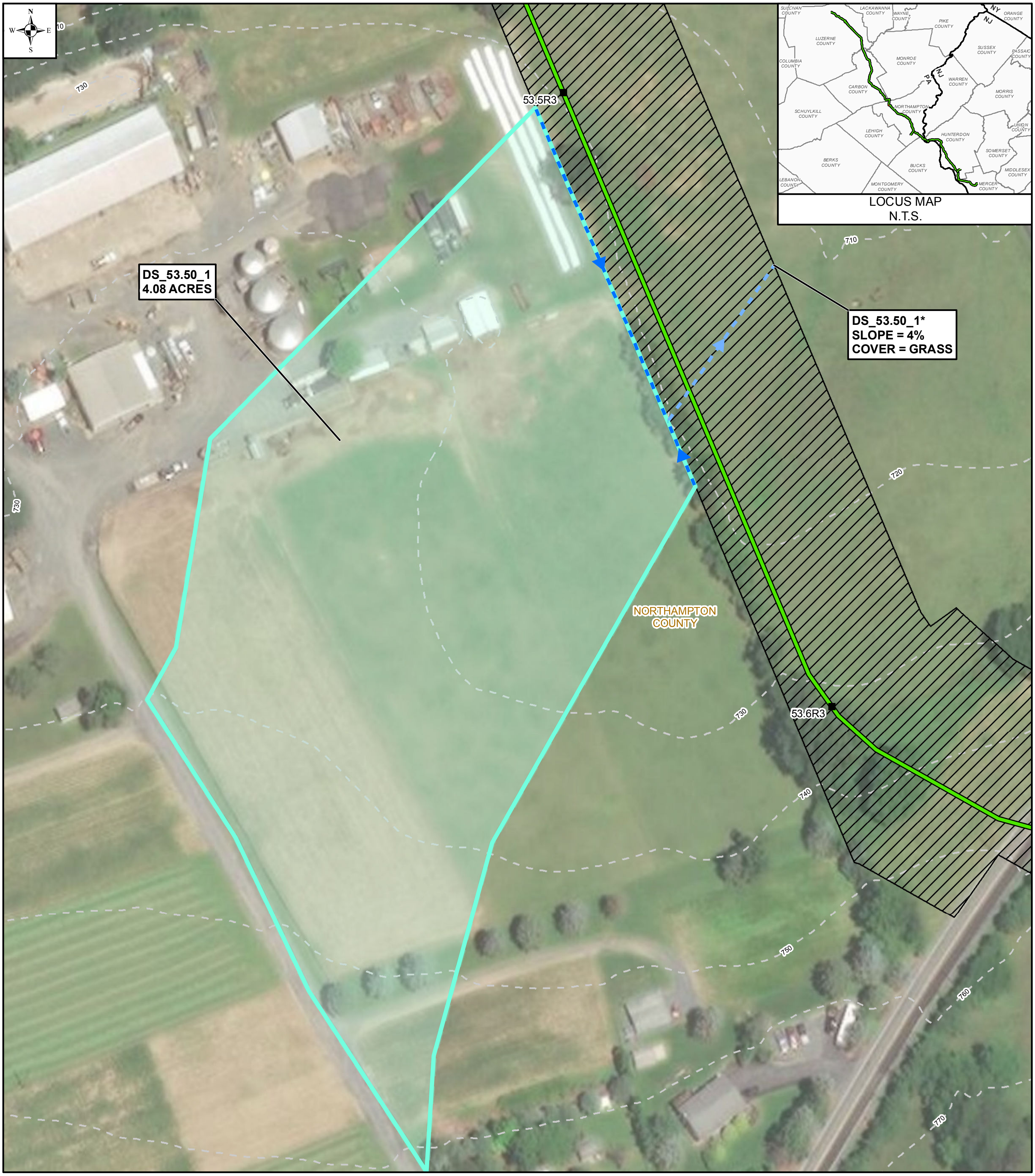
Appendix 2D

Northampton County



LEGEND

- 1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT

CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_53.50

NORTHAMPTON COUNTY, PENNSYLVANIA

0 50 100 FEET

PennEast PIPELINE

DRAWN BY:	SNP 10/2018	APPROVED BY:	MJD 10/2019	SCALE:	1 INCH = 100 FEET
CHECKED BY:	JMB 10/2019	REV. DATE:	10/2019	REV.:	1

DWG NO: PAGE 69 OF 114

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 53.50_1	100	0.4	0.070	8.63

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 53.50_1	488	SHORT GRASS	0.066	1.79	4.55

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
13.18

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 53.50_1	1	INDUSTRIAL	0.69	0.36	0.25	0.32
	2	OPEN SPACE	0.28	3.72	1.04	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	13.18	3.51	4.20	4.70	3.51	4.20	4.70

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.32	3.51	4.08	4.53	5.41	6.06

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_53.50_1		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	2		
ACRES	(AC)	4.08		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	4.53		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	7.86		
PROTECTIVE LINING[2,6]		EXISTING GRASS		
n (MANNING'S COEFFICIENT)[2]		0.07		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	1.07		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.00		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	0.44		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	14.71 / 0		
D (TOTAL DEPTH)	(FT)	1.50		
CHANNEL TOP WIDTH @ D	(FT)	22.06		
d (CALCULATED FLOW DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	14.71		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	7.35		
R (HYDRAULIC RADIUS)		0.47		
S (BED SLOPE)[3, 7]	(FT/FT)	0.007		
S_C (CRITICAL SLOPE)	(FT/FT)	0.098		
$.7S_c$	(FT/FT)	0.069		
$1.3S_c$	(FT/FT)	0.128		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

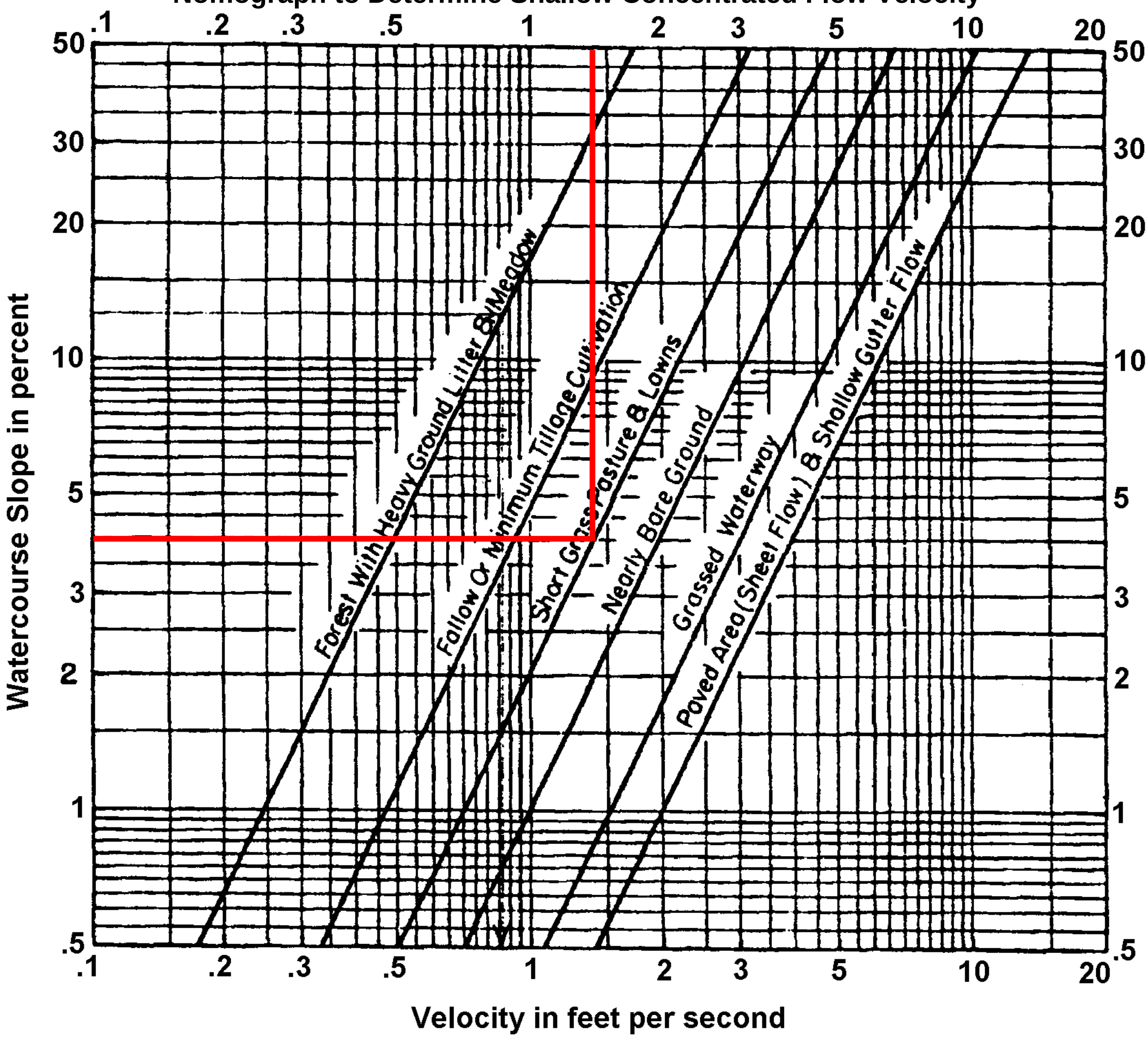
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_53.50_1

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity

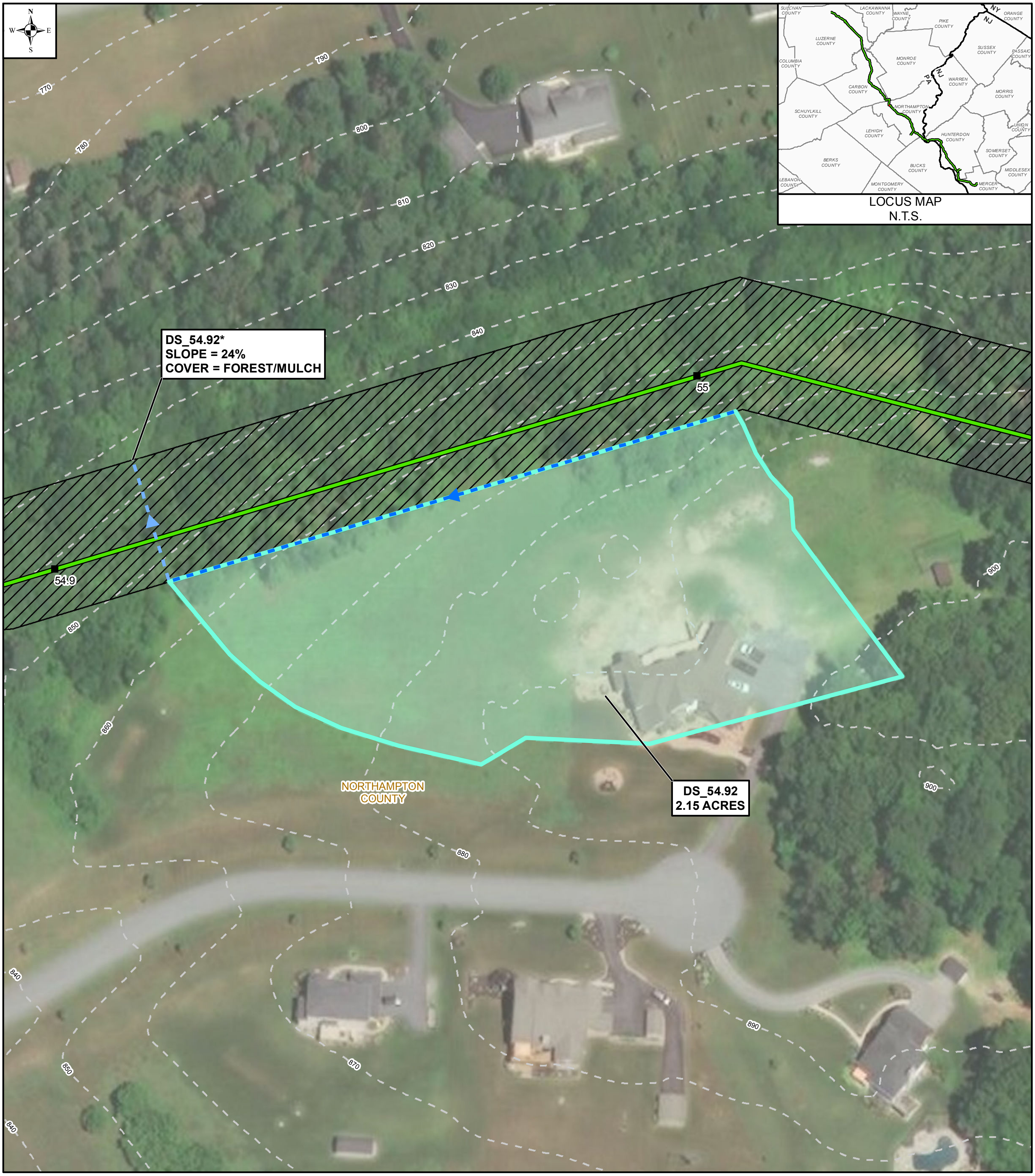


TR-55

<u>DOWNSLOPE CONDITION</u>
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 4%

SHALLOW CONCENTRATED FLOW VELOCITY = 1.4 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

1.4 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.



LEGEND

- 1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT
CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_54.92
NORTHAMPTON COUNTY, PENNSYLVANIA

0 50 100 FEET

PennEast PIPELINE

DRAWN BY:	SNP 10/2018	APPROVED BY:	MJD 10/2019	SCALE:	1 INCH = 100 FEET
CHECKED BY:	JMB 10/2019	REV. DATE:	10/2019	REV.:	1

DWG NO: PAGE 70 OF 114

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 54.92	73	0.4	0.013	11.04

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 54.92	566	SHORT GRASS	0.083	2.01	4.70

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
15.75

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 54.92	1	INDUSTRIAL	0.69	0.18	0.12	0.31
	2	OPEN SPACE	0.28	1.80	0.50	
	3	FOREST	0.20	0.17	0.03	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	15.75	3.24	3.89	4.39	3.24	3.89	4.39

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.31	3.24	2.15	2.14	2.57	2.91

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_54.92		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	2		
ACRES	(AC)	2.15		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	2.14		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	2.60		
PROTECTIVE LINING[2,6]		C125		
n (MANNING'S COEFFICIENT)[2]		0.022		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	4.96		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	2.25		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	1.47		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	4.18 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	4.18		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	2.09		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	0.52		
R (HYDRAULIC RADIUS)		0.20		
S (BED SLOPE)[3, 7]	(FT/FT)	0.047		
S_C (CRITICAL SLOPE)	(FT/FT)	0.015		
$.7S_c$	(FT/FT)	0.011		
$1.3S_c$	(FT/FT)	0.020		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

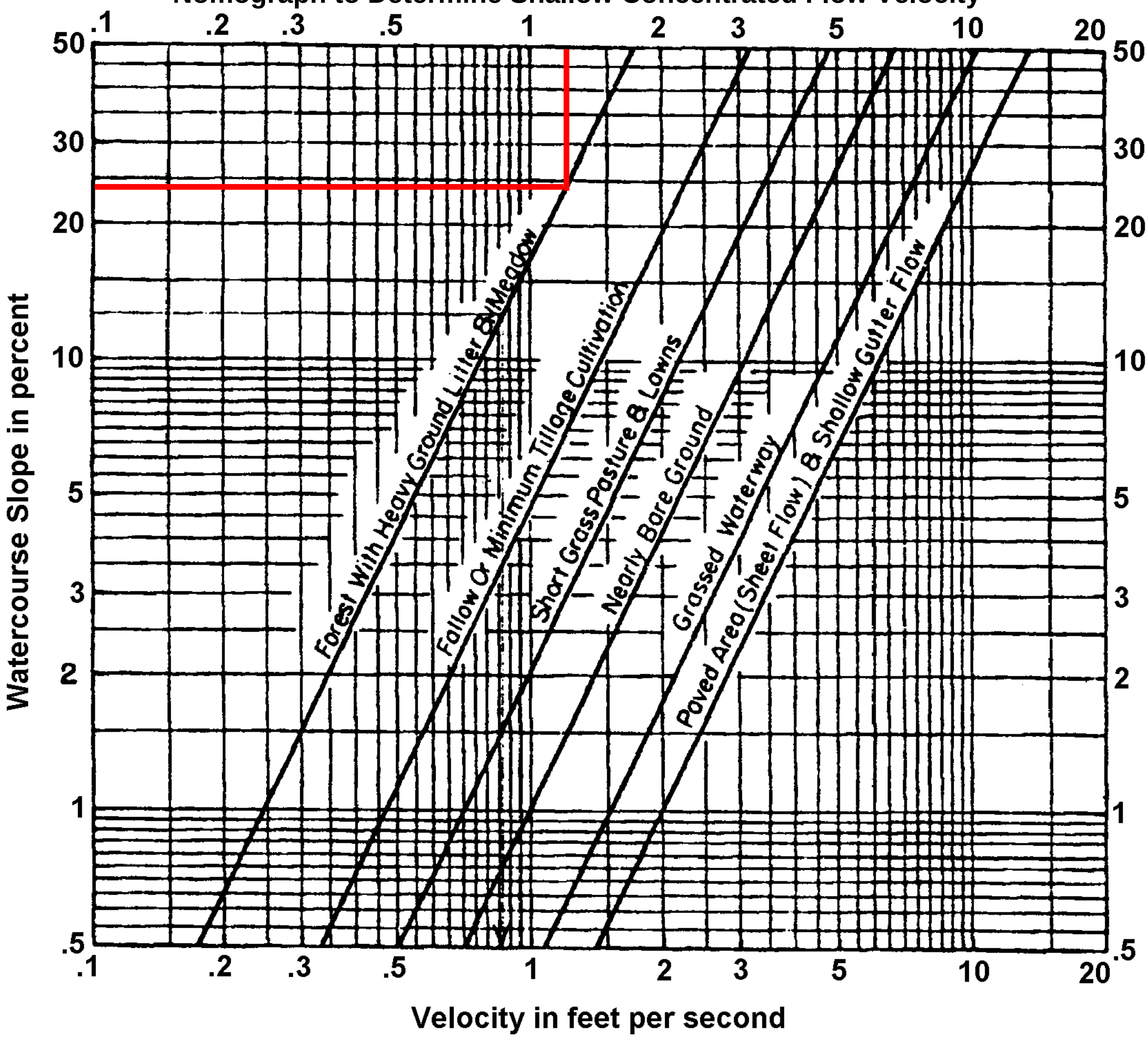
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_54.92

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity

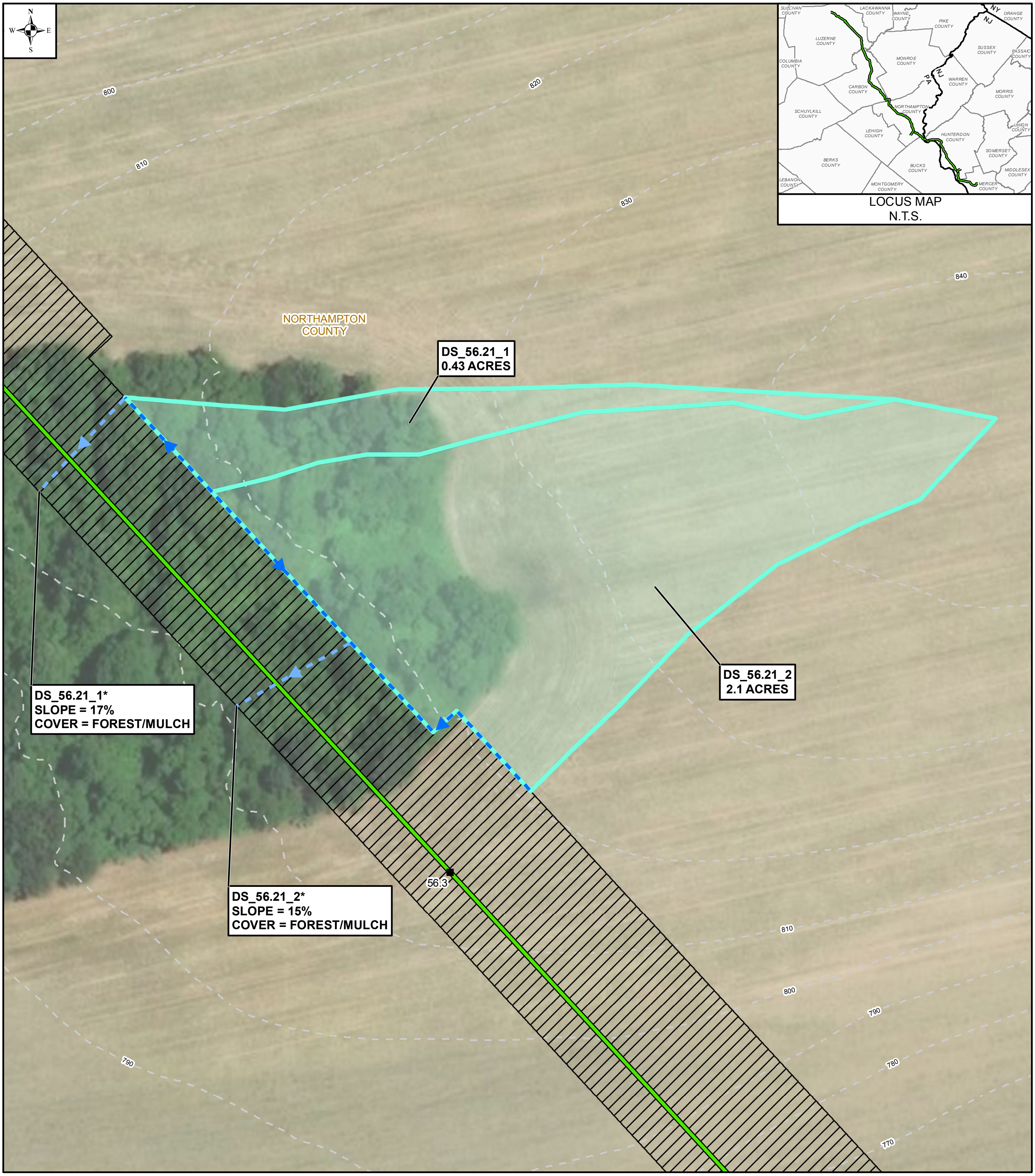


TR-55

DOWNSLOPE CONDITION
COVER TYPE = FOREST
PERCENT SLOPE = 24%

SHALLOW CONCENTRATED FLOW VELOCITY = 1.4 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 2 FPS FOR FORESTED/MULCH COVER TYPES.

1.4 FPS < 2.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.



LEGEND

- 1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT
CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_56.21
NORTHAMPTON COUNTY, PENNSYLVANIA

0 50 100 FEET

PennEast PIPELINE

DRAWN BY:	SNP 10/2018	APPROVED BY:	MJD 10/2019	SCALE:	1 INCH = 100 FEET
CHECKED BY:	JMB 10/2019	REV. DATE:	10/2019	REV.:	1

DWG NO: PAGE 71 OF 114

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_56.21_1
0.43 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 56.21_1	100	0.4	0.030	10.52

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 56.21_1	305	SHORT GRASS	0.046	1.49	3.40
	204	FOREST	0.044	0.53	6.44

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
20.37

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 56.21_1	1	PASTURE	0.50	0.17	0.09	0.29
	2	FOREST	0.16	0.26	0.04	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	20.37	2.84	3.43	3.92	2.84	3.43	3.92

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.29	2.84	0.43	0.36	0.43	0.50

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/2019
CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_56.21_1		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	2		
ACRES	(AC)	0.43		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	0.36		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	3.07		
PROTECTIVE LINING[2,6]		EXISTING GRASS		
n (MANNING'S COEFFICIENT)[2]		0.07		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	1.15		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.00		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	0.62		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	21.28 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	21.28		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	10.64		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	2.66		
R (HYDRAULIC RADIUS)		0.24		
S (BED SLOPE)[3, 7]	(FT/FT)	0.02		
S_C (CRITICAL SLOPE)	(FT/FT)	0.121		
$.7S_c$	(FT/FT)	0.084		
$1.3S_c$	(FT/FT)	0.157		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

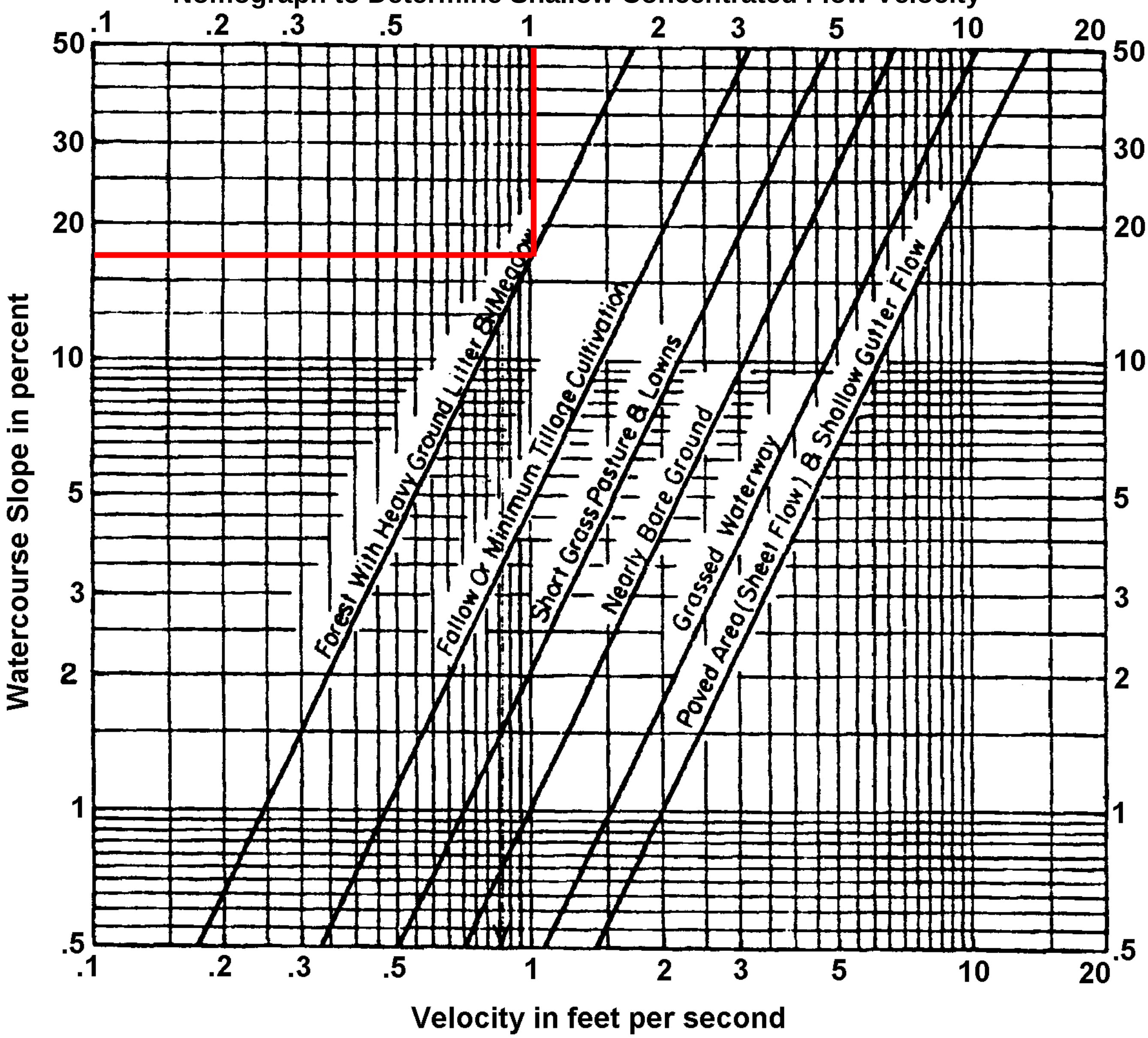
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_56.21_1

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = FOREST
PERCENT SLOPE = 17%

SHALLOW CONCENTRATED FLOW VELOCITY = 1.0 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 2 FPS FOR FORESTED/MULCH COVER TYPES.

1.0 FPS < 2.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_56.21_2
2.1 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME:	PENNEAST PIPELINE PROJECT		
LOCATION:	NORTHAMPTON COUNTY		
PREPARED BY:	MDN	DATE:	10/15/2018
CHECKED BY:	KEK / JMB	DATE:	10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 56.21_2	100	0.4	0.010	13.60

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 56.21_2	328	SHORT GRASS	0.041	1.41	3.88
	202	FOREST	0.050	0.56	5.98

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c* (minutes)
23.47

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 56.21_2	1	PASTURE	0.50	1.51	0.76	0.40
	2	FOREST	0.16	0.59	0.09	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	23.47	2.62	3.18	3.66	2.62	3.18	3.66

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.40	2.62	2.10	2.23	2.70	3.11

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_56.21_2		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	2		
ACRES	(AC)	2.1		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	2.23		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	2.27		
PROTECTIVE LINING[2,6]		S75		
n (MANNING'S COEFFICIENT)[2]		0.055		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	1.47		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.55		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	0.66		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	12.35 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	12.35		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	6.17		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.54		
R (HYDRAULIC RADIUS)		0.23		
S (BED SLOPE)[3, 7]	(FT/FT)	0.021		
S_C (CRITICAL SLOPE)	(FT/FT)	0.078		
$.7S_c$	(FT/FT)	0.055		
$1.3S_c$	(FT/FT)	0.101		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

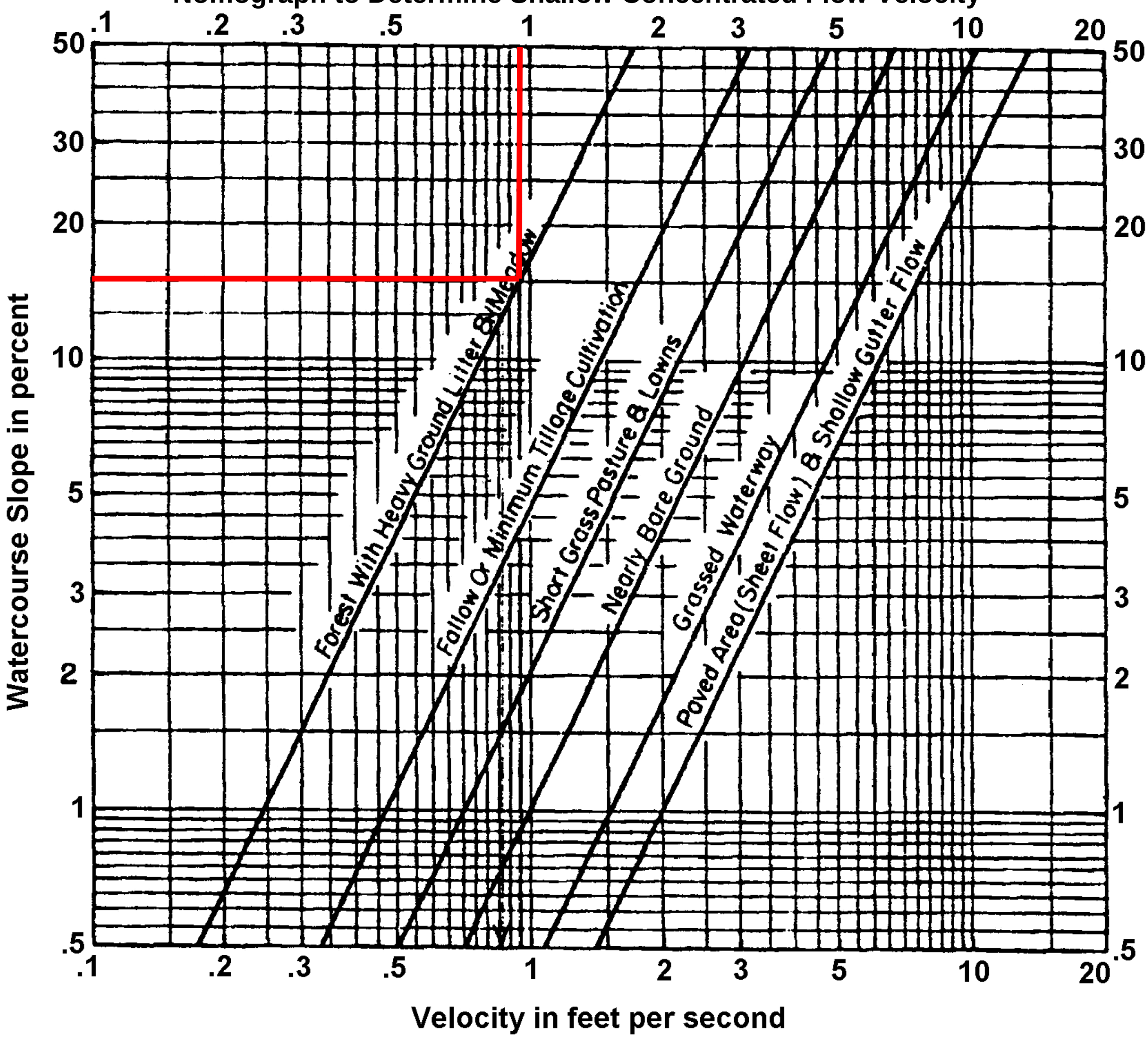
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_56.21_2

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity

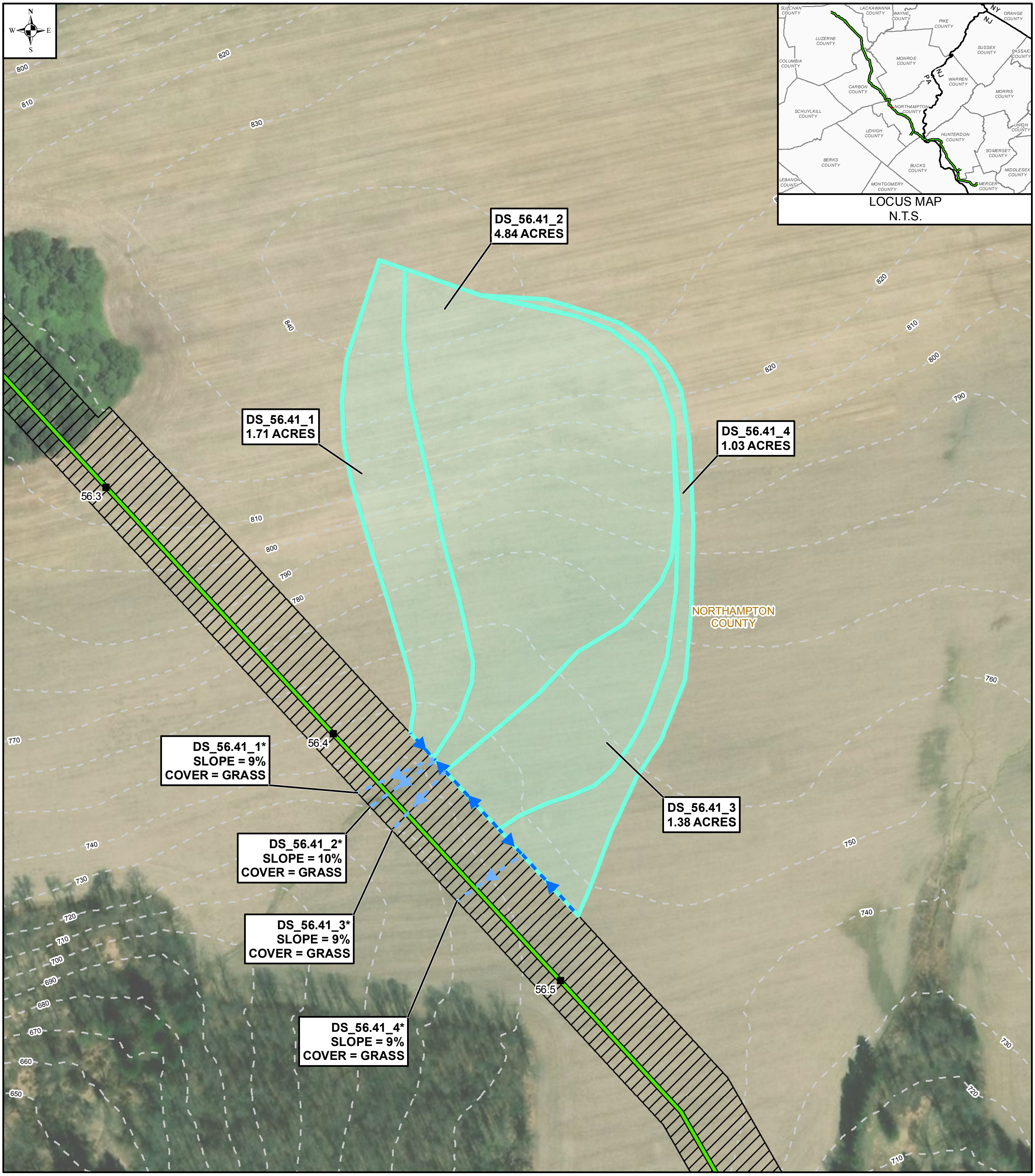


TR-55

DOWNSLOPE CONDITION
COVER TYPE = FOREST
PERCENT SLOPE = 15%

SHALLOW CONCENTRATED FLOW VELOCITY = 0.9 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 2 FPS FOR FORESTED/MULCH COVER TYPES.

0.9 FPS < 2.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.



LEGEND

- 1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT

CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_56.41

NORTHAMPTON COUNTY, PENNSYLVANIA

0 100 200 FEET

PennEast PIPELINE

DRAWN BY:	SNP 10/2018	APPROVED BY:	MJD 10/2019	SCALE:	1 INCH = 200 FEET
CHECKED BY:	JMB 10/2019	REV. DATE:	10/2019	REV.:	1

DWG NO: PAGE 72 OF 114

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_56.41_1
1.71 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 56.41_1	100	0.4	0.015	12.37

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 56.41_1	698	SHORT GRASS	0.143	2.63	4.42

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
16.79

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 56.41_1	1	PASTURE	0.50	1.71	0.86	0.50

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	16.79	3.14	3.77	4.27	3.14	3.77	4.27

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.50	3.14	1.71	2.68	3.22	3.65

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_56.41_1		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	2		
ACRES	(AC)	1.71		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	2.68		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	2.83		
PROTECTIVE LINING[2,6]		S75		
n (MANNING'S COEFFICIENT)[2]		0.055		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	1.97		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.55		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	1.19		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	11.49 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	11.49		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	5.75		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.44		
R (HYDRAULIC RADIUS)		0.23		
S (BED SLOPE)[3, 7]	(FT/FT)	0.038		
S_C (CRITICAL SLOPE)	(FT/FT)	0.079		
$.7S_c$	(FT/FT)	0.055		
$1.3S_c$	(FT/FT)	0.102		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

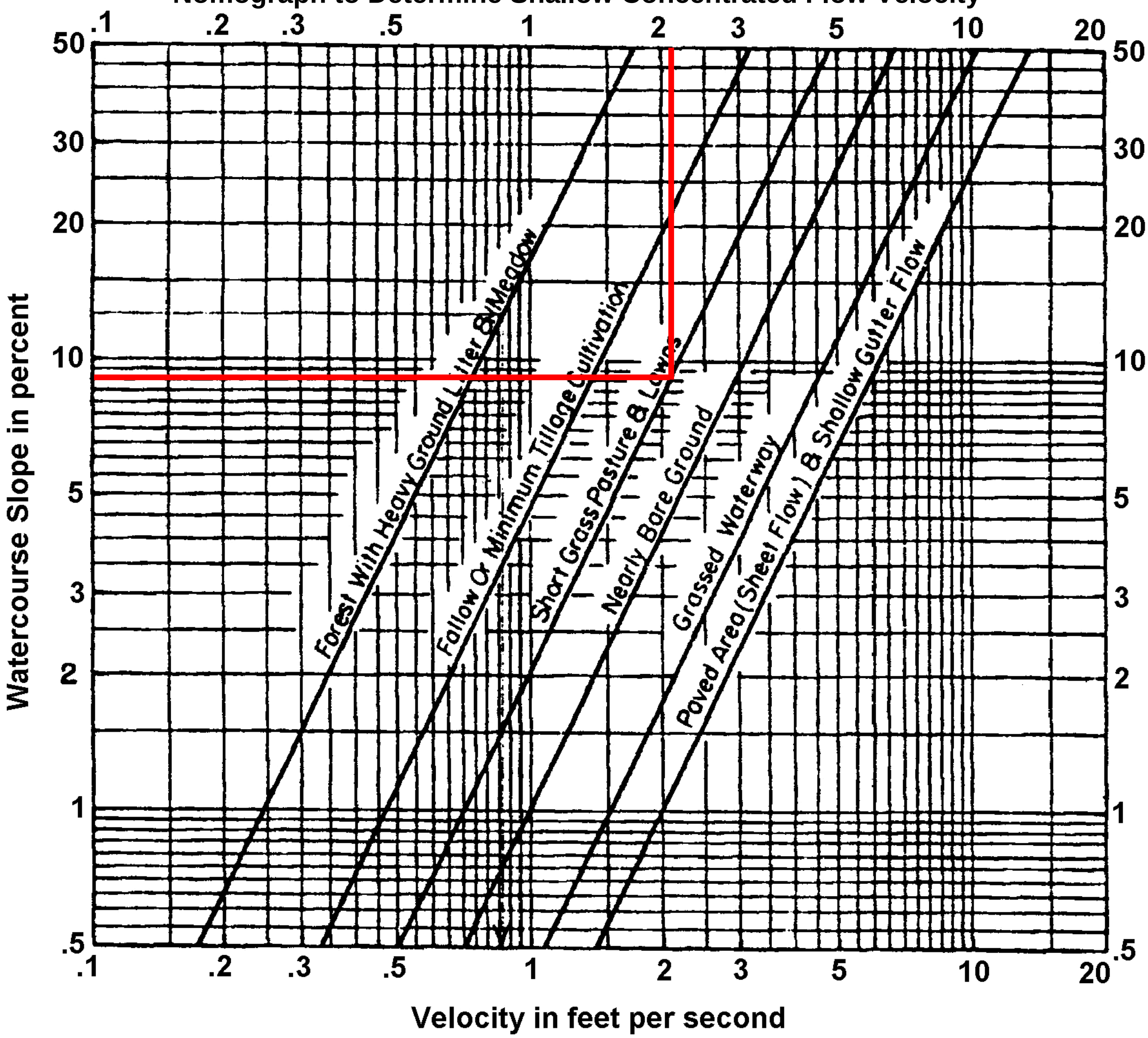
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_56.41_1

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 9%

SHALLOW CONCENTRATED FLOW VELOCITY = 2.1 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

2.1 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_56.41_2
4.84 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 56.41_2	100	0.4	0.016	12.19

$$T_{c(sheet\ flow)} = \left[\frac{2(n)}{3S^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 56.41_2	1130	SHORT GRASS	0.089	2.08	9.07

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c* (minutes)
21.26

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 56.41_2	1	PASTURE	0.50	4.84	2.42	0.50

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	21.26	2.77	3.35	3.84	2.77	3.35	3.84

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.50	2.77	4.84	6.71	8.12	9.30

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_56.41_2		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	2		
ACRES	(AC)	4.84		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	6.71		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	8.46		
PROTECTIVE LINING[2,6]		C125		
n (MANNING'S COEFFICIENT)[2]		0.022		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	5.28		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	2.25		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	1.34		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	12.82 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	12.82		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	6.41		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.60		
R (HYDRAULIC RADIUS)		0.23		
S (BED SLOPE)[3, 7]	(FT/FT)	0.043		
S_C (CRITICAL SLOPE)	(FT/FT)	0.012		
$.7S_c$	(FT/FT)	0.009		
$1.3S_c$	(FT/FT)	0.016		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

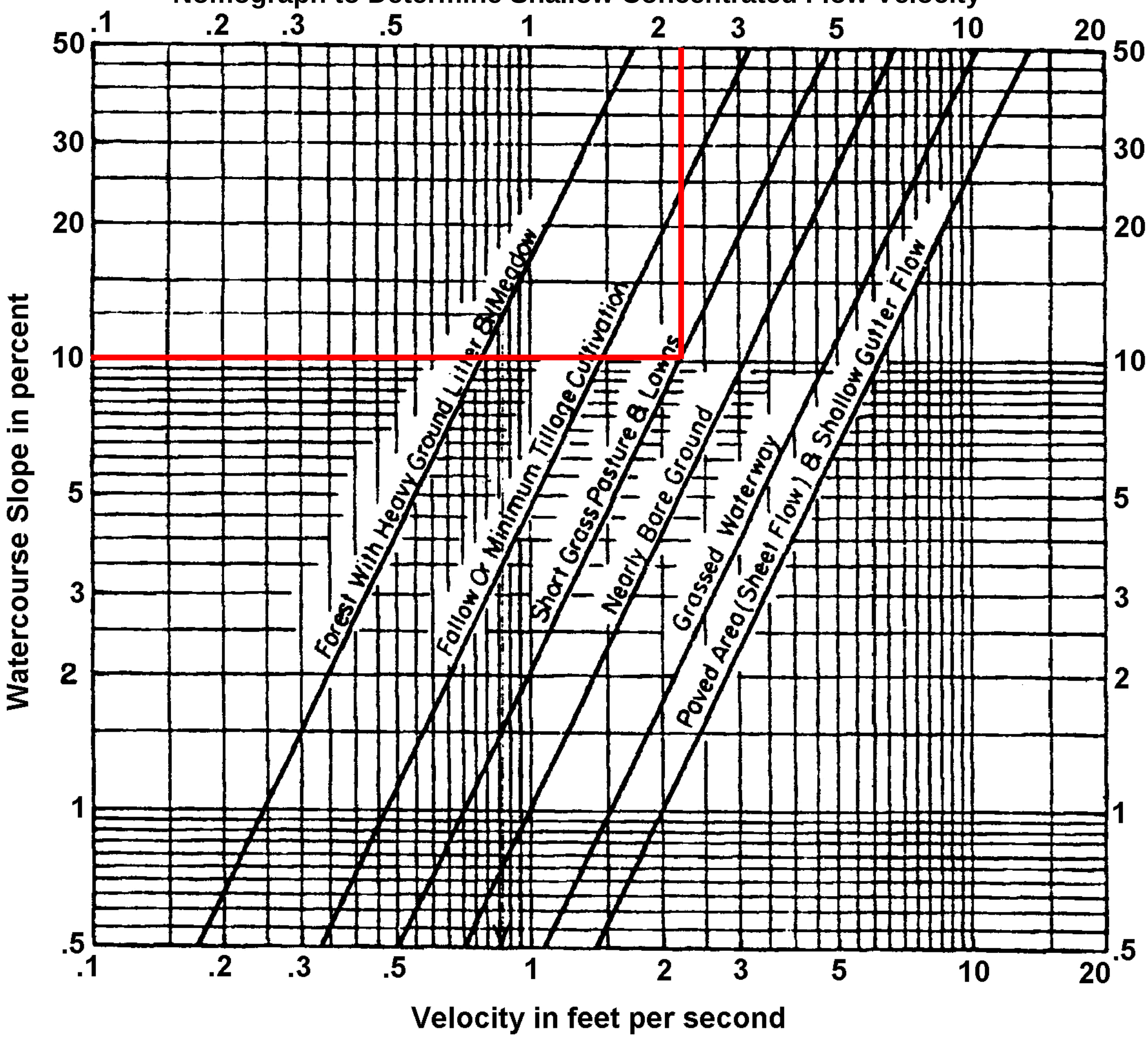
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_56.41_2

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 10%

SHALLOW CONCENTRATED FLOW VELOCITY = 2.2 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

2.2 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_56.41_3
1.38 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 56.41_3	100	0.4	0.160	7.12

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 56.41_3	680	SHORT GRASS	0.076	1.92	5.90

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
13.02

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 56.41_3	1	PASTURE	0.50	1.38	0.69	0.50

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	13.02	3.53	4.22	4.72	3.53	4.22	4.72

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.50	3.53	1.38	2.44	2.91	3.26

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_56.41_3		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	2		
ACRES	(AC)	1.38		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	2.44		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	2.60		
PROTECTIVE LINING[2,6]		S75		
n (MANNING'S COEFFICIENT)[2]		0.055		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	1.58		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.55		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	0.75		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	13.16 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	13.16		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	6.58		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.64		
R (HYDRAULIC RADIUS)		0.23		
S (BED SLOPE)[3, 7]	(FT/FT)	0.024		
S_C (CRITICAL SLOPE)	(FT/FT)	0.077		
$.7S_c$	(FT/FT)	0.054		
$1.3S_c$	(FT/FT)	0.101		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

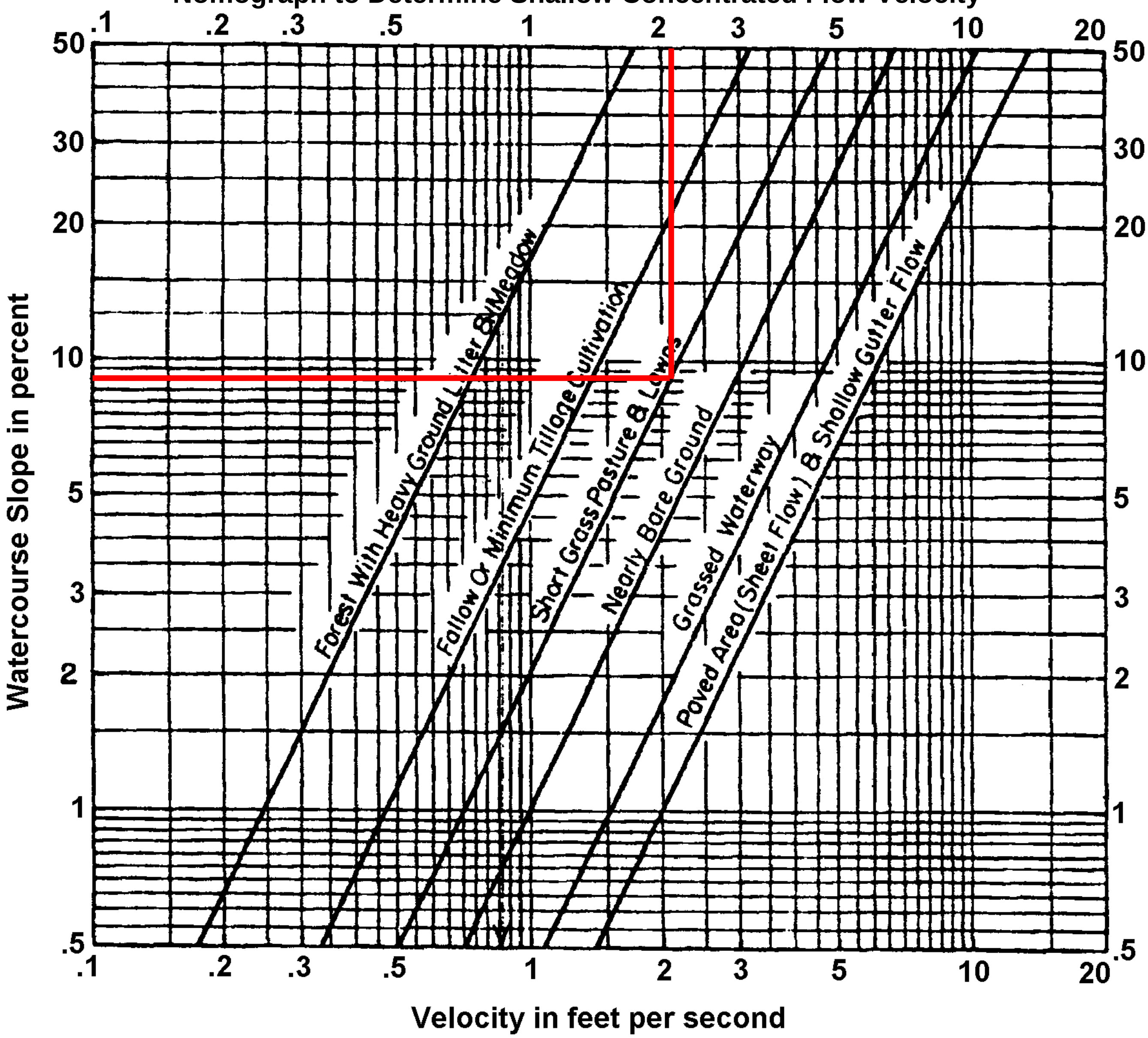
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_56.41_3

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 9%

SHALLOW CONCENTRATED FLOW VELOCITY = 2.1 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

2.1 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_56.41_4
1.03 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 56.41_4	100	0.4	0.019	11.71

$$T_{c\,(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 56.41_4	1137	SHORT GRASS	0.082	1.99	9.51

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
21.21

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 56.41_4	1	PASTURE	0.50	1.03	0.52	0.50

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	21.21	2.77	3.36	3.84	2.77	3.36	3.84

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.50	2.77	1.03	1.43	1.73	1.98

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_56.41_4		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	2		
ACRES	(AC)	1.03		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	1.43		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	1.72		
PROTECTIVE LINING[2,6]		EXISTING GRASS		
n (MANNING'S COEFFICIENT)[2]		0.07		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	1.10		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.00		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	0.59		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	12.5 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	12.50		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	6.25		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.56		
R (HYDRAULIC RADIUS)		0.23		
S (BED SLOPE)[3, 7]	(FT/FT)	0.019		
S_C (CRITICAL SLOPE)	(FT/FT)	0.126		
$.7S_c$	(FT/FT)	0.088		
$1.3S_c$	(FT/FT)	0.164		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

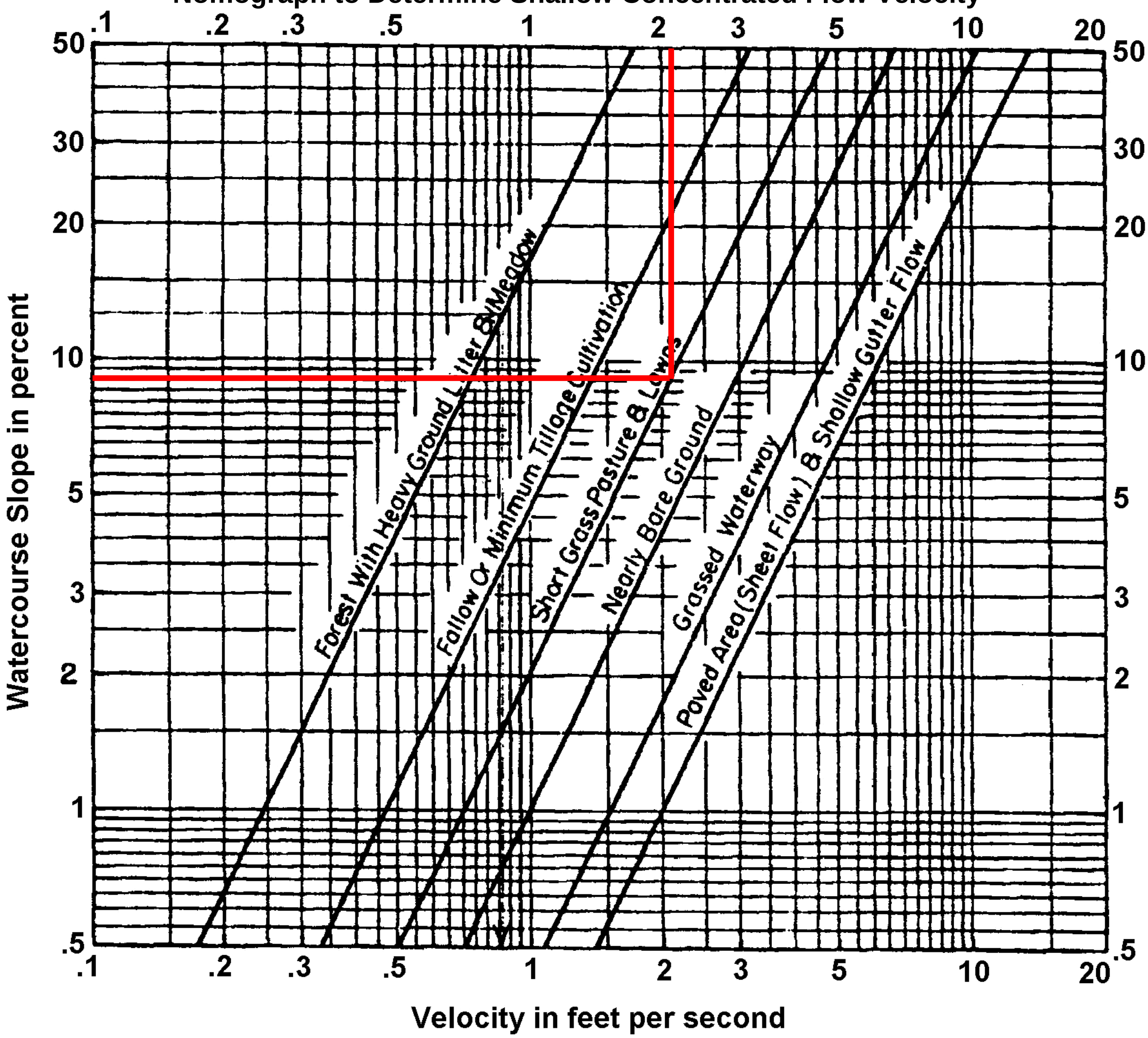
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_56.41_4

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity

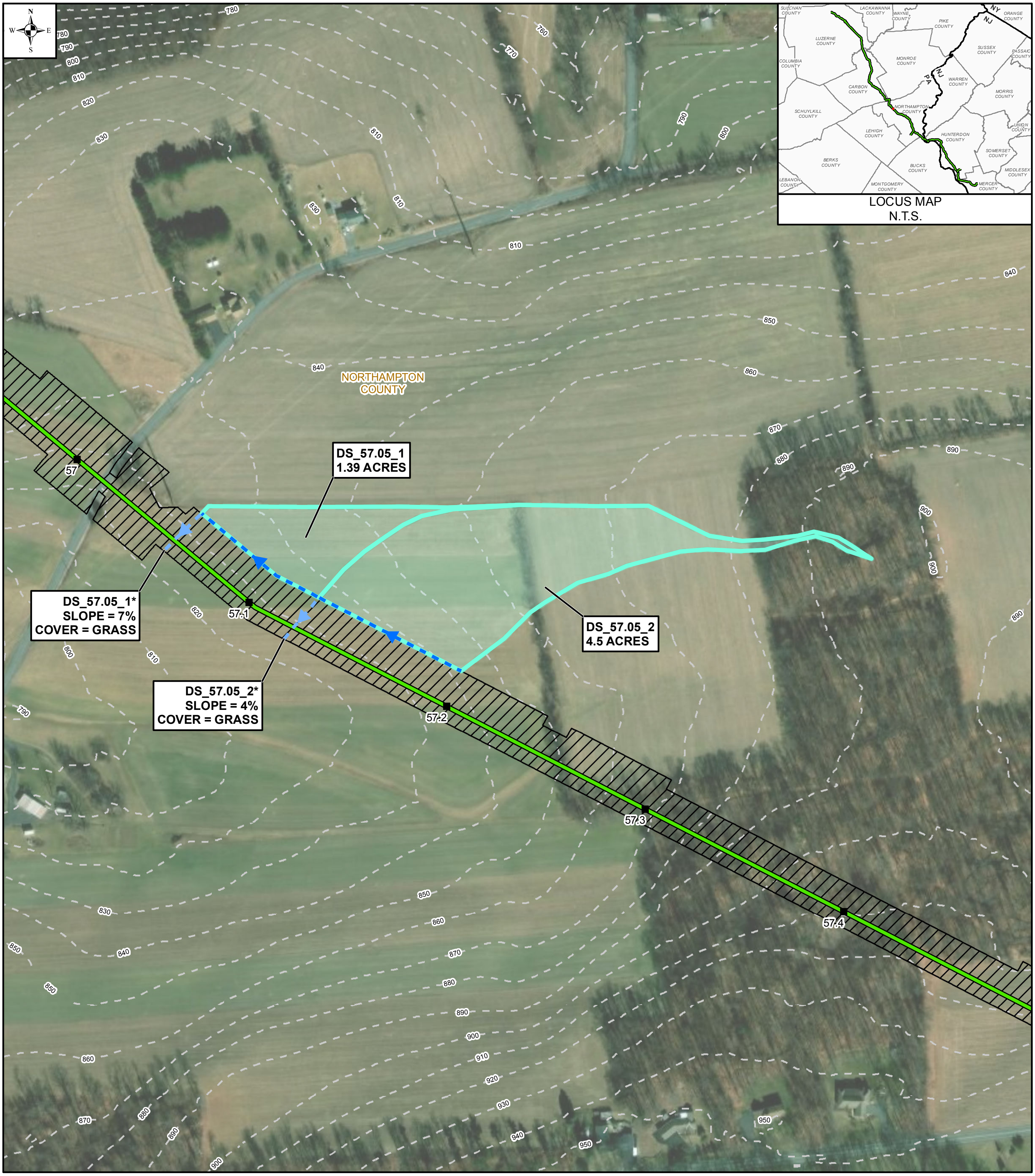


TR-55

DOWNSLOPE CONDITION
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 9%

SHALLOW CONCENTRATED FLOW VELOCITY = 2.1 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

2.1 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.



