

DA-PI-028

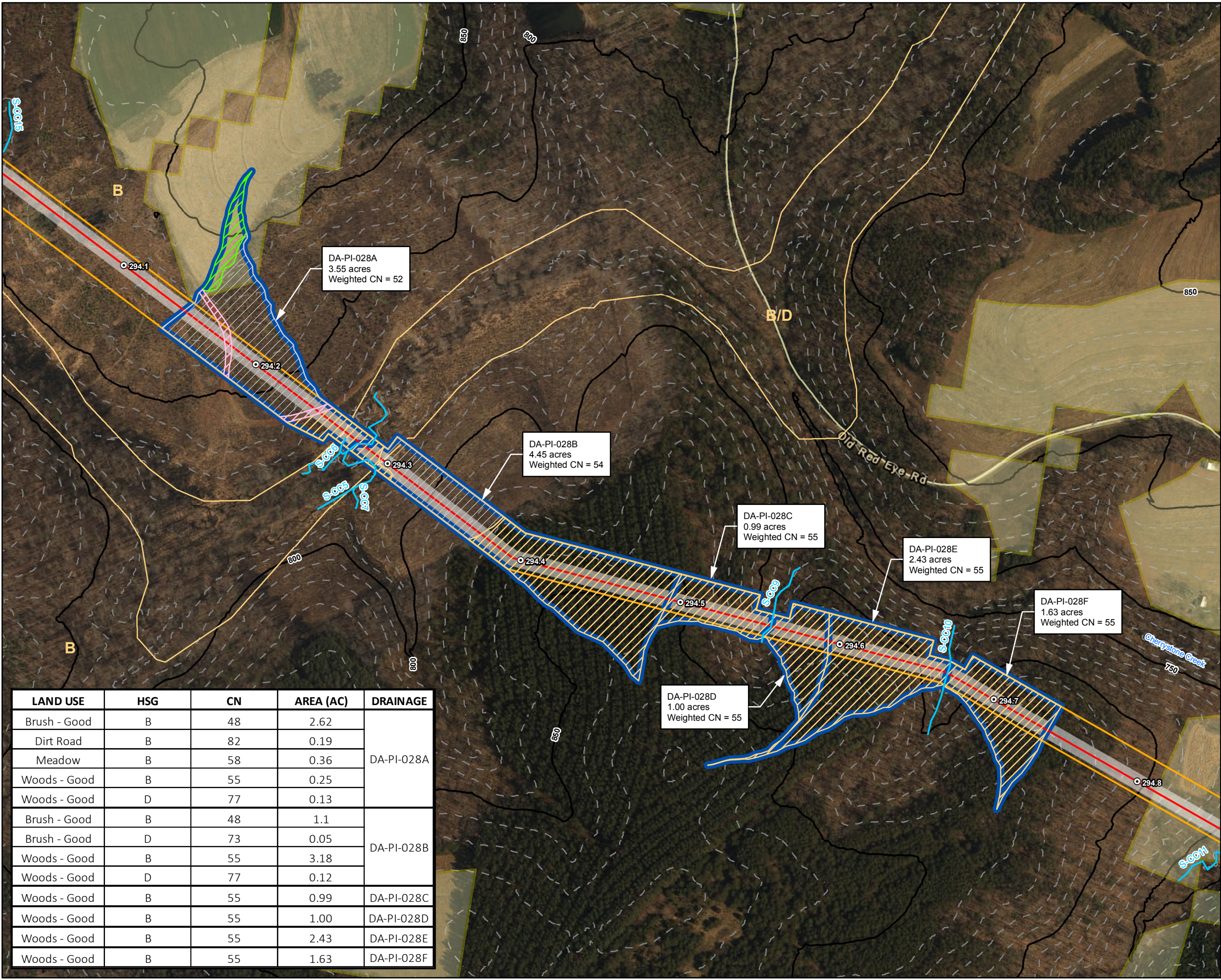
DA-PI-028 is located in a primarily forested area with undulating slopes. DA-PI-028 is bisected by an unnamed tributary to Cherrystone Creek and contains existing dirt roads that cover 1% of the overall drainage area. No new impervious areas are proposed within DA-PI-028. The total phosphorus load reduction required for DA-PI-028 is -1.09 lbs/yr. Multiple points of analysis were evaluated within DA-PI-028 to determine the effects on each receiving stream/channel following construction. Specifically, DA-PI-028 was sub-divided into six sub-drainage areas (sub-areas A through F).

Stormwater quantity is met via the energy balance method for each of the sub-areas - DA-PI-028A, DA-PI-028B, DA-PI-028C, DA-PI-028D, DA-PI-028E, and DA-PI-028F. The Hydraflow hydrographs 10-year 24-hour peak discharge results indicate a 0.74 cfs increase in flow in sub-area DA-PI-028A and a decrease in flow ranging from 0.00 cfs to 0.33 cfs in the remaining sub-areas (as seen in table below). The increase in 10-yr peak flow in sub-area DA-PI-028A will have little/no impact on flood stage in the downstream channel.

Sub-area	Pre-peak Flow, 10-yr Q (cfs)	Post-peak Flow, 10-yr Q (cfs)	Flow Differential
DA-PI-028A	3.62	4.36	0.74
DA-PI-028B	4.04	4.04	0.00
DA-PI-028C	1.24	0.91	-0.33
DA-PI-028D	1.46	1.34	-0.12
DA-PI-028E	3.25	2.98	-0.27
DA-PI-028F	1.92	1.61	-0.31

Figures and calculations for DA-PI-028 follow. See Appendix D of the Annual Standards and Specifications for further detail on stormwater methodology.

Note that the DA-PI-028E time of concentration flow path for the Post-Construction condition accounts for a permanent waterbar that is not sited within the drainage area. This permanent waterbar was removed due to existing cross-slope conditions within the permanent ROW, and resulting changes to the stormwater calculations were flagged during the QA/QC review process. This change was considered to be inconsequential because no stormwater BMPs are sited in DA-PI-028E, so the resulting changes were not made to the stormwater calculations prior to submittal.



Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Brush
- Dirt Road
- Meadow
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

1:3,600

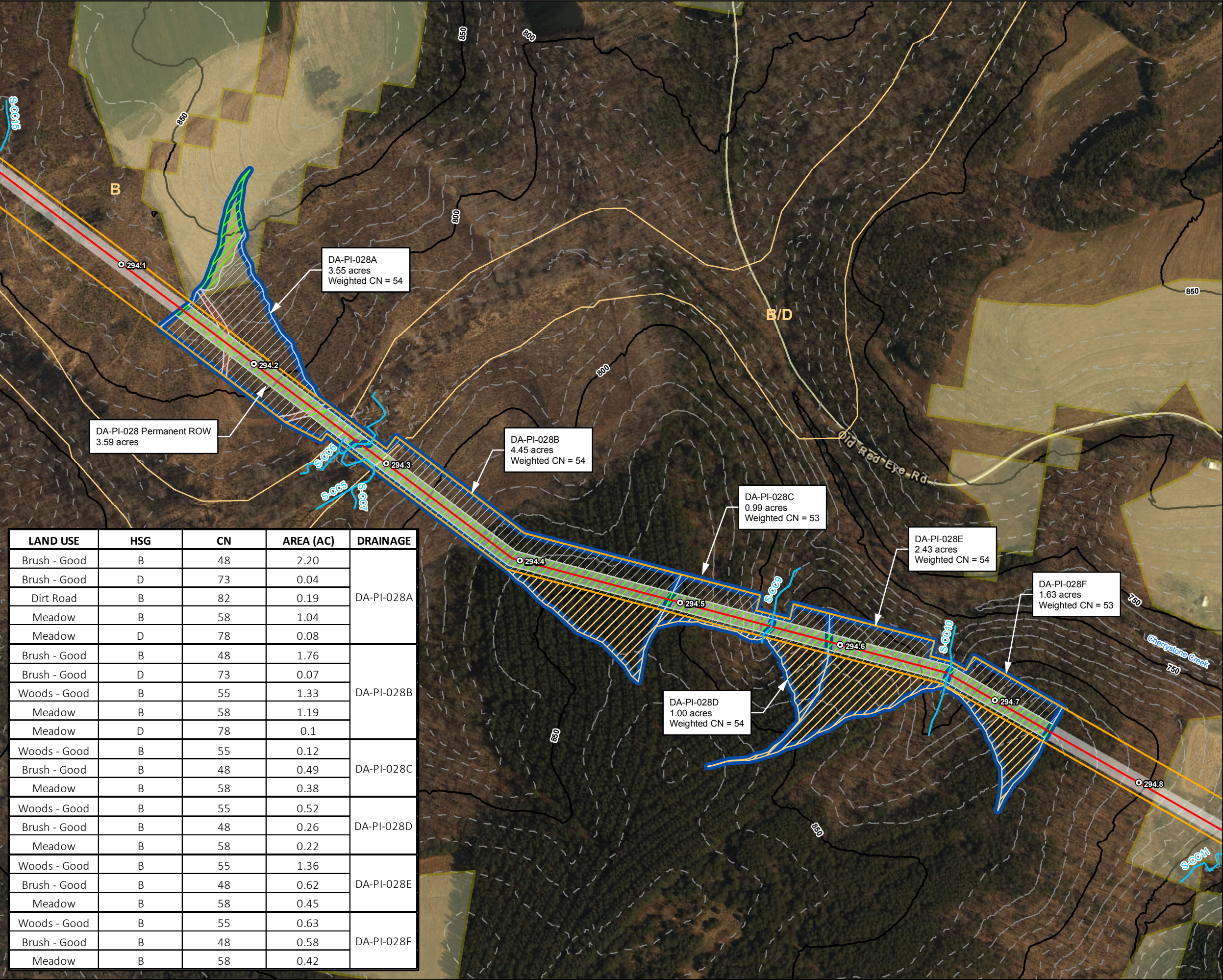
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W N E S

LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Brush - Good	B	48	2.62	DA-PI-028A
Dirt Road	B	82	0.19	
Meadow	B	58	0.36	
Woods - Good	B	55	0.25	
Woods - Good	D	77	0.13	DA-PI-028B
Brush - Good	B	48	1.1	
Brush - Good	D	73	0.05	
Woods - Good	B	55	3.18	
Woods - Good	D	77	0.12	DA-PI-028C
Woods - Good	B	55	0.99	
Woods - Good	B	55	1.00	DA-PI-028D
Woods - Good	B	55	2.43	DA-PI-028E
Woods - Good	B	55	1.63	DA-PI-028F

Mountain Valley Pipeline Project**Pre-Construction Drainage Area Map**
DA-PI-028
Spread 11
Figure 1
Pittsylvania County, Virginia
August, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015, Agricultural Area from National Land Cover Dataset 2011.



Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Brush
- Dirt Road
- Meadow
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

3001500

Feet

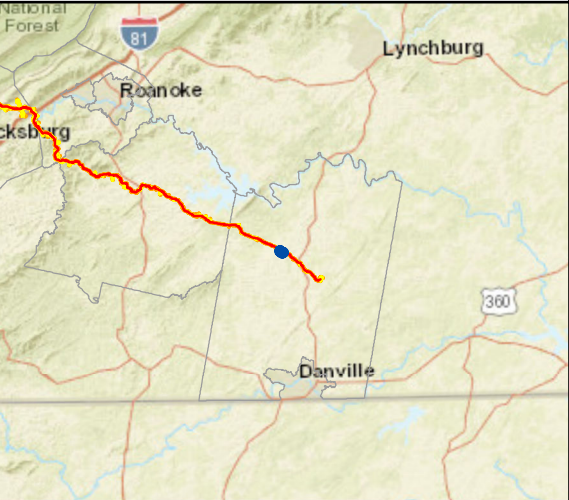
W

N

E

S

LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Brush - Good	B	48	2.20	DA-PI-028A
Brush - Good	D	73	0.04	
Dirt Road	B	82	0.19	
Meadow	B	58	1.04	
Meadow	D	78	0.08	
Brush - Good	B	48	1.76	DA-PI-028B
Brush - Good	D	73	0.07	
Woods - Good	B	55	1.33	
Meadow	B	58	1.19	
Meadow	D	78	0.1	
Woods - Good	B	55	0.12	DA-PI-028C
Brush - Good	B	48	0.49	
Meadow	B	58	0.38	
Woods - Good	B	55	0.52	DA-PI-028D
Brush - Good	B	48	0.26	
Meadow	B	58	0.22	
Woods - Good	B	55	1.36	DA-PI-028E
Brush - Good	B	48	0.62	
Meadow	B	58	0.45	
Woods - Good	B	55	0.63	DA-PI-028F
Brush - Good	B	48	0.58	
Meadow	B	58	0.42	



Mountain Valley Pipeline Project

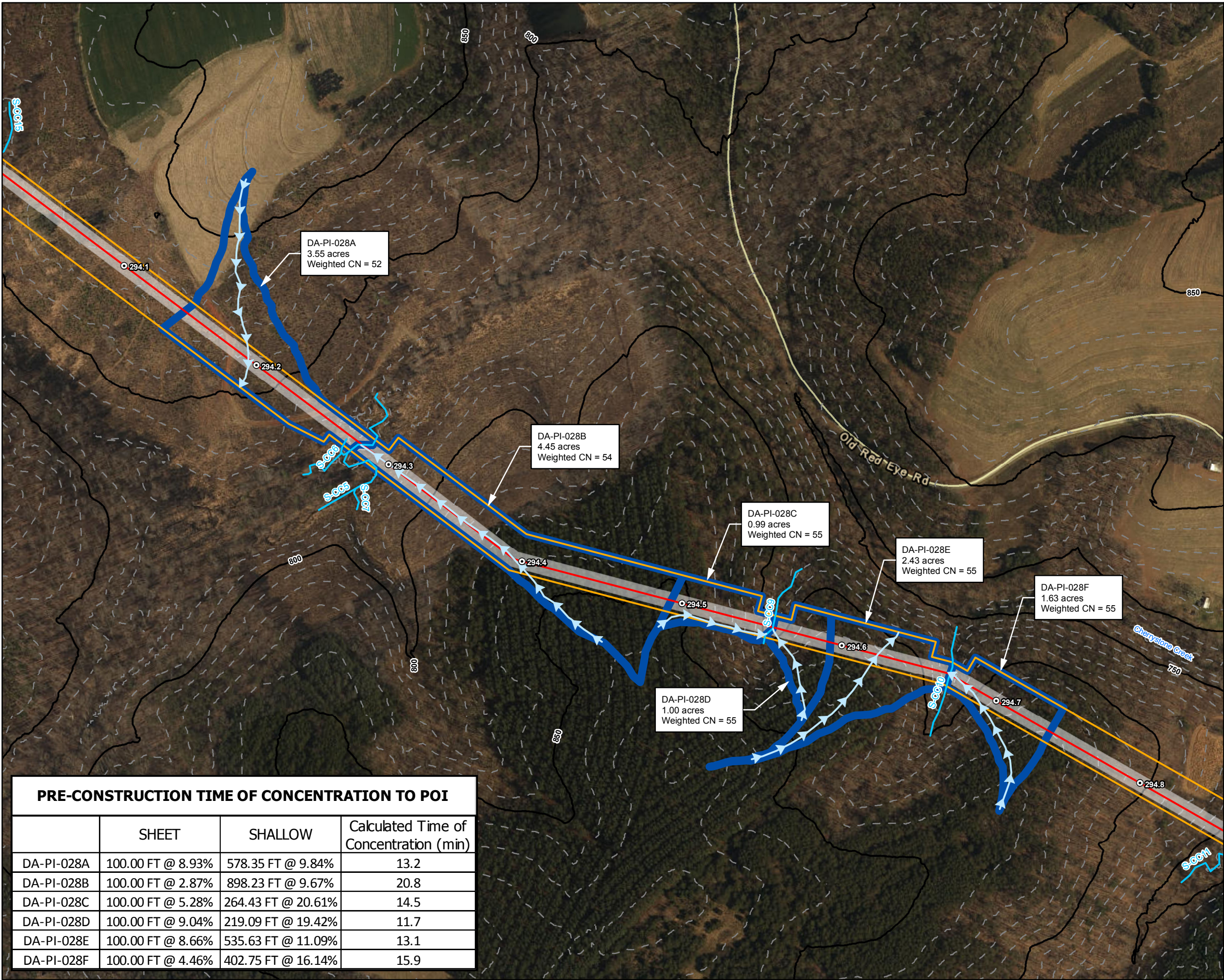
Post-Construction Drainage Area Map
DA-PI-028
Spread 11

Figure 2
Pittsylvania County, Virginia

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LIDAR provided by EQT 2016, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015, Agricultural Area from National Land Cover Dataset 2011.

Document Path: P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Pittsylvania\MVP_PCSM_DA-PI-028_Post.mxd



Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:3,600

300 150 0 300 Feet

Mountain Valley Pipeline Project

Mountain Valley
PIPELINE

**Pre-Construction Drainage Area
and Time of Concentration**
DA-PI-028
Spread 11

Figure 3
Pittsylvania County, Virginia
August, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016.

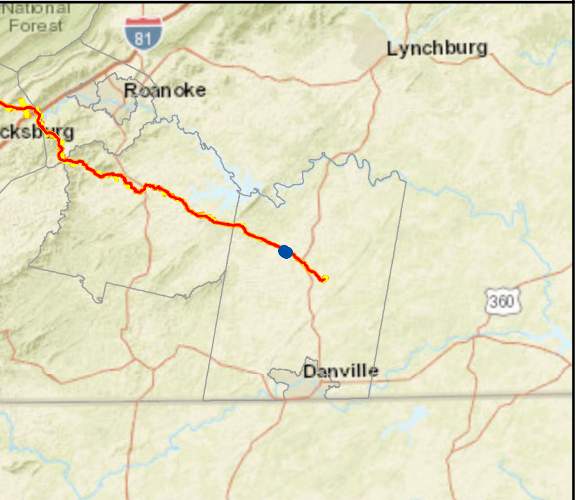
POST-CONSTRUCTION TIME OF CONCENTRATION TO POI						
	SHEET 1	SHEET 2	SHALLOW1	SHALLOW2	CHANNEL1	Calculated Time of Concentration (min)
DA-PI-028A	100.00 FT @ 8.93%	-	578.35 FT @ 9.84%	-	-	13.2
DA-PI-028B	100.00 FT @ 2.87%	-	381.08 FT @ 6.65%	517.89 FT @ 11.94%	18.72 FT @ 5.00%	20.9
DA-PI-028C	81.65 FT @ 4.94%	18.35 FT @ 6.78%	264.43 FT @ 20.16%	-	-	18.4
DA-PI-028D	100.00 FT @ 9.04%	-	219.09 FT @ 19.42%	-	-	11.7
DA-PI-028E	100.00 FT @ 8.66%	-	435.42 FT @ 9.10%	77.59 FT @ 21.23%	43.56 FT @ 5.00%	13.2
DA-PI-028F	100.00 FT @ 4.46%	-	315.22 FT @ 13.40%	95.33 FT @ 25.45%	41.60 FT @ 5.00%	16.1

- Legend**
- Milepost
 - Permanent Waterbars
 - Delineated Stream
 - Existing 50' Contour
 - Existing 10' Contour
 - Road Centerline
 - Alignment Centerline
 - Limit of Disturbance
 - Permanent Right-of-Way
 - Time of Concentration
 - Drainage Area

NAD 1983 UTM 17N (feet)

1:3,600

300 150 0 300 Feet



Mountain Valley Pipeline Project



Post-Construction Drainage Area
and Time of Concentration
DA-PI-028
Spread 11

Figure 4
Pittsylvania County, Virginia
September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016.

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DEQ Virginia Runoff Reduction Method Re-Development Compliance Spreadsheet - Version 3.0

BMP Design Specifications List: 2013 Draft Stds & Specs

Site Summary - Linear Development Project***

Total Rainfall (in):	43
Total Disturbed Acreage:	3.59

Site Land Cover Summary

Pre-ReDevelopment Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	% of Total
Forest/Open (acres)	0.00	3.35	0.00	0.18	3.53	98
Managed Turf (acres)	0.00	0.00	0.00	0.00	0.00	0
Impervious Cover (acres)	0.00	0.06	0.00	0.00	0.06	2
					3.59	100

Post-ReDevelopment Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	% of Total
Forest/Open (acres)	0.00	3.35	0.00	0.18	3.53	98
Managed Turf (acres)	0.00	0.00	0.00	0.00	0.00	0
Impervious Cover (acres)	0.00	0.06	0.00	0.00	0.06	2
					3.59	100

* Forest/Open Space areas must be protected in accordance with the Virginia Runoff Reduction Method

Site Tv and Land Cover Nutrient Loads

	Final Post-Development (Post-ReDevelopment & New Impervious)	Post- ReDevelopment	Post- Development (New Impervious)	Adjusted Pre- ReDevelopment
Site Rv	0.05	0.05	--	0.05
Treatment Volume (ft ³)	604	604	--	604
TP Load (lb/yr)	0.38	0.38	--	0.38

Baseline TP Load (lb/yr): 1.4719* **Reduction below new development load limitation not required*

Pre- ReDevelopment TP Load per acre (lb/acre/yr)	Final Post-Development TP Load per acre (lb/acre/yr)	Post-ReDevelopment TP Load per acre (lb/acre/yr)
0.11	0.11	0.11

Total TP Load Reduction Required (lb/yr)	-1.09	N/A***	N/A***
--	-------	--------	--------

***This is a linear development project

	Final Post-Development Load (Post-ReDevelopment & New Impervious)	Pre- ReDevelopment
TN Load (lb/yr)	2.72	2.72

Site Compliance Summary - ***Linear Development Project

Maximum % Reduction Required Below Pre-ReDevelopment Load	20%
--	-----

* Note: % Reduction will reduce post-development TP load to less than or equal to baseline load of 1.47 lb/yr (0.41 lb/ac/yr)
 [Post-Dev Reduction Requirement = Post-Dev TP load - baseline load of 1.47 lb/yr], baseline load = site area x 0.41 lb/ac/yr

Total Runoff Volume Reduction (ft ³)	0
Total TP Load Reduction Achieved (lb/yr)	0.00
Total TN Load Reduction Achieved (lb/yr)	0.00
Remaining Post Development TP Load (lb/yr)	0.38
Remaining TP Load Reduction (lb/yr) Required	0.00

**** TARGET TP REDUCTION EXCEEDED BY 1.09 LB/YEAR ****

**Reduction below new development load limitation not required*

DA-PI-028A

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.041	1,133
Developed Condition	0.087	1,585
Pre-Developed (Forest) Condition	0.207	2,107

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1:

$$Q_{\text{developed}} \leq \text{IF} \times [(Q_{\text{pre-developed}} \times \text{RV}_{\text{pre-developed}}) / \text{RV}_{\text{developed}}] \text{ ----->}$$

Q (cfs)

0.087

≤

Q (cfs)

0.023

N/A - See Check #3

Check #2:

$$Q_{\text{developed}} \leq Q_{\text{pre-developed}} \text{ ----->}$$

0.087

≤

0.041

N/A - See Check #3

Check #3:

$$Q_{\text{developed}} \text{ shall not be required to be } \leq (Q_{\text{forest}} \times \text{RV}_{\text{forest}}) / \text{RV}_{\text{developed}} \text{ --->}$$

0.087

shall not be required to be ≤

0.275

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning's n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<i>Note:</i> Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted. ¹For Paved Road land surface types a Manning's n of 0.011 was used <i>Sources:</i> -USACE, 1998, HEC-1 Flood Hydrograph Package User's Manual, Hydrologic Engineering Center, Davis, CA -Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC	

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-PI-028A Pre
2	SCS Runoff	DA-PI-028A Post
3	SCS Runoff	DA-PI-028A Pre-Forested

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.041	1	751	1,133	-----	-----	-----	DA-PI-028A Pre
2	SCS Runoff	0.087	1	735	1,585	-----	-----	-----	DA-PI-028A Post
3	SCS Runoff	0.207	1	727	2,107	-----	-----	-----	DA-PI-028A Pre-Forested
DA-PI-028A.gpw					Return Period: 1 Year			Wednesday, 08 / 16 / 2017	

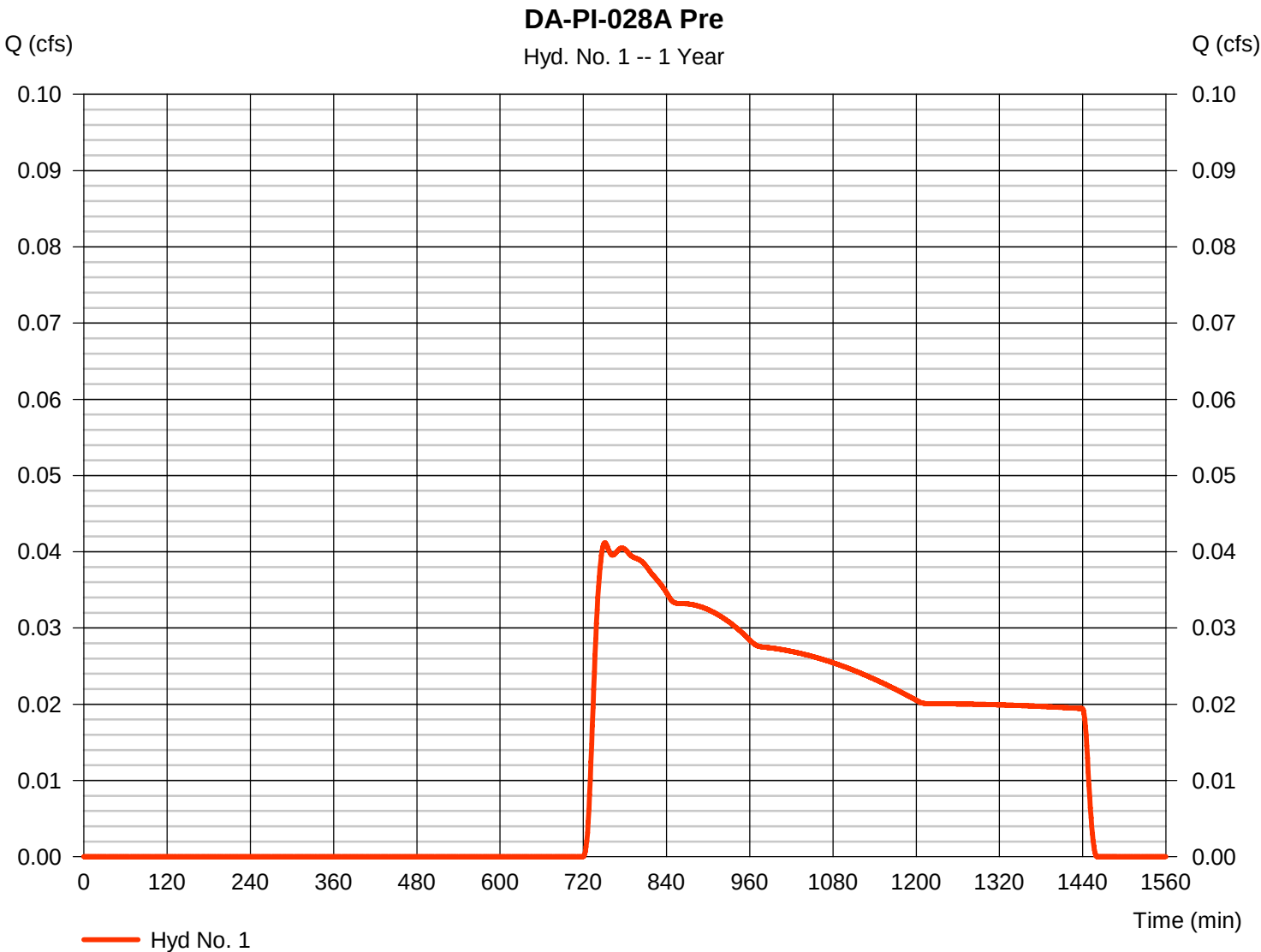
Hydrograph Report

Hyd. No. 1

DA-PI-028A Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.041 cfs
Storm frequency	= 1 yrs	Time to peak	= 751 min
Time interval	= 1 min	Hyd. volume	= 1,133 cuft
Drainage area	= 3.550 ac	Curve number	= 52*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.20 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(2.620 x 48) + (0.190 x 82) + (0.360 x 58) + (0.250 x 55) + (0.130 x 77)] / 3.550



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-PI-028A Pre

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00	
Land slope (%)	= 8.93	0.00	0.00	
Travel Time (min)	= 11.29	+	0.00	+
			0.00	= 11.29
Shallow Concentrated Flow				
Flow length (ft)	= 578.35	0.00	0.00	
Watercourse slope (%)	= 9.84	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=5.06	0.00	0.00	
Travel Time (min)	= 1.90	+	0.00	+
			0.00	= 1.90
Channel Flow				
X sectional flow area (sqft)	= 0.00	0.00	0.00	
Wetted perimeter (ft)	= 0.00	0.00	0.00	
Channel slope (%)	= 0.00	0.00	0.00	
Manning's n-value	= 0.030	0.015	0.015	
Velocity (ft/s)	=0.00	0.00	0.00	
Flow length (ft)	(0)0.0	0.0	0.0	
Travel Time (min)	= 0.00	+	0.00	+
			0.00	= 0.00
Total Travel Time, Tc				13.20 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

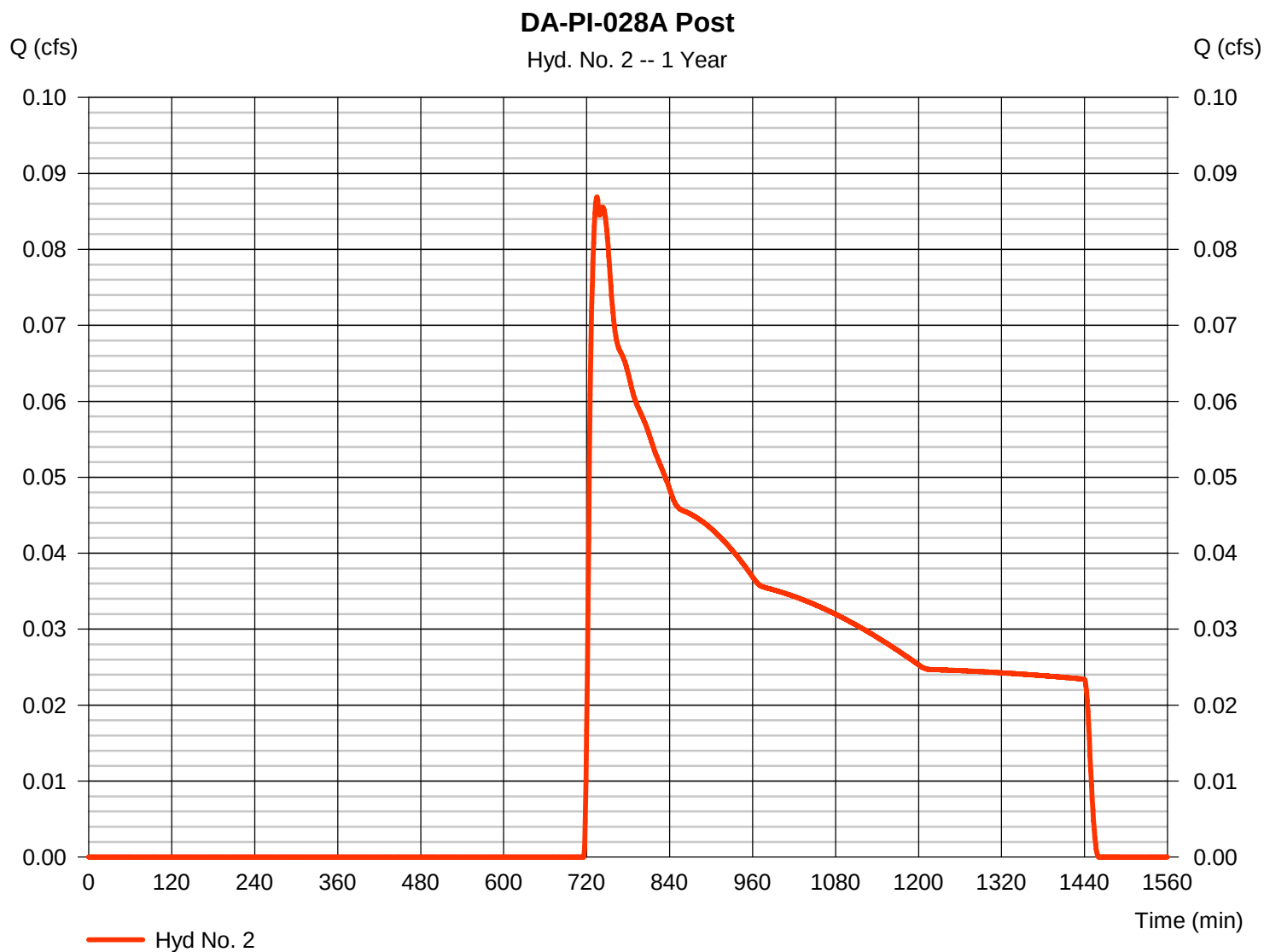
Wednesday, 08 / 16 / 2017

Hyd. No. 2

DA-PI-028A Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.087 cfs
Storm frequency	= 1 yrs	Time to peak	= 735 min
Time interval	= 1 min	Hyd. volume	= 1,585 cuft
Drainage area	= 3.550 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.20 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(2.200 \times 48) + (0.040 \times 73) + (0.190 \times 82) + (1.040 \times 58) + (0.080 \times 78)] / 3.550$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-PI-028A Post

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 8.93	0.00	0.00				
Travel Time (min)	= 11.29	+	0.00	+	0.00	=	11.29
Shallow Concentrated Flow							
Flow length (ft)	= 578.35	0.00	0.00				
Watercourse slope (%)	= 9.84	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=5.06	0.00	0.00				
Travel Time (min)	= 1.90	+	0.00	+	0.00	=	1.90
Channel Flow							
X sectional flow area (sqft)	= 0.00	0.00	0.00				
Wetted perimeter (ft)	= 0.00	0.00	0.00				
Channel slope (%)	= 0.00	0.00	0.00				
Manning's n-value	= 0.040	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	((0))0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc				13.20 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

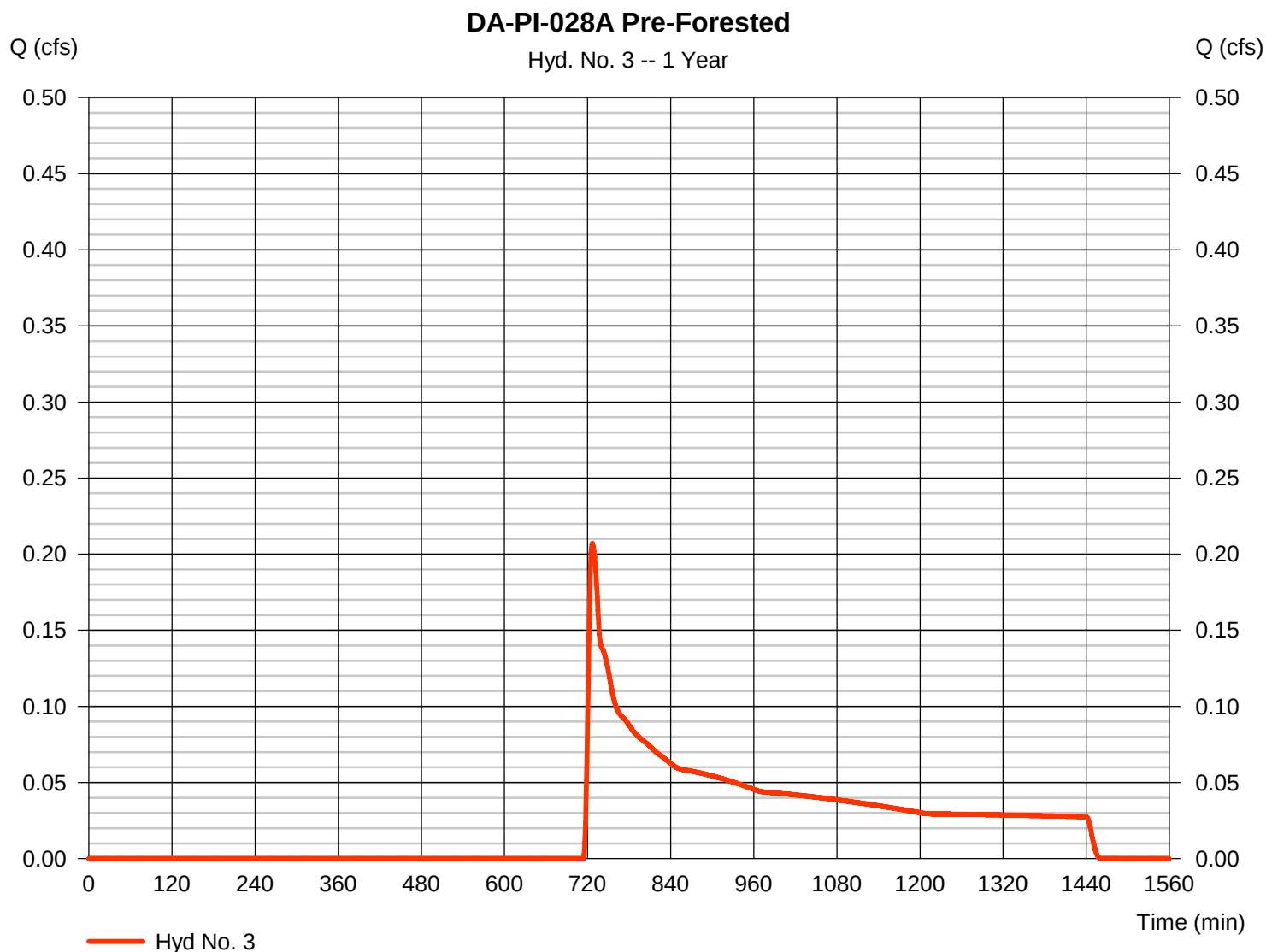
Wednesday, 08 / 16 / 2017

Hyd. No. 3

DA-PI-028A Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 0.207 cfs
Storm frequency	= 1 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 2,107 cuft
Drainage area	= 3.550 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.20 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(3.420 \times 55) + (0.130 \times 77)] / 3.550$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-PI-028A Pre-Forested

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 8.93	0.00	0.00				
Travel Time (min)	= 11.29	+	0.00	+	0.00	=	11.29
Shallow Concentrated Flow							
Flow length (ft)	= 578.35	0.00	0.00				
Watercourse slope (%)	= 9.84	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=5.06	0.00	0.00				
Travel Time (min)	= 1.90	+	0.00	+	0.00	=	1.90
Channel Flow							
X sectional flow area (sqft)	= 0.00	0.00	0.00				
Wetted perimeter (ft)	= 0.00	0.00	0.00				
Channel slope (%)	= 0.00	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	((0})0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc				13.20 min			

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.439	1	726	3,185	-----	-----	-----	DA-PI-028A Pre
2	SCS Runoff	0.744	1	725	3,968	-----	-----	-----	DA-PI-028A Post
3	SCS Runoff	1.112	1	724	4,821	-----	-----	-----	DA-PI-028A Pre-Forested
DA-PI-028A.gpw					Return Period: 2 Year			Wednesday, 08 / 16 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

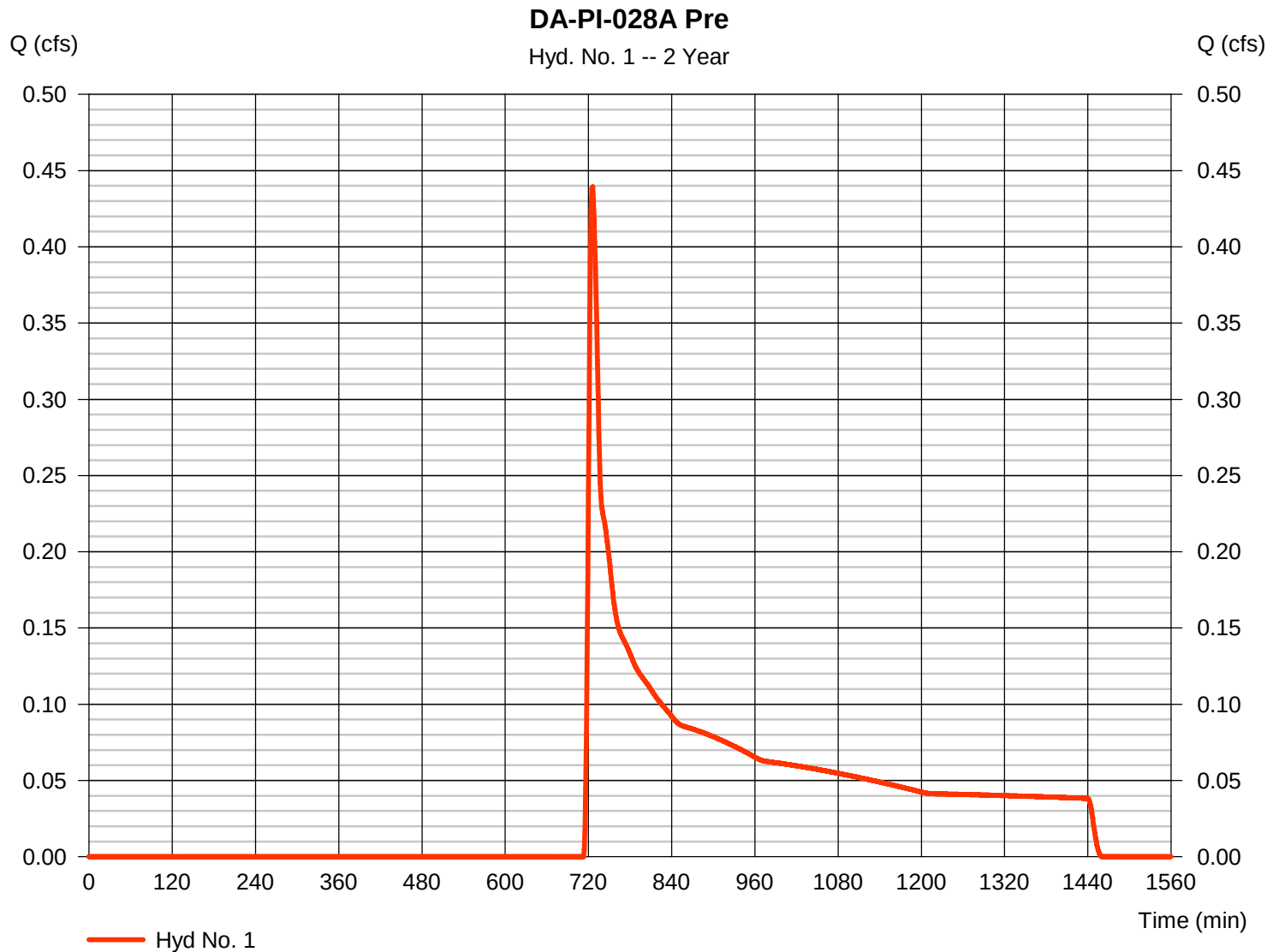
Wednesday, 08 / 16 / 2017

Hyd. No. 1

DA-PI-028A Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.439 cfs
Storm frequency	= 2 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 3,185 cuft
Drainage area	= 3.550 ac	Curve number	= 52*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.20 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(2.620 \times 48) + (0.190 \times 82) + (0.360 \times 58) + (0.250 \times 55) + (0.130 \times 77)] / 3.550$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

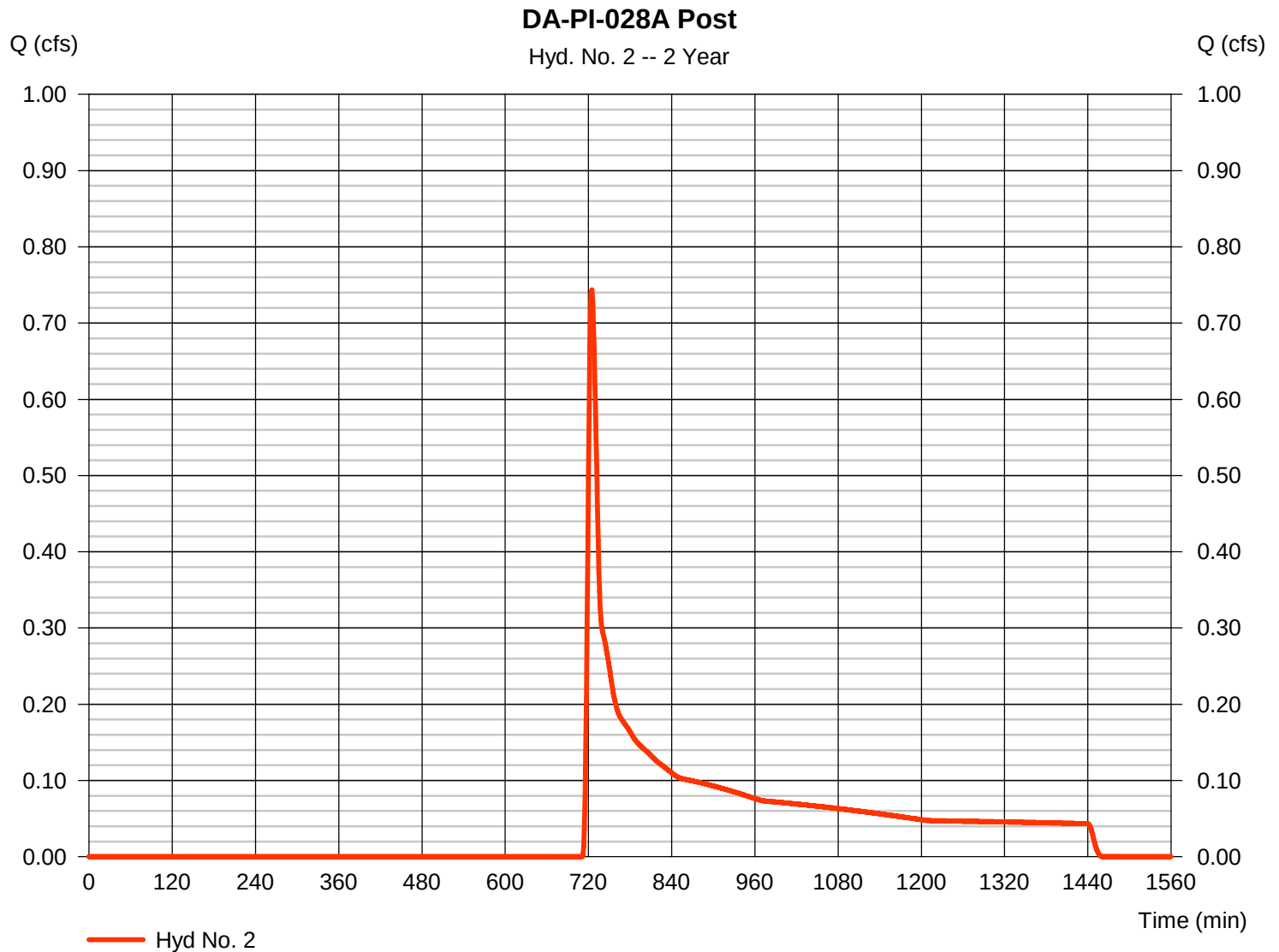
Wednesday, 08 / 16 / 2017

Hyd. No. 2

DA-PI-028A Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.744 cfs
Storm frequency	= 2 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 3,968 cuft
Drainage area	= 3.550 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.20 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(2.200 \times 48) + (0.040 \times 73) + (0.190 \times 82) + (1.040 \times 58) + (0.080 \times 78)] / 3.550$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

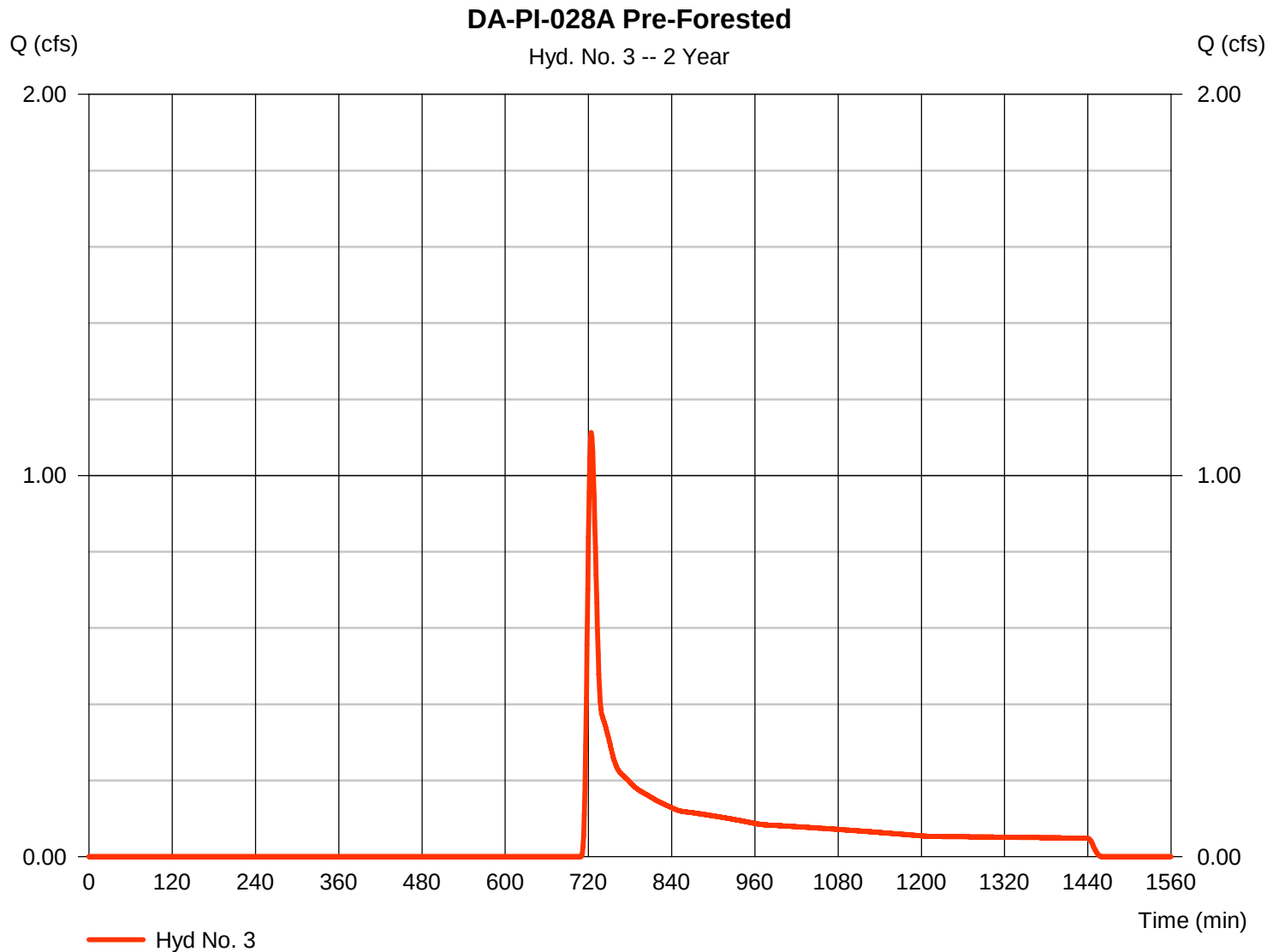
Wednesday, 08 / 16 / 2017

Hyd. No. 3

DA-PI-028A Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	1.112 cfs
Storm frequency	=	2 yrs	Time to peak	=	724 min
Time interval	=	1 min	Hyd. volume	=	4,821 cuft
Drainage area	=	3.550 ac	Curve number	=	56*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	13.20 min
Total precip.	=	3.50 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(3.420 \times 55) + (0.130 \times 77)] / 3.550$



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	3.616	1	723	11,338	-----	-----	-----	DA-PI-028A Pre
2	SCS Runoff	4.360	1	722	12,906	-----	-----	-----	DA-PI-028A Post
3	SCS Runoff	5.135	1	722	14,541	-----	-----	-----	DA-PI-028A Pre-Forested
DA-PI-028A.gpw					Return Period: 10 Year			Wednesday, 08 / 16 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

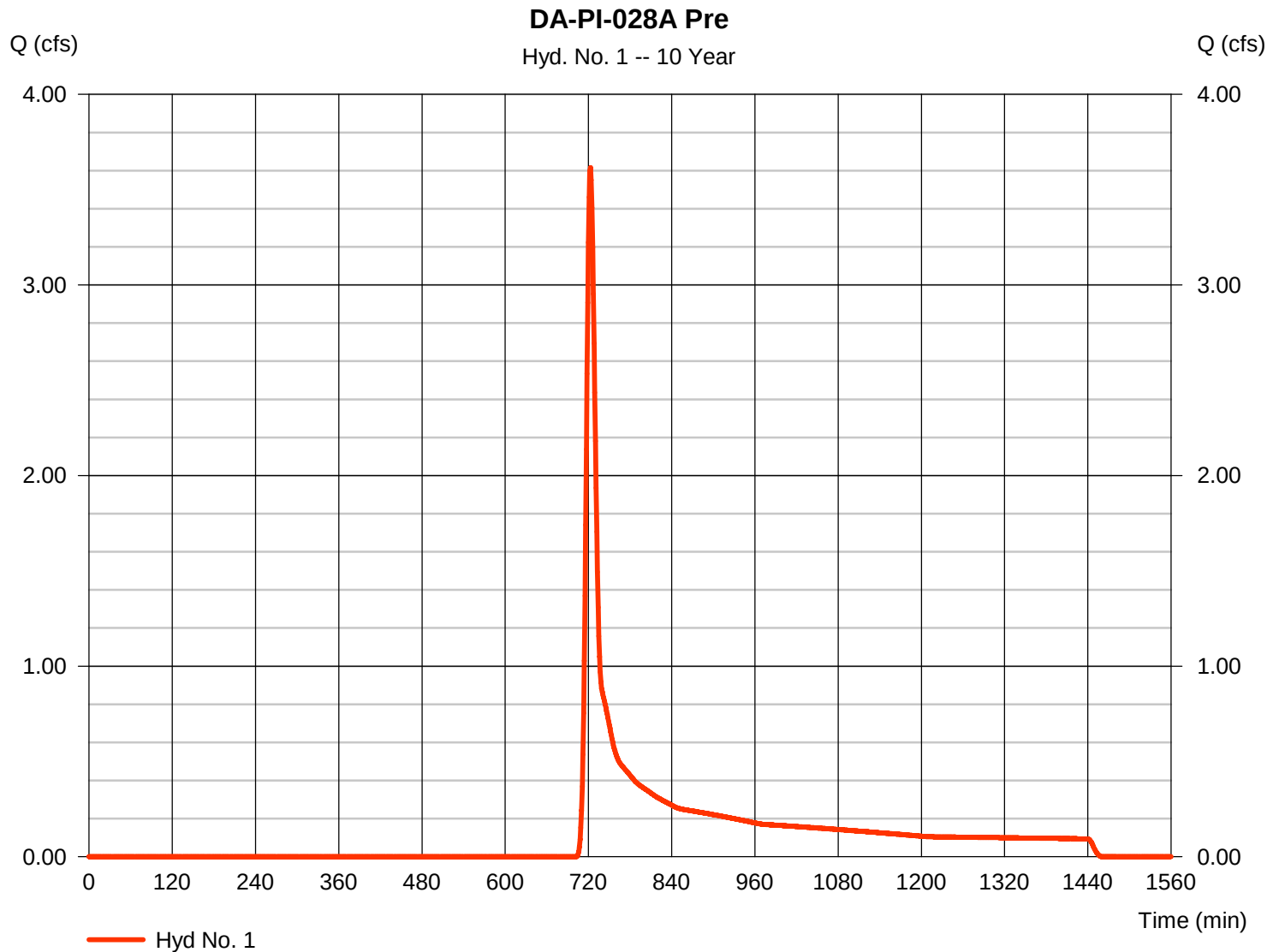
Wednesday, 08 / 16 / 2017

Hyd. No. 1

DA-PI-028A Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 3.616 cfs
Storm frequency	= 10 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 11,338 cuft
Drainage area	= 3.550 ac	Curve number	= 52*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.20 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(2.620 \times 48) + (0.190 \times 82) + (0.360 \times 58) + (0.250 \times 55) + (0.130 \times 77)] / 3.550$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

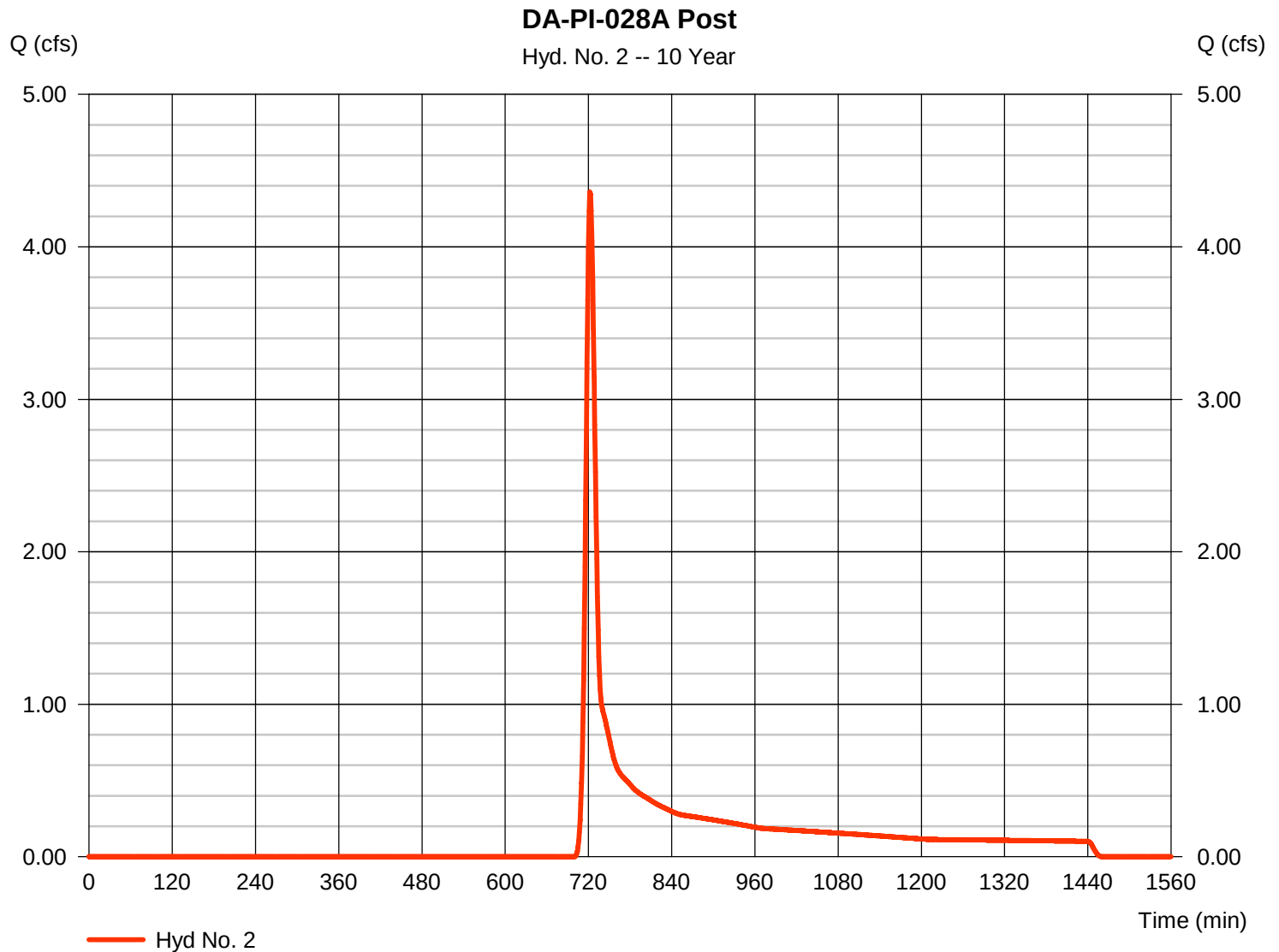
Wednesday, 08 / 16 / 2017

Hyd. No. 2

DA-PI-028A Post

Hydrograph type	= SCS Runoff	Peak discharge	= 4.360 cfs
Storm frequency	= 10 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 12,906 cuft
Drainage area	= 3.550 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.20 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(2.200 \times 48) + (0.040 \times 73) + (0.190 \times 82) + (1.040 \times 58) + (0.080 \times 78)] / 3.550$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

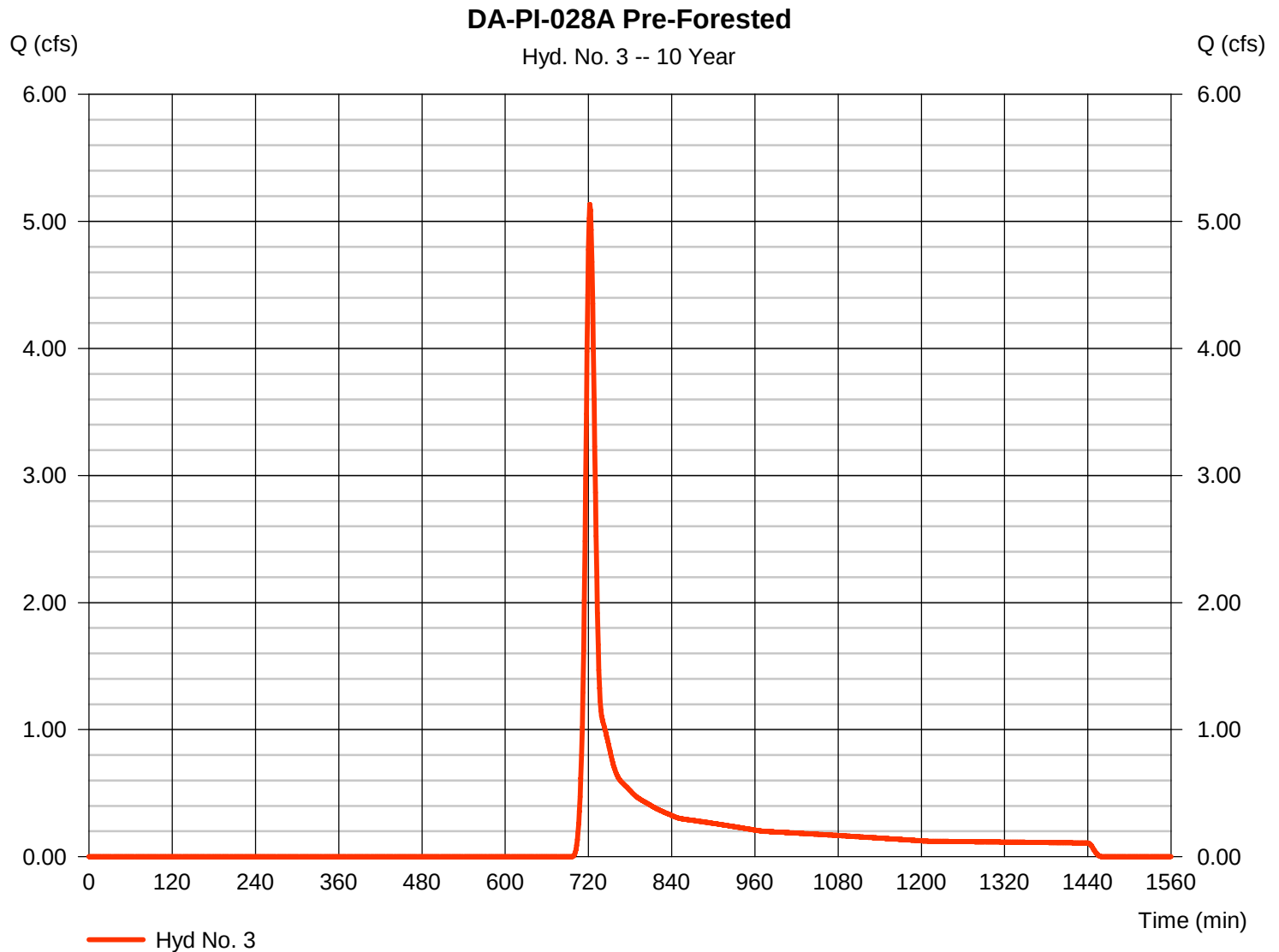
Wednesday, 08 / 16 / 2017

Hyd. No. 3

DA-PI-028A Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 5.135 cfs
Storm frequency	= 10 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 14,541 cuft
Drainage area	= 3.550 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.20 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(3.420 \times 55) + (0.130 \times 77)] / 3.550$



DA-PI-028B

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.110	2,038
Developed Condition	0.110	2,038
Pre-Developed (Forest) Condition	0.211	2,709

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1:

$$Q_{\text{developed}} \leq \text{IF} \times [(Q_{\text{pre-developed}} \times \text{RV}_{\text{pre-developed}}) / \text{RV}_{\text{developed}}] \text{ ----->}$$

Q (cfs)

0.110

≤

Q (cfs)

0.088

N/A - See Check #3

Check #2:

$$Q_{\text{developed}} \leq Q_{\text{pre-developed}} \text{ ----->}$$

0.110

≤

0.110

N/A - See Check #3

Check #3:

$$Q_{\text{developed}} \text{ shall not be required to be } \leq (Q_{\text{forest}} \times \text{RV}_{\text{forest}}) / \text{RV}_{\text{developed}} \text{ --->}$$

0.110

shall not be required to be ≤

0.280

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning's n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<i>Note:</i> Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted. ¹For Paved Road land surface types a Manning's n of 0.011 was used <i>Sources:</i> -USACE, 1998, HEC-1 Flood Hydrograph Package User's Manual, Hydrologic Engineering Center, Davis, CA -Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC	

Table 2 – Manning’s n Values for Open Channel Flow

Channel Type	Manning n		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹For the developed condition, a conservative Manning’s n value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar, level spreader diversion, or grass channel. ²For the pre-developed condition and post-development condition, a Manning’s n value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-PI-028B Pre
2	SCS Runoff	DA-PI-028B Post
3	SCS Runoff	DA-PI-028B Pre-Forested

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.110	1	747	2,038	-----	-----	-----	DA-PI-028B Pre
2	SCS Runoff	0.110	1	747	2,038	-----	-----	-----	DA-PI-028B Post
3	SCS Runoff	0.211	1	739	2,709	-----	-----	-----	DA-PI-028B Pre-Forested
DA-PI-028B.gpw					Return Period: 1 Year			Thursday, 08 / 17 / 2017	

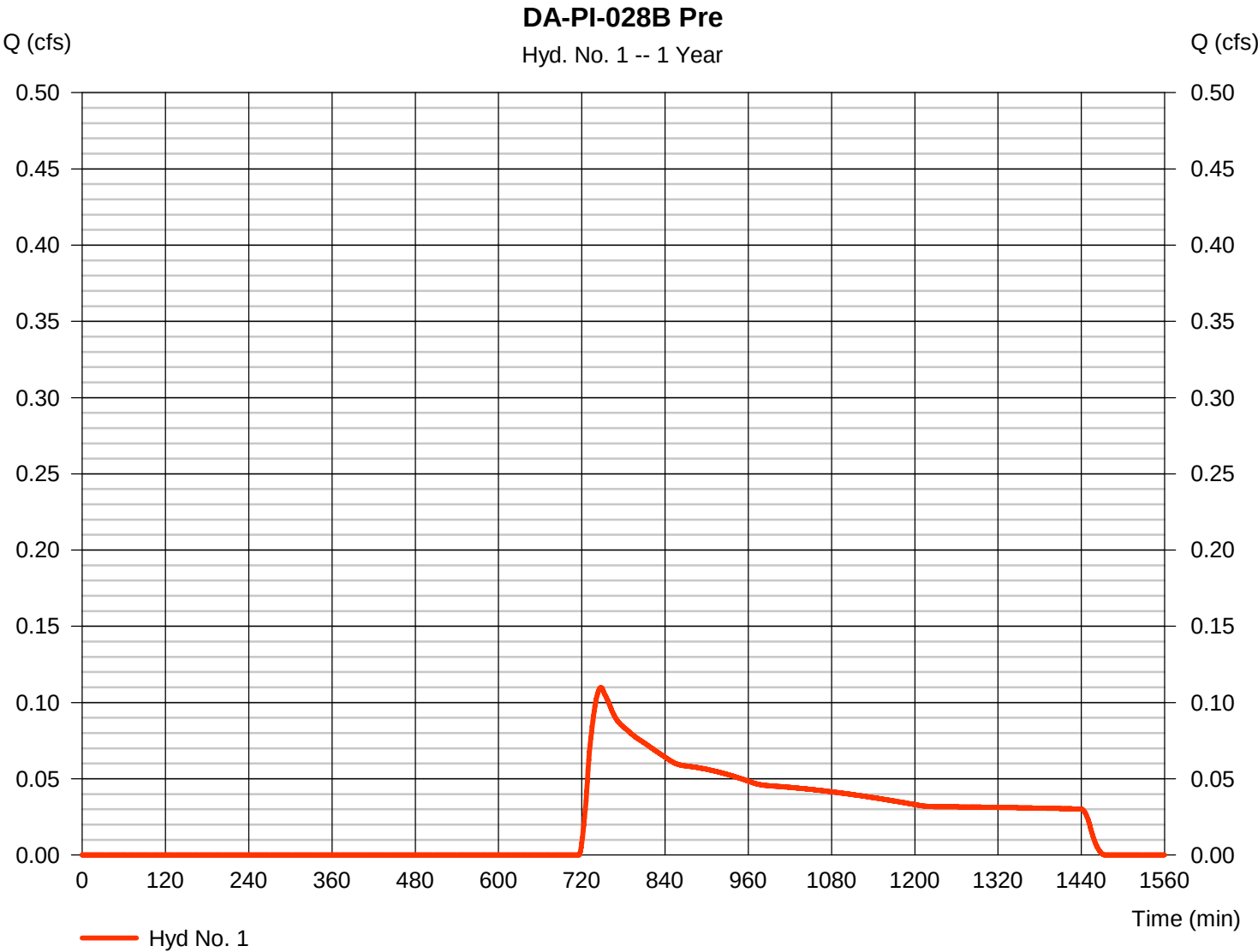
Hydrograph Report

Hyd. No. 1

DA-PI-028B Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.110 cfs
Storm frequency	= 1 yrs	Time to peak	= 747 min
Time interval	= 1 min	Hyd. volume	= 2,038 cuft
Drainage area	= 4.450 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 20.80 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(1.100 x 48) + (0.050 x 73) + (3.180 x 55) + (0.120 x 77)] / 4.450



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-PI-028B Pre

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00	
Land slope (%)	= 2.87	0.00	0.00	
Travel Time (min)	= 17.77	+	0.00	+
			0.00	= 17.77
Shallow Concentrated Flow				
Flow length (ft)	= 898.23	0.00	0.00	
Watercourse slope (%)	= 9.67	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=5.02	0.00	0.00	
Travel Time (min)	= 2.98	+	0.00	+
			0.00	= 2.98
Channel Flow				
X sectional flow area (sqft)	= 0.00	0.00	0.00	
Wetted perimeter (ft)	= 0.00	0.00	0.00	
Channel slope (%)	= 0.00	0.00	0.00	
Manning's n-value	= 0.030	0.015	0.015	
Velocity (ft/s)	=0.00	0.00	0.00	
Flow length (ft)	(0)0.0	0.0	0.0	
Travel Time (min)	= 0.00	+	0.00	+
			0.00	= 0.00
Total Travel Time, Tc				20.80 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

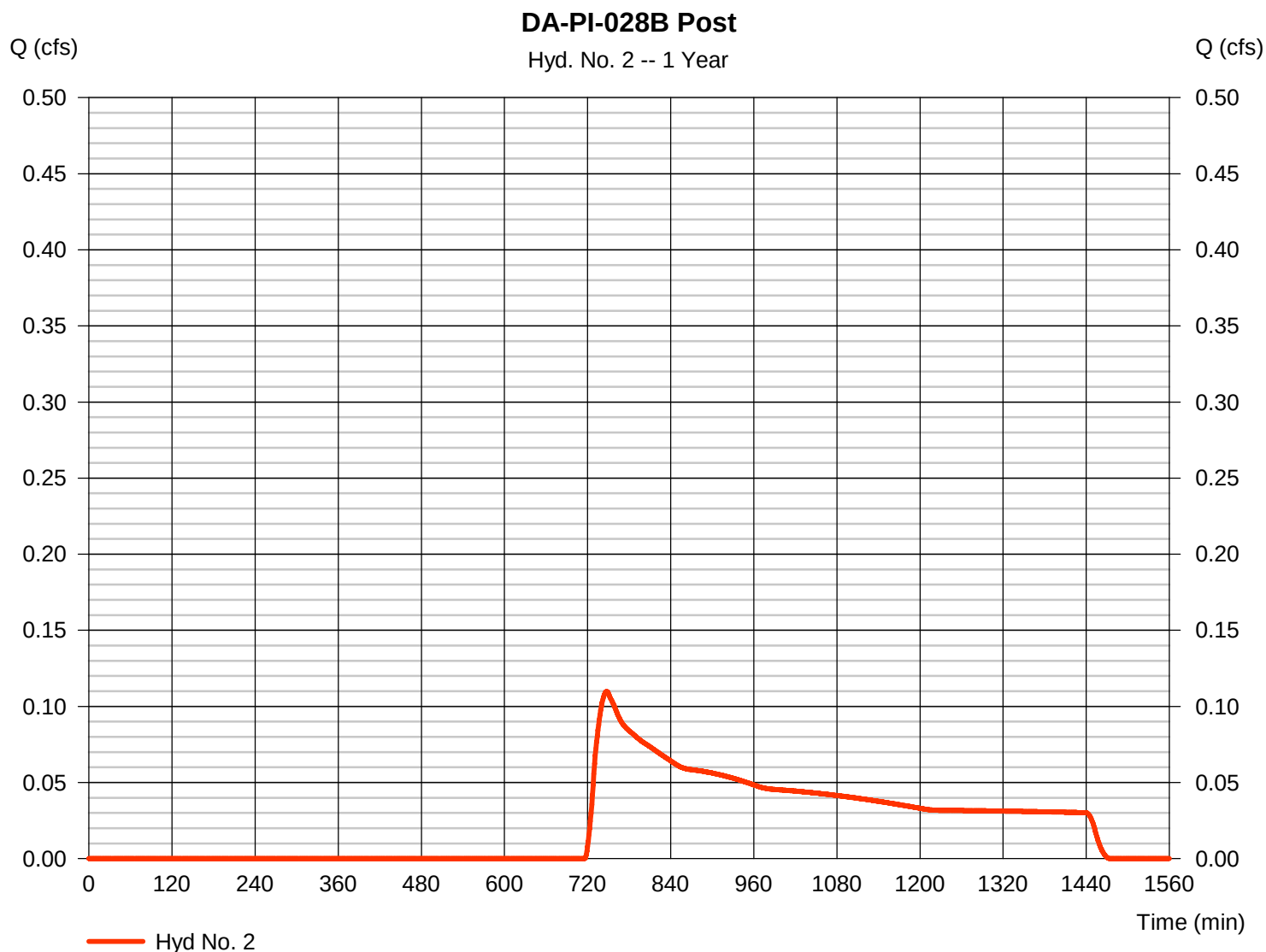
Thursday, 08 / 17 / 2017

Hyd. No. 2

DA-PI-028B Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.110 cfs
Storm frequency	= 1 yrs	Time to peak	= 747 min
Time interval	= 1 min	Hyd. volume	= 2,038 cuft
Drainage area	= 4.450 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 20.90 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.760 \times 48) + (0.070 \times 73) + (1.330 \times 55) + (1.190 \times 58) + (0.100 \times 78)] / 4.450$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-PI-028B Post

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 2.87	0.00	0.00				
Travel Time (min)	= 17.77	+	0.00	+	0.00	=	17.77
Shallow Concentrated Flow							
Flow length (ft)	= 381.08	517.89	0.00				
Watercourse slope (%)	= 6.65	11.94	0.00				
Surface description	= Unpaved	Unpaved	Paved				
Average velocity (ft/s)	=4.16	5.58	0.00				
Travel Time (min)	= 1.53	+	1.55	+	0.00	=	3.07
Channel Flow							
X sectional flow area (sqft)	= 2.00	0.00	0.00				
Wetted perimeter (ft)	= 4.47	0.00	0.00				
Channel slope (%)	= 5.00	0.00	0.00				
Manning's n-value	= 0.040	0.015	0.015				
Velocity (ft/s)	=4.86	0.00	0.00				
Flow length (ft)	($\{0\}$)18.7	0.0	0.0				
Travel Time (min)	= 0.06	+	0.00	+	0.00	=	0.06
Total Travel Time, Tc					20.90 min		

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

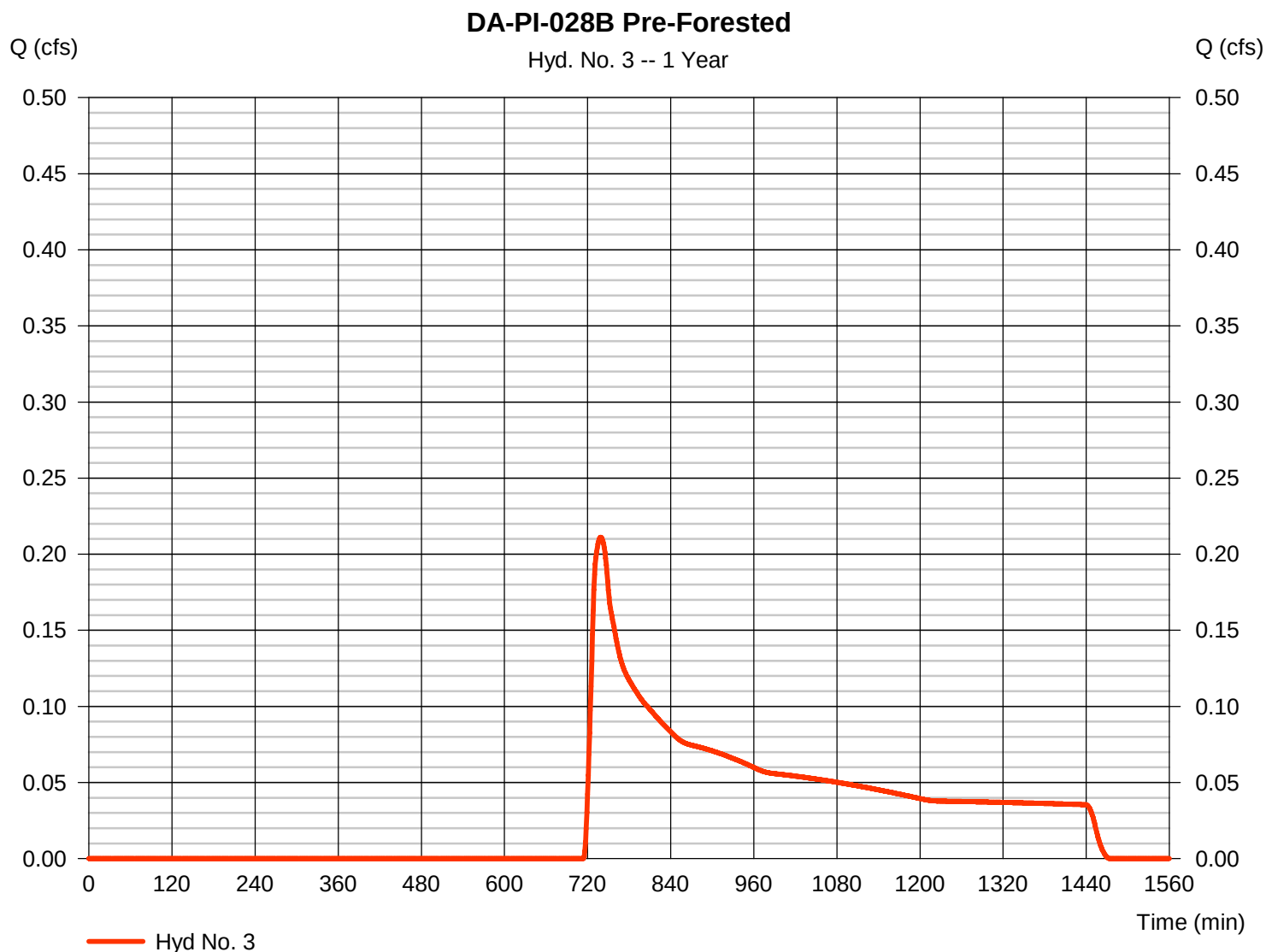
Thursday, 08 / 17 / 2017

Hyd. No. 3

DA-PI-028B Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 0.211 cfs
Storm frequency	= 1 yrs	Time to peak	= 739 min
Time interval	= 1 min	Hyd. volume	= 2,709 cuft
Drainage area	= 4.450 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 20.80 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(4.280 \times 55) + (0.170 \times 77)] / 4.450$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-PI-028B Pre-Forested

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00	
Land slope (%)	= 2.87	0.00	0.00	
Travel Time (min)	= 17.77	+ 0.00	+ 0.00	= 17.77
Shallow Concentrated Flow				
Flow length (ft)	= 898.23	0.00	0.00	
Watercourse slope (%)	= 9.67	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=5.02	0.00	0.00	
Travel Time (min)	= 2.98	+ 0.00	+ 0.00	= 2.98
Channel Flow				
X sectional flow area (sqft)	= 0.00	0.00	0.00	
Wetted perimeter (ft)	= 0.00	0.00	0.00	
Channel slope (%)	= 0.00	0.00	0.00	
Manning's n-value	= 0.030	0.015	0.015	
Velocity (ft/s)	=0.00	0.00	0.00	
Flow length (ft)	(0)0.0	0.0	0.0	
Travel Time (min)	= 0.00	+ 0.00	+ 0.00	= 0.00
Total Travel Time, Tc				20.80 min

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.679	1	731	5,101	-----	-----	-----	DA-PI-028B Pre
2	SCS Runoff	0.679	1	731	5,101	-----	-----	-----	DA-PI-028B Post
3	SCS Runoff	1.007	1	730	6,199	-----	-----	-----	DA-PI-028B Pre-Forested
DA-PI-028B.gpw					Return Period: 2 Year			Thursday, 08 / 17 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

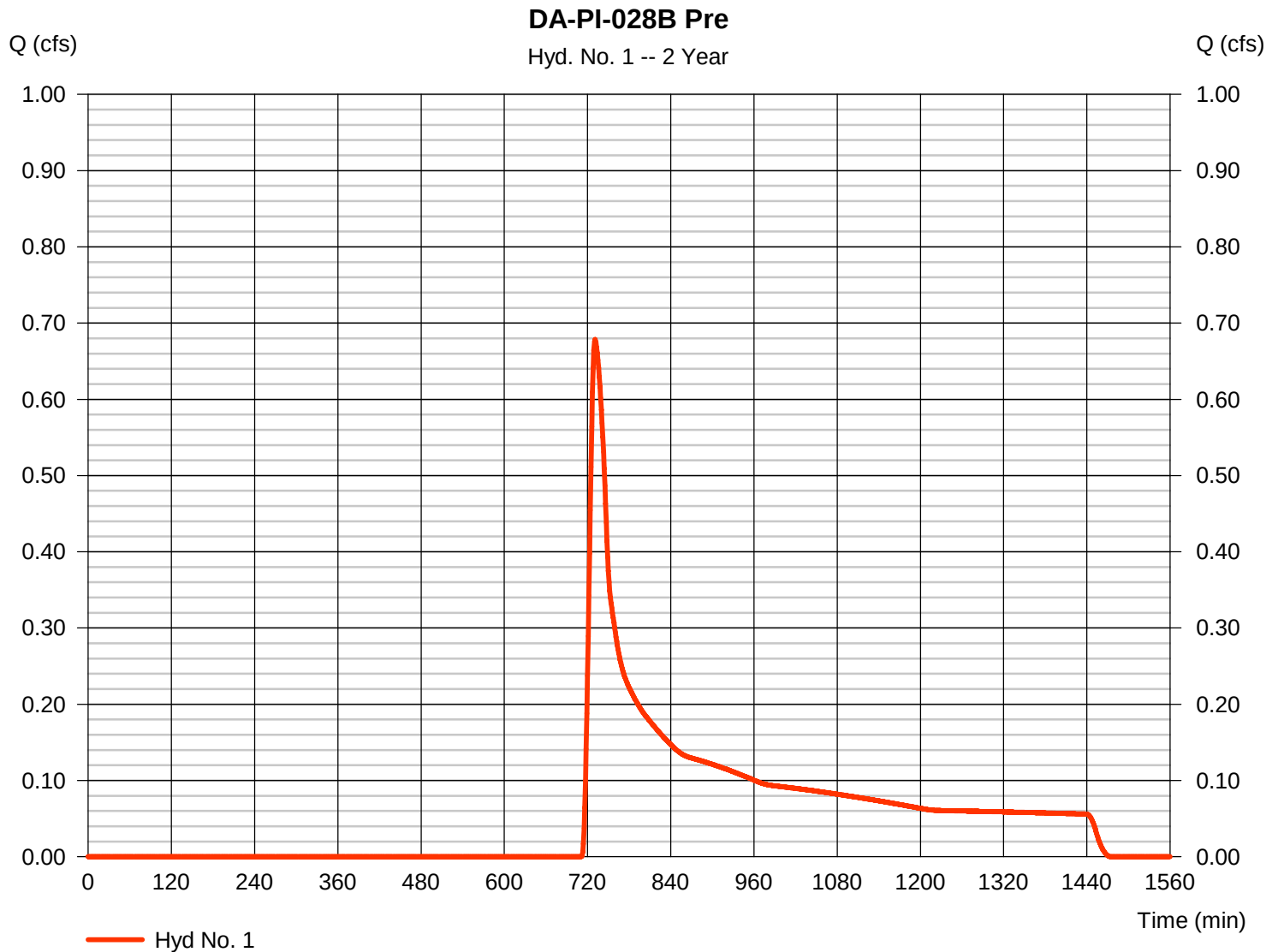
Thursday, 08 / 17 / 2017

Hyd. No. 1

DA-PI-028B Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.679 cfs
Storm frequency	= 2 yrs	Time to peak	= 731 min
Time interval	= 1 min	Hyd. volume	= 5,101 cuft
Drainage area	= 4.450 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 20.80 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.100 \times 48) + (0.050 \times 73) + (3.180 \times 55) + (0.120 \times 77)] / 4.450$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

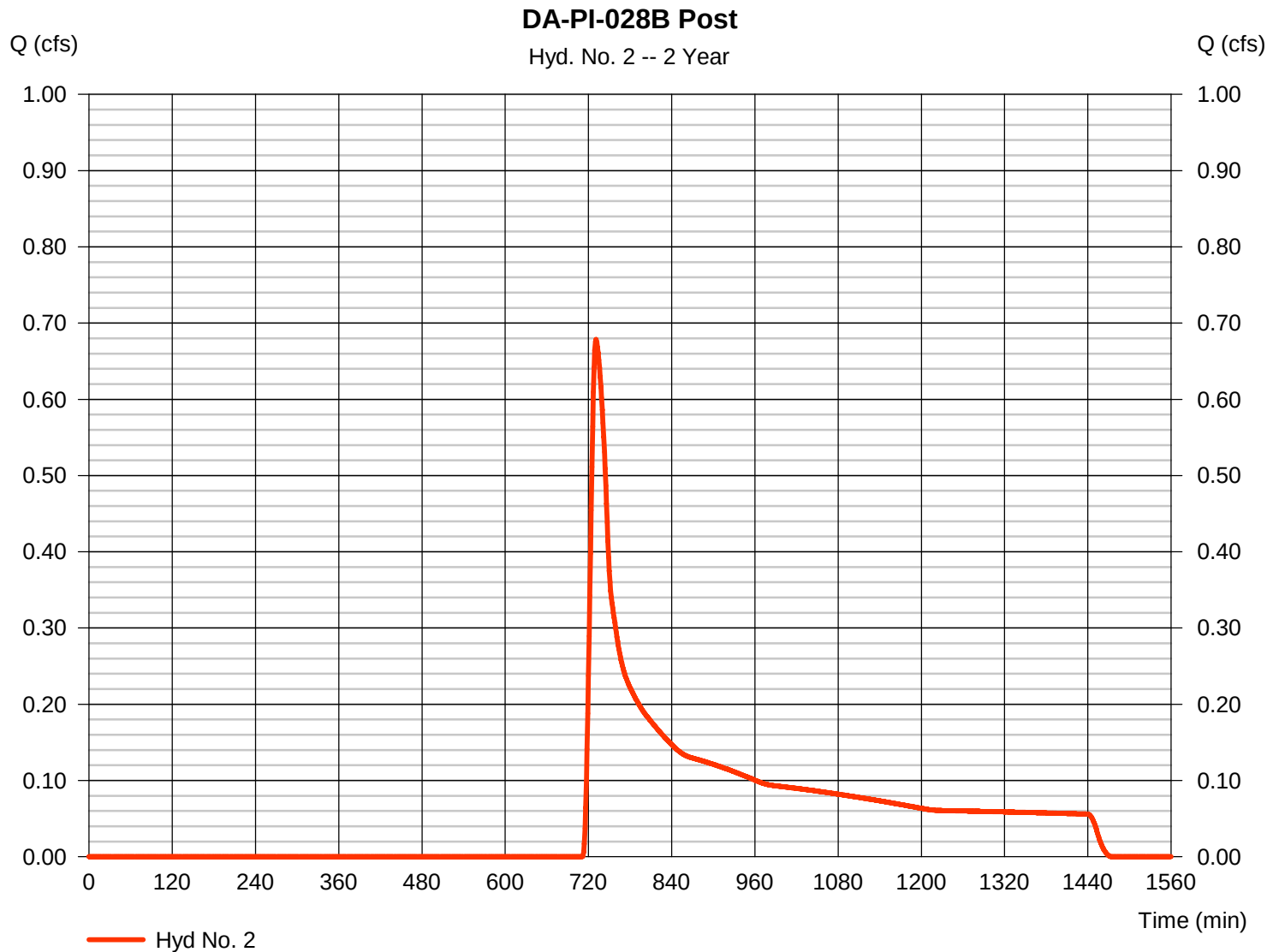
Thursday, 08 / 17 / 2017

Hyd. No. 2

DA-PI-028B Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.679 cfs
Storm frequency	= 2 yrs	Time to peak	= 731 min
Time interval	= 1 min	Hyd. volume	= 5,101 cuft
Drainage area	= 4.450 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 20.90 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.760 \times 48) + (0.070 \times 73) + (1.330 \times 55) + (1.190 \times 58) + (0.100 \times 78)] / 4.450$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

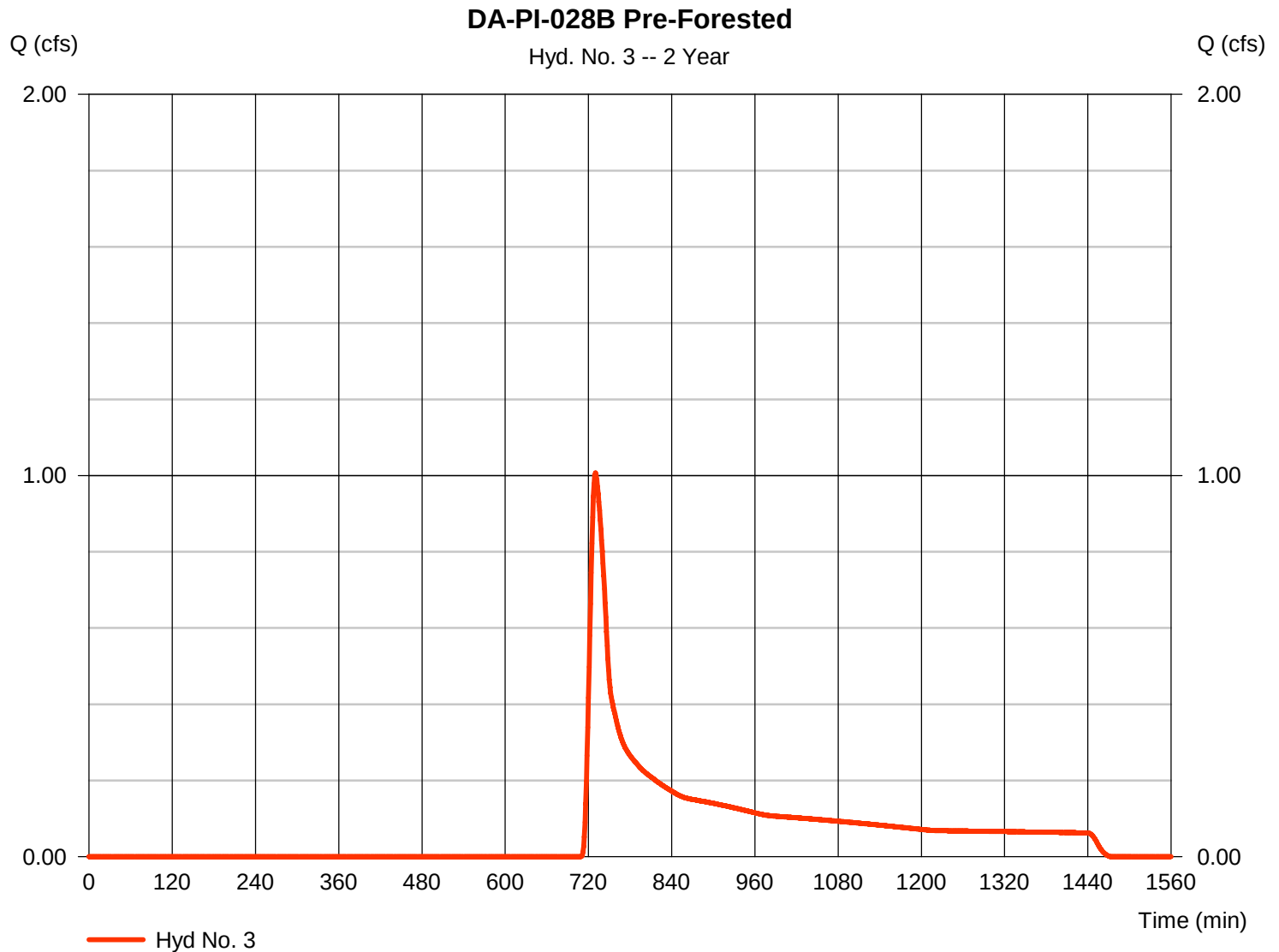
Thursday, 08 / 17 / 2017

Hyd. No. 3

DA-PI-028B Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 1.007 cfs
Storm frequency	= 2 yrs	Time to peak	= 730 min
Time interval	= 1 min	Hyd. volume	= 6,199 cuft
Drainage area	= 4.450 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 20.80 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(4.280 \times 55) + (0.170 \times 77)] / 4.450$



