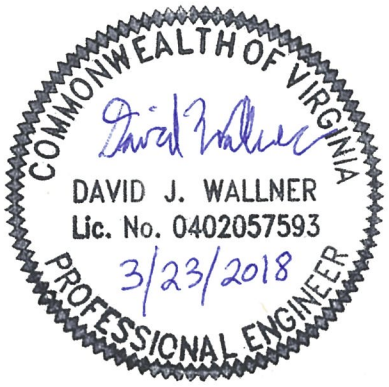
By virtue of this seal and signature, all supporting documents included in this package are accurate and support the design presented herein.



Water Bar 1.1 Site Specific Analysis

I. Drainage Area

As shown, the drainage area to Water Bar 1.1 is 2.17 Acres. This is greater than the 1.5 acre-maximum in the MVP 17.3 Water Bar End Treatment Detail and, therefore, requires a site-specific analysis to determine the water bar end treatment length.

II. Runoff Coefficient

The flowpath for Water Bar 1.1 begins as sheet flow in a HSG B wooded area with slopes greater than 6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.15.

The flowpath exiting the Water Bar 1.1 end treatment will be along HSG B meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.19.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration (T_c)

As shown, the time of concentration of Water Bar 1.1 is 19 minutes.

Equation	Reference
$T_{t(sheet)} = 0.225*L_{sheet}^{0.42}*s^{-0.19}*C^{-1.0}$	Seelye Method for calculating overland flow time (VDOT's preferred method, described in Appendix 6D-1 of the VDOT Drainage Manual)
$V_{unpaved} = 16.1345*s^{0.5}$	Equation for average velocity for "Unpaved" surface condition from TR-55, Appendix F
$V_{paved} = 20.3282*s^{0.5}$	Equation for average velocity for "Paved" surface condition from TR-55, Appendix F
$T_{t(shallow)} = L_{shallow}/(3600*V_{unpaved/paved})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for shallow concentrated flow)
$r = a/p_w$	Definition of hydraulic radius (r), which is equal to the cross sectional flow area (a) divided by the wetted perimeter (p_w)
$V_{channel} = (1.49*r^{2/3}*s^{1/2})/n$	Equation 3-4 (Manning's Equation) from TR-55, Chapter 3
$T_{t(channel)} = L_{channel}/(3600*V_{channel})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for channel flow)
$T_c = T_{t(sheet)} + T_{t(shallow)} + T_{t(channel)}$	Equation 3-2 for time of concentration from TR-55, Chapter 3

Sheet Flow

ID	Description	[1]Rational Method Runoff Coefficient, C	[2]Flow Length, L_{sheet} (ft)	Land Slope, s (ft/ft)	Travel Time, $T_{t(sheet)}$ (hr)
AB	Sheet Flow	0.15	100.0	0.130	0.255

Shallow Concentrated Flow

ID	Description	Paved/Unpaved	[3]Flow Length, $L_{shallow}$ (ft)	[4]Watercourse Slope, s (ft/ft)	Average Velocity, $V_{unpaved/paved}$ (ft/s)	Travel Time, $T_{t(shallow)}$ (hr)
BC	Downslope	Unpaved	1438.0	0.200	7.22	0.055
CD	Waterbar	Unpaved	25.0	0.050	3.61	0.002

Channel Flow

ID	Description	[5]Manning's n	[6]Cross Sectional Flow Area, a (sf)	[6]Wetted Perimeter, p_w (ft)	Hydraulic Radius, r (ft)	Flow Length, $L_{channel}$ (ft)	Channel Slope, s (ft/ft)	Average Velocity, $V_{channel}$ (ft/s)	Travel Time, $T_{t(channel)}$ (hr)
								T_c (hr) =	0.312
								T_c (min) =	19

[1] Selected appropriate Rational Method runoff coefficient (C) from Table 4-5b in the Virginia Stormwater Management Handbook

[2] Assume a maximum sheet flow length of 100-ft per PS&S

[3] Assume a maximum shallow concentrated flow length of 1,000-ft in Franklin County and Roanoke County per the PS&S

[4] For waterbars, assume a channel slope of 5% (i.e., the maximum slope per General Detail MVP-17) to be conservative

[5] Assume n=0.03 for all natural/man-made channels to be conservative

[6] Assume bank-full elevation per TR-55

IV. Summary

As shown, the water bar end treatment calculator indicates a 16 foot long end treatment will ensure sheet flow conditions leaving Water Bar 1.1. For ease of construction, a water bar end treatment length of 20 feet will be used for Water Bar 1.1.

End Treatment Length Calculator				
Enter Site Specific Data	Tc =	19	time of concentration to water bar, min	
	A =	2.17	water bar drainage area, ac	
	S =	0.200	weir discharge overland slope, ft/ft	
Computed	i =	4.2	computed from IDF, in/hr	
Enter Flow Parameters	C =	0.19	assumes >6% slope, meadow (conservative)	
	Cw =	3.33	weir coefficient (rectangular)	
	n =	0.24	sheetflow, dense grasses	
	H =	0.1	sheetflow depth over weir, ft	
Computed Weir Length ------>			**16 ft**	
Velocity Check ------>			**0.60 fps**	

Water Bar 1.2 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 1.2 is 0.3 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 1.2 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 1.2 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 5 foot long end treatment will ensure sheet flow conditions leaving Water Bar 1.2. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 1.2.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.30	water bar drainage area, ac
	S =	0.530	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **5 ft**

Velocity Check ------> **0.97 fps**

Water Bar 2 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 2 is 0.07 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 2 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 2 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 1 foot long end treatment will ensure sheet flow conditions leaving Water Bar 2. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 2.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.07	water bar drainage area, ac
	S =	0.435	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **1 ft**

Velocity Check ------> **0.88 fps**

Water Bar 3 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 3 is 0.09 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 3 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 3 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 1 foot long end treatment will ensure sheet flow conditions leaving Water Bar 3. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 3.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.09	water bar drainage area, ac
	S =	0.476	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **1 ft**

Velocity Check ------> **0.92 fps**

Water Bar 4 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 4 is 0.26 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 4 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 4 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 4 foot long end treatment will ensure sheet flow conditions leaving Water Bar 4. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 4.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.26	water bar drainage area, ac
	S =	0.364	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **4 ft**

Velocity Check ------> **0.81 fps**

Water Bar 5 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 5 is 0.14 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 5 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 5 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 2 foot long end treatment will ensure sheet flow conditions leaving Water Bar 5. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 5.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.14	water bar drainage area, ac
	S =	0.260	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **2 ft**

Velocity Check ------> **0.68 fps**

Water Bar 6 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 6 is 1.79 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area.Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath for Water Bar 6 begins as sheet flow in a HSG B wooded area with slopes greater than 6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.15.

The flowpath exiting the Water Bar 6 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration (T_c)

As shown, the time of concentration of Water Bar 6 is 16 minutes.

Equation	Reference
$T_{t(sheet)} = 0.225*L_{sheet}^{0.42}*s^{-0.19}*C^{-1.0}$	Seelye Method for calculating overland flow time (VDOT's preferred method, described in Appendix 6D-1 of the VDOT Drainage Manual)
$V_{unpaved} = 16.1345*s^{0.5}$	Equation for average velocity for "Unpaved" surface condition from TR-55, Appendix F
$V_{paved} = 20.3282*s^{0.5}$	Equation for average velocity for "Paved" surface condition from TR-55, Appendix F
$T_{t(shallow)} = L_{shallow}/(3600*V_{unpaved/paved}$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for shallow concentrated flow)
$r = a/p_w$	Definition of hydraulic radius (r), which is equal to the cross sectional flow area (a) divided by the wetted perimeter (p_w)
$V_{channel} = (1.49*r^{2/3}*s^{1/2})/n$	Equation 3-4 (Manning's Equation) from TR-55, Chapter 3
$T_{t(channel)} = L_{channel}/(3600*V_{channel})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for channel flow)
$T_c = T_{t(sheet)} + T_{t(shallow)} + T_{t(channel)}$	Equation 3-2 for time of concentration from TR-55, Chapter 3

Sheet Flow

ID	Description	[1]Rational Method Runoff Coefficient, C				[2]Flow Length, L_{sheet} (ft)	Land Slope, s (ft/ft)		Travel Time, $T_{t(sheet)}$ (hr)
AB	Sheet Flow	0.15				100.0	0.260		0.223

Shallow Concentrated Flow

ID	Description	Paved/Unpaved				[3]Flow Length, $L_{shallow}$ (ft)	[4]Watercourse Slope, s (ft/ft)	Average Velocity, $V_{unpaved/paved}$ (ft/s)	Travel Time, $T_{t(shallow)}$ (hr)
BC	Downslope	Unpaved				853.0	0.225	7.65	0.031
CD	Waterbar	Unpaved				78.0	0.050	3.61	0.006

Channel Flow

ID	Description	[5]Manning's n	[6]Cross Sectional Flow Area, a (sf)	[6]Wetted Perimeter, p_w (ft)	Hydraulic Radius, r (ft)	Flow Length, $L_{channel}$ (ft)	Channel Slope, s (ft/ft)	Average Velocity, $V_{channel}$ (ft/s)	Travel Time, $T_{t(channel)}$ (hr)
								T_c (hr) =	0.260
								T_c (min) =	16

[1] Selected appropriate Rational Method runoff coefficient (C) from Table 4-5b in the Virginia Stormwater Management Handbook

[2] Assume a maximum sheet flow length of 100-ft per PS&S

[3] Assume a maximum shallow concentrated flow length of 1,000-ft in Franklin County and Roanoke County per the PS&S

[4] For waterbars, assume a channel slope of 5% (i.e., the maximum slope per General Detail MVP-17) to be conservative

[5] Assume n=0.03 for all natural/man-made channels to be conservative

[6] Assume bank-full elevation per TR-55

IV. Summary

As shown, the water bar end treatment calculator indicates a 19 foot long end treatment will ensure sheet flow conditions leaving Water Bar 6. For ease of construction, a water bar end treatment length of 20 feet will be used for Water Bar 6.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	16	time of concentration to water bar, min
	A =	1.79	water bar drainage area, ac
	S =	0.110	weir discharge overland slope, ft/ft
Computed	i =	4.5	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **19 ft**

Velocity Check ------> **0.44 fps**

Water Bar 7 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 7 is 0.68 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area.Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath for Water Bar 7 begins as sheet flow in a HSG D meadow area with slopes greater than 6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.25.

The flowpath exiting the Water Bar 7 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration (T_c)

As shown, the time of concentration of Water Bar 7 is 9 minutes.

Equation	Reference
$T_{t(sheet)} = 0.225*L_{sheet}^{0.42}*s^{-0.19}*C^{-1.0}$	Seelye Method for calculating overland flow time (VDOT's preferred method, described in Appendix 6D-1 of the VDOT Drainage Manual)
$V_{unpaved} = 16.1345*s^{0.5}$	Equation for average velocity for "Unpaved" surface condition from TR-55, Appendix F
$V_{paved} = 20.3282*s^{0.5}$	Equation for average velocity for "Paved" surface condition from TR-55, Appendix F
$T_{t(shallow)} = L_{shallow}/(3600*V_{unpaved/paved}$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for shallow concentrated flow)
$r = a/p_w$	Definition of hydraulic radius (r), which is equal to the cross sectional flow area (a) divided by the wetted perimeter (p_w)
$V_{channel} = (1.49*r^{2/3}*s^{1/2})/n$	Equation 3-4 (Manning's Equation) from TR-55, Chapter 3
$T_{t(channel)} = L_{channel}/(3600*V_{channel})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for channel flow)
$T_c = T_{t(sheet)} + T_{t(shallow)} + T_{t(channel)}$	Equation 3-2 for time of concentration from TR-55, Chapter 3

Sheet Flow

ID	Description	[1]Rational Method Runoff Coefficient, C	[2]Flow Length, L_{sheet} (ft)	Land Slope, s (ft/ft)	Travel Time, $T_{t(sheet)}$ (hr)
AB	Sheet Flow	0.25	100.0	0.290	0.131

Shallow Concentrated Flow

ID	Description	Paved/Unpaved	[3]Flow Length, $L_{shallow}$ (ft)	[4]Watercourse Slope, s (ft/ft)	Average Velocity, $V_{unpaved/paved}$ (ft/s)	Travel Time, $T_{t(shallow)}$ (hr)
BC	Downslope	Unpaved	416.0	0.236	7.84	0.015
CD	Waterbar	Unpaved	40.0	0.050	3.61	0.003

Channel Flow

ID	Description	[5]Manning's n	[6]Cross Sectional Flow Area, a (sf)	[6]Wetted Perimeter, p_w (ft)	Hydraulic Radius, r (ft)	Flow Length, $L_{channel}$ (ft)	Channel Slope, s (ft/ft)	Average Velocity, $V_{channel}$ (ft/s)	Travel Time, $T_{t(channel)}$ (hr)

T_c (hr) =	0.149
T_c (min) =	9

[1] Selected appropriate Rational Method runoff coefficient (C) from Table 4-5b in the Virginia Stormwater Management Handbook

[2] Assume a maximum sheet flow length of 100-ft per PS&S

[3] Assume a maximum shallow concentrated flow length of 1,000-ft in Franklin County and Roanoke County per the PS&S

[4] For waterbars, assume a channel slope of 5% (i.e., the maximum slope per General Detail MVP-17) to be conservative

[5] Assume n=0.03 for all natural/man-made channels to be conservative

[6] Assume bank-full elevation per TR-55

IV. Summary

As shown, the water bar end treatment calculator indicates a 9 foot long end treatment will ensure sheet flow conditions leaving Water Bar 7. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 7.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	9	time of concentration to water bar, min
	A =	0.68	water bar drainage area, ac
	S =	0.085	weir discharge overland slope, ft/ft
Computed	i =	5.8	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **9 ft**

Velocity Check ------> **0.39 fps**

Water Bar 8 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 8 is 0.17 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 8 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 8 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 3 foot long end treatment will ensure sheet flow conditions leaving Water Bar 8. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 8.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.17	water bar drainage area, ac
	S =	0.430	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **3 ft**

Velocity Check ------> **0.88 fps**

Water Bar 9 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 9 is 0.18 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 9 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 9 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 3 foot long end treatment will ensure sheet flow conditions leaving Water Bar 9. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 9.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.18	water bar drainage area, ac
	S =	0.263	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **3 ft**

Velocity Check ------> **0.69 fps**

Water Bar 10 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 10 is 0.51 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area.Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath for Water Bar 10 begins as sheet flow in a HSG B meadow area with slopes greater than 6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.19.

The flowpath exiting the Water Bar 10 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration (T_c)

As shown, the time of concentration of Water Bar 10 is 13 minutes.

Equation	Reference
$T_{t(sheet)} = 0.225*L_{sheet}^{0.42}*s^{-0.19}*C^{-1.0}$	Seelye Method for calculating overland flow time (VDOT's preferred method, described in Appendix 6D-1 of the VDOT Drainage Manual)
$V_{unpaved} = 16.1345*s^{0.5}$	Equation for average velocity for "Unpaved" surface condition from TR-55, Appendix F
$V_{paved} = 20.3282*s^{0.5}$	Equation for average velocity for "Paved" surface condition from TR-55, Appendix F
$T_{t(shallow)} = L_{shallow}/(3600*V_{unpaved/paved}$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for shallow concentrated flow)
$r = a/p_w$	Definition of hydraulic radius (r), which is equal to the cross sectional flow area (a) divided by the wetted perimeter (p_w)
$V_{channel} = (1.49*r^{2/3}*s^{1/2})/n$	Equation 3-4 (Manning's Equation) from TR-55, Chapter 3
$T_{t(channel)} = L_{channel}/(3600*V_{channel})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for channel flow)
$T_c = T_{t(sheet)} + T_{t(shallow)} + T_{t(channel)}$	Equation 3-2 for time of concentration from TR-55, Chapter 3

Sheet Flow

ID	Description	[1]Rational Method Runoff Coefficient, C	[2]Flow Length, L_{sheet} (ft)	Land Slope, s (ft/ft)	Travel Time, $T_{t(sheet)}$ (hr)
AB	Sheet Flow	0.19	100.0	0.130	0.201

Shallow Concentrated Flow

ID	Description	Paved/Unpaved	[3]Flow Length, $L_{shallow}$ (ft)	[4]Watercourse Slope, s (ft/ft)	Average Velocity, $V_{unpaved/paved}$ (ft/s)	Travel Time, $T_{t(shallow)}$ (hr)
BC	Downslope	Unpaved	375.0	0.415	10.39	0.010
CD	Waterbar	Unpaved	48.0	0.050	3.61	0.004

Channel Flow

ID	Description	[5]Manning's n	[6]Cross Sectional Flow Area, a (sf)	[6]Wetted Perimeter, p_w (ft)	Hydraulic Radius, r (ft)	Flow Length, $L_{channel}$ (ft)	Channel Slope, s (ft/ft)	Average Velocity, $V_{channel}$ (ft/s)	Travel Time, $T_{t(channel)}$ (hr)

T_c (hr) =	0.215
T_c (min) =	13

[1] Selected appropriate Rational Method runoff coefficient (C) from Table 4-5b in the Virginia Stormwater Management Handbook

[2] Assume a maximum sheet flow length of 100-ft per PS&S

[3] Assume a maximum shallow concentrated flow length of 1,000-ft in Franklin County and Roanoke County per the PS&S

[4] For waterbars, assume a channel slope of 5% (i.e., the maximum slope per General Detail MVP-17) to be conservative

[5] Assume n=0.03 for all natural/man-made channels to be conservative

[6] Assume bank-full elevation per TR-55

IV. Summary

As shown, the water bar end treatment calculator indicates a 6 foot long end treatment will ensure sheet flow conditions leaving Water Bar 10. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 10.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	13	time of concentration to water bar, min
	A =	0.51	water bar drainage area, ac
	S =	0.222	weir discharge overland slope, ft/ft
Computed	i =	5.0	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **6 ft**

Velocity Check ------> **0.63 fps**

Water Bar 11 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 11 is 0.68 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area.Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath for Water Bar 11 begins as sheet flow in a HSG B meadow area with slopes greater than 6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.19.

The flowpath exiting the Water Bar 11 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration (T_c)

As shown, the time of concentration of Water Bar 11 is 14 minutes.

Equation	Reference
$T_{t(sheet)} = 0.225*L_{sheet}^{0.42}*s^{-0.19}*C^{-1.0}$	Seelye Method for calculating overland flow time (VDOT's preferred method, described in Appendix 6D-1 of the VDOT Drainage Manual)
$V_{unpaved} = 16.1345*s^{0.5}$	Equation for average velocity for "Unpaved" surface condition from TR-55, Appendix F
$V_{paved} = 20.3282*s^{0.5}$	Equation for average velocity for "Paved" surface condition from TR-55, Appendix F
$T_{t(shallow)} = L_{shallow}/(3600*V_{unpaved/paved}$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for shallow concentrated flow)
$r = a/p_w$	Definition of hydraulic radius (r), which is equal to the cross sectional flow area (a) divided by the wetted perimeter (p_w)
$V_{channel} = (1.49*r^{2/3}*s^{1/2})/n$	Equation 3-4 (Manning's Equation) from TR-55, Chapter 3
$T_{t(channel)} = L_{channel}/(3600*V_{channel})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for channel flow)
$T_c = T_{t(sheet)} + T_{t(shallow)} + T_{t(channel)}$	Equation 3-2 for time of concentration from TR-55, Chapter 3

Sheet Flow

ID	Description	[1]Rational Method Runoff Coefficient, C				[2]Flow Length, L_{sheet} (ft)	Land Slope, s (ft/ft)		Travel Time, $T_{t(sheet)}$ (hr)
AB	Sheet Flow	0.19				100.0	0.100		0.211

Shallow Concentrated Flow

ID	Description	Paved/Unpaved				[3]Flow Length, $L_{shallow}$ (ft)	[4]Watercourse Slope, s (ft/ft)	Average Velocity, $V_{unpaved/paved}$ (ft/s)	Travel Time, $T_{t(shallow)}$ (hr)
BC	Downslope	Unpaved				335.0	0.287	8.64	0.011
CD	Waterbar	Unpaved				79.0	0.050	3.61	0.006

Channel Flow

ID	Description	[5]Manning's n	[6]Cross Sectional Flow Area, a (sf)	[6]Wetted Perimeter, p_w (ft)	Hydraulic Radius, r (ft)	Flow Length, $L_{channel}$ (ft)	Channel Slope, s (ft/ft)	Average Velocity, $V_{channel}$ (ft/s)	Travel Time, $T_{t(channel)}$ (hr)
								T_c (hr) =	0.228
								T_c (min) =	14

[1] Selected appropriate Rational Method runoff coefficient (C) from Table 4-5b in the Virginia Stormwater Management Handbook

[2] Assume a maximum sheet flow length of 100-ft per PS&S

[3] Assume a maximum shallow concentrated flow length of 1,000-ft in Franklin County and Roanoke County per the PS&S

[4] For waterbars, assume a channel slope of 5% (i.e., the maximum slope per General Detail MVP-17) to be conservative

[5] Assume n=0.03 for all natural/man-made channels to be conservative

[6] Assume bank-full elevation per TR-55

IV. Summary

As shown, the water bar end treatment calculator indicates a 8 foot long end treatment will ensure sheet flow conditions leaving Water Bar 11. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 11.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	14	time of concentration to water bar, min
	A =	0.68	water bar drainage area, ac
	S =	0.310	weir discharge overland slope, ft/ft
Computed	i =	4.8	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **8 ft**

Velocity Check ------> **0.74 fps**

Water Bar 12 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 12 is 0.46 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 12 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 12 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 7 foot long end treatment will ensure sheet flow conditions leaving Water Bar 12. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 12.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.46	water bar drainage area, ac
	S =	0.410	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **7 ft**

Velocity Check ------> **0.86 fps**

Water Bar 13 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 13 is 0.28 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 13 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 13 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 4 foot long end treatment will ensure sheet flow conditions leaving Water Bar 13. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 13.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.28	water bar drainage area, ac
	S =	0.253	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **4 ft**

Velocity Check ------> **0.67 fps**

Water Bar 14 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 14 is 0.19 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 14 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 14 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 3 foot long end treatment will ensure sheet flow conditions leaving Water Bar 14. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 14.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.19	water bar drainage area, ac
	S =	0.299	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **3 ft**

Velocity Check ------> **0.73 fps**

Water Bar 17 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 17 is 0.87 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area.Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath for Water Bar 17 begins as sheet flow in a HSG D wooded area with slopes greater than 6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.21.

The flowpath exiting the Water Bar 17 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration (T_c)

As shown, the time of concentration of Water Bar 17 is 10 minutes.

Equation	Reference
$T_{t(sheet)} = 0.225*L_{sheet}^{0.42}*s^{-0.19}*C^{-1.0}$	Seelye Method for calculating overland flow time (VDOT's preferred method, described in Appendix 6D-1 of the VDOT Drainage Manual)
$V_{unpaved} = 16.1345*s^{0.5}$	Equation for average velocity for "Unpaved" surface condition from TR-55, Appendix F
$V_{paved} = 20.3282*s^{0.5}$	Equation for average velocity for "Paved" surface condition from TR-55, Appendix F
$T_{t(shallow)} = L_{shallow}/(3600*V_{unpaved/paved}$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for shallow concentrated flow)
$r = a/p_w$	Definition of hydraulic radius (r), which is equal to the cross sectional flow area (a) divided by the wetted perimeter (p_w)
$V_{channel} = (1.49*r^{2/3}*s^{1/2})/n$	Equation 3-4 (Manning's Equation) from TR-55, Chapter 3
$T_{t(channel)} = L_{channel}/(3600*V_{channel})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for channel flow)
$T_c = T_{t(sheet)} + T_{t(shallow)} + T_{t(channel)}$	Equation 3-2 for time of concentration from TR-55, Chapter 3

Sheet Flow

ID	Description	[1]Rational Method Runoff Coefficient, C	[2]Flow Length, L_{sheet} (ft)	Land Slope, s (ft/ft)	Travel Time, $T_{t(sheet)}$ (hr)
AB	Sheet Flow	0.21	100.0	0.300	0.155

Shallow Concentrated Flow

ID	Description	Paved/Unpaved	[3]Flow Length, $L_{shallow}$ (ft)	[4]Watercourse Slope, s (ft/ft)	Average Velocity, $V_{unpaved/paved}$ (ft/s)	Travel Time, $T_{t(shallow)}$ (hr)
BC	Downslope	Unpaved	391.0	0.266	8.32	0.013
CD	Waterbar	Unpaved	0.0	0.050	3.61	0.000

Channel Flow

ID	Description	[5]Manning's n	[6]Cross Sectional Flow Area, a (sf)	[6]Wetted Perimeter, p_w (ft)	Hydraulic Radius, r (ft)	Flow Length, $L_{channel}$ (ft)	Channel Slope, s (ft/ft)	Average Velocity, $V_{channel}$ (ft/s)	Travel Time, $T_{t(channel)}$ (hr)
								T_c (hr) =	0.168
								T_c (min) =	10

[1] Selected appropriate Rational Method runoff coefficient (C) from Table 4-5b in the Virginia Stormwater Management Handbook

[2] Assume a maximum sheet flow length of 100-ft per PS&S

[3] Assume a maximum shallow concentrated flow length of 1,000-ft in Franklin County and Roanoke County per the PS&S

[4] For waterbars, assume a channel slope of 5% (i.e., the maximum slope per General Detail MVP-17) to be conservative

[5] Assume n=0.03 for all natural/man-made channels to be conservative

[6] Assume bank-full elevation per TR-55

IV. Summary

As shown, the water bar end treatment calculator indicates a 11 foot long end treatment will ensure sheet flow conditions leaving Water Bar 17. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 17.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	10	time of concentration to water bar, min
	A =	0.87	water bar drainage area, ac
	S =	0.330	weir discharge overland slope, ft/ft
Computed	i =	5.3	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **11 ft**

Velocity Check ------> **0.77 fps**

Water Bar 18 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 18 is 0.1 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 18 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 18 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 2 foot long end treatment will ensure sheet flow conditions leaving Water Bar 18. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 18.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.10	water bar drainage area, ac
	S =	0.240	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **2 ft**

Velocity Check ------> **0.66 fps**

Water Bar 19 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 19 is 0.19 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 19 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 19 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 3 foot long end treatment will ensure sheet flow conditions leaving Water Bar 19. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 19.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.19	water bar drainage area, ac
	S =	0.290	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **3 ft**

Velocity Check ------> **0.72 fps**

Water Bar 20 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 20 is 0.36 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 20 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 20 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 5 foot long end treatment will ensure sheet flow conditions leaving Water Bar 20. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 20.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.36	water bar drainage area, ac
	S =	0.290	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **5 ft**

Velocity Check ------> **0.72 fps**

Water Bar 21 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 21 is 0.05 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 21 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 21 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 1 foot long end treatment will ensure sheet flow conditions leaving Water Bar 21. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 21.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.05	water bar drainage area, ac
	S =	0.290	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **1 ft**

Velocity Check ------> **0.72 fps**

Water Bar 22 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 22 is 0.05 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 22 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 22 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 1 foot long end treatment will ensure sheet flow conditions leaving Water Bar 22. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 22.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.05	water bar drainage area, ac
	S =	0.290	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **1 ft**

Velocity Check ------> **0.72 fps**

Water Bar 23 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 23 is 0.06 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 23 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 23 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 1 foot long end treatment will ensure sheet flow conditions leaving Water Bar 23. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 23.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.06	water bar drainage area, ac
	S =	0.290	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **1 ft**

Velocity Check ------> **0.72 fps**

Water Bar 24 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 24 is 0.18 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 24 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 24 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 3 foot long end treatment will ensure sheet flow conditions leaving Water Bar 24. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 24.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.18	water bar drainage area, ac
	S =	0.370	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **3 ft**

Velocity Check ------> **0.81 fps**

Water Bar 25 Site Specific Analysis

I. Drainage Area

As shown, the drainage area to Water Bar 25 is 1.92 Acres. This is greater than the 1.5 acre-maximum in the MVP 17.3 Water Bar End Treatment Detail and, therefore, requires a site-specific analysis to determine the water bar end treatment length.

II. Runoff Coefficient

The flowpath for Water Bar 25 begins as sheet flow in a HSG B wooded area with slopes greater than 6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.15.

The flowpath exiting the Water Bar 25 end treatment will be along HSG B meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.19.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration (T_c)

As shown, the time of concentration of Water Bar 25 is 16 minutes.

Equation	Reference
$T_{t(sheet)} = 0.225*L_{sheet}^{0.42}*s^{-0.19}*C^{-1.0}$	Seelye Method for calculating overland flow time (VDOT's preferred method, described in Appendix 6D-1 of the VDOT Drainage Manual)
$V_{unpaved} = 16.1345*s^{0.5}$	Equation for average velocity for "Unpaved" surface condition from TR-55, Appendix F
$V_{paved} = 20.3282*s^{0.5}$	Equation for average velocity for "Paved" surface condition from TR-55, Appendix F
$T_{t(shallow)} = L_{shallow}/(3600*V_{unpaved/paved}$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for shallow concentrated flow)
$r = a/p_w$	Definition of hydraulic radius (r), which is equal to the cross sectional flow area (a) divided by the wetted perimeter (p_w)
$V_{channel} = (1.49*r^{2/3}*s^{1/2})/n$	Equation 3-4 (Manning's Equation) from TR-55, Chapter 3
$T_{t(channel)} = L_{channel}/(3600*V_{channel})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for channel flow)
$T_c = T_{t(sheet)} + T_{t(shallow)} + T_{t(channel)}$	Equation 3-2 for time of concentration from TR-55, Chapter 3

Sheet Flow

ID	Description	[1]Rational Method Runoff Coefficient, C	[2]Flow Length, L_{sheet} (ft)	Land Slope, s (ft/ft)	Travel Time, $T_{t(sheet)}$ (hr)
AB	Sheet Flow	0.15	100.0	0.200	0.235

Shallow Concentrated Flow

ID	Description	Paved/Unpaved	[3]Flow Length, $L_{shallow}$ (ft)	[4]Watercourse Slope, s (ft/ft)	Average Velocity, $V_{unpaved/paved}$ (ft/s)	Travel Time, $T_{t(shallow)}$ (hr)
BC	Downslope	Unpaved	850.0	0.184	6.91	0.034
CD	Waterbar	Unpaved	12.9	0.050	3.61	0.001

Channel Flow

ID	Description	[5]Manning's n	[6]Cross Sectional Flow Area, a (sf)	[6]Wetted Perimeter, p_w (ft)	Hydraulic Radius, r (ft)	Flow Length, $L_{channel}$ (ft)	Channel Slope, s (ft/ft)	Average Velocity, $V_{channel}$ (ft/s)	Travel Time, $T_{t(channel)}$ (hr)
								T_c (hr) =	0.270
								T_c (min) =	16

[1] Selected appropriate Rational Method runoff coefficient (C) from Table 4-5b in the Virginia Stormwater Management Handbook

[2] Assume a maximum sheet flow length of 100-ft per PS&S

[3] Assume a maximum shallow concentrated flow length of 1,000-ft in Franklin County and Roanoke County per the PS&S

[4] For waterbars, assume a channel slope of 5% (i.e., the maximum slope per General Detail MVP-17) to be conservative

[5] Assume n=0.03 for all natural/man-made channels to be conservative

[6] Assume bank-full elevation per TR-55

IV. Summary

As shown, the water bar end treatment calculator indicates a 15 foot long end treatment will ensure sheet flow conditions leaving Water Bar 25. For ease of construction, a water bar end treatment length of 20 feet will be used for Water Bar 25.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	16	time of concentration to water bar, min
	A =	1.92	water bar drainage area, ac
	S =	0.230	weir discharge overland slope, ft/ft
Computed	i =	4.4	computed from IDF, in/hr
Enter Flow Parameters	C =	0.19	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **15 ft**

Velocity Check ------> **0.64 fps**

Water Bar 26 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 26 is 0.27 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 26 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 26 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 4 foot long end treatment will ensure sheet flow conditions leaving Water Bar 26. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 26.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.27	water bar drainage area, ac
	S =	0.330	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **4 ft**

Velocity Check ------> **0.77 fps**

Water Bar 27 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 27 is 0.68 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area.Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath for Water Bar 27 begins as sheet flow in a HSG C wooded area with slopes greater than 6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.17.

The flowpath exiting the Water Bar 27 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration (T_c)

As shown, the time of concentration of Water Bar 27 is 14 minutes.

