orifice/Grate** (Controls 0.00 cfs)

Pond 2P: Pipe Storage

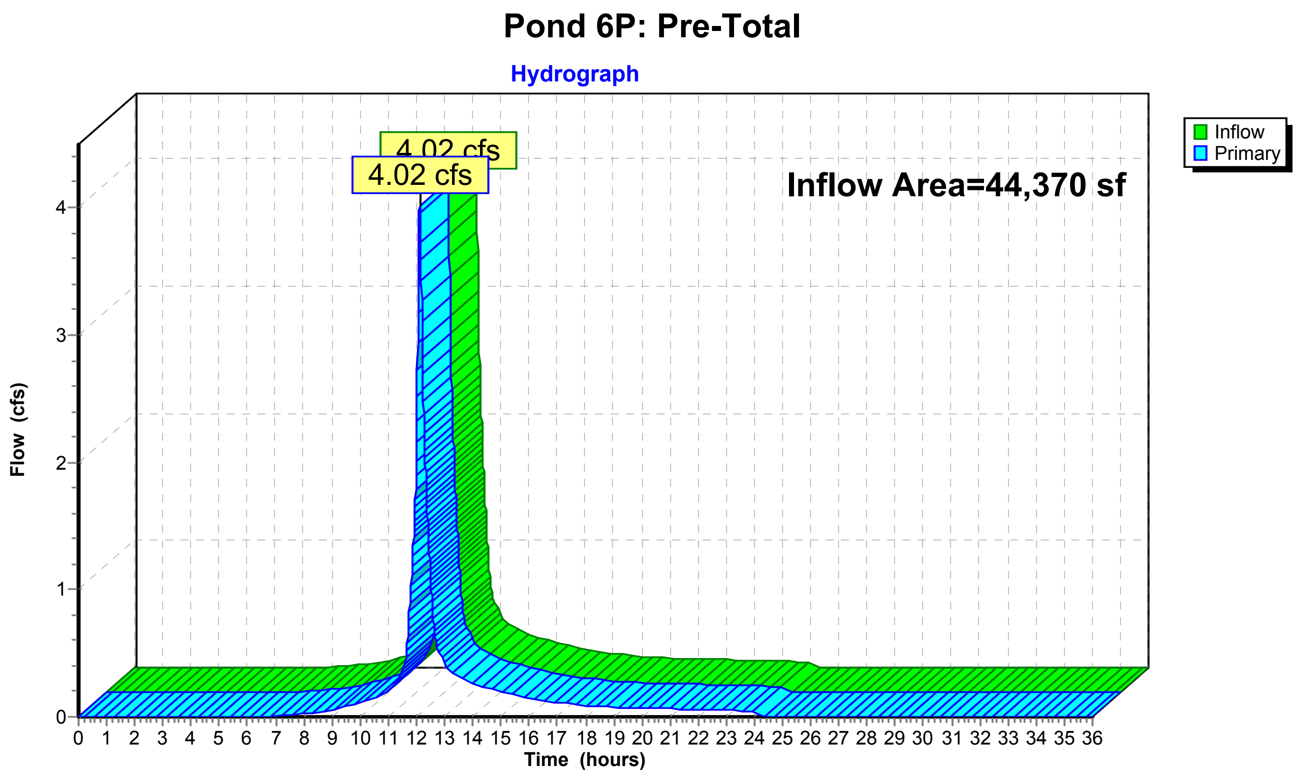


Summary for Pond 6P: Pre-Total

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 44,370 sf, 19.24% Impervious, Inflow Depth = 3.66" for 25-Year event
Inflow = 4.02 cfs @ 12.11 hrs, Volume= 13,531 cf
Primary = 4.02 cfs @ 12.11 hrs, Volume= 13,531 cf, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs



Summary for Pond 10P: Basin

Inflow Area = 4,400 sf, 54.55% Impervious, Inflow Depth = 4.35" for 25-Year event
Inflow = 0.60 cfs @ 12.00 hrs, Volume= 1,595 cf
Outflow = 0.08 cfs @ 12.48 hrs, Volume= 1,243 cf, Atten= 87%, Lag= 28.3 min
Discarded = 0.01 cfs @ 12.48 hrs, Volume= 874 cf
Primary = 0.07 cfs @ 12.48 hrs, Volume= 369 cf

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Peak Elev= 97.65' @ 12.48 hrs Surf.Area= 1,449 sf Storage= 827 cf

Plug-Flow detention time= 453.8 min calculated for 1,242 cf (78% of inflow)
Center-of-Mass det. time= 374.5 min (1,159.6 - 785.1)

Volume	Invert	Avail.Storage	Storage Description
#1	97.00'	1,373 cf	**Custom Stage Data (Prismatic)**Listed below (Recalc)

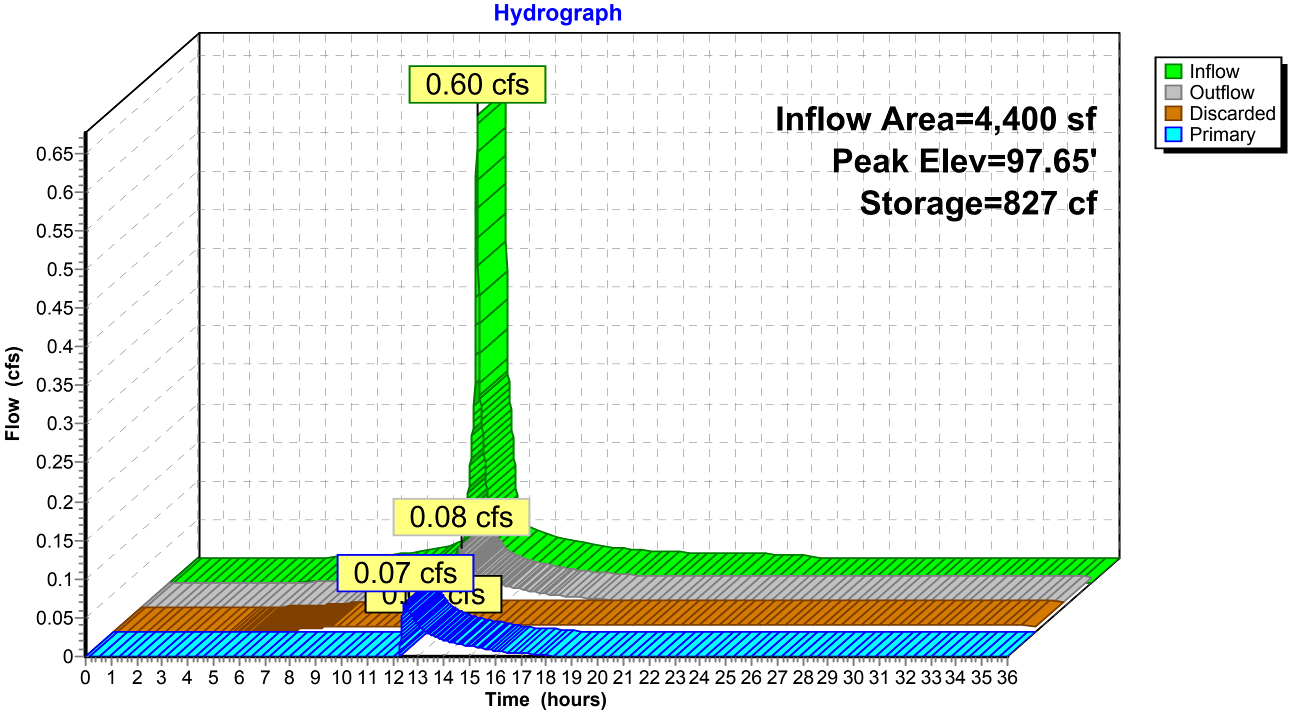
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
97.00	1,111	0	0
98.00	1,635	1,373	1,373

Device	Routing	Invert	Outlet Devices
#1	Discarded	97.00'	**0.270 in/hr Exfiltration over Surface area**
#2	Primary	97.60'	**8.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Discarded OutFlow Max=0.01 cfs @ 12.48 hrs HW=97.65' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.01 cfs)

Primary OutFlow Max=0.07 cfs @ 12.48 hrs HW=97.65' (Free Discharge)
└─**2=Orifice/Grate** (Weir Controls 0.07 cfs @ 0.70 fps)

Pond 10P: Basin



Time span=0.00-36.00 hrs, dt=0.01 hrs, 3601 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 0S: Post-Street Runoff Area=6,350 sf 14.90% Impervious Runoff Depth=4.92"
Flow Length=64' Slope=0.1000 '/' Tc=2.9 min CN=82 Runoff=0.93 cfs 2,601 cf

Subcatchment 1S: Post-CB1 Runoff Area=5,213 sf 0.00% Impervious Runoff Depth=4.58"
Flow Length=165' Tc=7.5 min CN=79 Runoff=0.61 cfs 1,992 cf

Subcatchment 2S: Post-CB2 Runoff Area=420 sf 0.00% Impervious Runoff Depth=4.58"
Flow Length=20' Slope=0.1000 '/' Tc=1.3 min CN=79 Runoff=0.06 cfs 160 cf

Subcatchment 3S: Post-1 Runoff Area=18,392 sf 67.08% Impervious Runoff Depth=6.05"
Flow Length=171' Tc=3.7 min CN=92 Runoff=3.02 cfs 9,280 cf

Subcatchment 4S: Post-Roof Runoff Area=4,400 sf 54.55% Impervious Runoff Depth=5.71"
Flow Length=35' Tc=0.2 min CN=89 Runoff=0.78 cfs 2,093 cf

Subcatchment 5S: Post-2 Runoff Area=9,597 sf 66.35% Impervious Runoff Depth=6.05"
Flow Length=160' Slope=0.0200 '/' Tc=5.1 min CN=92 Runoff=1.50 cfs 4,842 cf

Subcatchment 6S: Pre-CB1 Runoff Area=6,022 sf 0.00% Impervious Runoff Depth=4.58"
Flow Length=197' Tc=8.3 min CN=79 Runoff=0.68 cfs 2,301 cf

Subcatchment 7S: Pre-Street Runoff Area=37,415 sf 22.82% Impervious Runoff Depth=5.03"
Flow Length=263' Slope=0.0250 '/' Tc=8.1 min CN=83 Runoff=4.62 cfs 15,676 cf

Subcatchment 8S: Pre-CB2 Runoff Area=933 sf 0.00% Impervious Runoff Depth=4.58"
Flow Length=28' Slope=0.0250 '/' Tc=3.1 min CN=79 Runoff=0.13 cfs 356 cf

Reach 8R: ADS Pipe Avg. Flow Depth=0.11' Max Vel=4.79 fps Inflow=0.19 cfs 6,187 cf
8.0" Round Pipe n=0.012 L=27.0' S=0.0519 '/' Capacity=2.98 cfs Outflow=0.19 cfs 6,186 cf

Pond 0P: Post-Total Inflow=1.50 cfs 10,939 cf
Primary=1.50 cfs 10,939 cf

Pond 1P: CB1 Inflow=0.64 cfs 8,178 cf
Primary=0.64 cfs 8,178 cf

Pond 2P: Pipe Storage Peak Elev=87.73' Storage=11,054 cf Inflow=4.57 cfs 14,934 cf
Outflow=0.19 cfs 6,187 cf

Pond 6P: Pre-Total Inflow=5.39 cfs 18,333 cf
Primary=5.39 cfs 18,333 cf

Pond 10P: Basin Peak Elev=97.70' Storage=911 cf Inflow=0.78 cfs 2,093 cf
Discarded=0.01 cfs 904 cf Primary=0.23 cfs 812 cf Outflow=0.24 cfs 1,716 cf

Total Runoff Area = 88,742 sf Runoff Volume = 39,302 cf Average Runoff Depth = 5.31"
65.53% Pervious = 58,152 sf 34.47% Impervious = 30,590 sf

Summary for Subcatchment 0S: Post-Street

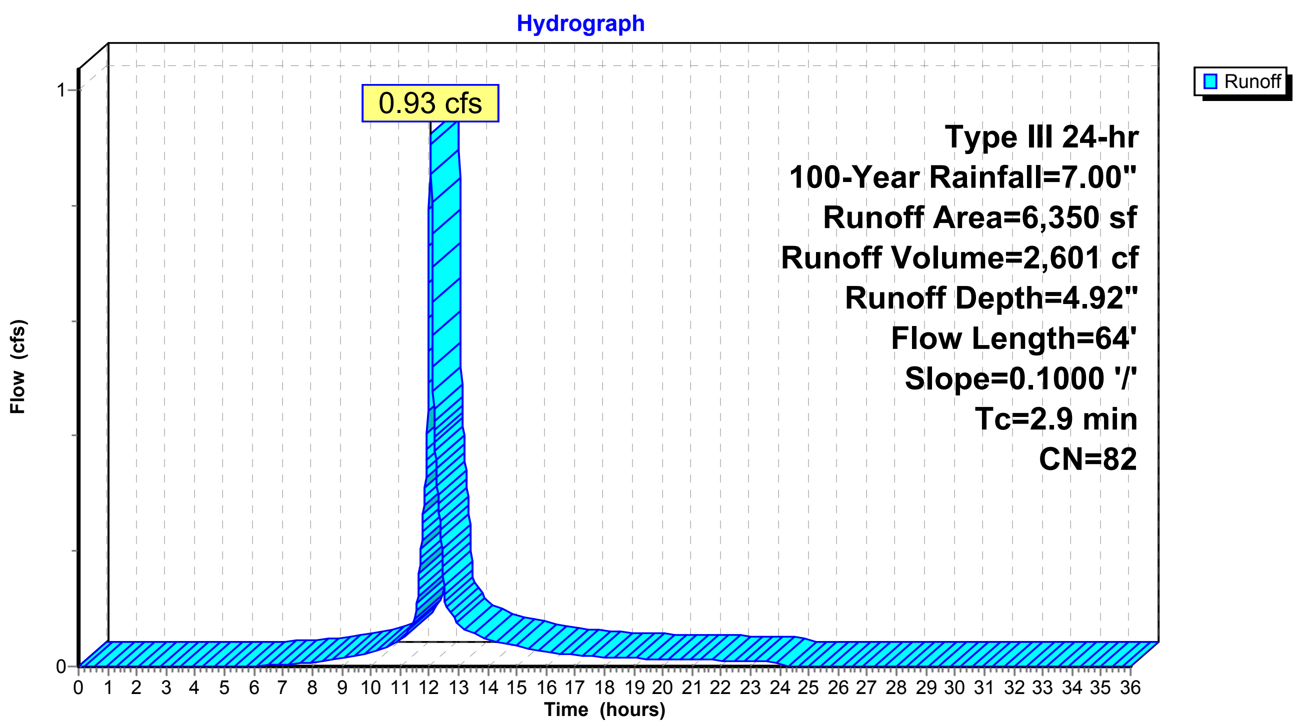
Runoff = 0.93 cfs @ 12.04 hrs, Volume= 2,601 cf, Depth= 4.92"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-Year Rainfall=7.00"

Area (sf)	CN	Description
0	98	Roofs, HSG C
946	98	Paved parking, HSG C
0	98	Unconnected pavement, HSG C
5,404	79	50-75% Grass cover, Fair, HSG C
0	73	Woods, Fair, HSG C
6,350	82	Weighted Average
5,404		85.10% Pervious Area
946		14.90% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.8	50	0.1000	0.30		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.60"
0.1	14	0.1000	2.21		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
2.9	64	Total			

Subcatchment 0S: Post-Street



Summary for Subcatchment 1S: Post-CB1

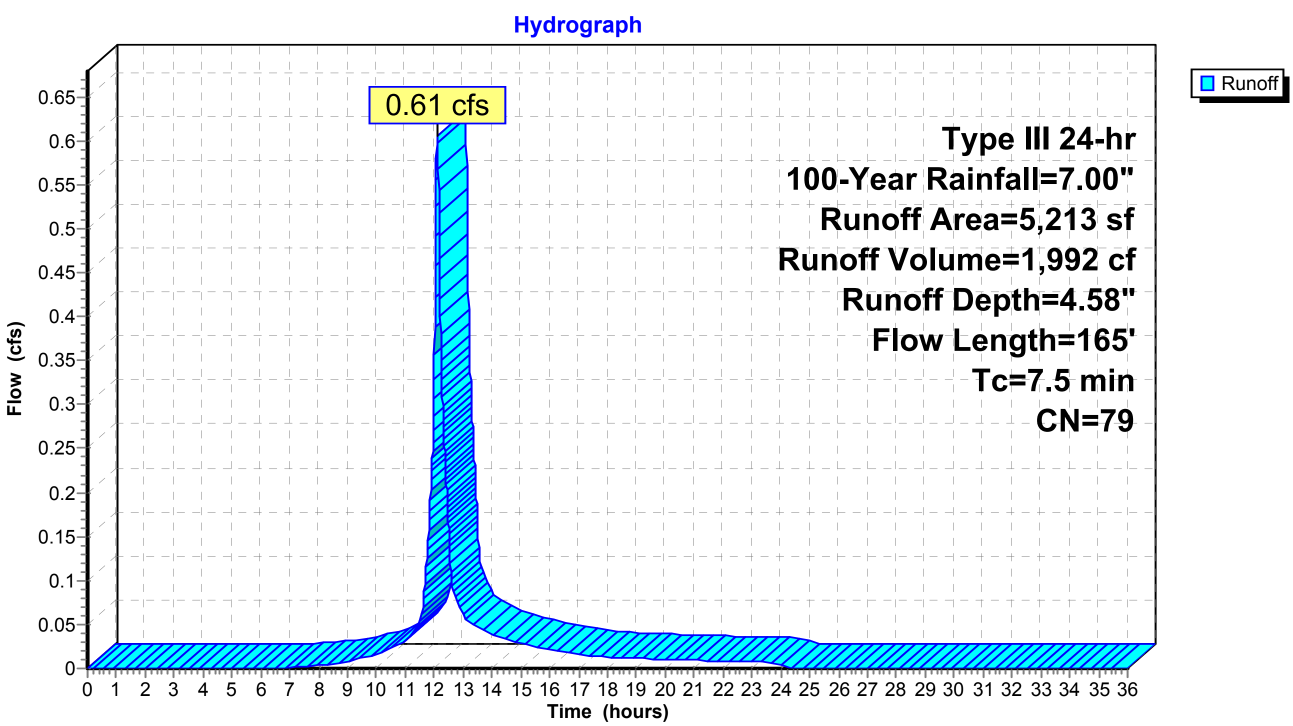
Runoff = 0.61 cfs @ 12.11 hrs, Volume= 1,992 cf, Depth= 4.58"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-Year Rainfall=7.00"

Area (sf)	CN	Description
0	98	Roofs, HSG C
0	98	Paved parking, HSG C
0	98	Unconnected pavement, HSG C
5,213	79	50-75% Grass cover, Fair, HSG C
0	73	Woods, Fair, HSG C
5,213	79	Weighted Average
5,213		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.5	50	0.0120	0.13		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.60"
1.0	115	0.0750	1.92		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
7.5	165	Total			

Subcatchment 1S: Post-CB1



Summary for Subcatchment 2S: Post-CB2

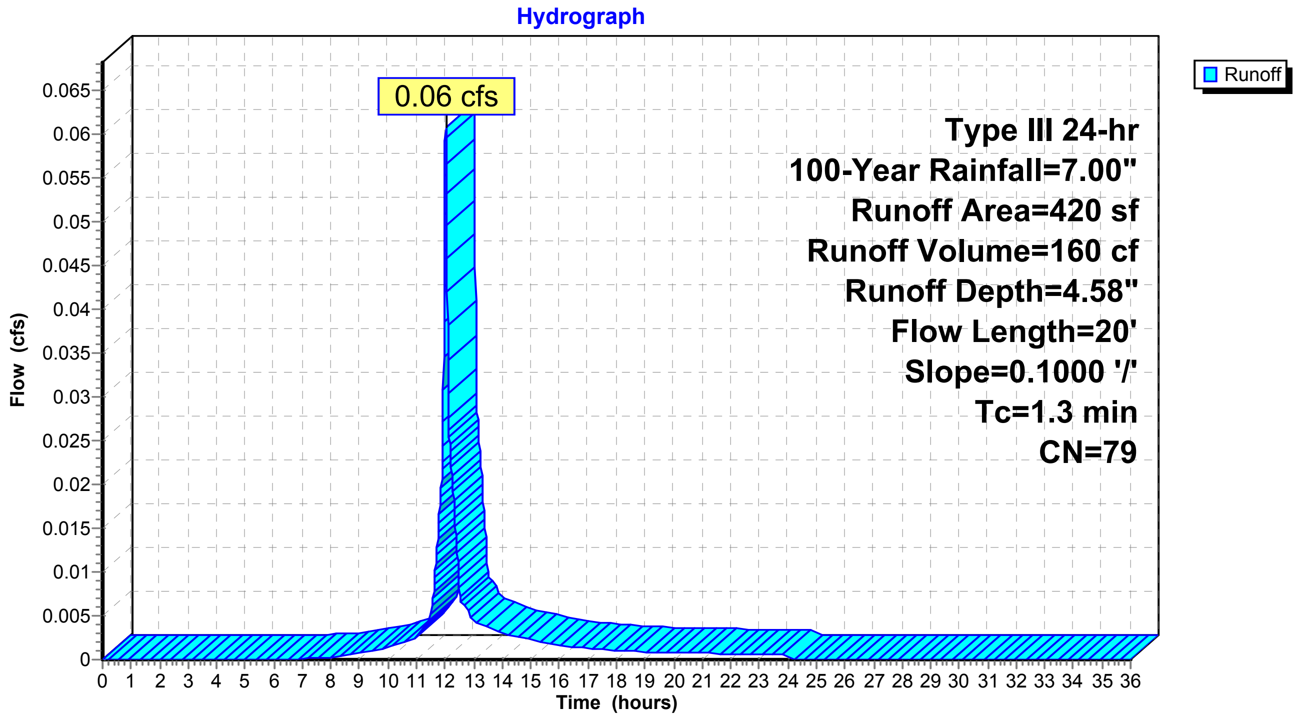
Runoff = 0.06 cfs @ 12.02 hrs, Volume= 160 cf, Depth= 4.58"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-Year Rainfall=7.00"