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	4.042	1	728	16,593	-----	-----	-----	DA-PI-028B Pre
2	SCS Runoff	4.042	1	728	16,593	-----	-----	-----	DA-PI-028B Post
3	SCS Runoff	4.802	1	728	18,695	-----	-----	-----	DA-PI-028B Pre-Forested
DA-PI-028B.gpw					Return Period: 10 Year			Thursday, 08 / 17 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

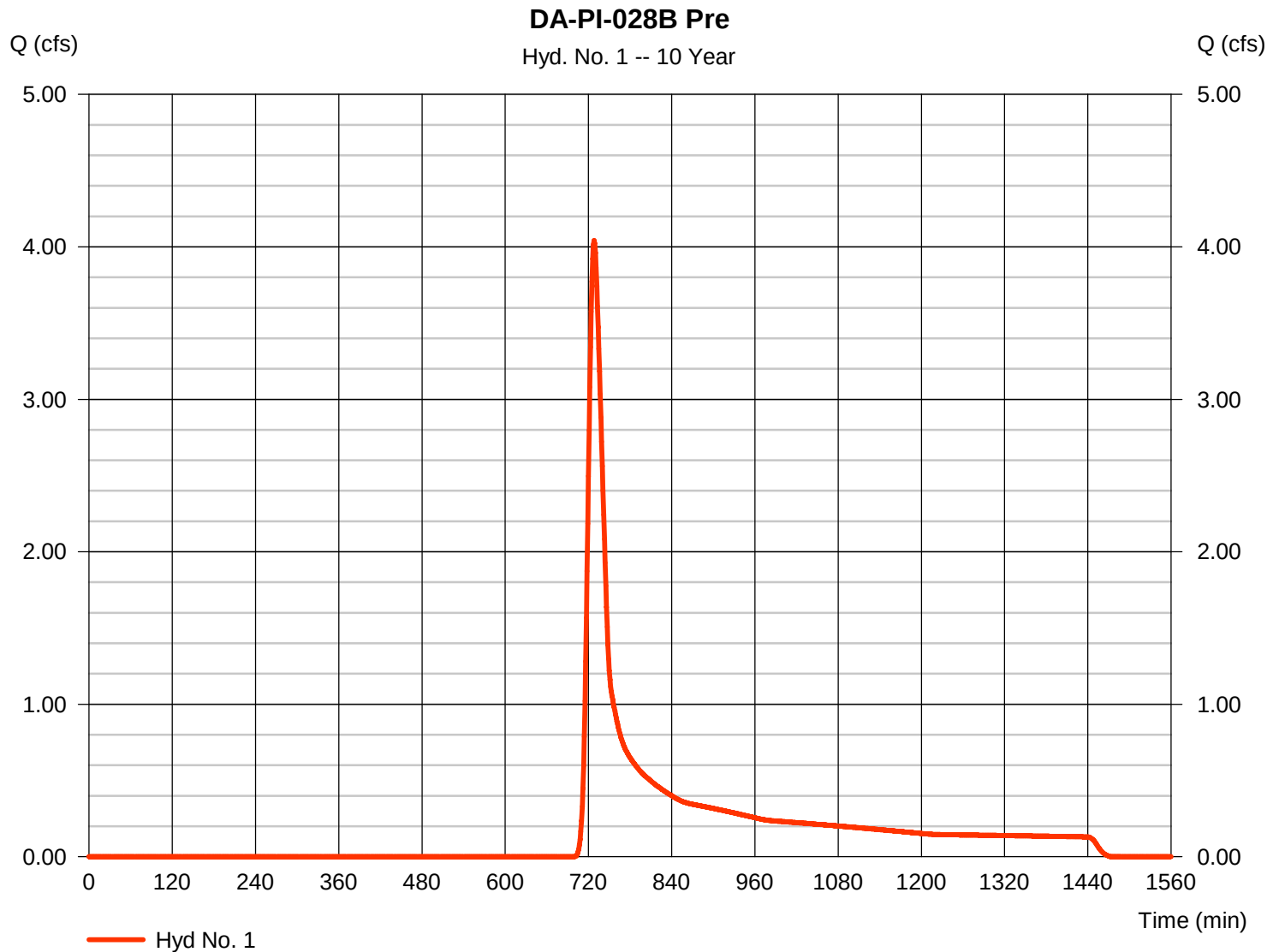
Thursday, 08 / 17 / 2017

Hyd. No. 1

DA-PI-028B Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 4.042 cfs
Storm frequency	= 10 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 16,593 cuft
Drainage area	= 4.450 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 20.80 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(1.100 x 48) + (0.050 x 73) + (3.180 x 55) + (0.120 x 77)] / 4.450



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

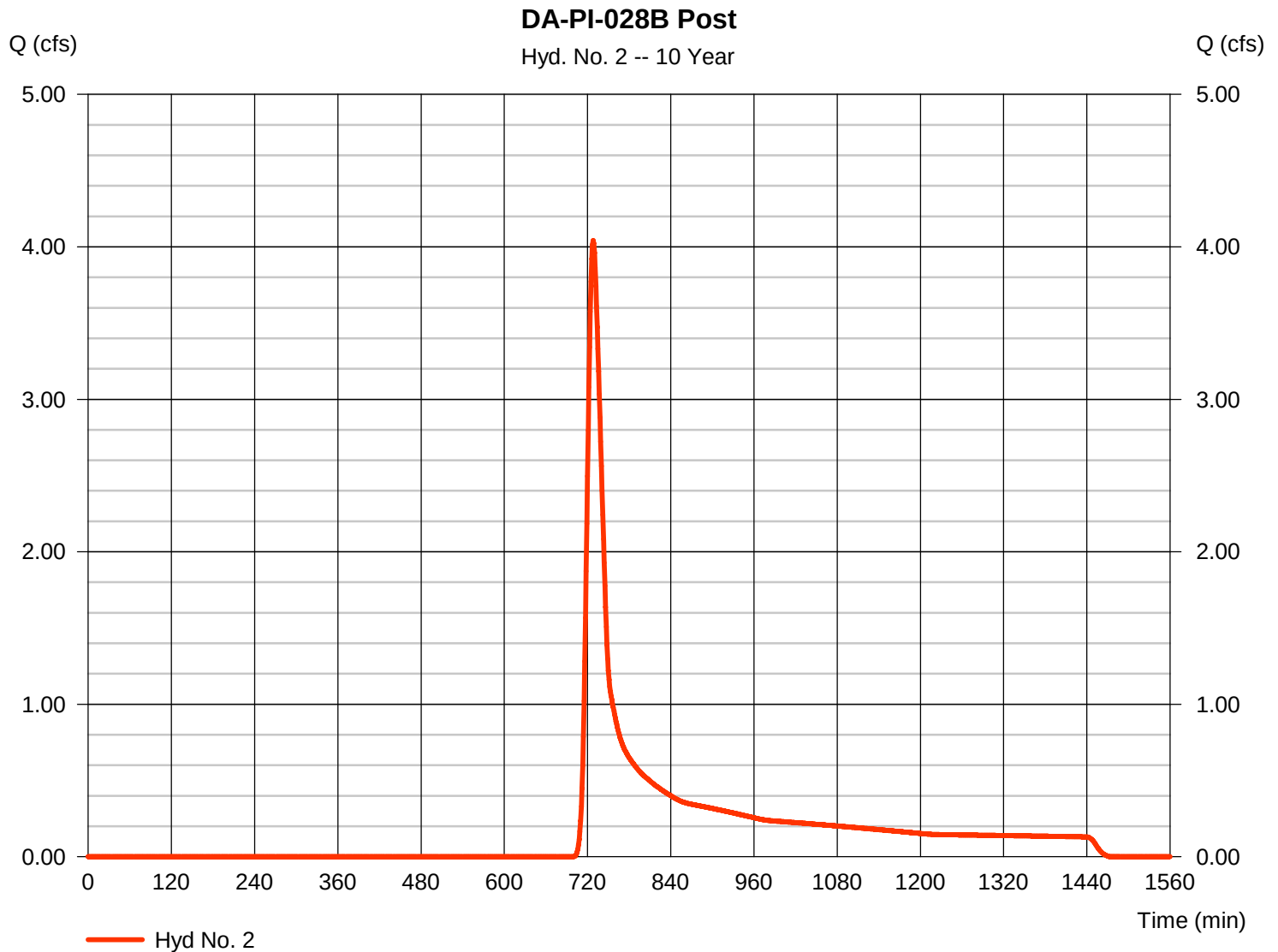
Thursday, 08 / 17 / 2017

Hyd. No. 2

DA-PI-028B Post

Hydrograph type	= SCS Runoff	Peak discharge	= 4.042 cfs
Storm frequency	= 10 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 16,593 cuft
Drainage area	= 4.450 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 20.90 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.760 \times 48) + (0.070 \times 73) + (1.330 \times 55) + (1.190 \times 58) + (0.100 \times 78)] / 4.450$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

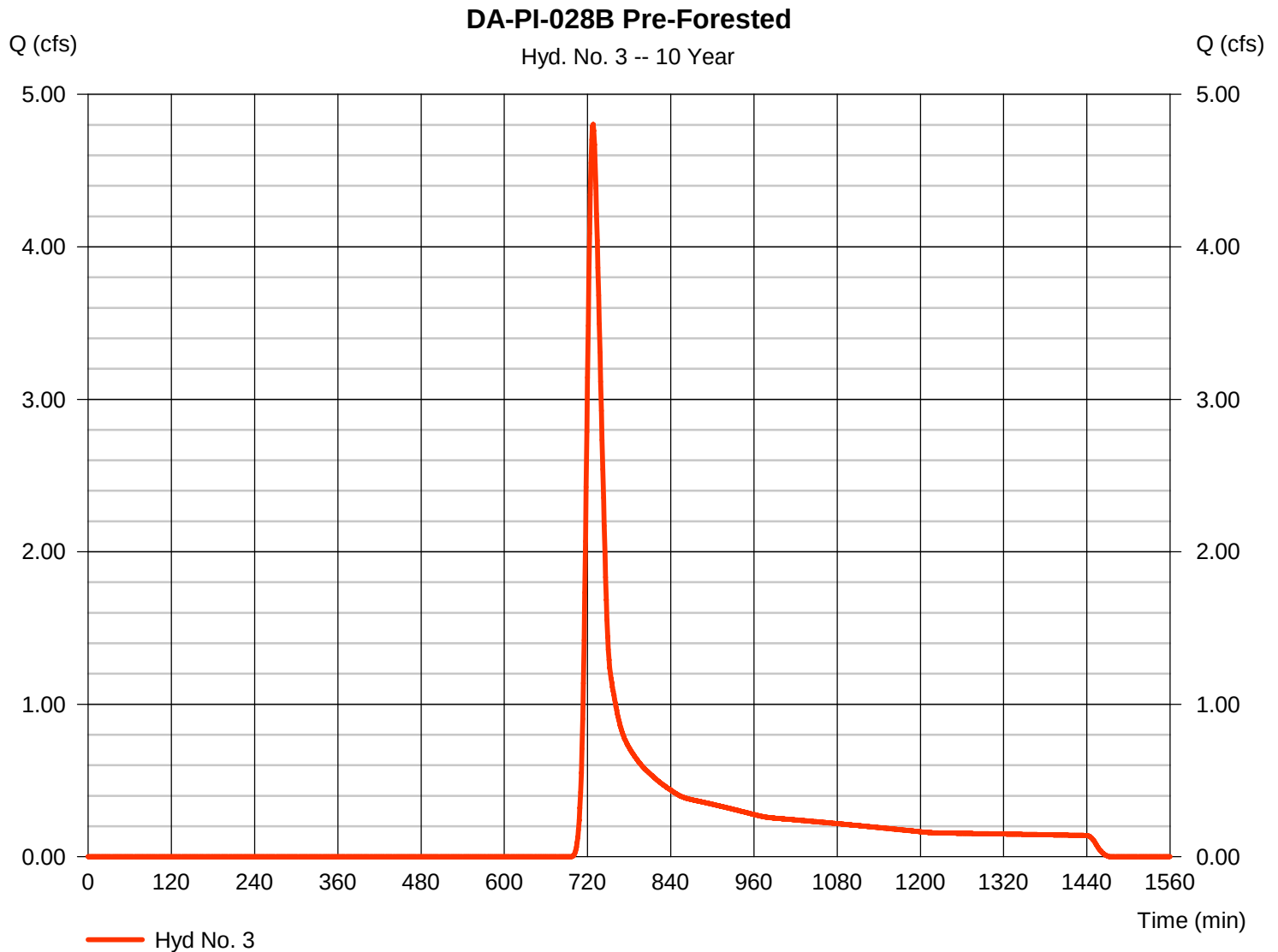
Thursday, 08 / 17 / 2017

Hyd. No. 3

DA-PI-028B Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 4.802 cfs
Storm frequency	= 10 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 18,695 cuft
Drainage area	= 4.450 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 20.80 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(4.280 \times 55) + (0.170 \times 77)] / 4.450$



DA-PI-028C

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.036	520
Developed Condition	0.017	378
Pre-Developed (Forest) Condition	0.036	520

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.9

Calculations:

Check #1:

$$Q_{\text{developed}} \leq \text{IF} \times [(Q_{\text{pre-developed}} \times \text{RV}_{\text{pre-developed}}) / \text{RV}_{\text{developed}}] \text{ ----->}$$

Q (cfs)

0.017

≤

N/A - See Check #3

Q (cfs)

0.045

Check #2:

$$Q_{\text{developed}} \leq Q_{\text{pre-developed}} \text{ ----->}$$

0.017

≤

N/A - See Check #3

0.036

Check #3:

$$Q_{\text{developed}} \text{ shall not be required to be } \leq (Q_{\text{forest}} \times \text{RV}_{\text{forest}}) / \text{RV}_{\text{developed}} \text{ --->}$$

0.017

shall not be required to be ≤

0.050

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning's n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<i>Note:</i> Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted. ¹For Paved Road land surface types a Manning's n of 0.011 was used <i>Sources:</i> -USACE, 1998, HEC-1 Flood Hydrograph Package User's Manual, Hydrologic Engineering Center, Davis, CA -Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC	

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-PI-028C Pre
2	SCS Runoff	DA-PI-028C Post
3	SCS Runoff	DA-PI-028C Pre-Forested

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.036	1	733	520	-----	-----	-----	DA-PI-028C Pre
2	SCS Runoff	0.017	1	751	378	-----	-----	-----	DA-PI-028C Post
3	SCS Runoff	0.036	1	733	520	-----	-----	-----	DA-PI-028C Pre-Forested
DA-PI-028C.gpw					Return Period: 1 Year			Wednesday, 08 / 16 / 2017	

Hydrograph Report

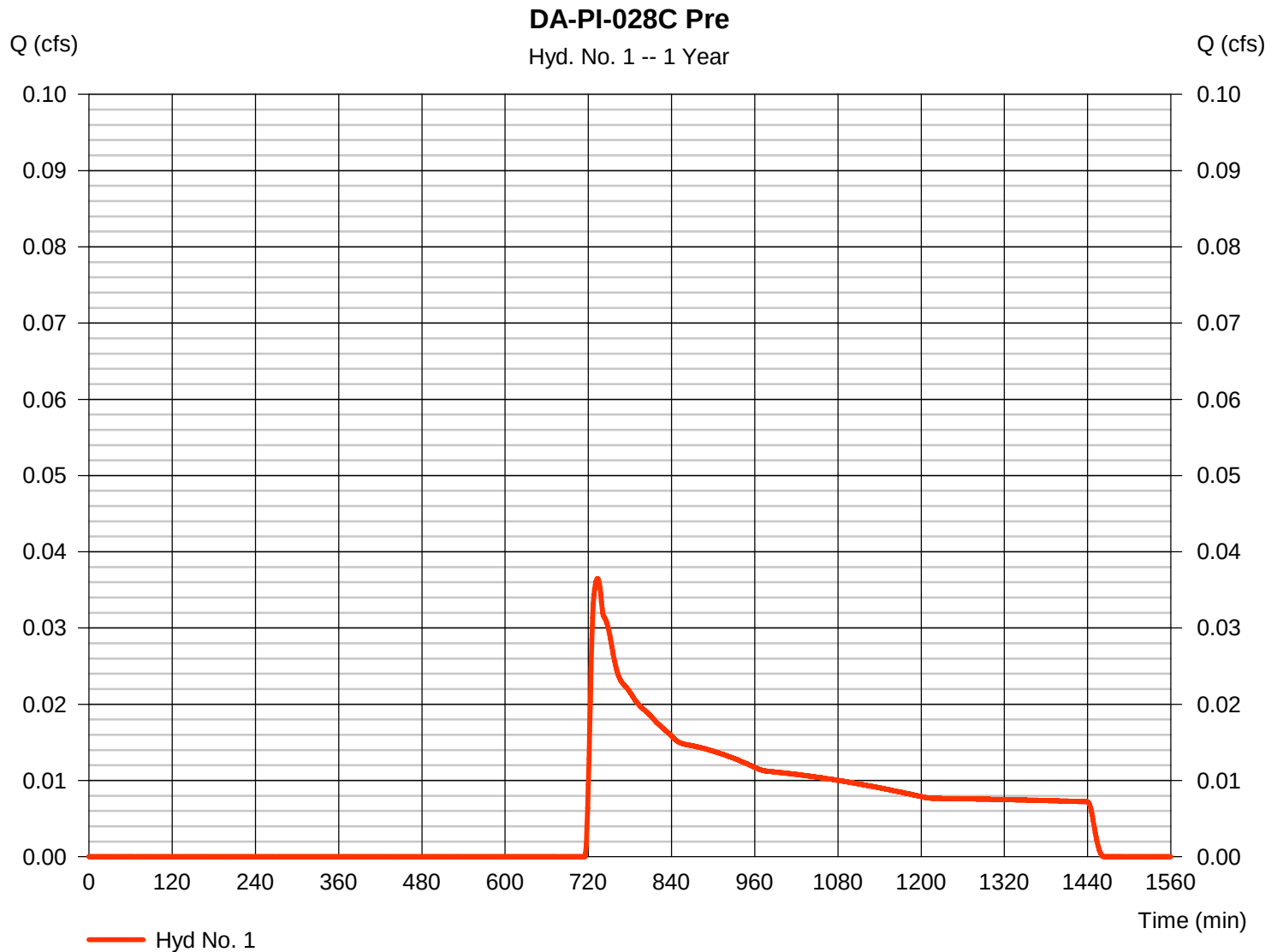
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Wednesday, 08 / 16 / 2017

Hyd. No. 1

DA-PI-028C Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.036 cfs
Storm frequency	= 1 yrs	Time to peak	= 733 min
Time interval	= 1 min	Hyd. volume	= 520 cuft
Drainage area	= 0.990 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.50 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.990 \times 55)] / 0.990$ 

TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-PI-028C Pre

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00	
Land slope (%)	= 5.28	0.00	0.00	
Travel Time (min)	= 13.93	+	0.00	+
			0.00	= 13.93
Shallow Concentrated Flow				
Flow length (ft)	= 264.43	0.00	0.00	
Watercourse slope (%)	= 20.61	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=7.32	0.00	0.00	
Travel Time (min)	= 0.60	+	0.00	+
			0.00	= 0.60
Channel Flow				
X sectional flow area (sqft)	= 0.00	0.00	0.00	
Wetted perimeter (ft)	= 0.00	0.00	0.00	
Channel slope (%)	= 0.00	0.00	0.00	
Manning's n-value	= 0.030	0.015	0.015	
Velocity (ft/s)	=0.00	0.00	0.00	
Flow length (ft)	(0)0.0	0.0	0.0	
Travel Time (min)	= 0.00	+	0.00	+
			0.00	= 0.00
Total Travel Time, Tc				14.50 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

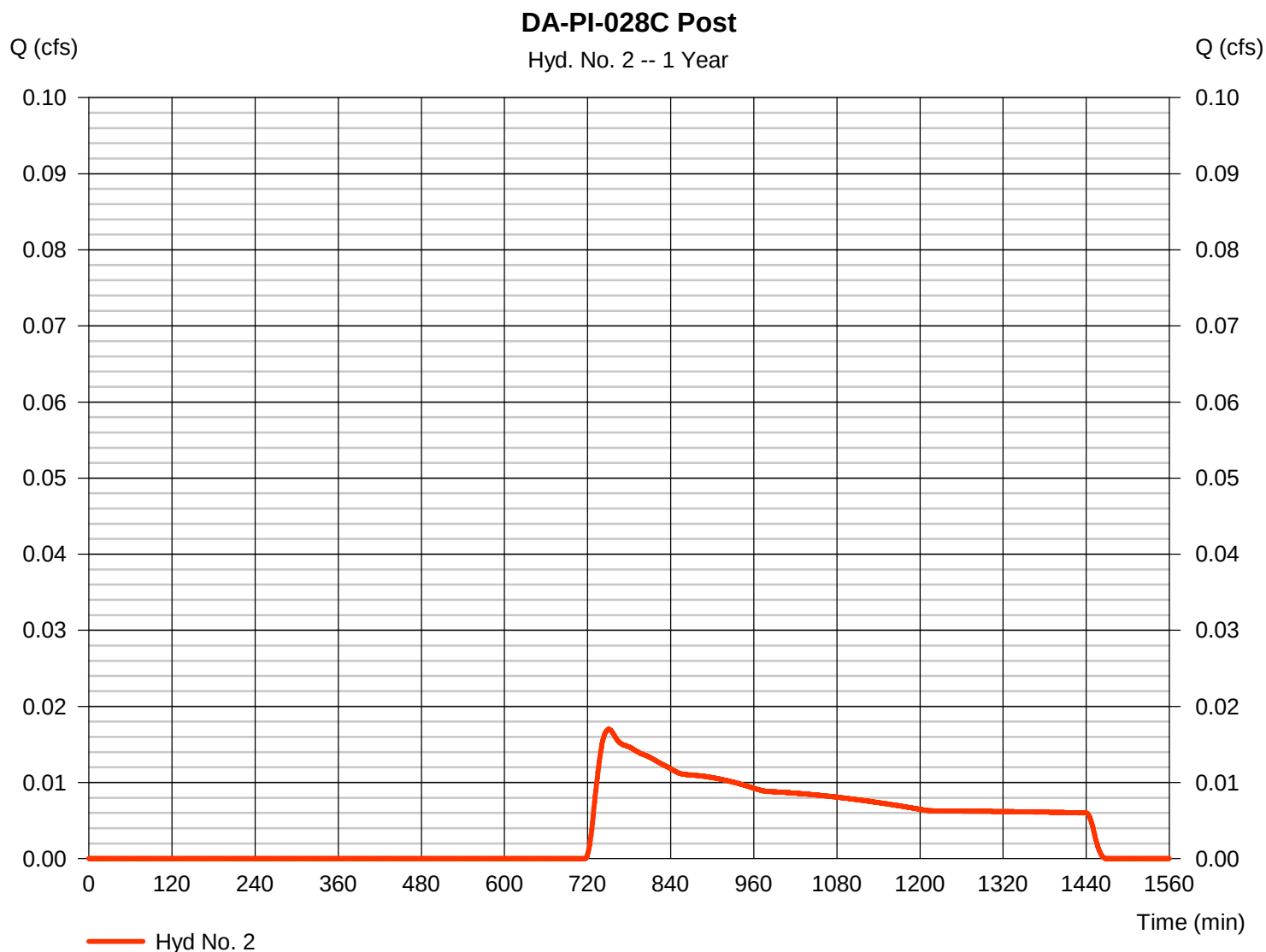
Wednesday, 08 / 16 / 2017

Hyd. No. 2

DA-PI-028C Post

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.017 cfs
Storm frequency	=	1 yrs	Time to peak	=	751 min
Time interval	=	1 min	Hyd. volume	=	378 cuft
Drainage area	=	0.990 ac	Curve number	=	53*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	18.40 min
Total precip.	=	2.80 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(0.120 \times 55) + (0.490 \times 48) + (0.380 \times 58)] / 0.990$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-PI-028C Post

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.800	0.011	
Flow length (ft)	= 81.7	18.3	0.0	
Two-year 24-hr precip. (in)	= 3.50	3.50	0.00	
Land slope (%)	= 4.94	6.78	0.00	
Travel Time (min)	= 12.16	+	5.65	+
			0.00	= 17.81
Shallow Concentrated Flow				
Flow length (ft)	= 264.43	0.00	0.00	
Watercourse slope (%)	= 20.61	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=7.32	0.00	0.00	
Travel Time (min)	= 0.60	+	0.00	+
			0.00	= 0.60
Channel Flow				
X sectional flow area (sqft)	= 0.00	0.00	0.00	
Wetted perimeter (ft)	= 0.00	0.00	0.00	
Channel slope (%)	= 0.00	0.00	0.00	
Manning's n-value	= 0.040	0.015	0.015	
Velocity (ft/s)	=0.00	0.00	0.00	
Flow length (ft)	(0)0.0	0.0	0.0	
Travel Time (min)	= 0.00	+	0.00	+
			0.00	= 0.00
Total Travel Time, Tc				18.40 min

Hydrograph Report

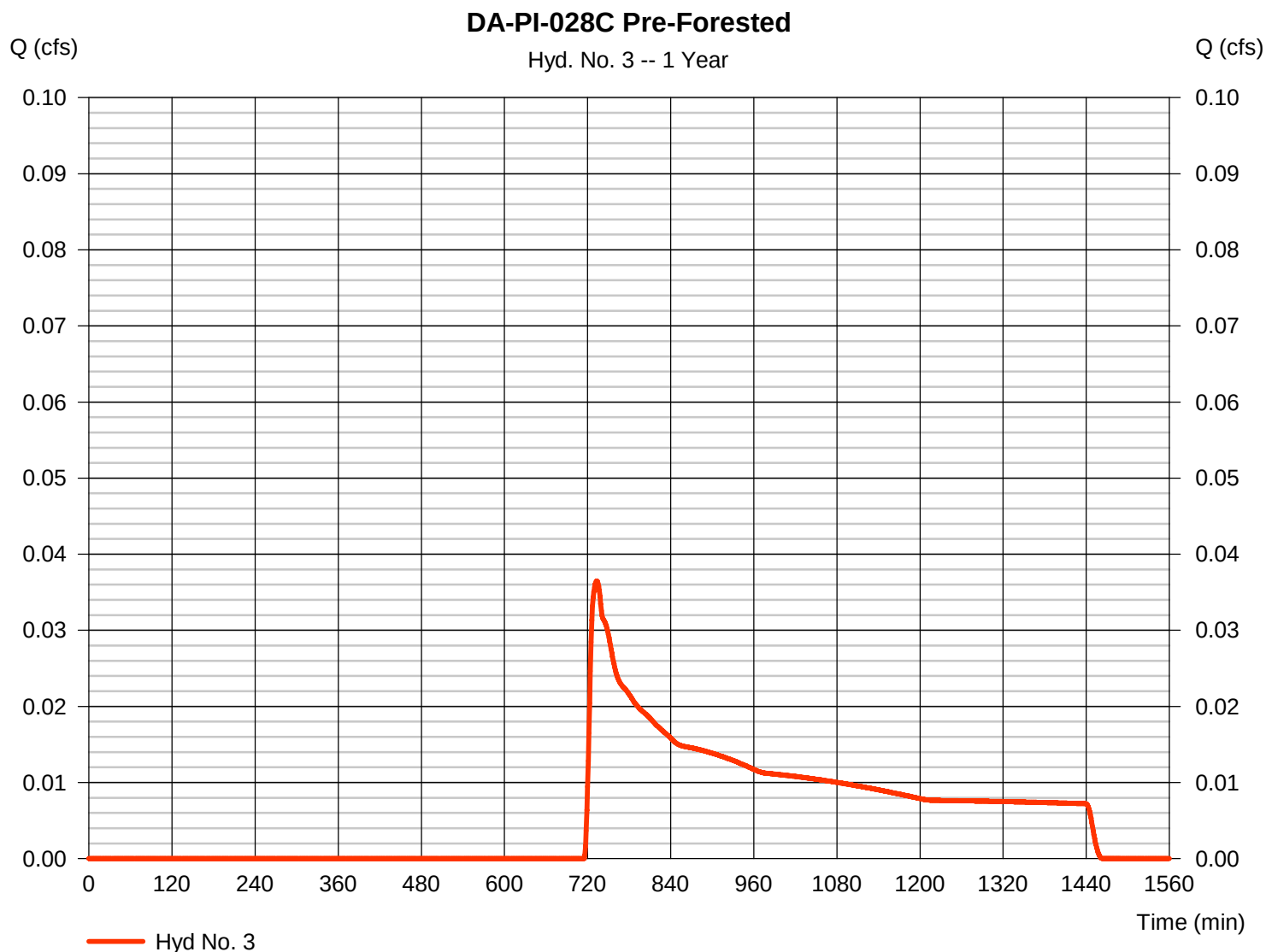
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Wednesday, 08 / 16 / 2017

Hyd. No. 3

DA-PI-028C Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.036 cfs
Storm frequency	=	1 yrs	Time to peak	=	733 min
Time interval	=	1 min	Hyd. volume	=	520 cuft
Drainage area	=	0.990 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	14.50 min
Total precip.	=	2.80 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(0.990 \times 55)] / 0.990$ 

TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-PI-028C Pre-Forested

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00	
Land slope (%)	= 5.28	0.00	0.00	
Travel Time (min)	= 13.93	+	0.00	+
			0.00	= 13.93
Shallow Concentrated Flow				
Flow length (ft)	= 264.43	0.00	0.00	
Watercourse slope (%)	= 20.61	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=7.32	0.00	0.00	
Travel Time (min)	= 0.60	+	0.00	+
			0.00	= 0.60
Channel Flow				
X sectional flow area (sqft)	= 0.00	0.00	0.00	
Wetted perimeter (ft)	= 0.00	0.00	0.00	
Channel slope (%)	= 0.00	0.00	0.00	
Manning's n-value	= 0.030	0.015	0.015	
Velocity (ft/s)	=0.00	0.00	0.00	
Flow length (ft)	(0)0.0	0.0	0.0	
Travel Time (min)	= 0.00	+	0.00	+
			0.00	= 0.00
Total Travel Time, Tc				14.50 min

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.238	1	726	1,242	-----	-----	-----	DA-PI-028C Pre
2	SCS Runoff	0.132	1	729	999	-----	-----	-----	DA-PI-028C Post
3	SCS Runoff	0.238	1	726	1,242	-----	-----	-----	DA-PI-028C Pre-Forested
DA-PI-028C.gpw					Return Period: 2 Year			Wednesday, 08 / 16 / 2017	

Hydrograph Report

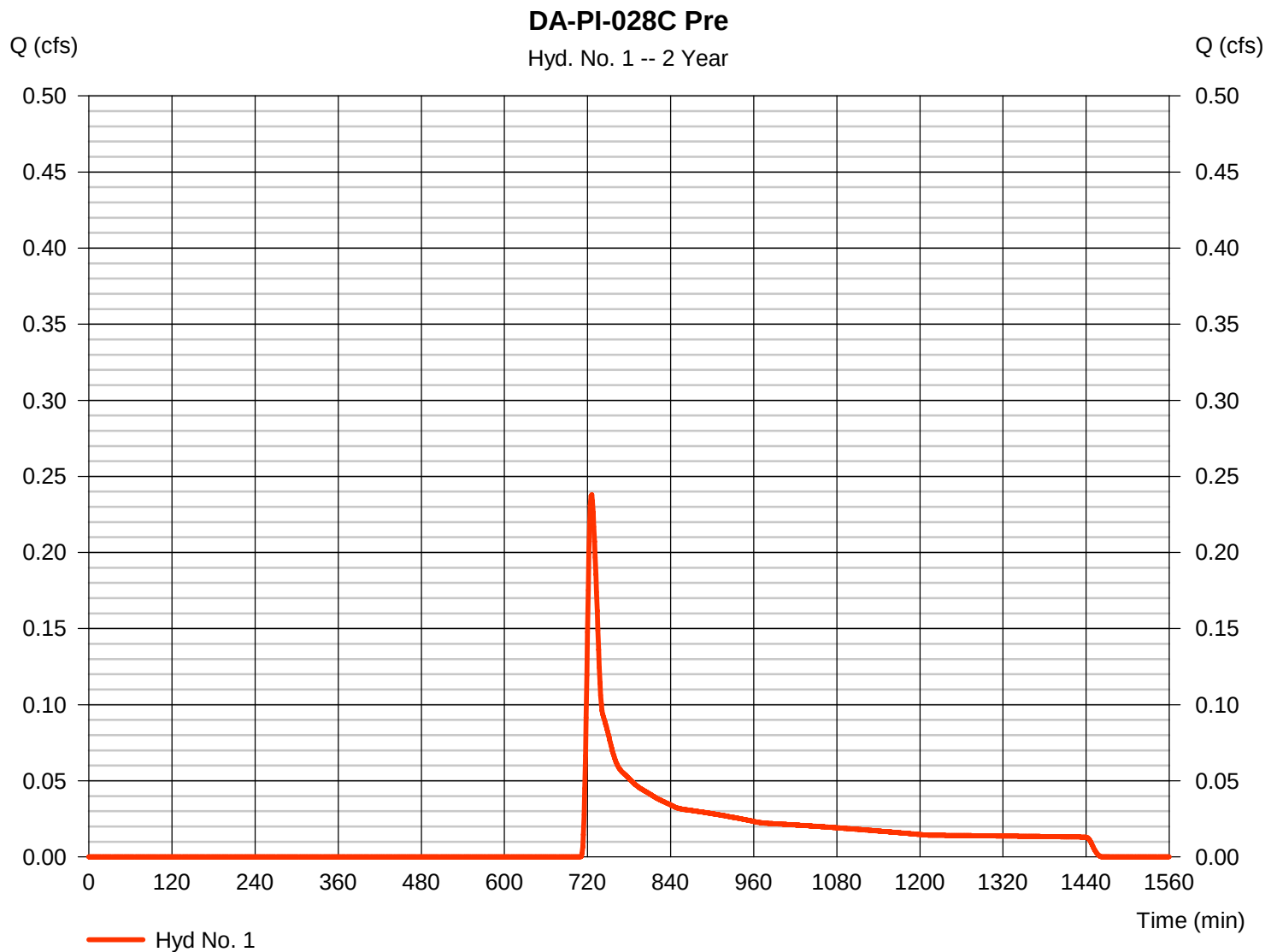
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Wednesday, 08 / 16 / 2017

Hyd. No. 1

DA-PI-028C Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.238 cfs
Storm frequency	= 2 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 1,242 cuft
Drainage area	= 0.990 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.50 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.990 \times 55)] / 0.990$ 

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

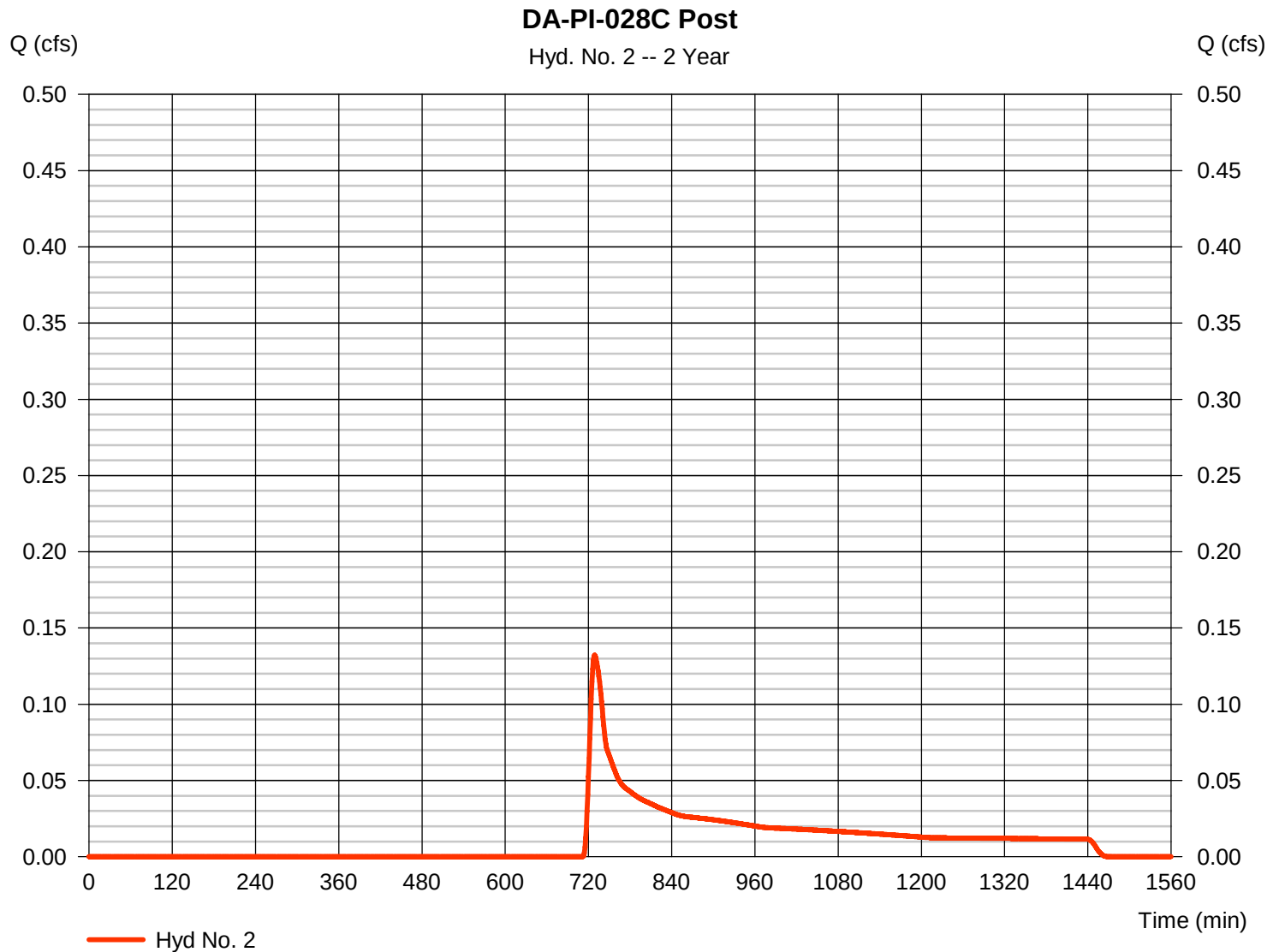
Wednesday, 08 / 16 / 2017

Hyd. No. 2

DA-PI-028C Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.132 cfs
Storm frequency	= 2 yrs	Time to peak	= 729 min
Time interval	= 1 min	Hyd. volume	= 999 cuft
Drainage area	= 0.990 ac	Curve number	= 53*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.40 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.120 \times 55) + (0.490 \times 48) + (0.380 \times 58)] / 0.990$



Hydrograph Report

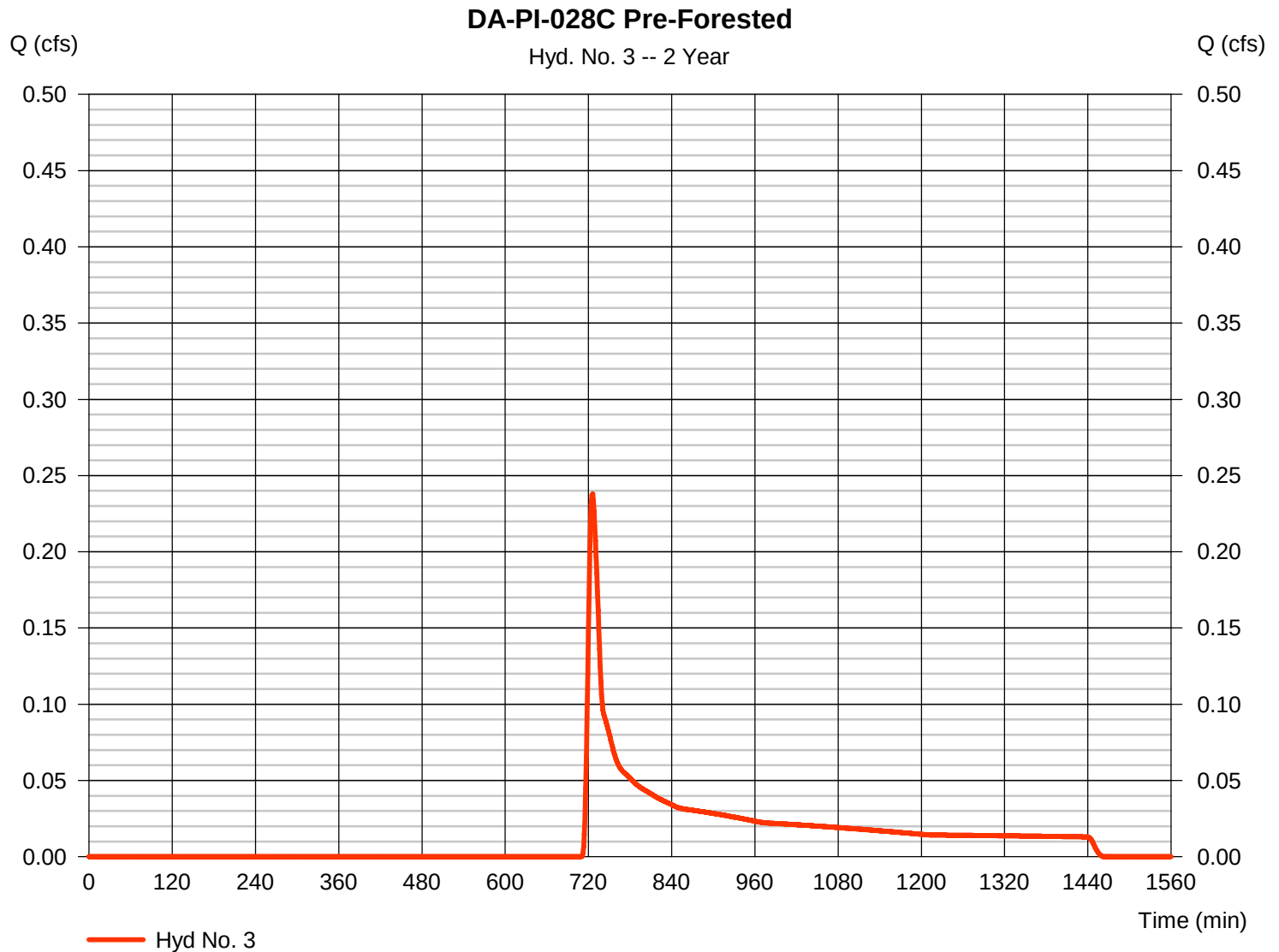
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Wednesday, 08 / 16 / 2017

Hyd. No. 3

DA-PI-028C Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.238 cfs
Storm frequency	=	2 yrs	Time to peak	=	726 min
Time interval	=	1 min	Hyd. volume	=	1,242 cuft
Drainage area	=	0.990 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	14.50 min
Total precip.	=	3.50 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(0.990 \times 55)] / 0.990$ 

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	1.242	1	723	3,886	-----	-----	-----	DA-PI-028C Pre
2	SCS Runoff	0.911	1	726	3,393	-----	-----	-----	DA-PI-028C Post
3	SCS Runoff	1.242	1	723	3,886	-----	-----	-----	DA-PI-028C Pre-Forested
DA-PI-028C.gpw					Return Period: 10 Year			Wednesday, 08 / 16 / 2017	

Hydrograph Report

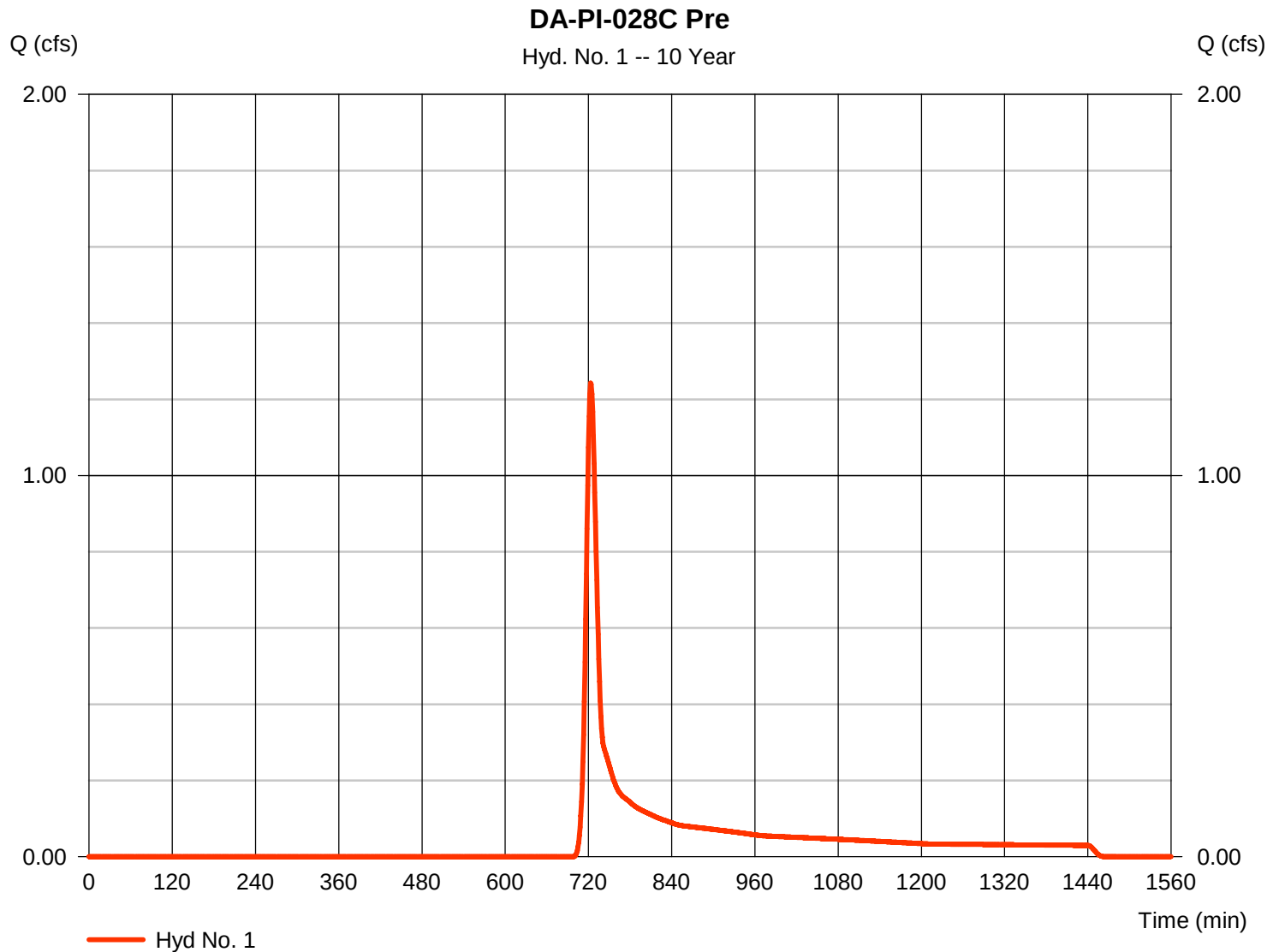
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Wednesday, 08 / 16 / 2017

Hyd. No. 1

DA-PI-028C Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 1.242 cfs
Storm frequency	= 10 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 3,886 cuft
Drainage area	= 0.990 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.50 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.990 \times 55)] / 0.990$ 

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

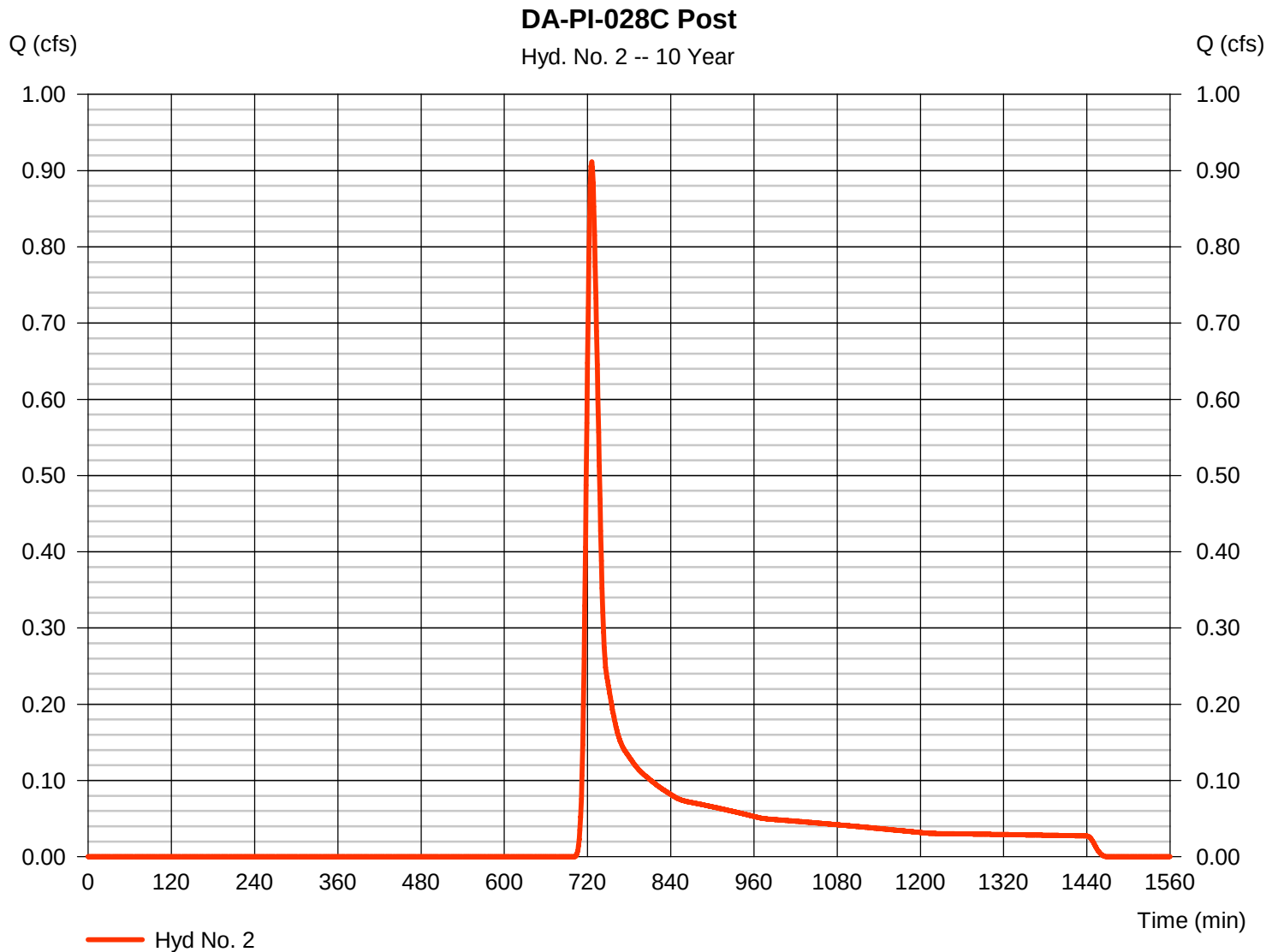
Wednesday, 08 / 16 / 2017

Hyd. No. 2

DA-PI-028C Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.911 cfs
Storm frequency	= 10 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 3,393 cuft
Drainage area	= 0.990 ac	Curve number	= 53*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.40 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.120 \times 55) + (0.490 \times 48) + (0.380 \times 58)] / 0.990$



Hydrograph Report

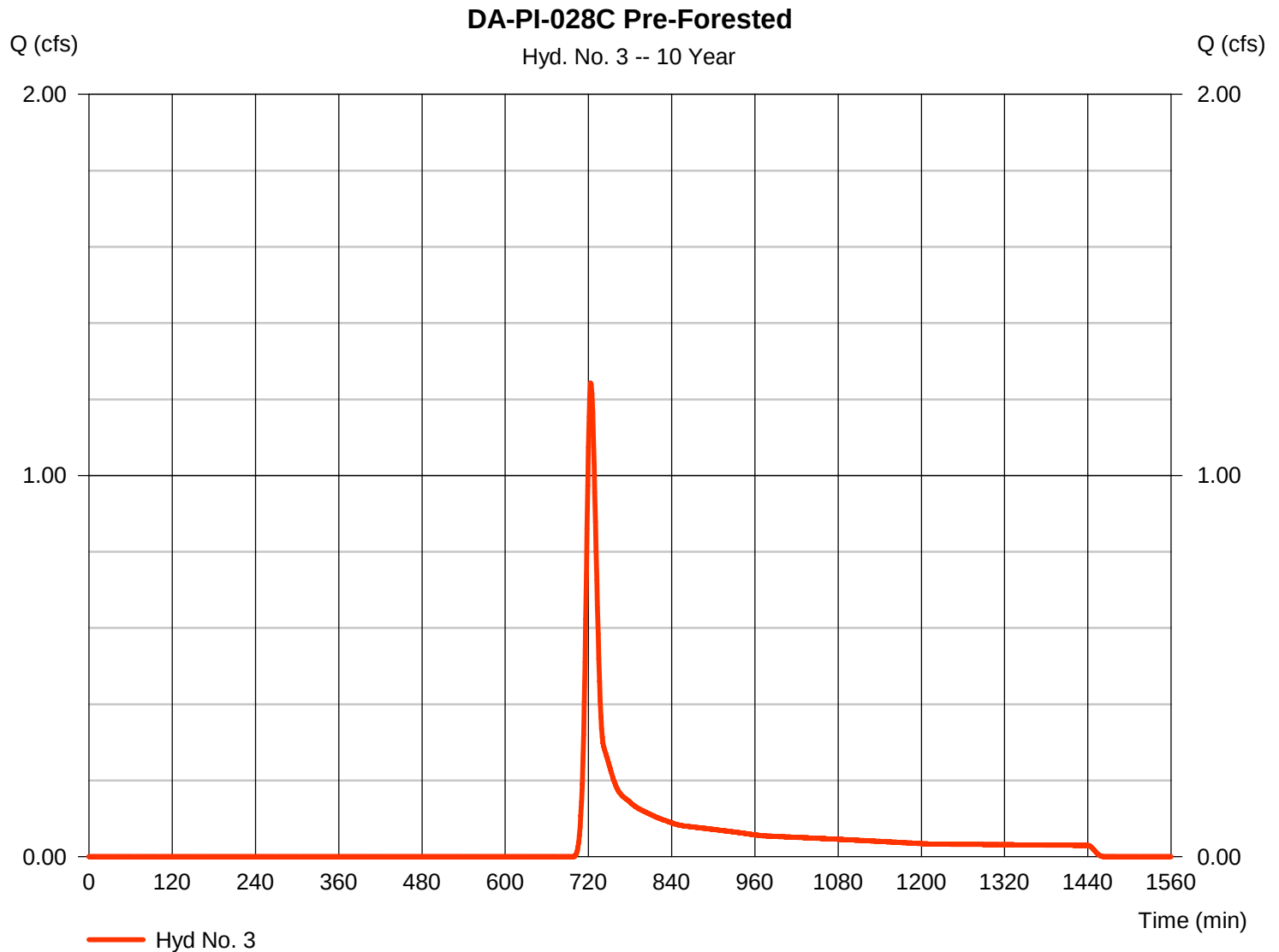
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Wednesday, 08 / 16 / 2017

Hyd. No. 3

DA-PI-028C Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 1.242 cfs
Storm frequency	= 10 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 3,886 cuft
Drainage area	= 0.990 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.50 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.990 \times 55)] / 0.990$ 

Return Period (Yrs)	Intensity-Duration-Frequency Equation Coefficients (FHA)			
	B	D	E	(N/A)
1	0.0000	0.0000	0.0000	-----
2	69.8703	13.1000	0.8658	-----
3	0.0000	0.0000	0.0000	-----
5	79.2597	14.6000	0.8369	-----
10	88.2351	15.5000	0.8279	-----
25	102.6072	16.5000	0.8217	-----
50	114.8193	17.2000	0.8199	-----
100	127.1596	17.8000	0.8186	-----

File name: SampleFHA.idf

$$\text{Intensity} = B / (Tc + D)^E$$

Return Period (Yrs)	Intensity Values (in/hr)											
	5 min	10	15	20	25	30	35	40	45	50	55	60
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	5.69	4.61	3.89	3.38	2.99	2.69	2.44	2.24	2.07	1.93	1.81	1.70
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	6.57	5.43	4.65	4.08	3.65	3.30	3.02	2.79	2.59	2.42	2.27	2.15
10	7.24	6.04	5.21	4.59	4.12	3.74	3.43	3.17	2.95	2.77	2.60	2.46
25	8.25	6.95	6.03	5.34	4.80	4.38	4.02	3.73	3.48	3.26	3.07	2.91
50	9.04	7.65	6.66	5.92	5.34	4.87	4.49	4.16	3.88	3.65	3.44	3.25
100	9.83	8.36	7.30	6.50	5.87	5.36	4.94	4.59	4.29	4.03	3.80	3.60

Tc = time in minutes. Values may exceed 60.

Precip. file name: P:\Watres\Projects\MVP\ Pittsylvania_7252017\ Packages\Pittsylvania.pcp

[illegible]

DA-PI-028D

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.040	535
Developed Condition	0.025	462
Pre-Developed (Forest) Condition	0.040	535

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1:

$$Q_{\text{developed}} \leq \text{IF} \times [(Q_{\text{pre-developed}} \times \text{RV}_{\text{pre-developed}}) / \text{RV}_{\text{developed}}] \text{ ----->}$$

Q (cfs)

0.025

≤

Q (cfs)

0.037

N/A - See Check #3

Check #2:

$$Q_{\text{developed}} \leq Q_{\text{pre-developed}} \text{ ----->}$$

0.025

≤

0.040

N/A - See Check #3

Check #3:

$$Q_{\text{developed}} \text{ shall not be required to be } \leq (Q_{\text{forest}} \times \text{RV}_{\text{forest}}) / \text{RV}_{\text{developed}} \text{ --->}$$

0.025

shall not be required to be ≤

0.046

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning's n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<i>Note:</i> Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted. ¹For Paved Road land surface types a Manning's n of 0.011 was used <i>Sources:</i> -USACE, 1998, HEC-1 Flood Hydrograph Package User's Manual, Hydrologic Engineering Center, Davis, CA -Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC	

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Watershed Model Schematic

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Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-PI-028D Pre
2	SCS Runoff	DA-PI-028D Post
3	SCS Runoff	DA-PI-028D Pre-Forested

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.040	1	728	535	-----	-----	-----	DA-PI-028D Pre
2	SCS Runoff	0.025	1	733	462	-----	-----	-----	DA-PI-028D Post
3	SCS Runoff	0.040	1	728	535	-----	-----	-----	DA-PI-028D Pre-Forested
DA-PI-028D.gpw					Return Period: 1 Year			Wednesday, 08 / 16 / 2017	

Hydrograph Report

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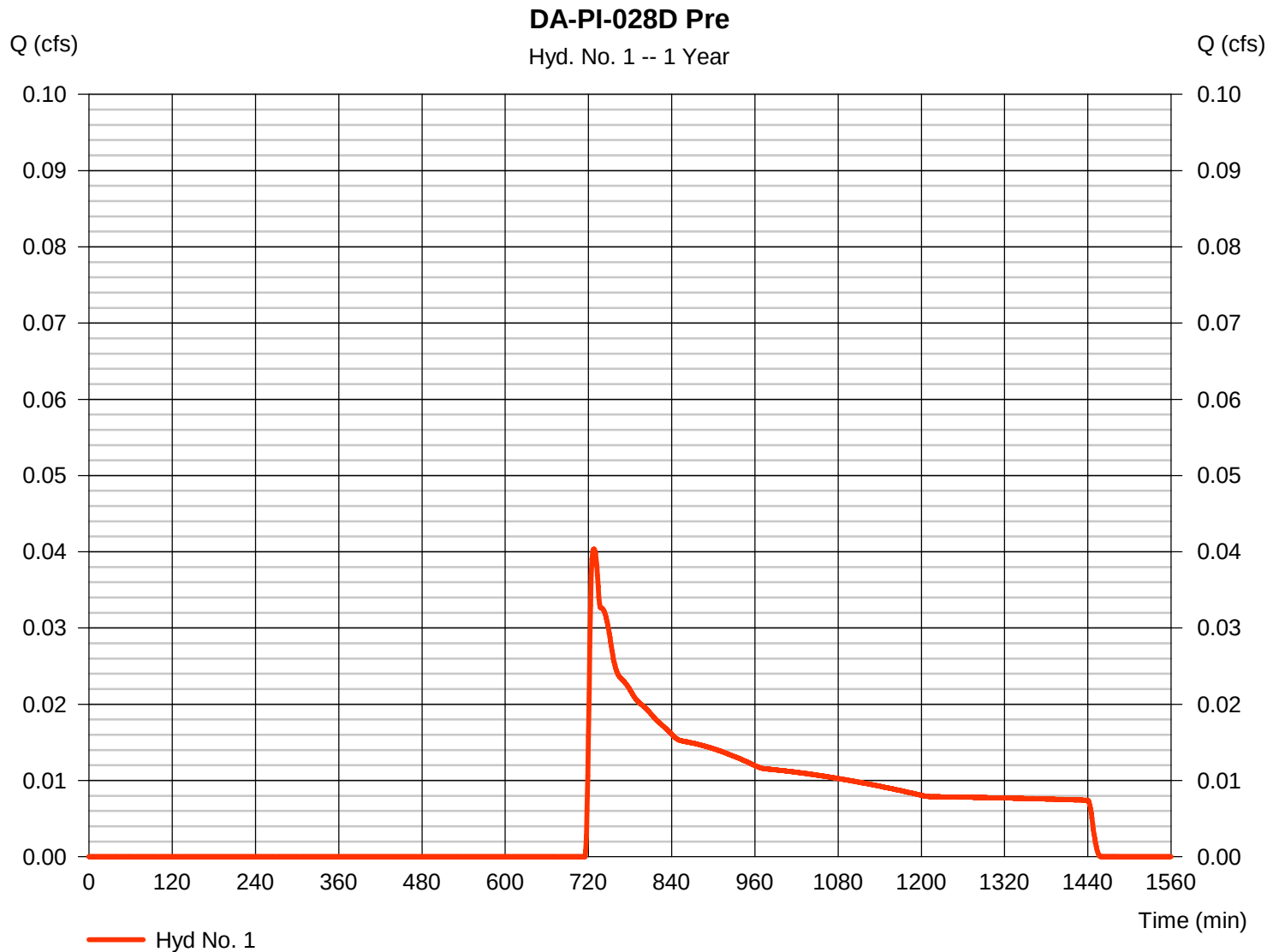
Wednesday, 08 / 16 / 2017

Hyd. No. 1

DA-PI-028D Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.040 cfs
Storm frequency	= 1 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 535 cuft
Drainage area	= 1.000 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.70 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(1.000 x 55)] / 1.000



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-PI-028D Pre

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 9.04	0.00	0.00				
Travel Time (min)	= 11.23	+	0.00	+	0.00	=	11.23
Shallow Concentrated Flow							
Flow length (ft)	= 219.09	0.00	0.00				
Watercourse slope (%)	= 19.42	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=7.11	0.00	0.00				
Travel Time (min)	= 0.51	+	0.00	+	0.00	=	0.51
Channel Flow							
X sectional flow area (sqft)	= 0.00	0.00	0.00				
Wetted perimeter (ft)	= 0.00	0.00	0.00				
Channel slope (%)	= 0.00	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	((0})0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc				11.70 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

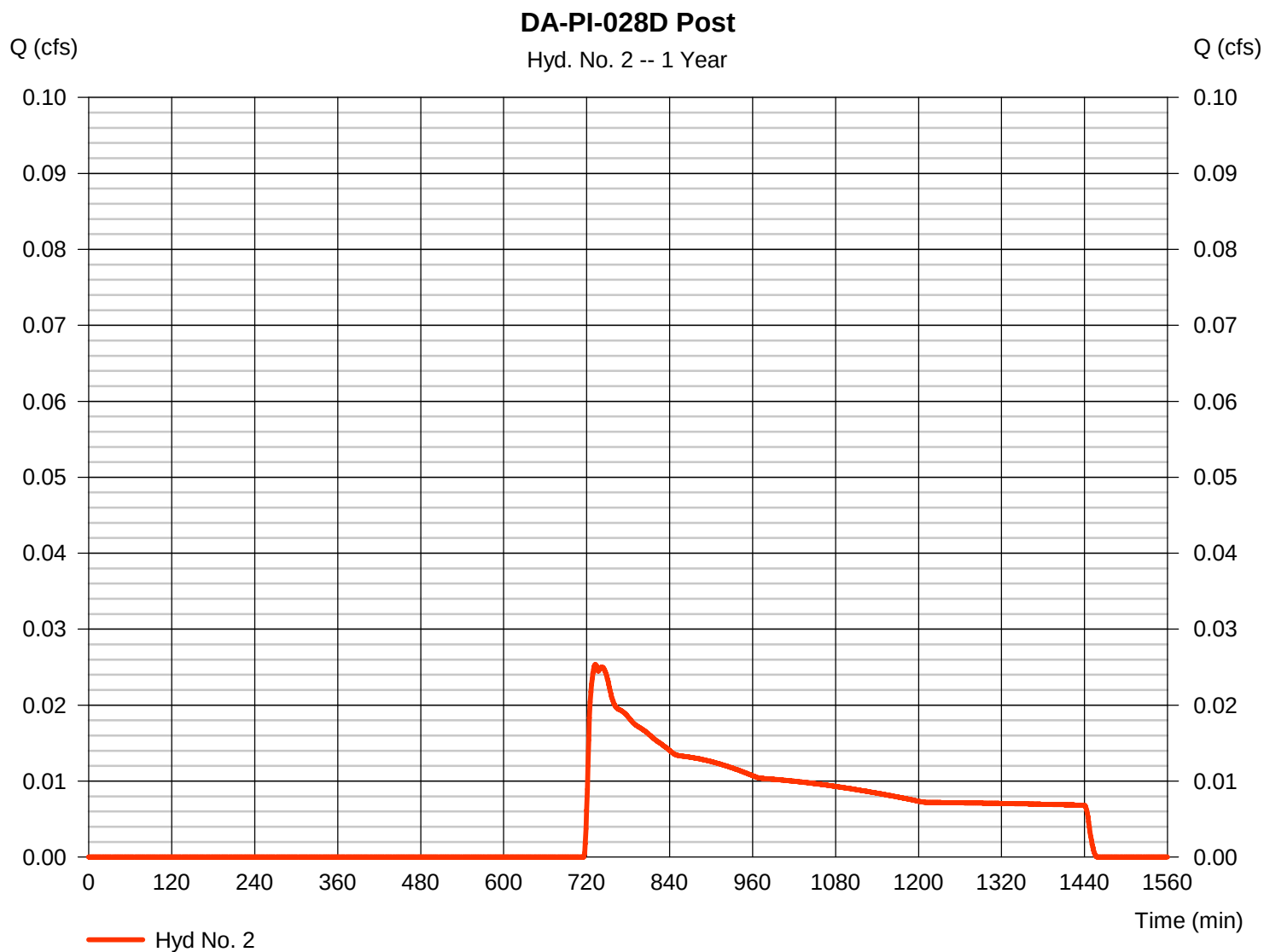
Wednesday, 08 / 16 / 2017

Hyd. No. 2

DA-PI-028D Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.025 cfs
Storm frequency	= 1 yrs	Time to peak	= 733 min
Time interval	= 1 min	Hyd. volume	= 462 cuft
Drainage area	= 1.000 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.70 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.520 \times 55) + (0.260 \times 48) + (0.220 \times 58)] / 1.000$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-PI-028D Post

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00	
Land slope (%)	= 9.04	0.00	0.00	
Travel Time (min)	= 11.23	+	0.00	+
			0.00	= 11.23
Shallow Concentrated Flow				
Flow length (ft)	= 219.09	0.00	0.00	
Watercourse slope (%)	= 19.42	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=7.11	0.00	0.00	
Travel Time (min)	= 0.51	+	0.00	+
			0.00	= 0.51
Channel Flow				
X sectional flow area (sqft)	= 0.00	0.00	0.00	
Wetted perimeter (ft)	= 0.00	0.00	0.00	
Channel slope (%)	= 0.00	0.00	0.00	
Manning's n-value	= 0.040	0.015	0.015	
Velocity (ft/s)	=0.00	0.00	0.00	
Flow length (ft)	(0)0.0	0.0	0.0	
Travel Time (min)	= 0.00	+	0.00	+
			0.00	= 0.00
Total Travel Time, Tc				11.70 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

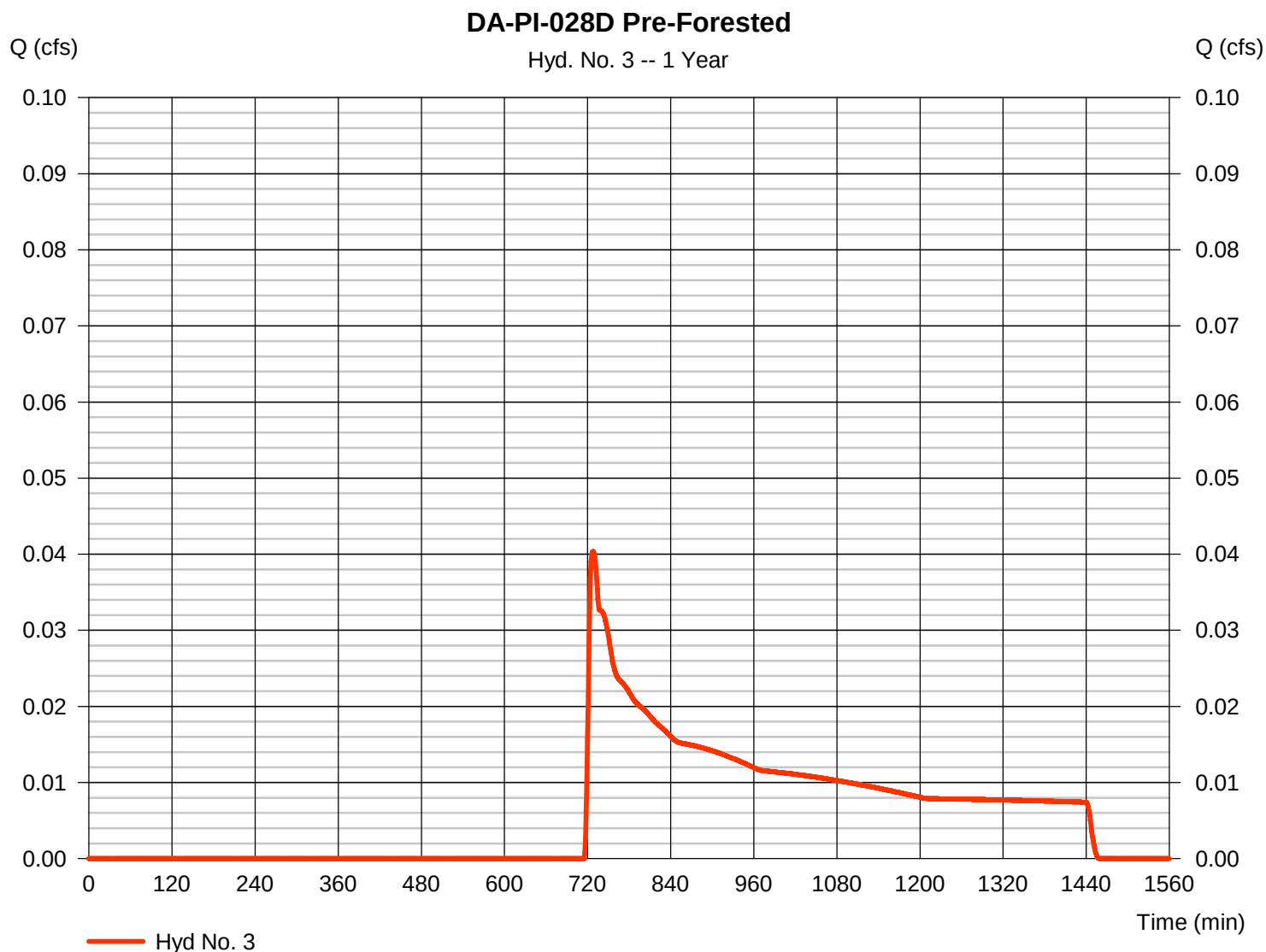
Wednesday, 08 / 16 / 2017

Hyd. No. 3

DA-PI-028D Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 0.040 cfs
Storm frequency	= 1 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 535 cuft
Drainage area	= 1.000 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.70 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(1.000 x 55)] / 1.000



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-PI-028D Pre-Forested

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00	
Land slope (%)	= 9.04	0.00	0.00	
Travel Time (min)	= 11.23	+	0.00	+
			0.00	= 11.23
Shallow Concentrated Flow				
Flow length (ft)	= 219.09	0.00	0.00	
Watercourse slope (%)	= 19.42	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=7.11	0.00	0.00	
Travel Time (min)	= 0.51	+	0.00	+
			0.00	= 0.51
Channel Flow				
X sectional flow area (sqft)	= 0.00	0.00	0.00	
Wetted perimeter (ft)	= 0.00	0.00	0.00	
Channel slope (%)	= 0.00	0.00	0.00	
Manning's n-value	= 0.030	0.015	0.015	
Velocity (ft/s)	=0.00	0.00	0.00	
Flow length (ft)	(0)0.0	0.0	0.0	
Travel Time (min)	= 0.00	+	0.00	+
			0.00	= 0.00
Total Travel Time, Tc				11.70 min

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.285	1	723	1,277	-----	-----	-----	DA-PI-028D Pre
2	SCS Runoff	0.231	1	724	1,156	-----	-----	-----	DA-PI-028D Post
3	SCS Runoff	0.285	1	723	1,277	-----	-----	-----	DA-PI-028D Pre-Forested
DA-PI-028D.gpw					Return Period: 2 Year			Wednesday, 08 / 16 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

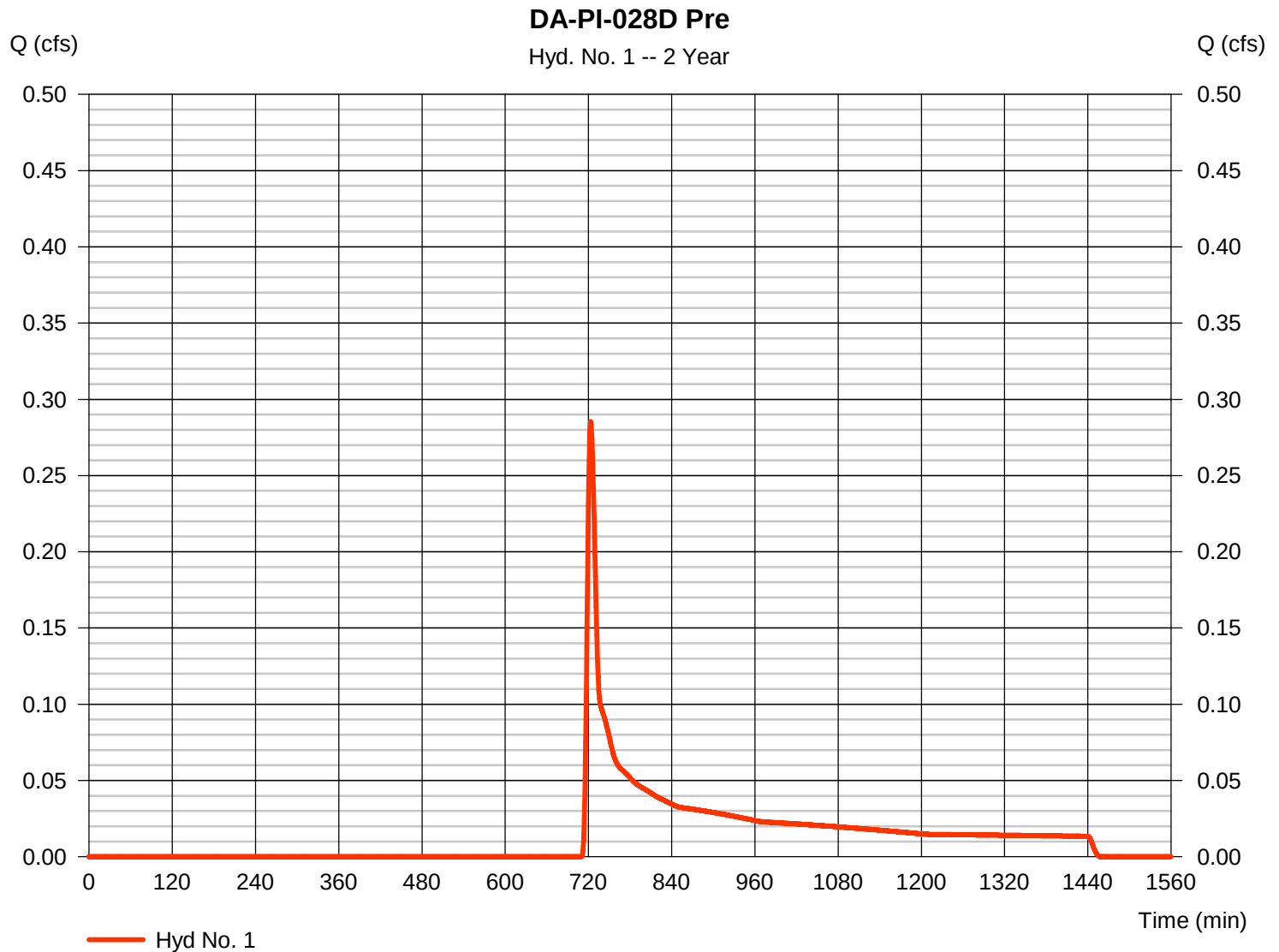
Wednesday, 08 / 16 / 2017

Hyd. No. 1

DA-PI-028D Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.285 cfs
Storm frequency	= 2 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 1,277 cuft
Drainage area	= 1.000 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.70 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(1.000 x 55)] / 1.000



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

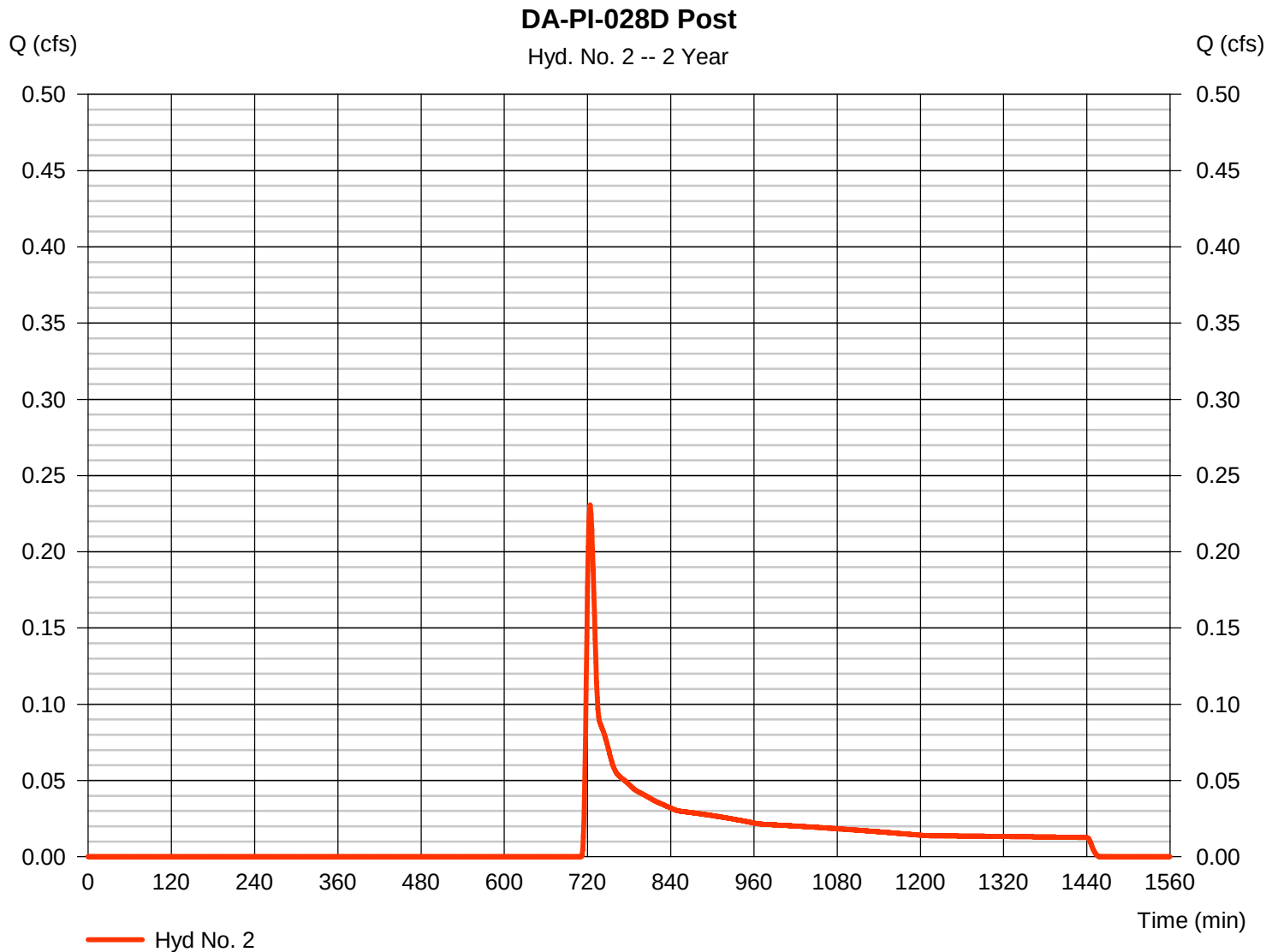
Wednesday, 08 / 16 / 2017

Hyd. No. 2

DA-PI-028D Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.231 cfs
Storm frequency	= 2 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 1,156 cuft
Drainage area	= 1.000 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.70 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.520 \times 55) + (0.260 \times 48) + (0.220 \times 58)] / 1.000$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

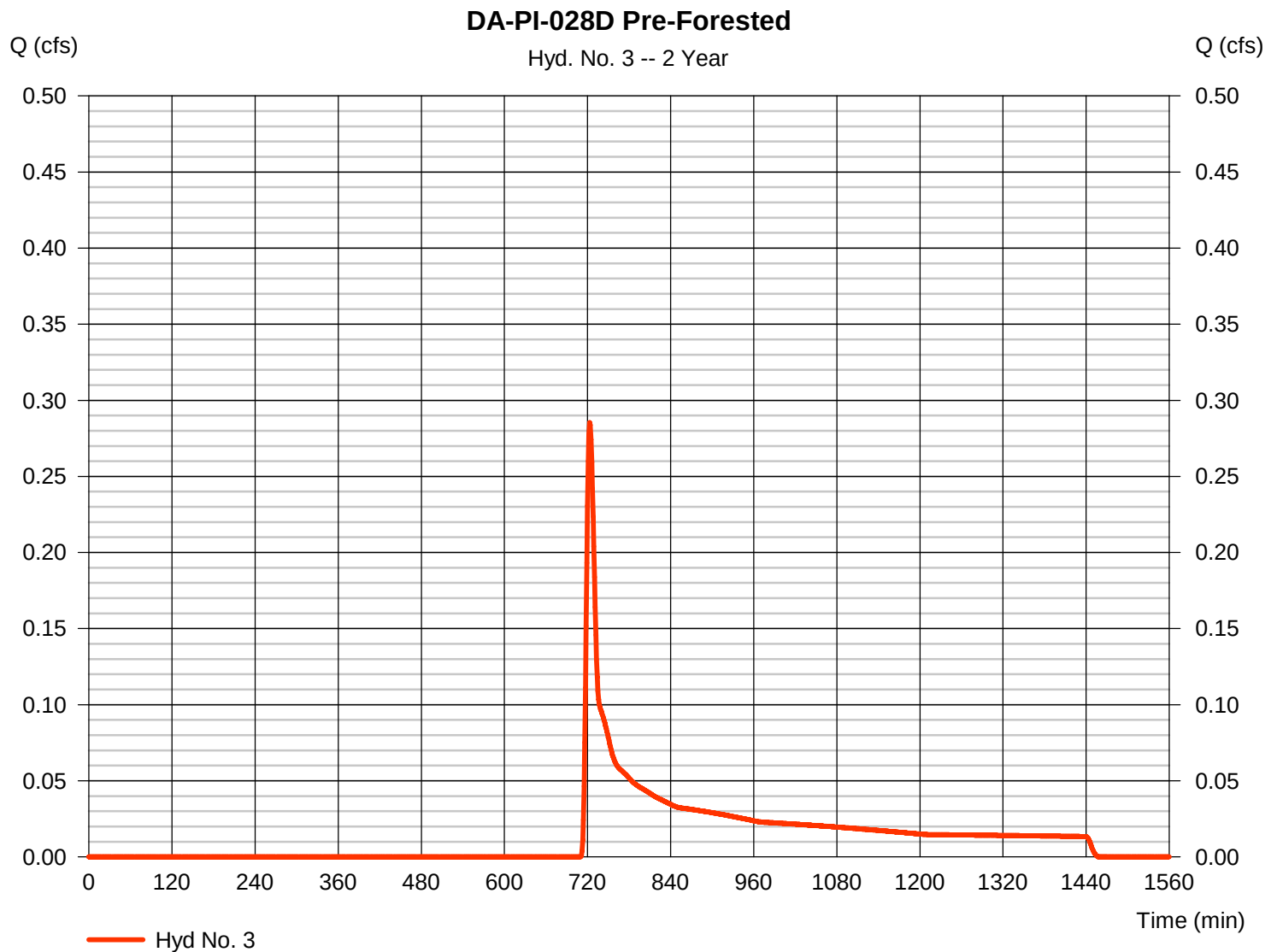
Wednesday, 08 / 16 / 2017

Hyd. No. 3

DA-PI-028D Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 0.285 cfs
Storm frequency	= 2 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 1,277 cuft
Drainage area	= 1.000 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.70 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(1.000 x 55)] / 1.000



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	1.458	1	721	3,995	-----	-----	-----	DA-PI-028D Pre
2	SCS Runoff	1.341	1	721	3,759	-----	-----	-----	DA-PI-028D Post
3	SCS Runoff	1.458	1	721	3,995	-----	-----	-----	DA-PI-028D Pre-Forested
DA-PI-028D.gpw					Return Period: 10 Year			Wednesday, 08 / 16 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

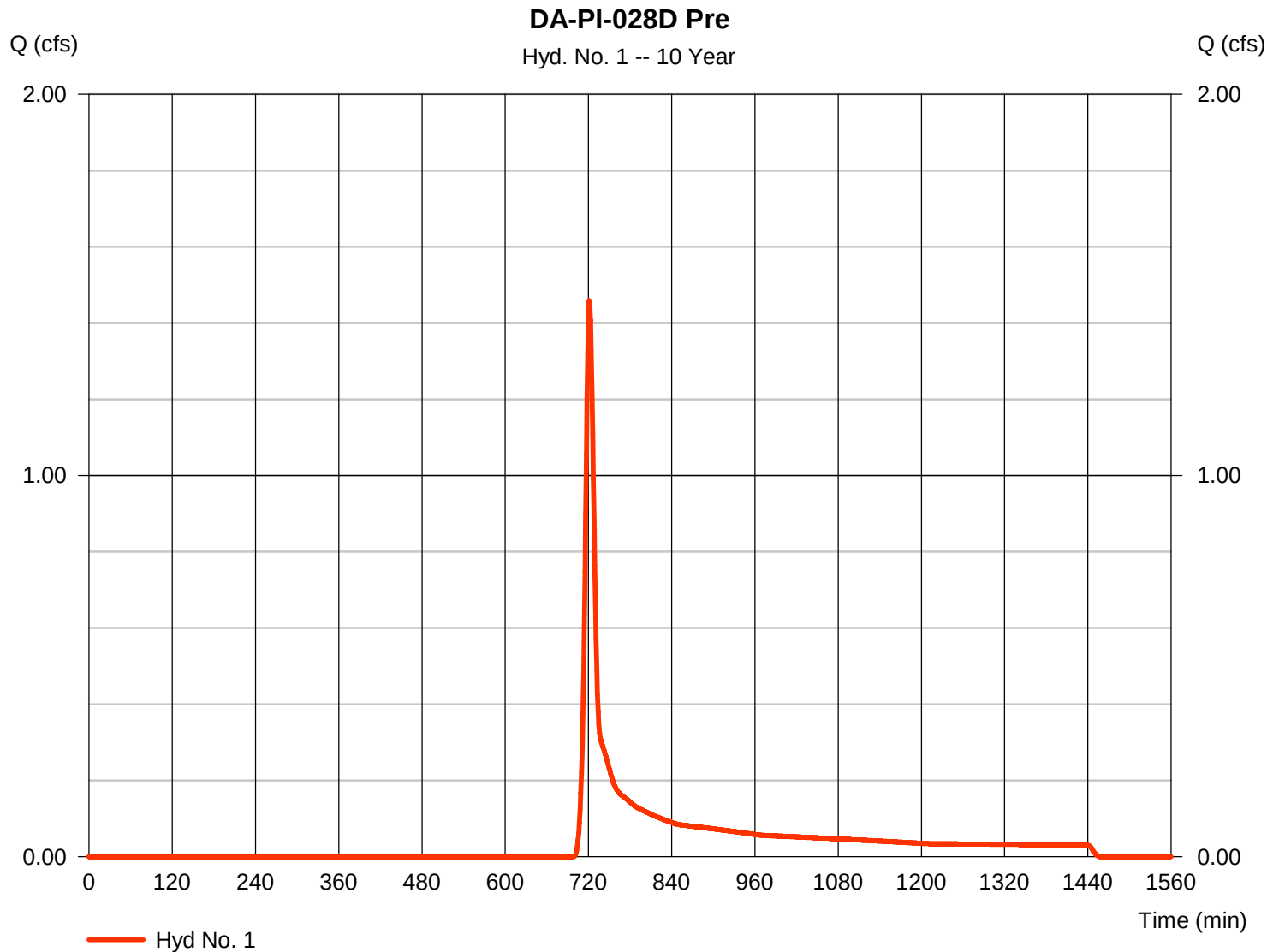
Wednesday, 08 / 16 / 2017

Hyd. No. 1

DA-PI-028D Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 1.458 cfs
Storm frequency	= 10 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 3,995 cuft
Drainage area	= 1.000 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.70 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(1.000 x 55)] / 1.000



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

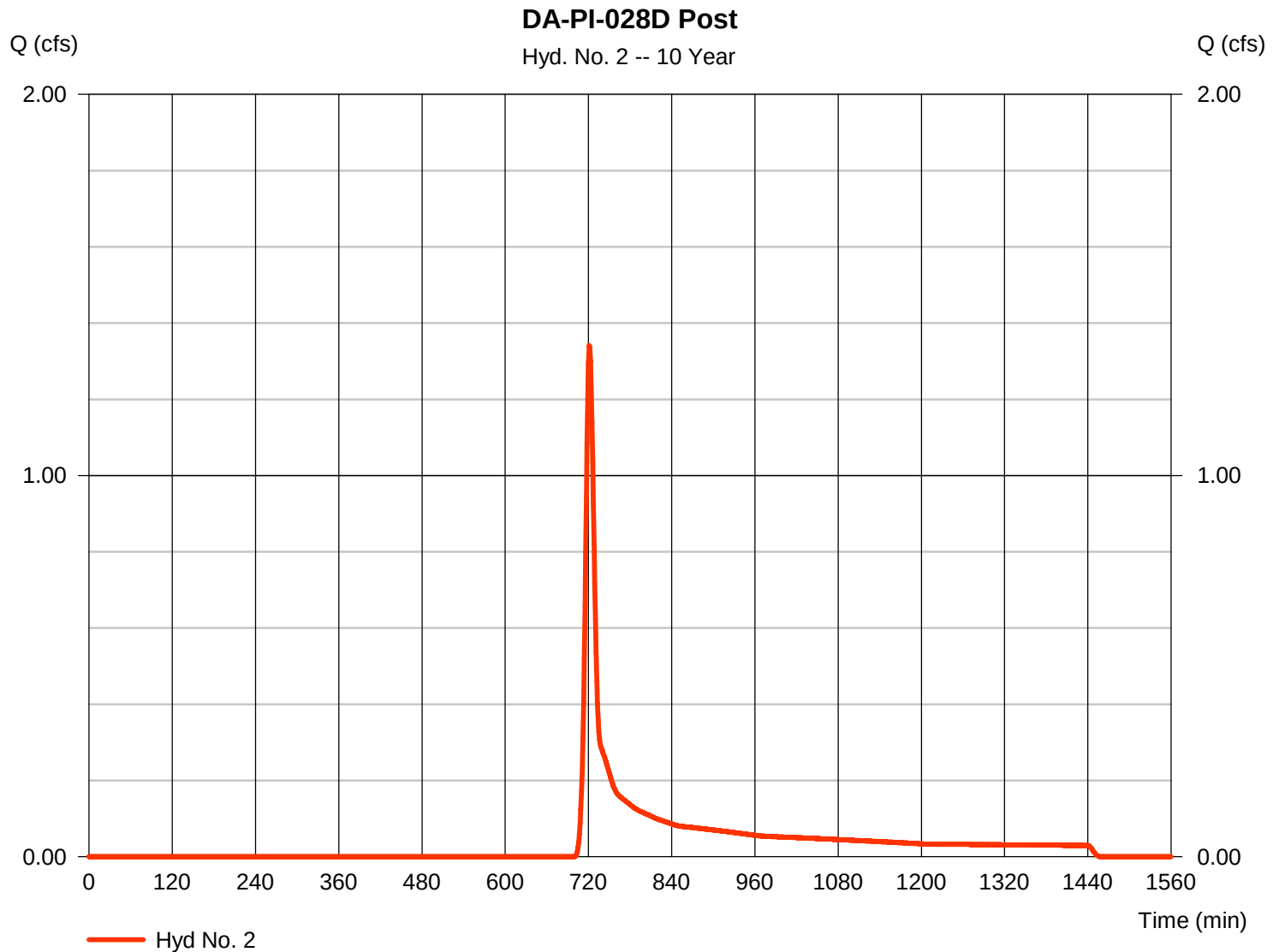
Wednesday, 08 / 16 / 2017

Hyd. No. 2

DA-PI-028D Post

Hydrograph type	= SCS Runoff	Peak discharge	= 1.341 cfs
Storm frequency	= 10 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 3,759 cuft
Drainage area	= 1.000 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.70 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.520 \times 55) + (0.260 \times 48) + (0.220 \times 58)] / 1.000$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