Equation	Reference
$T_{t(sheet)} = 0.225*L_{sheet}^{0.42}*s^{-0.19}*C^{-1.0}$	Seelye Method for calculating overland flow time (VDOT's preferred method, described in Appendix 6D-1 of the VDOT Drainage Manual)
$V_{unpaved} = 16.1345*s^{0.5}$	Equation for average velocity for "Unpaved" surface condition from TR-55, Appendix F
$V_{paved} = 20.3282*s^{0.5}$	Equation for average velocity for "Paved" surface condition from TR-55, Appendix F
$T_{t(shallow)} = L_{shallow}/(3600*V_{unpaved/paved}$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for shallow concentrated flow)
$r = a/p_w$	Definition of hydraulic radius (r), which is equal to the cross sectional flow area (a) divided by the wetted perimeter (p_w)
$V_{channel} = (1.49*r^{2/3}*s^{1/2})/n$	Equation 3-4 (Manning's Equation) from TR-55, Chapter 3
$T_{t(channel)} = L_{channel}/(3600*V_{channel})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for channel flow)
$T_c = T_{t(sheet)} + T_{t(shallow)} + T_{t(channel)}$	Equation 3-2 for time of concentration from TR-55, Chapter 3

Sheet Flow

ID	Description	[1]Rational Method Runoff Coefficient, C	[2]Flow Length, L_{sheet} (ft)	Land Slope, s (ft/ft)	Travel Time, $T_{t(sheet)}$ (hr)
AB	Sheet Flow	0.17	100.0	0.150	0.219

Shallow Concentrated Flow

ID	Description	Paved/Unpaved	[3]Flow Length, $L_{shallow}$ (ft)	[4]Watercourse Slope, s (ft/ft)	Average Velocity, $V_{unpaved/paved}$ (ft/s)	Travel Time, $T_{t(shallow)}$ (hr)
BC	Downslope	Unpaved	443.0	0.235	7.82	0.016
CD	Waterbar	Unpaved	79.0	0.050	3.61	0.006

Channel Flow

ID	Description	[5]Manning's n	[6]Cross Sectional Flow Area, a (sf)	[6]Wetted Perimeter, p_w (ft)	Hydraulic Radius, r (ft)	Flow Length, $L_{channel}$ (ft)	Channel Slope, s (ft/ft)	Average Velocity, $V_{channel}$ (ft/s)	Travel Time, $T_{t(channel)}$ (hr)
								T_c (hr) =	0.241
								T_c (min) =	14

[1] Selected appropriate Rational Method runoff coefficient (C) from Table 4-5b in the Virginia Stormwater Management Handbook

[2] Assume a maximum sheet flow length of 100-ft per PS&S

[3] Assume a maximum shallow concentrated flow length of 1,000-ft in Franklin County and Roanoke County per the PS&S

[4] For waterbars, assume a channel slope of 5% (i.e., the maximum slope per General Detail MVP-17) to be conservative

[5] Assume n=0.03 for all natural/man-made channels to be conservative

[6] Assume bank-full elevation per TR-55

IV. Summary

As shown, the water bar end treatment calculator indicates a 7 foot long end treatment will ensure sheet flow conditions leaving Water Bar 27. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 27.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	14	time of concentration to water bar, min
	A =	0.68	water bar drainage area, ac
	S =	0.330	weir discharge overland slope, ft/ft
Computed	i =	4.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **7 ft**

Velocity Check ------> **0.77 fps**

Water Bar 28 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 28 is 0.52 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area.Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath for Water Bar 28 begins as sheet flow in a HSG C wooded area with slopes greater than 6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.17.

The flowpath exiting the Water Bar 28 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration (T_c)

As shown, the time of concentration of Water Bar 28 is 15 minutes.

Equation	Reference
$T_{t(sheet)} = 0.225*L_{sheet}^{0.42}*s^{-0.19}*C^{-1.0}$	Seelye Method for calculating overland flow time (VDOT's preferred method, described in Appendix 6D-1 of the VDOT Drainage Manual)
$V_{unpaved} = 16.1345*s^{0.5}$	Equation for average velocity for "Unpaved" surface condition from TR-55, Appendix F
$V_{paved} = 20.3282*s^{0.5}$	Equation for average velocity for "Paved" surface condition from TR-55, Appendix F
$T_{t(shallow)} = L_{shallow}/(3600*V_{unpaved/paved}$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for shallow concentrated flow)
$r = a/p_w$	Definition of hydraulic radius (r), which is equal to the cross sectional flow area (a) divided by the wetted perimeter (p_w)
$V_{channel} = (1.49*r^{2/3}*s^{1/2})/n$	Equation 3-4 (Manning's Equation) from TR-55, Chapter 3
$T_{t(channel)} = L_{channel}/(3600*V_{channel})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for channel flow)
$T_c = T_{t(sheet)} + T_{t(shallow)} + T_{t(channel)}$	Equation 3-2 for time of concentration from TR-55, Chapter 3

Sheet Flow

ID	Description	[1]Rational Method Runoff Coefficient, C	[2]Flow Length, L_{sheet} (ft)	Land Slope, s (ft/ft)	Travel Time, $T_{t(sheet)}$ (hr)
AB	Sheet Flow	0.17	100.0	0.160	0.216

Shallow Concentrated Flow

ID	Description	Paved/Unpaved	[3]Flow Length, $L_{shallow}$ (ft)	[4]Watercourse Slope, s (ft/ft)	Average Velocity, $V_{unpaved/paved}$ (ft/s)	Travel Time, $T_{t(shallow)}$ (hr)
BC	Downslope	Unpaved	606.0	0.191	7.06	0.024
CD	Waterbar	Unpaved	118.5	0.050	3.61	0.009

Channel Flow

ID	Description	[5]Manning's n	[6]Cross Sectional Flow Area, a (sf)	[6]Wetted Perimeter, p_w (ft)	Hydraulic Radius, r (ft)	Flow Length, $L_{channel}$ (ft)	Channel Slope, s (ft/ft)	Average Velocity, $V_{channel}$ (ft/s)	Travel Time, $T_{t(channel)}$ (hr)
								T_c (hr) =	0.249
								T_c (min) =	15

[1] Selected appropriate Rational Method runoff coefficient (C) from Table 4-5b in the Virginia Stormwater Management Handbook

[2] Assume a maximum sheet flow length of 100-ft per PS&S

[3] Assume a maximum shallow concentrated flow length of 1,000-ft in Franklin County and Roanoke County per the PS&S

[4] For waterbars, assume a channel slope of 5% (i.e., the maximum slope per General Detail MVP-17) to be conservative

[5] Assume n=0.03 for all natural/man-made channels to be conservative

[6] Assume bank-full elevation per TR-55

IV. Summary

As shown, the water bar end treatment calculator indicates a 6 foot long end treatment will ensure sheet flow conditions leaving Water Bar 28. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 28.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	15	time of concentration to water bar, min
	A =	0.52	water bar drainage area, ac
	S =	0.300	weir discharge overland slope, ft/ft
Computed	i =	4.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **6 ft**

Velocity Check ------> **0.73 fps**

Water Bar 29 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 29 is 0.08 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 29 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 29 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 1 foot long end treatment will ensure sheet flow conditions leaving Water Bar 29. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 29.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.08	water bar drainage area, ac
	S =	0.290	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **1 ft**

Velocity Check ------> **0.72 fps**

Water Bar 30 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 30 is 0.09 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 30 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 30 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 1 foot long end treatment will ensure sheet flow conditions leaving Water Bar 30. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 30.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.09	water bar drainage area, ac
	S =	0.270	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **1 ft**

Velocity Check ------> **0.69 fps**

Water Bar 31 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 31 is 0.08 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 31 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 31 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 1 foot long end treatment will ensure sheet flow conditions leaving Water Bar 31. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 31.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.08	water bar drainage area, ac
	S =	0.244	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **1 ft**

Velocity Check ------> **0.66 fps**

Water Bar 32 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 32 is 0.11 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 32 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 32 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 2 foot long end treatment will ensure sheet flow conditions leaving Water Bar 32. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 32.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.11	water bar drainage area, ac
	S =	0.317	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **2 ft**

Velocity Check ------> **0.75 fps**

Water Bar 33 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 33 is 0.09 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 33 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 33 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 1 foot long end treatment will ensure sheet flow conditions leaving Water Bar 33. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 33.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.09	water bar drainage area, ac
	S =	0.233	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **1 ft**

Velocity Check ------> **0.65 fps**

Water Bar 34 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 34 is 0.13 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 34 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 34 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 2 foot long end treatment will ensure sheet flow conditions leaving Water Bar 34. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 34.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.13	water bar drainage area, ac
	S =	0.189	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **2 ft**

Velocity Check ------> **0.58 fps**

Water Bar 35 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 35 is 0.2 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 35 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 35 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 3 foot long end treatment will ensure sheet flow conditions leaving Water Bar 35. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 35.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.20	water bar drainage area, ac
	S =	0.360	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **3 ft**

Velocity Check ------> **0.80 fps**

Water Bar 36 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 36 is 0.1 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 36 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 36 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 2 foot long end treatment will ensure sheet flow conditions leaving Water Bar 36. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 36.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.10	water bar drainage area, ac
	S =	0.263	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **2 ft**

Velocity Check ------> **0.69 fps**

Water Bar 36.1 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 36.1 is 0.09 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 36.1 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 36.1 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 1 foot long end treatment will ensure sheet flow conditions leaving Water Bar 36.1. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 36.1.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.09	water bar drainage area, ac
	S =	0.354	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **1 ft**

Velocity Check ------> **0.80 fps**

Water Bar 36.2 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 36.2 is 0.08 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 36.2 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 36.2 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 1 foot long end treatment will ensure sheet flow conditions leaving Water Bar 36.2. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 36.2.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.08	water bar drainage area, ac
	S =	0.321	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **1 ft**

Velocity Check ------> **0.76 fps**

Water Bar 36.3 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 36.3 is 0.06 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 36.3 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 36.3 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 1 foot long end treatment will ensure sheet flow conditions leaving Water Bar 36.3. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 36.3.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.06	water bar drainage area, ac
	S =	0.353	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **1 ft**

Velocity Check ------> **0.79 fps**

Water Bar 36.4 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 36.4 is 0.13 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 36.4 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 36.4 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 2 foot long end treatment will ensure sheet flow conditions leaving Water Bar 36.4. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 36.4.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.13	water bar drainage area, ac
	S =	0.4	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **2 ft**

Velocity Check ------> **0.85 fps**

Water Bar 36.5 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 36.5 is 0.22 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 36.5 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 36.5 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 3 foot long end treatment will ensure sheet flow conditions leaving Water Bar 36.5. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 36.5.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.22	water bar drainage area, ac
	S =	0.392	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **3 ft**

Velocity Check ------> **0.84 fps**

Water Bar 36.6 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 36.6 is 0.16 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 36.6 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 36.6 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 3 foot long end treatment will ensure sheet flow conditions leaving Water Bar 36.6. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 36.6.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.16	water bar drainage area, ac
	S =	0.476	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **3 ft**

Velocity Check ------> **0.92 fps**

Water Bar 36.7 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 36.7 is 0.22 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 36.7 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 36.7 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 3 foot long end treatment will ensure sheet flow conditions leaving Water Bar 36.7. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 36.7.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.22	water bar drainage area, ac
	S =	0.508	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **3 ft**

Velocity Check ------> **0.95 fps**

Water Bar 36.8 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 36.8 is 0.15 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 36.8 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 36.8 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 2 foot long end treatment will ensure sheet flow conditions leaving Water Bar 36.8. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 36.8.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.15	water bar drainage area, ac
	S =	0.694	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **2 ft**

Velocity Check ------> **1.11 fps**

Water Bar 37 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 37 is 0.08 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

Composite Curve Number (CN) Calculator				
LAND USE	**HSG**	**CN**	**AREA (%)**	**AreaWeighted CN**
Impervious	D	98	45%	44
Meadow	D	78	55%	43
Wooded	D	77	0%	0
			100%	87

II. Runoff Coefficient

The drainage area for Water Bar 37 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.54 was calculated as shown below to more accurately represent the runoff condition within the drainage area.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

Composite Runoff Coefficient (C) Calculator					
LAND USE	**HSG**	**C**	**Area %**	**Area Weighted C**	
Impervious	D	0.9	45%	0.41	
Meadow	D	0.25	55%	0.14	
Wooded	D	0.21	0%	0.00	
			100%	0.54	<--- Composite C

III. Time of Concentration (T_c)

A minimum time of concentration of 5 minutes was assumed for Water Bar 37 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 3 foot long end treatment will ensure sheet flow conditions leaving Water Bar 37. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 37.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.08	water bar drainage area, ac
	S =	0.465	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.54	calculated composite runoff coefficient
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **3 ft**

Velocity Check ------> **0.91 fps**

Water Bar 38 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 38 is 0.1 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 38 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 38 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 2 foot long end treatment will ensure sheet flow conditions leaving Water Bar 38. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 38.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.10	water bar drainage area, ac
	S =	0.200	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **2 ft**

Velocity Check ------> **0.60 fps**

Water Bar 39 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 39 is 0.74 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area.Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath for Water Bar 39 begins as sheet flow in a HSG C meadow area with slopes greater than 6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.22.

The flowpath exiting the Water Bar 39 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration (T_c)

As shown, the time of concentration of Water Bar 39 is 11 minutes.

Equation	Reference
$T_{t(sheet)} = 0.225*L_{sheet}^{0.42}*s^{-0.19}*C^{-1.0}$	Seelye Method for calculating overland flow time (VDOT's preferred method, described in Appendix 6D-1 of the VDOT Drainage Manual)
$V_{unpaved} = 16.1345*s^{0.5}$	Equation for average velocity for "Unpaved" surface condition from TR-55, Appendix F
$V_{paved} = 20.3282*s^{0.5}$	Equation for average velocity for "Paved" surface condition from TR-55, Appendix F
$T_{t(shallow)} = L_{shallow}/(3600*V_{unpaved/paved}$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for shallow concentrated flow)
$r = a/p_w$	Definition of hydraulic radius (r), which is equal to the cross sectional flow area (a) divided by the wetted perimeter (p_w)
$V_{channel} = (1.49*r^{2/3}*s^{1/2})/n$	Equation 3-4 (Manning's Equation) from TR-55, Chapter 3
$T_{t(channel)} = L_{channel}/(3600*V_{channel})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for channel flow)
$T_c = T_{t(sheet)} + T_{t(shallow)} + T_{t(channel)}$	Equation 3-2 for time of concentration from TR-55, Chapter 3

Sheet Flow

ID	Description	[1]Rational Method Runoff Coefficient, C	[2]Flow Length, L_{sheet} (ft)	Land Slope, s (ft/ft)	Travel Time, $T_{t(sheet)}$ (hr)
AB	Sheet Flow	0.22	100.0	0.160	0.167

Shallow Concentrated Flow

ID	Description	Paved/Unpaved	[3]Flow Length, $L_{shallow}$ (ft)	[4]Watercourse Slope, s (ft/ft)	Average Velocity, $V_{unpaved/paved}$ (ft/s)	Travel Time, $T_{t(shallow)}$ (hr)
BC	Downslope	Unpaved	469.0	0.196	7.14	0.018
CD	Waterbar	Unpaved	40.0	0.050	3.61	0.003

Channel Flow

ID	Description	[5]Manning's n	[6]Cross Sectional Flow Area, a (sf)	[6]Wetted Perimeter, p_w (ft)	Hydraulic Radius, r (ft)	Flow Length, $L_{channel}$ (ft)	Channel Slope, s (ft/ft)	Average Velocity, $V_{channel}$ (ft/s)	Travel Time, $T_{t(channel)}$ (hr)
								T_c (hr) =	0.188
								T_c (min) =	11

[1] Selected appropriate Rational Method runoff coefficient (C) from Table 4-5b in the Virginia Stormwater Management Handbook

[2] Assume a maximum sheet flow length of 100-ft per PS&S

[3] Assume a maximum shallow concentrated flow length of 1,000-ft in Franklin County and Roanoke County per the PS&S

[4] For waterbars, assume a channel slope of 5% (i.e., the maximum slope per General Detail MVP-17) to be conservative

[5] Assume n=0.03 for all natural/man-made channels to be conservative

[6] Assume bank-full elevation per TR-55

IV. Summary

As shown, the water bar end treatment calculator indicates a 9 foot long end treatment will ensure sheet flow conditions leaving Water Bar 39. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 39.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	11	time of concentration to water bar, min
	A =	0.74	water bar drainage area, ac
	S =	0.200	weir discharge overland slope, ft/ft
Computed	i =	5.1	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **9 ft**

Velocity Check ------> **0.60 fps**

Water Bar 40 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 40 is 0.07 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 40 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 40 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 1 foot long end treatment will ensure sheet flow conditions leaving Water Bar 40. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 40.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.07	water bar drainage area, ac
	S =	0.270	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **1 ft**

Velocity Check ------> **0.69 fps**

Water Bar 41 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 41 is 0.12 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 41 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 41 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 2 foot long end treatment will ensure sheet flow conditions leaving Water Bar 41. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 41.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.12	water bar drainage area, ac
	S =	0.217	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **2 ft**

Velocity Check ------> **0.62 fps**

Water Bar 42 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 42 is 0.13 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 42 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 42 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 2 foot long end treatment will ensure sheet flow conditions leaving Water Bar 42. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 42.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.13	water bar drainage area, ac
	S =	0.377	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **2 ft**

Velocity Check ------> **0.82 fps**

Water Bar 43 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 43 is 0.34 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 43 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 43 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 5 foot long end treatment will ensure sheet flow conditions leaving Water Bar 43. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 43.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.34	water bar drainage area, ac
	S =	0.357	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **5 ft**

Velocity Check ------> **0.80 fps**

Water Bar 44 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 44 is 0.29 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 44 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 44 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 4 foot long end treatment will ensure sheet flow conditions leaving Water Bar 44. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 44.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.29	water bar drainage area, ac
	S =	0.417	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **4 ft**

Velocity Check ------> **0.86 fps**

Water Bar 45 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 45 is 0.41 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 45 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 45 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 6 foot long end treatment will ensure sheet flow conditions leaving Water Bar 45. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 45.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.41	water bar drainage area, ac
	S =	0.240	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **6 ft**

Velocity Check ------> **0.66 fps**

Water Bar 46 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 46 is 0.26 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

Composite Curve Number (CN) Calculator				
LAND USE	**HSG**	**CN**	**AREA (%)**	**AreaWeighted CN**
Impervious	C	98	3%	3
Turf Grass	C	74	40%	30
Wooded	C	70	57%	40
			100%	72

II. Runoff Coefficient

The drainage area for Water Bar 46 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a and open space (turf grass), which has a runoff coefficient of of 0.24 per Table 4-5a (type C soil; 6+% slopes). Therefore, a composite C of 0.22 was calculated as shown below to more accurately represent the runoff condition within the drainage area

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

Composite Runoff Coefficient (C) Calculator					
LAND USE	**HSG**	**C**	**Area %**	**Area Weighted C**	
Impervious	C	0.9	3%	0.03	
Turf Grass	C	0.24	40%	0.10	
Wooded	C	0.17	57%	0.10	
			100%	0.22	**<--- Composite C**

III. Time of Concentration (T_c)

A minimum time of concentration of 5 minutes was assumed for Water Bar 46 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 3 foot long end treatment will ensure sheet flow conditions leaving Water Bar 46. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 46.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.26	water bar drainage area, ac
	S =	0.351	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.22	calculated composite runoff coefficient
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **3 ft**

Velocity Check ------> **0.79 fps**

Water Bar 47 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 47 is 0.74 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

Composite Curve Number (CN) Calculator				
LAND USE	**HSG**	**CN**	**AREA (%)**	**AreaWeighted CN**
Impervious	C	98	7%	7
Turf Grass	C	74	45%	33
Wooded	C	70	48%	34
			100%	74

II. Runoff Coefficient

The flowpath for Water Bar 47 begins as sheet flow in a HSG C turf grass area with slopes greater than 6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.24.

The drainage area for Water Bar 47 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a and open space (turf grass), which has a runoff coefficient of of 0.24 per Table 4-5a (type C soil; 6+% slopes). Therefore, a composite C of 0.25 was calculated as shown below to more accurately represent the runoff condition within the drainage area.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

Composite Runoff Coefficient (C) Calculator					
LAND USE	**HSG**	**C**	**Area %**	**Area Weighted C**	
Impervious	C	0.9	7%	0.06	
Turf Grass	C	0.24	45%	0.11	
Wooded	C	0.17	48%	0.08	
			100%	0.25	<--- Composite C

III. Time of Concentration (T_c)

As shown, the time of concentration of Water Bar 47 is 11 minutes.

Equation	Reference
$T_{t(sheet)} = 0.225*L_{sheet}^{0.42}*s^{-0.19}*C^{-1.0}$	Seelye Method for calculating overland flow time (VDOT's preferred method, described in Appendix 6D-1 of the VDOT Drainage Manual)
$V_{unpaved} = 16.1345*s^{0.5}$	Equation for average velocity for "Unpaved" surface condition from TR-55, Appendix F
$V_{paved} = 20.3282*s^{0.5}$	Equation for average velocity for "Paved" surface condition from TR-55, Appendix F
$T_{t(shallow)} = L_{shallow}/(3600*V_{unpaved/paved})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for shallow concentrated flow)
$r = a/p_w$	Definition of hydraulic radius (r), which is equal to the cross sectional flow area (a) divided by the wetted perimeter (p_w)
$V_{channel} = (1.49*r^{2/3}*s^{1/2})/n$	Equation 3-4 (Manning's Equation) from TR-55, Chapter 3
$T_{t(channel)} = L_{channel}/(3600*V_{channel})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for channel flow)
$T_c = T_{t(sheet)} + T_{t(shallow)} + T_{t(channel)}$	Equation 3-2 for time of concentration from TR-55, Chapter 3

Sheet Flow

ID	Description	[1]Rational Method Runoff Coefficient, C	[2]Flow Length, L_{sheet} (ft)	Land Slope, s (ft/ft)	Travel Time, $T_{t(sheet)}$ (hr)
AB	Sheet Flow	0.24	100.0	0.090	0.171

Shallow Concentrated Flow

ID	Description	Paved/Unpaved	[3]Flow Length, $L_{shallow}$ (ft)	[4]Watercourse Slope, s (ft/ft)	Average Velocity, $V_{unpaved/paved}$ (ft/s)	Travel Time, $T_{t(shallow)}$ (hr)
BC	Downslope	Unpaved	349.0	0.223	7.62	0.013
CD	Waterbar	Unpaved	38.0	0.050	3.61	0.003

Channel Flow

ID	Description	[5]Manning's n	[6]Cross Sectional Flow Area, a (sf)	[6]Wetted Perimeter, p_w (ft)	Hydraulic Radius, r (ft)	Flow Length, $L_{channel}$ (ft)	Channel Slope, s (ft/ft)	Average Velocity, $V_{channel}$ (ft/s)	Travel Time, $T_{t(channel)}$ (hr)

T_c (hr) =	0.186
T_c (min) =	11

[1] Selected appropriate Rational Method runoff coefficient (C) from Table 4-5b in the Virginia Stormwater Management Handbook

[2] Assume a maximum sheet flow length of 100-ft per PS&S

[3] Assume a maximum shallow concentrated flow length of 1,000-ft in Franklin County and Roanoke County per the PS&S

[4] For waterbars, assume a channel slope of 5% (i.e., the maximum slope per General Detail MVP-17) to be conservative

[5] Assume n=0.03 for all natural/man-made channels to be conservative

[6] Assume bank-full elevation per TR-55

IV. Summary

As shown, the water bar end treatment calculator indicates a 9 foot long end treatment will ensure sheet flow conditions leaving Water Bar 47. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 47.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	11	time of concentration to water bar, min
	A =	0.74	water bar drainage area, ac
	S =	0.270	weir discharge overland slope, ft/ft
Computed	i =	5.1	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	calculated composite runoff coefficient
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **9 ft**

Velocity Check ------> **0.69 fps**

Water Bar 48 Site Specific Analysis

I. Drainage Area

As shown, the drainage area to Water Bar 48 is 1.98 Acres. This is greater than the 1.5 acre-maximum in the MVP 17.3 Water Bar End Treatment Detail and, therefore, requires a site-specific analysis to determine the water bar end treatment length.

II. Runoff Coefficient

The flowpath for Water Bar 48 begins as sheet flow in a HSG B meadow area with slopes greater than 6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.19.

The flowpath exiting the Water Bar 48 end treatment will be along HSG B meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.19.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration (T_c)

As shown, the time of concentration of Water Bar 48 is 14 minutes.

Equation	Reference
$T_{t(sheet)} = 0.225*L_{sheet}^{0.42}*s^{-0.19}*C^{-1.0}$	Seelye Method for calculating overland flow time (VDOT's preferred method, described in Appendix 6D-1 of the VDOT Drainage Manual)
$V_{unpaved} = 16.1345*s^{0.5}$	Equation for average velocity for "Unpaved" surface condition from TR-55, Appendix F
$V_{paved} = 20.3282*s^{0.5}$	Equation for average velocity for "Paved" surface condition from TR-55, Appendix F
$T_{t(shallow)} = L_{shallow}/(3600*V_{unpaved/paved}$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for shallow concentrated flow)
$r = a/p_w$	Definition of hydraulic radius (r), which is equal to the cross sectional flow area (a) divided by the wetted perimeter (p_w)
$V_{channel} = (1.49*r^{2/3}*s^{1/2})/n$	Equation 3-4 (Manning's Equation) from TR-55, Chapter 3
$T_{t(channel)} = L_{channel}/(3600*V_{channel})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for channel flow)
$T_c = T_{t(sheet)} + T_{t(shallow)} + T_{t(channel)}$	Equation 3-2 for time of concentration from TR-55, Chapter 3

Sheet Flow

ID	Description	[1]Rational Method Runoff Coefficient, C	[2]Flow Length, L_{sheet} (ft)	Land Slope, s (ft/ft)	Travel Time, $T_{t(sheet)}$ (hr)
AB	Sheet Flow	0.19	100.0	0.150	0.196

Shallow Concentrated Flow

ID	Description	Paved/Unpaved	[3]Flow Length, $L_{shallow}$ (ft)	[4]Watercourse Slope, s (ft/ft)	Average Velocity, $V_{unpaved/paved}$ (ft/s)	Travel Time, $T_{t(shallow)}$ (hr)
BC	Downslope	Unpaved	864.0	0.274	8.45	0.028
CD	Waterbar	Unpaved	42.0	0.050	3.61	0.003

Channel Flow

ID	Description	[5]Manning's n	[6]Cross Sectional Flow Area, a (sf)	[6]Wetted Perimeter, p_w (ft)	Hydraulic Radius, r (ft)	Flow Length, $L_{channel}$ (ft)	Channel Slope, s (ft/ft)	Average Velocity, $V_{channel}$ (ft/s)	Travel Time, $T_{t(channel)}$ (hr)

T_c (hr) =	0.227
T_c (min) =	14

[1] Selected appropriate Rational Method runoff coefficient (C) from Table 4-5b in the Virginia Stormwater Management Handbook

[2] Assume a maximum sheet flow length of 100-ft per PS&S

[3] Assume a maximum shallow concentrated flow length of 1,000-ft in Franklin County and Roanoke County per the PS&S

[4] For waterbars, assume a channel slope of 5% (i.e., the maximum slope per General Detail MVP-17) to be conservative

[5] Assume n=0.03 for all natural/man-made channels to be conservative

[6] Assume bank-full elevation per TR-55

IV. Summary

As shown, the water bar end treatment calculator indicates a 17 foot long end treatment will ensure sheet flow conditions leaving Water Bar 48. For ease of construction, a water bar end treatment length of 20 feet will be used for Water Bar 48.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	14	time of concentration to water bar, min
	A =	1.98	water bar drainage area, ac
	S =	0.263	weir discharge overland slope, ft/ft
Computed	i =	4.8	computed from IDF, in/hr
Enter Flow Parameters	C =	0.19	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **17 ft**

Velocity Check ------> **0.69 fps**

Water Bar 49 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 49 is 0.13 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 49 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 49 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 2 foot long end treatment will ensure sheet flow conditions leaving Water Bar 49. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 49.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.13	water bar drainage area, ac
	S =	0.250	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **2 ft**

Velocity Check ------> **0.67 fps**

Water Bar 50 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 50 is 0.08 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 50 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 50 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 1 foot long end treatment will ensure sheet flow conditions leaving Water Bar 50. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 50.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.08	water bar drainage area, ac
	S =	0.335	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **1 ft**

Velocity Check ------> **0.77 fps**

Water Bar 51 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 51 is 0.05 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 51 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 51 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 1 foot long end treatment will ensure sheet flow conditions leaving Water Bar 51. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 51.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.05	water bar drainage area, ac
	S =	0.385	weir discharge overland slope, ft/ft
Computed	i =	6.6	assumes >6% slope, meadow (conservative)
Enter Flow Parameters	C =	0.25	calculated composite runoff coefficient
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **1 ft**

Velocity Check ------> **0.83 fps**

Water Bar 52 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 52 is 0.04 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 52 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 52 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 1 foot long end treatment will ensure sheet flow conditions leaving Water Bar 52. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 52.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.04	water bar drainage area, ac
	S =	0.447	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **1 ft**

Velocity Check ------> **0.89 fps**

Water Bar 53 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 53 is 0.04 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 53 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 53 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 1 foot long end treatment will ensure sheet flow conditions leaving Water Bar 53. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 53.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.04	water bar drainage area, ac
	S =	0.477	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **1 ft**

Velocity Check ------> **0.92 fps**

Water Bar 55 Site Specific Analysis

I. Drainage Area

As shown, the drainage area to Water Bar 55 is 1.7 Acres. This is greater than the 1.5 acre-maximum in the MVP 17.3 Water Bar End Treatment Detail and, therefore, requires a site-specific analysis to determine the water bar end treatment length.

II. Runoff Coefficient

The flowpath for Water Bar 55 begins as sheet flow in a HSG A wooded area with slopes greater than 6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.08.

The flowpath exiting the Water Bar 55 end treatment will be along HSG A meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.1.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration (T_c)

As shown, the time of concentration of Water Bar 55 is 28 minutes.

Equation	Reference
$T_{t(sheet)} = 0.225*L_{sheet}^{0.42}*s^{-0.19}*C^{-1.0}$	Seelye Method for calculating overland flow time (VDOT's preferred method, described in Appendix 6D-1 of the VDOT Drainage Manual)
$V_{unpaved} = 16.1345*s^{0.5}$	Equation for average velocity for "Unpaved" surface condition from TR-55, Appendix F
$V_{paved} = 20.3282*s^{0.5}$	Equation for average velocity for "Paved" surface condition from TR-55, Appendix F
$T_{t(shallow)} = L_{shallow}/(3600*V_{unpaved/paved}$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for shallow concentrated flow)
$r = a/p_w$	Definition of hydraulic radius (r), which is equal to the cross sectional flow area (a) divided by the wetted perimeter (p_w)
$V_{channel} = (1.49*r^{2/3}*s^{1/2})/n$	Equation 3-4 (Manning's Equation) from TR-55, Chapter 3
$T_{t(channel)} = L_{channel}/(3600*V_{channel})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for channel flow)
$T_c = T_{t(sheet)} + T_{t(shallow)} + T_{t(channel)}$	Equation 3-2 for time of concentration from TR-55, Chapter 3

Sheet Flow

ID	Description	[1]Rational Method Runoff Coefficient, C				[2]Flow Length, L_{sheet} (ft)	Land Slope, s (ft/ft)		Travel Time, $T_{t(sheet)}$ (hr)
AB	Sheet Flow	0.08				100.0	0.170		0.454

Shallow Concentrated Flow

ID	Description	Paved/Unpaved				[3]Flow Length, $L_{shallow}$ (ft)	[4]Watercourse Slope, s (ft/ft)	Average Velocity, $V_{unpaved/paved}$ (ft/s)	Travel Time, $T_{t(shallow)}$ (hr)
BC	Downslope	Unpaved				537.0	0.300	8.84	0.017
CD	Waterbar	Unpaved				33.0	0.050	3.61	0.003

Channel Flow

ID	Description	[5]Manning's n	[6]Cross Sectional Flow Area, a (sf)	[6]Wetted Perimeter, p_w (ft)	Hydraulic Radius, r (ft)	Flow Length, $L_{channel}$ (ft)	Channel Slope, s (ft/ft)	Average Velocity, $V_{channel}$ (ft/s)	Travel Time, $T_{t(channel)}$ (hr)

T_c (hr) =	0.474
T_c (min) =	28

[1] Selected appropriate Rational Method runoff coefficient (C) from Table 4-5b in the Virginia Stormwater Management Handbook

[2] Assume a maximum sheet flow length of 100-ft per PS&S

[3] Assume a maximum shallow concentrated flow length of 1,000-ft in Franklin County and Roanoke County per the PS&S

[4] For waterbars, assume a channel slope of 5% (i.e., the maximum slope per General Detail MVP-17) to be conservative

[5] Assume n=0.03 for all natural/man-made channels to be conservative

[6] Assume bank-full elevation per TR-55

IV. Summary

As shown, the water bar end treatment calculator indicates a 5 foot long end treatment will ensure sheet flow conditions leaving Water Bar 55. For ease of construction, a water bar end treatment length of 20 feet will be used for Water Bar 55.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	28	time of concentration to water bar, min
	A =	1.7	water bar drainage area, ac
	S =	0.330	weir discharge overland slope, ft/ft
Computed	i =	3.3	computed from IDF, in/hr
Enter Flow Parameters	C =	0.10	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **5 ft**

Velocity Check ------> **0.77 fps**

Water Bar 56 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 56 is 0.93 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

Composite Curve Number (CN) Calculator				
LAND USE	**HSG**	**CN**	**AREA (%)**	**AreaWeighted CN**
Impervious	C	98	4%	4
Meadow	C	71	51%	36
Wooded	C	70	45%	32
			100%	72

II. Runoff Coefficient

The flowpath for Water Bar 56 begins as sheet flow in a HSG A wooded area with slopes greater than 6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.17.

