

STANDARD E&S WORKSHEET #9

Determination of Time of Concentration (T_c)

PROJECT NAME: Northeast Supply Enhancement - Quarryville Loop
 LOCATION: Drumore Township, Lancaster County, PA
 PREPARED BY: MAG DATE: 8/18/25
 LAST REVISED BY: _____ DATE: _____

DIV-1681.0

OVERLAND FLOW:

PATH NUMBER	Length L (ft)	"n" VALUE	AVG. SLOPE (S) (ft/ft)	TIME (minutes)
A-B	100	0.3	0.09	7.21

$$T_{c(\text{sheet flow})} = \left[\frac{2.48 L^n}{49.49 S^{0.5}} \right]^{0.4673}$$

- n Type of Cover**
 0.02 smooth pavement
 0.1 bare parched soil
 0.3 poor grass cover
 0.4 average grass cover
 0.8 dense grass cover
 (L = 150' maximum)

SHALLOW CONCENTRATED FLOW:

PATH NUMBER	Length (ft)	TYPE OF COVER	AVG. SLOPE (ft/ft)	V (ft/sec)	TIME (minutes)
B-C	115	Meadow	0.07	1.90	1.01

CHANNEL FLOW:

PATH NUMBER	Length (ft)	AREA (sq. ft.)	AVG. SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME (minutes)	T _c * (minutes)
C-D	85	7.75	0.05	27	0.56	0.029	7.81	0.18	8.40

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)
C-D	0	1.5	10	1.5	19.3

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PROJECT NAME: Northeast Supply Enhancement - Quarryville Loop
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 LAST REVISED BY: _____ DATE: _____

DIV-1681.2

OVERLAND FLOW:

PATH NUMBER	Length L (ft)	"n" VALUE	AVG. SLOPE (S) (ft/ft)	TIME (minutes)
A-B	100	0.4	0.08	8.44

$$T_{c(\text{sheet flow})} = \left[\frac{2.48 L^n}{48.3 S^{0.5}} \right]^{0.4673}$$

n	Type of Cover
0.02	smooth pavement
0.1	bare parched soil
0.3	poor grass cover
0.4	average grass cover
0.8	dense grass cover
(L = 150' maximum)	

SHALLOW CONCENTRATED FLOW:

PATH NUMBER	Length (ft)	TYPE OF COVER	AVG. SLOPE (ft/ft)	V (ft/sec)	TIME (minutes)
B-C	245	Forest	0.07	0.62	6.59

CHANNEL FLOW:

PATH NUMBER	Length (ft)	AREA (sq. ft.)	AVG. SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME (minutes)	T _c * (minutes)
C-D	275	7.75	0.04	27	0.56	0.029	6.98	0.66	15.69

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)
C-D	0	1.5	10	1.5	19.3

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Determination of Time of Concentration (T_c)

PROJECT NAME: Northeast Supply Enhancement - Quarryville Loop
 LOCATION: Drumore Township, Lancaster County, PA
 PREPARED BY: MAG DATE: 9/5/25
 LAST REVISED BY: _____ DATE: _____

DIV-1686A

OVERLAND FLOW:

PATH NUMBER	Length L (ft)	"n" VALUE	AVG. SLOPE (S) (ft/ft)	TIME (minutes)
A-B	100	0.4	0.01	13.60

$$T_{c(\text{sheet flow})} = \left[\frac{2.48 L^n}{48.3 S^{0.5}} \right]^{0.4673}$$

- n Type of Cover**
- 0.02 smooth pavement
 - 0.1 bare parched soil
 - 0.3 poor grass cover
 - 0.4 average grass cover
 - 0.8 dense grass cover
- (L = 150' maximum)

SHALLOW CONCENTRATED FLOW:

PATH NUMBER	Length (ft)	TYPE OF COVER	AVG. SLOPE (ft/ft)	V (ft/sec)	TIME (minutes)
B-C	195	Meadow	0.06	1.60	2.03

CHANNEL FLOW:

PATH NUMBER	Length (ft)	AREA (sq. ft.)	AVG. SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME (minutes)	T_c^* (minutes)
C-D	810	7.75	0.01	27	0.56	0.034	3.12	4.32	19.96