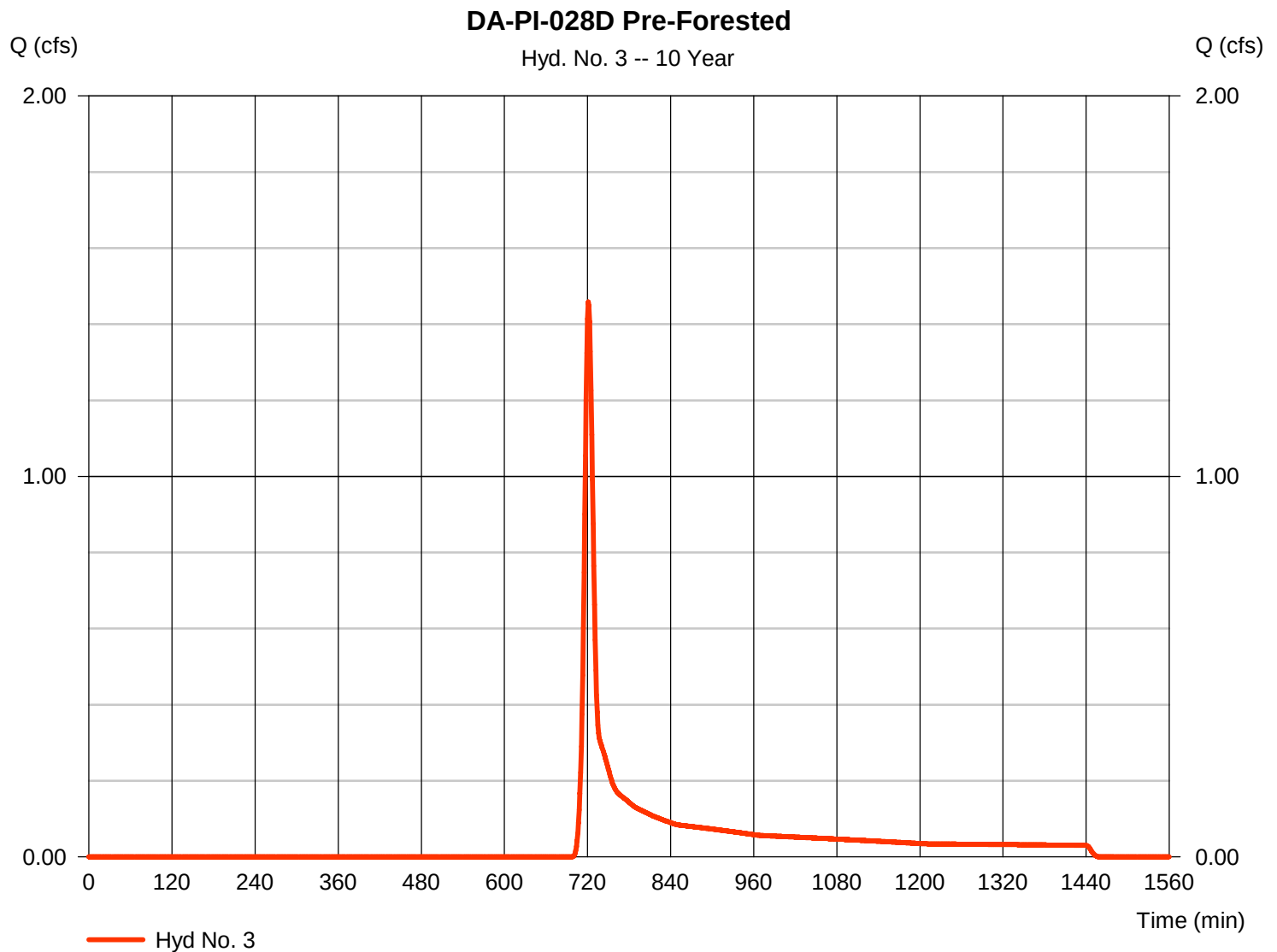
Wednesday, 08 / 16 / 2017

Hyd. No. 3

DA-PI-028D Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	1.458 cfs
Storm frequency	=	10 yrs	Time to peak	=	721 min
Time interval	=	1 min	Hyd. volume	=	3,995 cuft
Drainage area	=	1.000 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	11.70 min
Total precip.	=	5.20 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(1.000 x 55)] / 1.000



DA-PI-028E

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.092	1,257
Developed Condition	0.059	1,085
Pre-Developed (Forest) Condition	0.092	1,257

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1:

$$Q_{\text{developed}} \leq \text{IF} \times [(Q_{\text{pre-developed}} \times \text{RV}_{\text{pre-developed}}) / \text{RV}_{\text{developed}}] \text{ ----->}$$

Q (cfs)

0.059

≤

Q (cfs)

0.085

N/A - See Check #3

Check #2:

$$Q_{\text{developed}} \leq Q_{\text{pre-developed}} \text{ ----->}$$

0.059

≤

0.092

N/A - See Check #3

Check #3:

$$Q_{\text{developed}} \text{ shall not be required to be } \leq (Q_{\text{forest}} \times \text{RV}_{\text{forest}}) / \text{RV}_{\text{developed}} \text{ --->}$$

0.059

shall not be required to be ≤

0.107

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning's n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<i>Note:</i> Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted. ¹For Paved Road land surface types a Manning's n of 0.011 was used <i>Sources:</i> -USACE, 1998, HEC-1 Flood Hydrograph Package User's Manual, Hydrologic Engineering Center, Davis, CA -Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC	

Table 2 – Manning's n Values for Open Channel Flow

Channel Type	Manning n		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹For the developed condition, a conservative Manning's n value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar, level spreader diversion, or grass channel. ²For the pre-developed condition and post-development condition, a Manning's n value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-PI-028E Pre
2	SCS Runoff	DA-PI-028E Post
3	SCS Runoff	DA-PI-028E Pre-Forested

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.092	1	730	1,257	-----	-----	-----	DA-PI-028E Pre
2	SCS Runoff	0.059	1	735	1,085	-----	-----	-----	DA-PI-028E Post
3	SCS Runoff	0.092	1	730	1,257	-----	-----	-----	DA-PI-028E Pre-Forested
DA-PI-028E.gpw					Return Period: 1 Year			Thursday, 08 / 17 / 2017	

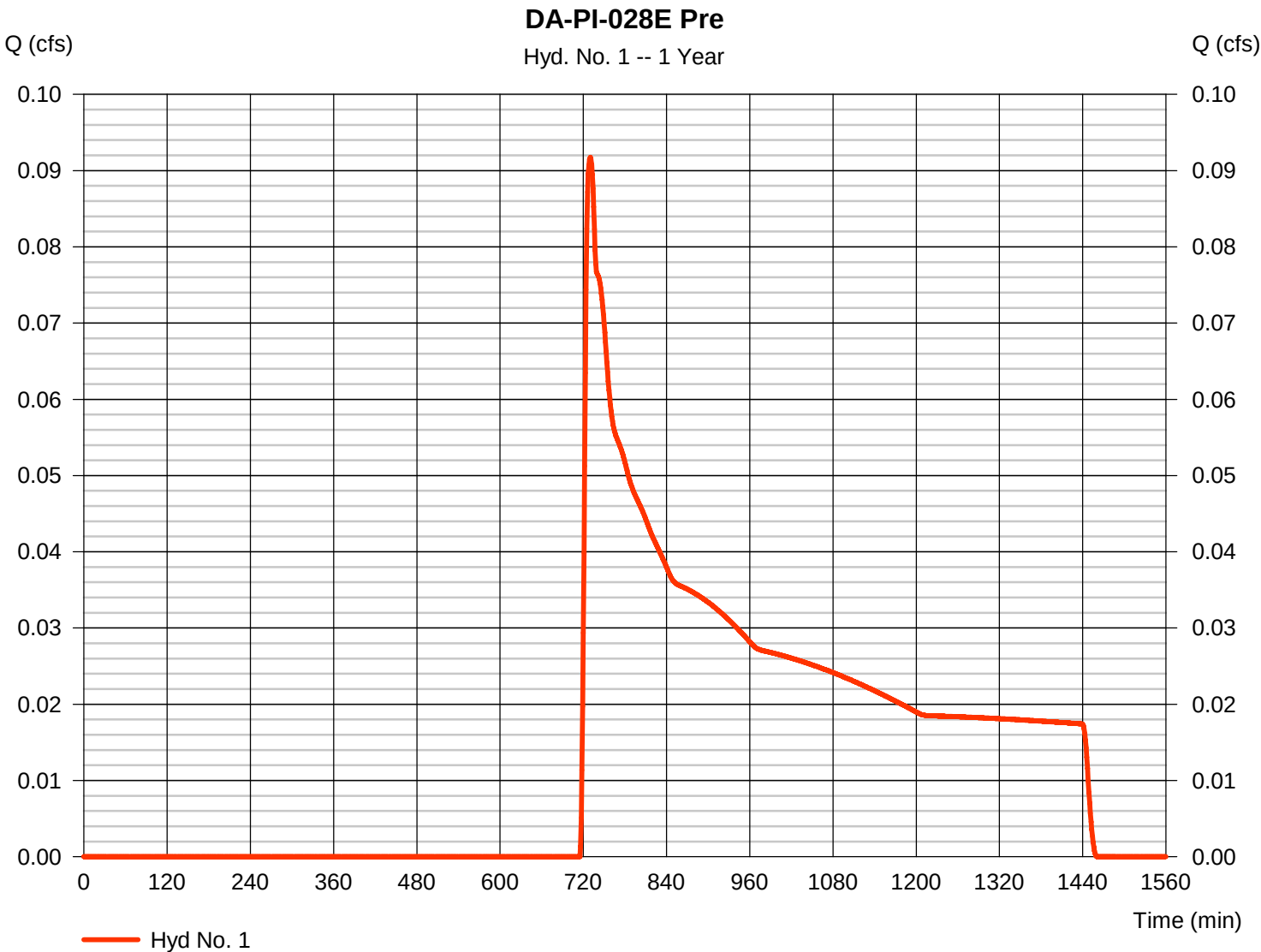
Hydrograph Report

Hyd. No. 1

DA-PI-028E Pre

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.092 cfs
Storm frequency	=	1 yrs	Time to peak	=	730 min
Time interval	=	1 min	Hyd. volume	=	1,257 cuft
Drainage area	=	2.430 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	13.10 min
Total precip.	=	2.80 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(2.430 x 55)] / 2.430



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-PI-028E Pre

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 8.66	0.00	0.00				
Travel Time (min)	= 11.42	+	0.00	+	0.00	=	11.42
Shallow Concentrated Flow							
Flow length (ft)	= 535.63	0.00	0.00				
Watercourse slope (%)	= 11.09	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=5.37	0.00	0.00				
Travel Time (min)	= 1.66	+	0.00	+	0.00	=	1.66
Channel Flow							
X sectional flow area (sqft)	= 0.00	0.00	0.00				
Wetted perimeter (ft)	= 0.00	0.00	0.00				
Channel slope (%)	= 0.00	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	((0})0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc				13.10 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Thursday, 08 / 17 / 2017

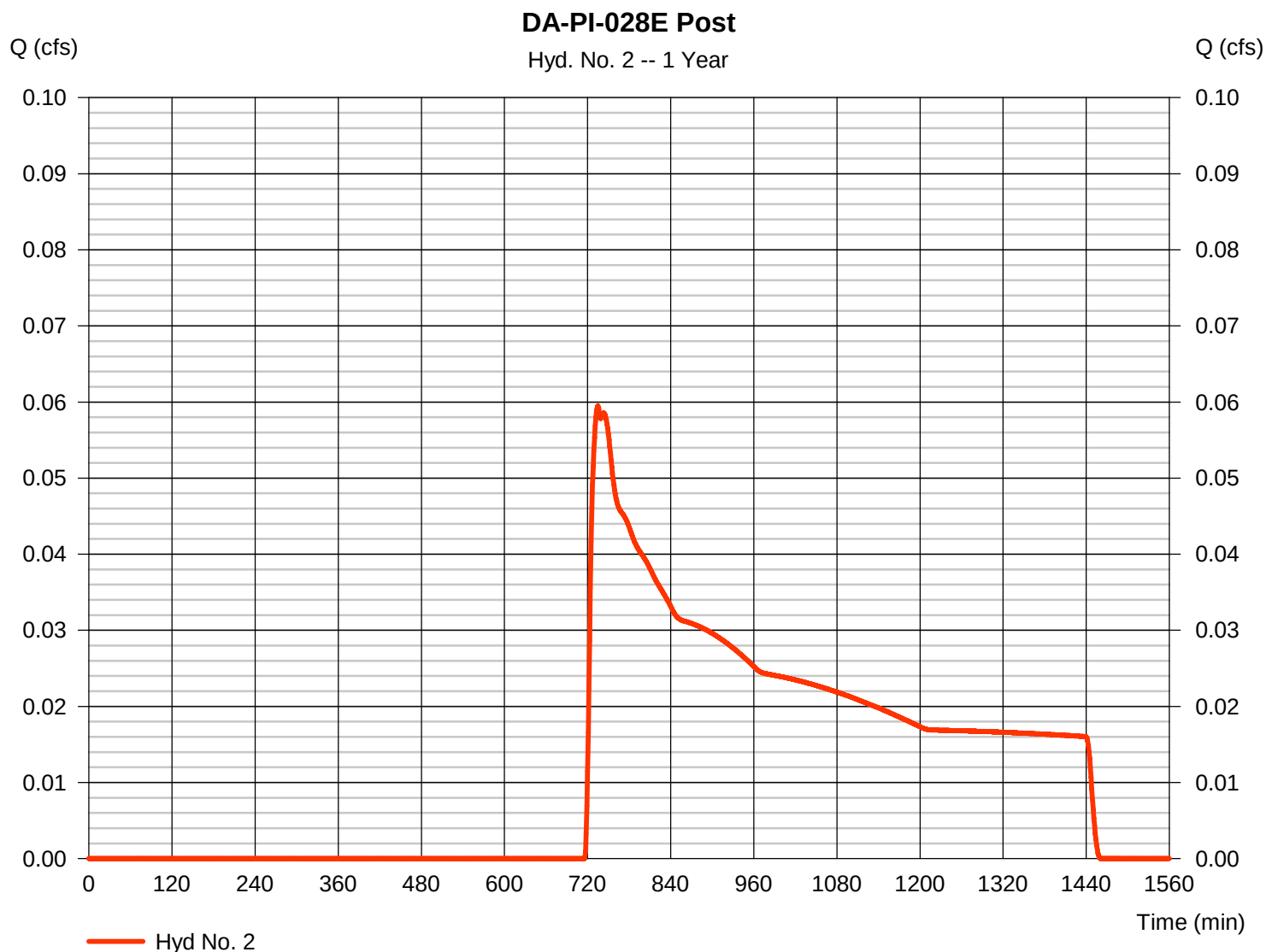
Hyd. No. 2

DA-PI-028E Post

Hydrograph type = SCS Runoff
 Storm frequency = 1 yrs
 Time interval = 1 min
 Drainage area = 2.430 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 2.80 in
 Storm duration = 24 hrs

Peak discharge = 0.059 cfs
 Time to peak = 735 min
 Hyd. volume = 1,085 cuft
 Curve number = 54*
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 13.20 min
 Distribution = Type II
 Shape factor = 484

* Composite (Area/CN) = $[(1.360 \times 55) + (0.620 \times 48) + (0.450 \times 58)] / 2.430$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-PI-028E Post

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 8.66	0.00	0.00				
Travel Time (min)	= 11.42	+	0.00	+	0.00	=	11.42
Shallow Concentrated Flow							
Flow length (ft)	= 435.42	77.59	0.00				
Watercourse slope (%)	= 9.10	21.23	0.00				
Surface description	= Unpaved	Unpaved	Paved				
Average velocity (ft/s)	=4.87	7.43	0.00				
Travel Time (min)	= 1.49	+	0.17	+	0.00	=	1.66
Channel Flow							
X sectional flow area (sqft)	= 2.00	0.00	0.00				
Wetted perimeter (ft)	= 4.47	0.00	0.00				
Channel slope (%)	= 5.00	0.00	0.00				
Manning's n-value	= 0.040	0.015	0.015				
Velocity (ft/s)	=4.86	0.00	0.00				
Flow length (ft)	(0)43.6	0.0	0.0				
Travel Time (min)	= 0.15	+	0.00	+	0.00	=	0.15
Total Travel Time, Tc					13.20 min		

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Thursday, 08 / 17 / 2017

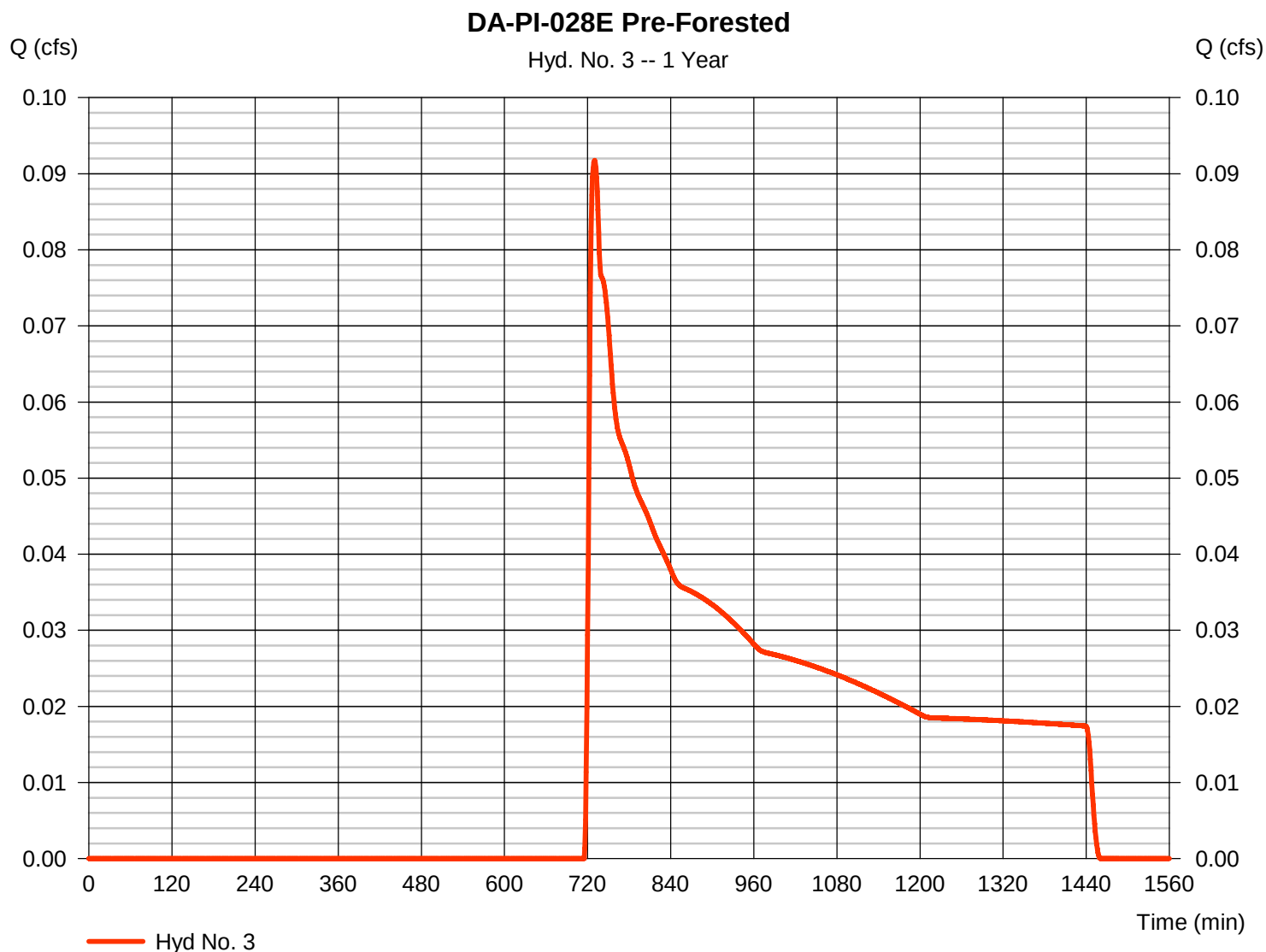
Hyd. No. 3

DA-PI-028E Pre-Forested

Hydrograph type = SCS Runoff
 Storm frequency = 1 yrs
 Time interval = 1 min
 Drainage area = 2.430 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 2.80 in
 Storm duration = 24 hrs

Peak discharge = 0.092 cfs
 Time to peak = 730 min
 Hyd. volume = 1,257 cuft
 Curve number = 55*
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 13.10 min
 Distribution = Type II
 Shape factor = 484

* Composite (Area/CN) = $[(2.430 \times 55)] / 2.430$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-PI-028E Pre-Forested

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00	
Land slope (%)	= 8.66	0.00	0.00	
Travel Time (min)	= 11.42	+ 0.00	+ 0.00	= 11.42
Shallow Concentrated Flow				
Flow length (ft)	= 535.63	0.00	0.00	
Watercourse slope (%)	= 11.09	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=5.37	0.00	0.00	
Travel Time (min)	= 1.66	+ 0.00	+ 0.00	= 1.66
Channel Flow				
X sectional flow area (sqft)	= 0.00	0.00	0.00	
Wetted perimeter (ft)	= 0.00	0.00	0.00	
Channel slope (%)	= 0.00	0.00	0.00	
Manning's n-value	= 0.030	0.015	0.015	
Velocity (ft/s)	=0.00	0.00	0.00	
Flow length (ft)	(0)0.0	0.0	0.0	
Travel Time (min)	= 0.00	+ 0.00	+ 0.00	= 0.00
Total Travel Time, Tc				13.10 min

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.629	1	724	3,002	-----	-----	-----	DA-PI-028E Pre
2	SCS Runoff	0.509	1	725	2,716	-----	-----	-----	DA-PI-028E Post
3	SCS Runoff	0.629	1	724	3,002	-----	-----	-----	DA-PI-028E Pre-Forested
DA-PI-028E.gpw					Return Period: 2 Year			Thursday, 08 / 17 / 2017	

Hydrograph Report

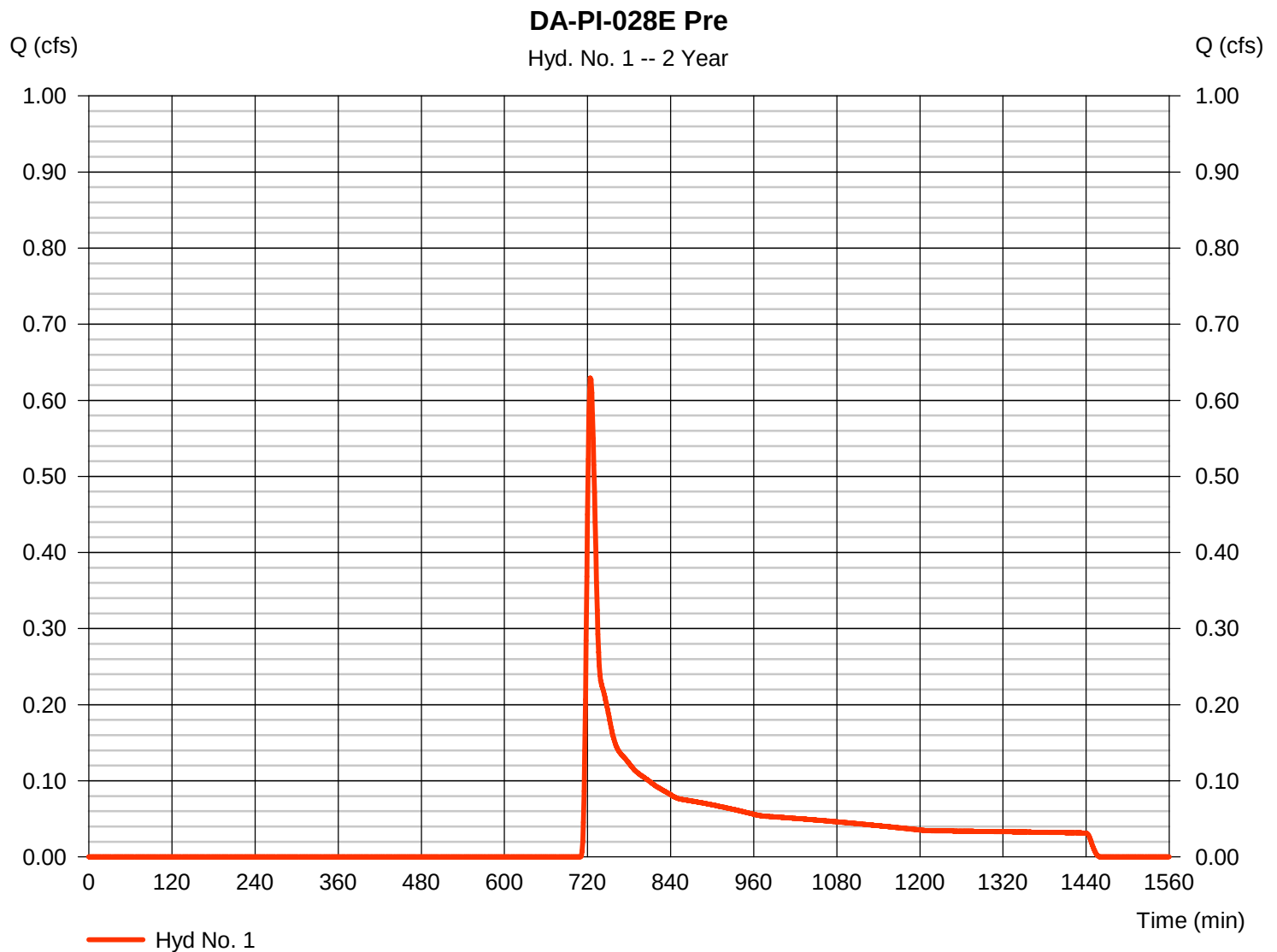
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Thursday, 08 / 17 / 2017

Hyd. No. 1

DA-PI-028E Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.629 cfs
Storm frequency	= 2 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 3,002 cuft
Drainage area	= 2.430 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.10 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(2.430 \times 55)] / 2.430$ 

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

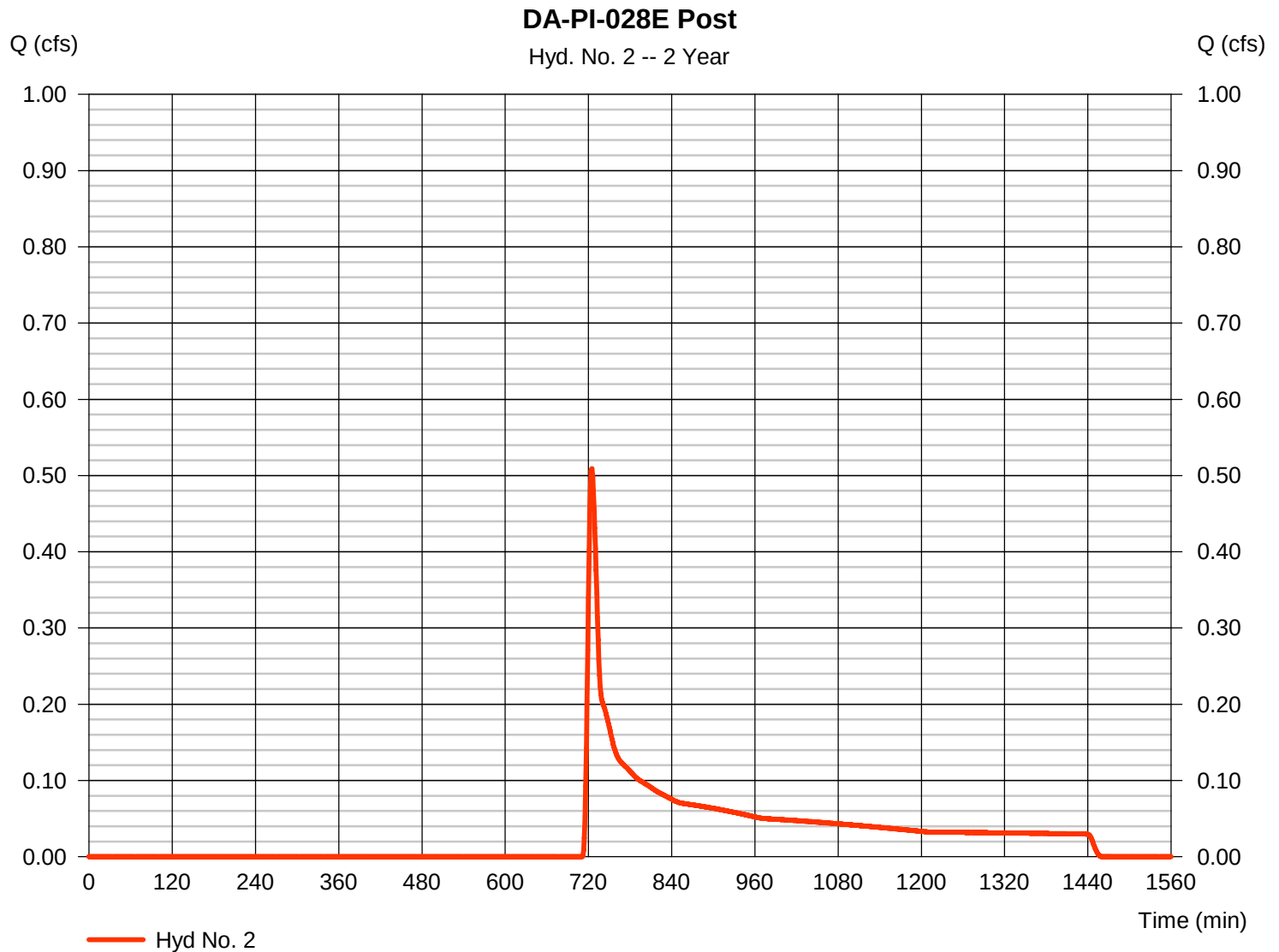
Thursday, 08 / 17 / 2017

Hyd. No. 2

DA-PI-028E Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.509 cfs
Storm frequency	= 2 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 2,716 cuft
Drainage area	= 2.430 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.20 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.360 \times 55) + (0.620 \times 48) + (0.450 \times 58)] / 2.430$



Hydrograph Report

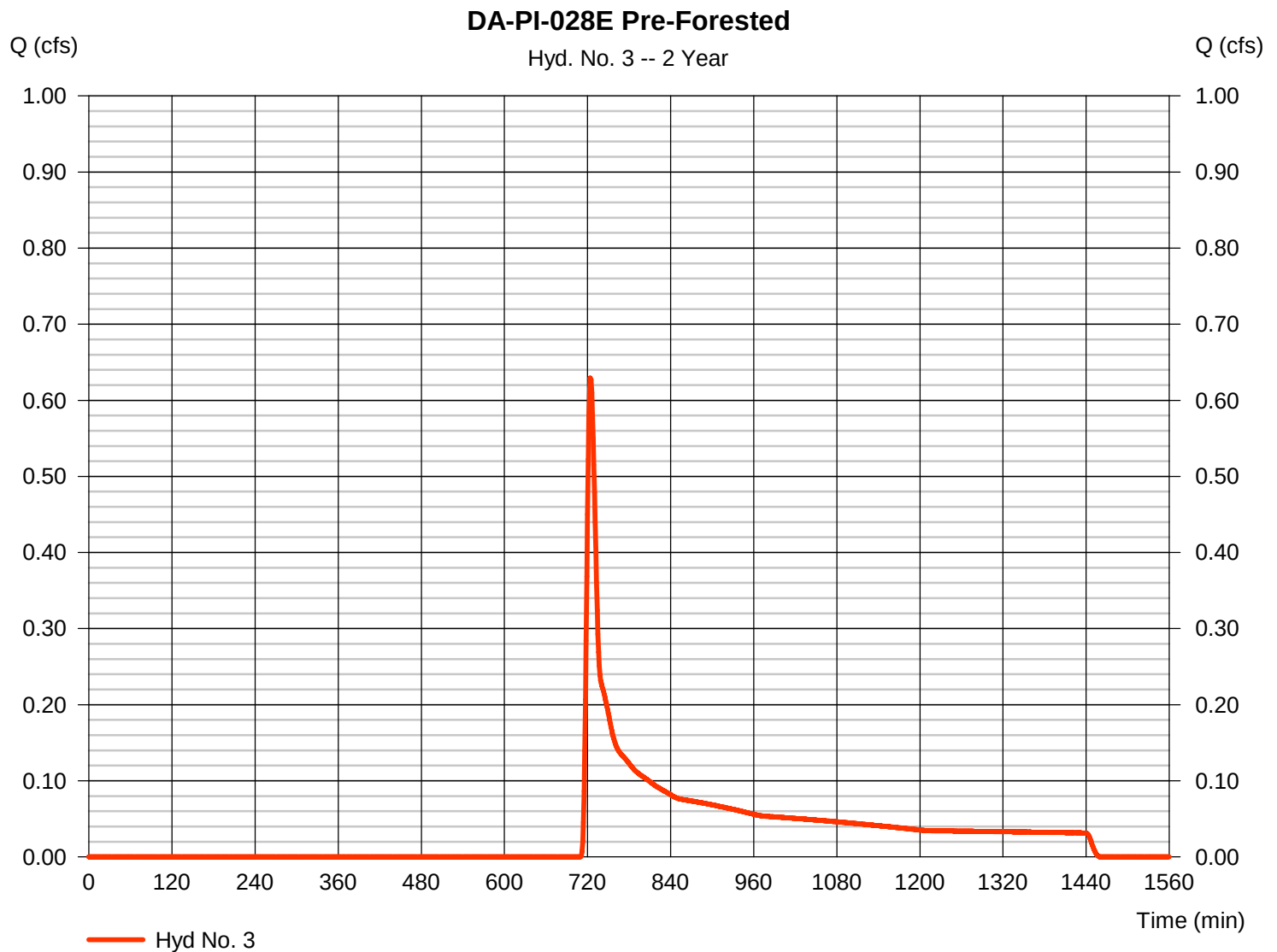
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Thursday, 08 / 17 / 2017

Hyd. No. 3

DA-PI-028E Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.629 cfs
Storm frequency	=	2 yrs	Time to peak	=	724 min
Time interval	=	1 min	Hyd. volume	=	3,002 cuft
Drainage area	=	2.430 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	13.10 min
Total precip.	=	3.50 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(2.430 \times 55)] / 2.430$ 

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	3.248	1	722	9,388	-----	-----	-----	DA-PI-028E Pre
2	SCS Runoff	2.984	1	722	8,834	-----	-----	-----	DA-PI-028E Post
3	SCS Runoff	3.248	1	722	9,388	-----	-----	-----	DA-PI-028E Pre-Forested
DA-PI-028E.gpw					Return Period: 10 Year			Thursday, 08 / 17 / 2017	

Hydrograph Report

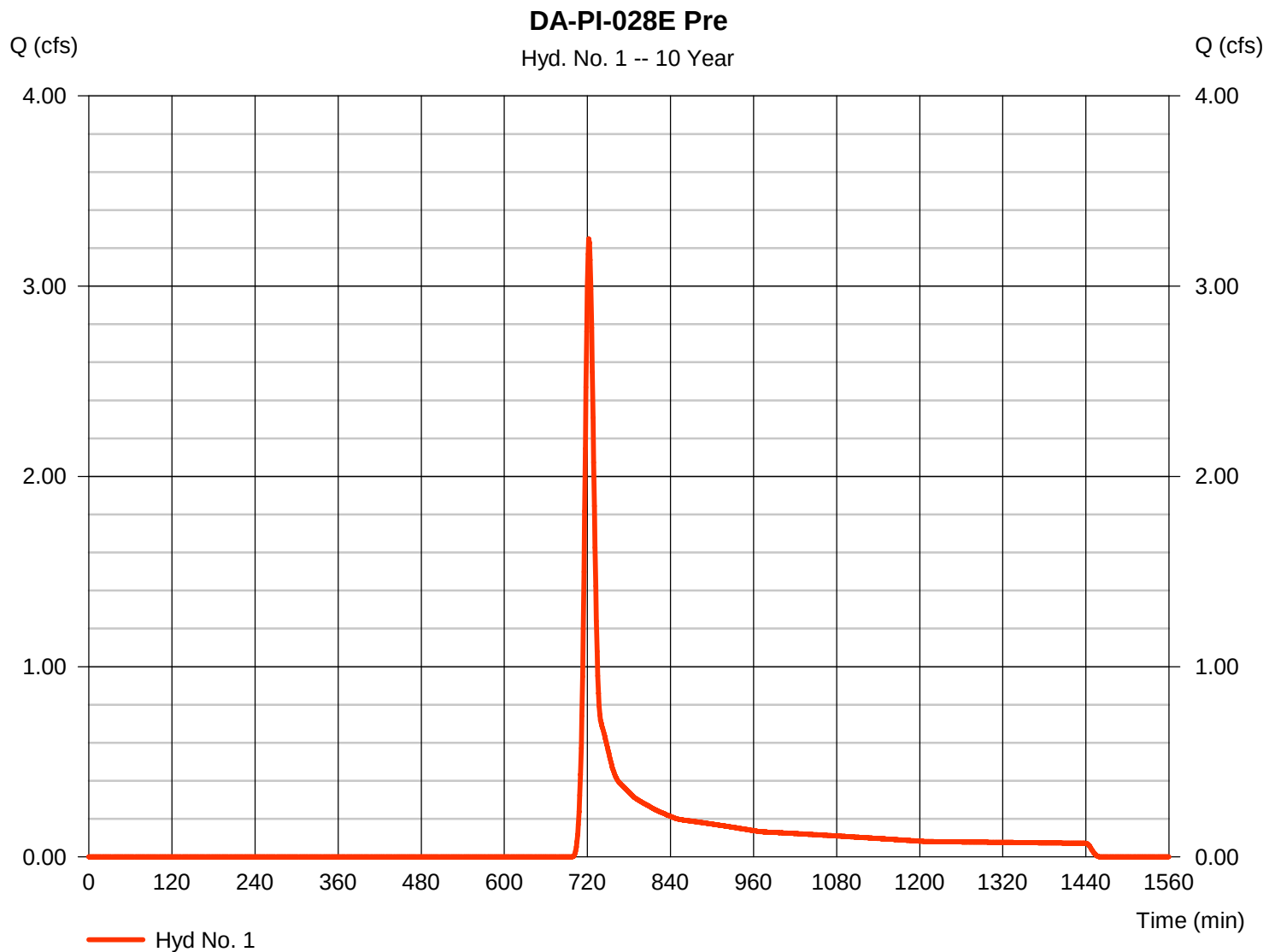
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Thursday, 08 / 17 / 2017

Hyd. No. 1

DA-PI-028E Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 3.248 cfs
Storm frequency	= 10 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 9,388 cuft
Drainage area	= 2.430 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.10 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(2.430 \times 55)] / 2.430$ 

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

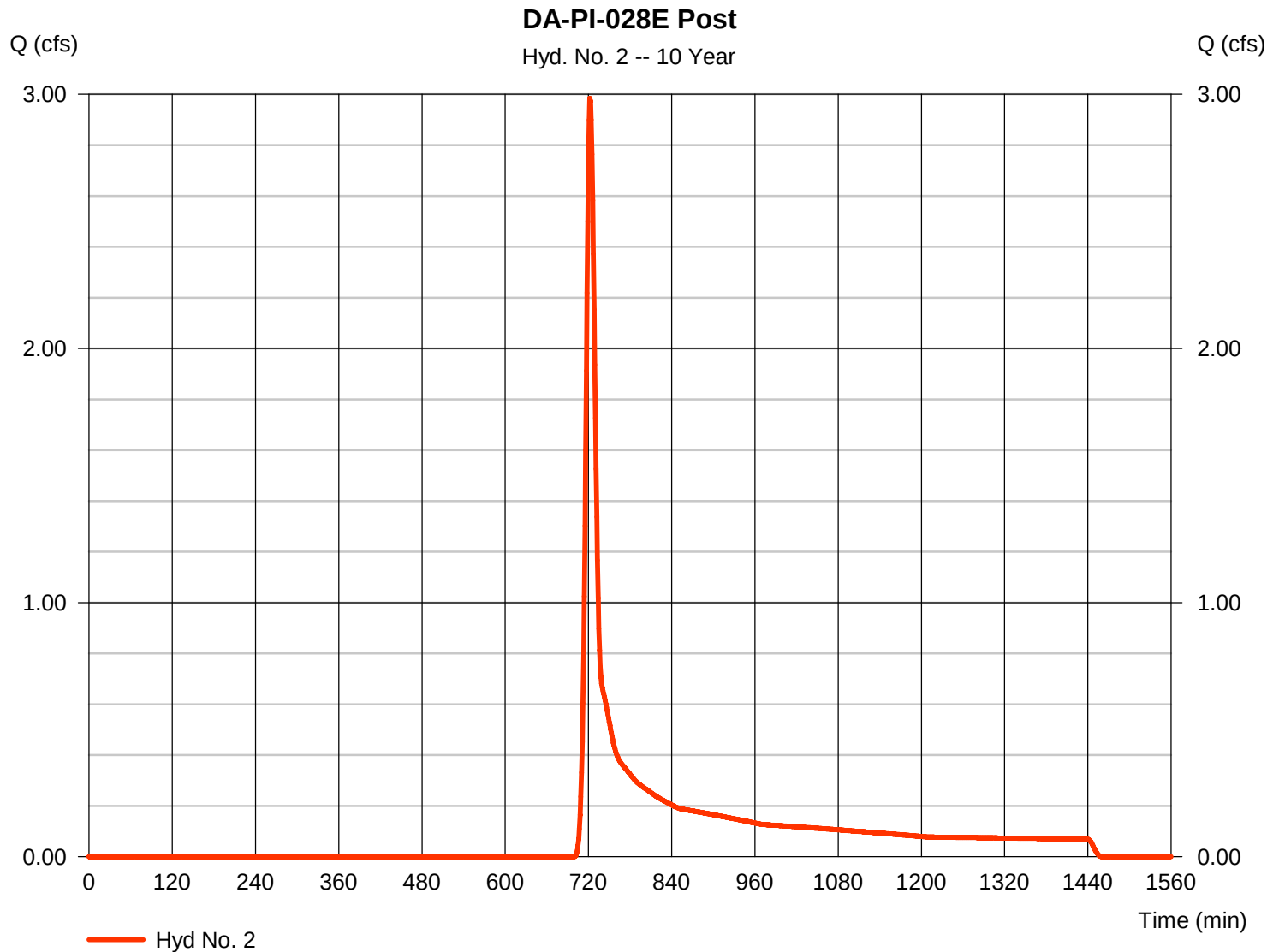
Thursday, 08 / 17 / 2017

Hyd. No. 2

DA-PI-028E Post

Hydrograph type	= SCS Runoff	Peak discharge	= 2.984 cfs
Storm frequency	= 10 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 8,834 cuft
Drainage area	= 2.430 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.20 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.360 \times 55) + (0.620 \times 48) + (0.450 \times 58)] / 2.430$



Hydrograph Report

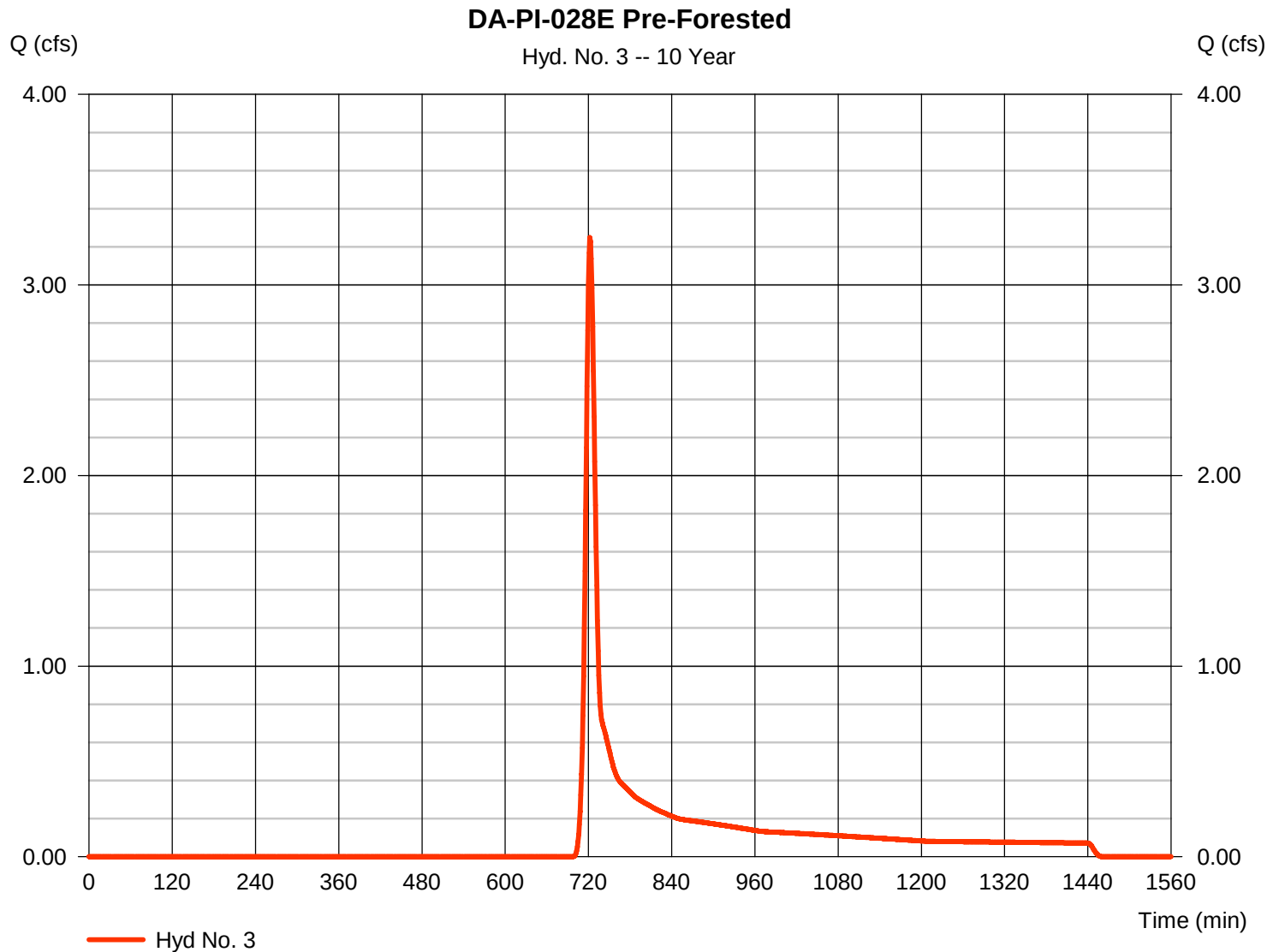
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Thursday, 08 / 17 / 2017

Hyd. No. 3

DA-PI-028E Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	3.248 cfs
Storm frequency	=	10 yrs	Time to peak	=	722 min
Time interval	=	1 min	Hyd. volume	=	9,388 cuft
Drainage area	=	2.430 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	13.10 min
Total precip.	=	5.20 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(2.430 \times 55)] / 2.430$ 

DA-PI-028F

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.059	867
Developed Condition	0.029	638
Pre-Developed (Forest) Condition	0.059	867

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1:

$$Q_{\text{developed}} \leq \text{IF} \times [(Q_{\text{pre-developed}} \times \text{RV}_{\text{pre-developed}}) / \text{RV}_{\text{developed}}] \text{ ----->}$$

Q (cfs)

0.029

≤

N/A - See Check #3

Q (cfs)

0.064

Check #2:

$$Q_{\text{developed}} \leq Q_{\text{pre-developed}} \text{ ----->}$$

0.029

≤

N/A - See Check #3

0.059

Check #3:

$$Q_{\text{developed}} \text{ shall not be required to be } \leq (Q_{\text{forest}} \times \text{RV}_{\text{forest}}) / \text{RV}_{\text{developed}} \text{ --->}$$

0.029

shall not be required to be ≤

0.080

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning's n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<i>Note:</i> Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted. ¹For Paved Road land surface types a Manning's n of 0.011 was used <i>Sources:</i> -USACE, 1998, HEC-1 Flood Hydrograph Package User's Manual, Hydrologic Engineering Center, Davis, CA -Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC	

Table 2 – Manning’s n Values for Open Channel Flow

Channel Type	Manning n		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹ For the developed condition, a conservative Manning’s n value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar, level spreader diversion, or grass channel. ² For the pre-developed condition and post-development condition, a Manning’s n value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-PI-028F Pre
2	SCS Runoff	DA-PI-028F Post
3	SCS Runoff	DA-PI-028F Pre-Forested

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.059	1	736	867	-----	-----	-----	DA-PI-028F Pre
2	SCS Runoff	0.029	1	750	638	-----	-----	-----	DA-PI-028F Post
3	SCS Runoff	0.059	1	736	867	-----	-----	-----	DA-PI-028F Pre-Forested
DA-PI-028F.gpw					Return Period: 1 Year			Thursday, 08 / 17 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

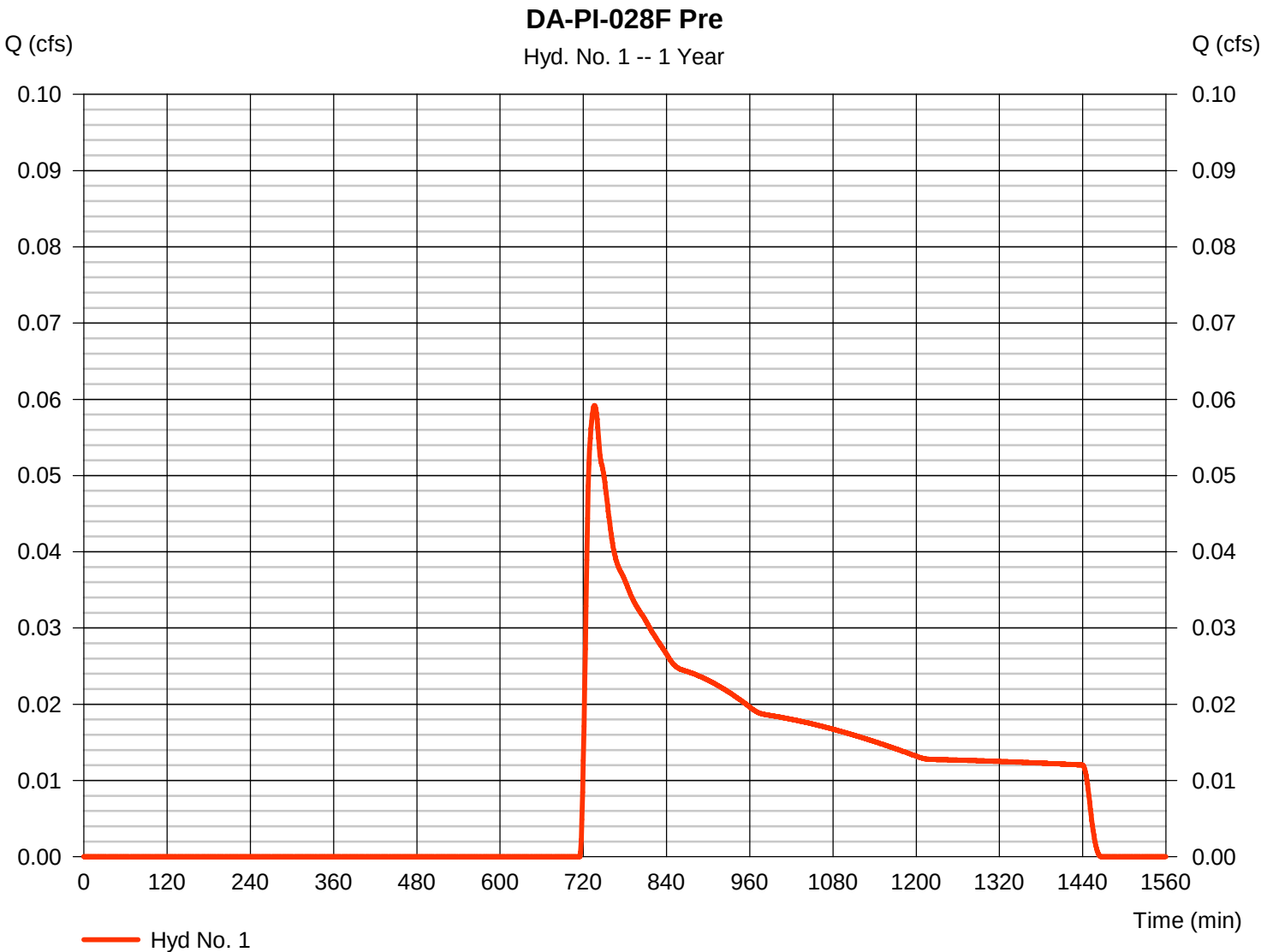
Thursday, 08 / 17 / 2017

Hyd. No. 1

DA-PI-028F Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.059 cfs
Storm frequency	= 1 yrs	Time to peak	= 736 min
Time interval	= 1 min	Hyd. volume	= 867 cuft
Drainage area	= 1.630 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.90 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(1.630 x 55)] / 1.630



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-PI-028F Pre

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 4.46	0.00	0.00				
Travel Time (min)	= 14.90	+	0.00	+	0.00	=	14.90
Shallow Concentrated Flow							
Flow length (ft)	= 402.74	0.00	0.00				
Watercourse slope (%)	= 16.14	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=6.48	0.00	0.00				
Travel Time (min)	= 1.04	+	0.00	+	0.00	=	1.04
Channel Flow							
X sectional flow area (sqft)	= 0.00	0.00	0.00				
Wetted perimeter (ft)	= 0.00	0.00	0.00				
Channel slope (%)	= 0.00	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	(0)0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc				15.90 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

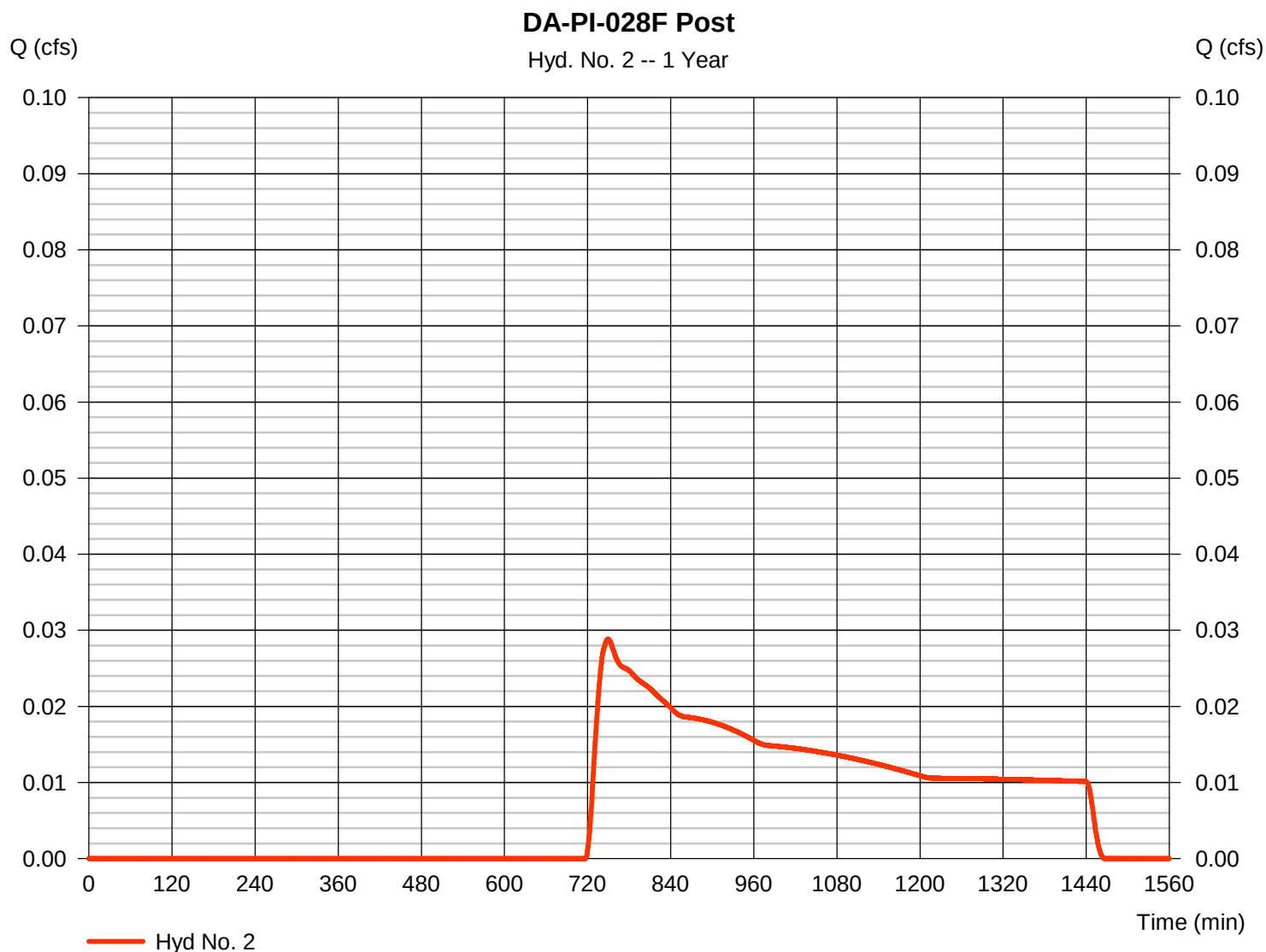
Thursday, 08 / 17 / 2017

Hyd. No. 2

DA-PI-028F Post

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.029 cfs
Storm frequency	=	1 yrs	Time to peak	=	750 min
Time interval	=	1 min	Hyd. volume	=	638 cuft
Drainage area	=	1.630 ac	Curve number	=	53*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	16.10 min
Total precip.	=	2.80 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(0.630 \times 55) + (0.580 \times 48) + (0.420 \times 58)] / 1.630$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-PI-028F Post

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 4.46	0.00	0.00				
Travel Time (min)	= 14.90	+	0.00	+	0.00	=	14.90
Shallow Concentrated Flow							
Flow length (ft)	= 315.21	95.33	0.00				
Watercourse slope (%)	= 13.40	25.45	0.00				
Surface description	= Unpaved	Unpaved	Paved				
Average velocity (ft/s)	=5.91	8.14	0.00				
Travel Time (min)	= 0.89	+	0.20	+	0.00	=	1.08
Channel Flow							
X sectional flow area (sqft)	= 2.00	0.00	0.00				
Wetted perimeter (ft)	= 4.47	0.00	0.00				
Channel slope (%)	= 5.00	0.00	0.00				
Manning's n-value	= 0.040	0.015	0.015				
Velocity (ft/s)	=4.86	0.00	0.00				
Flow length (ft)	(0)}41.6	0.0	0.0				
Travel Time (min)	= 0.14	+	0.00	+	0.00	=	0.14
Total Travel Time, Tc				16.10 min			

Hydrograph Report

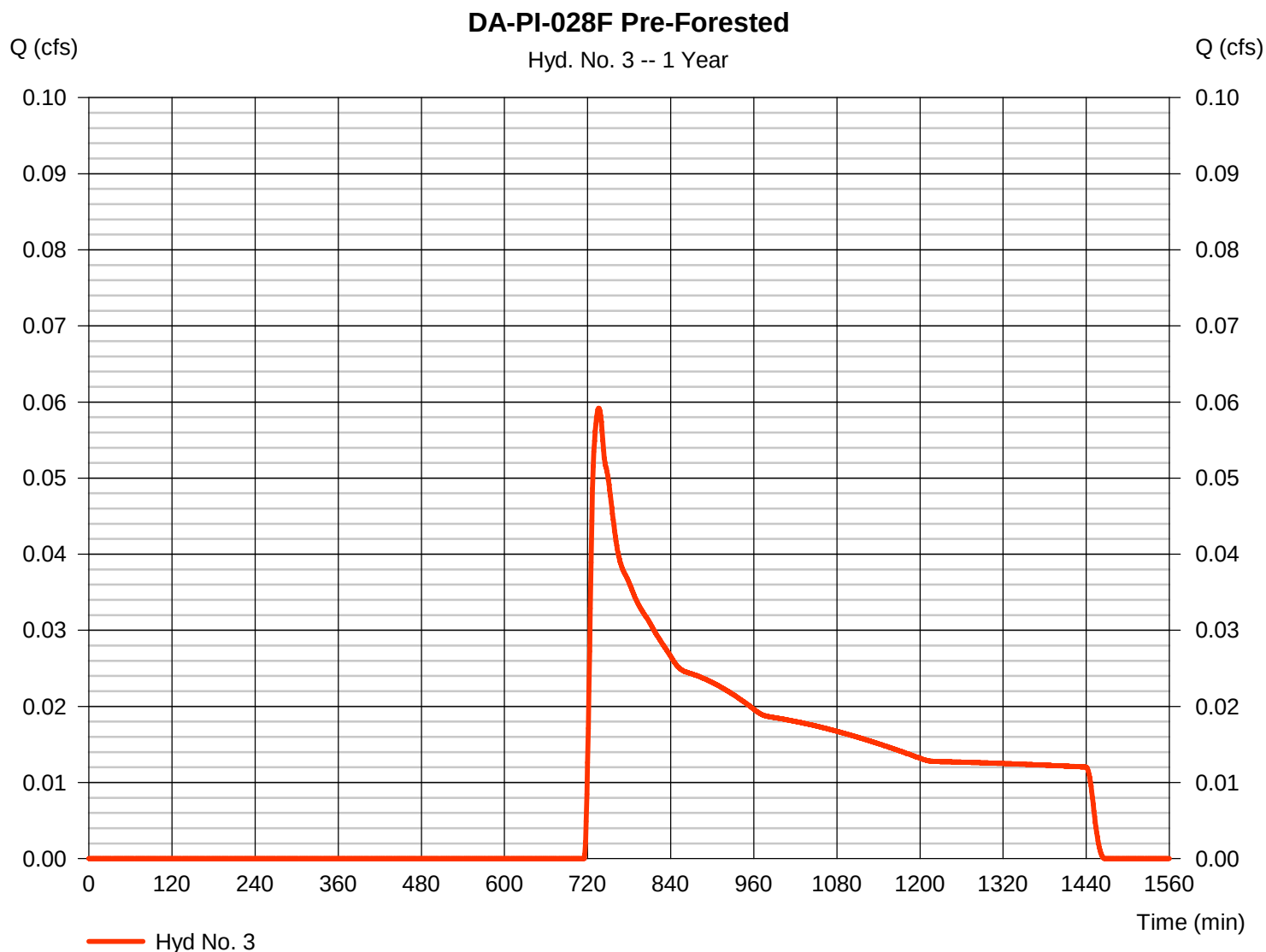
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Thursday, 08 / 17 / 2017

Hyd. No. 3

DA-PI-028F Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 0.059 cfs
Storm frequency	= 1 yrs	Time to peak	= 736 min
Time interval	= 1 min	Hyd. volume	= 867 cuft
Drainage area	= 1.630 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.90 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.630 \times 55)] / 1.630$ 

TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-PI-028F Pre-Forested

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 4.46	0.00	0.00				
Travel Time (min)	= 14.90	+	0.00	+	0.00	=	14.90
Shallow Concentrated Flow							
Flow length (ft)	= 402.74	0.00	0.00				
Watercourse slope (%)	= 16.14	0.00	0.00				
Surface description	= Unpaved	Unpaved	Paved				
Average velocity (ft/s)	=6.48	0.00	0.00				
Travel Time (min)	= 1.04	+	0.00	+	0.00	=	1.04
Channel Flow							
X sectional flow area (sqft)	= 0.00	0.00	0.00				
Wetted perimeter (ft)	= 0.00	0.00	0.00				
Channel slope (%)	= 0.00	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	(0)0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc				15.90 min			

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.366	1	727	2,071	-----	-----	-----	DA-PI-028F Pre
2	SCS Runoff	0.233	1	728	1,685	-----	-----	-----	DA-PI-028F Post
3	SCS Runoff	0.366	1	727	2,071	-----	-----	-----	DA-PI-028F Pre-Forested
DA-PI-028F.gpw					Return Period: 2 Year			Thursday, 08 / 17 / 2017	

Hydrograph Report

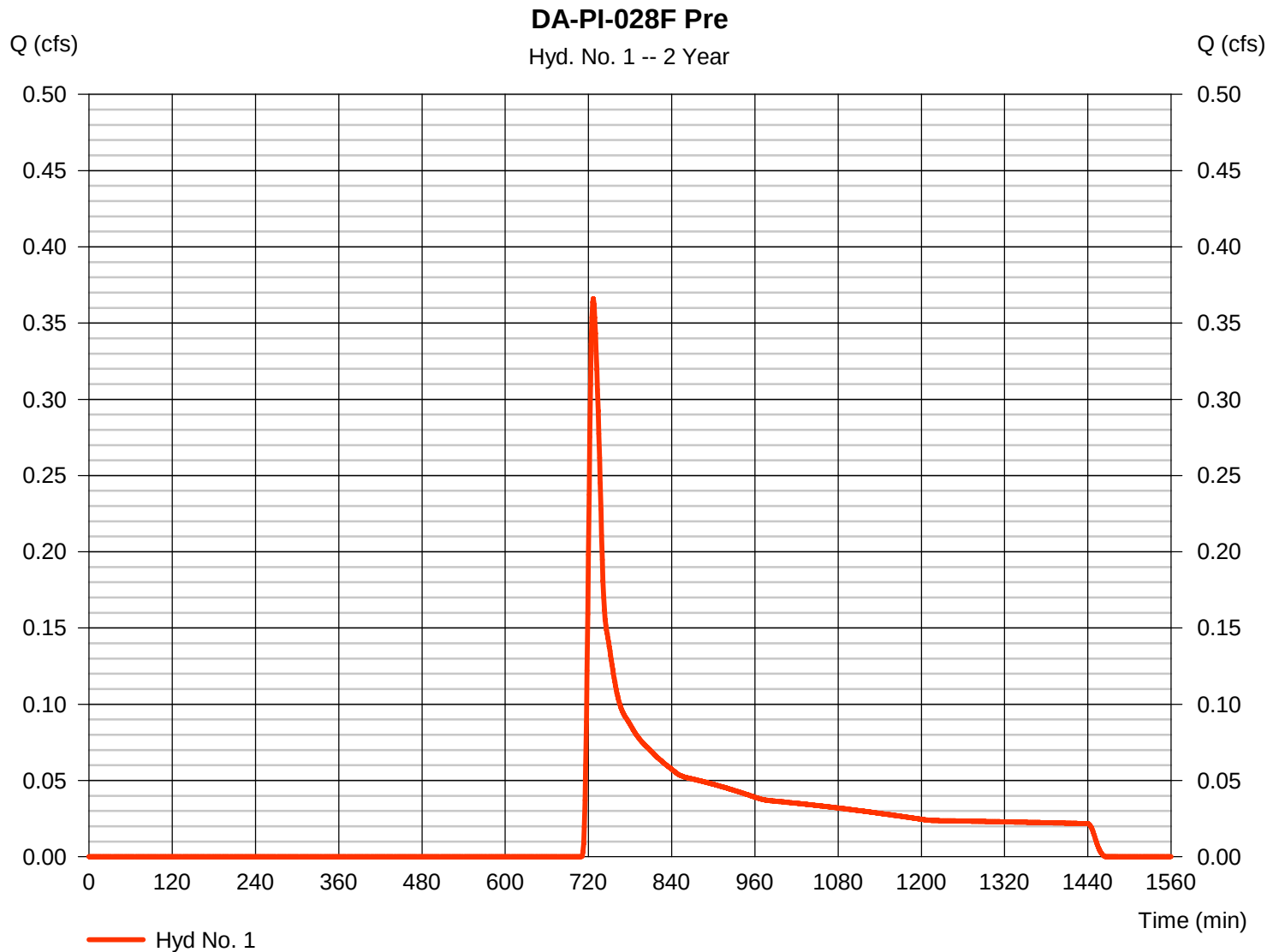
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Thursday, 08 / 17 / 2017

Hyd. No. 1

DA-PI-028F Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.366 cfs
Storm frequency	= 2 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 2,071 cuft
Drainage area	= 1.630 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.90 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.630 \times 55)] / 1.630$ 

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

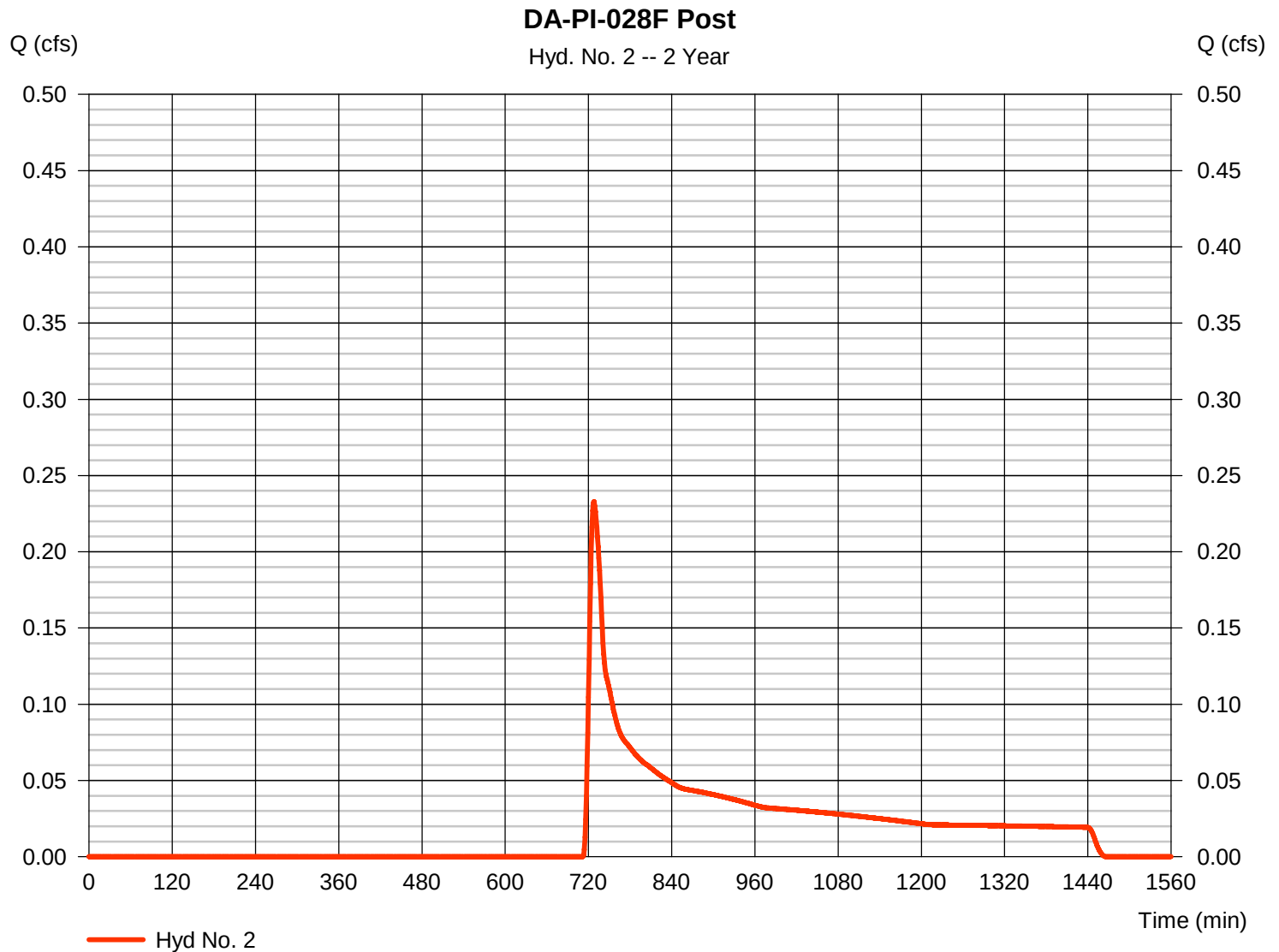
Thursday, 08 / 17 / 2017

Hyd. No. 2

DA-PI-028F Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.233 cfs
Storm frequency	= 2 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 1,685 cuft
Drainage area	= 1.630 ac	Curve number	= 53*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.10 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.630 \times 55) + (0.580 \times 48) + (0.420 \times 58)] / 1.630$



Hydrograph Report

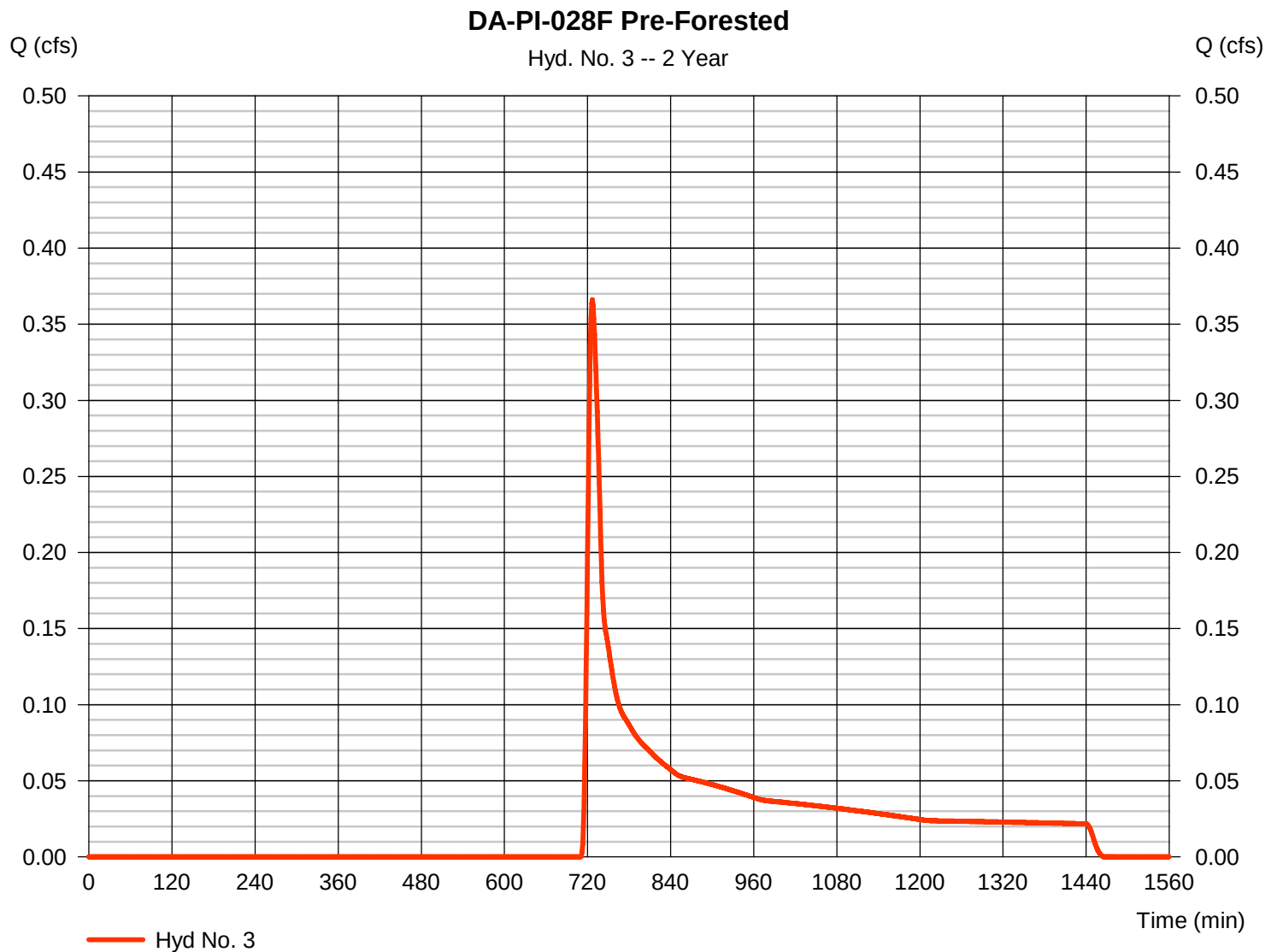
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Thursday, 08 / 17 / 2017

Hyd. No. 3

DA-PI-028F Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.366 cfs
Storm frequency	=	2 yrs	Time to peak	=	727 min
Time interval	=	1 min	Hyd. volume	=	2,071 cuft
Drainage area	=	1.630 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	15.90 min
Total precip.	=	3.50 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(1.630 \times 55)] / 1.630$ 

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	1.924	1	725	6,477	-----	-----	-----	DA-PI-028F Pre
2	SCS Runoff	1.609	1	725	5,721	-----	-----	-----	DA-PI-028F Post
3	SCS Runoff	1.924	1	725	6,477	-----	-----	-----	DA-PI-028F Pre-Forested
DA-PI-028F.gpw					Return Period: 10 Year			Thursday, 08 / 17 / 2017	

Hydrograph Report

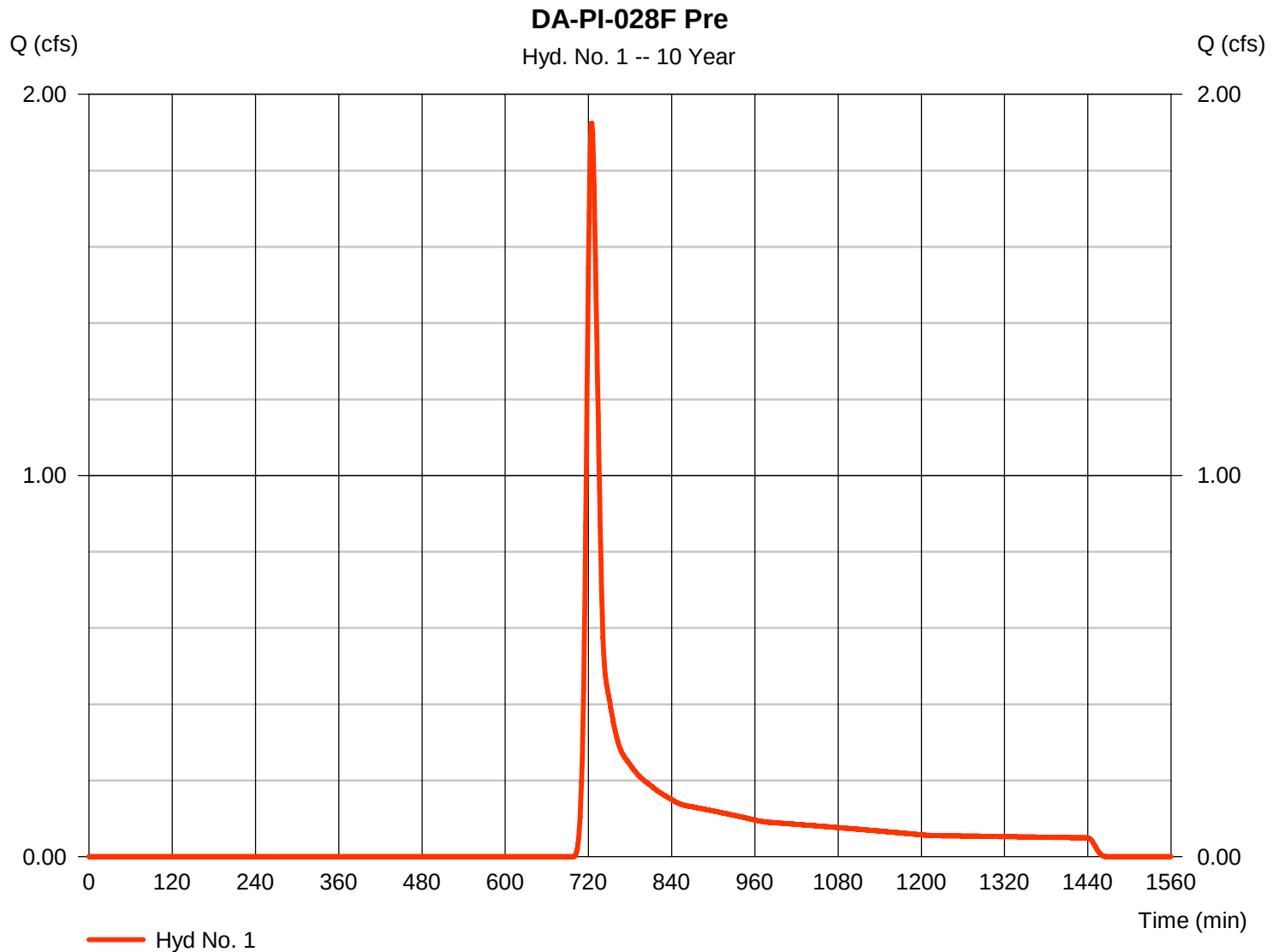
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Thursday, 08 / 17 / 2017

Hyd. No. 1

DA-PI-028F Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 1.924 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 6,477 cuft
Drainage area	= 1.630 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.90 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.630 \times 55)] / 1.630$ 

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

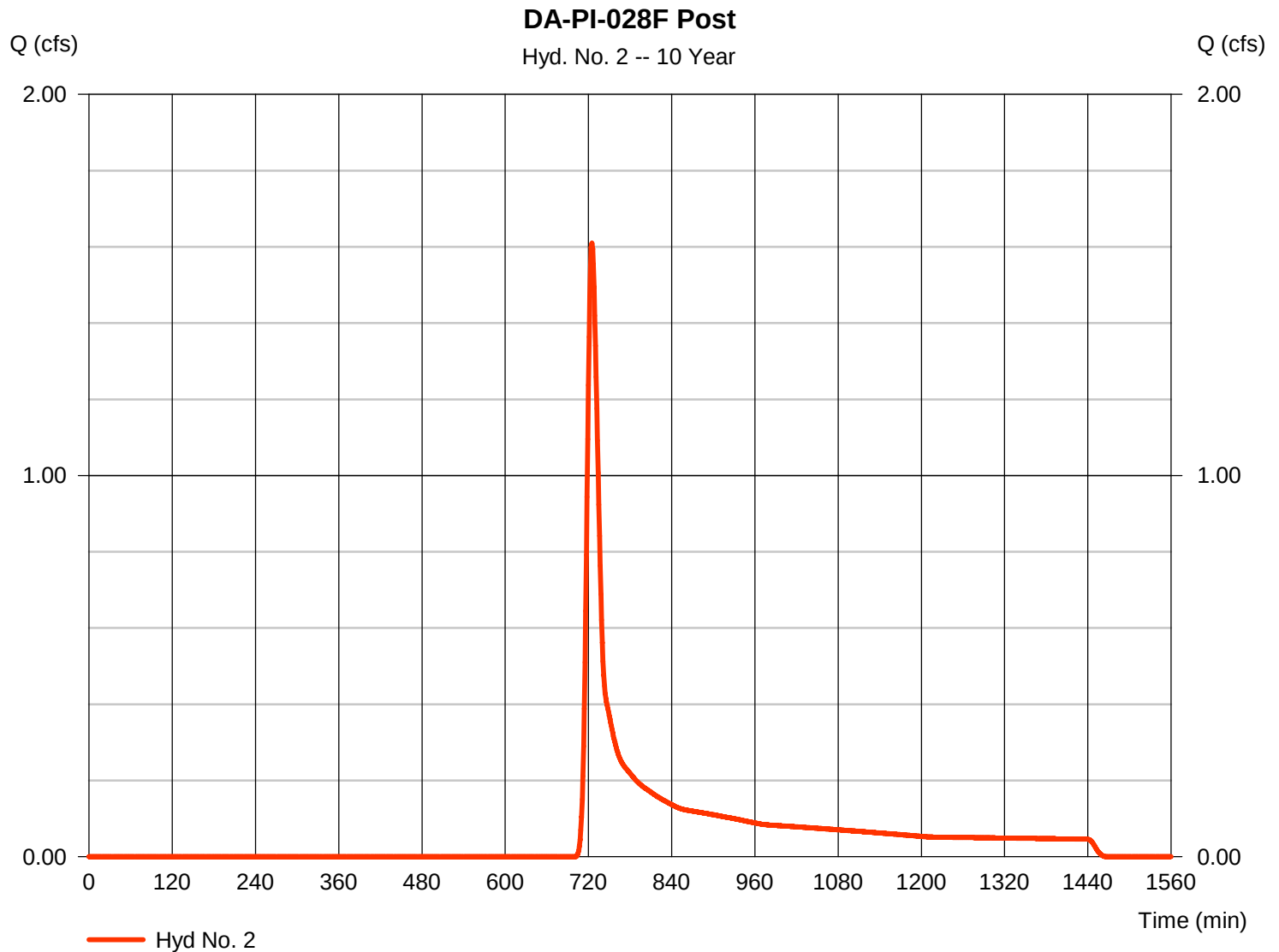
Thursday, 08 / 17 / 2017

Hyd. No. 2

DA-PI-028F Post

Hydrograph type	= SCS Runoff	Peak discharge	= 1.609 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 5,721 cuft
Drainage area	= 1.630 ac	Curve number	= 53*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.10 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.630 \times 55) + (0.580 \times 48) + (0.420 \times 58)] / 1.630$



Hydrograph Report

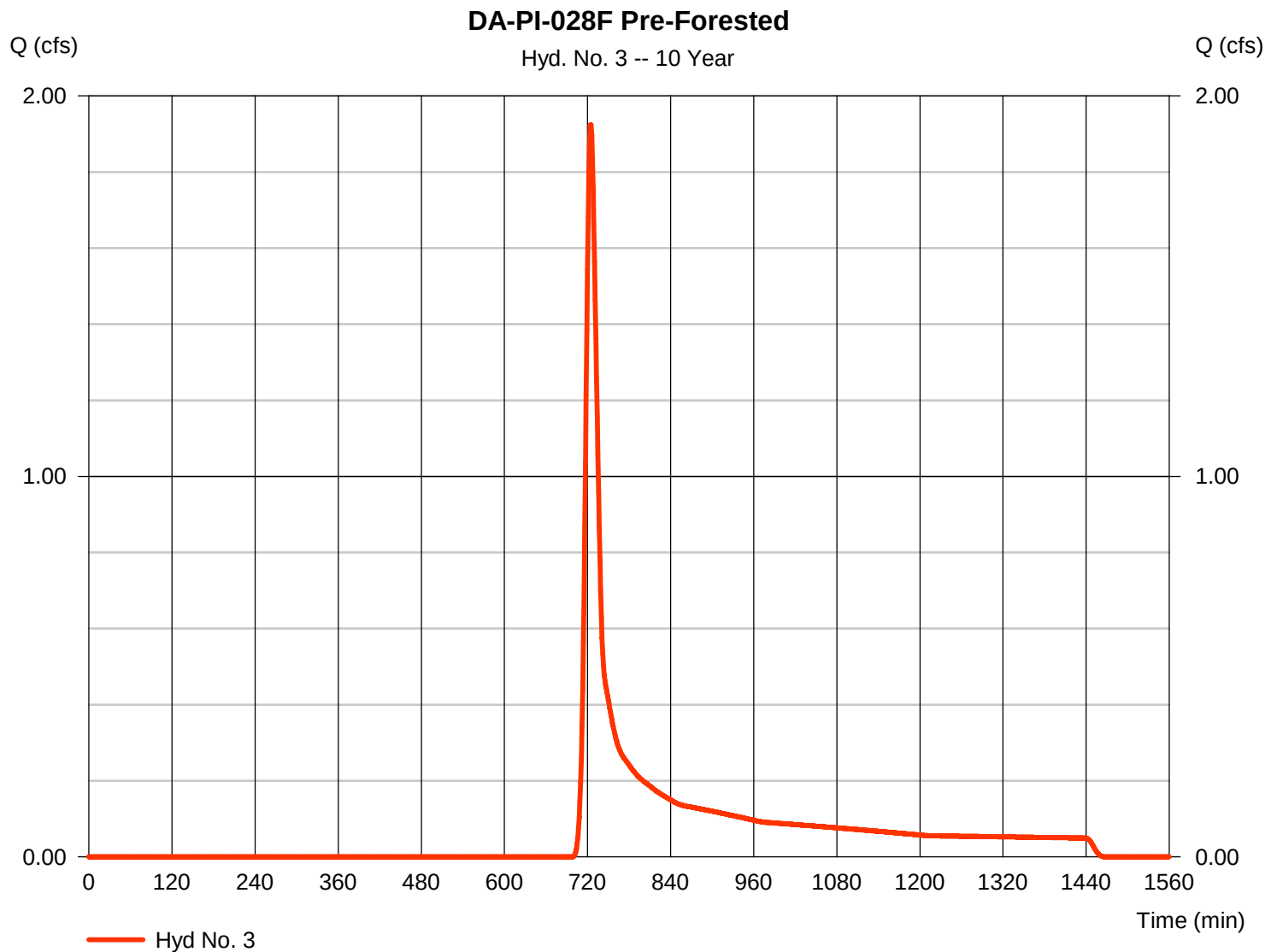
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Thursday, 08 / 17 / 2017

Hyd. No. 3

DA-PI-028F Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	1.924 cfs
Storm frequency	=	10 yrs	Time to peak	=	725 min
Time interval	=	1 min	Hyd. volume	=	6,477 cuft
Drainage area	=	1.630 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	15.90 min
Total precip.	=	5.20 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(1.630 \times 55)] / 1.630$ 

DA-PI-029

DA-PI-029 is located in a primarily forested area with undulating slopes, with a local unknown tributary to Cherry Stone Creek running through the drainage area. DA-PI-029 contains dirt roads that cover less than 1% of the overall drainage area. No new impervious areas are proposed within DA-PI-029. Multiple points of analysis were evaluated within DA-PI-029 to determine the effects on each receiving stream/channel following construction. Specifically, DA-PI-029 was sub-divided into two sub-drainage areas (sub-areas A and B). Sub-areas DA-PI-029A and DA-PI-029B both contain agricultural area within the limits of disturbance (LOD).

Pre-construction agricultural areas will be returned to agricultural land use (i.e., returned to crop production, in identical condition) following construction, but in non-agricultural areas, land use will be restored following construction as noted in the Stormwater Management (SWM) Narrative and the Annual Standards and Specifications. Agricultural areas within the LOD are included in the SWM quality analysis and the total permanent ROW is analyzed via VRRM; in these calculations agricultural areas are considered "Forest/Open Space". The total phosphorus load reduction required for DA-PI-029 is -0.53 lbs/yr.

Stormwater quantity is met via the energy balance method for each sub-area – DA-PI-029A and DA-PI-029B. Agricultural areas within the study area are included in the SWM quantity analysis, but an improvement factor of 1.00 is used when applying the energy balance method. This improvement factor is used to account for the exemption of agricultural areas (§ 62.1-44.15:34 and 9VAC25-870-300) since such areas will be returned to agricultural land use (i.e., returned to crop production, in identical condition) following construction.

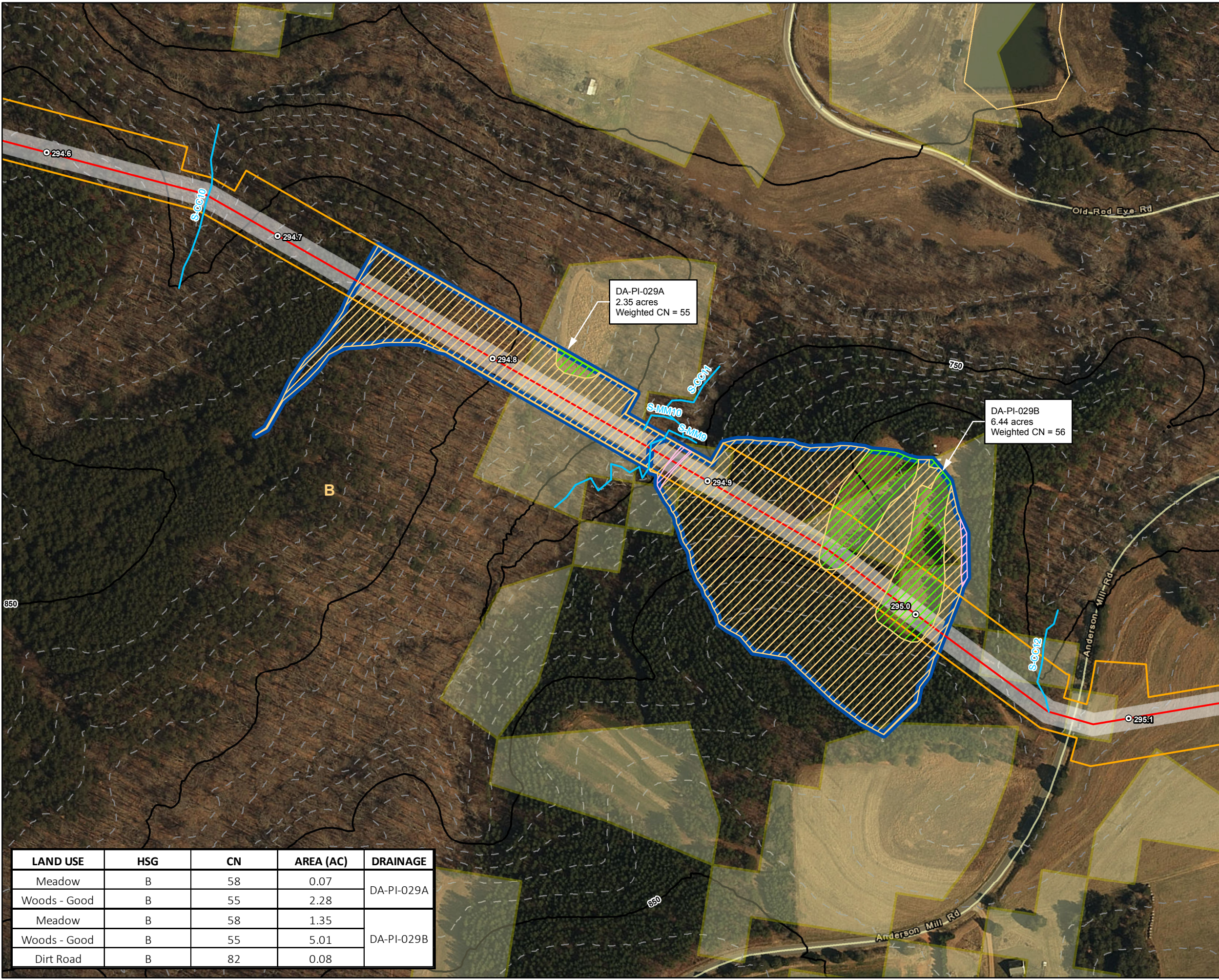
In addition, the Hydraflow hydrographs 10-year 24-hour peak discharge results indicate a decrease in flow ranging from 0.43 cfs to 0.65 cfs (as seen in table below).

