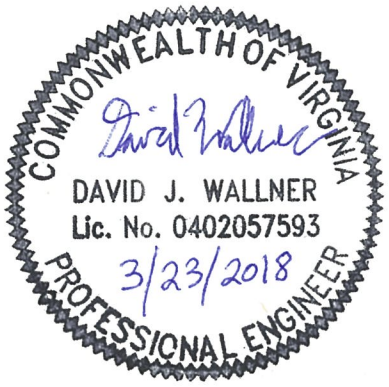
By virtue of this seal and signature, all supporting documents included in this package are accurate and support the design presented herein.



Water Bar 06 Site Specific Analysis

I. Drainage Area

As shown, the drainage area to Water Bar 06 is 1.57 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 06 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 06 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 0.1.

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 06 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	0.1852		0.447

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				339.1	0.420	10.46	0.009
CD	Waterbar	Unpaved				78.3	0.020	2.28	0.010

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) =	0.465
								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 06. For ease of construction, a water bar end treatment length of 20 feet will be used for Water Bar 06.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	28	time of concentration to water bar, min
	A =	1.57	water bar drainage area, ac
	S =	0.443	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 =	0.10	sheetflow depth over weir, ft

Computed Weir Length ------> **5.0 ft**

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

Water Bar 18 Site Specific Analysis

I. Drainage Area

As shown, the drainage area to Water Bar 18 is 2.04 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 18 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 18 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 18 is 41 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 1	0.08				50.0	0.140		0.352
BC	Sheet Flow 2	0.08				50.0	0.360		0.294

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)
CD	Downslope	Unpaved				930.6	0.345	9.48	0.027
DE	Water bar	Unpaved				31.9	0.020	2.28	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) =	0.678
								T_c (min) =	41

[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 12 foot long end treatment will ensure sheet flow conditions leaving Water Bar 18. For ease of construction, a water bar end treatment length of 20 feet will be used for Water Bar 18.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	41	time of concentration to water bar, min
	A =	2.04	water bar drainage area, ac
	S =	0.330	weir discharge overland slope, ft/ft
Computed	i =	3.2	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 ------> **12 ft**

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

Water Bar 45 Site Specific Analysis

I. Drainage Area

As shown, the drainage area to Water Bar 45 is 1.57 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 45 begins as sheet flow in a HSG B wooded area with slopes between 2-6%. Therefore, the runoff coefficient used in the sheet flow time of concentration calculation will be 0.11.

The flowpath exiting the Water Bar 45 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 45 is 27 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	0.11				100.0	0.040		0.435

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				466.5	0.220	7.57	0.017
CD	Water bar	Unpaved				42.1	0.020	2.28	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) =	0.457
								T_c (min) =	27

[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 10 foot long end treatment will ensure sheet flow conditions leaving Water Bar 45. For ease of construction, a water bar end treatment length of 20 feet will be used for Water Bar 45.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	27	time of concentration to water bar, min
	A =	1.57	water bar drainage area, ac
	S =	0.420	weir discharge overland slope, ft/ft
Computed	i =	3.4	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 ------> **9.6 ft**

Velocity Check ------> **0.87 fps**

Water Bar 46 Site Specific Analysis

I. Drainage Area

As shown, the drainage area to Water Bar 46 is 1.82 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. This plan assumes the existing Mystery Ridge Road drainage ditch will empty into Water Bar 46. Field conditioins may warrant re-sizing the water bar and end treatment length.

II. Runoff Coefficient

The flowpath for Water Bar 46 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 46 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 46 is 20 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	0.087	0.275

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	816.4	0.121	5.62	0.040
CD	Waterbar	Unpaved	82.0	0.020	2.28	0.010

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) =	0.325
T_c (min) =	20

[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 13 foot long end treatment will ensure sheet flow conditions leaving Water Bar 46. For ease of construction, a water bar end treatment length of 20 feet will be used for Water Bar 46.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	20	time of concentration to water bar, min
	A =	1.82	water bar drainage area, ac
	S =	0.220	weir discharge overland slope, ft/ft
Computed	i =	4.1	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 ------> **12.9 ft**

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

Water Bar 49 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 49 is 1.35 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 49 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 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 (T_c)