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)
D-E	2	1.5	10	1.5	19.3

STANDARD E&S WORKSHEET #9

Determination of Time of Concentration (T_c)

PROJECT NAME: Northeast Supply Enhancement - Quarryville Loop
 LOCATION: Drumore Township, Lancaster County, PA
 PREPARED BY: MAG DATE: 9/5/25
 LAST REVISED BY: _____ DATE: _____

DIV-1686B

OVERLAND FLOW:

PATH NUMBER	Length L (ft)	"n" VALUE	AVG. SLOPE (S) (ft/ft)	TIME (minutes)
A-B	50	0.4	0.10	5.75

$$T_{c(\text{sheet flow})} = \left[\frac{2.48 L^n}{48.3 S^{0.5}} \right]^{0.4673}$$

- n Type of Cover**
- 0.02 smooth pavement
 - 0.1 bare parched soil
 - 0.3 poor grass cover
 - 0.4 average grass cover
 - 0.8 dense grass cover
- (L = 150' maximum)

SHALLOW CONCENTRATED FLOW:

PATH NUMBER	Length (ft)	TYPE OF COVER	AVG. SLOPE (ft/ft)	V (ft/sec)	TIME (minutes)
B-C	310	Meadow	0.10	2.25	2.30

CHANNEL FLOW:

PATH NUMBER	Length (ft)	AREA (sq. ft.)	AVG. SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME (minutes)	T_c^* (minutes)
C-D	90	7.75	0.01	27	0.56	0.034	2.98	0.50	8.55

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)
D-E	2	1.5	10	1.5	19.3

STANDARD E&S WORKSHEET #10 (Modified)
Determination of Peak Runoff (Q) Using the Rational Formula

PROJECT NAME: Northeast Supply Enhancement - Quarryville Loop
 LOCATION: Drumore Township, Lancaster County, PA
 PREPARED BY: MAG DATE: 8/18/25
 CHECKED BY: _____ DATE: _____

DETERMINE WATERSHED "C" VALUES

DRAINAGE AREA	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C x A)	C _w
DIV-1681.0	A	Forest	0.11	0.00	0.00	0.22
	B	Meadow	0.22	0.22	0.05	
	C					
	TOTAL			0.22	0.05	

DETERMINE RAINFALL INTENSITY

DRAINAGE AREA	T _c	Rainfall Depth R ₂	R ₅	R ₁₀	Rainfall Intensity I ₂	I ₅	I ₁₀
DIV-1681.0	8.40					4.9	5.4

DETERMINE PEAK FLOW RATES (Q = C x I x A)

DRAINAGE AREA	C _w	A (acres)	Q ₂ (cfs)	Q ₅ (cfs)	Q ₁₀ (cfs)
DIV-1681.0	0.22	0.22		0.24	0.26

STANDARD E&S WORKSHEET #10 (Modified)
Determination of Peak Runoff (Q) Using the Rational Formula

PROJECT NAME: Northeast Supply Enhancement - Quarryville Loop
 LOCATION: Drumore Township, Lancaster County, PA
 PREPARED BY: MAG DATE: 8/18/25
 CHECKED BY: _____ DATE: _____

DETERMINE WATERSHED "C" VALUES

DRAINAGE AREA	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C x A)	C _w
DIV-1681.2	A	Forest	0.11	0.47	0.05	0.15
	B	Meadow	0.22	0.23	0.05	
	C					
	TOTAL			0.70	0.10	

DETERMINE RAINFALL INTENSITY

DRAINAGE AREA	T _c	Rainfall Depth R ₂	R ₅	R ₁₀	Rainfall Intensity I ₂	I ₅	I ₁₀
DIV-1681.2	15.69					3.9	4.4

DETERMINE PEAK FLOW RATES (Q = C x I x A)

DRAINAGE AREA	C _w	A (acres)	Q ₂ (cfs)	Q ₅ (cfs)	Q ₁₀ (cfs)
DIV-1681.2	0.15	0.70		0.40	0.45