Sub-area	Pre-peak Flow, 10-yr Q (cfs)	Post-peak Flow, 10-yr Q (cfs)	Flow Differential
DA-PI-029A	2.59	2.16	-0.43
DA-PI-029B	8.25	7.60	-0.65

Figures and calculations for DA-PI-029 follow. See Appendix D of the Annual Standards and Specifications for further detail on stormwater methodology.

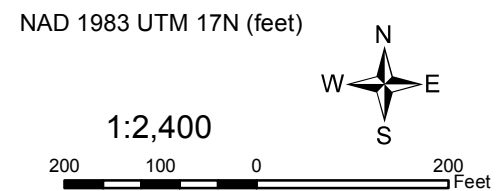
Note that the DA-PI-029A time of concentration flow path for the Post-Construction condition accounts for a permanent waterbar that is not sited within the drainage area. This permanent waterbar was removed because it was sited in an agricultural area, and resulting changes to the stormwater calculations were flagged during the QA/QC review process. This change was considered to be inconsequential because no stormwater

BMPs are sited in DA-PI-029A, so the resulting changes were not made to the stormwater calculations prior to submittal.



LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Meadow	B	58	0.07	DA-PI-029A
Woods - Good	B	55	2.28	
Meadow	B	58	1.35	DA-PI-029B
Woods - Good	B	55	5.01	
Dirt Road	B	82	0.08	

- Legend**
- Milepost
 - Delineated Stream
 - Existing 50' Contour
 - Existing 10' Contour
 - Road Centerline
 - Alignment Centerline
 - Limit of Disturbance
 - Permanent Right-of-Way
 - Dirt Road
 - Meadow
 - Woods
 - Agricultural Area
 - Drainage Area
 - Hydrologic Soil Groups



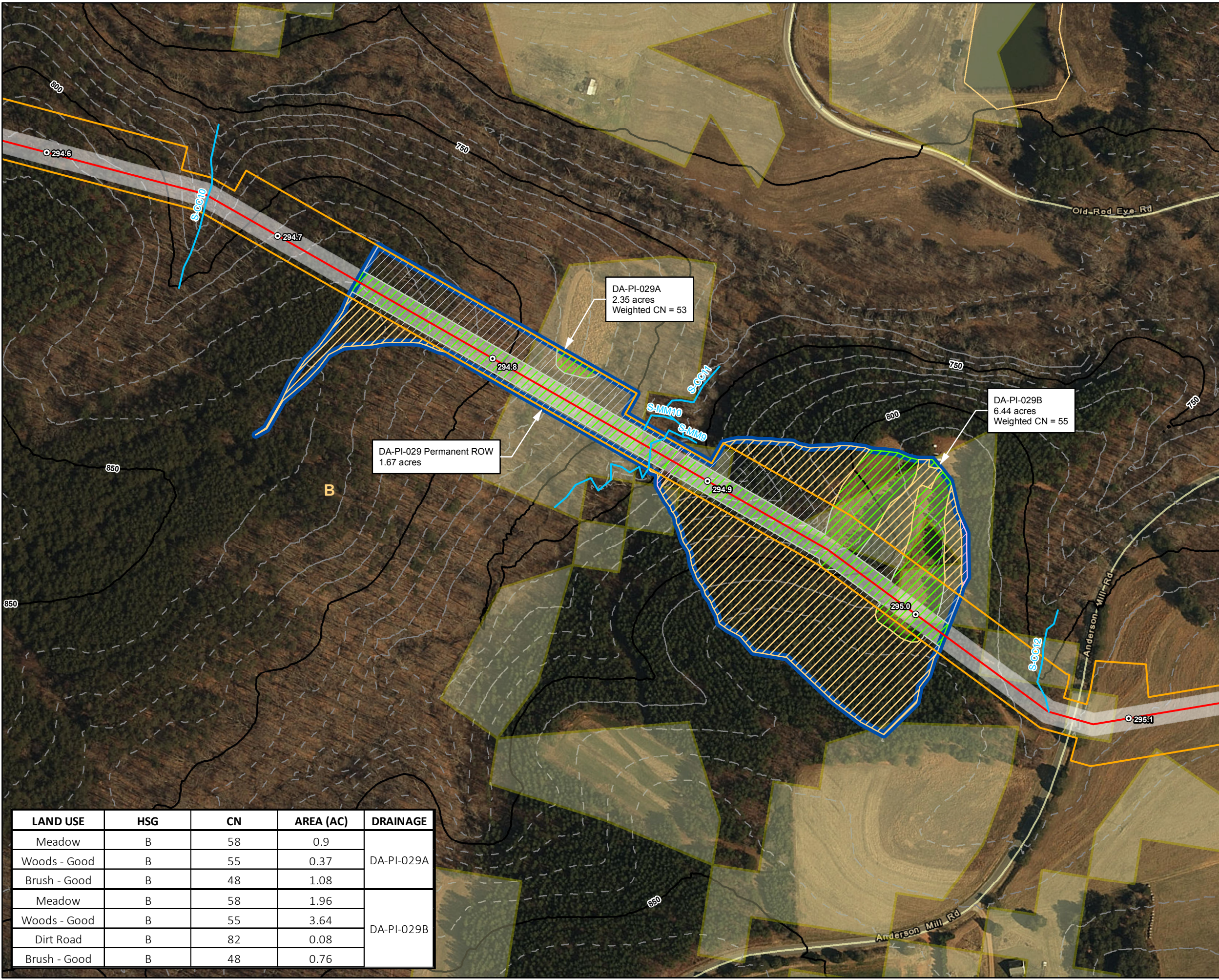
Mountain Valley Pipeline Project

Pre-Construction Drainage Area Map
DA-PI-029
Spread 11

Figure 1
Pittsylvania County, Virginia

August, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LIDAR provided by EQT 2016, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015, Agricultural Area from National Land Cover Dataset 2011.



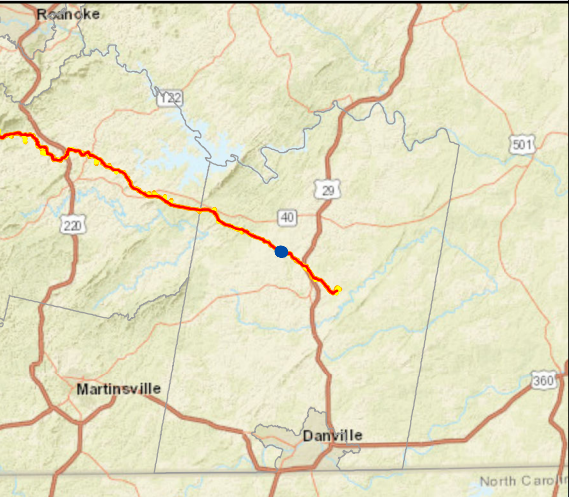
Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Brush
- Dirt Road
- Meadow
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

1:2,400

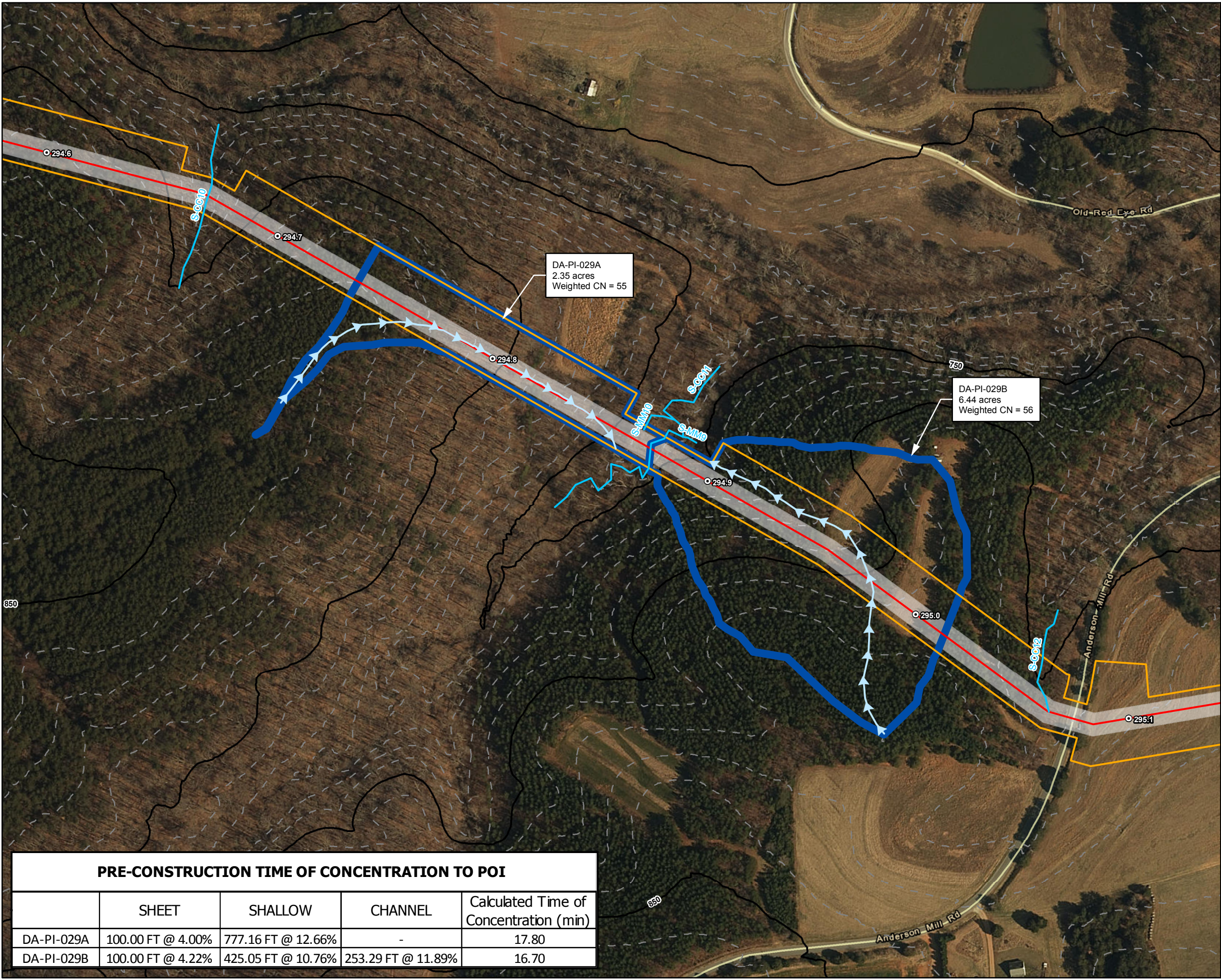
200 100 0 200 Feet



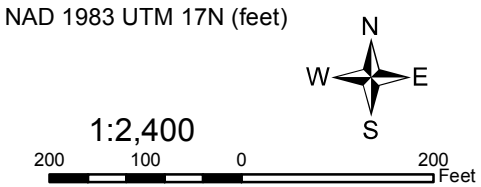
LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Meadow	B	58	0.9	DA-PI-029A
Woods - Good	B	55	0.37	
Brush - Good	B	48	1.08	
Meadow	B	58	1.96	DA-PI-029B
Woods - Good	B	55	3.64	
Dirt Road	B	82	0.08	
Brush - Good	B	48	0.76	

Mountain Valley Pipeline Project**Post-Construction Drainage Area Map**
DA-PI-029
Spread 11
Figure 2
Pittsylvania County, Virginia
August, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LIDAR provided by EQT 2016, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015, Agricultural Area from National Land Cover Dataset 2011.



- Legend**
- Milepost
 - Delineated Stream
 - Existing 50' Contour
 - - Existing 10' Contour
 - Road Centerline
 - Alignment Centerline
 - Limit of Disturbance
 - Permanent Right-of-Way
 - Time of Concentration
 - ▭ Drainage Area



Mountain Valley Pipeline Project

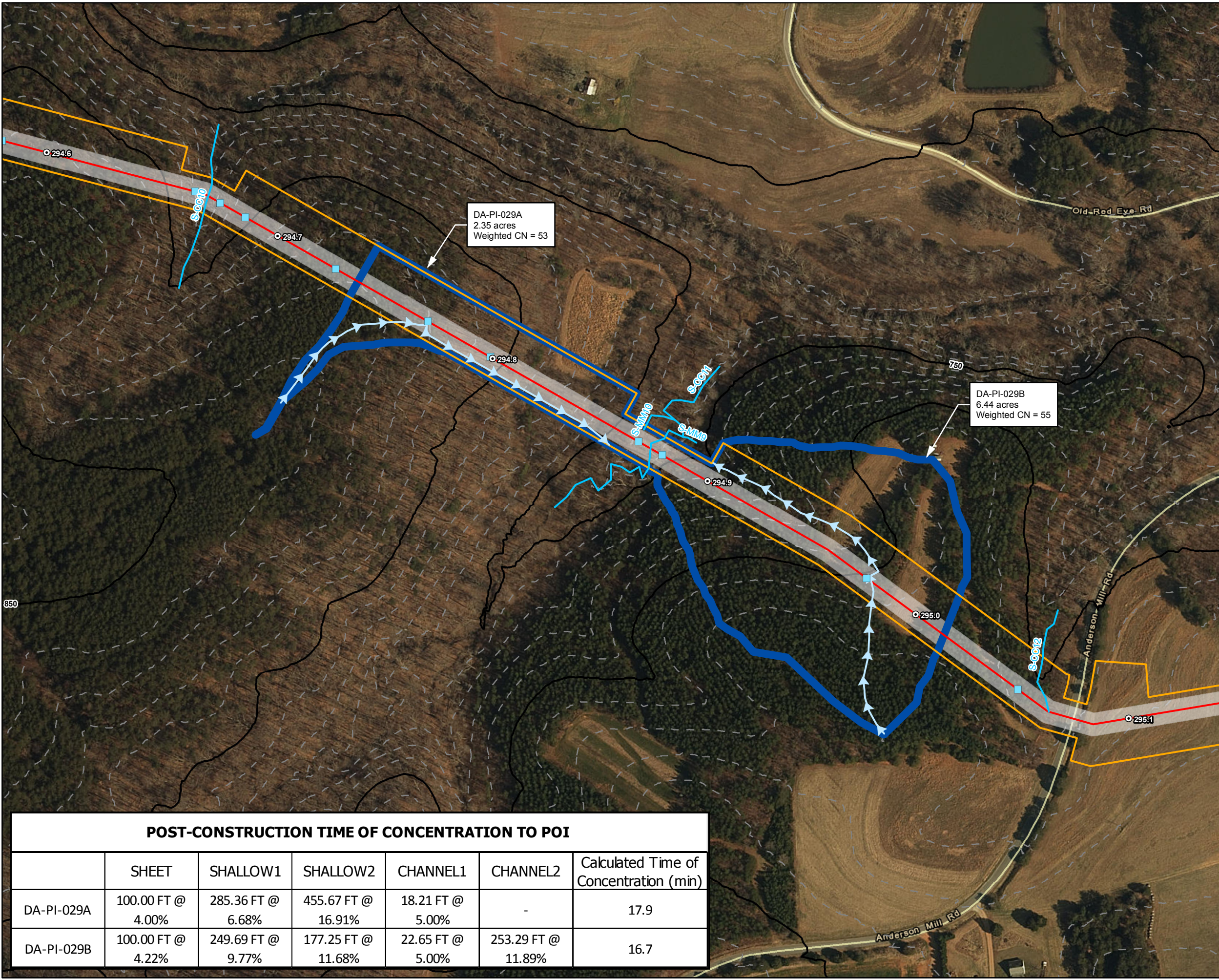


**Pre-Construction Drainage Area
and Time of Concentration
DA-PI-029
Spread 11**

Figure 3
Pittsylvania County, Virginia
August, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016.

PRE-CONSTRUCTION TIME OF CONCENTRATION TO POI				
	SHEET	SHALLOW	CHANNEL	Calculated Time of Concentration (min)
DA-PI-029A	100.00 FT @ 4.00%	777.16 FT @ 12.66%	-	17.80
DA-PI-029B	100.00 FT @ 4.22%	425.05 FT @ 10.76%	253.29 FT @ 11.89%	16.70



Legend

- Milepost
- Permanent Waterbars
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:2,400

2001000

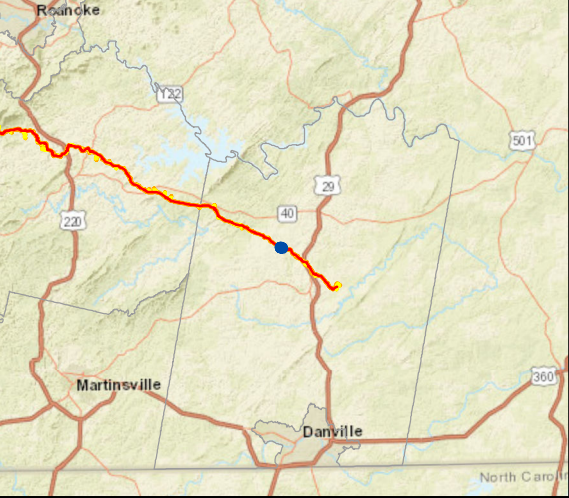
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POST-CONSTRUCTION TIME OF CONCENTRATION TO POI						
	SHEET	SHALLOW1	SHALLOW2	CHANNEL1	CHANNEL2	Calculated Time of Concentration (min)
DA-PI-029A	100.00 FT @ 4.00%	285.36 FT @ 6.68%	455.67 FT @ 16.91%	18.21 FT @ 5.00%	-	17.9
DA-PI-029B	100.00 FT @ 4.22%	249.69 FT @ 9.77%	177.25 FT @ 11.68%	22.65 FT @ 5.00%	253.29 FT @ 11.89%	16.7

Mountain Valley Pipeline Project



Post-Construction Drainage Area and Time of Concentration

DA-PI-029

Spread 11

Figure 4

Pittsylvania County, Virginia

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016.

Document Path: P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Pittsylvania\MVP_PCSM_DA-PI-029_Post_ToC_HH.mxd

DEQ Virginia Runoff Reduction Method Re-Development Compliance Spreadsheet - Version 3.0

BMP Design Specifications List: 2013 Draft Stds & Specs

Site Summary - Linear Development Project***

Total Rainfall (in):	43
Total Disturbed Acreage:	1.67

Site Land Cover Summary

Pre-ReDevelopment Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	% of Total
Forest/Open (acres)	0.00	1.65	0.00	0.00	1.65	99
Managed Turf (acres)	0.00	0.00	0.00	0.00	0.00	0
Impervious Cover (acres)	0.00	0.02	0.00	0.00	0.02	1
					1.67	100

Post-ReDevelopment Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	% of Total
Forest/Open (acres)	0.00	1.65	0.00	0.00	1.65	99
Managed Turf (acres)	0.00	0.00	0.00	0.00	0.00	0
Impervious Cover (acres)	0.00	0.02	0.00	0.00	0.02	1
					1.67	100

* Forest/Open Space areas must be protected in accordance with the Virginia Runoff Reduction Method

Site Tv and Land Cover Nutrient Loads

	Final Post-Development (Post-ReDevelopment & New Impervious)	Post- ReDevelopment	Post- Development (New Impervious)	Adjusted Pre- ReDevelopment
Site Rv	0.04	0.04	--	0.04
Treatment Volume (ft ³)	249	249	--	249
TP Load (lb/yr)	0.16	0.16	--	0.16

Baseline TP Load (lb/yr): 0.6847* *Reduction below new development load limitation not required

Pre- ReDevelopment TP Load per acre (lb/acre/yr)	Final Post-Development TP Load per acre (lb/acre/yr)	Post-ReDevelopment TP Load per acre (lb/acre/yr)
0.09	0.09	0.09

Total TP Load Reduction Required (lb/yr)	-0.53	N/A***	N/A***
--	-------	--------	--------

***This is a linear development project

	Final Post-Development Load (Post-ReDevelopment & New Impervious)	Pre- ReDevelopment
TN Load (lb/yr)	1.12	1.12

Site Compliance Summary - ***Linear Development Project

Maximum % Reduction Required Below Pre-ReDevelopment Load	20%
--	-----

* Note: % Reduction will reduce post-development TP load to less than or equal to baseline load of 0.68 lb/yr (0.41 lb/ac/yr)
 [Post-Dev Reduction Requirement = Post-Dev TP load - baseline load of 0.68 lb/yr], baseline load = site area x 0.41 lb/ac/yr

Total Runoff Volume Reduction (ft ³)	0
Total TP Load Reduction Achieved (lb/yr)	0.00
Total TN Load Reduction Achieved (lb/yr)	0.00
Remaining Post Development TP Load (lb/yr)	0.16
Remaining TP Load Reduction (lb/yr) Required	0.00

**** TARGET TP REDUCTION EXCEEDED BY 0.53 LB/YEAR ****

**Reduction below new development load limitation not required*

DA-PI-029A

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.820	1,221
Developed Condition	0.040	898
Pre-Developed (Forest) Condition	0.820	1,221

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 1

Calculations:

Check #1:

$$Q_{\text{developed}} \leq \text{IF} \times [(Q_{\text{pre-developed}} \times \text{RV}_{\text{pre-developed}}) / \text{RV}_{\text{developed}}] \text{ ----->}$$

Q (cfs)

0.040

≤

OK

Q (cfs)

1.115

Check #2:

$$Q_{\text{developed}} \leq Q_{\text{pre-developed}} \text{ ----->}$$

0.040

≤

N/A - See Check #3

0.820

Check #3:

$$Q_{\text{developed}} \text{ shall not be required to be } \leq (Q_{\text{forest}} \times \text{RV}_{\text{forest}}) / \text{RV}_{\text{developed}} \text{ --->}$$

0.040

shall not be required to be ≤

1.115

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning's n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<i>Note:</i> Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted. ¹For Paved Road land surface types a Manning's n of 0.011 was used <i>Sources:</i> -USACE, 1998, HEC-1 Flood Hydrograph Package User's Manual, Hydrologic Engineering Center, Davis, CA -Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC	

Table 2 – Manning's n Values for Open Channel Flow

Channel Type	Manning n		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹For the developed condition, a conservative Manning's n value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar, level spreader diversion, or grass channel. ²For the pre-developed condition and post-development condition, a Manning's n value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

1



2



3



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-PI-029A Pre
2	SCS Runoff	DA-PI-029A Post
3	SCS Runoff	DA-PI-029A Pre-Forested

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.082	1	738	1,221	-----	-----	-----	DA-PI-029A Pre
2	SCS Runoff	0.040	1	751	898	-----	-----	-----	DA-PI-029A Post
3	SCS Runoff	0.082	1	738	1,221	-----	-----	-----	DA-PI-029A Pre-Forested
DA-PI-029A.gpw					Return Period: 1 Year			Thursday, 09 / 7 / 2017	

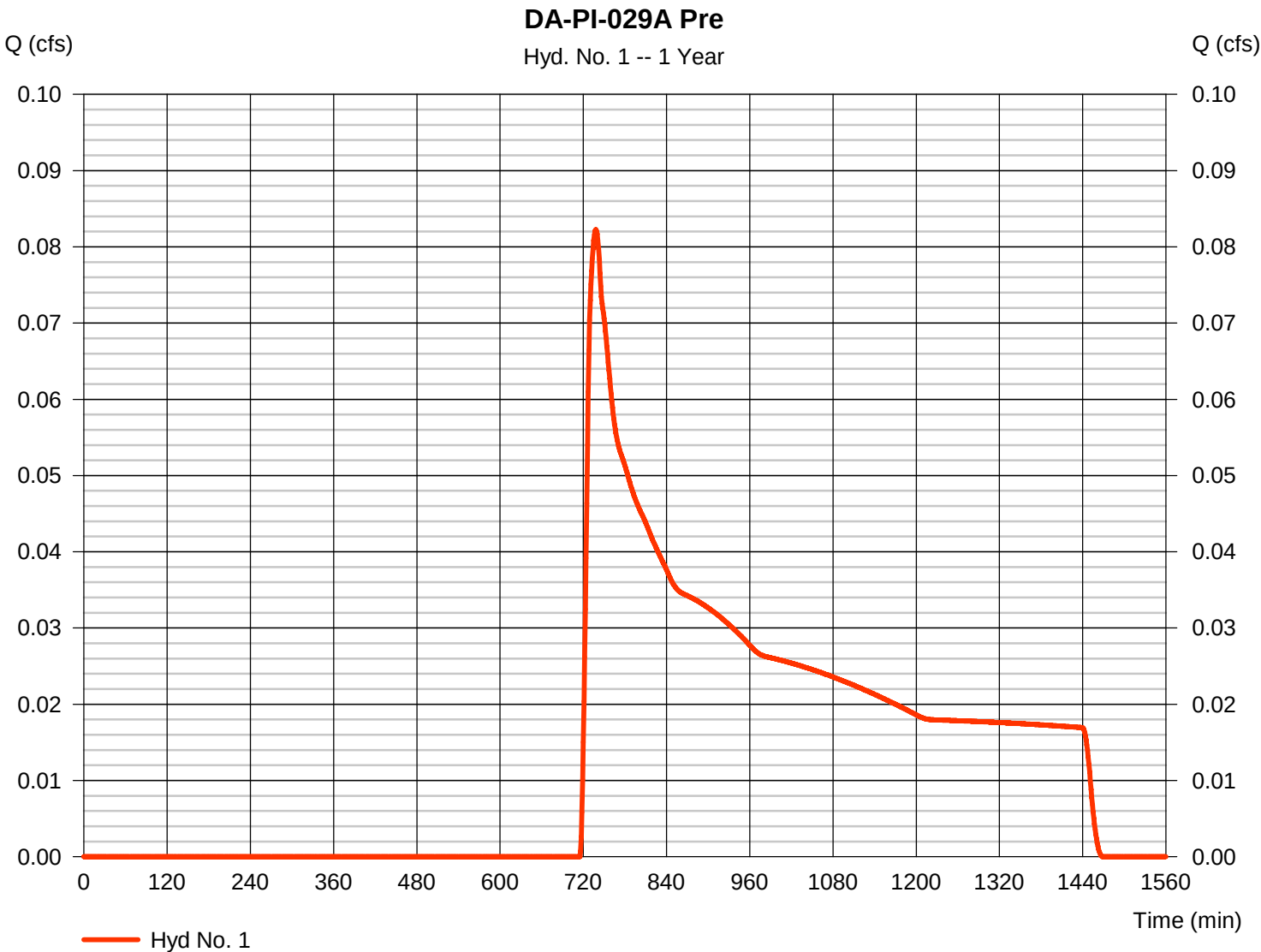
Hydrograph Report

Hyd. No. 1

DA-PI-029A Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.082 cfs
Storm frequency	= 1 yrs	Time to peak	= 738 min
Time interval	= 1 min	Hyd. volume	= 1,221 cuft
Drainage area	= 2.350 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 17.80 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.070 x 58) + (2.280 x 55)] / 2.350



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-PI-029A Pre

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 4.00	0.00	0.00				
Travel Time (min)	= 15.56	+	0.00	+	0.00	=	15.56
Shallow Concentrated Flow							
Flow length (ft)	= 777.16	0.00	0.00				
Watercourse slope (%)	= 12.66	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=5.74	0.00	0.00				
Travel Time (min)	= 2.26	+	0.00	+	0.00	=	2.26
Channel Flow							
X sectional flow area (sqft)	= 0.00	0.00	0.00				
Wetted perimeter (ft)	= 0.00	0.00	0.00				
Channel slope (%)	= 0.00	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	((0})0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc				17.80 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

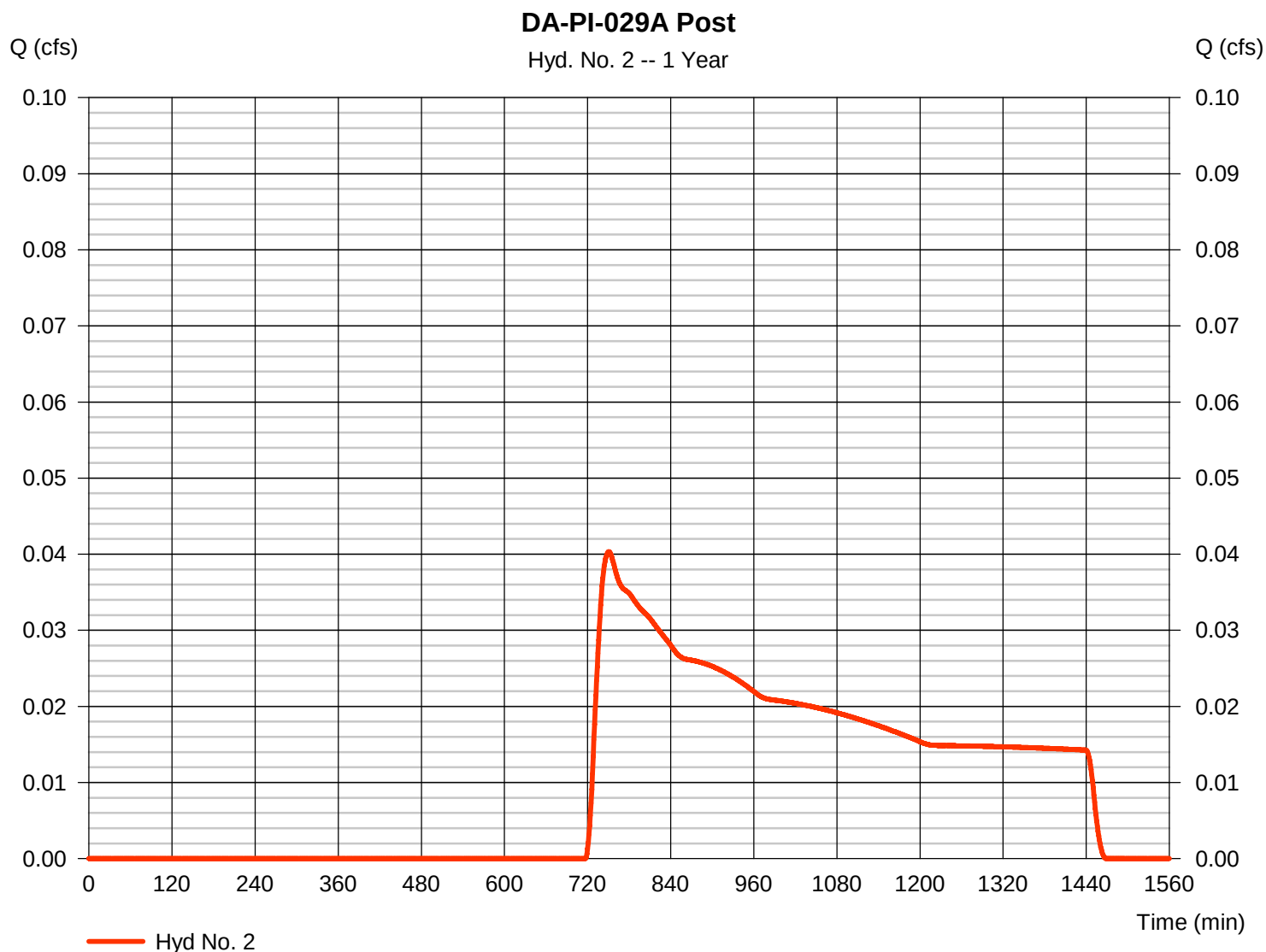
Thursday, 09 / 7 / 2017

Hyd. No. 2

DA-PI-029A Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.040 cfs
Storm frequency	= 1 yrs	Time to peak	= 751 min
Time interval	= 1 min	Hyd. volume	= 898 cuft
Drainage area	= 2.350 ac	Curve number	= 53*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 17.90 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.900 \times 58) + (0.370 \times 55) + (1.080 \times 48)] / 2.350$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-PI-029A Post

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00	
Land slope (%)	= 4.00	0.00	0.00	
Travel Time (min)	= 15.56	+	0.00	+
			0.00	= 15.56
Shallow Concentrated Flow				
Flow length (ft)	= 285.36	455.67	0.00	
Watercourse slope (%)	= 6.68	16.91	0.00	
Surface description	= Unpaved	Unpaved	Paved	
Average velocity (ft/s)	=4.17	6.63	0.00	
Travel Time (min)	= 1.14	+	1.14	+
			0.00	= 2.29
Channel Flow				
X sectional flow area (sqft)	= 2.00	0.00	0.00	
Wetted perimeter (ft)	= 4.47	0.00	0.00	
Channel slope (%)	= 5.00	0.00	0.00	
Manning's n-value	= 0.040	0.015	0.015	
Velocity (ft/s)	=4.86	0.00	0.00	
			0.00	
Flow length (ft)	({})18.2	0.0	0.0	
Travel Time (min)	= 0.06	+	0.00	+
			0.00	= 0.06
Total Travel Time, Tc				17.90 min

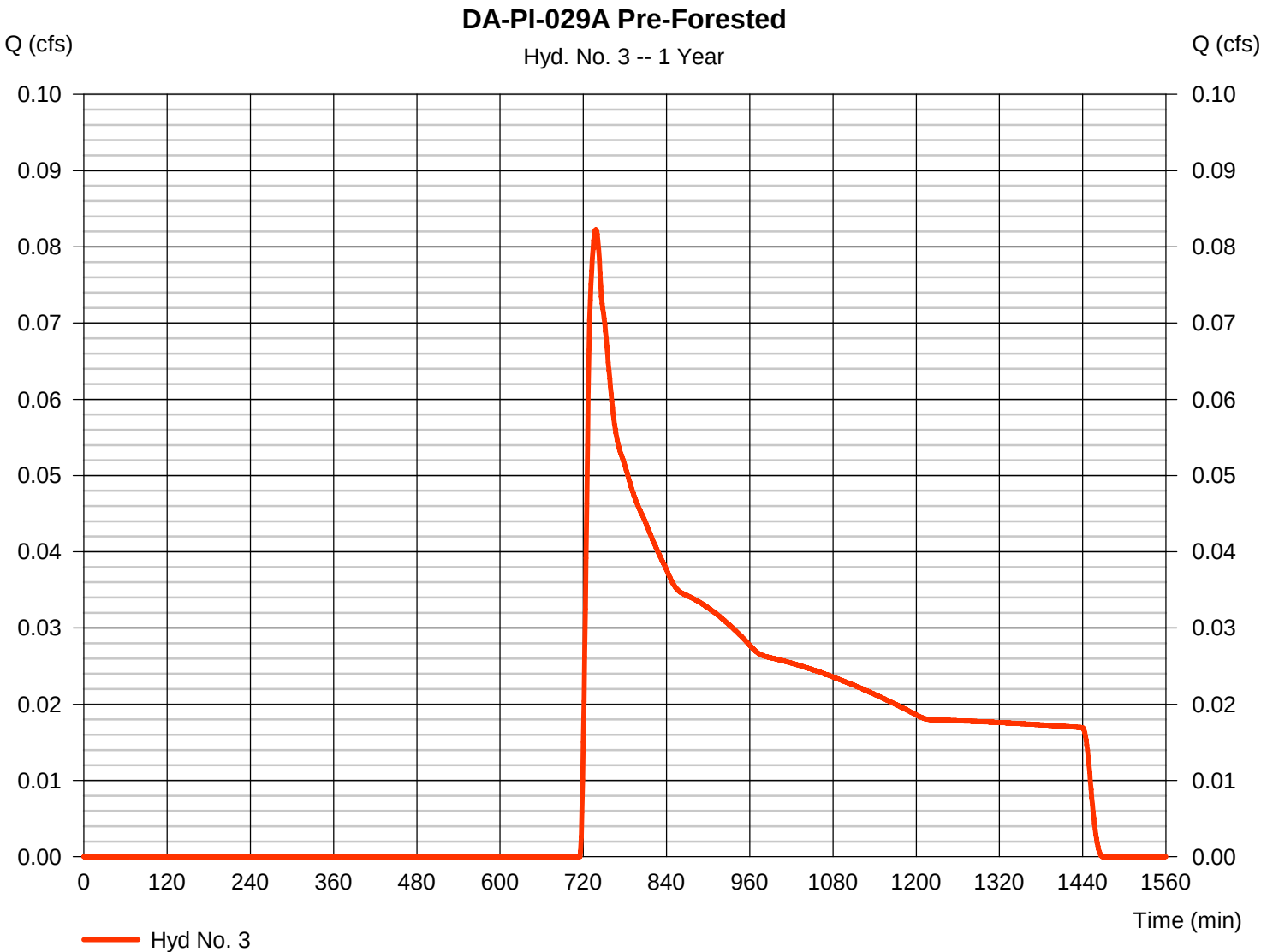
Hydrograph Report

Hyd. No. 3

DA-PI-029A Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.082 cfs
Storm frequency	=	1 yrs	Time to peak	=	738 min
Time interval	=	1 min	Hyd. volume	=	1,221 cuft
Drainage area	=	2.350 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	17.80 min
Total precip.	=	2.80 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(2.350 x 55)] / 2.350



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-PI-029A Pre-Forested

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00	
Land slope (%)	= 4.00	0.00	0.00	
Travel Time (min)	= 15.56	+ 0.00	+ 0.00	= 15.56
Shallow Concentrated Flow				
Flow length (ft)	= 777.16	0.00	0.00	
Watercourse slope (%)	= 12.66	0.00	0.00	
Surface description	= Unpaved	Unpaved	Paved	
Average velocity (ft/s)	=5.74	0.00	0.00	
Travel Time (min)	= 2.26	+ 0.00	+ 0.00	= 2.26
Channel Flow				
X sectional flow area (sqft)	= 0.00	0.00	0.00	
Wetted perimeter (ft)	= 0.00	0.00	0.00	
Channel slope (%)	= 0.00	0.00	0.00	
Manning's n-value	= 0.030	0.015	0.015	
Velocity (ft/s)	=0.00	0.00	0.00	
Flow length (ft)	(0)0.0	0.0	0.0	
Travel Time (min)	= 0.00	+ 0.00	+ 0.00	= 0.00
Total Travel Time, Tc				17.80 min

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.492	1	728	2,916	-----	-----	-----	DA-PI-029A Pre
2	SCS Runoff	0.314	1	729	2,372	-----	-----	-----	DA-PI-029A Post
3	SCS Runoff	0.492	1	728	2,916	-----	-----	-----	DA-PI-029A Pre-Forested
DA-PI-029A.gpw					Return Period: 2 Year			Thursday, 09 / 7 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

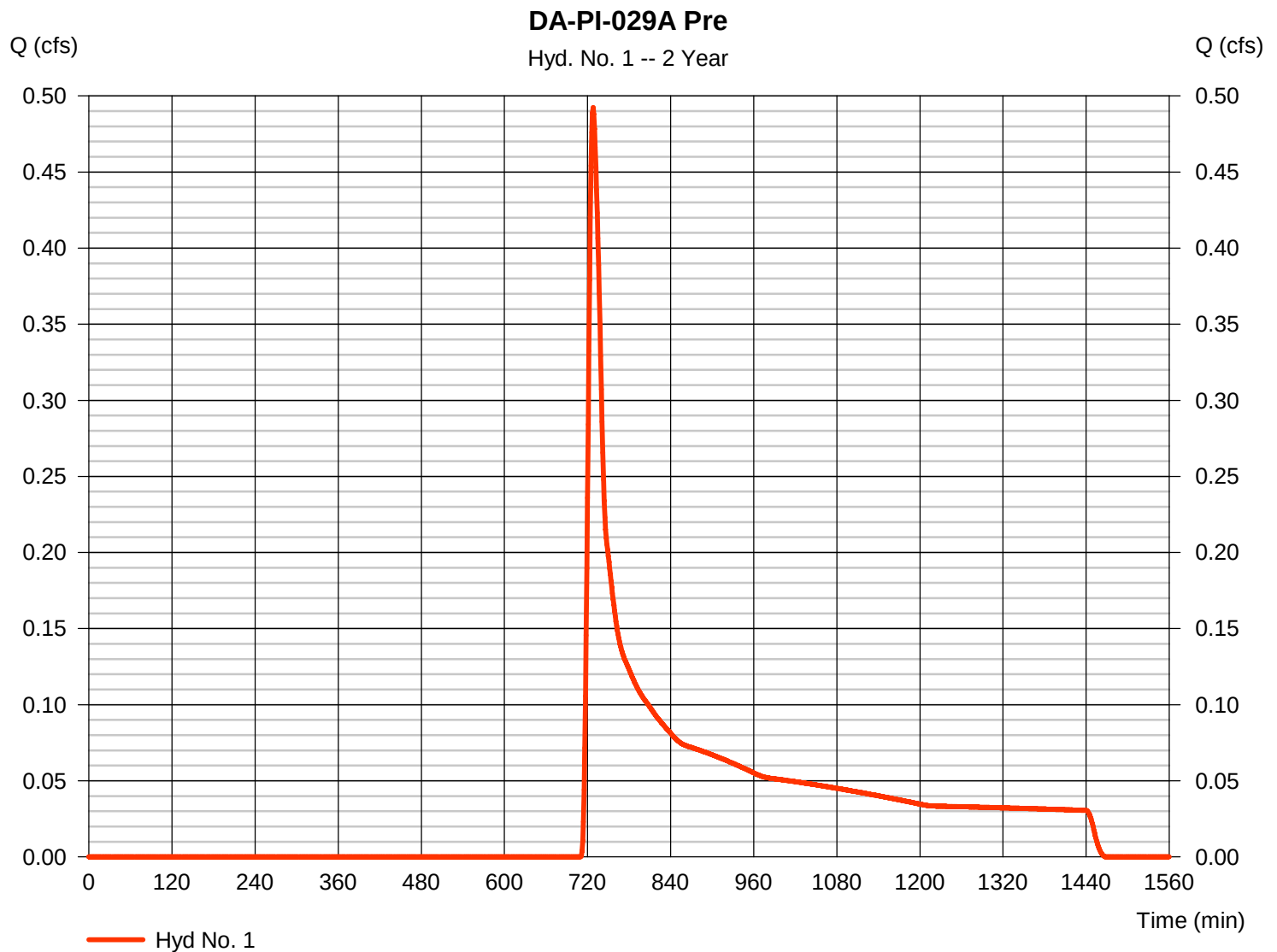
Thursday, 09 / 7 / 2017

Hyd. No. 1

DA-PI-029A Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.492 cfs
Storm frequency	= 2 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 2,916 cuft
Drainage area	= 2.350 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 17.80 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.070 \times 58) + (2.280 \times 55)] / 2.350$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

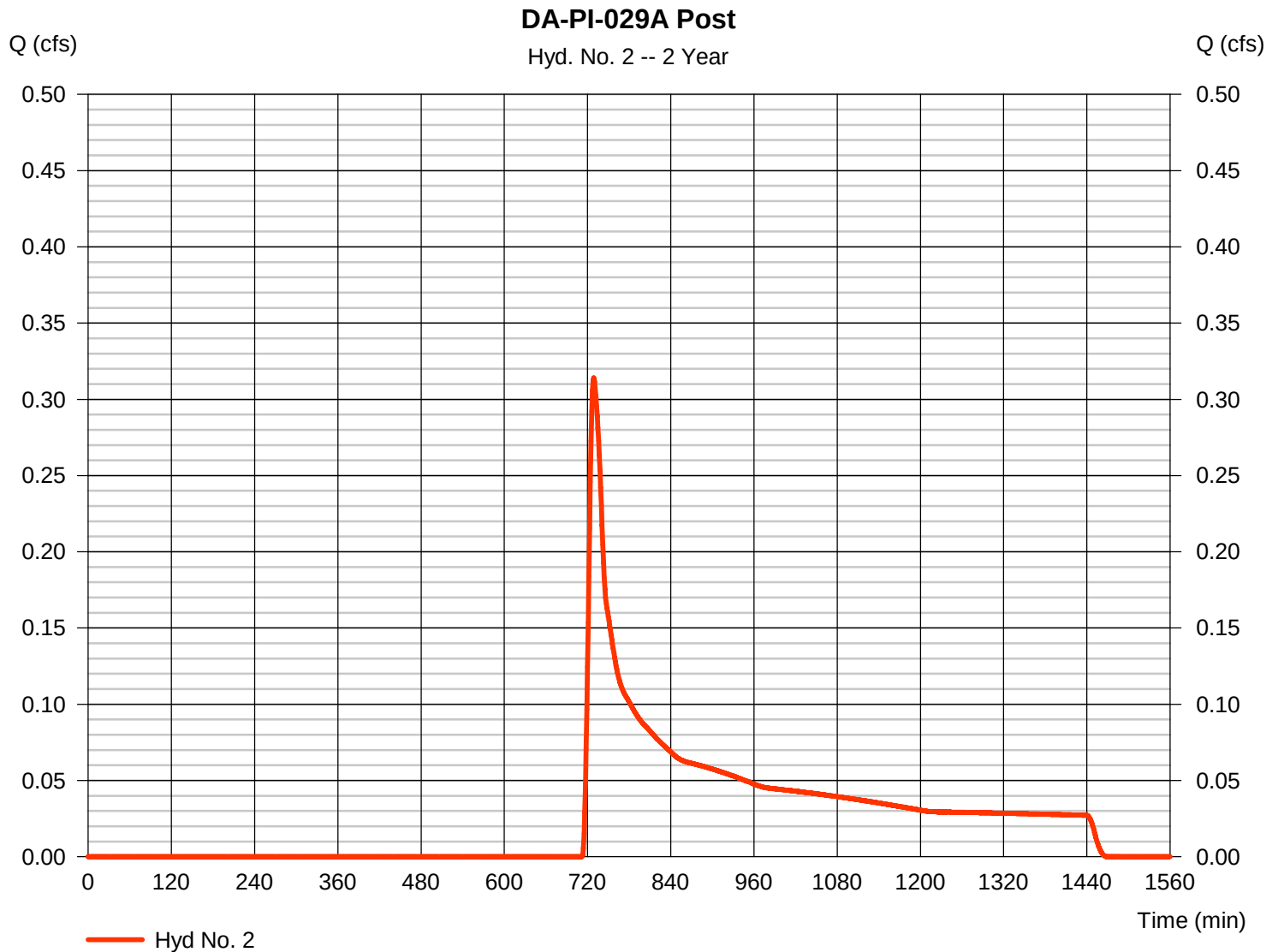
Thursday, 09 / 7 / 2017

Hyd. No. 2

DA-PI-029A Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.314 cfs
Storm frequency	= 2 yrs	Time to peak	= 729 min
Time interval	= 1 min	Hyd. volume	= 2,372 cuft
Drainage area	= 2.350 ac	Curve number	= 53*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 17.90 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.900 \times 58) + (0.370 \times 55) + (1.080 \times 48)] / 2.350$



Hydrograph Report

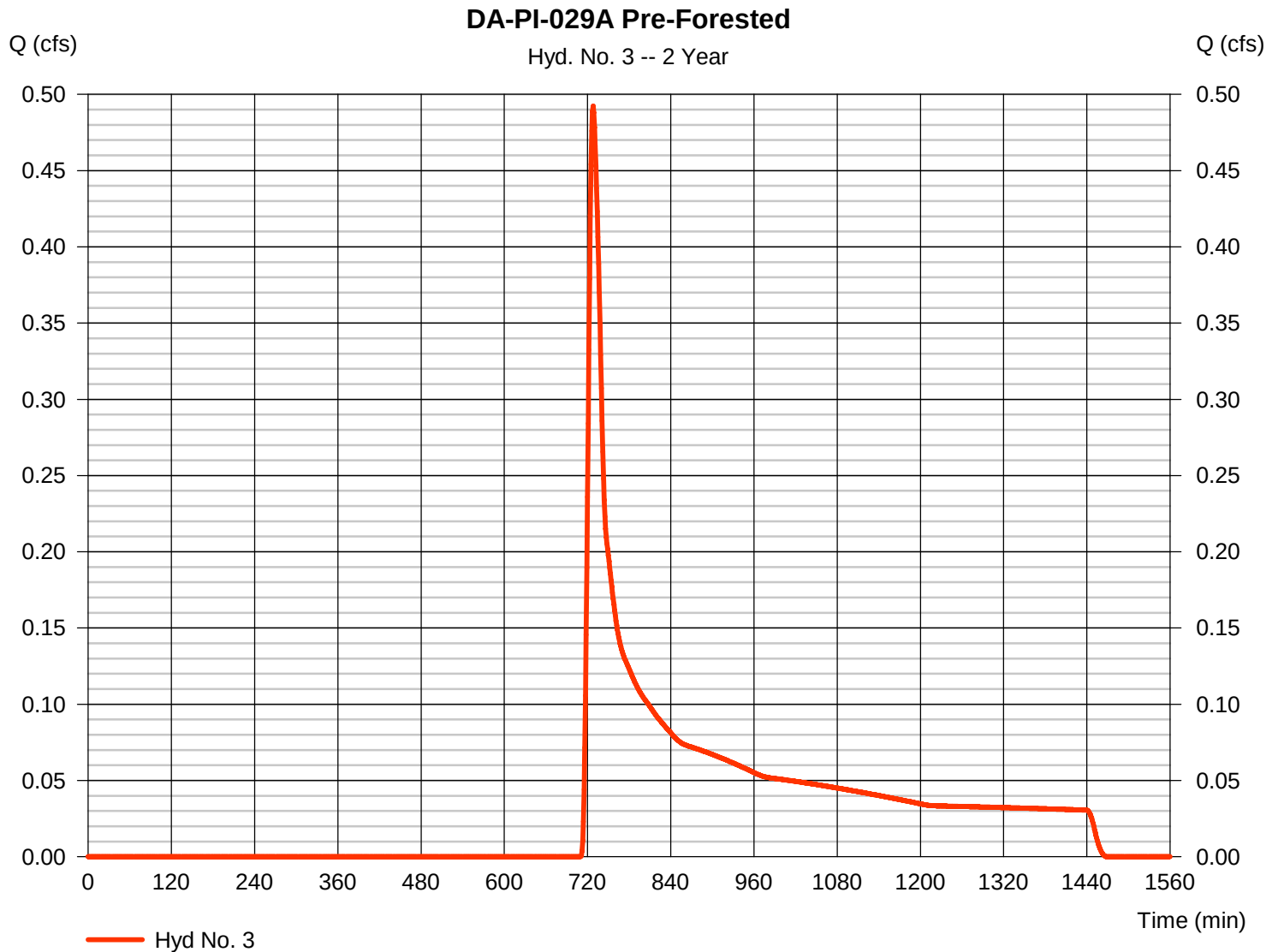
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Thursday, 09 / 7 / 2017

Hyd. No. 3

DA-PI-029A Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.492 cfs
Storm frequency	=	2 yrs	Time to peak	=	728 min
Time interval	=	1 min	Hyd. volume	=	2,916 cuft
Drainage area	=	2.350 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	17.80 min
Total precip.	=	3.50 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(2.350 \times 55)] / 2.350$ 

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	2.590	1	726	9,119	-----	-----	-----	DA-PI-029A Pre
2	SCS Runoff	2.163	1	726	8,053	-----	-----	-----	DA-PI-029A Post
3	SCS Runoff	2.590	1	726	9,119	-----	-----	-----	DA-PI-029A Pre-Forested
DA-PI-029A.gpw					Return Period: 10 Year			Thursday, 09 / 7 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

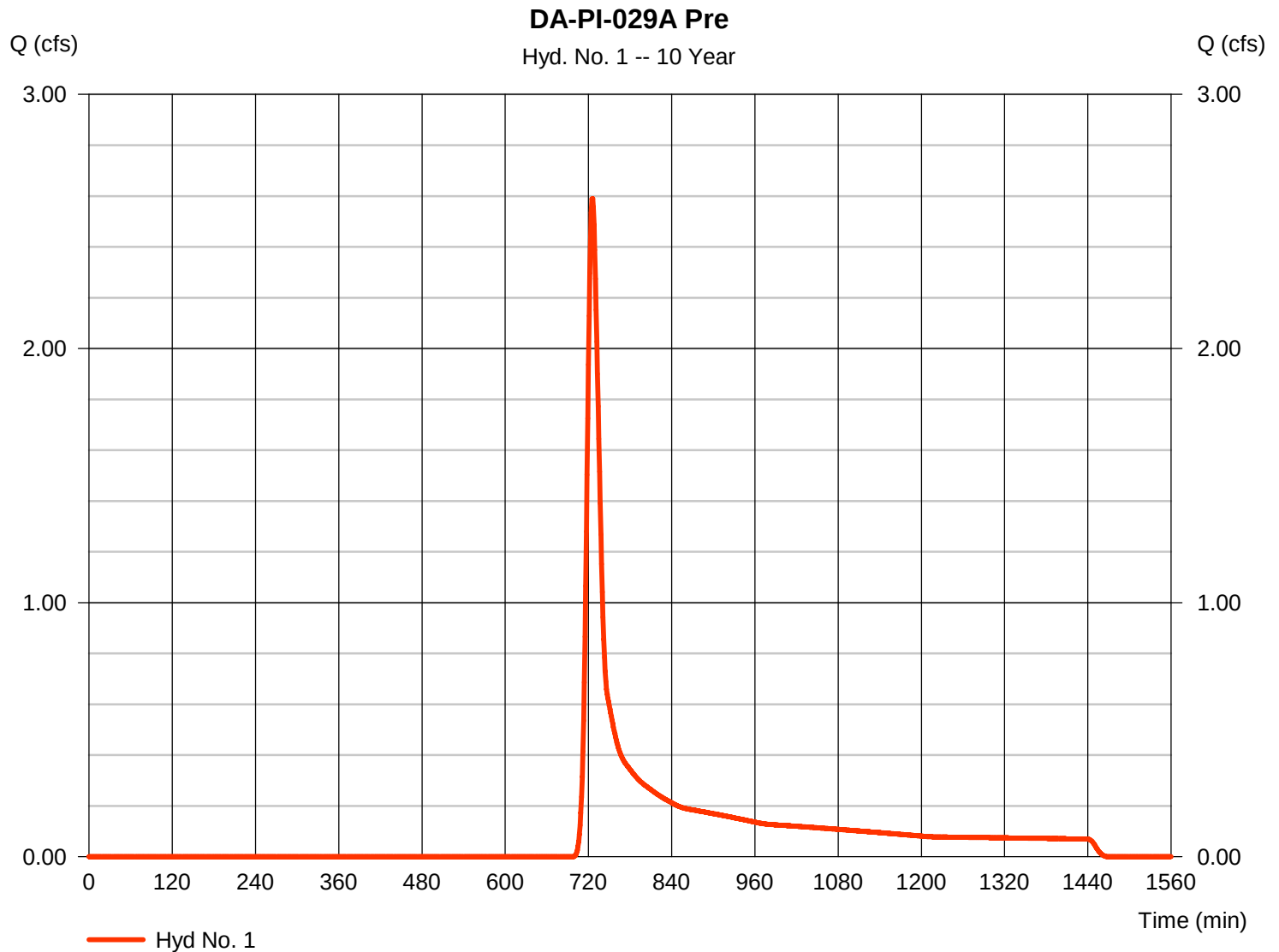
Thursday, 09 / 7 / 2017

Hyd. No. 1

DA-PI-029A Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 2.590 cfs
Storm frequency	= 10 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 9,119 cuft
Drainage area	= 2.350 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 17.80 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.070 \times 58) + (2.280 \times 55)] / 2.350$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

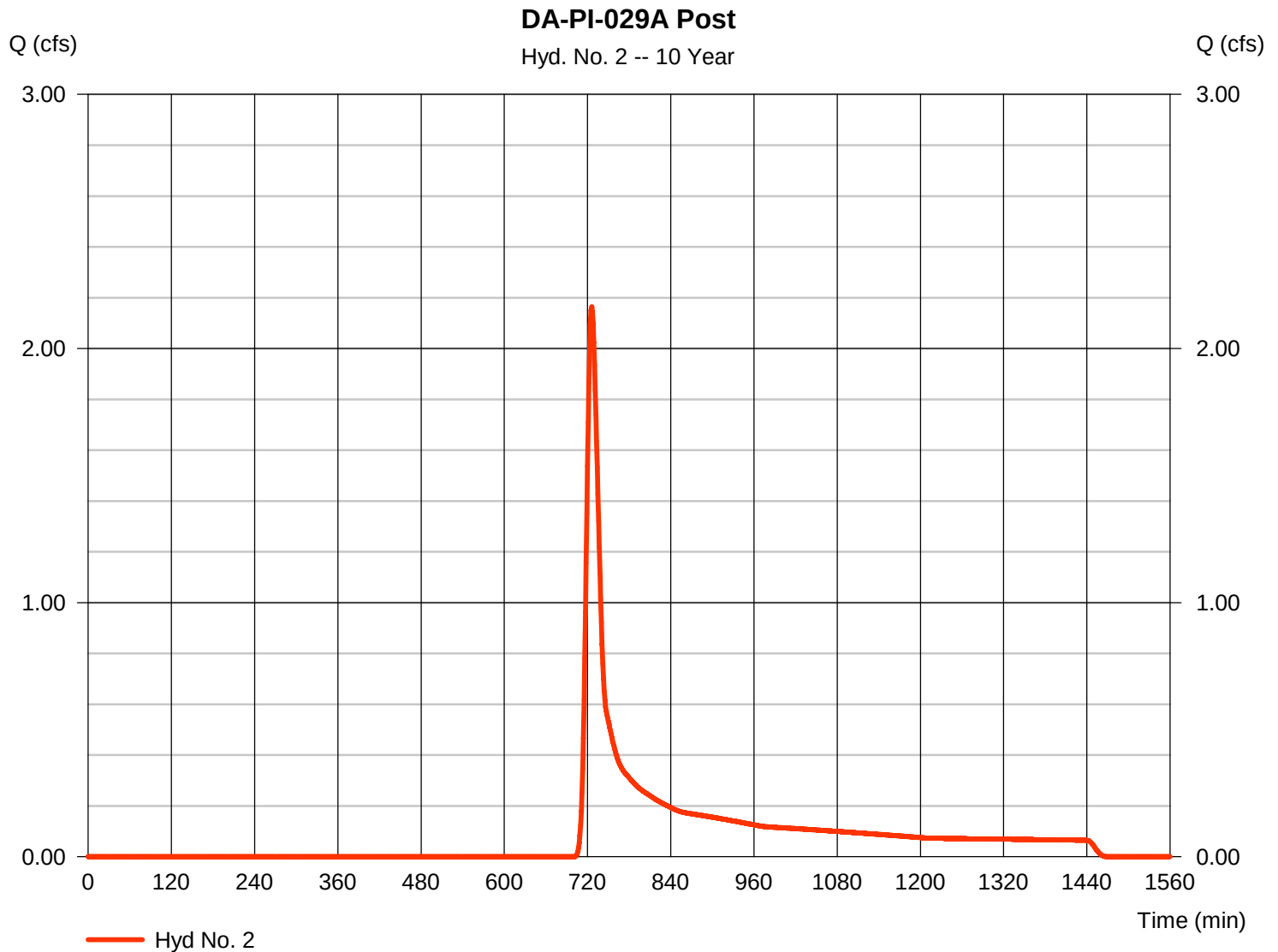
Thursday, 09 / 7 / 2017

Hyd. No. 2

DA-PI-029A Post

Hydrograph type	= SCS Runoff	Peak discharge	= 2.163 cfs
Storm frequency	= 10 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 8,053 cuft
Drainage area	= 2.350 ac	Curve number	= 53*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 17.90 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.900 \times 58) + (0.370 \times 55) + (1.080 \times 48)] / 2.350$



Hydrograph Report

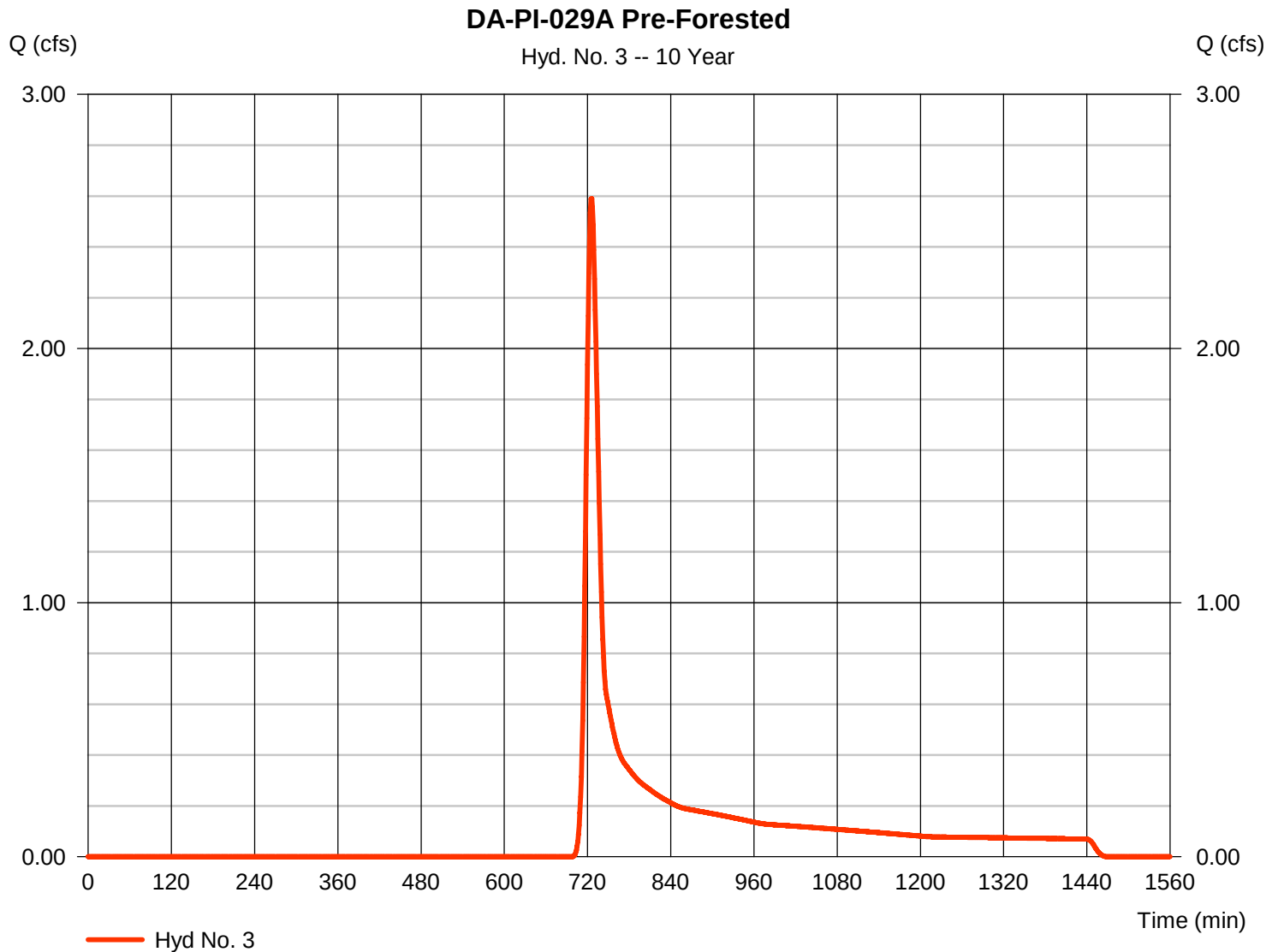
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Thursday, 09 / 7 / 2017

Hyd. No. 3

DA-PI-029A Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	2.590 cfs
Storm frequency	=	10 yrs	Time to peak	=	726 min
Time interval	=	1 min	Hyd. volume	=	9,119 cuft
Drainage area	=	2.350 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	17.80 min
Total precip.	=	5.20 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(2.350 \times 55)] / 2.350$ 

DA-PI-029B

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.337	3,931
Developed Condition	0.234	3,426
Pre-Developed (Forest) Condition	0.234	3,426

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 1

Calculations:

Check #1:

$$Q_{\text{developed}} \leq \text{IF} \times [(Q_{\text{pre-developed}} \times \text{RV}_{\text{pre-developed}}) / \text{RV}_{\text{developed}}] \text{ ----->}$$

Q (cfs)

0.234

≤

OK

Q (cfs)

0.387

Check #2:

$$Q_{\text{developed}} \leq Q_{\text{pre-developed}} \text{ ----->}$$

0.234

≤

OK

0.337

Check #3:

$$Q_{\text{developed}} \text{ shall not be required to be } \leq (Q_{\text{forest}} \times \text{RV}_{\text{forest}}) / \text{RV}_{\text{developed}} \text{ --->}$$

0.234

shall not be required to be ≤

0.234

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning's n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<i>Note:</i> Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted. ¹For Paved Road land surface types a Manning's n of 0.011 was used <i>Sources:</i> -USACE, 1998, HEC-1 Flood Hydrograph Package User's Manual, Hydrologic Engineering Center, Davis, CA -Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC	

Table 2 – Manning's n Values for Open Channel Flow

Channel Type	Manning n		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹For the developed condition, a conservative Manning's n value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar, level spreader diversion, or grass channel. ²For the pre-developed condition and post-development condition, a Manning's n value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-PI-029B Pre
2	SCS Runoff	DA-PI-029B Post
3	SCS Runoff	DA-PI-029B Pre-Forested

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.337	1	732	3,931	-----	-----	-----	DA-PI-029B Pre
2	SCS Runoff	0.234	1	736	3,426	-----	-----	-----	DA-PI-029B Post
3	SCS Runoff	0.234	1	736	3,426	-----	-----	-----	DA-PI-029B Pre-Forested
DA-PI-029B.gpw					Return Period: 1 Year			Thursday, 08 / 17 / 2017	

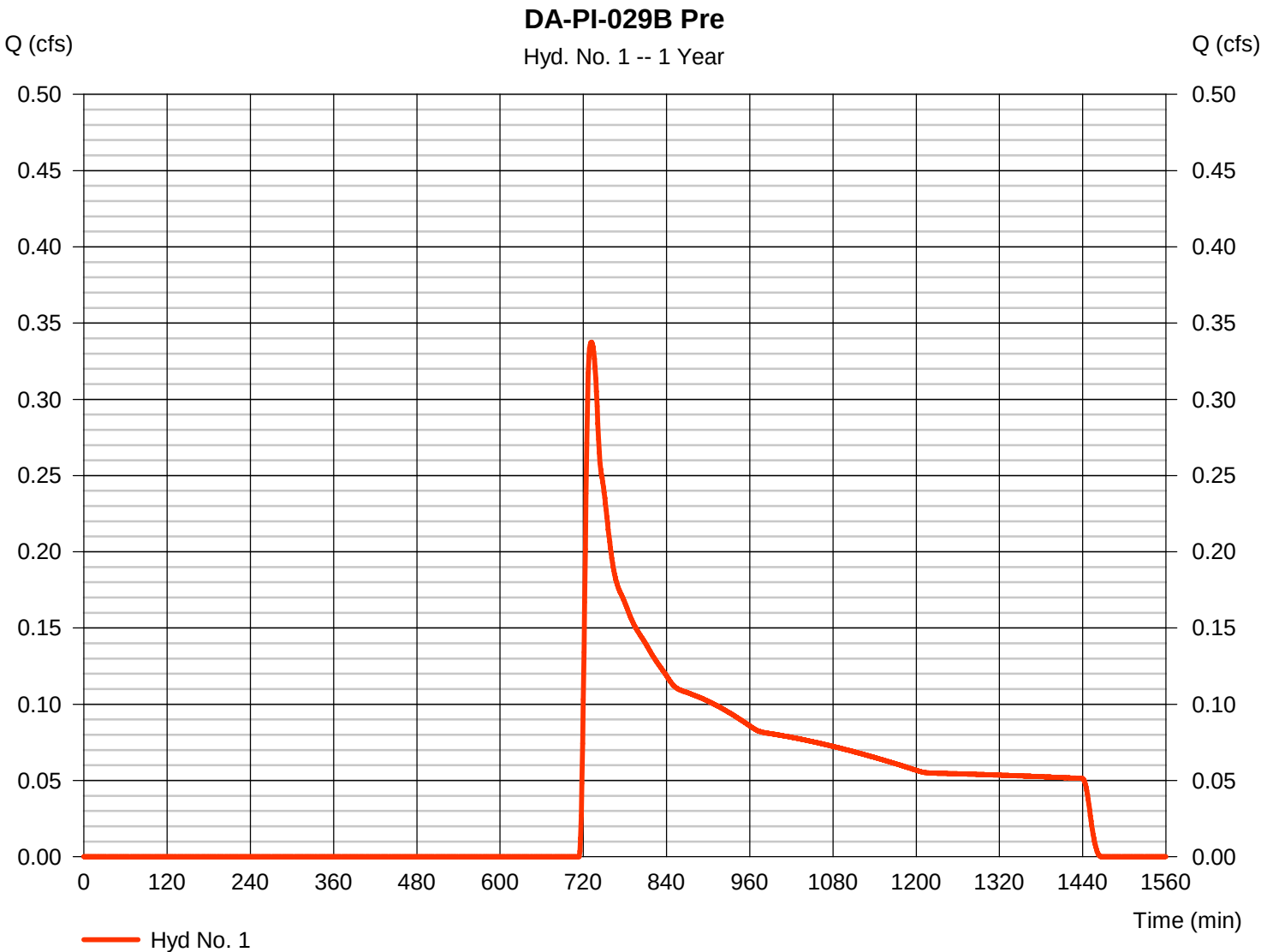
Hydrograph Report

Hyd. No. 1

DA-PI-029B Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.337 cfs
Storm frequency	= 1 yrs	Time to peak	= 732 min
Time interval	= 1 min	Hyd. volume	= 3,931 cuft
Drainage area	= 6.440 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.70 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(1.350 x 58) + (5.010 x 55) + (0.080 x 82)] / 6.440



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-PI-029B Pre

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 4.22	0.00	0.00				
Travel Time (min)	= 15.23	+	0.00	+	0.00	=	15.23
Shallow Concentrated Flow							
Flow length (ft)	= 425.05	0.00	0.00				
Watercourse slope (%)	= 10.76	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=5.29	0.00	0.00				
Travel Time (min)	= 1.34	+	0.00	+	0.00	=	1.34
Channel Flow							
X sectional flow area (sqft)	= 172.58	0.00	0.00				
Wetted perimeter (ft)	= 92.76	0.00	0.00				
Channel slope (%)	= 11.89	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=25.96	0.00	0.00				
Flow length (ft)	(0)}253.3	0.0	0.0				
Travel Time (min)	= 0.16	+	0.00	+	0.00	=	0.16
Total Travel Time, Tc				16.70 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

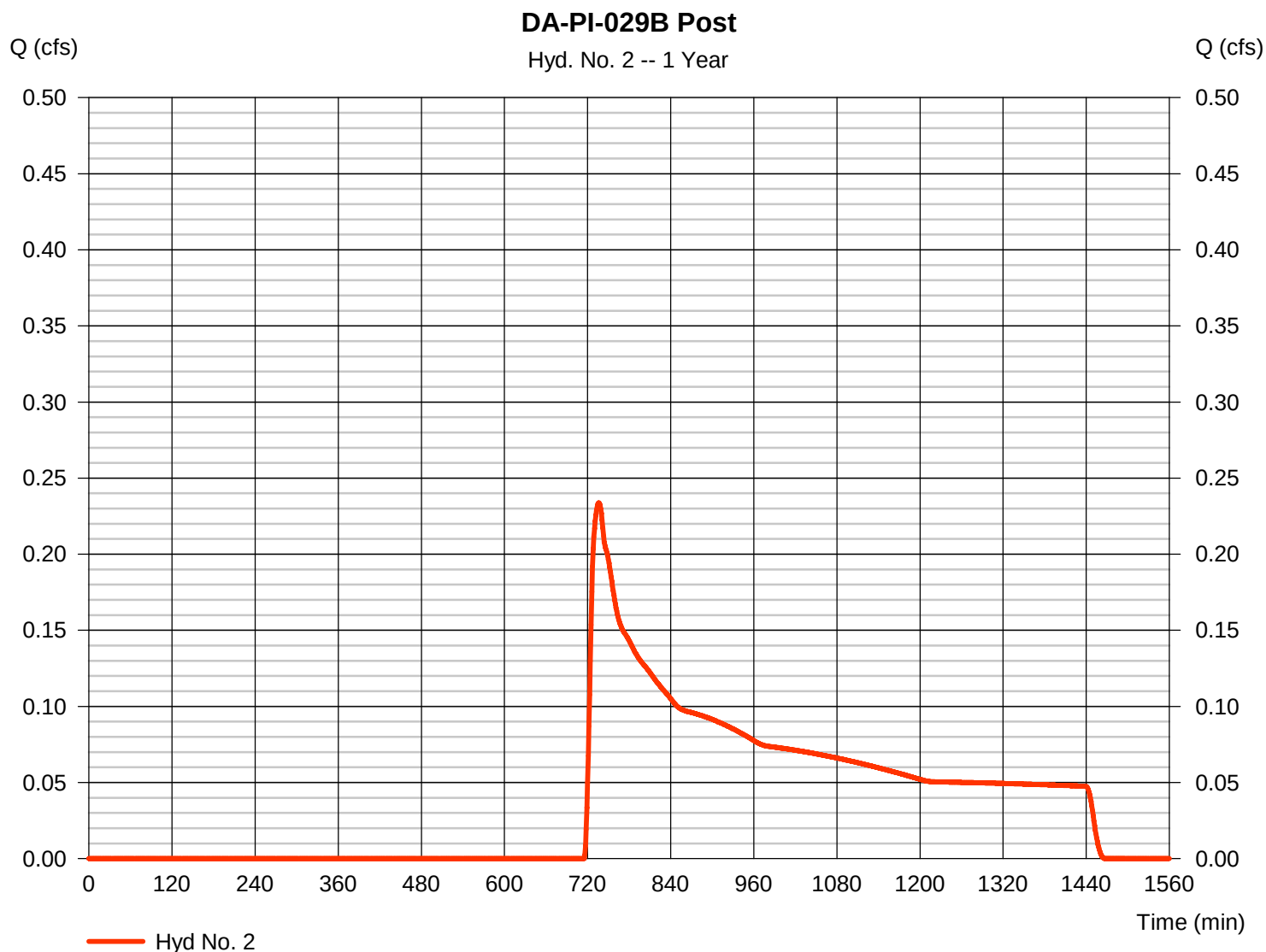
Thursday, 08 / 17 / 2017

Hyd. No. 2

DA-PI-029B Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.234 cfs
Storm frequency	= 1 yrs	Time to peak	= 736 min
Time interval	= 1 min	Hyd. volume	= 3,426 cuft
Drainage area	= 6.440 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.70 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.960 \times 58) + (3.640 \times 55) + (0.080 \times 82) + (0.760 \times 48)] / 6.440$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-PI-029B Post

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 4.22	0.00	0.00				
Travel Time (min)	= 15.23	+	0.00	+	0.00	=	15.23
Shallow Concentrated Flow							
Flow length (ft)	= 249.69	177.25	0.00				
Watercourse slope (%)	= 9.77	11.68	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=5.04	6.95	0.00				
Travel Time (min)	= 0.83	+	0.43	+	0.00	=	1.25
Channel Flow							
X sectional flow area (sqft)	= 2.00	172.58	0.00				
Wetted perimeter (ft)	= 4.47	92.76	0.00				
Channel slope (%)	= 5.00	11.89	0.00				
Manning's n-value	= 0.040	0.030	0.015				
Velocity (ft/s)	=4.86	25.96	0.00				
Flow length (ft)	({0})22.6	253.3	0.0				
Travel Time (min)	= 0.08	+	0.16	+	0.00	=	0.24
Total Travel Time, Tc				16.70 min			

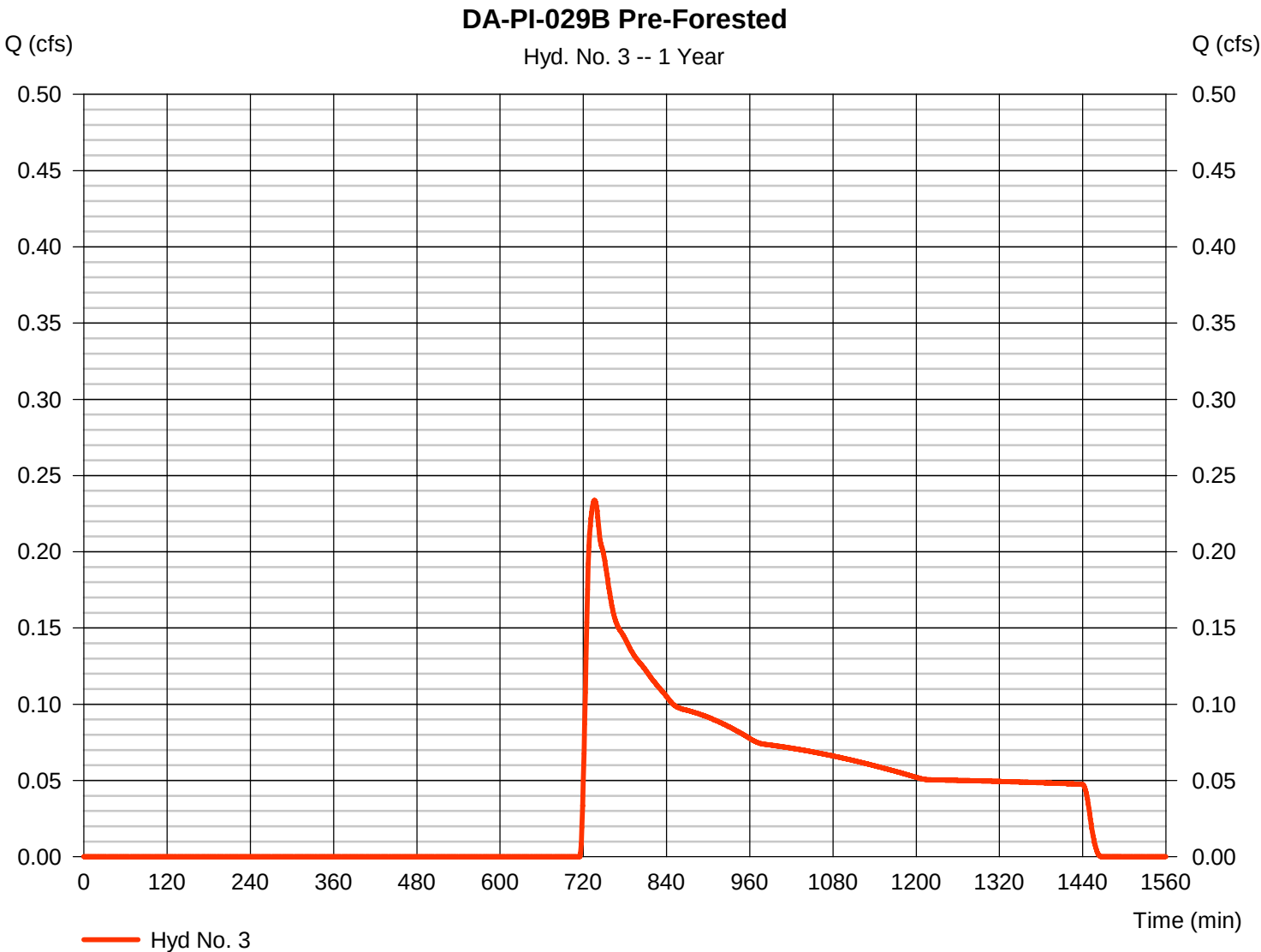
Hydrograph Report

Hyd. No. 3

DA-PI-029B Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.234 cfs
Storm frequency	=	1 yrs	Time to peak	=	736 min
Time interval	=	1 min	Hyd. volume	=	3,426 cuft
Drainage area	=	6.440 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	16.70 min
Total precip.	=	2.80 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(6.440 x 55)] / 6.440



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-PI-029B Pre-Forested

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 4.22	0.00	0.00				
Travel Time (min)	= 15.23	+	0.00	+	0.00	=	15.23
Shallow Concentrated Flow							
Flow length (ft)	= 425.05	0.00	0.00				
Watercourse slope (%)	= 10.76	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=5.29	0.00	0.00				
Travel Time (min)	= 1.34	+	0.00	+	0.00	=	1.34
Channel Flow							
X sectional flow area (sqft)	= 172.58	0.00	0.00				
Wetted perimeter (ft)	= 92.76	0.00	0.00				
Channel slope (%)	= 11.89	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=25.96	0.00	0.00				
Flow length (ft)	((0})253.3	0.0	0.0				
Travel Time (min)	= 0.16	+	0.00	+	0.00	=	0.16
Total Travel Time, Tc				16.70 min			

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	1.744	1	727	8,996	-----	-----	-----	DA-PI-029B Pre
2	SCS Runoff	1.446	1	727	8,183	-----	-----	-----	DA-PI-029B Post
3	SCS Runoff	1.446	1	727	8,183	-----	-----	-----	DA-PI-029B Pre-Forested
DA-PI-029B.gpw					Return Period: 2 Year			Thursday, 08 / 17 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

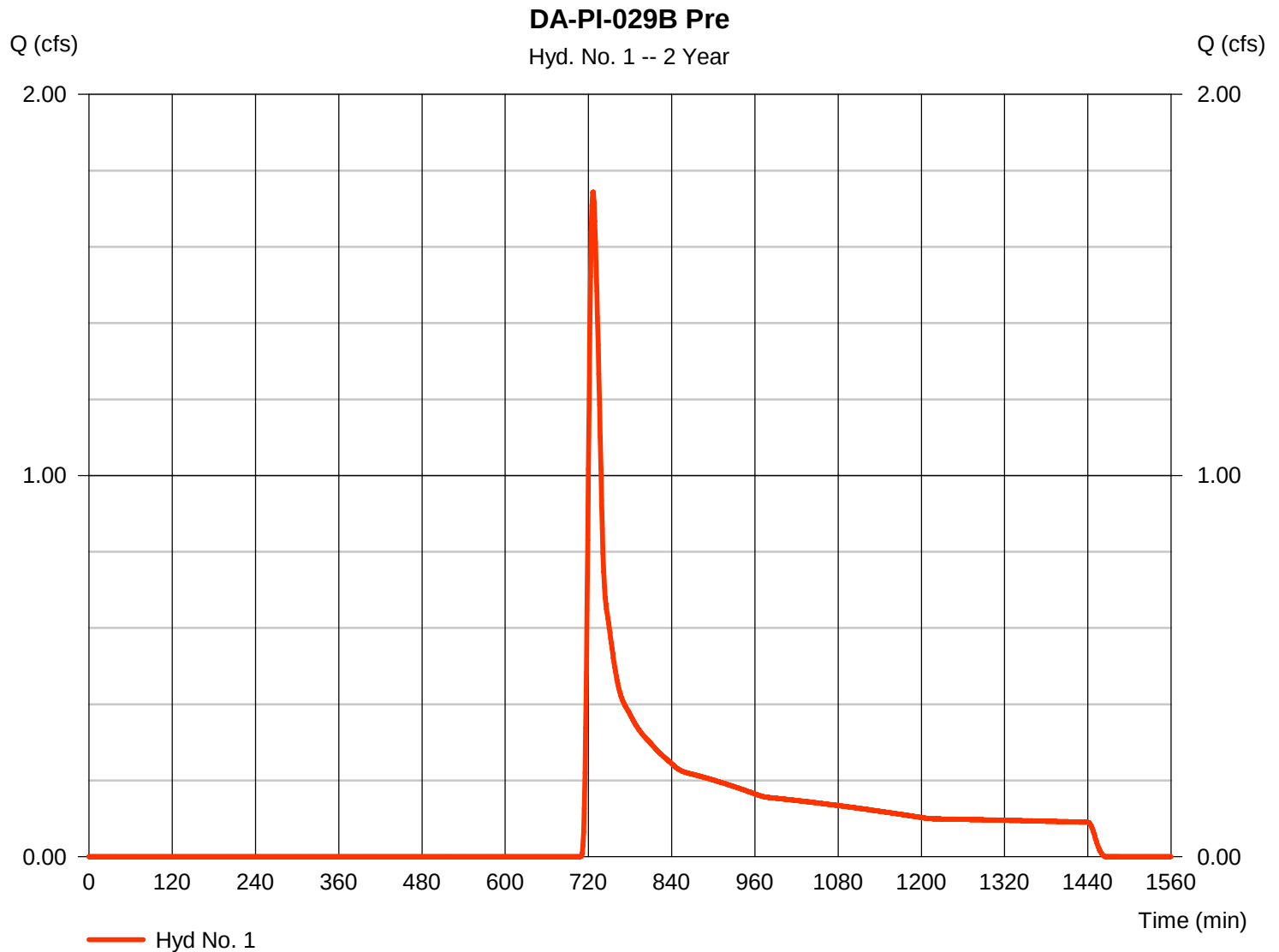
Thursday, 08 / 17 / 2017

Hyd. No. 1

DA-PI-029B Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 1.744 cfs
Storm frequency	= 2 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 8,996 cuft
Drainage area	= 6.440 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.70 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.350 \times 58) + (5.010 \times 55) + (0.080 \times 82)] / 6.440$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

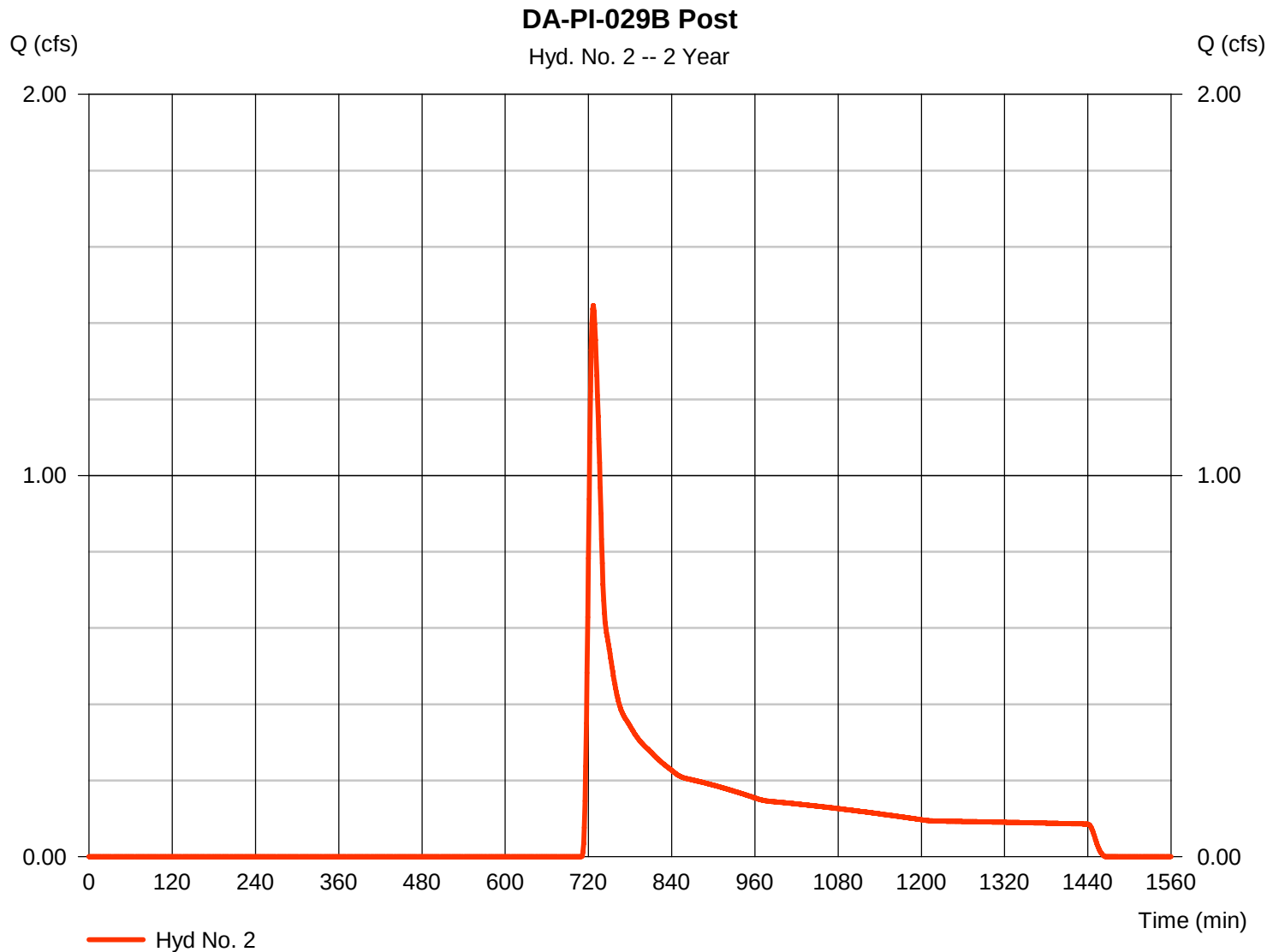
Thursday, 08 / 17 / 2017

Hyd. No. 2

DA-PI-029B Post

Hydrograph type	= SCS Runoff	Peak discharge	= 1.446 cfs
Storm frequency	= 2 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 8,183 cuft
Drainage area	= 6.440 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.70 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.960 \times 58) + (3.640 \times 55) + (0.080 \times 82) + (0.760 \times 48)] / 6.440$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

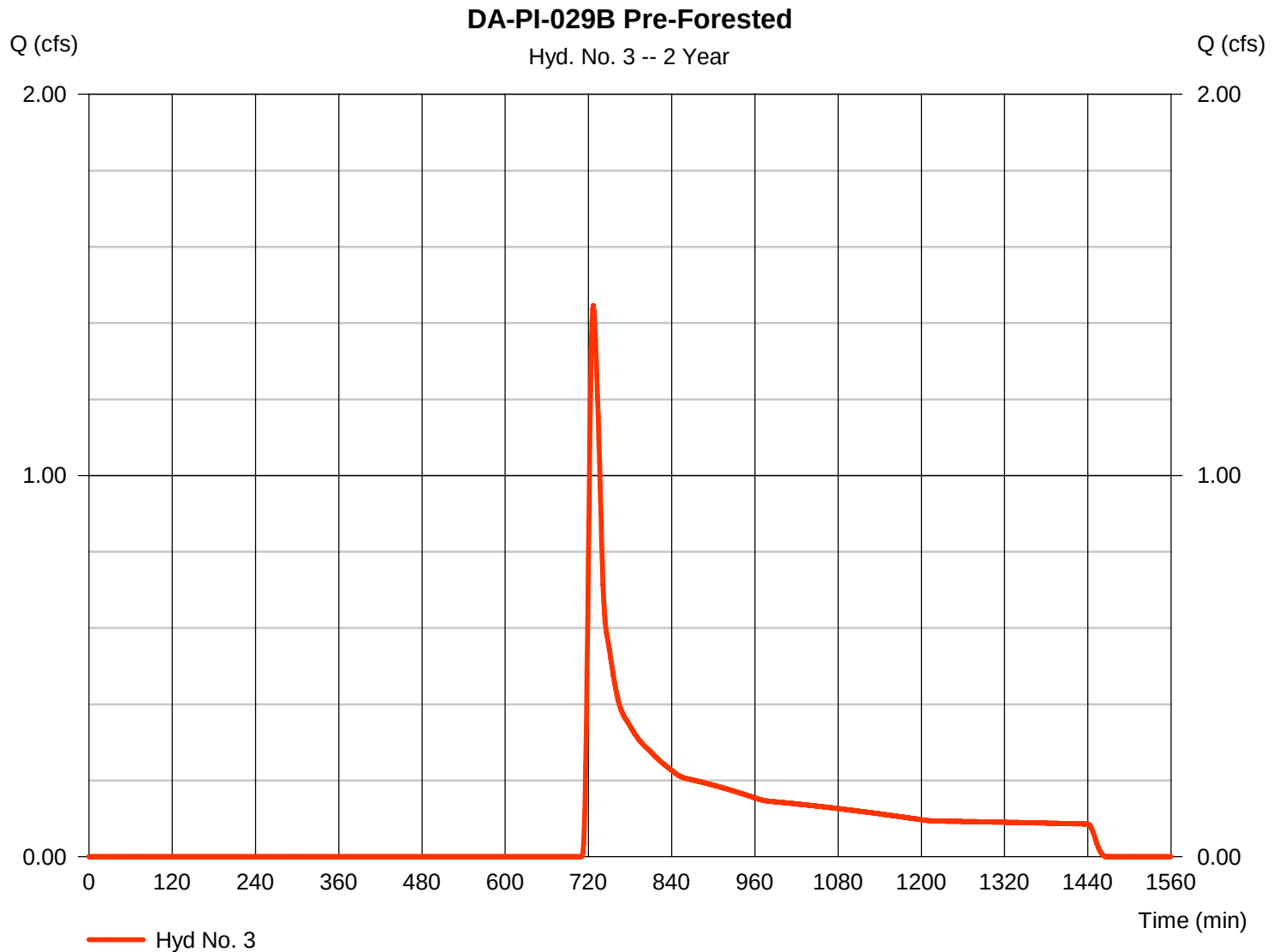
Thursday, 08 / 17 / 2017

Hyd. No. 3

DA-PI-029B Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 1.446 cfs
Storm frequency	= 2 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 8,183 cuft
Drainage area	= 6.440 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.70 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(6.440 x 55)] / 6.440



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	8.250	1	724	27,133	-----	-----	-----	DA-PI-029B Pre
2	SCS Runoff	7.602	1	725	25,592	-----	-----	-----	DA-PI-029B Post
3	SCS Runoff	7.602	1	725	25,592	-----	-----	-----	DA-PI-029B Pre-Forested
DA-PI-029B.gpw					Return Period: 10 Year			Thursday, 08 / 17 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

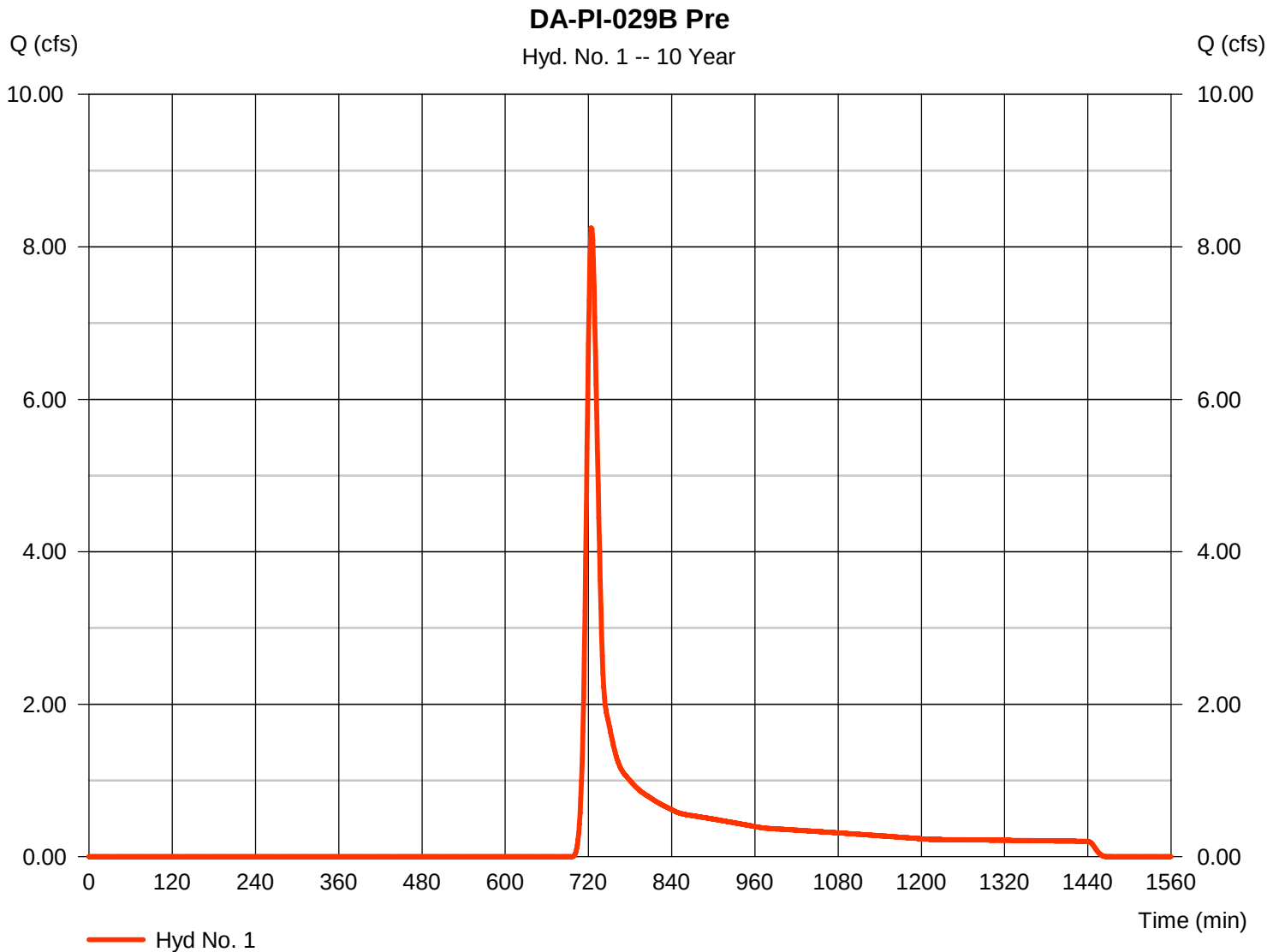
Thursday, 08 / 17 / 2017

Hyd. No. 1

DA-PI-029B Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 8.250 cfs
Storm frequency	= 10 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 27,133 cuft
Drainage area	= 6.440 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.70 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.350 \times 58) + (5.010 \times 55) + (0.080 \times 82)] / 6.440$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

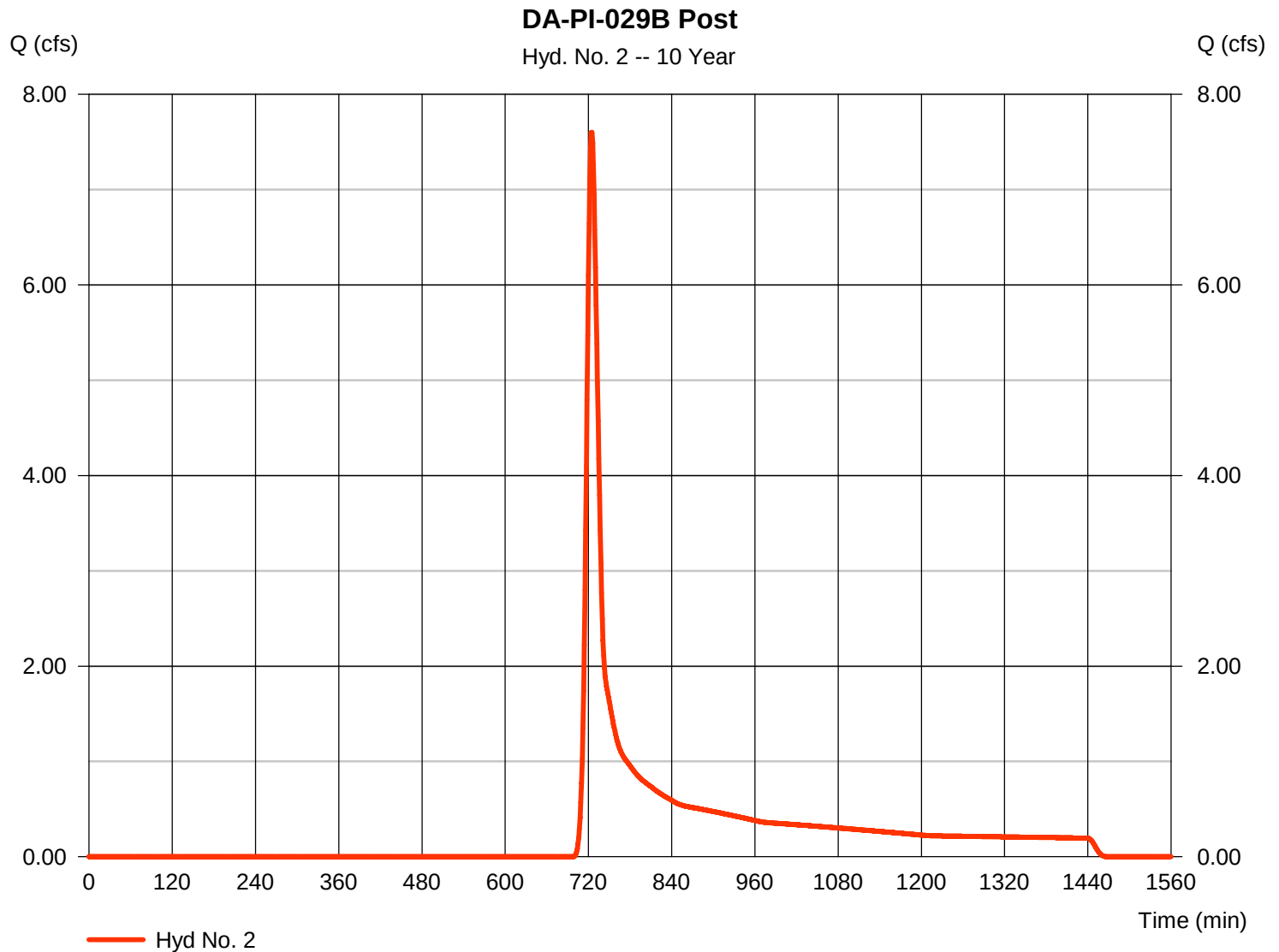
Thursday, 08 / 17 / 2017

Hyd. No. 2

DA-PI-029B Post

Hydrograph type	= SCS Runoff	Peak discharge	= 7.602 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 25,592 cuft
Drainage area	= 6.440 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.70 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.960 \times 58) + (3.640 \times 55) + (0.080 \times 82) + (0.760 \times 48)] / 6.440$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

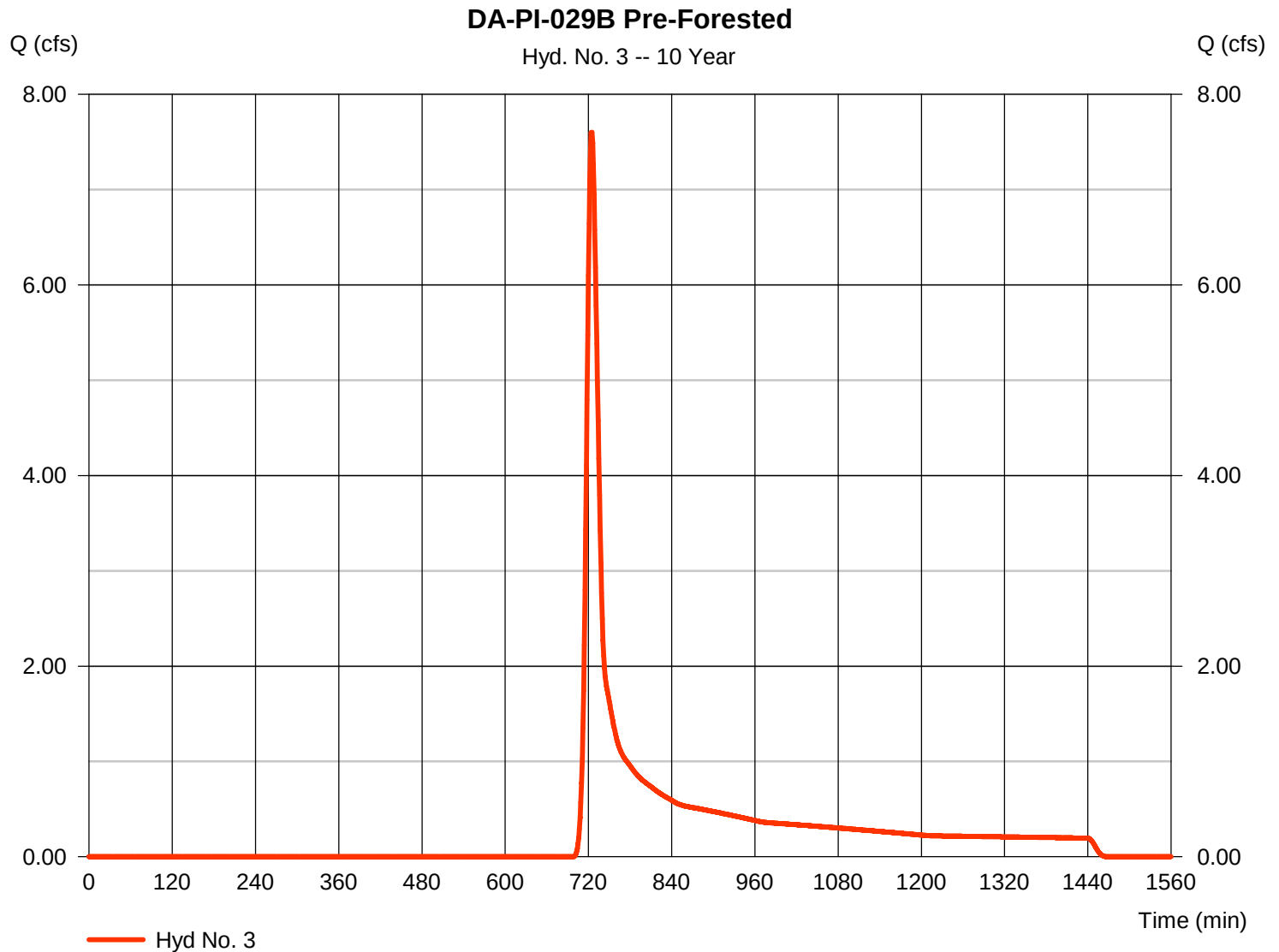
Thursday, 08 / 17 / 2017

Hyd. No. 3

DA-PI-029B Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	7.602 cfs
Storm frequency	=	10 yrs	Time to peak	=	725 min
Time interval	=	1 min	Hyd. volume	=	25,592 cuft
Drainage area	=	6.440 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	16.70 min
Total precip.	=	5.20 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(6.440 x 55)] / 6.440



BMPs are sited in DA-PI-029A, so the resulting changes were not made to the stormwater calculations prior to submittal.