LEGEND

- 1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT
CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_57.05
NORTHAMPTON COUNTY, PENNSYLVANIA

0 150 300 FEET

PennEast PIPELINE

DRAWN BY:	SNP 10/2018	APPROVED BY:	MJD 10/2019	SCALE:	1 INCH = 300 FEET
CHECKED BY:	JMB 10/2019	REV. DATE:	10/2019	REV.:	1

DWG NO: PAGE 73 OF 114

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_57.05_1
1.39 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 57.05_1	100	0.4	0.030	10.52

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 57.05_1	657	SHORT GRASS	0.043	1.44	7.58

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
18.11

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 57.05_1	1	PASTURE	0.40	1.39	0.56	0.40

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	18.11	3.02	3.64	4.14	3.02	3.64	4.14

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.40	3.02	1.39	1.68	2.02	2.30

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_57.05_1		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	2		
ACRES	(AC)	1.39		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	1.68		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	2.10		
PROTECTIVE LINING[2,6]		S75		
n (MANNING'S COEFFICIENT)[2]		0.055		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	1.12		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.55		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	0.37		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	14.93 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	14.93		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	7.46		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.87		
R (HYDRAULIC RADIUS)		0.23		
S (BED SLOPE)[3, 7]	(FT/FT)	0.012		
S_C (CRITICAL SLOPE)	(FT/FT)	0.076		
$.7S_c$	(FT/FT)	0.054		
$1.3S_c$	(FT/FT)	0.099		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

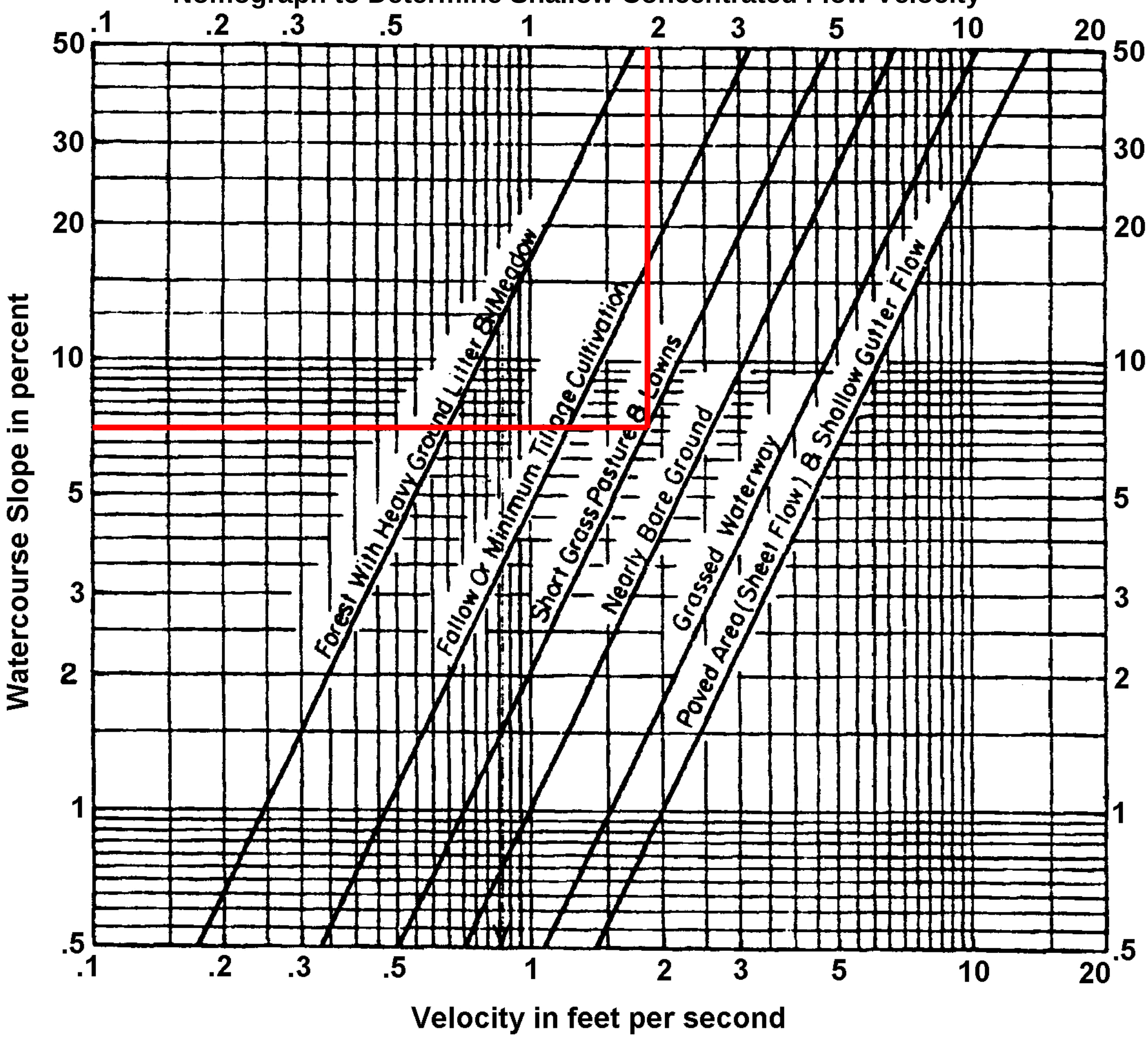
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_57.05_1

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 7%

SHALLOW CONCENTRATED FLOW VELOCITY = 1.9 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

1.9 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_57.05_2
4.5 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 57.05_2	100	0.8	0.040	13.60

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 57.05_2	183	FOREST	0.050	0.56	5.42
	1130	SHORT GRASS	0.042	1.43	13.20

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
32.22

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 57.05_2	1	PASTURE	0.40	4.29	1.72	0.39
	2	FOREST	0.16	0.21	0.03	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	32.22	2.15	2.64	3.08	2.15	2.64	3.08

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.39	2.15	4.50	3.77	4.61	5.39

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_57.05_2		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	2		
ACRES	(AC)	4.5		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	3.77		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	12.03		
PROTECTIVE LINING[2,6]		S75		
n (MANNING'S COEFFICIENT)[2]		0.0437		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	2.53		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.55		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	1.00		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	9.52 / 0		
D (TOTAL DEPTH)	(FT)	1.50		
CHANNEL TOP WIDTH @ D	(FT)	14.29		
d (CALCULATED FLOW DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	9.52		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	4.76		
R (HYDRAULIC RADIUS)		0.45		
S (BED SLOPE)[3, 7]	(FT/FT)	0.016		
S_C (CRITICAL SLOPE)	(FT/FT)	0.040		
$.7S_c$	(FT/FT)	0.028		
$1.3S_c$	(FT/FT)	0.052		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

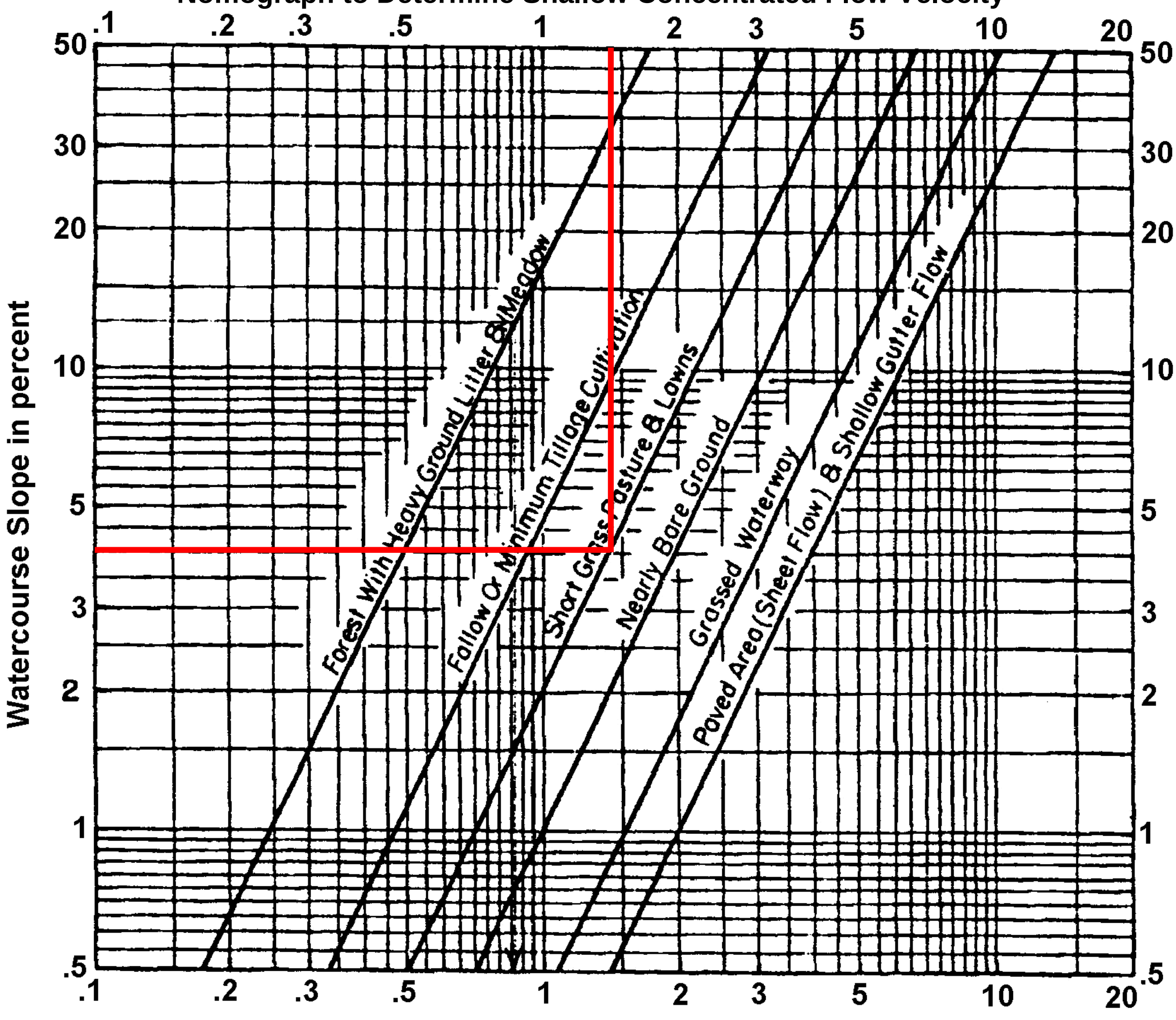
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_57.05_2

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity

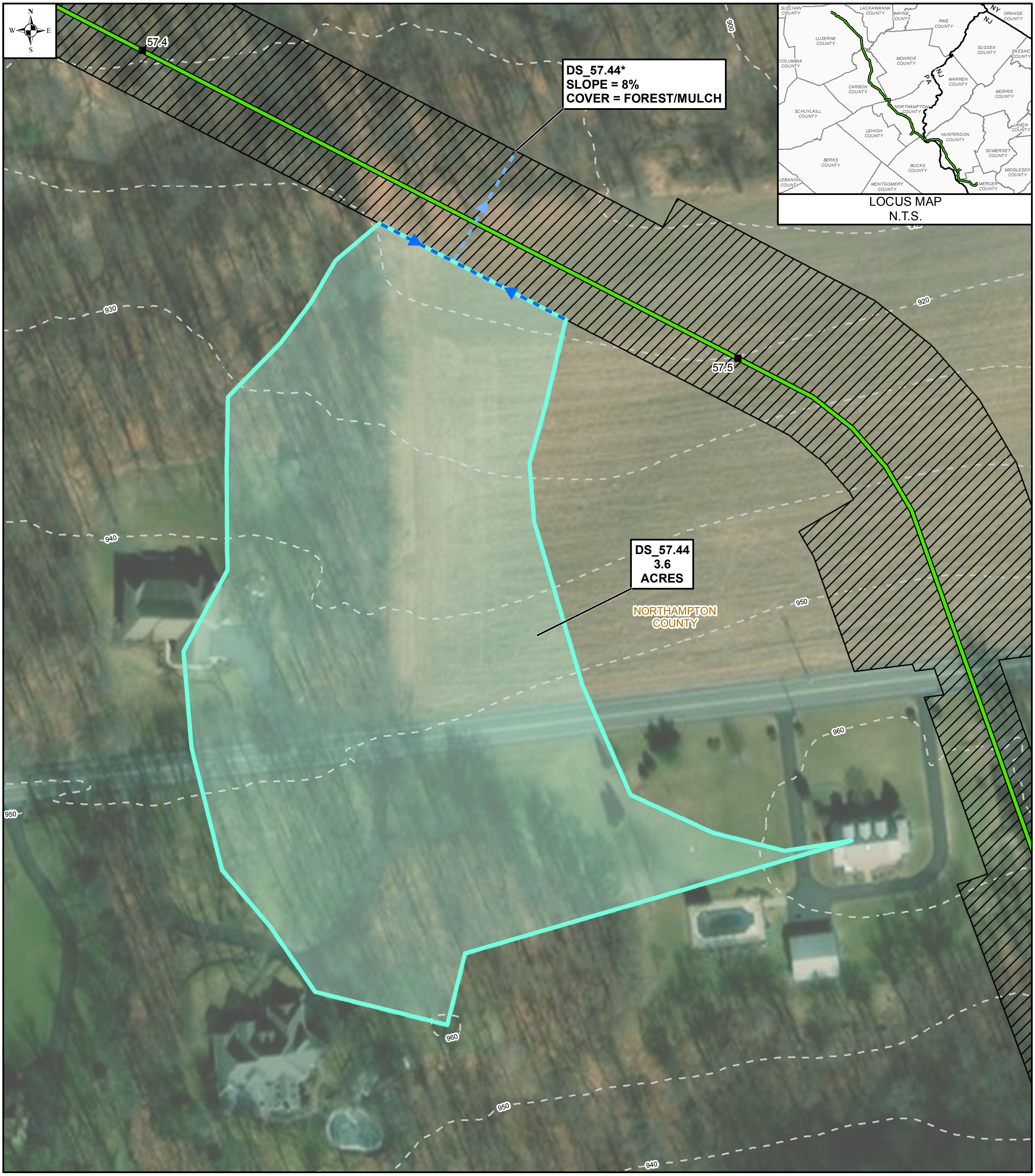


TR-55

DOWNSLOPE CONDITION
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 4%

SHALLOW CONCENTRATED FLOW VELOCITY = 1.4 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

1.4 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.



LEGEND

- 1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT

CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_57.44

NORTHAMPTON COUNTY, PENNSYLVANIA

DRAWN BY:	SNP 10/2018	APPROVED BY:	MJD 10/2019	SCALE:	1 INCH = 100 FEET
CHECKED BY:	JMB 10/2019	REV. DATE:	10/2019	REV.:	1

0 50 100 FEET

PennEast PIPELINE

DWG NO: PAGE 74 OF 114

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 57.44	60	0.4	0.117	6.03

$$T_{c\,(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 57.44	88	PAVEMENT	0.034	3.75	0.39
	236	SHORT GRASS	0.047	1.51	2.61
	92	PAVEMENT	0.054	4.72	0.32
	319	FOREST	0.047	0.55	9.75

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c* (minutes)
19.10

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 57.44	1	OPEN SPACE	0.21	1.62	0.34	0.24
	2	FOREST	0.16	1.61	0.26	
	3	INDUSTRIAL	0.69	0.37	0.26	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	19.10	2.94	3.54	4.04	2.94	3.54	4.04

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.24	2.94	3.60	2.50	3.02	3.44

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_57.44		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	2		
ACRES	(AC)	3.6		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	2.51		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	4.68		
PROTECTIVE LINING[2,6]		S75		
n (MANNING'S COEFFICIENT)[2]		0.055		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	2.21		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.55		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	1.44		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	16.95 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	16.95		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	8.47		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	2.12		
R (HYDRAULIC RADIUS)		0.24		
S (BED SLOPE)[3, 7]	(FT/FT)	0.046		
S_C (CRITICAL SLOPE)	(FT/FT)	0.076		
$.7S_c$	(FT/FT)	0.053		
$1.3S_c$	(FT/FT)	0.098		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

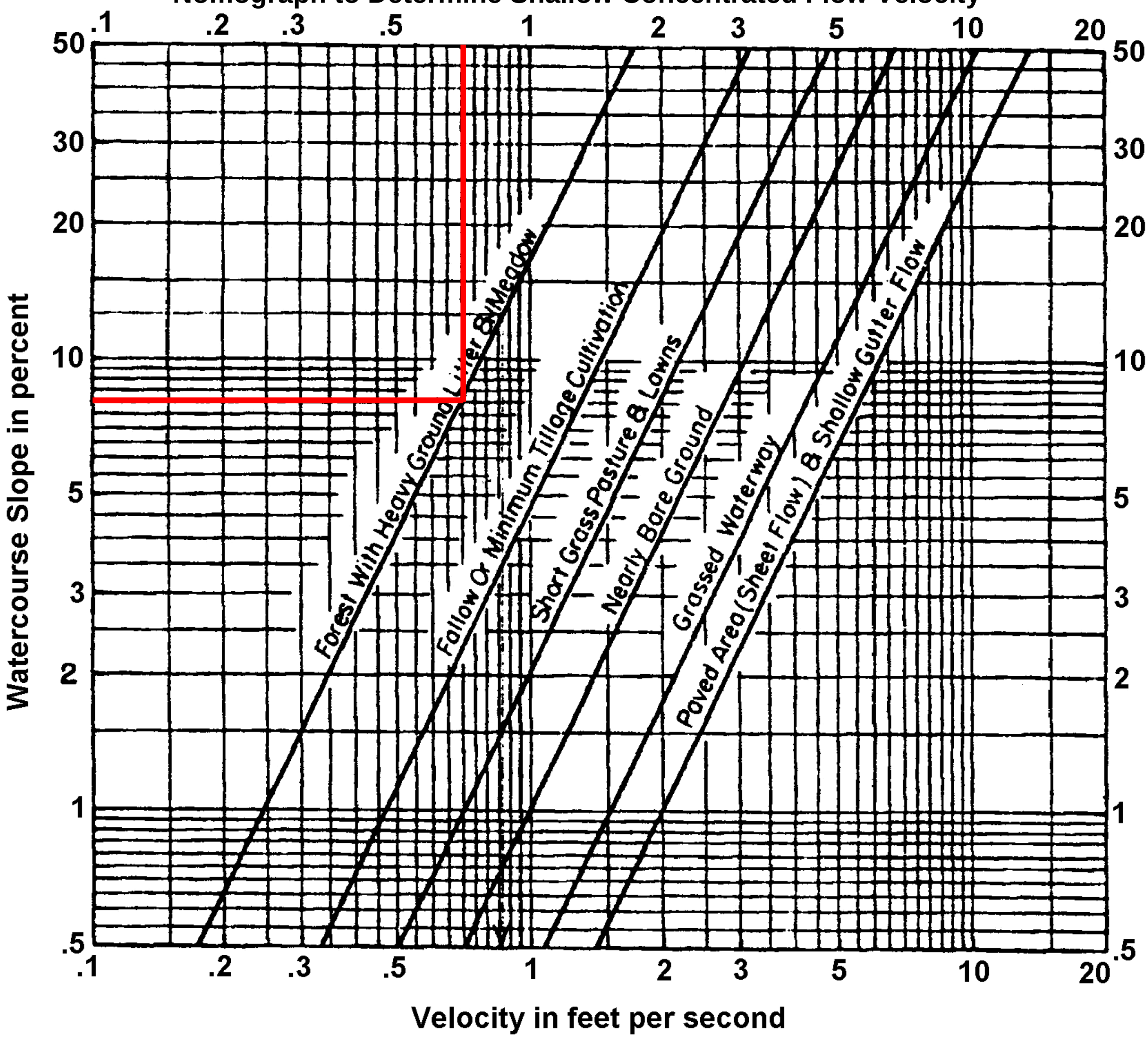
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_57.44

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity

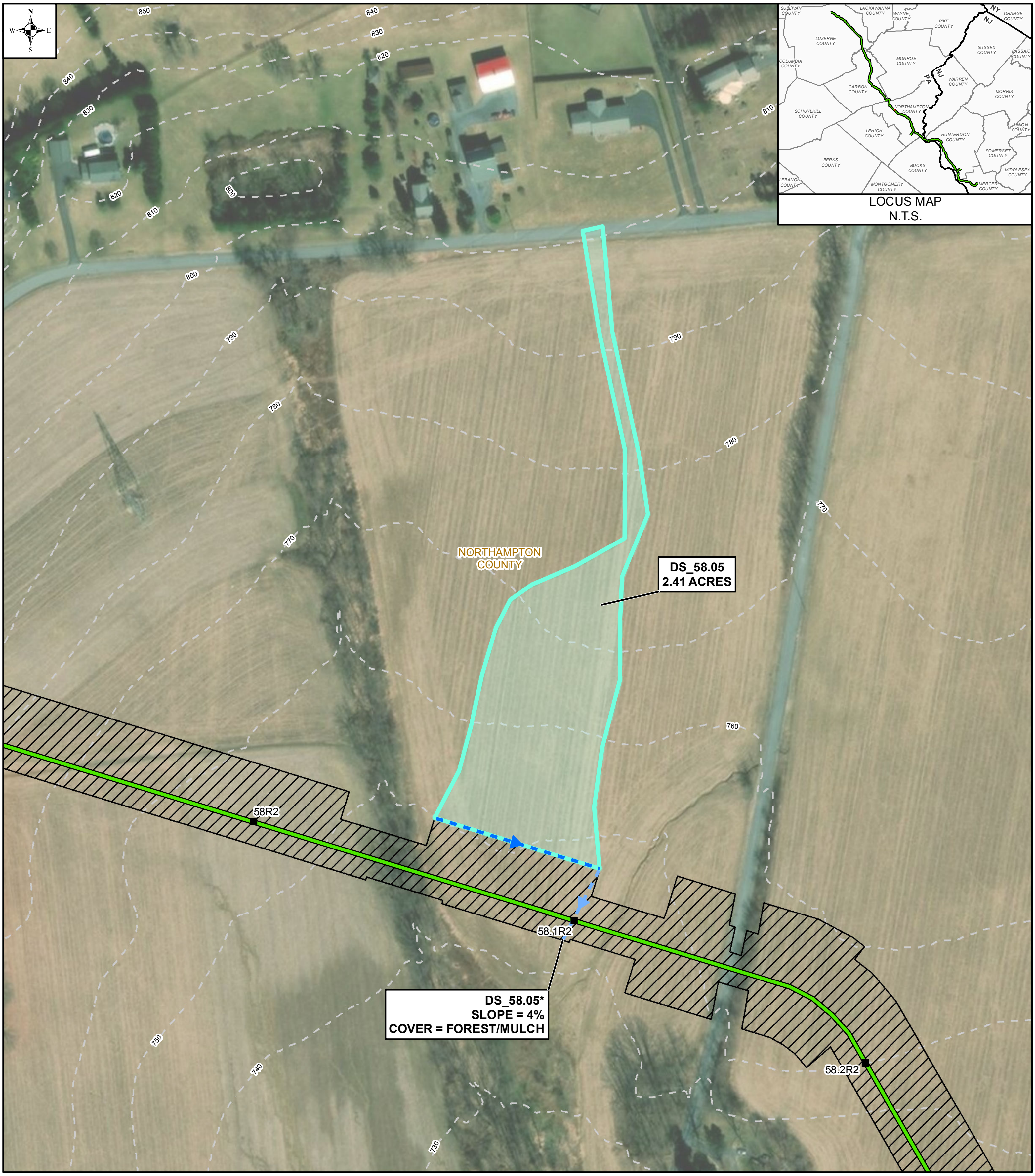


TR-55

DOWNSLOPE CONDITION
COVER TYPE = FOREST
PERCENT SLOPE = 8%

SHALLOW CONCENTRATED FLOW VELOCITY = 0.7 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 2 FPS FOR FORESTED/MULCH COVER TYPES.

0.7 FPS < 2.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.



LEGEND

- 1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT

CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_58.05

NORTHAMPTON COUNTY, PENNSYLVANIA

0 100 200 FEET

PennEast PIPELINE

DRAWN BY:	SNP 10/2018	APPROVED BY:	MJD 10/2019	SCALE:	1 INCH = 200 FEET
CHECKED BY:	JMB 10/2019	REV. DATE:	10/2019	REV.:	1

DWG NO: PAGE 75 OF 114

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 58.05	100	0.4	0.060	8.950

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 58.05	961	SHORT GRASS	0.046	1.493	10.727

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
19.68

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 58.05	1	PASTURE	0.40	2.41	0.96	0.40

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	19.68	2.89	3.49	3.98	2.89	3.49	3.98

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.40	3.49	2.41	2.79	3.36	3.84

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_58.05		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	2.67		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	3.37		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	3.52		
PROTECTIVE LINING[2,6]		SC150		
n (MANNING'S COEFFICIENT)[2]		0.05		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	1.35		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	2.00		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	0.44		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	20.83 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	20.83		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	10.42		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	2.60		
R (HYDRAULIC RADIUS)		0.24		
S (BED SLOPE)[3, 7]	(FT/FT)	0.014		
S_C (CRITICAL SLOPE)	(FT/FT)	0.062		
$.7S_c$	(FT/FT)	0.043		
$1.3S_c$	(FT/FT)	0.080		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

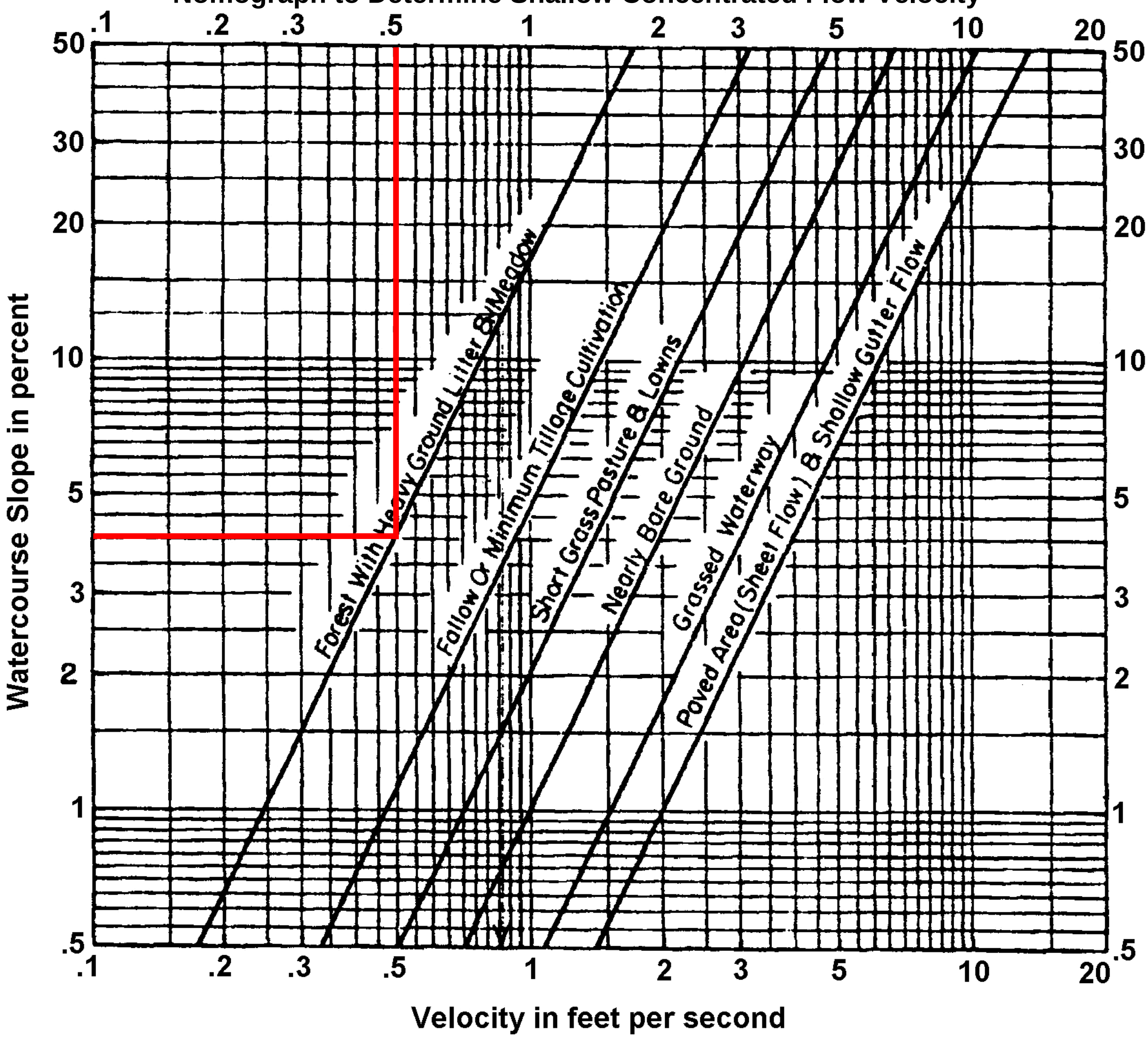
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_58.05

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity

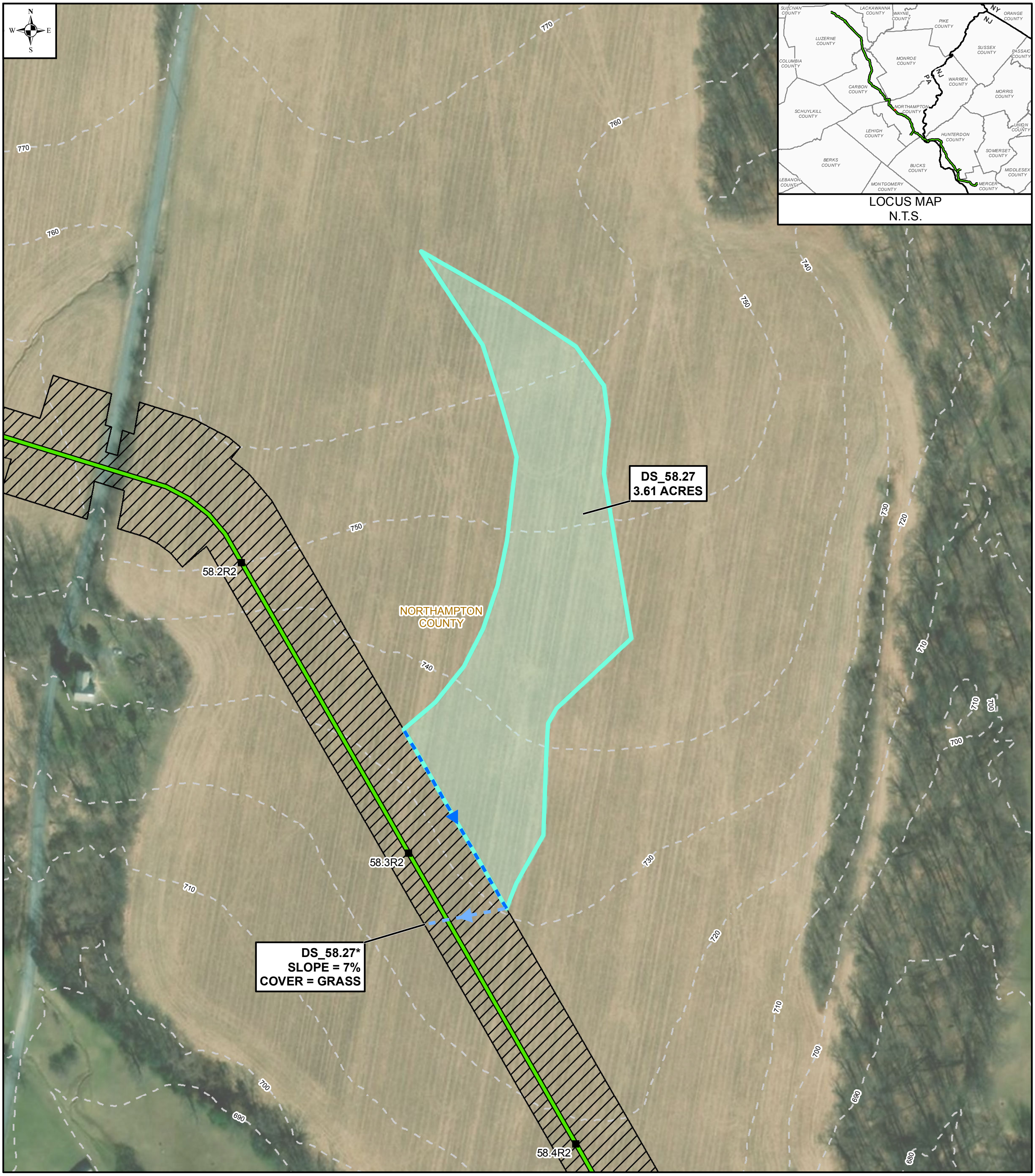


TR-55

DOWNSLOPE CONDITION
COVER TYPE = FOREST
PERCENT SLOPE = 4%

SHALLOW CONCENTRATED FLOW VELOCITY = 0.5 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 2 FPS FOR FORESTED/MULCH COVER TYPES.

0.5 FPS < 2.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.



LEGEND

- 1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT
CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_58.27
NORTHAMPTON COUNTY, PENNSYLVANIA

0 100 200 FEET

PennEast PIPELINE

DRAWN BY:	SNP 10/2018	APPROVED BY:	MJD 10/2019	SCALE:	1 INCH = 200 FEET
CHECKED BY:	JMB 10/2019	REV. DATE:	10/2019	REV.:	1

DWG NO: PAGE 76 OF 114

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 58.27	100	0.4	0.023	11.20

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 58.27	1159	SHORT GRASS	0.032	1.25	15.51

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
26.71

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 58.27	1	PASTURE	0.40	3.61	1.44	0.40

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	26.71	2.43	2.95	3.42	2.43	2.95	3.42

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.40	2.95	3.61	3.50	4.26	4.94

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_58.27		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	3.61		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	4.25		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	7.40		
PROTECTIVE LINING[2,6]		C125		
n (MANNING'S COEFFICIENT)[2]		0.022		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	2.60		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	2.25		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	0.31		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	22.73 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	22.73		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	11.36		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	2.84		
R (HYDRAULIC RADIUS)		0.24		
S (BED SLOPE)[3, 7]	(FT/FT)	0.01		
S_C (CRITICAL SLOPE)	(FT/FT)	0.012		
$.7S_c$	(FT/FT)	0.008		
$1.3S_c$	(FT/FT)	0.015		
STABLE FLOW?	(Y/N)	N		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	0.5		
FREEBOARD BASED ON STABLE FLOW	(FT)	N/A		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

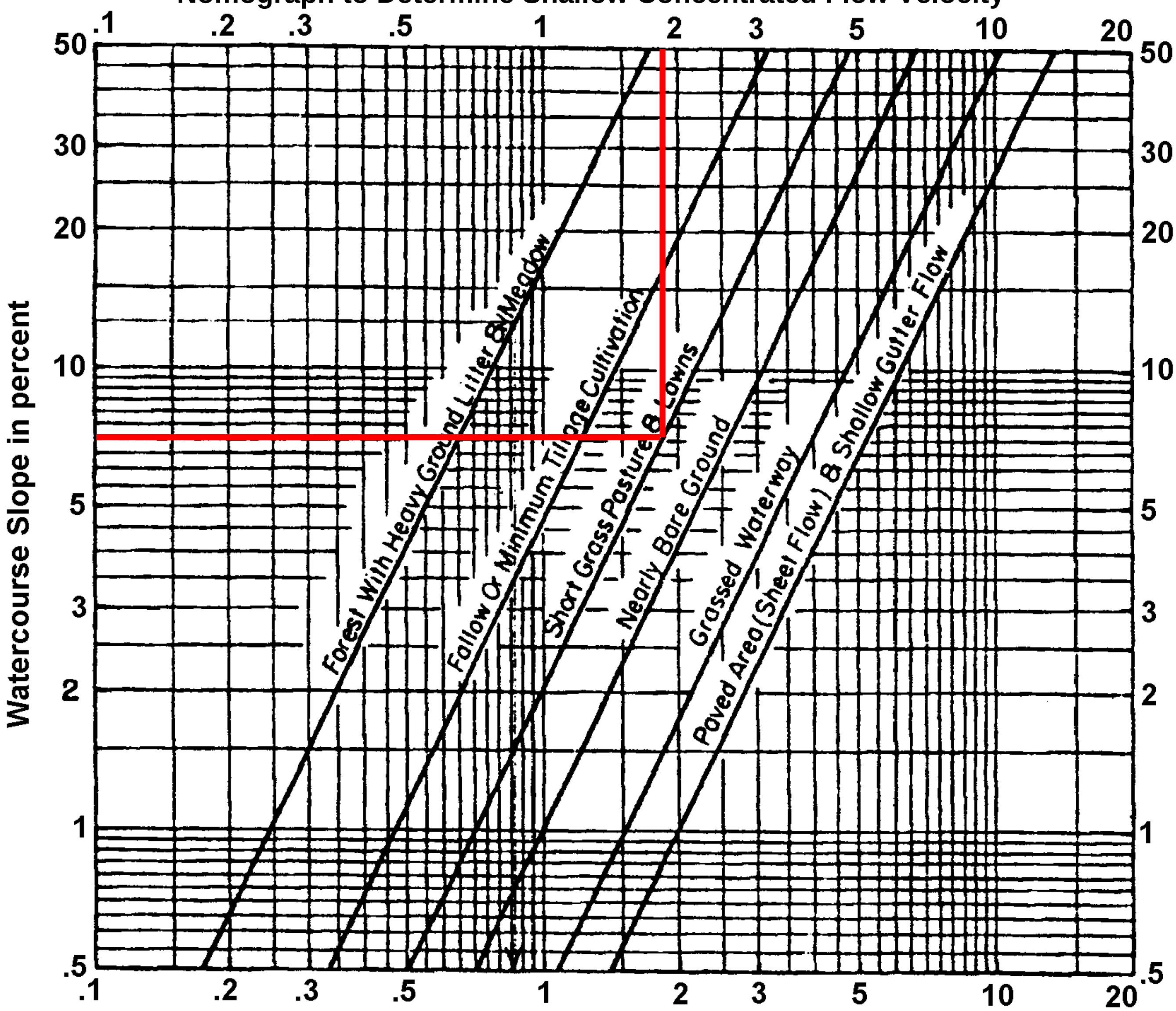
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_58.27

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity

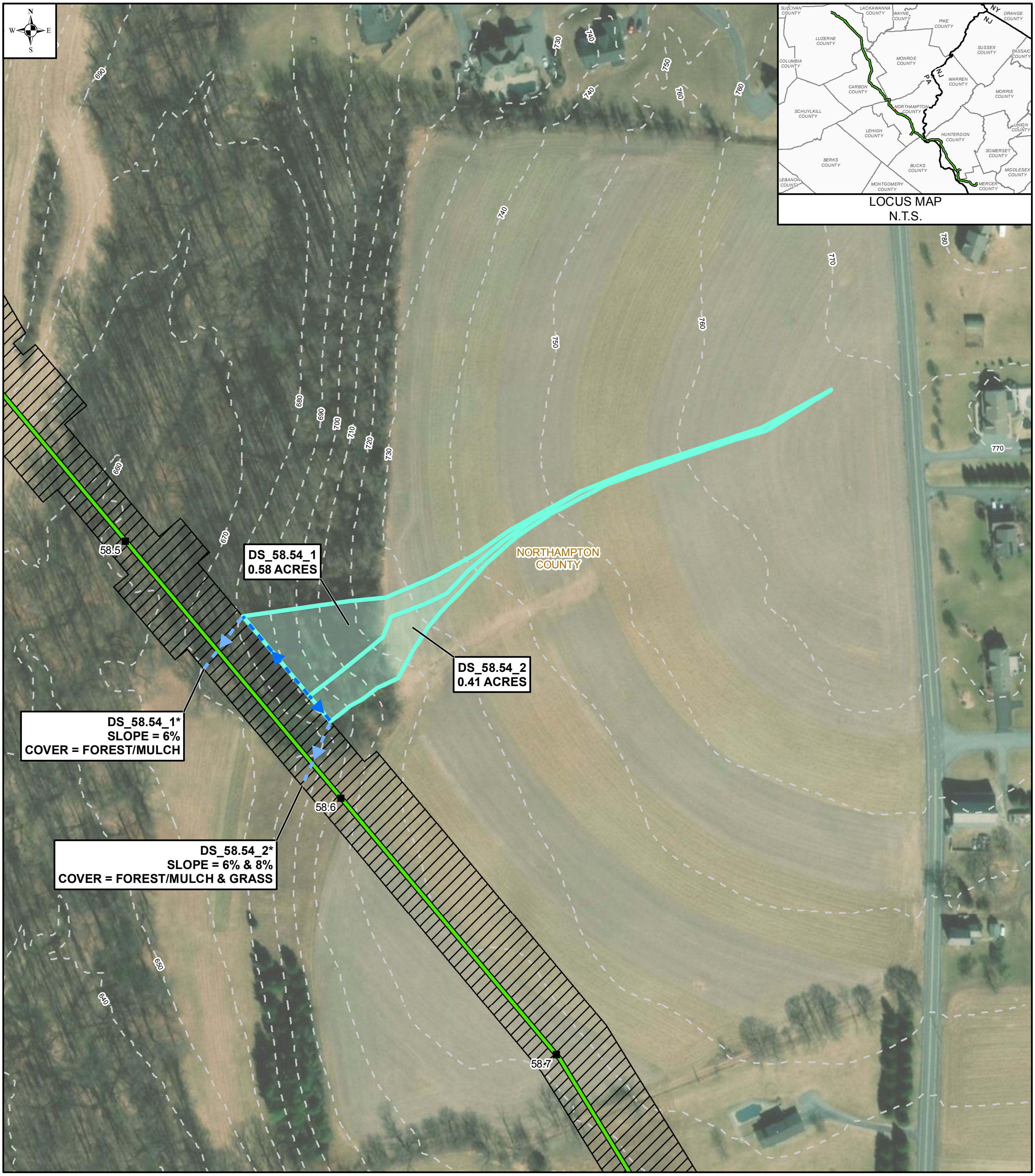


TR-55

DOWNSLOPE CONDITION
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 7%

SHALLOW CONCENTRATED FLOW VELOCITY = 1.9 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

1.9 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.



LEGEND

- 1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT

CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_58.54

NORTHAMPTON COUNTY, PENNSYLVANIA

0 100 200 FEET

PennEast PIPELINE

DRAWN BY:	SNP 10/2018	APPROVED BY:	MJD 10/2019	SCALE:	1 INCH = 200 FEET
CHECKED BY:	JMB 10/2019	REV. DATE:	10/2019	REV.:	1

DWG NO: PAGE 77 OF 114

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_58.54_1
0.58 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 58.54_1	100	0.4	0.040	9.84

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 58.54_1	249	SHORT GRASS	0.080	1.97	2.11
	227	FOREST	0.211	1.16	3.27

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
15.22

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 58.54_1	1	PASTURE	0.40	0.12	0.05	0.24
	2	FOREST	0.20	0.46	0.09	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	15.22	3.29	3.94	4.45	3.29	3.94	4.45

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.24	3.94	0.58	0.46	0.55	0.62

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_58.54_1		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	0.58		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	0.55		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	2.81		
PROTECTIVE LINING[2,6]		C125		
n (MANNING'S COEFFICIENT)[2]		0.022		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	5.85		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	2.25		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	2.09		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	3.85 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	3.85		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	1.92		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	0.48		
R (HYDRAULIC RADIUS)		0.19		
S (BED SLOPE)[3, 7]	(FT/FT)	0.067		
S_C (CRITICAL SLOPE)	(FT/FT)	0.016		
$.7S_c$	(FT/FT)	0.011		
$1.3S_c$	(FT/FT)	0.020		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

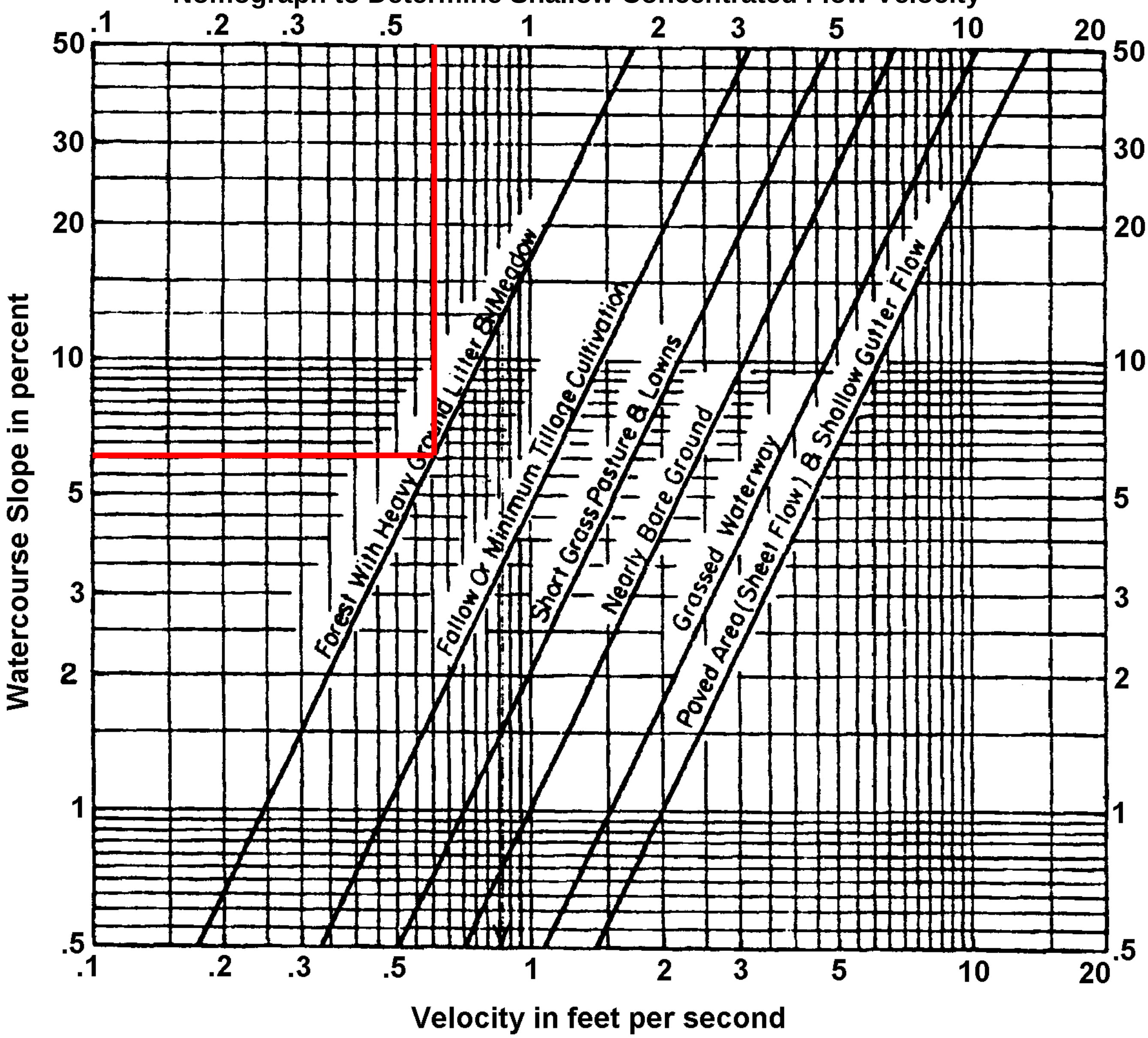
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_58.54_1

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = FOREST
PERCENT SLOPE = 6%

SHALLOW CONCENTRATED FLOW VELOCITY = 0.6 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 2 FPS FOR FORESTED/MULCH COVER TYPES.