Area (sf)	CN	Description
0	98	Roofs, HSG C
0	98	Paved parking, HSG C
0	98	Unconnected pavement, HSG C
420	79	50-75% Grass cover, Fair, HSG C
0	73	Woods, Fair, HSG C
420	79	Weighted Average
420		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
1.3	20	0.1000	0.25		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.60"

Subcatchment 2S: Post-CB2



Summary for Subcatchment 3S: Post-1

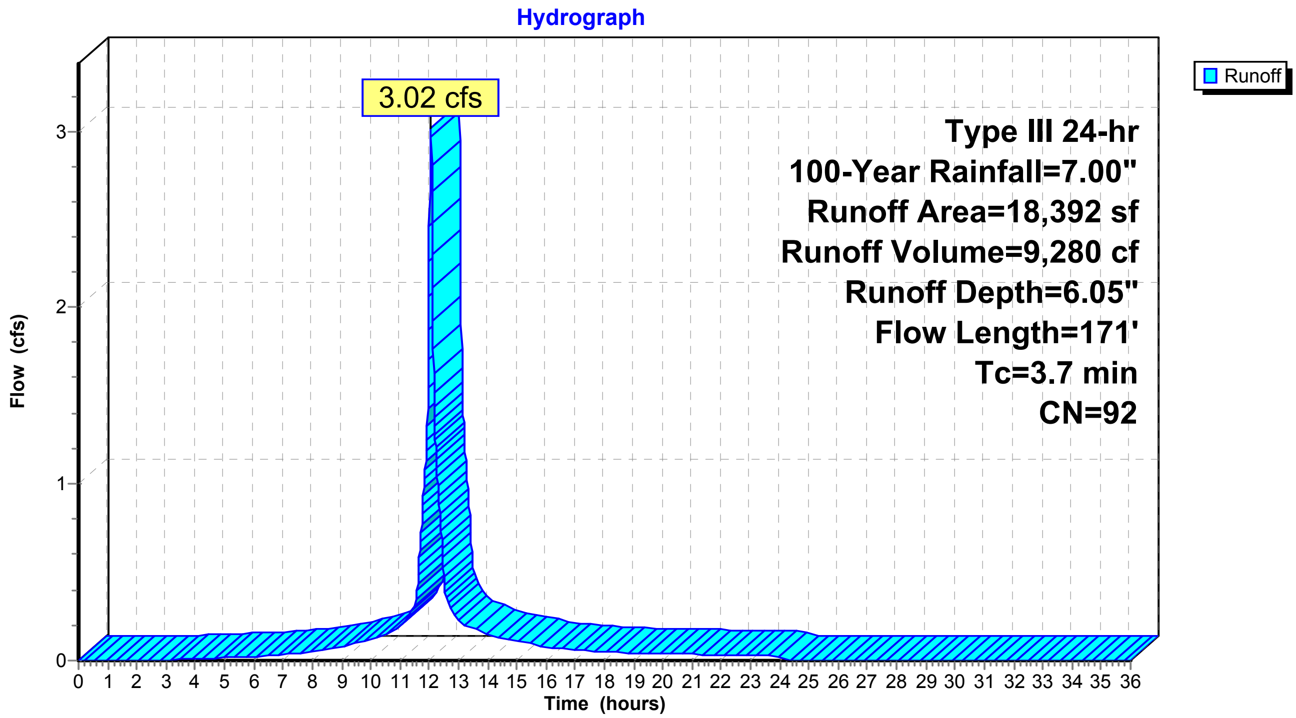
Runoff = 3.02 cfs @ 12.05 hrs, Volume= 9,280 cf, Depth= 6.05"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-Year Rainfall=7.00"

Area (sf)	CN	Description
1,560	98	Roofs, HSG C
9,716	98	Paved parking, HSG C
1,062	98	Unconnected pavement, HSG C
6,054	79	50-75% Grass cover, Fair, HSG C
0	73	Woods, Fair, HSG C
18,392	92	Weighted Average
6,054		32.92% Pervious Area
12,338		67.08% Impervious Area
1,062		8.61% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.7	41	0.0730	0.25		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.60"
0.3	15	0.0200	1.00		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 3.60"
0.7	115	0.0200	2.87		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
3.7	171	Total			

Subcatchment 3S: Post-1



Summary for Subcatchment 4S: Post-Roof

[49] Hint: Tc<2dt may require smaller dt

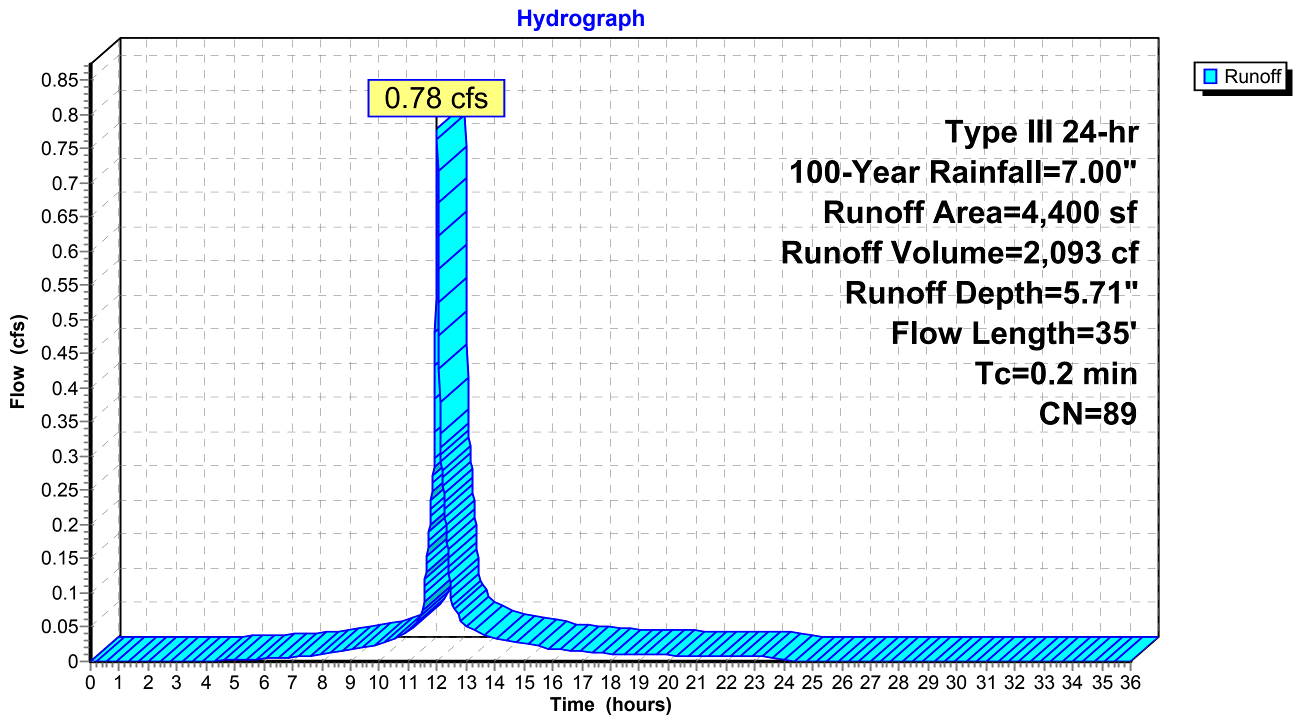
Runoff = 0.78 cfs @ 12.00 hrs, Volume= 2,093 cf, Depth= 5.71"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-Year Rainfall=7.00"

Area (sf)	CN	Description
2,400	98	Unconnected roofs, HSG C
2,000	79	50-75% Grass cover, Fair, HSG C
4,400	89	Weighted Average
2,000		45.45% Pervious Area
2,400		54.55% Impervious Area
2,400		100.00% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.1	20	0.3000	3.12		**Sheet Flow,** Smooth surfaces n= 0.011 P2= 3.60"
0.1	15	0.0200	2.12		**Shallow Concentrated Flow,** Grassed Waterway Kv= 15.0 fps
0.2	35	Total			

Subcatchment 4S: Post-Roof



Summary for Subcatchment 5S: Post-2

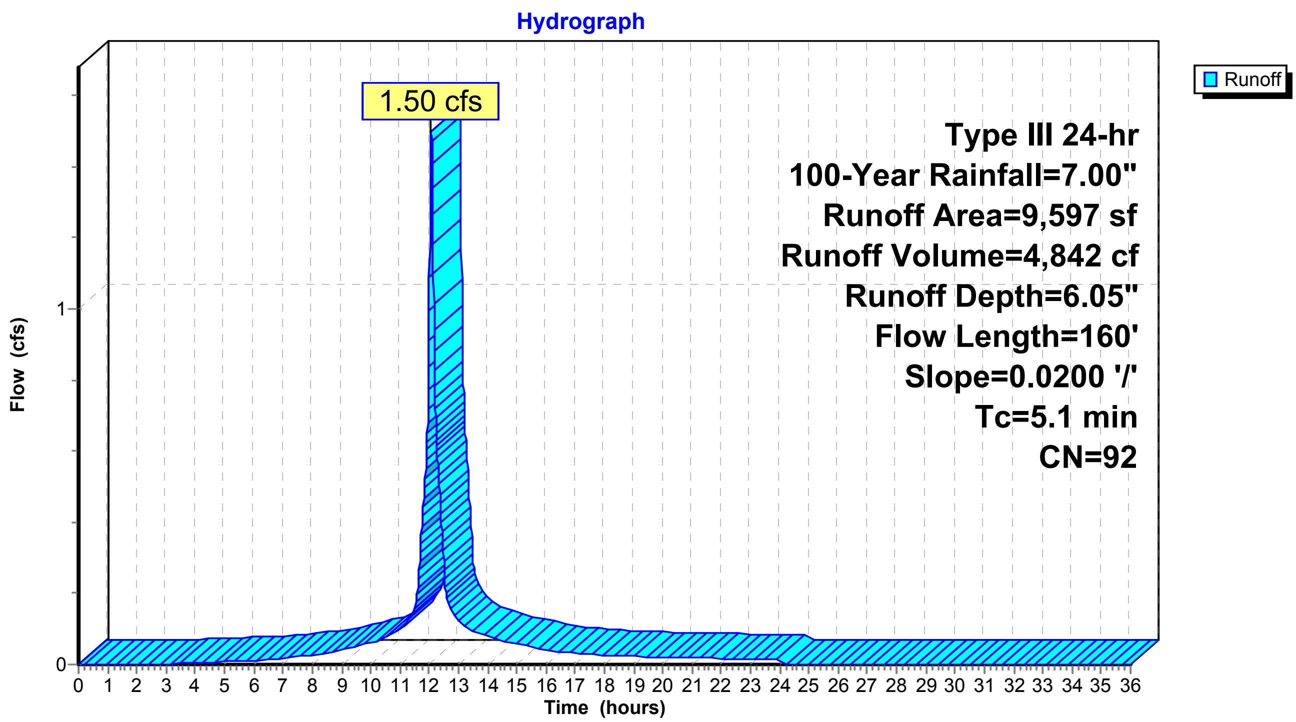
Runoff = 1.50 cfs @ 12.07 hrs, Volume= 4,842 cf, Depth= 6.05"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-Year Rainfall=7.00"

Area (sf)	CN	Description
0	98	Roofs, HSG C
5,951	98	Paved parking, HSG C
417	98	Unconnected pavement, HSG C
3,229	79	50-75% Grass cover, Fair, HSG C
0	73	Woods, Fair, HSG C
9,597	92	Weighted Average
3,229		33.65% Pervious Area
6,368		66.35% Impervious Area
417		6.55% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.4	40	0.0200	0.15		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.60"
0.7	120	0.0200	2.87		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
5.1	160	Total			

Subcatchment 5S: Post-2



Summary for Subcatchment 6S: Pre-CB1

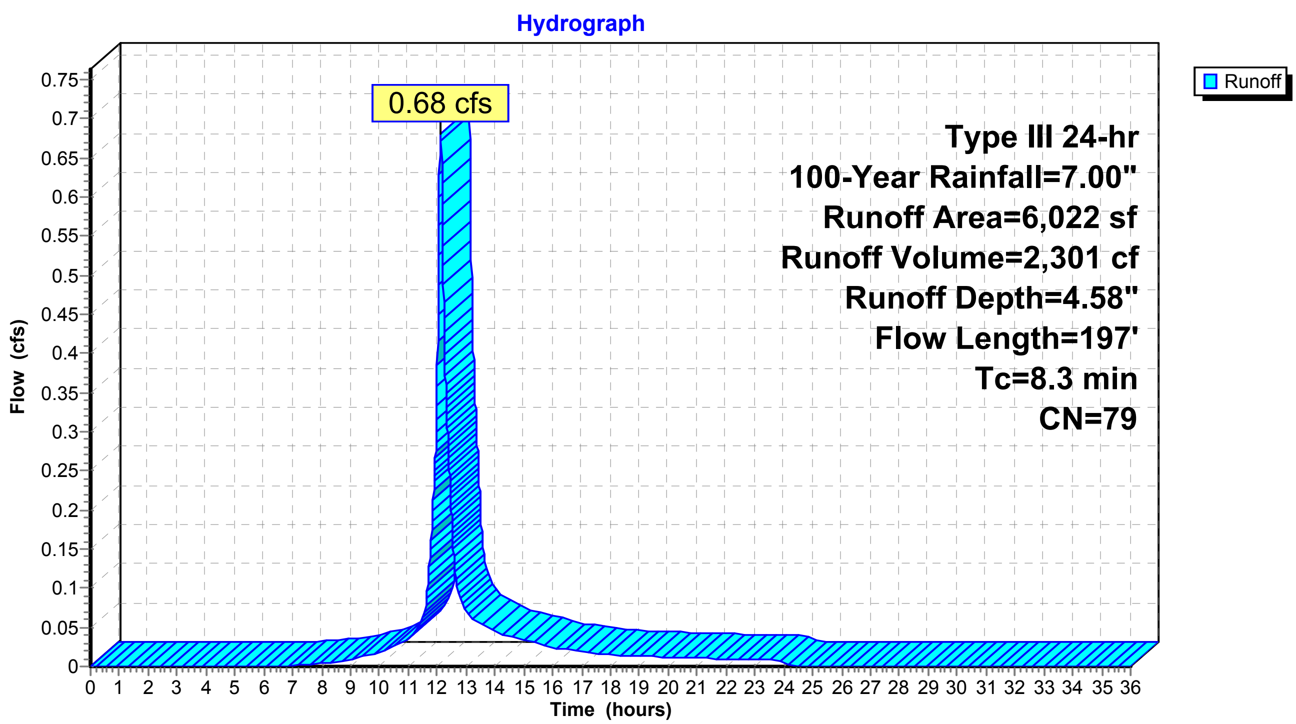
Runoff = 0.68 cfs @ 12.12 hrs, Volume= 2,301 cf, Depth= 4.58"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-Year Rainfall=7.00"

Area (sf)	CN	Description
0	98	Roofs, HSG C
0	98	Paved parking, HSG C
0	98	Unconnected pavement, HSG C
0	96	Gravel surface, HSG C
6,022	79	50-75% Grass cover, Fair, HSG C
0	73	Woods, Fair, HSG C
6,022	79	Weighted Average
6,022		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.1	50	0.1000	0.14		**Sheet Flow,** Woods: Light underbrush n= 0.400 P2= 3.60"
2.2	147	0.0500	1.12		**Shallow Concentrated Flow,** Woodland Kv= 5.0 fps
8.3	197	Total			

Subcatchment 6S: Pre-CB1



Summary for Subcatchment 7S: Pre-Street

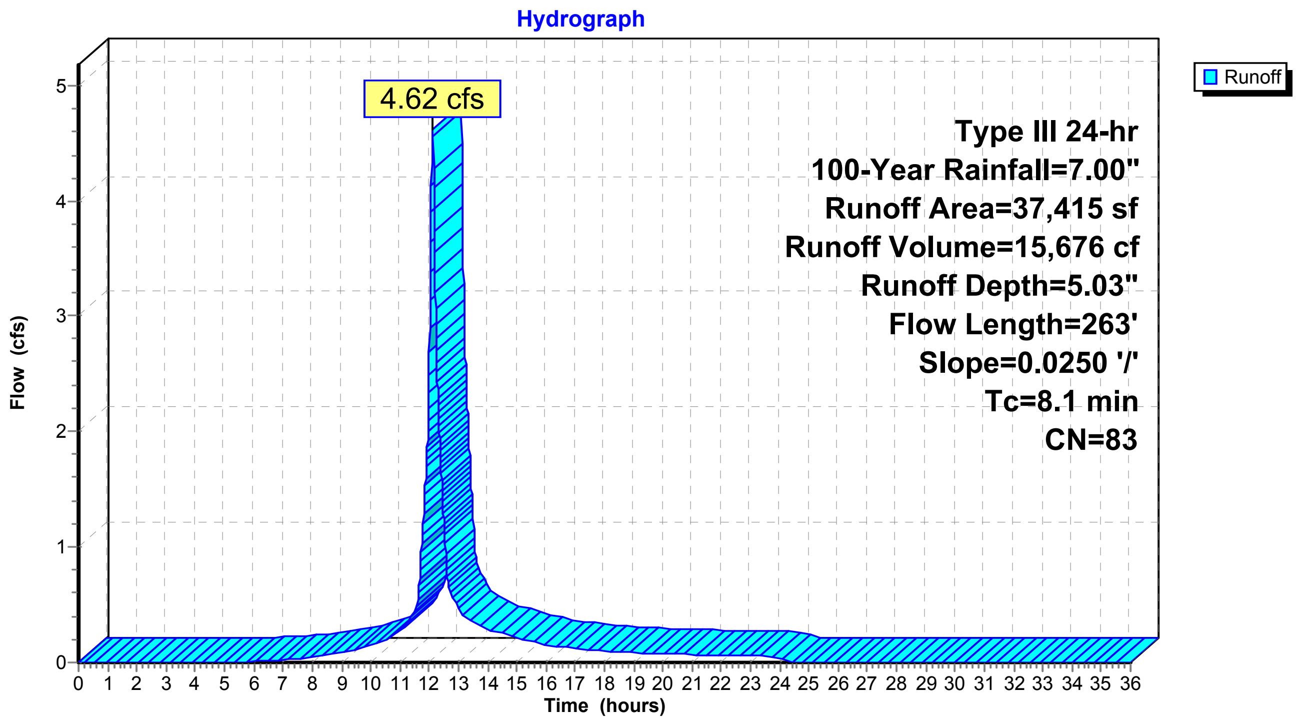
Runoff = 4.62 cfs @ 12.11 hrs, Volume= 15,676 cf, Depth= 5.03"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-Year Rainfall=7.00"

Area (sf)	CN	Description
986	98	Roofs, HSG C
7,388	98	Paved parking, HSG C
164	98	Unconnected pavement, HSG C
0	96	Gravel surface, HSG C
28,877	79	50-75% Grass cover, Fair, HSG C
0	73	Woods, Fair, HSG C
37,415	83	Weighted Average
28,877		77.18% Pervious Area
8,538		22.82% Impervious Area
164		1.92% Unconnected

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.9	50	0.0250	0.17		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.60"
3.2	213	0.0250	1.11		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
8.1	263	Total			