DA-PI-030

DA-PI-030 is located in a meadow and forested area with low to moderate slopes. DA-PI-030 contains existing dirt roads and impervious area, including Anderson Mill Road, which cover 6% of the overall drainage area. No new impervious areas are proposed within DA-PI-030. Multiple points of analysis were evaluated within DA-PI-030 to determine the effects on each receiving stream/channel following construction. Specifically, DA-PI-030 was sub-divided into two sub-drainage areas (sub-areas A and B). Sub-areas DA-PI-030A and DA-PI-030B both contain agricultural area within the limits of disturbance (LOD).

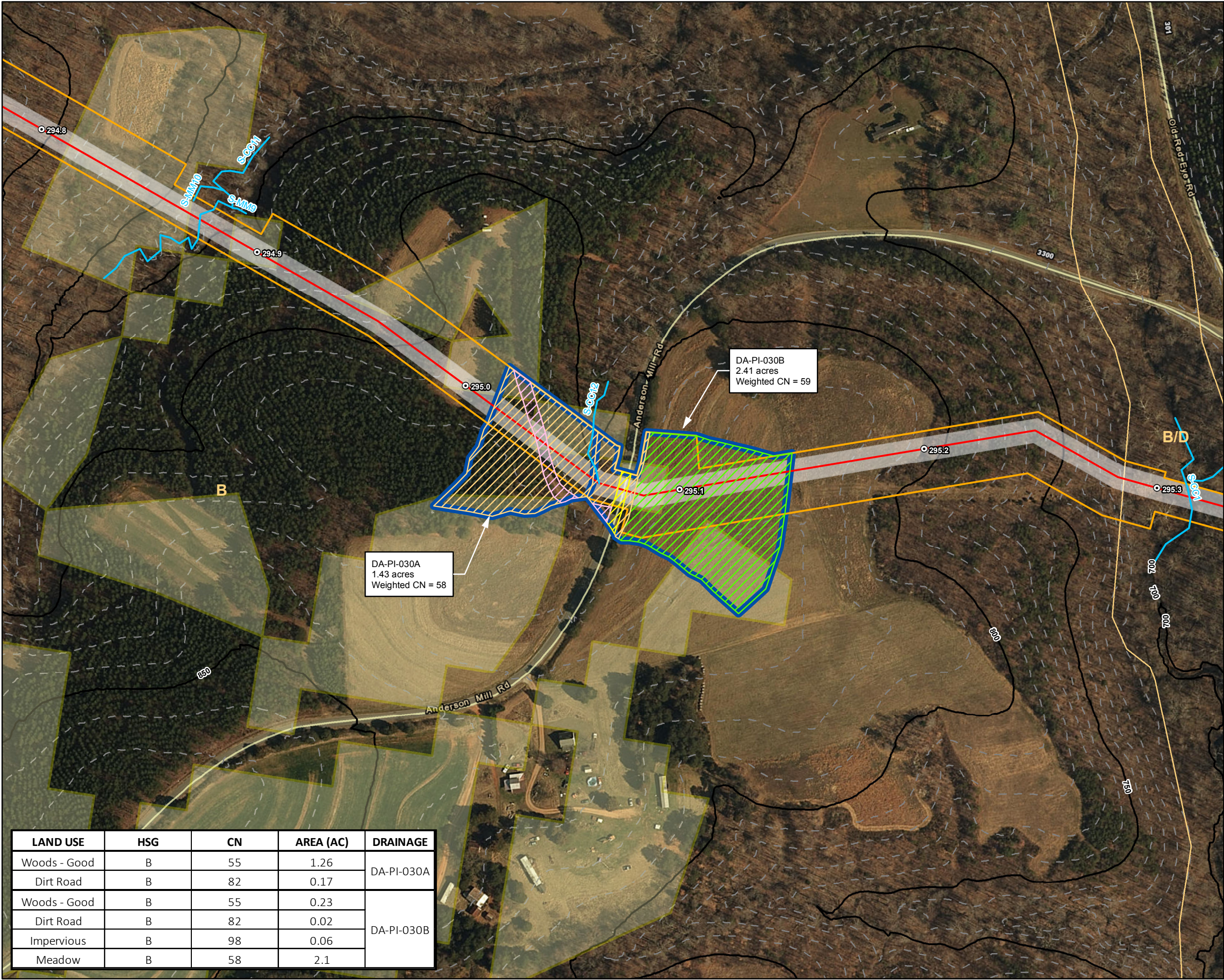
Pre-construction agricultural areas will be returned to agricultural land use (i.e., returned to crop production, in identical condition) following construction, but in non-agricultural areas, land use will be restored following construction as noted in the Stormwater Management (SWM) Narrative and the Annual Standards and Specifications. Agricultural areas within the LOD are included in the SWM quality analysis and the total permanent ROW is analyzed via VRRM; in these calculations agricultural areas are considered "Forest/Open Space". The total phosphorus load reduction required for DA-PI-030 is -0.13 lbs/yr.

Stormwater quantity is met via the energy balance method for each sub-area – DA-PI-030A and DA-PI-030B. Agricultural areas within the study area are included in the SWM quantity analysis, but an improvement factor of 1.00 is used when applying the energy balance method. This improvement factor is used to account for the exemption of agricultural areas (§ 62.1-44.15:34 and 9VAC25-870-300) since such areas will be returned to agricultural land use (i.e., returned to crop production, in identical condition) following construction.

In addition, the Hydraflow hydrographs 10-year 24-hour peak discharge results indicate a decrease in flow ranging from 0.00 cfs to 0.14 cfs (as seen in table below).

Sub-area	Pre-peak Flow, 10-yr Q (cfs)	Post-peak Flow, 10-yr Q (cfs)	Flow Differential
DA-PI-030A	1.99	1.85	-0.14
DA-PI-030B	2.82	2.82	0.00

Figures and calculations for DA-PI-030 follow. See Appendix D of the Annual Standards and Specifications for further detail on stormwater methodology.



LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Woods - Good	B	55	1.26	DA-PI-030A
Dirt Road	B	82	0.17	
Woods - Good	B	55	0.23	DA-PI-030B
Dirt Road	B	82	0.02	
Impervious	B	98	0.06	
Meadow	B	58	2.1	

Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Dirt Road
- Impervious
- Meadow
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

1:2,400

200 100 0 200 Feet

W N E S

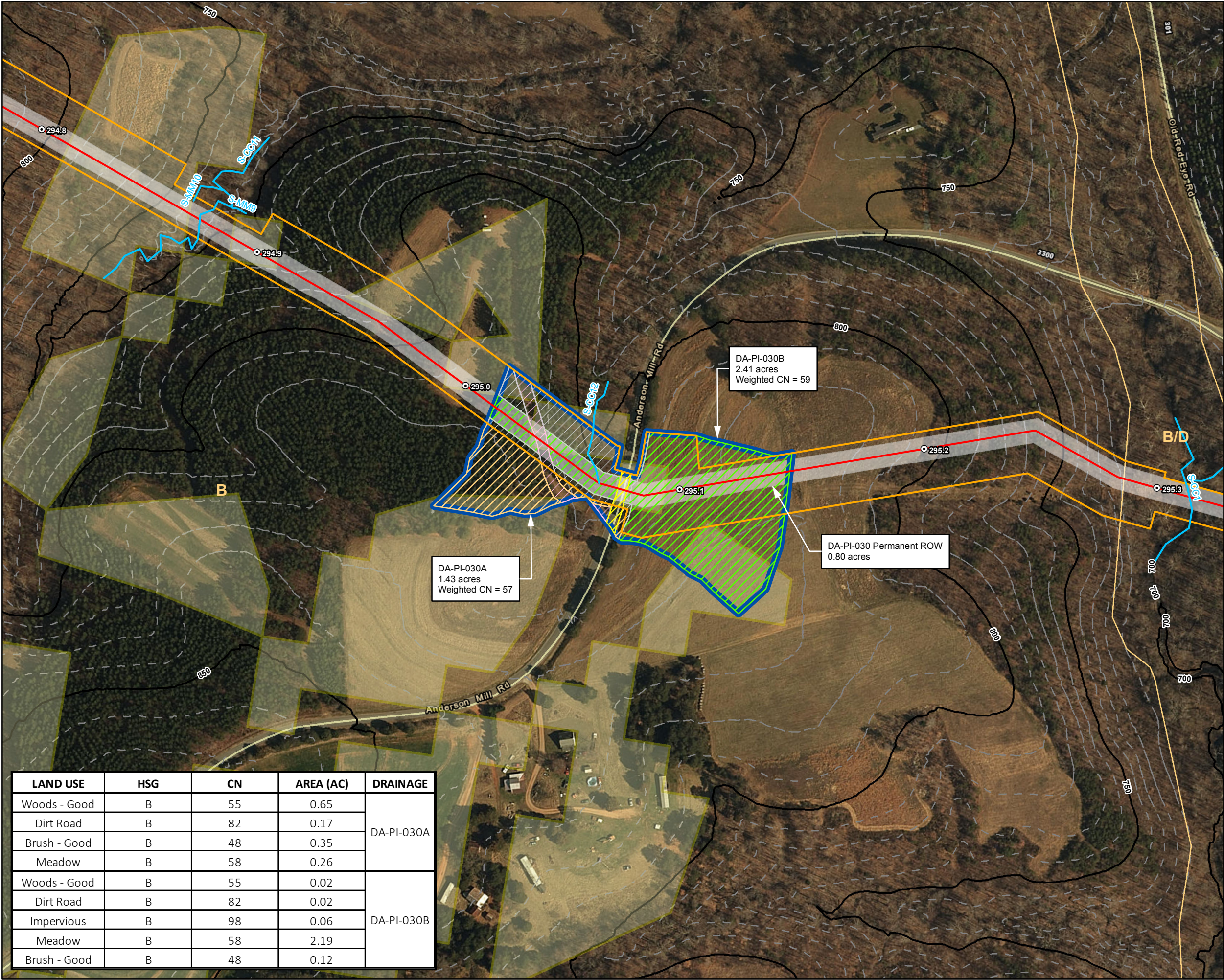
Mountain Valley Pipeline Project

Pre-Construction Drainage Area Map
DA-PI-030
Spread 11

Figure 1
Pittsylvania County, Virginia

August, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LIDAR provided by EQT 2016, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015, Agricultural Area from National Land Cover Dataset 2011.



Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Brush
- Dirt Road
- Impervious
- Meadow
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

1:2,400

200 100 0 200 Feet

North Arrow



Mountain Valley Pipeline Project



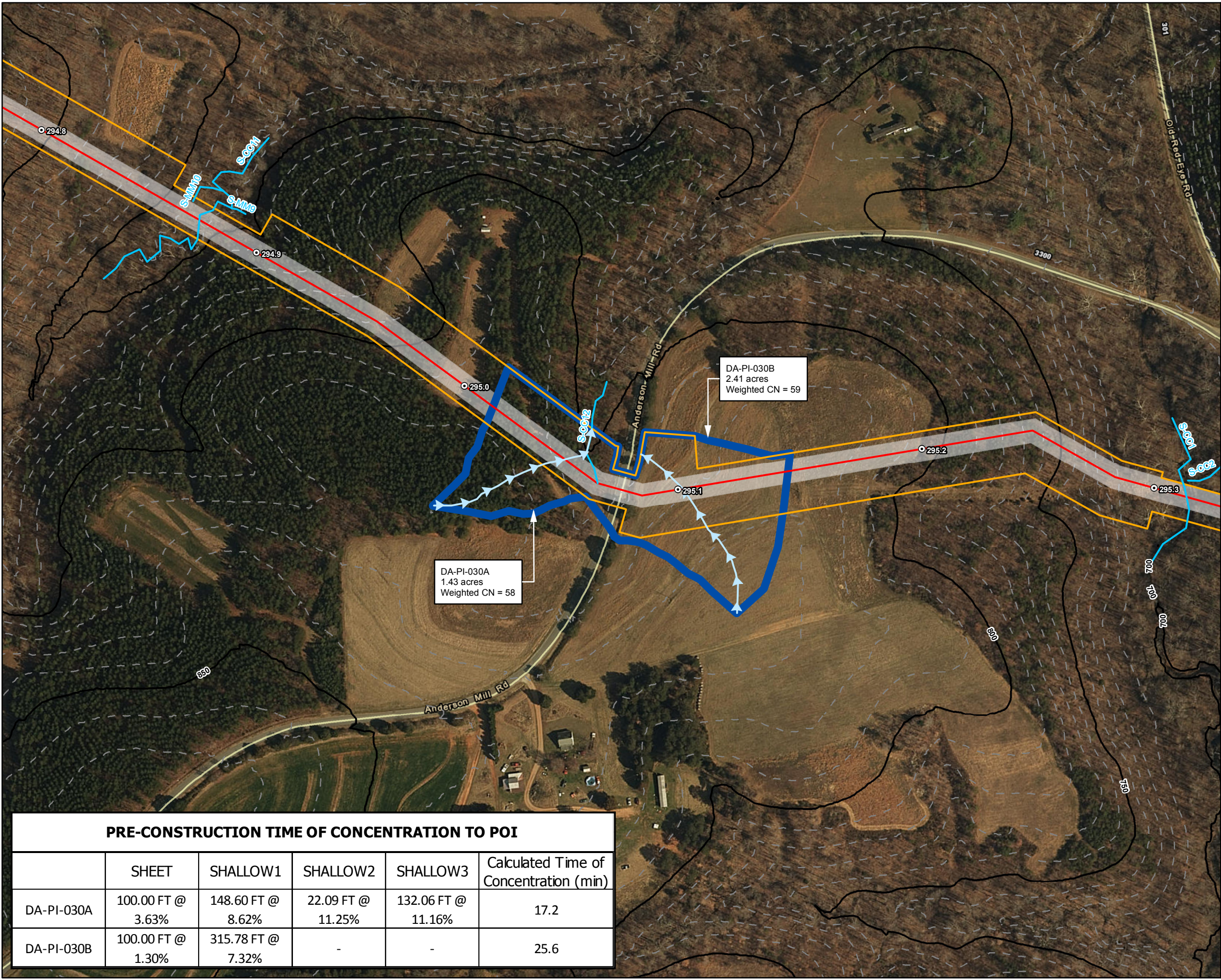
Post-Construction Drainage Area Map
DA-PI-030
Spread 11

Figure 2
Pittsylvania County, Virginia

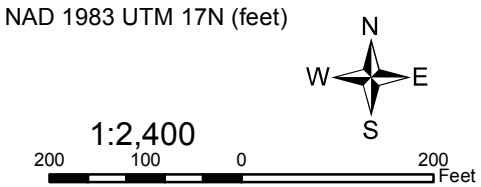
August, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LIDAR provided by EQT 2016, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015, Agricultural Area from National Land Cover Dataset 2011.

LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Woods - Good	B	55	0.65	DA-PI-030A
Dirt Road	B	82	0.17	
Brush - Good	B	48	0.35	
Meadow	B	58	0.26	
Woods - Good	B	55	0.02	DA-PI-030B
Dirt Road	B	82	0.02	
Impervious	B	98	0.06	
Meadow	B	58	2.19	
Brush - Good	B	48	0.12	



- Legend**
- Milepost
 - Delineated Stream
 - Existing 50' Contour
 - - Existing 10' Contour
 - Road Centerline
 - Alignment Centerline
 - Limit of Disturbance
 - Permanent Right-of-Way
 - Time of Concentration
 - Drainage Area



PRE-CONSTRUCTION TIME OF CONCENTRATION TO POI					
	SHEET	SHALLOW1	SHALLOW2	SHALLOW3	Calculated Time of Concentration (min)
DA-PI-030A	100.00 FT @ 3.63%	148.60 FT @ 8.62%	22.09 FT @ 11.25%	132.06 FT @ 11.16%	17.2
DA-PI-030B	100.00 FT @ 1.30%	315.78 FT @ 7.32%	-	-	25.6

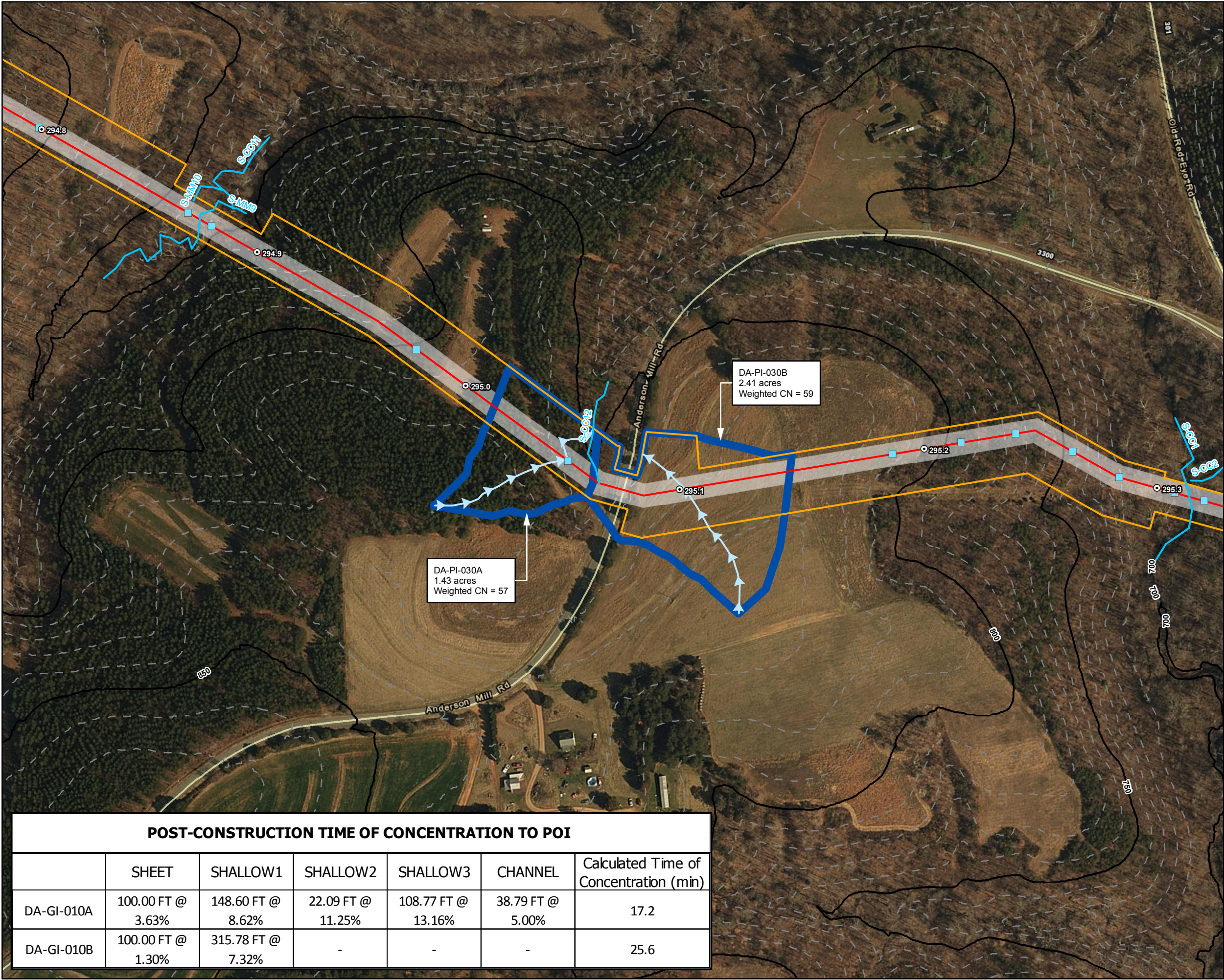
Mountain Valley Pipeline Project



**Pre-Construction Drainage Area
and Time of Concentration
DA-PI-030
Spread 11**

Figure 3
Pittsylvania County, Virginia
August, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016.



Legend

- Milepost
- Permanent Waterbars
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:2,400

200 100 0 200 Feet

W N E S

Mountain Valley Pipeline Project

Mountain Valley
PIPELINE

**Post-Construction Drainage Area
and Time of Concentration**

DA-PI-030

Spread 11

Figure 4
Pittsylvania County, Virginia
September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016.

POST-CONSTRUCTION TIME OF CONCENTRATION TO POI						
	SHEET	SHALLOW1	SHALLOW2	SHALLOW3	CHANNEL	Calculated Time of Concentration (min)
DA-GI-010A	100.00 FT @ 3.63%	148.60 FT @ 8.62%	22.09 FT @ 11.25%	108.77 FT @ 13.16%	38.79 FT @ 5.00%	17.2
DA-GI-010B	100.00 FT @ 1.30%	315.78 FT @ 7.32%	-	-	-	25.6

DEQ Virginia Runoff Reduction Method Re-Development Compliance Spreadsheet - Version 3.0

BMP Design Specifications List: 2013 Draft Stds & Specs

Site Summary - Linear Development Project***

Total Rainfall (in):	43
Total Disturbed Acreage:	0.80

Site Land Cover Summary

Pre-ReDevelopment Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	% of Total
Forest/Open (acres)	0.00	0.73	0.00	0.00	0.73	91
Managed Turf (acres)	0.00	0.00	0.00	0.00	0.00	0
Impervious Cover (acres)	0.00	0.07	0.00	0.00	0.07	9
					0.80	100

Post-ReDevelopment Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	% of Total
Forest/Open (acres)	0.00	0.73	0.00	0.00	0.73	91
Managed Turf (acres)	0.00	0.00	0.00	0.00	0.00	0
Impervious Cover (acres)	0.00	0.07	0.00	0.00	0.07	9
					0.80	100

* Forest/Open Space areas must be protected in accordance with the Virginia Runoff Reduction Method

Site Tv and Land Cover Nutrient Loads

	Final Post-Development (Post-ReDevelopment & New Impervious)	Post- ReDevelopment	Post- Development (New Impervious)	Adjusted Pre- ReDevelopment
Site Rv	0.11	0.11	--	0.11
Treatment Volume (ft ³)	321	321	--	321
TP Load (lb/yr)	0.20	0.20	--	0.20

Baseline TP Load (lb/yr): 0.328* *Reduction below new development load limitation not required

Pre- ReDevelopment TP Load per acre (lb/acre/yr)	Final Post-Development TP Load per acre (lb/acre/yr)	Post-ReDevelopment TP Load per acre (lb/acre/yr)
0.25	0.25	0.25

Total TP Load Reduction Required (lb/yr)	-0.13	N/A***	N/A***
--	-------	--------	--------

***This is a linear development project

	Final Post-Development Load (Post-ReDevelopment & New Impervious)	Pre- ReDevelopment
TN Load (lb/yr)	1.44	1.44

Site Compliance Summary - ***Linear Development Project

Maximum % Reduction Required Below Pre-ReDevelopment Load	20%
--	-----

* Note: % Reduction will reduce post-development TP load to less than or equal to baseline load of 0.33 lb/yr (0.41 lb/ac/yr)
 [Post-Dev Reduction Requirement = Post-Dev TP load - baseline load of 0.33 lb/yr], baseline load = site area x 0.41 lb/ac/yr

Total Runoff Volume Reduction (ft ³)	0
Total TP Load Reduction Achieved (lb/yr)	0.00
Total TN Load Reduction Achieved (lb/yr)	0.00
Remaining Post Development TP Load (lb/yr)	0.20
Remaining TP Load Reduction (lb/yr) Required	0.00

**** TARGET TP REDUCTION EXCEEDED BY 0.13 LB/YEAR ****

**Reduction below new development load limitation not required*

DA-PI-030A

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.134	1,091
Developed Condition	0.099	968
Pre-Developed (Forest) Condition	0.050	743

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 1

Calculations:

Check #1:

$$Q_{\text{developed}} \leq \text{IF} \times [(Q_{\text{pre-developed}} \times \text{RV}_{\text{pre-developed}}) / \text{RV}_{\text{developed}}] \text{ ----->}$$

Q (cfs)

0.099

≤

OK

Q (cfs)

0.151

Check #2:

$$Q_{\text{developed}} \leq Q_{\text{pre-developed}} \text{ ----->}$$

0.099

≤

OK

0.134

Check #3:

$$Q_{\text{developed}} \text{ shall not be required to be } \leq (Q_{\text{forest}} \times \text{RV}_{\text{forest}}) / \text{RV}_{\text{developed}} \text{ --->}$$

0.099

shall not be required to be ≤

0.038

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning's n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<i>Note:</i> Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted. ¹For Paved Road land surface types a Manning's n of 0.011 was used <i>Sources:</i> -USACE, 1998, HEC-1 Flood Hydrograph Package User's Manual, Hydrologic Engineering Center, Davis, CA -Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC	

Table 2 – Manning’s n Values for Open Channel Flow

Channel Type	Manning n		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹ For the developed condition, a conservative Manning’s n value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar, level spreader diversion, or grass channel. ² For the pre-developed condition and post-development condition, a Manning’s n value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-PI-030A Pre
2	SCS Runoff	DA-PI-030A Post
3	SCS Runoff	DA-PI-030A Pre-Forested

Hydrograph Return Period Recap

Hydroflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)								Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	-----	0.134	0.500	-----	-----	1.987	-----	-----	-----	DA-PI-030A Pre
2	SCS Runoff	-----	0.099	0.428	-----	-----	1.849	-----	-----	-----	DA-PI-030A Post
3	SCS Runoff	-----	0.050	0.300	-----	-----	1.576	-----	-----	-----	DA-PI-030A Pre-Forested
Proj. file: DA-PI-030A.gpw											Thursday, 08 / 17 / 2017

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.134	1	729	1,091	-----	-----	-----	DA-PI-030A Pre
2	SCS Runoff	0.099	1	730	968	-----	-----	-----	DA-PI-030A Post
3	SCS Runoff	0.050	1	738	743	-----	-----	-----	DA-PI-030A Pre-Forested
DA-PI-030A.gpw					Return Period: 1 Year			Thursday, 08 / 17 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

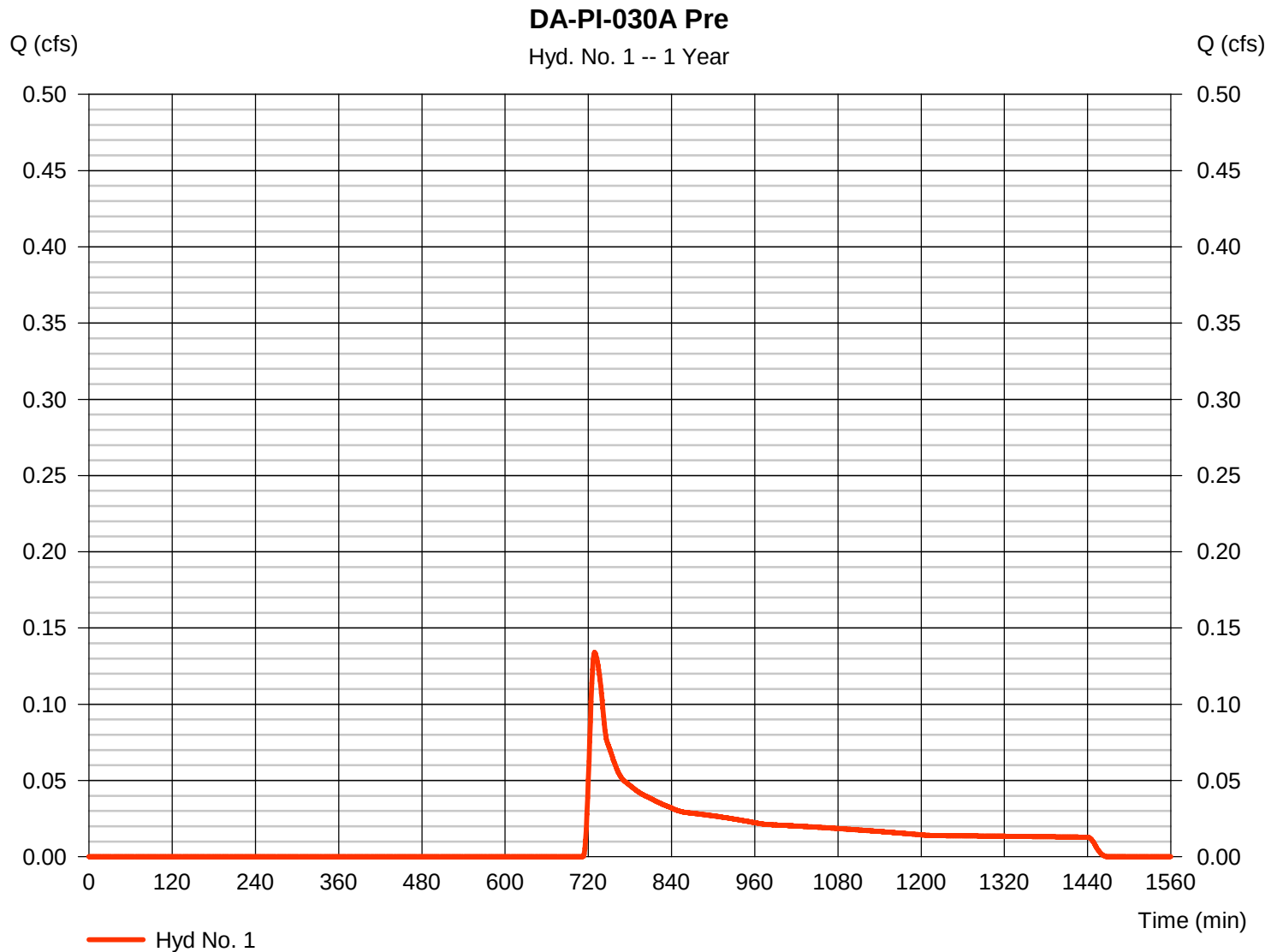
Thursday, 08 / 17 / 2017

Hyd. No. 1

DA-PI-030A Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.134 cfs
Storm frequency	= 1 yrs	Time to peak	= 729 min
Time interval	= 1 min	Hyd. volume	= 1,091 cuft
Drainage area	= 1.430 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 17.20 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.260 \times 55) + (0.170 \times 82)] / 1.430$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-PI-030A Pre

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 3.63	0.00	0.00				
Travel Time (min)	= 16.18	+	0.00	+	0.00	=	16.18
Shallow Concentrated Flow							
Flow length (ft)	= 148.60	22.09	132.06				
Watercourse slope (%)	= 8.62	11.25	11.16				
Surface description	= Unpaved	Paved	Unpaved				
Average velocity (ft/s)	=4.74	6.82	5.39				
Travel Time (min)	= 0.52	+	0.05	+	0.41	=	0.99
Channel Flow							
X sectional flow area (sqft)	= 0.00	0.00	0.00				
Wetted perimeter (ft)	= 0.00	0.00	0.00				
Channel slope (%)	= 0.00	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	(0)0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc				17.20 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

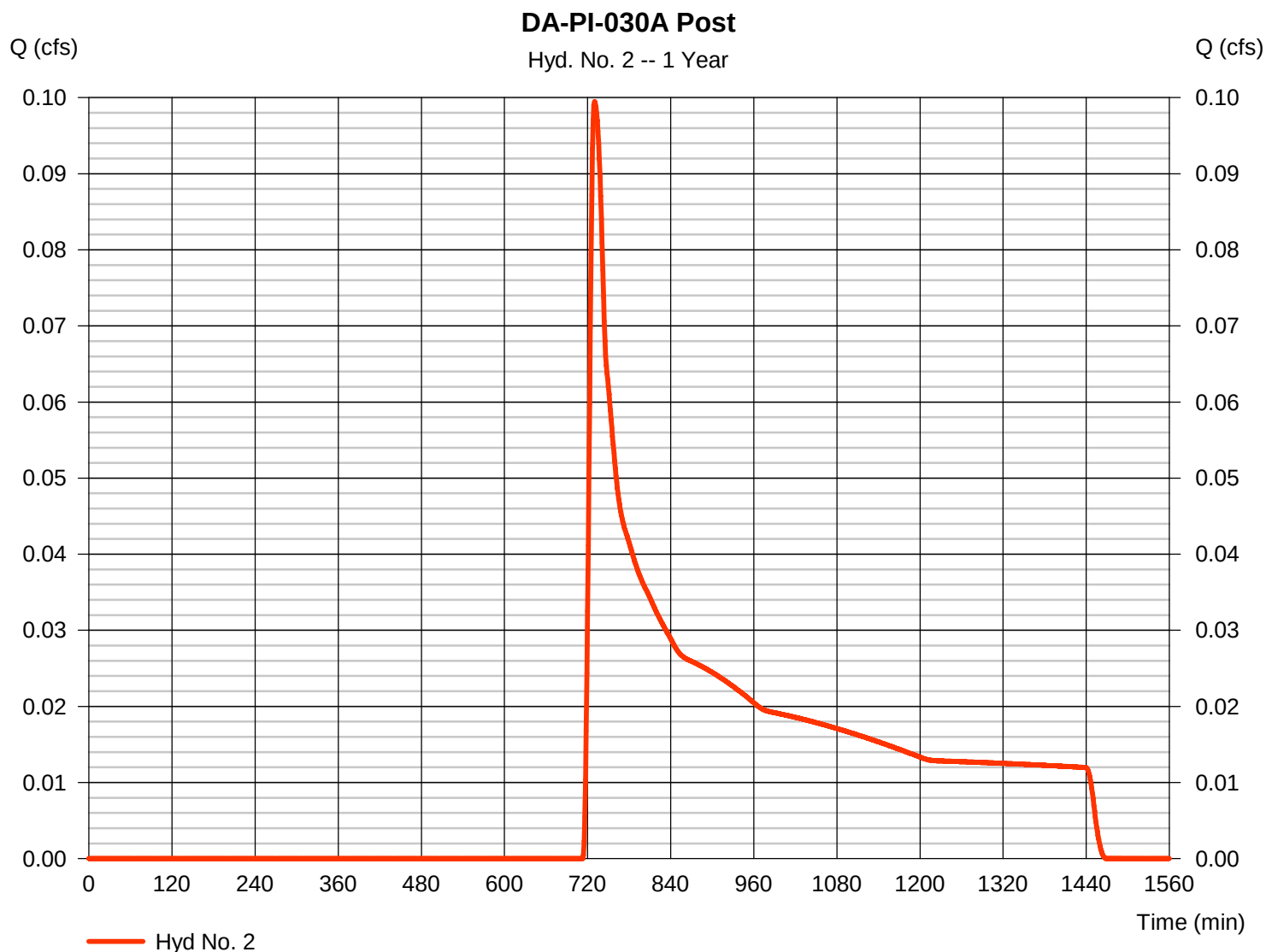
Thursday, 08 / 17 / 2017

Hyd. No. 2

DA-PI-030A Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.099 cfs
Storm frequency	= 1 yrs	Time to peak	= 730 min
Time interval	= 1 min	Hyd. volume	= 968 cuft
Drainage area	= 1.430 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 17.20 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.650 \times 55) + (0.170 \times 82) + (0.350 \times 48) + (0.260 \times 58)] / 1.430$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-PI-030A Post

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00	
Land slope (%)	= 3.63	0.00	0.00	
Travel Time (min)	= 16.18	+	0.00	+
			0.00	= 16.18
Shallow Concentrated Flow				
Flow length (ft)	= 148.60	22.09	108.77	
Watercourse slope (%)	= 8.62	11.25	13.16	
Surface description	= Unpaved	Paved	Unpaved	
Average velocity (ft/s)	=4.74	6.82	5.85	
Travel Time (min)	= 0.52	+	0.05	+
			0.31	= 0.89
Channel Flow				
X sectional flow area (sqft)	= 2.00	0.00	0.00	
Wetted perimeter (ft)	= 4.47	0.00	0.00	
Channel slope (%)	= 5.00	0.00	0.00	
Manning's n-value	= 0.040	0.015	0.015	
Velocity (ft/s)	=4.86	0.00	0.00	
			0.00	
Flow length (ft)	({})38.8	0.0	0.0	
Travel Time (min)	= 0.13	+	0.00	+
			0.00	= 0.13
Total Travel Time, Tc				17.20 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Thursday, 08 / 17 / 2017

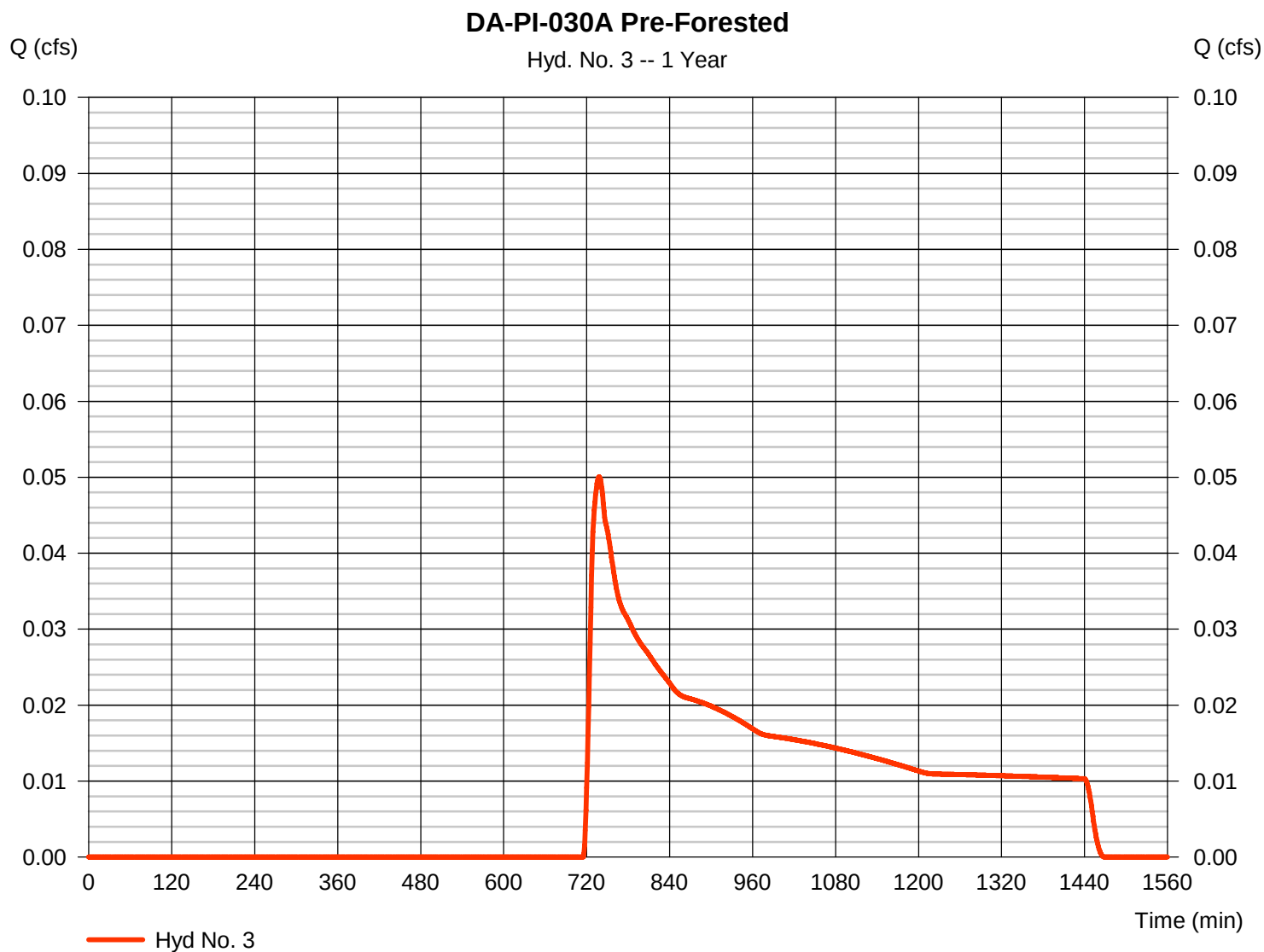
Hyd. No. 3

DA-PI-030A Pre-Forested

Hydrograph type = SCS Runoff
 Storm frequency = 1 yrs
 Time interval = 1 min
 Drainage area = 1.430 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 2.80 in
 Storm duration = 24 hrs

Peak discharge = 0.050 cfs
 Time to peak = 738 min
 Hyd. volume = 743 cuft
 Curve number = 55*
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 17.20 min
 Distribution = Type II
 Shape factor = 484

* Composite (Area/CN) = $[(1.430 \times 55)] / 1.430$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-PI-030A Pre-Forested

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 3.63	0.00	0.00				
Travel Time (min)	= 16.18	+	0.00	+	0.00	=	16.18
Shallow Concentrated Flow							
Flow length (ft)	= 148.60	22.09	132.06				
Watercourse slope (%)	= 8.62	11.25	11.16				
Surface description	= Unpaved	Unpaved	Unpaved				
Average velocity (ft/s)	=4.74	5.41	5.39				
Travel Time (min)	= 0.52	+	0.07	+	0.41	=	1.00
Channel Flow							
X sectional flow area (sqft)	= 0.00	0.00	0.00				
Wetted perimeter (ft)	= 0.00	0.00	0.00				
Channel slope (%)	= 0.00	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	((0})0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc				17.20 min			

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.500	1	727	2,325	-----	-----	-----	DA-PI-030A Pre
2	SCS Runoff	0.428	1	727	2,134	-----	-----	-----	DA-PI-030A Post
3	SCS Runoff	0.300	1	728	1,774	-----	-----	-----	DA-PI-030A Pre-Forested
DA-PI-030A.gpw					Return Period: 2 Year			Thursday, 08 / 17 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

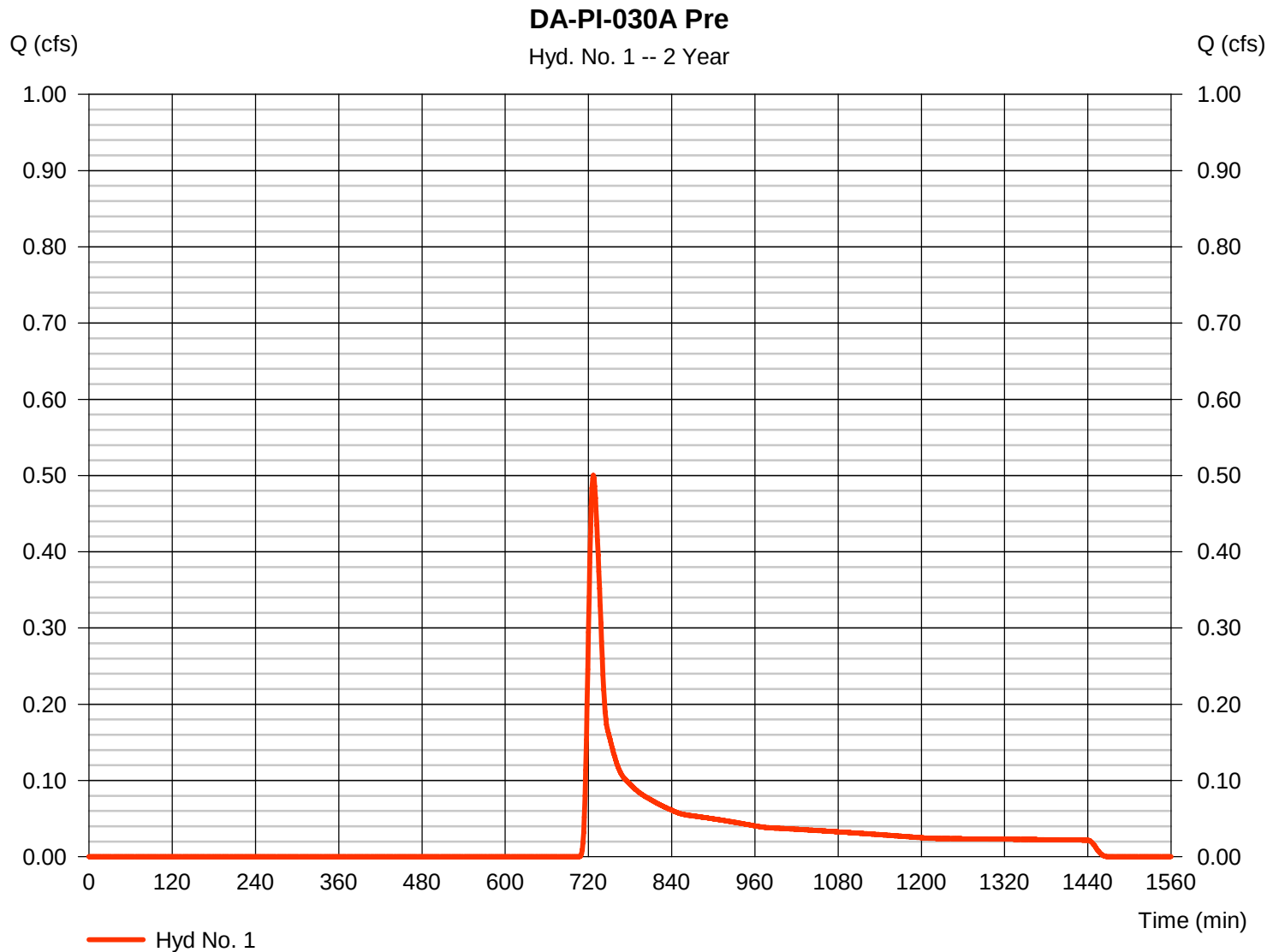
Thursday, 08 / 17 / 2017

Hyd. No. 1

DA-PI-030A Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.500 cfs
Storm frequency	= 2 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 2,325 cuft
Drainage area	= 1.430 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 17.20 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.260 \times 55) + (0.170 \times 82)] / 1.430$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

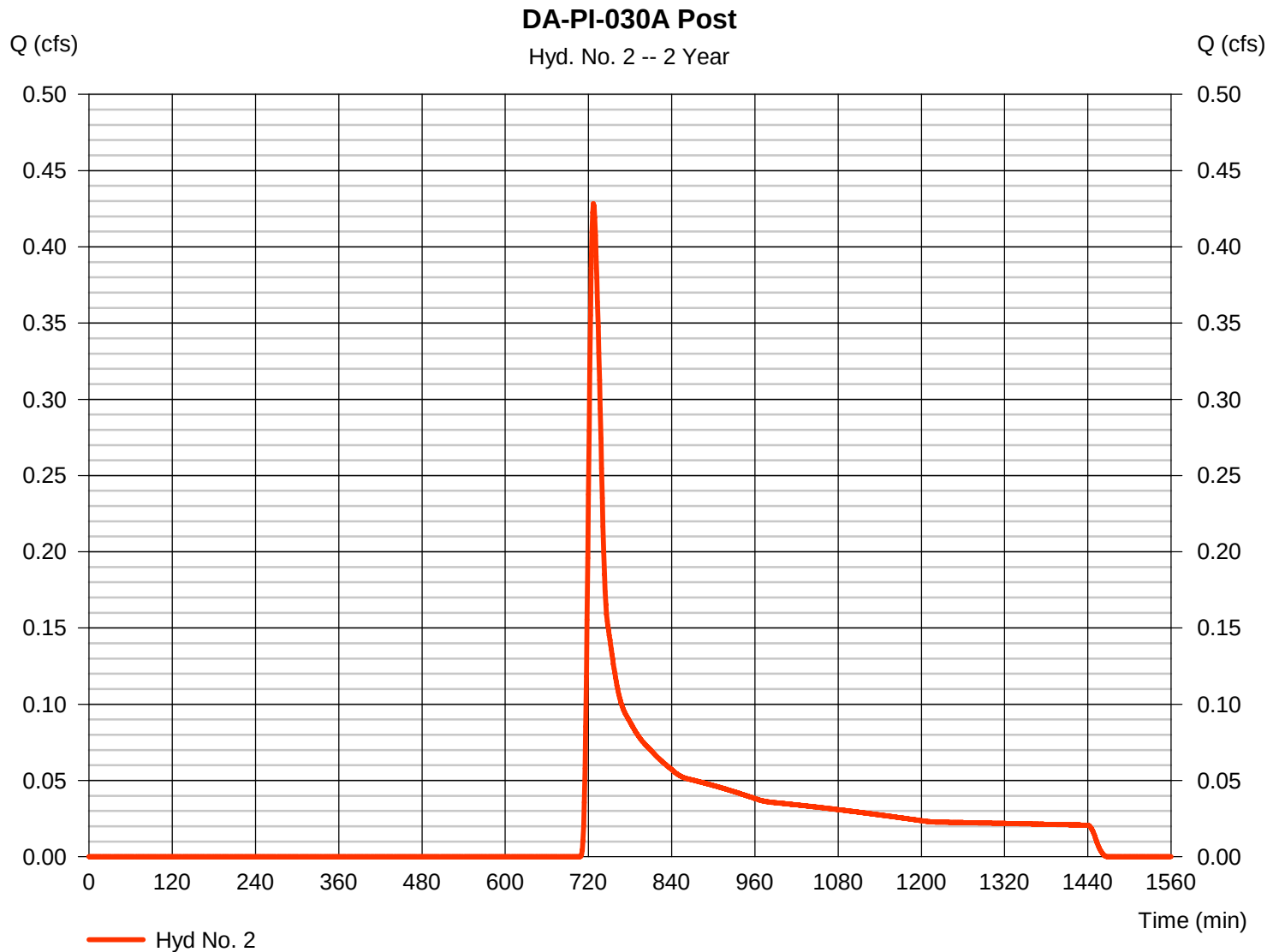
Thursday, 08 / 17 / 2017

Hyd. No. 2

DA-PI-030A Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.428 cfs
Storm frequency	= 2 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 2,134 cuft
Drainage area	= 1.430 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 17.20 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.650 \times 55) + (0.170 \times 82) + (0.350 \times 48) + (0.260 \times 58)] / 1.430$



Hydrograph Report

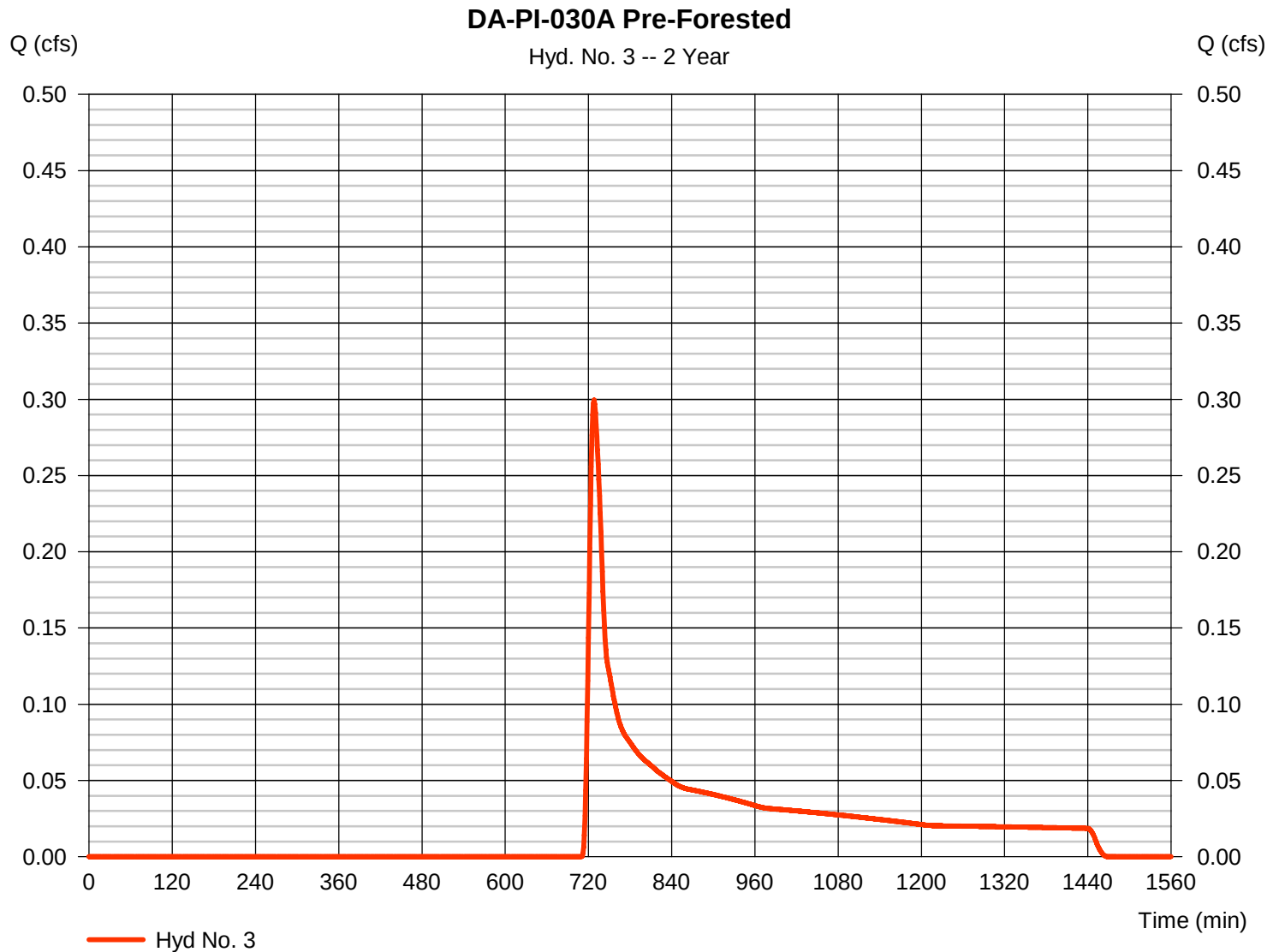
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Thursday, 08 / 17 / 2017

Hyd. No. 3

DA-PI-030A Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 0.300 cfs
Storm frequency	= 2 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 1,774 cuft
Drainage area	= 1.430 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 17.20 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.430 \times 55)] / 1.430$ 

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	1.987	1	725	6,571	-----	-----	-----	DA-PI-030A Pre
2	SCS Runoff	1.849	1	725	6,224	-----	-----	-----	DA-PI-030A Post
3	SCS Runoff	1.576	1	726	5,549	-----	-----	-----	DA-PI-030A Pre-Forested
DA-PI-030A.gpw					Return Period: 10 Year			Thursday, 08 / 17 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

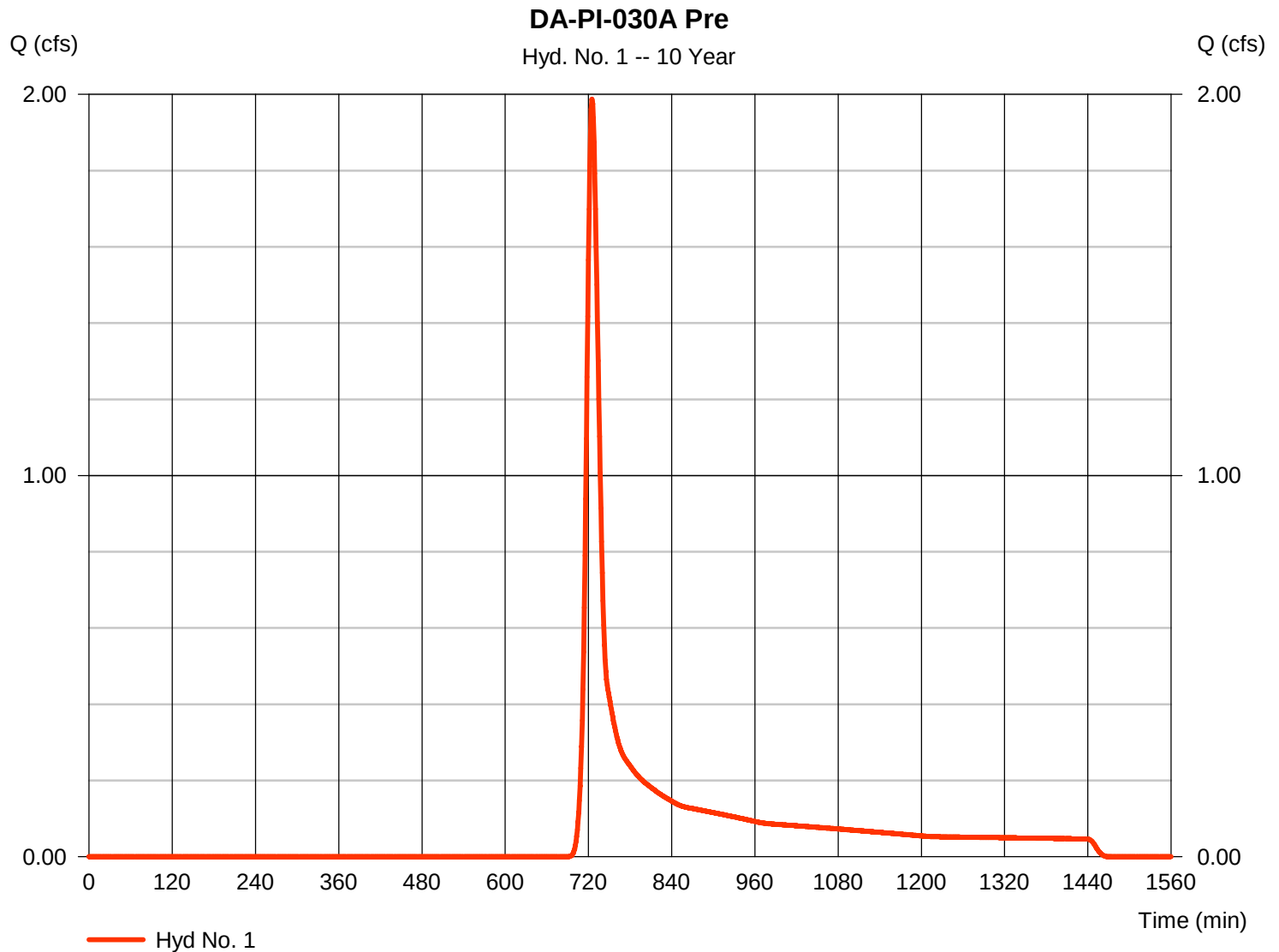
Thursday, 08 / 17 / 2017

Hyd. No. 1

DA-PI-030A Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 1.987 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 6,571 cuft
Drainage area	= 1.430 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 17.20 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.260 \times 55) + (0.170 \times 82)] / 1.430$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

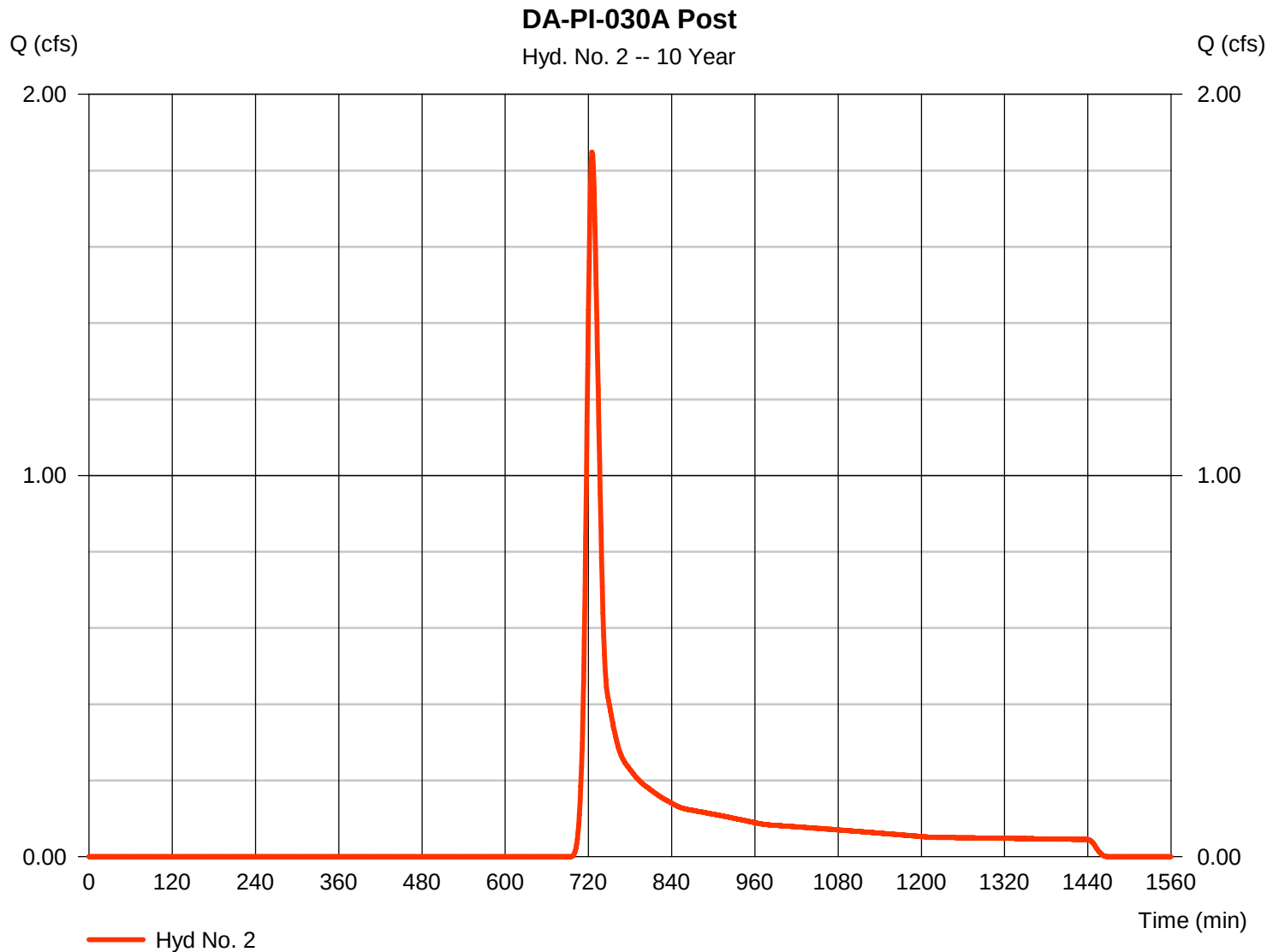
Thursday, 08 / 17 / 2017

Hyd. No. 2

DA-PI-030A Post

Hydrograph type	= SCS Runoff	Peak discharge	= 1.849 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 6,224 cuft
Drainage area	= 1.430 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 17.20 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.650 \times 55) + (0.170 \times 82) + (0.350 \times 48) + (0.260 \times 58)] / 1.430$



Hydrograph Report

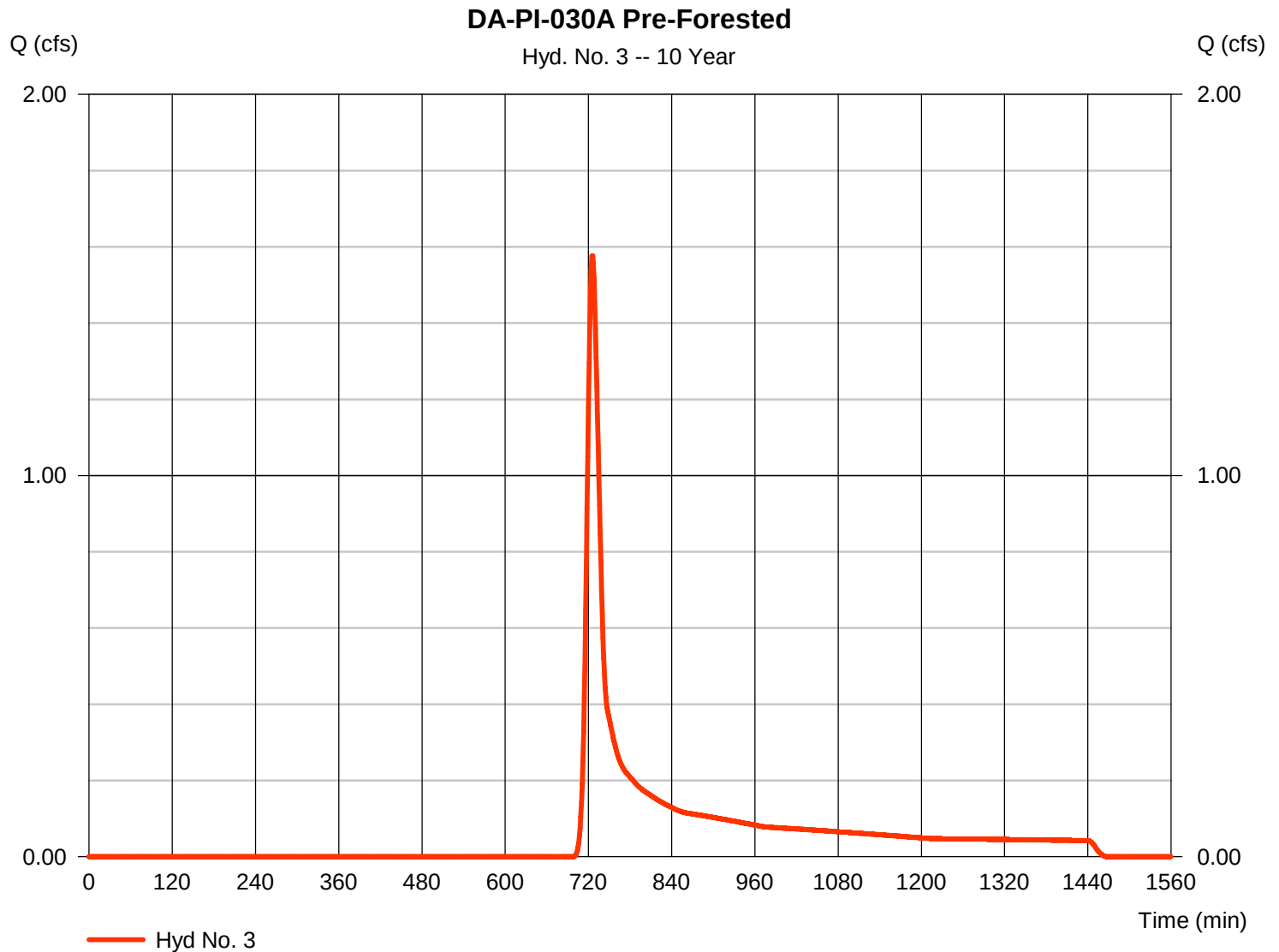
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Thursday, 08 / 17 / 2017

Hyd. No. 3

DA-PI-030A Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	1.576 cfs
Storm frequency	=	10 yrs	Time to peak	=	726 min
Time interval	=	1 min	Hyd. volume	=	5,549 cuft
Drainage area	=	1.430 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	17.20 min
Total precip.	=	5.20 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(1.430 \times 55)] / 1.430$ 

DA-PI-030B

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.231	2,097
Developed Condition	0.231	2,097
Pre-Developed (Forest) Condition	0.079	1,276

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 1

Calculations:

Check #1:

$$Q_{\text{developed}} \leq \text{IF} \times [(Q_{\text{pre-developed}} \times \text{RV}_{\text{pre-developed}}) / \text{RV}_{\text{developed}}] \text{ ----->}$$

Q (cfs)

0.231

≤

OK

Q (cfs)

0.231

Check #2:

$$Q_{\text{developed}} \leq Q_{\text{pre-developed}} \text{ ----->}$$

0.231

≤

OK

0.231

Check #3:

$$Q_{\text{developed}} \text{ shall not be required to be } \leq (Q_{\text{forest}} \times \text{RV}_{\text{forest}}) / \text{RV}_{\text{developed}} \text{ --->}$$

0.231

shall not be required to be ≤

0.048

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning's n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<i>Note:</i> Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted. ¹For Paved Road land surface types a Manning's n of 0.011 was used <i>Sources:</i> -USACE, 1998, HEC-1 Flood Hydrograph Package User's Manual, Hydrologic Engineering Center, Davis, CA -Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC	

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-PI-030B Pre
2	SCS Runoff	DA-PI-030B Post
3	SCS Runoff	DA-PI-030B Pre-Forested

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.231	1	736	2,097	-----	-----	-----	DA-PI-030B Pre
2	SCS Runoff	0.231	1	736	2,097	-----	-----	-----	DA-PI-030B Post
3	SCS Runoff	0.079	1	749	1,276	-----	-----	-----	DA-PI-030B Pre-Forested
DA-PI-030B.gpw					Return Period: 1 Year			Thursday, 08 / 17 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

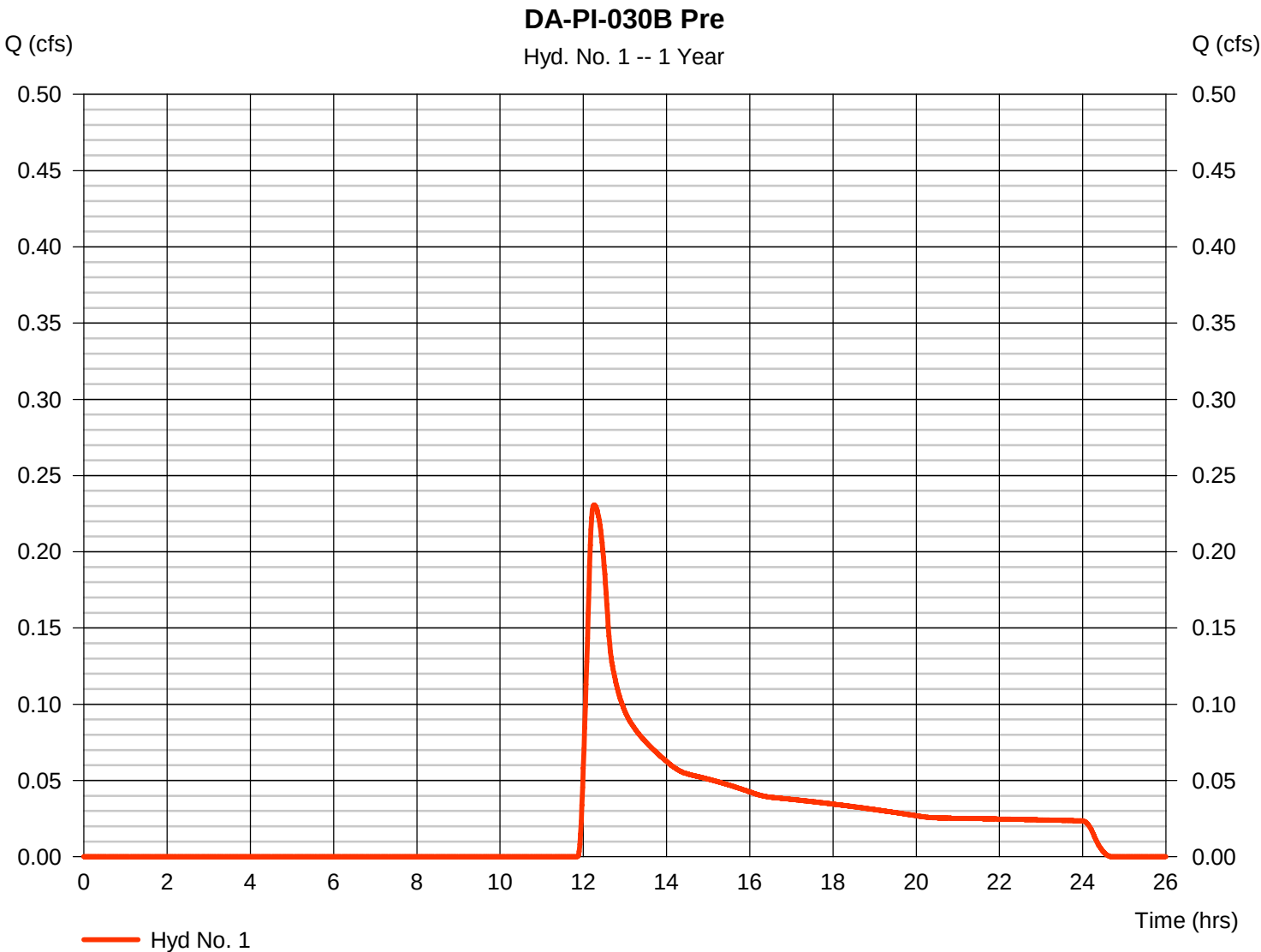
Thursday, 08 / 17 / 2017

Hyd. No. 1

DA-PI-030B Pre

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.231 cfs
Storm frequency	=	1 yrs	Time to peak	=	12.27 hrs
Time interval	=	1 min	Hyd. volume	=	2,097 cuft
Drainage area	=	2.410 ac	Curve number	=	59*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	25.60 min
Total precip.	=	2.80 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.230 x 55) + (0.020 x 82) + (0.060 x 98) + (2.100 x 58)] / 2.410



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-PI-030B Pre

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00	
Land slope (%)	= 1.30	0.00	0.00	
Travel Time (min)	= 24.39	+	0.00	+
			0.00	= 24.39
Shallow Concentrated Flow				
Flow length (ft)	= 315.78	0.00	0.00	
Watercourse slope (%)	= 7.32	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=4.37	0.00	0.00	
Travel Time (min)	= 1.21	+	0.00	+
			0.00	= 1.21
Channel Flow				
X sectional flow area (sqft)	= 0.00	0.00	0.00	
Wetted perimeter (ft)	= 0.00	0.00	0.00	
Channel slope (%)	= 0.00	0.00	0.00	
Manning's n-value	= 0.030	0.015	0.015	
Velocity (ft/s)	=0.00	0.00	0.00	
Flow length (ft)	(0)0.0	0.0	0.0	
Travel Time (min)	= 0.00	+	0.00	+
			0.00	= 0.00
Total Travel Time, Tc				25.60 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

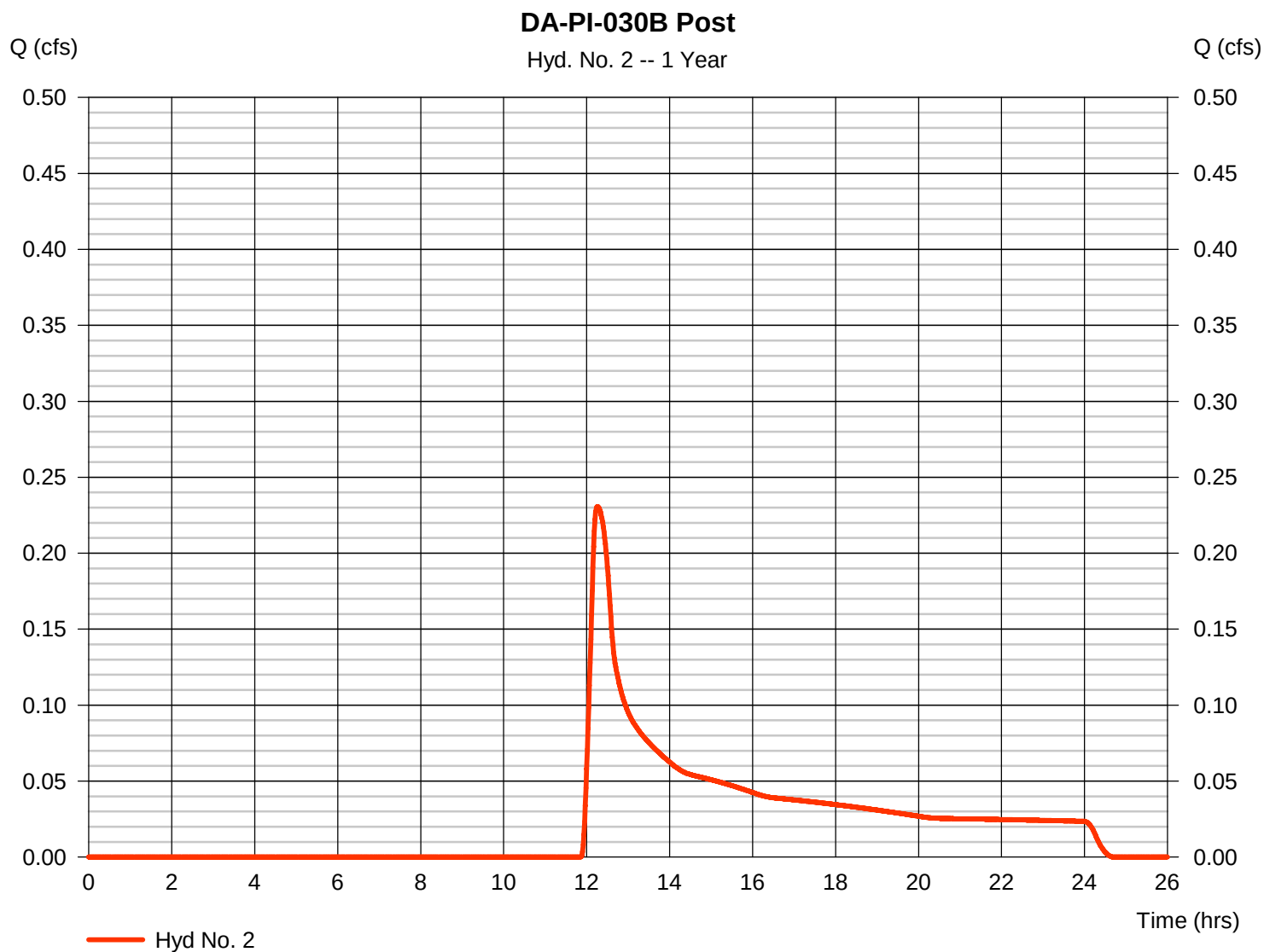
Thursday, 08 / 17 / 2017

Hyd. No. 2

DA-PI-030B Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.231 cfs
Storm frequency	= 1 yrs	Time to peak	= 12.27 hrs
Time interval	= 1 min	Hyd. volume	= 2,097 cuft
Drainage area	= 2.410 ac	Curve number	= 59*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 25.60 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.020 \times 55) + (0.020 \times 82) + (0.060 \times 98) + (2.190 \times 58) + (0.120 \times 48)] / 2.410$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-PI-030B Post

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00	
Land slope (%)	= 1.30	0.00	0.00	
Travel Time (min)	= 24.39	+ 0.00	+ 0.00	= 24.39
Shallow Concentrated Flow				
Flow length (ft)	= 315.78	0.00	0.00	
Watercourse slope (%)	= 7.32	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=4.37	0.00	0.00	
Travel Time (min)	= 1.21	+ 0.00	+ 0.00	= 1.21
Channel Flow				
X sectional flow area (sqft)	= 0.00	0.00	0.00	
Wetted perimeter (ft)	= 0.00	0.00	0.00	
Channel slope (%)	= 0.00	0.00	0.00	
Manning's n-value	= 0.040	0.015	0.015	
Velocity (ft/s)	=0.00	0.00	0.00	
Flow length (ft)	(0)0.0	0.0	0.0	
Travel Time (min)	= 0.00	+ 0.00	+ 0.00	= 0.00
Total Travel Time, Tc				25.60 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Thursday, 08 / 17 / 2017

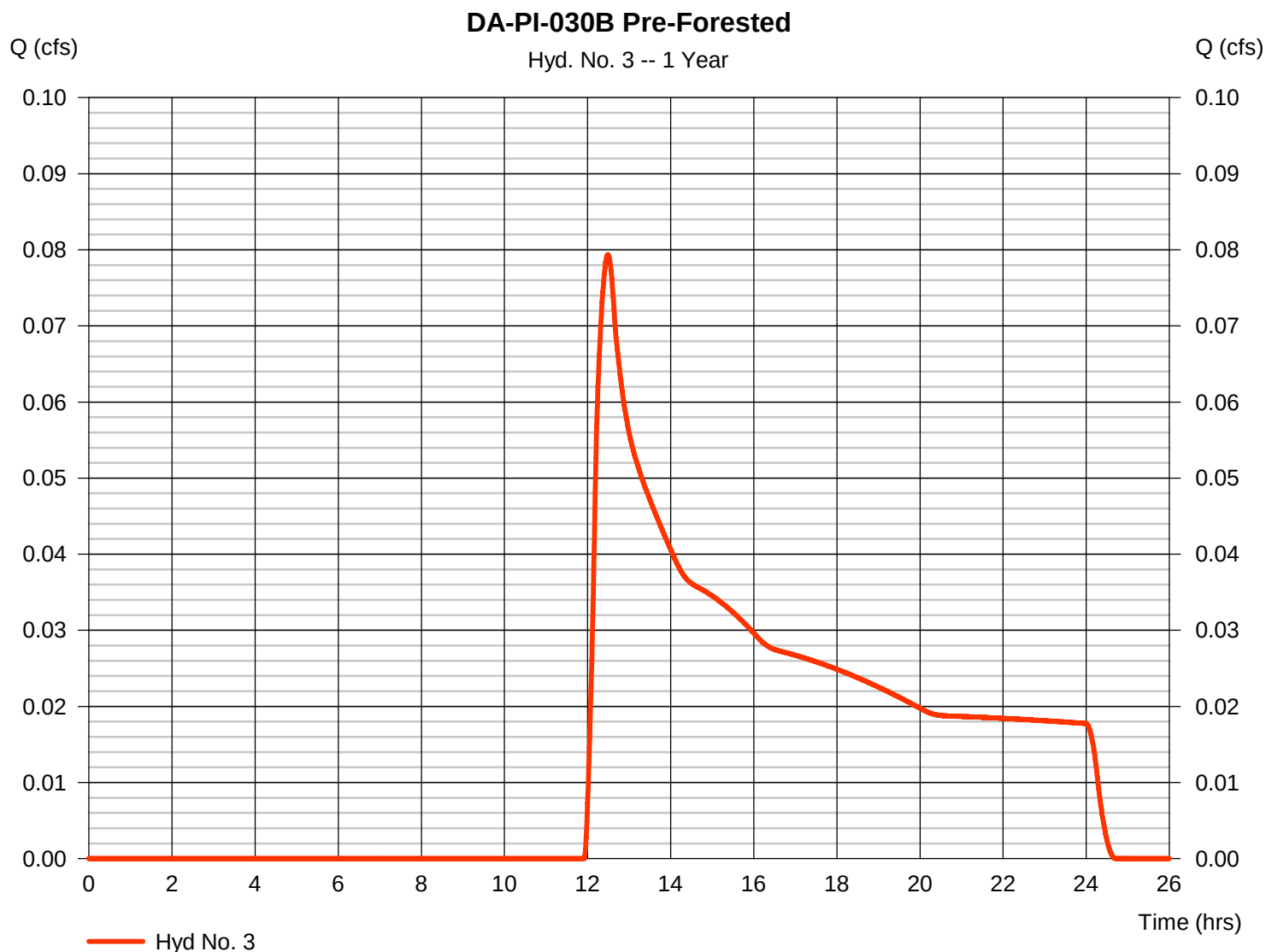
Hyd. No. 3

DA-PI-030B Pre-Forested

Hydrograph type = SCS Runoff
 Storm frequency = 1 yrs
 Time interval = 1 min
 Drainage area = 2.410 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 2.80 in
 Storm duration = 24 hrs

Peak discharge = 0.079 cfs
 Time to peak = 12.48 hrs
 Hyd. volume = 1,276 cuft
 Curve number = 55*
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 25.60 min
 Distribution = Type II
 Shape factor = 484

* Composite (Area/CN) = $[(2.410 \times 55)] / 2.410$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-PI-030B Pre-Forested