The drainage area for Water Bar 56 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.22 was calculated as shown below to more accurately represent the runoff condition within the drainage area.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

Composite Runoff Coefficient (C) Calculator					
LAND USE	**HSG**	**C**	**Area %**	**Area Weighted C**	
Impervious	C	0.9	4%	0.04	
Meadow	C	0.22	51%	0.11	
Wooded	C	0.17	45%	0.08	
			100%	0.22	**<--- Composite C**

III. Time of Concentration (T_c)

As shown, the time of concentration of Water Bar 56 is 13 minutes.

Equation	Reference
$T_{t(sheet)} = 0.225*L_{sheet}^{0.42}*s^{-0.19}*C^{-1.0}$	Seelye Method for calculating overland flow time (VDOT's preferred method, described in Appendix 6D-1 of the VDOT Drainage Manual)
$V_{unpaved} = 16.1345*s^{0.5}$	Equation for average velocity for "Unpaved" surface condition from TR-55, Appendix F
$V_{paved} = 20.3282*s^{0.5}$	Equation for average velocity for "Paved" surface condition from TR-55, Appendix F
$T_{t(shallow)} = L_{shallow}/(3600*V_{unpaved/paved}$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for shallow concentrated flow)
$r = a/p_w$	Definition of hydraulic radius (r), which is equal to the cross sectional flow area (a) divided by the wetted perimeter (p_w)
$V_{channel} = (1.49*r^{2/3}*s^{1/2})/n$	Equation 3-4 (Manning's Equation) from TR-55, Chapter 3
$T_{t(channel)} = L_{channel}/(3600*V_{channel})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for channel flow)
$T_c = T_{t(sheet)} + T_{t(shallow)} + T_{t(channel)}$	Equation 3-2 for time of concentration from TR-55, Chapter 3

Sheet Flow

ID	Description	[1]Rational Method Runoff Coefficient, C				[2]Flow Length, L_{sheet} (ft)	Land Slope, s (ft/ft)		Travel Time, $T_{t(sheet)}$ (hr)
AB	Sheet Flow	0.17				100.0	0.280		0.194

Shallow Concentrated Flow

ID	Description	Paved/Unpaved				[3]Flow Length, $L_{shallow}$ (ft)	[4]Watercourse Slope, s (ft/ft)	Average Velocity, $V_{unpaved/paved}$ (ft/s)	Travel Time, $T_{t(shallow)}$ (hr)
BC	Downslope	Unpaved				460.0	0.204	7.29	0.018
CD	Waterbar	Unpaved				65.0	0.050	3.61	0.005

Channel Flow

ID	Description	[5]Manning's n	[6]Cross Sectional Flow Area, a (sf)	[6]Wetted Perimeter, p_w (ft)	Hydraulic Radius, r (ft)	Flow Length, $L_{channel}$ (ft)	Channel Slope, s (ft/ft)	Average Velocity, $V_{channel}$ (ft/s)	Travel Time, $T_{t(channel)}$ (hr)

T_c (hr) =	0.217
T_c (min) =	13

[1] Selected appropriate Rational Method runoff coefficient (C) from Table 4-5b in the Virginia Stormwater Management Handbook

[2] Assume a maximum sheet flow length of 100-ft per PS&S

[3] Assume a maximum shallow concentrated flow length of 1,000-ft in Franklin County and Roanoke County per the PS&S

[4] For waterbars, assume a channel slope of 5% (i.e., the maximum slope per General Detail MVP-17) to be conservative

[5] Assume n=0.03 for all natural/man-made channels to be conservative

[6] Assume bank-full elevation per TR-55

IV. Summary

As shown, the water bar end treatment calculator indicates a 9 foot long end treatment will ensure sheet flow conditions leaving Water Bar 56. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 56.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	13	time of concentration to water bar, min
	A =	0.93	water bar drainage area, ac
	S =	0.054	weir discharge overland slope, ft/ft
Computed	i =	4.8	computed from IDF, in/hr
Enter Flow Parameters	C =	0.22	calculated composite runoff coefficient
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **9 ft**

Velocity Check ------> **0.31 fps**

Water Bar 58 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 58 is 0.13 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

Composite Curve Number (CN) Calculator				
LAND USE	**HSG**	**CN**	**AREA (%)**	**AreaWeighted CN**
Impervious	C	98	20%	20
Meadow	C	71	30%	21
Wooded	C	70	50%	35
			100%	76

II. Runoff Coefficient

The drainage area for Water Bar 58 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.33 was calculated as shown below to more accurately represent the runoff condition within the drainage area.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

Composite Runoff Coefficient (C) Calculator				
LAND USE	**HSG**	**C**	**Area %**	**Area Weighted C**
Impervious	C	0.9	20%	0.18
Meadow	C	0.22	30%	0.07
Wooded	C	0.17	50%	0.09
			100%	0.33

<--- Composite C

III. Time of Concentration (T_c)

A minimum time of concentration of 5 minutes was assumed for Water Bar 58 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 3 foot long end treatment will ensure sheet flow conditions leaving Water Bar 58. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 58.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.13	water bar drainage area, ac
	S =	0.200	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.33	calculated composite runoff coefficient
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **3 ft**

Velocity Check ------> **0.60 fps**

Water Bar 59 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 59 is 0.08 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

Composite Curve Number (CN) Calculator				
LAND USE	**HSG**	**CN**	**AREA (%)**	**AreaWeighted CN**
Impervious	C	98	17%	17
Meadow	C	71	0%	0
Wooded	C	70	83%	58
			100%	75

II. Runoff Coefficient

The drainage area for Water Bar 59 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.29 was calculated as shown below to more accurately represent the runoff condition within the drainage area.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

Composite Runoff Coefficient (C) Calculator				
LAND USE	**HSG**	**C**	**Area %**	**Area Weighted C**
Impervious	C	0.9	17%	0.15
Meadow	C	0.22	0%	0.00
Wooded	C	0.17	83%	0.14
			100%	0.29

<--- Composite C

III. Time of Concentration (T_c)

A minimum time of concentration of 5 minutes was assumed for Water Bar 59 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 1 foot long end treatment will ensure sheet flow conditions leaving Water Bar 59. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 59.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.08	water bar drainage area, ac
	S =	0.100	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.29	calculated composite runoff coefficient
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **1 ft**

Velocity Check ------> **0.42 fps**

Water Bar 60 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 60 is 0.1 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

Composite Curve Number (CN) Calculator				
LAND USE	**HSG**	**CN**	**AREA (%)**	**AreaWeighted CN**
Impervious	C	98	16%	16
Meadow	C	71	0%	0
Wooded	C	70	84%	59
			100%	74

II. Runoff Coefficient

The drainage area for Water Bar 60 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.29 was calculated as shown below to more accurately represent the runoff condition within the drainage area.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

Composite Runoff Coefficient (C) Calculator				
LAND USE	**HSG**	**C**	**Area %**	**Area Weighted C**
Impervious	C	0.9	16%	0.14
Meadow	C	0.22	0%	0.00
Wooded	C	0.17	84%	0.14
			100%	0.29

<--- Composite C

III. Time of Concentration (T_c)

A minimum time of concentration of 5 minutes was assumed for Water Bar 60 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 2 foot long end treatment will ensure sheet flow conditions leaving Water Bar 60. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 60.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.1	water bar drainage area, ac
	S =	0.050	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.29	calculated composite runoff coefficient
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **2 ft**

Velocity Check ------> **0.30 fps**

Water Bar 61 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 61 is 0.07 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

Composite Curve Number (CN) Calculator				
LAND USE	**HSG**	**CN**	**AREA (%)**	**AreaWeighted CN**
Impervious	C	98	25%	25
Meadow	C	71	0%	0
Wooded	C	70	75%	53
			100%	77

II. Runoff Coefficient

The drainage area for Water Bar 61 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.35 was calculated as shown below to more accurately represent the runoff condition within the drainage area.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

Composite Runoff Coefficient (C) Calculator					
LAND USE	**HSG**	**C**	**Area %**	**Area Weighted C**	
Impervious	C	0.9	25%	0.23	
Meadow	C	0.22	0%	0.00	
Wooded	C	0.17	75%	0.13	
			100%	0.35	<--- Composite C

III. Time of Concentration (T_c)

A minimum time of concentration of 5 minutes was assumed for Water Bar 61 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 2 foot long end treatment will ensure sheet flow conditions leaving Water Bar 61. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 61.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.07	water bar drainage area, ac
	S =	0.140	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.35	calculated composite runoff coefficient
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **2 ft**

Velocity Check ------> **0.50 fps**

Water Bar 62 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 62 is 0.06 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

Composite Curve Number (CN) Calculator				
LAND USE	**HSG**	**CN**	**AREA (%)**	**AreaWeighted CN**
Impervious	C	98	45%	44
Meadow	C	71	0%	0
Wooded	C	70	55%	39
			100%	83

II. Runoff Coefficient

The drainage area for Water Bar 62 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.5 was calculated as shown below to more accurately represent the runoff condition within the drainage area.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

Composite Runoff Coefficient (C) Calculator					
LAND USE	**HSG**	**C**	**Area %**	**Area Weighted C**	
Impervious	C	0.9	45%	0.41	
Meadow	C	0.22	0%	0.00	
Wooded	C	0.17	55%	0.09	
			100%	0.50	<--- Composite C

III. Time of Concentration (T_c)

A minimum time of concentration of 5 minutes was assumed for Water Bar 62 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 2 foot long end treatment will ensure sheet flow conditions leaving Water Bar 62. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 62.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.06	water bar drainage area, ac
	S =	0.140	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.50	calculated composite runoff coefficient
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **2 ft**

Velocity Check ------> **0.50 fps**

Water Bar 63 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 63 is 0.31 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 63 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 63 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 5 foot long end treatment will ensure sheet flow conditions leaving Water Bar 63. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 63.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.31	water bar drainage area, ac
	S =	0.070	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **5 ft**

Velocity Check ------> **0.35 fps**

Water Bar 66 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 66 is 0.14 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 66 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 66 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 2 foot long end treatment will ensure sheet flow conditions leaving Water Bar 66. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 66.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.14	water bar drainage area, ac
	S =	0.320	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **2 ft**

Velocity Check ------> **0.76 fps**

Water Bar 67 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 67 is 0.17 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 67 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 67 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 3 foot long end treatment will ensure sheet flow conditions leaving Water Bar 67. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 67.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.17	water bar drainage area, ac
	S =	0.210	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **3 ft**

Velocity Check ------> **0.61 fps**

Water Bar 68 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 68 is 0.51 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

Composite Curve Number (CN) Calculator				
LAND USE	**HSG**	**CN**	**AREA (%)**	**AreaWeighted CN**
Impervious	D	98	5%	5
Meadow	D	78	75%	59
Wooded	D	77	20%	15
			100%	79

II. Runoff Coefficient

The flowpath for Water Bar 68 begins as sheet flow in a HSG D wooded area with slopes greater than 6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.21.

The drainage area for Water Bar 68 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.27 was calculated as shown below to more accurately represent the runoff condition within the drainage area.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

Composite Runoff Coefficient (C) Calculator					
LAND USE	**HSG**	**C**	**Area %**	**Area Weighted C**	
Impervious	D	0.9	5%	0.05	
Meadow	D	0.25	75%	0.19	
Wooded	D	0.21	20%	0.04	
			100%	0.27	**<--- Composite C**

III. Time of Concentration (T_c)

As shown, the time of concentration of Water Bar 68 is 13 minutes.

Equation	Reference
$T_{t(sheet)} = 0.225*L_{sheet}^{0.42}*s^{-0.19}*C^{-1.0}$	Seelye Method for calculating overland flow time (VDOT's preferred method, described in Appendix 6D-1 of the VDOT Drainage Manual)
$V_{unpaved} = 16.1345*s^{0.5}$	Equation for average velocity for "Unpaved" surface condition from TR-55, Appendix F
$V_{paved} = 20.3282*s^{0.5}$	Equation for average velocity for "Paved" surface condition from TR-55, Appendix F
$T_{t(shallow)} = L_{shallow}/(3600*V_{unpaved/paved}$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for shallow concentrated flow)
$r = a/p_w$	Definition of hydraulic radius (r), which is equal to the cross sectional flow area (a) divided by the wetted perimeter (p_w)
$V_{channel} = (1.49*r^{2/3}*s^{1/2})/n$	Equation 3-4 (Manning's Equation) from TR-55, Chapter 3
$T_{t(channel)} = L_{channel}/(3600*V_{channel})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for channel flow)
$T_c = T_{t(sheet)} + T_{t(shallow)} + T_{t(channel)}$	Equation 3-2 for time of concentration from TR-55, Chapter 3

Sheet Flow

ID	Description	[1]Rational Method Runoff Coefficient, C				[2]Flow Length, L_{sheet} (ft)	Land Slope, s (ft/ft)		Travel Time, $T_{t(sheet)}$ (hr)
AB	Sheet Flow	0.21				100.0	0.090		0.195

Shallow Concentrated Flow

ID	Description	Paved/Unpaved				[3]Flow Length, $L_{shallow}$ (ft)	[4]Watercourse Slope, s (ft/ft)	Average Velocity, $V_{unpaved/paved}$ (ft/s)	Travel Time, $T_{t(shallow)}$ (hr)
BC	Downslope	Unpaved				364.0	0.176	6.77	0.015
CD	Waterbar	Unpaved				78.0	0.050	3.61	0.006

Channel Flow

ID	Description	[5]Manning's n	[6]Cross Sectional Flow Area, a (sf)	[6]Wetted Perimeter, p_w (ft)	Hydraulic Radius, r (ft)	Flow Length, $L_{channel}$ (ft)	Channel Slope, s (ft/ft)	Average Velocity, $V_{channel}$ (ft/s)	Travel Time, $T_{t(channel)}$ (hr)

T_c (hr) =	0.216
T_c (min) =	13

[1] Selected appropriate Rational Method runoff coefficient (C) from Table 4-5b in the Virginia Stormwater Management Handbook

[2] Assume a maximum sheet flow length of 100-ft per PS&S

[3] Assume a maximum shallow concentrated flow length of 1,000-ft in Franklin County and Roanoke County per the PS&S

[4] For waterbars, assume a channel slope of 5% (i.e., the maximum slope per General Detail MVP-17) to be conservative

[5] Assume n=0.03 for all natural/man-made channels to be conservative

[6] Assume bank-full elevation per TR-55

IV. Summary

As shown, the water bar end treatment calculator indicates a 6 foot long end treatment will ensure sheet flow conditions leaving Water Bar 68. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 68.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	13	time of concentration to water bar, min
	A =	0.51	water bar drainage area, ac
	S =	0.190	weir discharge overland slope, ft/ft
Computed	i =	5.0	computed from IDF, in/hr
Enter Flow Parameters	C =	0.27	calculated composite runoff coefficient
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **6 ft**

Velocity Check ------> **0.58 fps**

Water Bar 69 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 69 is 0.37 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 69 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 69 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 6 foot long end treatment will ensure sheet flow conditions leaving Water Bar 69. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 69.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.37	water bar drainage area, ac
	S =	0.170	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **6 ft**

Velocity Check ------> **0.55 fps**

Water Bar 70 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 70 is 0.14 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 70 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 70 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 2 foot long end treatment will ensure sheet flow conditions leaving Water Bar 70. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 70.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.14	water bar drainage area, ac
	S =	0.360	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **2 ft**

Velocity Check ------> **0.80 fps**

Water Bar 71 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 71 is 0.2 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 71 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 71 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 3 foot long end treatment will ensure sheet flow conditions leaving Water Bar 71. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 71.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.20	water bar drainage area, ac
	S =	0.270	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **3 ft**

Velocity Check ------> **0.69 fps**

Water Bar 72 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 72 is 1.34 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

Composite Curve Number (CN) Calculator				
LAND USE	**HSG**	**CN**	**AREA (%)**	**AreaWeighted CN**
Impervious	C	98	13%	13
Meadow	C	71	77%	55
Wooded	C	70	10%	7
			100%	74

II. Runoff Coefficient

The flowpath for Water Bar 72 begins as sheet flow in a HSG A meadow area with slopes greater than 6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.1.

The drainage area for Water Bar 72 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.3 was calculated as shown below to more accurately represent the runoff condition within the drainage area.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

Composite Runoff Coefficient (C) Calculator					
LAND USE	**HSG**	**C**	**Area %**	**Area Weighted C**	
Impervious	C	0.9	13%	0.12	
Meadow	C	0.22	77%	0.17	
Wooded	C	0.17	10%	0.02	
			100%	0.30	**<--- Composite C**

III. Time of Concentration (T_c)

As shown, the time of concentration of Water Bar 72 is 24 minutes.

Equation	Reference
$T_{t(sheet)} = 0.225*L_{sheet}^{0.42}*s^{-0.19}*C^{-1.0}$	Seelye Method for calculating overland flow time (VDOT's preferred method, described in Appendix 6D-1 of the VDOT Drainage Manual)
$V_{unpaved} = 16.1345*s^{0.5}$	Equation for average velocity for "Unpaved" surface condition from TR-55, Appendix F
$V_{paved} = 20.3282*s^{0.5}$	Equation for average velocity for "Paved" surface condition from TR-55, Appendix F
$T_{t(shallow)} = L_{shallow}/(3600*V_{unpaved/paved}$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for shallow concentrated flow)
$r = a/p_w$	Definition of hydraulic radius (r), which is equal to the cross sectional flow area (a) divided by the wetted perimeter (p_w)
$V_{channel} = (1.49*r^{2/3}*s^{1/2})/n$	Equation 3-4 (Manning's Equation) from TR-55, Chapter 3
$T_{t(channel)} = L_{channel}/(3600*V_{channel})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for channel flow)
$T_c = T_{t(sheet)} + T_{t(shallow)} + T_{t(channel)}$	Equation 3-2 for time of concentration from TR-55, Chapter 3

Sheet Flow

ID	Description	[1]Rational Method Runoff Coefficient, C				[2]Flow Length, L_{sheet} (ft)	Land Slope, s (ft/ft)		Travel Time, $T_{t(sheet)}$ (hr)
AB	Sheet Flow	0.10				100.0	0.150		0.372

Shallow Concentrated Flow

ID	Description	Paved/Unpaved				[3]Flow Length, $L_{shallow}$ (ft)	[4]Watercourse Slope, s (ft/ft)	Average Velocity, $V_{unpaved/paved}$ (ft/s)	Travel Time, $T_{t(shallow)}$ (hr)
BC	Downslope	Unpaved				414.0	0.082	4.62	0.025
CD	Waterbar	Unpaved				21.0	0.050	3.61	0.002

Channel Flow

ID	Description	[5]Manning's n	[6]Cross Sectional Flow Area, a (sf)	[6]Wetted Perimeter, p_w (ft)	Hydraulic Radius, r (ft)	Flow Length, $L_{channel}$ (ft)	Channel Slope, s (ft/ft)	Average Velocity, $V_{channel}$ (ft/s)	Travel Time, $T_{t(channel)}$ (hr)

T_c (hr) =	0.399
T_c (min) =	24

[1] Selected appropriate Rational Method runoff coefficient (C) from Table 4-5b in the Virginia Stormwater Management Handbook

[2] Assume a maximum sheet flow length of 100-ft per PS&S

[3] Assume a maximum shallow concentrated flow length of 1,000-ft in Franklin County and Roanoke County per the PS&S

[4] For waterbars, assume a channel slope of 5% (i.e., the maximum slope per General Detail MVP-17) to be conservative

[5] Assume n=0.03 for all natural/man-made channels to be conservative

[6] Assume bank-full elevation per TR-55

IV. Summary

As shown, the water bar end treatment calculator indicates a 14 foot long end treatment will ensure sheet flow conditions leaving Water Bar 72. For ease of construction, a water bar end treatment length of 20 feet will be used for Water Bar 72.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	24	time of concentration to water bar, min
	A =	1.34	water bar drainage area, ac
	S =	0.200	weir discharge overland slope, ft/ft
Computed	i =	3.7	computed from IDF, in/hr
Enter Flow Parameters	C =	0.30	calculated composite runoff coefficient
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **14 ft**

Velocity Check ------> **0.60 fps**

Water Bar 74 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 74 is 0.08 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

Composite Curve Number (CN) Calculator				
LAND USE	HSG	CN	AREA (%)	AreaWeighted CN
Impervious	C	98	25%	25
Meadow	C	71	0%	0
Wooded	C	70	75%	53
			100%	77

II. Runoff Coefficient

The drainage area for Water Bar 74 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.35 was calculated as shown below to more accurately represent the runoff condition within the drainage area.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

Composite Runoff Coefficient (C) Calculator					
LAND USE	HSG	C	Area %	Area Weighted C	
Impervious	C	0.9	25%	0.23	
Meadow	C	0.22	0%	0.00	
Wooded	C	0.17	75%	0.13	
			100%	0.35	<--- Composite C

III. Time of Concentration (T_c)

A minimum time of concentration of 5 minutes was assumed for Water Bar 74 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 2 foot long end treatment will ensure sheet flow conditions leaving Water Bar 74. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 74.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.08	water bar drainage area, ac
	S =	0.410	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.35	calculated composite runoff coefficient
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **2 ft**

Velocity Check ------> **0.86 fps**

Water Bar 75 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 75 is 0.12 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

Composite Curve Number (CN) Calculator				
LAND USE	**HSG**	**CN**	**AREA (%)**	**AreaWeighted CN**
Impervious	C	98	8%	8
Meadow	C	71	92%	65
Wooded	C	70	0%	0
			100%	73

II. Runoff Coefficient

The drainage area for Water Bar 75 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.27 was calculated as shown below to more accurately represent the runoff condition within the drainage area.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

Composite Runoff Coefficient (C) Calculator				
LAND USE	**HSG**	**C**	**Area %**	**Area Weighted C**
Impervious	C	0.9	8%	0.07
Meadow	C	0.22	92%	0.20
Wooded	C	0.17	0%	0.00
			100%	0.27

<--- **Composite C**

III. Time of Concentration (T_c)

A minimum time of concentration of 5 minutes was assumed for Water Bar 75 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 2 foot long end treatment will ensure sheet flow conditions leaving Water Bar 75. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 75.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.12	water bar drainage area, ac
	S =	0.030	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.27	calculated composite runoff coefficient
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **2 ft**

Velocity Check ------> **0.23 fps**

Water Bar 76 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 76 is 0.56 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

Composite Curve Number (CN) Calculator				
LAND USE	**HSG**	**CN**	**AREA (%)**	**AreaWeighted CN**
Impervious	C	98	7%	7
Meadow	C	71	93%	66
Wooded	C	70	0%	0
			100%	73

II. Runoff Coefficient

The flowpath for Water Bar 76 begins as sheet flow in a HSG C meadow area with slopes greater than 6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.22.

The drainage area for Water Bar 76 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.27 was calculated as shown below to more accurately represent the runoff condition within the drainage area.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

Composite Runoff Coefficient (C) Calculator				
LAND USE	**HSG**	**C**	**Area %**	**Area Weighted C**
Impervious	C	0.9	7%	0.06
Meadow	C	0.22	93%	0.20
Wooded	C	0.17	0%	0.00
			100%	0.27 **<--- Composite C**

III. Time of Concentration (T_c)

As shown, the time of concentration of Water Bar 76 is 12 minutes.

Equation	Reference
$T_{t(sheet)} = 0.225*L_{sheet}^{0.42}*s^{-0.19}*C^{-1.0}$	Seelye Method for calculating overland flow time (VDOT's preferred method, described in Appendix 6D-1 of the VDOT Drainage Manual)
$V_{unpaved} = 16.1345*s^{0.5}$	Equation for average velocity for "Unpaved" surface condition from TR-55, Appendix F
$V_{paved} = 20.3282*s^{0.5}$	Equation for average velocity for "Paved" surface condition from TR-55, Appendix F
$T_{t(shallow)} = L_{shallow}/(3600*V_{unpaved/paved}$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for shallow concentrated flow)
$r = a/p_w$	Definition of hydraulic radius (r), which is equal to the cross sectional flow area (a) divided by the wetted perimeter (p_w)
$V_{channel} = (1.49*r^{2/3}*s^{1/2})/n$	Equation 3-4 (Manning's Equation) from TR-55, Chapter 3
$T_{t(channel)} = L_{channel}/(3600*V_{channel})$	Equation 3-1 for travel time from TR-55, Chapter 3 (equation as noted defines variables used when estimating travel time specifically for channel flow)
$T_c = T_{t(sheet)} + T_{t(shallow)} + T_{t(channel)}$	Equation 3-2 for time of concentration from TR-55, Chapter 3

Sheet Flow

ID	Description	[1]Rational Method Runoff Coefficient, C				[2]Flow Length, L_{sheet} (ft)	Land Slope, s (ft/ft)		Travel Time, $T_{t(sheet)}$ (hr)
AB	Sheet Flow	0.22				100.0	0.070		0.195

Shallow Concentrated Flow

ID	Description	Paved/Unpaved				[3]Flow Length, $L_{shallow}$ (ft)	[4]Watercourse Slope, s (ft/ft)	Average Velocity, $V_{unpaved/paved}$ (ft/s)	Travel Time, $T_{t(shallow)}$ (hr)
BC	Downslope	Unpaved				98.0	0.224	7.64	0.004
CD	Waterbar	Unpaved				10.0	0.050	3.61	0.001

Channel Flow

ID	Description	[5]Manning's n	[6]Cross Sectional Flow Area, a (sf)	[6]Wetted Perimeter, p_w (ft)	Hydraulic Radius, r (ft)	Flow Length, $L_{channel}$ (ft)	Channel Slope, s (ft/ft)	Average Velocity, $V_{channel}$ (ft/s)	Travel Time, $T_{t(channel)}$ (hr)

T_c (hr) =	0.200
T_c (min) =	12

[1] Selected appropriate Rational Method runoff coefficient (C) from Table 4-5b in the Virginia Stormwater Management Handbook

[2] Assume a maximum sheet flow length of 100-ft per PS&S

[3] Assume a maximum shallow concentrated flow length of 1,000-ft in Franklin County and Roanoke County per the PS&S

[4] For waterbars, assume a channel slope of 5% (i.e., the maximum slope per General Detail MVP-17) to be conservative

[5] Assume n=0.03 for all natural/man-made channels to be conservative

[6] Assume bank-full elevation per TR-55

IV. Summary

As shown, the water bar end treatment calculator indicates a 7 foot long end treatment will ensure sheet flow conditions leaving Water Bar 76. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 76.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	12	time of concentration to water bar, min
	A =	0.56	water bar drainage area, ac
	S =	0.240	weir discharge overland slope, ft/ft
Computed	i =	5.1	computed from IDF, in/hr
Enter Flow Parameters	C =	0.27	calculated composite runoff coefficient
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **7 ft**

Velocity Check ------> **0.66 fps**

Water Bar 77 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 77 is 0.15 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

Composite Curve Number (CN) Calculator				
LAND USE	**HSG**	**CN**	**AREA (%)**	**AreaWeighted CN**
Impervious	C	98	7%	7
Meadow	C	71	93%	66
Wooded	C	70	0%	0
			100%	73

II. Runoff Coefficient

The drainage area for Water Bar 77 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.27 was calculated as shown below to more accurately represent the runoff condition within the drainage area.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

Composite Runoff Coefficient (C) Calculator					
LAND USE	**HSG**	**C**	**Area %**	**Area Weighted C**	
Impervious	C	0.9	7%	0.06	
Meadow	C	0.22	93%	0.20	
Wooded	C	0.17	0%	0.00	
			100%	0.27	<--- Composite C

III. Time of Concentration (T_c)

A minimum time of concentration of 5 minutes was assumed for Water Bar 77 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 3 foot long end treatment will ensure sheet flow conditions leaving Water Bar 77. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 77.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.15	water bar drainage area, ac
	S =	0.130	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.27	calculated composite runoff coefficient
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **3 ft**

Velocity Check ------> **0.48 fps**

Water Bar 78 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 78 is 0.06 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

Composite Curve Number (CN) Calculator				
LAND USE	**HSG**	**CN**	**AREA (%)**	**AreaWeighted CN**
Impervious	C	98	17%	17
Meadow	C	71	83%	59
Wooded	C	70	0%	0
			100%	76

II. Runoff Coefficient

The drainage area for Water Bar 78 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.34 was calculated as shown below to more accurately represent the runoff condition within the drainage area.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

Composite Runoff Coefficient (C) Calculator				
LAND USE	**HSG**	**C**	**Area %**	**Area Weighted C**
Impervious	C	0.9	17%	0.15
Meadow	C	0.22	83%	0.18
Wooded	C	0.17	0%	0.00
			100%	0.34 <--- **Composite C**

III. Time of Concentration (T_c)

A minimum time of concentration of 5 minutes was assumed for Water Bar 78 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 1 foot long end treatment will ensure sheet flow conditions leaving Water Bar 78. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 78.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.06	water bar drainage area, ac
	S =	0.030	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.34	calculated composite runoff coefficient
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **1 ft**

Velocity Check ------> **0.23 fps**

Water Bar 79 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 79 is 0.14 acres, and has a curve number (CN) greater than 71 based on the soil and land uses present within the drainage area. Therefore, this drainage area requires a site-specific analysis to determine the water bar end treatment length per the MVP 17.3 Water Bar End Treatment Detail.

II. Runoff Coefficient

The flowpath exiting the Water Bar 79 end treatment will be along HSG D meadow with slopes greater than 6%. Therefore, the runoff coefficient used in the end treatment calculation will be 0.25.

TABLE 4-5B

Rational Equation Coefficients for SCS Hydrologic Soil Groups (A, B, C, D)

Rural Land Use

STORM FREQUENCIES OF LESS THAN 25 YEARS

Land Use	Treatment / Practice	Hydrologic Condition	HYDROLOGIC SOIL GROUP/SLOPE											
			A			B			C			D		
			0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Pasture or Range		Good	0.07	0.09	0.10	0.18	0.20	0.22	0.27	0.29	0.31	0.32	0.34	0.35
	Contoured	Good	0.03	0.04	0.06	0.11	0.12	0.14	0.24	0.26	0.28	0.31	0.33	0.34
Meadow			0.06	0.08	0.10	0.10	0.14	0.19	0.12	0.17	0.22	0.15	0.20	0.25
Wooded		Good	0.05	0.07	0.08	0.08	0.11	0.15	0.10	0.13	0.17	0.12	0.15	0.21

Source: Maryland State Highway Administration

III. Time of Concentration

A minimum time of concentration of 5 minutes was assumed for Water Bar 79 because the drainage area is less than or equal to 0.5 acres.

IV. Summary

As shown, the water bar end treatment calculator indicates a 2 foot long end treatment will ensure sheet flow conditions leaving Water Bar 79. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 79.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.14	water bar drainage area, ac
	S =	0.150	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.25	assumes >6% slope, meadow (conservative)
	Cw =	3.33	weir coefficient (rectangular)
	n =	0.24	sheetflow, dense grasses
	H =	0.1	sheetflow depth over weir, ft

Computed Weir Length ------> **2 ft**

Velocity Check ------> **0.52 fps**

i. New Impervious Cover: Access Roads

New impervious cover in Spread 9 includes three (3) access roads (MVP-MLV-AR-25 through -27). Increased volumes of stormwater runoff resulting from access roads will be controlled utilizing the methodology established in *MVP-33.1 through MVP-33.3 Gap Graded Gravel Detail for Mainline Valve Pads and Permanent Access Roads*.

Each access road consists of a geogrid, underlain by a 2-inch layer of clean-washed choker stone, geotextile fabric, an open-graded subbase reservoir, and compacted earthen baffles to detain water within the access road. The access road surface will consist of two gravel tracks, with a center aisle top-dressed with soil and seeded with a meadow seed mix per *MVP-ES11.2 Upland Meadow Seed Mix and Application Rates* or *MVP-ES11.3 Upland Steep Slope Seed Mix and Application Rates*.