Subcatchment 7S: Pre-Street



Summary for Subcatchment 8S: Pre-CB2

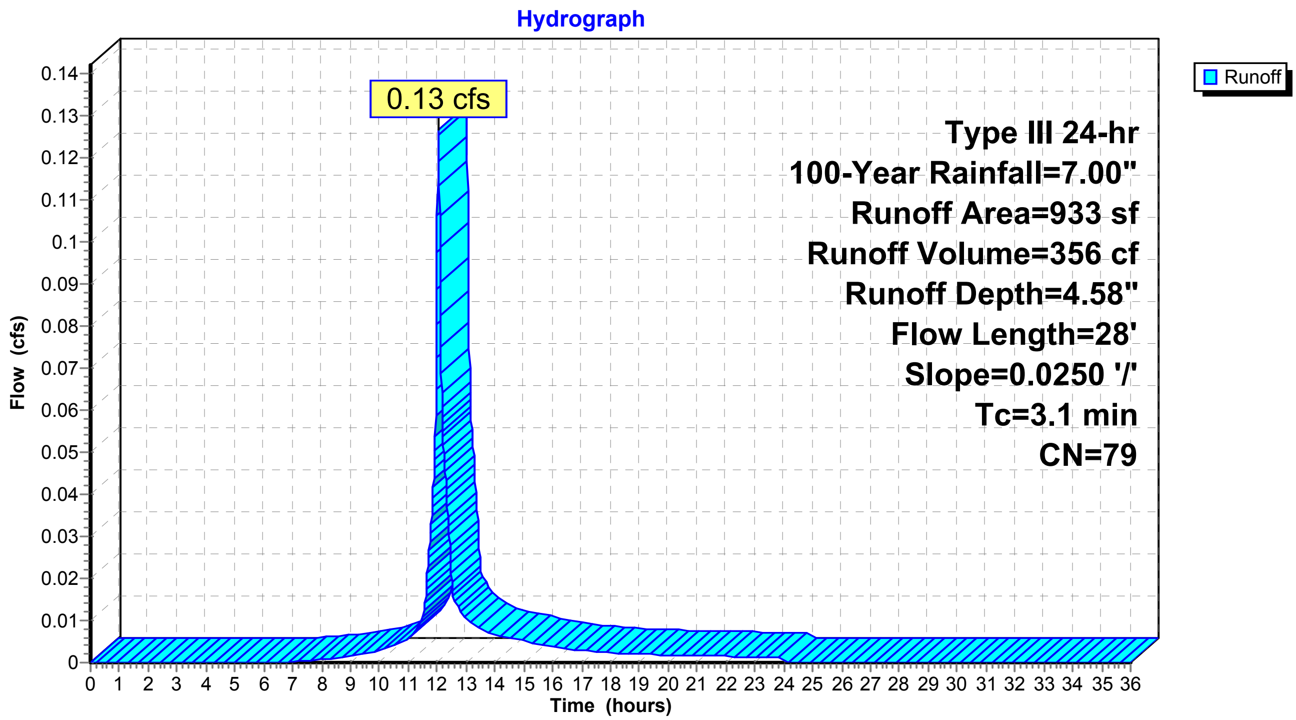
Runoff = 0.13 cfs @ 12.05 hrs, Volume= 356 cf, Depth= 4.58"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Type III 24-hr 100-Year Rainfall=7.00"

Area (sf)	CN	Description
0	98	Roofs, HSG C
0	98	Paved parking, HSG C
0	98	Unconnected pavement, HSG C
0	96	Gravel surface, HSG C
933	79	50-75% Grass cover, Fair, HSG C
0	73	Woods, Fair, HSG C
933	79	Weighted Average
933		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.1	28	0.0250	0.15		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.60"

Subcatchment 8S: Pre-CB2



Summary for Reach 8R: ADS Pipe

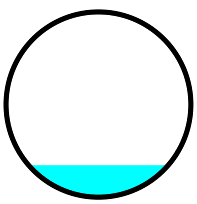
[52] Hint: Inlet/Outlet conditions not evaluated
[79] Warning: Submerged Pond 2P Primary device # 1 by 0.11'

Inflow Area = 32,389 sf, 65.16% Impervious, Inflow Depth > 2.29" for 100-Year event
Inflow = 0.19 cfs @ 14.97 hrs, Volume= 6,187 cf
Outflow = 0.19 cfs @ 14.98 hrs, Volume= 6,186 cf, Atten= 0%, Lag= 0.2 min

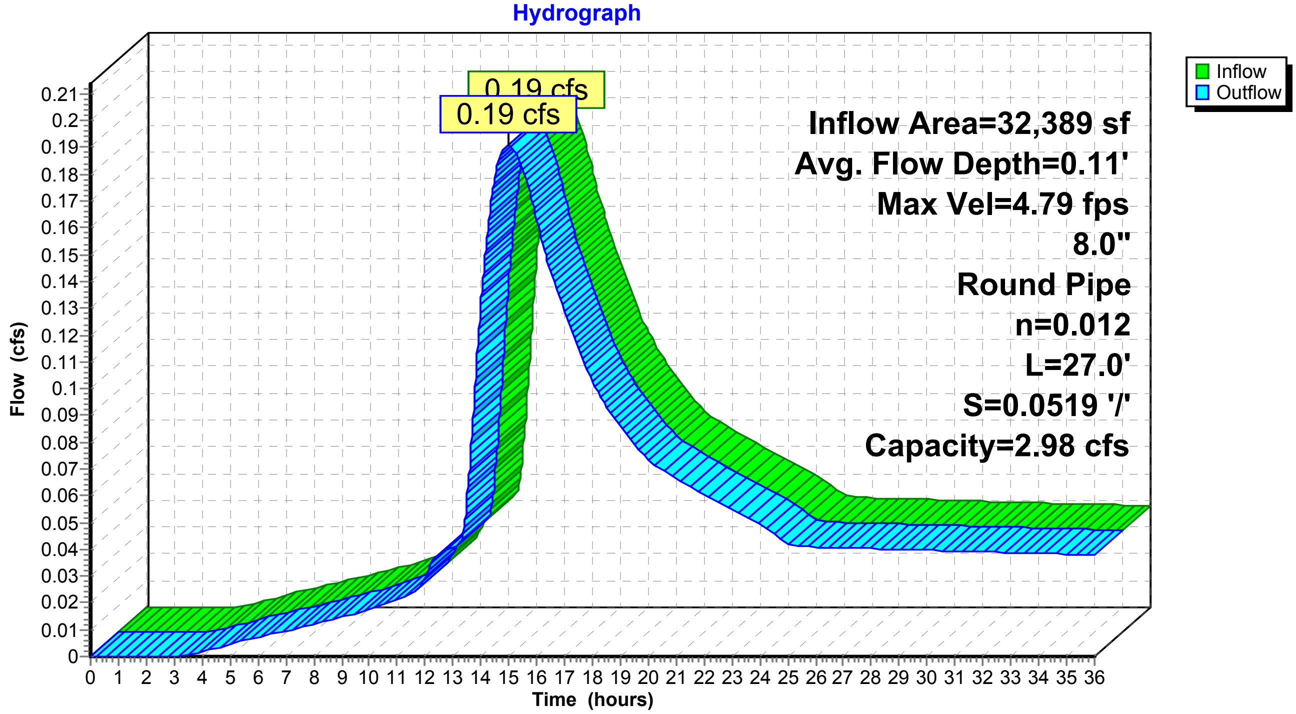
Routing by Stor-Ind+Trans method, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Max. Velocity= 4.79 fps, Min. Travel Time= 0.1 min
Avg. Velocity = 2.98 fps, Avg. Travel Time= 0.2 min

Peak Storage= 1 cf @ 14.98 hrs
Average Depth at Peak Storage= 0.11'
Bank-Full Depth= 0.67' Flow Area= 0.3 sf, Capacity= 2.98 cfs

8.0" Round Pipe
n= 0.012 Corrugated PP, smooth interior
Length= 27.0' Slope= 0.0519 '/'
Inlet Invert= 85.00', Outlet Invert= 83.60'



Reach 8R: ADS Pipe

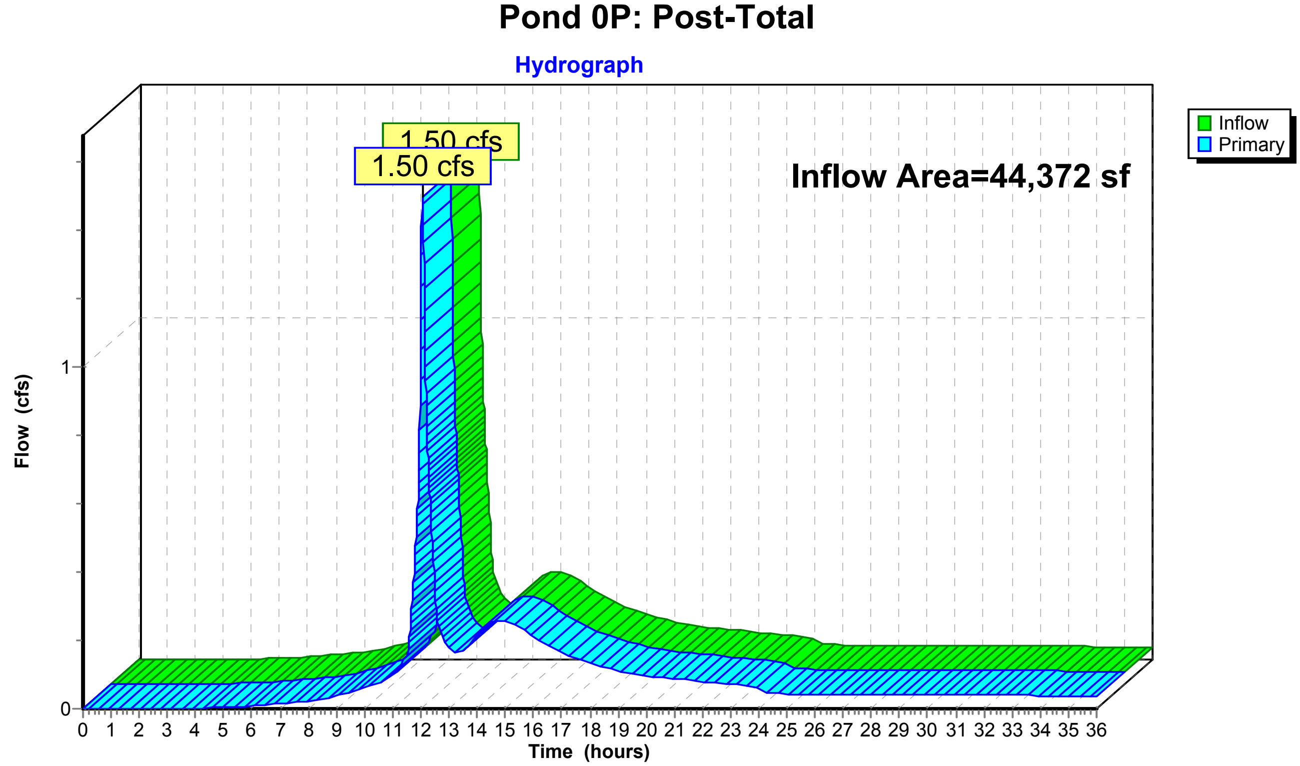


Summary for Pond 0P: Post-Total

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area =	44,372 sf,	49.70% Impervious,	Inflow Depth > 2.96"	for 100-Year event
Inflow =	1.50 cfs @	12.06 hrs, Volume=	10,939 cf	
Primary =	1.50 cfs @	12.06 hrs, Volume=	10,939 cf,	Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs



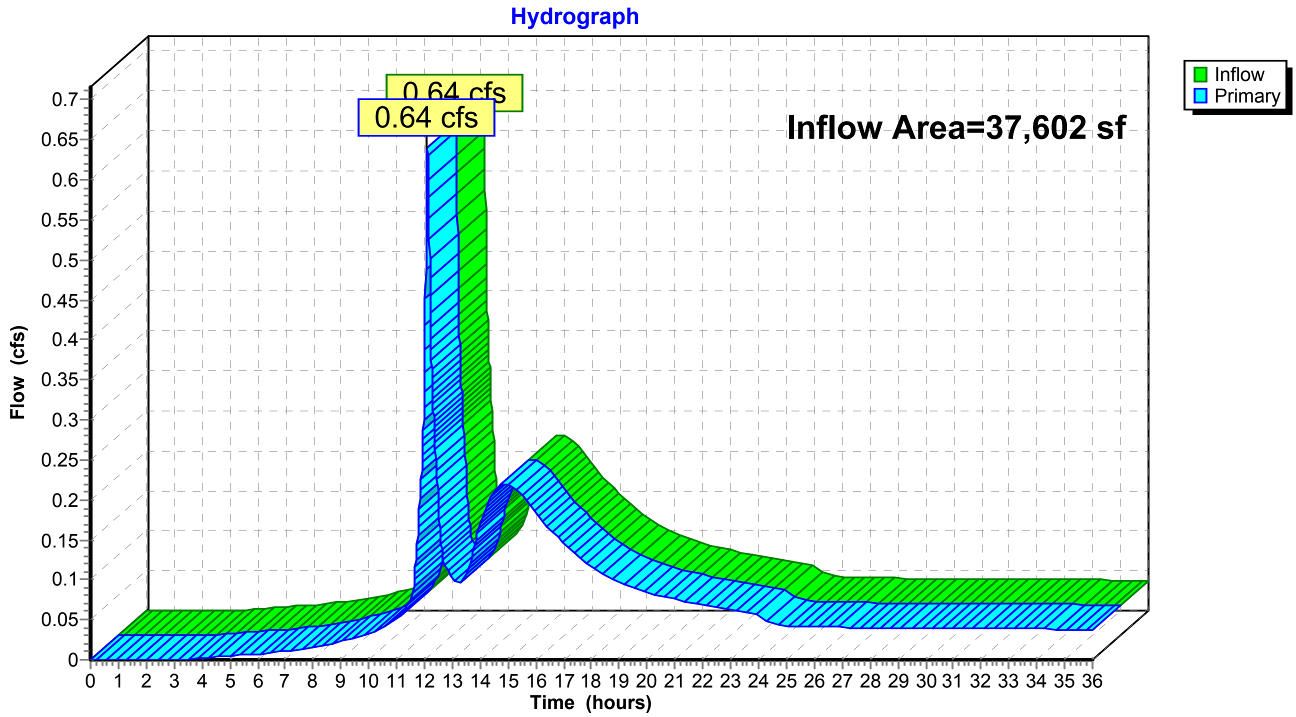
Summary for Pond 1P: CB1

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area =	37,602 sf,	56.13% Impervious,	Inflow Depth > 2.61"	for 100-Year event
Inflow =	0.64 cfs @	12.11 hrs, Volume=	8,178 cf	
Primary =	0.64 cfs @	12.11 hrs, Volume=	8,178 cf,	Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs

Pond 1P: CB1



Summary for Pond 2P: Pipe Storage

Inflow Area = 32,389 sf, 65.16% Impervious, Inflow Depth = 5.53" for 100-Year event
Inflow = 4.57 cfs @ 12.06 hrs, Volume= 14,934 cf
Outflow = 0.19 cfs @ 14.97 hrs, Volume= 6,187 cf, Atten= 96%, Lag= 174.8 min
Primary = 0.19 cfs @ 14.97 hrs, Volume= 6,187 cf

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 87.73' @ 14.97 hrs Surf.Area= 2,843 sf Storage= 11,054 cf

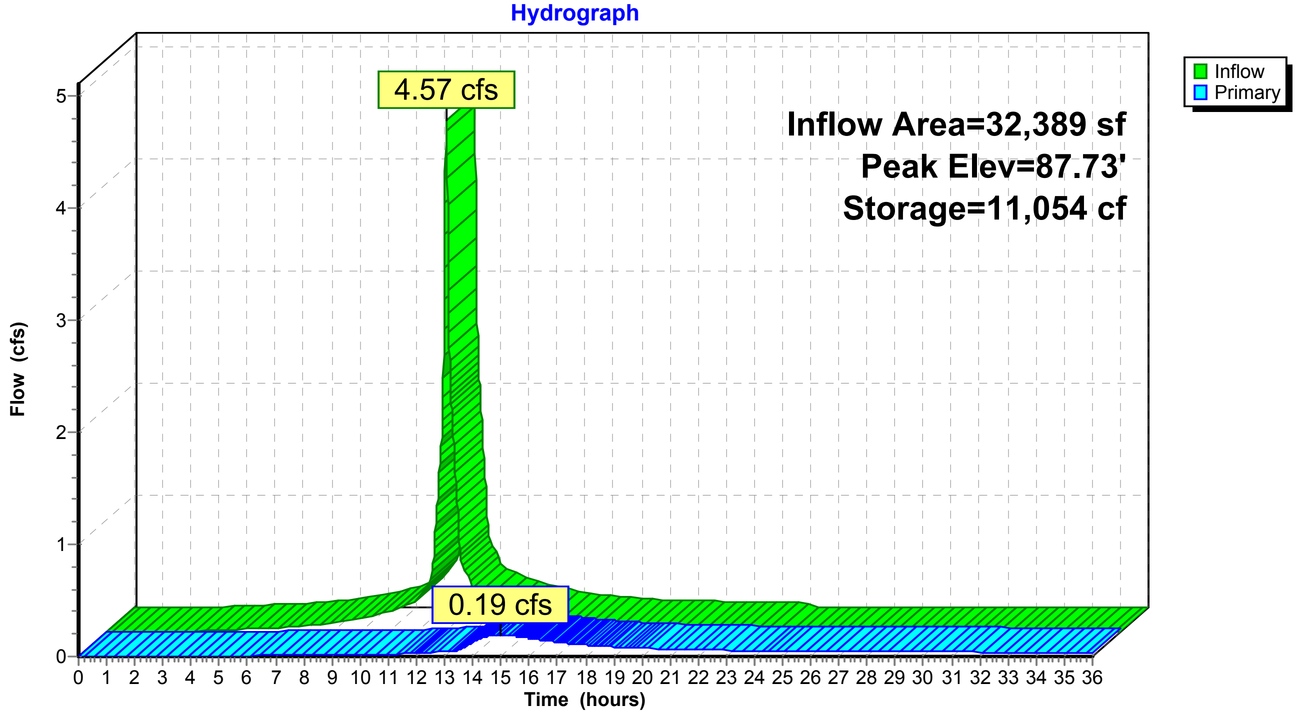
Plug-Flow detention time= 578.6 min calculated for 6,185 cf (41% of inflow)
Center-of-Mass det. time= 448.9 min (1,221.8 - 772.9)

Volume	Invert	Avail.Storage	Storage Description
#1	85.00'	11,133 cf	**36.0" Round RCP_Round 36"** x 7 L= 225.0'
#2	85.00'	250 cf	**5.00'W x 10.00'L x 5.00'H Tank Housing**
#3	85.00'	250 cf	**5.00'W x 10.00'L x 5.00'H Tank Housing**
#4	85.00'	250 cf	**5.00'W x 10.00'L x 5.00'H Tank Housing**
		11,883 cf	Total Available Storage

Device	Routing	Invert	Outlet Devices
#1	Primary	85.00'	**1.0" Vert. Orifice/Grate** C= 0.600
#2	Primary	87.50'	**6.0" Vert. Orifice/Grate** C= 0.600

Primary OutFlow Max=0.19 cfs @ 14.97 hrs HW=87.73' (Free Discharge)
↑—**1=Orifice/Grate** (Orifice Controls 0.04 cfs @ 7.90 fps)
└—**2=Orifice/Grate** (Orifice Controls 0.15 cfs @ 1.64 fps)

Pond 2P: Pipe Storage

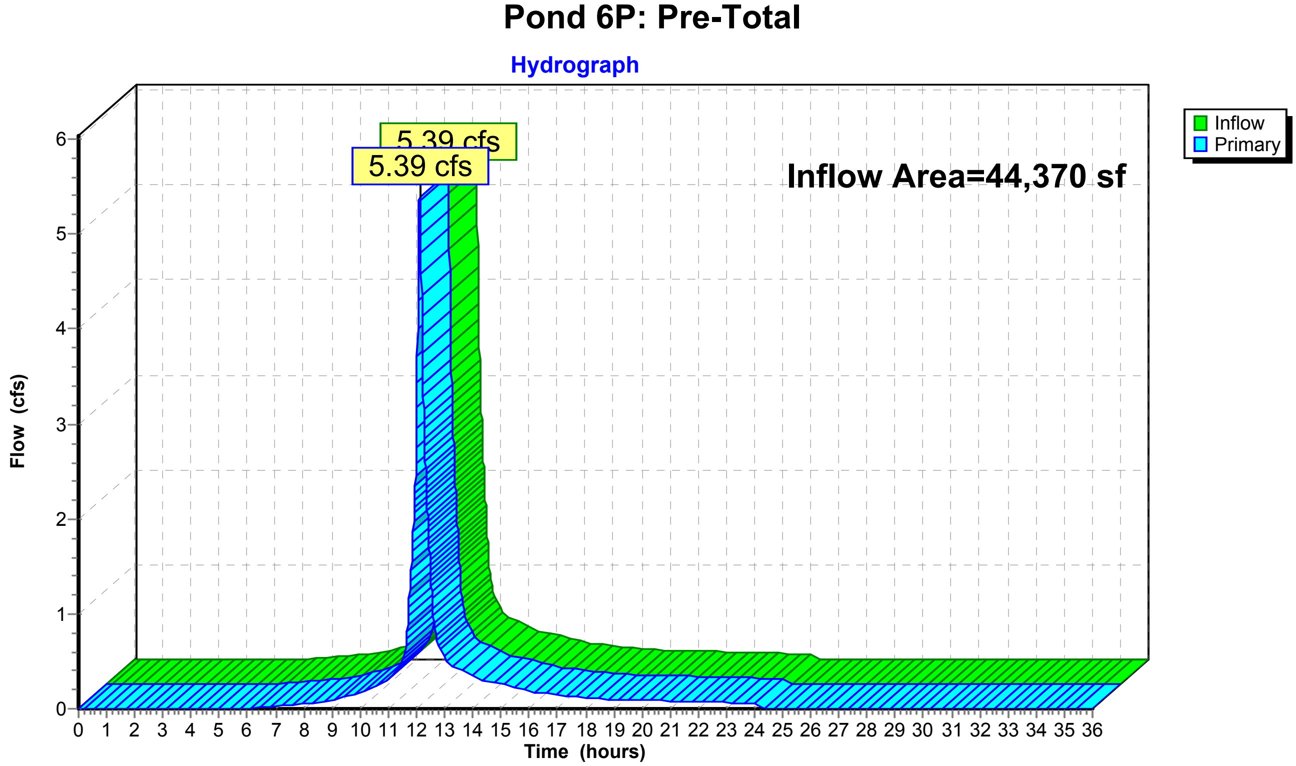


Summary for Pond 6P: Pre-Total

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area =	44,370 sf, 19.24% Impervious,	Inflow Depth = 4.96"	for 100-Year event
Inflow =	5.39 cfs @ 12.11 hrs, Volume=	18,333 cf	
Primary =	5.39 cfs @ 12.11 hrs, Volume=	18,333 cf, Atten= 0%, Lag= 0.0 min	