0.6 FPS < 2.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_58.54_2
0.41 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 58.54_2	100	0.4	0.020	11.57

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 58.54_2	723	SHORT GRASS	0.059	1.69	7.13
	149	FOREST	0.208	1.15	2.16

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
20.86

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 58.54_2	1	PASTURE	0.40	0.22	0.09	0.31
	2	FOREST	0.20	0.19	0.04	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	20.86	2.80	3.39	3.88	2.80	3.39	3.88

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.31	3.39	0.41	0.35	0.43	0.49

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_58.54_2		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	0.41		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	0.43		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	0.78		
PROTECTIVE LINING[2,6]		S75		
n (MANNING'S COEFFICIENT)[2]		0.055		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	1.74		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.55		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	1.19		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	3.58 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	3.58		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	1.79		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	0.45		
R (HYDRAULIC RADIUS)		0.19		
S (BED SLOPE)[3, 7]	(FT/FT)	0.038		
S_C (CRITICAL SLOPE)	(FT/FT)	0.101		
$.7S_c$	(FT/FT)	0.071		
$1.3S_c$	(FT/FT)	0.131		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

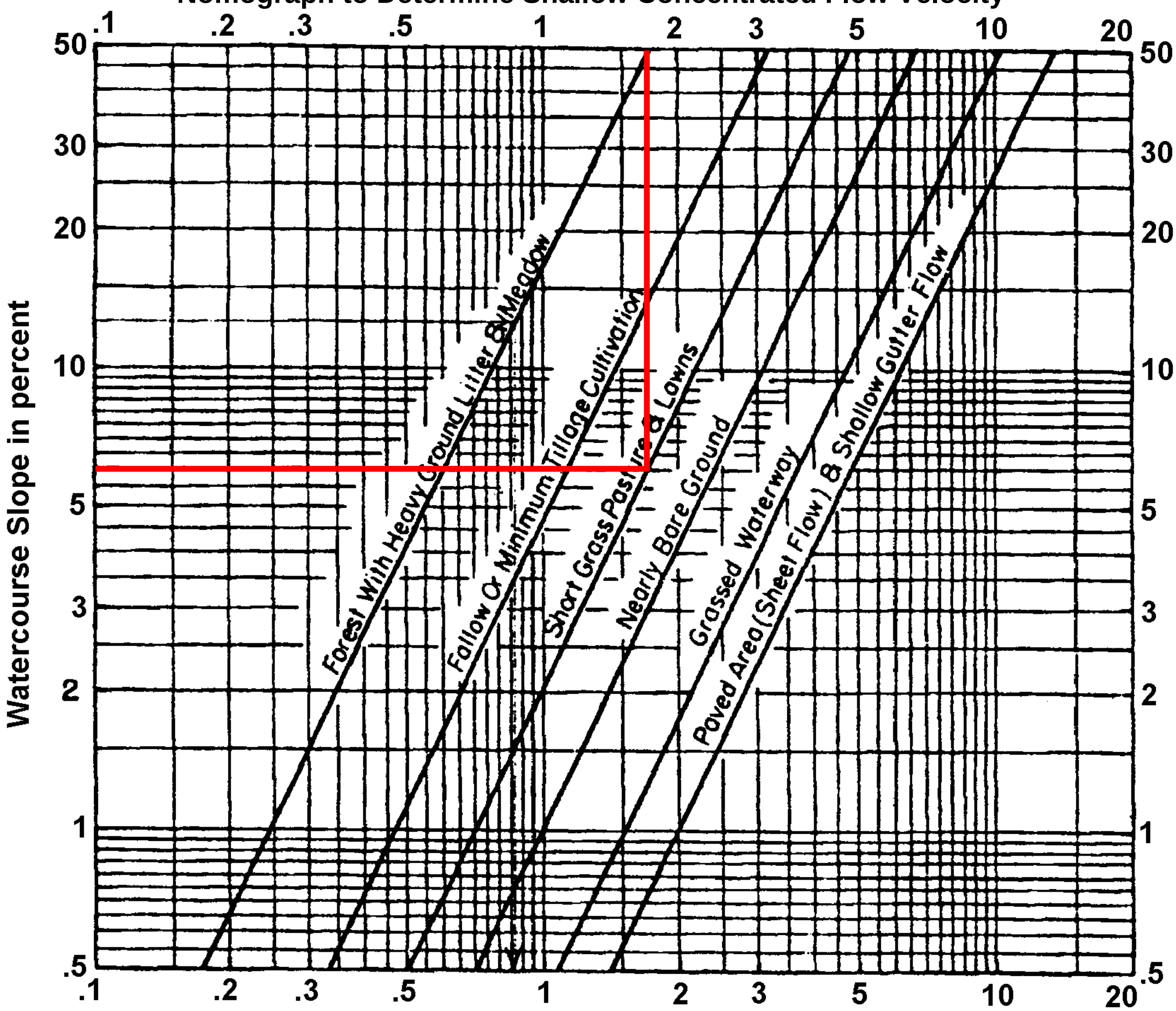
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_58.54_2

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 6%

SHALLOW CONCENTRATED FLOW VELOCITY = 1.7 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

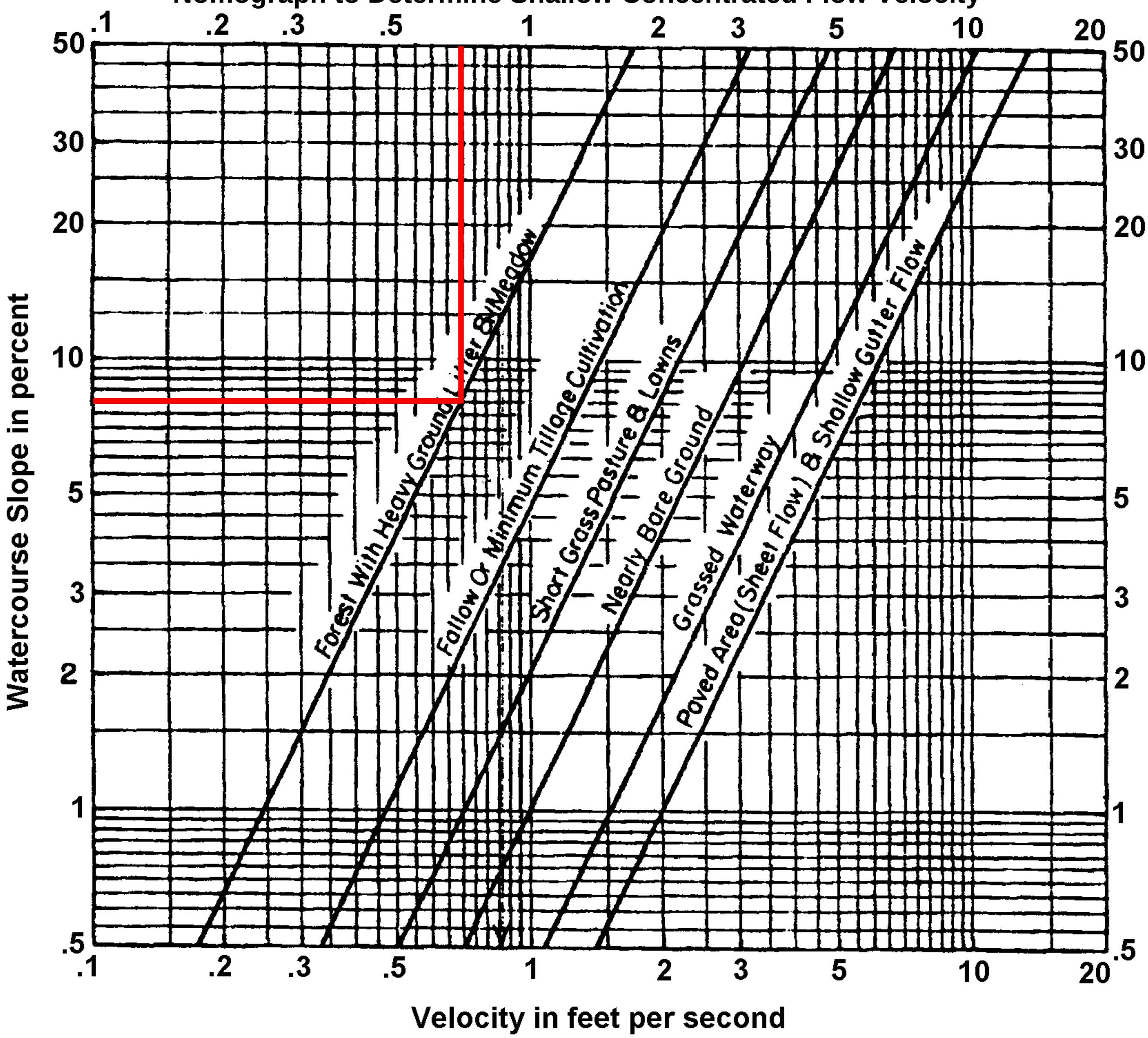
1.7 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.

CLEAN WATER DIVERSION ID:
DS_58.54_2

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity

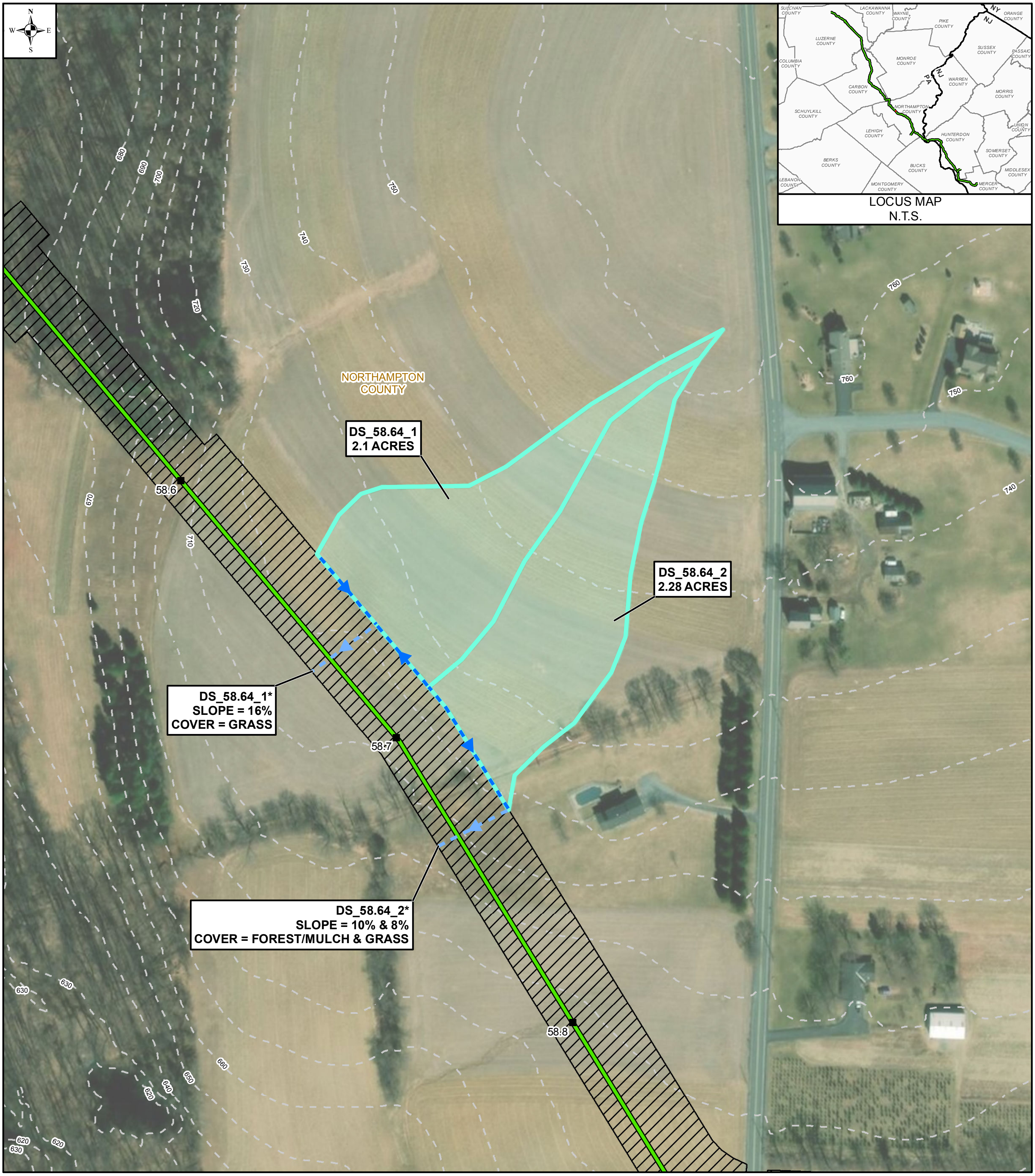


TR-55

DOWNSLOPE CONDITION
COVER TYPE = FOREST
PERCENT SLOPE = 8%

SHALLOW CONCENTRATED FLOW VELOCITY = 0.7 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 2 FPS FOR FORESTED/MULCH COVER TYPES.

0.7 FPS < 2.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.



LEGEND

- 1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT

CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_58.64

NORTHAMPTON COUNTY, PENNSYLVANIA

0 100 200 FEET

PennEast PIPELINE

DRAWN BY:	SNP 10/2018	APPROVED BY:	MJD 10/2019	SCALE:	1 INCH = 200 FEET
CHECKED BY:	JMB 10/2019	REV. DATE:	10/2019	REV.:	1

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_58.64_1
2.1 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 58.64_1	100	0.4	0.010	13.60

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 58.64_1	658	SHORT GRASS	0.053	1.60	6.84

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c* (minutes)
20.45

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 58.64_1	1	PASTURE	0.40	2.10	0.84	0.40

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	20.45	2.83	3.42	3.91	2.83	3.42	3.91

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.40	3.42	2.10	2.38	2.87	3.29

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_58.64_1		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	2.1		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	2.88		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	2.95		
PROTECTIVE LINING[2,6]		S75		
n (MANNING'S COEFFICIENT)[2]		0.055		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	1.56		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.55		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	0.72		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	15.15 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	15.15		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	7.58		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.89		
R (HYDRAULIC RADIUS)		0.23		
S (BED SLOPE)[3, 7]	(FT/FT)	0.023		
S_C (CRITICAL SLOPE)	(FT/FT)	0.076		
$.7S_c$	(FT/FT)	0.053		
$1.3S_c$	(FT/FT)	0.099		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

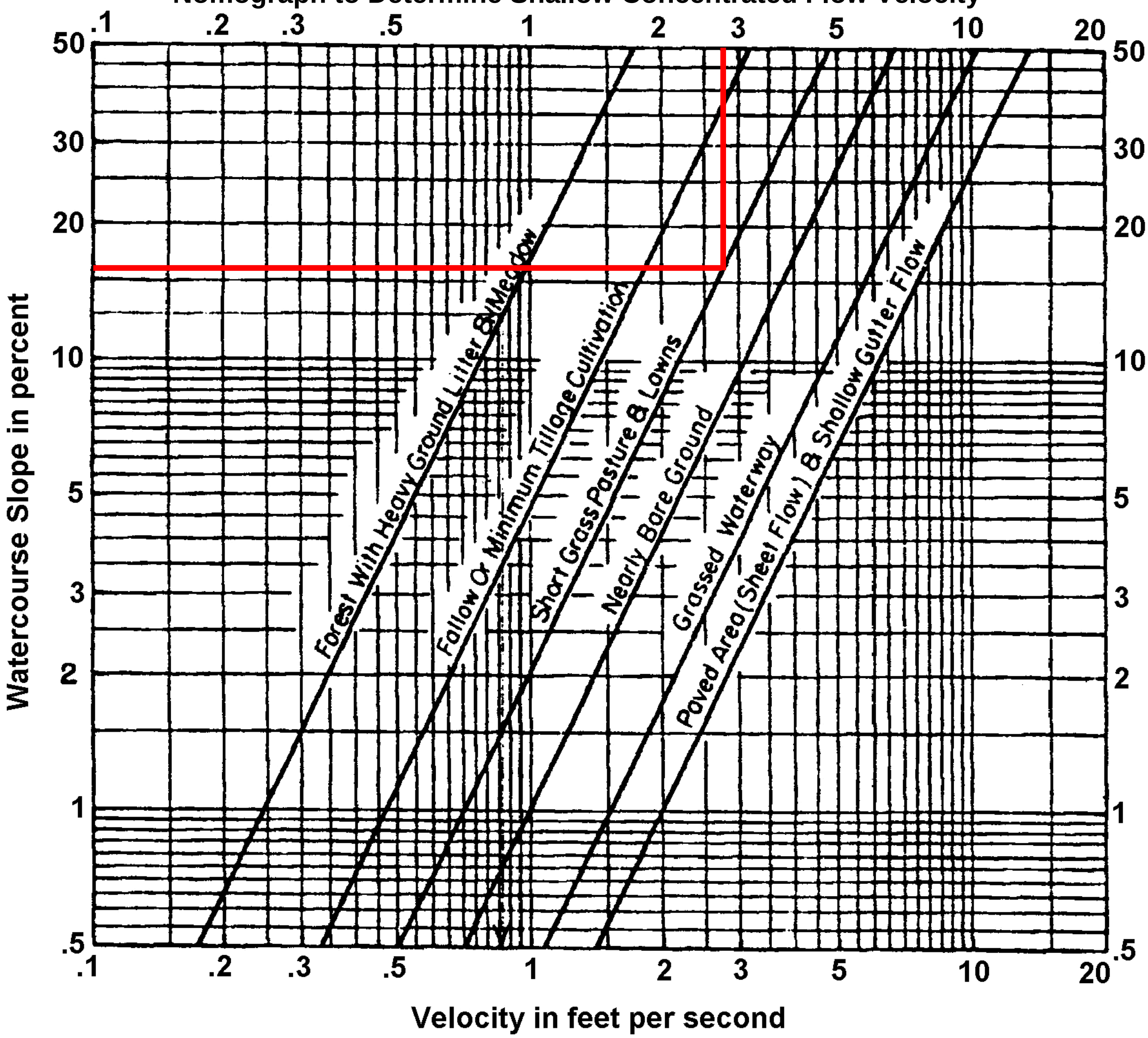
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_58.64_1

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 16%

SHALLOW CONCENTRATED FLOW VELOCITY = 2.9 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

2.9 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_58.64_2
2.28 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 58.64_2	100	0.4	0.030	10.52

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 58.64_2	697	SHORT GRASS	0.057	1.66	6.99

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c* (minutes)
17.51

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 58.64_2	1	PASTURE	0.40	2.23	0.89	0.40
	2	OPEN SPACE	0.21	0.05	0.01	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	17.51	3.07	3.70	4.20	3.07	3.70	4.20

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.40	3.70	2.28	2.77	3.34	3.79

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME:	PENNEAST PIPELINE PROJECT	
LOCATION:	NORTHAMPTON COUNTY	
PREPARED BY:	MDN	DATE: 10/2019
CHECKED BY:	KEK / JMB	DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_58.64_2		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	2.28		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	3.34		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	3.38		
PROTECTIVE LINING[2,6]		SC150		
n (MANNING'S COEFFICIENT)[2]		0.05		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	1.95		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	2.00		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	0.94		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	13.89 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	13.89		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	6.94		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.74		
R (HYDRAULIC RADIUS)		0.23		
S (BED SLOPE)[3, 7]	(FT/FT)	0.03		
S_C (CRITICAL SLOPE)	(FT/FT)	0.064		
$.7S_c$	(FT/FT)	0.045		
$1.3S_c$	(FT/FT)	0.083		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

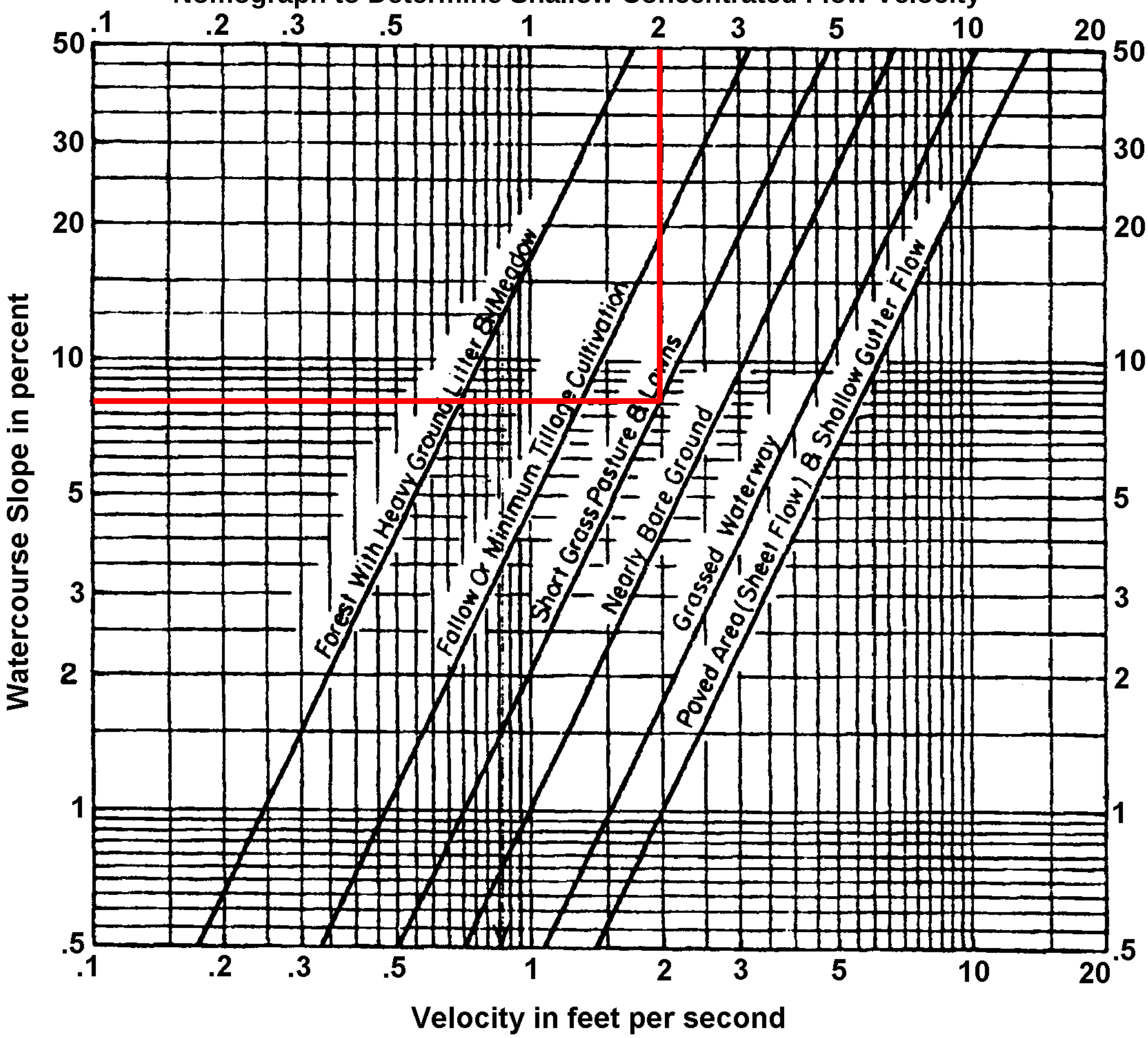
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_58.64_2

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 8%

SHALLOW CONCENTRATED FLOW VELOCITY = 2.0 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

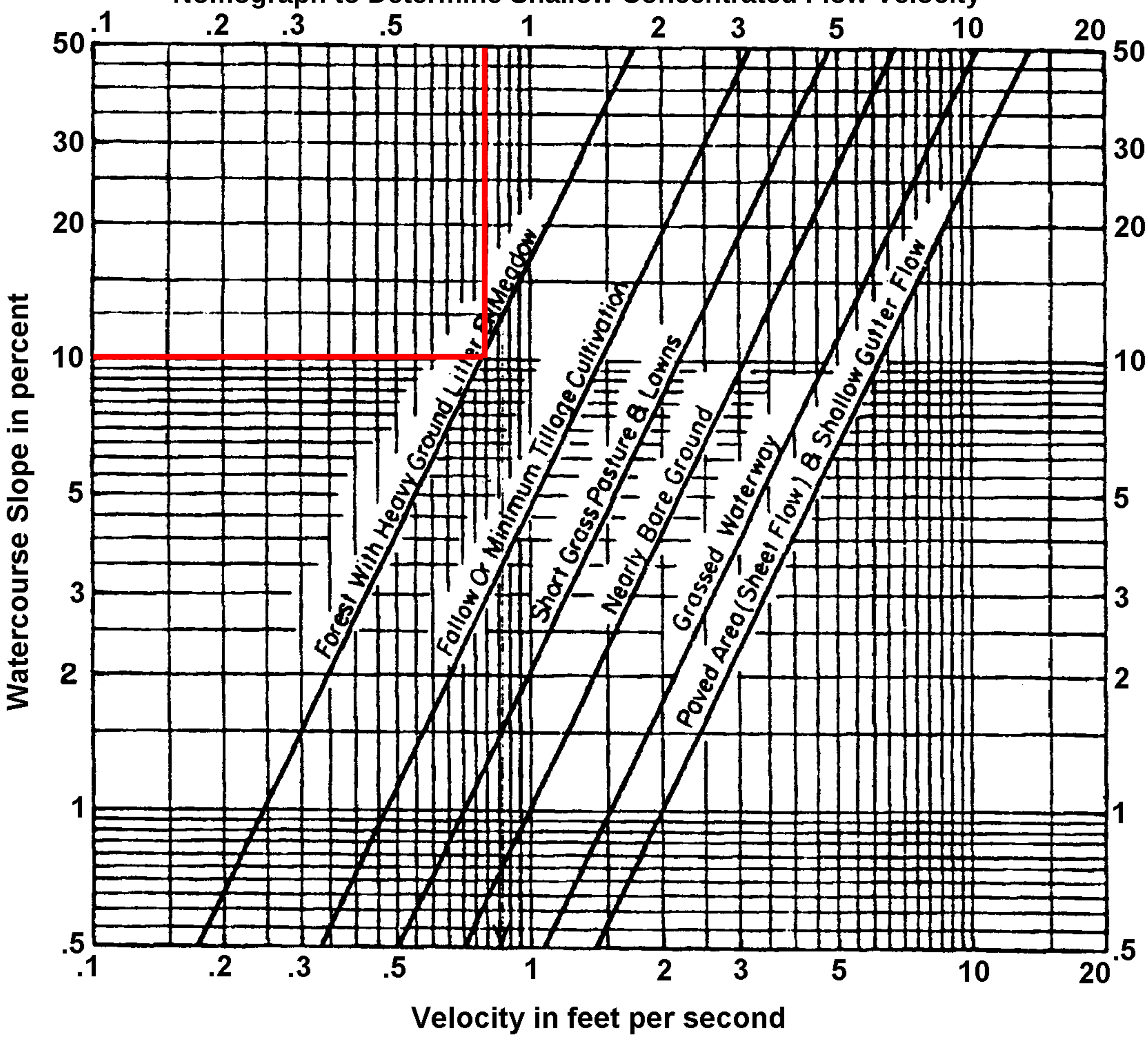
2.0 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.

CLEAN WATER DIVERSION ID:
DS_58.64_2

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity

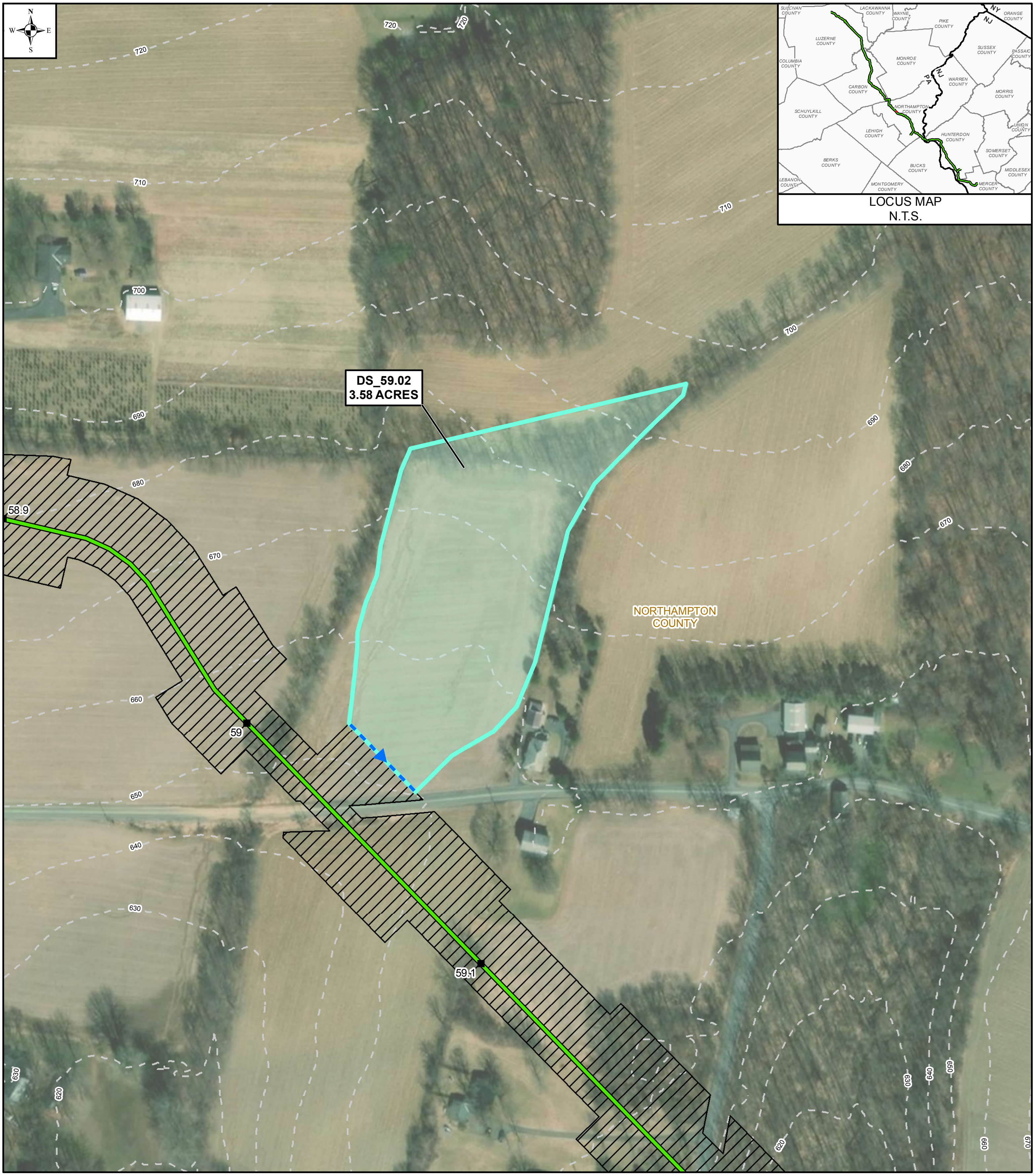


TR-55

DOWNSLOPE CONDITION
COVER TYPE = FOREST
PERCENT SLOPE = 10%

SHALLOW CONCENTRATED FLOW VELOCITY = 0.8 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 2 FPS FOR FORESTED/MULCH COVER TYPES.

0.8 FPS < 2.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.



LEGEND

- 1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT
CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_59.02
NORTHAMPTON COUNTY, PENNSYLVANIA

0 100 200 FEET

PennEast PIPELINE

DRAWN BY:	SNP 10/2018	APPROVED BY:	MJD 10/2019	SCALE:	1 INCH = 200 FEET
CHECKED BY:	JMB 10/2019	REV. DATE:	10/2019	REV.:	1

DWG NO: PAGE 79 OF 114

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 59.02	100	0.4	0.030	10.52

$$T_{c\,(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 59.02	792	SHORT GRASS	0.049	1.54	8.57

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
19.09

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 59.02	1	PASTURE	0.40	3.17	1.27	0.38
	2	OPEN SPACE	0.21	0.41	0.09	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	19.09	2.94	3.54	4.04	2.94	3.54	4.04

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.38	3.54	3.58	3.98	4.80	5.47

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

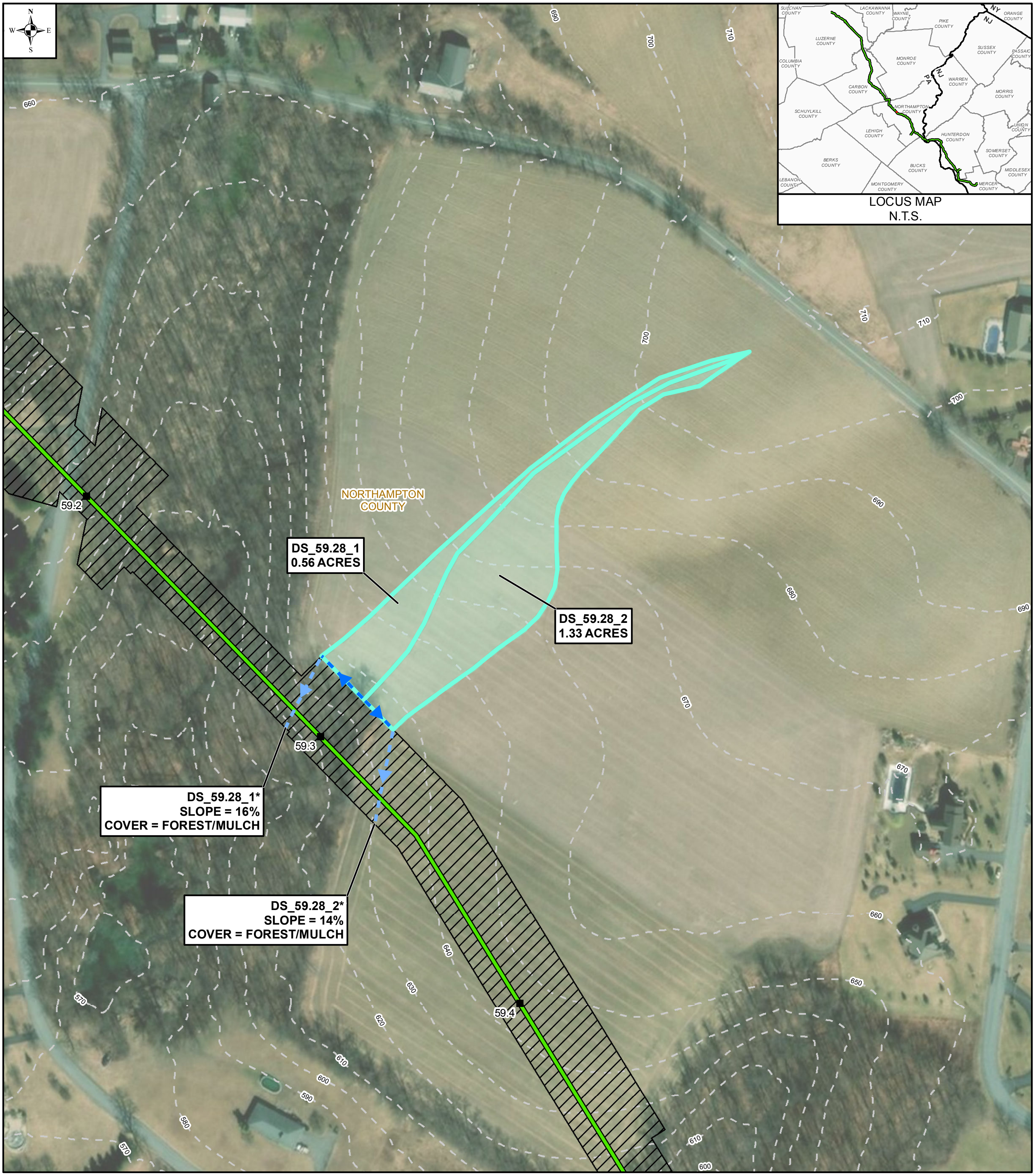
LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_59.02		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	3.58		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	4.8		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	4.86		
PROTECTIVE LINING[2,6]		S75		
n (MANNING'S COEFFICIENT)[2]		0.055		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	1.48		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.55		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	0.62		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	26.32 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	26.32		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	13.16		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	3.29		
R (HYDRAULIC RADIUS)		0.24		
S (BED SLOPE)[3, 7]	(FT/FT)	0.02		
S_C (CRITICAL SLOPE)	(FT/FT)	0.074		
$.7S_c$	(FT/FT)	0.051		
$1.3S_c$	(FT/FT)	0.096		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		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 seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.



LEGEND

- 1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT

CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_59.28

NORTHAMPTON COUNTY, PENNSYLVANIA

0 100 200 FEET

DRAWN BY:	SNP 10/2018	APPROVED BY:	MJD 10/2019	SCALE:	1 INCH = 200 FEET
CHECKED BY:	JMB 10/2019	REV. DATE:	10/2019	REV.:	1

DWG NO: PAGE 80 OF 114

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_59.28_1
0.56 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 59.28_1	100	0.4	0.044	9.62

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 59.28_1	739	SHORT GRASS	0.078	1.94	6.33

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
15.96

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 59.28_1	1	PASTURE	0.40	0.56	0.22	0.40

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	15.96	3.22	3.86	4.36	3.22	3.86	4.36

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.40	3.86	0.56	0.72	0.87	0.98

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_59.28_1		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	0.56		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	0.87		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	1.00		
PROTECTIVE LINING[2,6]		S75		
n (MANNING'S COEFFICIENT)[2]		0.055		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	0.99		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.55		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	0.31		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	8.13 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	8.13		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	4.07		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.02		
R (HYDRAULIC RADIUS)		0.22		
S (BED SLOPE)[3, 7]	(FT/FT)	0.01		
S_C (CRITICAL SLOPE)	(FT/FT)	0.082		
$.7S_c$	(FT/FT)	0.058		
$1.3S_c$	(FT/FT)	0.107		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

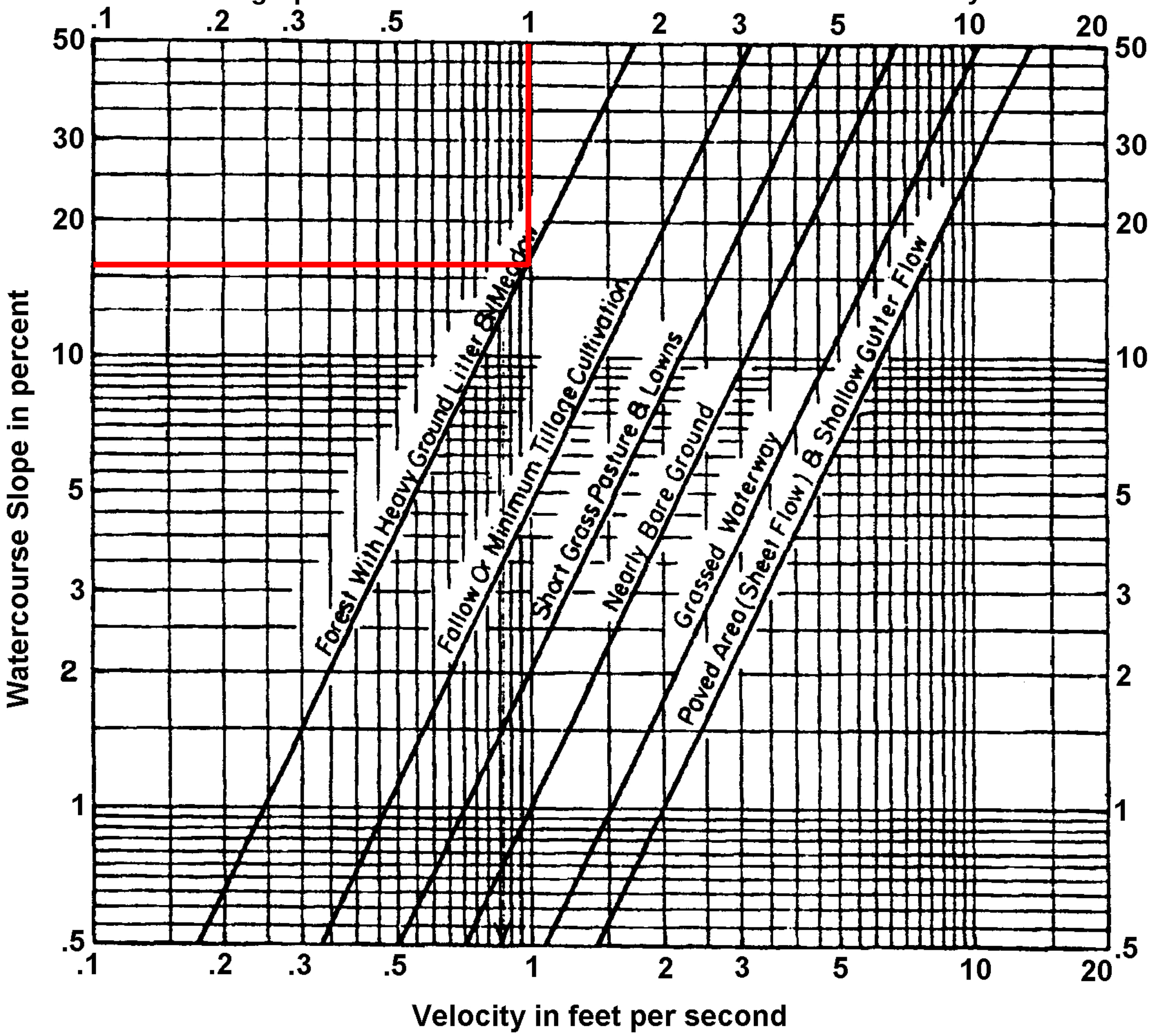
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_59.28_1

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = FOREST
PERCENT SLOPE = 16%

SHALLOW CONCENTRATED FLOW VELOCITY = 1.0 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 2 FPS FOR FORESTED/MULCH COVER TYPES.

1.0 FPS < 2.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_59.28_2
1.33 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 59.28_1	100	0.4	0.048	9.43

$$T_{c\,(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 59.28_1	756	SHORT GRASS	0.089	2.08	6.07

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
15.50

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 59.28_1	1	PASTURE	0.50	1.33	0.67	0.50

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	15.50	3.26	3.91	4.42	3.26	3.91	4.42

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.50	3.91	1.33	2.17	2.60	2.94

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_59.28_2		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	1.33		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	2.6		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	5.67		
PROTECTIVE LINING[2,6]		C125		
n (MANNING'S COEFFICIENT)[2]		0.022		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	5.26		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	2.25		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	1.40		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	8.62 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	8.62		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	4.31		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.08		
R (HYDRAULIC RADIUS)		0.22		
S (BED SLOPE)[3, 7]	(FT/FT)	0.045		
S_C (CRITICAL SLOPE)	(FT/FT)	0.013		
$.7S_c$	(FT/FT)	0.009		
$1.3S_c$	(FT/FT)	0.017		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

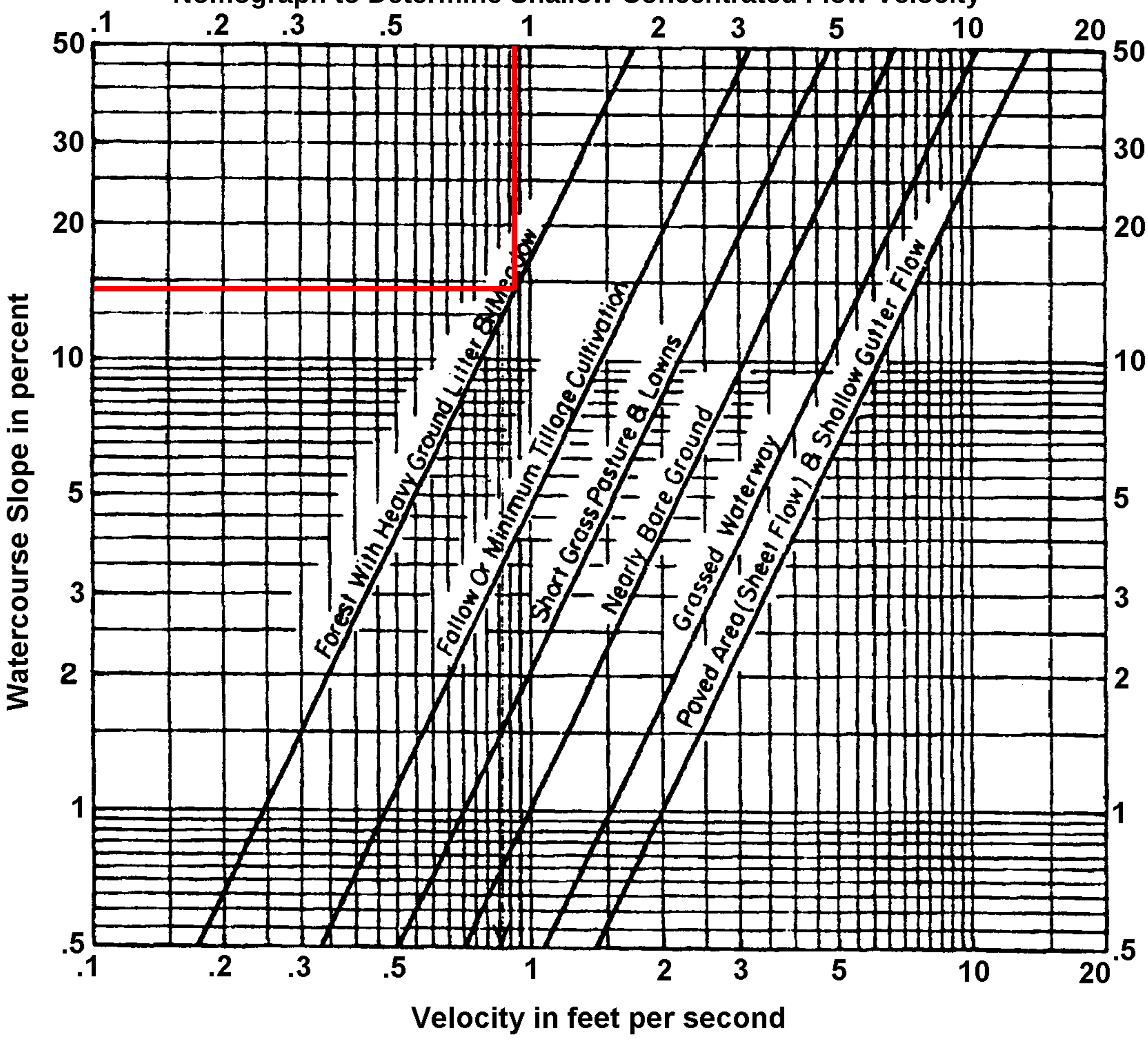
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_59.28_2

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity

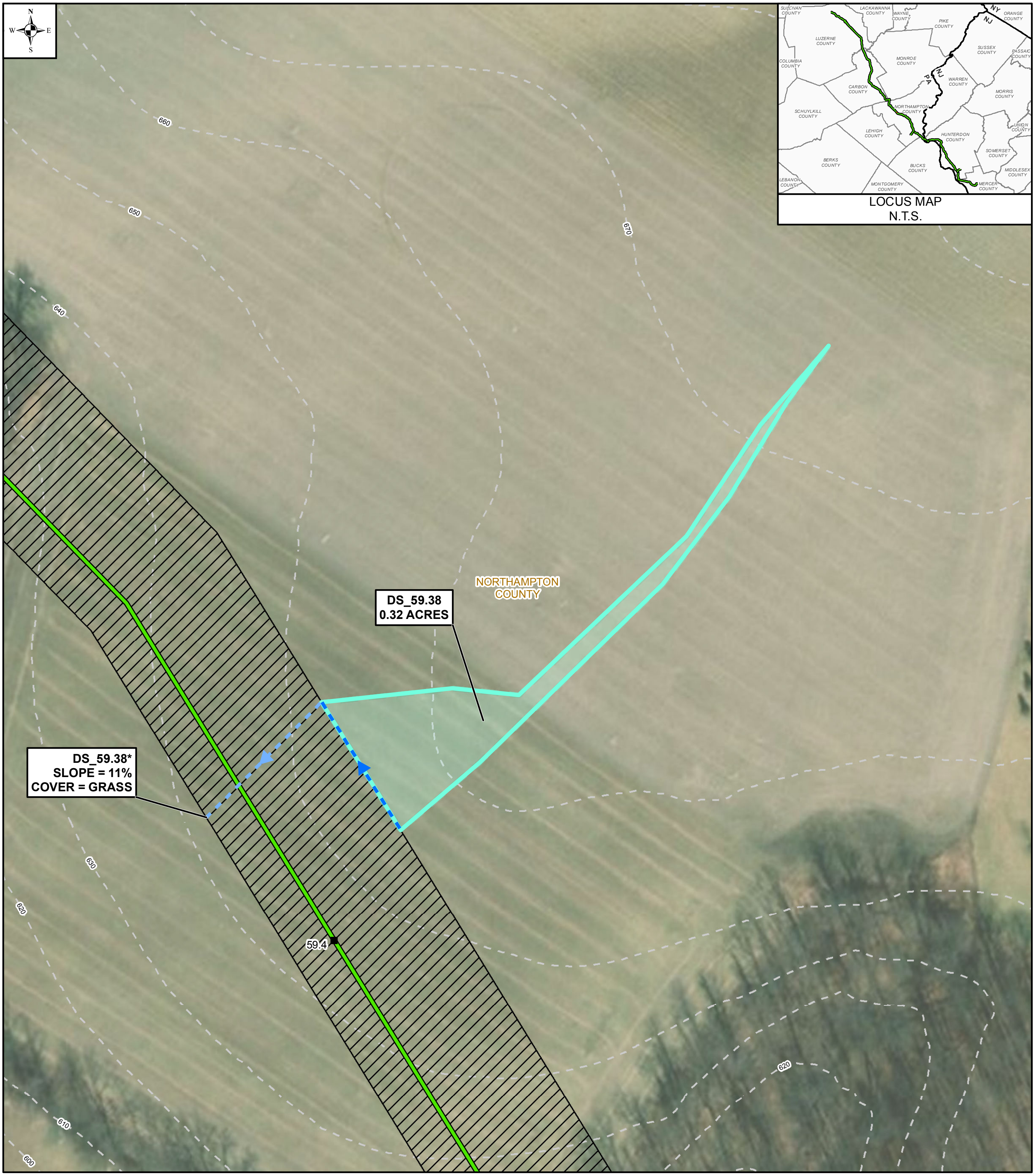


TR-55

DOWNSLOPE CONDITION
COVER TYPE = FOREST
PERCENT SLOPE = 14%

SHALLOW CONCENTRATED FLOW VELOCITY = 0.9 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 2 FPS FOR FORESTED/MULCH COVER TYPES.