Pre- and post-construction runoff volumes for the 10-year 24-hour storm were calculated using the Giles and Montgomery County design storm values of 4.70 and 5.00 inches, respectively, per *PSS&S Section 4.2.2 Design Storms*. Runoff volumes were calculated for both the drainage area to each gap graded gravel access road and for the access road footprint alone. Results are shown below.

10-YEAR STORM DATA FULL RUN-ON DRAINAGE AREA					
SITE	TIME OF CONCENTRATION (PRE / POST) [HR]	CURVE NUMBER (PRE / POST)	DRAINAGE AREA [FT^2]	Q_{10} PEAK FLOW (PRE / POST) [CFS]	Q_{10} VOLUME (PRE / POST) [FT^3]
MLV-AR-25	0.28 / 0.28	56 / 56	684,148	13.31 / 13.31	50,475 / 50,475
MLV-AR-26	0.15 / 0.12	60 / 67	3,523	0.14 / 0.21	381 / 529
MLV-AR-27	0.33 / 0.33	70 / 70	410,321	20.14 / 20.14	69,266 / 69,266

10-YEAR STORM DATA ACCESS ROAD FOOTPRINT					
SITE	TIME OF CONCENTRATION (PRE / POST) [HR]	CURVE NUMBER (PRE / POST)	DRAINAGE AREA [FT^2]	Q_{10} PEAK FLOW (PRE / POST) [CFS]	Q_{10} VOLUME (PRE / POST) [FT^3]
MLV-AR-25	0.10 / 0.10	78 / 78	19,776	1.69 / 1.69	4,088 / 4,088
MLV-AR-26	0.10 / 0.10	58 / 78	1,263	0.05 / 0.12	123 / 285
MLV-AR-27	0.10 / 0.10	73 / 85	16,988	1.35 / 1.97	3,223 / 4,748

Increases in run-off volumes for both the drainage area and access road only are further summarized below.

		Peak Flow (cfs)	Hydrograph Volume (ac-ft)	Hydrograph Volume (ft^3)	Required Treatment Volume (ft^3)
MLV-AR-25 FULL DA	Pre	13.31	1.15875	50475	0
	Post	13.31	1.15875	50475	
MLV-AR-25 AR ONLY	Pre	1.69	0.092	4008	0
	Post	1.69	0.092	4008	

MLV-AR-26 FULL DA	Pre	0.14	0.00875	381	148
	Post	0.21	0.01214	529	
MLV-AR-26 AR ONLY	Pre	0.05	0.00282	123	162
	Post	0.12	0.00654	285	

MLV-AR-27 FULL DA	Pre	20.14	1.59013	69266	0
	Post	20.14	1.59013	69266	
MLV-AR-27 AR ONLY	Pre	1.35	0.074	3223	1525
	Post	1.97	0.109	4748	

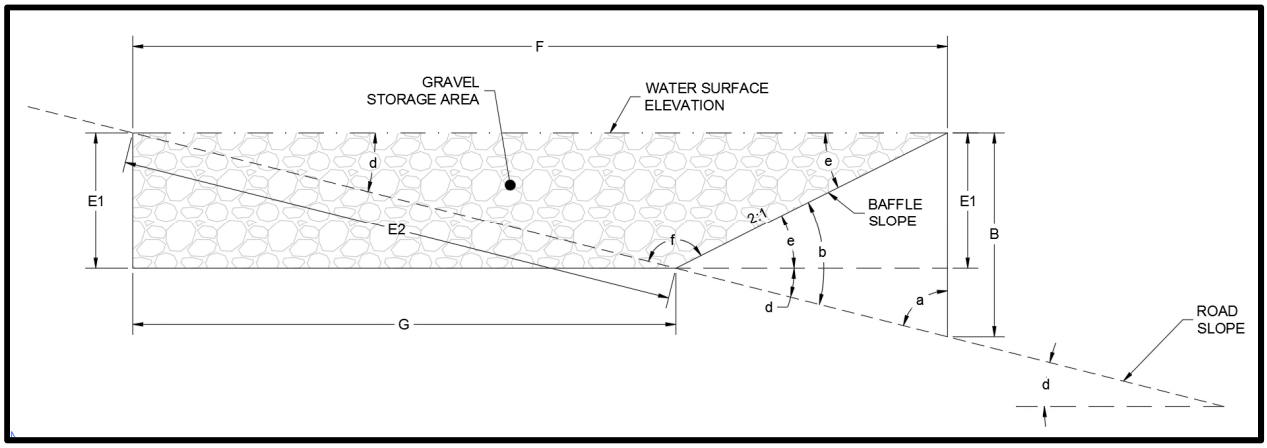
The runoff volume increase when considering only the access road is greater than the resulting runoff volume increase when considering the full drainage area. As a result, the reservoir within the access road is conservatively sized to accommodate the required volume computed using the road footprint only. Any increase in runoff volume from pre- to post-construction condition must be stored within the gap graded gravel to meet flood protection requirements per 9VAC25-870-66.C.2.

A site-specific analysis was performed for all access roads to determine the number of earthen baffles, earthen baffle spacing, and subbase reservoir depth required to detain the increased volume from the 10-year storm, and allow the excess stormwater to infiltrate into the underlying soil. Details of the analysis are provided below.

Site	Road Length (ft)	Road Slope (ft/ft)	# of Baffles	Baffle Spacing (ft)	Baffle Height (ft)
MVP-MLV-AR-25	50	0.410	1	50	1
	920	0.120	1	920	1
	683	0.057	1	683	1
MVP-MLV-AR-26	13	0.060	1	14	1
	8	0.240	1	8	1
	22	0.053	2	11	1
	7	0.100	1	7.5	1
MVP-MLV-AR-27	17	0.180	1	17	1

	200	0.074	5	40	1
	121	0.026	2	60	1
	89	0.099	2	44	1
	54	0.301	1	54	1
	253	0.367	1	253	1
	129	0.051	4	32	1
	92	0.028	2	46	1
	127	0.202	1	127	1
	200	0.082	5	40	1

Because the slopes of the access roads vary significantly, storage calculations were performed for each, using the following methodology:



1. Determine the cross-section area (CSA) of storage behind each baffle, assuming a triangle based on bottom slope.

$$CSA = 0.5 \times A \times F \times \sin(e) + 0.5 \times E1 \times E2 \times \sin(a)$$

where CSA = Cross-sectional area; ft^2

$a = 90 - \tan^{-1}(\text{road slope})$

$b = \tan^{-1}(\text{road slope}) + \tan^{-1}(\text{baffle slope})$

$d = \tan^{-1}(\text{road slope})$

$e = \tan^{-1}(\text{baffle slope})$

$f = 180 - b$

$A = B \times (\sin(a)/\sin(b))$

B = baffle height

$E1 = A \times \sin(e)$

$E2 = A \times (\sin(e)/\sin(d))$

$F = A \times (\sin(f)/\sin(d))$

G = F - E1/baffle slope

2. Determine the storage volume available per earthen baffle.

$$Vavailable = CSA \times W \times n$$

where Vavailable = Storage volume per earthen baffle; ft^3

W = Stone width (12 ft)
n = Stone porosity (0.40)

3. Determine the number of baffle cells needed by dividing the storage volume per earthen baffle into the required treatment volume. Because it is necessary to round up to the next integer, the baffle design volume will always exceed the required treatment volume.

4. Determine the baffle cell spacing by dividing the number of baffles needed into the access road length.

To ensure the roads drain with the 72-hour maximum drawdown time, the design volumes were divided by the most conservative saturated hydraulic conductivity (Ksat) of the underlying soils. Each calculated drawdown time used the maximum depth of each triangular CSA and was multiplied by a Safety Factor of 2, resulting in the following drawdown times (all less than the 72-hour maximum). Note that several access roads span more than one different soil types with different Ksat rates.

MVP-MLV-AR-25		
MUSYM	14E	[-]
HSG	B	[-]
K_{SAT}	1.84	[IN/HR]
Max Depth	0.90	[FT]
Drawdown Time	12	[HR]
MVP-MLV-AR-26		
MUSYM	11B	[-]
HSG	B	[-]
K_{SAT}	1.28	[IN/HR]
Max Depth	1.13	[FT]
Drawdown Time	21	[HR]
MUSYM	11B	[-]
HSG	B	[-]
K_{SAT}	1.28	[IN/HR]
Max Depth	1.13	[FT]
Drawdown Time	21	[HR]
MUSYM	11B	[-]
HSG	B	[-]
K_{SAT}	1.28	[IN/HR]
Max Depth	1.13	[FT]
Drawdown Time	21	[HR]

MVP-MLV-AR-27		
MUSYM	30C	[-]
HSG	B	[-]
K_{SAT}	2.18	[IN/HR]
Max Depth	0.95	[FT]
Drawdown Time	11	[HR]
MUSYM	8E	[-]
HSG	C	[-]
K_{SAT}	0.24	[IN/HR]
Max Depth	0.95	[FT]
Drawdown Time*	48	[HR]
MUSYM	33E	[-]
HSG	D	[-]
K_{SAT}	0.7	[IN/HR]
Max Depth	0.95	[FT]
Drawdown Time	33	[HR]

*Note: 72-hour maximum drawdown time satisfied by reducing safety factor.

ii. New Impervious Cover: Main Line Valve Pads

New impervious cover in Spread 9 also includes four (4) main line valve sites (MVP-MLV-25 through -27 with two pads at MVP-MLV-25). Increased volumes of stormwater runoff resulting from the main line valve pads will be controlled utilizing the methodology established in *MVP-33.1 through MVP-33.3 Gap Graded Gravel Detail for Mainline Valve Pads and Permanent Access Roads*. All pads will be located on relatively flat ground. The runoff volume increase when considering only the pad is greater than the resulting runoff volume increase when considering the full drainage area. As a result, the reservoir within the gap graded gravel pad is conservatively sized to accommodate the required volume computed using the pad footprint only.

Pre- and post-construction runoff volumes for the 10-year 24-hour storm were calculated using the Giles and Montgomery County design storm values of 4.70 and 5.00 inches, respectively, per *PSS&S Section 4.2.2 Design Storms*.

10-YEAR STORM DATA					
SITE	TIME OF CONCENTRATION (PRE / POST) [HR]	CURVE NUMBER (PRE / POST)	DRAINAGE AREA [FT^2]	Q_{10} PEAK FLOW (PRE / POST) [CFS]	Q_{10} VOLUME (PRE / POST) [FT^3]
MLV-25 PAD 1	0.10 / 0.10	55 / 85	2,396	0.06 / 0.26	174 / 610
MLV-25 PAD 2	0.10 / 0.10	55 / 85	218	0.00 / 0.00	13 / 44

MLV-26	0.10 / 0.10	58 / 85	2,396	0.09 / 0.28	218 / 653
MLV-27	0.10 / 0.10	58 / 85	2,396	0.09 / 0.28	218 / 653

Any increase in runoff volume from pre- to post-construction condition must be stored within the gap graded gravel to meet flood protection requirements per 9VAC25-870-66.C.2. The calculated treatment volume required was then divided by the pad footprint and 40% void space to determine the depth of gravel required to store the 10-year 24-hour storm event. In this instance, calculated gravel depths for all pads were less than the 8-inch minimum required per *MVP-33.1 through MVP-33.3 Gap Graded Gravel Detail for Mainline Valve Pads and Permanent Access Roads*. Therefore, gravel depths for all pads are 8 inches, providing storage beyond the 10-year 24-hour storm event.

MLV-25 Pad 1	Vreq	436	cf
	Area	2376	sf
	Dreq	0.46	ft
	Ddesign	8	in
	Vdesign	634	cf

MLV-25 Pad 2	Vreq	30	cf
	Area	225	sf
	Dreq	0.33	ft
	Ddesign	8	in
	Vdesign	60	cf

MLV-26 Pad	Vreq	436	cf
	Area	2376	sf
	Dreq	0.46	ft
	Ddesign	8	in
	Vdesign	634	cf

MLV-27 Pad	Vreq	436	cf
	Area	2376	sf
	Dreq	0.46	ft
	Ddesign	8	in
	Vdesign	634	cf

To ensure the gravel pads drain with the 72-hour maximum drawdown time, the design volumes were divided by the most conservative saturated hydraulic conductivity (Ksat) of the underlying soils. Each calculated drawdown time was multiplied by a Safety Factor of 2, resulting in the following drawdown times (all less than the 72-hour maximum).

MVP-MLV-25 PADS 1 & 2		
MUSYM	14E	[-]
HSG	B	[-]
K_{SAT}	1.84	[IN/HR]
Depth	8	[IN]
Drawdown Time	9	[HR]

MVP-MLV-26		
MUSYM	11B	[-]
HSG	B	[-]
K_{SAT}	1.28	[IN/HR]
Depth	8	[IN]
Drawdown Time	13	[HR]

MVP-MLV-27		
MUSYM	30C	[-]
HSG	B	[-]
K_{SAT}	2.18	[IN/HR]
Depth	8	[IN]
Drawdown Time	7	[HR]

Results show the 10-year 24-hour storm event will be stored within the gravel layer with no overtopping, and with reasonable drawdown times before the next storm event.

		Culvert Design					[1]Riprap Apron Outlet Protection Design						
Station	Corresponding Stream	[3]Culvert Diameter, d_o (in)	Culvert Material	[2]Pipe Slope (ft/ft)	Q (cfs)	Design Flow Frequency	d_{50} Riprap Size, d_{50} (in)	AASHTO Riprap Class	Placement Thickness per NSA Riprap Gradation, d (in)	Placement Thickness per AASHTO Riprap Gradation, d (in)	Apron Length, L_a (ft)	Apron Initial Width, W_i (ft)	Apron Terminal Width, W (ft)
33+35.49	S-MN32	N/A (Box Culvert: Span=12.0-ft, Rise=8.0-ft)	Concrete	0.0060	524.55	10-Yr	N/A - Scour protection needs to withstand tailwater velocity of 7.796 ft/s and shear stress of 2.29 psf. Suggest AASHTO Riprap Class A or equivalent. Note that scour protection should be placed within the channel from top-of-bank to top-of-bank, and extend from the culvert outlet to the limit of disturbance.						

[1]Designed in accordance with VESCH Std & Spec 3.18 assuming minimum tailwater condition ($T_w < 0.5d_o$).

[2]The slope was calculated from a combination of LIDAR and field notes taken for the stream channel characteristics.

[3]Requires roadway grading (fill of 4.667 feet) to install culvert with minimum recommended cover of 2 inches.

DA-RO-SM32
426.08 acres
Weighted CN = 62

Land Use	HSG	CN	Area (AC)
Woods	A	30	5.82
Woods	B	55	276.54
Woods	D	77	134.17
Meadow	A	30	2.75
Meadow	B	58	0.23
Meadow	D	78	1.44
Dirt Road	A	72	0.29
Dirt Road	B	82	2.29
Dirt Road	D	89	2.38
Impervious		98	0.05
Gravel	A	76	0.07
Gravel	B	85	0.04

Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Dirt Road
- Gravel
- Impervious
- Meadow
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

1:7,920

660 330 0 660 Feet

N W E S

Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Pre-Construction Drainage Area Map
DA-RO-SM32
Spread 9

Figure 1
Montgomery and Roanoke County, Virginia

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Agricultural Area from National Land Cover Database (NLCD) 2011, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016 and Radford University DEMs, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015.

Document Path: P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Roanoke\MVP_PCSM_DA-RO-SM32_Pre.mxd

DA-RO-SM32
426.08 acres
Weighted CN = 62

DA-RO-SM32 Permanent ROW
3.98 acres

Land Use	HSG	CN	Area (AC)
Woods	A	30	5.82
Woods	B	55	270.81
Woods	D	77	134.17
Meadow	A	30	2.75
Meadow	B	58	4.16
Meadow	D	78	1.44
Dirt Road	A	72	0.29
Dirt Road	B	82	2.29
Dirt Road	D	89	2.38
Impervious		98	0.05
Gravel	A	76	0.07
Gravel	B	85	0.06
Brush	B	48	1.79

Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Brush
- Dirt Road
- Gravel
- Impervious
- Meadow
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

1:7,920

660 330 0 660 Feet

N W E S

Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Post-Construction Drainage Area Map
DA-RO-SM32
Spread 9

Figure 2
Montgomery and Roanoke County, Virginia

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Agricultural Area from National Land Cover Database (NLCD) 2011, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016 and Radford University DEMs, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015.

Document Path: P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Roanoke\MVP_PCSM_DA-RO-SM32_Post.mxd

DA-RO-SM32
426.08 acres
Weighted CN = 62

Pre-Construction Time of Concentration				
	Sheet	Shallow	Channel A	Calculated Time of Concentration (min)
S-MN32	100 FT @ 15%	1503.36 FT @ 39.58%	6354 FT @ 14.68%	27.8

Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:7,920

660 330 0 660 Feet

N W E S

Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Pre-Construction Drainage Area and Time of Concentration DA-RO-SM32 Spread 9

Figure 3

Montgomery and Roanoke County, Virginia

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016 and Radford University DEMs.

Document Path: P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Roanoke\Figures 3-4\MVP_PCSM_DA-RO-SM32_3.mxd

DA-RO-SM32
426.08 acres
Weighted CN = 62

Post-Construction Time of Concentration				
	Sheet	Shallow	Channel A	Calculated Time of Concentration (min)
S-MN32	100 FT @ 15%	1503.36 FT @ 39.58%	6354 FT @ 14.68%	27.8

Legend

- Milepost
- Permanent Waterbars
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:7,920

660 330 0 660 Feet

N W E S

Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Post-Construction Drainage Area and Time of Concentration DA-RO-SM32 Spread 9

Figure 4

Montgomery and Roanoke County, Virginia

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016 and Radford University DEMs.

Document Path: P:GIS\EQT_MVP\Mapdocs\Drainage\MXD\Roanoke\Figures 3-4\MVP_PCSM_DA-RO-SM32_4.mxd

COMPOSITE CURVE NUMBER COMPUTATION SHEET

S-MN32 Pre-Construction				
LAND USE	**HSG**	**CN**	**AREA (AC)**	**Area Weighted CN**
Woods	A	30	5.822	0.41
Woods	B	55	276.54	35.70
Woods	D	77	134.17	24.25
Meadow	A	30	2.749	0.19
Meadow	B	58	0.229	0.03
Meadow	D	78	1.436	0.26
Dirt Road	A	72	0.294	0.05
Dirt Road	B	82	2.293	0.44
Dirt Road	D	89	2.376	0.50
Impervious	N/A	98	0.053	0.01
Gravel	A	76	0.074	0.01
Gravel	B	85	0.043	0.01
			426.08	62

= Composite CN

COMPOSITE CURVE NUMBER COMPUTATION SHEET

S-MN32 Post-Construction				
LAND USE	**HSG**	**CN**	**AREA (AC)**	**Area Weighted CN**
Woods	A	30	5.822	0.41
Woods	B	55	270.81	34.96
Woods	D	77	134.17	24.25
Meadow	A	30	2.749	0.19
Meadow	B	58	4.163	0.57
Meadow	D	78	1.436	0.26
Dirt Road	A	72	0.294	0.05
Dirt Road	B	82	2.293	0.44
Dirt Road	D	89	2.376	0.50
Impervious	N/A	98	0.053	0.01
Gravel	A	76	0.074	0.01
Gravel	B	85	0.056	0.01
Brush	B	48	1.790	0.20
			426.08	62

= Composite CN

Table 1 – Manning's n Values for Sheet Flow

Land Surface Type	**Manning n**
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40

Note:

Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.

Sources:

-USACE, 1998, HEC-1 Flood Hydrograph Package User's Manual, Hydrologic Engineering Center, Davis, CA

-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC

Table 2 – Manning's n Values for Open Channel Flow

Channel Type	Manning n		
	Min.	Normal	Max.
1. Excavated or Dredged Channels[1]			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels[2]			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150

Notes:

[1]A Manning's n value of 0.040 was used in Hydraflow Hydrographs for roadside channels.

[2]A Manning's n value of 0.030 was used in Hydraflow Hydrographs for existing/natural channels.

Sources:

-ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY

-Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY

Hydraflow Table of Contents

Watershed Model Schematic

Legend

Hyd.	Origin	Description
1	SCS Runoff	Culvt S-MN32 Pre-
2	SCS Runoff	Culvt S-MN32 Post-
3	SCS Runoff	Culvt S-MN32 Preforested-

Hydrograph Return Period Recap

Hyd. No.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)							Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	------	37.41	-------	-------	-------	524.55	-------	-------	-------	Culvt S-MN32 Pre-
2	SCS Runoff	------	37.41	-------	-------	-------	524.55	-------	-------	-------	Culvt S-MN32 Post-
3	SCS Runoff	------	37.41	-------	-------	-------	524.55	-------	-------	-------	Culvt S-MN32 Preforested-

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11

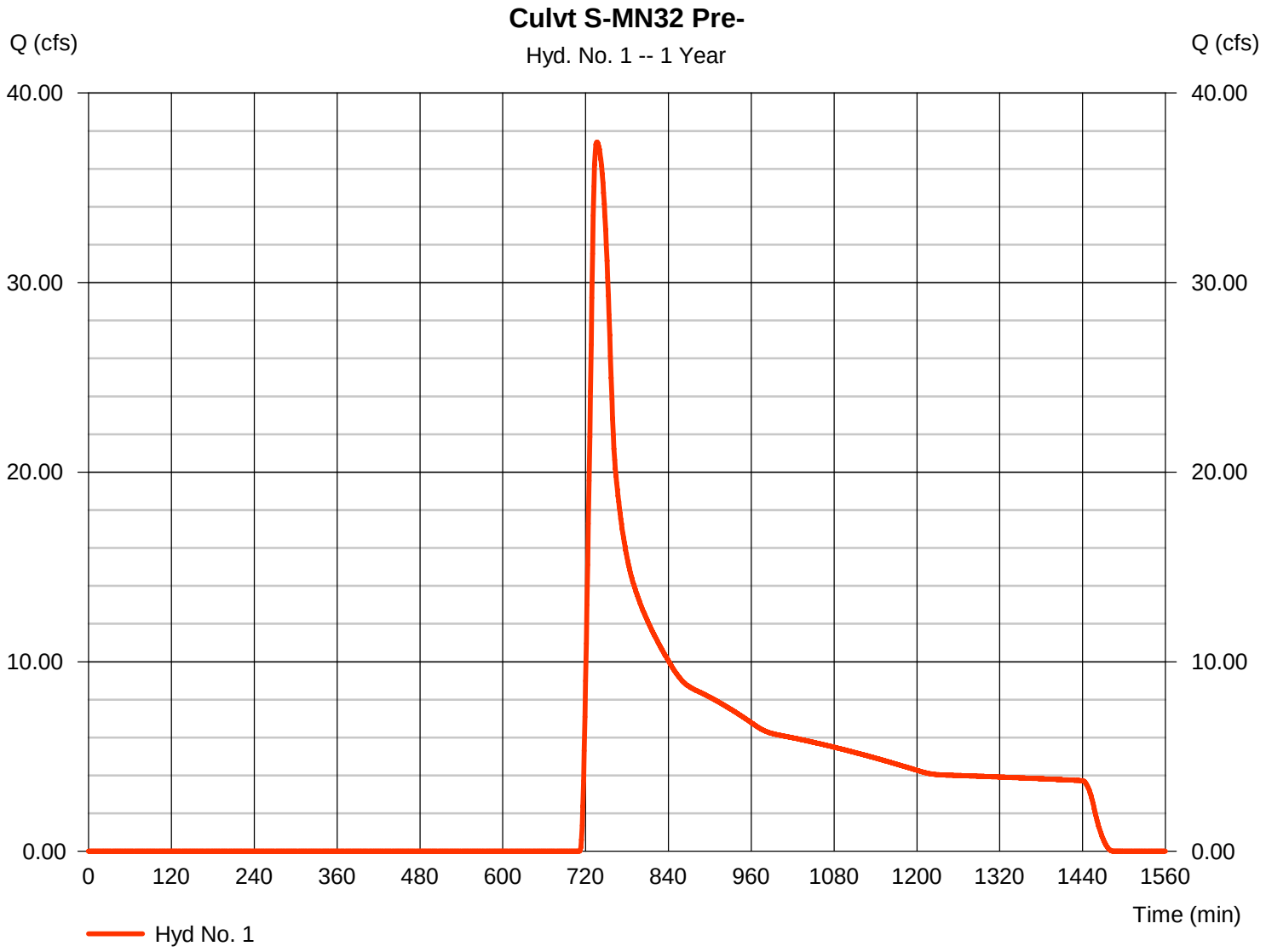
Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	37.41	1	736	336,699	------	------	------	Culvt S-MN32 Pre-
2	SCS Runoff	37.41	1	736	336,699	------	------	------	Culvt S-MN32 Post-
3	SCS Runoff	37.41	1	736	336,699	------	------	------	Culvt S-MN32 Preforested-

Hydrograph Report

Hyd. No. 1

Culvt S-MN32 Pre-

Hydrograph type	=	SCS Runoff	Peak discharge	=	37.41 cfs
Storm frequency	=	1 yrs	Time to peak	=	736 min
Time interval	=	1 min	Hyd. volume	=	336,699 cuft
Drainage area	=	426.080 ac	Curve number	=	62
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	27.80 min
Total precip.	=	2.50 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484



TR55 Tc Worksheet

Hyd. No. 1

Culvt S-MN32 Pre-

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.800		0.011		0.011		
Flow length (ft)	= 100.0		0.0		0.0		
Two-year 24-hr precip. (in)	= 3.00		0.00		0.00		
Land slope (%)	= 15.00		0.00		0.00		
Travel Time (min)	**= 17.25**	**+**	**0.00**	**+**	**0.00**	**=**	**17.25**
Shallow Concentrated Flow							
Flow length (ft)	= 1503.36		0.00		0.00		
Watercourse slope (%)	= 39.58		0.00		0.00		
Surface description	= Unpaved		Unpaved		Paved		
Average velocity (ft/s)	=10.15		0.00		0.00		
Travel Time (min)	**= 2.47**	**+**	**0.00**	**+**	**0.00**	**=**	**2.47**
Channel Flow							
X sectional flow area (sqft)	= 5.33		0.00		0.00		
Wetted perimeter (ft)	= 9.33		0.00		0.00		
Channel slope (%)	= 14.68		0.00		0.00		
Manning's n-value	= 0.030		0.015		0.015		
Velocity (ft/s)	=13.08						
			0.00				
					0.00		
Flow length (ft)	({0})6354.0		0.0		0.0		
Travel Time (min)	**= 8.10**	**+**	**0.00**	**+**	**0.00**	**=**	**8.10**

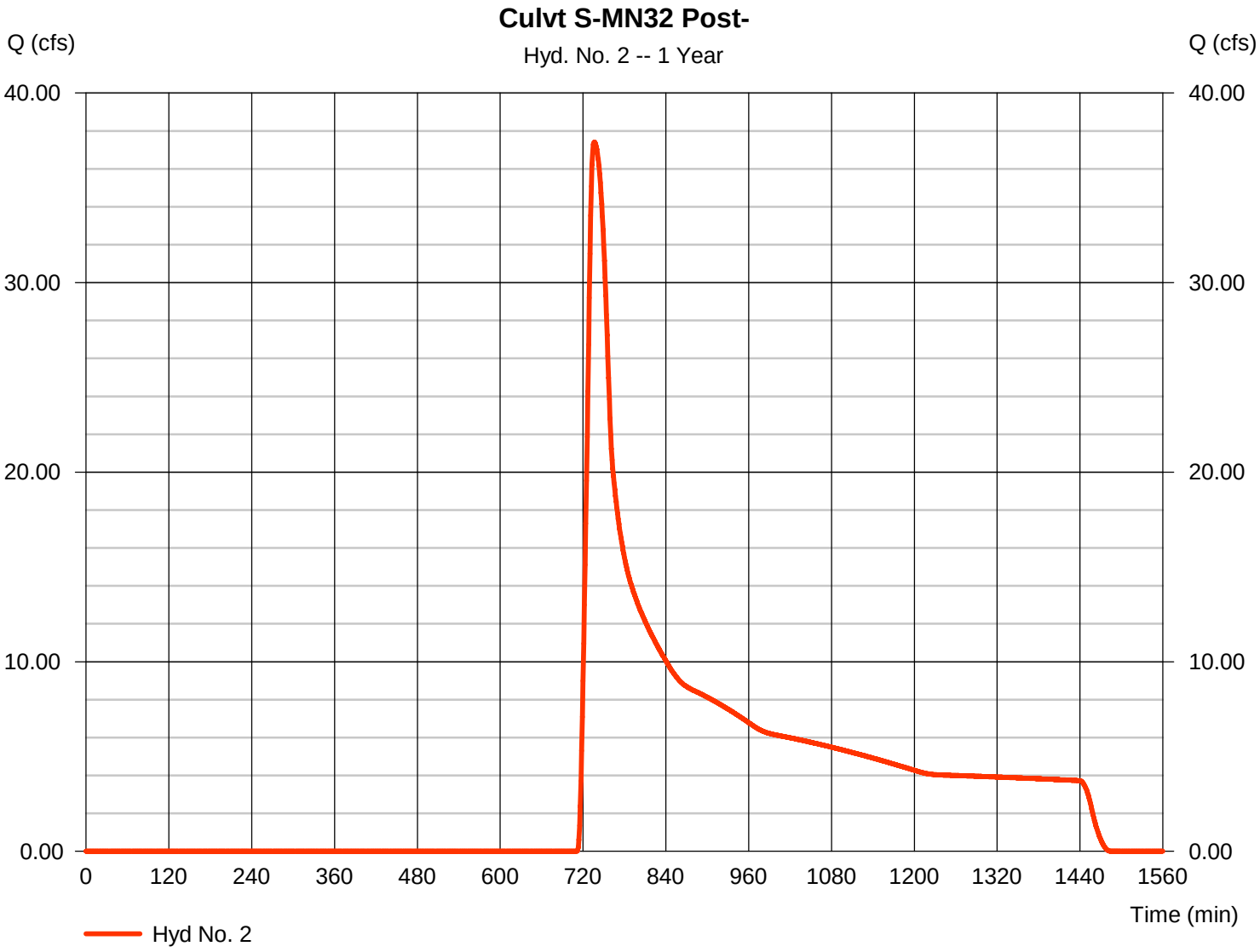
Total Travel Time, Tc ..... 27.80 min

Hydrograph Report

Hyd. No. 2

Culvt S-MN32 Post-

Hydrograph type	=	SCS Runoff	Peak discharge	=	37.41 cfs
Storm frequency	=	1 yrs	Time to peak	=	736 min
Time interval	=	1 min	Hyd. volume	=	336,699 cuft
Drainage area	=	426.080 ac	Curve number	=	62
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	27.80 min
Total precip.	=	2.50 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484



TR55 Tc Worksheet

Hyd. No. 2

Culvt S-MN32 Post-

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.800		0.011		0.011		
Flow length (ft)	= 100.0		0.0		0.0		
Two-year 24-hr precip. (in)	= 3.00		0.00		0.00		
Land slope (%)	= 15.00		0.00		0.00		
Travel Time (min)	**= 17.25**	**+**	**0.00**	**+**	**0.00**	**=**	**17.25**
Shallow Concentrated Flow							
Flow length (ft)	= 1503.36		0.00		0.00		
Watercourse slope (%)	= 39.58		0.00		0.00		
Surface description	= Unpaved		Unpaved		Paved		
Average velocity (ft/s)	=10.15		0.00		0.00		
Travel Time (min)	**= 2.47**	**+**	**0.00**	**+**	**0.00**	**=**	**2.47**
Channel Flow							
X sectional flow area (sqft)	= 5.33		0.00		0.00		
Wetted perimeter (ft)	= 9.33		0.00		0.00		
Channel slope (%)	= 14.68		0.00		0.00		
Manning's n-value	= 0.030		0.015		0.015		
Velocity (ft/s)	=13.08						
			0.00				
					0.00		
Flow length (ft)	({0})6354.0		0.0		0.0		
Travel Time (min)	**= 8.10**	**+**	**0.00**	**+**	**0.00**	**=**	**8.10**