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs



Summary for Pond 10P: Basin

Inflow Area = 4,400 sf, 54.55% Impervious, Inflow Depth = 5.71" for 100-Year event
Inflow = 0.78 cfs @ 12.00 hrs, Volume= 2,093 cf
Outflow = 0.24 cfs @ 12.24 hrs, Volume= 1,716 cf, Atten= 70%, Lag= 14.2 min
Discarded = 0.01 cfs @ 12.24 hrs, Volume= 904 cf
Primary = 0.23 cfs @ 12.24 hrs, Volume= 812 cf

Routing by Stor-Ind method, Time Span= 0.00-36.00 hrs, dt= 0.01 hrs
Peak Elev= 97.70' @ 12.24 hrs Surf.Area= 1,480 sf Storage= 911 cf

Plug-Flow detention time= 345.9 min calculated for 1,715 cf (82% of inflow)
Center-of-Mass det. time= 275.1 min (1,052.9 - 777.8)

Volume	Invert	Avail.Storage	Storage Description
#1	97.00'	1,373 cf	**Custom Stage Data (Prismatic)**Listed below (Recalc)

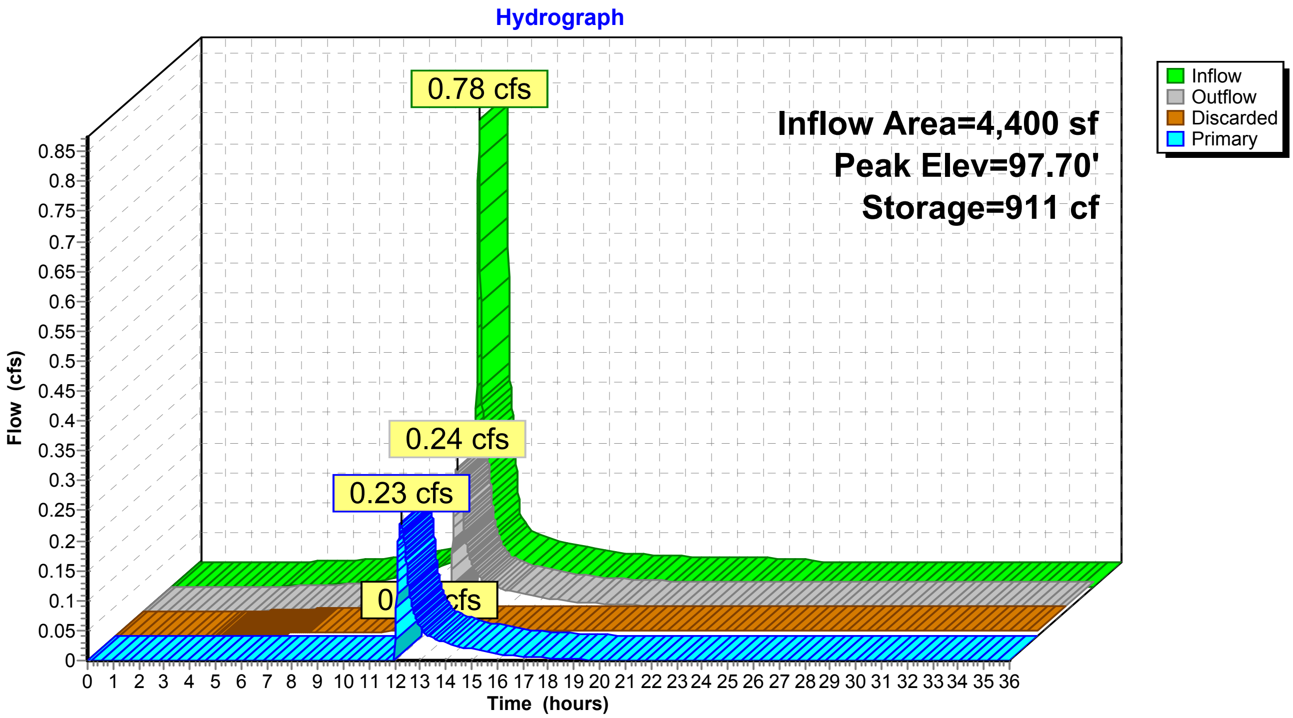
Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
97.00	1,111	0	0
98.00	1,635	1,373	1,373

Device	Routing	Invert	Outlet Devices
#1	Discarded	97.00'	**0.270 in/hr Exfiltration over Surface area**
#2	Primary	97.60'	**8.0" Horiz. Orifice/Grate** C= 0.600 Limited to weir flow at low heads

Discarded OutFlow Max=0.01 cfs @ 12.24 hrs HW=97.70' (Free Discharge)
└─**1=Exfiltration** (Exfiltration Controls 0.01 cfs)

Primary OutFlow Max=0.23 cfs @ 12.24 hrs HW=97.70' (Free Discharge)
└─**2=Orifice/Grate** (Weir Controls 0.23 cfs @ 1.05 fps)

Pond 10P: Basin



Section II
Stormwater Management

- **STANDARD #1 No New Stormwater Conveyances**
  The proposed development proposes no new stormwater conveyances that discharge untreated stormwater off-site or cause down gradient erosion.

- **STANDARD #2 Post Development Peak Discharge**
  The overall site analysis demonstrates that the stormwater management system has been designed so that the post-development peak discharge rates do not exceed the pre-development discharge rate for the 2yr, 10 yr, 25yr & 100 yr 24 hr storm events.

- **STANDARD #3 RECHARGE TO GROUNDWATER**

  High groundwater and poor soils restrict the feasibility of onsite infiltration of stormwater. This project is for the redevelopment of an existing dwelling and proposes to reduce peak flows from the 2, 10, 25, and 100 year storm events. This project proposes to recharge stormwater from new development.

Total proposed site impervious area	= 22,500 square feet (sf)
Total existing site impervious area	= 8,538 sf
Total new development site impervious area = 22,500 – 8,538	= 13,962 sf

  13,962 sf (C-soils) x ¼” x 1’/12” = 291 cubic feet (cf)

  <u>Drawdown Within 72 Hours</u>
  Storage volume below outlet = 830 cf
  Time = (830 cf) / (0.27”/hr x 1’/12” x 1,133 sf) = 33 hours < 72 hours

- **STANDARD #4 WATER QUALITY**

  High groundwater and poor soils restrict the feasibility of onsite infiltration of stormwater. This project is for the redevelopment of an existing dwelling and proposes to reduce peak flows from the 2, 10, 25, and 100 year storm events. This project proposes to treat stormwater from new development.

  BASIN

  <u>Required water quality volume</u>
  Vwq = 0.5” x 1’/12” x 13,962 sf = 582 cf

  <u>Total Proposed</u>
  Retained volume below Nyloplast yard drain emergency outlet = 798 cf

  For Contech CDS 1515-3, see attached calculations from Contech.

- **TSS REMOVAL** (see TSS Removal Work Sheet)

INSTRUCTIONS:
1. In BMP Column, click on Blue Cell to Activate Drop Down Menu
2. Select BMP from Drop Down Menu
3. After BMP is selected, TSS Removal and other Columns are automatically completed.

Version 1, Automated: Mar. 4, 2008

Location: 345 Oak Street, Pembroke

TSS Removal Calculation Worksheet

B BMP[1]	C TSS Removal Rate[1]	D Starting TSS Load*	E Amount Removed (C*D)	F Remaining Load (D-E)
Infiltration Basin	0.80	1.00	0.80	0.20
	0.00	0.20	0.00	0.20
	0.00	0.20	0.00	0.20
	0.00	0.20	0.00	0.20
	0.00	0.20	0.00	0.20

Total TSS Removal = 80%

Separate Form Needs to be Completed for Each Outlet or BMP Train

Project: 18-365
Prepared By: BK
Date: 8/21/2019

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

Non-automated TSS Calculation Sheet must be used if Proprietary BMP Proposed

1. From MassDEP Stormwater Handbook Vol. 1

Mass. Dept. of Environmental Protection

Project: **345 Oak St**
Location: **Pembroke, MA**
Prepared For: **Grady Consulting / Brendan King**

CONTECH ENGINEERED SOLUTIONS

Purpose: To calculate the water quality flow rate (WQF) over a given site area. In this situation the WQF is derived from the first 1" of runoff from the contributing impervious surface.

Reference: Massachusetts Dept. of Environmental Protection Wetlands Program / United States Department of Agriculture Natural Resources Conservation Service TR-55 Manual

Procedure: Determine unit peak discharge using Figure 1 or 2. Figure 2 is in tabular form so is preferred. Using the tc, read the unit peak discharge (qu) from Figure 1 or Table in Figure 2. qu is expressed in the following units: cfs/mi^2/watershed inches (csm/in).

Compute Q Rate using the following equation:

Q = (qu) (A) (WQV)

where:

Q = flow rate associated with first 1" of runoff
qu = the unit peak discharge, in csm/in.
A = impervious surface drainage area (in square miles)
WQV = water quality volume in watershed inches (1" in this case)

Structure Name	Impv. (acres)	A ($miles^2$)	t_c (min)	t_c (hr)	WQV (in)	qu (csm/in.)	Q (cfs)
WQS 1	0.48	0.0007500	5.0	0.083	1.00	795.00	0.60

CDS ESTIMATED NET ANNUAL SOLIDS LOAD REDUCTION
BASED ON THE RATIONAL RAINFALL METHOD

345 OAK ST
PEMBROKE, MA

Area	**0.48 ac**	Unit Site Designation	**WQS 1**
Weighted C	**0.9**	Rainfall Station #	**68**
t_c	**5 min**		
CDS Model	**1515-3**	CDS Treatment Capacity	**1.0 cfs**

Rainfall Intensity[1] (in/hr)	Percent Rainfall Volume[1]	Cumulative Rainfall Volume	Total Flowrate (cfs)	Treated Flowrate (cfs)	Incremental Removal (%)
0.02	9.3%	9.3%	0.01	0.01	9.0
0.04	9.5%	18.8%	0.02	0.02	9.1
0.06	8.7%	27.5%	0.03	0.03	8.3
0.08	10.1%	37.6%	0.03	0.03	9.6
0.10	7.2%	44.8%	0.04	0.04	6.8
0.12	6.0%	50.8%	0.05	0.05	5.6
0.14	6.3%	57.1%	0.06	0.06	5.9
0.16	5.6%	62.7%	0.07	0.07	5.2
0.18	4.7%	67.4%	0.08	0.08	4.3
0.20	3.6%	71.0%	0.09	0.09	3.3
0.25	8.2%	79.1%	0.11	0.11	7.3
0.50	14.9%	94.0%	0.22	0.22	12.3
0.75	3.2%	97.3%	0.32	0.32	2.4
1.00	1.2%	98.5%	0.43	0.43	0.8
1.50	0.7%	99.2%	0.65	0.65	0.4
2.00	0.8%	100.0%	0.86	0.86	0.3
0.00	0.0%	100.0%	0.00	0.00	0.0
0.00	0.0%	100.0%	0.00	0.00	0.0
0.00	0.0%	100.0%	0.00	0.00	0.0
0.00	0.0%	100.0%	0.00	0.00	0.0
0.00	0.0%	100.0%	0.00	0.00	0.0
					90.6

Removal Efficiency Adjustment[2] =	6.5%
Predicted % Annual Rainfall Treated =	93.5%
Predicted Net Annual Load Removal Efficiency =	**84.2%**

1 - Based on 10 years of rainfall data from NCDC station 736, Blue Hill, Norfolk County, MA
2 - Reduction due to use of 60-minute data for a site that has a time of concentration less than 30-minutes.

- **STANDARD #5 Land Uses With Higher Potential Pollutant Loads**
  The site and use is not a LUHPPL

- **STANDARD #6 Critical Areas**
  The site is not located near an Outstanding Resource Water Resource.

- **STANDARD #7 Redevelopment**
  This project is a redevelopment project.

- **STANDARD #8 Erosion & Sediment Control Plan**
  Erosion and sediment controls are detailed within the site plan.

- **STANDARD #9 Operation & Maintenance Plan**
  See O&M plan attached hereto.

- **STANDARD #10 Illicit Discharge Statement**
  "All illicit discharges to the stormwater management system are prohibited."

This statement is intended to meet Standard #10 of the Stormwater Management requirements

Illicit discharges to the stormwater management system are discharges that are not entirely comprised of stormwater.

Except for the potential for deliberate criminal act of discharge by an unauthorized entity for which the property owner has no control, there are to be no illicit discharges into the stormwater system.

[signature] AGENT

Applicant\Owner

Massachusetts Department of Environmental Protection
Bureau of Resource Protection - Wetlands Program

Checklist for Stormwater Report

A. Introduction

Important: When filling out forms on the computer, use only the tab key to move your cursor - do not use the return key.

A Stormwater Report must be submitted with the Notice of Intent permit application to document compliance with the Stormwater Management Standards. The following checklist is NOT a substitute for the Stormwater Report (which should provide more substantive and detailed information) but is offered here as a tool to help the applicant organize their Stormwater Management documentation for their Report and for the reviewer to assess this information in a consistent format. As noted in the Checklist, the Stormwater Report must contain the engineering computations and supporting information set forth in Volume 3 of the Massachusetts Stormwater Handbook. The Stormwater Report must be prepared and certified by a Registered Professional Engineer (RPE) licensed in the Commonwealth.

The Stormwater Report must include:

- The Stormwater Checklist completed and stamped by a Registered Professional Engineer (see page 2) that certifies that the Stormwater Report contains all required submittals.[1] This Checklist is to be used as the cover for the completed Stormwater Report.
- Applicant/Project Name
- Project Address
- Name of Firm and Registered Professional Engineer that prepared the Report
- Long-Term Pollution Prevention Plan required by Standards 4-6
- Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan required by Standard 8[2]
- Operation and Maintenance Plan required by Standard 9

In addition to all plans and supporting information, the Stormwater Report must include a brief narrative describing stormwater management practices, including environmentally sensitive site design and LID techniques, along with a diagram depicting runoff through the proposed BMP treatment train. Plans are required to show existing and proposed conditions, identify all wetland resource areas, NRCS soil types, critical areas, Land Uses with Higher Potential Pollutant Loads (LUHPPL), and any areas on the site where infiltration rate is greater than 2.4 inches per hour. The Plans shall identify the drainage areas for both existing and proposed conditions at a scale that enables verification of supporting calculations.

As noted in the Checklist, the Stormwater Management Report shall document compliance with each of the Stormwater Management Standards as provided in the Massachusetts Stormwater Handbook. The soils evaluation and calculations shall be done using the methodologies set forth in Volume 3 of the Massachusetts Stormwater Handbook.

To ensure that the Stormwater Report is complete, applicants are required to fill in the Stormwater Report Checklist by checking the box to indicate that the specified information has been included in the Stormwater Report. If any of the information specified in the checklist has not been submitted, the applicant must provide an explanation. The completed Stormwater Report Checklist and Certification must be submitted with the Stormwater Report.

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[1] The Stormwater Report may also include the Illicit Discharge Compliance Statement required by Standard 10. If not included in the Stormwater Report, the Illicit Discharge Compliance Statement must be submitted prior to the discharge of stormwater runoff to the post-construction best management practices.

[2] For some complex projects, it may not be possible to include the Construction Period Erosion and Sedimentation Control Plan in the Stormwater Report. In that event, the issuing authority has the discretion to issue an Order of Conditions that approves the project and includes a condition requiring the proponent to submit the Construction Period Erosion and Sedimentation Control Plan before commencing any land disturbance activity on the site.

Checklist for Stormwater Report

B. Stormwater Checklist and Certification

The following checklist is intended to serve as a guide for applicants as to the elements that ordinarily need to be addressed in a complete Stormwater Report. The checklist is also intended to provide conservation commissions and other reviewing authorities with a summary of the components necessary for a comprehensive Stormwater Report that addresses the ten Stormwater Standards.

Note: Because stormwater requirements vary from project to project, it is possible that a complete Stormwater Report may not include information on some of the subjects specified in the Checklist. If it is determined that a specific item does not apply to the project under review, please note that the item is not applicable (N.A.) and provide the reasons for that determination.

A complete checklist must include the Certification set forth below signed by the Registered Professional Engineer who prepared the Stormwater Report.

Registered Professional Engineer's Certification

I have reviewed the Stormwater Report, including the soil evaluation, computations, Long-term Pollution Prevention Plan, the Construction Period Erosion and Sedimentation Control Plan (if included), the Long-term Post-Construction Operation and Maintenance Plan, the Illicit Discharge Compliance Statement (if included) and the plans showing the stormwater management system, and have determined that they have been prepared in accordance with the requirements of the Stormwater Management Standards as further elaborated by the Massachusetts Stormwater Handbook. I have also determined that the information presented in the Stormwater Checklist is accurate and that the information presented in the Stormwater Report accurately reflects conditions at the site as of the date of this permit application.

Registered Professional Engineer Block and Signature

COMMONWEALTH OF MASSACHUSETTS
RICHARD J. GRADY
No. 38072
REGISTERED PROFESSIONAL CIVIL ENGINEER

Richard Grady 9/20/2019

Signature and Date

Checklist

Project Type: Is the application for new development, redevelopment, or a mix of new and redevelopment?

☐ New development

☐ Redevelopment

☒ Mix of New Development and Redevelopment

Checklist (continued)

LID Measures: Stormwater Standards require LID measures to be considered. Document what environmentally sensitive design and LID Techniques were considered during the planning and design of the project:

☒ No disturbance to any Wetland Resource Areas

☐ Site Design Practices (e.g. clustered development, reduced frontage setbacks)

☐ Reduced Impervious Area (Redevelopment Only)

☐ Minimizing disturbance to existing trees and shrubs

☐ LID Site Design Credit Requested:

- ☐ Credit 1
- ☐ Credit 2
- ☐ Credit 3

☐ Use of “country drainage” versus curb and gutter conveyance and pipe

☐ Bioretention Cells (includes Rain Gardens)

☐ Constructed Stormwater Wetlands (includes Gravel Wetlands designs)

☐ Treebox Filter

☐ Water Quality Swale

☐ Grass Channel

☐ Green Roof

☐ Other (describe): ____________________

Standard 1: No New Untreated Discharges

☒ No new untreated discharges

☒ Outlets have been designed so there is no erosion or scour to wetlands and waters of the Commonwealth

☐ Supporting calculations specified in Volume 3 of the Massachusetts Stormwater Handbook included.

Checklist for Stormwater Report

Checklist (continued)

Standard 2: Peak Rate Attenuation

☐ Standard 2 waiver requested because the project is located in land subject to coastal storm flowage and stormwater discharge is to a wetland subject to coastal flooding.

☐ Evaluation provided to determine whether off-site flooding increases during the 100-year 24-hour storm.

☒ Calculations provided to show that post-development peak discharge rates do not exceed pre-development rates for the 2-year and 10-year 24-hour storms. If evaluation shows that off-site flooding increases during the 100-year 24-hour storm, calculations are also provided to show that post-development peak discharge rates do not exceed pre-development rates for the 100-year 24-hour storm.

Standard 3: Recharge

☒ Soil Analysis provided.

☒ Required Recharge Volume calculation provided.

☐ Required Recharge volume reduced through use of the LID site Design Credits.

☒ Sizing the infiltration, BMPs is based on the following method: Check the method used.

☒ Static ☐ Simple Dynamic ☐ Dynamic Field[1]

☐ Runoff from all impervious areas at the site discharging to the infiltration BMP.

☒ Runoff from all impervious areas at the site is *not* discharging to the infiltration BMP and calculations are provided showing that the drainage area contributing runoff to the infiltration BMPs is sufficient to generate the required recharge volume.

☐ Recharge BMPs have been sized to infiltrate the Required Recharge Volume.

☒ Recharge BMPs have been sized to infiltrate the Required Recharge Volume *only* to the maximum extent practicable for the following reason:

- ☒ Site is comprised solely of C and D soils and/or bedrock at the land surface
- ☐ M.G.L. c. 21E sites pursuant to 310 CMR 40.0000
- ☐ Solid Waste Landfill pursuant to 310 CMR 19.000
- ☐ Project is otherwise subject to Stormwater Management Standards only to the maximum extent practicable.

☒ Calculations showing that the infiltration BMPs will drain in 72 hours are provided.

☐ Property includes a M.G.L. c. 21E site or a solid waste landfill and a mounding analysis is included.