0.9 FPS < 2.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.



LEGEND

- 1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT

CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_59.38

NORTHAMPTON COUNTY, PENNSYLVANIA

0 50 100 FEET

PennEast PIPELINE

DRAWN BY: SNP 10/2018	APPROVED BY: MJD 10/2019	SCALE: 1 INCH = 100 FEET
CHECKED BY: JMB 10/2019	REV. DATE: 10/2019	REV.: 1

DWG NO: PAGE 81 OF 114

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 59.38	100	0.4	0.055	9.13

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 59.38	425	SHORT GRASS	0.040	1.39	5.09

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
14.22

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 59.38	1	PASTURE	0.40	0.32	0.13	0.40

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	14.22	3.40	4.06	4.57	3.40	4.06	4.57

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.40	4.06	0.32	0.43	0.52	0.58

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_59.38		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	0.32		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	0.52		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	1.36		
PROTECTIVE LINING[2,6]		EXISTING GRASS		
n (MANNING'S COEFFICIENT)[2]		0.07		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	1.03		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.00		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	0.53		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	10.53 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	10.53		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	5.26		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.32		
R (HYDRAULIC RADIUS)		0.23		
S (BED SLOPE)[3, 7]	(FT/FT)	0.017		
S_C (CRITICAL SLOPE)	(FT/FT)	0.129		
$.7S_c$	(FT/FT)	0.090		
$1.3S_c$	(FT/FT)	0.167		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

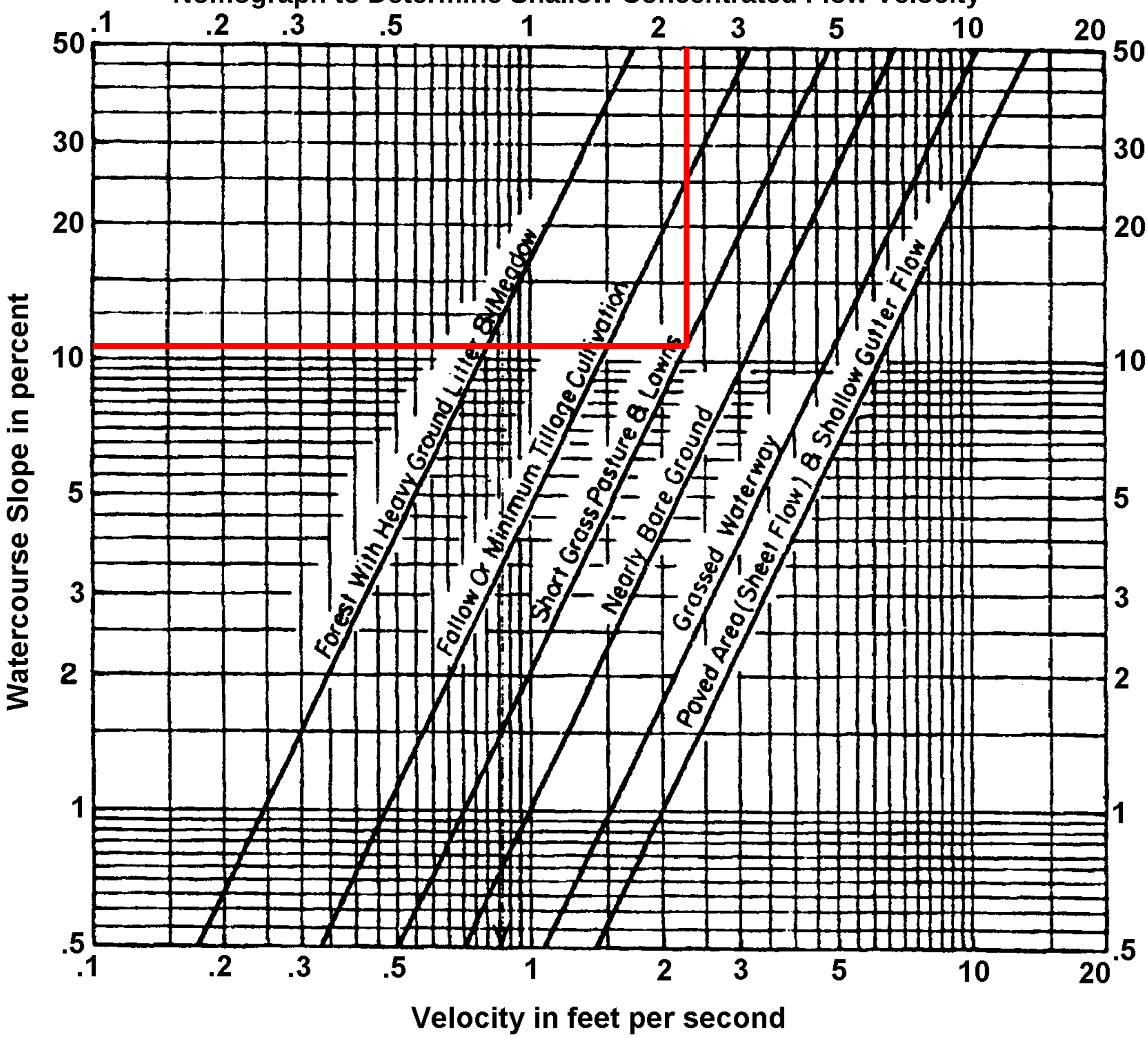
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_59.38

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity

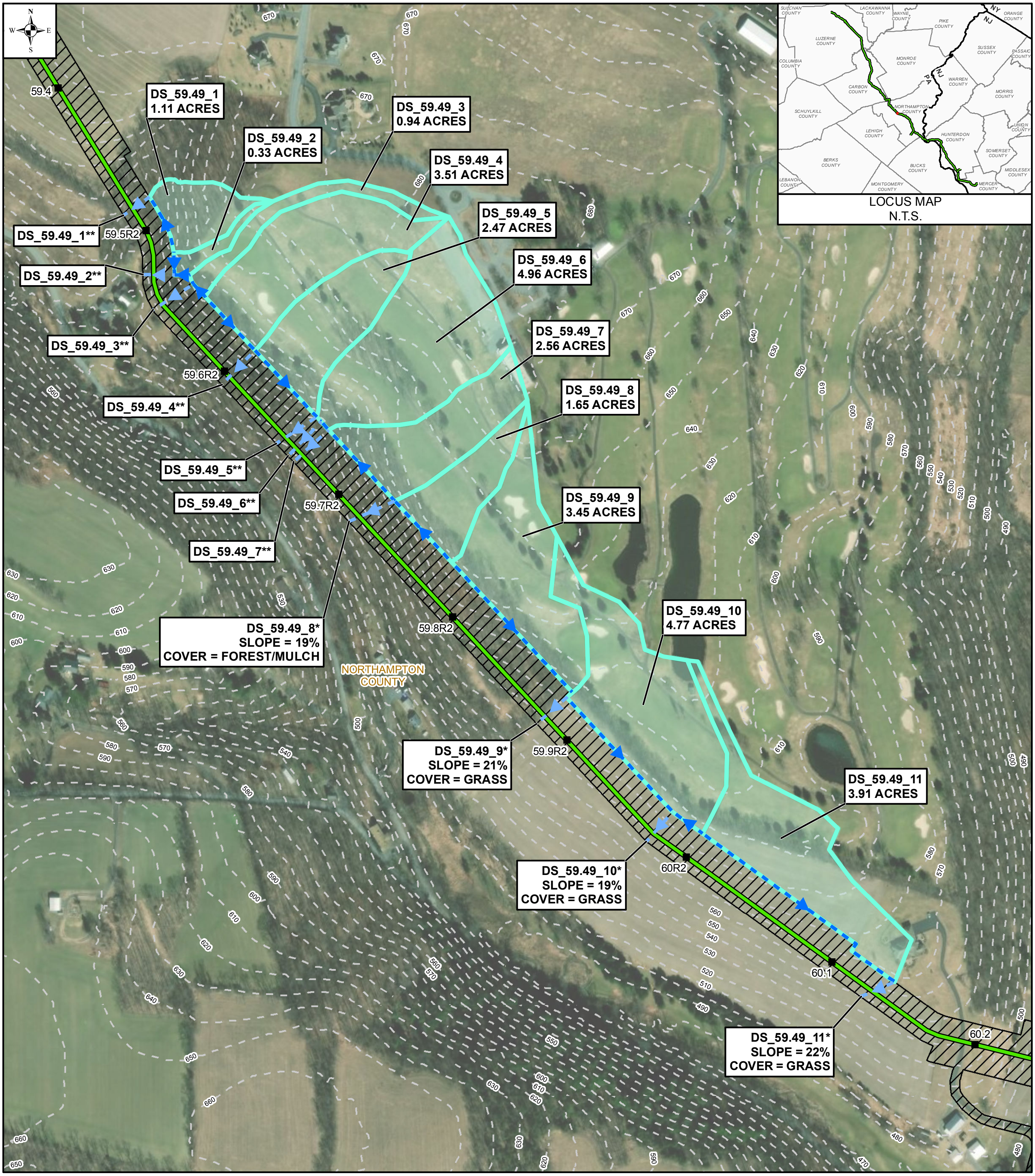


TR-55

DOWNSLOPE CONDITION
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 11%

SHALLOW CONCENTRATED FLOW VELOCITY = 2.3 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

2.3 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.



LEGEND

- 1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT

CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_59.49

NORTHAMPTON COUNTY, PENNSYLVANIA

0 200 400 FEET

PennEast PIPELINE

DRAWN BY:	SNP 10/2018	APPROVED BY:	MJD 10/2019	SCALE:	1 INCH = 400 FEET
CHECKED BY:	JMB 10/2019	REV. DATE:	10/2019	REV.:	1

DWG NO: PAGE 82 OF 114

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_59.49_1
1.11 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 59.49_1	100	0.4	0.110	7.77

$$T_{c(sheet\ flow)} = \left[\frac{2L(n)}{3S^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 59.49_1	331	FOREST	0.202	1.13	4.88

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
12.65

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 59.49_1	1	OPEN SPACE	0.28	0.20	0.06	0.22
	2	INDUSTRIAL	0.69	0.01	0.01	
	3	FOREST	0.20	0.90	0.18	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	12.65	3.58	4.27	4.77	3.58	4.27	4.77

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.22	4.27	1.11	0.87	1.04	1.16

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_59.49_1		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	1.11		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	1.04		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	1.55		
PROTECTIVE LINING[2,6]		P300		
n (MANNING'S COEFFICIENT)[2]		0.034		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	4.23		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	3.00		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	2.90		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	2.92 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	2.92		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	1.46		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	0.37		
R (HYDRAULIC RADIUS)		0.18		
S (BED SLOPE)[3, 7]	(FT/FT)	0.093		
S_C (CRITICAL SLOPE)	(FT/FT)	0.042		
$.7S_c$	(FT/FT)	0.029		
$1.3S_c$	(FT/FT)	0.054		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		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 seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_59.49_2
0.33 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 59.49_2	100	0.4	0.140	7.34

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 59.49_2	153	SHORT GRASS	0.118	2.39	1.07
	125	FOREST	0.216	1.17	1.78

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
10.19

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 59.49_2	1	OPEN SPACE	0.28	0.22	0.06	0.27
	2	INDUSTRIAL	0.69	0.01	0.01	
	3	FOREST	0.20	0.10	0.02	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	10.19	3.90	4.62	5.12	3.90	4.62	5.12

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.27	4.62	0.33	0.35	0.41	0.45

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_59.49_2	DS_59.49_2	
TEMPORARY OR PERMANENT?	(T OR P)	T	T	
DESIGN STORM	(2, 5, OR 10 YR)	5	5	
ACRES	(AC)	0.33	0.33	
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A	N/A	
Q_r (REQUIRED CAPACITY)	(CFS)	0.41	0.41	
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	2.17	2.17	
PROTECTIVE LINING[2,6]		P300 (Unvegetated)	P300 (Vegetated)	
n (MANNING'S COEFFICIENT)[2]		0.034	0.034	
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A	N/A	
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	5.32	5.32	
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	3.00	8.00	
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	4.40	4.40	
CHANNEL BOTTOM WIDTH	(FT)	0	0	
CHANNEL SIDE SLOPES	(H:V)	3.26 / 0	3.26 / 0	
D (TOTAL DEPTH)	(FT)	1.00	1.00	
CHANNEL TOP WIDTH @ D	(FT)	3.26	3.26	
d (CALCULATED FLOW DEPTH)	(FT)	0.50	0.50	
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	1.63	1.63	
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0	0	
d_{50} STONE SIZE	(IN)	N/A	N/A	
A (CROSS-SECTIONAL AREA)	(SQ. FT)	0.41	0.41	
R (HYDRAULIC RADIUS)		0.18	0.18	
S (BED SLOPE)[3, 7]	(FT/FT)	0.141	0.141	
S_C (CRITICAL SLOPE)	(FT/FT)	0.040	0.040	
$.7S_c$	(FT/FT)	0.028	0.028	
$1.3S_c$	(FT/FT)	0.052	0.052	
STABLE FLOW?	(Y/N)	Y	Y	
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A	N/A	
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50	0.50	
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50	0.50	
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S	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 seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_59.49_3
0.94 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 59.49_3	100	0.4	0.052	9.25

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 59.49_3	844	SHORT GRASS	0.084	2.02	6.97

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
16.23

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN   DATE: 10/15/2018
CHECKED BY: KEK / JMB   DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 59.49_3	1	OPEN SPACE	0.28	0.85	0.24	0.28
	2	INDUSTRIAL	0.69	0.02	0.01	
	3	FOREST	0.20	0.07	0.01	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	16.23	3.19	3.83	4.33	3.19	3.83	4.33

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.28	3.83	0.94	0.85	1.02	1.15

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_59.49_3		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	0.94		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	1.01		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	1.42		
PROTECTIVE LINING[2,6]		S150		
n (MANNING'S COEFFICIENT)[2]		0.055		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	2.21		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.75		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	1.72		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	5.15 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	5.15		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	2.58		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	0.64		
R (HYDRAULIC RADIUS)		0.21		
S (BED SLOPE)[3, 7]	(FT/FT)	0.055		
S_C (CRITICAL SLOPE)	(FT/FT)	0.090		
$.7S_c$	(FT/FT)	0.063		
$1.3S_c$	(FT/FT)	0.118		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		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 seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_59.49_4
3.51 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 59.49_4	100	0.4	0.036	10.08

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 59.49_4	822	SHORT GRASS	0.088	2.07	6.63

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
16.72

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 59.49_4	1	OPEN SPACE	0.28	3.10	0.87	0.29
	2	INDUSTRIAL	0.69	0.14	0.10	
	3	FOREST	0.20	0.27	0.05	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	16.72	3.14	3.78	4.28	3.14	3.78	4.28

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.29	3.78	3.51	3.20	3.85	4.36

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_59.49_4		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	3.51		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	3.85		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	13.52		
PROTECTIVE LINING[2,6]		C125		
n (MANNING'S COEFFICIENT)[2]		0.019		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	7.65		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	2.25		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	2.18		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	3.53 / 0		
D (TOTAL DEPTH)	(FT)	1.50		
CHANNEL TOP WIDTH @ D	(FT)	5.30		
d (CALCULATED FLOW DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	3.53		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.77		
R (HYDRAULIC RADIUS)		0.38		
S (BED SLOPE)[3, 7]	(FT/FT)	0.035		
S_C (CRITICAL SLOPE)	(FT/FT)	0.010		
$.7S_c$	(FT/FT)	0.007		
$1.3S_c$	(FT/FT)	0.012		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		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 seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_59.49_5
2.47 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 59.49_5	100	0.4	0.069	8.66

$$T_{c(sheet\ flow)} = \left[\frac{2(\ )(n)}{3(\ )^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 59.49_5	523	SHORT GRASS	0.188	3.02	2.89

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
11.55

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 59.49_5	1	OPEN SPACE	0.28	1.92	0.54	0.28
	2	INDUSTRIAL	0.69	0.08	0.06	
	3	FOREST	0.20	0.47	0.09	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	11.55	3.71	4.42	4.92	3.71	4.42	4.92

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.28	4.42	2.47	2.55	3.03	3.38

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_59.49_5	DS_59.49_5	
TEMPORARY OR PERMANENT?	(T OR P)	T	T	
DESIGN STORM	(2, 5, OR 10 YR)	5	5	
ACRES	(AC)	2.47	2.47	
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A	N/A	
Q_r (REQUIRED CAPACITY)	(CFS)	3.04	3.04	
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	10.18	10.18	
PROTECTIVE LINING[2,6]		P300 (Unvegetated)	P300 (Vegetated)	
n (MANNING'S COEFFICIENT)[2]		0.029	0.029	
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A	N/A	
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	7.49	7.49	
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	3.00	8.00	
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	5.43	5.43	
CHANNEL BOTTOM WIDTH	(FT)	0	0	
CHANNEL SIDE SLOPES	(H:V)	2.72 / 0	2.72 / 0	
D (TOTAL DEPTH)	(FT)	1.50	1.50	
CHANNEL TOP WIDTH @ D	(FT)	4.08	4.08	
d (CALCULATED FLOW DEPTH)	(FT)	1.00	1.00	
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	2.72	2.72	
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0	0	
d_{50} STONE SIZE	(IN)	N/A	N/A	
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.36	1.36	
R (HYDRAULIC RADIUS)		0.35	0.35	
S (BED SLOPE)[3, 7]	(FT/FT)	0.087	0.087	
S_C (CRITICAL SLOPE)	(FT/FT)	0.025	0.025	
$.7S_c$	(FT/FT)	0.017	0.017	
$1.3S_c$	(FT/FT)	0.032	0.032	
STABLE FLOW?	(Y/N)	Y	Y	
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A	N/A	
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50	0.50	
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50	0.50	
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S	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 seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_59.49_6
4.96 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 59.49_6	100	0.4	0.028	10.69

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 59.49_6	262	SHORT GRASS	0.023	1.06	4.14
	159	PAVEMENT	0.013	2.32	1.14
	483	SHORT GRASS	0.130	2.51	3.21
	119	FOREST	0.328	1.44	1.38

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c* (minutes)
20.56

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 59.49_6	1	OPEN SPACE	0.28	3.59	1.01	0.34
	2	INDUSTRIAL	0.69	0.84	0.58	
	3	FOREST	0.20	0.53	0.11	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	20.56	2.82	3.41	3.90	2.82	3.41	3.90

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.34	3.41	4.96	4.77	5.77	6.60

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/2019
CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_59.49_6		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	4.96		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	5.77		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	10.68		
PROTECTIVE LINING[2,6]		C125		
n (MANNING'S COEFFICIENT)[2]		0.019		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	6.71		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	2.25		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	1.75		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	3.18 / 0		
D (TOTAL DEPTH)	(FT)	1.50		
CHANNEL TOP WIDTH @ D	(FT)	4.78		
d (CALCULATED FLOW DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	3.18		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.59		
R (HYDRAULIC RADIUS)		0.37		
S (BED SLOPE)[3, 7]	(FT/FT)	0.028		
S_C (CRITICAL SLOPE)	(FT/FT)	0.010		
$.7S_c$	(FT/FT)	0.007		
$1.3S_c$	(FT/FT)	0.013		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		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 seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_59.49_7
2.56 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 59.49_7	100	0.02	0.010	3.35

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 59.49_7	44	PAVEMENT	0.023	3.08	0.24
	485	SHORT GRASS	0.078	1.94	4.16
	74	FOREST	0.311	1.40	0.88

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c* (minutes)
8.63

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 59.49_7	1	OPEN SPACE	0.28	1.78	0.50	0.28
	2	INDUSTRIAL	0.69	0.15	0.10	
	3	FOREST	0.20	0.63	0.13	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	8.63	4.14	4.89	5.37	4.14	4.89	5.37

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.28	4.89	2.56	3.01	3.56	3.91

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_59.49_7	DS_59.49_7	
TEMPORARY OR PERMANENT?	(T OR P)	T	T	
DESIGN STORM	(2, 5, OR 10 YR)	5	5	
ACRES	(AC)	2.56	2.56	
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A	N/A	
Q_r (REQUIRED CAPACITY)	(CFS)	3.56	3.56	
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	11.63	11.63	
PROTECTIVE LINING[2,6]		SC250 (Unvegetated)	SC250 (Vegetated)	
n (MANNING'S COEFFICIENT)[2]		0.031	0.031	
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A	N/A	
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	8.72	8.72	
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	3.00	10.00	
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	8.49	8.49	
CHANNEL BOTTOM WIDTH	(FT)	0	0	
CHANNEL SIDE SLOPES	(H:V)	2.67 / 0	2.67 / 0	
D (TOTAL DEPTH)	(FT)	1.50	1.50	
CHANNEL TOP WIDTH @ D	(FT)	4.00	4.00	
d (CALCULATED FLOW DEPTH)	(FT)	1.00	1.00	
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	2.67	2.67	
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0	0	
d_{50} STONE SIZE	(IN)	N/A	N/A	
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.33	1.33	
R (HYDRAULIC RADIUS)		0.35	0.35	
S (BED SLOPE)[3, 7]	(FT/FT)	0.136	0.136	
S_C (CRITICAL SLOPE)	(FT/FT)	0.029	0.029	
$.7S_c$	(FT/FT)	0.020	0.020	
$1.3S_c$	(FT/FT)	0.037	0.037	
STABLE FLOW?	(Y/N)	Y	Y	
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A	N/A	
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50	0.50	
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50	0.50	
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S	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 seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_59.49_8
1.65 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 59.49_8	100	0.4	0.020	11.57

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 59.49_8	478	SHORT GRASS	0.084	2.02	3.95

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
15.52

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 59.49_8	1	OPEN SPACE	0.28	1.23	0.34	0.27
	2	INDUSTRIAL	0.69	0.05	0.03	
	3	FOREST	0.20	0.37	0.07	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	15.52	3.26	3.91	4.41	3.26	3.91	4.41

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.27	3.91	1.65	1.48	1.77	2.00

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_59.49_8		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	1.65		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	1.77		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	2.17		
PROTECTIVE LINING[2,6]		C125		
n (MANNING'S COEFFICIENT)[2]		0.022		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	5.21		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	2.25		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	1.75		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	3.33 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	3.33		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	1.67		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	0.42		
R (HYDRAULIC RADIUS)		0.19		
S (BED SLOPE)[3, 7]	(FT/FT)	0.056		
S_C (CRITICAL SLOPE)	(FT/FT)	0.017		
$.7S_c$	(FT/FT)	0.012		
$1.3S_c$	(FT/FT)	0.022		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

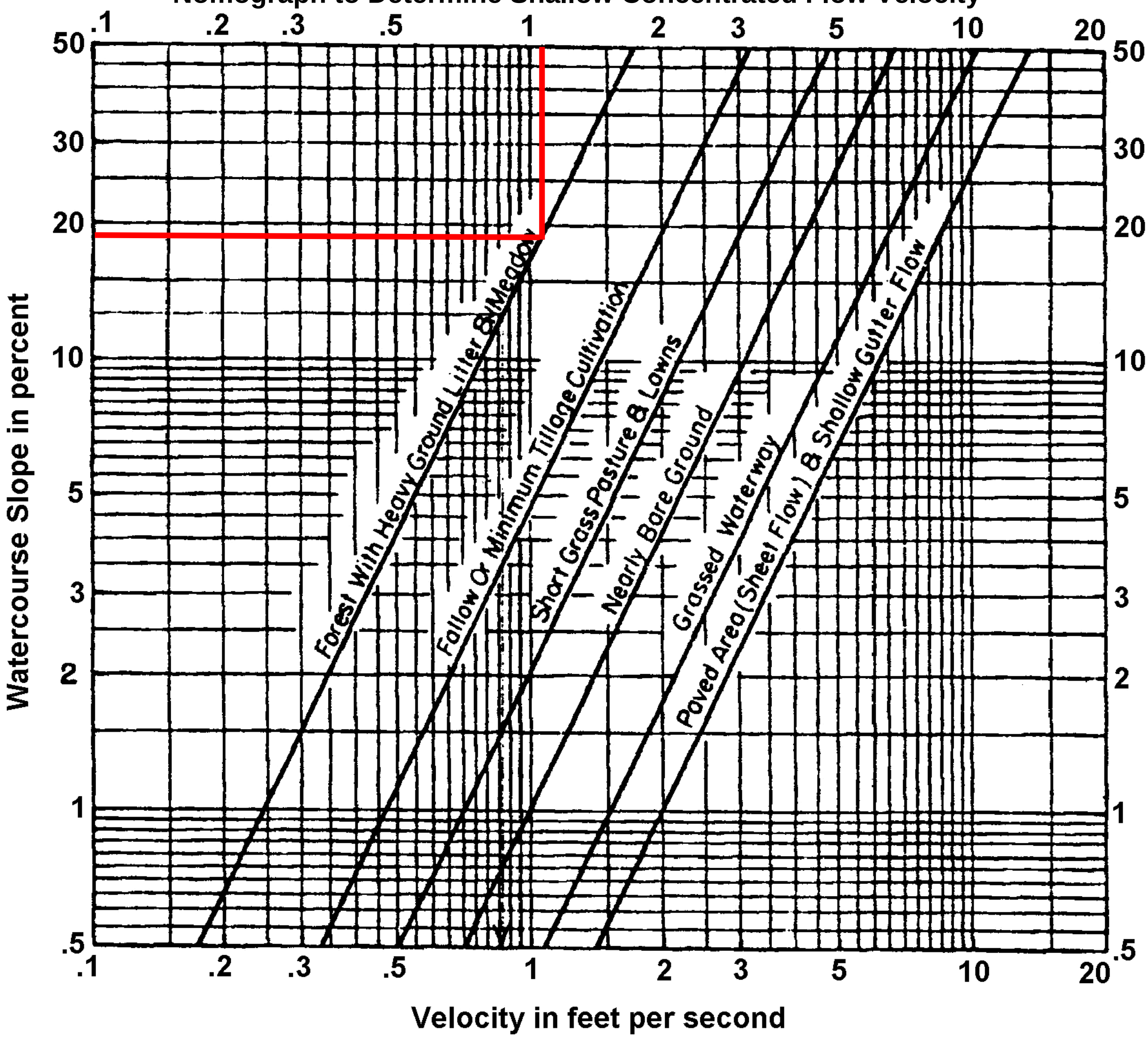
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_59.49_8

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = FOREST
PERCENT SLOPE = 19%

SHALLOW CONCENTRATED FLOW VELOCITY = 1.1 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 2 FPS FOR FORESTED/MULCH COVER TYPES.

1.1 FPS < 2.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_59.49_9
3.45 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 59.49_9	100	0.4	0.040	9.84

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 59.49_9	1050	SHORT GRASS	0.076	1.92	9.12

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
18.96

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 59.49_9	1	OPEN SPACE	0.28	2.70	0.76	0.28
	2	INDUSTRIAL	0.69	0.10	0.07	
	3	FOREST	0.20	0.65	0.13	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	18.96	2.95	3.56	4.05	2.95	3.56	4.05

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.28	3.56	3.45	2.82	3.40	3.87

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_59.49_9		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	3.45		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	3.4		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	4.22		
PROTECTIVE LINING[2,6]		C125		
n (MANNING'S COEFFICIENT)[2]		0.022		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	5.67		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	2.25		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	1.75		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	5.95 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	5.95		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	2.98		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	0.74		
R (HYDRAULIC RADIUS)		0.21		
S (BED SLOPE)[3, 7]	(FT/FT)	0.056		
S_C (CRITICAL SLOPE)	(FT/FT)	0.014		
$.7S_c$	(FT/FT)	0.010		
$1.3S_c$	(FT/FT)	0.018		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

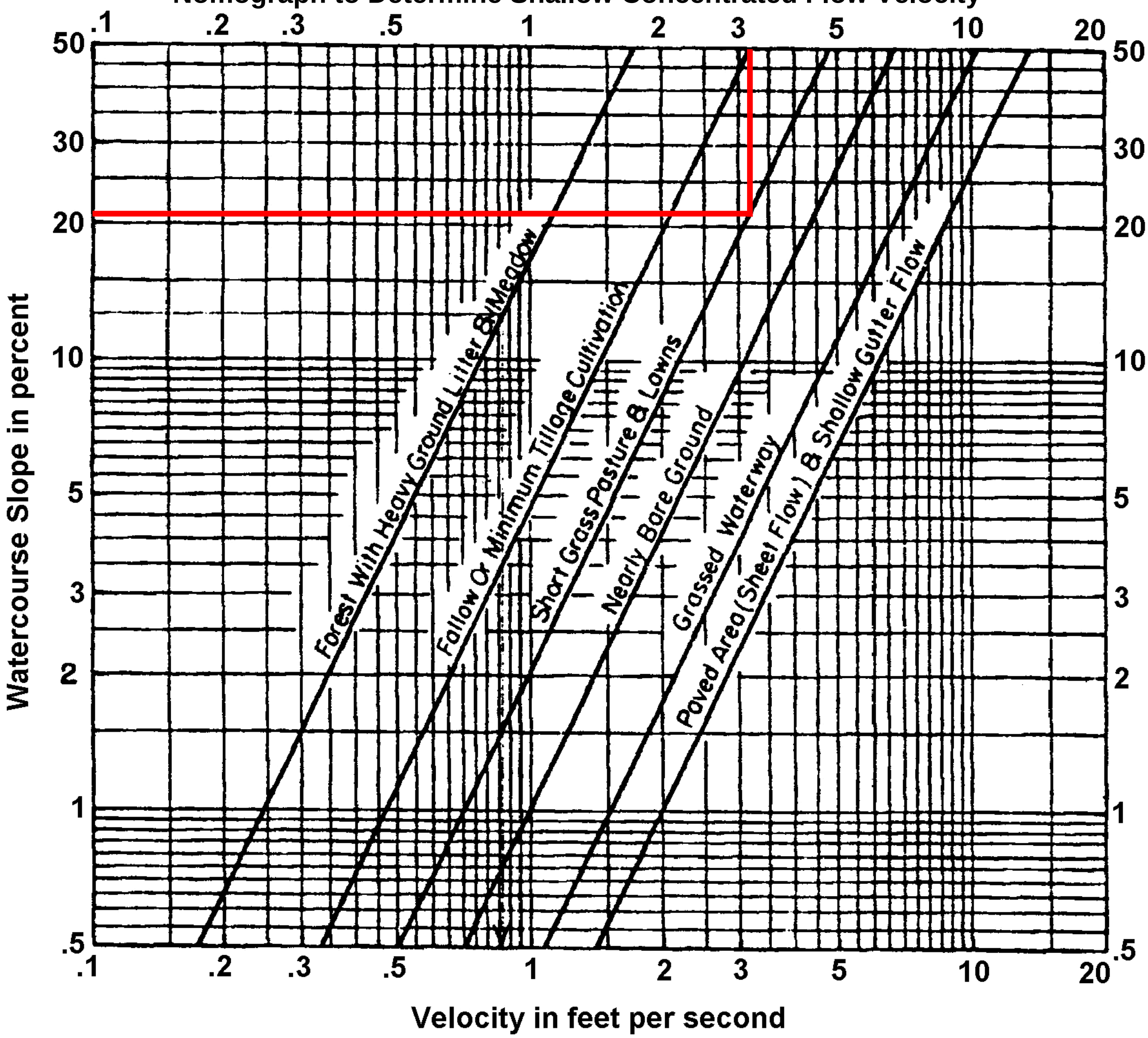
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_59.49_9

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 21%

SHALLOW CONCENTRATED FLOW VELOCITY = 3.1 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

3.1 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_59.49_10
4.77 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 59.49_10	100	0.4	0.105	7.85

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 59.49_10	1102	SHORT GRASS	0.041	1.41	13.03

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
20.88

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 59.49_10	1	OPEN SPACE	0.28	4.02	1.13	0.29
	2	INDUSTRIAL	0.69	0.24	0.17	
	3	FOREST	0.20	0.51	0.10	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	20.88	2.80	3.38	3.87	2.80	3.38	3.87

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.29	3.38	4.77	3.90	4.72	5.40

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/2019
CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_59.49_10		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	4.77		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	4.72		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	9.39		
PROTECTIVE LINING[2,6]		S75		
n (MANNING'S COEFFICIENT)[2]		0.044		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	2.54		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.55		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	1.06		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	7.41 / 0		
D (TOTAL DEPTH)	(FT)	1.50		
CHANNEL TOP WIDTH @ D	(FT)	11.11		
d (CALCULATED FLOW DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	7.41		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	3.70		
R (HYDRAULIC RADIUS)		0.44		
S (BED SLOPE)[3, 7]	(FT/FT)	0.017		
S_C (CRITICAL SLOPE)	(FT/FT)	0.042		
$.7S_c$	(FT/FT)	0.030		
$1.3S_c$	(FT/FT)	0.055		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

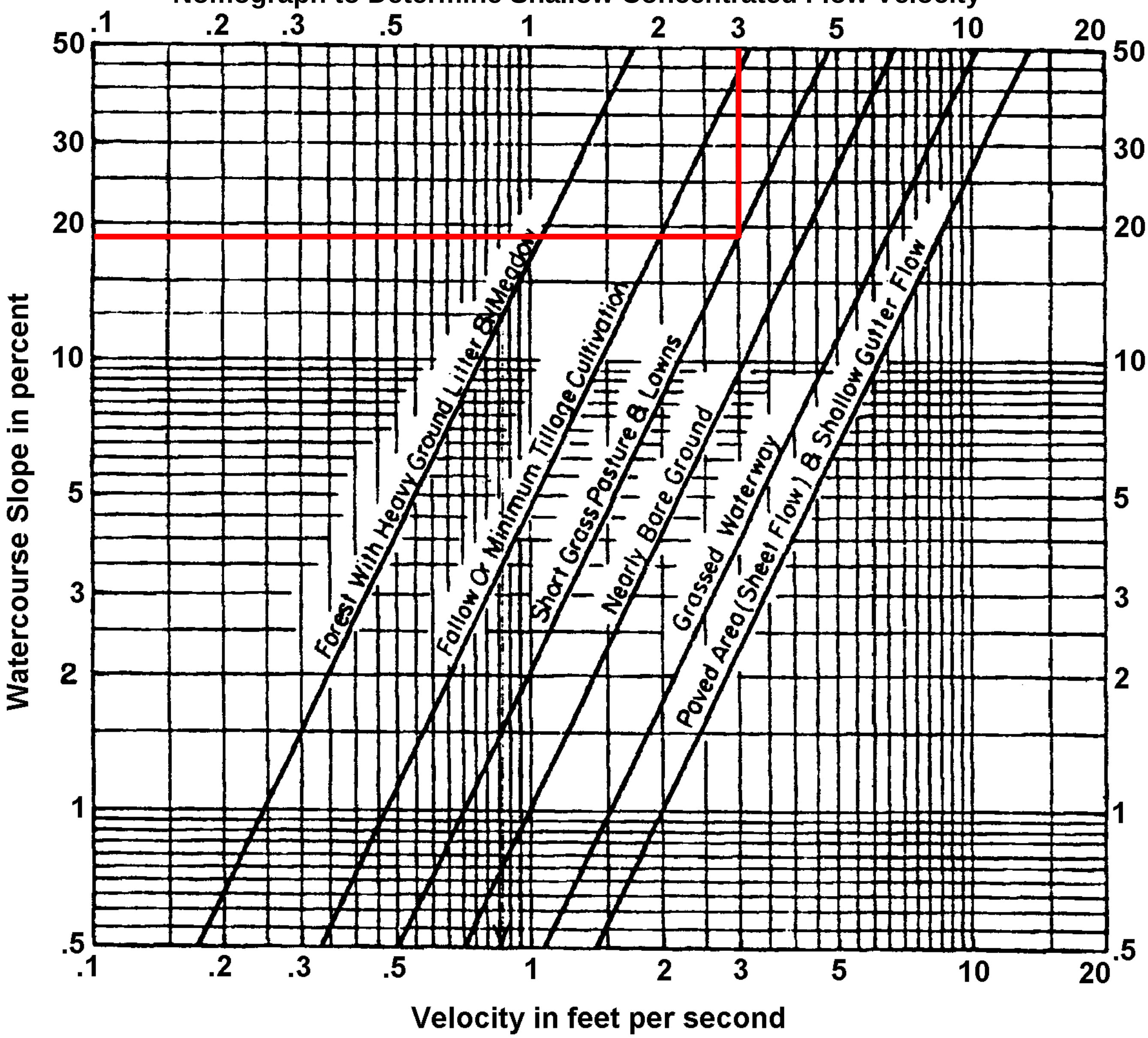
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_59.49_10

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 19%

SHALLOW CONCENTRATED FLOW VELOCITY = 3.0 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

3.0 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_59.49_11
3.91 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 59.49_11	100	0.4	0.070	8.63

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 59.49_11	1218	SHORT GRASS	0.045	1.48	13.75

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
22.38

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 59.49_11	1	OPEN SPACE	0.21	1.80	0.38	0.29
	2	INDUSTRIAL	0.69	0.07	0.05	
	3	FOREST	0.20	0.46	0.09	
	4	PASTURE	0.40	1.58	0.63	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	22.38	2.69	3.26	3.75	2.69	3.26	3.75

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.29	3.26	3.91	3.10	3.75	4.31

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_59.49_11		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	3.91		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	3.75		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	6.70		
PROTECTIVE LINING[2,6]		C125		
n (MANNING'S COEFFICIENT)[2]		0.022		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	5.10		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	2.25		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	1.28		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	10.53 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	10.53		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	5.26		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.32		
R (HYDRAULIC RADIUS)		0.23		
S (BED SLOPE)[3, 7]	(FT/FT)	0.041		
S_C (CRITICAL SLOPE)	(FT/FT)	0.013		
$.7S_c$	(FT/FT)	0.009		
$1.3S_c$	(FT/FT)	0.017		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

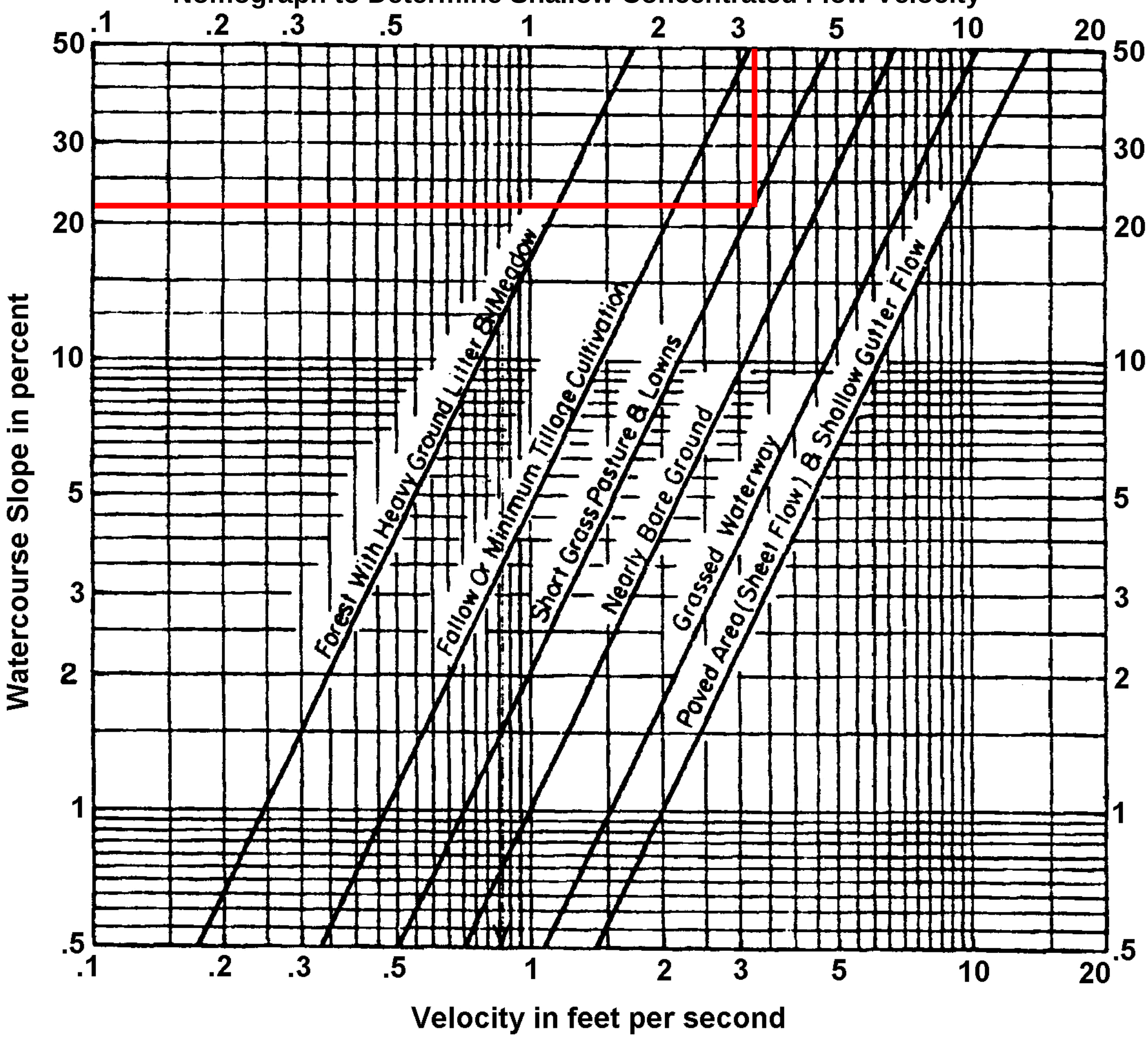
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_59.49_11

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 22%

SHALLOW CONCENTRATED FLOW VELOCITY = 3.1 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

3.1 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.

LEGEND

- 1R — MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT
CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_62.00
NORTHAMPTON COUNTY, PENNSYLVANIA

0 100 200 FEET

PennEast PIPELINE

DRAWN BY:	SNP 10/2018	APPROVED BY:	MJD 10/2019	SCALE:	1 INCH = 200 FEET
CHECKED BY:	JMB 10/2019	REV. DATE:	10/2019	REV.:	1

DWG NO: PAGE 83 OF 114

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME:	PENNEAST PIPELINE PROJECT		
LOCATION:	NORTHAMPTON COUNTY		
PREPARED BY:	MDN	DATE:	10/15/2018
CHECKED BY:	KEK / JMB	DATE:	10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 62.00	100	0.4	0.060	8.95

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 62.00	1305	SHORT GRASS	0.084	2.02	10.78

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
19.73

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 62.00	1	OPEN SPACE	0.28	0.33	0.09	0.49
	2	INDUSTRIAL	0.69	0.30	0.21	
	3	PASTURE	0.50	0.91	0.46	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	19.73	2.89	3.49	3.98	2.89	3.49	3.98

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.49	3.49	1.54	2.18	2.63	3.00

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

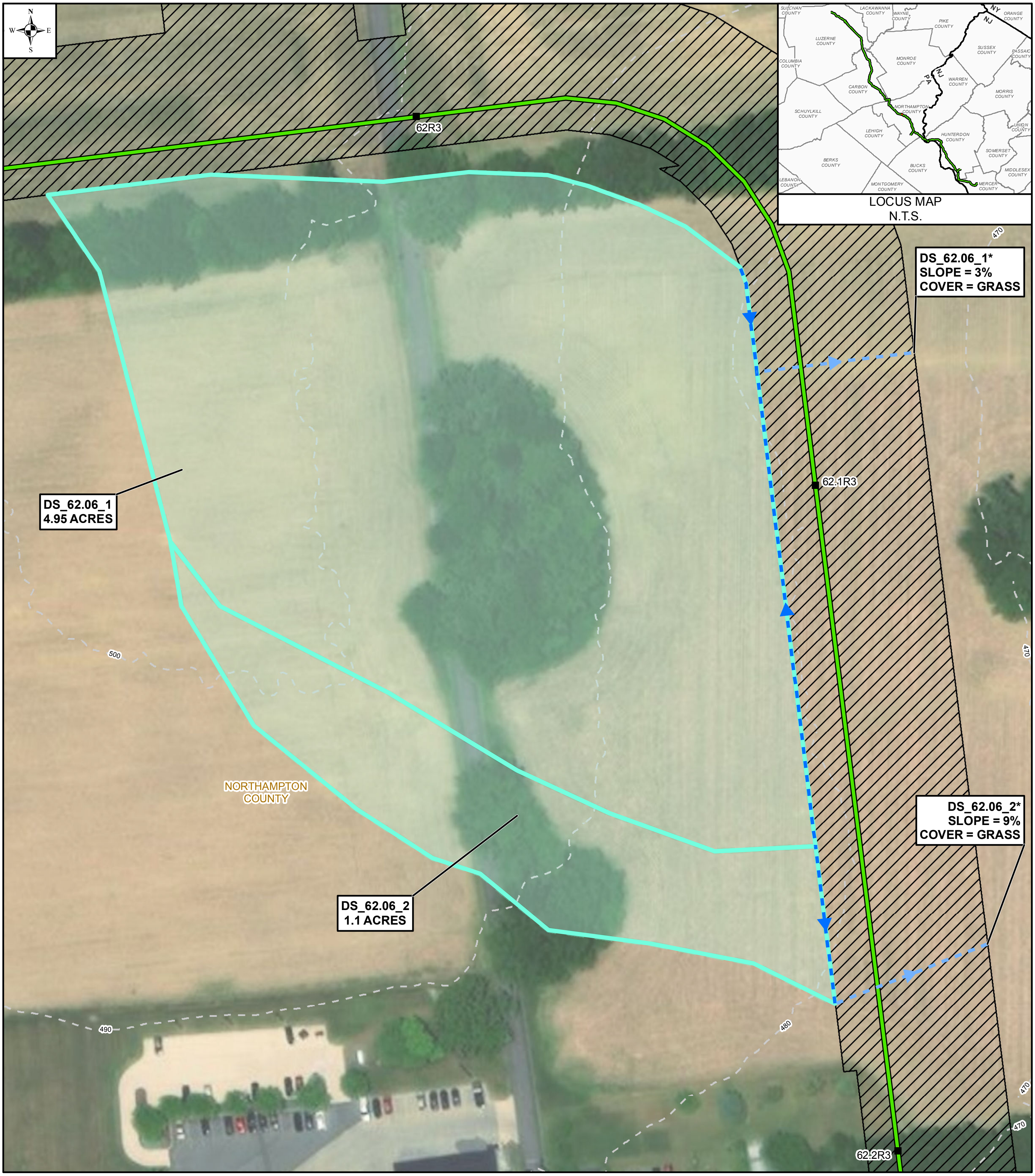
LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_62.00		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	1.54		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	2.63		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	3.18		
PROTECTIVE LINING[2,6]		S75		
n (MANNING'S COEFFICIENT)[2]		0.055		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	1.98		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.55		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	1.19		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	12.82 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	12.82		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	6.41		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.60		
R (HYDRAULIC RADIUS)		0.23		
S (BED SLOPE)[3, 7]	(FT/FT)	0.038		
S_C (CRITICAL SLOPE)	(FT/FT)	0.078		
$.7S_c$	(FT/FT)	0.054		
$1.3S_c$	(FT/FT)	0.101		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		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 seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.



LEGEND

- 1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT

CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_62.06

NORTHAMPTON COUNTY, PENNSYLVANIA

0 50 100 FEET

PennEast PIPELINE

DRAWN BY:	SNP 10/2018	APPROVED BY:	MJD 10/2019	SCALE:	1 INCH = 100 FEET
CHECKED BY:	JMB 10/2019	REV. DATE:	10/2019	REV.:	1

DWG NO: PAGE 84 OF 114

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_62.06_1
4.95 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 62.06_1	100	0.4	0.010	13.60

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 62.06_1	722	SHORT GRASS	0.030	1.21	9.98

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c* (minutes)
23.58

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 62.06_1	1	OPEN SPACE	0.21	3.82	0.80	0.27
	2	INDUSTRIAL	0.69	0.28	0.19	
	3	PASTURE	0.40	0.85	0.34	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	23.58	2.61	3.17	3.65	2.61	3.17	3.65

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.27	3.17	4.95	3.49	4.23	4.87

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_62.06_1		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	4.95		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	4.23		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	6.49		
PROTECTIVE LINING[2,6]		C125		
n (MANNING'S COEFFICIENT)[2]		0.022		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	3.95		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	2.25		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	0.75		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	13.16 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	13.16		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	6.58		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.64		
R (HYDRAULIC RADIUS)		0.23		
S (BED SLOPE)[3, 7]	(FT/FT)	0.024		
S_C (CRITICAL SLOPE)	(FT/FT)	0.012		
$.7S_c$	(FT/FT)	0.009		
$1.3S_c$	(FT/FT)	0.016		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

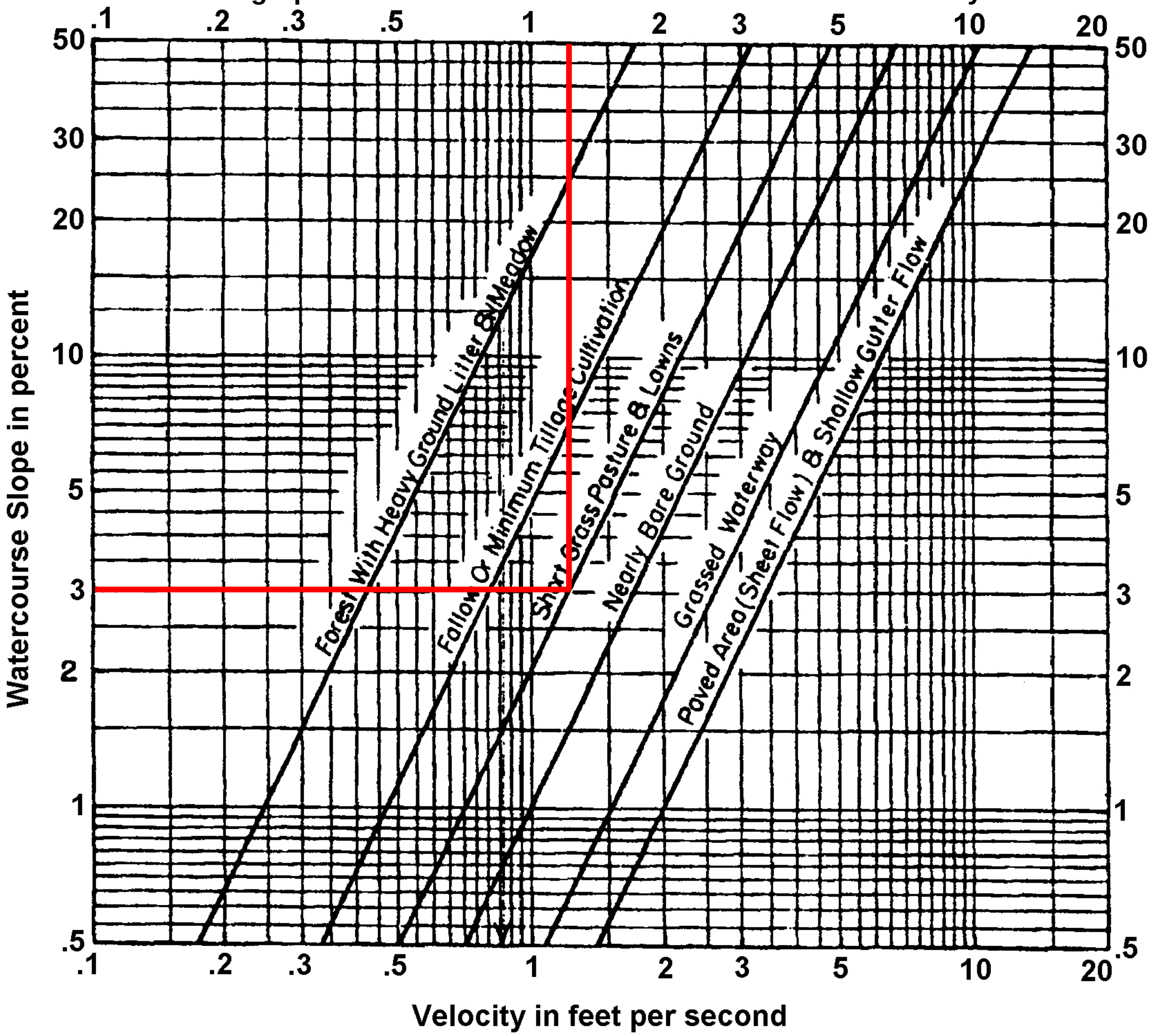
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_62.06_1

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 3%

SHALLOW CONCENTRATED FLOW VELOCITY = 1.3 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

1.3 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_62.06_2
1.1 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 62.06_2	100	0.4	0.026	10.88

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 62.06_2	581	SHORT GRASS	0.037	1.34	7.23

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
18.11

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 62.06_2	1	OPEN SPACE	0.21	0.87	0.18	0.23
	2	INDUSTRIAL	0.69	0.06	0.04	
	3	FOREST	0.16	0.17	0.03	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	18.11	3.02	3.64	4.13	3.02	3.64	4.13

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.23	3.64	1.10	0.76	0.91	1.04

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_62.06_2		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	1.1		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	0.91		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	3.61		
PROTECTIVE LINING[2,6]		EXISTING GRASS		
n (MANNING'S COEFFICIENT)[2]		0.07		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	1.04		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.00		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	0.50		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	27.78 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	27.78		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	13.89		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	3.47		
R (HYDRAULIC RADIUS)		0.24		
S (BED SLOPE)[3, 7]	(FT/FT)	0.016		
S_C (CRITICAL SLOPE)	(FT/FT)	0.119		
$.7S_c$	(FT/FT)	0.083		
$1.3S_c$	(FT/FT)	0.154		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

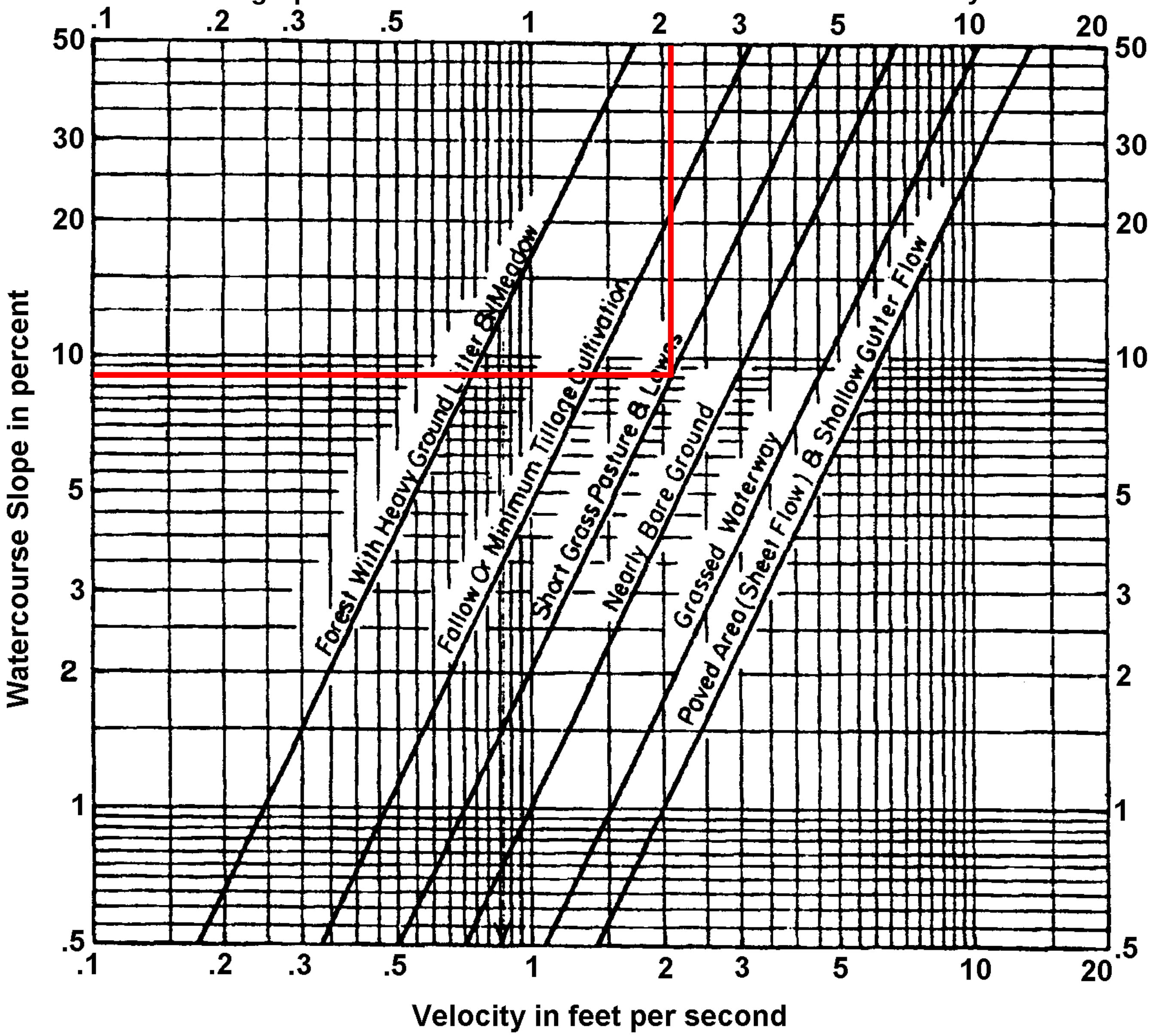
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_62.06_2

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity

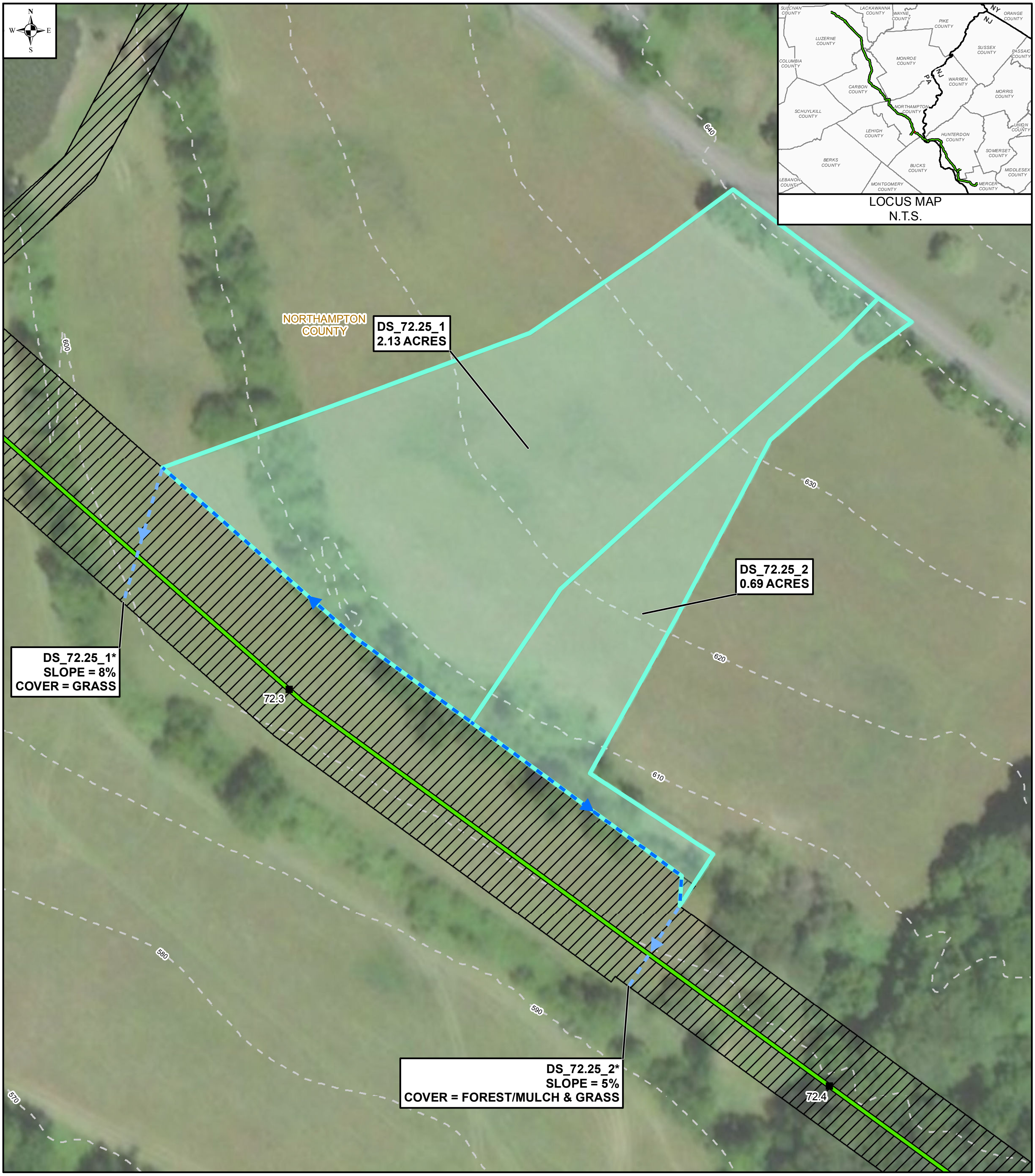


TR-55

DOWNSLOPE CONDITION
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 9%

SHALLOW CONCENTRATED FLOW VELOCITY = 2.1 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

2.1 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.