As shown, the time of concentration of Water Bar 49 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	0.21	100.0	0.250	0.161

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	795.6	0.331	9.28	0.024
CD	Waterbar	Unpaved	18.1	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) =	0.186
								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 16 foot long end treatment will ensure sheet flow conditions leaving Water Bar 49. For ease of construction, a water bar end treatment length of 20 feet will be used for Water Bar 49.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	11	time of concentration to water bar, min
	A =	1.35	water bar drainage area, ac
	S =	0.110	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 ------> **16 ft**

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

Water Bar 50 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 50 is 0.35 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 5 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 =	0.35	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 ------> **5 ft**

Velocity Check ------> **0.55 fps**

Water Bar 51 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 51 is 0.32 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 5 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 =	0.32	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 ------> **5 ft**

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

Water Bar 52 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 52 is 0.83 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 52 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 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 (T_c)

As shown, the time of concentration of Water Bar 52 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	0.21	100.0	0.290	0.156

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	619.0	0.375	9.88	0.017
CD	Waterbar	Unpaved	55.0	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) =	0.178
								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 10 foot long end treatment will ensure sheet flow conditions leaving Water Bar 52. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 52.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	11	time of concentration to water bar, min
	A =	0.83	water bar drainage area, ac
	S =	0.290	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 ------> **10 ft**

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

Water Bar 53 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 53 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 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 4 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 =	0.26	water bar drainage area, ac
	S =	0.310	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 ------> **0.74 fps**

Water Bar 54 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 54 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 54 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 54 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 54. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 54.

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 =	0.400	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 ------> **0.85 fps**

Water Bar 55 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 55 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 55 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 55 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 55. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 55.

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 =	0.444	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 ------> **0.89 fps**

Water Bar 56 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 56 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 56 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 56 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 56. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 56.

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 =	0.443	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 ------> **0.89 fps**

Water Bar 57 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 57 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 57 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 57 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 57. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 57.

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 =	0.417	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 ------> **3 ft**

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

Water Bar 58 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 58 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 58 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 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 5 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 =	0.31	water bar drainage area, ac
	S =	0.444	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 ------> **0.89 fps**

Water Bar 59 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 59 is 1.2 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 for Water Bar 59 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 59 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 59 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	0.21	100.0	0.220	0.165

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	513.0	0.370	9.82	0.015
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) =	0.182
								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 15 foot long end treatment will ensure sheet flow conditions leaving Water Bar 59. For ease of construction, a water bar end treatment length of 20 feet will be used for Water Bar 59.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	11	time of concentration to water bar, min
	A =	1.2	water bar drainage area, ac
	S =	0.400	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 ------> **15 ft**

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

Water Bar 60 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 60 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 60 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 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 3 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 =	0.16	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 ------> **3 ft**

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

Water Bar 61 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 61 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 61 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 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 1 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 =	0.06	water bar drainage area, ac
	S =	0.400	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 ------> **0.85 fps**

Water Bar 62 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 62 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 62 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 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 1 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 =	0.05	water bar drainage area, ac
	S =	0.345	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 63 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 63 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 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 1 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 =	0.05	water bar drainage area, ac
	S =	0.307	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 ------> **0.74 fps**

Water Bar 64 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 64 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 64 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 64 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 64. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 64.

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 =	0.274	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 ------> **0.70 fps**

Water Bar 65 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 65 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 65 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 65 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 65. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 65.

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 =	0.307	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 ------> **0.74 fps**

Water Bar 66 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 66 is 0.23 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 3 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 =	0.23	water bar drainage area, ac
	S =	0.126	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 ------> **0.47 fps**

Water Bar 67 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 67 is 1.2 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 for Water Bar 67 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 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 (T_c)

As shown, the time of concentration of Water Bar 67 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	0.110	0.208

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	181.0	0.188	6.99	0.007
CD	Waterbar	Unpaved	50.0	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) =	0.219
								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 14 foot long end treatment will ensure sheet flow conditions leaving Water Bar 67. For ease of construction, a water bar end treatment length of 20 feet will be used for Water Bar 67.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	13	time of concentration to water bar, min
	A =	1.2	water bar drainage area, ac
	S =	0.180	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 ------> **14 ft**