STANDARD E&S WORKSHEET #10 (Modified)
Determination of Peak Runoff (Q) Using the Rational Formula

PROJECT NAME: Northeast Supply Enhancement - Quarryville Loop
 LOCATION: Drumore Township, Lancaster County, PA
 PREPARED BY: MAG DATE: 9/5/25
 CHECKED BY: _____ DATE: _____

DETERMINE WATERSHED "C" VALUES

DRAINAGE AREA	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C x A)	C _w
DIV-1686A	A	Meadow	0.30	8.26	2.48	0.30
	B					
	C					
	TOTAL			8.26	2.48	

DETERMINE RAINFALL INTENSITY

DRAINAGE AREA	T _c	Rainfall Depth R ₂	R ₅	R ₁₀	Rainfall Intensity I ₂	I ₅	I ₁₀
DIV-1686A	19.96					3.5	4.0

DETERMINE PEAK FLOW RATES (Q = C x I x A)

DRAINAGE AREA	C _w	A (acres)	Q ₂ (cfs)	Q ₅ (cfs)	Q ₁₀ (cfs)
DIV-1686A	0.30	8.26		8.58	9.80

STANDARD E&S WORKSHEET #10 (Modified)
Determination of Peak Runoff (Q) Using the Rational Formula

PROJECT NAME: Northeast Supply Enhancement - Quarryville Loop
 LOCATION: Drumore Township, Lancaster County, PA
 PREPARED BY: MAG DATE: 9/5/25
 CHECKED BY: _____ DATE: _____

DETERMINE WATERSHED "C" VALUES

DRAINAGE AREA	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C x A)	C _w
DIV-1686B	A	Meadow	0.30	1.97	0.59	0.30
	B					
	C					
	TOTAL			1.97	0.59	

DETERMINE RAINFALL INTENSITY

DRAINAGE AREA	T _c	Rainfall Depth R ₂	R ₅	R ₁₀	Rainfall Intensity I ₂	I ₅	I ₁₀
DIV-1686B	8.55					4.9	5.4

DETERMINE PEAK FLOW RATES (Q = C x I x A)

DRAINAGE AREA	C _w	A (acres)	Q ₂ (cfs)	Q ₅ (cfs)	Q ₁₀ (cfs)
DIV-1686B	0.30	1.97		2.90	3.19

STANDARD E&S WORKSHEET #11

Channel Design Data

PROJECT NAME:	Northeast Supply Enhancement - Quarryville Loop		
LOCATION:	Lancaster County, PA		
PREPARED BY:	CRB	DATE:	2/21/2018
CHECKED BY:	PPH	DATE:	2/21/2018

CHANNEL OR CHANNEL SECTION	DIV 1681.0	DIV 1681.2
TEMPORARY OR PERMANENT (T OR P)	T	T
DESIGN STORM (2, 5, 10 OR 25 YR)	5	5
ACRES (AC)	0.22	0.70
MULTIPLIER (1.6, 2.25. or 2.75) ¹	N/A	N/A
Q _r (REQUIRED CAPACITY) (CFS)	0.24	0.26
Q (CALCULATED AT FLOW DEPTH d) (CFS)	0.24	0.26
PROTECTIVE LINING ²	P300	P300
n (MANNING'S COEFFICIENT) ²	0.034	0.034
V _a (ALLOWABLE VELOCITY) (FPS)	9.0	9.0
V (CALCULATED AT FLOW DEPTH d) (FPS)	1.5	1.5
τ _a (MAX ALLOWABLE SHEAR STRESS) (LB/FT ²)	3.0	3.0
τ _d (CALC'D SHEAR STRESS AT FLOW DEPTH d) (LB/FT ²)	N/A	N/A
CHANNEL BOTTOM WIDTH (FT)	2.0	2.0
Z ₁ - CHANNEL SIDE SLOPES (H:V)	1.5	1.5
Z ₂ - CHANNEL SIDE SLOPES (H:V)	10	3
D (TOTAL DEPTH) (FT)	1.5	1.5
CHANNEL TOP WIDTH @ D (FT)	19.3	8.8
d (CALCULATED FLOW DEPTH) (FT)	0.07	0.08
CHANNEL TOP WIDTH @ FLOW DEPTH d (FT)	2.8	2.4
BOTTOM WIDTH:FLOW DEPTH RATIO (12:1 MAX)	29.31	25.36
d ₅₀ STONE SIZE (IN)	N/A	N/A
A (CROSS-SECTIONAL AREA) (SQ. FT)	0.16	0.17
R - HYDRAULIC RADIUS	0.06	0.07
S (BED SLOPE) ³ (FT/FT)	0.05	0.04
S _c (CRITICAL SLOPE) (FT/FT)	0.0438	0.0411
0.7S _c (FT/FT)	0.0307	0.0288
1.3S _c (FT/FT)	0.0570	0.0535
STABLE FLOW? (Y/N)	N	N
FREEBOARD BASED ON UNSTABLE FLOW (FT)	0.01	0.01
FREEBOARD BASED ON STABLE FLOW (FT)	0.02	0.02
MINIMUM REQUIRED FREEBOARD ⁴ (FT)	0.50	0.50
PROVIDED FREEBOARD (FT)	1.43	1.42
DESIGN METHOD FOR PROTECTIVE LINING ⁵	V	V
PERMISSABLE VELOCITY(V) OR SHEAR STRESS (S)		