LEGEND

- 1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT

CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_72.25

NORTHAMPTON COUNTY, PENNSYLVANIA

0 50 100 FEET

PennEast PIPELINE

DRAWN BY:	SNP 10/2018	APPROVED BY:	MJD 10/2019	SCALE:	1 INCH = 100 FEET
CHECKED BY:	JMB 10/2019	REV. DATE:	10/2019	REV.:	1

DWG NO: PAGE 85 OF 114

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_72.25_1
2.13 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 72.25_1	100	0.4	0.080	8.37

$$T_{c(sheet\ flow)} = \left[\frac{2L(n)}{3S^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 72.25_1	406	SHORT GRASS	0.066	1.79	3.78

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
12.15

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 72.25_1	1	OPEN SPACE	0.28	2.13	0.60	0.28

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	12.15	3.64	4.33	4.84	3.64	4.33	4.84

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.28	4.33	2.13	2.17	2.58	2.88

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_72.25_1		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	2		
ACRES	(AC)	2.13		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	2.169		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	2.26		
PROTECTIVE LINING[2,6]		SC150		
n (MANNING'S COEFFICIENT)[2]		0.05		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	1.28		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	2.00		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	0.41		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	14.08 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	14.08		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	7.04		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.76		
R (HYDRAULIC RADIUS)		0.23		
S (BED SLOPE)[3, 7]	(FT/FT)	0.013		
S_C (CRITICAL SLOPE)	(FT/FT)	0.064		
$.7S_c$	(FT/FT)	0.044		
$1.3S_c$	(FT/FT)	0.083		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

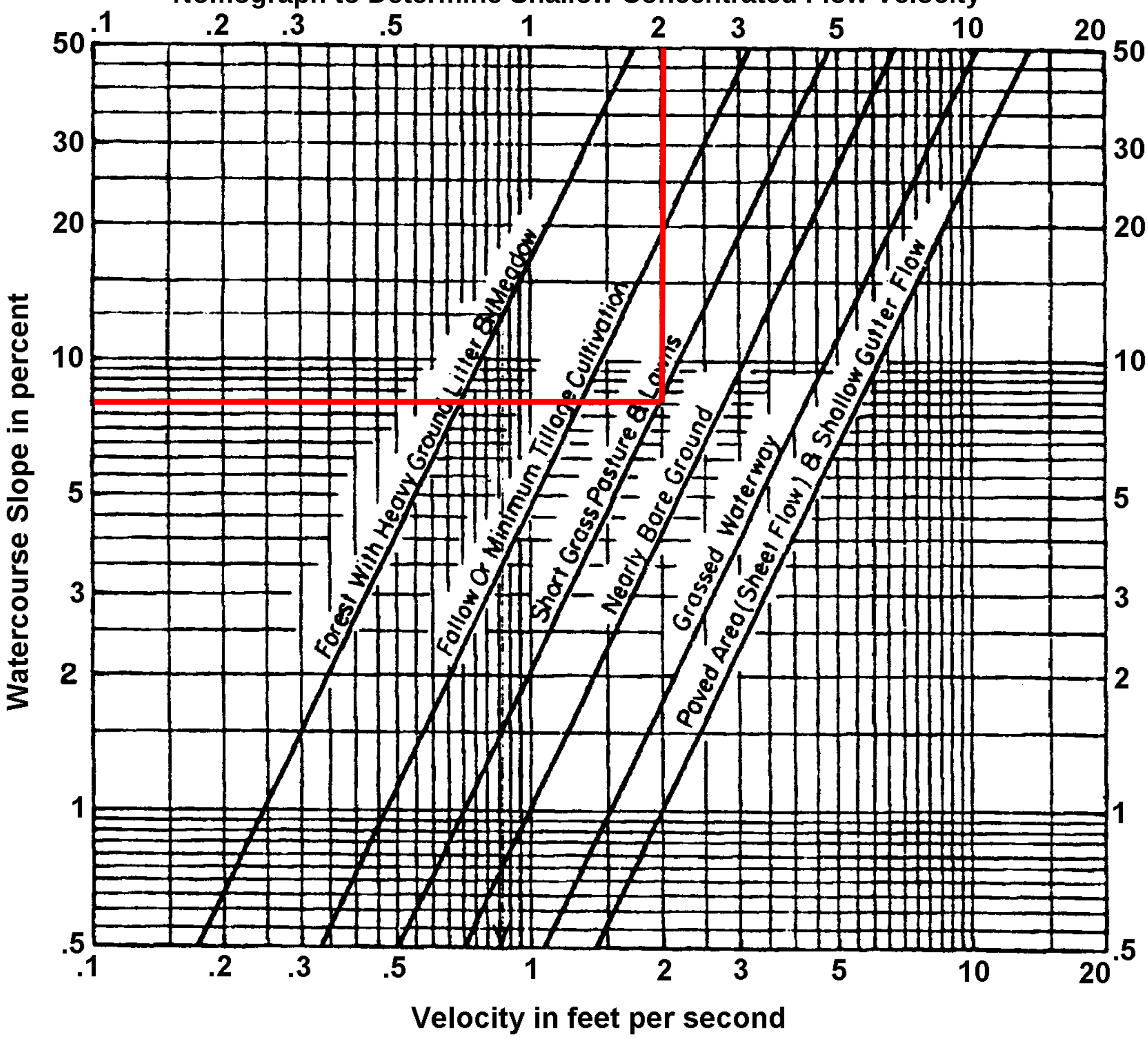
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_72.25_1

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 8%

SHALLOW CONCENTRATED FLOW VELOCITY = 2.0 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

2.0 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_72.25_2
0.69 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 72.25_2	25	0.4	0.160	3.72

$$T_{c\,(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 72.25_2	441	SHORT GRASS	0.068	1.82	4.05

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
7.77

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 72.25_2	1	OPEN SPACE	0.28	0.50	0.14	0.26
	2	FOREST	0.20	0.19	0.04	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	7.77	4.28	5.04	5.52	4.28	5.04	5.52

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.26	5.04	0.69	0.76	0.90	0.98

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_72.25_2		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	2		
ACRES	(AC)	0.69		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	0.9		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	1.84		
PROTECTIVE LINING[2,6]		EXISTING GRASS		
n (MANNING'S COEFFICIENT)[2]		0.07		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	1.23		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.00		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	0.75		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	11.9 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	11.90		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	5.95		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.49		
R (HYDRAULIC RADIUS)		0.23		
S (BED SLOPE)[3, 7]	(FT/FT)	0.024		
S_C (CRITICAL SLOPE)	(FT/FT)	0.127		
$.7S_c$	(FT/FT)	0.089		
$1.3S_c$	(FT/FT)	0.165		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

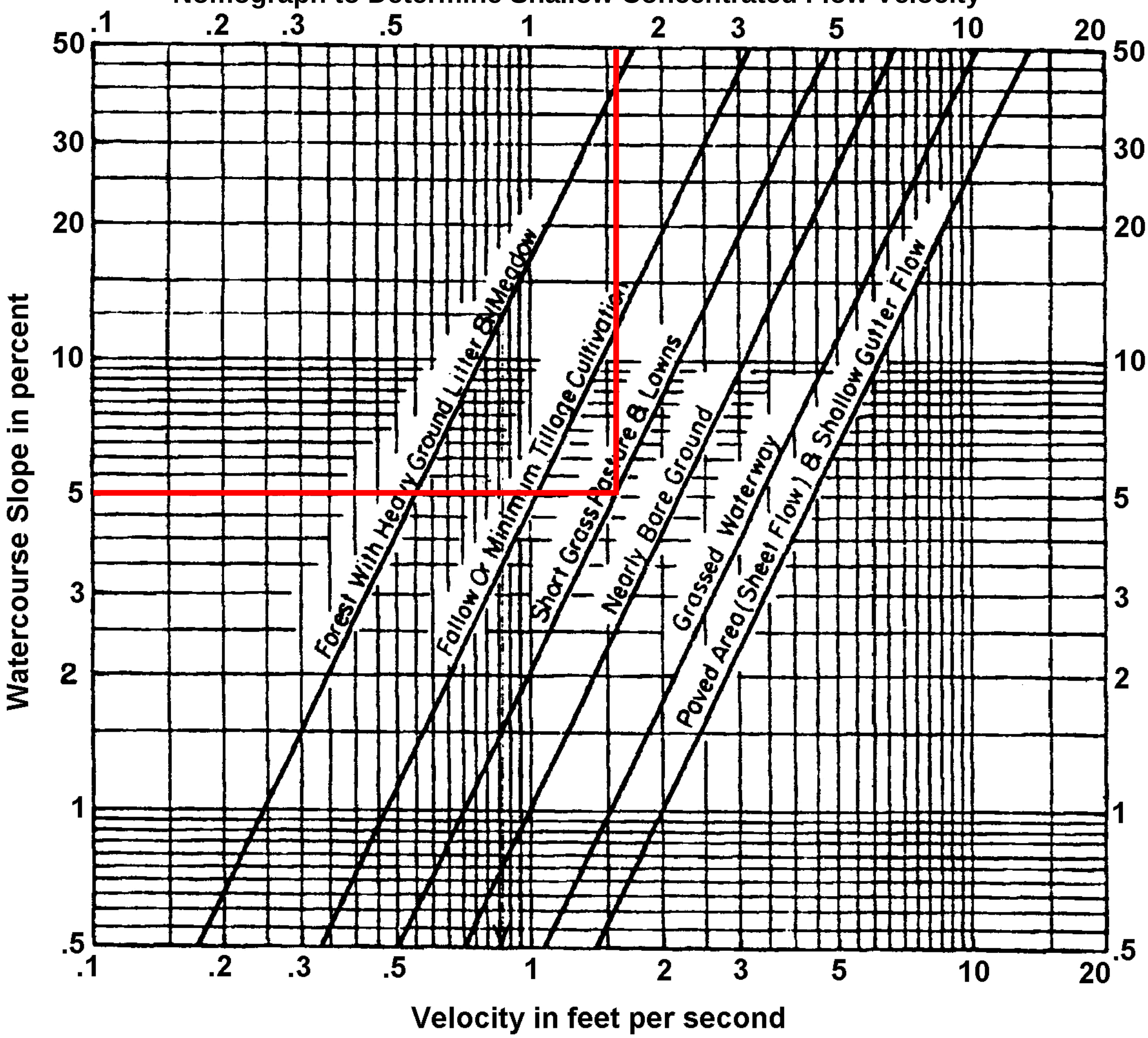
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_72.25_2

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 5%

SHALLOW CONCENTRATED FLOW VELOCITY = 1.6 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

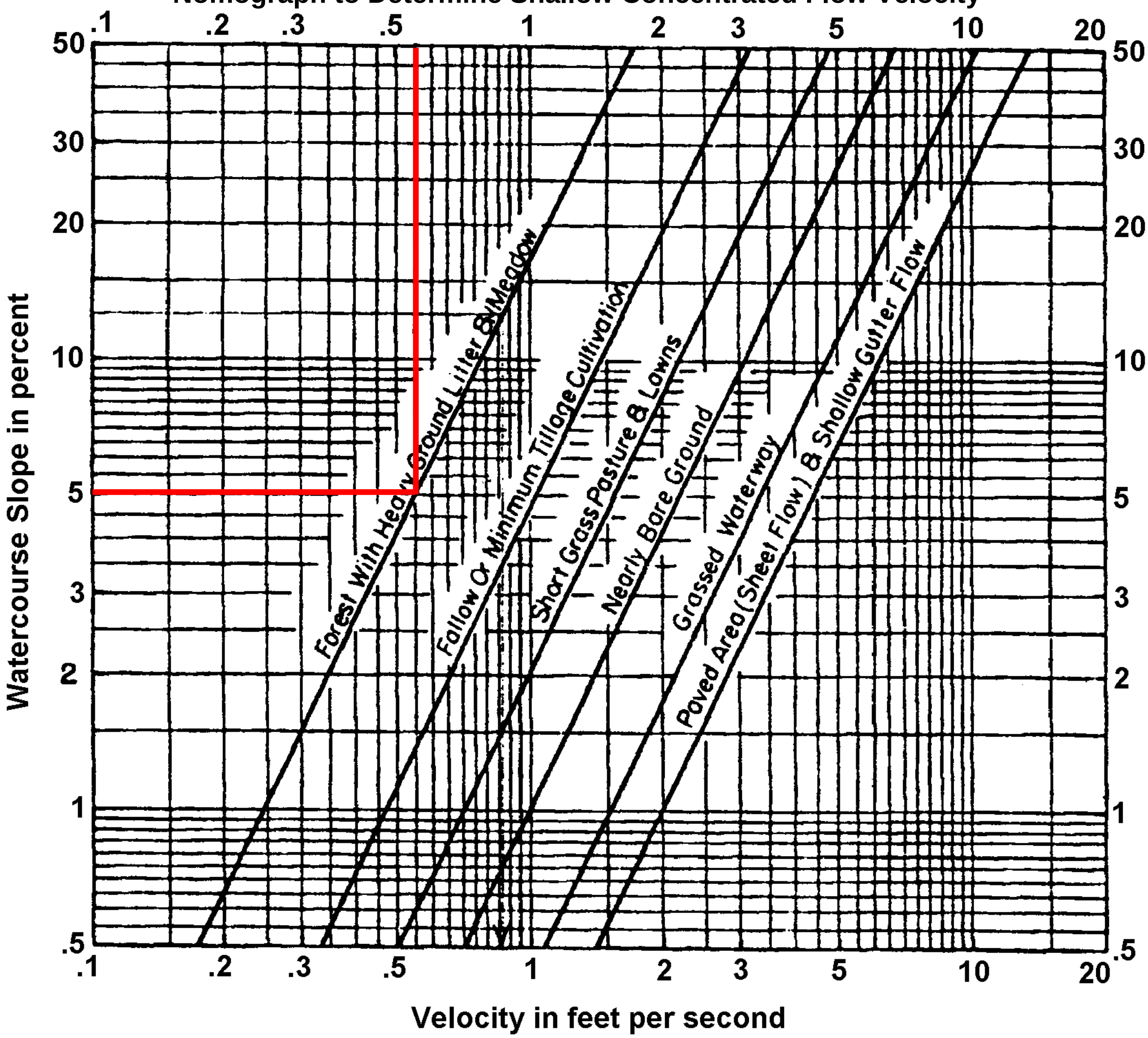
1.6 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.

CLEAN WATER DIVERSION ID:
DS_72.25_2

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity

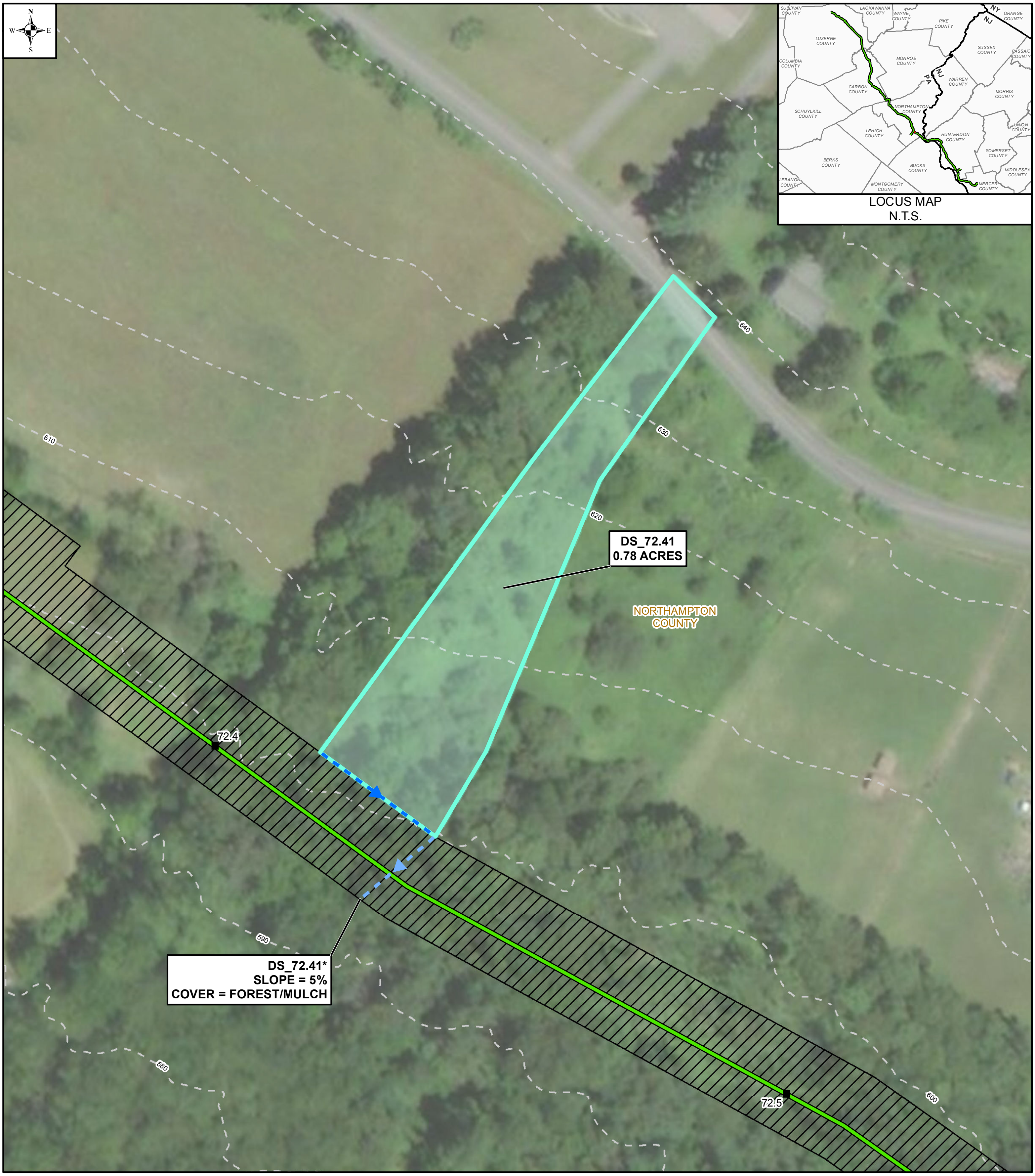


TR-55

DOWNSLOPE CONDITION
COVER TYPE = FOREST
PERCENT SLOPE = 5%

SHALLOW CONCENTRATED FLOW VELOCITY = 0.6 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 2 FPS FOR FORESTED/MULCH COVER TYPES.

0.6 FPS < 2.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.



LEGEND

1R	MILE POST (STATION EQUATON DUE TO RE-ROUTE)
	PROPOSED PENNEAST PIPELINE
	BLUE MOUNTAIN LATERAL
	HELLERTOWN LATERAL
	DIVERSION SOCK
	SLOPE PIPE
	DRAINAGE AREA
	PROPOSED CONSTRUCTION WORKSPACE
	INDEX CONTOUR
	COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT

CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_72.41

NORTHAMPTON COUNTY, PENNSYLVANIA

0 50 100 FEET

PennEast PIPELINE

DRAWN BY: SNP 10/2018	APPROVED BY: MJD 10/2019	SCALE: 1 INCH = 100 FEET	
CHECKED BY: JMB 10/2019	REV. DATE: 10/2019	REV.: 1	DWG NO: PAGE 86 OF 114

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME:	PENNEAST PIPELINE PROJECT
LOCATION:	NORTHAMPTON COUNTY
PREPARED BY:	MDN
DATE:	10/15/2018
CHECKED BY:	KEK / JMB
DATE:	10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 72.41	21	0.02	0.048	1.12

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 72.41	319	SHORT GRASS	0.094	2.13	2.49
	126	FOREST	0.063	0.63	3.33

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c* (minutes)
6.94

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 72.41	1	OPEN SPACE	0.28	0.21	0.06	0.23
	2	INDUSTRIAL	0.69	0.02	0.01	
	3	FOREST	0.20	0.55	0.11	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	6.94	4.43	5.20	5.68	4.43	5.20	5.68

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.23	5.20	0.78	0.81	0.95	1.04

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_72.41		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	2		
ACRES	(AC)	0.78		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	0.81		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	2.97		
PROTECTIVE LINING[2,6]		EXISTING GRASS		
n (MANNING'S COEFFICIENT)[2]		0.06		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	1.52		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.00		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	0.81		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	15.63 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	15.63		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	7.81		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.95		
R (HYDRAULIC RADIUS)		0.23		
S (BED SLOPE)[3, 7]	(FT/FT)	0.026		
S_C (CRITICAL SLOPE)	(FT/FT)	0.091		
$.7S_c$	(FT/FT)	0.063		
$1.3S_c$	(FT/FT)	0.118		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

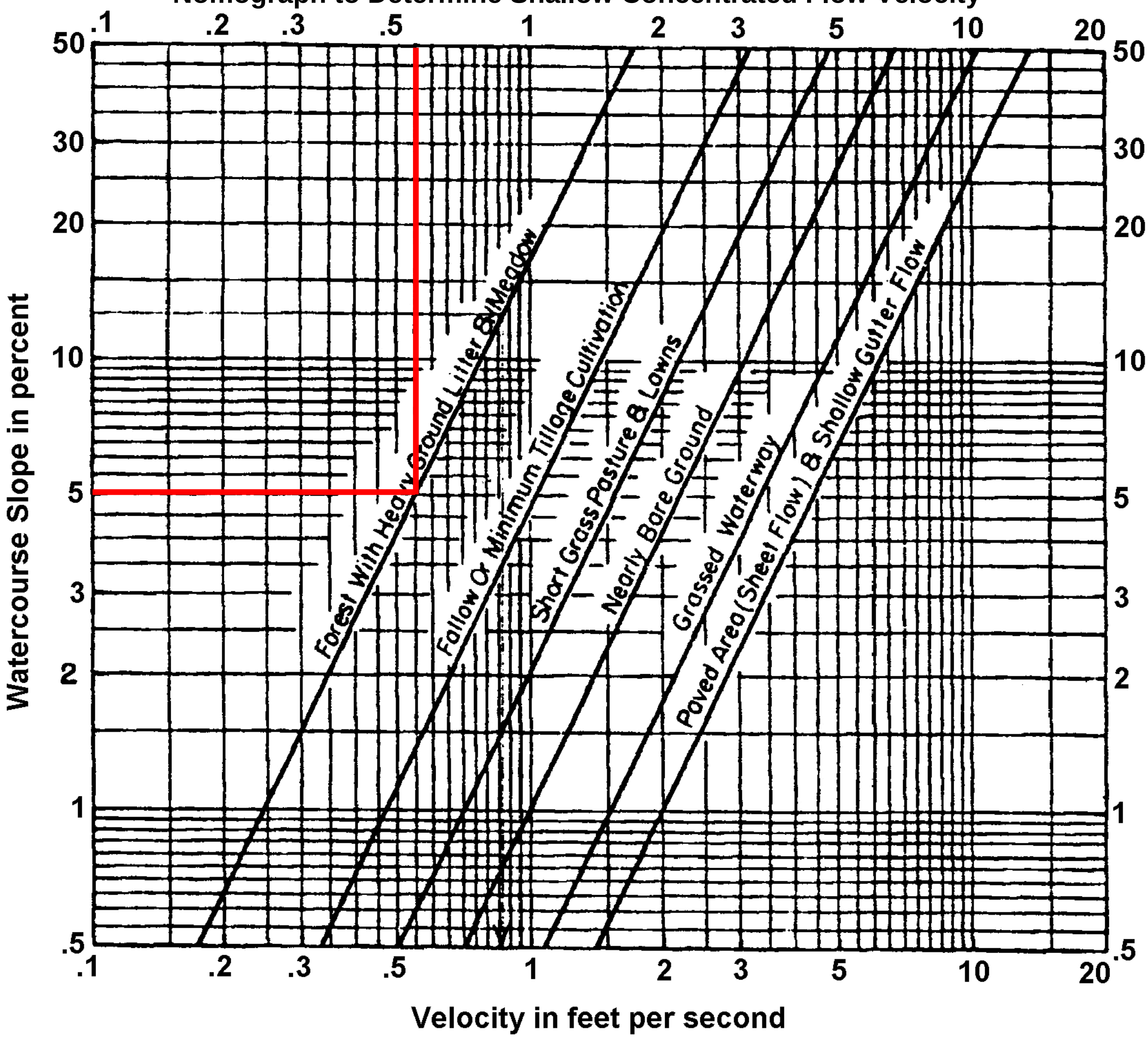
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_72.41

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = FOREST
PERCENT SLOPE = 5%

SHALLOW CONCENTRATED FLOW VELOCITY = 0.6 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 2 FPS FOR FORESTED/MULCH COVER TYPES.

0.6 FPS < 2.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.

LEGEND

- 1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT
CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_72.46
NORTHAMPTON COUNTY, PENNSYLVANIA

0 50 100 FEET

DRAWN BY:	SNP 10/2018	APPROVED BY:	MJD 10/2019	SCALE:	1 INCH = 100 FEET
CHECKED BY:	JMB 10/2019	REV. DATE:	10/2019	REV.:	1

PennEast PIPELINE

DWG NO: PAGE 87 OF 114

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 72.46	100	0.4	0.125	7.54

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 72.46	151	SHORT GRASS	0.058	1.68	1.50
	81	PAVEMENT	0.040	4.07	0.33
	118	SHORT GRASS	0.127	2.48	0.79
	77	FOREST	0.156	0.99	1.29

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
11.46

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 72.46	1	OPEN SPACE	0.28	2.26	0.63	0.31
	2	INDUSTRIAL	0.69	0.30	0.21	
	3	FOREST	0.20	0.50	0.10	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	11.46	3.72	4.43	4.93	3.72	4.43	4.93

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.31	4.43	3.06	3.50	4.17	4.64

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_72.46		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	2		
ACRES	(AC)	3.06		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	4.17		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	4.54		
PROTECTIVE LINING[2,6]		SC150		
n (MANNING'S COEFFICIENT)[2]		0.05		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	2.03		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	2.00		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	1.00		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	17.86 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	17.86		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	8.93		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	2.23		
R (HYDRAULIC RADIUS)		0.24		
S (BED SLOPE)[3, 7]	(FT/FT)	0.032		
S_C (CRITICAL SLOPE)	(FT/FT)	0.062		
$.7S_c$	(FT/FT)	0.044		
$1.3S_c$	(FT/FT)	0.081		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

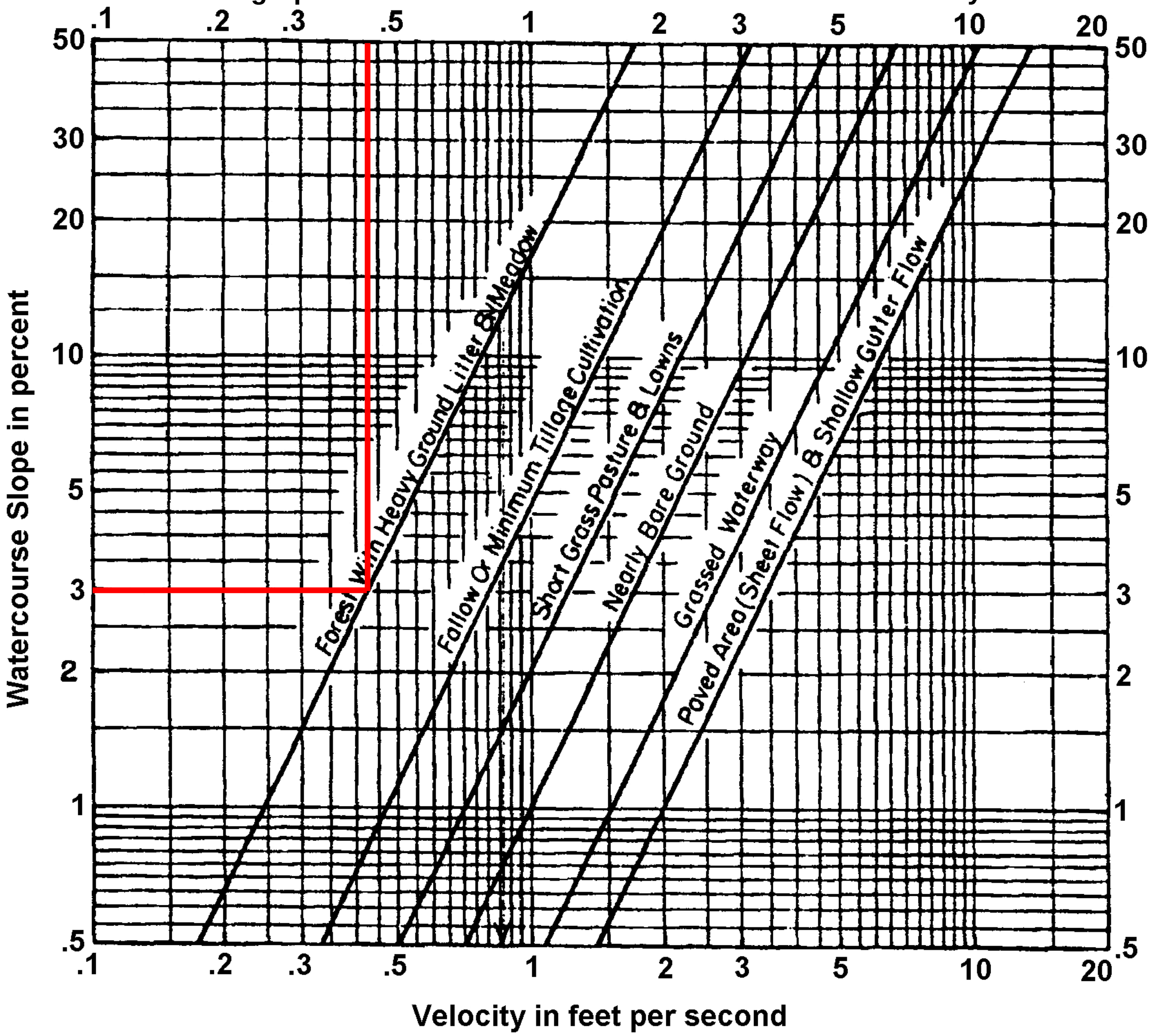
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_72.46

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = FOREST
PERCENT SLOPE = 3%

SHALLOW CONCENTRATED FLOW VELOCITY = 0.4 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 2 FPS FOR FORESTED/MULCH COVER TYPES.

0.4 FPS < 2.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.

LEGEND

- 1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT
CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_72.59
NORTHAMPTON COUNTY, PENNSYLVANIA

0 100 200 FEET

PennEast PIPELINE

DRAWN BY:	SNP 10/2018	APPROVED BY:	MJD 10/2019	SCALE:	1 INCH = 200 FEET
CHECKED BY:	JMB 10/2019	REV. DATE:	10/2019	REV.:	1

DWG NO: PAGE 88 OF 114

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 72.59	100	0.8	0.200	9.34

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 72.59	638	FOREST	0.085	0.73	14.50

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
23.84

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 72.59	1	FOREST	0.20	4.20	0.84	0.20

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	23.84	2.60	3.15	3.63	2.60	3.15	3.63

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.20	2.60	4.20	2.18	2.65	3.05

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_72.59		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	2		
ACRES	(AC)	4.2		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	2.18		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	4.99		
PROTECTIVE LINING[2,6]		EXISTING GRASS		
n (MANNING'S COEFFICIENT)[2]		0.07		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	1.28		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.00		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	0.75		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	31.25 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	31.25		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	15.63		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	3.91		
R (HYDRAULIC RADIUS)		0.24		
S (BED SLOPE)[3, 7]	(FT/FT)	0.024		
S_C (CRITICAL SLOPE)	(FT/FT)	0.118		
$.7S_c$	(FT/FT)	0.083		
$1.3S_c$	(FT/FT)	0.154		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		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 seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

LEGEND

- 1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT

CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_72.73

NORTHAMPTON COUNTY, PENNSYLVANIA

0 50 100 FEET

PennEast PIPELINE

DRAWN BY:	SNP 10/2018	APPROVED BY:	MJD 10/2019	SCALE:	1 INCH = 100 FEET
CHECKED BY:	JMB 10/2019	REV. DATE:	10/2019	REV.:	1

DWG NO: PAGE 89 OF 114

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 72.73	100	0.02	0.020	2.85

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 72.73	106	PAVEMENT	0.019	2.80	0.63
	487	FOREST	0.084	0.73	11.13

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c* (minutes)
14.61

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 72.73	1	FOREST	0.20	2.76	0.55	0.21
	2	INDUSTRIAL	0.69	0.04	0.03	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	14.61	3.35	4.02	4.52	3.35	4.02	4.52

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.21	3.35	2.80	1.94	2.33	2.62

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

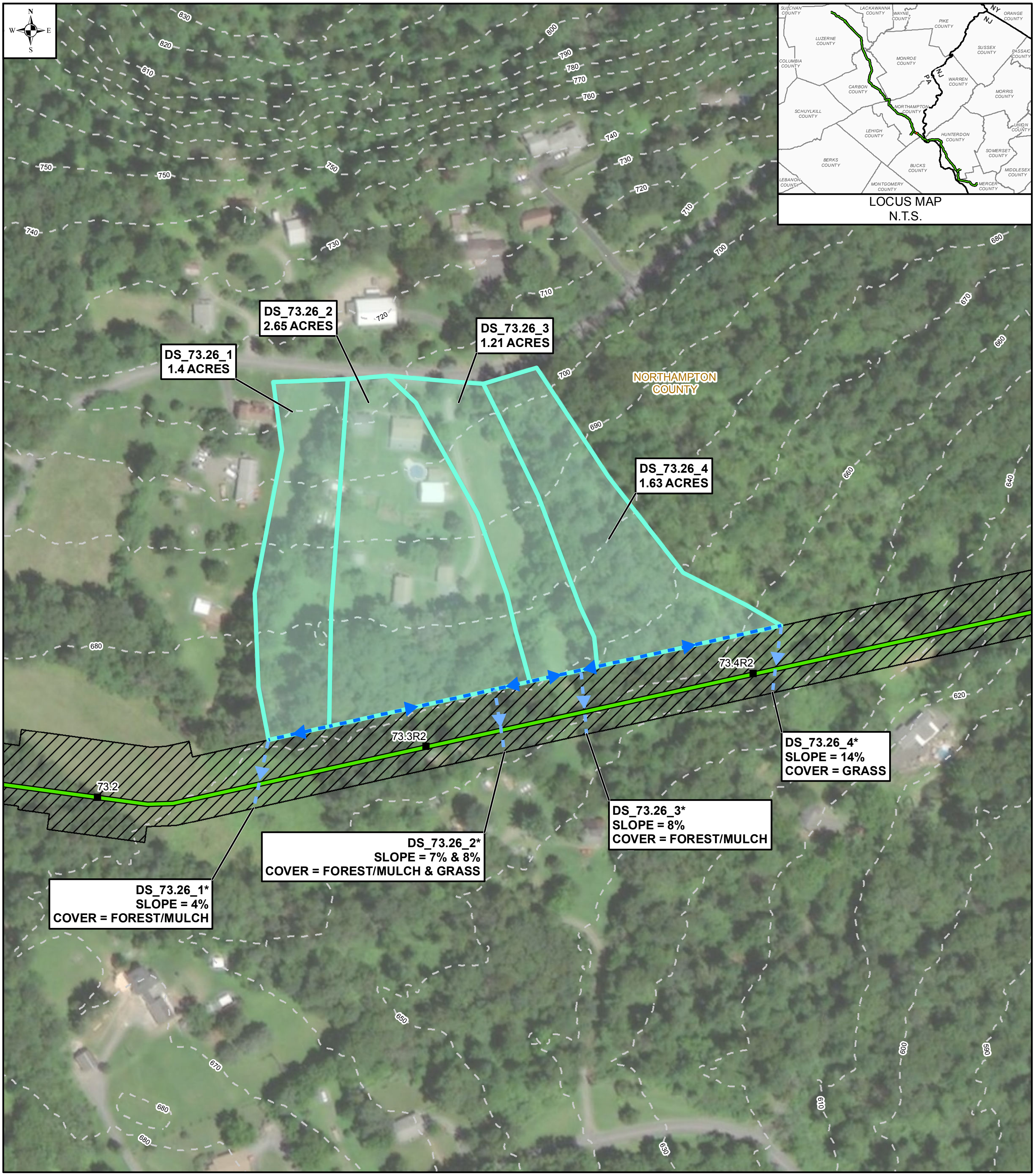
LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_72.73		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	2		
ACRES	(AC)	2.8		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	1.94		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	6.13		
PROTECTIVE LINING[2,6]		S75		
n (MANNING'S COEFFICIENT)[2]		0.055		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	2.11		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.55		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	1.28		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	23.26 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	23.26		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	11.63		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	2.91		
R (HYDRAULIC RADIUS)		0.24		
S (BED SLOPE)[3, 7]	(FT/FT)	0.041		
S_C (CRITICAL SLOPE)	(FT/FT)	0.074		
$.7S_c$	(FT/FT)	0.052		
$1.3S_c$	(FT/FT)	0.096		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		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 seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.



LEGEND

- 1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT

CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_73.26

NORTHAMPTON COUNTY, PENNSYLVANIA

0 100 200 FEET

PennEast PIPELINE

DRAWN BY:	SNP 10/2018	APPROVED BY:	MJD 10/2019	SCALE:	1 INCH = 200 FEET
CHECKED BY:	JMB 10/2019	REV. DATE:	10/2019	REV.:	1

DWG NO: PAGE 90 OF 114

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_73.26_1
1.4 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 73.26_1	100	0.4	0.090	8.14

$$T_{c\,(sheet\ flow)} = \left[\frac{2L(n)}{3S^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 73.26_1	236	SHORT GRASS	0.085	2.03	1.94
	233	FOREST	0.060	0.62	6.30

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
16.38

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 73.26_1	1	FOREST	0.20	0.75	0.15	0.24
	2	INDUSTRIAL	0.69	0.01	0.01	
	3	OPEN SPACE	0.28	0.64	0.18	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	16.38	3.18	3.82	4.32	3.18	3.82	4.32

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.24	3.82	1.40	1.07	1.28	1.45

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/2019
CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_73.26_1		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	1.4		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	1.28		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	2.08		
PROTECTIVE LINING[2,6]		EXISTING GRASS		
n (MANNING'S COEFFICIENT)[2]		0.08		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	0.72		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.00		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	0.31		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	23.26 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	23.26		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	11.63		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	2.91		
R (HYDRAULIC RADIUS)		0.24		
S (BED SLOPE)[3, 7]	(FT/FT)	0.01		
S_C (CRITICAL SLOPE)	(FT/FT)	0.157		
$.7S_c$	(FT/FT)	0.110		
$1.3S_c$	(FT/FT)	0.204		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

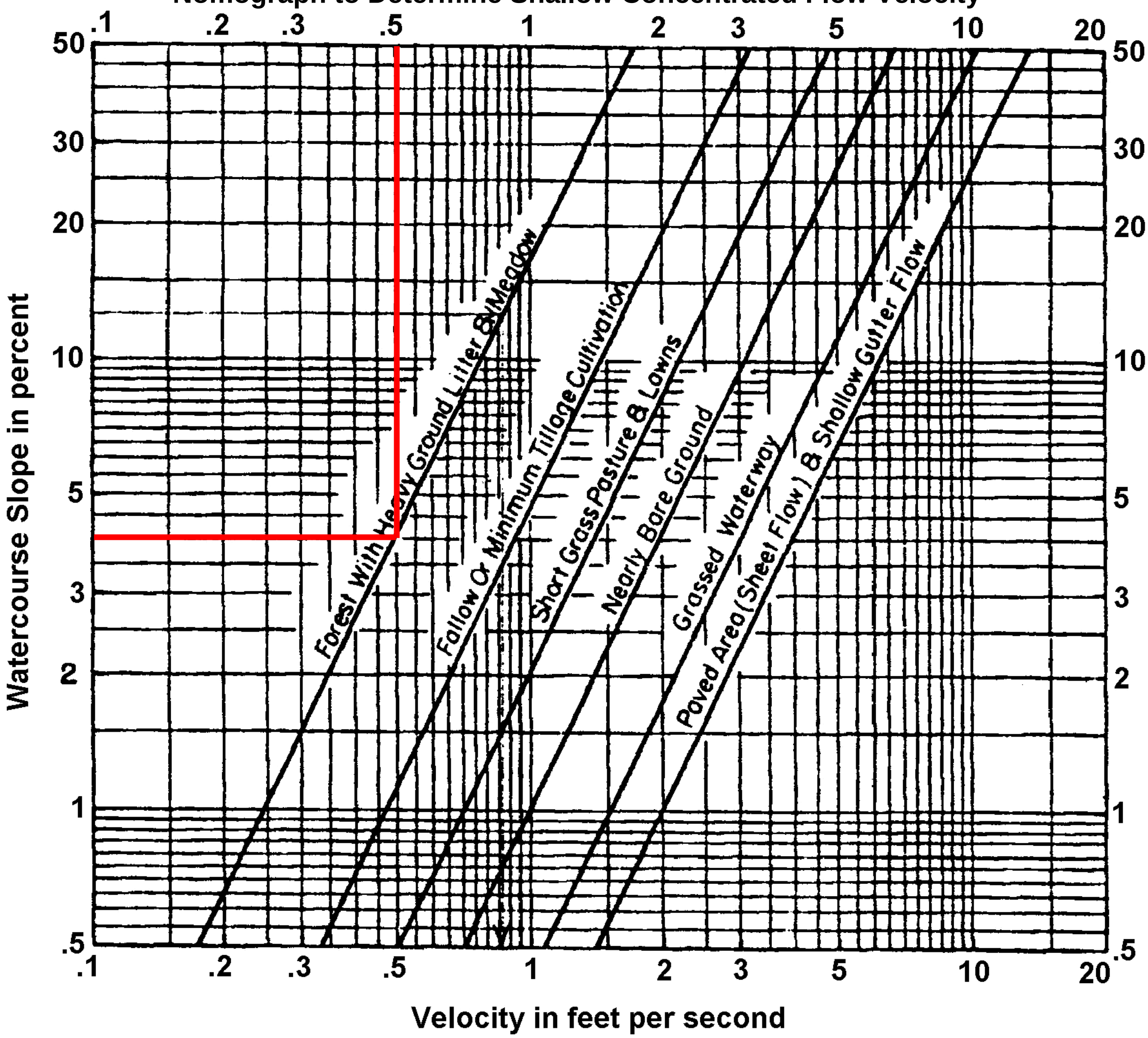
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_73.26_1

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = FOREST
PERCENT SLOPE = 4%

SHALLOW CONCENTRATED FLOW VELOCITY = 0.5 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 2 FPS FOR FORESTED/MULCH COVER TYPES.

0.5 FPS < 2.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_73.26_2
2.65 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 73.26_2	100	0.4	0.040	9.84

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 73.26_2	310	SHORT GRASS	0.084	2.02	2.56
	128	FOREST	0.078	0.70	3.04

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
15.44

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 73.26_2	1	FOREST	0.20	1.19	0.24	0.28
	2	INDUSTRIAL	0.69	0.24	0.17	
	3	OPEN SPACE	0.28	1.22	0.34	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	15.44	3.27	3.92	4.42	3.27	3.92	4.42

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.28	3.92	2.65	2.44	2.92	3.30

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_73.26_2		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	2.65		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	2.92		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	5.00		
PROTECTIVE LINING[2,6]		C125		
n (MANNING'S COEFFICIENT)[2]		0.022		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	3.40		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	2.25		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	0.56		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	11.76 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	11.76		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	5.88		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.47		
R (HYDRAULIC RADIUS)		0.23		
S (BED SLOPE)[3, 7]	(FT/FT)	0.018		
S_C (CRITICAL SLOPE)	(FT/FT)	0.013		
$.7S_c$	(FT/FT)	0.009		
$1.3S_c$	(FT/FT)	0.016		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

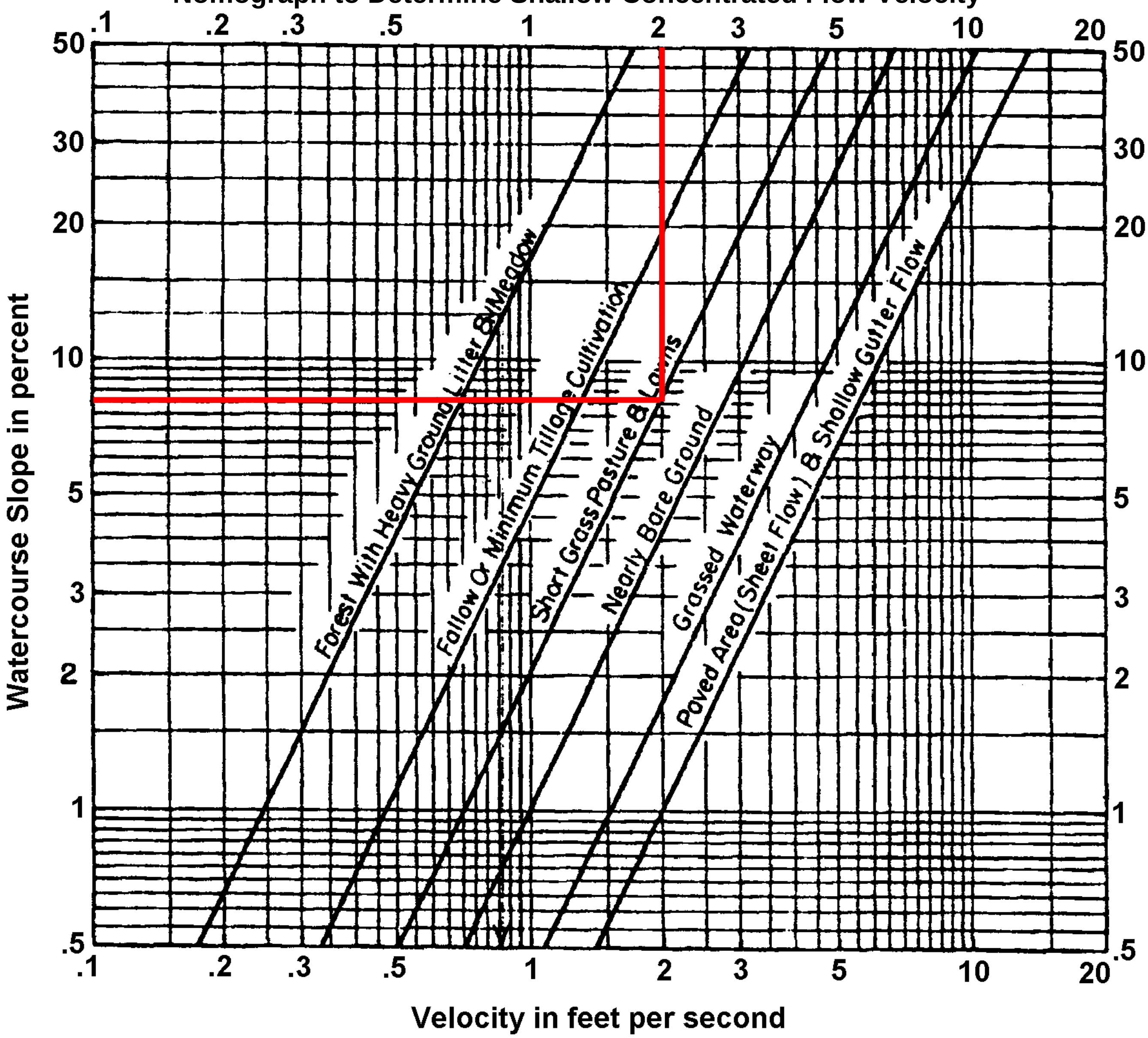
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_73.26_2

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 8%

SHALLOW CONCENTRATED FLOW VELOCITY = 2.0 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

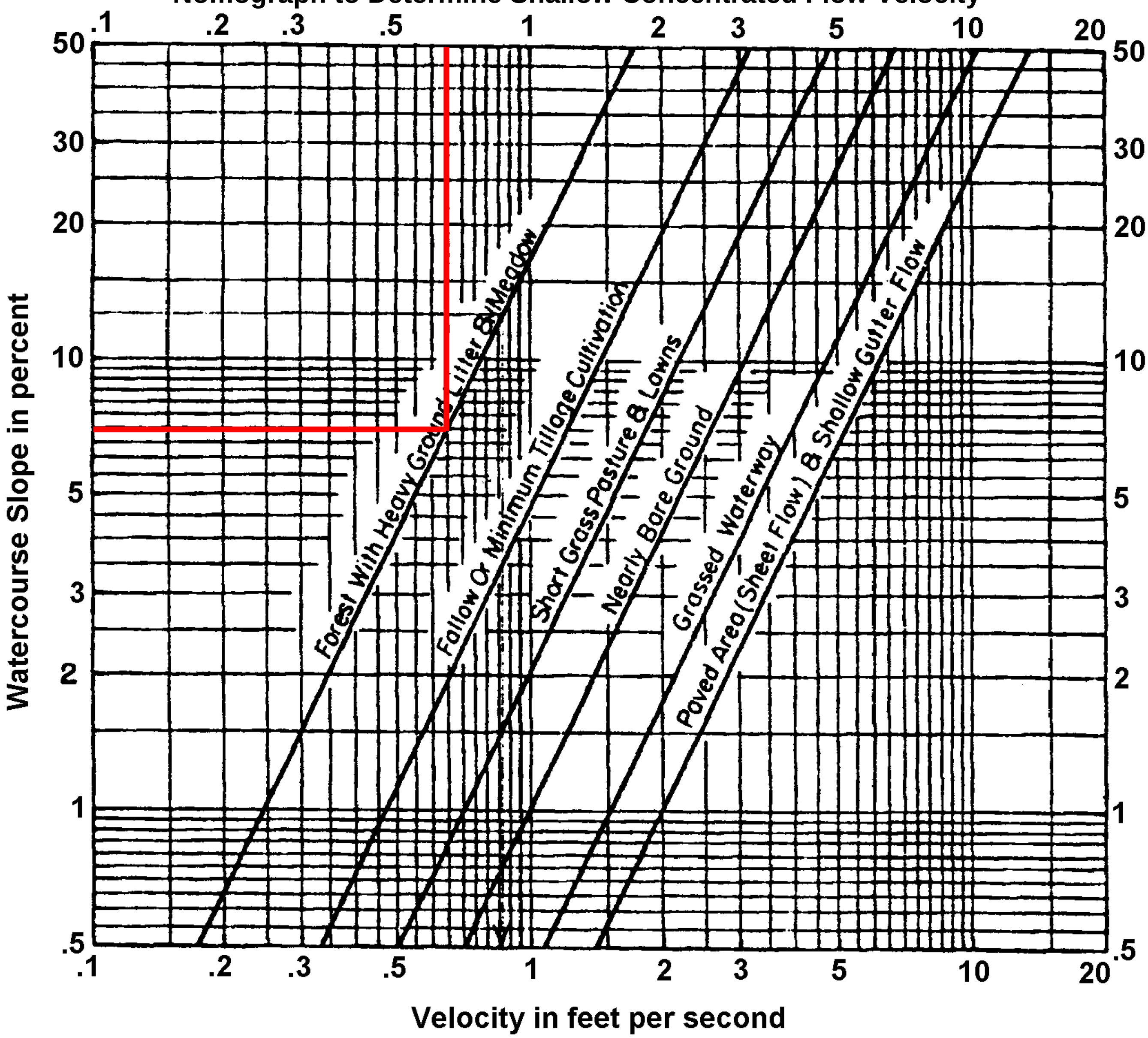
2.0 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.