Velocity Check ------> **0.57 fps**

Water Bar 68 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 68 is 0.97 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 68 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 68 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 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	0.19	100.0	0.110	0.208

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	300.0	0.160	6.45	0.013
CD	Waterbar	Unpaved	44.0	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) =	0.224
								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 11 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 =	0.97	water bar drainage area, ac
	S =	0.160	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 ------> **11 ft**

Velocity Check ------> **0.53 fps**

Water Bar 69 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 69 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 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 1 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 =	0.05	water bar drainage area, ac
	S =	0.235	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 70 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 70 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 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 1 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 =	0.08	water bar drainage area, ac
	S =	0.304	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 ------> **0.74 fps**

Water Bar 71 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 71 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 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 1 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 =	0.09	water bar drainage area, ac
	S =	0.296	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 ------> **0.73 fps**

Water Bar 72 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 72 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 72 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 72 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 72. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 72.

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 =	0.215	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 ------> **0.62 fps**

Water Bar 73 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 73 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 73 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 73 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 73. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 73.

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 =	0.179	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 ------> **0.57 fps**

Water Bar 74 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 74 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 74 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 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 =	0.11	water bar drainage area, ac
	S =	0.252	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 75 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 75 is 0.33 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	9%	9
Turf Grass	D	80	36%	29
Wooded	D	77	55%	42
			100%	80

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 and open space(turf grass), which has a runoff coefficient of of 0.28 per Table 4-5a (type D soil; 6+% slopes). 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	D	0.9	9%	0.08	
Turf Grass	D	0.28	36%	0.10	
Wooded	D	0.21	55%	0.12	
			100%	0.30	**<--- 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 6 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 =	0.33	water bar drainage area, ac
	S =	0.267	weir discharge overland slope, ft/ft
Computed	i =	6.6	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 ------> **6 ft**

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

Water Bar 76 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 76 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.

Composite Curve Number (CN) Calculator				
LAND USE	HSG	CN	AREA (%)	AreaWeighted CN
Impervious	D	98	19%	19
Turf Grass	D	80	31%	25
Wooded	D	77	50%	39
			100%	82

II. Runoff Coefficient

The drainage area for Water Bar 76 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 0.28 per Table 4-5a (type D soil; 6+% slopes). Therefore, a composite C of 0.36 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	19%	0.17	
Turf Grass	D	0.28	31%	0.09	
Wooded	D	0.21	50%	0.11	
			100%	0.36	<--- Composite C

III. Time of Concentration (T_c)

A minimum time of concentration of 5 minutes was assumed for Water Bar 76 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 76. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 76.

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 =	0.311	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.36	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 ------> **4 ft**

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

Water Bar 77 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 77 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 77 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 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 1 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 =	0.07	water bar drainage area, ac
	S =	0.316	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 ------> **0.75 fps**

Water Bar 78 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 78 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 78 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 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 =	0.05	water bar drainage area, ac
	S =	0.279	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 ------> **0.71 fps**

Water Bar 79 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 79 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 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 1 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 =	0.05	water bar drainage area, ac
	S =	0.277	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 ------> **0.70 fps**

Water Bar 80 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 80 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 80 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 80 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 80. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 80.

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 =	0.355	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 81 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 81 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 81 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 81 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 81. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 81.

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 =	0.302	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 82 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 82 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 82 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 82 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 82. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 82.

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 =	0.378	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 ------> **0.82 fps**

Water Bar 83 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 83 is 0.49 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 83 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 83 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 8 foot long end treatment will ensure sheet flow conditions leaving Water Bar 83. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 83.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.49	water bar drainage area, ac
	S =	0.352	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 ------> **8 ft**

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

Water Bar 84 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 84 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 84 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 84 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 84. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 84.

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 =	0.515	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 ------> **0.96 fps**

Water Bar 85 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 85 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 85 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 85 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 85. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 85.