1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in separate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft or 1/4 Total Channel Depth, whichever is greater.
5. Permissible velocity lining design method is not acceptable for channels with a bed slope of 10% or greater. Shear stress lining design method is required for channels with a bed slope of 10% or greater. Shear stress lining design method may be used for any channel bed slope.

STANDARD E&S WORKSHEET #11

Channel Design Data

PROJECT NAME: Northeast Supply Enhancement - Quarryville Loop
 LOCATION: Lancaster County, PA
 PREPARED BY: MAG DATE: 9/4/2025
 REVISED BY: _____ DATE: _____

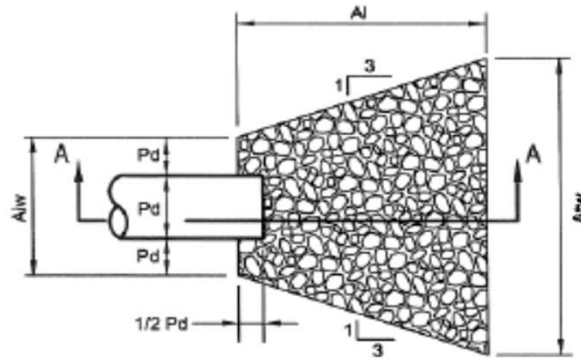
CHANNEL OR CHANNEL SECTION	DIV 1686A	DIV 1686B
TEMPORARY OR PERMANENT (T OR P)	T	T
DESIGN STORM (2, 5, 10 OR 25 YR)	5	5
ACRES (AC)	8.26	1.97
MULTIPLIER (1.6, 2.25. or 2.75) ¹	N/A	N/A
Q _r (REQUIRED CAPACITY) (CFS)	8.58	2.90
Q (CALCULATED AT FLOW DEPTH d) (CFS)	8.58	2.90
PROTECTIVE LINING ²	P300	P300
n (MANNING'S COEFFICIENT) ²	0.032	0.034
V _a (ALLOWABLE VELOCITY) (FPS)	9.0	9.0
V (CALCULATED AT FLOW DEPTH d) (FPS)	2.2	1.8
τ _a (MAX ALLOWABLE SHEAR STRESS) (LB/FT ²)	3.0	3.0
τ _d (CALC'D SHEAR STRESS AT FLOW DEPTH d) (LB/FT ²)	N/A	N/A
CHANNEL BOTTOM WIDTH (FT)	0.0	0.0
Z ₁ - CHANNEL SIDE SLOPES (H:V)	1.5	1.5
Z ₂ - CHANNEL SIDE SLOPES (H:V)	15	10
D (TOTAL DEPTH) (FT)	1.5	1.5
CHANNEL TOP WIDTH @ D (FT)	24.8	17.3
d (CALCULATED FLOW DEPTH) (FT)	0.68	0.53
CHANNEL TOP WIDTH @ FLOW DEPTH d (FT)	11.3	6.1
BOTTOM WIDTH:FLOW DEPTH RATIO (12:1 MAX)	0.00	0.00
d ₅₀ STONE SIZE (IN)	N/A	N/A
A (CROSS-SECTIONAL AREA) (SQ. FT)	3.86	1.62
R - HYDRAULIC RADIUS	0.33	0.26
S (BED SLOPE) ³ (FT/FT)	0.01	0.01
S _c (CRITICAL SLOPE) (FT/FT)	0.0223	0.0268
0.7S _c (FT/FT)	0.0156	0.0188
1.3S _c (FT/FT)	0.0290	0.0348
STABLE FLOW? (Y/N)	Y	Y
FREEBOARD BASED ON UNSTABLE FLOW (FT)	0.11	0.07
FREEBOARD BASED ON STABLE FLOW (FT)	0.17	0.13
MINIMUM REQUIRED FREEBOARD ⁴ (FT)	0.50	0.50
PROVIDED FREEBOARD (FT)	0.82	0.97
DESIGN METHOD FOR PROTECTIVE LINING ⁵	V	V
PERMISSABLE VELOCITY(V) OR SHEAR STRESS (S)		