Total Travel Time, Tc ..... 27.80 min

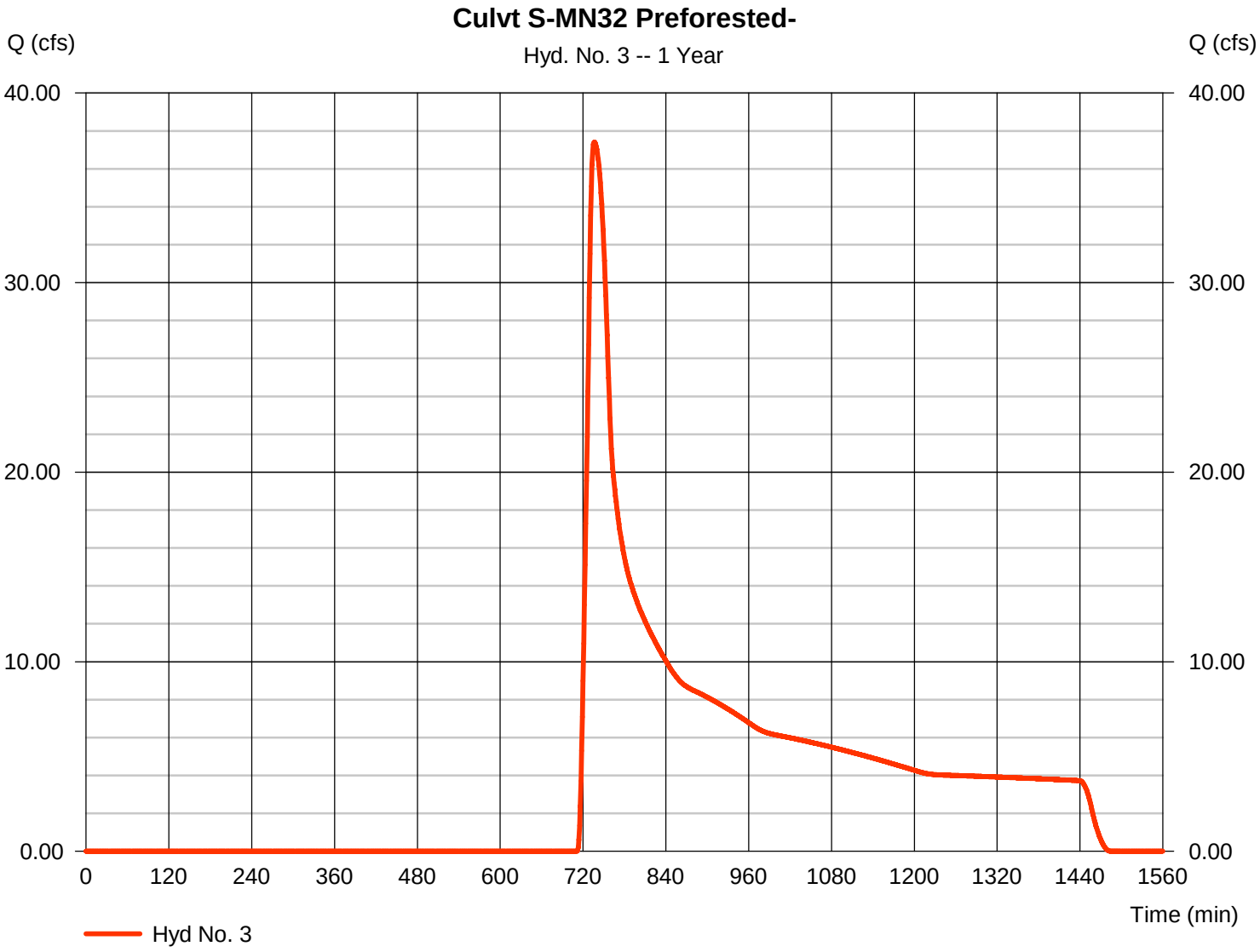
Hydrograph Report

Hyd. No. 3

Culvt S-MN32 Preforested-

Hydrograph type	=	SCS Runoff	Peak discharge	=	37.41 cfs
Storm frequency	=	1 yrs	Time to peak	=	736 min
Time interval	=	1 min	Hyd. volume	=	336,699 cuft
Drainage area	=	426.080 ac	Curve number	=	62*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	27.80 min
Total precip.	=	2.50 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(8.980 x 30) + (279.110 x 55) + (137.990 x 77)] / 426.080



TR55 Tc Worksheet

Hyd. No. 3

Culvt S-MN32 Preforested-

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.800		0.011		0.011		
Flow length (ft)	= 100.0		0.0		0.0		
Two-year 24-hr precip. (in)	= 3.00		0.00		0.00		
Land slope (%)	= 15.00		0.00		0.00		
Travel Time (min)	**= 17.25**	**+**	**0.00**	**+**	**0.00**	**=**	**17.25**
Shallow Concentrated Flow							
Flow length (ft)	= 1503.36		0.00		0.00		
Watercourse slope (%)	= 39.58		0.00		0.00		
Surface description	= Unpaved		Unpaved		Paved		
Average velocity (ft/s)	=10.15		0.00		0.00		
Travel Time (min)	**= 2.47**	**+**	**0.00**	**+**	**0.00**	**=**	**2.47**
Channel Flow							
X sectional flow area (sqft)	= 5.33		0.00		0.00		
Wetted perimeter (ft)	= 9.33		0.00		0.00		
Channel slope (%)	= 14.68		0.00		0.00		
Manning's n-value	= 0.030		0.015		0.015		
Velocity (ft/s)	=13.08						
			0.00				
					0.00		
Flow length (ft)	({0})6354.0		0.0		0.0		
Travel Time (min)	**= 8.10**	**+**	**0.00**	**+**	**0.00**	**=**	**8.10**

Total Travel Time, Tc ..... 27.80 min

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11

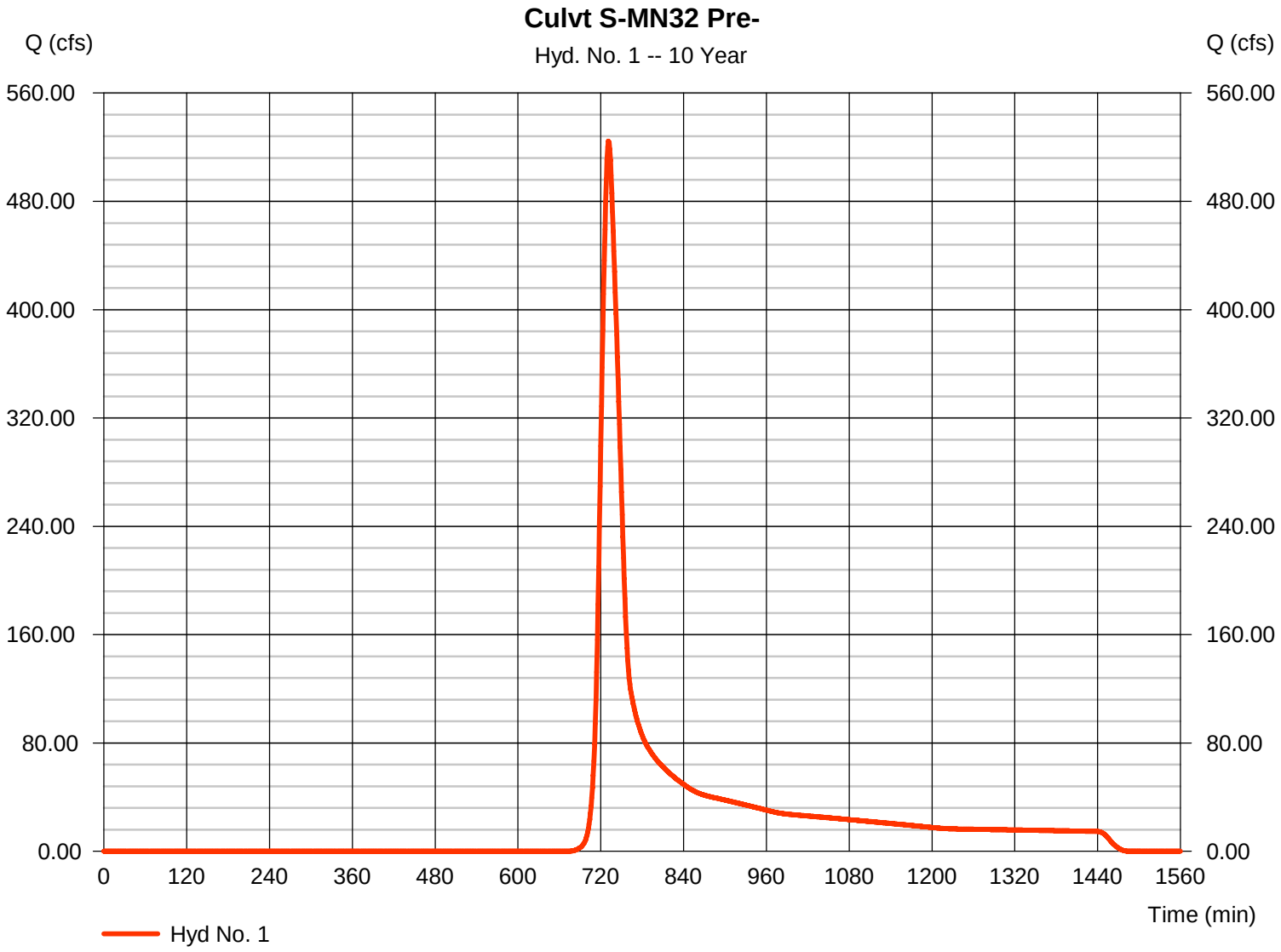
Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	524.55	1	731	2,208,332	------	------	------	Culvt S-MN32 Pre-
2	SCS Runoff	524.55	1	731	2,208,332	------	------	------	Culvt S-MN32 Post-
3	SCS Runoff	524.55	1	731	2,208,332	------	------	------	Culvt S-MN32 Preforested-

Hydrograph Report

Hyd. No. 1

Culvt S-MN32 Pre-

Hydrograph type	= SCS Runoff	Peak discharge	= 524.55 cfs
Storm frequency	= 10 yrs	Time to peak	= 731 min
Time interval	= 1 min	Hyd. volume	= 2,208,332 cuft
Drainage area	= 426.080 ac	Curve number	= 62
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 27.80 min
Total precip.	= 5.00 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

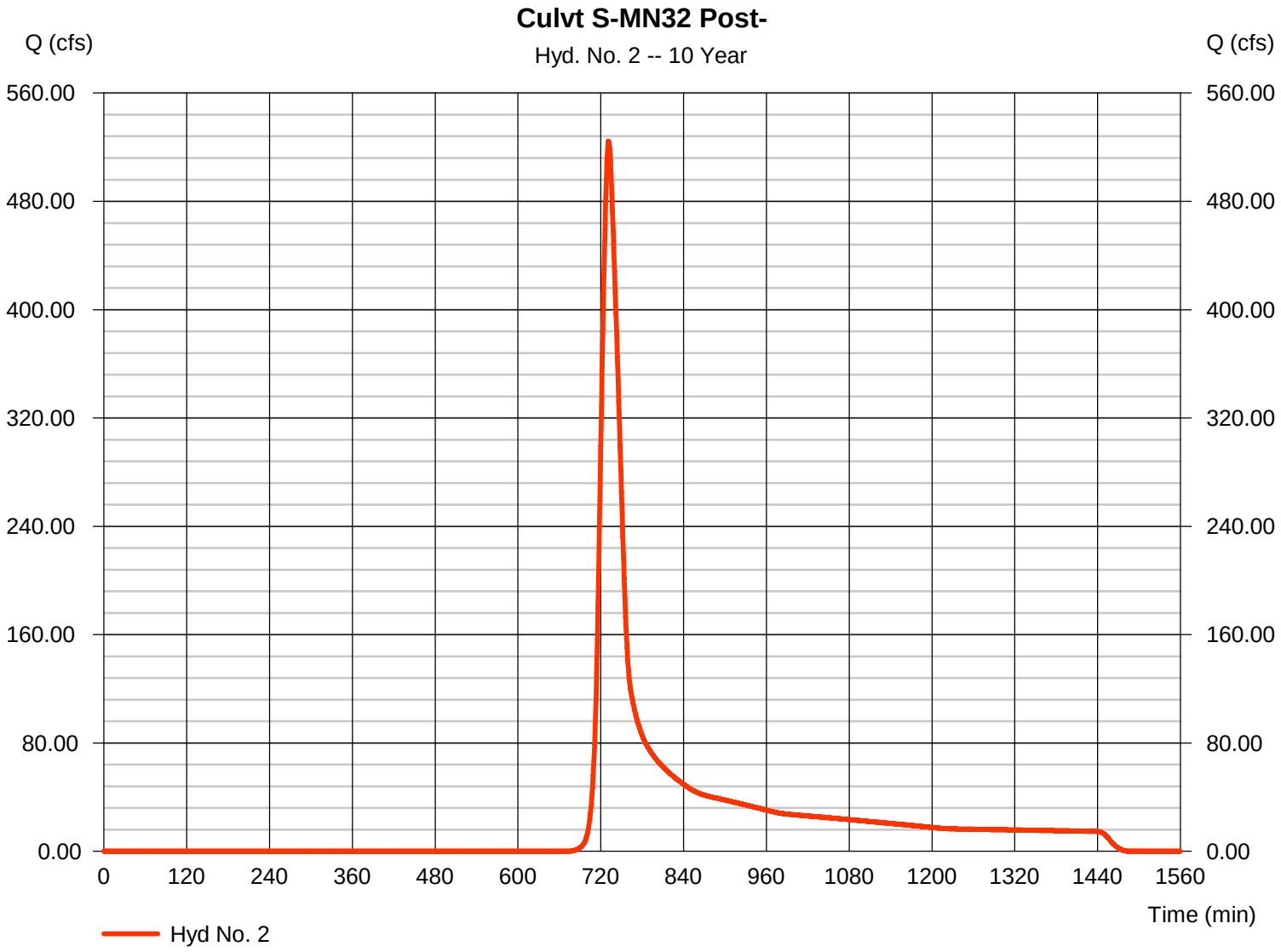


Hydrograph Report

Hyd. No. 2

Culvt S-MN32 Post-

Hydrograph type	= SCS Runoff	Peak discharge	= 524.55 cfs
Storm frequency	= 10 yrs	Time to peak	= 731 min
Time interval	= 1 min	Hyd. volume	= 2,208,332 cuft
Drainage area	= 426.080 ac	Curve number	= 62
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 27.80 min
Total precip.	= 5.00 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



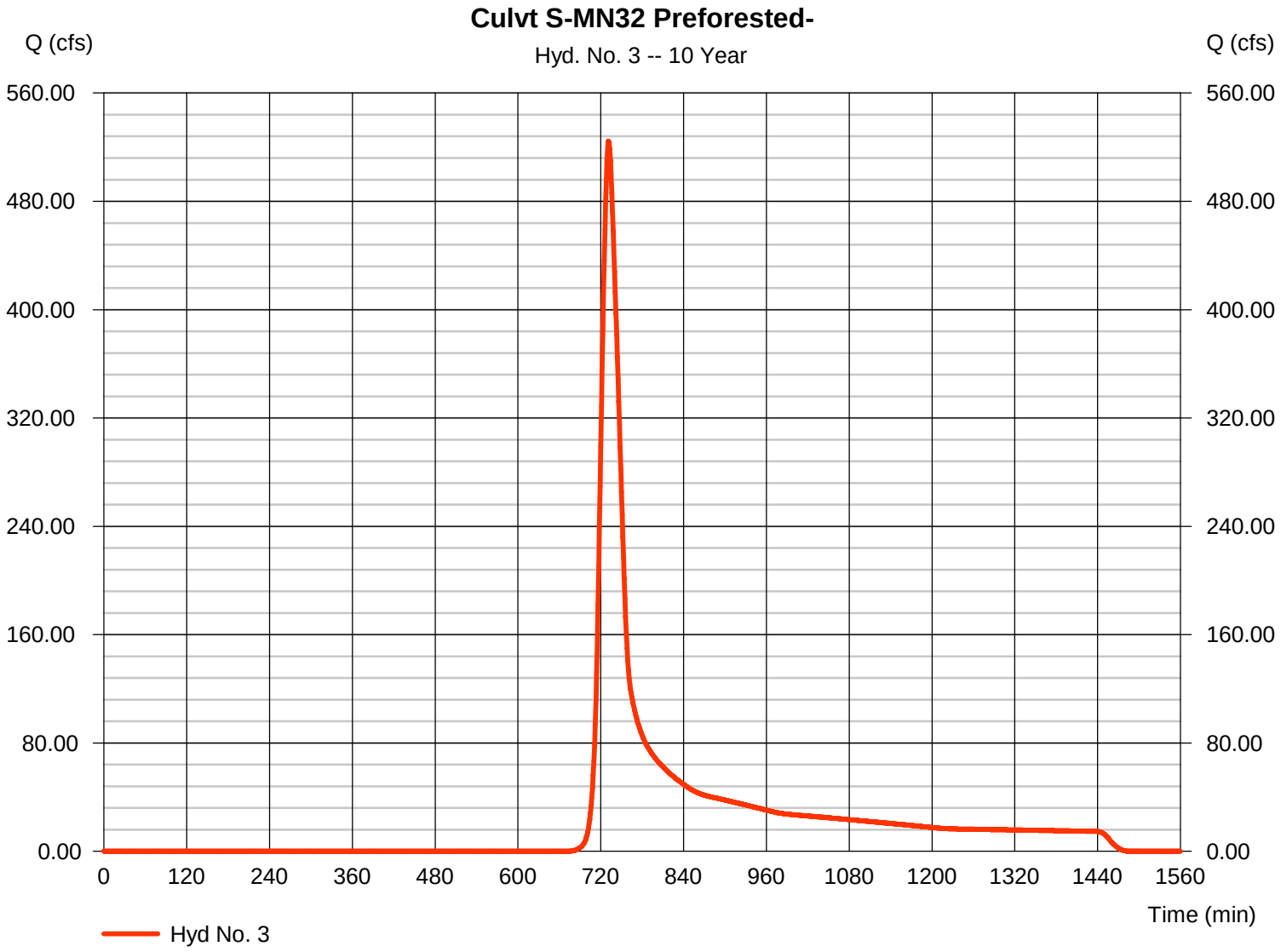
Hydrograph Report

Hyd. No. 3

Culvt S-MN32 Preforested-

Hydrograph type	=	SCS Runoff	Peak discharge	=	524.55 cfs
Storm frequency	=	10 yrs	Time to peak	=	731 min
Time interval	=	1 min	Hyd. volume	=	2,208,332 cuft
Drainage area	=	426.080 ac	Curve number	=	62*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	27.80 min
Total precip.	=	5.00 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(8.980 x 30) + (279.110 x 55) + (137.990 x 77)] / 426.080



Hydraflow Rainfall Report

Return Period (Yrs)	Intensity-Duration-Frequency Equation Coefficients (FHA)			
	B	D	E	(N/A)
1	0.0000	0.0000	0.0000	--------
2	69.8703	13.1000	0.8658	--------
3	0.0000	0.0000	0.0000	--------
5	79.2597	14.6000	0.8369	--------
10	88.2351	15.5000	0.8279	--------
25	102.6072	16.5000	0.8217	--------
50	114.8193	17.2000	0.8199	--------
100	127.1596	17.8000	0.8186	--------

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

Return Period (Yrs)	Intensity Values (in/hr)											
	5 min	10	15	20	25	30	35	40	45	50	55	60
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	5.69	4.61	3.89	3.38	2.99	2.69	2.44	2.24	2.07	1.93	1.81	1.70
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	6.57	5.43	4.65	4.08	3.65	3.30	3.02	2.79	2.59	2.42	2.27	2.15
10	7.24	6.04	5.21	4.59	4.12	3.74	3.43	3.17	2.95	2.77	2.60	2.46
25	8.25	6.95	6.03	5.34	4.80	4.38	4.02	3.73	3.48	3.26	3.07	2.91
50	9.04	7.65	6.66	5.92	5.34	4.87	4.49	4.16	3.88	3.65	3.44	3.25
100	9.83	8.36	7.30	6.50	5.87	5.36	4.94	4.59	4.29	4.03	3.80	3.60

Tc = time in minutes. Values may exceed 60.

rk Sladic\EQT\Project\112IC07157 MVP\Virginia Stormwater\Culvert Design - Other\Culvert S-MN32\Montgomery.pcp

Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	2.50	0.00	0.00	0.00	5.00	5.50	0.00	0.00
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	37.410	336,699
Developed Condition	37.410	336,699
Pre-Developed (Forest) Condition	37.410	336,699

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Calculations:

[1] ***Check #1:***	$Q_{developed} \leq IF \times [(Q_{pre\text{-}developed} \times RV_{pre\text{-}developed}) / RV_{developed}]$ ---------->	37.410	≤ OK	37.410
Check #2:	$Q_{developed} \leq Q_{pre\text{-}developed}$ ---------->	37.410	≤ OK	37.410
Check #3:	$Q_{developed}$ *shall not* be required to be $\leq (Q_{forest} \times RV_{forest}) / RV_{developed}$ --->	37.410	*shall not* be required to be ≤	37.410

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

[1] Per VADEQ, the improvement factor can be waived if the road is being maintained within the current footprint.

HY-8 Culvert Analysis Report

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 524.55 cfs

Design Flow: 524.55 cfs

Maximum Flow: 524.55 cfs

Table 1 - Summary of Culvert Flows at Crossing: S-MN32

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert S-MN32 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
1322.49	524.55	524.55	0.00	1
1322.49	524.55	524.55	0.00	1
1322.49	524.55	524.55	0.00	1
1322.49	524.55	524.55	0.00	1
1322.49	524.55	524.55	0.00	1
1322.49	524.55	524.55	0.00	1
1322.49	524.55	524.55	0.00	1
1322.49	524.55	524.55	0.00	1
1322.49	524.55	524.55	0.00	1
1322.49	524.55	524.55	0.00	1
1322.49	524.55	524.55	0.00	1
1322.56	531.38	531.38	0.00	Overtopping

Rating Curve Plot for Crossing: S-MN32

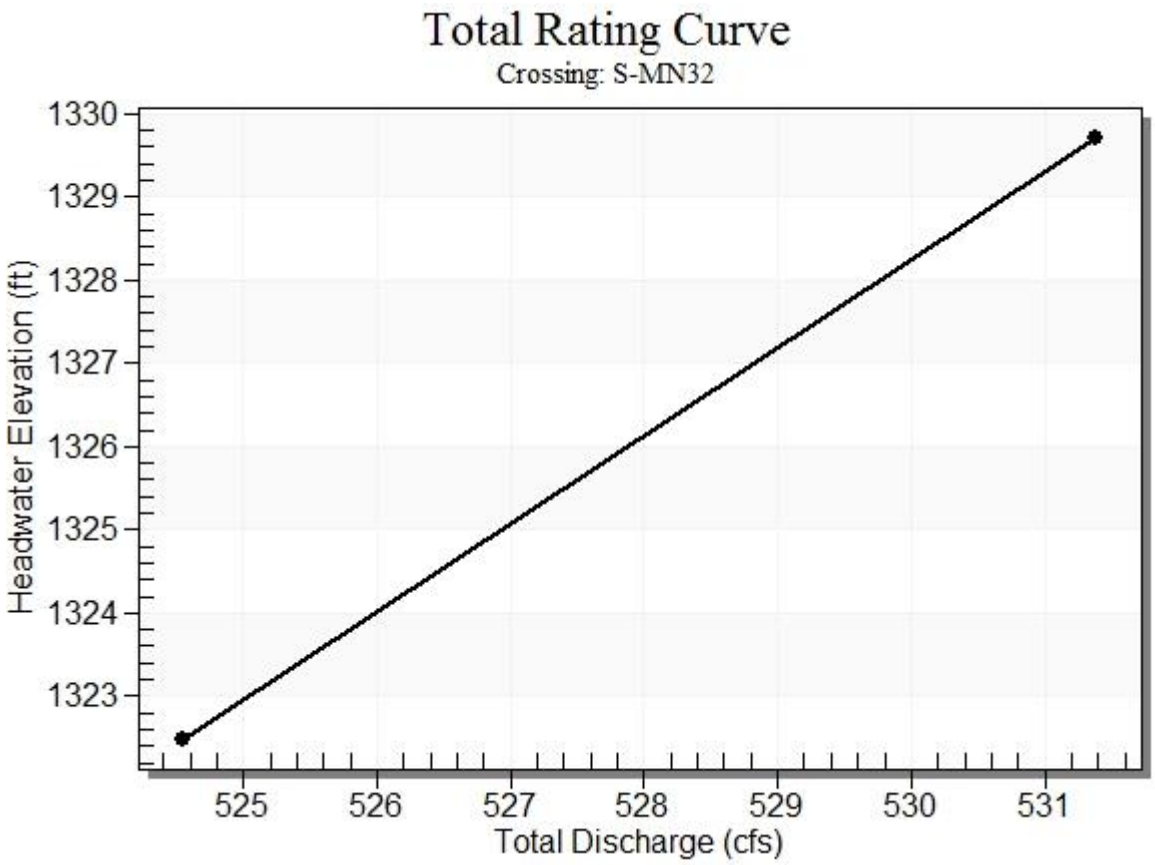


Table 2 - Culvert Summary Table: Culvert S-MN32

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
524.55	524.55	1322.49	6.460	7.596	7-M1t	4.146	3.895	6.117	6.117	7.146	7.796
524.55	524.55	1322.49	6.460	7.596	7-M1t	4.146	3.895	6.117	6.117	7.146	7.796
524.55	524.55	1322.49	6.460	7.596	7-M1t	4.146	3.895	6.117	6.117	7.146	7.796
524.55	524.55	1322.49	6.460	7.596	7-M1t	4.146	3.895	6.117	6.117	7.146	7.796
524.55	524.55	1322.49	6.460	7.596	7-M1t	4.146	3.895	6.117	6.117	7.146	7.796
524.55	524.55	1322.49	6.460	7.596	7-M1t	4.146	3.895	6.117	6.117	7.146	7.796
524.55	524.55	1322.49	6.460	7.596	7-M1t	4.146	3.895	6.117	6.117	7.146	7.796
524.55	524.55	1322.49	6.460	7.596	7-M1t	4.146	3.895	6.117	6.117	7.146	7.796
524.55	524.55	1322.49	6.460	7.596	7-M1t	4.146	3.895	6.117	6.117	7.146	7.796
524.55	524.55	1322.49	6.460	7.596	7-M1t	4.146	3.895	6.117	6.117	7.146	7.796
524.55	524.55	1322.49	6.460	7.596	7-M1t	4.146	3.895	6.117	6.117	7.146	7.796

****

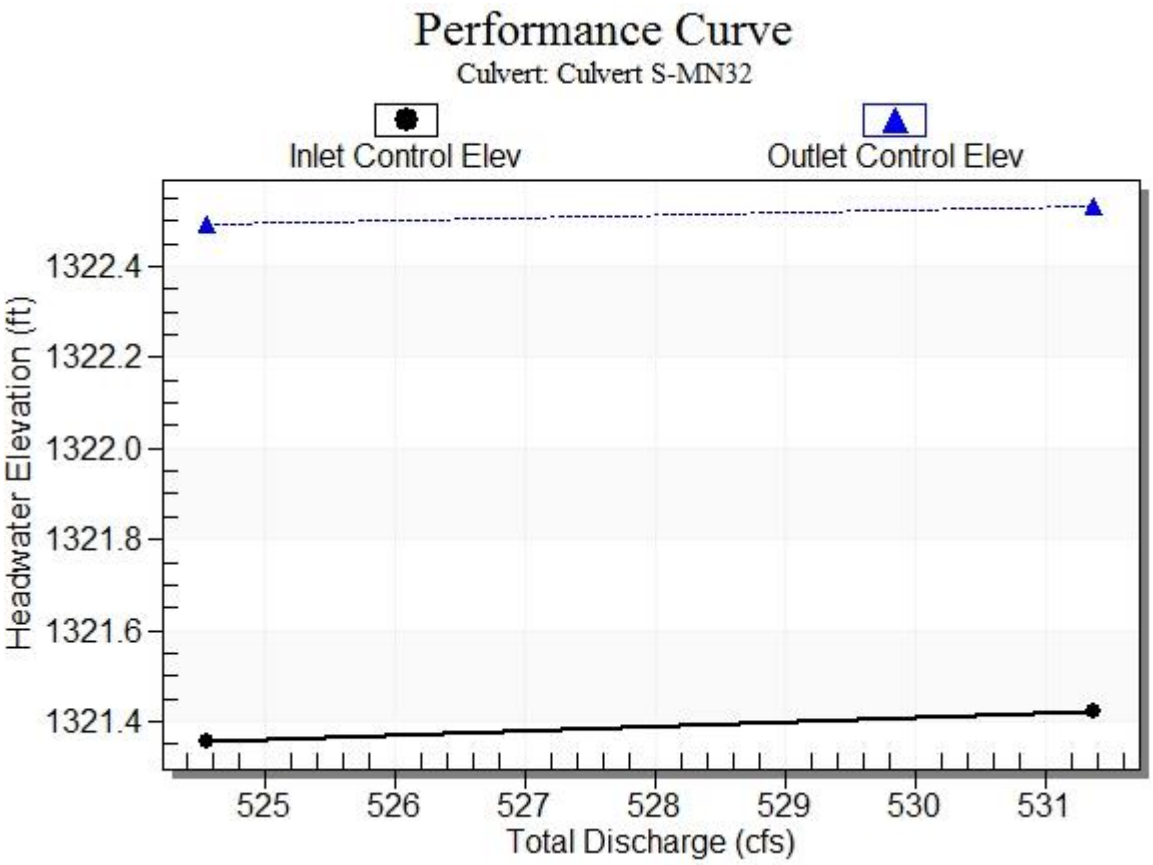
Straight Culvert

Inlet Elevation (invert): 1314.90 ft, Outlet Elevation (invert): 1314.83 ft

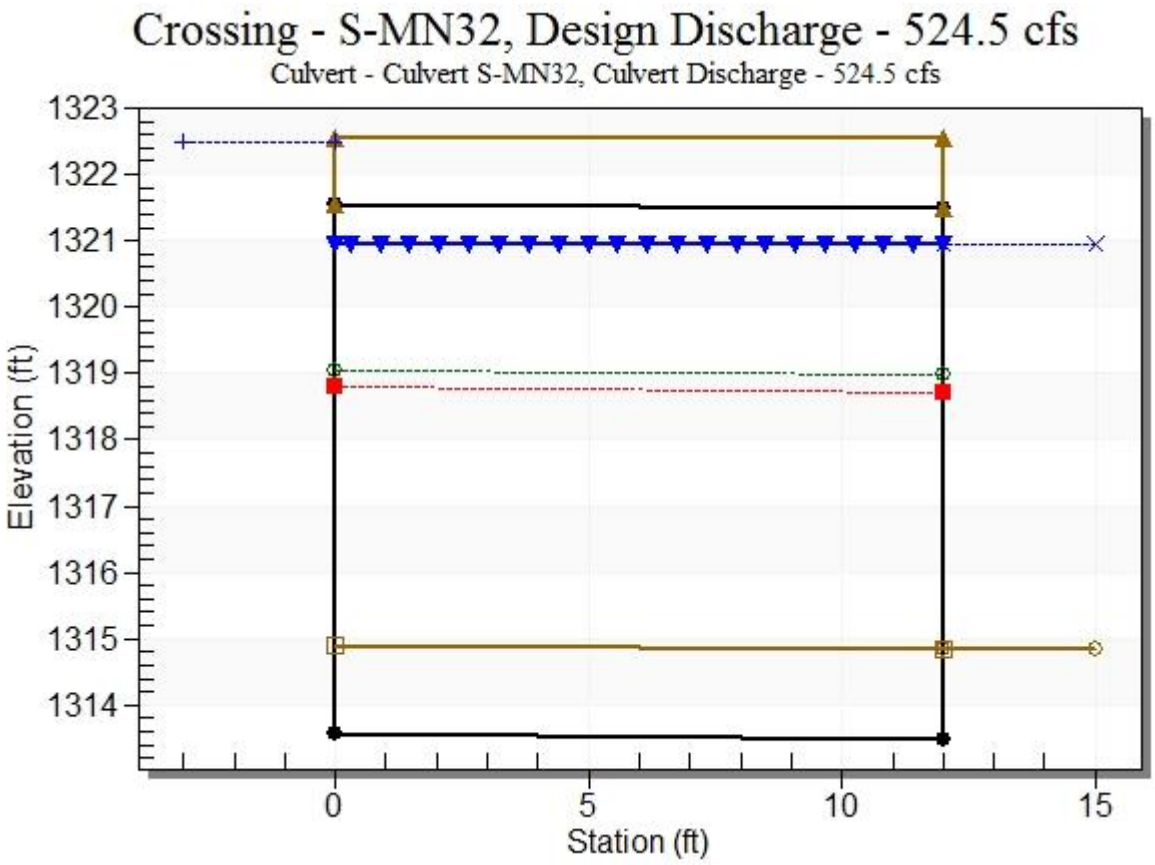
Culvert Length: 12.00 ft, Culvert Slope: 0.0057

****

Culvert Performance Curve Plot: Culvert S-MN32



Water Surface Profile Plot for Culvert: Culvert S-MN32



Site Data - Culvert S-MN32

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 1313.56 ft

Outlet Station: 12.00 ft

Outlet Elevation: 1313.49 ft

Number of Barrels: 1

Culvert Data Summary - Culvert S-MN32

Barrel Shape: Concrete Box

Barrel Span: 12.00 ft

Barrel Rise: 8.00 ft

Barrel Material: Concrete

Embedment: 16.00 in

Barrel Manning's n: 0.0120 (top and sides)

Manning's n: 0.0300 (bottom)

Culvert Type: Straight

Inlet Configuration: Thin Edge Projecting

Inlet Depression: NONE

Table 3 - Downstream Channel Rating Curve (Crossing: S-MN32)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
524.55	1320.94	6.12	7.80	2.29	0.56
524.55	1320.94	6.12	7.80	2.29	0.56
524.55	1320.94	6.12	7.80	2.29	0.56
524.55	1320.94	6.12	7.80	2.29	0.56
524.55	1320.94	6.12	7.80	2.29	0.56
524.55	1320.94	6.12	7.80	2.29	0.56
524.55	1320.94	6.12	7.80	2.29	0.56
524.55	1320.94	6.12	7.80	2.29	0.56
524.55	1320.94	6.12	7.80	2.29	0.56
524.55	1320.94	6.12	7.80	2.29	0.56
524.55	1320.94	6.12	7.80	2.29	0.56

Tailwater Channel Data - S-MN32

Tailwater Channel Option: Rectangular Channel

Bottom Width: 11.00 ft

Channel Slope: 0.0060

Channel Manning's n: 0.0300

Channel Invert Elevation: 1314.83 ft

Roadway Data for Crossing: S-MN32

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 10.00 ft

Crest Elevation: 1322.56 ft

Roadway Surface: Gravel

Roadway Top Width: 12.00 ft

		Culvert Design					[1]Riprap Apron Outlet Protection Design						
Station	Corresponding Stream	[3]Culvert Diameter, d_o (in)	Culvert Material	[2]Pipe Slope (ft/ft)	Q (cfs)	Design Flow Frequency	d_{50} Riprap Size, d_{50} (in)	AASHTO Riprap Class	Placement Thickness per NSA Riprap Gradation, d (in)	Placement Thickness per AASHTO Riprap Gradation, d (in)	Apron Length, L_a (ft)	Apron Initial Width, W_i (ft)	Apron Terminal Width, W (ft)
25 + 83.30	S-MN33	N/A (Box Culvert: Span=4.0-ft, Rise=3.0-ft)	Concrete	0.0215	40.40	10-Yr	N/A - Scour protection needs to withstand tailwater velocity of 6.60 ft/s and shear stress of 2.05 psf. Suggest AASHTO Riprap Class A or equivalent. Note that scour protection should be placed within the channel from top-of-bank to top-of-bank, and extend from the culvert outlet to the limit of disturbance.						