CLEAN WATER DIVERSION ID:
DS_73.26_2

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = FOREST
PERCENT SLOPE = 7%

SHALLOW CONCENTRATED FLOW VELOCITY = 0.7 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 2 FPS FOR FORESTED/MULCH COVER TYPES.

0.7 FPS < 2.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_73.26_3
1.21 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 73.26_3	100	0.02	0.049	2.31

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 73.26_3	51	PAVEMENT	0.039	4.01	0.21
	482	FOREST	0.073	0.68	11.82

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c* (minutes)
14.34

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 73.26_3	1	FOREST	0.20	0.47	0.09	0.26
	2	INDUSTRIAL	0.69	0.04	0.03	
	3	OPEN SPACE	0.28	0.70	0.20	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	14.34	3.38	4.05	4.55	3.38	4.05	4.55

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.26	4.05	1.21	1.07	1.29	1.45

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_73.26_3		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	1.21		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	1.29		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	1.73		
PROTECTIVE LINING[2,6]		EXISTING GRASS		
n (MANNING'S COEFFICIENT)[2]		0.07		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	1.23		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.00		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	0.75		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	11.24 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	11.24		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	5.62		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.40		
R (HYDRAULIC RADIUS)		0.23		
S (BED SLOPE)[3, 7]	(FT/FT)	0.024		
S_C (CRITICAL SLOPE)	(FT/FT)	0.128		
$.7S_c$	(FT/FT)	0.089		
$1.3S_c$	(FT/FT)	0.166		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

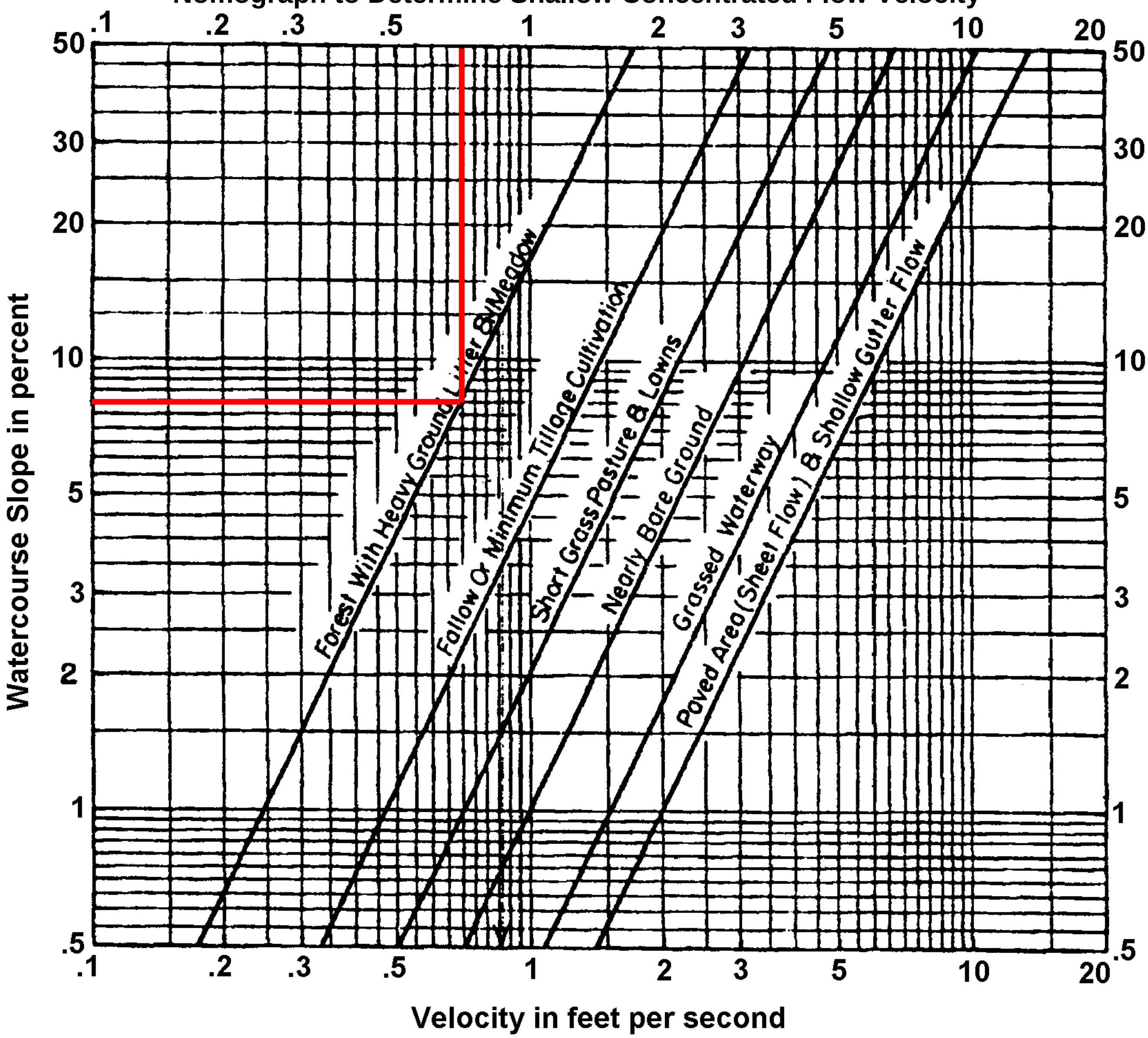
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_73.26_3

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = FOREST
PERCENT SLOPE = 8%

SHALLOW CONCENTRATED FLOW VELOCITY = 0.7 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 2 FPS FOR FORESTED/MULCH COVER TYPES.

0.7 FPS < 2.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_73.26_4
1.63 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 73.26_4	100	0.8	0.090	11.26

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 73.26_4	473	FOREST	0.080	0.71	11.08

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
22.33

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 73.26_4	1	FOREST	0.20	1.63	0.33	0.20

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	22.33	2.69	3.27	3.75	2.69	3.27	3.75

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.20	3.27	1.63	0.88	1.06	1.22

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_73.26_4		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	1.63		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	1.07		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	3.63		
PROTECTIVE LINING[2,6]		S75		
n (MANNING'S COEFFICIENT)[2]		0.055		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	2.21		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.55		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	1.47		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	13.16 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	13.16		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	6.58		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.64		
R (HYDRAULIC RADIUS)		0.23		
S (BED SLOPE)[3, 7]	(FT/FT)	0.047		
S_C (CRITICAL SLOPE)	(FT/FT)	0.077		
$.7S_c$	(FT/FT)	0.054		
$1.3S_c$	(FT/FT)	0.101		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

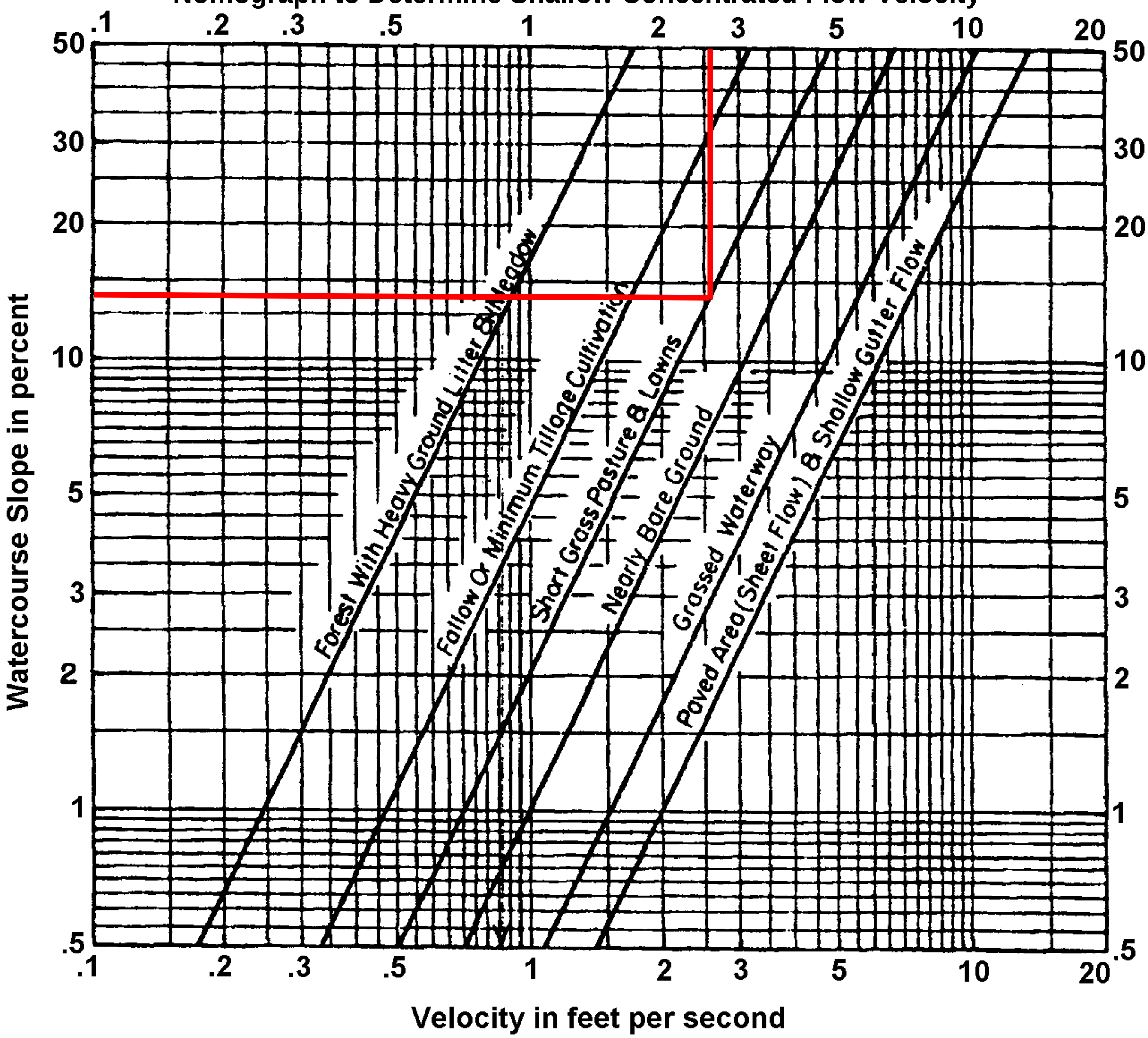
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_73.26_4

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity

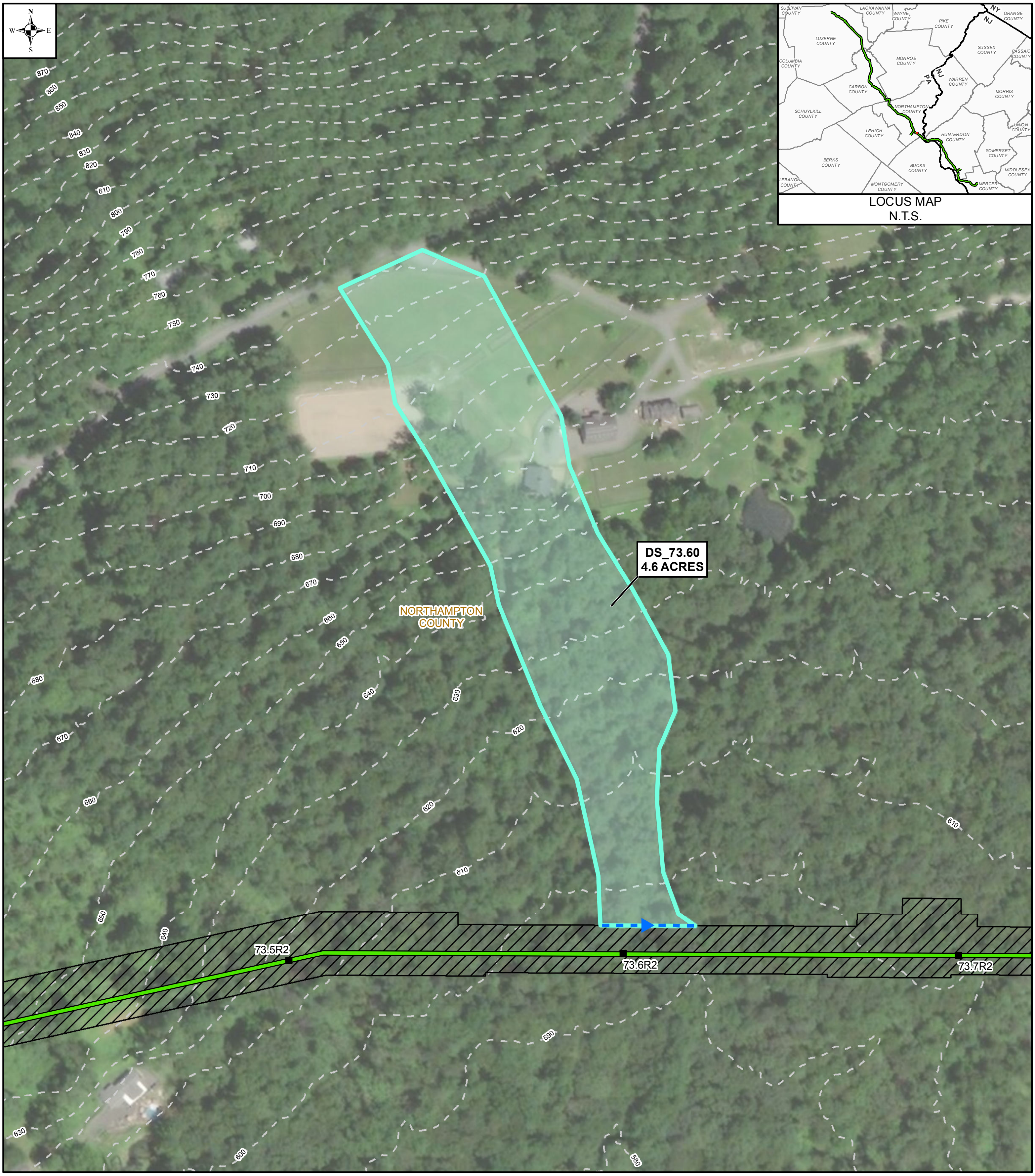


TR-55

<u>DOWNSLOPE CONDITION</u>
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 14%

SHALLOW CONCENTRATED FLOW VELOCITY = 2.6 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

2.6 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.



LEGEND

- 1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT

CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_73.60

NORTHAMPTON COUNTY, PENNSYLVANIA

0 100 200 FEET

PennEast PIPELINE

DRAWN BY:	SNP 10/2018	APPROVED BY:	MJD 10/2019	SCALE:	1 INCH = 200 FEET
CHECKED BY:	JMB 10/2019	REV. DATE:	10/2019	REV.:	1

DWG NO: PAGE 91 OF 114

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 73.60	100	0.4	0.170	7.02

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 73.60	258	SHORT GRASS	0.171	2.88	1.49
	741	FOREST	0.115	0.85	14.47

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
22.99

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NOTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 73.60	1	FOREST	0.20	2.81	0.56	0.24
	2	OPEN SPACE	0.28	1.70	0.48	
	3	INDUSTRIAL	0.69	0.09	0.06	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	22.99	2.65	3.22	3.70	2.65	3.22	3.70

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.24	3.22	4.60	2.92	3.54	4.07

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_73.60		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	4.6		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	3.54		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	4.16		
PROTECTIVE LINING[2,6]		EXISTING GRASS		
n (MANNING'S COEFFICIENT)[2]		0.07		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	1.16		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.00		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	0.62		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	28.57 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	28.57		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	14.29		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	3.57		
R (HYDRAULIC RADIUS)		0.24		
S (BED SLOPE)[3, 7]	(FT/FT)	0.02		
S_C (CRITICAL SLOPE)	(FT/FT)	0.119		
$.7S_c$	(FT/FT)	0.083		
$1.3S_c$	(FT/FT)	0.154		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		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 seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

LOCUS MAP
N.T.S.

LEGEND

1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)	SLOPE PIPE
PROPOSED PENNEAST PIPELINE	DRAINAGE AREA
BLUE MOUNTAIN LATERAL	PROPOSED CONSTRUCTION WORKSPACE
HELLERTOWN LATERAL	INDEX CONTOUR
DIVERSION SOCK	COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT
CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_73.92
NORTHAMPTON COUNTY, PENNSYLVANIA

0 50 100 FEET

PennEast PIPELINE

DRAWN BY:	SNP 10/2018	APPROVED BY:	MJD 10/2019	SCALE:	1 INCH = 100 FEET
CHECKED BY:	JMB 10/2019	REV. DATE:	10/2019	REV.:	1

DWG NO: PAGE 92 OF 114

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 73.92	100	0.8	0.620	7.17

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 73.92	574	FOREST	0.145	0.96	9.99

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
17.16

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 73.92	1	FOREST	0.20	1.43	0.29	0.20

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	17.16	3.10	3.73	4.23	3.10	3.73	4.23

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.20	3.73	1.43	0.89	1.07	1.21

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

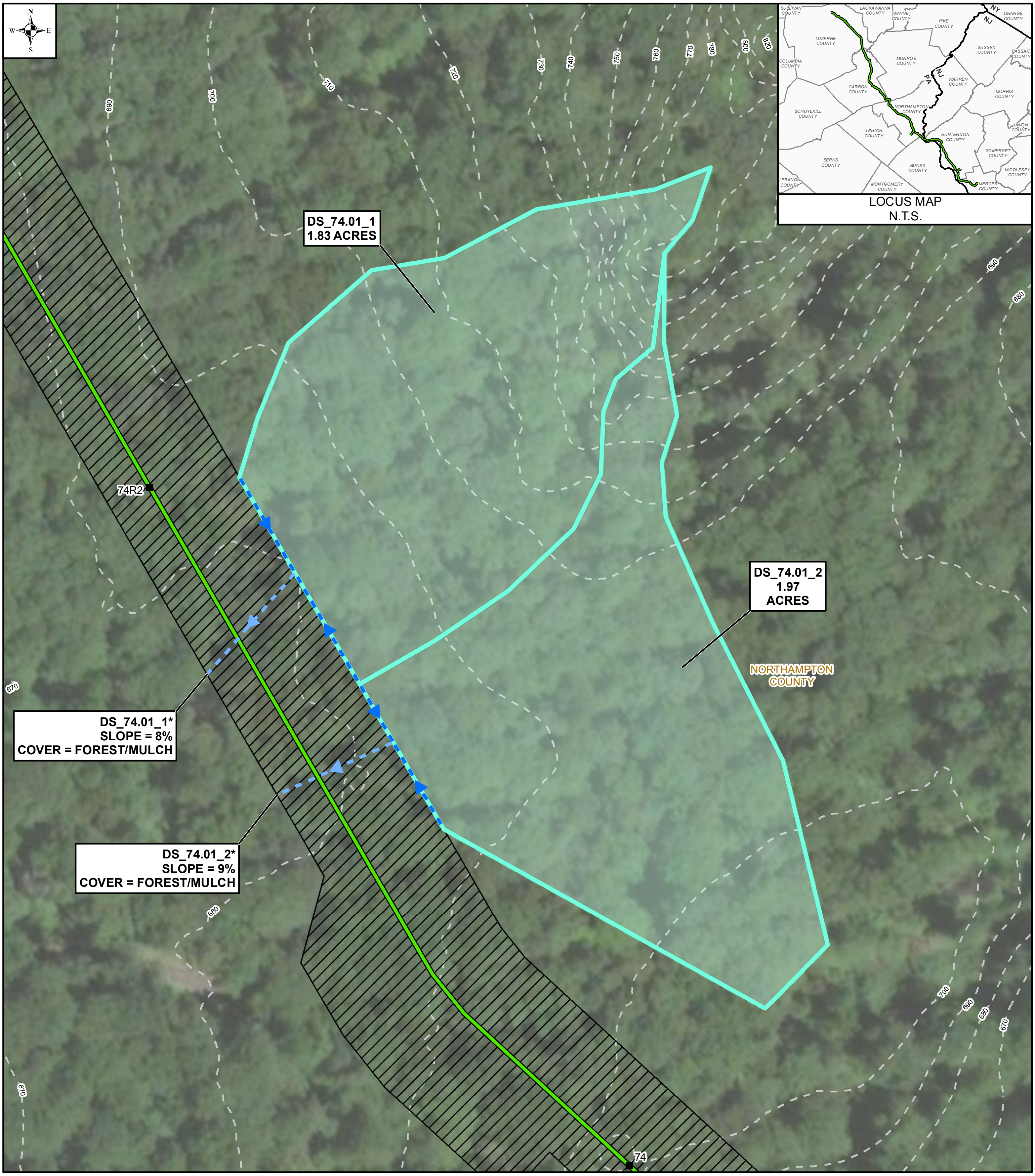
LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_73.92		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	1.43		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	1.07		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	2.20		
PROTECTIVE LINING[2,6]		S75		
n (MANNING'S COEFFICIENT)[2]		0.055		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	2.08		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.55		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	1.37		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	8.47 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	8.47		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	4.24		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.06		
R (HYDRAULIC RADIUS)		0.22		
S (BED SLOPE)[3, 7]	(FT/FT)	0.044		
S_C (CRITICAL SLOPE)	(FT/FT)	0.082		
$.7S_c$	(FT/FT)	0.057		
$1.3S_c$	(FT/FT)	0.106		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		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 seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.



LEGEND

- 1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT
CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_74.01
NORTHAMPTON COUNTY, PENNSYLVANIA

0 50 100 FEET

PennEast PIPELINE

DRAWN BY:	SNP 10/2018	APPROVED BY:	MJD 10/2019	SCALE:	1 INCH = 100 FEET
CHECKED BY:	JMB 10/2019	REV. DATE:	10/2019	REV.:	1

DWG NO: PAGE 93 OF 114

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_74.01_1
1.83 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 74.01_1	100	0.8	0.500	7.54

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 74.01_1	382	FOREST	0.147	0.96	6.60

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
14.14

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 74.01_1	1	FOREST	0.20	1.83	0.37	0.20

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	14.14	3.40	4.07	4.58	3.40	4.07	4.58

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.20	4.07	1.83	1.25	1.49	1.68

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_74.01_1		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	1.83		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	1.49		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	1.94		
PROTECTIVE LINING[2,6]		S75		
n (MANNING'S COEFFICIENT)[2]		0.055		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	1.83		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.55		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	1.06		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	8.47 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	8.47		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	4.24		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.06		
R (HYDRAULIC RADIUS)		0.22		
S (BED SLOPE)[3, 7]	(FT/FT)	0.034		
S_C (CRITICAL SLOPE)	(FT/FT)	0.082		
$.7S_c$	(FT/FT)	0.057		
$1.3S_c$	(FT/FT)	0.106		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

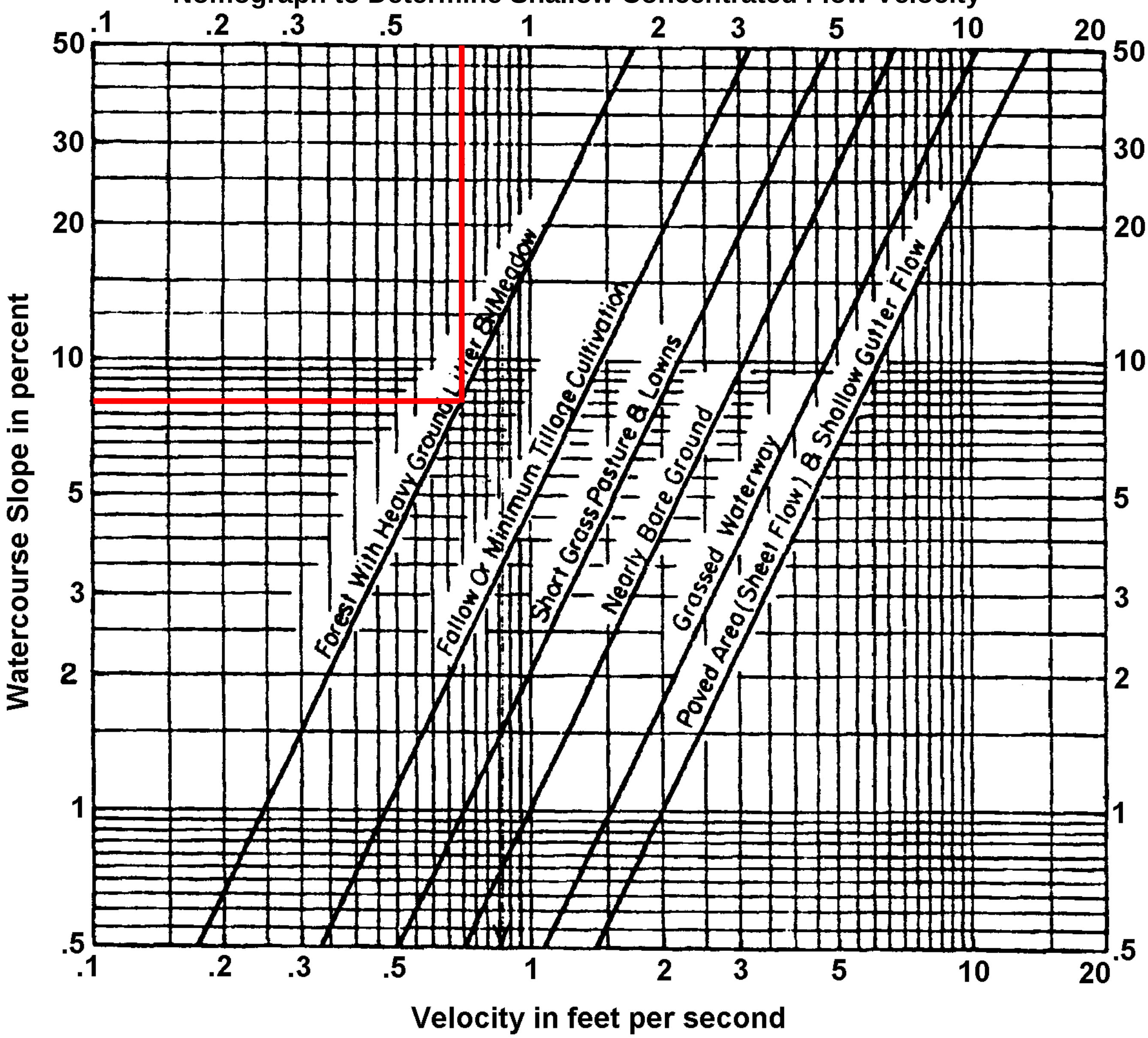
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_74.01_1

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = FOREST
PERCENT SLOPE = 8%

SHALLOW CONCENTRATED FLOW VELOCITY = 0.7 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 2 FPS FOR FORESTED/MULCH COVER TYPES.

0.7 FPS < 2.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_74.01_2
1.97 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 74.01_2	100	0.8	0.480	7.61

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 74.01_2	347	FOREST	0.165	1.02	5.66

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
13.27

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 74.01_2	1	FOREST	0.20	1.97	0.39	0.20

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	13.27	3.50	4.18	4.69	3.50	4.18	4.69

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.20	4.18	1.97	1.38	1.65	1.85

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/2019
CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_74.01_2		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	1.97		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	1.65		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	3.62		
PROTECTIVE LINING[2,6]		SC150		
n (MANNING'S COEFFICIENT)[2]		0.05		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	2.78		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	2.00		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	1.97		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	10.42 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	10.42		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	5.21		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.30		
R (HYDRAULIC RADIUS)		0.23		
S (BED SLOPE)[3, 7]	(FT/FT)	0.063		
S_C (CRITICAL SLOPE)	(FT/FT)	0.066		
$.7S_c$	(FT/FT)	0.046		
$1.3S_c$	(FT/FT)	0.085		
STABLE FLOW?	(Y/N)	N		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	0.50		
FREEBOARD BASED ON STABLE FLOW	(FT)	N/A		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

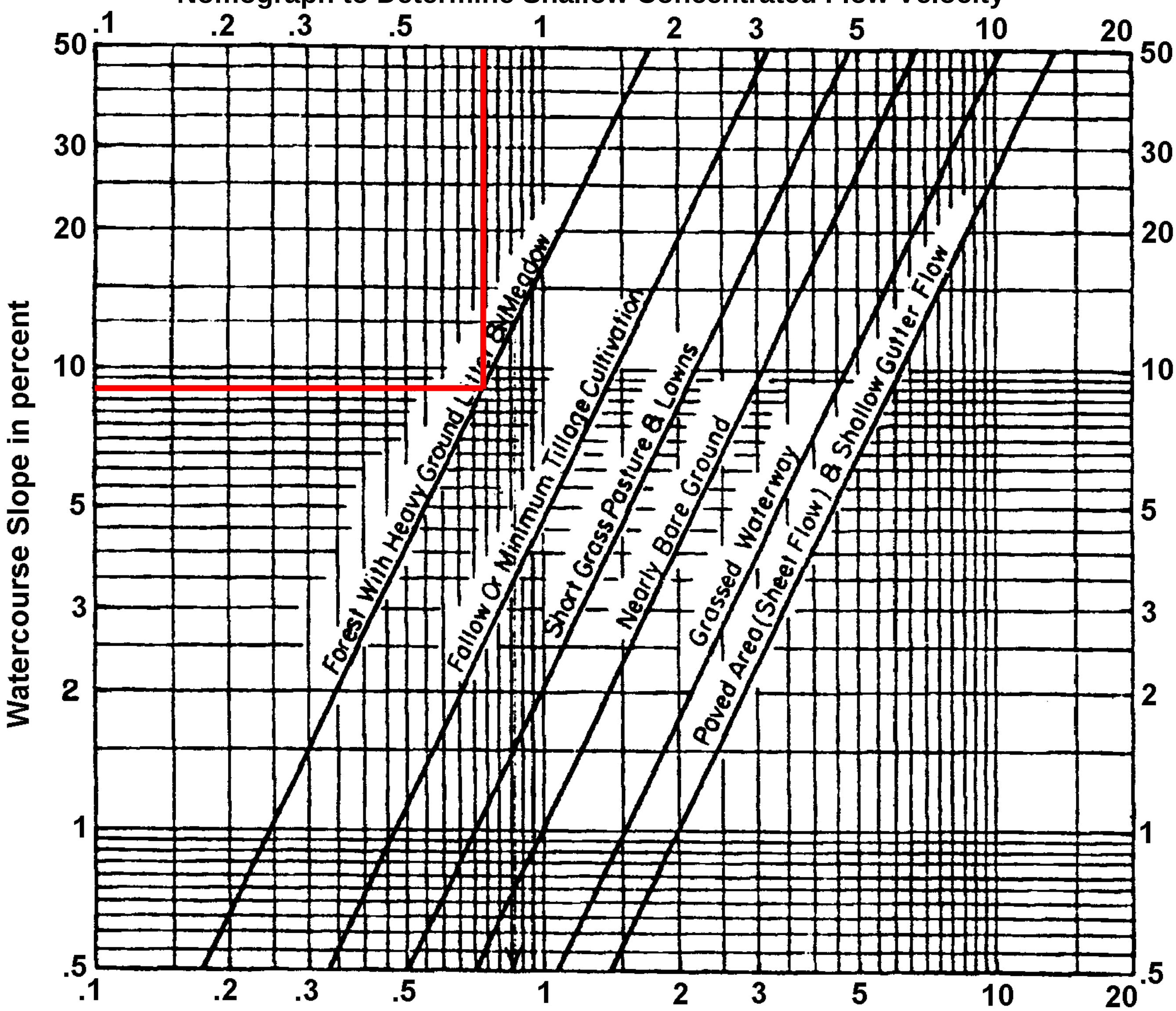
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_74.01_2

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = FOREST
PERCENT SLOPE = 9%

SHALLOW CONCENTRATED FLOW VELOCITY = 0.8 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 2 FPS FOR FORESTED/MULCH COVER TYPES.

0.8 FPS < 2.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.

LEGEND

- 1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT
CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_74.89
NORTHAMPTON COUNTY, PENNSYLVANIA

0 50 100 FEET

PennEast PIPELINE

DRAWN BY:	SNP 10/2018	APPROVED BY:	MJD 10/2019	SCALE:	1 INCH = 100 FEET
CHECKED BY:	JMB 10/2019	REV. DATE:	10/2019	REV.:	1

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 74.89	100	0.4	0.060	8.95

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 74.89	441	SHORT GRASS	0.050	1.56	4.72

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
13.67

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 74.89	1	FOREST	0.20	0.19	0.04	0.31
	2	OPEN SPACE	0.28	0.28	0.08	
	3	INDUSTRIAL	0.69	0.07	0.05	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	13.67	3.46	4.13	4.64	3.46	4.13	4.64

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.31	4.13	0.54	0.57	0.68	0.76

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_74.89		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	0.54		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	0.68		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	2.03		
PROTECTIVE LINING[2,6]		EXISTING GRASS		
n (MANNING'S COEFFICIENT)[2]		0.07		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	1.14		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.00		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	0.62		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	14.29 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	14.29		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	7.14		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.79		
R (HYDRAULIC RADIUS)		0.23		
S (BED SLOPE)[3, 7]	(FT/FT)	0.02		
S_C (CRITICAL SLOPE)	(FT/FT)	0.124		
$.7S_c$	(FT/FT)	0.087		
$1.3S_c$	(FT/FT)	0.162		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		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 seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

LEGEND

- 1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT
CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_75.15
NORTHAMPTON COUNTY, PENNSYLVANIA

0 100 200 FEET

PennEast PIPELINE

DRAWN BY:	SNP 10/2018	APPROVED BY:	MJD 10/2019	SCALE:	1 INCH = 200 FEET
CHECKED BY:	JMB 10/2019	REV. DATE:	10/2019	REV.:	1

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME:	PENNEAST PIPELINE PROJECT		
LOCATION:	NORTHAMPTON COUNTY		
PREPARED BY:	MDN	DATE:	10/15/2018
CHECKED BY:	KEK / JMB	DATE:	10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 75.15	100	0.4	0.090	8.14

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 75.15	499	SHORT GRASS	0.124	2.45	3.39
	386	FOREST	0.192	1.10	5.84
	247	SHORT GRASS	0.093	2.12	1.94

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c* (minutes)
19.31

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 75.15	1	FOREST	0.20	1.48	0.30	0.36
	2	PASTURE	0.50	1.43	0.72	
	3	INDUSTRIAL	0.69	0.11	0.08	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	19.31	2.92	3.52	4.02	2.92	3.52	4.02

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.36	3.52	3.02	3.17	3.83	4.37

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_75.15		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	3.02		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	3.83		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	5.94		
PROTECTIVE LINING[2,6]		C125		
n (MANNING'S COEFFICIENT)[2]		0.022		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	3.52		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	2.25		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	0.59		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	13.51 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	13.51		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	6.76		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.69		
R (HYDRAULIC RADIUS)		0.23		
S (BED SLOPE)[3, 7]	(FT/FT)	0.019		
S_C (CRITICAL SLOPE)	(FT/FT)	0.012		
$.7S_c$	(FT/FT)	0.009		
$1.3S_c$	(FT/FT)	0.016		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

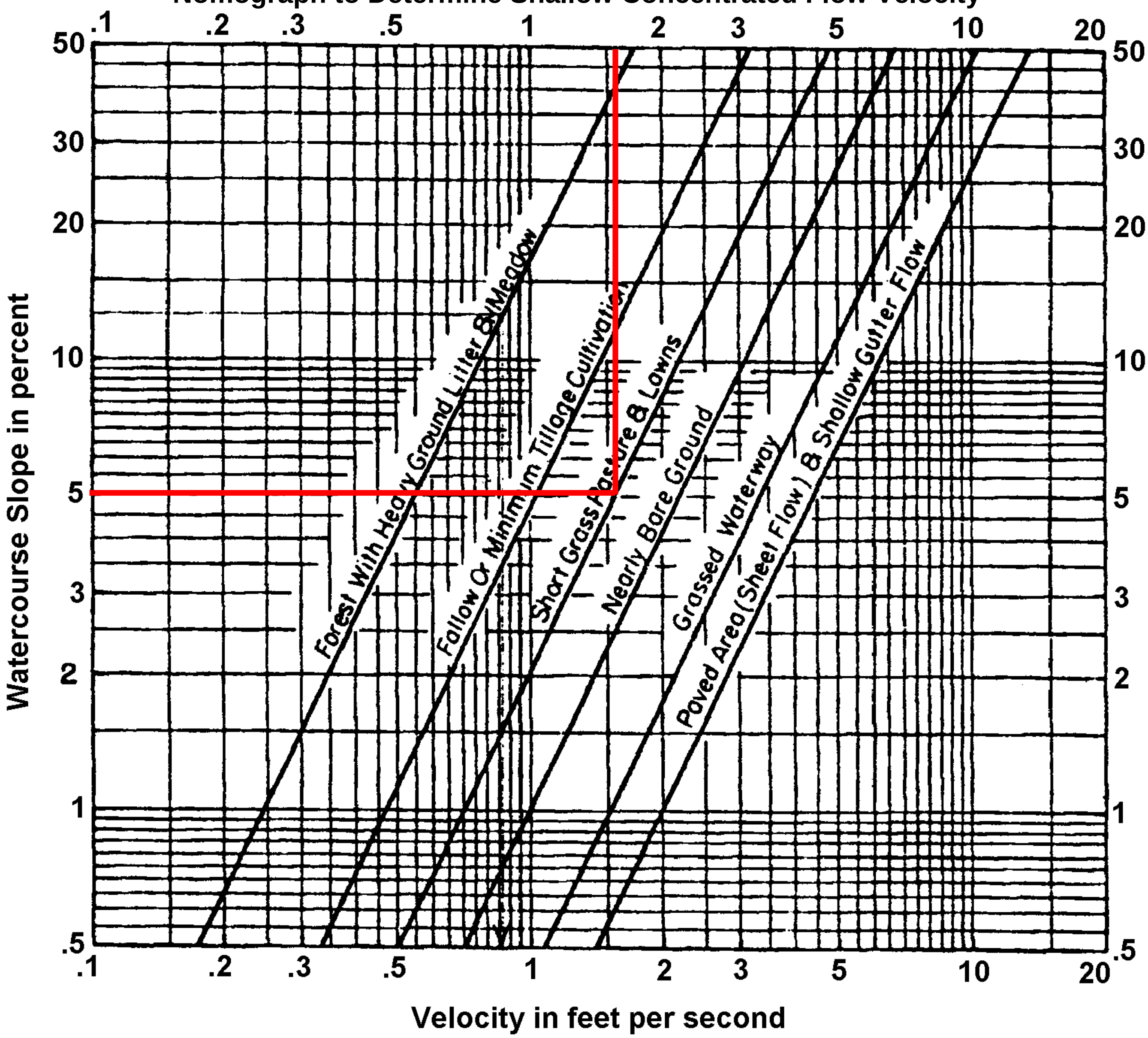
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_75.15

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity

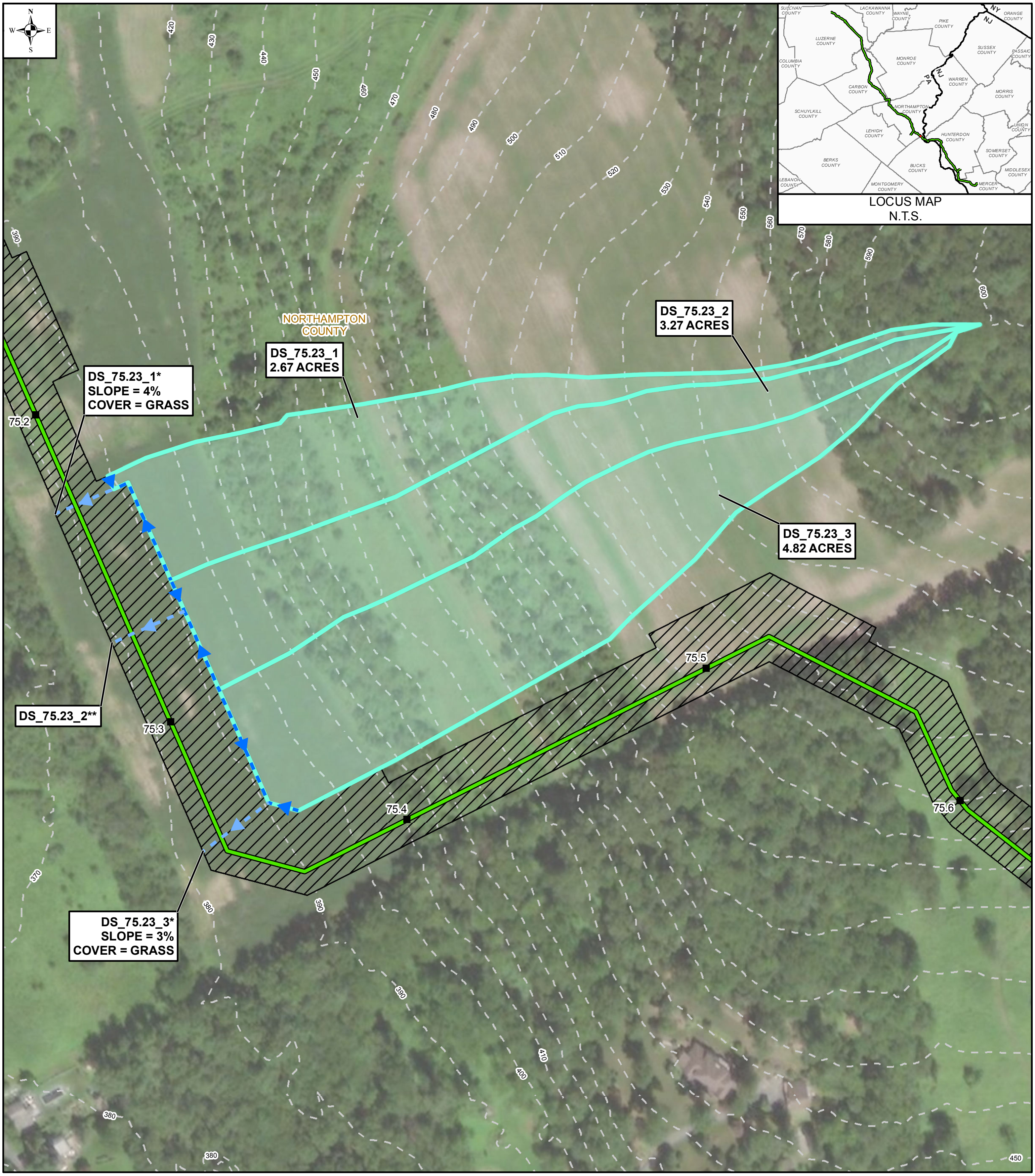


TR-55

DOWNSLOPE CONDITION
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 5%

SHALLOW CONCENTRATED FLOW VELOCITY = 1.6 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

1.6 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.



LEGEND

- 1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT
CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_75.23
NORTHAMPTON COUNTY, PENNSYLVANIA

0 100 200 FEET

PennEast PIPELINE

DRAWN BY: SNP 10/2018	APPROVED BY: MJD 10/2019	SCALE: 1 INCH = 200 FEET
CHECKED BY: JMB 10/2019	REV. DATE: 10/2019	REV.: 1

DWG NO: PAGE 96 OF 114

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_75.23_1
2.67 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 75.23_1	100	0.8	0.040	13.60

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 75.23_1	177	FOREST	0.141	0.94	3.12
	545	SHORT GRASS	0.116	2.37	3.83
	426	FOREST	0.235	1.22	5.82
	161	SHORT GRASS	0.118	2.39	1.12

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
27.50

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 75.23_1	1	FOREST	0.20	1.53	0.31	0.34
	2	PASTURE	0.50	0.99	0.50	
	3	INDUSTRIAL	0.69	0.15	0.10	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	27.50	2.38	2.90	3.37	2.38	2.90	3.37

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.34	2.90	2.67	2.15	2.63	3.04

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/2019
CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_75.23_1		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	2.67		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	2.63		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	3.76		
PROTECTIVE LINING[2,6]		C125		
n (MANNING'S COEFFICIENT)[2]		0.022		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	3.16		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	2.25		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	0.50		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	9.52 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	9.52		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	4.76		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.19		
R (HYDRAULIC RADIUS)		0.23		
S (BED SLOPE)[3, 7]	(FT/FT)	0.016		
S_C (CRITICAL SLOPE)	(FT/FT)	0.013		
$.7S_c$	(FT/FT)	0.009		
$1.3S_c$	(FT/FT)	0.017		
STABLE FLOW?	(Y/N)	N		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	0.50		
FREEBOARD BASED ON STABLE FLOW	(FT)	N/A		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

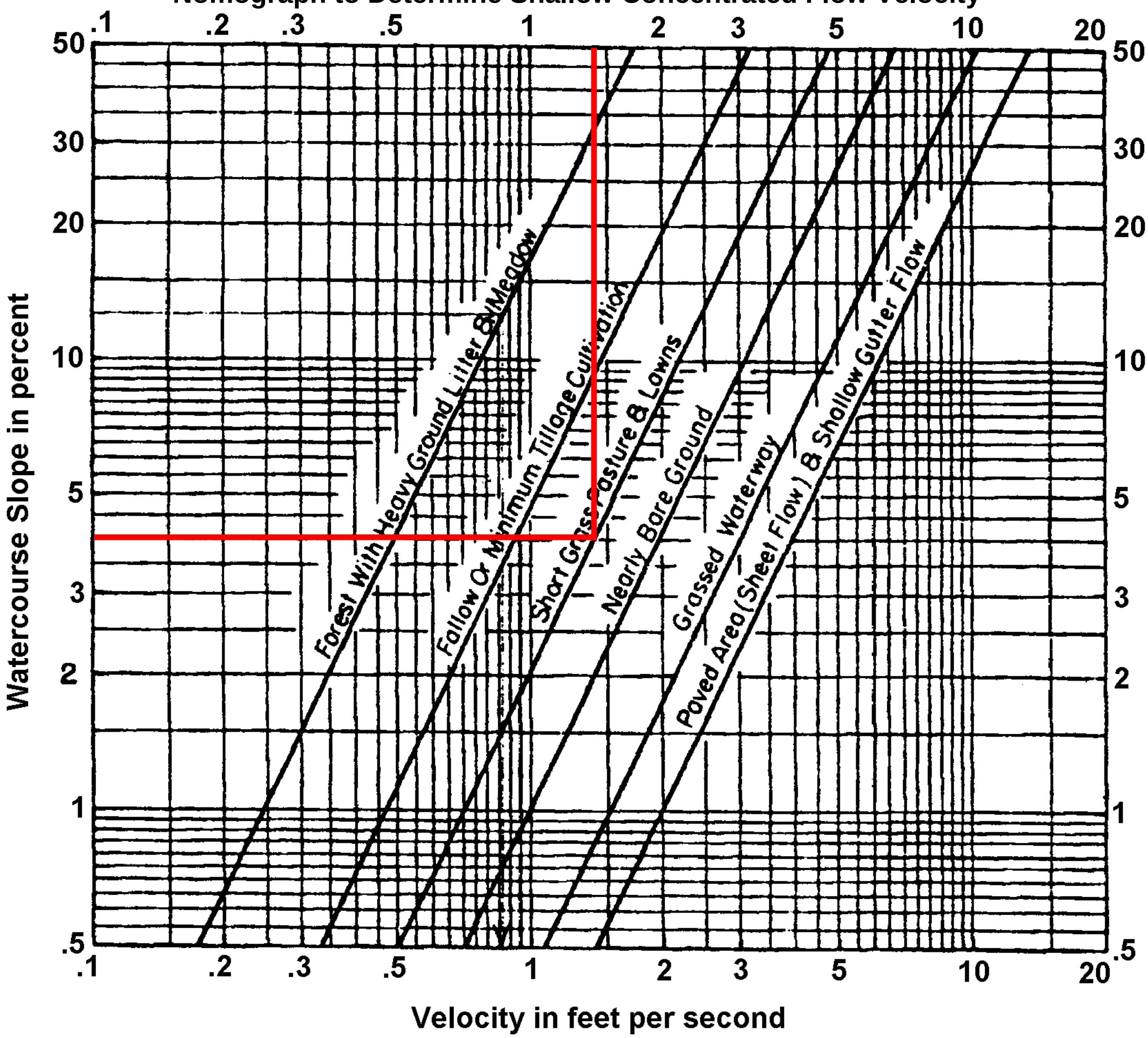
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_75.23_1

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 4%

SHALLOW CONCENTRATED FLOW VELOCITY = 1.4 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

1.4 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_75.23_2
3.27 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 75.23_2	100	0.8	0.038	13.77

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}} \right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 75.23_2	187	FOREST	0.144	0.95	3.26
	500	SHORT GRASS	0.114	2.35	3.55
	430	FOREST	0.233	1.21	5.90
	131	SHORT GRASS	0.153	2.72	0.80

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
27.28

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 75.23_2	1	FOREST	0.20	1.68	0.34	0.35
	2	PASTURE	0.50	1.53	0.77	
	3	INDUSTRIAL	0.69	0.06	0.04	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	27.28	2.39	2.92	3.38	2.39	2.92	3.38

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.35	2.92	3.27	2.73	3.33	3.86

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_75.23_2		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	3.27		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	3.33		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	3.76		
PROTECTIVE LINING[2,6]		C125		
n (MANNING'S COEFFICIENT)[2]		0.022		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	3.43		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	2.25		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	0.59		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	8.77 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	8.77		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	4.39		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.10		
R (HYDRAULIC RADIUS)		0.22		
S (BED SLOPE)[3, 7]	(FT/FT)	0.019		
S_C (CRITICAL SLOPE)	(FT/FT)	0.013		
$.7S_c$	(FT/FT)	0.009		
$1.3S_c$	(FT/FT)	0.017		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		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 seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_75.23_3
4.82 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME:	PENNEAST PIPELINE PROJECT
LOCATION:	NORTHAMPTON COUNTY
PREPARED BY:	MDN
DATE:	10/15/2018
CHECKED BY:	KEK / JMB
DATE:	10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 75.23_3	100	0.8	0.070	11.94

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 75.23_3	137	FOREST	0.161	1.01	2.26
	492	SHORT GRASS	0.128	2.49	3.29
	427	FOREST	0.220	1.18	6.03
	244	SHORT GRASS	0.086	2.04	1.99

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
25.51

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 75.23_3	1	FOREST	0.20	2.38	0.48	0.36
	2	PASTURE	0.50	2.31	1.16	
	3	INDUSTRIAL	0.69	0.13	0.09	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	25.51	2.49	3.03	3.50	2.49	3.03	3.50

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.36	3.03	4.82	4.29	5.22	6.03

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_75.23_3		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	4.82		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	5.22		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	5.85		
PROTECTIVE LINING[2,6]		C125		
n (MANNING'S COEFFICIENT)[2]		0.022		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	5.05		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	2.25		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	1.28		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	9.26 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	9.26		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	4.63		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.16		
R (HYDRAULIC RADIUS)		0.22		
S (BED SLOPE)[3, 7]	(FT/FT)	0.041		
S_C (CRITICAL SLOPE)	(FT/FT)	0.013		
$.7S_c$	(FT/FT)	0.009		
$1.3S_c$	(FT/FT)	0.017		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

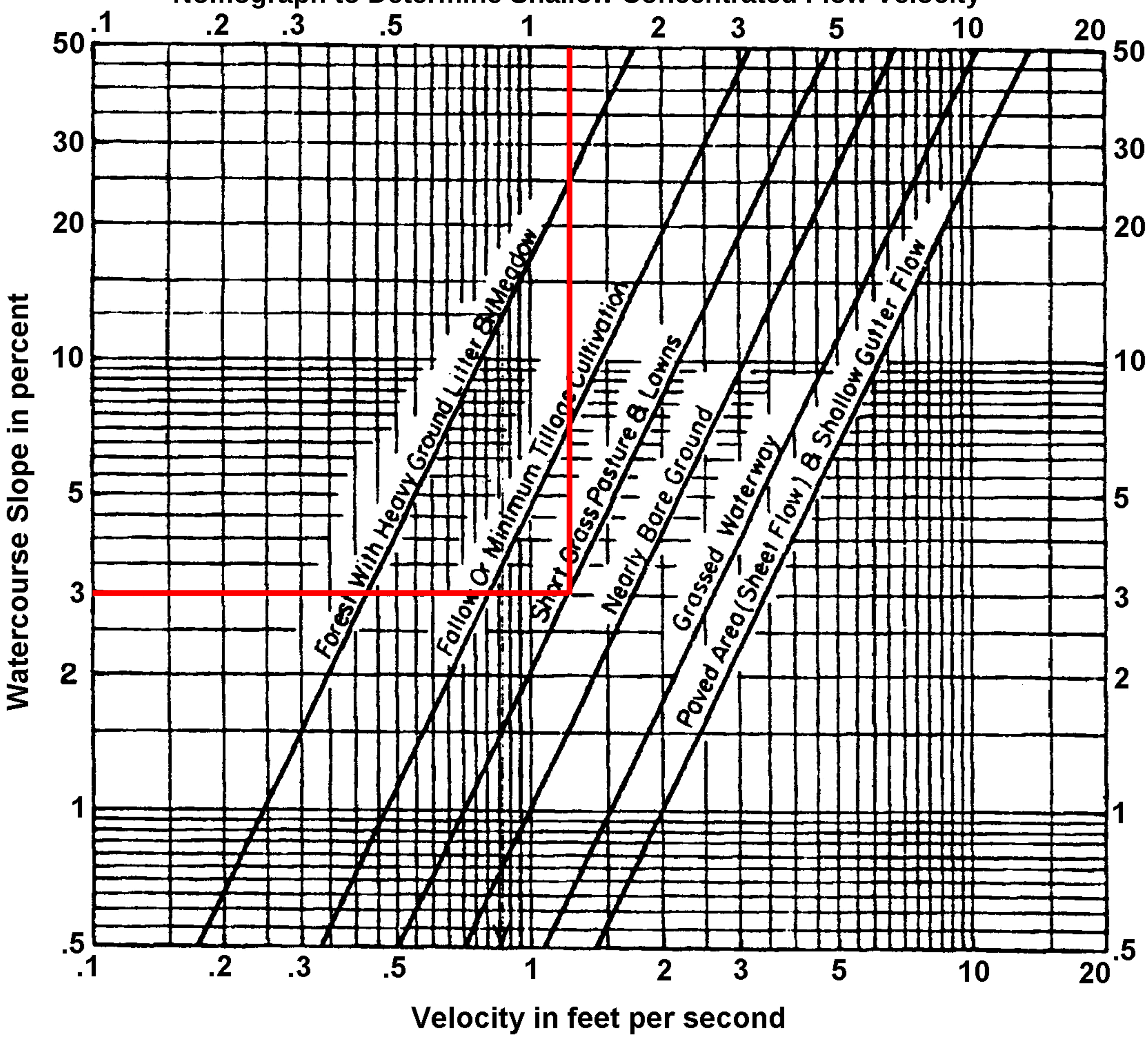
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_75.23_3

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity

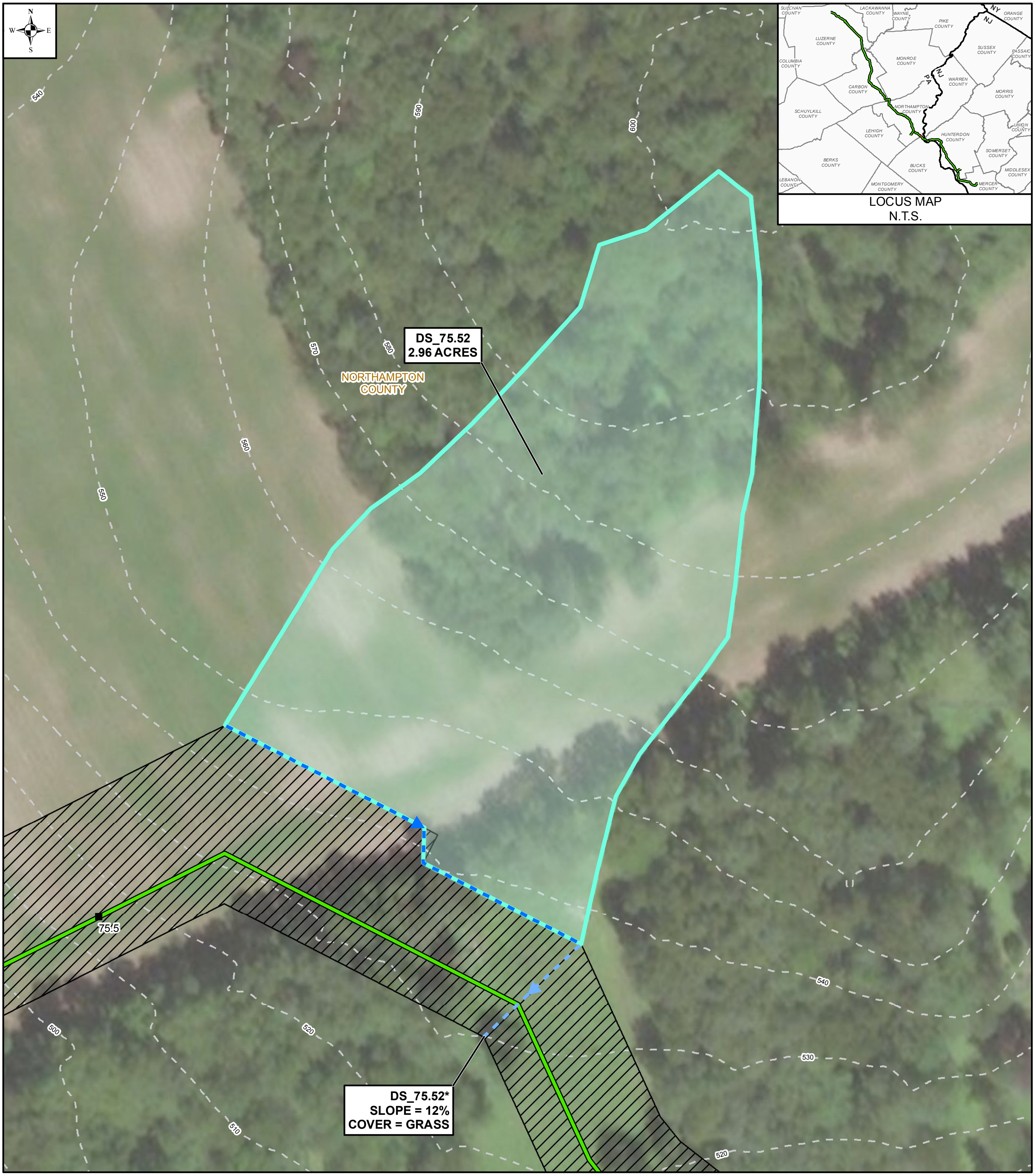


TR-55

DOWNSLOPE CONDITION
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 3%

SHALLOW CONCENTRATED FLOW VELOCITY = 1.3 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

1.3 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.