1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in separate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft or 1/4 Total Channel Depth, whichever is greater.
5. Permissible velocity lining design method is not acceptable for channels with a bed slope of 10% or greater. Shear stress lining design method is required for channels with a bed slope of 10% or greater. Shear stress lining design method may be used for any channel bed slope.

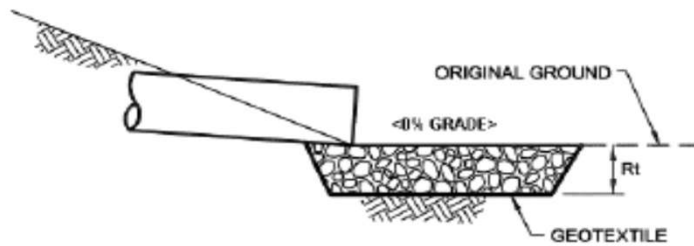
STANDARD E&S WORKSHEET #20

Riprap Apron Outlet Protection

PROJECT NAME: Northeast Supply Enhancement - Quarryville Loop
 LOCATION: Drumore Township, Lancaster County, PA
 PREPARED BY: MAG DATE: 8/19/2025
 REVISED BY: MAG DATE: 9/5/2025



PLAN VIEW



SECTION A - A

APRON NO.	FLOW WIDTH D_0^3 (in)	TAIL WATER COND. (MAX OR MIN)	MAN. "n" FOR CHANNEL	CHANNEL SLOPE (FT/FT)	Q^2 (CFS)	v^1 (FPS)	RIPRAP SIZE	Rt (in)	L_a^4 (FT)	Aiw (FT)	Atw (FT)
A-1	15	MAX	0.012	0.034	14.93	12.2	R-6	36	33	3.8	17.0
A-2	24	MIN	0.034	0.050	0.24	1.7	R-3	9	12	6.0	18.0
A-3	24	MIN	0.034	0.040	0.40	2.2	R-3	9	12	6.0	18.0
A-4	27	MIN	0.034	0.010	8.6	2.2	R-3	9	14	6.8	20.8
A-5	24	MIN	0.034	0.010	2.9	1.8	R-3	9	12	6.0	18.0

¹ The anticipated velocity (V) should not exceed the maximum permissible shown in Table 6.6 for the proposed riprap protection.

** Velocity obtained from Module 1, Appx D.5: Culvert Design Calculations, Standard E&S Worksheet #11

² Culvert design flow converted to a theoretical "pipe flowing full" using the continuity equation ($Q = VA$) using the calculated velocity.

³ Channel/Berm flow width is 2' minimum, or calculated using pipe diameter equivalent of cross-sectional area at flow depth

⁴ Determine apron length using Figure 9.3 for minimum tailwater condition and Figure 9.4 for maximum tailwater condition