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 1.30	0.00	0.00				
Travel Time (min)	= 24.39	+	0.00	+	0.00	=	24.39
Shallow Concentrated Flow							
Flow length (ft)	= 315.78	0.00	0.00				
Watercourse slope (%)	= 7.32	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=4.37	0.00	0.00				
Travel Time (min)	= 1.21	+	0.00	+	0.00	=	1.21
Channel Flow							
X sectional flow area (sqft)	= 0.00	0.00	0.00				
Wetted perimeter (ft)	= 0.00	0.00	0.00				
Channel slope (%)	= 0.00	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	((0})0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc				25.60 min			

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.749	1	733	4,333	-----	-----	-----	DA-PI-030B Pre
2	SCS Runoff	0.749	1	733	4,333	-----	-----	-----	DA-PI-030B Post
3	SCS Runoff	0.393	1	734	3,048	-----	-----	-----	DA-PI-030B Pre-Forested
DA-PI-030B.gpw					Return Period: 2 Year			Thursday, 08 / 17 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

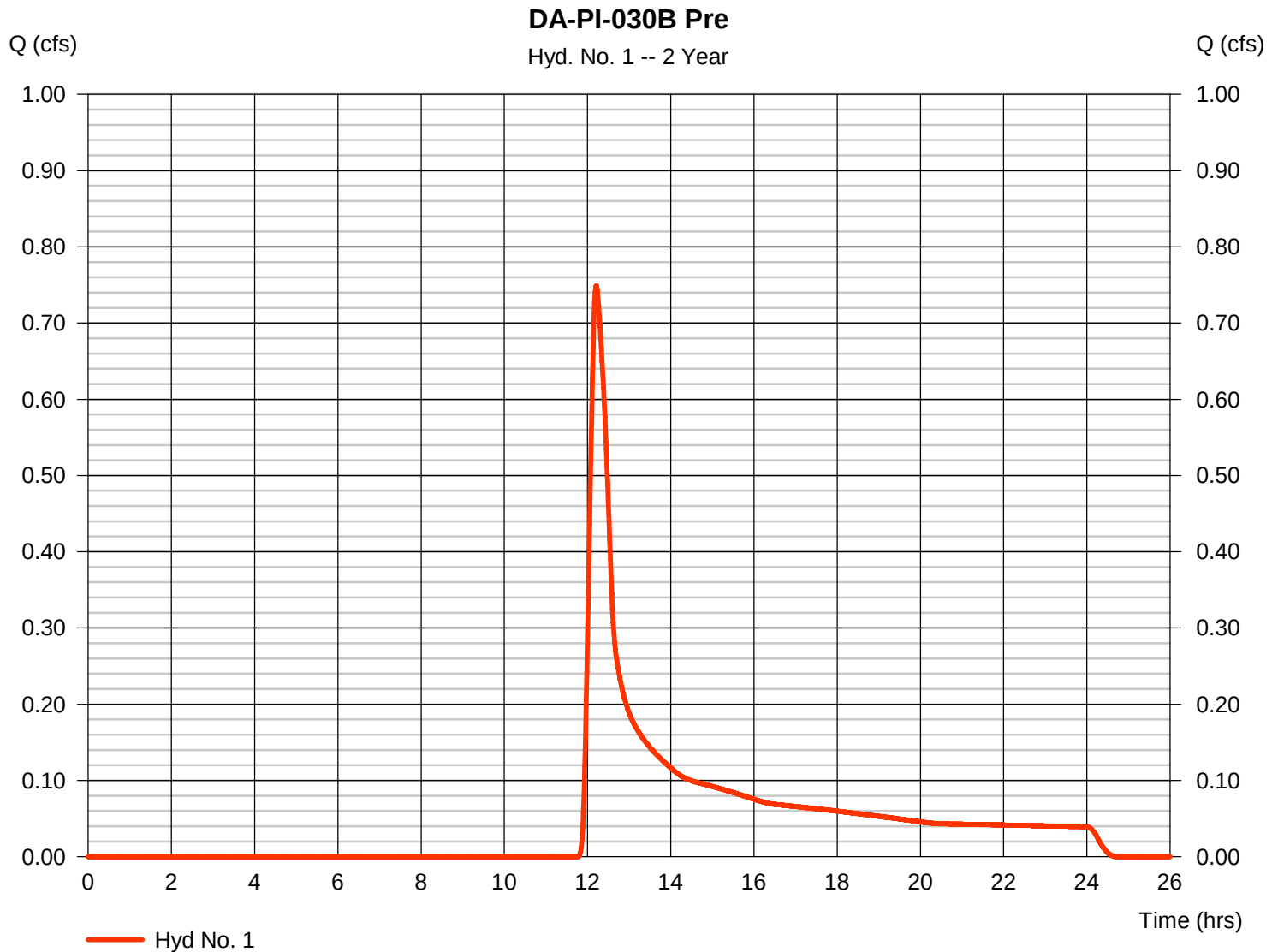
Thursday, 08 / 17 / 2017

Hyd. No. 1

DA-PI-030B Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.749 cfs
Storm frequency	= 2 yrs	Time to peak	= 12.22 hrs
Time interval	= 1 min	Hyd. volume	= 4,333 cuft
Drainage area	= 2.410 ac	Curve number	= 59*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 25.60 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.230 \times 55) + (0.020 \times 82) + (0.060 \times 98) + (2.100 \times 58)] / 2.410$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

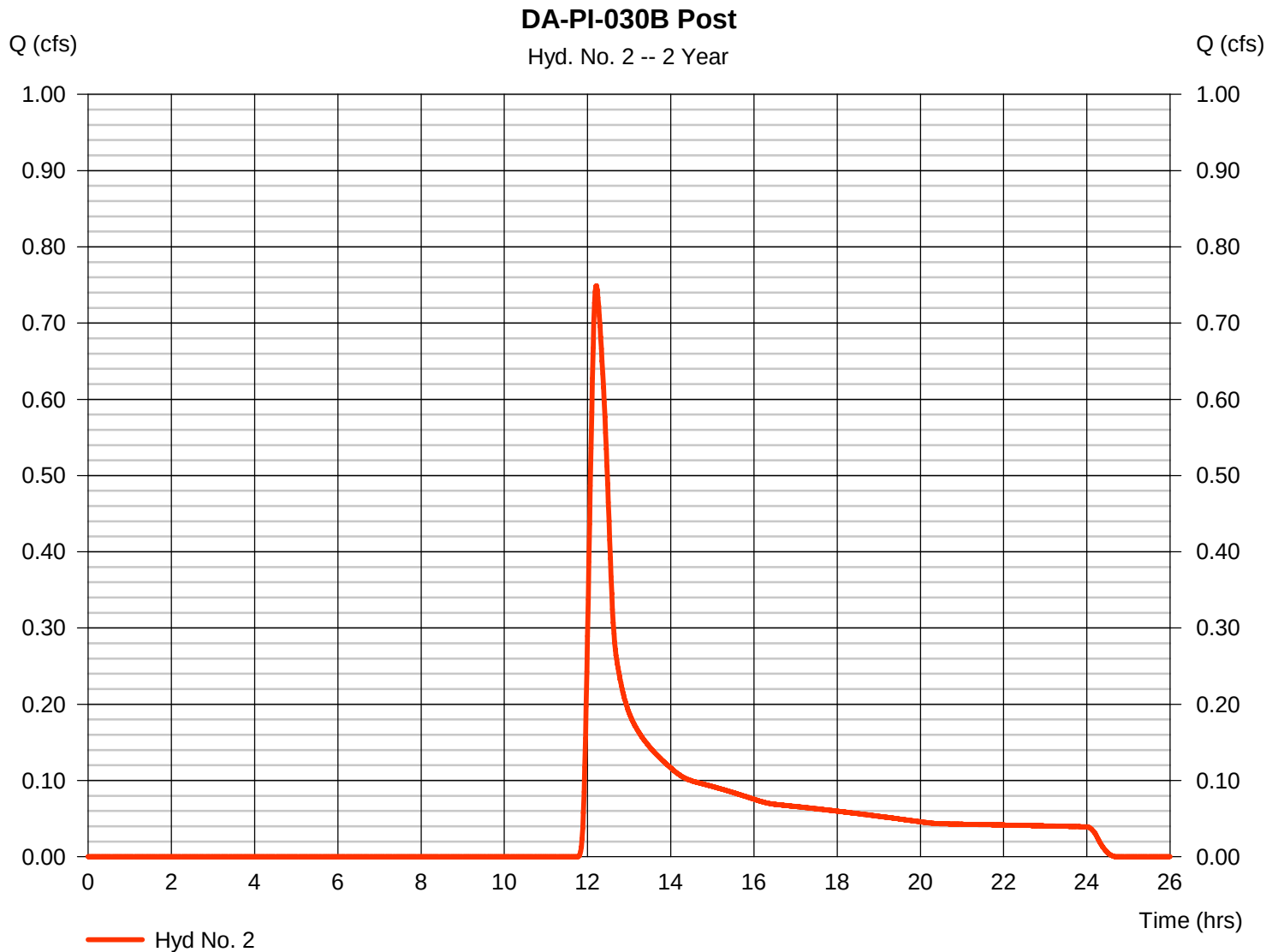
Thursday, 08 / 17 / 2017

Hyd. No. 2

DA-PI-030B Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.749 cfs
Storm frequency	= 2 yrs	Time to peak	= 12.22 hrs
Time interval	= 1 min	Hyd. volume	= 4,333 cuft
Drainage area	= 2.410 ac	Curve number	= 59*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 25.60 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.020 \times 55) + (0.020 \times 82) + (0.060 \times 98) + (2.190 \times 58) + (0.120 \times 48)] / 2.410$



Hydrograph Report

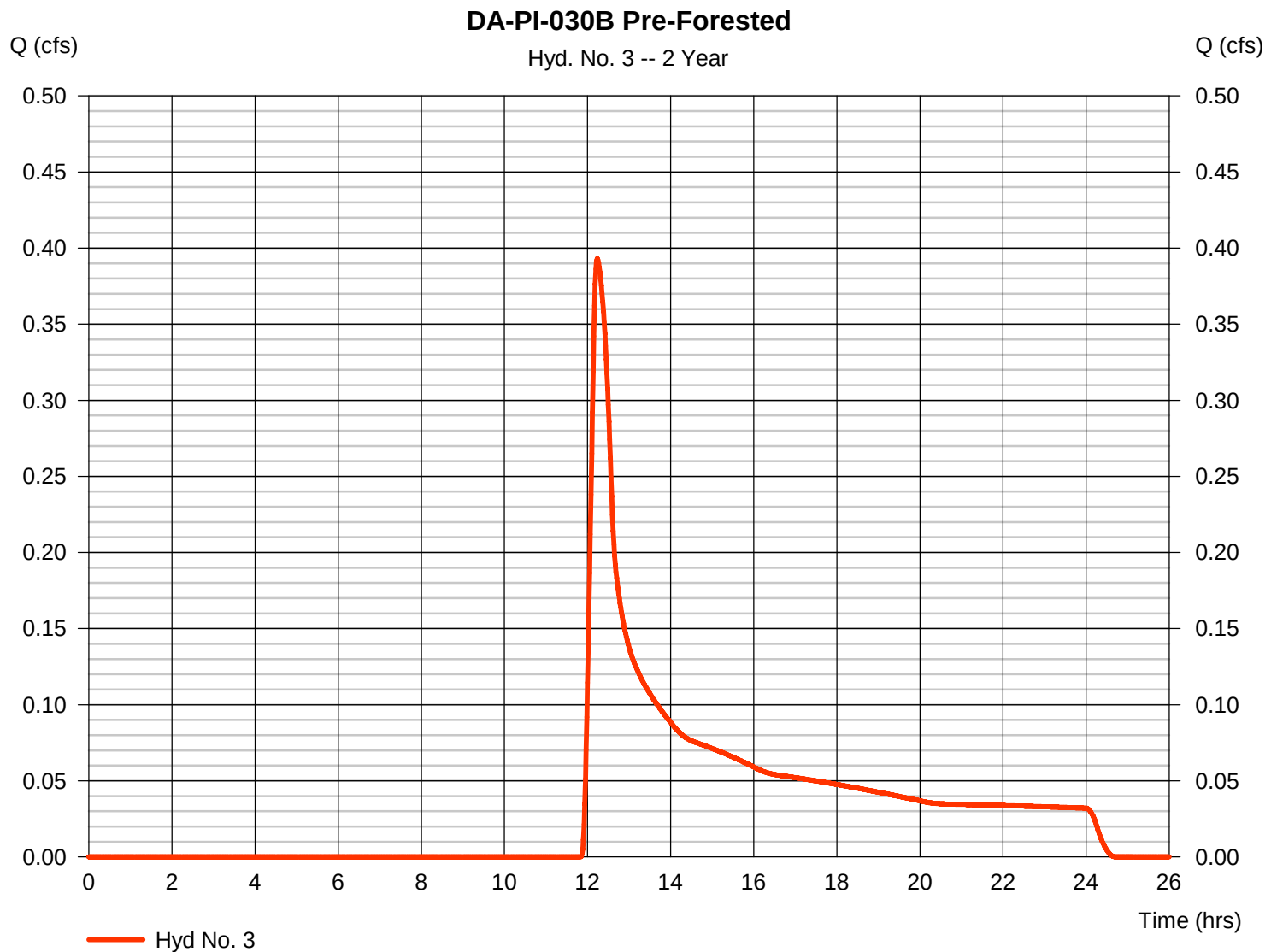
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Thursday, 08 / 17 / 2017

Hyd. No. 3

DA-PI-030B Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.393 cfs
Storm frequency	=	2 yrs	Time to peak	=	12.23 hrs
Time interval	=	1 min	Hyd. volume	=	3,048 cuft
Drainage area	=	2.410 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	25.60 min
Total precip.	=	3.50 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(2.410 \times 55)] / 2.410$ 

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	2.820	1	731	11,896	-----	-----	-----	DA-PI-030B Pre
2	SCS Runoff	2.820	1	731	11,896	-----	-----	-----	DA-PI-030B Post
3	SCS Runoff	2.069	1	731	9,533	-----	-----	-----	DA-PI-030B Pre-Forested
DA-PI-030B.gpw					Return Period: 10 Year			Thursday, 08 / 17 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

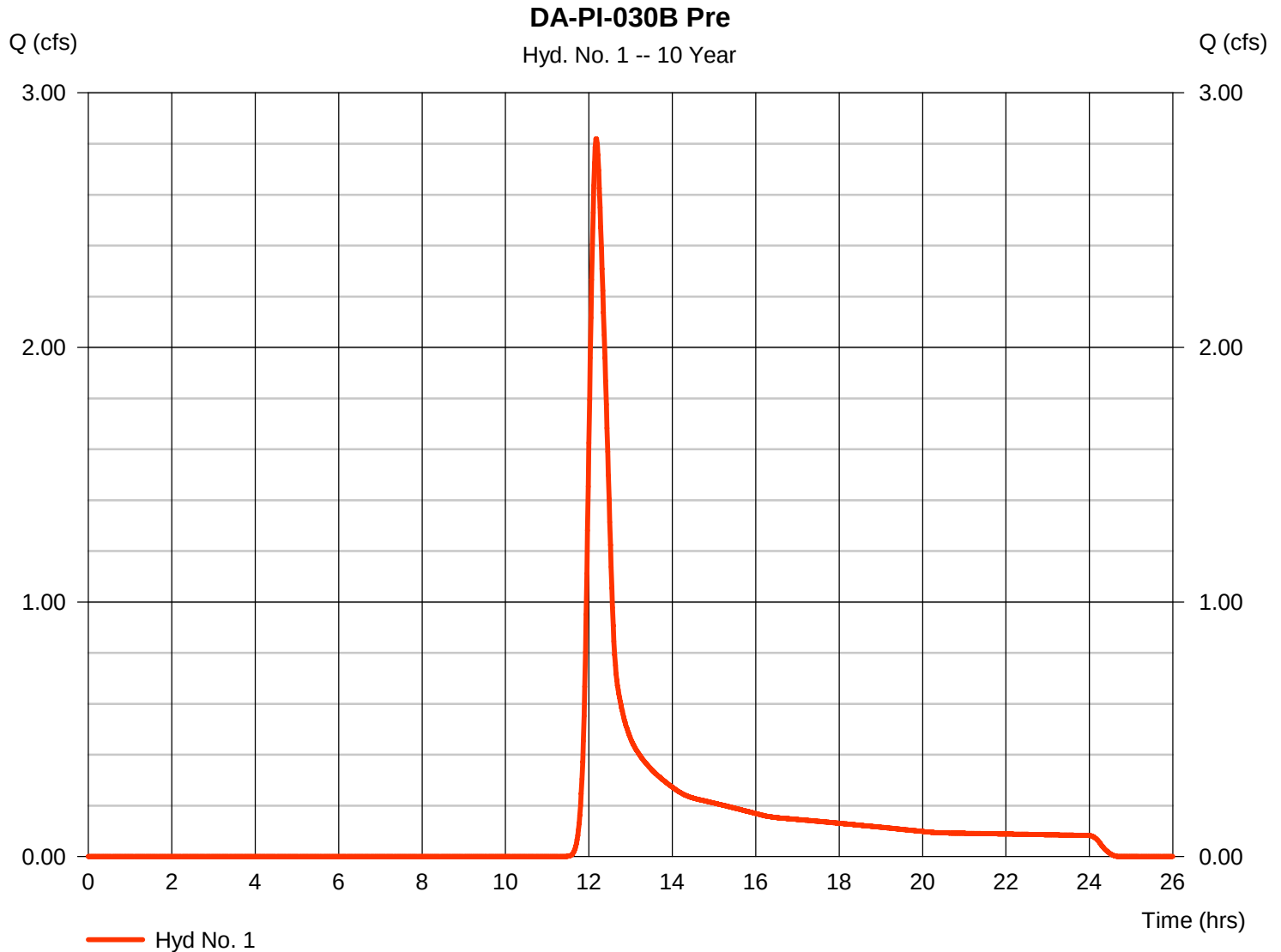
Thursday, 08 / 17 / 2017

Hyd. No. 1

DA-PI-030B Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 2.820 cfs
Storm frequency	= 10 yrs	Time to peak	= 12.18 hrs
Time interval	= 1 min	Hyd. volume	= 11,896 cuft
Drainage area	= 2.410 ac	Curve number	= 59*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 25.60 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.230 \times 55) + (0.020 \times 82) + (0.060 \times 98) + (2.100 \times 58)] / 2.410$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

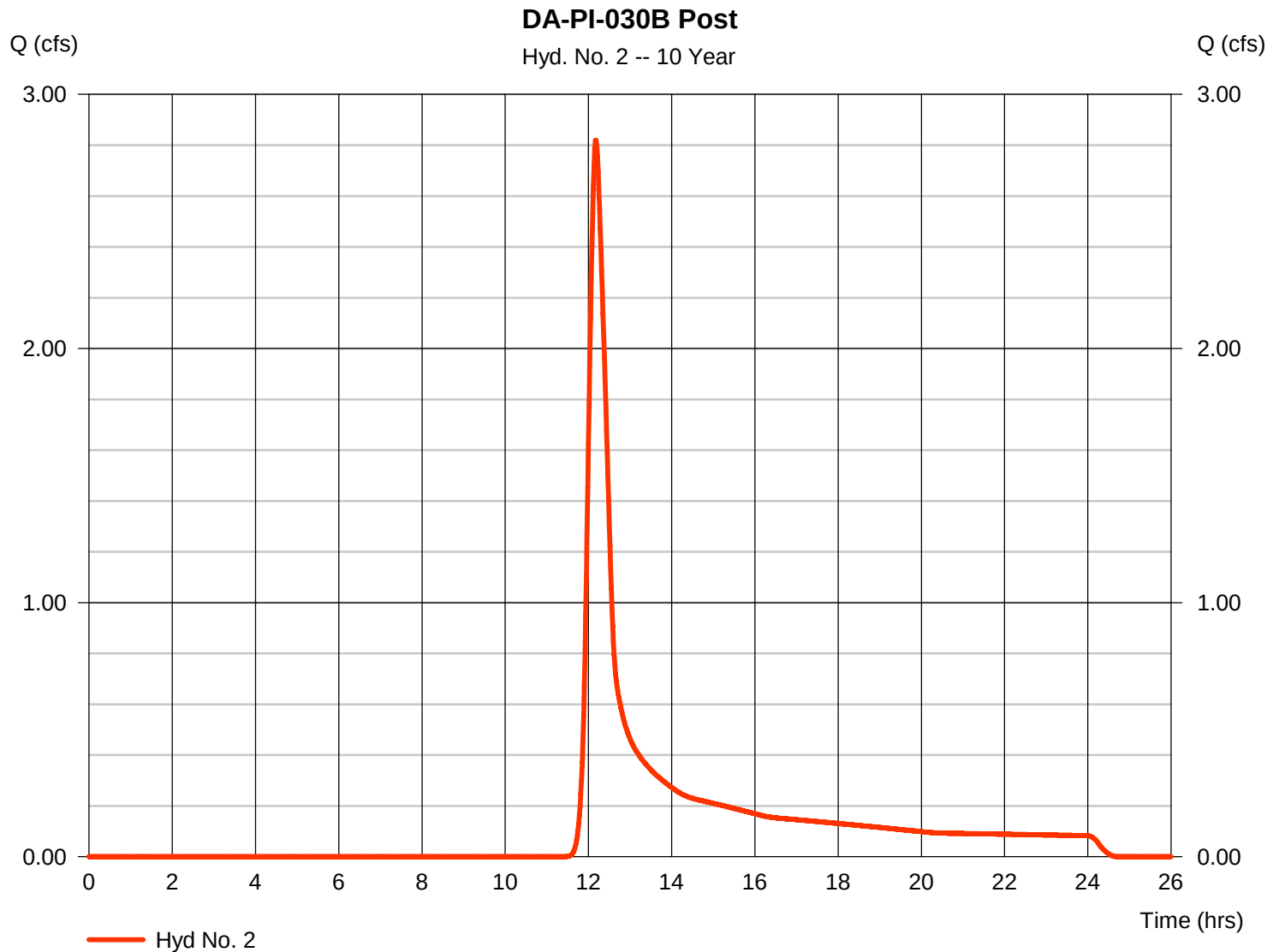
Thursday, 08 / 17 / 2017

Hyd. No. 2

DA-PI-030B Post

Hydrograph type	= SCS Runoff	Peak discharge	= 2.820 cfs
Storm frequency	= 10 yrs	Time to peak	= 12.18 hrs
Time interval	= 1 min	Hyd. volume	= 11,896 cuft
Drainage area	= 2.410 ac	Curve number	= 59*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 25.60 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.020 \times 55) + (0.020 \times 82) + (0.060 \times 98) + (2.190 \times 58) + (0.120 \times 48)] / 2.410$



Hydrograph Report

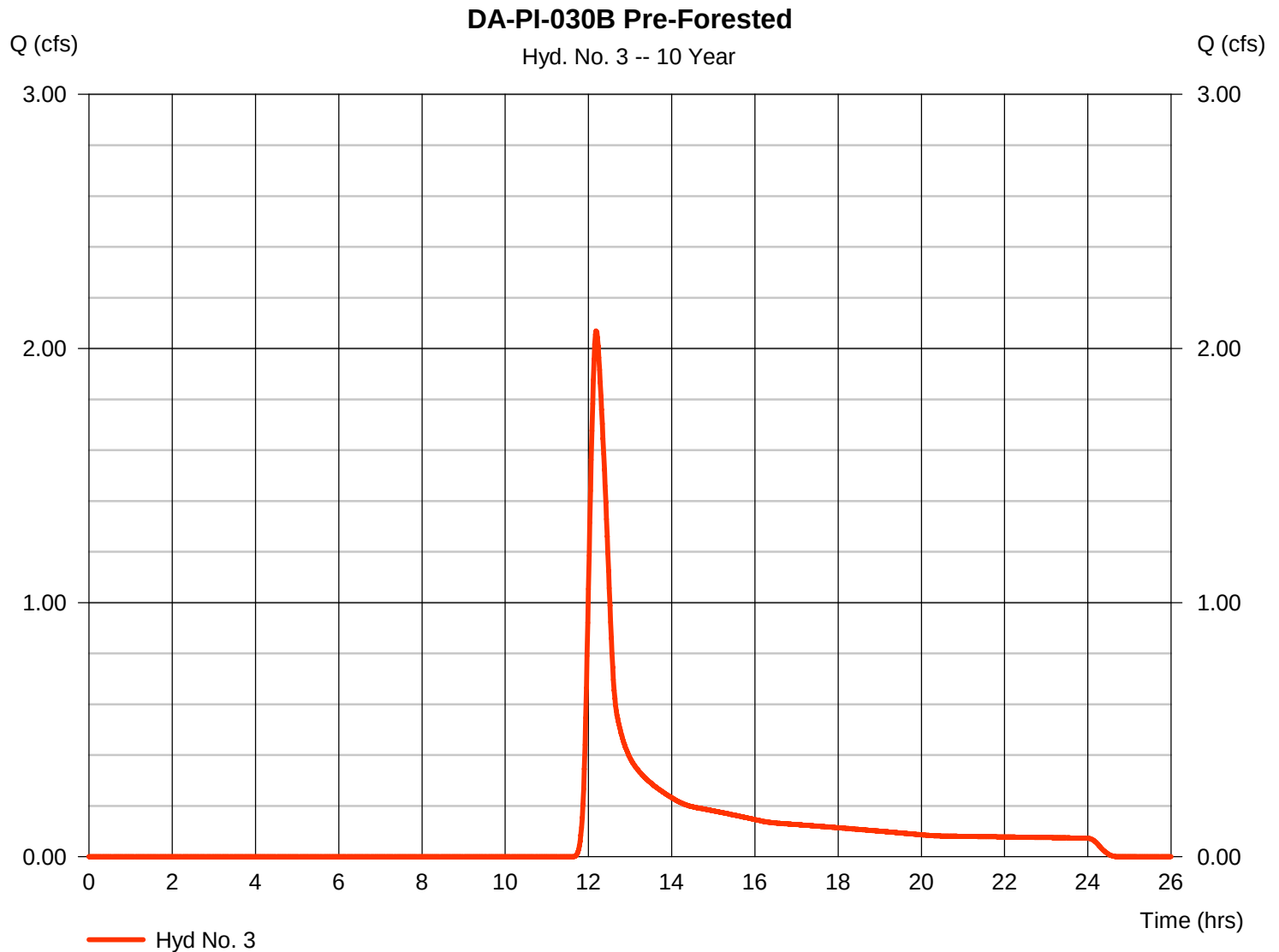
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Thursday, 08 / 17 / 2017

Hyd. No. 3

DA-PI-030B Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	2.069 cfs
Storm frequency	=	10 yrs	Time to peak	=	12.18 hrs
Time interval	=	1 min	Hyd. volume	=	9,533 cuft
Drainage area	=	2.410 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	25.60 min
Total precip.	=	5.20 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(2.410 \times 55)] / 2.410$ 

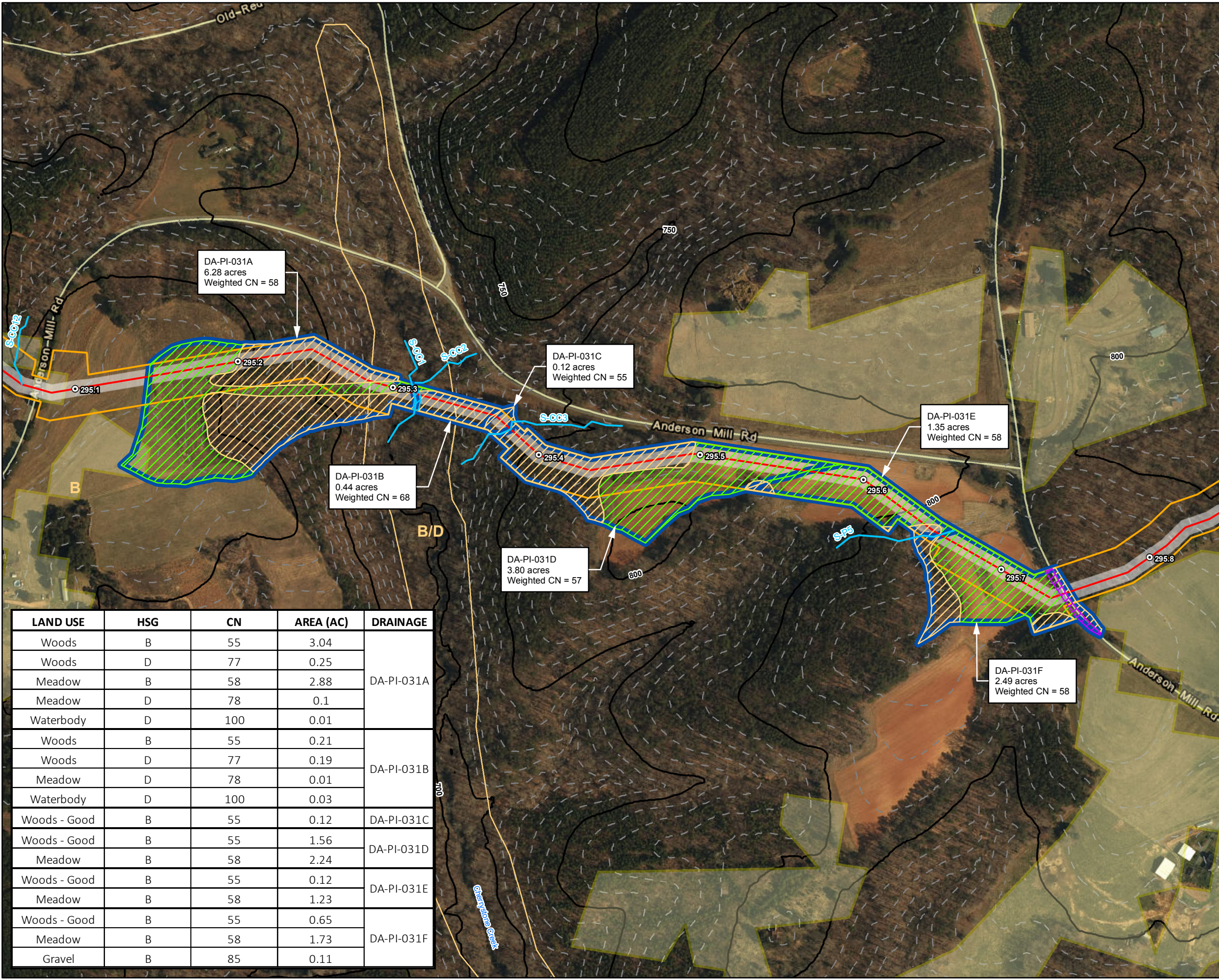
DA-PI-031

DA-PI-031 is located in a meadow and forested area with undulating slopes. DA-PI-031 contains existing gravel areas, such as Anderson Mill Road, and a waterbody, Cherrystone Creek, which cover less than 1% of the overall drainage area. No new impervious areas are proposed within DA-PI-031. The total phosphorus load reduction required for DA-PI-031 is -1.19 lbs/yr. Multiple points of analysis were evaluated within DA-PI-031 to determine the effects on each receiving stream/channel following construction. Specifically, DA-PI-031 was sub-divided into six sub-drainage areas (sub-areas A through F).

Stormwater quantity is met via the energy balance method for each of the sub-areas – DA-PI-031A, DA-PI-031B, DA-PI-031C, DA-PI-031D, DA-PI-031E, and DA-PI-031F - a 2 ft by 38 ft compost amended waterbar area in sub-area DA-PI-031B, a 2 ft by 18 ft compost amended waterbar area in sub-area DA-PI-031E, and 2 ft by 14 ft compost amended waterbar area in sub area DA-PI-031F (see General Detail MVP-ES38 for a full schedule). In addition, the Hydraflow hydrographs 10-year 24-hour peak discharge results indicate a decrease in flow ranging from 0.00 cfs to 0.61 cfs (as seen in table below).

Sub-area	Pre-peak Flow, 10-yr Q (cfs)	Post-peak Flow, 10-yr Q (cfs)	Flow Differential
DA-PI-031A	8.73	8.12	-0.61
DA-PI-031B	1.35	1.35	0.00
DA-PI-031C	0.22	0.22	0.00
DA-PI-031D	5.92	5.50	-0.42
DA-PI-031E	2.25	2.25	0.00
DA-PI-031F	6.10	6.10	0.00

Figures and calculations for DA-PI-031 follow. See Appendix D of the Annual Standards and Specifications for further detail on stormwater methodology.



Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Gravel
- Meadow
- Waterbody
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

1:3,600

300 150 0 300 Feet

W N E S

LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Woods	B	55	3.04	DA-PI-031A
Woods	D	77	0.25	
Meadow	B	58	2.88	
Meadow	D	78	0.1	
Waterbody	D	100	0.01	
Woods	B	55	0.21	DA-PI-031B
Woods	D	77	0.19	
Meadow	D	78	0.01	
Waterbody	D	100	0.03	
Woods - Good	B	55	0.12	DA-PI-031C
Woods - Good	B	55	1.56	DA-PI-031D
Meadow	B	58	2.24	DA-PI-031E
Woods - Good	B	55	0.12	
Meadow	B	58	1.23	
Woods - Good	B	55	0.65	DA-PI-031F
Meadow	B	58	1.73	
Gravel	B	85	0.11	



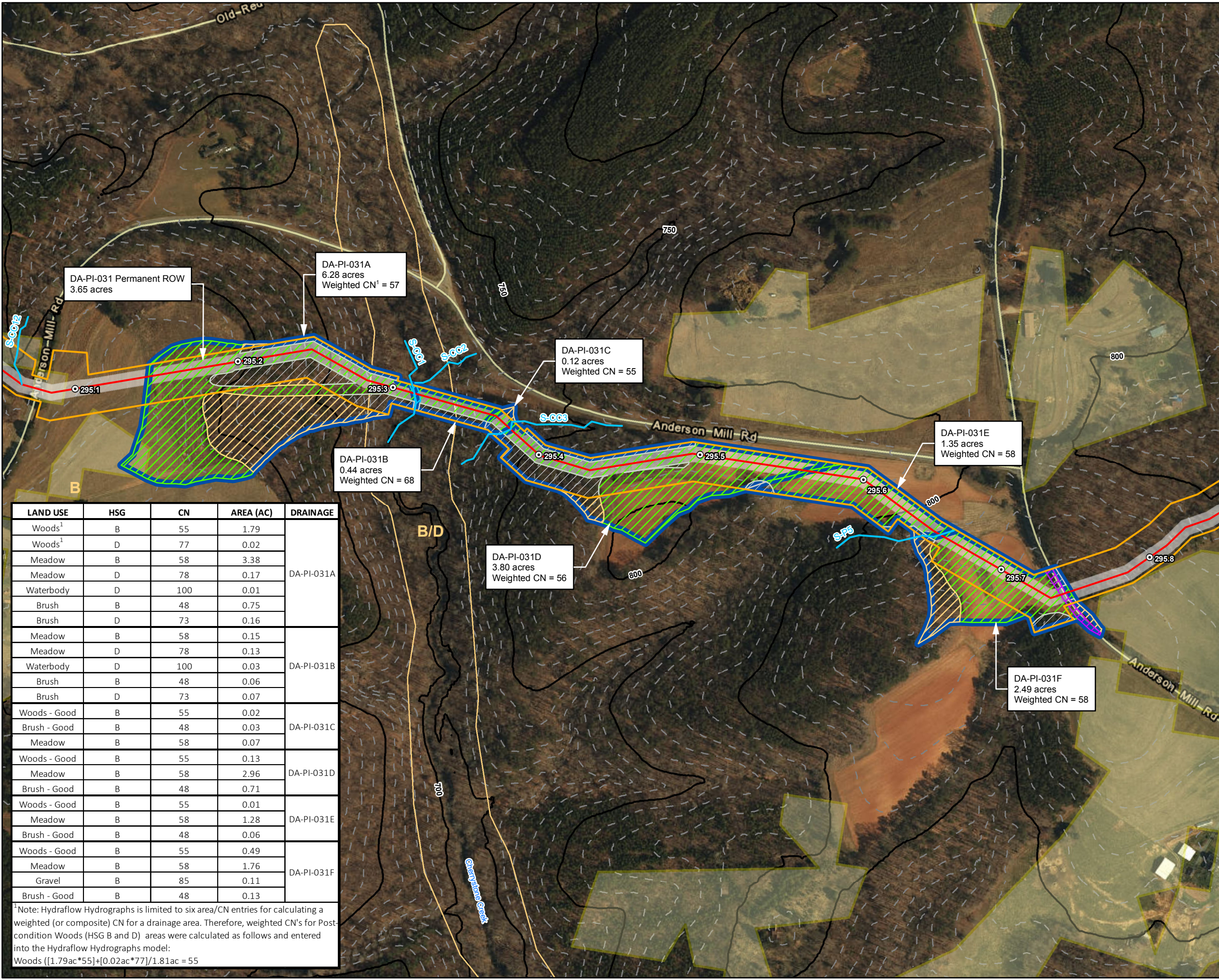
Mountain Valley Pipeline Project

Pre-Construction Drainage Area Map
DA-PI-031
Spread 11

Figure 1
Pittsylvania County, Virginia

August, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LIDAR provided by EQT 2016, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015, Agricultural Area from National Land Cover Dataset 2011.



Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Brush
- Gravel
- Meadow
- Waterbody
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

1:3,600

300 150 0 300 Feet

N

W

S

E



LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Woods ¹	B	55	1.79	DA-PI-031A
Woods ¹	D	77	0.02	
Meadow	B	58	3.38	
Meadow	D	78	0.17	
Waterbody	D	100	0.01	
Brush	B	48	0.75	DA-PI-031B
Brush	D	73	0.16	
Meadow	B	58	0.15	
Meadow	D	78	0.13	
Waterbody	D	100	0.03	
Brush	B	48	0.06	DA-PI-031C
Brush	D	73	0.07	
Meadow	B	58	0.07	
Woods - Good	B	55	0.13	DA-PI-031D
Meadow	B	58	2.96	
Brush - Good	B	48	0.71	DA-PI-031E
Woods - Good	B	55	0.01	
Meadow	B	58	1.28	
Brush - Good	B	48	0.06	DA-PI-031F
Woods - Good	B	55	0.49	
Meadow	B	58	1.76	
Gravel	B	85	0.11	
Brush - Good	B	48	0.13	

¹Note: Hydraflow Hydrographs is limited to six area/CN entries for calculating a weighted (or composite) CN for a drainage area. Therefore, weighted CN's for Post-condition Woods (HSG B and D) areas were calculated as follows and entered into the Hydraflow Hydrographs model:
Woods [(1.79ac*55)+[0.02ac*77)]/1.81ac = 55

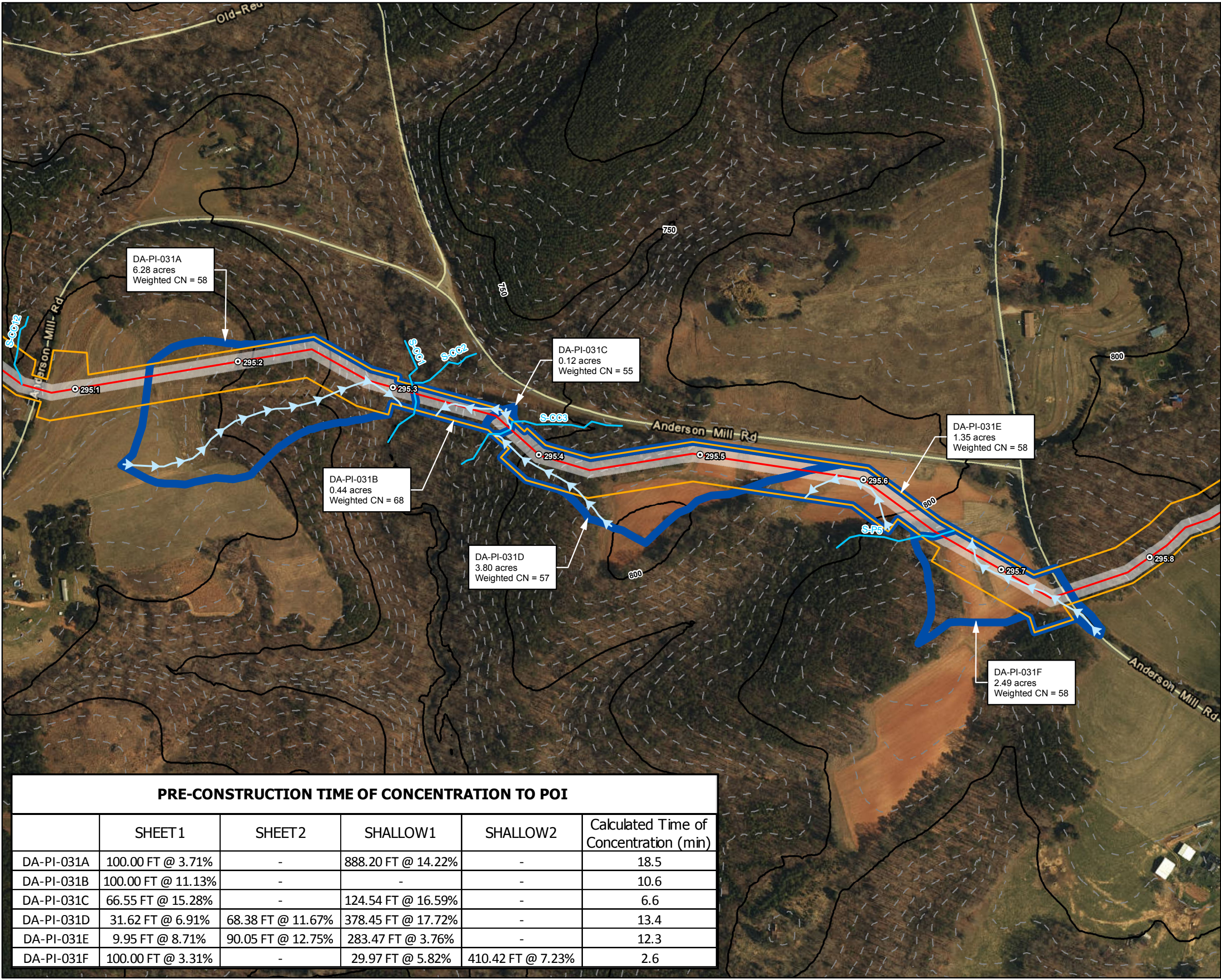
Mountain Valley Pipeline Project

Post-Construction Drainage Area Map
DA-PI-031
Spread 11

Figure 2
Pittsylvania County, Virginia

August, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LIDAR provided by EQT 2016, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015, Agricultural Area from National Land Cover Dataset 2011.



Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:3,600

300 150 0 300 Feet

W N E S

Mountain Valley Pipeline Project

Mountain Valley
PIPELINE

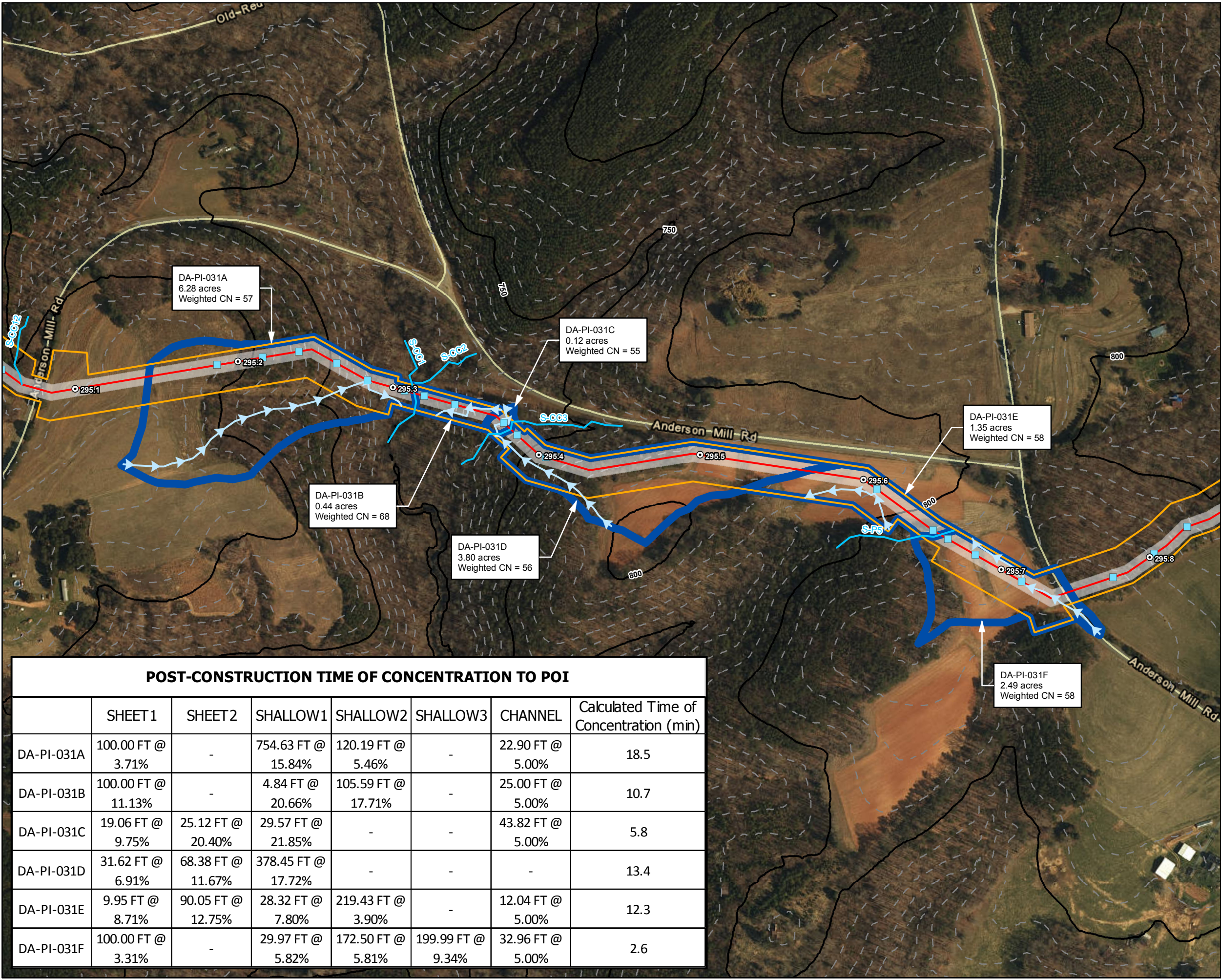
**Pre-Construction Drainage Area
and Time of Concentration**

**DA-PI-031
Spread 11**

Figure 3
Pittsylvania County, Virginia
August, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016.

PRE-CONSTRUCTION TIME OF CONCENTRATION TO POI					
	SHEET 1	SHEET 2	SHALLOW1	SHALLOW2	Calculated Time of Concentration (min)
DA-PI-031A	100.00 FT @ 3.71%	-	888.20 FT @ 14.22%	-	18.5
DA-PI-031B	100.00 FT @ 11.13%	-	-	-	10.6
DA-PI-031C	66.55 FT @ 15.28%	-	124.54 FT @ 16.59%	-	6.6
DA-PI-031D	31.62 FT @ 6.91%	68.38 FT @ 11.67%	378.45 FT @ 17.72%	-	13.4
DA-PI-031E	9.95 FT @ 8.71%	90.05 FT @ 12.75%	283.47 FT @ 3.76%	-	12.3
DA-PI-031F	100.00 FT @ 3.31%	-	29.97 FT @ 5.82%	410.42 FT @ 7.23%	2.6



Legend

- Milepost
- Permanent Waterbars
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:3,600

300 150 0 300 Feet

Mountain Valley Pipeline Project

Post-Construction Drainage Area and Time of Concentration

DA-PI-031 Spread 11

Figure 4

Pittsylvania County, Virginia

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016.

POST-CONSTRUCTION TIME OF CONCENTRATION TO POI							
	SHEET 1	SHEET 2	SHALLOW1	SHALLOW2	SHALLOW3	CHANNEL	Calculated Time of Concentration (min)
DA-PI-031A	100.00 FT @ 3.71%	-	754.63 FT @ 15.84%	120.19 FT @ 5.46%	-	22.90 FT @ 5.00%	18.5
DA-PI-031B	100.00 FT @ 11.13%	-	4.84 FT @ 20.66%	105.59 FT @ 17.71%	-	25.00 FT @ 5.00%	10.7
DA-PI-031C	19.06 FT @ 9.75%	25.12 FT @ 20.40%	29.57 FT @ 21.85%	-	-	43.82 FT @ 5.00%	5.8
DA-PI-031D	31.62 FT @ 6.91%	68.38 FT @ 11.67%	378.45 FT @ 17.72%	-	-	-	13.4
DA-PI-031E	9.95 FT @ 8.71%	90.05 FT @ 12.75%	28.32 FT @ 7.80%	219.43 FT @ 3.90%	-	12.04 FT @ 5.00%	12.3
DA-PI-031F	100.00 FT @ 3.31%	-	29.97 FT @ 5.82%	172.50 FT @ 5.81%	199.99 FT @ 9.34%	32.96 FT @ 5.00%	2.6

DEQ Virginia Runoff Reduction Method Re-Development Compliance Spreadsheet - Version 3.0

BMP Design Specifications List: 2013 Draft Stds & Specs

Site Summary - Linear Development Project***

Total Rainfall (in):	43
Total Disturbed Acreage:	3.65

Site Land Cover Summary

Pre-ReDevelopment Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	% of Total
Forest/Open (acres)	0.00	3.31	0.00	0.32	3.63	99
Managed Turf (acres)	0.00	0.00	0.00	0.00	0.00	0
Impervious Cover (acres)	0.00	0.02	0.00	0.00	0.02	1
					3.65	100

Post-ReDevelopment Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	% of Total
Forest/Open (acres)	0.00	3.31	0.00	0.32	3.63	99
Managed Turf (acres)	0.00	0.00	0.00	0.00	0.00	0
Impervious Cover (acres)	0.00	0.02	0.00	0.00	0.02	1
					3.65	100

* Forest/Open Space areas must be protected in accordance with the Virginia Runoff Reduction Method

Site Tv and Land Cover Nutrient Loads

	Final Post-Development (Post-ReDevelopment & New Impervious)	Post- ReDevelopment	Post- Development (New Impervious)	Adjusted Pre- ReDevelopment
Site Rv	0.04	0.04	--	0.04
Treatment Volume (ft ³)	488	488	--	488
TP Load (lb/yr)	0.31	0.31	--	0.31

Baseline TP Load (lb/yr): 1.4965* *Reduction below new development load limitation not required

Pre- ReDevelopment TP Load per acre (lb/acre/yr)	Final Post-Development TP Load per acre (lb/acre/yr)	Post-ReDevelopment TP Load per acre (lb/acre/yr)
0.08	0.08	0.08

Total TP Load Reduction Required (lb/yr)	-1.19	N/A***	N/A***
--	-------	--------	--------

***This is a linear development project

	Final Post-Development Load (Post-ReDevelopment & New Impervious)	Pre- ReDevelopment
TN Load (lb/yr)	2.19	2.19

Site Compliance Summary - ***Linear Development Project

Maximum % Reduction Required Below Pre-ReDevelopment Load	20%
--	-----

* Note: % Reduction will reduce post-development TP load to less than or equal to baseline load of 1.5 lb/yr (0.41 lb/ac/yr)
 [Post-Dev Reduction Requirement = Post-Dev TP load - baseline load of 1.5 lb/yr], baseline load = site area x 0.41 lb/ac/yr

Total Runoff Volume Reduction (ft ³)	0
Total TP Load Reduction Achieved (lb/yr)	0.00
Total TN Load Reduction Achieved (lb/yr)	0.00
Remaining Post Development TP Load (lb/yr)	0.31
Remaining TP Load Reduction (lb/yr) Required	0.00

**** TARGET TP REDUCTION EXCEEDED BY 1.19 LB/YEAR ****

**Reduction below new development load limitation not required*

DA-PI-031A

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.588	4,792
Developed Condition	0.437	4,253
Pre-Developed (Forest) Condition	0.313	3,743

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1:

$$Q_{\text{developed}} \leq \text{IF} \times [(Q_{\text{pre-developed}} \times \text{RV}_{\text{pre-developed}}) / \text{RV}_{\text{developed}}] \text{ ----->}$$

Q (cfs)

0.437

≤

OK

Q (cfs)

0.530

Check #2:

$$Q_{\text{developed}} \leq Q_{\text{pre-developed}} \text{ ----->}$$

0.437

≤

OK

0.588

Check #3:

$$Q_{\text{developed}} \text{ shall not be required to be } \leq (Q_{\text{forest}} \times \text{RV}_{\text{forest}}) / \text{RV}_{\text{developed}} \text{ --->}$$

0.437

shall not be required to be ≤

0.275

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning's n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<i>Note:</i> <i>Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</i> ¹<i>For Paved Road land surface types a Manning's n of 0.011 was used</i> <i>Sources:</i> <i>-USACE, 1998, HEC-1 Flood Hydrograph Package User's Manual, Hydrologic Engineering Center, Davis, CA</i> <i>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</i>	

Table 2 – Manning's n Values for Open Channel Flow

Channel Type	Manning n		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹ For the developed condition, a conservative Manning's n value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar, level spreader diversion, or grass channel. ² For the pre-developed condition and post-development condition, a Manning's n value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

1



2



3



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-PI-031A Pre
2	SCS Runoff	DA-PI-031A Post
3	SCS Runoff	DA-PI-031A Pre-Forested

Hydrograph Return Period Recap

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

[illegible]

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.588	1	729	4,792	-----	-----	-----	DA-PI-031A Pre
2	SCS Runoff	0.437	1	730	4,253	-----	-----	-----	DA-PI-031A Post
3	SCS Runoff	0.313	1	734	3,743	-----	-----	-----	DA-PI-031A Pre-Forested
DA-PI-031A.gpw					Return Period: 1 Year			Monday, 08 / 21 / 2017	

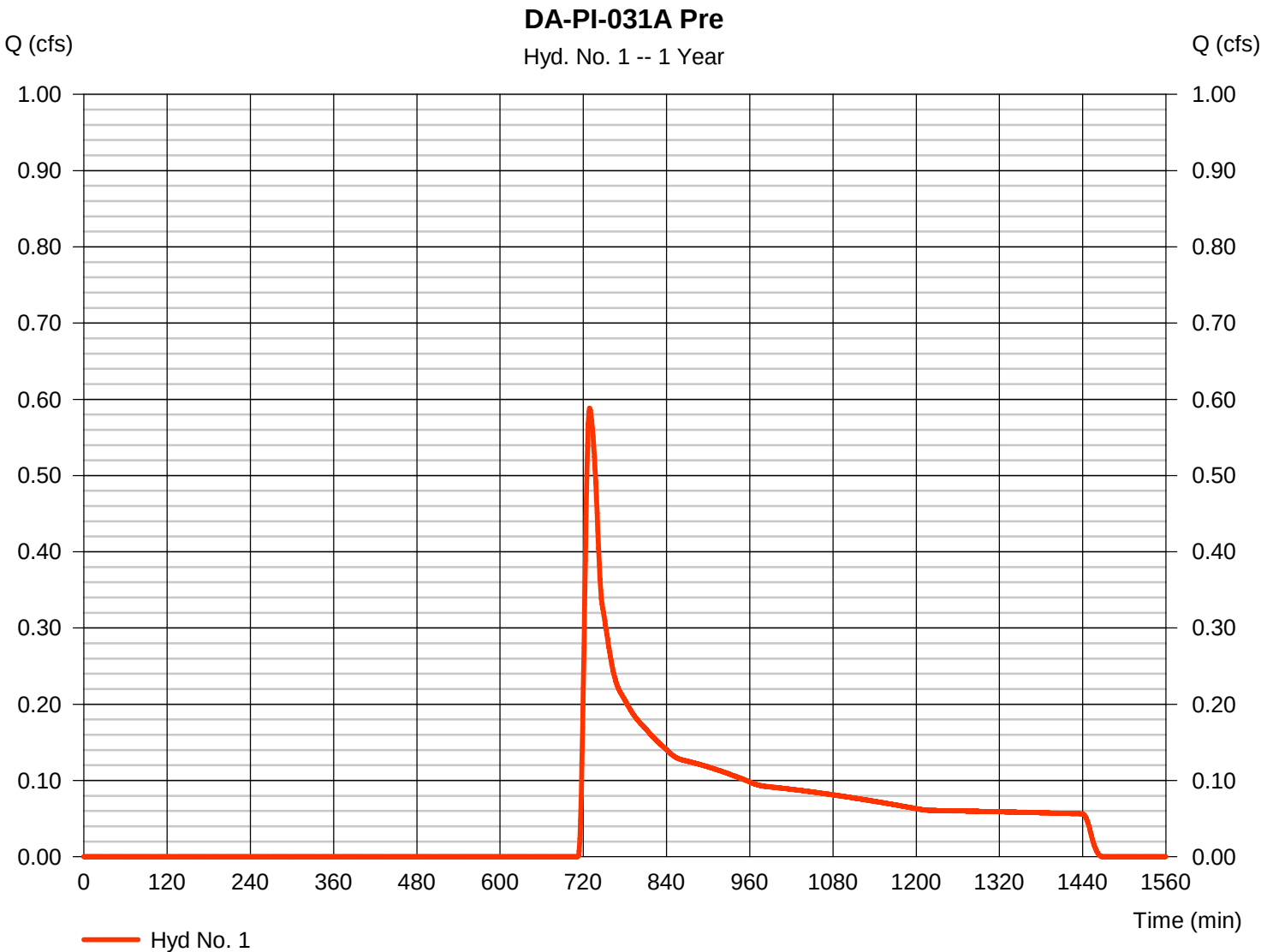
Hydrograph Report

Hyd. No. 1

DA-PI-031A Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.588 cfs
Storm frequency	= 1 yrs	Time to peak	= 729 min
Time interval	= 1 min	Hyd. volume	= 4,792 cuft
Drainage area	= 6.280 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.50 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(3.040 x 55) + (0.250 x 77) + (2.880 x 58) + (0.100 x 78) + (0.010 x 100)] / 6.280



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-PI-031A Pre

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 3.71	0.00	0.00				
Travel Time (min)	= 16.04	+	0.00	+	0.00	=	16.04
Shallow Concentrated Flow							
Flow length (ft)	= 888.20	0.00	0.00				
Watercourse slope (%)	= 14.22	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=6.08	0.00	0.00				
Travel Time (min)	= 2.43	+	0.00	+	0.00	=	2.43
Channel Flow							
X sectional flow area (sqft)	= 0.00	0.00	0.00				
Wetted perimeter (ft)	= 0.00	0.00	0.00				
Channel slope (%)	= 0.00	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	((0})0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc				18.50 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

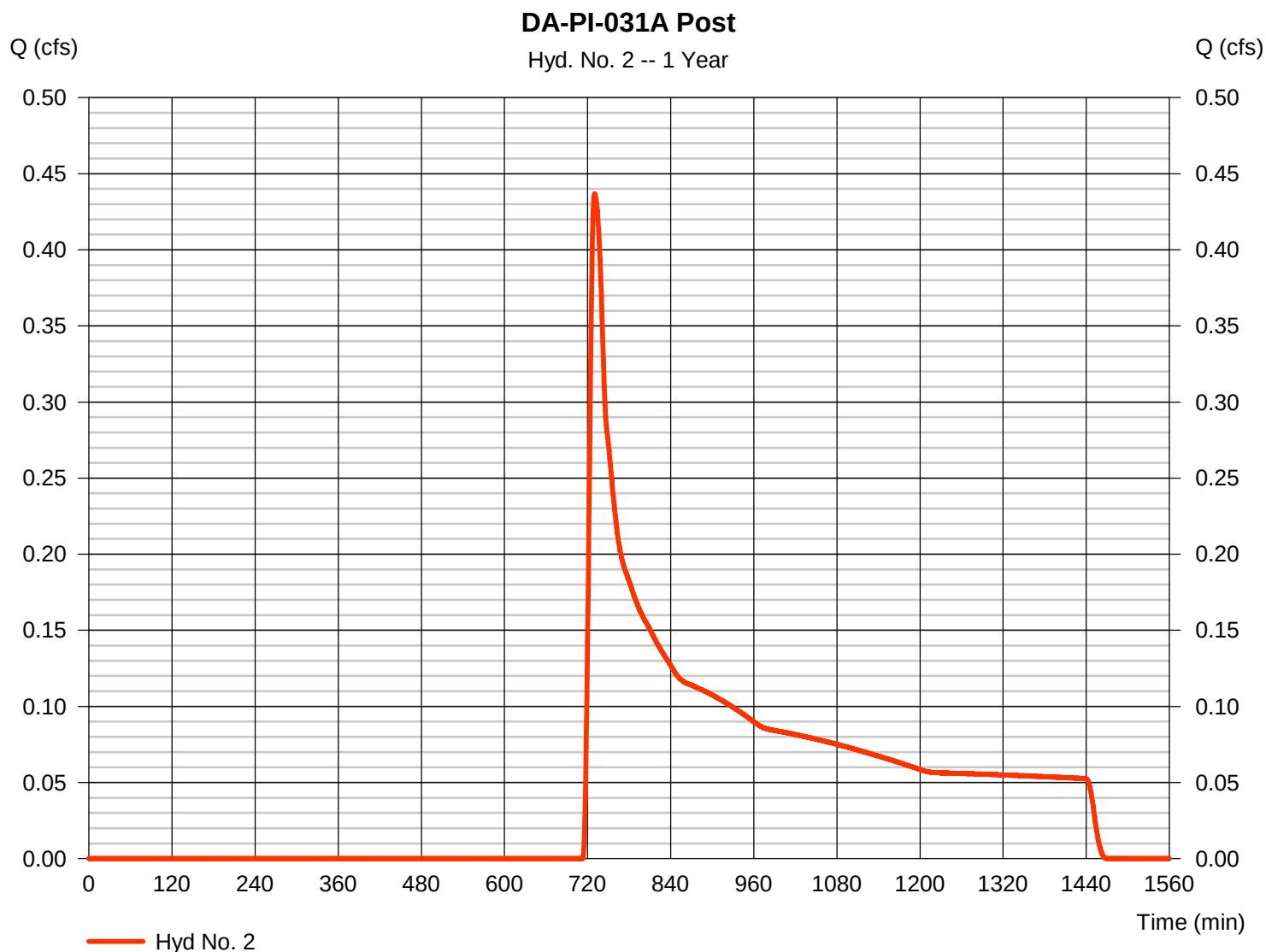
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-PI-031A Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.437 cfs
Storm frequency	= 1 yrs	Time to peak	= 730 min
Time interval	= 1 min	Hyd. volume	= 4,253 cuft
Drainage area	= 6.280 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.50 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.810 \times 55) + (3.380 \times 58) + (0.170 \times 78) + (0.010 \times 100) + (0.750 \times 48) + (0.160 \times 73)] / 6.280$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-PI-031A Post

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 3.71	0.00	0.00				
Travel Time (min)	= 16.04	+	0.00	+	0.00	=	16.04
Shallow Concentrated Flow							
Flow length (ft)	= 754.63	120.19	0.00				
Watercourse slope (%)	= 15.84	5.46	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=6.42	4.75	0.00				
Travel Time (min)	= 1.96	+	0.42	+	0.00	=	2.38
Channel Flow							
X sectional flow area (sqft)	= 2.00	0.00	0.00				
Wetted perimeter (ft)	= 4.47	0.00	0.00				
Channel slope (%)	= 5.00	0.00	0.00				
Manning's n-value	= 0.040	0.015	0.015				
Velocity (ft/s)	=4.86	0.00	0.00				
Flow length (ft)	(0)}22.9	0.0	0.0				
Travel Time (min)	= 0.08	+	0.00	+	0.00	=	0.08
Total Travel Time, Tc				18.50 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

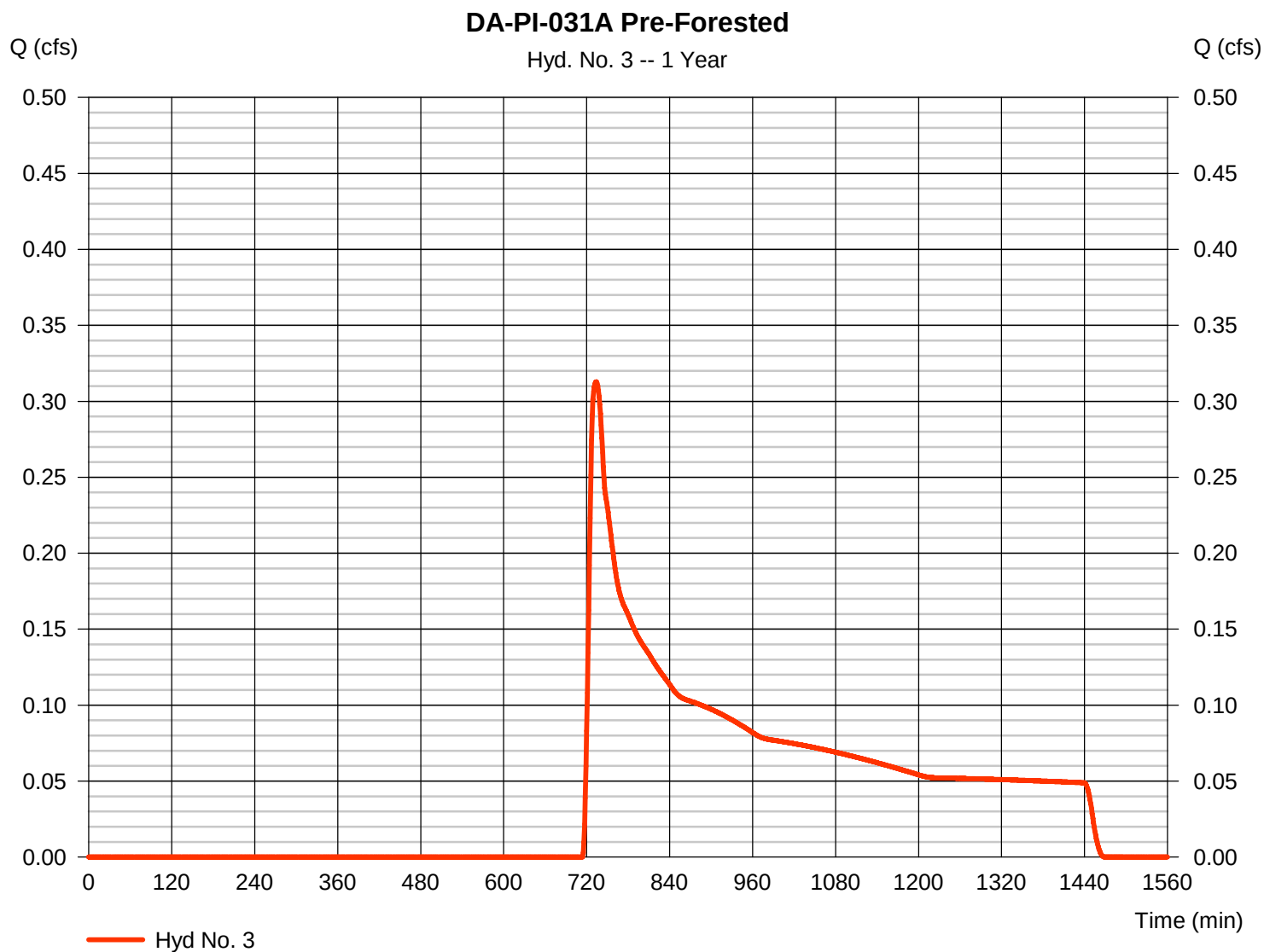
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-PI-031A Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.313 cfs
Storm frequency	=	1 yrs	Time to peak	=	734 min
Time interval	=	1 min	Hyd. volume	=	3,743 cuft
Drainage area	=	6.280 ac	Curve number	=	56*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	18.50 min
Total precip.	=	2.80 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(5.920 \times 55) + (0.360 \times 77)] / 6.280$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-PI-031A Pre-Forested

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00	
Land slope (%)	= 3.71	0.00	0.00	
Travel Time (min)	= 16.04	+ 0.00	+ 0.00	= 16.04
Shallow Concentrated Flow				
Flow length (ft)	= 888.20	0.00	0.00	
Watercourse slope (%)	= 14.22	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=6.08	0.00	0.00	
Travel Time (min)	= 2.43	+ 0.00	+ 0.00	= 2.43
Channel Flow				
X sectional flow area (sqft)	= 0.00	0.00	0.00	
Wetted perimeter (ft)	= 0.00	0.00	0.00	
Channel slope (%)	= 0.00	0.00	0.00	
Manning's n-value	= 0.030	0.015	0.015	
Velocity (ft/s)	=0.00	0.00	0.00	
Flow length (ft)	(0)0.0	0.0	0.0	
Travel Time (min)	= 0.00	+ 0.00	+ 0.00	= 0.00
Total Travel Time, Tc				18.50 min

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	2.198	1	727	10,209	-----	-----	-----	DA-PI-031A Pre
2	SCS Runoff	1.881	1	727	9,372	-----	-----	-----	DA-PI-031A Post
3	SCS Runoff	1.586	1	728	8,566	-----	-----	-----	DA-PI-031A Pre-Forested
DA-PI-031A.gpw					Return Period: 2 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

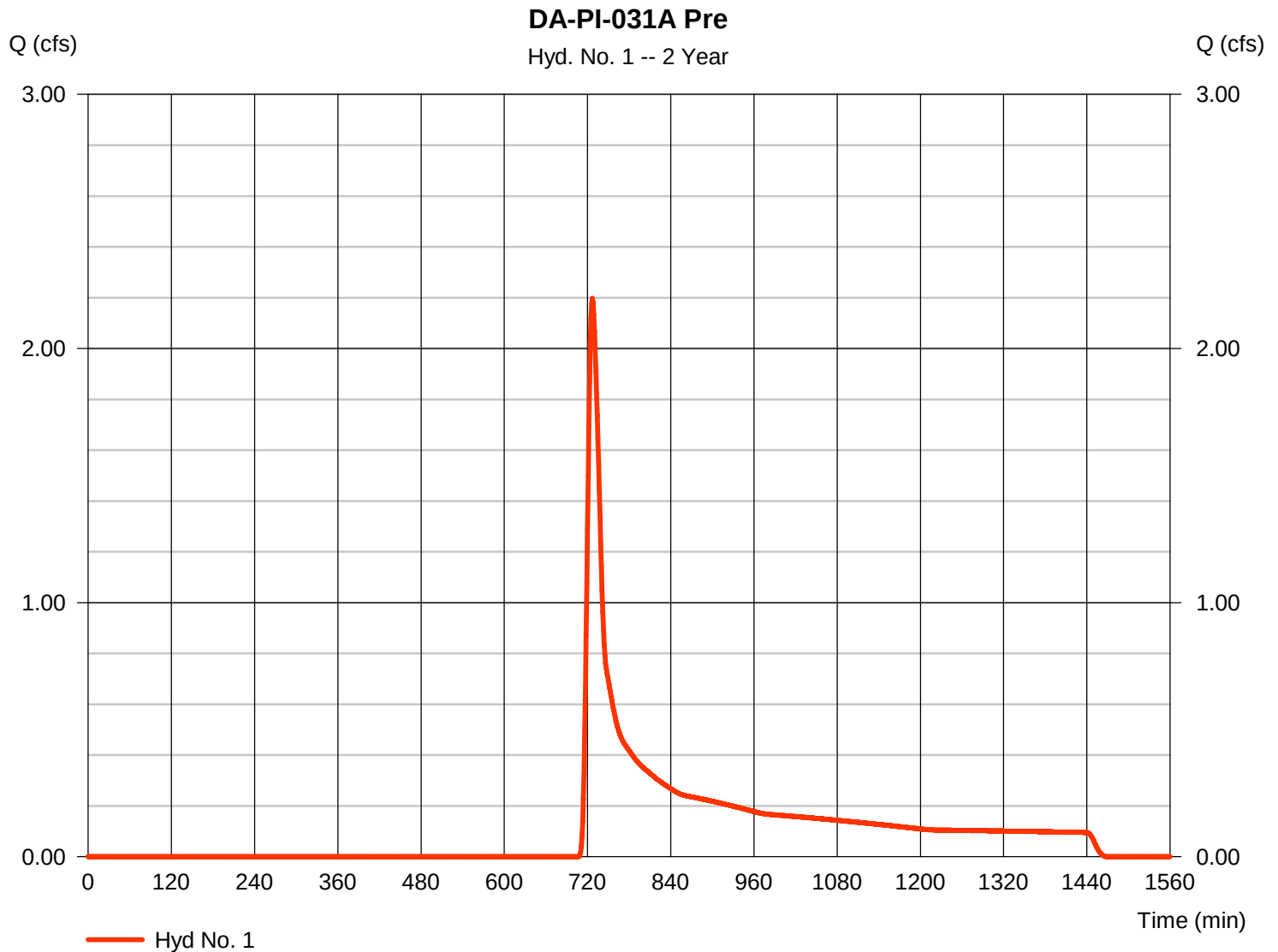
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-PI-031A Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 2.198 cfs
Storm frequency	= 2 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 10,209 cuft
Drainage area	= 6.280 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.50 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(3.040 \times 55) + (0.250 \times 77) + (2.880 \times 58) + (0.100 \times 78) + (0.010 \times 100)] / 6.280$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

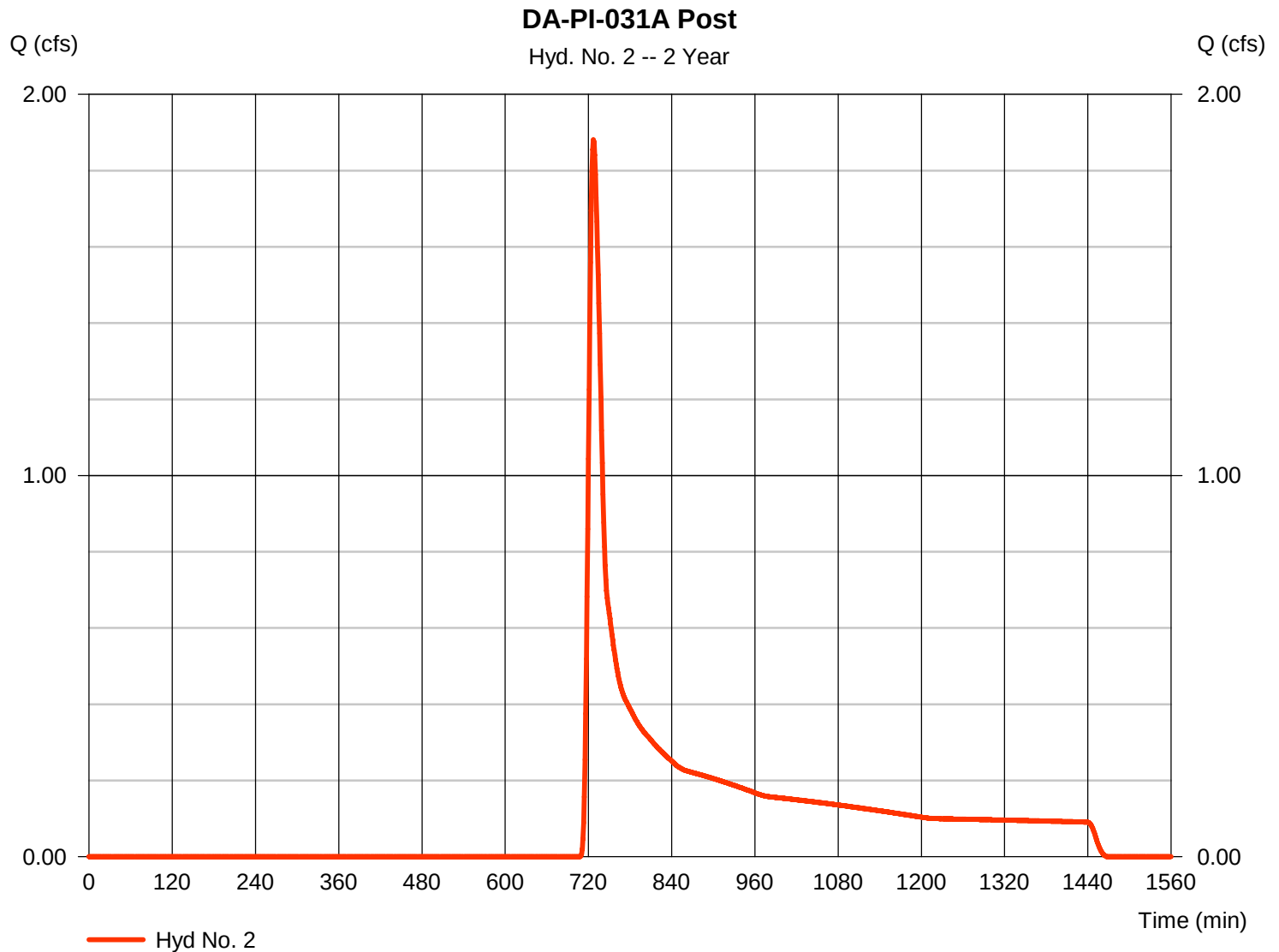
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-PI-031A Post

Hydrograph type	= SCS Runoff	Peak discharge	= 1.881 cfs
Storm frequency	= 2 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 9,372 cuft
Drainage area	= 6.280 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.50 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.810 \times 55) + (3.380 \times 58) + (0.170 \times 78) + (0.010 \times 100) + (0.750 \times 48) + (0.160 \times 73)] / 6.280$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

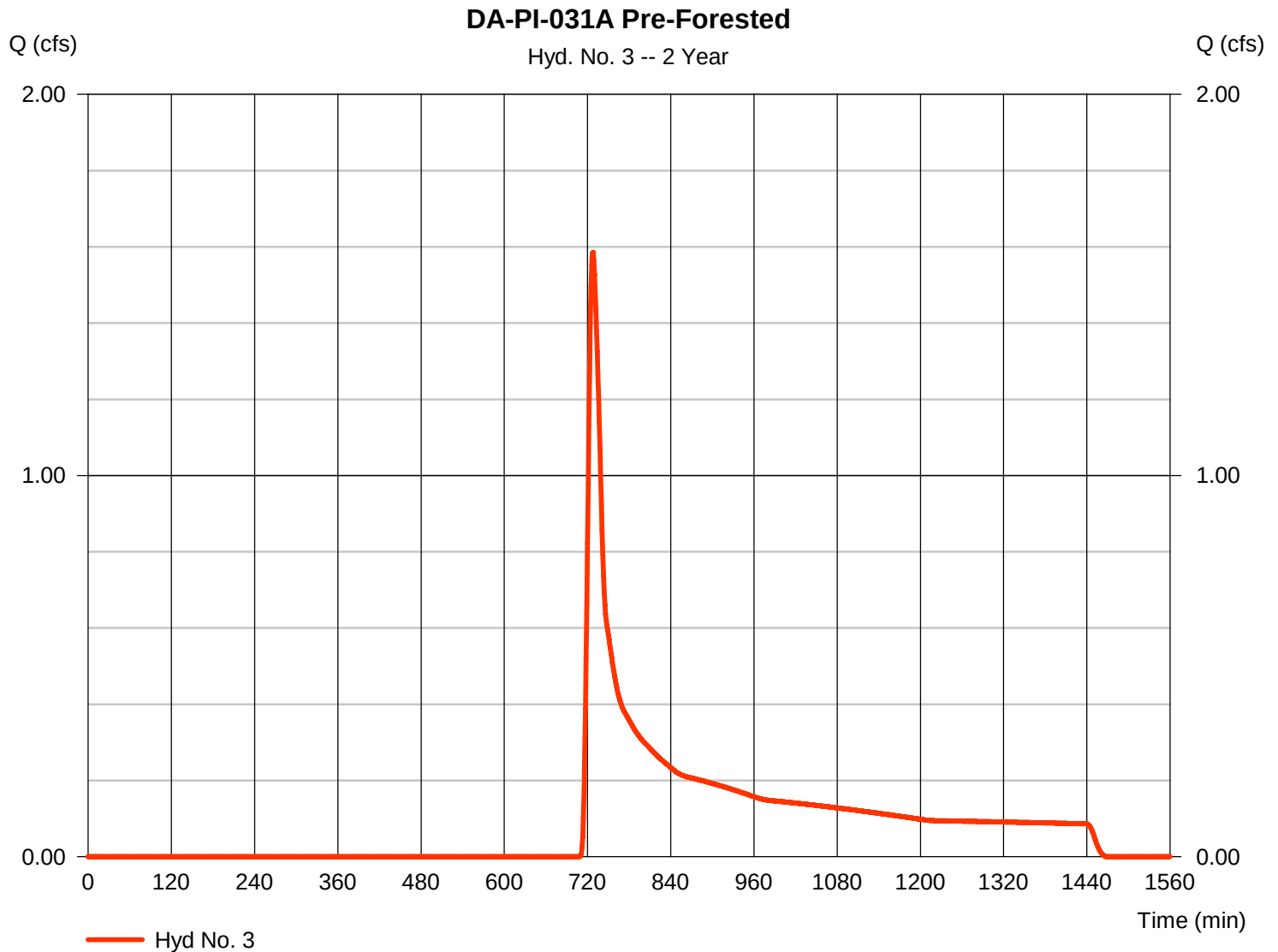
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-PI-031A Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	1.586 cfs
Storm frequency	=	2 yrs	Time to peak	=	728 min
Time interval	=	1 min	Hyd. volume	=	8,566 cuft
Drainage area	=	6.280 ac	Curve number	=	56*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	18.50 min
Total precip.	=	3.50 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(5.920 \times 55) + (0.360 \times 77)] / 6.280$



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	8.728	1	725	28,857	-----	-----	-----	DA-PI-031A Pre
2	SCS Runoff	8.119	1	725	27,332	-----	-----	-----	DA-PI-031A Post
3	SCS Runoff	7.516	1	725	25,835	-----	-----	-----	DA-PI-031A Pre-Forested
DA-PI-031A.gpw					Return Period: 10 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

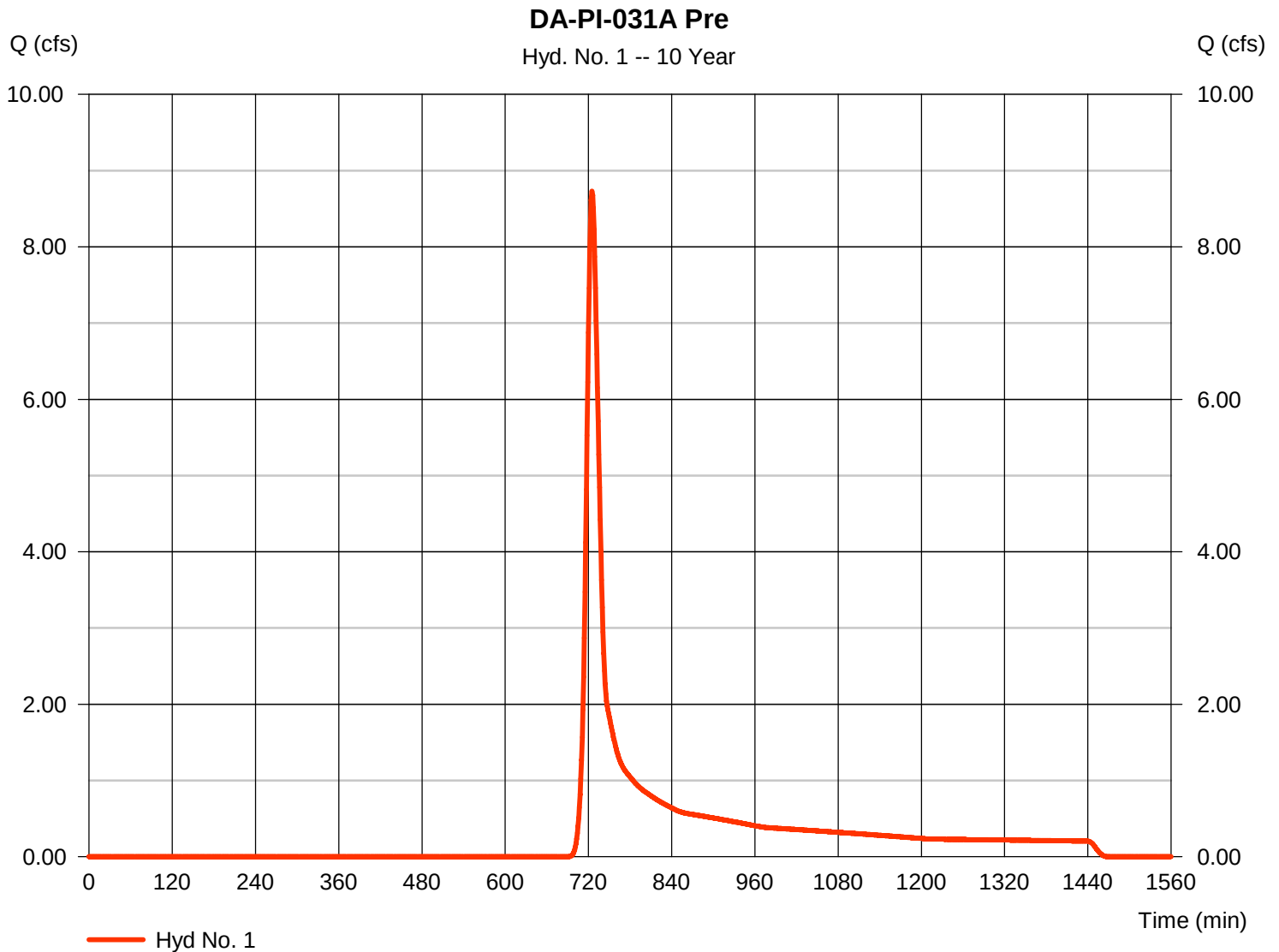
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-PI-031A Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 8.728 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 28,857 cuft
Drainage area	= 6.280 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.50 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(3.040 \times 55) + (0.250 \times 77) + (2.880 \times 58) + (0.100 \times 78) + (0.010 \times 100)] / 6.280$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

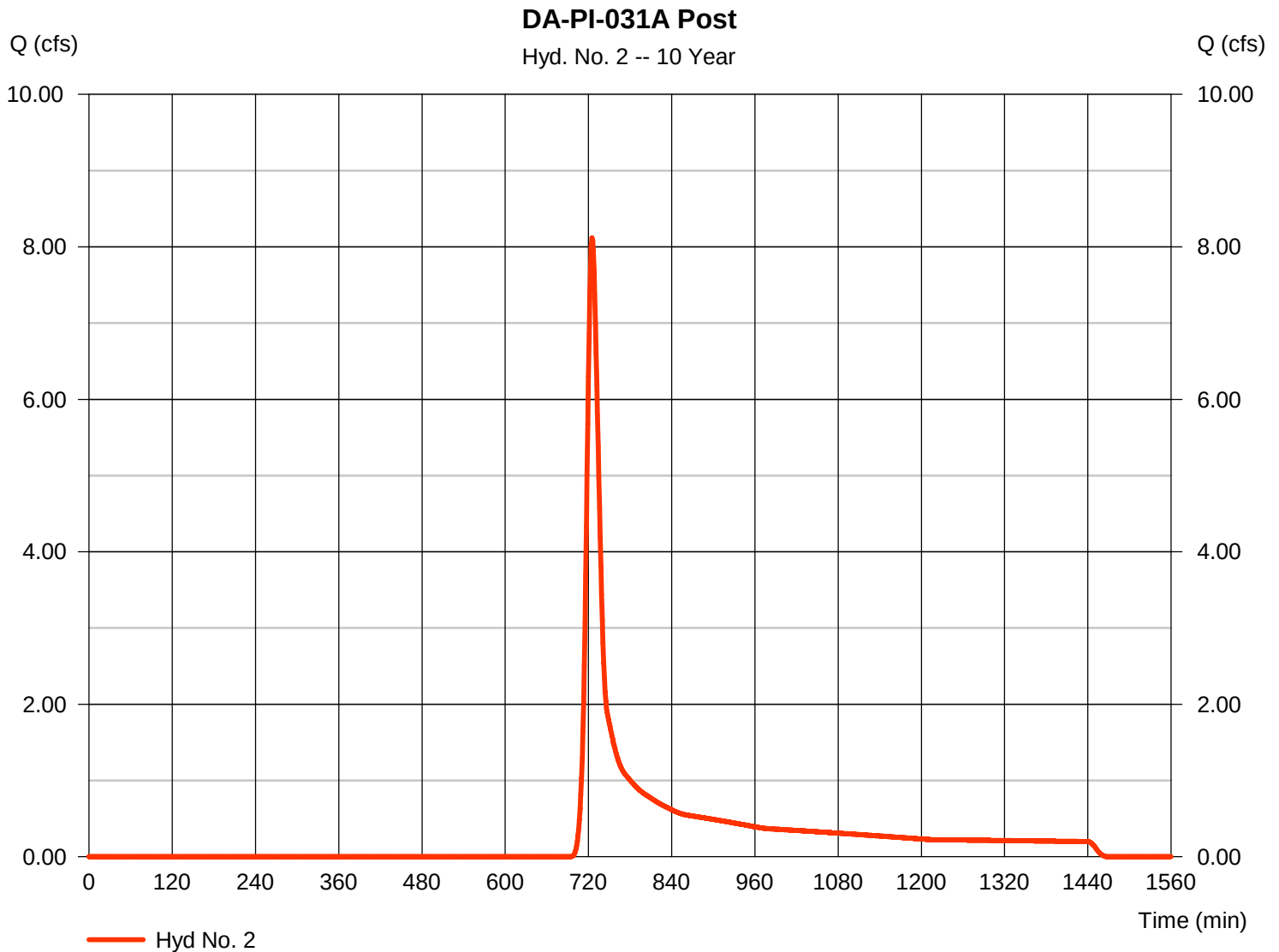
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-PI-031A Post

Hydrograph type	= SCS Runoff	Peak discharge	= 8.119 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 27,332 cuft
Drainage area	= 6.280 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.50 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.810 \times 55) + (3.380 \times 58) + (0.170 \times 78) + (0.010 \times 100) + (0.750 \times 48) + (0.160 \times 73)] / 6.280$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

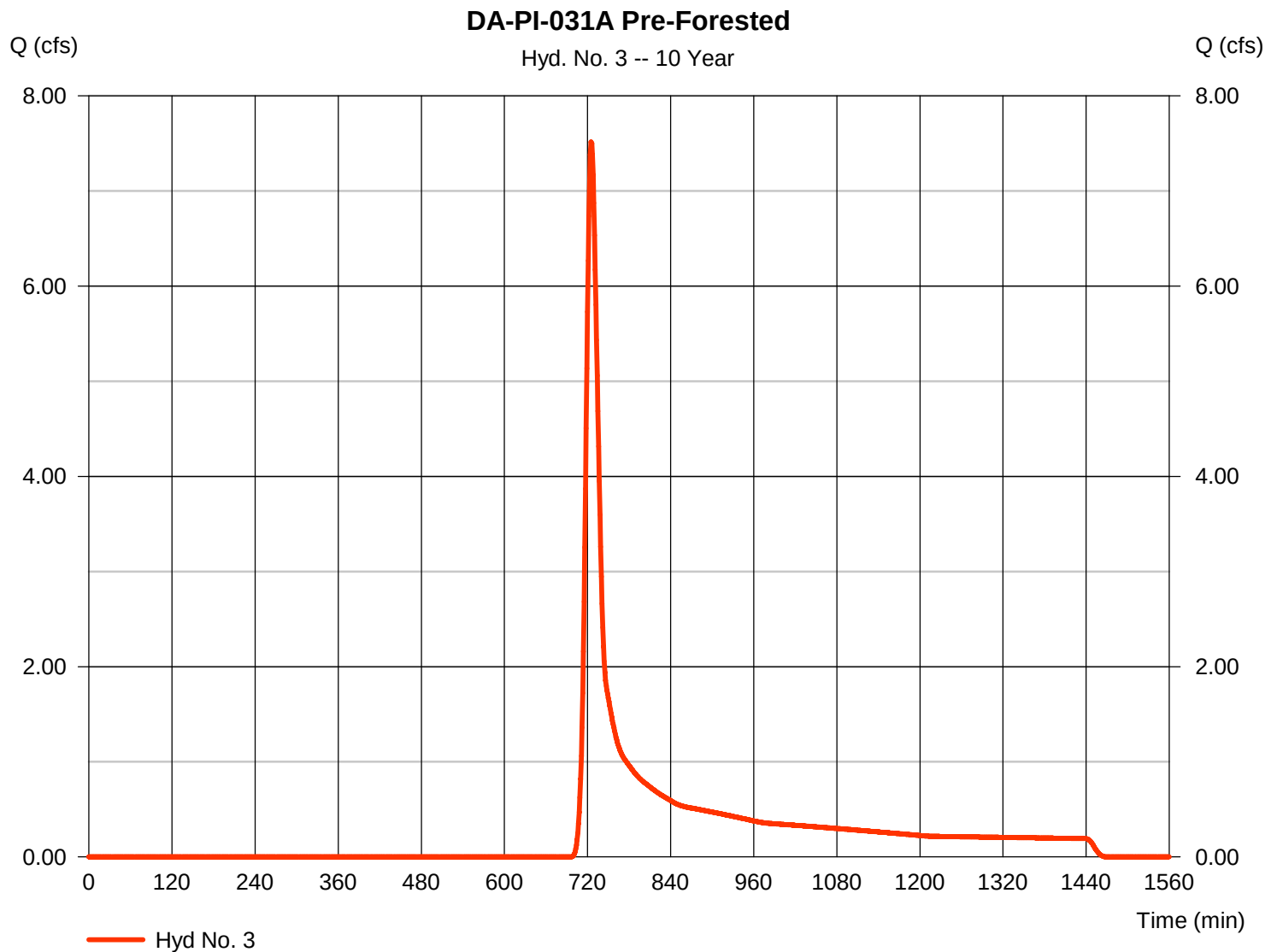
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-PI-031A Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	7.516 cfs
Storm frequency	=	10 yrs	Time to peak	=	725 min
Time interval	=	1 min	Hyd. volume	=	25,835 cuft
Drainage area	=	6.280 ac	Curve number	=	56*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	18.50 min
Total precip.	=	5.20 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(5.920 \times 55) + (0.360 \times 77)] / 6.280$



DA-PI-031B

STORAGE VOLUME OF WATERBAR WITH SOIL COMPOST AMENDMENT AREA

Equations Used: ¹V_{gravel} storage = L*W*D_{gravel}*(40/100)
²V_{soil} storage = L*W*D_{soil}*(20/100)
³V_{surface} storage = [W*S*D²/2]+[L*S*D²/2]+[W*L*D]+[((2*S*D)²/2)/3]
¹Equation #2b under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, assuming that gravel is made up of 40% voids.
²Equation #2b under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, assuming that soil compost amendment is made up of 20% voids.
³Equation #1 under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, but calculation also takes into account surface side slopes.