[1]Designed in accordance with VESCH Std & Spec 3.18 assuming minimum tailwater condition ($T_w < 0.5d_o$).

[2]The slope was calculated from a combination of LIDAR and field notes taken for the stream channel characteristics.

[3]Requires roadway grading (fill of 0.750 feet) to install culvert with minimum recommended cover of 2 inches.

DA-RO-SM33
14.23 acres
Weighted CN = 75

Land Use	HSG	CN	Area (AC)
Woods	B	55	1.30
Woods	C	70	0.00
Woods	D	77	12.92

Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

1:2,160

180 90 0 180 Feet

Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Pre-Construction Drainage Area Map
DA-RO-SM33
Spread 9

Figure 1
Montgomery and Roanoke County, Virginia

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Agricultural Area from National Land Cover Database (NLCD) 2011, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016 and Radford University DEMs, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015.

Document Path: P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Roanoke\MVP_PCSM_DA-RO-SM33_Pre.mxd

DA-RO-SM33
14.23 acres
Weighted CN = 75

DA-RO-SM33 Permanent ROW
0.0077 acres

Land Use	HSG	CN	Area (AC)
Woods	B	55	1.29
Woods	D	77	12.91
Gravel	C	89	0.00
Gravel	D	91	0.00
Meadow	B	58	0.00
Meadow	C	71	0.00
Meadow	D	78	0.01
Brush	B	48	0.00
Brush	C	65	0.00
Brush	D	73	0.00

Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Brush
- Gravel
- Meadow
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

1:2,160

180 90 0 180 Feet

N W E S

Blacksburg Roanoke Virginia

Mountain Valley Pipeline Project

Mountain Valley PIPELINE

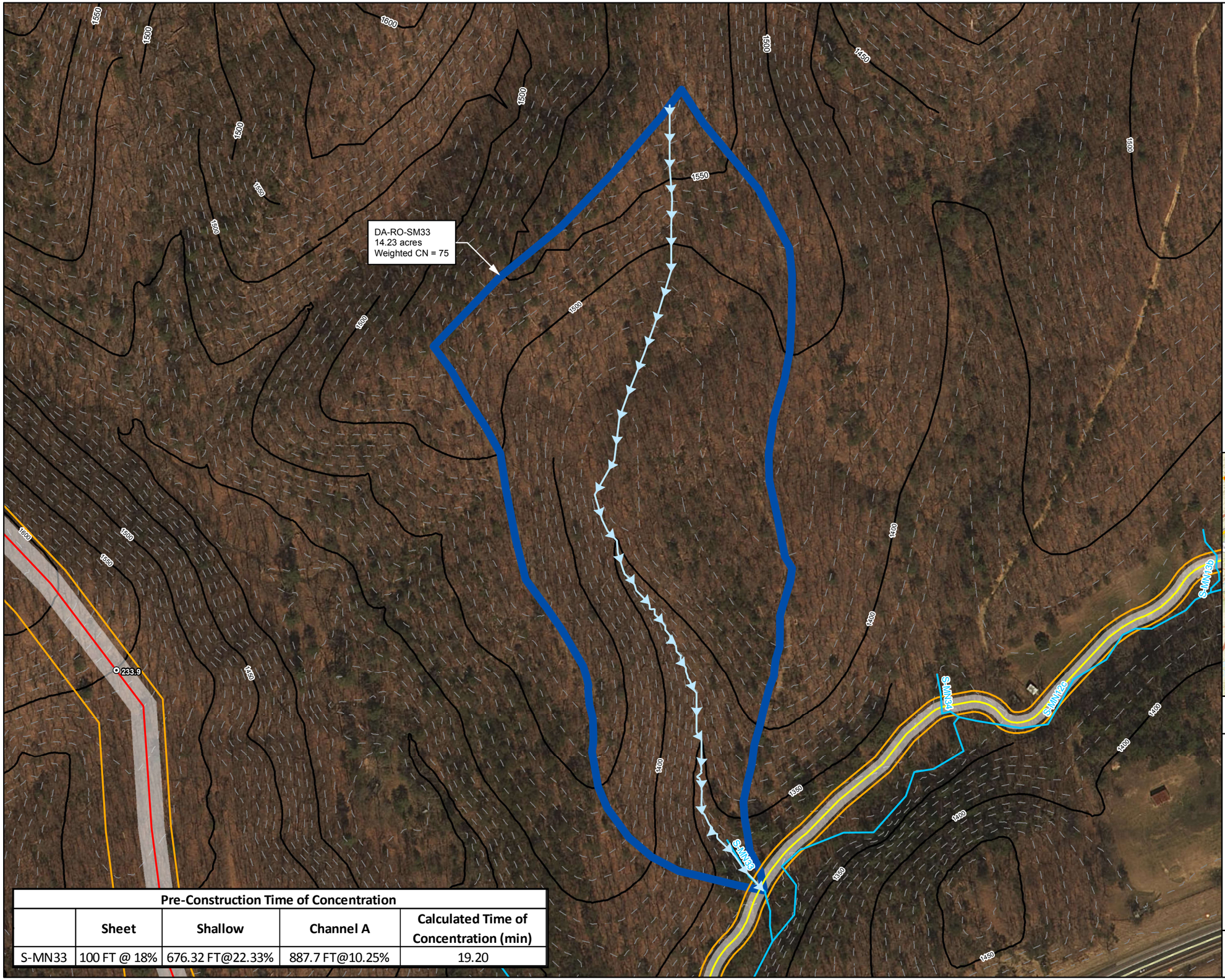
Post-Construction Drainage Area Map
DA-RO-SM33
Spread 9

Figure 2
Montgomery and Roanoke County, Virginia

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Agricultural Area from National Land Cover Database (NLCD) 2011, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016 and Radford University DEMs, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015.

Document Path: P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Roanoke\MVP_PCSM_DA-RO-SM33_Post.mxd



Pre-Construction Time of Concentration				
	Sheet	Shallow	Channel A	Calculated Time of Concentration (min)
S-MN33	100 FT @ 18%	676.32 FT@22.33%	887.7 FT@10.25%	19.20

Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:2,160

180 90 0 180 Feet

N W E S

Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Pre-Construction Drainage Area and Time of Concentration
DA-RO-SM33
Spread 9

Figure 3
Montgomery and Roanoke County, Virginia

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016 and Radford University DEMs.

Document Path: PGH P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Roanoke\Figures 3-4\MVP_PCSM_DA-RO-SM33_3.mxd

DA-RO-SM33
14.23 acres
Weighted CN = 75

S-MN33

S-MN34

S-MN35

S-MN36

233.9

Pre-Construction Time of Concentration				
	Sheet	Shallow	Channel A	Calculated Time of Concentration (min)
S-MN33	100 FT @ 18%	676.32 FT@22.33%	887.7 FT@10.25%	19.20

Legend

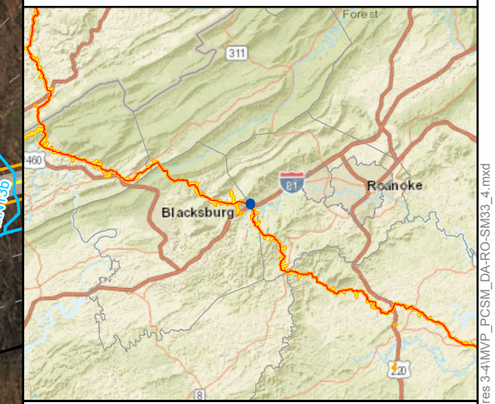
- Milepost
- Permanent Waterbars
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:2,160

180 90 0 180 Feet

N W E S



Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Post-Construction Drainage Area and Time of Concentration DA-RO-SM33 Spread 9

Figure 4

Montgomery and Roanoke County, Virginia

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016 and Radford University DEMs.

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COMPOSITE CURVE NUMBER COMPUTATION SHEET

S-MN33 Pre-Construction
See calculation in Hydraflow report

S-MN33 Post-Construction				
LAND USE	**HSG**	**CN**	**AREA (AC)**	**Area Weighted CN**
Woods	B	55	1.295	5.00
Woods	D	77	12.91	69.86
Gravel	C	89	0.003	0.02
Gravel	D	91	0.005	0.03
Meadow	B	58	0.002	0.01
Meadow	C	71	0.001	0.01
Meadow	D	78	0.005	0.03
Brush	B	48	0.004	0.01
Brush	C	65	0.000	0.00
Brush	D	73	0.005	0.03
			14.23	75

= Composite CN

Table 1 – Manning's n Values for Sheet Flow

Land Surface Type	**Manning n**
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40

Note:

Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.

Sources:

-USACE, 1998, HEC-1 Flood Hydrograph Package User's Manual, Hydrologic Engineering Center, Davis, CA

-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC

Table 2 – Manning's n Values for Open Channel Flow

Channel Type	Manning n		
	Min.	Normal	Max.
1. Excavated or Dredged Channels[1]			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels[2]			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150

Notes:

[1]A Manning's n value of 0.040 was used in Hydraflow Hydrographs for roadside channels.

[2]A Manning's n value of 0.030 was used in Hydraflow Hydrographs for existing/natural channels.

Sources:

-ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY

-Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY

Hydraflow Table of Contents

Watershed Model Schematic

Legend

Hyd.	Origin	Description
1	SCS Runoff	Culvt S-MN33 Pre-
2	SCS Runoff	Culvt S-MN33 Post-
3	SCS Runoff	Culvt S-MN33 Preforested-

Hydrograph Return Period Recap

Hyd. No.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)							Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	------	9.713	-------	-------	-------	40.40	-------	-------	-------	Culvt S-MN33 Pre-
2	SCS Runoff	------	9.713	-------	-------	-------	40.40	-------	-------	-------	Culvt S-MN33 Post-
3	SCS Runoff	------	9.713	-------	-------	-------	40.40	-------	-------	-------	Culvt S-MN33 Preforested-

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	9.713	1	726	33,603	------	------	------	Culvt S-MN33 Pre-
2	SCS Runoff	9.713	1	726	33,603	------	------	------	Culvt S-MN33 Post-
3	SCS Runoff	9.713	1	726	33,603	------	------	------	Culvt S-MN33 Preforested-

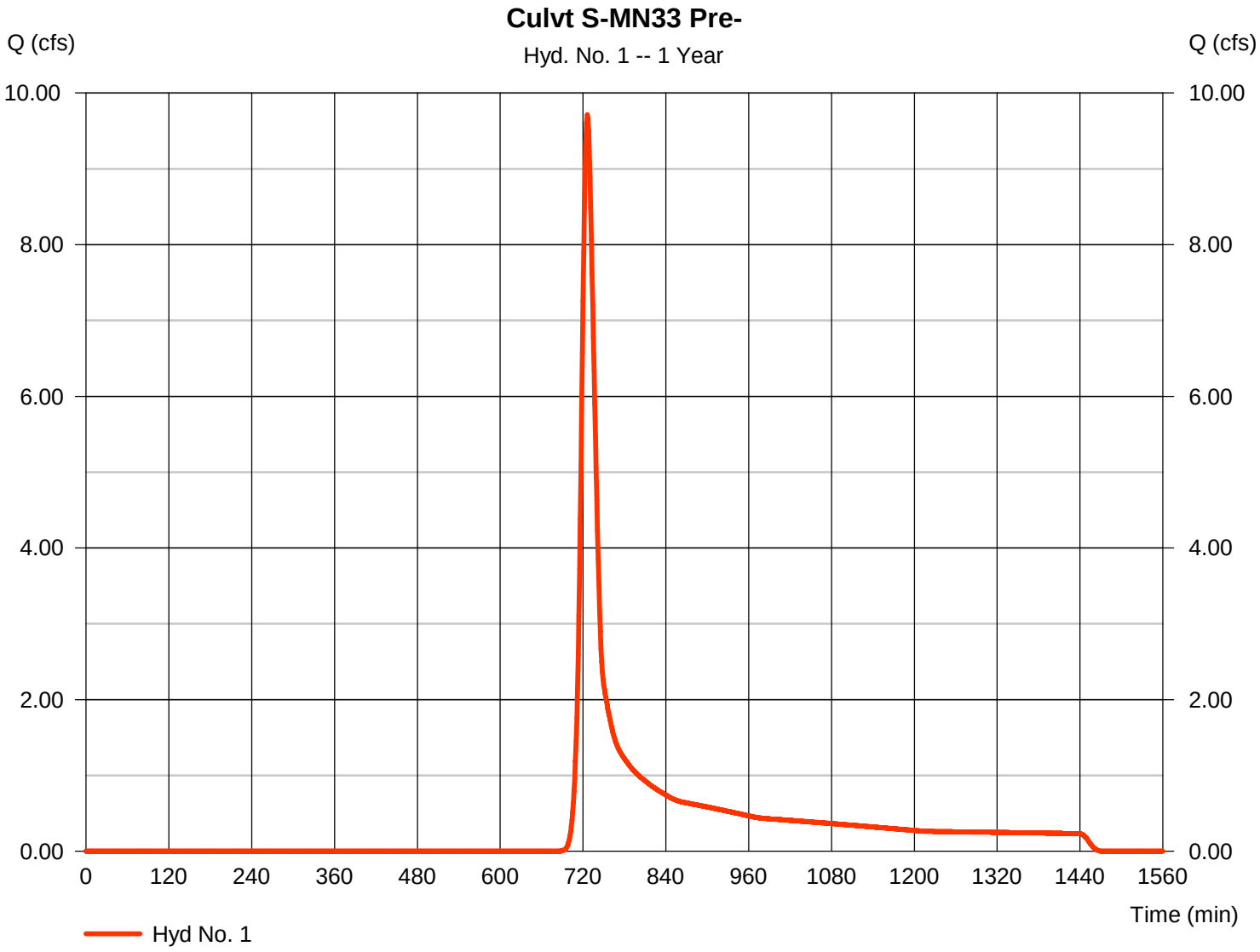
Hydrograph Report

Hyd. No. 1

Culvt S-MN33 Pre-

Hydrograph type	=	SCS Runoff	Peak discharge	=	9.713 cfs
Storm frequency	=	1 yrs	Time to peak	=	726 min
Time interval	=	1 min	Hyd. volume	=	33,603 cuft
Drainage area	=	14.230 ac	Curve number	=	75*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	19.20 min
Total precip.	=	2.50 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(1.300 x 55) + (0.004 x 70) + (12.923 x 77)] / 14.230



TR55 Tc Worksheet

Hyd. No. 1

Culvt S-MN33 Pre-

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.800		0.011		0.011		
Flow length (ft)	= 100.0		0.0		0.0		
Two-year 24-hr precip. (in)	= 3.00		0.00		0.00		
Land slope (%)	= 18.00		0.00		0.00		
Travel Time (min)	**= 16.03**	**+**	**0.00**	**+**	**0.00**	**=**	**16.03**
Shallow Concentrated Flow							
Flow length (ft)	= 676.32		0.00		0.00		
Watercourse slope (%)	= 22.33		0.00		0.00		
Surface description	= Unpaved		Unpaved		Paved		
Average velocity (ft/s)	=7.62		0.00		0.00		
Travel Time (min)	**= 1.48**	**+**	**0.00**	**+**	**0.00**	**=**	**1.48**
Channel Flow							
X sectional flow area (sqft)	= 2.00		0.00		0.00		
Wetted perimeter (ft)	= 5.00		0.00		0.00		
Channel slope (%)	= 10.25		0.00		0.00		
Manning's n-value	= 0.030		0.015		0.015		
Velocity (ft/s)	=8.61						
			0.00				
					0.00		
Flow length (ft)	({0})887.7		0.0		0.0		
Travel Time (min)	**= 1.72**	**+**	**0.00**	**+**	**0.00**	**=**	**1.72**

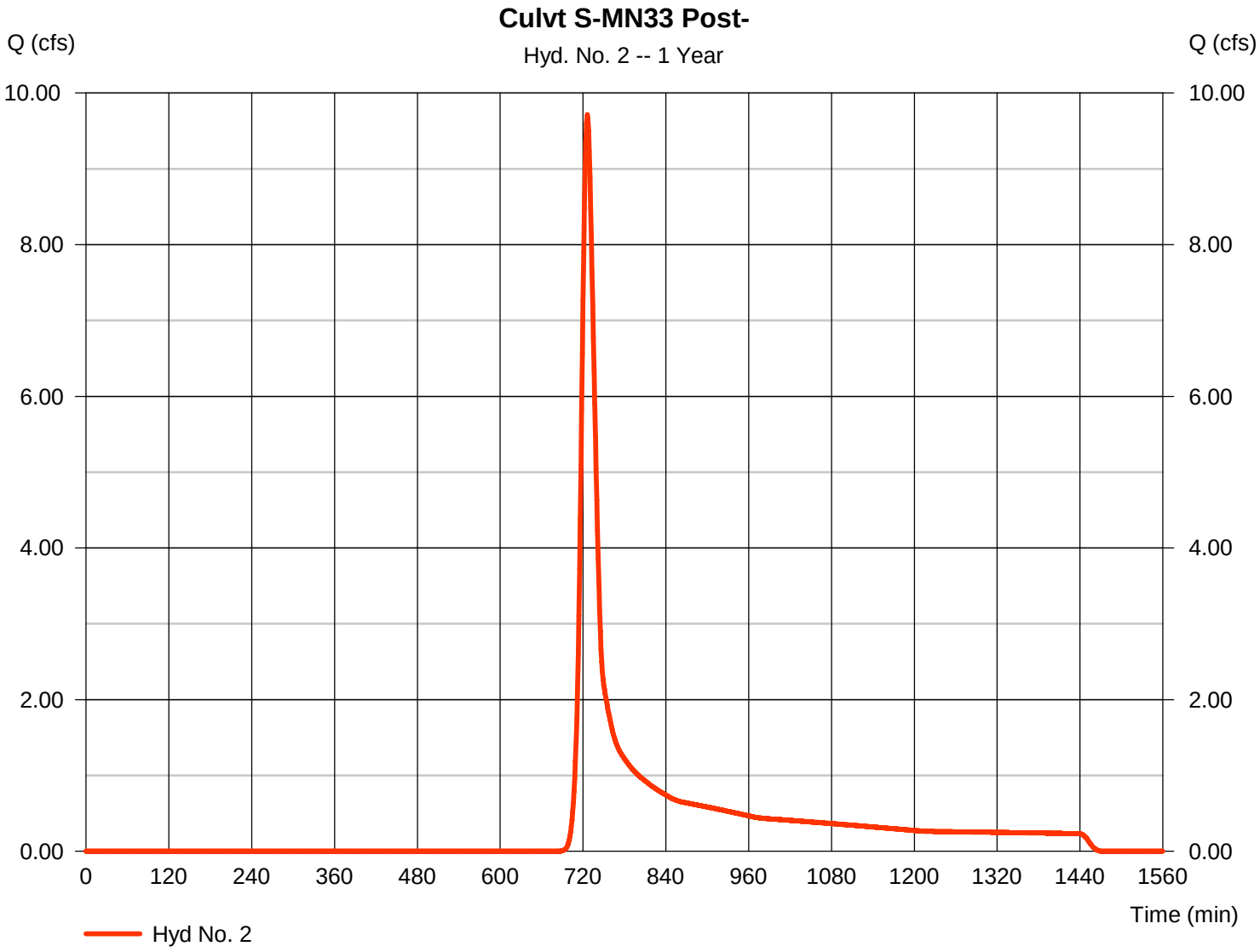
Total Travel Time, Tc ..... 19.20 min

Hydrograph Report

Hyd. No. 2

Culvt S-MN33 Post-

Hydrograph type	=	SCS Runoff	Peak discharge	=	9.713 cfs
Storm frequency	=	1 yrs	Time to peak	=	726 min
Time interval	=	1 min	Hyd. volume	=	33,603 cuft
Drainage area	=	14.230 ac	Curve number	=	75
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	19.20 min
Total precip.	=	2.50 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484



TR55 Tc Worksheet

Hyd. No. 2

Culvt S-MN33 Post-

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.800		0.011		0.011		
Flow length (ft)	= 100.0		0.0		0.0		
Two-year 24-hr precip. (in)	= 3.00		0.00		0.00		
Land slope (%)	= 18.00		0.00		0.00		
Travel Time (min)	**= 16.03**	**+**	**0.00**	**+**	**0.00**	**=**	**16.03**
Shallow Concentrated Flow							
Flow length (ft)	= 676.32		0.00		0.00		
Watercourse slope (%)	= 22.33		0.00		0.00		
Surface description	= Unpaved		Unpaved		Paved		
Average velocity (ft/s)	=7.62		0.00		0.00		
Travel Time (min)	**= 1.48**	**+**	**0.00**	**+**	**0.00**	**=**	**1.48**
Channel Flow							
X sectional flow area (sqft)	= 2.00		0.00		0.00		
Wetted perimeter (ft)	= 5.00		0.00		0.00		
Channel slope (%)	= 10.25		0.00		0.00		
Manning's n-value	= 0.030		0.015		0.015		
Velocity (ft/s)	=8.61						
			0.00				
					0.00		
Flow length (ft)	({0})887.7		0.0		0.0		
Travel Time (min)	**= 1.72**	**+**	**0.00**	**+**	**0.00**	**=**	**1.72**

Total Travel Time, Tc ..... 19.20 min

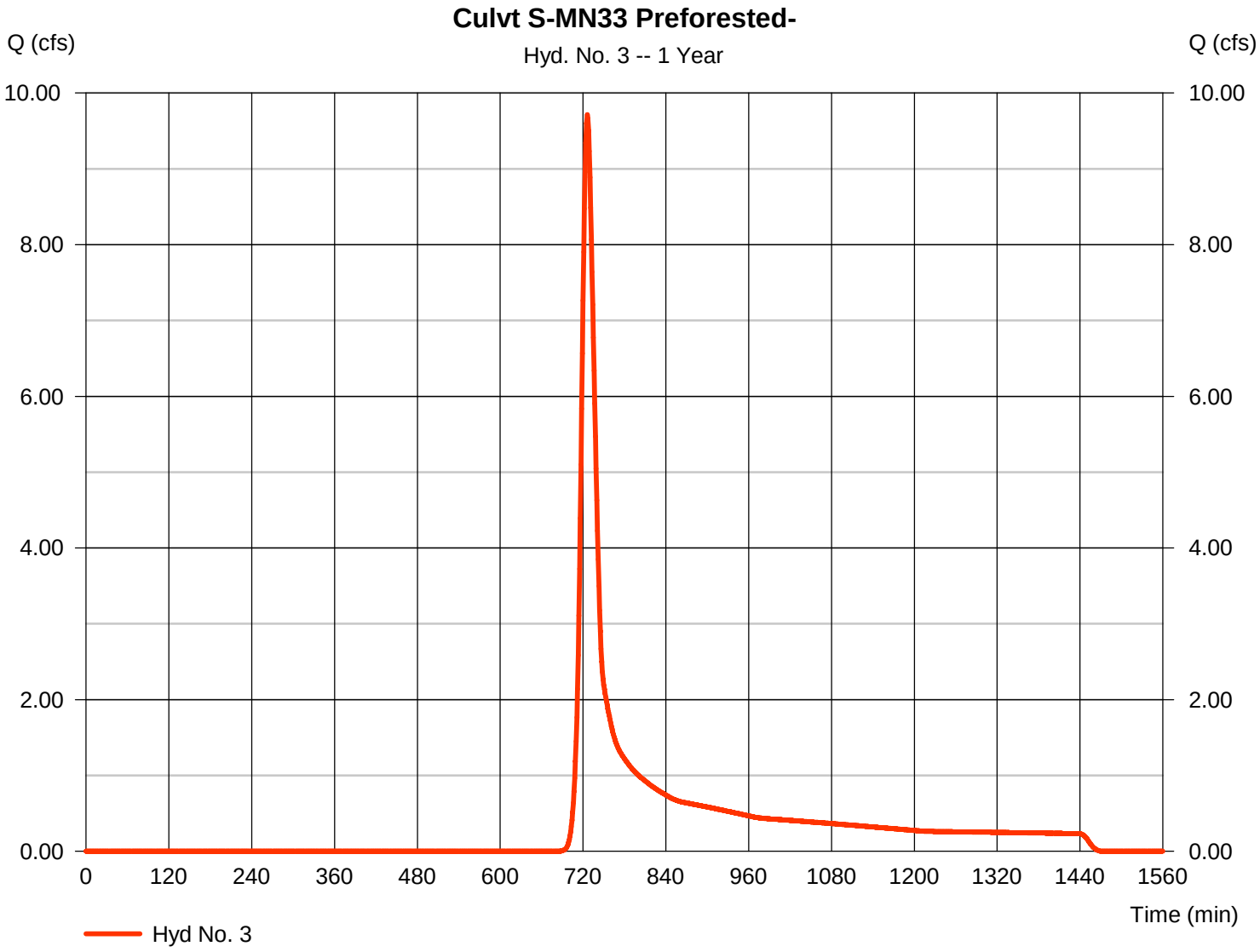
Hydrograph Report

Hyd. No. 3

Culvt S-MN33 Preforested-

Hydrograph type	= SCS Runoff	Peak discharge	= 9.713 cfs
Storm frequency	= 1 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 33,603 cuft
Drainage area	= 14.230 ac	Curve number	= 75*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 19.20 min
Total precip.	= 2.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(1.300 x 55) + (0.004 x 70) + (12.923 x 77)] / 14.230



TR55 Tc Worksheet

Hyd. No. 3

Culvt S-MN33 Preforested-

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.800		0.011		0.011		
Flow length (ft)	= 100.0		0.0		0.0		
Two-year 24-hr precip. (in)	= 3.00		0.00		0.00		
Land slope (%)	= 18.00		0.00		0.00		
Travel Time (min)	**= 16.03**	**+**	**0.00**	**+**	**0.00**	**=**	**16.03**
Shallow Concentrated Flow							
Flow length (ft)	= 676.32		0.00		0.00		
Watercourse slope (%)	= 22.33		0.00		0.00		
Surface description	= Unpaved		Unpaved		Paved		
Average velocity (ft/s)	=7.62		0.00		0.00		
Travel Time (min)	**= 1.48**	**+**	**0.00**	**+**	**0.00**	**=**	**1.48**
Channel Flow							
X sectional flow area (sqft)	= 2.00		0.00		0.00		
Wetted perimeter (ft)	= 5.00		0.00		0.00		
Channel slope (%)	= 10.25		0.00		0.00		
Manning's n-value	= 0.030		0.015		0.015		
Velocity (ft/s)	=8.61						
			0.00				
					0.00		
Flow length (ft)	({0})887.7		0.0		0.0		
Travel Time (min)	**= 1.72**	**+**	**0.00**	**+**	**0.00**	**=**	**1.72**

Total Travel Time, Tc ..... 19.20 min

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	40.40	1	725	126,517	------	------	------	Culvt S-MN33 Pre-
2	SCS Runoff	40.40	1	725	126,517	------	------	------	Culvt S-MN33 Post-
3	SCS Runoff	40.40	1	725	126,517	------	------	------	Culvt S-MN33 Preforested-

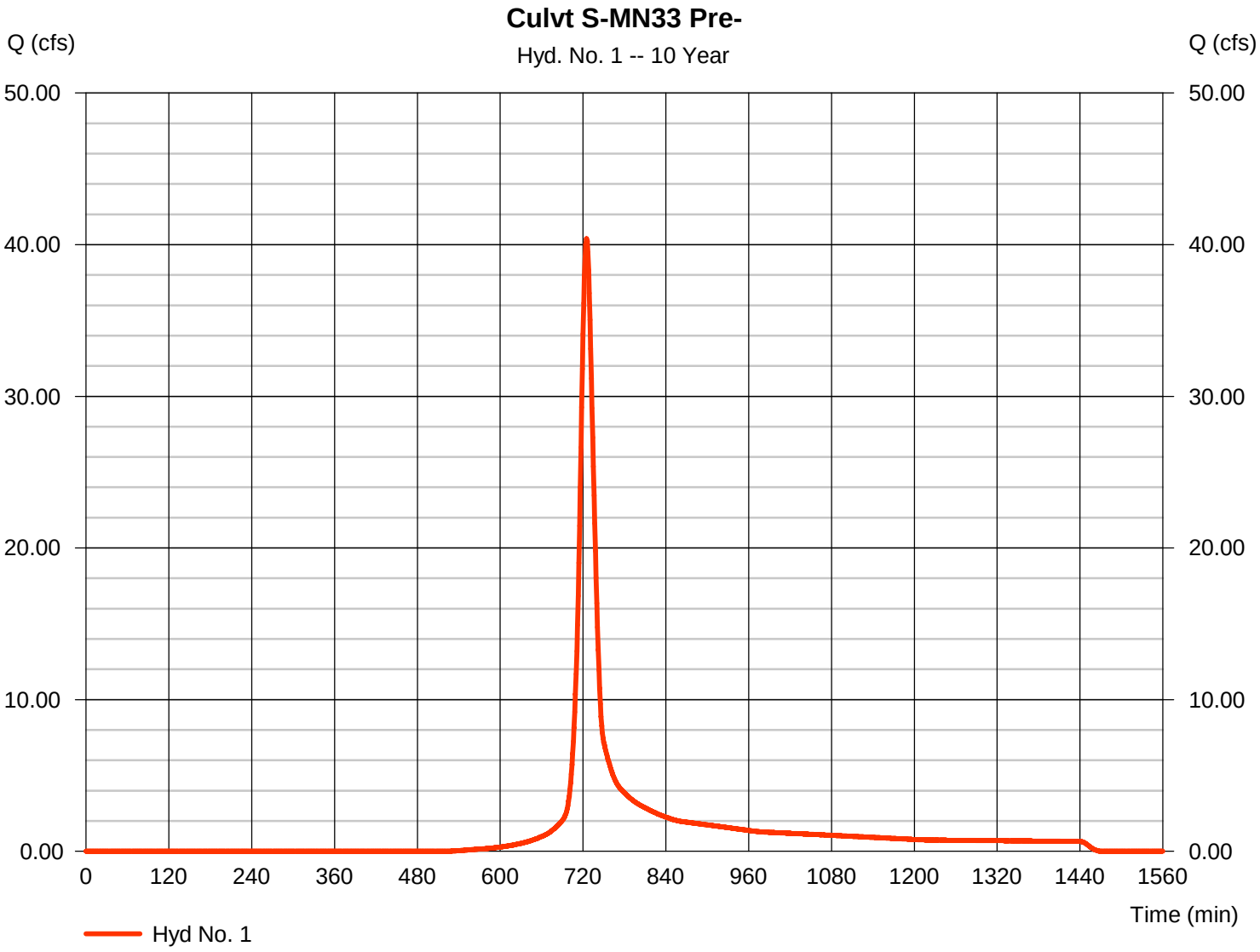
Hydrograph Report

Hyd. No. 1

Culvt S-MN33 Pre-

Hydrograph type	= SCS Runoff	Peak discharge	= 40.40 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 126,517 cuft
Drainage area	= 14.230 ac	Curve number	= 75*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 19.20 min
Total precip.	= 5.00 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(1.300 x 55) + (0.004 x 70) + (12.923 x 77)] / 14.230