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 =	0.380	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 ------> **0.82 fps**

Water Bar 86 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 86 is 0.59 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 86 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 86 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 86 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	0.21	100.0	0.280	0.157

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	731.0	0.216	7.50	0.027
CD	Waterbar	Unpaved	59.1	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) =	0.189
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 7 foot long end treatment will ensure sheet flow conditions leaving Water Bar 86. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 86.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	11	time of concentration to water bar, min
	A =	0.59	water bar drainage area, ac
	S =	0.378	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 ------> **7 ft**

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

Water Bar 87 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 87 is 0.32 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 87 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 87 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 87. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 87.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.32	water bar drainage area, ac
	S =	0.242	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 ------> **0.66 fps**

Water Bar 88 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 88 is 0.45 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 88 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 88 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 88. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 88.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.45	water bar drainage area, ac
	S =	0.232	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 ------> **0.64 fps**

Water Bar 89 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 89 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.

II. Runoff Coefficient

The flowpath for Water Bar 89 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 89 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 89 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	0.21	100.0	0.280	0.157

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	724.0	0.257	8.18	0.025
CD	Waterbar	Unpaved	43.2	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) =	0.185
								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 16 foot long end treatment will ensure sheet flow conditions leaving Water Bar 89. For ease of construction, a water bar end treatment length of 20 feet will be used for Water Bar 89.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	11	time of concentration to water bar, min
	A =	1.34	water bar drainage area, ac
	S =	0.284	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 ------> **16 ft**

Velocity Check ------> **0.71 fps**

Water Bar 90 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 90 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 90 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 90 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 90. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 90.

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 =	0.250	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 ------> **4 ft**

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

Water Bar 91 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 91 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 91 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 91 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 91. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 91.

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 92 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 92 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 92 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 92 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 92. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 92.

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 =	0.491	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 ------> **0.94 fps**

Water Bar 93 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 93 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 93 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 93 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 93. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 93.

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 =	0.490	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 ------> **0.94 fps**

Water Bar 94 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 94 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 94 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 94 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 94. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 94.

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 =	0.364	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 ------> **1 ft**

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

Water Bar 95 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 95 is 0.64 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 95 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 95 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 95 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	0.110	0.179

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	336.0	0.387	10.04	0.009
CD	Waterbar	Unpaved	3.5	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) =	0.189
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 8 foot long end treatment will ensure sheet flow conditions leaving Water Bar 95. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 95.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	11	time of concentration to water bar, min
	A =	0.64	water bar drainage area, ac
	S =	0.500	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 ------> **8 ft**

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

Water Bar 96 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 96 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 96 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 96 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 96. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 96.

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 =	0.476	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 ------> **2 ft**

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

Water Bar 97 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 97 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 97 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 97 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 97. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 97.

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 =	0.299	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 ------> **1 ft**

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

Water Bar 98 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 98 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 98 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 98 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 98. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 98.

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 =	0.370	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 99 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 99 is 0.47 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	10%	10
Meadow	C	71	90%	64
Wooded	C	70	0%	0
			100%	74

II. Runoff Coefficient

The drainage area for Water Bar 99 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	10%	0.09	
Meadow	C	0.22	90%	0.20	
Wooded	C	0.17	0%	0.00	
			100%	0.29	**<--- Composite C**

III. Time of Concentration (T_c)

A minimum time of concentration of 5 minutes was assumed for Water Bar 99 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 8 foot long end treatment will ensure sheet flow conditions leaving Water Bar 99. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 99.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.47	water bar drainage area, ac
	S =	0.391	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 ------> **8 ft**

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

Water Bar 104 Site Specific Analysis

I. Drainage Area

As shown, the drainage area to Water Bar 104 is 1.6 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.

Composite Curve Number (CN) Calculator				
LAND USE	**HSG**	**CN**	**AREA (%)**	**AreaWeighted CN**
Impervious	B	98	15%	15
Turf Grass	B	61	5%	3
Wooded	B	55	80%	44
			100%	62

II. Runoff Coefficient

The flowpath for Water Bar 104 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 drainage area for Water Bar 104 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 0.21 per Table 4-5a (type B soil; 6+% slopes). 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	B	0.9	15%	0.14	
Turf Grass	B	0.21	5%	0.01	
Wooded	B	0.15	80%	0.12	
			100%	0.27	**<--- Composite C**

III. Time of Concentration (T_c)

As shown, the time of concentration of Water Bar 104 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	0.103	0.266

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	904.7	0.140	6.04	0.042
CD	Waterbar	Unpaved	87.9	0.050	3.61	0.007