Inputs:

Depth of Gravel Layer, D _{gravel} (ft) =	0	
Depth of Soil Amendment Area, D _{soil} (ft) =	1	Refer to Table 4.3 in VA DEQ Stormwater Design Specification No. 4; Note that compost amendment may not be necessary for HSG A/B soils
Length of Waterbar Soil Amendment Area, L (ft) =	20	
Width of Waterbar Soil Amendment Area, W (ft) =	2	
Inside Embankment Side Slopes, S (H:V) =	2	Assume 2H:1V surface side slopes for waterbars
Number of Perm. Waterbars in Drainage Area, n =	2	
Design Infiltration Rate, IR (in/hr) =	0.2	Min. rate of 0.30 in/hr for HSG A soils and 0.15-0.30 in/hr for HSG B soils (see Chap. 4, p. 4-30 in VA Stormwater Management Handbook Volume II (First Edition, 1999)
Surface Ponding Depth, D (ft) =	0.5	Assume 0.5' CFS height at the end of waterbars

Calculations:

Total Storage Depth per BMP (ft) =	1.5
Surface Storage Volume per BMP (cf) =	31.66666667
Subsurface Storage Volume per BMP (cf) =	8
Total Storage Volume per BMP (cf) =	39.66666667
Total BMP Storage Volume in Drainage Area (cf) =	79.33333333
Calculated Infiltration Period per BMP (hr) =	59.5

Depth-Storage Data				
Depth (ft)	Width (ft)	Length (ft)	Storage Volume per BMP (cf)	Storage Volume in Drainage Area (cf)
0	2	20	0	0
0.5	2	20	4	8
1	2	20	8	16
1.5	4	22	39.66666667	79.33333333
2	6	24	97.33333333	194.66666667
2.5	8	26	185	370
3	10	28	306.6666667	613.3333333
3.5	12	30	466.3333333	932.6666667

ENERGY BALANCE METHOD

Inputs:

1-Yr Event		
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.300	856
Developed Condition	0.296	776
Pre-Developed (Forest) Condition	0.270	794

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.9

Calculations:	Check #1:	$Q_{\text{developed}} \leq IF \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}]$ ----->	Q (cfs)		Q (cfs)
			0.296	≤	0.298
				OK	
	Check #2:	$Q_{\text{developed}} \leq Q_{\text{pre-developed}}$ ----->	0.296	≤	0.300
				OK	
	Check #3:	$Q_{\text{developed}} \leq \text{shall not be required to be } \leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}}$ --->	0.296	<u>shall not</u>	0.276

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

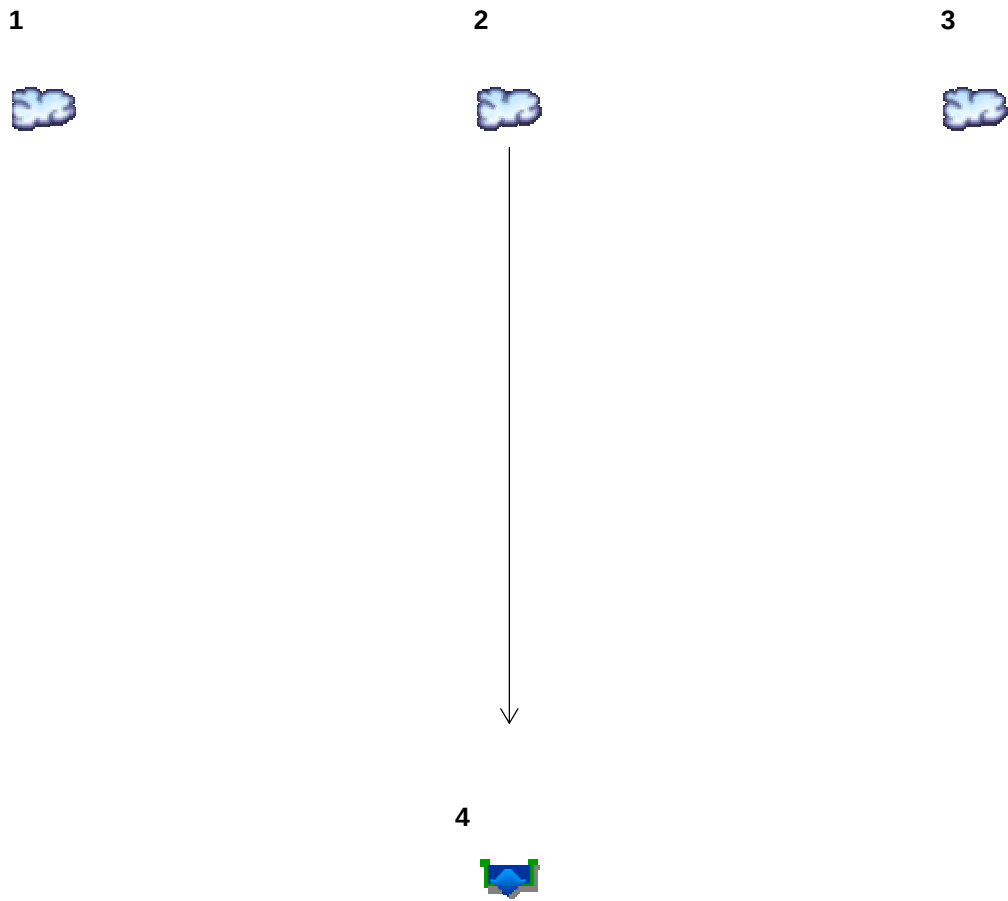
Table 1 – Manning's n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<i>Note:</i> Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted. ¹For Paved Road land surface types a Manning's n of 0.011 was used <i>Sources:</i> -USACE, 1998, HEC-1 Flood Hydrograph Package User's Manual, Hydrologic Engineering Center, Davis, CA -Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC	

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

Hyd.	Origin	Description
1	SCS Runoff	DA-PI-031B Pre
2	SCS Runoff	DA-PI-031B Post
3	SCS Runoff	DA-PI-031B Pre-Forested
4	Reservoir	WB Soil Amendment

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.300	1	721	856	-----	-----	-----	DA-PI-031B Pre
2	SCS Runoff	0.300	1	721	856	-----	-----	-----	DA-PI-031B Post
3	SCS Runoff	0.270	1	722	794	-----	-----	-----	DA-PI-031B Pre-Forested
4	Reservoir	0.296	1	723	776	2	725.58	97.1	WB Soil Amendment
DA-PI-031B.gpw					Return Period: 1 Year			Tuesday, 08 / 22 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

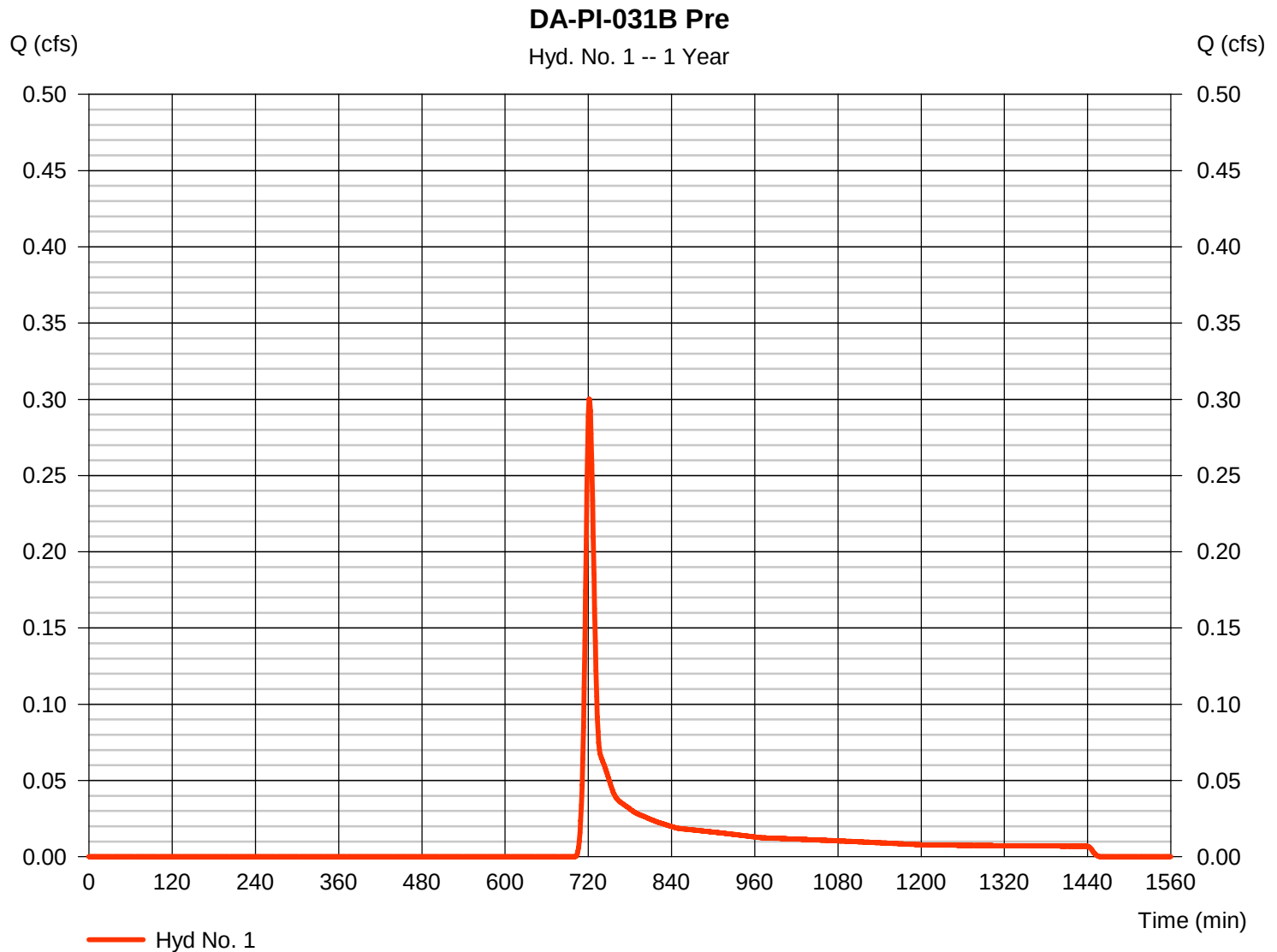
Tuesday, 08 / 22 / 2017

Hyd. No. 1

DA-PI-031B Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.300 cfs
Storm frequency	= 1 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 856 cuft
Drainage area	= 0.440 ac	Curve number	= 68*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 10.60 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.210 \times 55) + (0.190 \times 77) + (0.010 \times 78) + (0.030 \times 100)] / 0.440$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-PI-031B Pre

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 11.13	0.00	0.00				
Travel Time (min)	= 10.33	+	0.00	+	0.00	=	10.33
Shallow Concentrated Flow							
Flow length (ft)	= 124.54	0.00	0.00				
Watercourse slope (%)	= 16.59	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=6.57	0.00	0.00				
Travel Time (min)	= 0.32	+	0.00	+	0.00	=	0.32
Channel Flow							
X sectional flow area (sqft)	= 0.00	0.00	0.00				
Wetted perimeter (ft)	= 0.00	0.00	0.00				
Channel slope (%)	= 0.00	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	((0})0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc				10.60 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

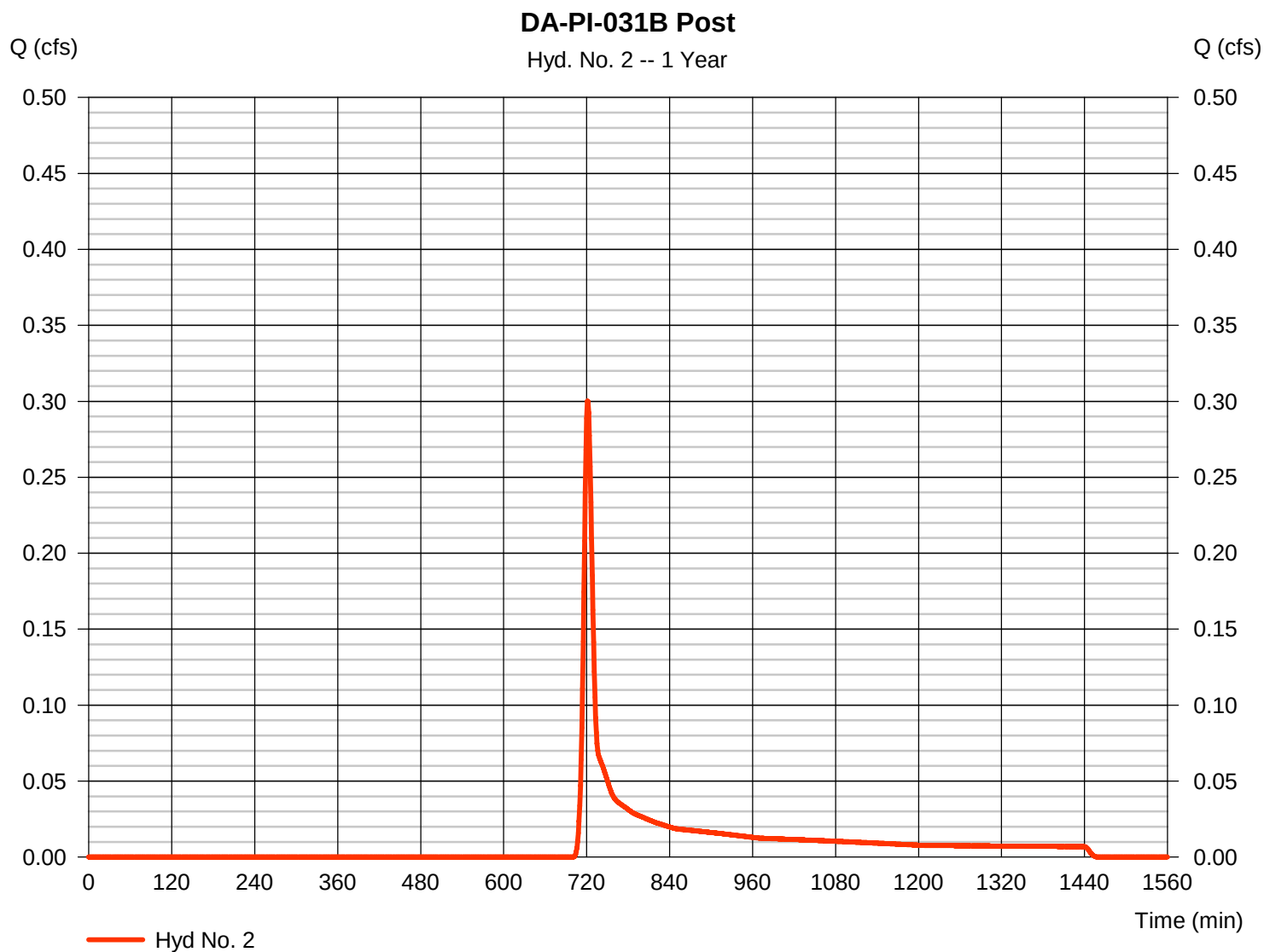
Tuesday, 08 / 22 / 2017

Hyd. No. 2

DA-PI-031B Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.300 cfs
Storm frequency	= 1 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 856 cuft
Drainage area	= 0.440 ac	Curve number	= 68*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 10.70 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.150 \times 58) + (0.130 \times 78) + (0.030 \times 100) + (0.060 \times 48) + (0.070 \times 73)] / 0.440$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-PI-031B Post

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00	
Land slope (%)	= 11.13	0.00	0.00	
Travel Time (min)	= 10.33	+	0.00	+
			0.00	= 10.33
Shallow Concentrated Flow				
Flow length (ft)	= 4.84	105.59	0.00	
Watercourse slope (%)	= 20.66	17.71	0.00	
Surface description	= Unpaved	Unpaved	Paved	
Average velocity (ft/s)	=7.33	6.79	0.00	
Travel Time (min)	= 0.01	+	0.26	+
			0.00	= 0.27
Channel Flow				
X sectional flow area (sqft)	= 2.00	0.00	0.00	
Wetted perimeter (ft)	= 4.47	0.00	0.00	
Channel slope (%)	= 5.00	0.00	0.00	
Manning's n-value	= 0.040	0.015	0.015	
Velocity (ft/s)	=4.86	0.00	0.00	
Flow length (ft)	(0)25.0	0.0	0.0	
Travel Time (min)	= 0.09	+	0.00	+
			0.00	= 0.09
Total Travel Time, Tc				10.70 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Tuesday, 08 / 22 / 2017

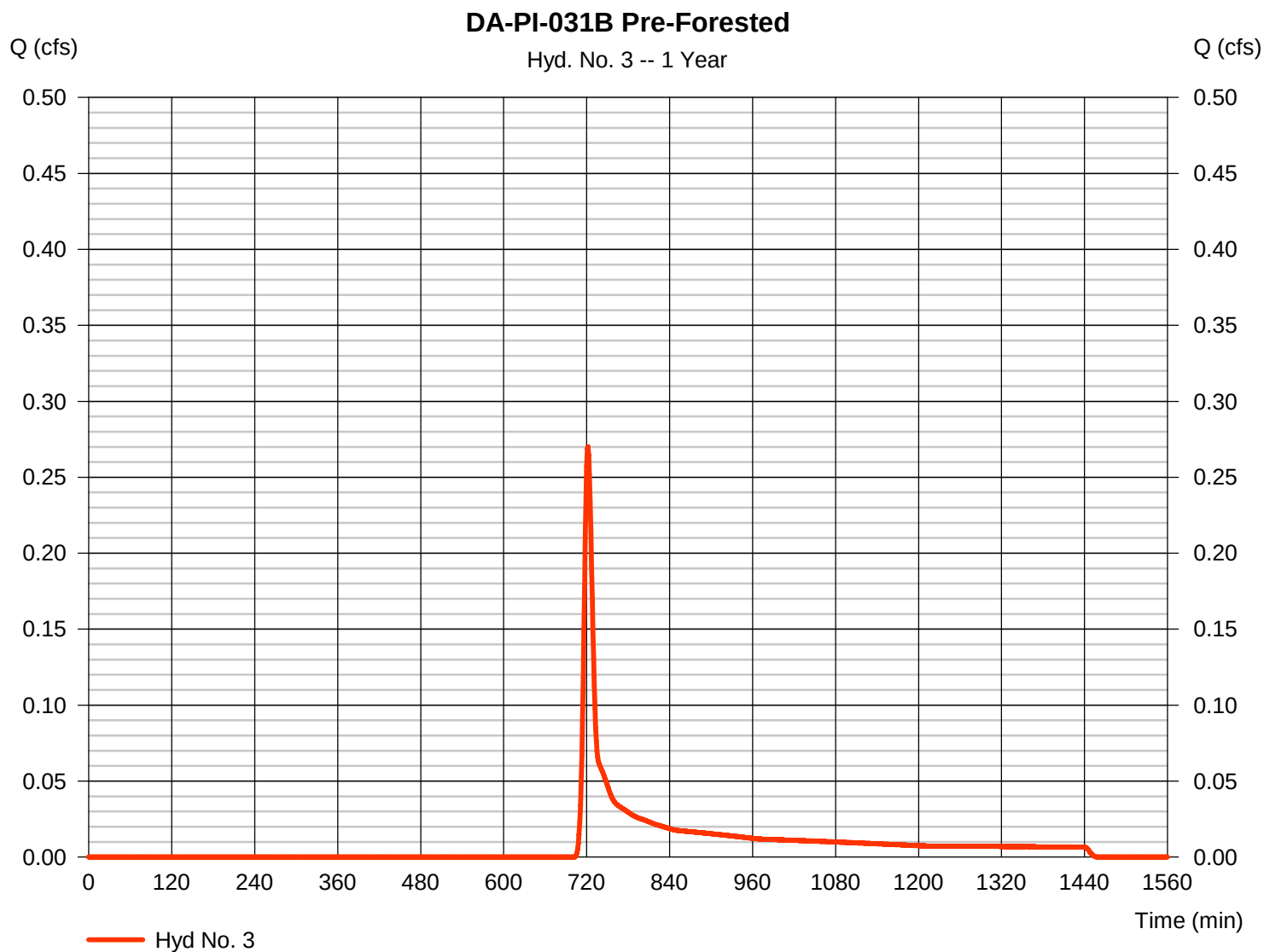
Hyd. No. 3

DA-PI-031B Pre-Forested

Hydrograph type = SCS Runoff
 Storm frequency = 1 yrs
 Time interval = 1 min
 Drainage area = 0.440 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 2.80 in
 Storm duration = 24 hrs

Peak discharge = 0.270 cfs
 Time to peak = 722 min
 Hyd. volume = 794 cuft
 Curve number = 67*
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 10.60 min
 Distribution = Type II
 Shape factor = 484

* Composite (Area/CN) = $[(0.210 \times 55) + (0.230 \times 77)] / 0.440$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-PI-031B Pre-Forested

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00	
Land slope (%)	= 11.13	0.00	0.00	
Travel Time (min)	= 10.33	+ 0.00	+ 0.00	= 10.33
Shallow Concentrated Flow				
Flow length (ft)	= 124.54	0.00	0.00	
Watercourse slope (%)	= 16.59	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=6.57	0.00	0.00	
Travel Time (min)	= 0.32	+ 0.00	+ 0.00	= 0.32
Channel Flow				
X sectional flow area (sqft)	= 0.00	0.00	0.00	
Wetted perimeter (ft)	= 0.00	0.00	0.00	
Channel slope (%)	= 0.00	0.00	0.00	
Manning's n-value	= 0.030	0.015	0.015	
Velocity (ft/s)	=0.00	0.00	0.00	
Flow length (ft)	(0)0.0	0.0	0.0	
Travel Time (min)	= 0.00	+ 0.00	+ 0.00	= 0.00
Total Travel Time, Tc				10.60 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

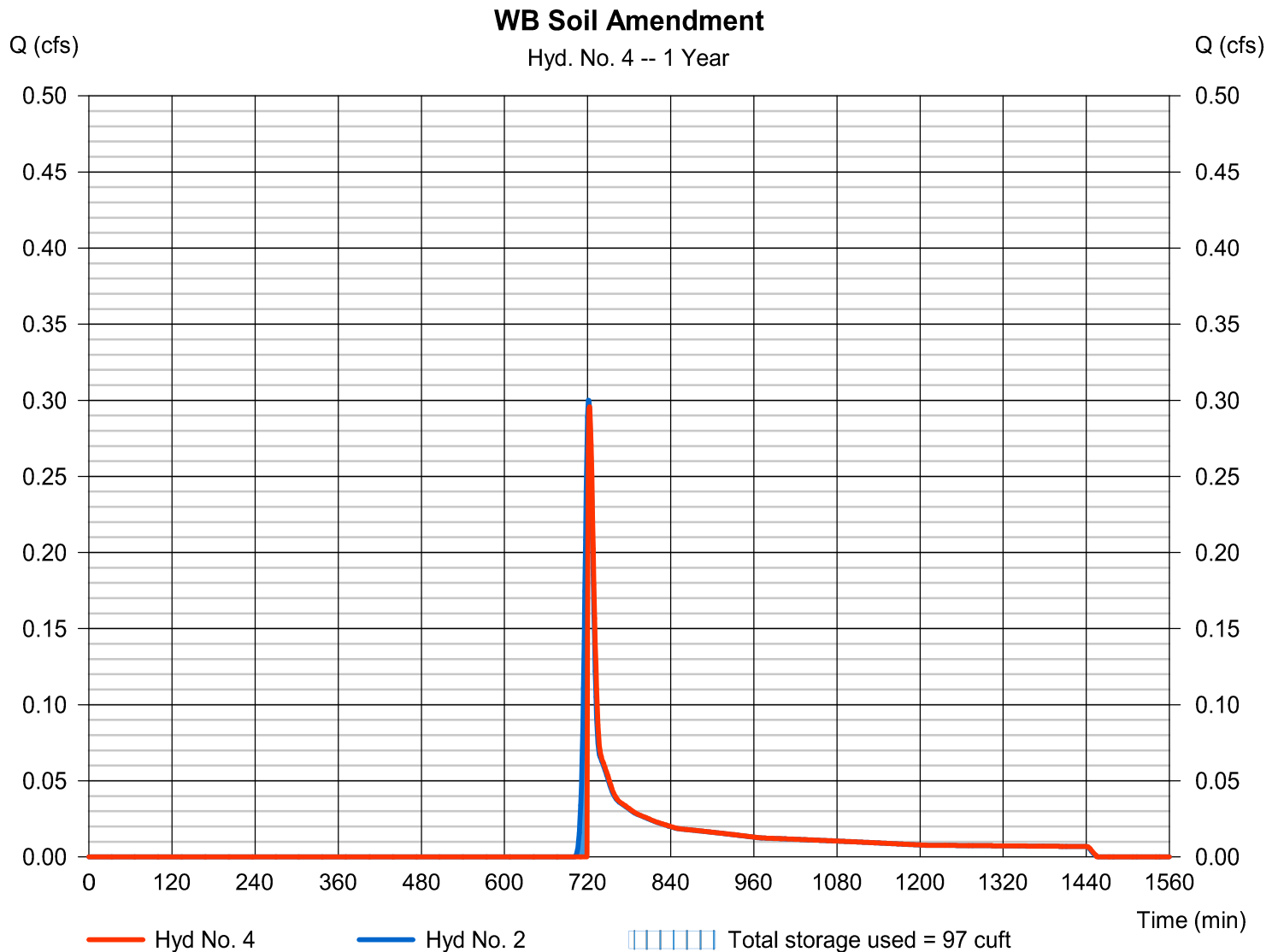
Tuesday, 08 / 22 / 2017

Hyd. No. 4

WB Soil Amendment

Hydrograph type	= Reservoir	Peak discharge	= 0.296 cfs
Storm frequency	= 1 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 776 cuft
Inflow hyd. No.	= 2 - DA-PI-031B Post	Max. Elevation	= 725.58 ft
Reservoir name	= DA-PI-031B Waterbar	Max. Storage	= 97 cuft

Storage Indication method used.



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.569	1	721	1,465	-----	-----	-----	DA-PI-031B Pre
2	SCS Runoff	0.569	1	721	1,465	-----	-----	-----	DA-PI-031B Post
3	SCS Runoff	0.529	1	721	1,382	-----	-----	-----	DA-PI-031B Pre-Forested
4	Reservoir	0.564	1	722	1,386	2	725.62	107	WB Soil Amendment
DA-PI-031B.gpw					Return Period: 2 Year			Tuesday, 08 / 22 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

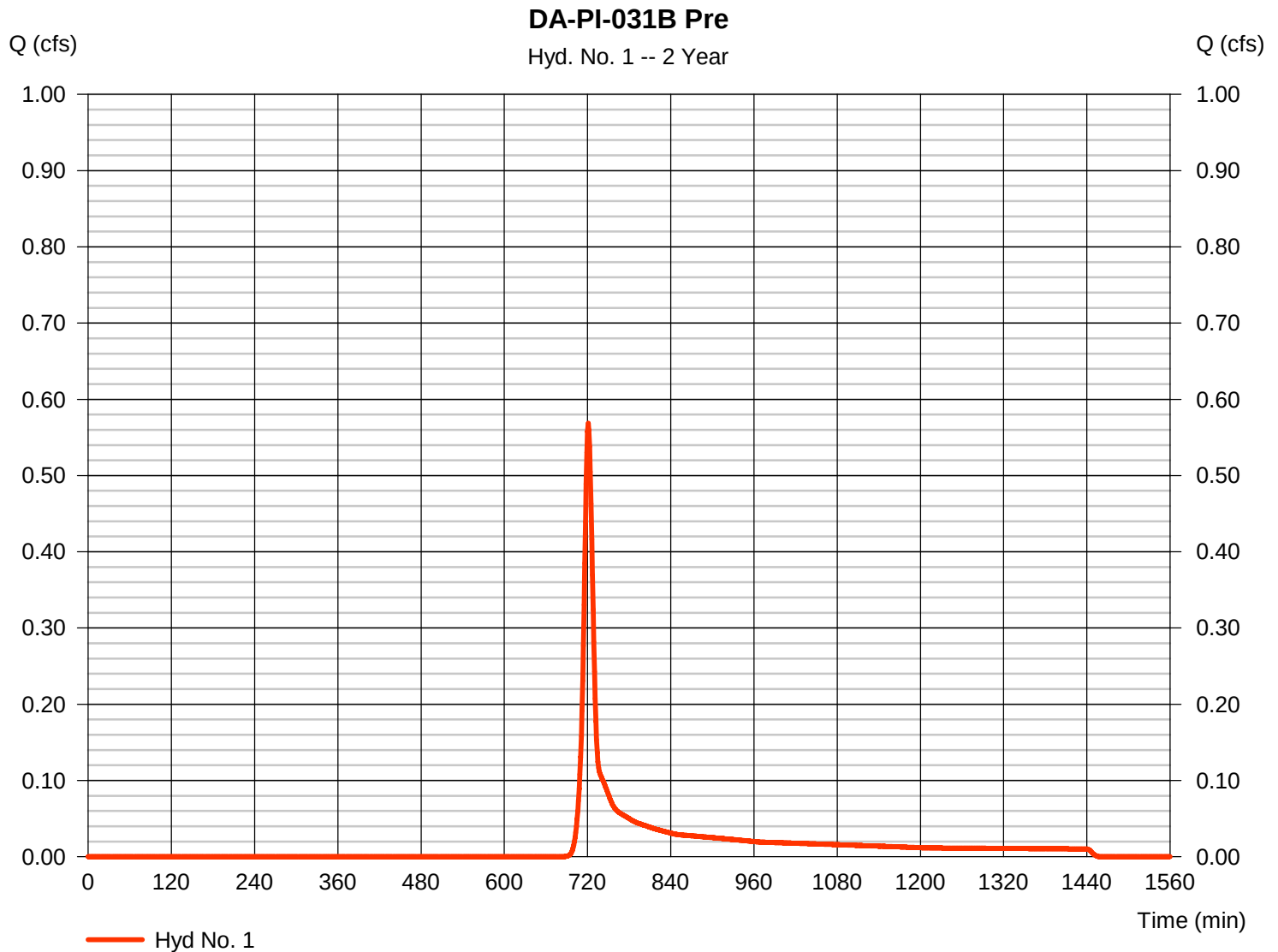
Tuesday, 08 / 22 / 2017

Hyd. No. 1

DA-PI-031B Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.569 cfs
Storm frequency	= 2 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 1,465 cuft
Drainage area	= 0.440 ac	Curve number	= 68*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 10.60 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.210 \times 55) + (0.190 \times 77) + (0.010 \times 78) + (0.030 \times 100)] / 0.440$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

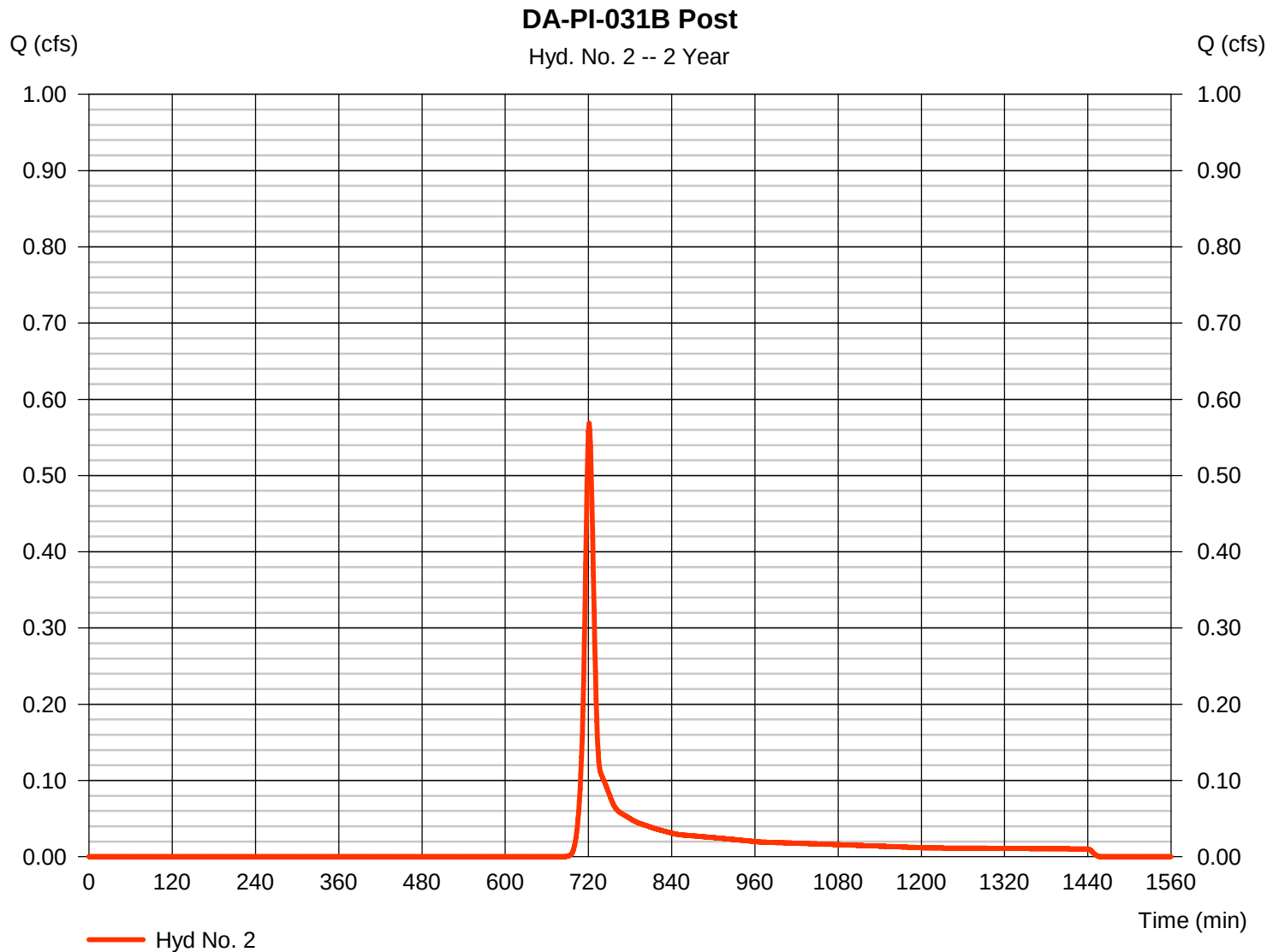
Tuesday, 08 / 22 / 2017

Hyd. No. 2

DA-PI-031B Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.569 cfs
Storm frequency	= 2 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 1,465 cuft
Drainage area	= 0.440 ac	Curve number	= 68*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 10.70 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.150 \times 58) + (0.130 \times 78) + (0.030 \times 100) + (0.060 \times 48) + (0.070 \times 73)] / 0.440$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

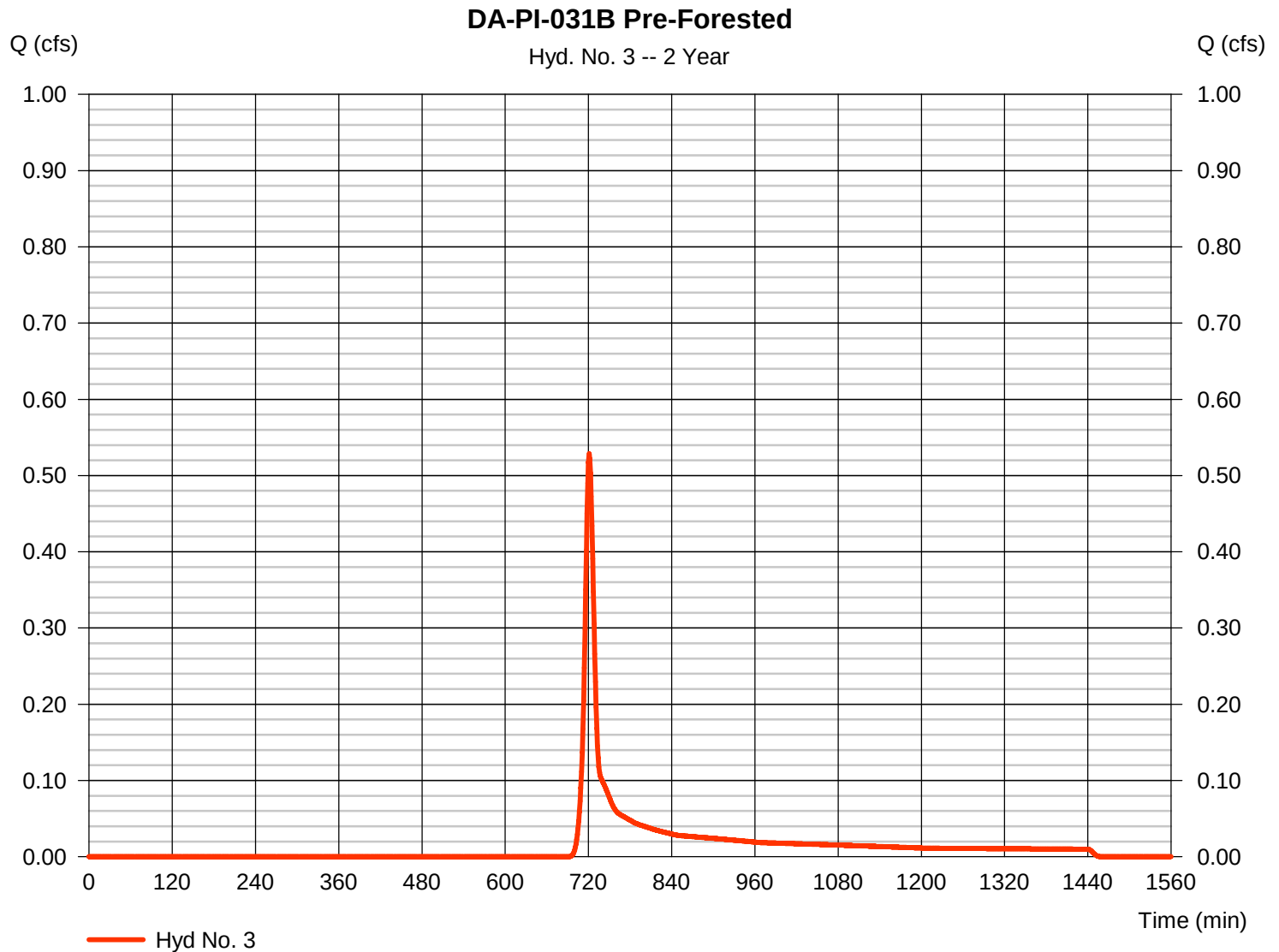
Tuesday, 08 / 22 / 2017

Hyd. No. 3

DA-PI-031B Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.529 cfs
Storm frequency	=	2 yrs	Time to peak	=	721 min
Time interval	=	1 min	Hyd. volume	=	1,382 cuft
Drainage area	=	0.440 ac	Curve number	=	67*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	10.60 min
Total precip.	=	3.50 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(0.210 \times 55) + (0.230 \times 77)] / 0.440$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

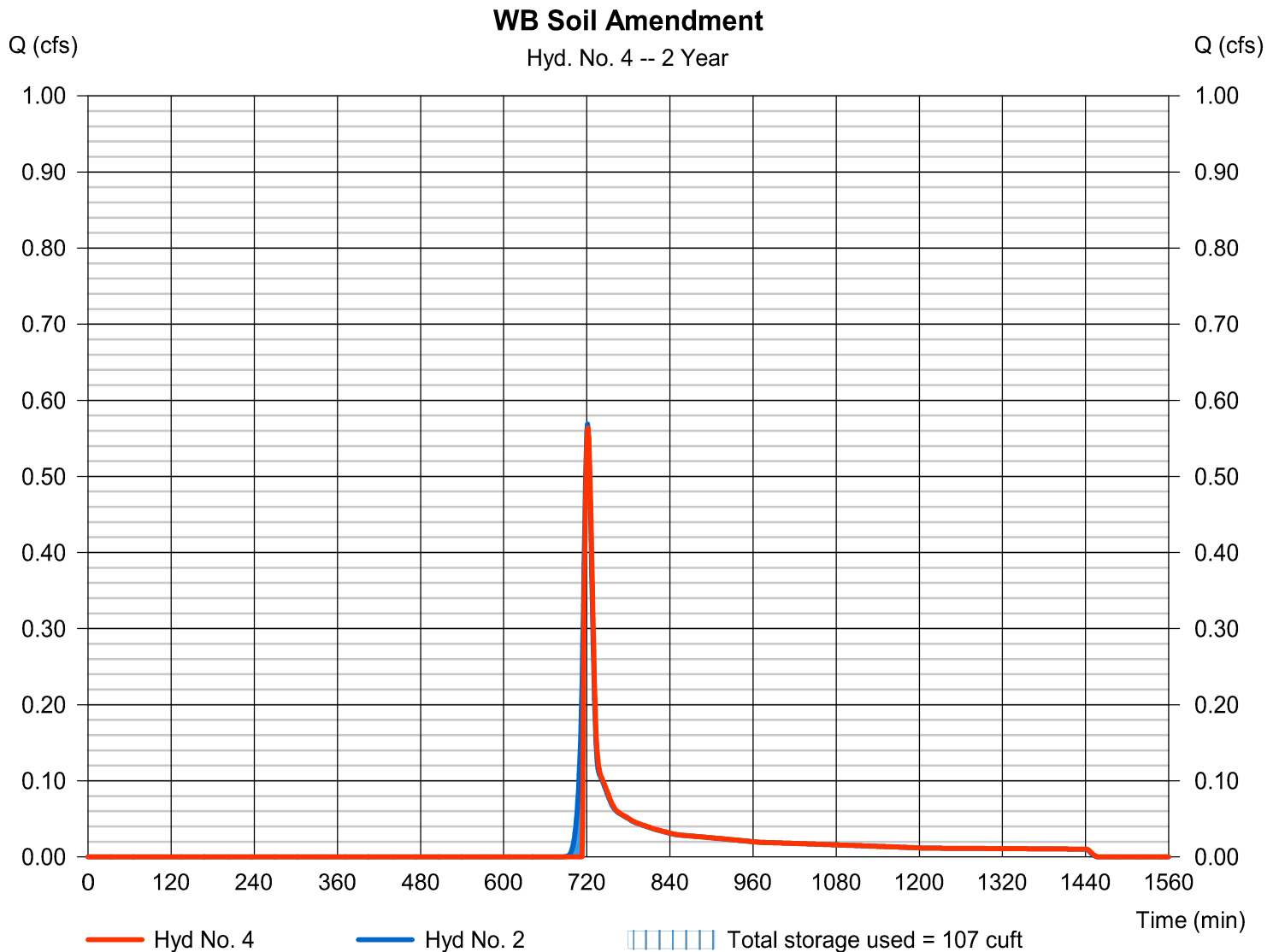
Tuesday, 08 / 22 / 2017

Hyd. No. 4

WB Soil Amendment

Hydrograph type	= Reservoir	Peak discharge	= 0.564 cfs
Storm frequency	= 2 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 1,386 cuft
Inflow hyd. No.	= 2 - DA-PI-031B Post	Max. Elevation	= 725.62 ft
Reservoir name	= DA-PI-031B Waterbar	Max. Storage	= 107 cuft

Storage Indication method used.



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	1.350	1	721	3,289	-----	-----	-----	DA-PI-031B Pre
2	SCS Runoff	1.350	1	721	3,289	-----	-----	-----	DA-PI-031B Post
3	SCS Runoff	1.293	1	721	3,160	-----	-----	-----	DA-PI-031B Pre-Forested
4	Reservoir	1.349	1	721	3,210	2	725.72	129	WB Soil Amendment
DA-PI-031B.gpw					Return Period: 10 Year			Tuesday, 08 / 22 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

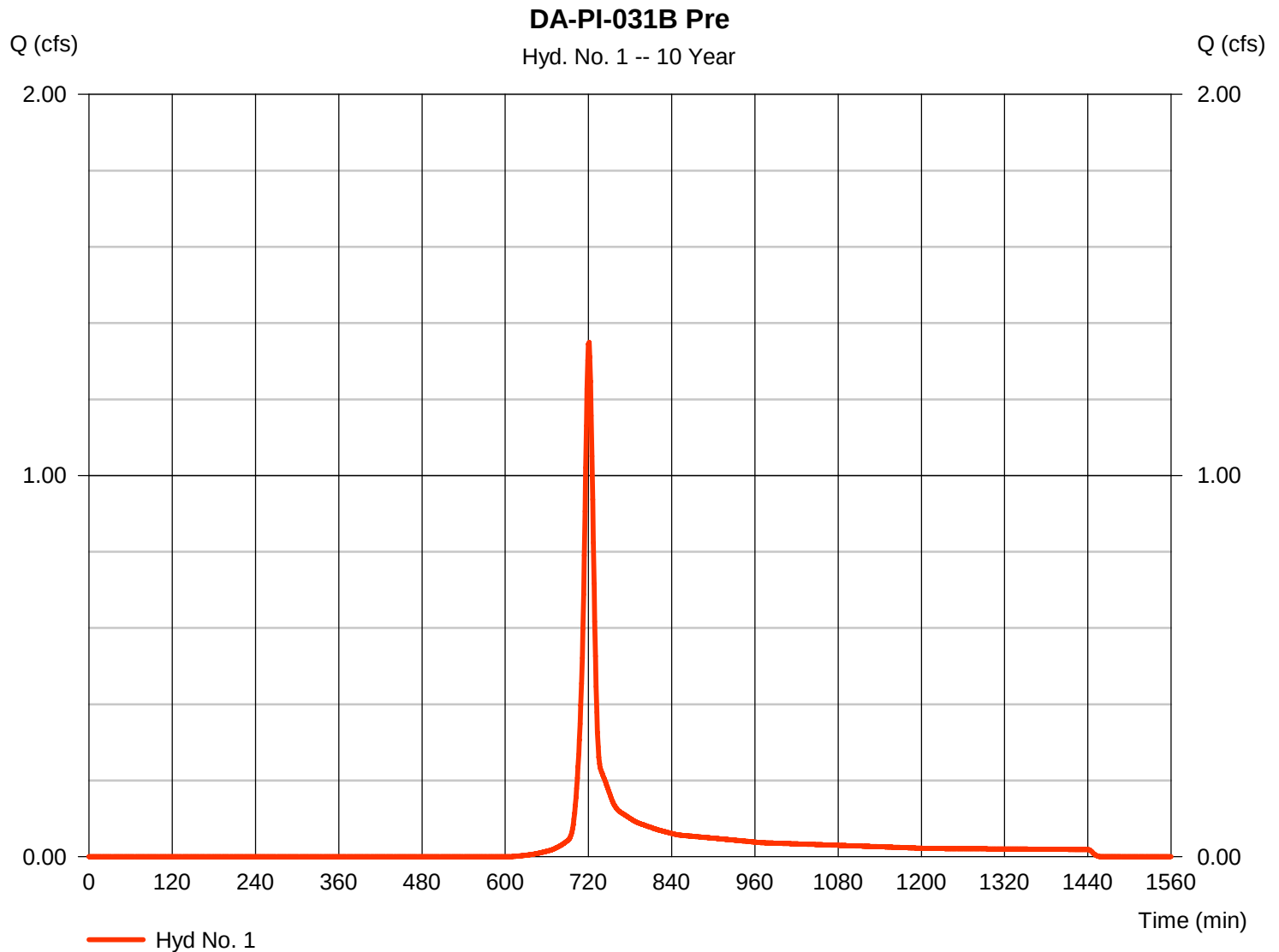
Tuesday, 08 / 22 / 2017

Hyd. No. 1

DA-PI-031B Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 1.350 cfs
Storm frequency	= 10 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 3,289 cuft
Drainage area	= 0.440 ac	Curve number	= 68*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 10.60 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.210 \times 55) + (0.190 \times 77) + (0.010 \times 78) + (0.030 \times 100)] / 0.440$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

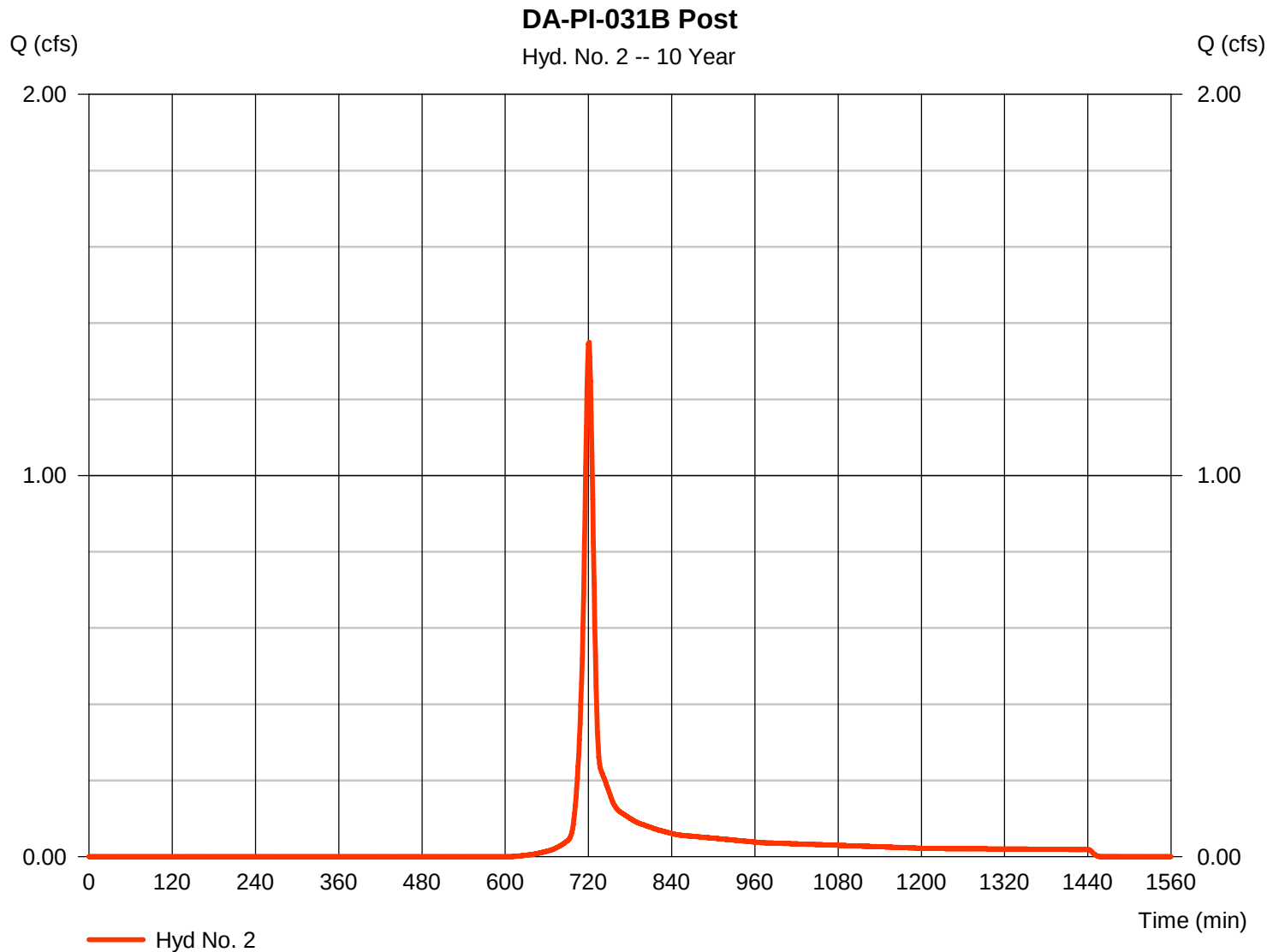
Tuesday, 08 / 22 / 2017

Hyd. No. 2

DA-PI-031B Post

Hydrograph type	= SCS Runoff	Peak discharge	= 1.350 cfs
Storm frequency	= 10 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 3,289 cuft
Drainage area	= 0.440 ac	Curve number	= 68*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 10.70 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.150 \times 58) + (0.130 \times 78) + (0.030 \times 100) + (0.060 \times 48) + (0.070 \times 73)] / 0.440$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

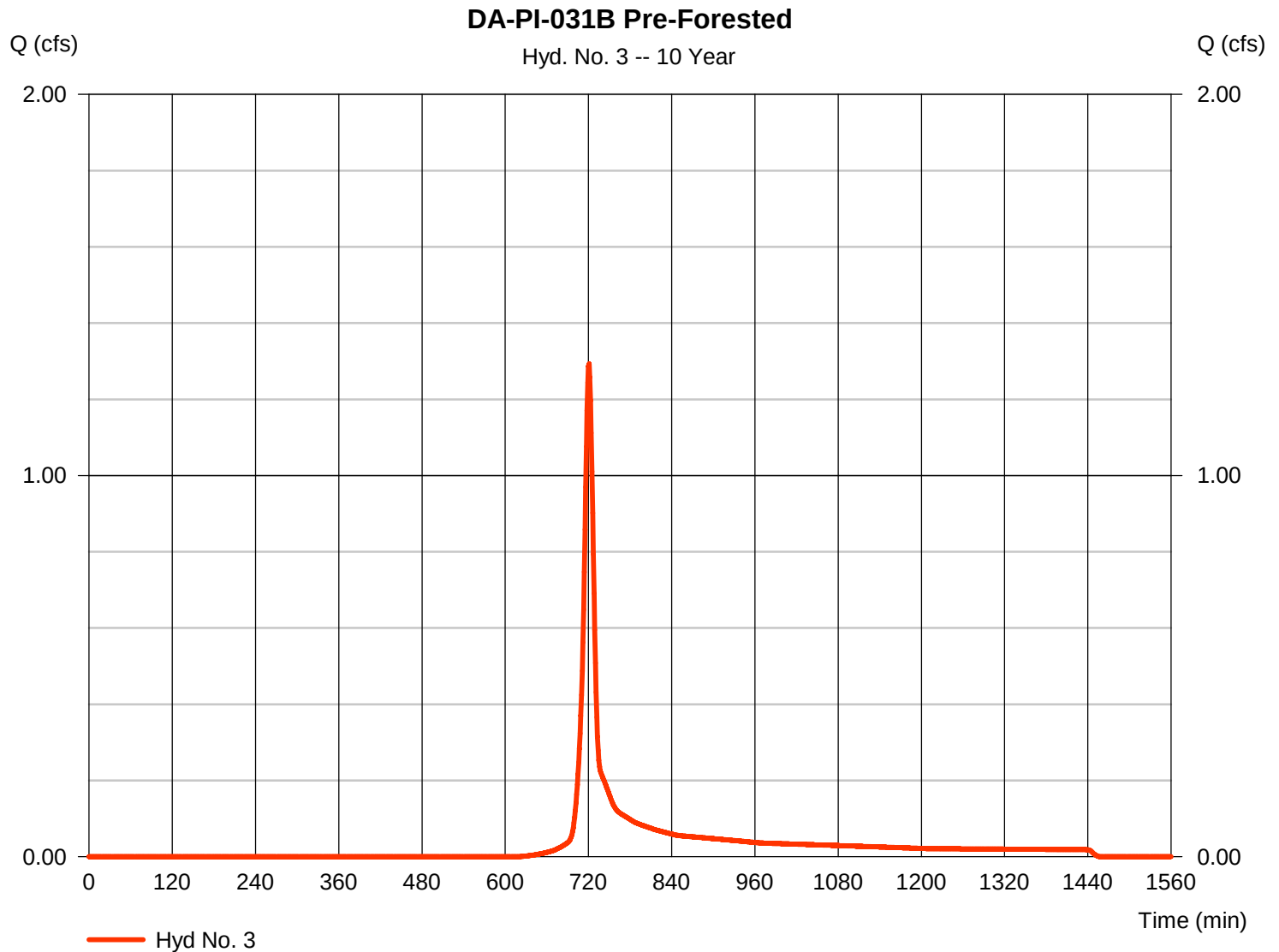
Tuesday, 08 / 22 / 2017

Hyd. No. 3

DA-PI-031B Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	1.293 cfs
Storm frequency	=	10 yrs	Time to peak	=	721 min
Time interval	=	1 min	Hyd. volume	=	3,160 cuft
Drainage area	=	0.440 ac	Curve number	=	67*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	10.60 min
Total precip.	=	5.20 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(0.210 \times 55) + (0.230 \times 77)] / 0.440$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

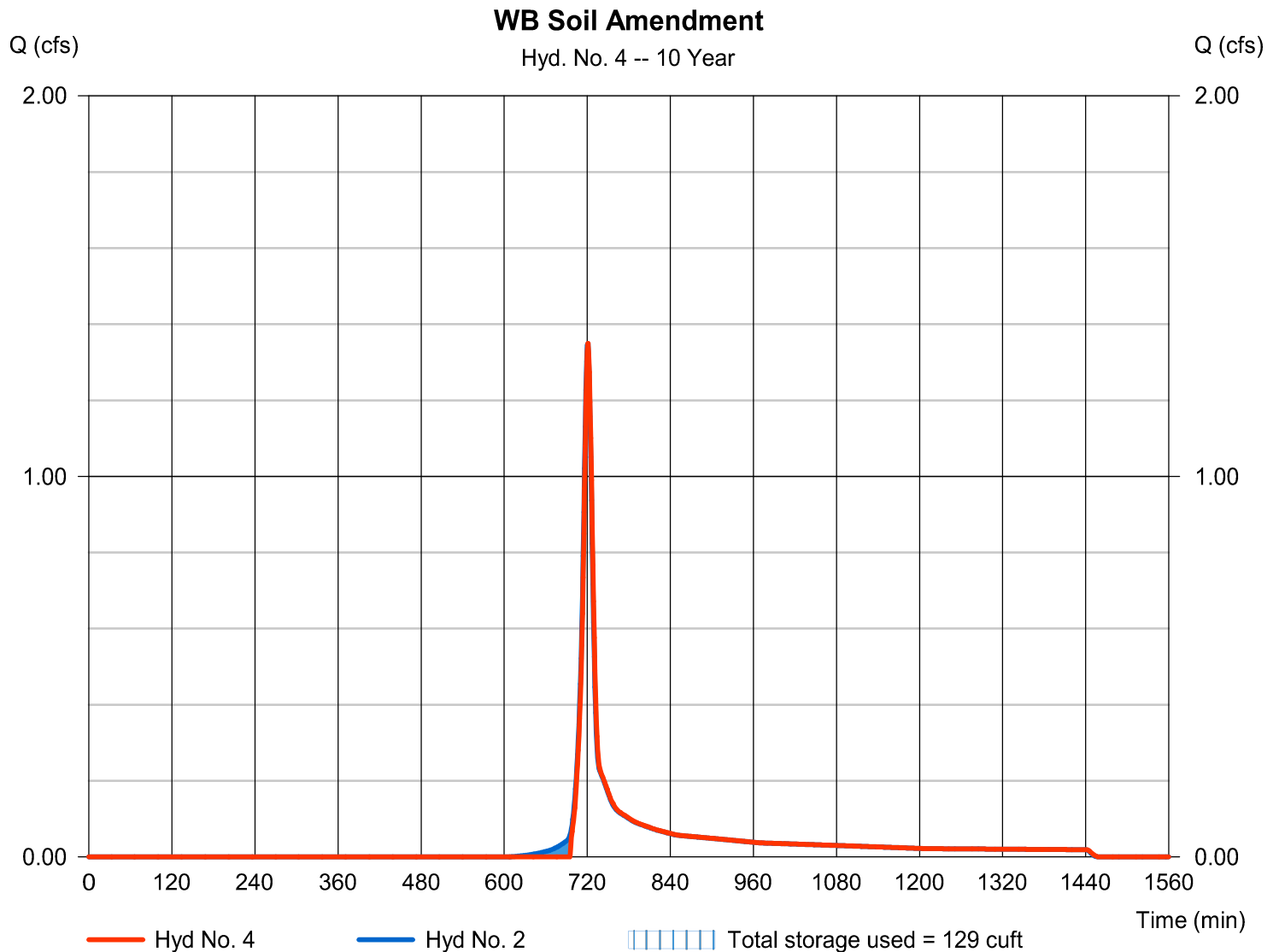
Tuesday, 08 / 22 / 2017

Hyd. No. 4

WB Soil Amendment

Hydrograph type	= Reservoir	Peak discharge	= 1.349 cfs
Storm frequency	= 10 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 3,210 cuft
Inflow hyd. No.	= 2 - DA-PI-031B Post	Max. Elevation	= 725.72 ft
Reservoir name	= DA-PI-031B Waterbar	Max. Storage	= 129 cuft

Storage Indication method used.



DA-PI-031C

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.007	65
Developed Condition	0.007	65
Pre-Developed (Forest) Condition	0.007	65

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.9

Calculations:

Check #1:

$$Q_{\text{developed}} \leq \text{IF} \times [(Q_{\text{pre-developed}} \times \text{RV}_{\text{pre-developed}}) / \text{RV}_{\text{developed}}] \text{ ----->}$$

Q (cfs)

0.007

≤

N/A - See Check #3

Q (cfs)

0.006

Check #2:

$$Q_{\text{developed}} \leq Q_{\text{pre-developed}} \text{ ----->}$$

0.007

≤

OK

0.007

Check #3:

$$Q_{\text{developed}} \text{ shall not be required to be } \leq (Q_{\text{forest}} \times \text{RV}_{\text{forest}}) / \text{RV}_{\text{developed}} \text{ --->}$$

0.007

shall not be required to be ≤

0.007

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning's n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<i>Note:</i> Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted. ¹For Paved Road land surface types a Manning's n of 0.011 was used <i>Sources:</i> -USACE, 1998, HEC-1 Flood Hydrograph Package User's Manual, Hydrologic Engineering Center, Davis, CA -Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC	

Table 2 – Manning's n Values for Open Channel Flow

Channel Type	Manning n		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹For the developed condition, a conservative Manning's n value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar, level spreader diversion, or grass channel. ²For the pre-developed condition and post-development condition, a Manning's n value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

1



2



3



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-PI-031C Pre
2	SCS Runoff	DA-PI-031C Post
3	SCS Runoff	DA-PI-031C Pre-Forested

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.007	1	722	65	-----	-----	-----	DA-PI-031C Pre
2	SCS Runoff	0.007	1	722	65	-----	-----	-----	DA-PI-031C Post
3	SCS Runoff	0.007	1	722	65	-----	-----	-----	DA-PI-031C Pre-Forested
DA-PI-031C.gpw					Return Period: 1 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

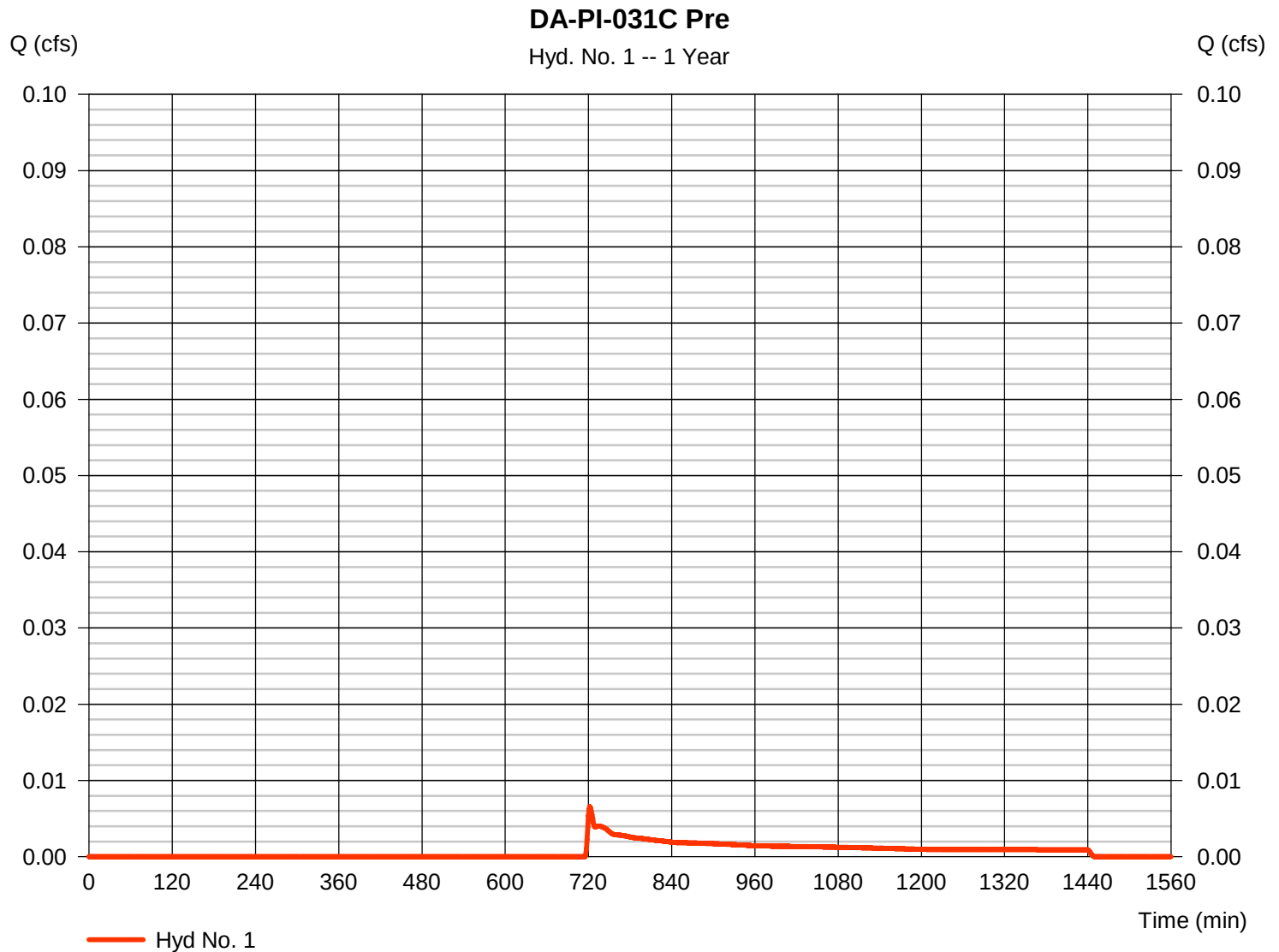
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Monday, 08 / 21 / 2017

Hyd. No. 1

DA-PI-031C Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.007 cfs
Storm frequency	= 1 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 65 cuft
Drainage area	= 0.120 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 6.60 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.120 \times 55)] / 0.120$ 

TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-PI-031C Pre

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 66.6	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 15.28	0.00	0.00				
Travel Time (min)	= 6.57	+	0.00	+	0.00	=	6.57
Shallow Concentrated Flow							
Flow length (ft)	= 0.00	0.00	0.00				
Watercourse slope (%)	= 0.00	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=0.00	0.00	0.00				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Channel Flow							
X sectional flow area (sqft)	= 0.00	0.00	0.00				
Wetted perimeter (ft)	= 0.00	0.00	0.00				
Channel slope (%)	= 0.00	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	(0)0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc				6.60 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

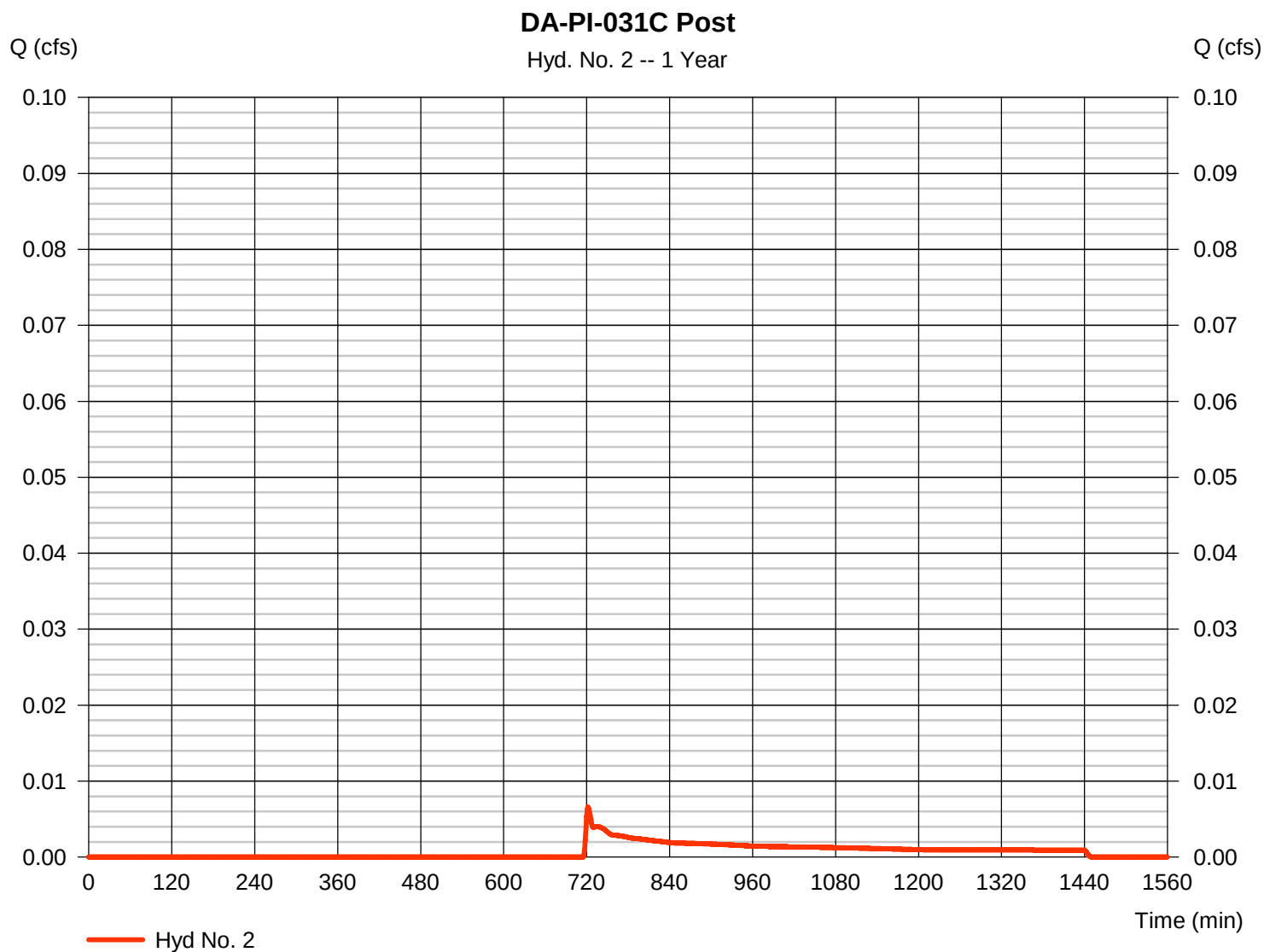
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-PI-031C Post

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.007 cfs
Storm frequency	=	1 yrs	Time to peak	=	722 min
Time interval	=	1 min	Hyd. volume	=	65 cuft
Drainage area	=	0.120 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	5.80 min
Total precip.	=	2.80 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(0.020 \times 55) + (0.030 \times 48) + (0.070 \times 58)] / 0.120$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-PI-031C Post

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.400	0.011	
Flow length (ft)	= 19.1	25.1	0.0	
Two-year 24-hr precip. (in)	= 3.50	3.50	0.00	
Land slope (%)	= 9.75	20.40	0.00	
Travel Time (min)	= 2.89	+	2.69	+
			0.00	= 5.58
Shallow Concentrated Flow				
Flow length (ft)	= 29.57	0.00	0.00	
Watercourse slope (%)	= 21.85	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=7.54	0.00	0.00	
Travel Time (min)	= 0.07	+	0.00	+
			0.00	= 0.07
Channel Flow				
X sectional flow area (sqft)	= 2.00	0.00	0.00	
Wetted perimeter (ft)	= 4.47	0.00	0.00	
Channel slope (%)	= 5.00	0.00	0.00	
Manning's n-value	= 0.040	0.015	0.015	
Velocity (ft/s)	=4.86	0.00	0.00	
Flow length (ft)	(0)43.8	0.0	0.0	
Travel Time (min)	= 0.15	+	0.00	+
			0.00	= 0.15
Total Travel Time, Tc				5.80 min

Hydrograph Report

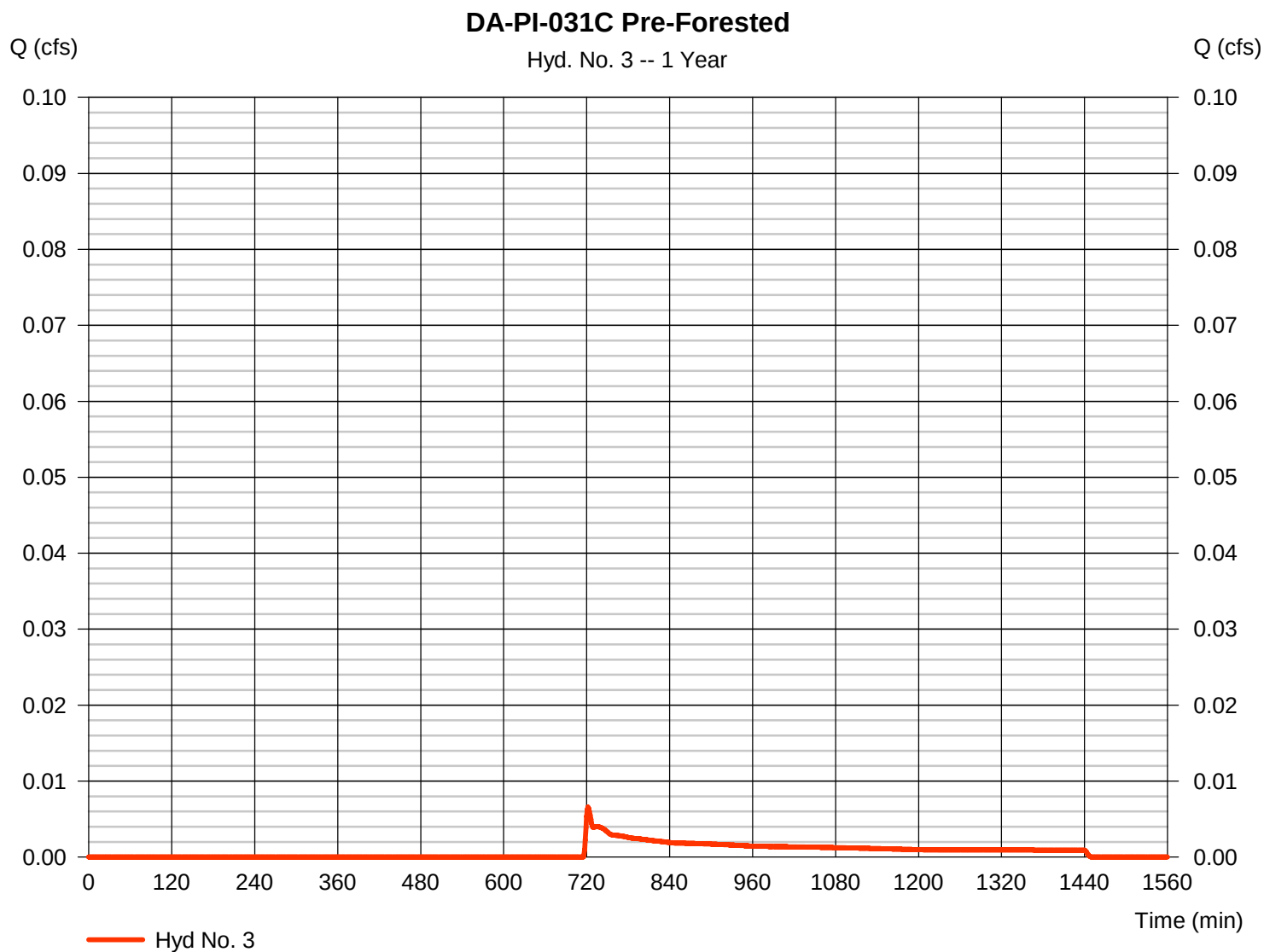
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Monday, 08 / 21 / 2017

Hyd. No. 3

DA-PI-031C Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.007 cfs
Storm frequency	=	1 yrs	Time to peak	=	722 min
Time interval	=	1 min	Hyd. volume	=	65 cuft
Drainage area	=	0.120 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	6.60 min
Total precip.	=	2.80 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(0.120 \times 55)] / 0.120$ 

TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-PI-031C Pre-Forested

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 66.6	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 15.28	0.00	0.00				
Travel Time (min)	= 6.57	+	0.00	+	0.00	=	6.57
Shallow Concentrated Flow							
Flow length (ft)	= 0.00	0.00	0.00				
Watercourse slope (%)	= 0.00	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=0.00	0.00	0.00				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Channel Flow							
X sectional flow area (sqft)	= 0.00	0.00	0.00				
Wetted perimeter (ft)	= 0.00	0.00	0.00				
Channel slope (%)	= 0.00	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	((0})0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc				6.60 min			

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.048	1	720	155	-----	-----	-----	DA-PI-031C Pre
2	SCS Runoff	0.048	1	720	155	-----	-----	-----	DA-PI-031C Post
3	SCS Runoff	0.048	1	720	155	-----	-----	-----	DA-PI-031C Pre-Forested
DA-PI-031C.gpw					Return Period: 2 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

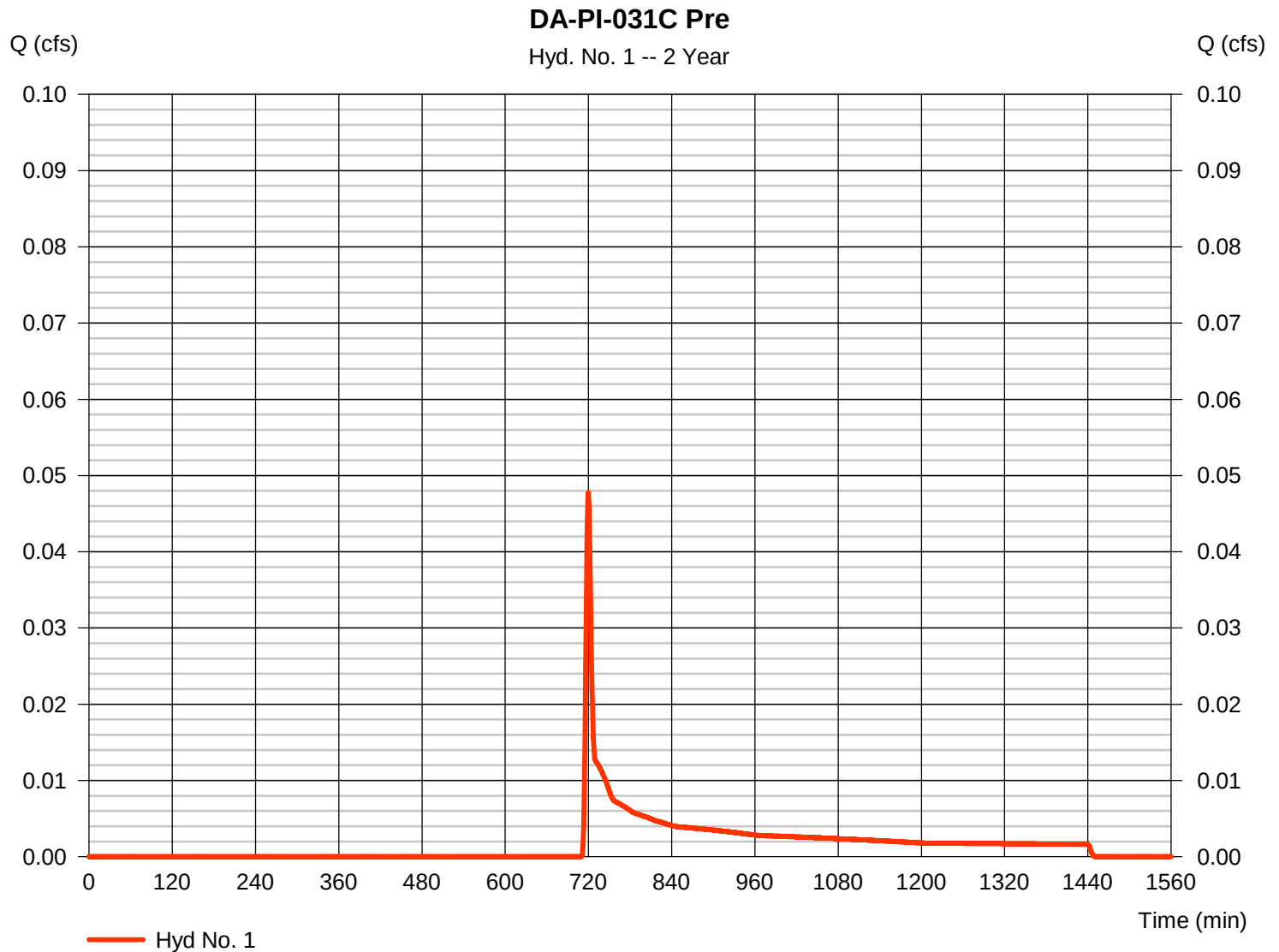
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Monday, 08 / 21 / 2017

Hyd. No. 1

DA-PI-031C Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.048 cfs
Storm frequency	= 2 yrs	Time to peak	= 720 min
Time interval	= 1 min	Hyd. volume	= 155 cuft
Drainage area	= 0.120 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 6.60 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.120 \times 55)] / 0.120$ 

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

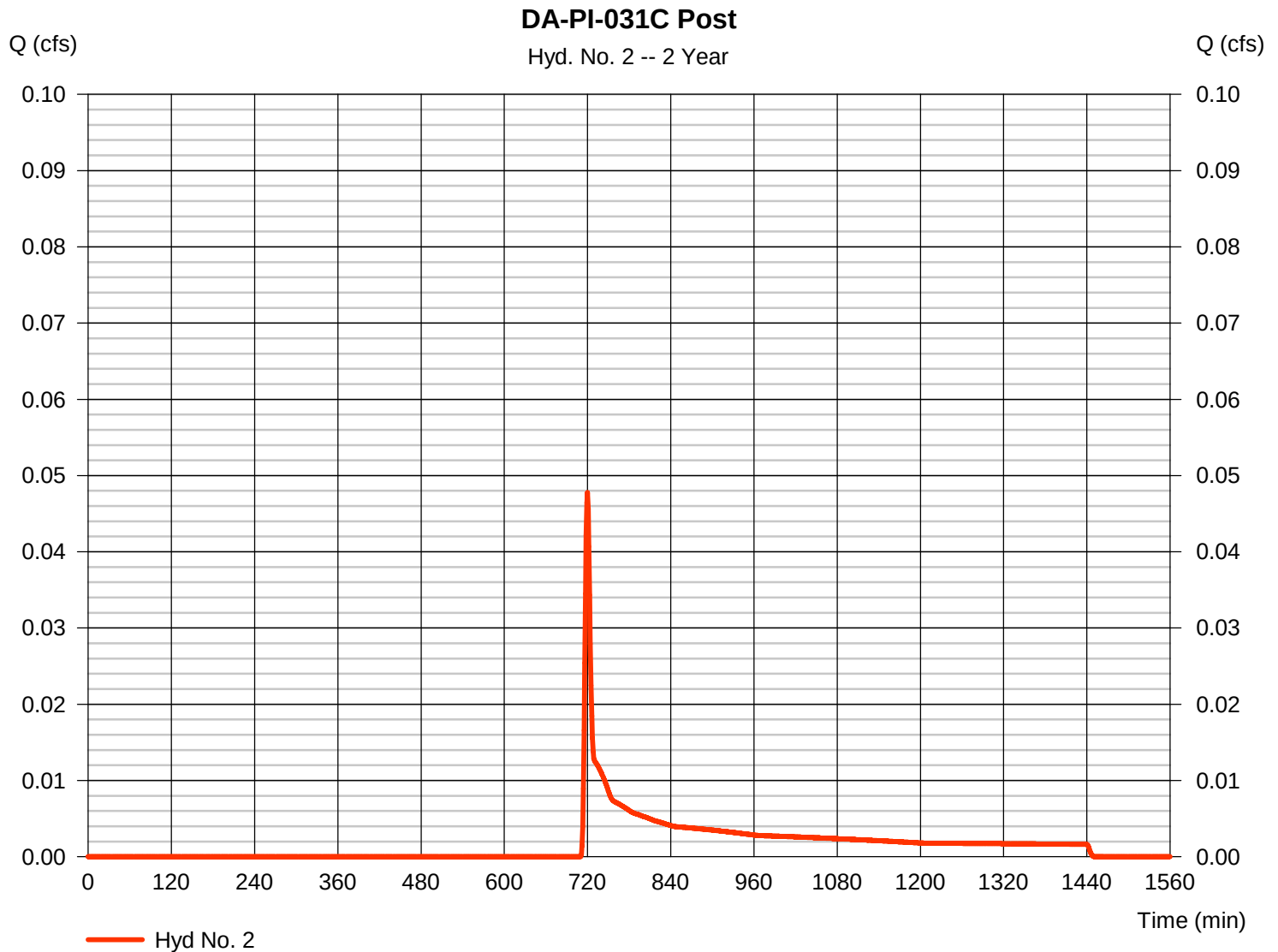
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-PI-031C Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.048 cfs
Storm frequency	= 2 yrs	Time to peak	= 720 min
Time interval	= 1 min	Hyd. volume	= 155 cuft
Drainage area	= 0.120 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 5.80 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.020 \times 55) + (0.030 \times 48) + (0.070 \times 58)] / 0.120$



Hydrograph Report

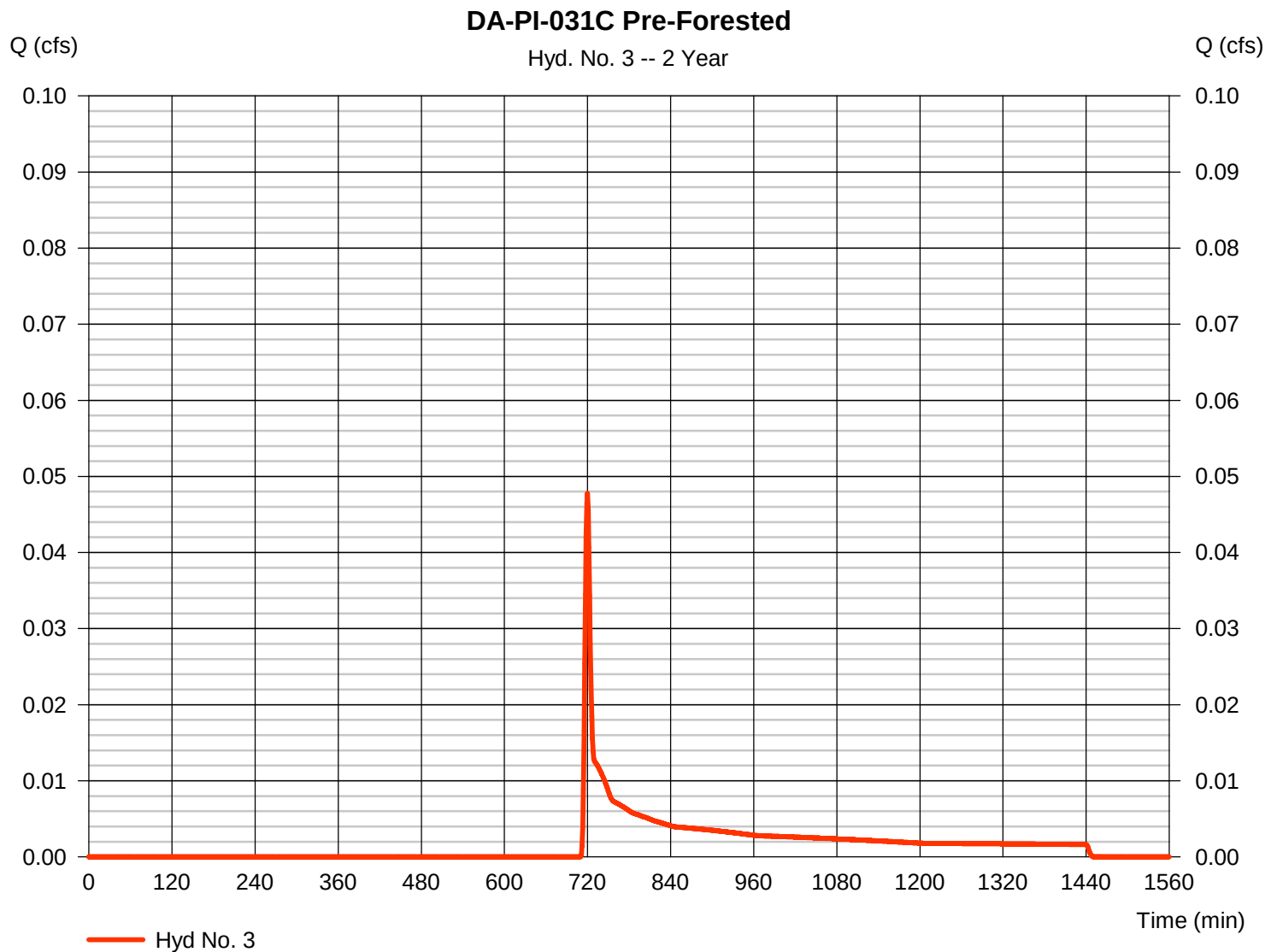
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Monday, 08 / 21 / 2017

Hyd. No. 3

DA-PI-031C Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.048 cfs
Storm frequency	=	2 yrs	Time to peak	=	720 min
Time interval	=	1 min	Hyd. volume	=	155 cuft
Drainage area	=	0.120 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	6.60 min
Total precip.	=	3.50 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(0.120 \times 55)] / 0.120$ 

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.223	1	718	486	-----	-----	-----	DA-PI-031C Pre
2	SCS Runoff	0.223	1	718	486	-----	-----	-----	DA-PI-031C Post
3	SCS Runoff	0.223	1	718	486	-----	-----	-----	DA-PI-031C Pre-Forested
DA-PI-031C.gpw					Return Period: 10 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

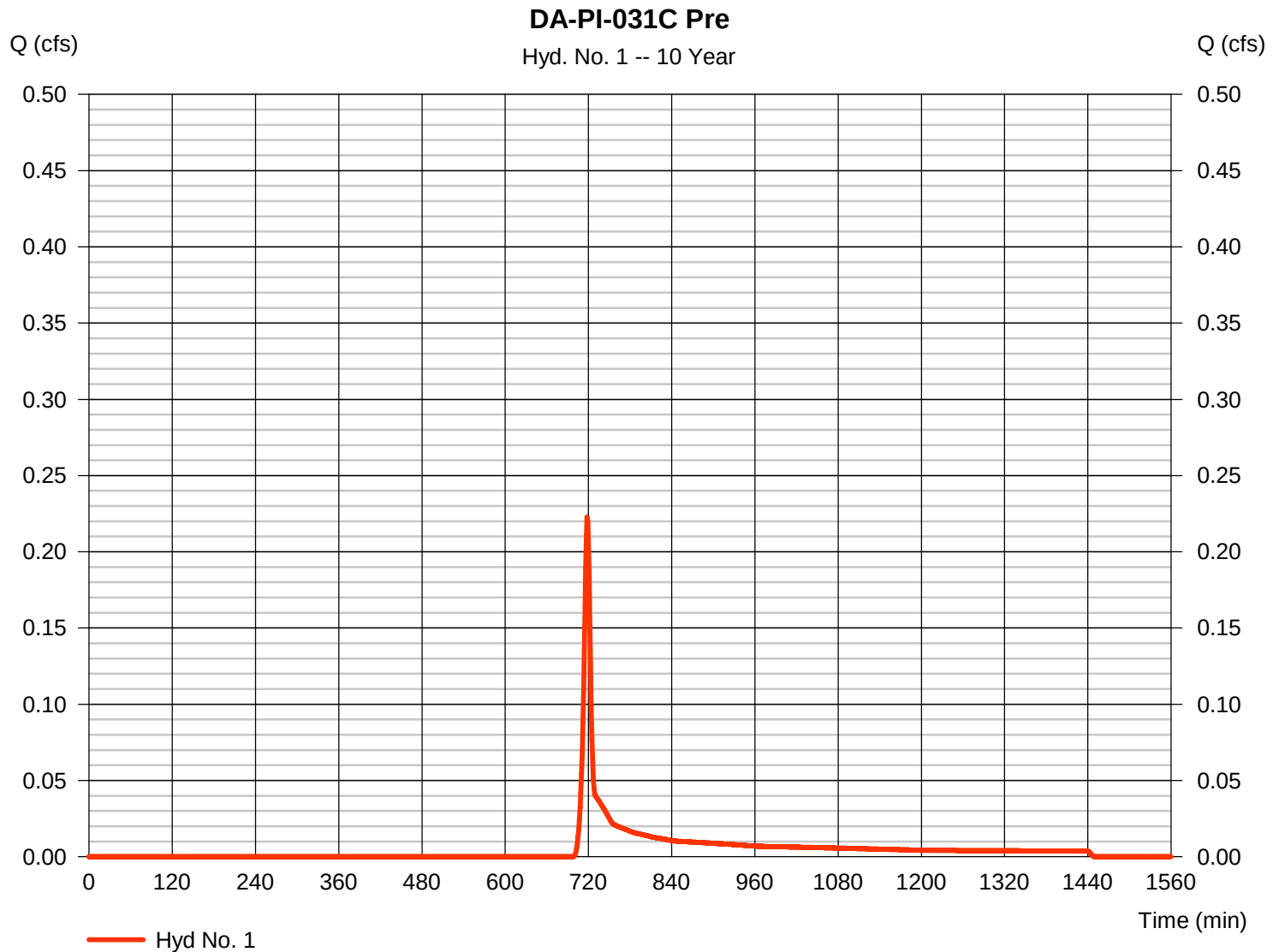
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Monday, 08 / 21 / 2017

Hyd. No. 1

DA-PI-031C Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.223 cfs
Storm frequency	= 10 yrs	Time to peak	= 718 min
Time interval	= 1 min	Hyd. volume	= 486 cuft
Drainage area	= 0.120 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 6.60 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.120 \times 55)] / 0.120$ 