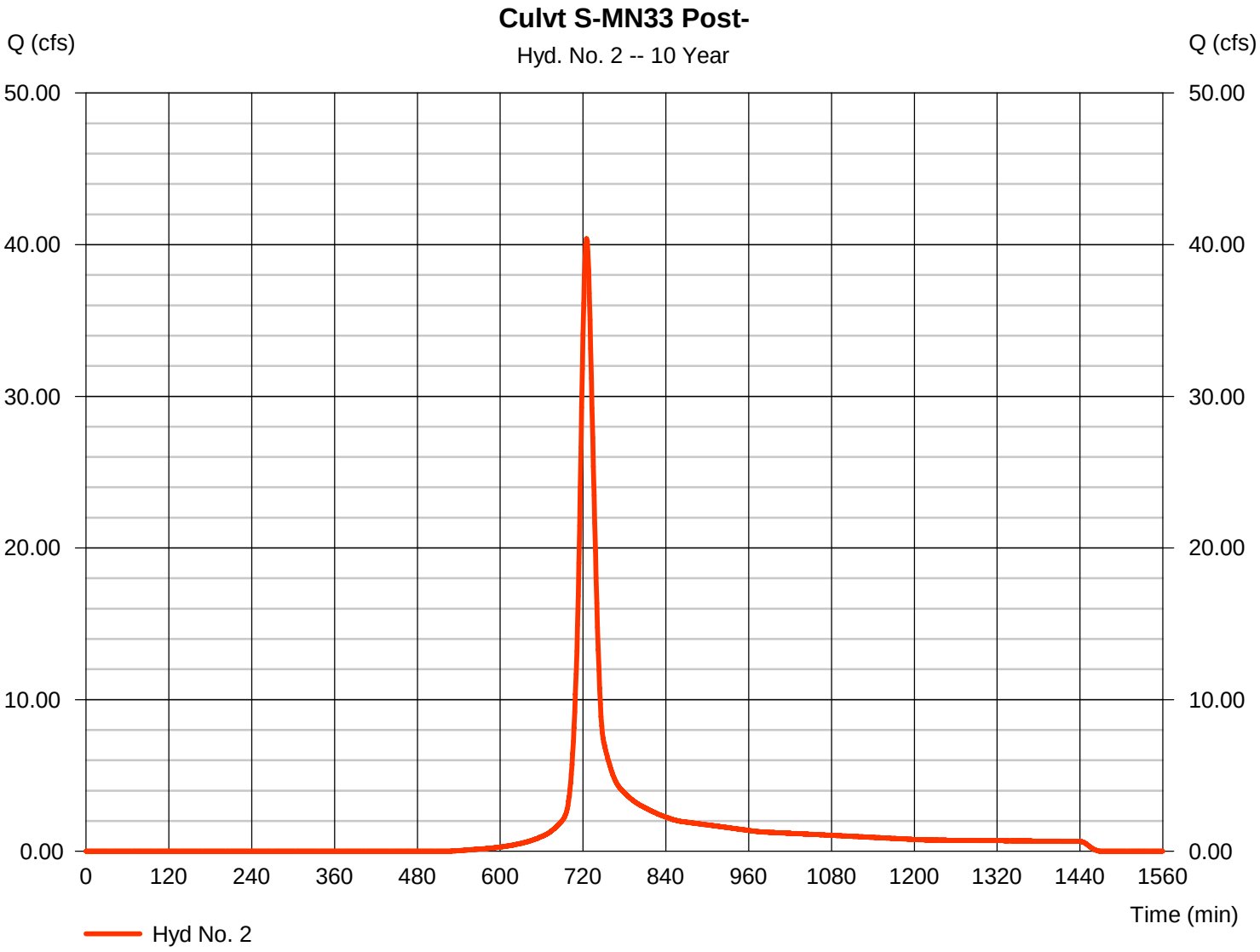


Hydrograph Report

Hyd. No. 2

Culvt S-MN33 Post-

Hydrograph type	=	SCS Runoff	Peak discharge	=	40.40 cfs
Storm frequency	=	10 yrs	Time to peak	=	725 min
Time interval	=	1 min	Hyd. volume	=	126,517 cuft
Drainage area	=	14.230 ac	Curve number	=	75
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	19.20 min
Total precip.	=	5.00 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484



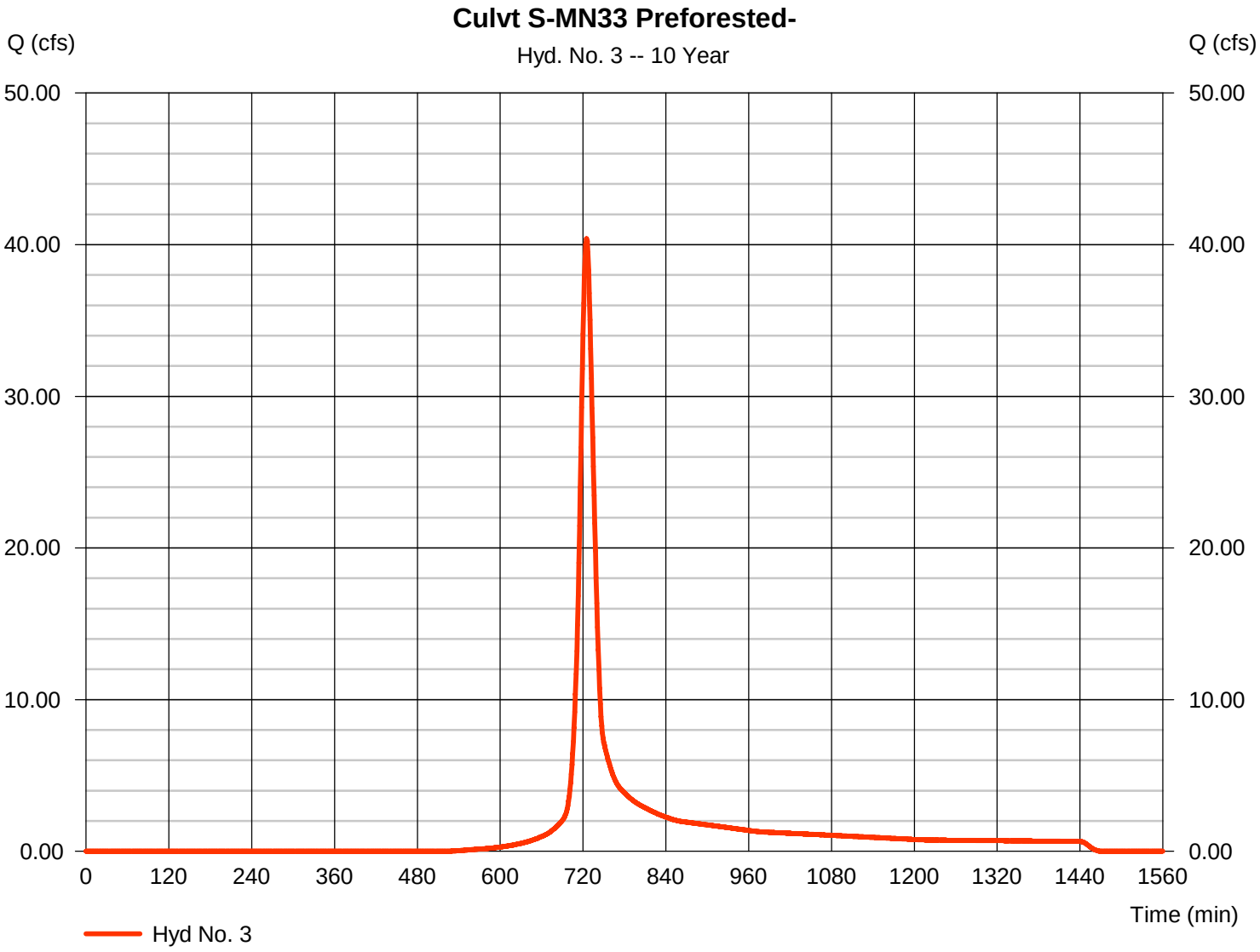
Hydrograph Report

Hyd. No. 3

Culvt S-MN33 Preforested-

Hydrograph type	=	SCS Runoff	Peak discharge	=	40.40 cfs
Storm frequency	=	10 yrs	Time to peak	=	725 min
Time interval	=	1 min	Hyd. volume	=	126,517 cuft
Drainage area	=	14.230 ac	Curve number	=	75*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	19.20 min
Total precip.	=	5.00 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(1.300 x 55) + (0.004 x 70) + (12.923 x 77)] / 14.230



Hydraflow Rainfall Report

Return Period (Yrs)	Intensity-Duration-Frequency Equation Coefficients (FHA)			
	B	D	E	(N/A)
1	0.0000	0.0000	0.0000	--------
2	69.8703	13.1000	0.8658	--------
3	0.0000	0.0000	0.0000	--------
5	79.2597	14.6000	0.8369	--------
10	88.2351	15.5000	0.8279	--------
25	102.6072	16.5000	0.8217	--------
50	114.8193	17.2000	0.8199	--------
100	127.1596	17.8000	0.8186	--------

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

Return Period (Yrs)	Intensity Values (in/hr)											
	5 min	10	15	20	25	30	35	40	45	50	55	60
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	5.69	4.61	3.89	3.38	2.99	2.69	2.44	2.24	2.07	1.93	1.81	1.70
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	6.57	5.43	4.65	4.08	3.65	3.30	3.02	2.79	2.59	2.42	2.27	2.15
10	7.24	6.04	5.21	4.59	4.12	3.74	3.43	3.17	2.95	2.77	2.60	2.46
25	8.25	6.95	6.03	5.34	4.80	4.38	4.02	3.73	3.48	3.26	3.07	2.91
50	9.04	7.65	6.66	5.92	5.34	4.87	4.49	4.16	3.88	3.65	3.44	3.25
100	9.83	8.36	7.30	6.50	5.87	5.36	4.94	4.59	4.29	4.03	3.80	3.60

Tc = time in minutes. Values may exceed 60.

rk Sladic\EQT\Project\112IC07157 MVP\Virginia Stormwater\Culvert Design - Other\Culvert S-MN33\Montgomery.pcp

Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	2.50	0.00	0.00	0.00	5.00	5.50	0.00	0.00
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	9.713	33,603
Developed Condition	9.713	33,603
Pre-Developed (Forest) Condition	9.713	33,603

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Calculations:

[1] ***Check #1:***	$Q_{developed} \leq IF \times [(Q_{pre\text{-}developed} \times RV_{pre\text{-}developed}) / RV_{developed}]$ ---------->	9.713	≤ OK	9.713
Check #2:	$Q_{developed} \leq Q_{pre\text{-}developed}$ ---------->	9.713	≤ OK	9.713
Check #3:	$Q_{developed}$ *shall not* be required to be $\leq (Q_{forest} \times RV_{forest}) / RV_{developed}$ --->	9.713	*shall not* be required to be ≤	9.713

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

[1] Per VADEQ, the improvement factor can be waived if the road is being maintained within the current footprint.

HY-8 Culvert Analysis Report

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 40.4 cfs

Design Flow: 40.4 cfs

Maximum Flow: 40.4 cfs

Table 1 - Summary of Culvert Flows at Crossing: S-MN33

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert S-MN33 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
1322.63	40.40	40.40	0.00	1
1322.63	40.40	40.40	0.00	1
1322.63	40.40	40.40	0.00	1
1322.63	40.40	40.40	0.00	1
1322.63	40.40	40.40	0.00	1
1322.63	40.40	40.40	0.00	1
1322.63	40.40	40.40	0.00	1
1322.63	40.40	40.40	0.00	1
1322.63	40.40	40.40	0.00	1
1322.63	40.40	40.40	0.00	1
1322.63	40.40	40.40	0.00	1
1322.74	41.86	41.86	0.00	Overtopping

Rating Curve Plot for Crossing: S-MN33

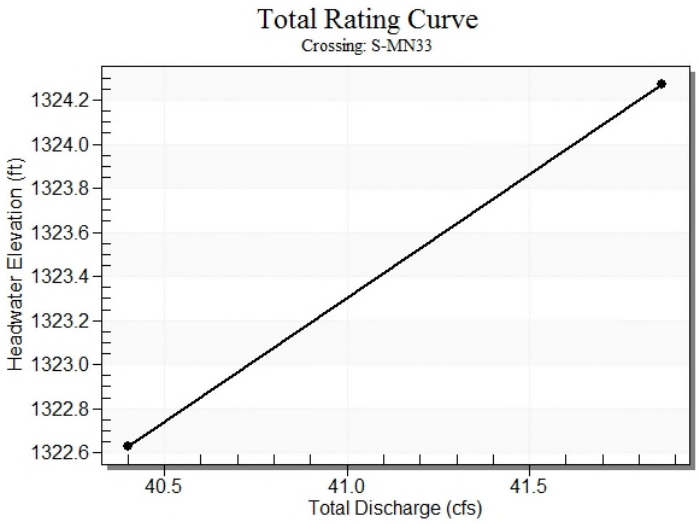


Table 2 - Culvert Summary Table: Culvert S-MN33

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
40.40	40.40	1322.63	2.637	2.291	5-S2n	1.261	1.459	1.313	1.530	7.496	6.603
40.40	40.40	1322.63	2.637	2.291	5-S2n	1.261	1.459	1.313	1.530	7.496	6.603
40.40	40.40	1322.63	2.637	2.291	5-S2n	1.261	1.459	1.313	1.530	7.496	6.603
40.40	40.40	1322.63	2.637	2.291	5-S2n	1.261	1.459	1.313	1.530	7.496	6.603
40.40	40.40	1322.63	2.637	2.291	5-S2n	1.261	1.459	1.313	1.530	7.496	6.603
40.40	40.40	1322.63	2.637	2.291	5-S2n	1.261	1.459	1.313	1.530	7.496	6.603
40.40	40.40	1322.63	2.637	2.291	5-S2n	1.261	1.459	1.313	1.530	7.496	6.603
40.40	40.40	1322.63	2.637	2.291	5-S2n	1.261	1.459	1.313	1.530	7.496	6.603
40.40	40.40	1322.63	2.637	2.291	5-S2n	1.261	1.459	1.313	1.530	7.496	6.603
40.40	40.40	1322.63	2.637	2.291	5-S2n	1.261	1.459	1.313	1.530	7.496	6.603
40.40	40.40	1322.63	2.637	2.291	5-S2n	1.261	1.459	1.313	1.530	7.496	6.603

****

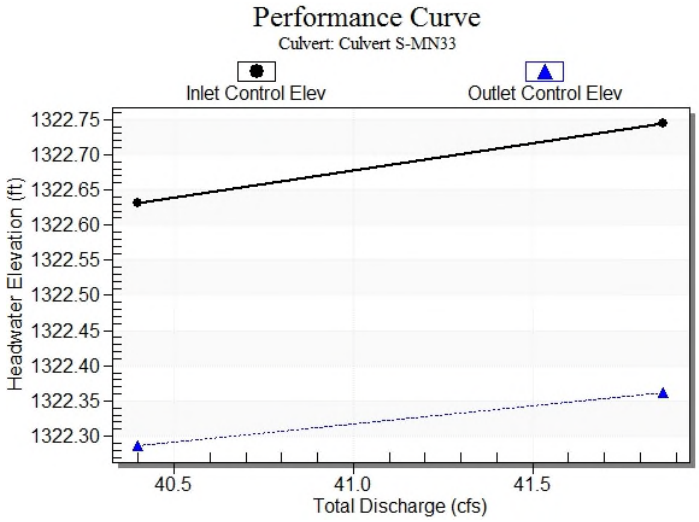
Straight Culvert

Inlet Elevation (invert): 1319.99 ft, Outlet Elevation (invert): 1319.74 ft

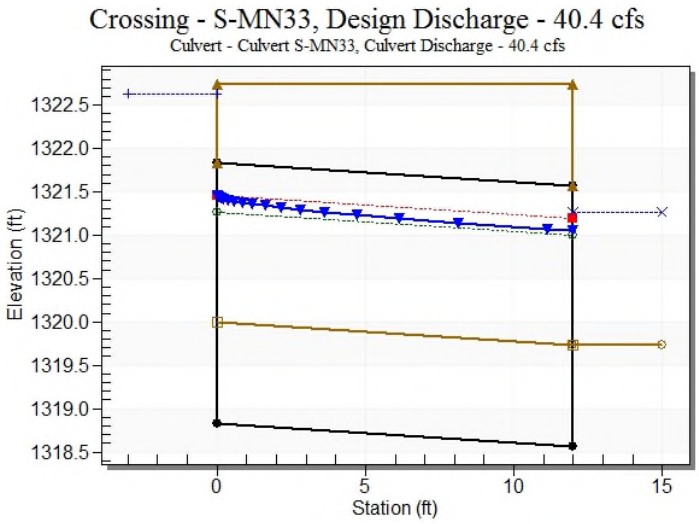
Culvert Length: 12.00 ft, Culvert Slope: 0.0215

****

Culvert Performance Curve Plot: Culvert S-MN33



Water Surface Profile Plot for Culvert: Culvert S-MN33



Site Data - Culvert S-MN33

Site Data Option: Culvert Invert Data
Inlet Station: 0.00 ft
Inlet Elevation: 1318.83 ft
Outlet Station: 12.00 ft
Outlet Elevation: 1318.57 ft
Number of Barrels: 1

Culvert Data Summary - Culvert S-MN33

Barrel Shape: Concrete Box
Barrel Span: 4.00 ft
Barrel Rise: 3.00 ft
Barrel Material: Concrete
Embedment: 14.00 in
Barrel Manning's n: 0.0120 (top and sides)
Manning's n: 0.0300 (bottom)
Culvert Type: Straight
Inlet Configuration: Thin Edge Projecting
Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: S-MN33)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
40.40	1321.27	1.53	6.60	2.05	0.94
40.40	1321.27	1.53	6.60	2.05	0.94
40.40	1321.27	1.53	6.60	2.05	0.94
40.40	1321.27	1.53	6.60	2.05	0.94
40.40	1321.27	1.53	6.60	2.05	0.94
40.40	1321.27	1.53	6.60	2.05	0.94
40.40	1321.27	1.53	6.60	2.05	0.94
40.40	1321.27	1.53	6.60	2.05	0.94
40.40	1321.27	1.53	6.60	2.05	0.94
40.40	1321.27	1.53	6.60	2.05	0.94
40.40	1321.27	1.53	6.60	2.05	0.94

Tailwater Channel Data - S-MN33

Tailwater Channel Option: Rectangular Channel

Bottom Width: 4.00 ft

Channel Slope: 0.0215

Channel Manning's n: 0.0300

Channel Invert Elevation: 1319.74 ft

Roadway Data for Crossing: S-MN33

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 10.00 ft

Crest Elevation: 1322.74 ft

Roadway Surface: Gravel

Roadway Top Width: 12.00 ft

		Culvert Design					[1]Riprap Apron Outlet Protection Design						
Station	Corresponding Stream	Culvert Diameter, d_o (in)	Culvert Material	[2]Pipe Slope (ft/ft)	Q (cfs)	Design Flow Frequency	d_{50} Riprap Size, d_{50} (in)	AASHTO Riprap Class	Placement Thickness per NSA Riprap Gradation, d (in)	Placement Thickness per AASHTO Riprap Gradation, d (in)	Apron Length, L_a (ft)	Apron Initial Width, W_i (ft)	Apron Terminal Width, W (ft)
20 + 88.96	S-MN34	N/A (Box Culvert: Span=9.0-ft, Rise=6.0-ft)	Concrete	0.070	278.12	10-Yr	N/A - Scour protection needs to withstand tailwater velocity of 15.6 ft/s and shear stress of 9.03 psf. Suggest grouted riprap or equivalent. Note that scour protection should be placed within the channel from top-of-bank to top-of-bank, and extend from the culvert outlet to the limit of disturbance.						

[1]Designed in accordance with VESCH Std & Spec 3.18 assuming minimum tailwater condition ($T_w < 0.5d_o$).

[2]The slope was calculated from a combination of LIDAR and field notes taken for the stream channel characteristics.

[3]Requires roadway grading (fill of 4.313 feet) to install culvert with minimum recommended cover of 2 inches.

DA-RO-SM34
87.49 acres
Weighted CN = 77

Land Use	HSG	CN	Area (AC)
Woods	D	77	86.54
Dirt Road	D	89	0.96

Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Dirt Road
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

1:4,800

400 200 0 400 Feet

Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Pre-Construction Drainage Area Map
DA-RO-SM34
Spread 9

Figure 1
Roanoke County, Virginia

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Agricultural Area from National Land Cover Database (NLCD) 2011, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016 and Radford University DEMs, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015.

Document Path: P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Roanoke\MVP_PCSM_DA-RO-SM34_Pre.mxd

DA-RO-SM34
87.49 acres
Weighted CN = 77

DA-RO-SM34 Permanent ROW
0.054 acres

Land Use	HSG	CN	Area (AC)
Woods	D	77	86.47
Dirt Road	D	89	0.96
Meadow	D	78	0.02
Gravel	D	91	0.02
Brush	D	73	0.02

Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Brush
- Dirt Road
- Gravel
- Meadow
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

1:4,800

400 200 0 400 Feet

N W E S

Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Post-Construction Drainage Area Map
DA-RO-SM34
Spread 9

Figure 2
Roanoke County, Virginia

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Agricultural Area from National Land Cover Database (NLCD) 2011, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016 and Radford Univeristy DEMs, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015.

Document Path: PGH P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Roanoke\MVP_PCSM_DA-RO-SM34_Post.mxd

DA-RO-SM34
87.49 acres
Weighted CN = 77

233.6
233.7
233.8

S-MN34
S-MN32
S-MN31
S-MN26

Pre-Construction Time of Concentration				
	Sheet	Shallow	Channel A	Calculated Time of Concentration (min)
S-MN34	100 FT @ 48%	891.83 FT @ 46.20%	3741.6 FT @ 13.20%	17.7

Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:4,800

400 200 0 400 Feet

N W E S

Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Pre-Construction Drainage Area and Time of Concentration
DA-RO-SM34
Spread 9

Figure 3
Roanoke County, Virginia

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016 and Radford Univeristy DEMs.

Document Path: P:\GIS\EOT_MVP\Mapdocs\Drainage\MXD\Roanoke\Figures 3-4\MVP_PCSM_DA-RO-SM34_3.mxd

DA-RO-SM34
87.49 acres
Weighted CN = 77

S-MN34
S-MN32
S-MN31
S-MN26

233.6
233.7
233.8

Post-Construction Time of Concentration

	Sheet	Shallow	Channel A	Calculated Time of Concentration (min)
S-MN34	100 FT @ 48%	891.83 FT @ 46.20%	3741.6 FT @ 13.20%	17.7

Legend

- Milepost
- Permanent Waterbars
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:4,800

400 200 0 400 Feet

N W E S

Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Post-Construction Drainage Area and Time of Concentration DA-RO-SM34 Spread 9

Figure 4
Roanoke County, Virginia
September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016 and Radford Univeristy DEMs.

Document Path: P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Roanoke\Figures 3-4\MVP_PCSM_DA-RO-SM34_4.mxd

Table 1 – Manning's n Values for Sheet Flow

Land Surface Type	**Manning n**
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40

Note:

Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.

Sources:

-USACE, 1998, HEC-1 Flood Hydrograph Package User's Manual, Hydrologic Engineering Center, Davis, CA

-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC

Table 2 – Manning's n Values for Open Channel Flow

Channel Type	Manning n		
	Min.	Normal	Max.
1. Excavated or Dredged Channels[1]			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels[2]			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150

Notes:

[1]A Manning's n value of 0.040 was used in Hydraflow Hydrographs for roadside channels.

[2]A Manning's n value of 0.030 was used in Hydraflow Hydrographs for existing/natural channels.

Sources:

-ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY

-Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY

Hydraflow Table of Contents

Watershed Model Schematic

Legend

Hyd.	Origin	Description
1	SCS Runoff	Culvt S-MN34 Pre-
2	SCS Runoff	Culvt S-MN34 Post-
3	SCS Runoff	Culvt S-MN34 Preforested-

Hydrograph Return Period Recap

Hyd. No.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)								Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	------	110.12	-------	-------	-------	278.12	-------	-------	-------	Culvt S-MN34 Pre-
2	SCS Runoff	------	110.12	-------	-------	-------	278.12	-------	-------	-------	Culvt S-MN34 Post-
3	SCS Runoff	------	110.12	-------	-------	-------	278.12	-------	-------	-------	Culvt S-MN34 Preforested-

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	110.12	1	725	336,284	------	------	------	Culvt S-MN34 Pre-
2	SCS Runoff	110.12	1	725	336,284	------	------	------	Culvt S-MN34 Post-
3	SCS Runoff	110.12	1	725	336,284	------	------	------	Culvt S-MN34 Preforested-

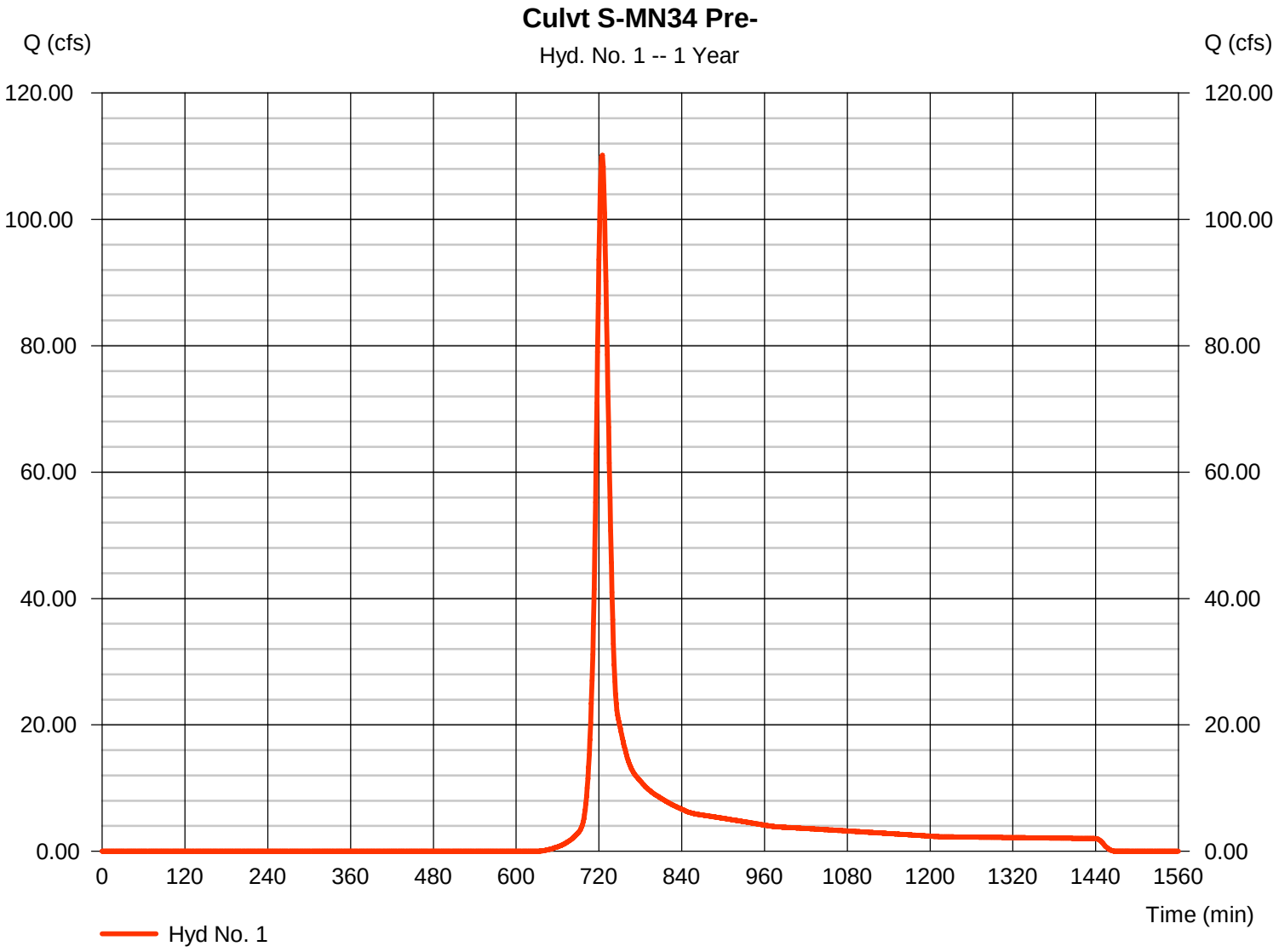
Hydrograph Report

Hyd. No. 1

Culvt S-MN34 Pre-

Hydrograph type	= SCS Runoff	Peak discharge	= 110.12 cfs
Storm frequency	= 1 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 336,284 cuft
Drainage area	= 87.490 ac	Curve number	= 77*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 17.70 min
Total precip.	= 3.00 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(86.537 x 77) + (0.957 x 89)] / 87.490



TR55 Tc Worksheet

Hyd. No. 1

Culvt S-MN34 Pre-

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.800		0.011		0.011		
Flow length (ft)	= 100.0		0.0		0.0		
Two-year 24-hr precip. (in)	= 3.50		0.00		0.00		
Land slope (%)	= 48.00		0.00		0.00		
Travel Time (min)	**= 10.03**	**+**	**0.00**	**+**	**0.00**	**=**	**10.03**
Shallow Concentrated Flow							
Flow length (ft)	= 891.83		0.00		0.00		
Watercourse slope (%)	= 46.20		0.00		0.00		
Surface description	= Unpaved		Unpaved		Paved		
Average velocity (ft/s)	=10.97		0.00		0.00		
Travel Time (min)	**= 1.36**	**+**	**0.00**	**+**	**0.00**	**=**	**1.36**
Channel Flow							
X sectional flow area (sqft)	= 2.25		0.00		0.00		
Wetted perimeter (ft)	= 5.50		0.00		0.00		
Channel slope (%)	= 13.20		0.00		0.00		
Manning's n-value	= 0.030		0.015		0.015		
Velocity (ft/s)	=9.91						
			0.00				
					0.00		
Flow length (ft)	({0})3741.6		0.0		0.0		
Travel Time (min)	**= 6.29**	**+**	**0.00**	**+**	**0.00**	**=**	**6.29**