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) =	0.315
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 17 foot long end treatment will ensure sheet flow conditions leaving Water Bar 104. For ease of construction, a water bar end treatment length of 20 feet will be used for Water Bar 104.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	19	time of concentration to water bar, min
	A =	1.6	water bar drainage area, ac
	S =	0.144	weir discharge overland slope, ft/ft
Computed	i =	4.2	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 ------> **17 ft**

Velocity Check ------> **0.51 fps**

Water Bar 104.1 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 104.1 is 1.43 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 104.1 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 104.1 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 (T_c)

As shown, the time of concentration of Water Bar 104.1 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	0.21				100.0	0.240		0.162

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				648.0	0.373	9.85	0.018
CD	Waterbar	Unpaved				7.0	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) =	0.181
								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 18 foot long end treatment will ensure sheet flow conditions leaving Water Bar 104.1. For ease of construction, a water bar end treatment length of 20 feet will be used for Water Bar 104.1.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	11	time of concentration to water bar, min
	A =	1.43	water bar drainage area, ac
	S =	0.373	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 ------> **18 ft**

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

Water Bar 104.2 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 104.2 is 0.5 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 104.2 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 104.2 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 8 foot long end treatment will ensure sheet flow conditions leaving Water Bar 104.2. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 104.2.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.50	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 ------> **8 ft**

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

Water Bar 104.3 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 104.3 is 0.83 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 104.3 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 104.3 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 (T_c)

As shown, the time of concentration of Water Bar 104.3 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	0.21	100.0	0.180	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	408.0	0.407	10.29	0.011
CD	Waterbar	Unpaved	55.0	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) =	0.186
								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 10 foot long end treatment will ensure sheet flow conditions leaving Water Bar 104.3. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 104.3.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	11	time of concentration to water bar, min
	A =	0.83	water bar drainage area, ac
	S =	0.247	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 ------> **10 ft**

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

Water Bar 104.4 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 104.4 is 0.65 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 104.4 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 104.4 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 (T_c)

As shown, the time of concentration of Water Bar 104.4 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	0.21				100.0	0.650		0.134

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				368.0	0.391	10.09	0.010
CD	Waterbar	Unpaved				47.0	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) =	0.148
								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 104.4. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 104.4.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	9	time of concentration to water bar, min
	A =	0.65	water bar drainage area, ac
	S =	0.475	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 ------> **0.92 fps**

Water Bar 104.5 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 104.5 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 104.5 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 104.5 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 104.5. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 104.5.

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 =	0.567	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 ------> **1.01 fps**

Water Bar 105 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 105 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 105 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 105 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 105. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 105.

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 =	0.379	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 ------> **0.82 fps**

Water Bar 106 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 106 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 106 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 106 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 106. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 106.

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 =	0.346	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 107 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 107 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 107 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 107 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 107. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 107.

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 =	0.286	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 108 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 108 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 108 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 108 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 108. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 108.

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 =	0.291	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 109 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 109 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 109 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 109 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 109. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 109.

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 =	0.195	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 ------> **0.59 fps**

Water Bar 110 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 110 is 0.25 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 110 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 110 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 110. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 110.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.25	water bar drainage area, ac
	S =	0.101	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 ------> **0.43 fps**

Water Bar 111 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 111 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 111 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 111 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 111. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 111.

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 =	0.400	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 ------> **0.85 fps**

Water Bar 112 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 112 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 112 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 112 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 112. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 112.

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 =	0.377	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 ------> **1 ft**

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

Water Bar 113 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 113 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 113 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 113 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 113. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 113.

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 =	0.345	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 114 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 114 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 114 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 114 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 114. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 114.

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 =	0.339	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 ------> **0.78 fps**

Water Bar 115 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 115 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 115 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 115 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 115. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 115.

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 =	0.392	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 ------> **1 ft**

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

Water Bar 116 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 116 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 116 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 116 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 116. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 116.

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 =	0.400	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 ------> **0.85 fps**

Water Bar 117 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 117 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 117 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 117 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 117. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 117.

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 =	0.426	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 ------> **0.87 fps**

Water Bar 118 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 118 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 118 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 118 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 118. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 118.

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 =	0.301	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 ------> **0.73 fps**

Water Bar 119 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 119 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 119 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 119 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 119. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 119.