[1] 80% TSS removal is required prior to discharge to infiltration BMP if Dynamic Field method is used.

Checklist (continued)

Standard 3: Recharge (continued)

☐ The infiltration BMP is used to attenuate peak flows during storms greater than or equal to the 10-year 24-hour storm and separation to seasonal high groundwater is less than 4 feet and a mounding analysis is provided.

☐ Documentation is provided showing that infiltration BMPs do not adversely impact nearby wetland resource areas.

Standard 4: Water Quality

The Long-Term Pollution Prevention Plan typically includes the following:
- Good housekeeping practices;
- Provisions for storing materials and waste products inside or under cover;
- Vehicle washing controls;
- Requirements for routine inspections and maintenance of stormwater BMPs;
- Spill prevention and response plans;
- Provisions for maintenance of lawns, gardens, and other landscaped areas;
- Requirements for storage and use of fertilizers, herbicides, and pesticides;
- Pet waste management provisions;
- Provisions for operation and management of septic systems;
- Provisions for solid waste management;
- Snow disposal and plowing plans relative to Wetland Resource Areas;
- Winter Road Salt and/or Sand Use and Storage restrictions;
- Street sweeping schedules;
- Provisions for prevention of illicit discharges to the stormwater management system;
- Documentation that Stormwater BMPs are designed to provide for shutdown and containment in the event of a spill or discharges to or near critical areas or from LUHPPL;
- Training for staff or personnel involved with implementing Long-Term Pollution Prevention Plan;
- List of Emergency contacts for implementing Long-Term Pollution Prevention Plan.

☐ A Long-Term Pollution Prevention Plan is attached to Stormwater Report and is included as an attachment to the Wetlands Notice of Intent.

☐ Treatment BMPs subject to the 44% TSS removal pretreatment requirement and the one inch rule for calculating the water quality volume are included, and discharge:

  ☐ is within the Zone II or Interim Wellhead Protection Area

  ☐ is near or to other critical areas

  ☐ is within soils with a rapid infiltration rate (greater than 2.4 inches per hour)

  ☐ involves runoff from land uses with higher potential pollutant loads.

☐ The Required Water Quality Volume is reduced through use of the LID site Design Credits.

☐ Calculations documenting that the treatment train meets the 80% TSS removal requirement and, if applicable, the 44% TSS removal pretreatment requirement, are provided.

Checklist (continued)

Standard 4: Water Quality (continued)

☒ The BMP is sized (and calculations provided) based on:

- ☒ The ½" or 1" Water Quality Volume or
- ☐ The equivalent flow rate associated with the Water Quality Volume and documentation is provided showing that the BMP treats the required water quality volume.

☒ The applicant proposes to use proprietary BMPs, and documentation supporting use of proprietary BMP and proposed TSS removal rate is provided. This documentation may be in the form of the propriety BMP checklist found in Volume 2, Chapter 4 of the Massachusetts Stormwater Handbook and submitting copies of the TARP Report, STEP Report, and/or other third party studies verifying performance of the proprietary BMPs.

☐ A TMDL exists that indicates a need to reduce pollutants other than TSS and documentation showing that the BMPs selected are consistent with the TMDL is provided.

Standard 5: Land Uses With Higher Potential Pollutant Loads (LUHPPLs)

☐ The NPDES Multi-Sector General Permit covers the land use and the Stormwater Pollution Prevention Plan (SWPPP) has been included with the Stormwater Report.

☐ The NPDES Multi-Sector General Permit covers the land use and the SWPPP will be submitted ***prior to*** the discharge of stormwater to the post-construction stormwater BMPs.

☐ The NPDES Multi-Sector General Permit does ***not*** cover the land use.

☐ LUHPPLs are located at the site and industry specific source control and pollution prevention measures have been proposed to reduce or eliminate the exposure of LUHPPLs to rain, snow, snow melt and runoff, and been included in the long term Pollution Prevention Plan.

☐ All exposure has been eliminated.

☐ All exposure has ***not*** been eliminated and all BMPs selected are on MassDEP LUHPPL list.

☐ The LUHPPL has the potential to generate runoff with moderate to higher concentrations of oil and grease (e.g. all parking lots with >1000 vehicle trips per day) and the treatment train includes an oil grit separator, a filtering bioretention area, a sand filter or equivalent.

Standard 6: Critical Areas

☐ The discharge is near or to a critical area and the treatment train includes only BMPs that MassDEP has approved for stormwater discharges to or near that particular class of critical area.

☐ Critical areas and BMPs are identified in the Stormwater Report.

Checklist (continued)

Standard 7: Redevelopments and Other Projects Subject to the Standards only to the maximum extent practicable

☒ The project is subject to the Stormwater Management Standards only to the maximum Extent Practicable as a:

- ☐ Limited Project
- ☐ Small Residential Projects: 5-9 single family houses or 5-9 units in a multi-family development provided there is no discharge that may potentially affect a critical area.
- ☐ Small Residential Projects: 2-4 single family houses or 2-4 units in a multi-family development with a discharge to a critical area
- ☐ Marina and/or boatyard provided the hull painting, service and maintenance areas are protected from exposure to rain, snow, snow melt and runoff
- ☐ Bike Path and/or Foot Path
- ☐ Redevelopment Project
- ☒ Redevelopment portion of mix of new and redevelopment.

☐ Certain standards are not fully met (Standard No. 1, 8, 9, and 10 must always be fully met) and an explanation of why these standards are not met is contained in the Stormwater Report.

☐ The project involves redevelopment and a description of all measures that have been taken to improve existing conditions is provided in the Stormwater Report. The redevelopment checklist found in Volume 2 Chapter 3 of the Massachusetts Stormwater Handbook may be used to document that the proposed stormwater management system (a) complies with Standards 2, 3 and the pretreatment and structural BMP requirements of Standards 4-6 to the maximum extent practicable and (b) improves existing conditions.

Standard 8: Construction Period Pollution Prevention and Erosion and Sedimentation Control

A Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan must include the following information:

- Narrative;
- Construction Period Operation and Maintenance Plan;
- Names of Persons or Entity Responsible for Plan Compliance;
- Construction Period Pollution Prevention Measures;
- Erosion and Sedimentation Control Plan Drawings;
- Detail drawings and specifications for erosion control BMPs, including sizing calculations;
- Vegetation Planning;
- Site Development Plan;
- Construction Sequencing Plan;
- Sequencing of Erosion and Sedimentation Controls;
- Operation and Maintenance of Erosion and Sedimentation Controls;
- Inspection Schedule;
- Maintenance Schedule;
- Inspection and Maintenance Log Form.

☒ A Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan containing the information set forth above has been included in the Stormwater Report.

Checklist (continued)

Standard 8: Construction Period Pollution Prevention and Erosion and Sedimentation Control (continued)

☐ The project is highly complex and information is included in the Stormwater Report that explains why it is not possible to submit the Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan with the application. A Construction Period Pollution Prevention and Erosion and Sedimentation Control has ***not*** been included in the Stormwater Report but will be submitted ***before*** land disturbance begins.

☐ The project is ***not*** covered by a NPDES Construction General Permit.

☐ The project is covered by a NPDES Construction General Permit and a copy of the SWPPP is in the Stormwater Report.

☐ The project is covered by a NPDES Construction General Permit but no SWPPP been submitted. The SWPPP will be submitted BEFORE land disturbance begins.

Standard 9: Operation and Maintenance Plan

☒ The Post Construction Operation and Maintenance Plan is included in the Stormwater Report and includes the following information:

- ☒ Name of the stormwater management system owners;
- ☒ Party responsible for operation and maintenance;
- ☒ Schedule for implementation of routine and non-routine maintenance tasks;
- ☒ Plan showing the location of all stormwater BMPs maintenance access areas;
- ☒ Description and delineation of public safety features;
- ☒ Estimated operation and maintenance budget; and
- ☒ Operation and Maintenance Log Form.

☐ The responsible party is ***not*** the owner of the parcel where the BMP is located and the Stormwater Report includes the following submissions:

- ☐ A copy of the legal instrument (deed, homeowner's association, utility trust or other legal entity) that establishes the terms of and legal responsibility for the operation and maintenance of the project site stormwater BMPs;
- ☐ A plan and easement deed that allows site access for the legal entity to operate and maintain BMP functions.

Standard 10: Prohibition of Illicit Discharges

☐ The Long-Term Pollution Prevention Plan includes measures to prevent illicit discharges;

☒ An Illicit Discharge Compliance Statement is attached;

☐ NO Illicit Discharge Compliance Statement is attached but will be submitted ***prior to*** the discharge of any stormwater to post-construction BMPs.

Section III

Operation & Maintenance

OPERATION AND MAINTENANCE PLAN

PROPOSED SITE WORK – DURING CONSTRUCTION

345 Oak Street, Assessors Map F15-38
Pembroke, Massachusetts

Owner:
Champion Builders Inc.
P.O. Box #1414
Duxbury, MA 02331
Contact: (781) 585-4114 Email: mdacey@championbuilders.com

Party Responsible for Operation and Maintenance:
Champion Builders Inc.
P.O. Box #1414
Duxbury, MA 02331
Contact: (781) 585-4114 Email: mdacey@championbuilders.com

Source of Funding:

Operation and Maintenance of this stormwater management system will be the responsibility of the property owner to include its successor and/or assigns, as the same may appear on record with the appropriate register of deeds.

During Construction:

Construction activities shall follow the Construction Sequence shown on the approved plans. During periods of active construction the stormwater management system shall be inspected on a weekly basis and within 24 hours of a storm event of greater than ½". Maintenance tasks shall be performed monthly or after significant rainfall events of 1" of rain or greater. During construction, silt-laden runoff shall be prevented from entering the drainage system and off-site properties. Temporary swales shall be constructed as needed during construction to direct runoff to sediment traps. Infiltration systems and subsurface storage systems shall not be placed in service until after the installation of base course pavement and vegetative stabilization of the areas contributing to the systems.

During dewatering operations, all water pumped from the dewatering shall be directed to a "dirt bag" pumped sediment removal system (or approved equal) as manufactured by ACF Environmental. Water from construction dewatering activities should not be directed into any of the existing or proposed stormwater management facilities system unless it is fully treated prior to discharge. The unit shall be placed on a crushed stone blanket. Disposal of such "dirt bag" shall occur when the device is full and can no longer effectively filter sediment or allow water to pass at a reasonable flow rate. Disposal of this unit shall be the responsibility of the contractor and shall be as directed by the owner in accordance with applicable local, state, and federal guidelines and regulations.

All erosion and sedimentation control measures shall be in place prior to the commencement of any site work or earthwork operations, and shall be maintained during construction, and shall remain in place until all site work is complete and ground cover is established.

2019-05-3

All exposed soils not to be paved shall be stabilized as soon as practical. Seed mixes shall only be applied during appropriate periods as recommended by the seed supplier, typically May 1 to October 15. Any exposed soils that cannot be stabilized by vegetation during these dates shall be stabilized with hay bales, hay mulch, check dams, jute netting or other acceptable means.

Once each structure is in place, it should be maintained in accordance with the procedures described in the post-construction Operations and Maintenance Plan.

During dry periods where dust is created by construction activities the following control measures should be implemented.

- Sprinkling – The contractor may sprinkle the ground along haul roads and traffic areas until moist.
- Vegetative cover – Areas that are not expected to be disturbed regularly may be stabilized with vegetative cover.
- Mulch – Mulching can be used as a quick and effective means of dust control in recently disturbed areas.
- Spray on chemical soil treatments may be utilized. Application rates shall conform to manufacturers recommendations.

Illicit Discharges

Illicit discharges to the stormwater management system are discharges that are not entirely comprised of stormwater. Illicit discharges are prohibited from the stormwater management system and the stormwater management system shall be inspected for illicit discharges annually.

STORMWATER MANAGEMENT
BEST MANAGEMENT PRACTICES
INSPECTION SCHEDULE AND EVALUATION CHECKLIST – CONSTRUCTION PHASE

PROJECT LOCATION: 345 Oak Street, Pembroke Latest Revision: May 30, 2019

Stormwater Control Manager: _____ **Stamp**

Best Management Practice	Inspection Frequency (1)	Date Inspected	Inspector	Minimum Maintenance and Key Items to Check	Cleaning/ Repair Needed yes/no List items	Date of Cleaning/Repair	Performed By	Water Level in Detention System
Silt socks & swales and silt traps	After every major storm event							
Dewatering Operations	Daily- during actual dewatering							
Temporary Construction Entrance	Daily or as needed.							

(1) Refer to the Massachusetts Stormwater Management, Volume Two: Stormwater Technical Handbook for recommendations regarding frequency for inspection and maintenance of specific BMPs.

Limited or no use of sodium chloride salts, fertilizers or pesticides recommended. Slow release fertilizer recommended.
Other notes:(Include deviations from: Con Com Order of Conditions, PB Approval, Construction Sequence and Approved Plan)

<u>OPERATION AND MAINTENANCE PLAN</u>
PROPOSED DRAINAGE SYSTEM – POST CONSTRUCTION
345 Oak Street, Assessors Map F15-38
Pembroke, Massachusetts

Owner:
Champion Builders Inc.
P.O. Box #1414
Duxbury, MA 02331
Contact: (781) 585-4114 Email: mdacey@championbuilders.com

Party Responsible for Operation and Maintenance:

After construction is complete the owner will be the party responsible for operation and maintenance of the drainage system. When the property is conveyed, the new owner will be the party responsible for operation and maintenance.

Source of Funding:
Operation and Maintenance of this stormwater management system will be the responsibility of the owner.

Schedule for Inspection and Maintenance:
<u>Outlet Structure</u>
After construction, the outlet structure should be inspected at least once per year to ensure that the system is operating as intended. If accumulated sediment is observed within the structure it should be removed as necessary. Any sediment removed should be disposed of in accordance with Town, State and Federal Regulations.

The 1" diameter orifice should be kept clear of debris, and should be inspected quarterly to ensure no blockage exists. Standing water in the storage pipes is an indicator of such a blockage.

<u>Contech CDS Unit</u>
See attached Contech CDS Guide: Operation, Design, Perfomance and Maintenance for information regarding operation & maintenance.

<u>Illicit Discharges</u>

> Illicit discharges to the stormwater management system are discharges that are not entirely comprised of stormwater. Illicit discharges are prohibited from the stormwater management system and the stormwater management system shall be inspected for illicit discharges annually.

This Standard prohibits illicit discharges to stormwater management systems. The stormwater management system is the system for conveying, treating, and infiltrating stormwater on-site, including stormwater best management practices and any pipes intended to transport stormwater to the groundwater, a surface water, or municipal separate storm sewer system. Illicit discharges to the stormwater management system are discharges that are not entirely comprised of stormwater. Notwithstanding the foregoing, an illicit discharge does not include discharges from the following activities or facilities: firefighting, water line flushing, landscape irrigation, uncontaminated groundwater, potable water sources, foundation drains, air conditioning condensation, footing drains, individual resident car washing, flows from riparian habitats and wetlands, dechlorinated water from swimming pools, water used for street washing and water used to clean residential buildings without detergents.

For additional information, refer to Performance Standards and Guidelines for Stormwater Management in Massachusetts, published by the Department of Environmental Protection.

STORMWATER MANAGEMENT
BEST MANAGEMENT PRACTICES

INSPECTION SCHEDULE AND EVALUATION CHECKLIST – POST CONSTRUCTION PHASE

PROJECT LOCATION: 345 Oak Street, Pembroke

Latest Revision January 23, 2019

Best Management Practice	Inspection Frequency (1)	Date Inspected	Inspector	Minimum Maintenance and Key Items to Check	Cleaning/ Repair Needed yes/no List items	Date of Cleaning/ Repair	Performed By	Water Level in Drainage System
Outlet Structure	Once per year							

(1) Refer to the Massachusetts Stormwater Management, Volume Two: Stormwater Technical Handbook for recommendations regarding frequency for inspection and maintenance of specific BMPs.
(2) records shall be kept for a minimum of three years.

Limited or no use of sodium chloride salts, fertilizers or pesticides recommended. Slow release fertilizer recommended.
Other notes:(Include deviations from: Con Com Order of Conditions, PB Approval, Construction Sequence and Approved Plan)

Stormwater Control Manager: _____

Stamp

Deep Sump Catch Basin

Description: Deep sump catch basins, also known as oil and grease or hooded catch basins, are underground retention systems designed to remove trash, debris, and coarse sediment from stormwater runoff, and serve as temporary spill containment devices for floatables such as oils and greases.

Ability to meet specific standards

Standard	Description
2 - Peak Flow	Provides no peak flow attenuation
3 - Recharge	Provides no groundwater recharge
4 - TSS Removal	25% TSS removal credit when used for pretreatment. Because of their limited effectiveness and storage capacity, deep sump catch basins receive credit for removing TSS only if they are used for pretreatment and designed as off-line systems.
5 - Higher Pollutant Loading	Recommended as pretreatment BMP. Although provides some spill control capability, a deep sump catch basin may not be used in place of an oil grit separator or sand filter for land uses that have the potential to generate runoff with high concentrations of oil and grease such as: high-intensity-use parking lots, gas stations, fleet storage areas, vehicle and/or equipment maintenance and service areas.
6 - Discharges near or to Critical Areas	May be used as pretreatment BMP. not an adequate spill control device for discharges near or to critical areas.
7 - Redevelopment	Highly suitable.

Advantages/Benefits:

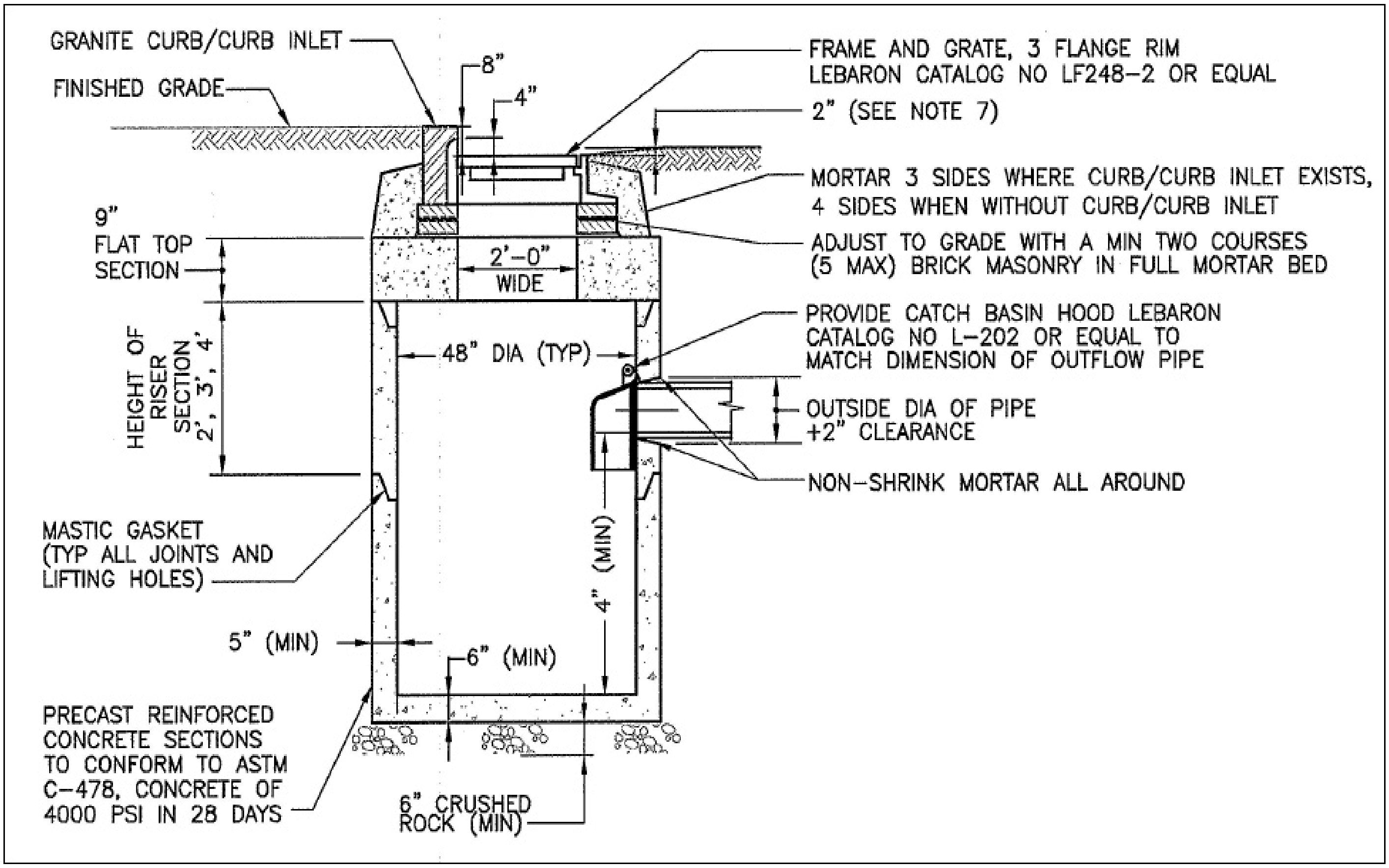
- Located underground, so limited lot size is not a deterrent.
- Compatible with subsurface storm drain systems.
- Can be used for retrofitting small urban lots where larger BMPs are not feasible.
- Provide pretreatment of runoff before it is delivered to other BMPs.
- Easily accessed for maintenance.
- Longevity is high with proper maintenance.