LEGEND

- 1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT
CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_75.52
NORTHAMPTON COUNTY, PENNSYLVANIA

0 50 100 FEET

PennEast PIPELINE

DRAWN BY:	SNP 10/2018	APPROVED BY:	MJD 10/2019	SCALE:	1 INCH = 100 FEET
CHECKED BY:	JMB 10/2019	REV. DATE:	10/2019	REV.:	1

DWG NO: PAGE 97 OF 114

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 75.52	100	0.8	0.030	14.55

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 75.52	151	FOREST	0.161	1.01	2.49
	403	SHORT GRASS	0.119	2.40	2.80

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c* (minutes)
19.84

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 75.52	1	FOREST	0.20	1.63	0.33	0.33
	2	PASTURE	0.50	1.33	0.67	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	19.84	2.88	3.48	3.97	2.88	3.48	3.97

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.33	3.48	2.96	2.85	3.44	3.93

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_75.52		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	2.96		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	3.45		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	10.10		
PROTECTIVE LINING[2,6]		S75		
n (MANNING'S COEFFICIENT)[2]		0.044		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	2.93		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.55		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	1.44		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	6.9 / 0		
D (TOTAL DEPTH)	(FT)	1.50		
CHANNEL TOP WIDTH @ D	(FT)	10.34		
d (CALCULATED FLOW DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	6.90		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	3.45		
R (HYDRAULIC RADIUS)		0.43		
S (BED SLOPE)[3, 7]	(FT/FT)	0.023		
S_C (CRITICAL SLOPE)	(FT/FT)	0.043		
$.7S_c$	(FT/FT)	0.030		
$1.3S_c$	(FT/FT)	0.056		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

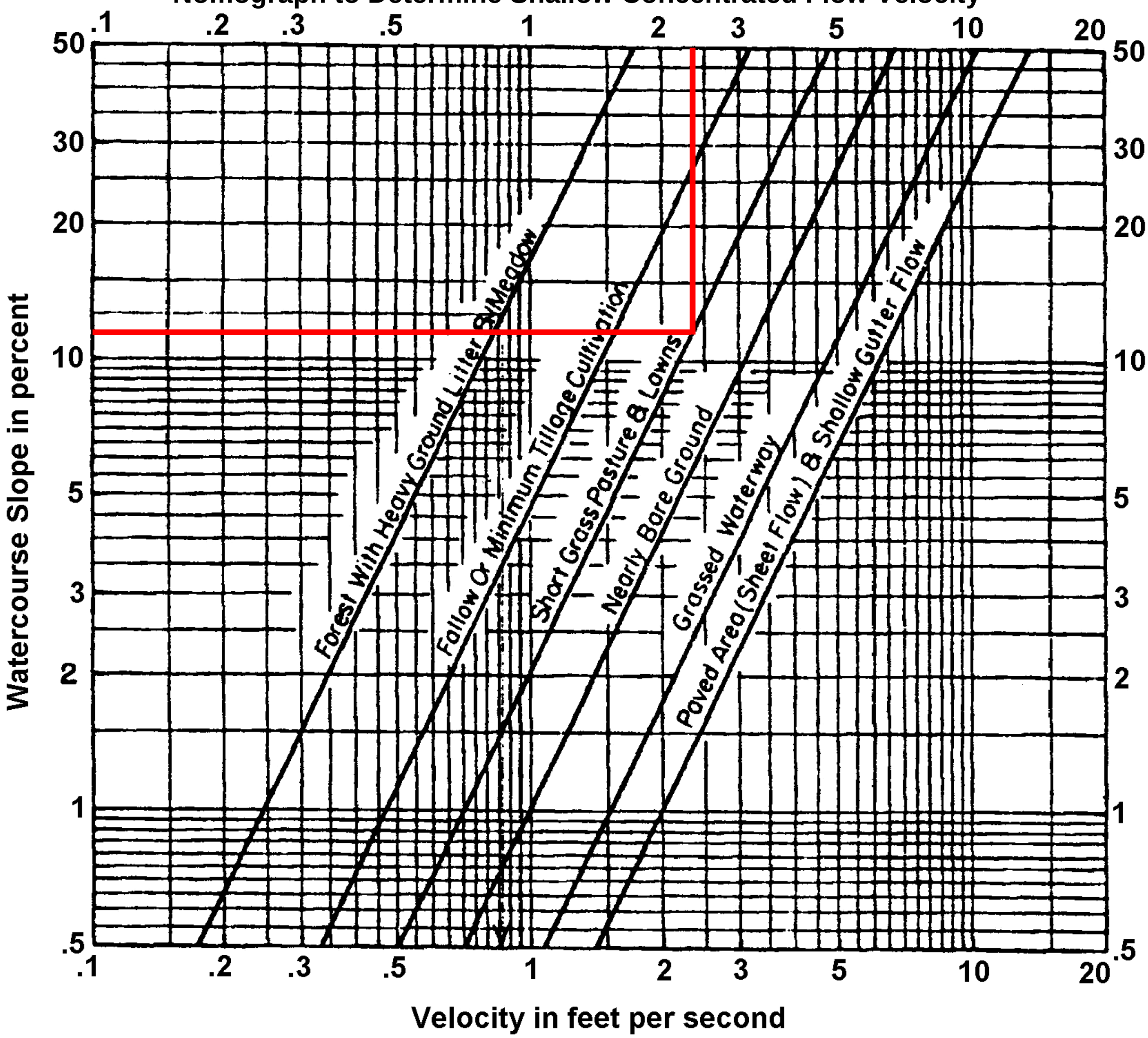
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_75.52

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity

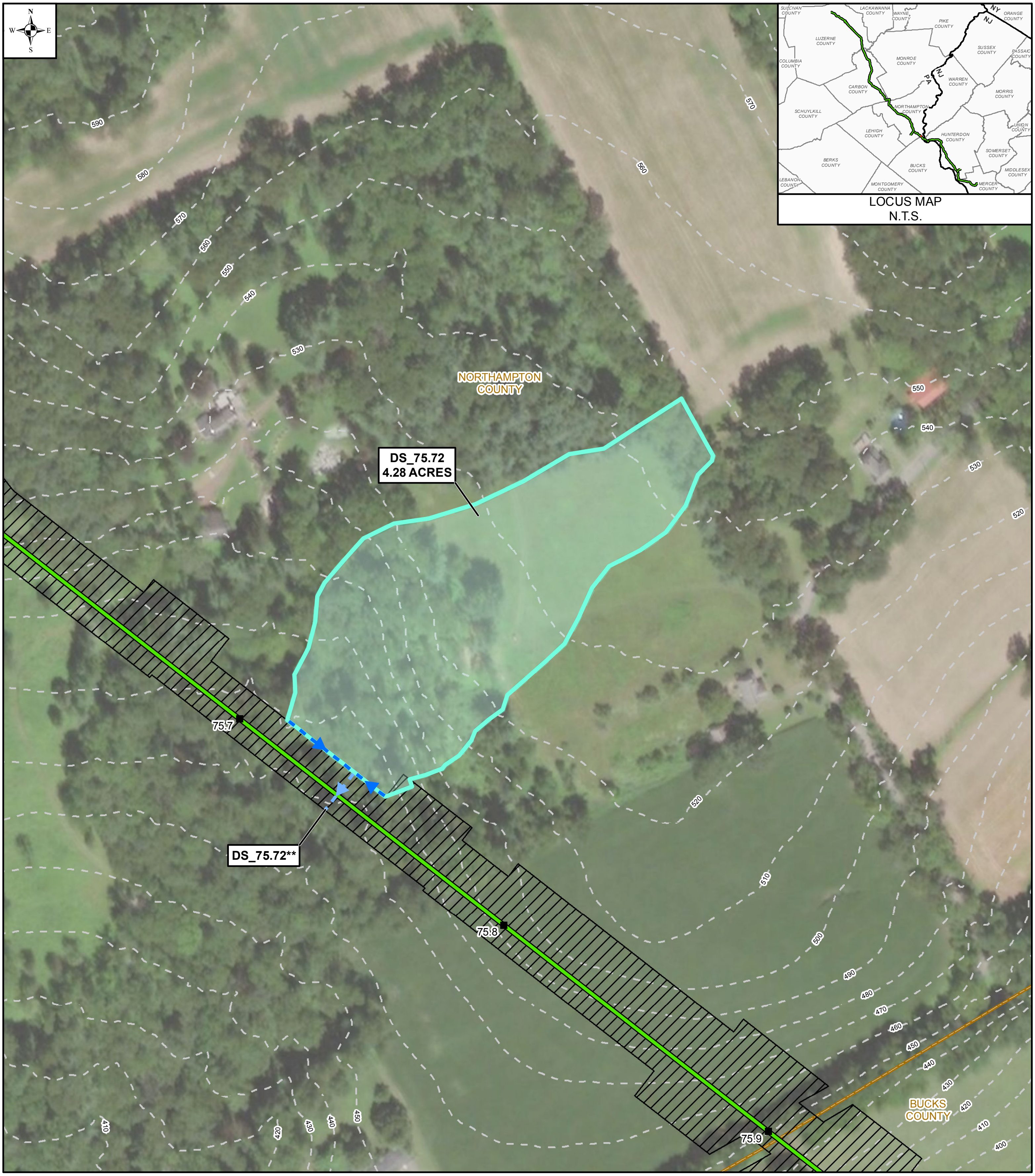


TR-55

DOWNSLOPE CONDITION
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 12%

SHALLOW CONCENTRATED FLOW VELOCITY = 2.4 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

2.4 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.



LEGEND

- 1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT
CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_75.72
NORTHAMPTON COUNTY, PENNSYLVANIA

0 100 200 FEET

PennEast PIPELINE

DRAWN BY:	SNP 10/2018	APPROVED BY:	MJD 10/2019	SCALE:	1 INCH = 200 FEET
CHECKED BY:	JMB 10/2019	REV. DATE:	10/2019	REV.:	1

DWG NO: PAGE 98 OF 114

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 75.72	100	0.8	0.075	11.75

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 75.72	134	FOREST	0.045	0.53	4.18
	238	SHORT GRASS	0.050	1.56	2.55
	403	FOREST	0.104	0.81	8.28

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
26.76

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 75.72	1	FOREST	0.20	2.59	0.52	0.23
	2	OPEN SPACE	0.28	1.69	0.47	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	26.76	2.42	2.95	3.42	2.42	2.95	3.42

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.23	2.95	4.28	2.40	2.92	3.39

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

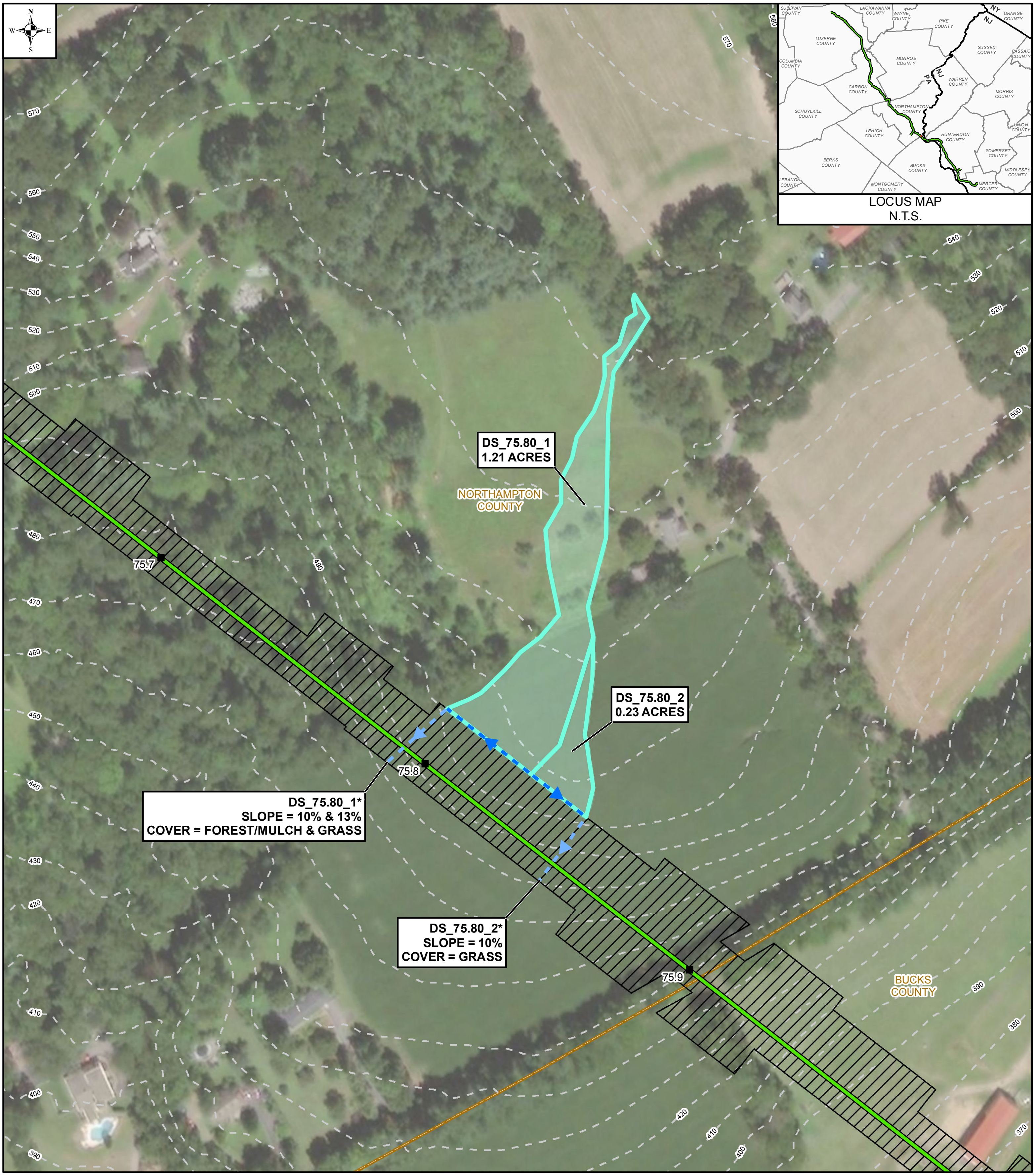
LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_75.72		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	4.28		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	2.92		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	6.31		
PROTECTIVE LINING[2,6]		C125		
n (MANNING'S COEFFICIENT)[2]		0.022		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	5.30		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	2.25		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	1.40		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	9.52 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	9.52		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	4.76		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.19		
R (HYDRAULIC RADIUS)		0.23		
S (BED SLOPE)[3, 7]	(FT/FT)	0.045		
S_C (CRITICAL SLOPE)	(FT/FT)	0.013		
$.7S_c$	(FT/FT)	0.009		
$1.3S_c$	(FT/FT)	0.017		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		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 seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.



LEGEND

1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)	SLOPE PIPE
PROPOSED PENNEAST PIPELINE	DRAINAGE AREA
BLUE MOUNTAIN LATERAL	PROPOSED CONSTRUCTION WORKSPACE
HELLERTOWN LATERAL	INDEX CONTOUR
DIVERSION SOCK	COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT

CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_75.80

NORTHAMPTON COUNTY, PENNSYLVANIA

0 100 200 FEET

PennEast PIPELINE

DRAWN BY:	SNP 10/2018	APPROVED BY:	MJD 10/2019	SCALE:	1 INCH = 200 FEET
CHECKED BY:	JMB 10/2019	REV. DATE:	10/2019	REV.:	1

DWG NO: PAGE 99 OF 114

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_75.80_1
1.21 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 75.80_1	100	0.8	0.060	12.37

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 75.80_1	43	FOREST	0.047	0.55	1.31
	665	SHORT GRASS	0.047	1.51	7.34

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c* (minutes)
21.03

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 75.80_1	1	FOREST	0.20	0.05	0.01	0.29
	2	OPEN SPACE	0.28	1.13	0.32	
	3	INDUSTRIAL	0.69	0.03	0.02	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	21.03	2.79	3.37	3.86	2.79	3.37	3.86

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.29	3.37	1.21	0.97	1.17	1.34

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_75.80_1		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	1.21		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	1.17		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	3.05		
PROTECTIVE LINING[2,6]		S75		
n (MANNING'S COEFFICIENT)[2]		0.055		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	2.08		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.55		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	1.31		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	11.76 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	11.76		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	5.88		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.47		
R (HYDRAULIC RADIUS)		0.23		
S (BED SLOPE)[3, 7]	(FT/FT)	0.042		
S_C (CRITICAL SLOPE)	(FT/FT)	0.078		
$.7S_c$	(FT/FT)	0.055		
$1.3S_c$	(FT/FT)	0.102		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

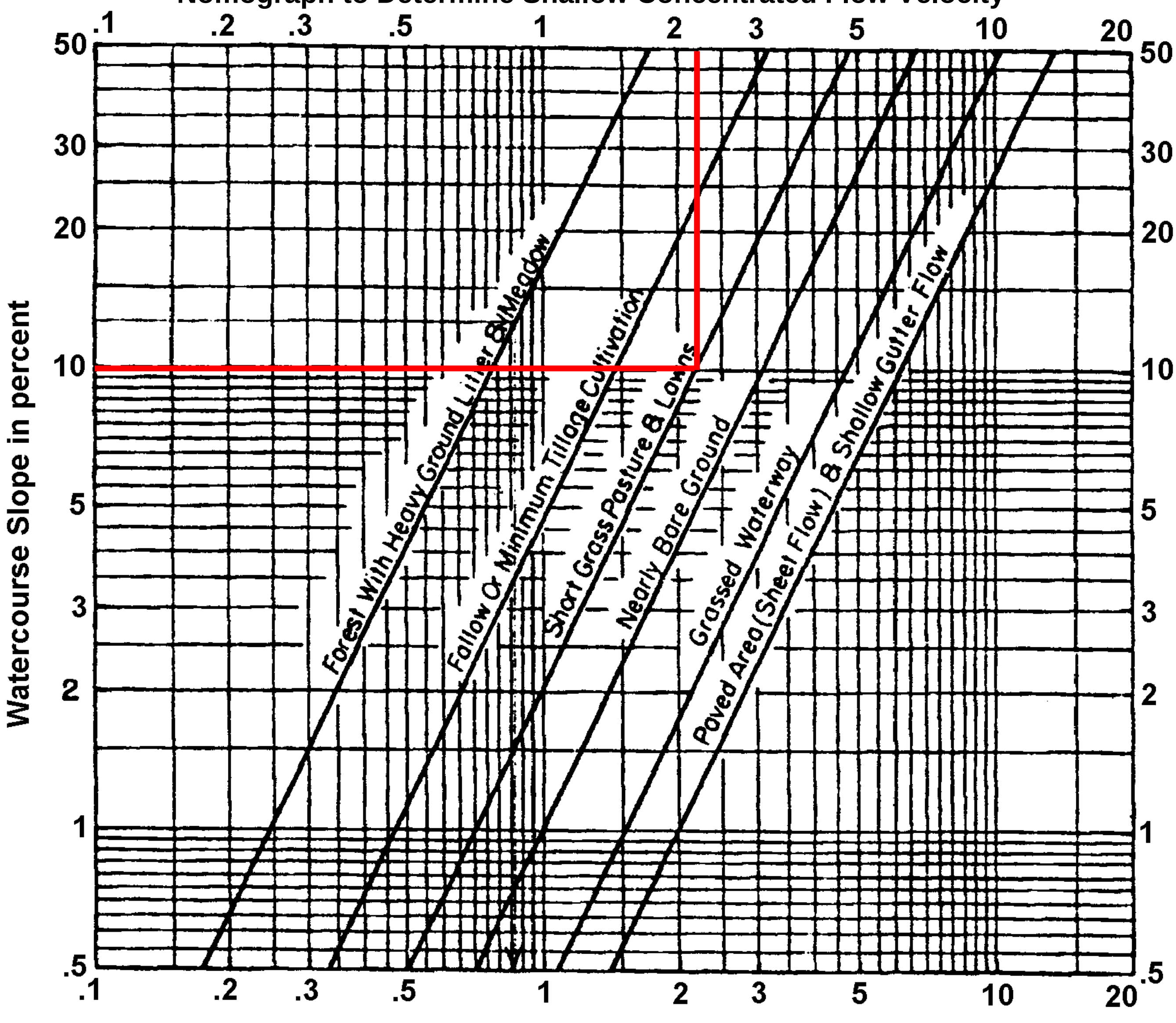
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_75.80_1

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 10%

SHALLOW CONCENTRATED FLOW VELOCITY = 2.2 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

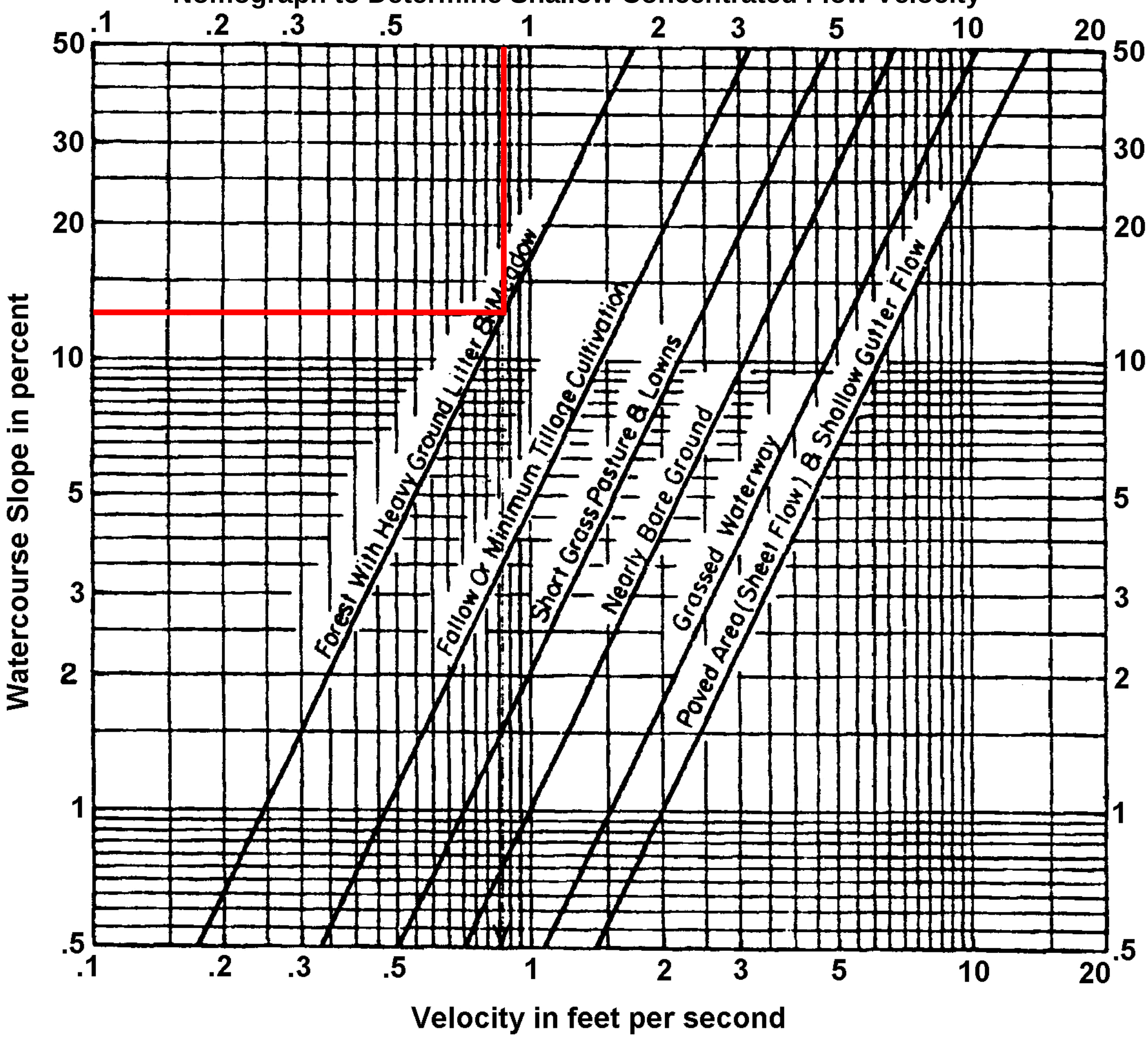
2.2 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.

CLEAN WATER DIVERSION ID:
DS_75.80_1

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = FOREST
PERCENT SLOPE = 13%

SHALLOW CONCENTRATED FLOW VELOCITY = 0.9 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 2 FPS FOR FORESTED/MULCH COVER TYPES.

0.9 FPS < 2.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_75.80_2
0.23 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 75.80_2	100	0.4	0.031	10.44

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 75.80_2	187	SHORT GRASS	0.079	1.96	1.59

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
12.04

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 75.80_2	1	PASTURE	0.50	0.15	0.08	0.42
	2	OPEN SPACE	0.28	0.08	0.02	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	12.04	3.65	4.35	4.85	3.65	4.35	4.85

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.42	4.35	0.23	0.36	0.42	0.47

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		DS_75.80_2		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	5		
ACRES	(AC)	0.23		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	0.42		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	3.05		
PROTECTIVE LINING[2,6]		S75		
n (MANNING'S COEFFICIENT)[2]		0.055		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	2.15		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.55		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	1.40		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	11.36 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	11.36		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	5.68		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.42		
R (HYDRAULIC RADIUS)		0.23		
S (BED SLOPE)[3, 7]	(FT/FT)	0.045		
S_C (CRITICAL SLOPE)	(FT/FT)	0.079		
$.7S_c$	(FT/FT)	0.055		
$1.3S_c$	(FT/FT)	0.102		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

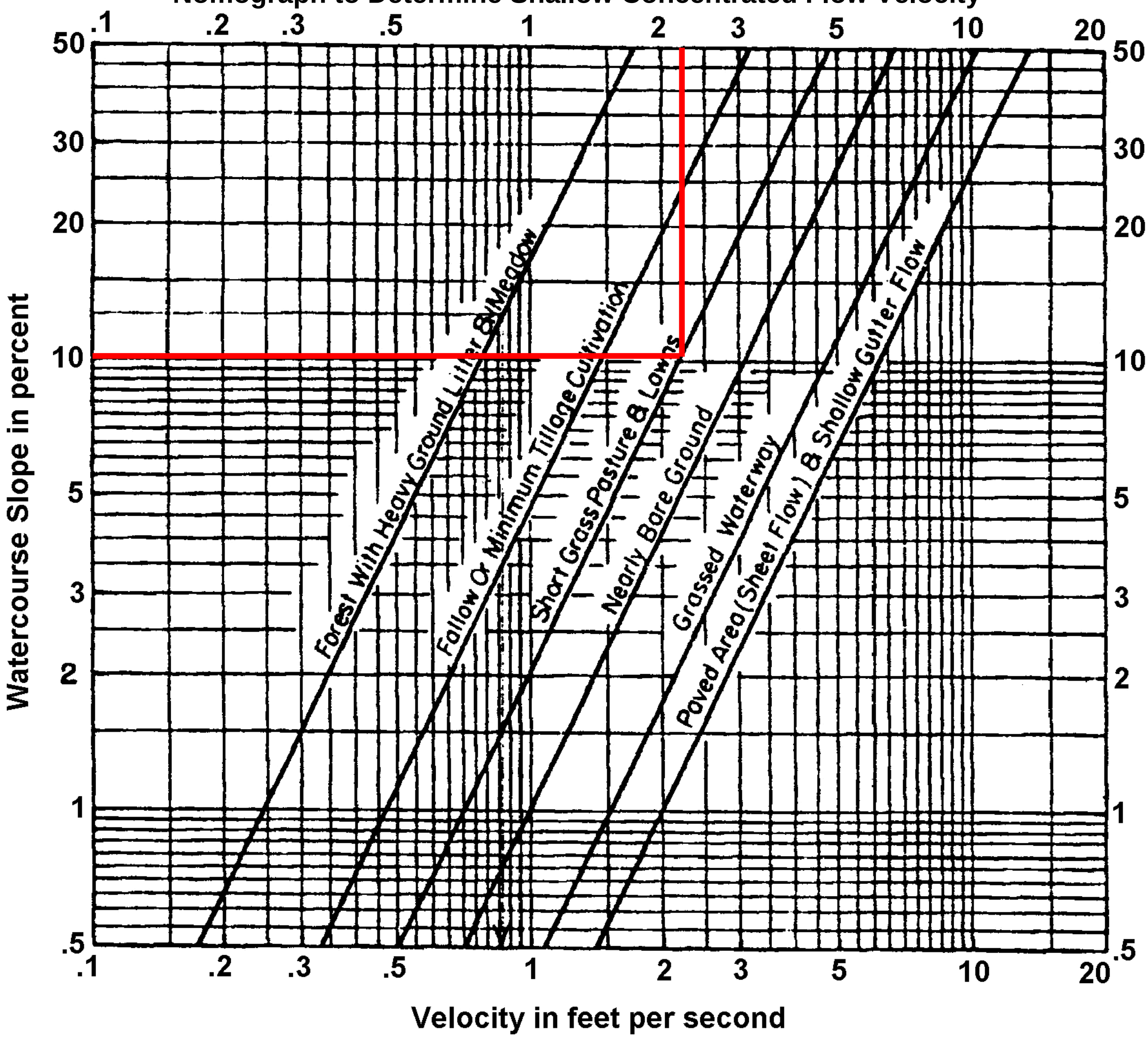
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_75.80_2

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity

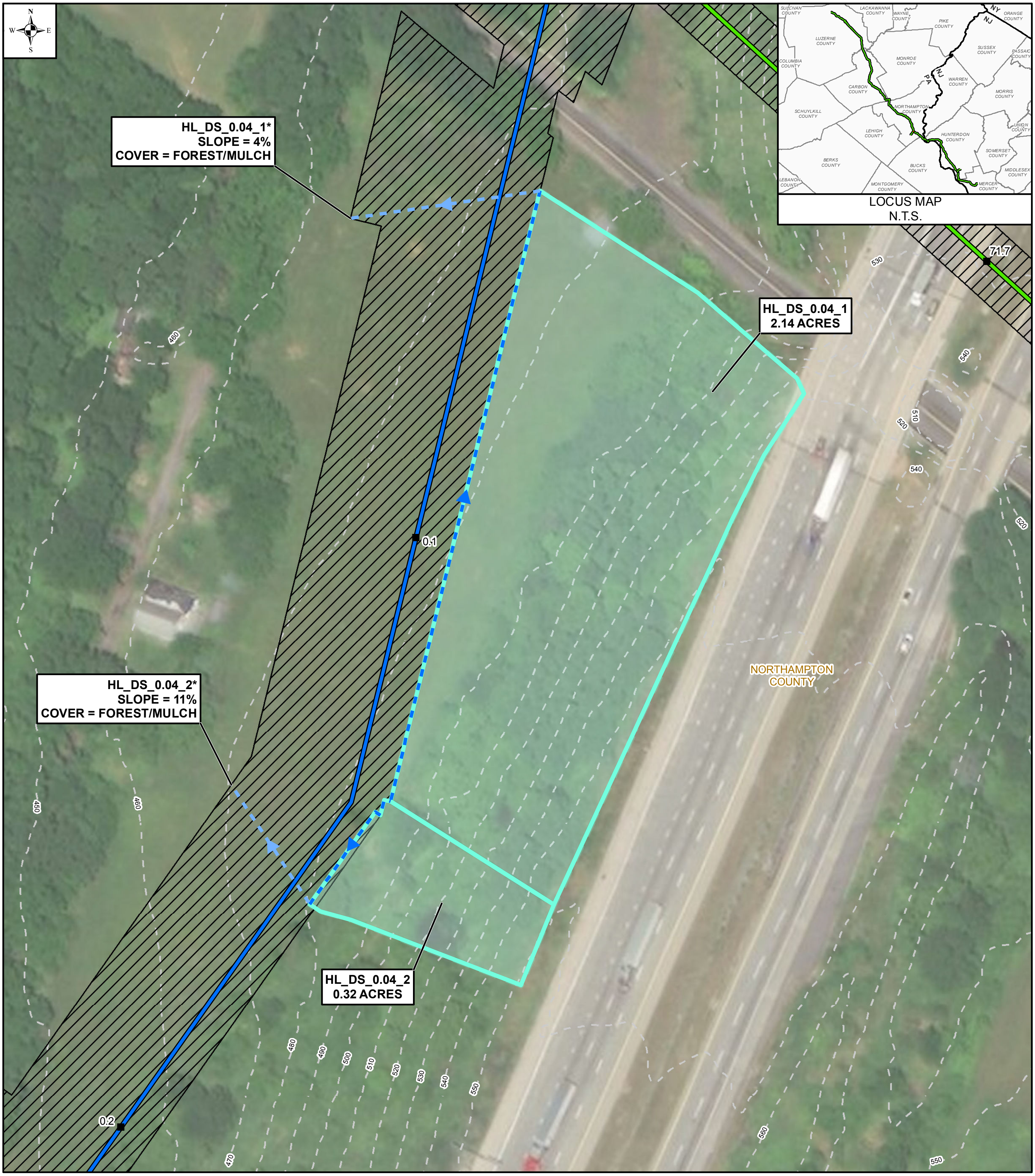


TR-55

DOWNSLOPE CONDITION
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 10%

SHALLOW CONCENTRATED FLOW VELOCITY = 2.2 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

2.2 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.



LEGEND

- 1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT
CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_HL_0.04
NORTHAMPTON COUNTY, PENNSYLVANIA

0 50 100 FEET

PennEast PIPELINE

DRAWN BY:	SNP 10/2018	APPROVED BY:	MJD 10/2019	SCALE:	1 INCH = 100 FEET
CHECKED BY:	JMB 10/2019	REV. DATE:	10/2019	REV.:	1

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_0.04_1
2.14 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 0.04_1	100	0.4	0.360	5.89

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 0.04_1	36	FOREST	0.111	0.84	0.72
	128	SHORT GRASS	0.102	2.22	0.96

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
7.56

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME:	PENNEAST PIPELINE PROJECT
LOCATION:	NORTHAMPTON COUNTY
PREPARED BY:	MDN — DATE: 10/15/2018
CHECKED BY:	KEK / JMB — DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 0.04_1	1	FOREST	0.20	1.46	0.29	0.23
	2	OPEN SPACE	0.28	0.68	0.19	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	7.56	4.32	5.08	5.56	4.32	5.08	5.56

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.23	4.32	2.14	2.08	2.45	2.68

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		HL_DS_0.04_1		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	2		
ACRES	(AC)	2.14		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	2.1		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	2.45		
PROTECTIVE LINING[2,6]		C125		
n (MANNING'S COEFFICIENT)[2]		0.022		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	3.53		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	2.25		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	0.69		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	5.56 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	5.56		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	2.78		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	0.69		
R (HYDRAULIC RADIUS)		0.21		
S (BED SLOPE)[3, 7]	(FT/FT)	0.022		
S_C (CRITICAL SLOPE)	(FT/FT)	0.014		
$.7S_c$	(FT/FT)	0.010		
$1.3S_c$	(FT/FT)	0.018		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

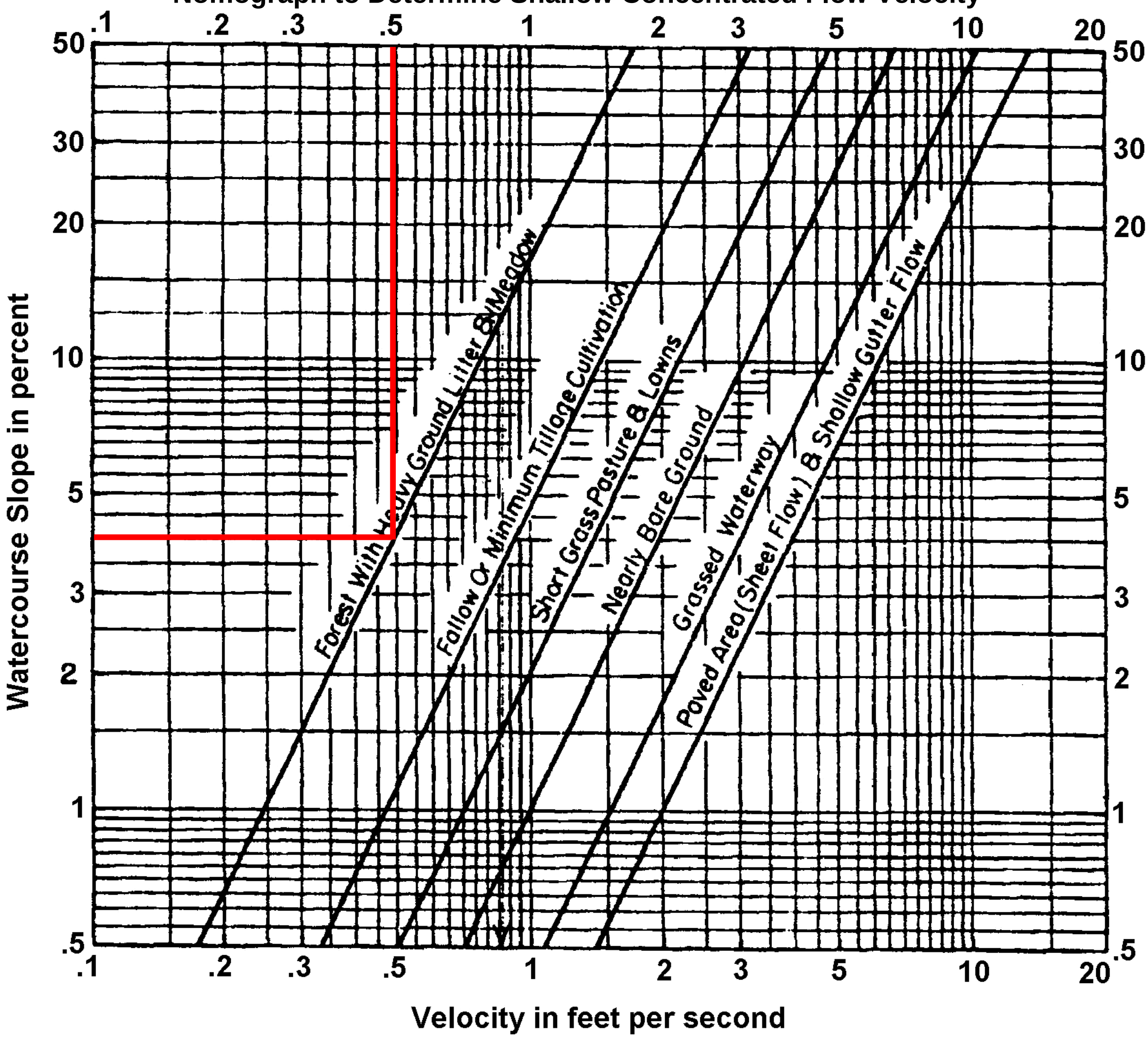
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_0.04_1

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = FOREST
PERCENT SLOPE = 4%

SHALLOW CONCENTRATED FLOW VELOCITY = 0.5 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 2 FPS FOR FORESTED/MULCH COVER TYPES.

0.5 FPS < 2.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_0.04_2
0.32 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 0.04_2	100	0.8	0.470	7.65

$$T_{c(sheet\ flow)} = \left[\frac{2 (n)}{3\ ^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 0.04_2	69	FOREST	0.321	1.43	0.81

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c* (minutes)
8.46

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 0.04_2	1	FOREST	0.20	0.32	0.06	0.20

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	8.46	4.16	4.92	5.40	4.16	4.92	5.40

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.20	4.16	0.32	0.27	0.31	0.35

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		HL_DS_0.04_2		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	2		
ACRES	(AC)	0.32		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	0.27		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	0.45		
PROTECTIVE LINING[2,6]		C125		
n (MANNING'S COEFFICIENT)[2]		0.022		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	2.56		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	2.25		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	0.46		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	12.66 / 0		
D (TOTAL DEPTH)	(FT)	0.67		
CHANNEL TOP WIDTH @ D	(FT)	8.44		
d (CALCULATED FLOW DEPTH)	(FT)	0.17		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	2.11		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	0.18		
R (HYDRAULIC RADIUS)		0.08		
S (BED SLOPE)[3, 7]	(FT/FT)	0.044		
S_C (CRITICAL SLOPE)	(FT/FT)	0.018		
$.7S_c$	(FT/FT)	0.013		
$1.3S_c$	(FT/FT)	0.023		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

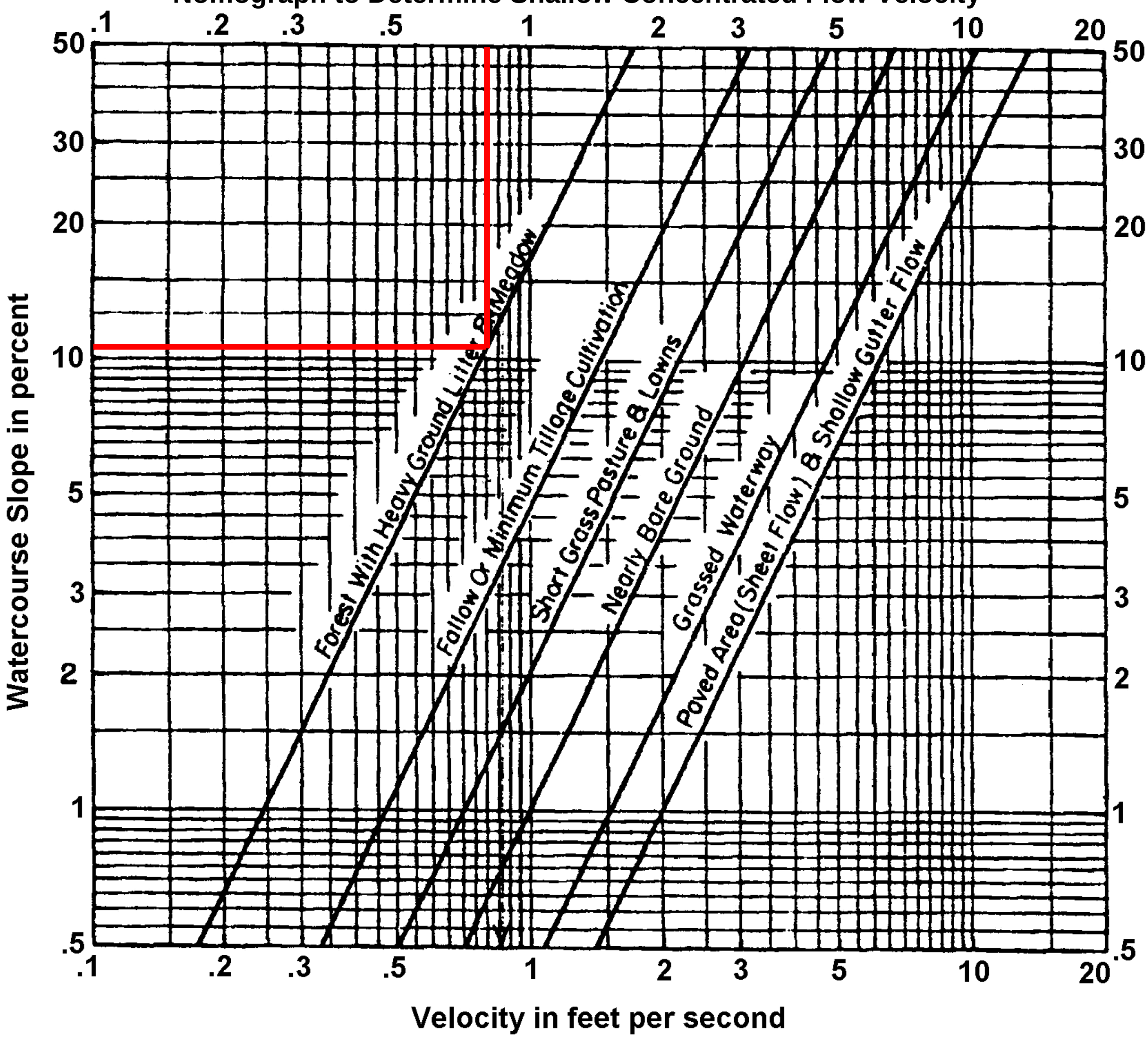
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID: DS_0.04_2

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity

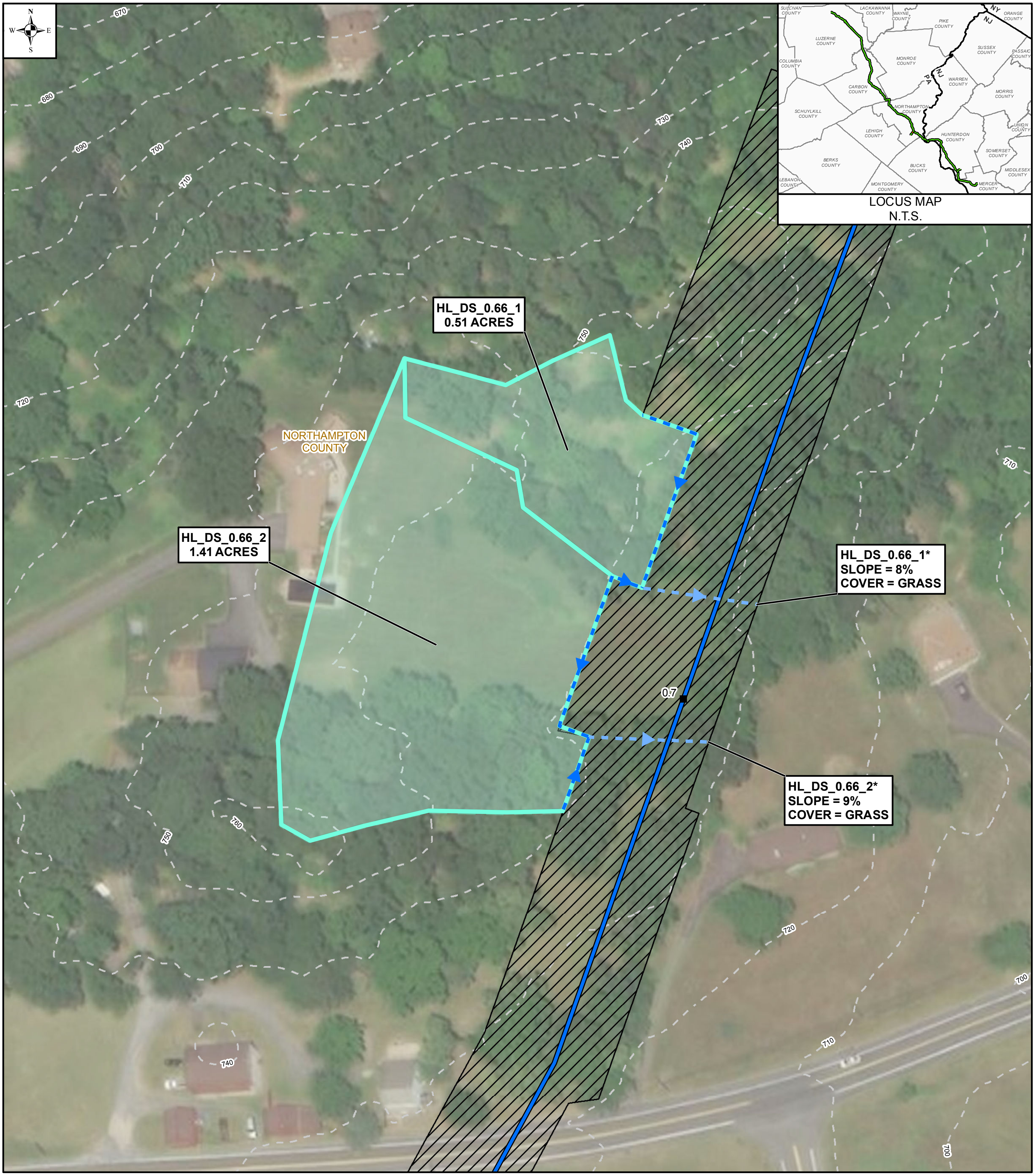


TR-55

DOWNSLOPE CONDITION
COVER TYPE = FOREST
PERCENT SLOPE = 11%

SHALLOW CONCENTRATED FLOW VELOCITY = 0.8 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 2 FPS FOR FORESTED/MULCH COVER TYPES.