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 =	0.269	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 120 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 120 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 120 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 120 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 120. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 120.

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 =	0.217	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 ------> **1 ft**

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

Water Bar 120.1 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 120.1 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 120.1 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 120.1 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 120.1. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 120.1.

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 =	0.233	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 120.2 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 120.2 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 120.2 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 120.2 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 120.2. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 120.2.

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 =	0.187	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 ------> **0.58 fps**

Water Bar 120.3 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 120.3 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 120.3 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 120.3 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 120.3. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 120.3.

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 =	0.196	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 ------> **0.59 fps**

Water Bar 120 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 120 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 120 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 120 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 120. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 120.

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 =	0.217	weir discharge overland slope, ft/ft
Computed	i =	6.6	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 ------> **1 ft**

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

Water Bar 121 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 121 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 121 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 121 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 121. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 121.

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 =	0.273	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 ------> **0.70 fps**

Water Bar 122 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 122 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 122 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 122 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 122. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 122.

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 =	0.286	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 123 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 123 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 123 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 123 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 123. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 123.

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 =	0.244	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 124 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 124 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 124 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 124 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 124. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 124.

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 =	0.435	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 125 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 125 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 125 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 125 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 125. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 125.

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 =	0.345	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 ------> **0.79 fps**

Water Bar 126 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 126 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 126 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 126 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 126. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 126.

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 =	0.432	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 127 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 127 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 127 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 127 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 127. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 127.

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 =	0.377	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 ------> **1 ft**

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

Water Bar 128 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 128 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 128 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 128 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 128. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 128.

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 =	0.315	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 ------> **0.75 fps**

Water Bar 129 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 129 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 129 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 129 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 129. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 129.

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 =	0.456	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 ------> **0.90 fps**

Water Bar 130 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 130 is 0.25 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 130 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 130 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 130. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 130.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.25	water bar drainage area, ac
	S =	0.365	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 131 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 131 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 131 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 131 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 131. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 131.

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 =	0.341	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 ------> **0.78 fps**

Water Bar 132 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 132 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.

Composite Curve Number (CN) Calculator				
LAND USE	**HSG**	**CN**	**AREA (%)**	**AreaWeighted CN**
Impervious	D	98	3%	3
Meadow	D	78	0%	0
Wooded	D	77	97%	75
			100%	78

II. Runoff Coefficient

The drainage area for Water Bar 132 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.23 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	3%	0.03
Meadow	D	0.25	0%	0.00
Wooded	D	0.21	97%	0.20
			100%	0.23 **<--- Composite C**

III. Time of Concentration (T_c)

A minimum time of concentration of 5 minutes was assumed for Water Bar 132 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 132. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 132.

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 =	0.303	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.23	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 ------> **4 ft**

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

Water Bar 133 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 133 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	D	98	5%	5
Meadow	D	78	0%	0
Wooded	D	77	95%	73
			100%	78

II. Runoff Coefficient

The drainage area for Water Bar 133 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.24 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	0%	0.00
Wooded	D	0.21	95%	0.20
			100%	0.24 **<--- Composite C**

III. Time of Concentration (T_c)

A minimum time of concentration of 5 minutes was assumed for Water Bar 133 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 133. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 133.

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 =	0.332	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.24	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 ------> **0.77 fps**

Water Bar 134 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 134 is 0.43 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	3%	3
Meadow	D	78	0%	0
Wooded	D	77	97%	75
			100%	78

II. Runoff Coefficient

The drainage area for Water Bar 134 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.23 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	3%	0.03
Meadow	D	0.25	0%	0.00
Wooded	D	0.21	97%	0.20
			100%	0.23

<--- Composite C

III. Time of Concentration (T_c)

A minimum time of concentration of 5 minutes was assumed for Water Bar 134 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 134. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 134.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.43	water bar drainage area, ac
	S =	0.388	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.23	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 ------> **0.83 fps**

Water Bar 135 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 135 is 0.32 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	3%	3
Meadow	D	78	0%	0
Wooded	D	77	97%	75
			100%	78

II. Runoff Coefficient

The drainage area for Water Bar 135 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.23 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	3%	0.03	
Meadow	D	0.25	0%	0.00	
Wooded	D	0.21	97%	0.20	
			100%	0.23	**<--- Composite C**