Disadvantages/Limitations:

- Limited pollutant removal.
- Expensive to install and maintain, resulting in high cost per unit area treated.
- No ability to control volume of stormwater
- Frequent maintenance is essential
- Requires proper disposal of trapped sediment and oil and grease
- Entrapment hazard for amphibians and other small animals

Pollutant Removal Efficiencies

- Total Suspended Solids (TSS) - 25% (for regulatory purposes)
- Nutrients (Nitrogen, phosphorus) - Insufficient data
- Metals (copper, lead, zinc, cadmium) - Insufficient data
- Pathogens (coliform, e coli) - Insufficient data



adapted from the University of New Hampshire

Maintenance

Activity	Frequency
Inspect units	Four times per year
Clean units	Four times per year or whenever the depth of deposits is greater than or equal to one half the depth from the bottom of the invert of the lowest pipe in the basin.

Special Features

All deep sump catch basins must include hoods. For MassHighway projects, consult the Stormwater Handbook for Highways and Bridges for hood requirements.

LID Alternative

Reduce Impervious Surface
Disconnect rooftop and non-rooftop runoff
Vegetated Filter Strip

Deep Sump Catch Basin

Suitable Applications

- Pretreatment
- Residential subdivisions
- Office
- Retail

Design Considerations

- The contributing drainage area to any deep sump catch basin should not exceed ¼ acre of impervious cover.
- Design and construct deep sump catch basins as off-line systems.
- Size the drainage area so that the flow rate does not exceed the capacity of the inlet grate.
- Divert excess flows to another BMP intended to meet the water quantity requirements (peak rate attenuation) or to a storm drain system. An off-line design enhances pollutant removal efficiency, because it prevents the resuspension of sediments in large storms.

Make the sump depth (distance from the bottom of the outlet pipe to the bottom of the basin) at least four feet times the diameter of the outlet pipe and more if the contributing drainage area has a high sediment load. The minimum sump depth is 4 feet. Double catch basins, those with 2 inlet grates, may require deeper sumps. Install the invert of the outlet pipe at least 4 feet from the bottom of the catch basin grate.

The inlet grate serves to prevent larger debris from entering the sump. To be effective, the grate must have a separation between the grates of one square inch or less. The inlet openings must not allow flows greater than 3 cfs to enter the deep sump catch basin. If the inlet grate is designed with a curb cut, the grate must reach the back of the curb cut to prevent bypassing. The inlet grate must be constructed of a durable material and fit tightly into the frame so it won't be dislodged by automobile traffic. The inlet grate must not be welded to the frame so that sediments may be easily removed. To facilitate maintenance, the inlet grate must be placed along the road shoulder or curb line rather than a traffic lane.

Note that within parking garages, the State Plumbing Code regulates inlet grates and other stormwater management controls. Inlet grates inside parking garages are currently required to have much smaller openings than those described herein.

To receive the 25% removal credit, hoods must be used in deep sump catch basins. Hoods also help contain oil spills. MassHighway may install catch basins without hoods provided they are designed, constructed, operated, and maintained in accordance with the Mass Highway Stormwater Handbook.

Install the weep hole above the outlet pipe. Never install the weep hole in the bottom of the catch basin barrel.

Site Constraints

A proponent may not be able to install a deep sump catch basin because of:

- Depth to bedrock;
- High groundwater;
- Presence of utilities; or
- Other site conditions that limit depth of excavation because of stability.

Maintenance

Regular maintenance is essential. Deep sump catch basins remain effective at removing pollutants only if they are cleaned out frequently. One study found that once 50% of the sump volume is filled, the catch basin is not able to retain additional sediments.

Inspect or clean deep sump basins at least four times per year and at the end of the foliage and snow-removal seasons. Sediments must also be removed four times per year or whenever the depth of deposits is greater than or equal to one half the depth from the bottom of the invert of the lowest pipe in the basin. If handling runoff from land uses with higher potential pollutant loads or discharging runoff near or to a critical area, more frequent cleaning may be necessary.

Clamshell buckets are typically used to remove sediment in Massachusetts. However, vacuum trucks are preferable, because they remove more trapped sediment and supernatant than clamshells. Vacuuming is also a speedier process and is less likely to snap the cast iron hood within the deep sump catch basin.

Always consider the safety of the staff cleaning deep sump catch basins. Cleaning a deep sump catch basin within a road with active traffic or even within a parking lot is dangerous, and a police detail may be necessary to safeguard workers.

Although catch basin debris often contains concentrations of oil and hazardous materials such as petroleum hydrocarbons and metals, MassDEP classifies them as solid waste. Unless there is evidence that they have been contaminated by a spill or other means, MassDEP does not routinely require catch basin cleanings to be tested before disposal. Contaminated catch basin cleanings must be evaluated in accordance with the Hazardous Waste Regulations, 310 CMR 30.000, and handled as hazardous waste.

In the absence of evidence of contamination, catch basin cleanings may be taken to a landfill or other facility permitted by MassDEP to accept solid waste, without any prior approval by MassDEP. However, some landfills require catch basin cleanings to be tested before they are accepted.

With prior MassDEP approval, catch basin cleanings may be used as grading and shaping materials at landfills undergoing closure (see Revised Guidelines for Determining Closure Activities at Inactive Unlined Landfill Sites) or as daily cover at active landfills. MassDEP also encourages the beneficial reuse of catch basin cleanings whenever possible. A Beneficial Reuse Determination is required for such use.

MassDEP regulations prohibit landfills from accepting materials that contain free-draining liquids. One way to remove liquids is to use a hydraulic lift truck during cleaning operations so that the material can be decanted at the site. After loading material from several catch basins into a truck, elevate the truck so that any free-draining liquid can flow back into the structure. If there is no free water in the truck, the material may be deemed to be sufficiently dry. Otherwise the catch basin cleanings must undergo a Paint Filter Liquids Test. Go to www. Mass.gov/dep/recycle/laws/cafacts.doc for information on all of the MassDEP requirements pertaining to the disposal of catch basin cleanings.

CDS Guide
Operation, Design, Performance and Maintenance

CDS®

Using patented continuous deflective separation technology, the CDS system screens, separates and traps debris, sediment, and oil and grease from stormwater runoff. The indirect screening capability of the system allows for 100% removal of floatables and neutrally buoyant material without blinding. Flow and screening controls physically separate captured solids, and minimize the re-suspension and release of previously trapped pollutants. Inline units can treat up to 6 cfs, and internally bypass flows in excess of 50 cfs (1416 L/s). Available precast or cast-in-place, offline units can treat flows from 1 to 300 cfs (28.3 to 8495 L/s). The pollutant removal capacity of the CDS system has been proven in lab and field testing.

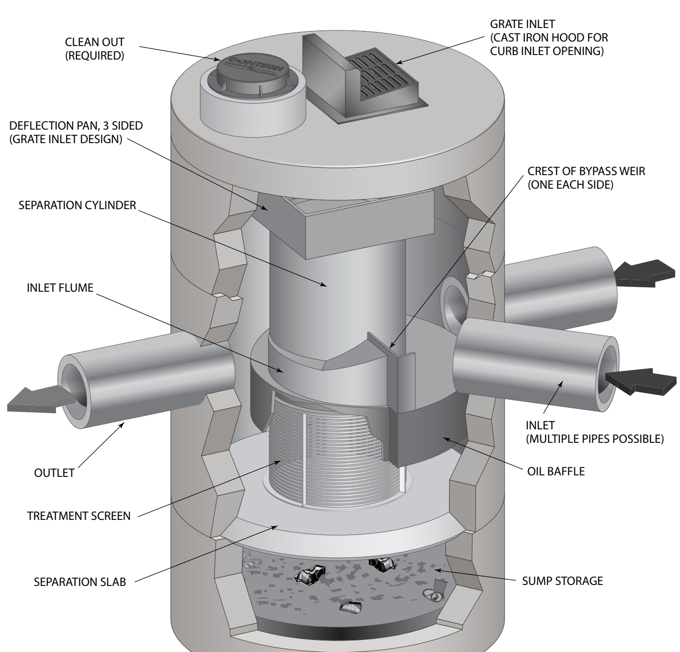
Operation Overview

Stormwater enters the diversion chamber where the diversion weir guides the flow into the unit's separation chamber and pollutants are removed from the flow. All flows up to the system's treatment design capacity enter the separation chamber and are treated.

Swirl concentration and screen deflection force floatables and solids to the center of the separation chamber where 100% of floatables and neutrally buoyant debris larger than the screen apertures are trapped.

Stormwater then moves through the separation screen, under the oil baffle and exits the system. The separation screen remains clog free due to continuous deflection.

During the flow events exceeding the treatment design capacity, the diversion weir bypasses excessive flows around the separation chamber, so captured pollutants are retained in the separation cylinder.



Design Basics

There are three primary methods of sizing a CDS system. The Water Quality Flow Rate Method determines which model size provides the desired removal efficiency at a given flow rate for a defined particle size. The Rational Rainfall Method™ or the and Probabilistic Method is used when a specific removal efficiency of the net annual sediment load is required.

Typically in the Unites States, CDS systems are designed to achieve an 80% annual solids load reduction based on lab generated performance curves for a gradation with an average particle size (d50) of 125 microns (μm). For some regulatory environments, CDS systems can also be designed to achieve an 80% annual solids load reduction based on an average particle size (d50) of 75 microns (μm) or 50 microns (μm).

Water Quality Flow Rate Method

In some cases, regulations require that a specific treatment rate, often referred to as the water quality design flow (WQQ), be treated. This WQQ represents the peak flow rate from either an event with a specific recurrence interval, e.g. the six-month storm, or a water quality depth, e.g. 1/2-inch (13 mm) of rainfall.

The CDS is designed to treat all flows up to the WQQ. At influent rates higher than the WQQ, the diversion weir will direct most flow exceeding the WQQ around the separation chamber. This allows removal efficiency to remain relatively constant in the separation chamber and eliminates the risk of washout during bypass flows regardless of influent flow rates.

Treatment flow rates are defined as the rate at which the CDS will remove a specific gradation of sediment at a specific removal efficiency. Therefore the treatment flow rate is variable, based on the gradation and removal efficiency specified by the design engineer.

Rational Rainfall Method™

Differences in local climate, topography and scale make every site hydraulically unique. It is important to take these factors into consideration when estimating the long-term performance of any stormwater treatment system. The Rational Rainfall Method combines site-specific information with laboratory generated performance data, and local historical precipitation records to estimate removal efficiencies as accurately as possible.

Short duration rain gauge records from across the United States and Canada were analyzed to determine the percent of the total annual rainfall that fell at a range of intensities. US stations' depths were totaled every 15 minutes, or hourly, and recorded in 0.01-inch increments. Depths were recorded hourly with 1-mm resolution at Canadian stations. One trend was consistent at all sites; the vast majority of precipitation fell at low intensities and high intensity storms contributed relatively little to the total annual depth.

These intensities, along with the total drainage area and runoff coefficient for each specific site, are translated into flow rates using the Rational Rainfall Method. Since most sites are relatively small and highly impervious, the Rational Rainfall Method is appropriate. Based on the runoff flow rates calculated for each intensity, operating rates within a proposed CDS system are determined. Performance efficiency curve determined from full scale laboratory tests on defined sediment PSDs is applied to calculate solids removal efficiency. The relative removal efficiency at each operating rate is added to produce a net annual pollutant removal efficiency estimate.

Probabilistic Rational Method

The Probabilistic Rational Method is a sizing program Contech developed to estimate a net annual sediment load reduction for a particular CDS model based on site size, site runoff coefficient, regional rainfall intensity distribution, and anticipated pollutant characteristics.

The Probabilistic Method is an extension of the Rational Method used to estimate peak discharge rates generated by storm events of varying statistical return frequencies (e.g. 2-year storm event). Under the Rational Method, an adjustment factor is used to adjust the runoff coefficient estimated for the 10-year event, correlating a known hydrologic parameter with the target storm event. The rainfall intensities vary depending on the return frequency of the storm event under consideration. In general, these two frequency dependent parameters (rainfall intensity and runoff coefficient) increase as the return frequency increases while the drainage area remains constant.

These intensities, along with the total drainage area and runoff coefficient for each specific site, are translated into flow rates using the Rational Method. Since most sites are relatively small and highly impervious, the Rational Method is appropriate. Based on the runoff flow rates calculated for each intensity, operating rates within a proposed CDS are determined. Performance efficiency curve on defined sediment PSDs is applied to calculate solids removal efficiency. The relative removal efficiency at each operating rate is added to produce a net annual pollutant removal efficiency estimate.

Treatment Flow Rate

The inlet throat area is sized to ensure that the WQQ passes through the separation chamber at a water surface elevation equal to the crest of the diversion weir. The diversion weir bypasses excessive flows around the separation chamber, thus preventing re-suspension or re-entrainment of previously captured particles.

Hydraulic Capacity

The hydraulic capacity of a CDS system is determined by the length and height of the diversion weir and by the maximum allowable head in the system. Typical configurations allow hydraulic capacities of up to ten times the treatment flow rate. The crest of the diversion weir may be lowered and the inlet throat may be widened to increase the capacity of the system at a given water surface elevation. The unit is designed to meet project specific hydraulic requirements.

Performance

Full-Scale Laboratory Test Results

A full-scale CDS system (Model CDS2020-5B) was tested at the facility of University of Florida, Gainesville, FL. This CDS unit was evaluated under controlled laboratory conditions of influent flow rate and addition of sediment.

Two different gradations of silica sand material (UF Sediment & OK-110) were used in the CDS performance evaluation. The particle size distributions (PSDs) of the test materials were analyzed using standard method "Gradation ASTM D-422 "Standard Test Method for Particle-Size Analysis of Soils" by a certified laboratory.

UF Sediment is a mixture of three different products produced by the U.S. Silica Company: "Sil-Co-Sil 106", "#1 DRY" and "20/40 Oil Frac". Particle size distribution analysis shows that the UF Sediment has a very fine gradation (d50 = 20 to 30 μm) covering a wide size range (Coefficient of Uniformity, C averaged at 10.6). In comparison with the hypothetical TSS gradation specified in the NJDEP (New Jersey Department of Environmental Protection) and NJCAT (New Jersey Corporation for Advanced Technology) protocol for lab testing, the UF Sediment covers a similar range of particle size but with a finer d50 (d50 for NJDEP is approximately 50 μm) (NJDEP, 2003).

The OK-110 silica sand is a commercial product of U.S. Silica Sand. The particle size distribution analysis of this material, also included in Figure 1, shows that 99.9% of the OK-110 sand is finer than 250 microns, with a mean particle size (d50) of 106 microns. The PSDs for the test material are shown in Figure 1.

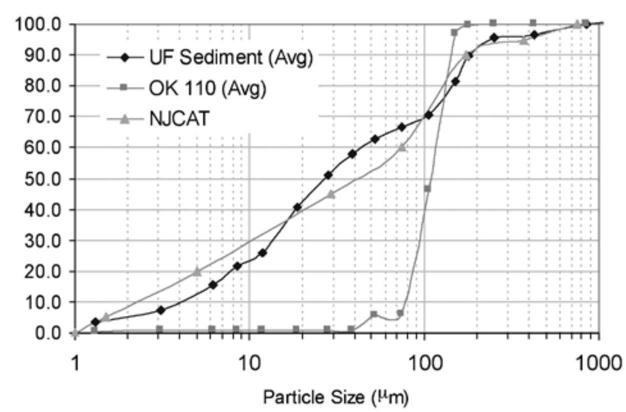


Figure 1. Particle size distributions

Tests were conducted to quantify the performance of a specific CDS unit (1.1 cfs (31.3-L/s) design capacity) at various flow rates, ranging from 1% up to 125% of the treatment design capacity of the unit, using the 2400 micron screen. All tests were conducted with controlled influent concentrations of approximately 200 mg/L. Effluent samples were taken at equal time intervals across the entire duration of each test run. These samples were then processed with a Dekaport Cone sample splitter to obtain representative sub-samples for Suspended Sediment Concentration (SSC) testing using ASTM D3977-97 "Standard Test Methods for Determining Sediment Concentration in Water Samples", and particle size distribution analysis.

Results and Modeling

Based on the data from the University of Florida, a performance model was developed for the CDS system. A regression analysis was used to develop a fitting curve representative of the scattered data points at various design flow rates. This model, which demonstrated good agreement with the laboratory data, can then be used to predict CDS system performance with respect to SSC removal for any particle size gradation, assuming the particles are inorganic sandy-silt. Figure 2 shows CDS predictive performance for two typical particle size gradations (NJCAT gradation and OK-110 sand) as a function of operating rate.

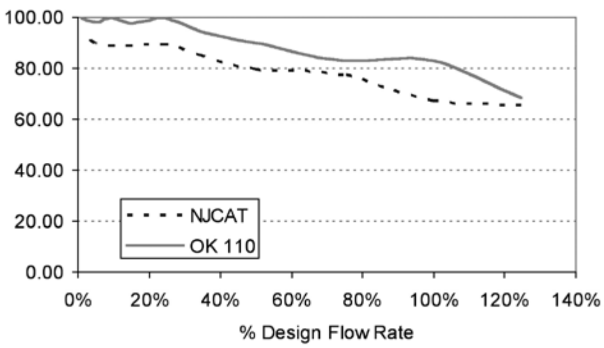


Figure 2. CDS stormwater treatment predictive performance for various particle gradations as a function of operating rate.

Many regulatory jurisdictions set a performance standard for hydrodynamic devices by stating that the devices shall be capable of achieving an 80% removal efficiency for particles having a mean particle size (d50) of 125 microns (e.g. Washington State Department of Ecology — WASDOE - 2008). The model can be used to calculate the expected performance of such a PSD (shown in Figure 3). The model indicates (Figure 4) that the CDS system with 2400 micron screen achieves approximately 80% removal at the design (100%) flow rate, for this particle size distribution (d50 = 125 μm).

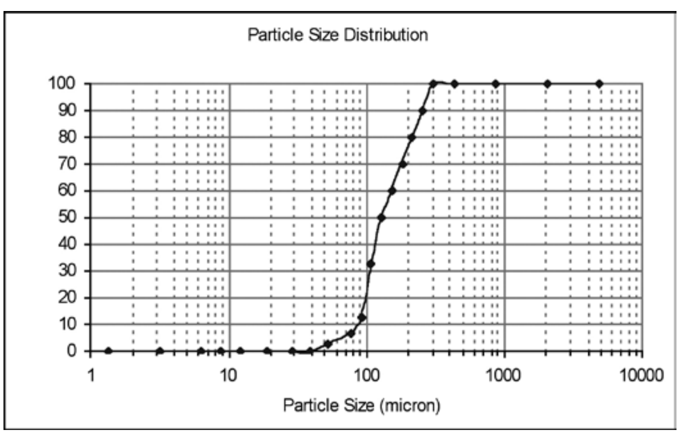


Figure 3. WASDOE PSD

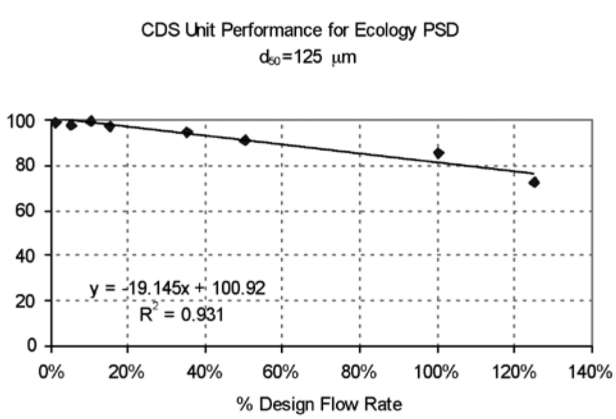


Figure 4. Modeled performance for WASDOE PSD.

Maintenance

The CDS system should be inspected at regular intervals and maintained when necessary to ensure optimum performance. The rate at which the system collects pollutants will depend more heavily on site activities than the size of the unit. For example, unstable soils or heavy winter sanding will cause the grit chamber to fill more quickly but regular sweeping of paved surfaces will slow accumulation.

Inspection

Inspection is the key to effective maintenance and is easily performed. Pollutant transport and deposition may vary from year to year and regular inspections will help ensure that the system is cleaned out at the appropriate time. At a minimum, inspections should be performed twice per year (e.g. spring and fall) however more frequent inspections may be necessary in climates where winter sanding operations may lead to rapid accumulations, or in equipment washdown areas. Installations should also be inspected more frequently where excessive amounts of trash are expected.

The visual inspection should ascertain that the system components are in working order and that there are no blockages or obstructions in the inlet and separation screen. The inspection should also quantify the accumulation of hydrocarbons, trash, and sediment in the system. Measuring pollutant accumulation can be done with a calibrated dipstick, tape measure or other measuring instrument. If absorbent material is used for enhanced removal of hydrocarbons, the level of discoloration of the sorbent material should also be identified

during inspection. It is useful and often required as part of an operating permit to keep a record of each inspection. A simple form for doing so is provided.