Total Travel Time, Tc ..... 17.70 min

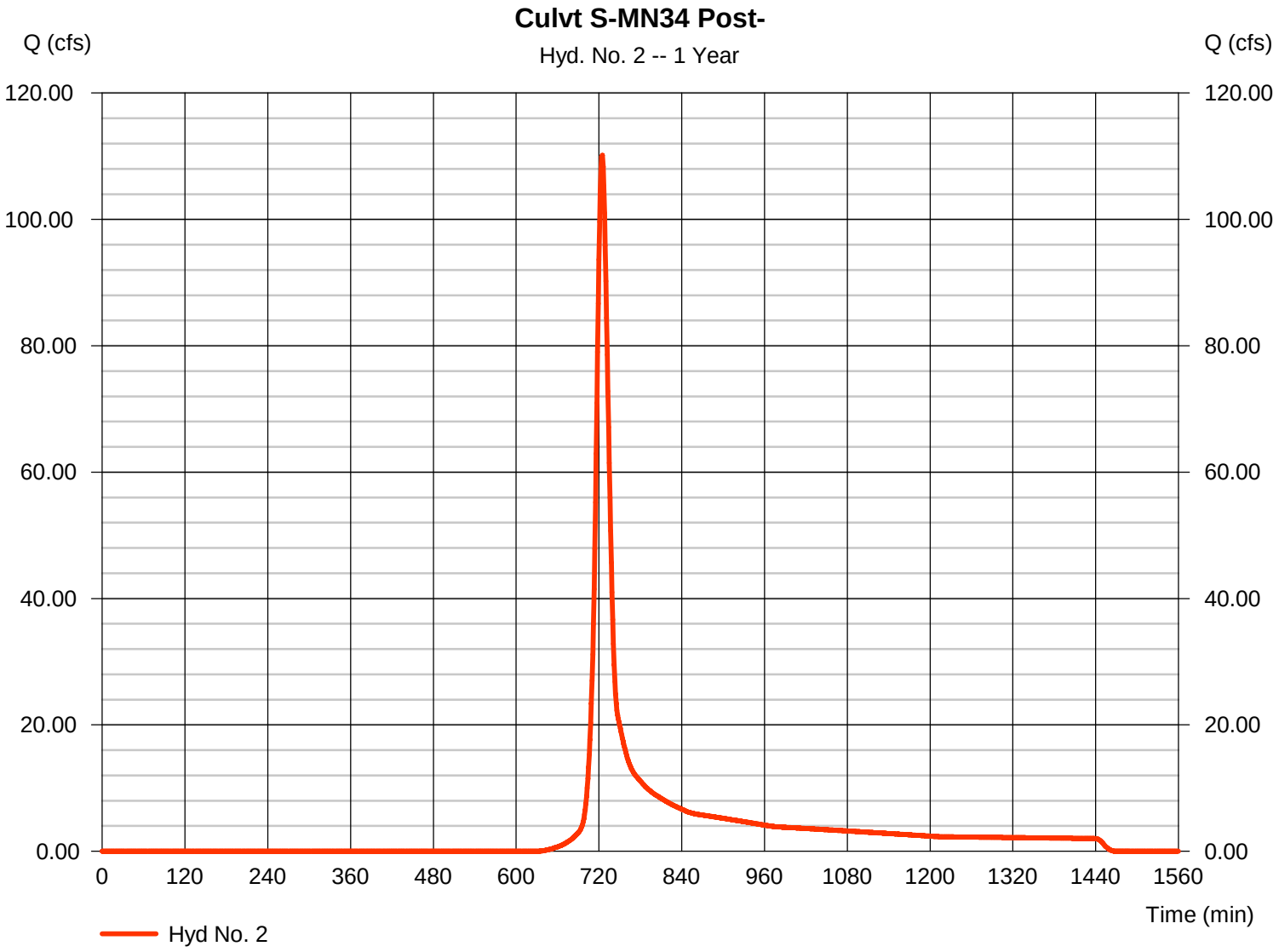
Hydrograph Report

Hyd. No. 2

Culvt S-MN34 Post-

Hydrograph type	= SCS Runoff	Peak discharge	= 110.12 cfs
Storm frequency	= 1 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 336,284 cuft
Drainage area	= 87.490 ac	Curve number	= 77*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 17.70 min
Total precip.	= 3.00 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(86.466 x 77) + (0.957 x 89) + (0.024 x 78) + (0.023 x 91) + (0.023 x 73)] / 87.490



TR55 Tc Worksheet

Hyd. No. 2

Culvt S-MN34 Post-

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.800		0.011		0.011		
Flow length (ft)	= 100.0		0.0		0.0		
Two-year 24-hr precip. (in)	= 3.50		0.00		0.00		
Land slope (%)	= 48.00		0.00		0.00		
Travel Time (min)	**= 10.03**	**+**	**0.00**	**+**	**0.00**	**=**	**10.03**
Shallow Concentrated Flow							
Flow length (ft)	= 891.83		0.00		0.00		
Watercourse slope (%)	= 46.20		0.00		0.00		
Surface description	= Unpaved		Unpaved		Paved		
Average velocity (ft/s)	=10.97		0.00		0.00		
Travel Time (min)	**= 1.36**	**+**	**0.00**	**+**	**0.00**	**=**	**1.36**
Channel Flow							
X sectional flow area (sqft)	= 2.25		0.00		0.00		
Wetted perimeter (ft)	= 5.50		0.00		0.00		
Channel slope (%)	= 13.20		0.00		0.00		
Manning's n-value	= 0.030		0.015		0.015		
Velocity (ft/s)	=9.91						
			0.00				
					0.00		
Flow length (ft)	({0})3741.6		0.0		0.0		
Travel Time (min)	**= 6.29**	**+**	**0.00**	**+**	**0.00**	**=**	**6.29**

Total Travel Time, Tc ..... 17.70 min

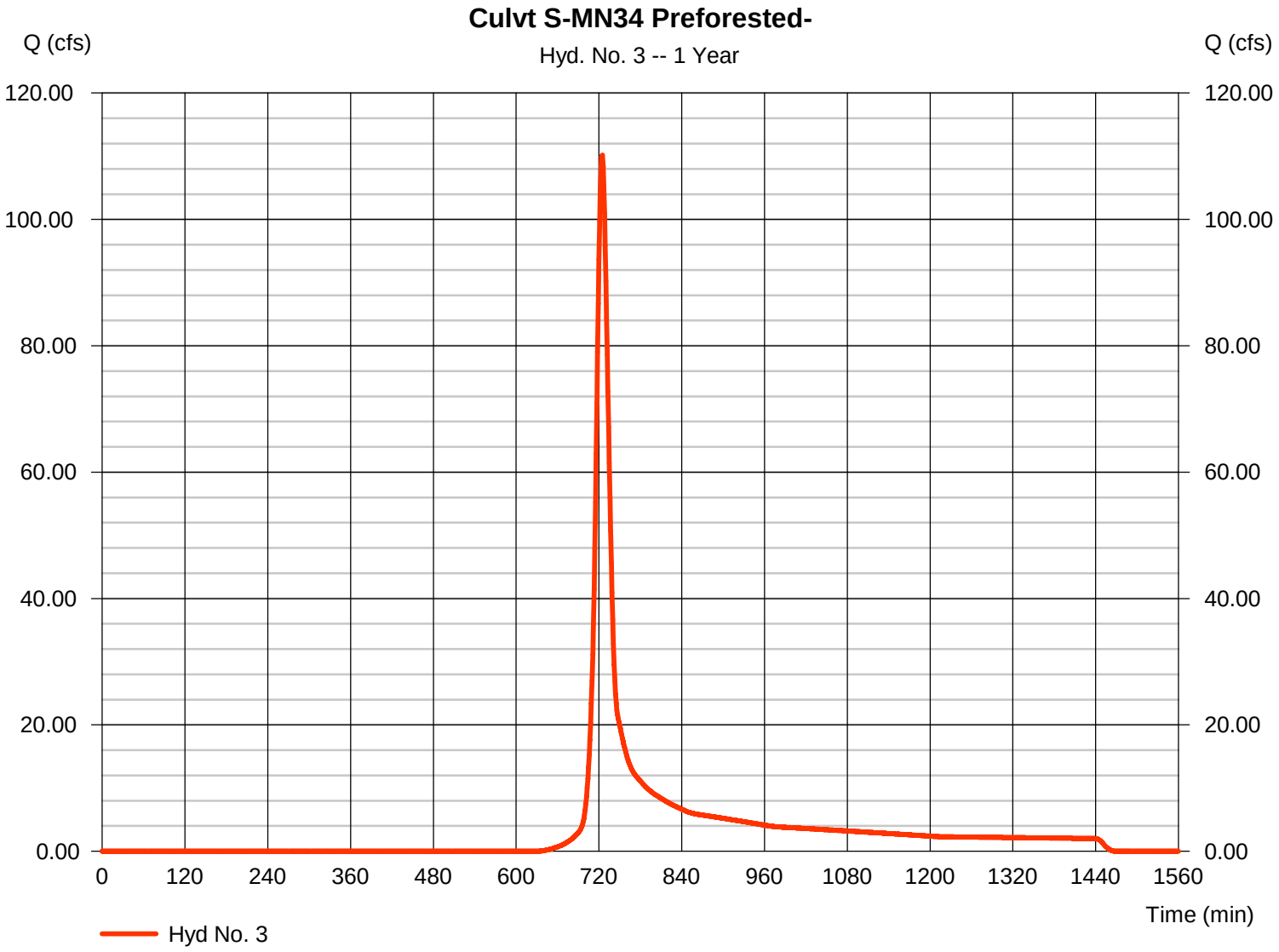
Hydrograph Report

Hyd. No. 3

Culvt S-MN34 Preforested-

Hydrograph type	= SCS Runoff	Peak discharge	= 110.12 cfs
Storm frequency	= 1 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 336,284 cuft
Drainage area	= 87.490 ac	Curve number	= 77*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 17.70 min
Total precip.	= 3.00 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(87.493 x 77)] / 87.490



TR55 Tc Worksheet

Hyd. No. 3

Culvt S-MN34 Preforested-

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.800		0.011		0.011		
Flow length (ft)	= 100.0		0.0		0.0		
Two-year 24-hr precip. (in)	= 3.50		0.00		0.00		
Land slope (%)	= 48.00		0.00		0.00		
Travel Time (min)	**= 10.03**	**+**	**0.00**	**+**	**0.00**	**=**	**10.03**
Shallow Concentrated Flow							
Flow length (ft)	= 891.83		0.00		0.00		
Watercourse slope (%)	= 46.20		0.00		0.00		
Surface description	= Unpaved		Unpaved		Paved		
Average velocity (ft/s)	=10.97		0.00		0.00		
Travel Time (min)	**= 1.36**	**+**	**0.00**	**+**	**0.00**	**=**	**1.36**
Channel Flow							
X sectional flow area (sqft)	= 2.25		0.00		0.00		
Wetted perimeter (ft)	= 5.50		0.00		0.00		
Channel slope (%)	= 13.20		0.00		0.00		
Manning's n-value	= 0.030		0.015		0.015		
Velocity (ft/s)	=9.91						
			0.00				
					0.00		
Flow length (ft)	({0})3741.6		0.0		0.0		
Travel Time (min)	**= 6.29**	**+**	**0.00**	**+**	**0.00**	**=**	**6.29**

Total Travel Time, Tc ..... 17.70 min

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v11

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	278.12	1	724	823,566	------	------	------	Culvt S-MN34 Pre-
2	SCS Runoff	278.12	1	724	823,566	------	------	------	Culvt S-MN34 Post-
3	SCS Runoff	278.12	1	724	823,566	------	------	------	Culvt S-MN34 Preforested-

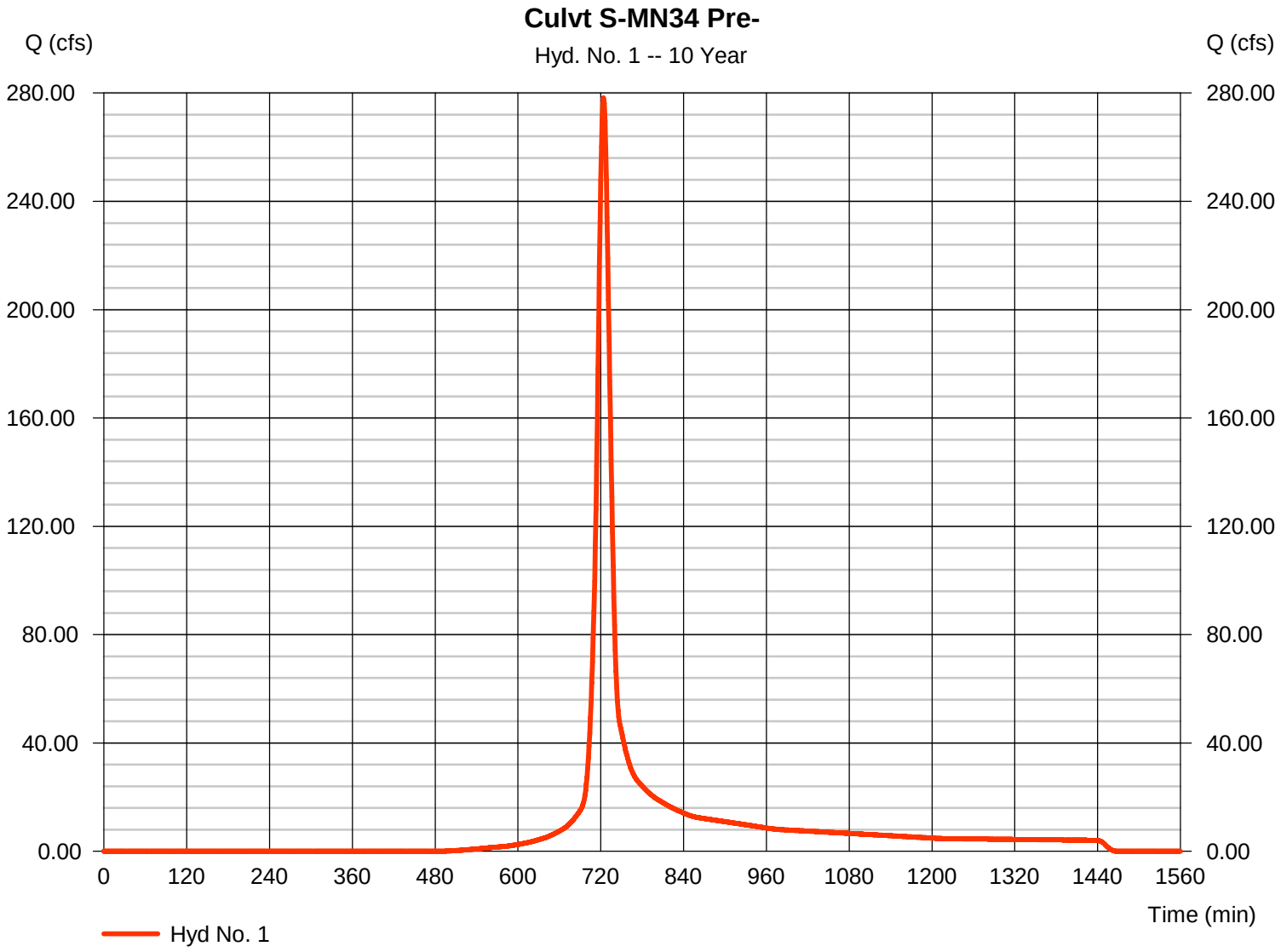
Hydrograph Report

Hyd. No. 1

Culvt S-MN34 Pre-

Hydrograph type	=	SCS Runoff	Peak discharge	=	278.12 cfs
Storm frequency	=	10 yrs	Time to peak	=	724 min
Time interval	=	1 min	Hyd. volume	=	823,566 cuft
Drainage area	=	87.490 ac	Curve number	=	77*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	17.70 min
Total precip.	=	5.00 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(86.537 x 77) + (0.957 x 89)] / 87.490



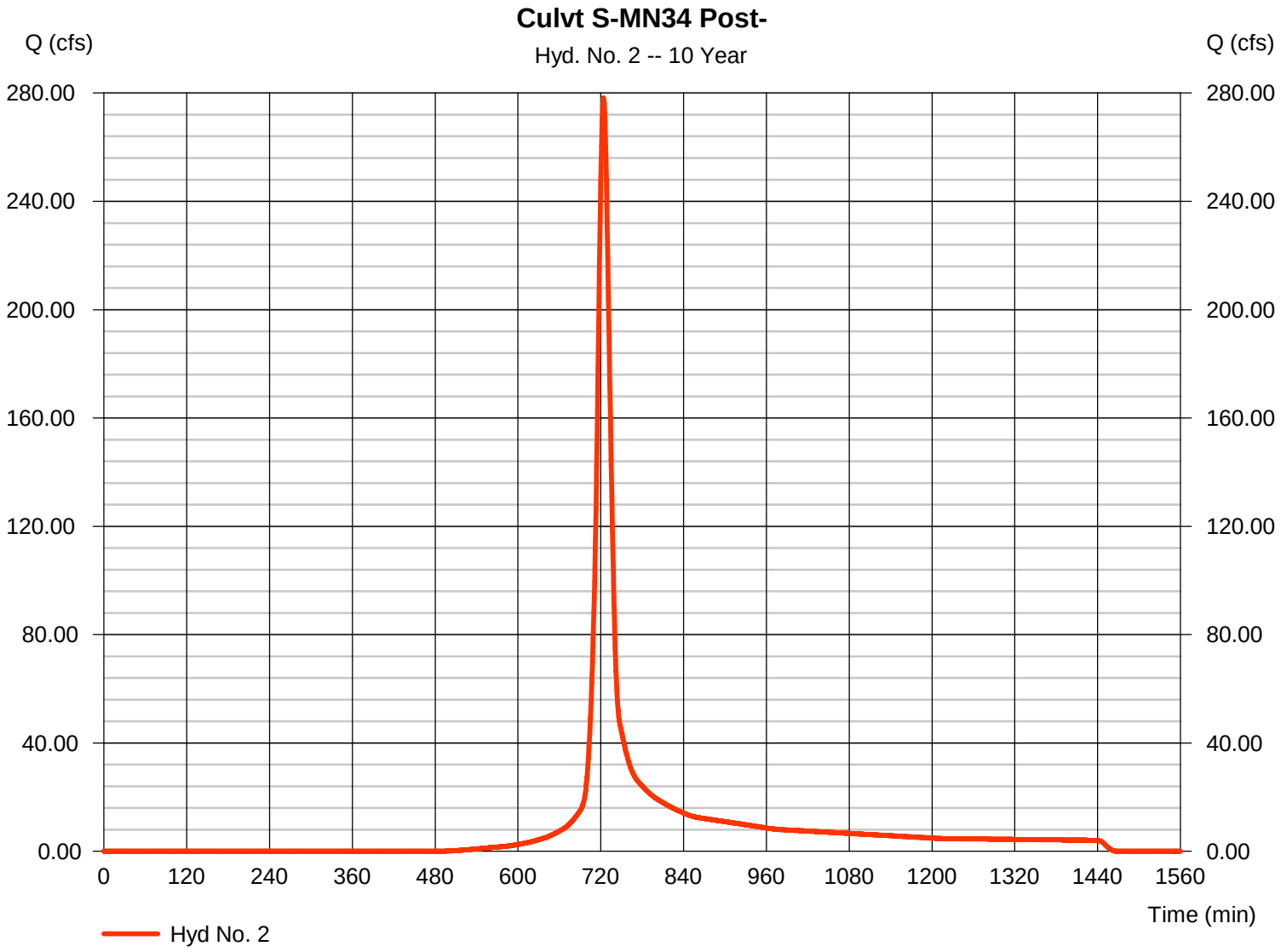
Hydrograph Report

Hyd. No. 2

Culvt S-MN34 Post-

Hydrograph type	=	SCS Runoff	Peak discharge	=	278.12 cfs
Storm frequency	=	10 yrs	Time to peak	=	724 min
Time interval	=	1 min	Hyd. volume	=	823,566 cuft
Drainage area	=	87.490 ac	Curve number	=	77*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	17.70 min
Total precip.	=	5.00 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(86.466 x 77) + (0.957 x 89) + (0.024 x 78) + (0.023 x 91) + (0.023 x 73)] / 87.490



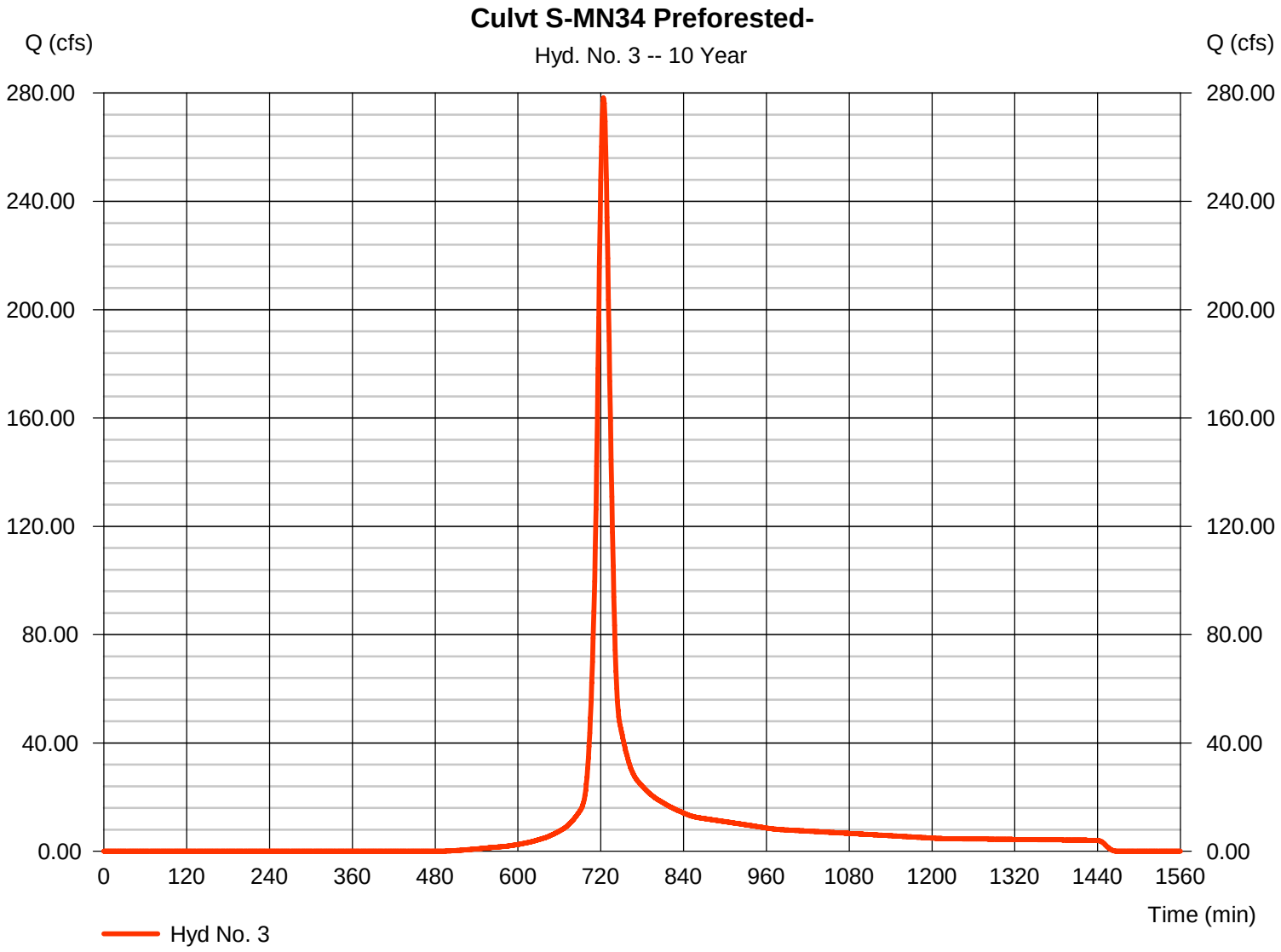
Hydrograph Report

Hyd. No. 3

Culvt S-MN34 Preforested-

Hydrograph type	=	SCS Runoff	Peak discharge	=	278.12 cfs
Storm frequency	=	10 yrs	Time to peak	=	724 min
Time interval	=	1 min	Hyd. volume	=	823,566 cuft
Drainage area	=	87.490 ac	Curve number	=	77*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	17.70 min
Total precip.	=	5.00 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(87.493 x 77)] / 87.490



Hydraflow Rainfall Report

Return Period (Yrs)	Intensity-Duration-Frequency Equation Coefficients (FHA)			
	B	D	E	(N/A)
1	0.0000	0.0000	0.0000	--------
2	69.8703	13.1000	0.8658	--------
3	0.0000	0.0000	0.0000	--------
5	79.2597	14.6000	0.8369	--------
10	88.2351	15.5000	0.8279	--------
25	102.6072	16.5000	0.8217	--------
50	114.8193	17.2000	0.8199	--------
100	127.1596	17.8000	0.8186	--------

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

Return Period (Yrs)	Intensity Values (in/hr)											
	5 min	10	15	20	25	30	35	40	45	50	55	60
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	5.69	4.61	3.89	3.38	2.99	2.69	2.44	2.24	2.07	1.93	1.81	1.70
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	6.57	5.43	4.65	4.08	3.65	3.30	3.02	2.79	2.59	2.42	2.27	2.15
10	7.24	6.04	5.21	4.59	4.12	3.74	3.43	3.17	2.95	2.77	2.60	2.46
25	8.25	6.95	6.03	5.34	4.80	4.38	4.02	3.73	3.48	3.26	3.07	2.91
50	9.04	7.65	6.66	5.92	5.34	4.87	4.49	4.16	3.88	3.65	3.44	3.25
100	9.83	8.36	7.30	6.50	5.87	5.36	4.94	4.59	4.29	4.03	3.80	3.60

Tc = time in minutes. Values may exceed 60.

- Mark Sladic\EQT\Project\112IC07157 MVP\Virginia Stormwater\Culvert Design - Other\Culvert S-MN34\Roanoke.pcp

Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.00	0.00	0.00	0.00	5.00	6.00	0.00	0.00
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	110.120	336,284
Developed Condition	110.120	336,284
Pre-Developed (Forest) Condition	110.120	336,284

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Calculations:

[1] ***Check #1:***	$Q_{developed} \leq IF \times [(Q_{pre\text{-}developed} \times RV_{pre\text{-}developed}) / RV_{developed}]$ ---------->	110.120	≤ OK	110.120
Check #2:	$Q_{developed} \leq Q_{pre\text{-}developed}$ ---------->	110.120	≤ OK	110.120
Check #3:	$Q_{developed}$ *shall not* be required to be $\leq (Q_{forest} \times RV_{forest}) / RV_{developed}$ --->	110.120	*shall not* be required to be ≤	110.120

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

[1] Per VADEQ, the improvement factor can be waived if the road is being maintained within the current footprint.

HY-8 Culvert Analysis Report

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Minimum Flow: 278.12 cfs

Design Flow: 278.12 cfs

Maximum Flow: 278.12 cfs

Table 1 - Summary of Culvert Flows at Crossing: S-MN34

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert S-MN34 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
1342.81	278.12	278.12	0.00	1
1342.81	278.12	278.12	0.00	1
1342.81	278.12	278.12	0.00	1
1342.81	278.12	278.12	0.00	1
1342.81	278.12	278.12	0.00	1
1342.81	278.12	278.12	0.00	1
1342.81	278.12	278.12	0.00	1
1342.81	278.12	278.12	0.00	1
1342.81	278.12	278.12	0.00	1
1342.81	278.12	278.12	0.00	1
1342.81	278.12	278.12	0.00	1
1342.90	283.11	283.11	0.00	Overtopping

Rating Curve Plot for Crossing: S-MN34

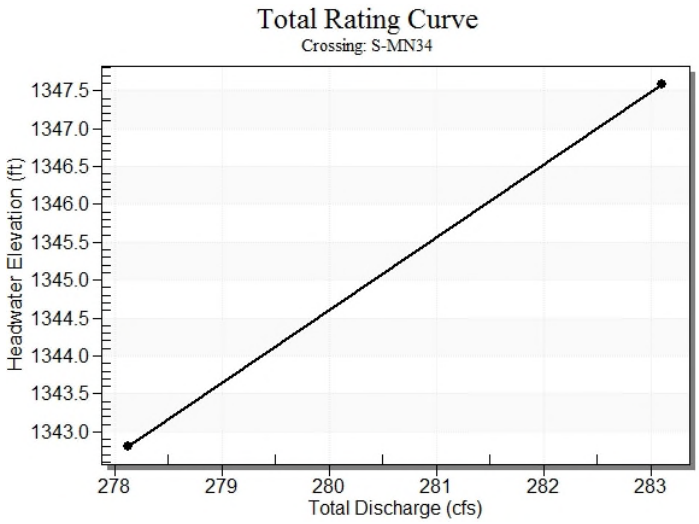


Table 2 - Culvert Summary Table: Culvert S-MN34

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
278.12	278.12	1342.81	5.230	3.820	5-S2n	1.805	3.089	2.266	2.065	13.287	15.602
278.12	278.12	1342.81	5.230	3.820	5-S2n	1.805	3.089	2.266	2.065	13.287	15.602
278.12	278.12	1342.81	5.230	3.820	5-S2n	1.805	3.089	2.266	2.065	13.287	15.602
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278.12	278.12	1342.81	5.230	3.820	5-S2n	1.805	3.089	2.266	2.065	13.287	15.602
278.12	278.12	1342.81	5.230	3.820	5-S2n	1.805	3.089	2.266	2.065	13.287	15.602
278.12	278.12	1342.81	5.230	3.820	5-S2n	1.805	3.089	2.266	2.065	13.287	15.602
278.12	278.12	1342.81	5.230	3.820	5-S2n	1.805	3.089	2.266	2.065	13.287	15.602

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Straight Culvert

Inlet Elevation (invert): 1337.58 ft,   Outlet Elevation (invert): 1336.74 ft

Culvert Length: 12.03 ft,   Culvert Slope: 0.0701

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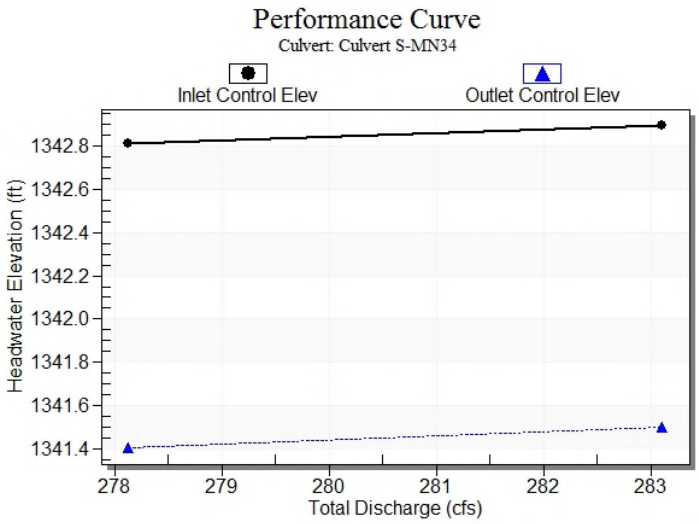
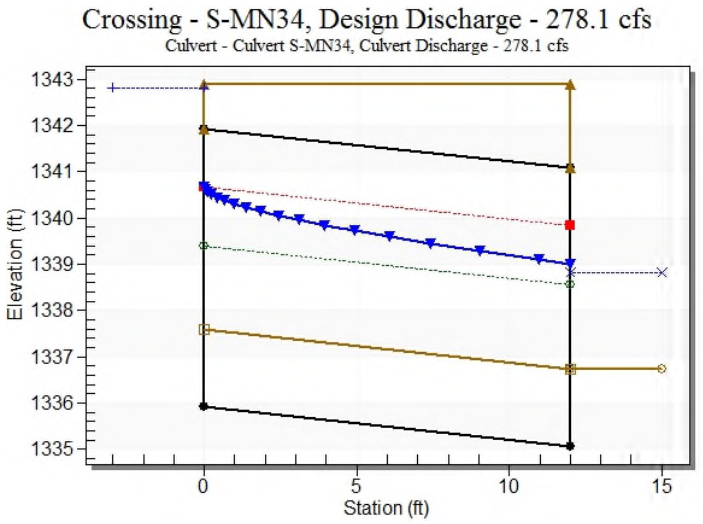
Culvert Performance Curve Plot: Culvert S-MN34



Water Surface Profile Plot for Culvert: Culvert S-MN34



Site Data - Culvert S-MN34

Site Data Option: Culvert Invert Data
Inlet Station: 0.00 ft
Inlet Elevation: 1335.92 ft
Outlet Station: 12.00 ft
Outlet Elevation: 1335.08 ft
Number of Barrels: 1

Culvert Data Summary - Culvert S-MN34

Barrel Shape: Concrete Box
Barrel Span: 9.00 ft
Barrel Rise: 6.00 ft
Barrel Material: Concrete
Embedment: 20.00 in
Barrel Manning's n: 0.0120 (top and sides)
Manning's n: 0.0300 (bottom)
Culvert Type: Straight
Inlet Configuration: Thin Edge Projecting
Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: S-MN34)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
278.12	1338.81	2.07	15.60	9.03	2.33
278.12	1338.81	2.07	15.60	9.03	2.33
278.12	1338.81	2.07	15.60	9.03	2.33
278.12	1338.81	2.07	15.60	9.03	2.33
278.12	1338.81	2.07	15.60	9.03	2.33
278.12	1338.81	2.07	15.60	9.03	2.33
278.12	1338.81	2.07	15.60	9.03	2.33
278.12	1338.81	2.07	15.60	9.03	2.33
278.12	1338.81	2.07	15.60	9.03	2.33
278.12	1338.81	2.07	15.60	9.03	2.33
278.12	1338.81	2.07	15.60	9.03	2.33

Tailwater Channel Data - S-MN34

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 4.50 ft

Side Slope (H:V): 2.00 (_:1)

Channel Slope: 0.0701

Channel Manning's n: 0.0300

Channel Invert Elevation: 1336.74 ft

Roadway Data for Crossing: S-MN34

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 10.00 ft

Crest Elevation: 1342.90 ft

Roadway Surface: Gravel

Roadway Top Width: 12.00 ft