III. Time of Concentration (T_c)

A minimum time of concentration of 5 minutes was assumed for Water Bar 135 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 135. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 135.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.32	water bar drainage area, ac
	S =	0.421	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.23	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 ------> **4 ft**

Velocity Check ------> **0.87 fps**

Water Bar 136 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 136 is 0.45 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	0%	0
Wooded	D	77	95%	73
			100%	78

II. Runoff Coefficient

The drainage area for Water Bar 136 includes impervious cover, which has a runoff coefficient (C) of 0.90 per Table 4-5a. Therefore, a composite C of 0.24 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	0%	0.00
Wooded	D	0.21	95%	0.20
			100%	0.24 **<--- Composite C**

III. Time of Concentration (T_c)

A minimum time of concentration of 5 minutes was assumed for Water Bar 136 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 136. For ease of construction, a water bar end treatment length of 10 feet will be used for Water Bar 136.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	5	time of concentration to water bar, min
	A =	0.45	water bar drainage area, ac
	S =	0.437	weir discharge overland slope, ft/ft
Computed	i =	6.6	computed from IDF, in/hr
Enter Flow Parameters	C =	0.24	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 ------> **0.88 fps**

Water Bar 137 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 137 is 0.58 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 137 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 137 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 137 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	0.085		0.197

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				423.0	0.286	8.63	0.014
CD	Waterbar	Unpaved				53.1	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 7 foot long end treatment will ensure sheet flow conditions leaving Water Bar 137. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 137.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	13	time of concentration to water bar, min
	A =	0.58	water bar drainage area, ac
	S =	0.377	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 ------> **7 ft**

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

Water Bar 138 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 138 is 0.54 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 138 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 138 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 138 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	0.098		0.192

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				440.0	0.231	7.75	0.016
CD	Waterbar	Unpaved				60.2	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) =	0.213
								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 138. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 138.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	13	time of concentration to water bar, min
	A =	0.54	water bar drainage area, ac
	S =	0.339	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 ------> **0.78 fps**

Water Bar 139 Site Specific Analysis

I. Drainage Area

The drainage area to Water Bar 139 is 0.63 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 139 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 139 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 139 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	0.075	0.202

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	453.0	0.200	7.21	0.017
CD	Waterbar	Unpaved	63.2	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) =	0.224
								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 7 foot long end treatment will ensure sheet flow conditions leaving Water Bar 139. For ease of construction, a water bar end treatment length of 15 feet will be used for Water Bar 139.

End Treatment Length Calculator

Enter Site Specific Data	Tc =	13	time of concentration to water bar, min
	A =	0.63	water bar drainage area, ac
	S =	0.345	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 ------> **7 ft**

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

i. New Impervious Cover: Access Roads

New impervious cover in Spread 8 includes two (2) access roads (MVP-MLV-AR-23 and MVP-MLV-AR-24). 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 TR-55 and the Giles County design storm value of 4.70 inches, per *PSS&S Section 4.2.2 Design Storms*. The drainage areas to each gap graded gravel access road were evaluated to calculate sizing and ensure stormwater management quantity requirements were satisfied. Results are shown below.

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-AR-23	0.10 / 0.11	56 / 64	4,843	0.13 / 0.22	348 / 566
MLV-AR-24	0.26 / 0.26	55 / 56	24,739	0.45 / 0.50	1,699 / 1,830

Increases in run-off volumes are further summarized below.