Access to the CDS unit is typically achieved through two manhole access covers. One opening allows for inspection and cleanout of the separation chamber (cylinder and screen) and isolated sump. The other allows for inspection and cleanout of sediment captured and retained outside the screen. For deep units, a single manhole access point would allows both sump cleanout and access outside the screen.

The CDS system should be cleaned when the level of sediment has reached 75% of capacity in the isolated sump or when an appreciable level of hydrocarbons and trash has accumulated. If absorbent material is used, it should be replaced when significant discoloration has occurred. Performance will not be impacted until 100% of the sump capacity is exceeded however it is recommended that the system be cleaned prior to that for easier removal of sediment. The level of sediment is easily determined by measuring from finished grade down to the top of the sediment pile. To avoid underestimating the level of sediment in the chamber, the measuring device must be lowered to the top of the sediment pile carefully. Particles at the top of the pile typically offer less resistance to the end of the rod than consolidated particles toward the bottom of the pile. Once this measurement is recorded, it should be compared to the as-built drawing for the unit to determine weather the height of the sediment pile off the bottom of the sump floor exceeds 75% of the total height of isolated sump.

Cleaning

Cleaning of a CDS systems should be done during dry weather conditions when no flow is entering the system. The use of a vacuum truck is generally the most effective and convenient method of removing pollutants from the system. Simply remove the manhole covers and insert the vacuum hose into the sump. The system should be completely drained down and the sump fully evacuated of sediment. The area outside the screen should also be cleaned out if pollutant build-up exists in this area.

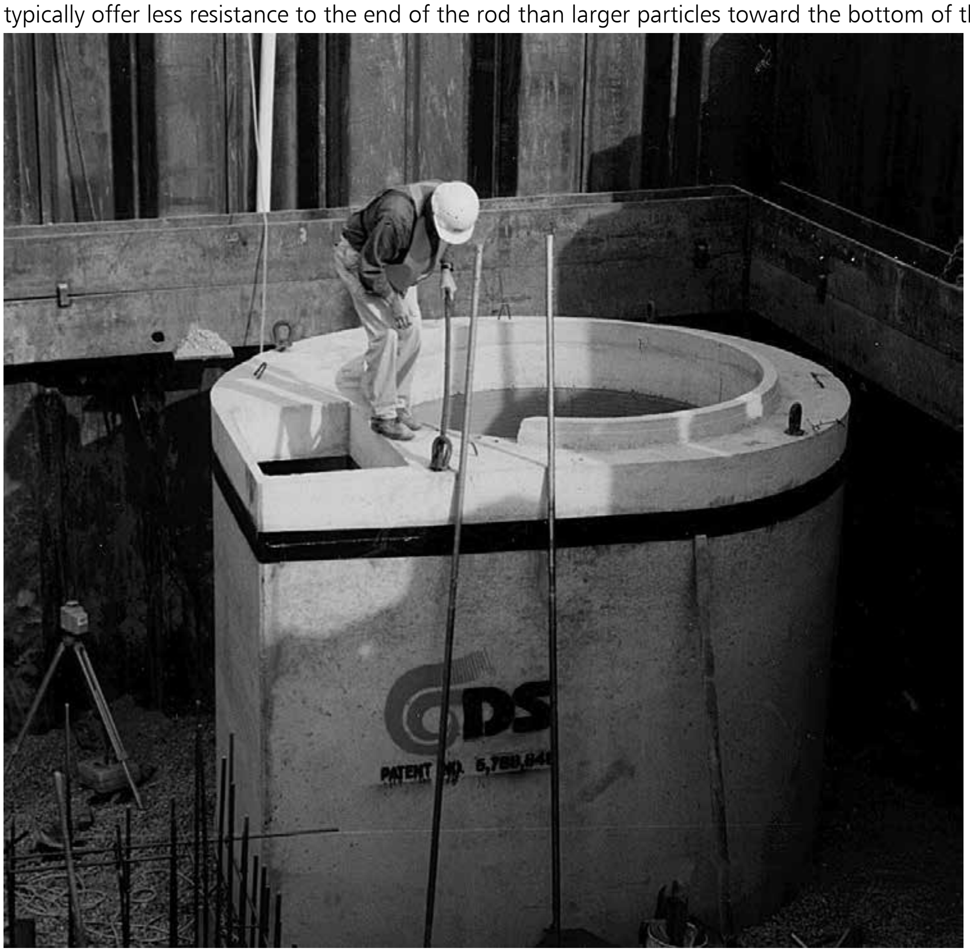
In installations where the risk of petroleum spills is small, liquid contaminants may not accumulate as quickly as sediment. However, the system should be cleaned out immediately in the event of an oil or gasoline spill. Motor oil and other hydrocarbons that accumulate on a more routine basis should be removed when an appreciable layer has been captured. To remove these pollutants, it may be preferable to use absorbent pads since they are usually less expensive to dispose than the oil/water emulsion that may be created by vacuuming the oily layer. Trash and debris can be netted out to separate it from the other pollutants. The screen should be cleaned to ensure it is free of trash and debris.

Manhole covers should be securely seated following cleaning activities to prevent leakage of runoff into the system from above and also to ensure that proper safety precautions have been followed. Confined space entry procedures need to be followed if physical access is required. Disposal of all material removed from the CDS system should be done in accordance with local regulations. In many jurisdictions, disposal of the sediments may be handled in the same manner as the disposal of sediments removed from catch basins or deep sump manholes. Check your local regulations for specific requirements on disposal.

CDS Model	Diameter		Distance from Water Surface to Top of Sediment Pile		Sediment Storage Capacity	
	ft	m	ft	m	y³	m³
CDS1515	3	0.9	3.0	0.9	0.5	0.4
CDS2015	4	1.2	3.0	0.9	0.9	0.7
CDS2015	5	1.5	3.0	0.9	1.3	1.0
CDS2020	5	1.5	3.5	1.1	1.3	1.0
CDS2025	5	1.5	4.0	1.2	1.3	1.0
CDS3020	6	1.8	4.0	1.2	2.1	1.6
CDS3025	6	1.8	4.0	1.2	2.1	1.6
CDS3030	6	1.8	4.6	1.4	2.1	1.6
CDS3035	6	1.8	5.0	1.5	2.1	1.6
CDS4030	8	2.4	4.6	1.4	5.6	4.3
CDS4040	8	2.4	5.7	1.7	5.6	4.3
CDS4045	8	2.4	6.2	1.9	5.6	4.3
CDS5640	10	3.0	6.3	1.9	8.7	6.7
CDS5653	10	3.0	7.7	2.3	8.7	6.7
CDS5668	10	3.0	9.3	2.8	8.7	6.7
CDS5678	10	3.0	10.3	3.1	8.7	6.7

Table 1: CDS Maintenance Indicators and Sediment Storage Capacities

Note: To avoid underestimating the volume of sediment in the chamber, carefully lower the measuring device to the top of the sediment pile. Finer silty particles at the top of the pile may be more difficult to feel with a measuring stick. These finer particles typically offer less resistance to the end of the rod than larger particles toward the bottom of the pile.



CDS Inspection & Maintenance Log

CDS Model: ______________________ Location: ______________________

Date	Water depth to sediment[1]	Floatable Layer Thickness[2]	Describe Maintenance Performed	Maintenance Personnel	Comments

1. The water depth to sediment is determined by taking two measurements with a stadia rod: one measurement from the manhole opening to the top of the sediment pile and the other from the manhole opening to the water surface. If the difference between these measurements is less than the values listed in table 1 the system should be cleaned out. **Note: to avoid underestimating the volume of sediment in the chamber, the measuring device must be carefully lowered to the top of the sediment pile**.

2. For optimum performance, the system should be cleaned out when the floating hydrocarbon layer accumulates to an appreciable thickness. In the event of an oil spill, the system should be cleaned immediately.

SUPPORT

- Drawings and specifications are available at www.ContechES.com.
- Site-specific design support is available from our engineers.

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RECYCLED PAPER

United States Department of Agriculture

NRCS

Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for

Plymouth County, Massachusetts

January 24, 2019

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (https://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?cid=nrcs142p2_053951).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Web Soil Survey, the site for official soil survey information.

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Contents

How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil scientists classified and named the soils in the survey area, they compared the individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Soil Map

Map Scale: 1:917 if printed on A landscape (11" x 8.5") sheet.

Meters: 0, 10, 20, 40, 60

Feet: 0, 40, 80, 160, 240

N

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 1:12,000.

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:
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: Plymouth County, Massachusetts
Survey Area Data: Version 11, Sep 7, 2018

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

Date(s) aerial images were photographed: Aug 26, 2014—Sep 4, 2014

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

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
636B	Montauk-Urban land complex, 0 to 8 percent slopes	1.6	100.0%
Totals for Area of Interest		**1.6**	**100.0%**

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Plymouth County, Massachusetts

636B—Montauk-Urban land complex, 0 to 8 percent slopes

Map Unit Setting

National map unit symbol: 2w7zx
Elevation: 0 to 230 feet
Mean annual precipitation: 36 to 71 inches
Mean annual air temperature: 39 to 55 degrees F
Frost-free period: 145 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition

Montauk and similar soils: 50 percent
Urban land: 40 percent
Minor components: 10 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Montauk

Setting

Landform: Hills, ground moraines, recessionial moraines, drumlins
Landform position (two-dimensional): Backslope, shoulder, summit
Landform position (three-dimensional): Side slope, crest
Down-slope shape: Linear, convex
Across-slope shape: Convex
Parent material: Coarse-loamy over sandy lodgment till derived from gneiss, granite, and/or schist

Typical profile

Ap - 0 to 4 inches: fine sandy loam
Bw1 - 4 to 26 inches: fine sandy loam
Bw2 - 26 to 34 inches: sandy loam
2Cd - 34 to 72 inches: gravelly loamy sand

Properties and qualities

Slope: 0 to 8 percent
Depth to restrictive feature: 20 to 39 inches to densic material
Natural drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately high (0.00 to 1.42 in/hr)
Depth to water table: About 18 to 37 inches
Frequency of flooding: None
Frequency of ponding: None
Salinity, maximum in profile: Nonsaline (0.0 to 1.9 mmhos/cm)
Available water storage in profile: Low (about 5.2 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 2e
Hydrologic Soil Group: C
Hydric soil rating: No

Description of Urban Land

Typical profile

M - 0 to 10 inches: cemented material

Properties and qualities

Slope: 0 to 8 percent
Depth to restrictive feature: 0 inches to manufactured layer
Runoff class: Very high
Capacity of the most limiting layer to transmit water (Ksat): Very low (0.00 to 0.00 in/hr)
Available water storage in profile: Very low (about 0.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 8
Hydrologic Soil Group: D
Hydric soil rating: Unranked

Minor Components

Scituate

Percent of map unit: 5 percent
Landform: Drumlins, hills, ground moraines
Landform position (two-dimensional): Summit, footslope, backslope
Landform position (three-dimensional): Crest, side slope
Down-slope shape: Linear, convex
Across-slope shape: Convex
Hydric soil rating: No

Udorthents, loamy

Percent of map unit: 5 percent
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear
Hydric soil rating: No

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Commonwealth of Massachusetts

______________, Massachusetts

Soil Suitability Assessment for On-site Sewage Disposal

Performed by: Brendan Kling
GRADY CONSULTING, L.L.C.
71 Evergreen Street, Suite 1
Kingston, MA 02364
Phone: (781) 585-2300 Fax: (781) 585-2378

Date: 1/29/19

Witnessed by: LISA CULLITY NO CHARGE : RESCHEDULE

Location Address or Lot #
345 OAK ST
PEMBROKE, MA

*Owner's Name STEVE TOMASI
*Address &
*Telephone # 781-354-7002

New Construction ✓ Repair ___

Office Review

Published Soil Survey Available: No X Yes___
Year Published: ______ Publication Scale: ______ Soil Map Unit: ______
Drainage Class: ______ Soil Limitations: ______

Published Soil Survey Available: No X Yes___
Year Published: ______ Publication Scale: ______
Geologic Material (Map Unit): ______
Landform: ______

Flood Insurance Rate Map:
Above 500 year flood boundary: **No** ___ **Yes** X
Within 500 year flood boundary **No** X **Yes** ___
Within 100 year flood boundary **No** X **Yes** ___

Wetland Area:
National Wetland Inventory Map (map unit): ______
Wetlands Conservancy Program Map (map unit): ______

Current Water Resource Conditions (USGS): **Month:** JANUARY
Range: **Above Normal** ✓ **Normal** ___ **Below Normal** ___

Other References Reviewed: ______

Depth of Naturally Occurring Pervious Material

Does at least four feet of naturally occurring pervious material exist in all areas observed throughout the area proposed for the soil absorption system?

If not, what is the depth of naturally occurring pervious material?

Certification

I certify that I am currently approved by the Department of Environmental Protection pursuant to 310 CMR 15.017 to conduct soil evaluations and that the above analysis has been performed by me consistent with the required training, expertise, and experience described in 310 CMR 15.017. I further certify that the results of my soil evaluation, as indicated on the attached soil evaluation form, are accurate and in accordance with CMR 15.100 through 15.107.

Signature: [signature] Date: 3/20/19

TITLE 5 ON-SITE REVIEW

Deep Hole # 1 **Date** 1/29 **Time** 9:00 AM **Weather** 30° OVERCAST
Location(identify on Site Plan)
Land Use grass **Slope(%)** 1-3 **Surface Stones** N/A
Vegetation grass **Landform**

Distances from: Open Water Body - ft. Possible Wet Area - ft. Drinking Water Well ft.

Drainageway ft. Propertyline 15 ft Other

DEEP OBSERVATION HOLE LOG

Depth From Surface (Inches)	Soil Horizon (USDA	Soil Texture (Munsell)	Soil Color	Soil Mottling	Other: Structures, Stones, Boulders, Consistency, %Gravel
0"-18"	FILL	—		—	—
18-36	B	SILTY LOAM	10 YR 5/6	—	— SOME COARSE SAND
36-108	C	SILTY LOAM	10YR 6/2	48"	TIGHT, 10% STONES
					POCKETS OF SANDY LOAM

Parent Material (geologic) **Depth to Bedrock**
Depth to Groundwater: **Standing Water in Hole:** **Weeping from Pit Face** 74"
Estimated Seasonal High Groundwater 48"

DETERMINATION FOR SEASONAL HIGH WATER TABLE

Method Used:
___ **Depth observed standing in observation hole:** ___ **inches** ✓ **Depth to soil mottles:** 48 **inches**
___ **Depth to weeping from side of observation hole:** ___ **inches** ___ **Groundwater adjustment** ___ **ft**
Index Well # ___ **Reading Date** ___ **Index well level** ___ **Adj.factor** ___ **Adj.Groundwater level** ___

PERCOLATION TEST

Date **Time**

Observation Hole # **Time at 9"**
Depth of Perc **Time at 6"**
Start Presoak **Time (9"-6")**
End Presoak **Rate Min/Inch**

Site Suitability Assessment: **Site Passed** ___ **Site Failed** ___ **Additional Testing Needed:**
Performed By Brendan Kling **Certification #**
Witnessed By Lisa Cullity
Comments:

TITLE 5 ON-SITE REVIEW

Deep Hole # 2 **Date** 1/29 **Time** 915 **Weather** 30°
Location(identify on Site Plan) 2
Land Use Woods **Slope(%)** 3-8 **Surface Stones** —
Vegetation ↑ deciduous **Landform** ____

Distances from: Open Water Body ✓ ft. Possible Wet Area — ft. Drinking Water Well ____ ft.

Drainageway ____ ft. Propertyline 10-15 ft Other ____

DEEP OBSERVATION HOLE LOG

Depth From Surface (Inches)	Soil Horizon (USDA	Soil Texture (Munsell)	Soil Color	Soil Mottling	Other: Structures, Stones, Boulders, Consistency,%Gravel
0"-18"	FILL	—			
18"-50"	B	LOAM	10YR 5/6	—	
50"-120"	C	SANDY LOAM	10YR 6/2	60"	15% STONES

Parent Material (geologic) ____ **Depth to Bedrock** ____
Depth to Groundwater: **Standing Water in Hole:** 120" **Weeping from Pit Face** ____
Estimated Seasonal High Groundwater 60"

DETERMINATION FOR SEASONAL HIGH WATER TABLE

Method Used:
___ **Depth observed standing in observation hole:** ____ **inches** ✓ **Depth to soil mottles:** 60 **inches**
___ **Depth to weeping from side of observation hole:** ____ **inches** ____ **Groundwater adjustment** ____ **ft**
Index Well # ____ **Reading Date** ____ **Index well level** ____ **Adj.factor** ____ **Adj.Groundwater level** ____

PERCOLATION TEST **Date** 1/29 **Time** 11:00

Observation Hole #	2		**Time at 9"**		
Depth of Perc	54"		**Time at 6"**		
Start Presoak	11:12		**Time (9"-6")**		
End Presoak	11:27		**Rate Min/Inch**		

Site Suitability Assessment: **Site Passed** ____ **Site Failed** ____ **Additional Testing Needed:**
Performed By Brendan Kling **Certification #** ____
Witnessed By Lisa
Comments: PERC AFTER LISA LEFT

10.75" @ 12:30

TITLE 5 ON-SITE REVIEW

Deep Hole # 3 **Date** 1/29 **Time** 930 **Weather** 30°

Location(identify on Site Plan) #3

Land Use grass **Slope(%)** 1-3 **Surface Stones** —

Vegetation grass **Landform** ____

Distances from: Open Water Body — ft. Possible Wet Area — ft. Drinking Water Well ____ ft.

Drainageway ____ ft. Propertyline 10-15 ft Other ____

DEEP OBSERVATION HOLE LOG

Depth From Surface (Inches)	Soil Horizon (USDA	Soil Texture (Munsell)	Soil Color	Soil Mottling	Other: Structures, Stones, Boulders, Consistency,%Gravel
0"-50"	Fill		10YR5/1		
50"-78"	C	Silty Loam	7.5YR 6/2	50"	

Parent Material (geologic) ____ **Depth to Bedrock** —

Depth to Groundwater: **Standing Water in Hole:** 72" **Weeping from Pit Face** 55"

Estimated Seasonal High Groundwater 50"

DETERMINATION FOR SEASONAL HIGH WATER TABLE

Method Used:

___ **Depth observed standing in observation hole:** ____ **inches** ✓ **Depth to soil mottles:** 50 **inches**

___ **Depth to weeping from side of observation hole:** ____ **inches** ____ **Groundwater adjustment** ____ **ft**

Index Well # ____ **Reading Date** ____ **Index well level** ____ **Adj.factor** ____ **Adj.Groundwater level** ____

PERCOLATION TEST **Date** ____ **Time** ____

Observation Hole #			**Time at 9"**		
Depth of Perc			**Time at 6"**		
Start Presoak			**Time (9"-6")**		
End Presoak			**Rate Min/Inch**		

Site Suitability Assessment: **Site Passed** ____ **Site Failed** ____ **Additional Testing Needed:**

Performed By Brendan Kling **Certification #** ____

Witnessed By Lisa Cullity

Comments:

TITLE 5 ON-SITE REVIEW

Deep Hole # 4 Date 1/29 Time 11:30 Weather 30°

Location(identify on Site Plan)______

Land Use Woods Slope(%) 3-8 Surface Stones —

Vegetation ↑ Landform ______

Distances from: Open Water Body — ft. Possible Wet Area — ft. Drinking Water Well____ft.

Drainageway____ft. Propertyline 10-15 ft Other______

DEEP OBSERVATION HOLE LOG

Depth From Surface (Inches)	Soil Horizon (USDA	Soil Texture (Munsell)	Soil Color	Soil Mottling	Other: Structures, Stones, Boulders, Consistency,%Gravel
0-18	FILL			—	
18"-42"	B	SANDY LOAM		—	
42-60	C	SANDY LOAM		48"	15% STONES

Parent Material (geologic)______ **Depth to Bedrock**______

Depth to Groundwater: **Standing Water in Hole:** 54" **Weeping from Pit Face**____

Estimated Seasonal High Groundwater 48"

DETERMINATION FOR SEASONAL HIGH WATER TABLE

Method Used:

___ **Depth observed standing in observation hole:** ____**inches** ✓ **Depth to soil mottles:** 48 **inches**

___ **Depth to weeping from side of observation hole:**____**inches** ____ **Groundwater adjustment**____**ft**

Index Well #____ **Reading Date**____ **Index well level**____ **Adj.factor**____ **Adj.Groundwater level**____

PERCOLATION TEST **Date**______ **Time**______

Observation Hole #			**Time at 9"**		
Depth of Perc			**Time at 6"**		
Start Presoak			**Time (9"-6")**		
End Presoak			**Rate Min/Inch**		

Site Suitability Assessment: **Site Passed**____ **Site Failed**____ **Additional Testing Needed:**

Performed By Brendan Kling **Certification #**______

Witnessed By —

Comments:

TITLE 5 ON-SITE REVIEW

Deep Hole # 5 **Date** 1/29 **Time** 11:45 **Weather** 30°

Location(identify on Site Plan)

Land Use **Slope(%)** 3-8 **Surface Stones**

Vegetation **Landform**

Distances from: Open Water Body – ft. Possible Wet Area – ft. Drinking Water Well ft.