0.8 FPS < 2.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.



LEGEND

- 1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT

CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_HL_0.66

NORTHAMPTON COUNTY, PENNSYLVANIA

0 50 100 FEET

PennEast PIPELINE

DRAWN BY:	SNP 10/2018	APPROVED BY:	MJD 10/2019	SCALE:	1 INCH = 100 FEET
CHECKED BY:	JMB 10/2019	REV. DATE:	10/2019	REV.:	1

DWG NO: PAGE 104 OF 114

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_0.66_1
0.51 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 0.66_1	100	0.4	0.050	9.34

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}} \right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 0.66_1	189	FOREST	0.058	0.61	5.20

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
14.54

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 0.66_1	1	FOREST	0.20	0.47	0.09	0.21
	2	OPEN SPACE	0.28	0.04	0.01	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	14.54	3.36	4.03	4.53	3.36	4.03	4.53

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.21	3.36	0.51	0.35	0.42	0.48

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		HL_DS_0.66_1		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	2		
ACRES	(AC)	0.51		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	0.35		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	1.61		
PROTECTIVE LINING[2,6]		EXISTING GRASS		
n (MANNING'S COEFFICIENT)[2]		0.08		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	0.84		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.00		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	0.44		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	15.38 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	15.38		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	7.69		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.92		
R (HYDRAULIC RADIUS)		0.23		
S (BED SLOPE)[3, 7]	(FT/FT)	0.014		
S_C (CRITICAL SLOPE)	(FT/FT)	0.161		
$.7S_c$	(FT/FT)	0.113		
$1.3S_c$	(FT/FT)	0.210		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

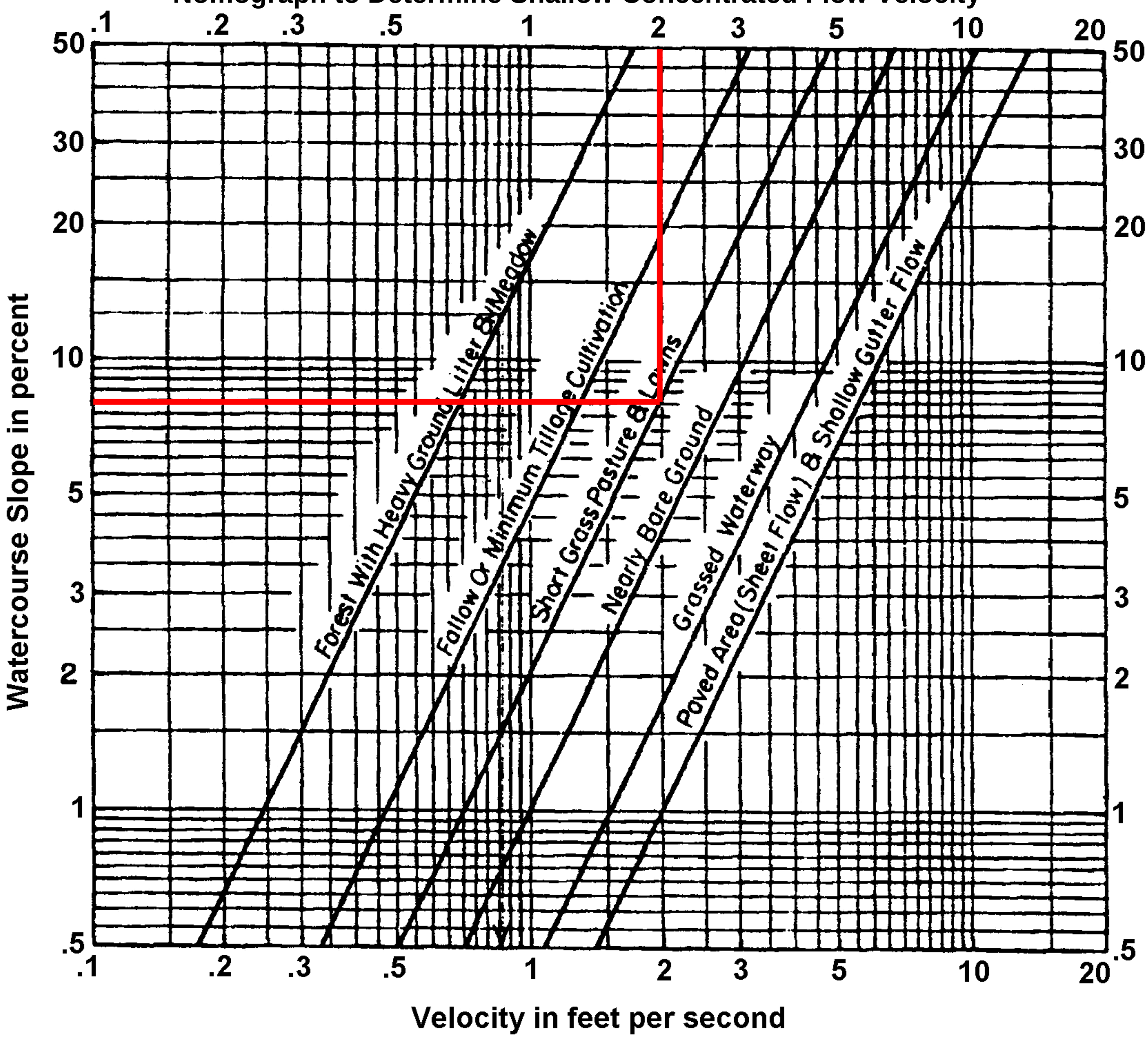
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_0.66_1

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 8%

SHALLOW CONCENTRATED FLOW VELOCITY = 2.0 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

2.0 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_0.66_2
1.41 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 0.66_2	100	0.4	0.040	9.84

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 0.66_2	162	SHORT GRASS	0.068	1.82	1.49

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
11.33

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 0.66_2	1	FOREST	0.20	0.61	0.12	0.25
	2	OPEN SPACE	0.28	0.78	0.22	
	3	INDUSTRIAL	0.69	0.02	0.01	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	11.33	3.74	4.45	4.95	3.74	4.45	4.95

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.25	3.74	1.41	1.33	1.58	1.75

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		HL_DS_0.66_2		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	2		
ACRES	(AC)	1.41		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	1.33		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	3.67		
PROTECTIVE LINING[2,6]		S75		
n (MANNING'S COEFFICIENT)[2]		0.055		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	2.23		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.55		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	1.50		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	13.16 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	13.16		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	6.58		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	1.64		
R (HYDRAULIC RADIUS)		0.23		
S (BED SLOPE)[3, 7]	(FT/FT)	0.048		
S_C (CRITICAL SLOPE)	(FT/FT)	0.077		
$.7S_c$	(FT/FT)	0.054		
$1.3S_c$	(FT/FT)	0.101		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

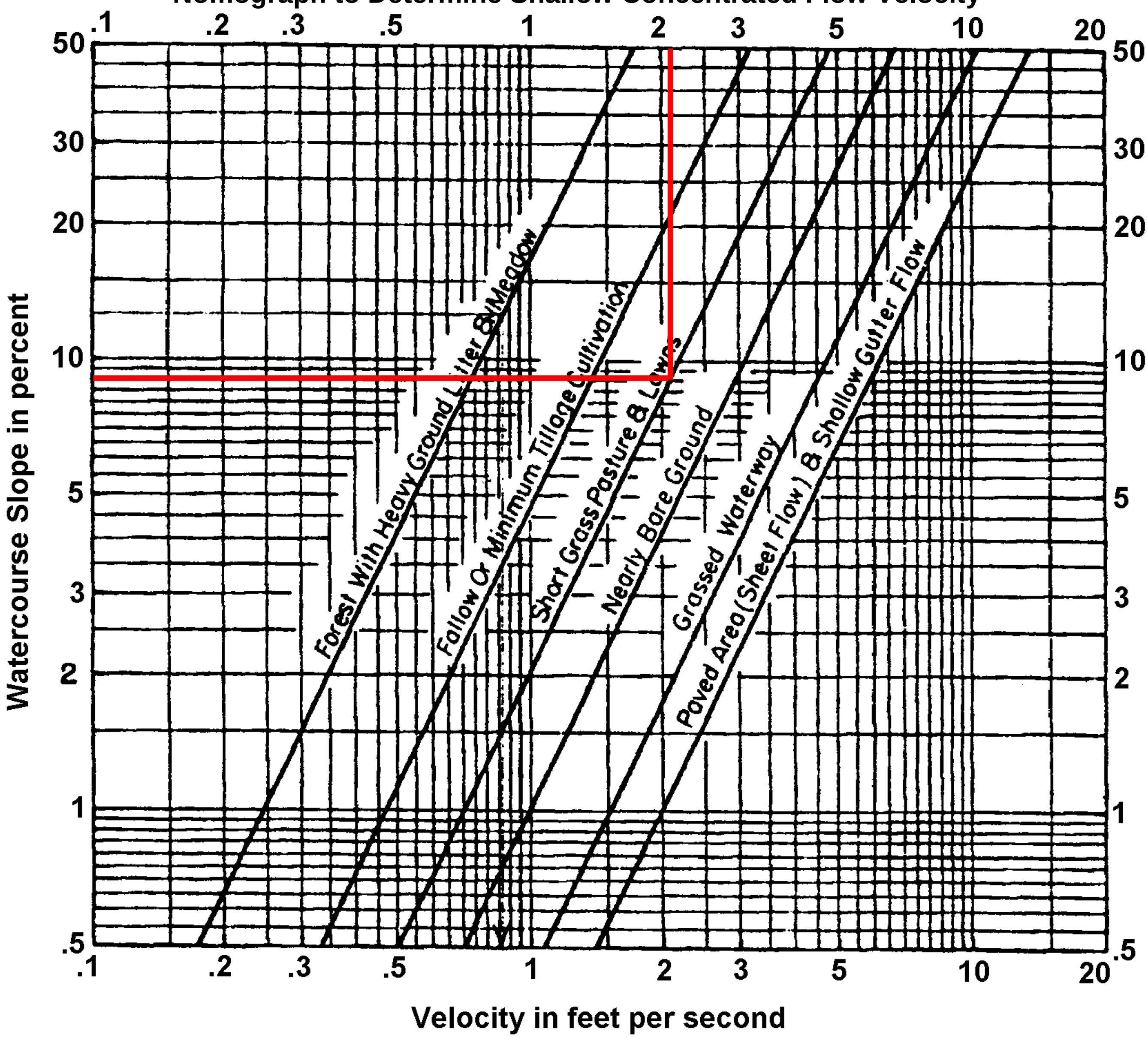
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_0.66_2

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity

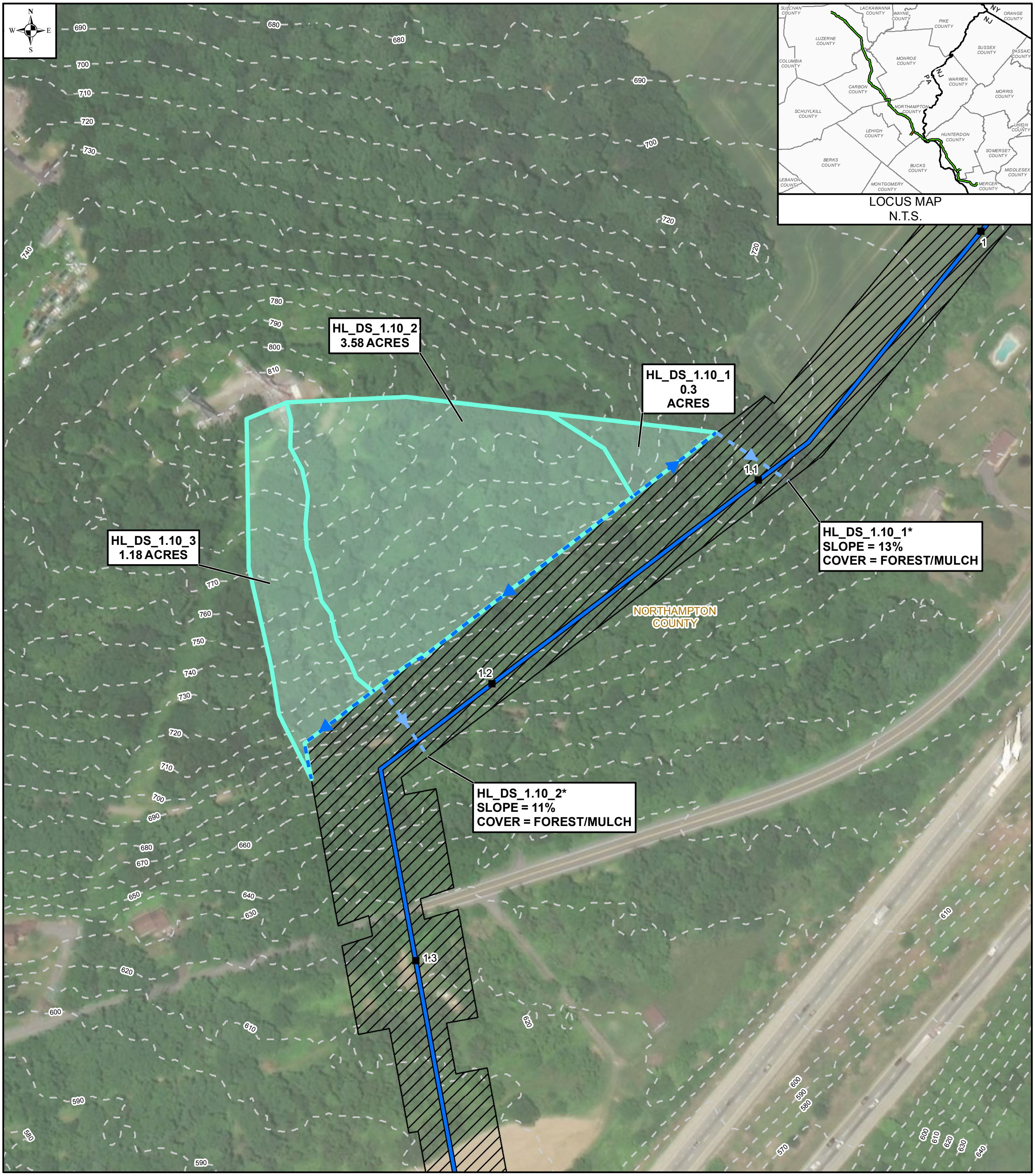


TR-55

DOWNSLOPE CONDITION
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 9%

SHALLOW CONCENTRATED FLOW VELOCITY = 2.1 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

2.1 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.



LEGEND

- 1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT

CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_HL_1.10

NORTHAMPTON COUNTY, PENNSYLVANIA

0 100 200 FEET

PennEast PIPELINE

DRAWN BY:	SNP 10/2018	APPROVED BY:	MJD 10/2019	SCALE:	1 INCH = 200 FEET
CHECKED BY:	JMB 10/2019	REV. DATE:	10/2019	REV.:	1

DWG NO:

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_1.10_1
0.3 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME:	PENNEAST PIPELINE PROJECT
LOCATION:	NORTHAMPTON COUNTY
PREPARED BY:	MDN DATE: 10/15/2018
CHECKED BY:	KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 1.10_1	100	0.8	0.060	12.37

$$T_{c\,(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S^{0.5})}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 1.10_1	165	FOREST	0.194	1.11	2.48

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c* (minutes)
14.86

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 1.10_1	1	FOREST	0.20	0.30	0.06	0.20

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	14.86	3.33	3.99	4.49	3.33	3.99	4.49

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.20	3.33	0.30	0.20	0.24	0.27

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		HL_DS_1.10_1		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	2		
ACRES	(AC)	0.3		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	0.2		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	2.21		
PROTECTIVE LINING[2,6]		P300		
n (MANNING'S COEFFICIENT)[2]		0.034		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	4.30		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	3.00		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	2.65		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	4.1 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	4.10		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	2.05		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	0.51		
R (HYDRAULIC RADIUS)		0.20		
S (BED SLOPE)[3, 7]	(FT/FT)	0.085		
S_C (CRITICAL SLOPE)	(FT/FT)	0.037		
$.7S_c$	(FT/FT)	0.026		
$1.3S_c$	(FT/FT)	0.048		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

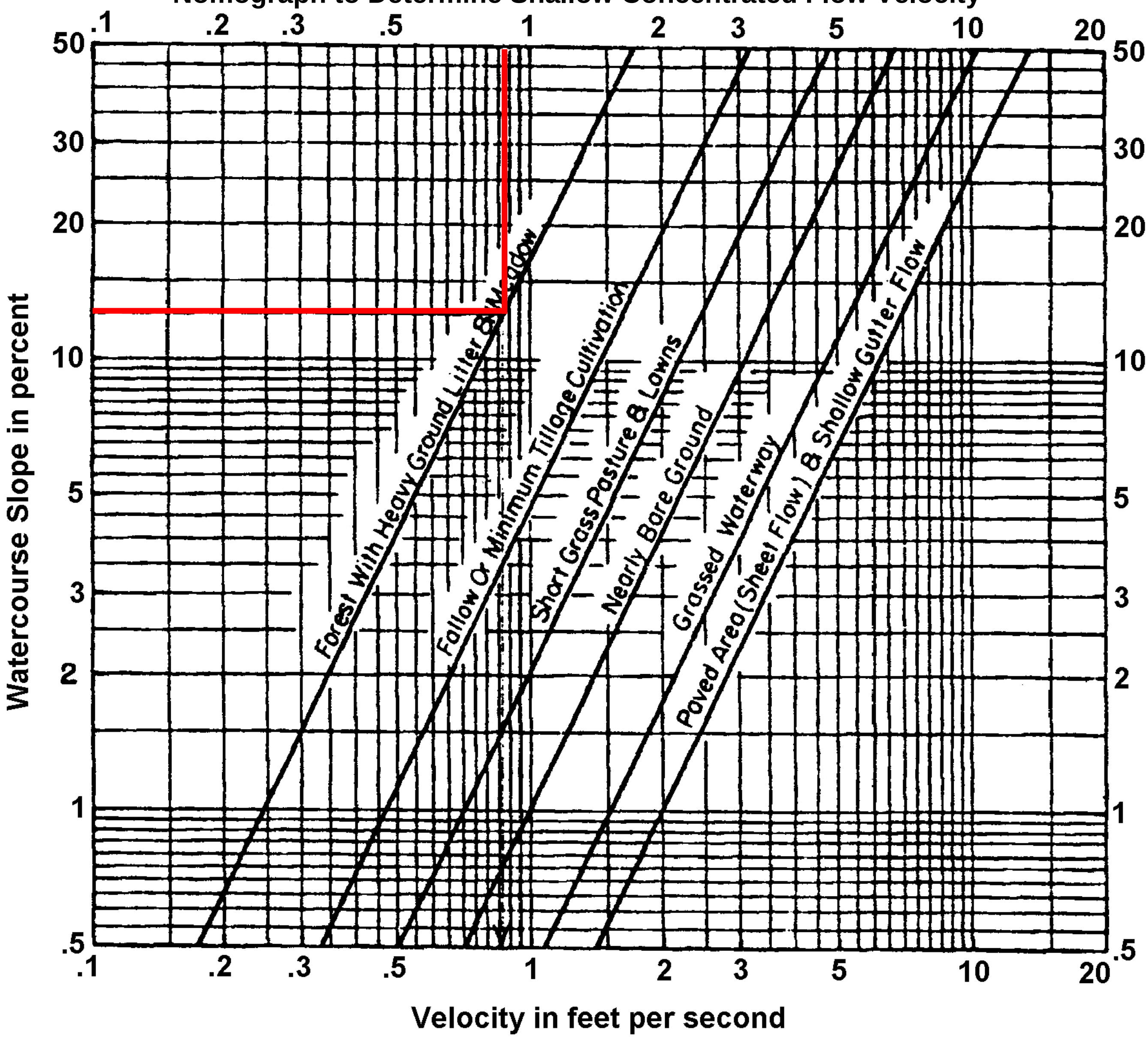
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_1.10_1

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = FOREST
PERCENT SLOPE = 13%

SHALLOW CONCENTRATED FLOW VELOCITY = 0.9 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 2 FPS FOR FORESTED/MULCH COVER TYPES.

0.9 FPS < 2.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_1.10_2
3.58 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 1.10_2	100	0.8	0.130	10.33

$$T_{c\,(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 1.10_2	506	FOREST	0.099	0.79	10.65

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c* (minutes)
20.98

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 1.10_2	1	FOREST	0.20	3.58	0.72	0.20

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	20.98	2.79	3.38	3.87	2.79	3.38	3.87

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.20	2.79	3.58	2.00	2.42	2.77

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		HL_DS_1.10_2		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	2		
ACRES	(AC)	3.58		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	2		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	2.18		
PROTECTIVE LINING[2,6]		P300		
n (MANNING'S COEFFICIENT)[2]		0.034		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	4.36		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	3.00		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	2.75		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	4 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	4.00		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	2.00		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	0.50		
R (HYDRAULIC RADIUS)		0.20		
S (BED SLOPE)[3, 7]	(FT/FT)	0.088		
S_C (CRITICAL SLOPE)	(FT/FT)	0.037		
$.7S_c$	(FT/FT)	0.026		
$1.3S_c$	(FT/FT)	0.048		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

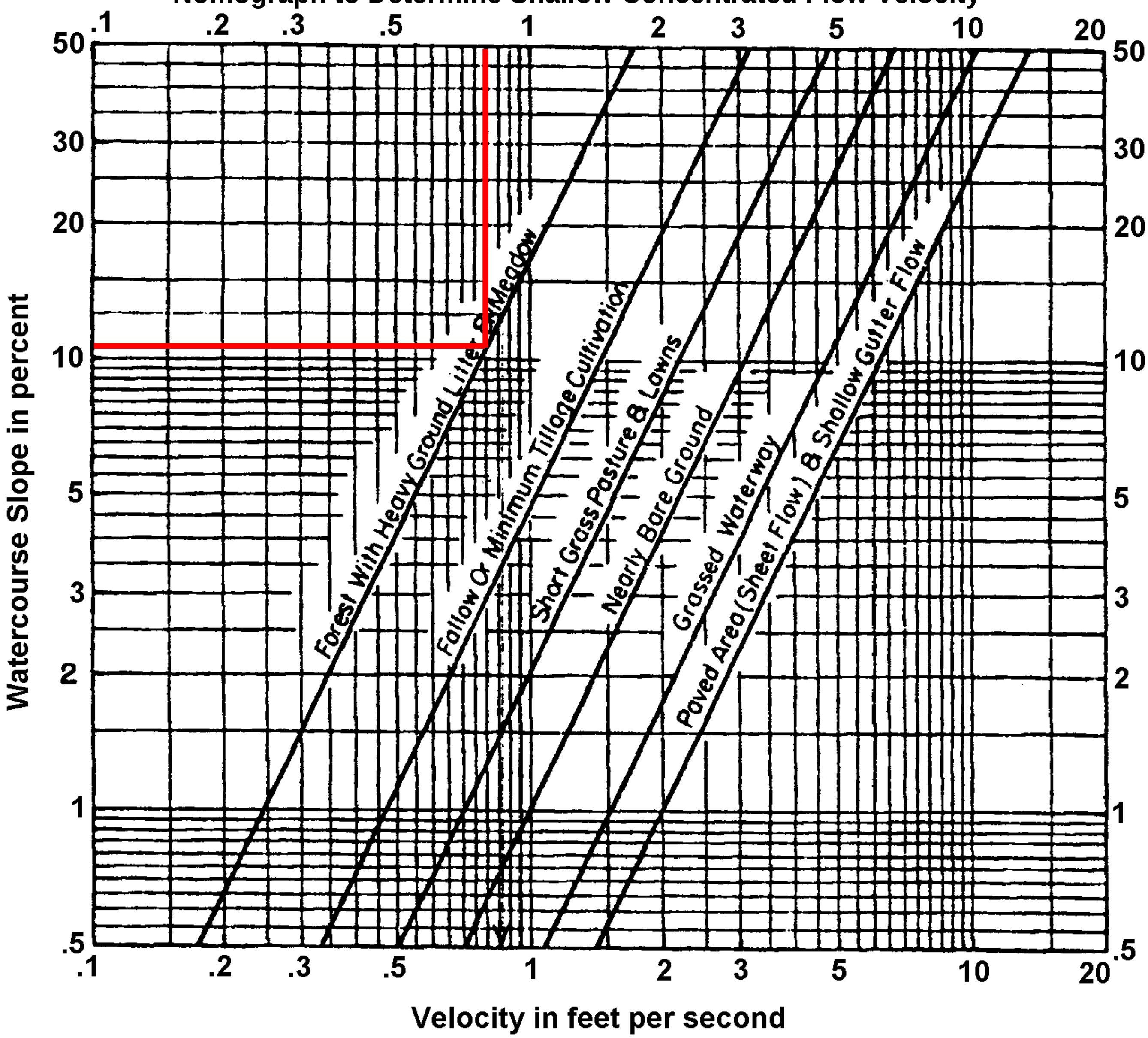
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_1.10_2

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = FOREST
PERCENT SLOPE = 11%

SHALLOW CONCENTRATED FLOW VELOCITY = 0.8 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 2 FPS FOR FORESTED/MULCH COVER TYPES.

0.8 FPS < 2.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.

CLEAN WATER DIVERSION

DRAINAGE AREA
DS_1.10_3
1.18 ACRES

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 1.10_3	100	0.8	0.030	14.55

$$T_{c(sheet\ flow)} = \left[\frac{2\,(n)}{3\,{}^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 1.10_3	552	FOREST	0.245	1.25	7.39

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c* (minutes)
21.94

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 1.10_3	1	FOREST	0.20	1.18	0.24	0.20

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	21.94	2.72	3.30	3.78	2.72	3.30	3.78

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

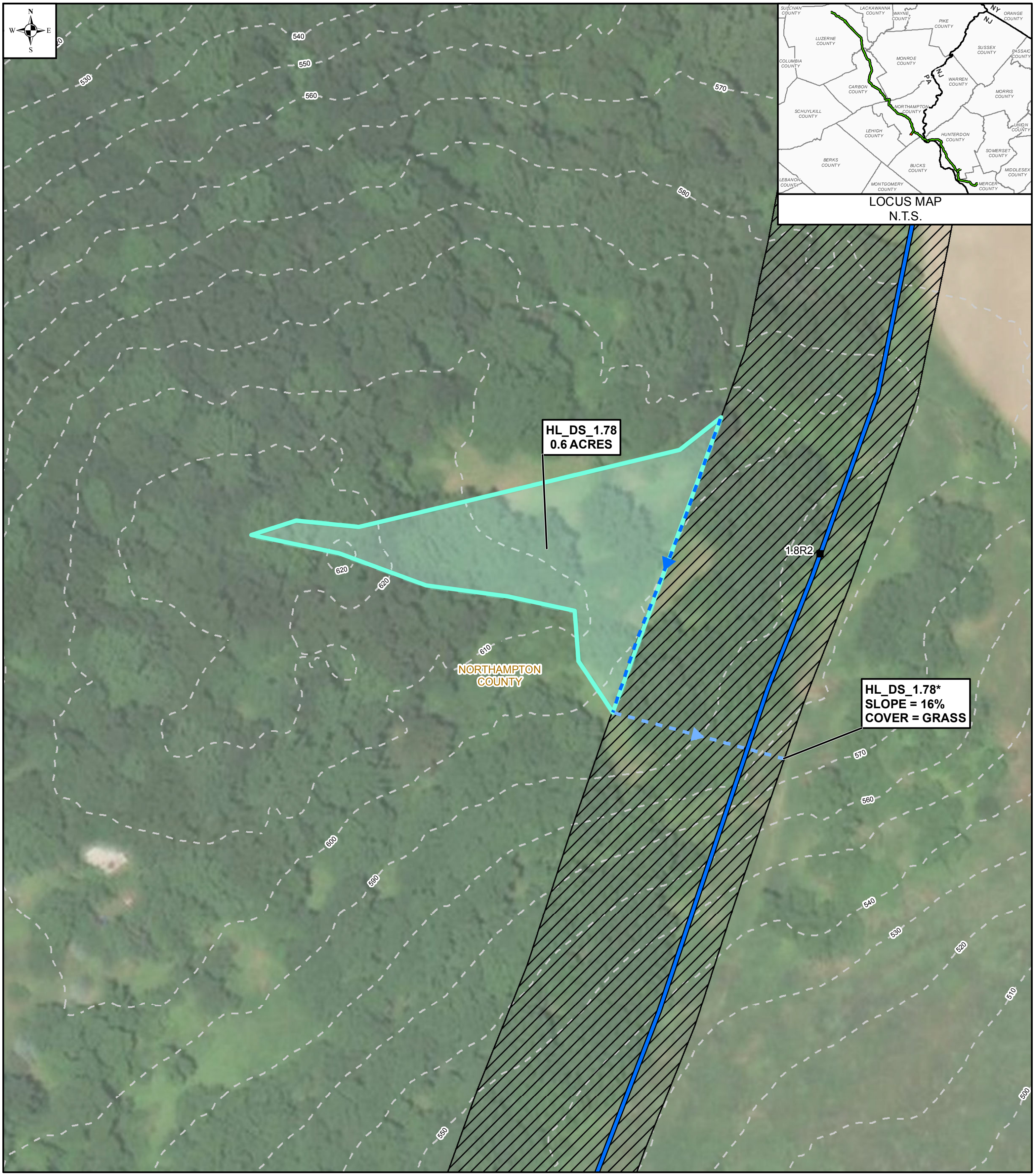
CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.20	2.72	1.18	0.64	0.78	0.89

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/2019
CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION[7]		HL_DS_1.10_3a	HL_DS_1.10_3b	**HL_DS_1.10_3b**
TEMPORARY OR PERMANENT?	(T OR P)	T	T	**T**
DESIGN STORM	(2, 5, OR 10 YR)	2	2	**2**
ACRES	(AC)	1.18	1.18	**1.18**
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A	N/A	**N/A**
Q_r (REQUIRED CAPACITY)	(CFS)	0.64	0.64	**0.64**
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	1.29	4.29	**4.29**
PROTECTIVE LINING[2,6]		P300	C350 (Unvegetated)	**C350 (Vegetated)**
n (MANNING'S COEFFICIENT)[2]		0.034	0.041	**0.041**
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A	N/A	**N/A**
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	4.01	7.54	**7.54**
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	3.00	3.20	**12.00**
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	2.78	11.48	**11.48**
CHANNEL BOTTOM WIDTH	(FT)	0	0	**0**
CHANNEL SIDE SLOPES	(H:V)	2.56 / 0	4.55 / 0	**4.55 / 0**
D (TOTAL DEPTH)	(FT)	1.00	1.00	**1.00**
CHANNEL TOP WIDTH @ D	(FT)	2.56	4.55	**4.55**
d (CALCULATED FLOW DEPTH)	(FT)	0.50	0.50	**0.50**
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	1.28	2.27	**2.27**
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0	0	**0**
d_{50} STONE SIZE	(IN)	N/A	N/A	**N/A**
A (CROSS-SECTIONAL AREA)	(SQ. FT)	0.32	0.57	**0.57**
R (HYDRAULIC RADIUS)		0.17	0.20	**0.20**
S (BED SLOPE)[3]	(FT/FT)	0.089	0.368	**0.368**
S_C (CRITICAL SLOPE)	(FT/FT)	0.044	0.052	**0.052**
$.7S_c$	(FT/FT)	0.031	0.036	**0.036**
$1.3S_c$	(FT/FT)	0.058	0.068	**0.068**
STABLE FLOW?	(Y/N)	Y	Y	**Y**
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A	N/A	**N/A**
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50	0.50	**0.50**
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50	0.50	**0.50**
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S	S	**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 seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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 methods 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. For this temporary channel, the percent slope changes along the diversion sock, therefore it was designed in two segments. The calculations above demonstrate that the shear stress and capacity were checked for both scenarios and the more conservative lining and diversion sock diameter were selected and implemented into the design. The table above shows both scenarios, and the column in bold is the more conservative design used to satisfy both scenarios.



LEGEND

- 1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT
CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_HL_1.78
NORTHAMPTON COUNTY, PENNSYLVANIA

0 50 100 FEET

PennEast PIPELINE

DRAWN BY:	SNP 10/2018	APPROVED BY:	MJD 10/2019	SCALE:	1 INCH = 100 FEET
CHECKED BY:	JMB 10/2019	REV. DATE:	10/2019	REV.:	1

DWG NO: PAGE 106 OF 114

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 1.78	100	0.8	0.070	11.94

$$T_{c\,(sheet\ flow)} = \left[\frac{2 (n)}{3 ^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 1.78	288	FOREST	0.069	0.66	7.26

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c* (minutes)
19.20

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 1.78	1	FOREST	0.20	0.60	0.12	0.20

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	19.20	2.93	3.53	4.03	2.93	3.53	4.03

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.20	2.93	0.60	0.35	0.42	0.48

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		HL_DS_1.78		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	2		
ACRES	(AC)	0.6		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	0.35		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	1.02		
PROTECTIVE LINING[2,6]		S75		
n (MANNING'S COEFFICIENT)[2]		0.055		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	1.76		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.55		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	1.12		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	4.63 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	4.63		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	2.31		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	0.58		
R (HYDRAULIC RADIUS)		0.20		
S (BED SLOPE)[3, 7]	(FT/FT)	0.036		
S_C (CRITICAL SLOPE)	(FT/FT)	0.093		
$.7S_c$	(FT/FT)	0.065		
$1.3S_c$	(FT/FT)	0.121		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

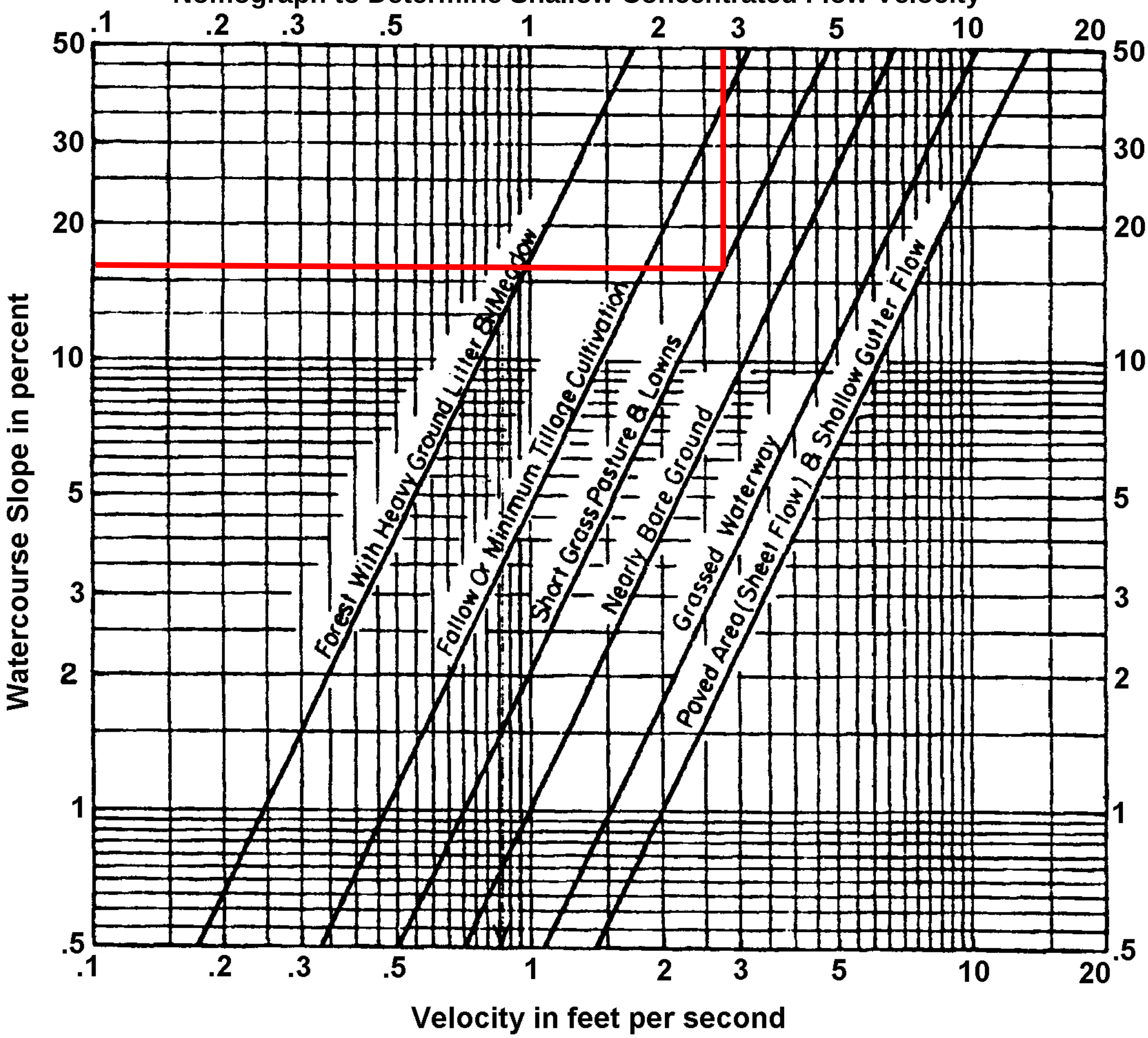
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_1.78

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity

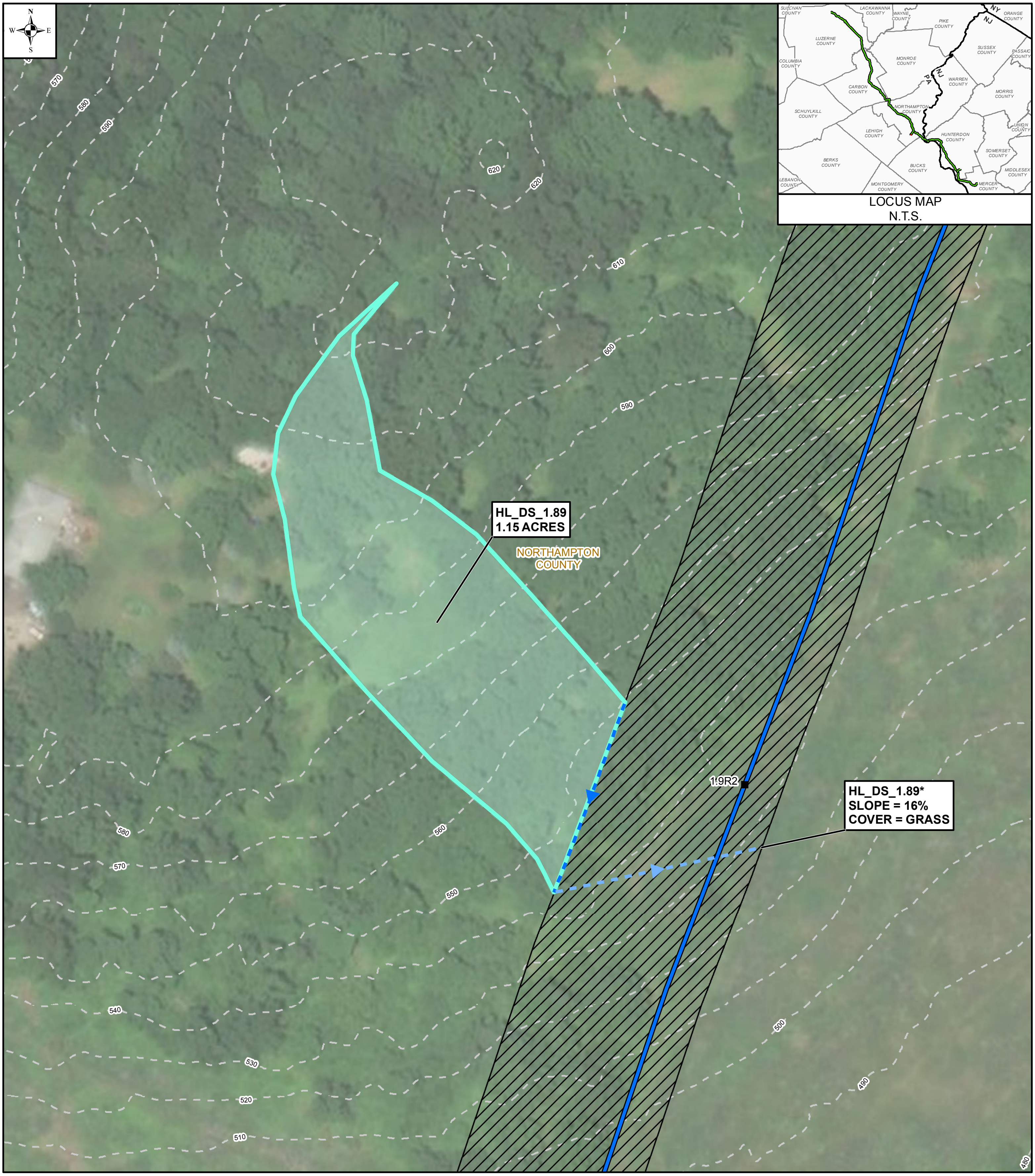


TR-55

DOWNSLOPE CONDITION
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 16%

SHALLOW CONCENTRATED FLOW VELOCITY = 2.9 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

2.9 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.



LEGEND

- 1R MILE POST (STATION EQUATON DUE TO RE-ROUTE)
- PROPOSED PENNEAST PIPELINE
- BLUE MOUNTAIN LATERAL
- HELLERTOWN LATERAL
- DIVERSION SOCK
- SLOPE PIPE
- DRAINAGE AREA
- PROPOSED CONSTRUCTION WORKSPACE
- INDEX CONTOUR
- COUNTY BOUNDARY

* CALLOUT INDICATES THE DOWNSLOPE CONDITIONS FROM THE LEVEL SPREADER AT THE POINT SHEET FLOW RETURNS TO CONCENTRATED FLOW.
** NO CONCENTRATED FLOW DOWNSLOPE OF LEVEL SPREADER. SHEET FLOW IS INTERCEPTED BY EXISTING DRAINAGE SYSTEM.
MAPS COMPILED UTILIZING ESRI BASEMAP AERIAL IMAGERY

PENNEAST PIPELINE PROJECT
CLEAN WATER DIVERSION MAPBOOK
DRAINAGE AREA DS_HL_1.89
NORTHAMPTON COUNTY, PENNSYLVANIA

0 50 100 FEET

PennEast PIPELINE

DRAWN BY:	SNP 10/2018	APPROVED BY:	MJD 10/2019	SCALE:	1 INCH = 100 FEET
CHECKED BY:	JMB 10/2019	REV. DATE:	10/2019	REV.:	1

DWG NO: PAGE 107 OF 114

STANDARD E&S WORKSHEET # 9
Time of Concentration

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

OVERLAND FLOW:

PATH NUMBER	LENGTH L (ft)	"n" VALUE	AVERAGE SLOPE S (ft/ft)	TIME T_{of} (minutes)
DS 1.89	100	0.8	0.101	10.96

$$T_{c(sheet\ flow)} = \left[\frac{2(L)(n)}{3(S)^{0.5}}\right]^{0.4673}$$

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	AVERAGE SLOPE (ft/ft)	V (ft/sec)	TIME T_{sc} (minutes)
DS 1.89	596	FOREST	0.146	0.96	10.33

CHANNEL FLOW:

PATH NUMBER	LENGTH (ft)	AREA (sq. ft.)	AVERAGE SLOPE (ft/ft)	WETTED PERIMETER (ft)	HYDRAULIC RADIUS (ft)	MANNING'S n	V (ft/sec)	CHANNEL TIME T_{ch} (minutes)

TIME OF CONCENTRATION:

T_c^* (minutes)
21.29

CHANNEL DIMENSIONS:

PATH NUMBER	BOTTOM WIDTH (ft)	LEFT SIDE SLOPE (H:V)	RIGHT SIDE SLOPE (H:V)	TOTAL DEPTH (ft)	TOP WIDTH (ft)

*Tc = Overland Flow Time + Shallow Concentrated Flow Time + Channel Flow Time

STANDARD E&S WORKSHEET # 10
Rational Equation

PROJECT NAME: PENNEAST PIPELINE PROJECT
LOCATION: NORTHAMPTON COUNTY
PREPARED BY: MDN DATE: 10/15/2018
CHECKED BY: KEK / JMB DATE: 10/15/2018

DETERMINE WATERSHED "C" VALUES

CHANNEL NUMBER	DRAINAGE AREA NUMBER	TYPE OF COVER	C VALUE	AREA (acres)	(C X A)	C_w
DS 1.89	1	FOREST	0.20	1.02	0.20	0.21
	2	OPEN SPACE	0.28	0.13	0.04	

DETERMINE RAINFALL INTENSITY:

CHANNEL NUMBER	T_c	Rainfall Depth R_2	R_5	R_{10}	Rainfall Intensity I_2	Rainfall Intensity I_5	Rainfall Intensity I_{10}
	21.29	2.77	3.35	3.84	2.77	3.35	3.84

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

CHANNEL NUMBER	C_w	I (inches/hr)	A (acres)	Q_2 (cfs)	Q_5 (cfs)	Q_{10} (cfs)
	0.21	2.77	1.15	0.67	0.81	0.92

STANDARD E&S WORKSHEET #11
Channel Design Data

PROJECT NAME: PENNEAST PIPELINE PROJECT

LOCATION: NORTHAMPTON COUNTY

PREPARED BY: MDN DATE: 10/2019

CHECKED BY: KEK / JMB DATE: 10/2019

CHANNEL OR CHANNEL SECTION		HL_DS_1.89		
TEMPORARY OR PERMANENT?	(T OR P)	T		
DESIGN STORM	(2, 5, OR 10 YR)	2		
ACRES	(AC)	1.15		
MULTIPLIER[1]	(1.6, 2.25, OR 2.75)[1]	N/A		
Q_r (REQUIRED CAPACITY)	(CFS)	0.67		
Q (CALCULATED AT FLOW DEPTH d)	(CFS)	1.15		
PROTECTIVE LINING[2,6]		S75		
n (MANNING'S COEFFICIENT)[2]		0.055		
V_a (ALLOWABLE VELOCITY)	(FPS)	N/A		
V (CALCUALTED AT FLOW DEPTH d)	(FPS)	1.95		
τ_a (MAX ALLOWABLE SHEAR STRESS)	(LB/FT^2)	1.55		
τ_d (CALC'D SHEAR STRESS AT FLOW DEPTH d)	(LB/FT^2)	1.37		
CHANNEL BOTTOM WIDTH	(FT)	0		
CHANNEL SIDE SLOPES	(H:V)	4.72 / 0		
D (TOTAL DEPTH)	(FT)	1.00		
CHANNEL TOP WIDTH @ D	(FT)	4.72		
d (CALCULATED FLOW DEPTH)	(FT)	0.50		
CHANNEL TOP WIDTH @ FLOW DEPTH d	(FT)	2.36		
BOTTOM WIDTH: FLOW DEPTH RATIO	(12:1 MAX)	0		
d_{50} STONE SIZE	(IN)	N/A		
A (CROSS-SECTIONAL AREA)	(SQ. FT)	0.59		
R (HYDRAULIC RADIUS)		0.20		
S (BED SLOPE)[3, 7]	(FT/FT)	0.044		
S_C (CRITICAL SLOPE)	(FT/FT)	0.093		
$.7S_c$	(FT/FT)	0.065		
$1.3S_c$	(FT/FT)	0.120		
STABLE FLOW?	(Y/N)	Y		
FREEBOARD BASED ON UNSTABLE FLOW	(FT)	N/A		
FREEBOARD BASED ON STABLE FLOW	(FT)	0.50		
MINIMUM REQUIRED FREEBOARD[4]	(FT)	0.50		
DESIGN METHOD FOR PROTECTIVE LINING[5] PERMISSIBLE VELOCITY (V) OR SHEAR STRESS (S)		S		

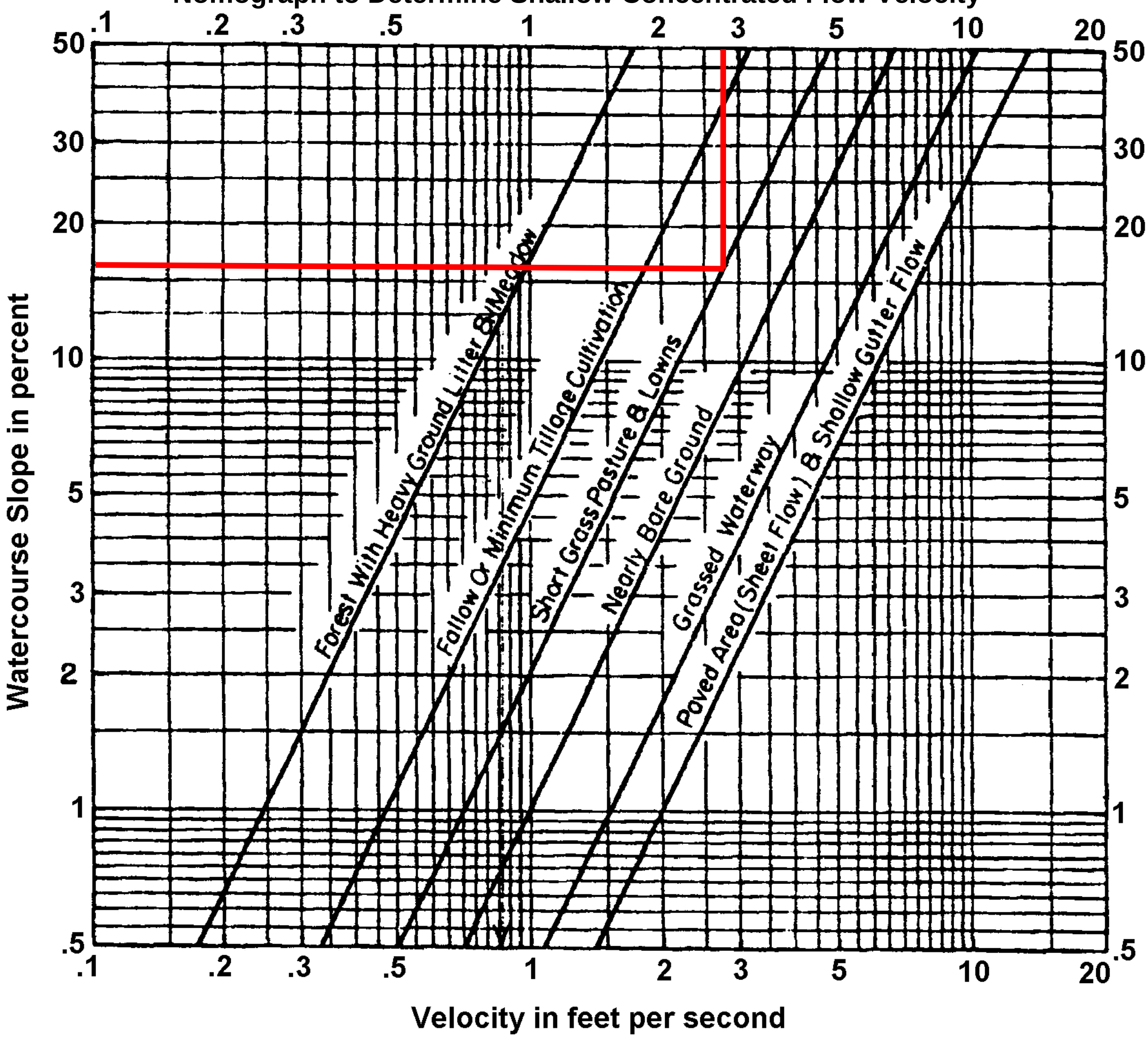
1. Use 1.6 for Temporary Channels; 2.25 for Temporary Channels in Special Protection (HQ or EV) Watersheds; 2.75 for Permanent Channels. For Rational Method, enter "N/A" and attach E&S Worksheets 9 and 10. For TR-55 enter "N/A" and attach appropriate Worksheets.
2. Adjust "n" value for changes in channel liner and flow depth. For vegetated channels, provide data for manufactured linings without vegetation and with vegetation in seperate columns.
3. Slopes may not be averaged.
4. Minimum Freeboard is 0.5 ft. or ¼ 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.
6. In cases where existing grass is sufficient for the channel lining, S75 RollMax lining or product equivalent can be used in its place.
7. There is no significant percent slope change along the entire temporary channel, therefore the channel capacity and shear stress have been calculated based on the single bed slope value shown above.

CLEAN WATER DIVERSION ID:
DS_1.89

Shallow Concentrated Flow

That portion of the flow path which is not channelized and cannot be considered sheet flow is considered shallow concentrated flow. The average velocity for shallow concentrated flow may be determined from Figure 5.1, in which average velocity is a function of slope and type of watercourse. **Note:** There is no maximum length for shallow concentrated flow in Pennsylvania.

FIGURE 5.1
Nomograph to Determine Shallow Concentrated Flow Velocity



TR-55

DOWNSLOPE CONDITION
COVER TYPE = SHORT GRASS PASTURE & LAWNS
PERCENT SLOPE = 16%

SHALLOW CONCENTRATED FLOW VELOCITY = 2.9 FPS (PER NOMOGRAPH)
PER TABLE G.1 OF THE E&S MANUAL, THE ALLOWABLE VELOCITY FOR DOWNSLOPE COVERS FOR CHANNELIZED FLOW IS 4 FPS FOR GRASS COVER TYPES.

2.9 FPS < 4.0 FPS THEREFORE THE ALLOWABLE VELOCITY IS NOT EXCEEDED.