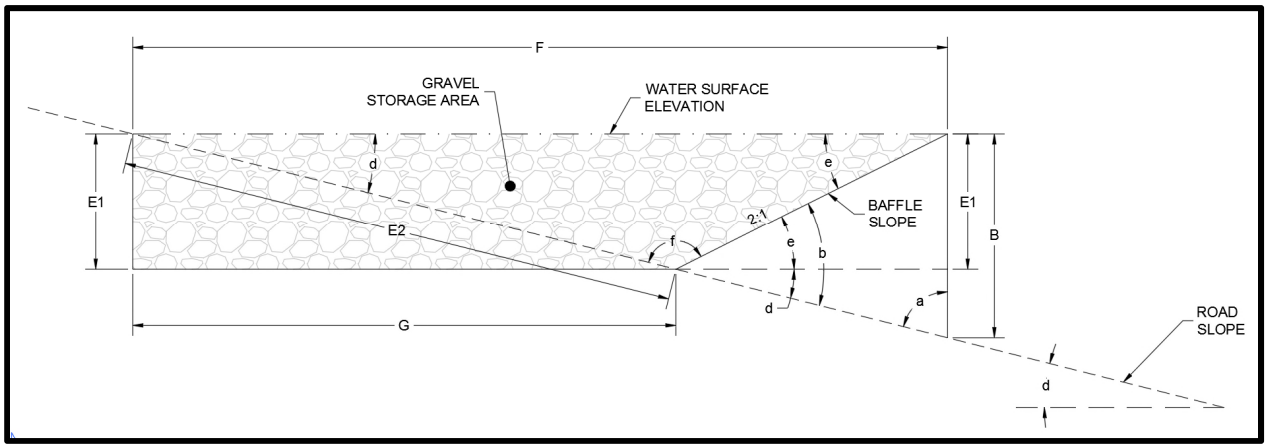
		Peak Flow (cfs)	Hydrograph Volume (ac-ft)	Hydrograph Volume (ft^3)	Required Treatment Volume (ft^3)
MVP-MLV-AR-23	Pre	0.13	0.008	348	218
	Post	0.22	0.013	566	
MVP-MLV-AR-24	Pre	0.45	0.039	1699	131
	Post	0.50	0.042	1830	

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-23	125	0.250	6	20	2
MVP-MLV-AR-24	400	0.085	3	133	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.

$$V_{available} = CSA \times W \times n$$

where $V_{available}$ = 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 MLV-AR-23 spans two different soil types with different Ksat rates.

MVP-MLV-AR-23		
MUSYM	30D	[-]
HSG	B	[-]
K_{SAT}	1.28	[IN/HR]
Max Depth	1.33	[FT]
Drawdown Time	25	[HR]
MUSYM	15D	[-]
HSG	B	[-]
K_{SAT}	1.54	[IN/HR]
Max Depth	1.33	[FT]
Drawdown Time	21	[HR]

MVP-MLV-AR-24		
MUSYM	4C	[-]
HSG	B	[-]
K_{SAT}	2.24	[IN/HR]
Max Depth	0.85	[FT]
Drawdown Time	9	[HR]

ii. New Impervious Cover: Main Line Valve Pads

New impervious cover in Spread 8 also includes two (2) main line valve sites (MVP-MLV-23 and MVP-MLV-24). 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*. Both 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. MLV-23 includes both a main pad (Pad 1) and a secondary equipment pad (Pad 2).

Pre- and post-construction runoff volumes for the 10-year 24-hour storm were calculated using TR-55 and the Giles County design storm value of 4.70 inches, 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-23 PAD 1	0.10 / 0.10	55 / 85	936	0.00 / 0.09	65 / 241
MLV-23 PAD 2	0.10 / 0.10	55 / 85	225	0.00 / 0.06	16 / 58
MLV-24 PAD	0.27 / 0.10	55 / 85	2,376	0.00 / 0.27	165 / 612

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 three 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-23 Pad 1	Vreq	176	cf
	Area	936	sf
	Dreq	0.47	ft

	Ddesign	8	in
	Vdesign	250	cf

MLV-23 Pad 2	Vreq	42	cf
	Area	225	sf
	Dreq	0.47	ft
	Ddesign	8	in
	Vdesign	60	cf

MLV-24 Pad	Vreq	447	cf
	Area	2376	sf
	Dreq	0.47	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.

MLV-23 Pad 1	Soil Name	30D	[-]
	HSG	B	[-]
	Ksat	1.28	[in/hr]
	Safety Factor	2	[-]
	Drawdown time	13	[hrs]

MLV-23 Pad 2	Soil Name	30D	[-]
	HSG	B	[-]
	Ksat	1.28	[in/hr]
	Safety Factor	2	[-]
	Drawdown time	13	[hrs]

MLV-24 Pad	Soil Name	4C	[-]
	HSG	B	[-]
	Ksat	2.24	[in/hr]
	Safety Factor	2	[-]
	Drawdown time	7	[hrs]

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.