Drainageway ft. Propertyline 20 ft Other

DEEP OBSERVATION HOLE LOG

Depth From Surface (Inches)	Soil Horizon (USDA	Soil Texture (Munsell)	Soil Color	Soil Mottling	Other: Structures, Stones, Boulders, Consistency,%Gravel
0-18	Fill	–			
18"-36"	B				
36"-66"	C	Sandy Loam		40"	20% Stones

Parent Material (geologic) **Depth to Bedrock**

Depth to Groundwater: **Standing Water in Hole:** **Weeping from Pit Face** 48"

Estimated Seasonal High Groundwater 40"

DETERMINATION FOR SEASONAL HIGH WATER TABLE

Method Used:

___ **Depth observed standing in observation hole:** ___ **inches** ✓ **Depth to soil mottles:** 40 **inches**

___ **Depth to weeping from side of observation hole:** ___ **inches** ___ **Groundwater adjustment** ___ **ft**

Index Well # ___ **Reading Date** ___ **Index well level** ___ **Adj.factor** ___ **Adj.Groundwater level** ___

PERCOLATION TEST **Date** **Time**

Observation Hole #			**Time at 9"**		
Depth of Perc			**Time at 6"**		
Start Presoak			**Time (9"-6")**		
End Presoak			**Rate Min/Inch**		

(15 min)

Site Suitability Assessment: **Site Passed** ___ **Site Failed** ___ **Additional Testing Needed:**

Performed By Brendan Kling **Certification #**

Witnessed By –

Comments:

TITLE 5 ON-SITE REVIEW

Deep Hole # 6 **Date** 1/29 **Time** 12:00 **Weather** 31°

Location(identify on Site Plan)

Land Use grass **Slope(%)** 1-3 **Surface Stones** –

Vegetation tall brush / thorns **Landform**

Distances from: Open Water Body – ft. Possible Wet Area – ft. Drinking Water Well ___ ft.

Drainageway ___ ft. Propertyline ≈20' ft Other ___

DEEP OBSERVATION HOLE LOG

Depth From Surface (Inches)	Soil Horizon (USDA	Soil Texture (Munsell)	Soil Color	Soil Mottling	Other: Structures, Stones, Boulders, Consistency,%Gravel
0"-42"	FILL				
42"-60"	C	SANDY LOAM		48"	20% Stones
					Some Boulders

Parent Material (geologic) ___ **Depth to Bedrock** ___

Depth to Groundwater: **Standing Water in Hole:** ___ **Weeping from Pit Face** ___

Estimated Seasonal High Groundwater ___

DETERMINATION FOR SEASONAL HIGH WATER TABLE

Method Used:

___ **Depth observed standing in observation hole:** ___ **inches** ✓ **Depth to soil mottles:** 48 **inches**

___ **Depth to weeping from side of observation hole:** ___ **inches** ___ **Groundwater adjustment** ___ **ft**

Index Well # ___ **Reading Date** ___ **Index well level** ___ **Adj.factor** ___ **Adj.Groundwater level** ___

PERCOLATION TEST **Date** ___ **Time** ___

Observation Hole #			**Time at 9"**		
Depth of Perc			**Time at 6"**		
Start Presoak			**Time (9"-6")**		
End Presoak			**Rate Min/Inch**		

Site Suitability Assessment: **Site Passed** ___ **Site Failed** ___ **Additional Testing Needed:**

Performed By Brendan Kling **Certification #** ___

Witnessed By –

Comments:

TITLE 5 ON-SITE REVIEW

Deep Hole # 7 **Date** 3-20-19 **Time** 8:30 AM **Weather** Sunny - 45°
Location(identify on Site Plan)
Land Use Wood **Slope(%)** 1-5% **Surface Stones** —
Vegetation oaks **Landform**

Distances from: Open Water Body 100+ ft. Possible Wet Area — ft. Drinking Water Well — ft.

Drainageway 50+ ft. Propertyline 15-20 ft Other

DEEP OBSERVATION HOLE LOG

Depth From Surface (Inches)	Soil Horizon (USDA	Soil Texture (Munsell)	Soil Color	Soil Mottling	Other: Structures, Stones, Boulders, Consistency,%Gravel
0-18	A	Fill	7.5YR 3/2		
18-48	B	Silty Loam	7.5YR 4/4		
48-84	C1	Silty Loam	7.5YR 5/3	60"	
84-150	C2	Sandy Loam	7.5YR 6/2		

Parent Material (geologic) **Depth to Bedrock**
Depth to Groundwater: **Standing Water in Hole:** 144 **Weeping from Pit Face**
Estimated Seasonal High Groundwater 60"

DETERMINATION FOR SEASONAL HIGH WATER TABLE

Method Used:
___ **Depth observed standing in observation hole:** 144 **inches** ✓ **Depth to soil mottles:** 60 **inches**
___ **Depth to weeping from side of observation hole:** ___ **inches** ___ **Groundwater adjustment** ___ **ft**
Index Well # ___ **Reading Date** ___ **Index well level** ___ **Adj.factor** ___ **Adj.Groundwater level** ___

PERCOLATION TEST **Date** **Time**

Observation Hole #	7	8	**Time at 9"**	10:41	10:42
Depth of Perc	84"-102"		**Time at 6"**	11:40	11:39
Start Presoak	9:02	9:10	**Time (9"-6")**	59 min	57 min
End Presoak	9:17	9:25	**Rate Min/Inch**	20	20

Site Suitability Assessment: **Site Passed** ✓ **Site Failed** ___ **Additional Testing Needed:**
Performed By Brendan Kling **Certification #**
Witnessed By Lisa Cullity
Comments:

Back filled w/ perc sand

TECHNICAL NOTE

Pipe Flotation

TN 5.05
March 2016

Introduction

The light weight of high density polyethylene (HDPE) and polypropylene (PP) pipe make it desirable because of the ease of handling and installation but this same benefit also makes these thermoplastic pipes prone to flotation. All pipe products, such as concrete and corrugated metal, are prone to flotation under the right circumstances. In fact, all pipe materials and other buried structures are subject to flotation. When the uplift on the pipe or structure exceeds the downward force of the weight and load it carries, the pipe (or structure) will rise or heave. Where flotation is a possibility, proper installation and/or anchoring of the pipe is critical. This document provides an analysis on minimum cover heights required to prevent pipe flotation for thermoplastic pipe sizes 12”-60”. Buoyant force due to flowable fill is also discussed.

Hydrostatic Uplift Due to a High Water Table

Buoyancy becomes an issue in buried pipe when the groundwater encroaches into the pipe zone. For projects where a high groundwater table or water surrounding the pipe is expected, precautions should be taken to prevent the floatation of thermoplastic pipe. The vertical hydrostatic uplift force, due to the water table, must be balanced by the soil overburden and the weight of the pipe in order to prevent flotation of the pipe. The vertical hydrostatic uplift force, U, can be calculated from Equation 1 below:

$$U = \frac{\pi}{4} D^2 \delta_w \qquad (1)$$

where U = lb/linear ft of pipe
D = O.D. of the pipe in question, ft.
δ_w = unit weight of water = 62.4 lb/ft^3

Soil loads experienced by a pipe at varying water table depths (W_{soil}) can be calculated from Equation 2. Figure 1 illustrates each of the three cases seen in field installations where buoyancy becomes a concern, and also clarifies all of the parameters contained within Equation 2.

$$W_{soil} = \delta_{dry} H_{dry} D + (\delta_{sat} - \delta_w)(H_{sub} + 0.1073D)D \quad (2)$$

where W_{soil} = weight of soil overburden, lb/linear ft of pipe
δ_{dry} = dry unit weight of the soil, lb/ft^3
H_{dry} = depth of dry soil, ft.
H_{sub} = depth of submerged soil over top of pipe, ft.
δ_{sat} = saturated unit weight of the soil, lb/ft^3
$\delta_{sat} - \delta_w$ = submerged unit weight of the soil, lb/ft^3

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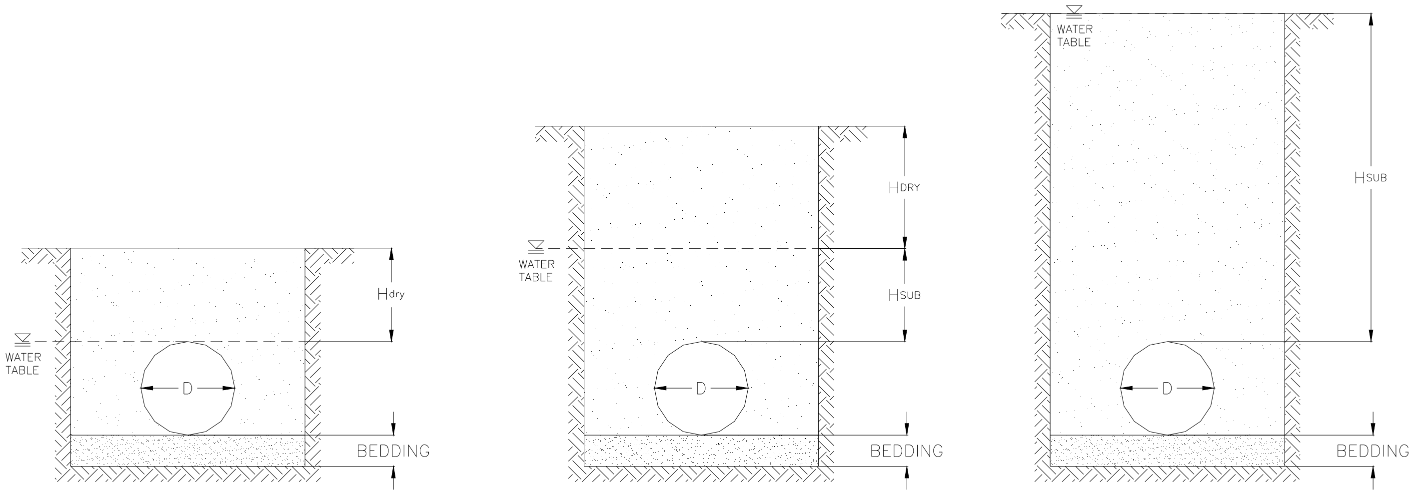
Figure 1
Installation Conditions for Possible Flotation of Thermoplastic Pipe



(a) Water table at pipe crown

(b) Water table exceeds pipe crown elevation

(c) Water table is at ground surface

The typical weights (W_{pipe}) and average outside diameters are shown in Table 1.

Table 1
Approximate Weights of ADS Thermoplastic Pipe

Nominal Diameter in. (mm)	Nominal OD in. (mm)	Dual Wall Pipe Weight lb/ft (kg/m)	Triple Wall Pipe Weight lb/ft (kg/m)
4 (100)	4.6 (117)	0.44 (0.6)	N/A
6 (150)	7.0 (178)	0.85 (1.3)	N/A
8 (200)	9.5 (241)	1.5 (2.2)	N/A
10 (250)	12 (305)	2.1 (3.1)	N/A
12 (300)	14.5 (368)	3.2 (4.7)	N/A
15 (375)	18 (457)	4.6 (6.8)	N/A
18 (450)	22 (559)	6.4 (9.5)	N/A
24 (600)	28 (711)	11.0 (16.4)	N/A
30 (750)	36 (914)	15.4 (22.9)	20.7 (30.8)
36 (900)	42 (1067)	19.8 (29.4)	24.2 (36.0)
42 (1050)	48 (1219)	26.4 (39.3)	31.9 (47.5)
48 (1200)	54 (1372)	31.3 (46.6)	41.8 (62.3)
60 (1500)	67 (1702)	45.2 (67.3)	55.0 (81.9)

N/A indicates the pipe is not available in the respective diameter

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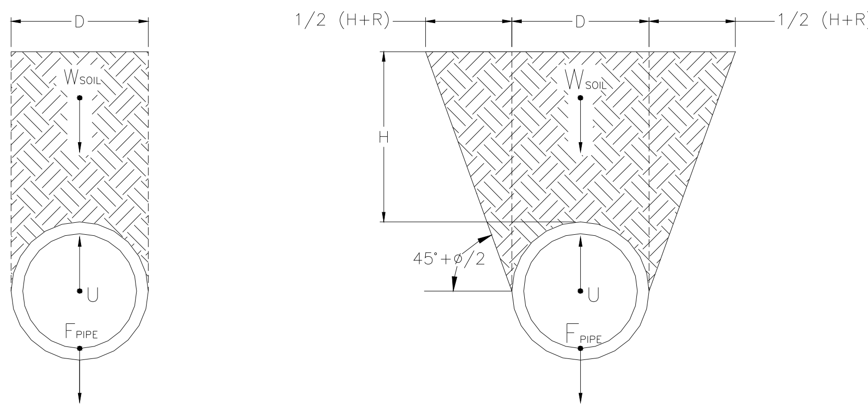
The minimum depth of cover (H) required to resist uplift can be calculated by equating the sum of the downward forces to the sum of the upward or buoyant forces. While there are varying methods to account for soil load distribution on the pipe, for conservative minimum cover requirements, the soil load is assumed to be the soil column directly above the outside diameter of the pipe as illustrated in Figure 2(a). Therefore, minimum cover is calculated using Equations 3 and 4 below:

$$U \leq W_{Soil} + W_{Pipe} \qquad (3)$$

where W_{pipe} = weight of the pipe, lb/linear ft of pipe

$$H = H_{dry} + H_{sub} \qquad (4)$$

Figure 2
Forces Affecting Flotation



(a) Soil Column Loading Conditions (b) Prism Loading Conditions

Table 2
Minimum Recommended Cover to Prevent Flotation of ADS Thermoplastic Pipe

Nominal Diameter in. (mm)	**Minimum Cover** in. (mm)
4 (100)	3 (77)
6 (150)	4 (102)
8 (200)	5 (127)
10 (250)	7 (178)
12 (300)	9 (228)
15 (375)	11 (280)
18 (450)	13 (330)
24 (600)	17 (432)
30 (750)	22 (559)
36 (900)	25 (635)
42 (1050)	29 (737)
48 (1200)	33 (838)
60 (1500)	40 (1016)

Calculation Notes:

1. The pipe is assumed to be empty. This not only simplifies the calculations but creates a condition that would encourage flotation. Unless the system is constructed to be watertight, this condition would not likely be found in an actual installation.
2. The outside diameter of the corrugated pipe was used to determine soil and water displacement.
3. Saturated soil density used was 130 pcf which is typical for many saturated soil mixtures. Soils of greater densities will reduce the chance of flotation.
4. The water table was assumed to be at the ground surface, as illustrated in Figure 1(c), simulating a fully saturated soil. This assumption creates a "worst case" condition to yield more conservative results.
5. The soil load prism shown in Figure 2(a) was used to determine soil weight.
6. For structural purposes, a minimum cover of 12" (0.3m) shall apply for 4"-48" (100-1200mm) pipe, and 24" (0.6m) for 60" (1500mm) pipe.

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<u>Example 1</u>: *Calculate the minimum depth of cover required to prevent 48” N-12 HDPE from floating when the water table is at the top of grade. The dry and saturated unit weights of the soil are 110 lb/ft^3 and 130 lb/ft^3, respectively.*

Solution: $U \leq W_{Soil} + W_{Pipe}$

W_{pipe} = 32.0 lb/ft (from Table 1)

$$U = \frac{\pi}{4}(4.5)^2(62.4) = 992.4 \text{ lb/ft}$$

The water table is at top of grade, so Figure 1(c) applies. Since H_{dry}=0, the first term in Equation 2 is eliminated:

Therefore, $W_{soil} = (130 - 62.4)[H_{sub} + (0.1073)(4.5)](4.5) + 32 = 304.2\ H_{sub} + 146.9 + 32$

Equation 3 then yields: $992.4 = 304.2\ H_{sub} + 178.9$

$\therefore\ H_{sub}$ = 2.67’ = 32.1” (use 33”)

Finally, calculate minimum cover from Equation 4: **$H = H_{sub}$ = <u>33</u>”**

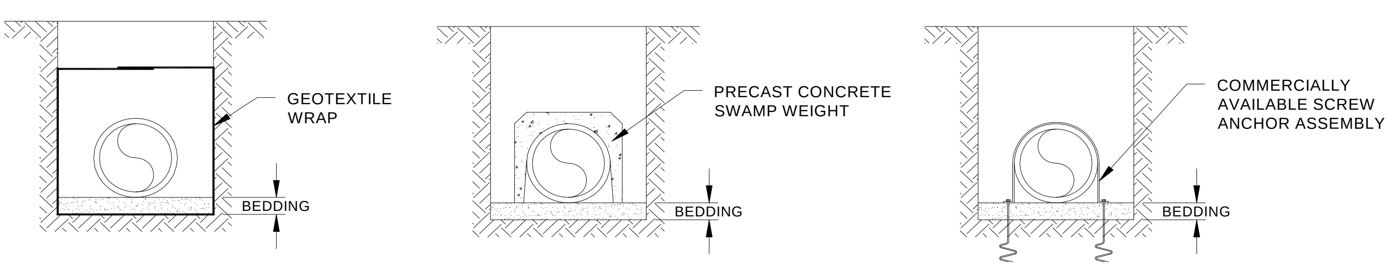
The above calculations are conservative. The angle of internal friction of the soil, ϕ, and the coefficient of lateral earth stress, K_o, are not accounted for in the above equations. These parameters are best left to the geotechnical engineer. If these parameters are added to the above calculations, the depth of cover required would be reduced.

Anchoring Systems

In many instances pipe flotation may simply be addressed with adequate cover. In those situations where adequate cover cannot be achieved, there are a number of acceptable alternate methods for restraining the pipe. Several examples are shown in Figure 3.

Due to the variations in in-situ soil densities, water table heights, and the restraining force of the anchors, the Engineer should evaluate the project-specific conditions to determine the required anchor type and spacing to prevent flotation. The maximum spacing between anchor supports should not exceed 10 feet. In this manner, pipe is supported at each joint and at the midpoint of each length of pipe to ensure adequate stabilization.

Figure 3
Pipe Stabilizing Alternatives



(a) Geotextile wrap (b) Concrete collar (c) Screw anchor

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Uplift Due to Flowable Fill Backfill

Flowable fill, also known as controlled low strength material (CLSM), controlled density fill (CDF), and slurry fill, is utilized as an alternate to compacted granular fill. Flowable fill typically consists of Portland Cement, sand, water, and fly ash. Uplift due to CLSM backfill can be calculated from Equation 5.

$$U = \frac{A_{disp}\delta_{FF}}{144} \qquad (5)$$

Where, A_{disp} = Area of pipe displaced by flowable fill, in^2
δ_{FF} = Unit weight of flowable fill, lb/ft^3
U = Uplift due to flowable fill backfill, lb/ft

Due to the vast differences in the unit weights between water and flowable fill, uplift caused by flowable fill can be greater than two times that of hydrostatic uplift. When backfilling with flowable fill, the pipe will float in the absence of soil overburden, since the weight of the pipe will not offset the vertical uplift. Precautions must be taken to ensure the pipe remains on its intended alignment and grade. This is commonly done by anchoring the pipe in place or placing the flowable fill in incremental lifts. Refer to Technical Note 5.02: Flowable Fill Backfill for Thermoplastic Pipe for common anchoring methods and additional technical information related to placing flowable fill as backfill.

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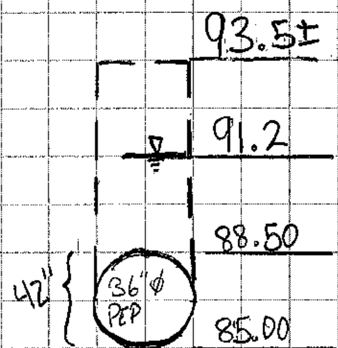
JOB 18-365: 345 OAK ST, PEMBROKE
SHEET ____ OF ____ SCALE: ____
CALCULATED BY: BK DATE: 8-14-19
CHECKED BY: ____ DATE: ____

BUOYANCY FOR 36"Ø PEP PIPE, 10' SECTION @ T.H 6



DENSITY: WATER = 62.4 pcf
CONCRETE = 150 pcf
SOIL (ASSUMED) = 85 pcf

36" INNER DIAMETER = 42" OUTER

APPROX PIPE WEIGHT = 19.8 lb/ft

U: BUOYANCY FORCE

$U = \frac{\pi}{4} D^2 \delta_w$ WHERE D = O.D. OF PIPE, δ_w = DENSITY OF WATER

$W_s = H D \delta_s$ WHERE H = DEPTH TO TOP OF PIPE, D = O.D. PIPE, δ_s = DENSITY OF SOIL

W_s: WEIGHT OF SOIL
W_p: WEIGHT OF PIPE = 19.8 lb/ft

$U = \frac{\pi}{4} \cdot (3.5')^2 \cdot 62.4 \frac{lb}{ft^3} = 601\ lb/ft$ ↑

$W_p = 19.8\ lb/ft$

$W_s = (93.5 - 88.5)'(3.5')(85\ lb/ft^3) = 1488\ lb/ft$

601 lb/ft ↑
1507 lb/ft ↓

PIPES WILL NOT FLOAT

MIN. COVER

$U = W_p + W_s$

$601\ lb/ft = H \cdot (3.5') \cdot (85\ lb/ft^3) + 19.8\ lb/ft$

$H = 1.95'$ OR 24"

USE: 2.5' OR 30"