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

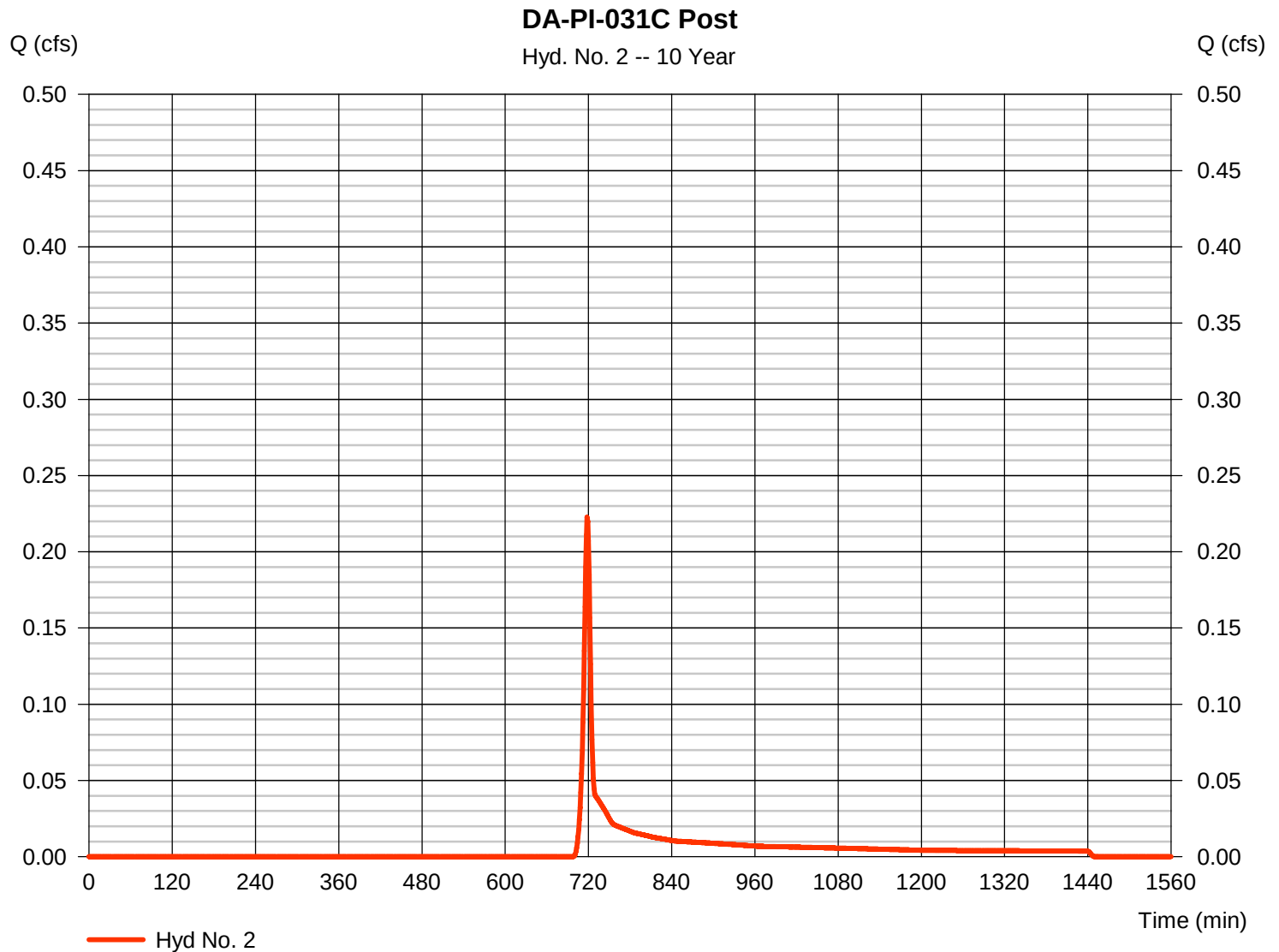
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-PI-031C Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.223 cfs
Storm frequency	= 10 yrs	Time to peak	= 718 min
Time interval	= 1 min	Hyd. volume	= 486 cuft
Drainage area	= 0.120 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 5.80 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.020 \times 55) + (0.030 \times 48) + (0.070 \times 58)] / 0.120$



Hydrograph Report

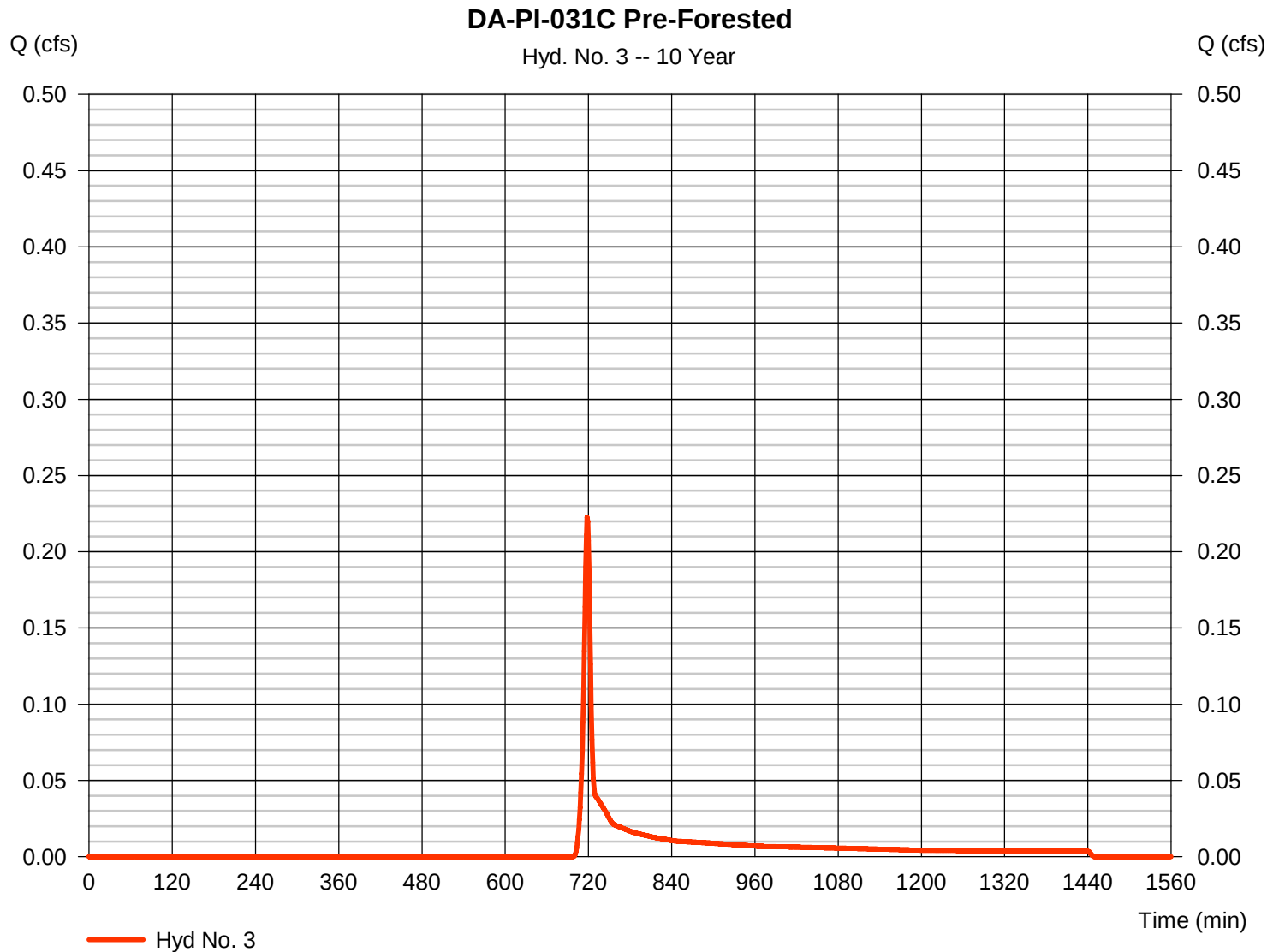
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Monday, 08 / 21 / 2017

Hyd. No. 3

DA-PI-031C Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.223 cfs
Storm frequency	=	10 yrs	Time to peak	=	718 min
Time interval	=	1 min	Hyd. volume	=	486 cuft
Drainage area	=	0.120 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	6.60 min
Total precip.	=	5.20 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(0.120 \times 55)] / 0.120$ 

DA-PI-031D

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.321	2,562
Developed Condition	0.222	2,255
Pre-Developed (Forest) Condition	0.143	1,965

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1:

$$Q_{\text{developed}} \leq \text{IF} \times [(Q_{\text{pre-developed}} \times \text{RV}_{\text{pre-developed}}) / \text{RV}_{\text{developed}}] \text{ ----->}$$

Q (cfs)

0.222

≤

OK

Q (cfs)

0.292

Check #2:

$$Q_{\text{developed}} \leq Q_{\text{pre-developed}} \text{ ----->}$$

0.222

≤

OK

0.321

Check #3:

$$Q_{\text{developed}} \text{ shall not be required to be } \leq (Q_{\text{forest}} \times \text{RV}_{\text{forest}}) / \text{RV}_{\text{developed}} \text{ --->}$$

0.222

shall not be required to be ≤

0.125

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning's n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<i>Note:</i> Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted. ¹For Paved Road land surface types a Manning's n of 0.011 was used <i>Sources:</i> -USACE, 1998, HEC-1 Flood Hydrograph Package User's Manual, Hydrologic Engineering Center, Davis, CA -Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC	

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

1



2



3



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-PI-031D Pre
2	SCS Runoff	DA-PI-031D Post
3	SCS Runoff	DA-PI-031D Pre-Forested

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.321	1	726	2,562	-----	-----	-----	DA-PI-031D Pre
2	SCS Runoff	0.222	1	727	2,255	-----	-----	-----	DA-PI-031D Post
3	SCS Runoff	0.143	1	730	1,965	-----	-----	-----	DA-PI-031D Pre-Forested
DA-PI-031D.gpw					Return Period: 1 Year			Monday, 08 / 21 / 2017	

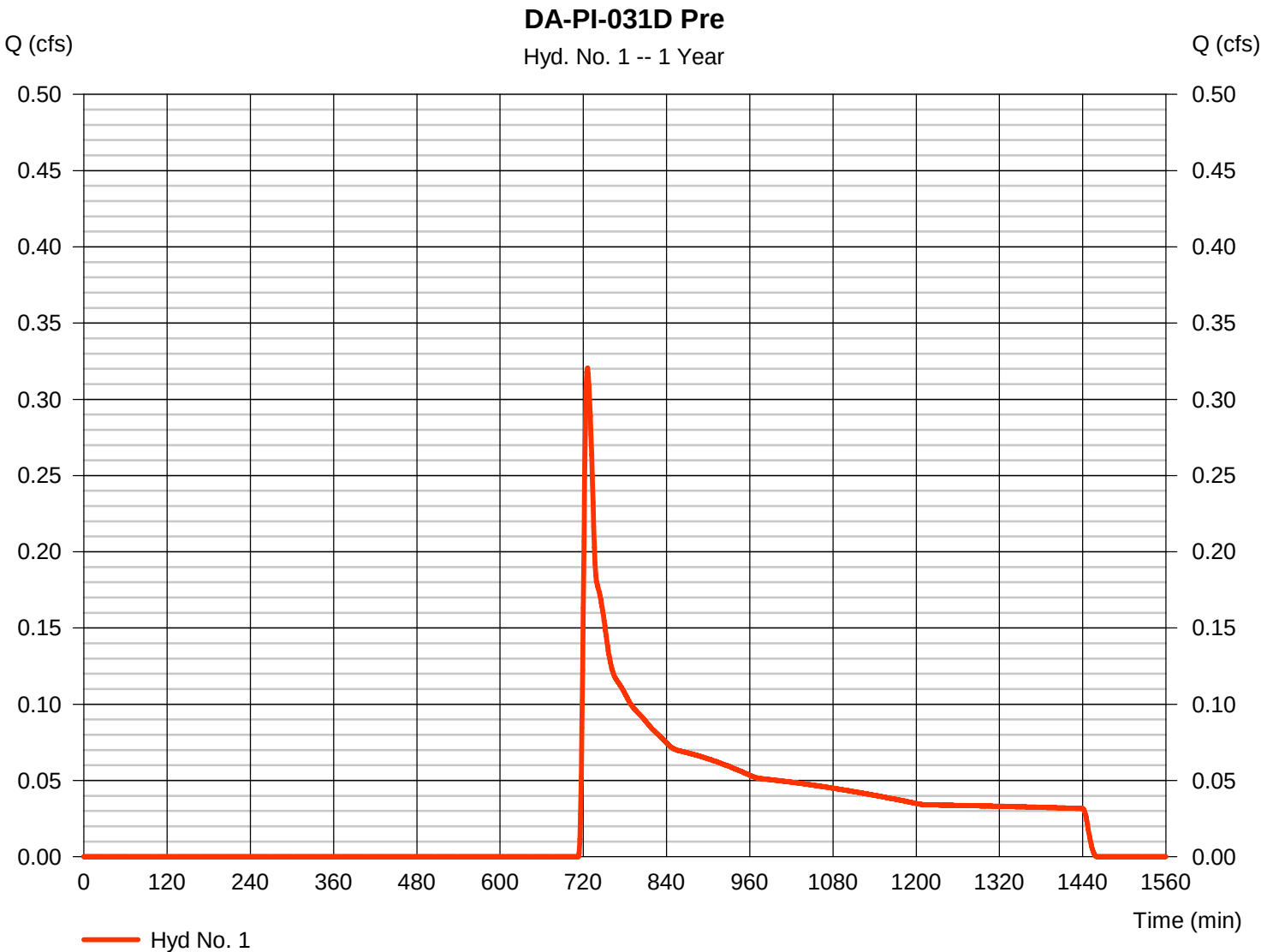
Hydrograph Report

Hyd. No. 1

DA-PI-031D Pre

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.321 cfs
Storm frequency	=	1 yrs	Time to peak	=	726 min
Time interval	=	1 min	Hyd. volume	=	2,562 cuft
Drainage area	=	3.800 ac	Curve number	=	57*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	13.40 min
Total precip.	=	2.80 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(1.560 x 55) + (2.240 x 58)] / 3.800



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-PI-031D Pre

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.400	0.011				
Flow length (ft)	= 31.6	68.4	0.0				
Two-year 24-hr precip. (in)	= 3.50	3.50	0.00				
Land slope (%)	= 6.91	11.67	0.00				
Travel Time (min)	= 4.98	+	7.48	+	0.00	=	12.46
Shallow Concentrated Flow							
Flow length (ft)	= 378.45	0.00	0.00				
Watercourse slope (%)	= 17.72	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=6.79	0.00	0.00				
Travel Time (min)	= 0.93	+	0.00	+	0.00	=	0.93
Channel Flow							
X sectional flow area (sqft)	= 0.00	0.00	0.00				
Wetted perimeter (ft)	= 0.00	0.00	0.00				
Channel slope (%)	= 0.00	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	((0))0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc				13.40 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

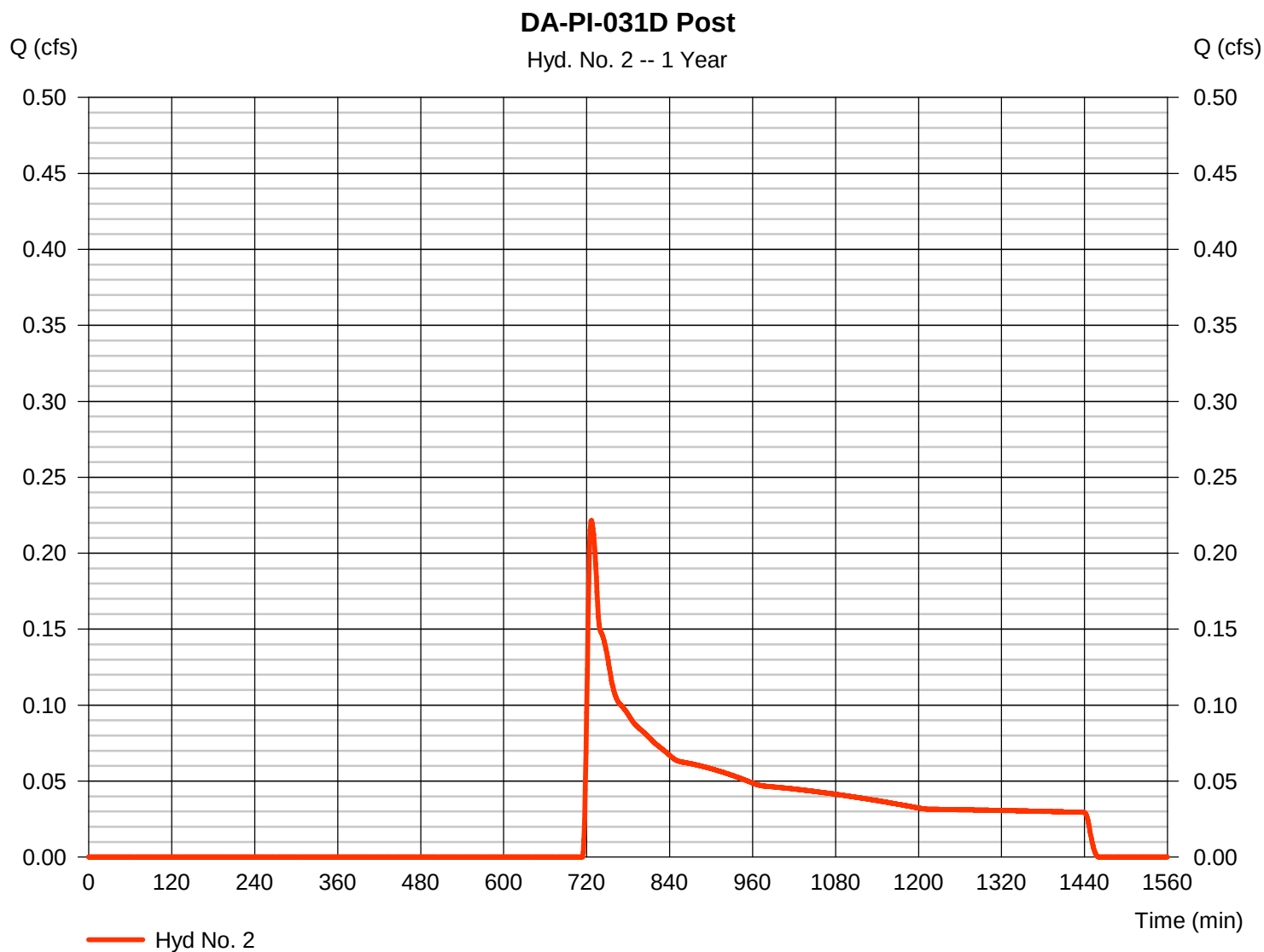
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-PI-031D Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.222 cfs
Storm frequency	= 1 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 2,255 cuft
Drainage area	= 3.800 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.40 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.130 \times 55) + (2.960 \times 58) + (0.710 \times 48)] / 3.800$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-PI-031D Post

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.400	0.011				
Flow length (ft)	= 31.6	68.4	0.0				
Two-year 24-hr precip. (in)	= 3.50	3.50	0.00				
Land slope (%)	= 6.91	11.67	0.00				
Travel Time (min)	= 4.98	+	7.48	+	0.00	=	12.46
Shallow Concentrated Flow							
Flow length (ft)	= 378.45	0.00	0.00				
Watercourse slope (%)	= 17.72	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=6.79	0.00	0.00				
Travel Time (min)	= 0.93	+	0.00	+	0.00	=	0.93
Channel Flow							
X sectional flow area (sqft)	= 0.00	0.00	0.00				
Wetted perimeter (ft)	= 0.00	0.00	0.00				
Channel slope (%)	= 0.00	0.00	0.00				
Manning's n-value	= 0.040	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	((0))0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc				13.40 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

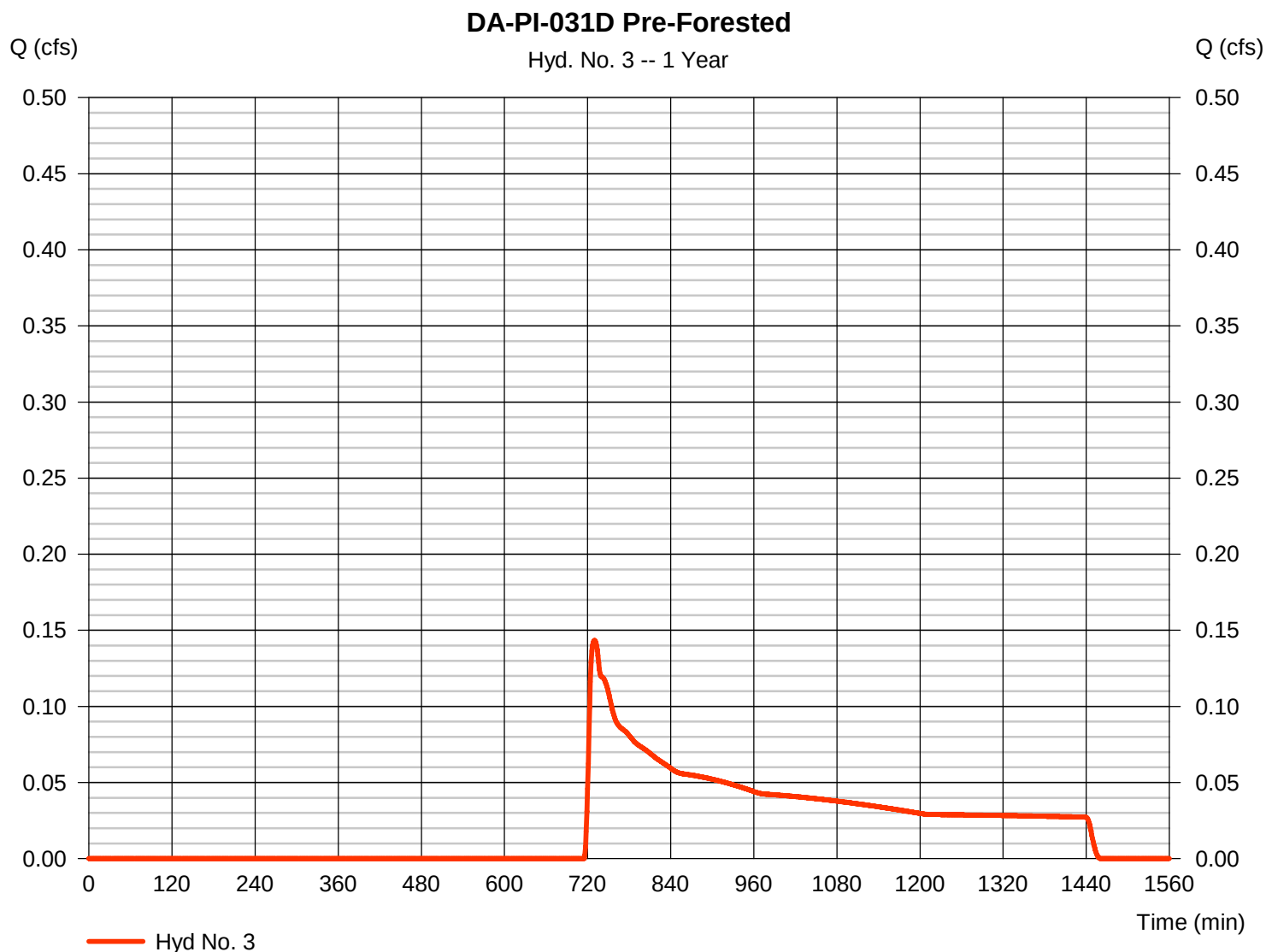
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-PI-031D Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.143 cfs
Storm frequency	=	1 yrs	Time to peak	=	730 min
Time interval	=	1 min	Hyd. volume	=	1,965 cuft
Drainage area	=	3.800 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	13.40 min
Total precip.	=	2.80 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(3.800 x 55)] / 3.800



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-PI-031D Pre-Forested

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.400	0.011				
Flow length (ft)	= 31.6	68.4	0.0				
Two-year 24-hr precip. (in)	= 3.50	3.50	0.00				
Land slope (%)	= 6.91	11.67	0.00				
Travel Time (min)	= 4.98	+	7.48	+	0.00	=	12.46
Shallow Concentrated Flow							
Flow length (ft)	= 378.45	0.00	0.00				
Watercourse slope (%)	= 17.72	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=6.79	0.00	0.00				
Travel Time (min)	= 0.93	+	0.00	+	0.00	=	0.93
Channel Flow							
X sectional flow area (sqft)	= 0.00	0.00	0.00				
Wetted perimeter (ft)	= 0.00	0.00	0.00				
Channel slope (%)	= 0.00	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	((0))0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc				13.40 min			

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	1.410	1	724	5,646	-----	-----	-----	DA-PI-031D Pre
2	SCS Runoff	1.191	1	724	5,161	-----	-----	-----	DA-PI-031D Post
3	SCS Runoff	0.984	1	724	4,695	-----	-----	-----	DA-PI-031D Pre-Forested
DA-PI-031D.gpw					Return Period: 2 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

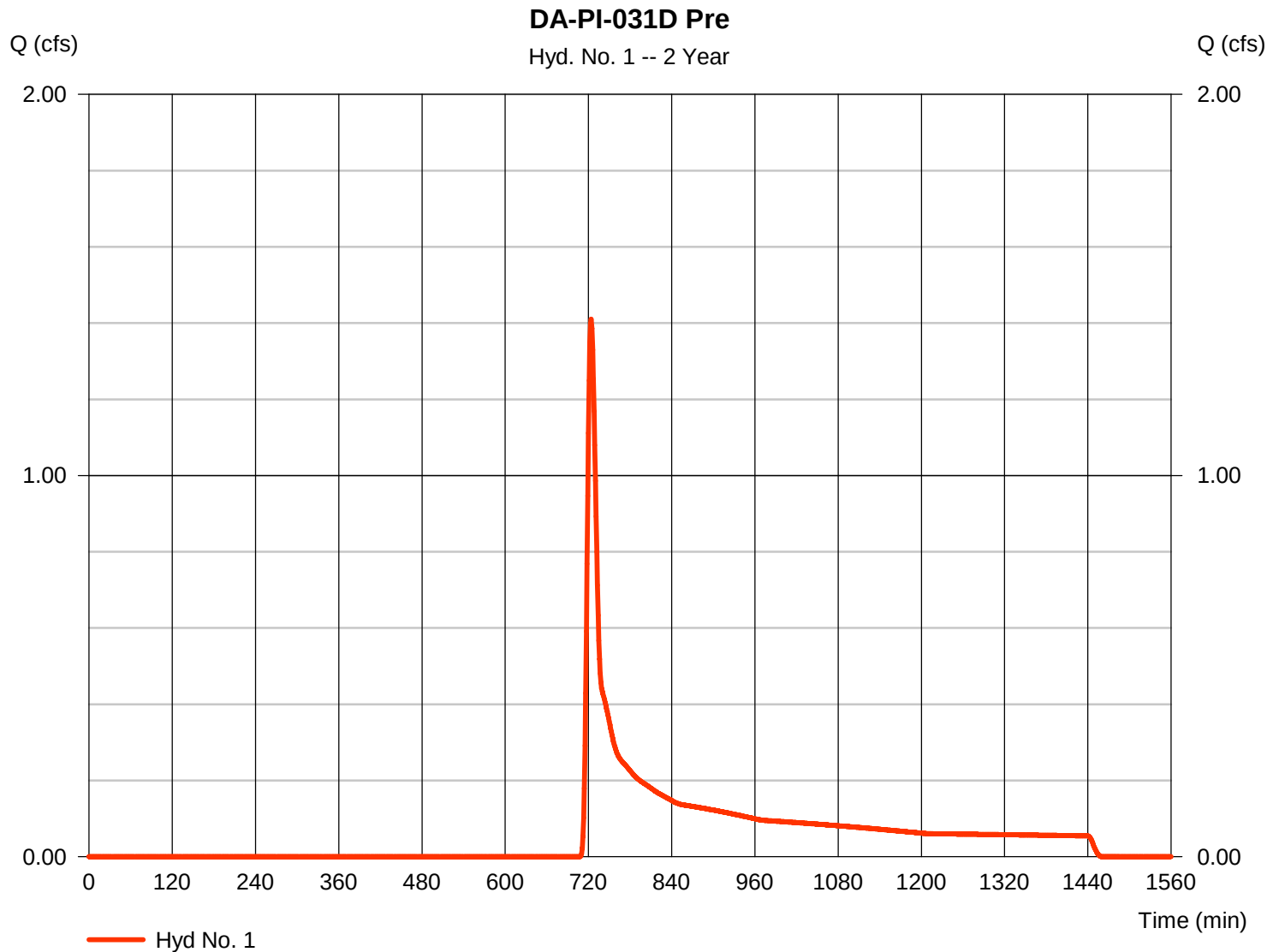
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-PI-031D Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 1.410 cfs
Storm frequency	= 2 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 5,646 cuft
Drainage area	= 3.800 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.40 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.560 \times 55) + (2.240 \times 58)] / 3.800$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

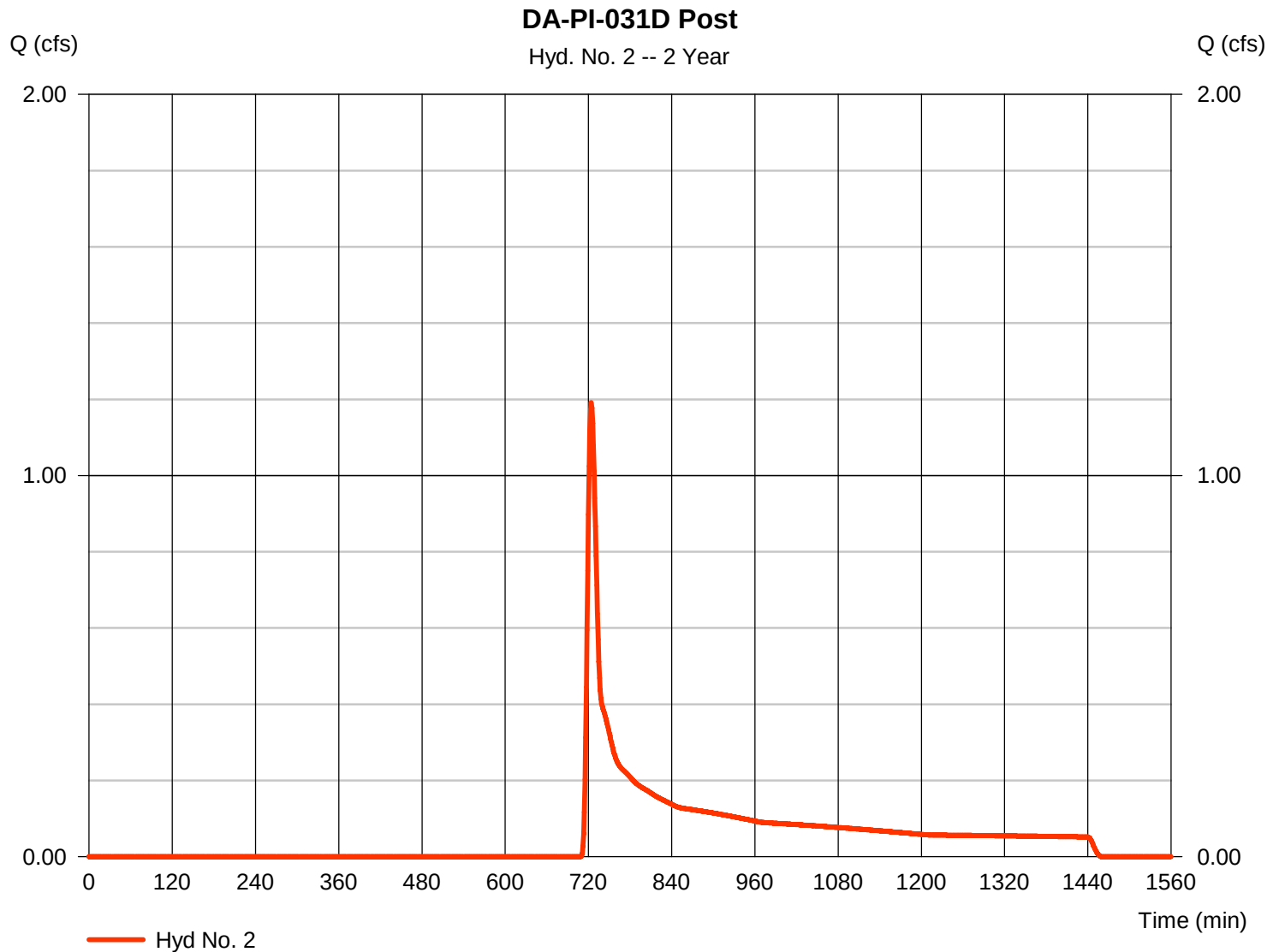
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-PI-031D Post

Hydrograph type	= SCS Runoff	Peak discharge	= 1.191 cfs
Storm frequency	= 2 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 5,161 cuft
Drainage area	= 3.800 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.40 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.130 \times 55) + (2.960 \times 58) + (0.710 \times 48)] / 3.800$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

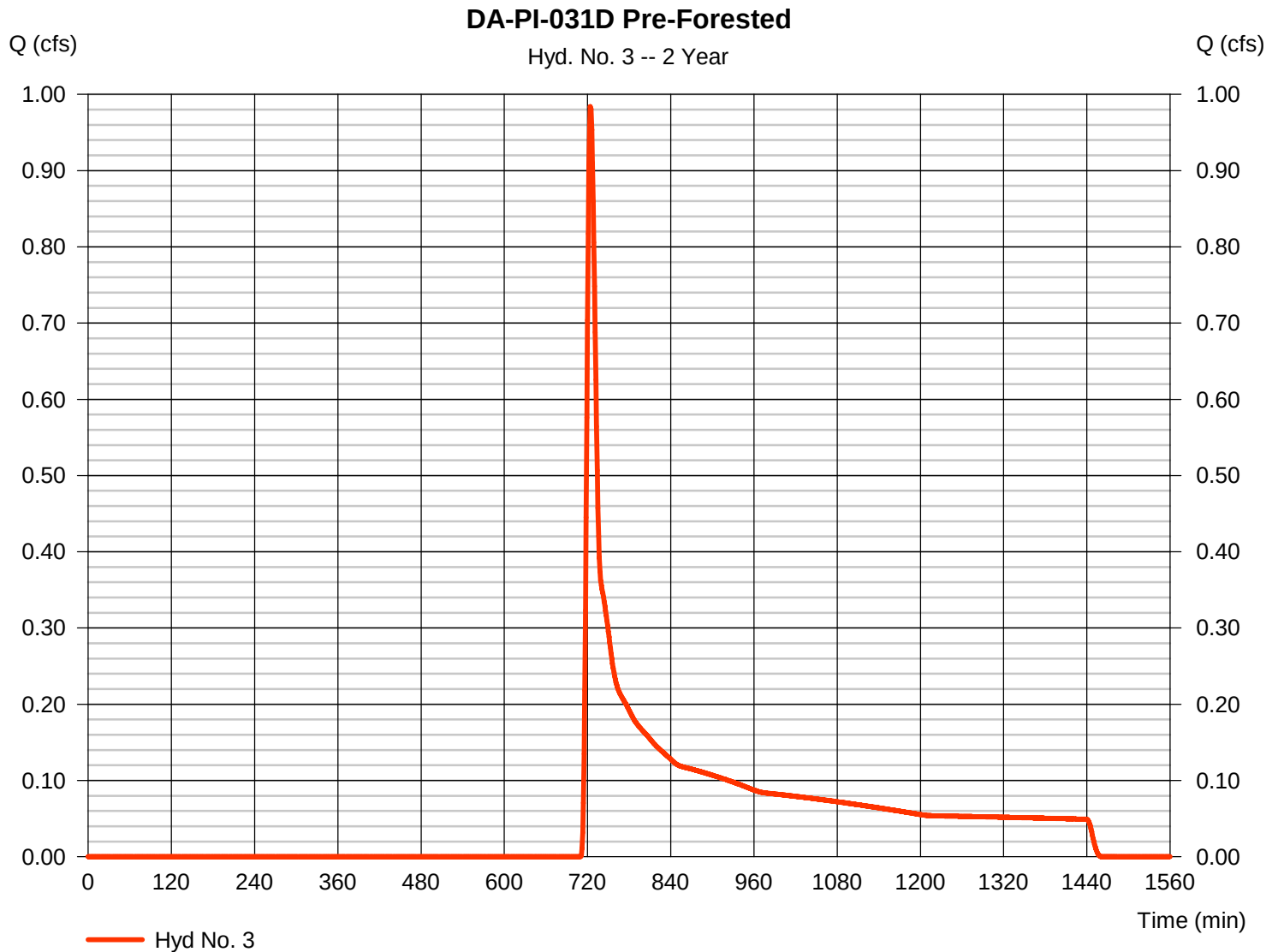
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-PI-031D Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 0.984 cfs
Storm frequency	= 2 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 4,695 cuft
Drainage area	= 3.800 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.40 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(3.800 x 55)] / 3.800



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	5.916	1	722	16,467	-----	-----	-----	DA-PI-031D Pre
2	SCS Runoff	5.496	1	722	15,565	-----	-----	-----	DA-PI-031D Post
3	SCS Runoff	5.080	1	722	14,681	-----	-----	-----	DA-PI-031D Pre-Forested
DA-PI-031D.gpw					Return Period: 10 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

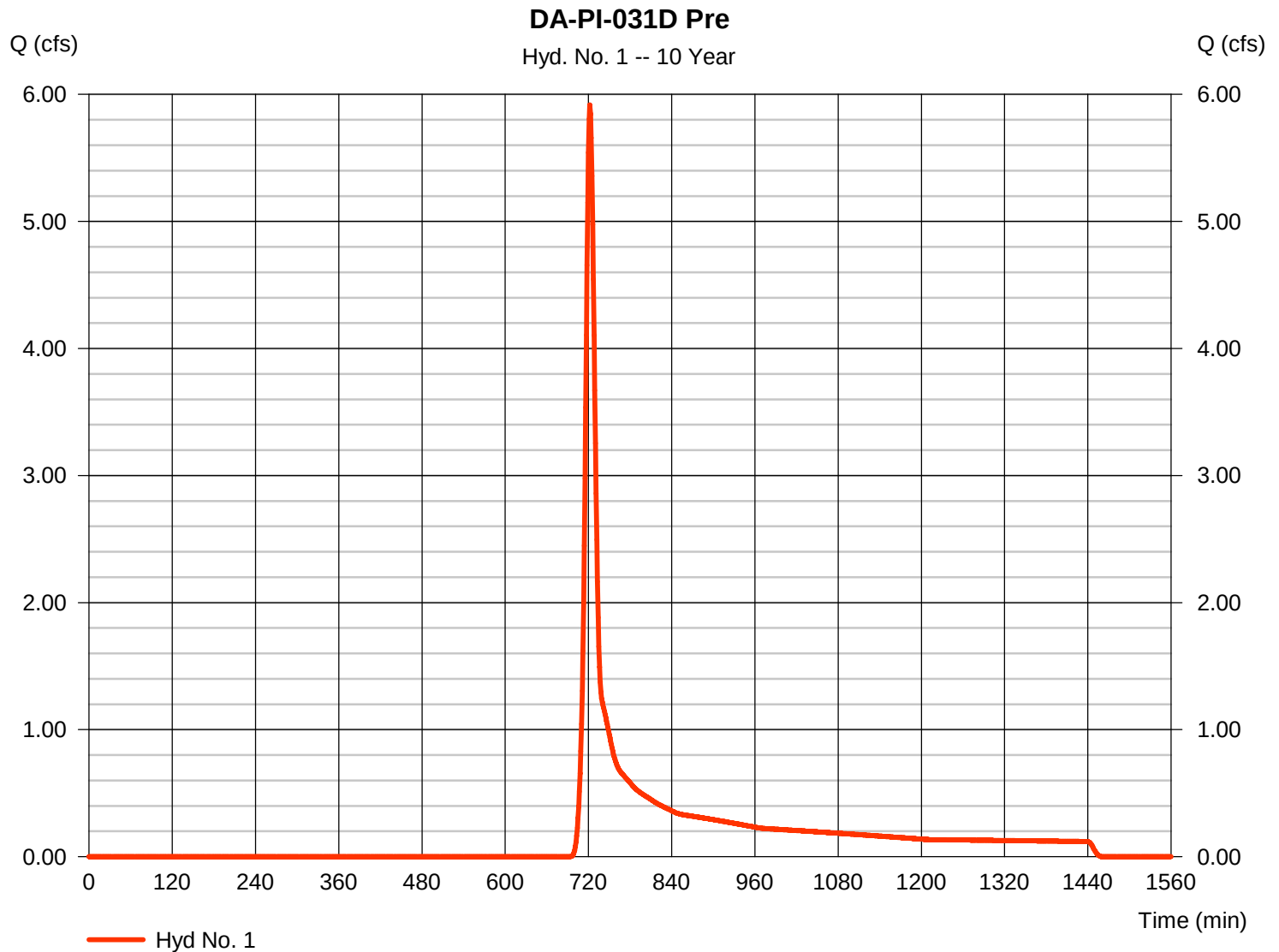
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-PI-031D Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 5.916 cfs
Storm frequency	= 10 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 16,467 cuft
Drainage area	= 3.800 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.40 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.560 \times 55) + (2.240 \times 58)] / 3.800$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

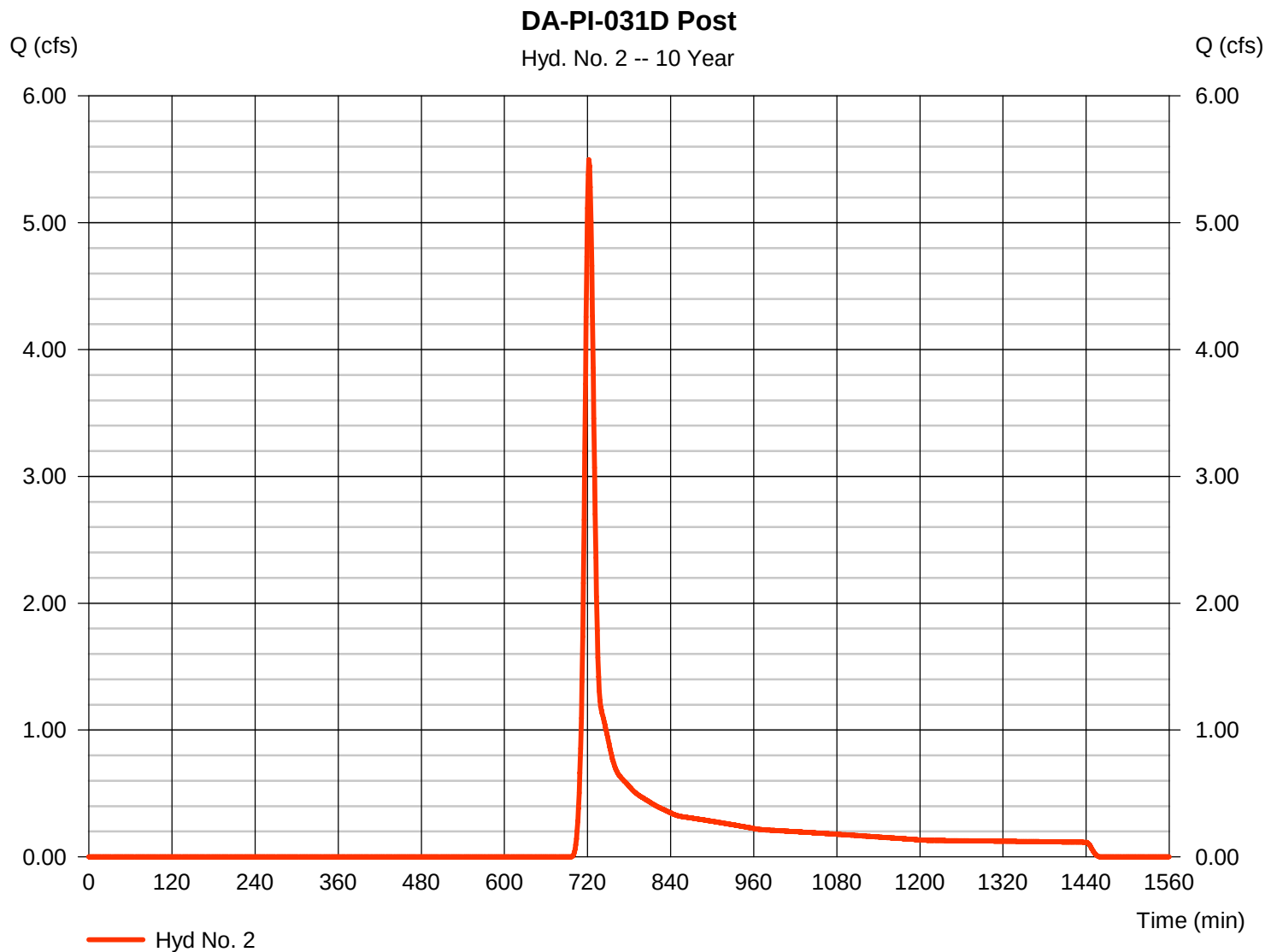
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-PI-031D Post

Hydrograph type	= SCS Runoff	Peak discharge	= 5.496 cfs
Storm frequency	= 10 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 15,565 cuft
Drainage area	= 3.800 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.40 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.130 \times 55) + (2.960 \times 58) + (0.710 \times 48)] / 3.800$



Hydrograph Report

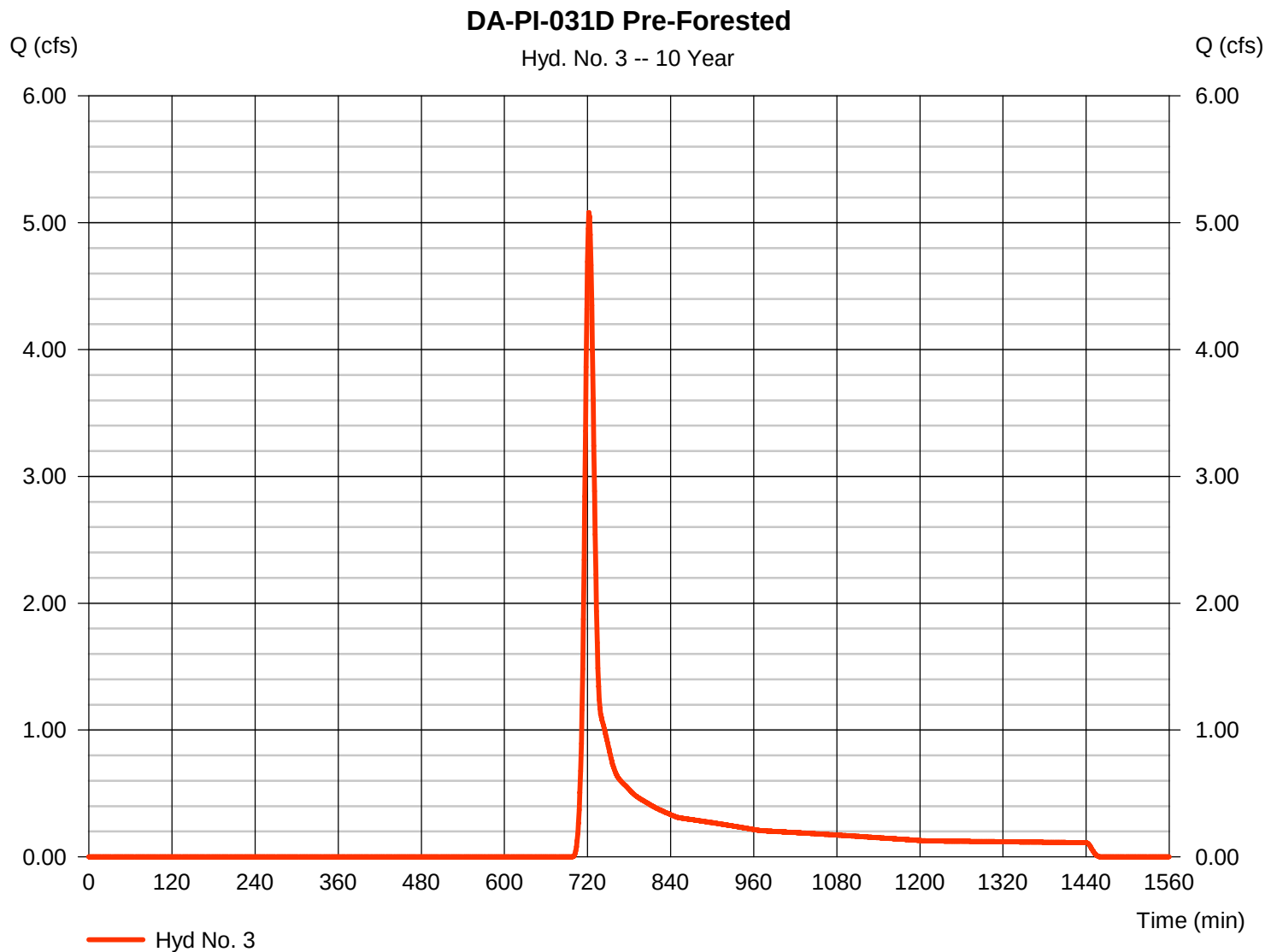
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Monday, 08 / 21 / 2017

Hyd. No. 3

DA-PI-031D Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	5.080 cfs
Storm frequency	=	10 yrs	Time to peak	=	722 min
Time interval	=	1 min	Hyd. volume	=	14,681 cuft
Drainage area	=	3.800 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	13.40 min
Total precip.	=	5.20 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(3.800 \times 55)] / 3.800$ 

DA-PI-031E

STORAGE VOLUME OF WATERBAR WITH SOIL COMPOST AMENDMENT AREA

Equations Used: ¹V_{gravel} storage = L*W*D_{gravel}*(40/100)
²V_{soil} storage = L*W*D_{soil}*(20/100)
³V_{surface} storage = [W*S*D²/2]+[L*S*D²/2]+[W*L*D]+[((2*S*D)²*D)/3]
¹Equation #2b under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, assuming that gravel is made up of 40% voids.
²Equation #2b under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, assuming that soil compost amendment is made up of 20% voids.
³Equation #1 under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, but calculation also takes into account surface side slopes.

Inputs:

Depth of Gravel Layer, D _{gravel} (ft) =	0	
Depth of Soil Amendment Area, D _{soil} (ft) =	1	Refer to Table 4.3 in VA DEQ Stormwater Design Specification No. 4; Note that compost amendment may not be necessary for HSG A/B soils
Length of Waterbar Soil Amendment Area, L (ft) =	18	
Width of Waterbar Soil Amendment Area, W (ft) =	2	
Inside Embankment Side Slopes, S (H:V) =	2	Assume 2H:1V surface side slopes for waterbars
Number of Perm. Waterbars in Drainage Area, n =	2	
Design Infiltration Rate, IR (in/hr) =	0.2	Min. rate of 0.30 in/hr for HSG A soils and 0.15-0.30 in/hr for HSG B soils (see Chap. 4, p. 4-30 in VA Stormwater Management Handbook Volume II (First Edition, 1999)
Surface Ponding Depth, D (ft) =	0.5	Assume 0.5' CFS height at the end of waterbars

Calculations:

Total Storage Depth per BMP (ft) =	1.5
Surface Storage Volume per BMP (cf) =	28.66666667
Subsurface Storage Volume per BMP (cf) =	7.2
Total Storage Volume per BMP (cf) =	35.86666667
Total BMP Storage Volume in Drainage Area (cf) =	71.73333333
Calculated Infiltration Period per BMP (hr) =	59.77777778

Depth-Storage Data				
Depth (ft)	Width (ft)	Length (ft)	Storage Volume per BMP (cf)	Storage Volume in Drainage Area (cf)
0	2	18	0	0
0.5	2	18	3.6	7.2
1	2	18	7.2	14.4
1.5	4	20	35.86666667	71.73333333
2	6	22	88.53333333	177.06666667
2.5	8	24	169.2	338.4
3	10	26	281.8666667	563.7333333
3.5	12	28	430.5333333	861.0666667

ENERGY BALANCE METHOD

Inputs:

1-Yr Event		
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.155	1,026
Developed Condition	0.129	954
Pre-Developed (Forest) Condition	0.051	698

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1:	$Q_{developed} \leq IF \times [(Q_{pre-developed} \times RV_{pre-developed}) / RV_{developed}]$ ----->	Q (cfs)	≤	Q (cfs)
		0.129		0.133
				OK
Check #2:	$Q_{developed} \leq Q_{pre-developed}$ ----->	Q (cfs)	≤	Q (cfs)
		0.129		0.155
				OK
Check #3:	$Q_{developed} \leq (Q_{forest} \times RV_{forest}) / RV_{developed}$ ---->	Q (cfs)	≤	Q (cfs)
		0.129		0.037
				<u>shall not</u> be required to be ≤

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning's n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<i>Note:</i> Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted. ¹For Paved Road land surface types a Manning's n of 0.011 was used Sources: -USACE, 1998, HEC-1 Flood Hydrograph Package User's Manual, Hydrologic Engineering Center, Davis, CA -Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC	

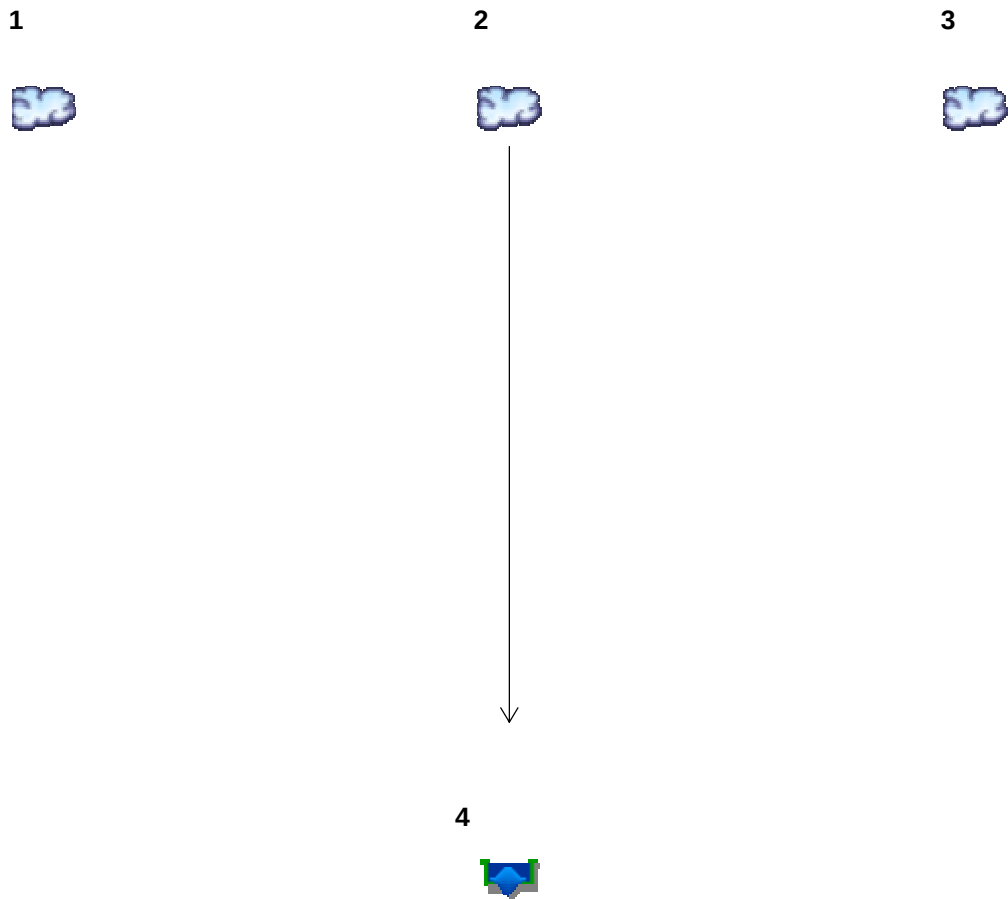
Table 2 – Manning's n Values for Open Channel Flow

Channel Type	Manning n		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹For the developed condition, a conservative Manning's n value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar, level spreader diversion, or grass channel. ²For the pre-developed condition and post-development condition, a Manning's n value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

Hyd.	Origin	Description
1	SCS Runoff	DA-PI-031E Pre
2	SCS Runoff	DA-PI-031E Post
3	SCS Runoff	DA-PI-031E Pre-Forested
4	Reservoir	WB Soil Amendment

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.155	1	725	1,026	-----	-----	-----	DA-PI-031E Pre
2	SCS Runoff	0.155	1	725	1,026	-----	-----	-----	DA-PI-031E Post
3	SCS Runoff	0.051	1	730	698	-----	-----	-----	DA-PI-031E Pre-Forested
4	Reservoir	0.129	1	730	954	2	790.54	80.9	WB Soil Amendment
DA-PI-031E.gpw					Return Period: 1 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

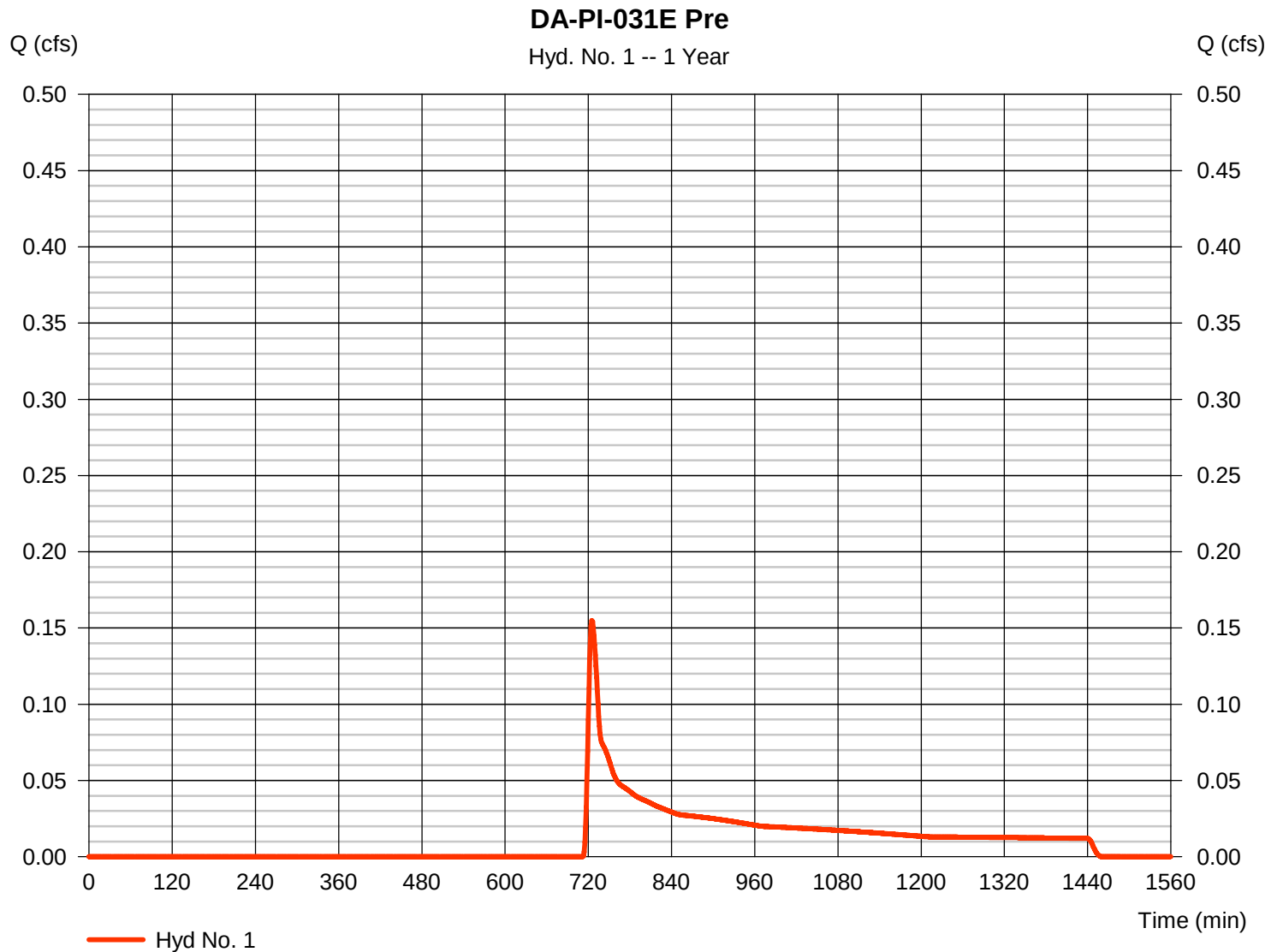
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-PI-031E Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.155 cfs
Storm frequency	= 1 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 1,026 cuft
Drainage area	= 1.350 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 12.30 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.120 \times 55) + (1.230 \times 58)] / 1.350$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-PI-031E Pre

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.400	0.011	
Flow length (ft)	= 9.9	90.1	0.0	
Two-year 24-hr precip. (in)	= 3.50	3.50	0.00	
Land slope (%)	= 8.71	12.75	0.00	
Travel Time (min)	= 1.80	+	9.00	+
			0.00	= 10.80
Shallow Concentrated Flow				
Flow length (ft)	= 283.47	0.00	0.00	
Watercourse slope (%)	= 3.76	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=3.13	0.00	0.00	
Travel Time (min)	= 1.51	+	0.00	+
			0.00	= 1.51
Channel Flow				
X sectional flow area (sqft)	= 0.00	0.00	0.00	
Wetted perimeter (ft)	= 0.00	0.00	0.00	
Channel slope (%)	= 0.00	0.00	0.00	
Manning's n-value	= 0.030	0.015	0.015	
Velocity (ft/s)	=0.00	0.00	0.00	
Flow length (ft)	(0)0.0	0.0	0.0	
Travel Time (min)	= 0.00	+	0.00	+
			0.00	= 0.00
Total Travel Time, Tc				12.30 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

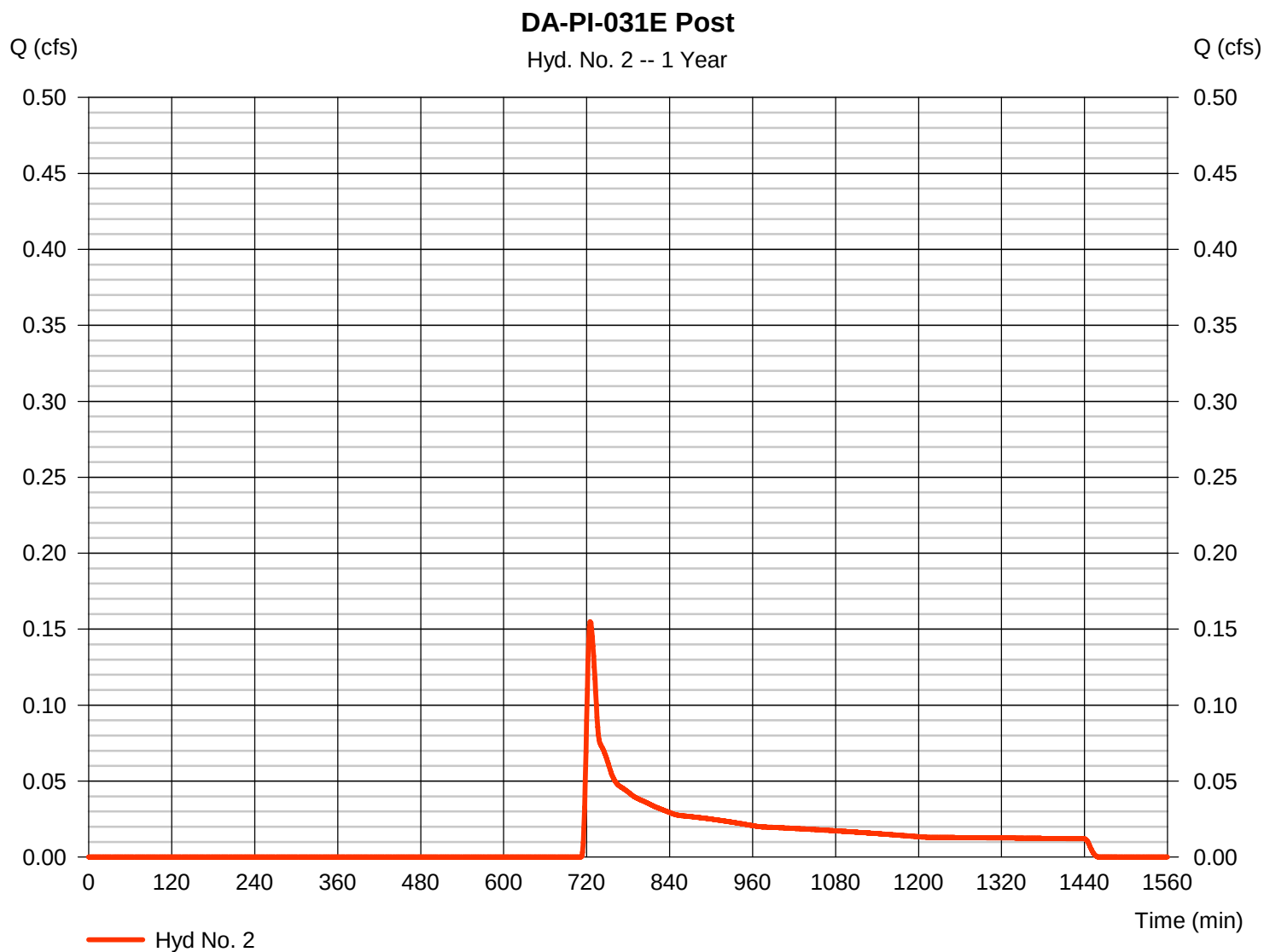
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-PI-031E Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.155 cfs
Storm frequency	= 1 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 1,026 cuft
Drainage area	= 1.350 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 12.30 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.010 \times 55) + (1.280 \times 58) + (0.060 \times 48)] / 1.350$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-PI-031E Post

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.800	0.400	0.011	
Flow length (ft)	= 9.9	90.1	0.0	
Two-year 24-hr precip. (in)	= 3.50	3.50	0.00	
Land slope (%)	= 8.71	12.75	0.00	
Travel Time (min)	= 3.13	+	9.00	+
			0.00	= 12.13
Shallow Concentrated Flow				
Flow length (ft)	= 28.32	0.00	0.00	
Watercourse slope (%)	= 7.80	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=4.51	0.00	0.00	
Travel Time (min)	= 0.10	+	0.00	+
			0.00	= 0.10
Channel Flow				
X sectional flow area (sqft)	= 2.00	0.00	0.00	
Wetted perimeter (ft)	= 4.47	0.00	0.00	
Channel slope (%)	= 5.00	0.00	0.00	
Manning's n-value	= 0.040	0.015	0.015	
Velocity (ft/s)	=4.86	0.00	0.00	
			0.00	
Flow length (ft)	({})12.0	0.0	0.0	
Travel Time (min)	= 0.04	+	0.00	+
			0.00	= 0.04
Total Travel Time, Tc				12.30 min

Hydrograph Report

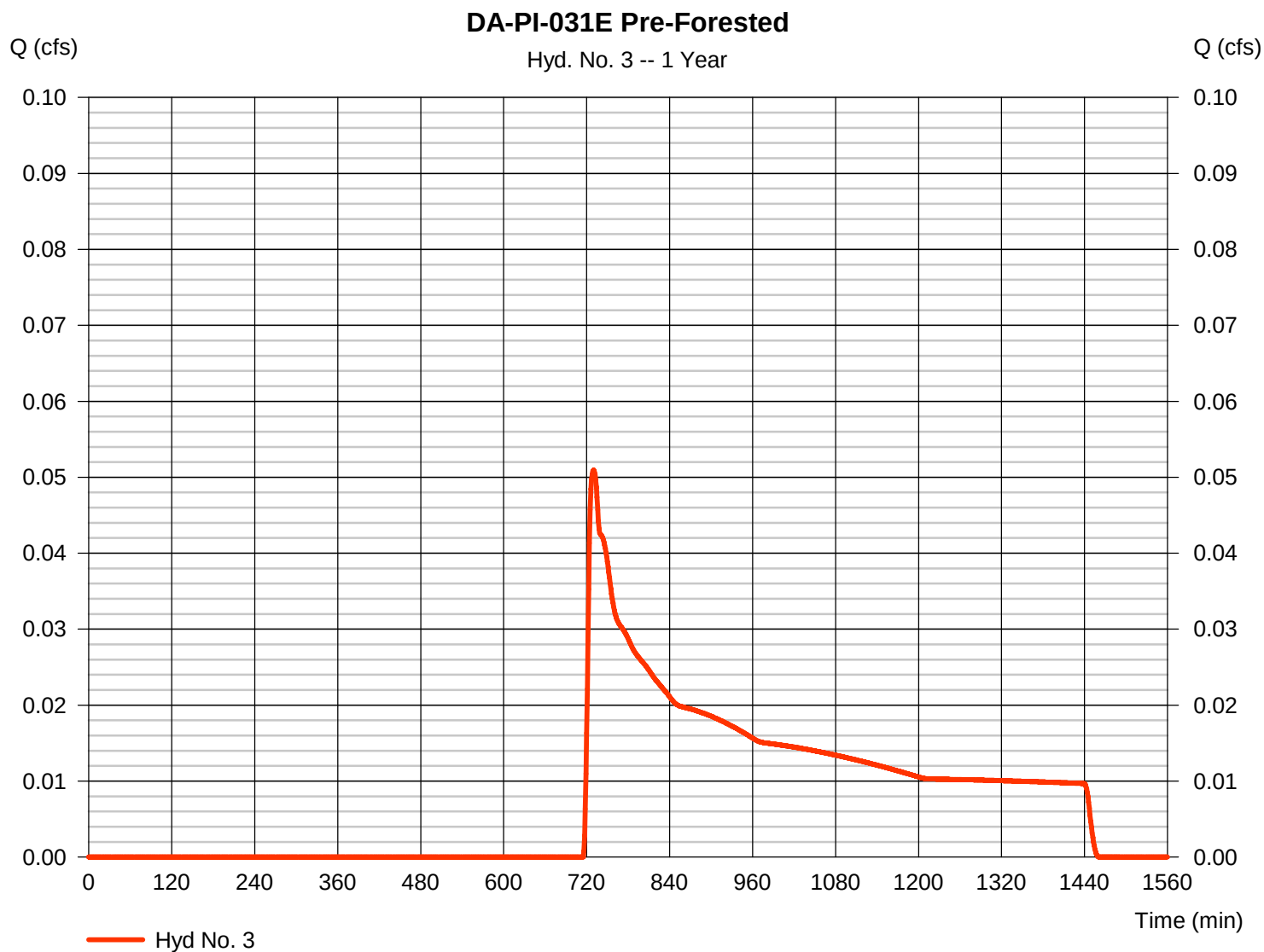
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Monday, 08 / 21 / 2017

Hyd. No. 3

DA-PI-031E Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 0.051 cfs
Storm frequency	= 1 yrs	Time to peak	= 730 min
Time interval	= 1 min	Hyd. volume	= 698 cuft
Drainage area	= 1.350 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 12.30 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.350 \times 55)] / 1.350$ 

TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-PI-031E Pre-Forested

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.400	0.011	
Flow length (ft)	= 9.9	90.1	0.0	
Two-year 24-hr precip. (in)	= 3.50	3.50	0.00	
Land slope (%)	= 8.71	12.75	0.00	
Travel Time (min)	= 1.80	+	9.00	+
			0.00	= 10.80
Shallow Concentrated Flow				
Flow length (ft)	= 283.47	0.00	0.00	
Watercourse slope (%)	= 3.76	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=3.13	0.00	0.00	
Travel Time (min)	= 1.51	+	0.00	+
			0.00	= 1.51
Channel Flow				
X sectional flow area (sqft)	= 0.00	0.00	0.00	
Wetted perimeter (ft)	= 0.00	0.00	0.00	
Channel slope (%)	= 0.00	0.00	0.00	
Manning's n-value	= 0.030	0.015	0.015	
Velocity (ft/s)	=0.00	0.00	0.00	
Flow length (ft)	(0)0.0	0.0	0.0	
Travel Time (min)	= 0.00	+	0.00	+
			0.00	= 0.00
Total Travel Time, Tc				12.30 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

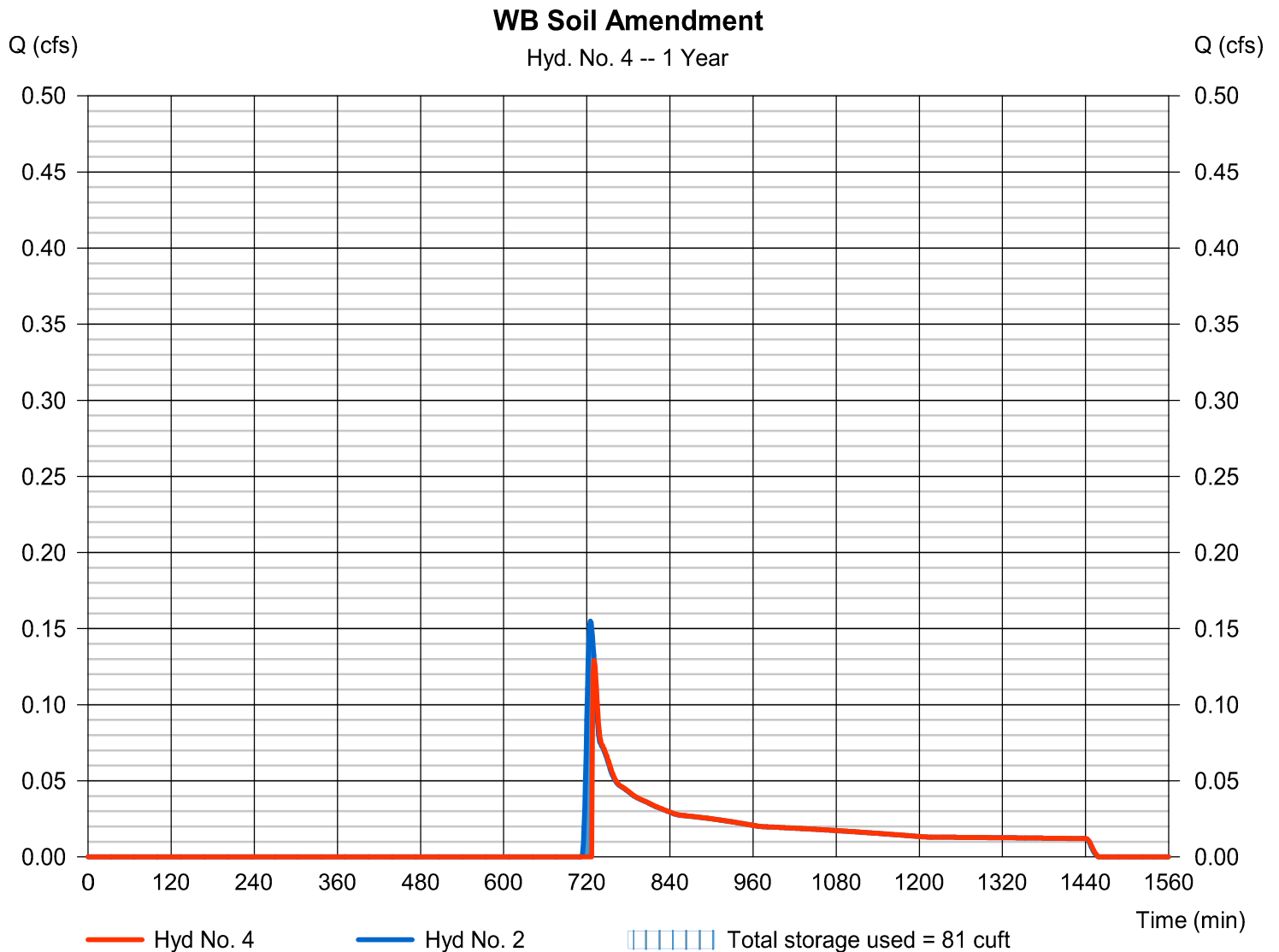
Monday, 08 / 21 / 2017

Hyd. No. 4

WB Soil Amendment

Hydrograph type	= Reservoir	Peak discharge	= 0.129 cfs
Storm frequency	= 1 yrs	Time to peak	= 730 min
Time interval	= 1 min	Hyd. volume	= 954 cuft
Inflow hyd. No.	= 2 - DA-PI-031E Post	Max. Elevation	= 790.54 ft
Reservoir name	= DA-PI-031E Waterbar	Max. Storage	= 81 cuft

Storage Indication method used.



Pond No. 1 - DA-PI-031E Waterbar

Pond Data

Pond storage is based on user-defined values.

Stage / Storage Table

Stage (ft)	Elevation (ft)	Contour area (sqft)	Incr. Storage (cuft)	Total storage (cuft)
0.00	789.00	n/a	0	0
0.50	789.50	n/a	7	7
1.00	790.00	n/a	7	14
1.50	790.50	n/a	57	72
2.00	791.00	n/a	105	177
2.50	791.50	n/a	161	338
3.00	792.00	n/a	225	564

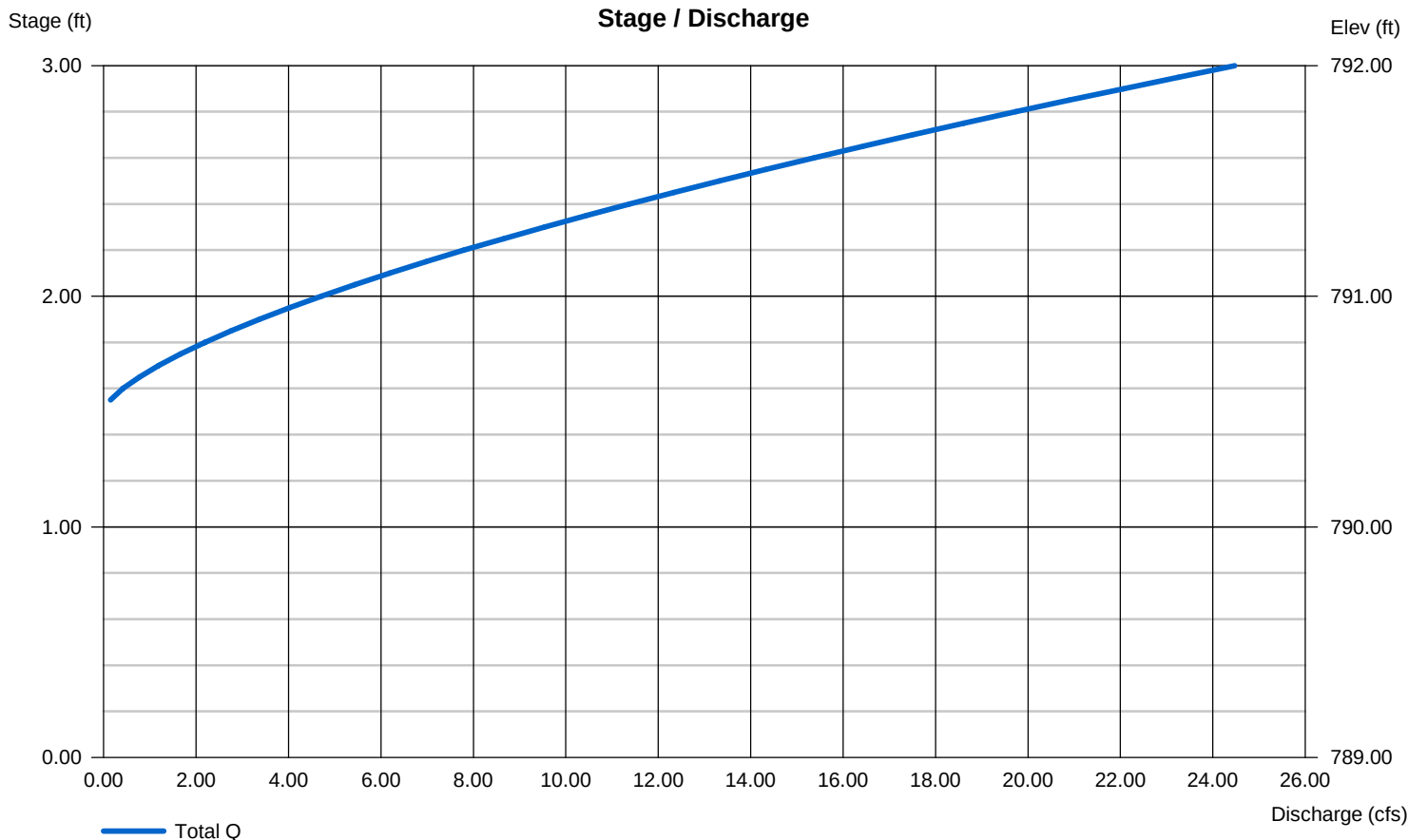
Culvert / Orifice Structures

	[A]	[B]	[C]	[PrfRsr]
Rise (in)	Inactive	0.00	0.00	0.00
Span (in)	= 0.00	0.00	0.00	0.00
No. Barrels	= 0	0	0	0
Invert El. (ft)	= 0.00	0.00	0.00	0.00
Length (ft)	= 0.00	0.00	0.00	0.00
Slope (%)	= 0.00	0.00	0.00	n/a
N-Value	= .013	.013	.013	n/a
Orifice Coeff.	= 0.60	0.60	0.60	0.60
Multi-Stage	= n/a	No	No	No

Weir Structures

	[A]	[B]	[C]	[D]
Crest Len (ft)	= 4.00	0.00	0.00	0.00
Crest El. (ft)	= 790.50	0.00	0.00	0.00
Weir Coeff.	= 3.33	3.33	3.33	3.33
Weir Type	= Rect	---	---	---
Multi-Stage	= No	No	No	No
Exfil.(in/hr)	= 0.000 (by Wet area)			
TW Elev. (ft)	= 0.00			

Note: Culvert/Orifice outflows are analyzed under inlet (ic) and outlet (oc) control. Weir risers checked for orifice conditions (ic) and submergence (s).



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.583	1	724	2,185	-----	-----	-----	DA-PI-031E Pre
2	SCS Runoff	0.583	1	724	2,185	-----	-----	-----	DA-PI-031E Post
3	SCS Runoff	0.350	1	724	1,668	-----	-----	-----	DA-PI-031E Pre-Forested
4	Reservoir	0.583	1	724	2,113	2	790.62	97.6	WB Soil Amendment
DA-PI-031E.gpw					Return Period: 2 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

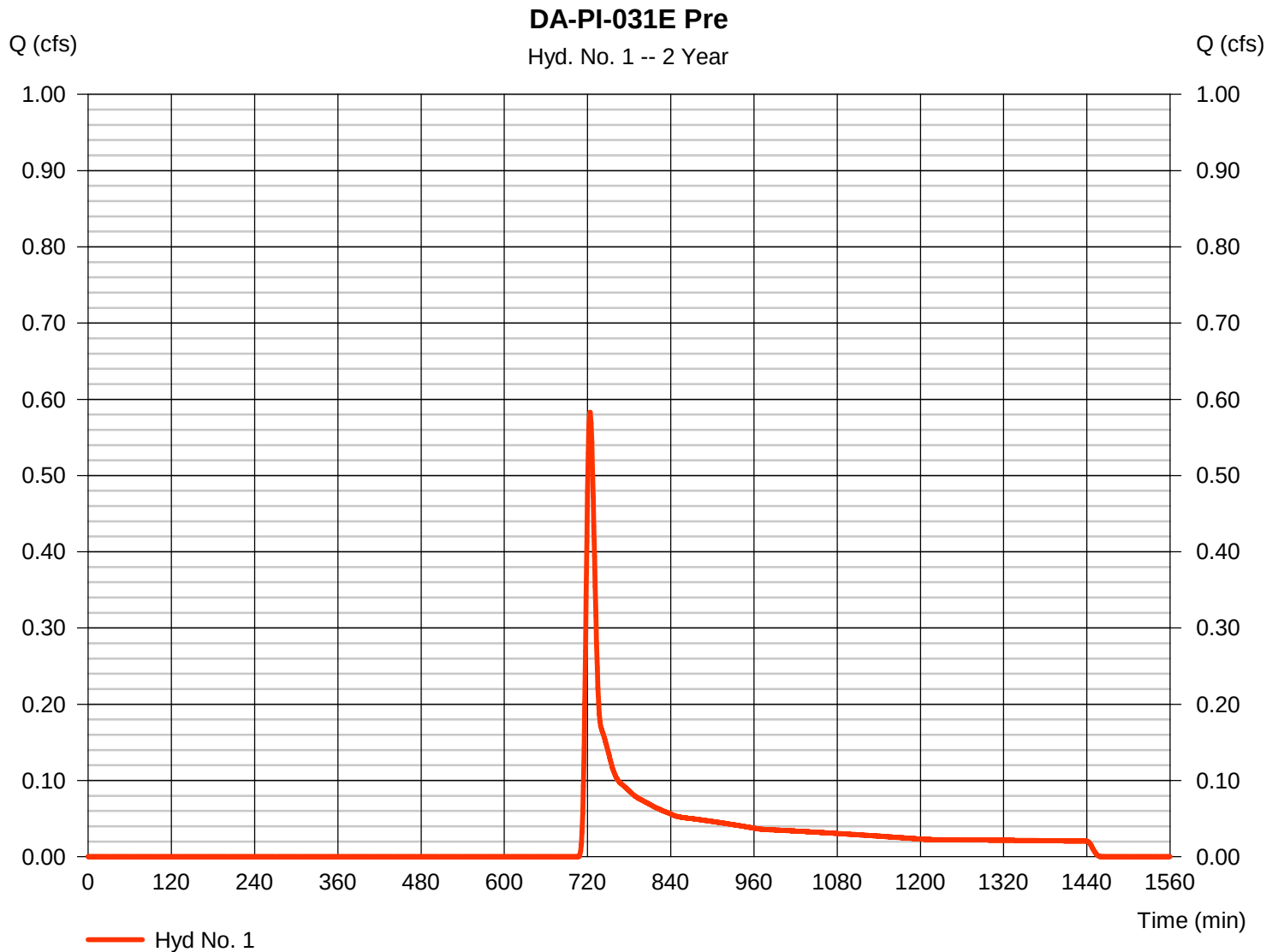
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-PI-031E Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.583 cfs
Storm frequency	= 2 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 2,185 cuft
Drainage area	= 1.350 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 12.30 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.120 \times 55) + (1.230 \times 58)] / 1.350$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

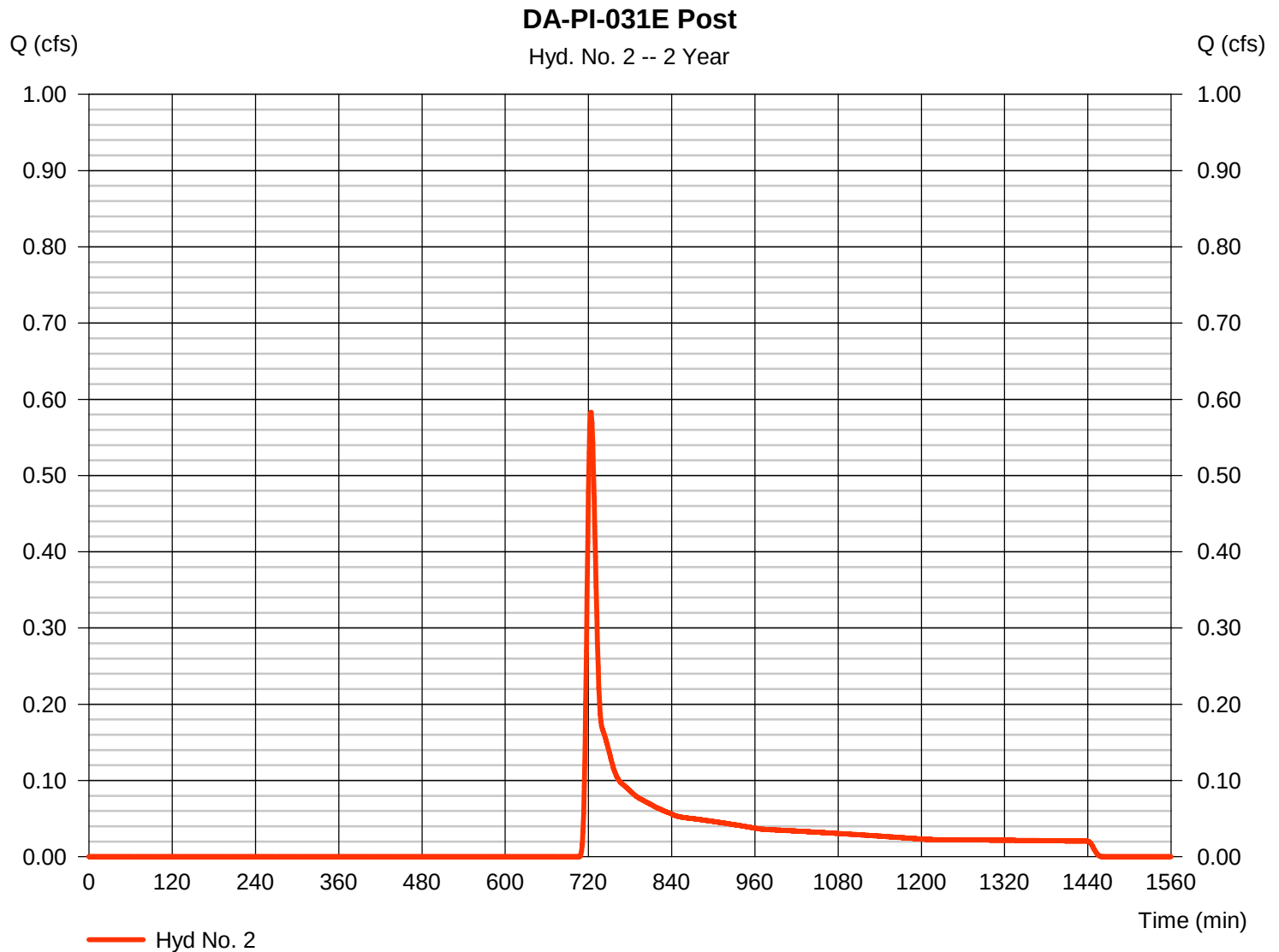
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Hyd. No. 2

DA-PI-031E Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.583 cfs
Storm frequency	= 2 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 2,185 cuft
Drainage area	= 1.350 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 12.30 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.010 \times 55) + (1.280 \times 58) + (0.060 \times 48)] / 1.350$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

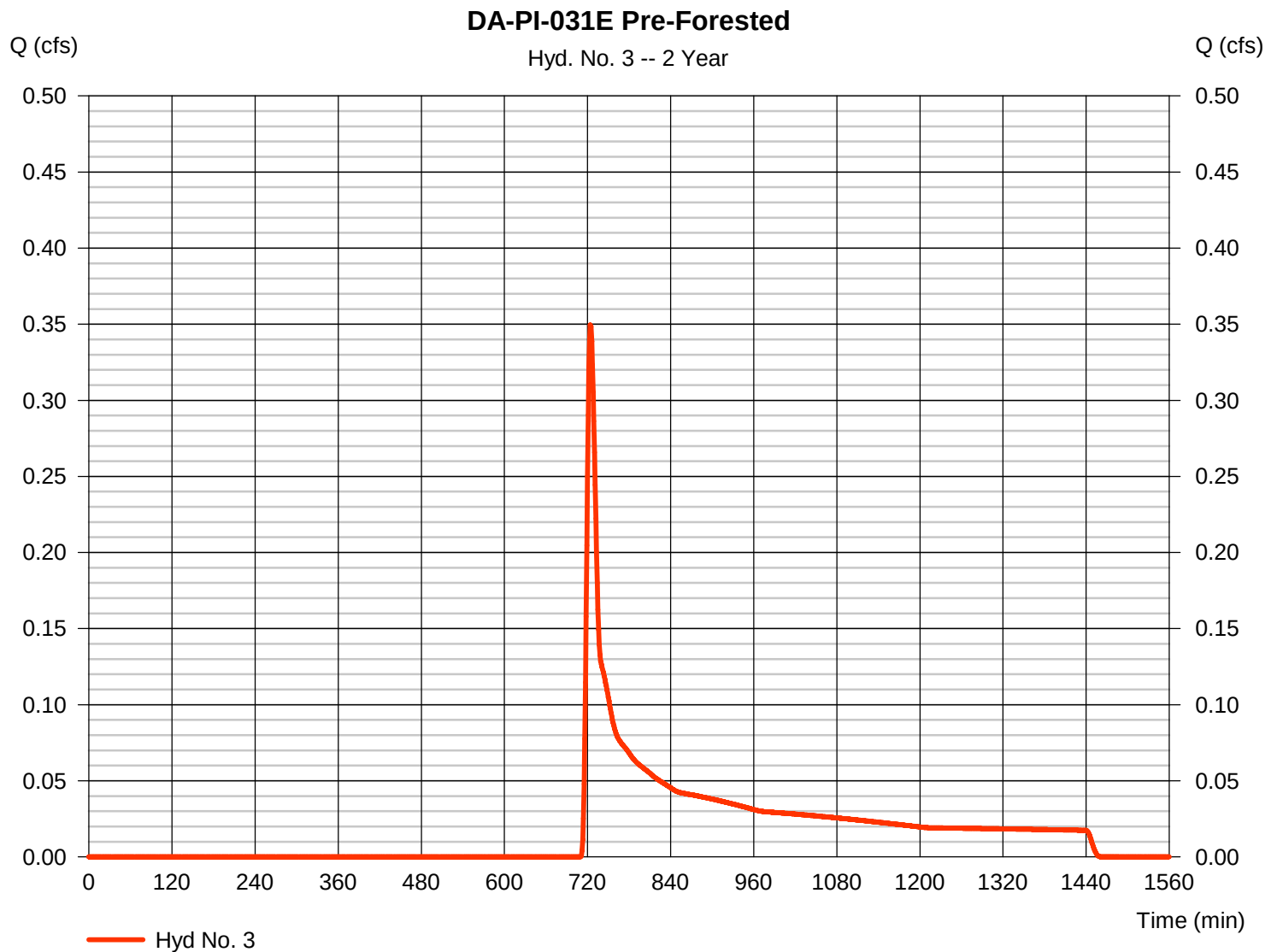
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Hyd. No. 3

DA-PI-031E Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 0.350 cfs
Storm frequency	= 2 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 1,668 cuft
Drainage area	= 1.350 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 12.30 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(1.350 x 55)] / 1.350



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

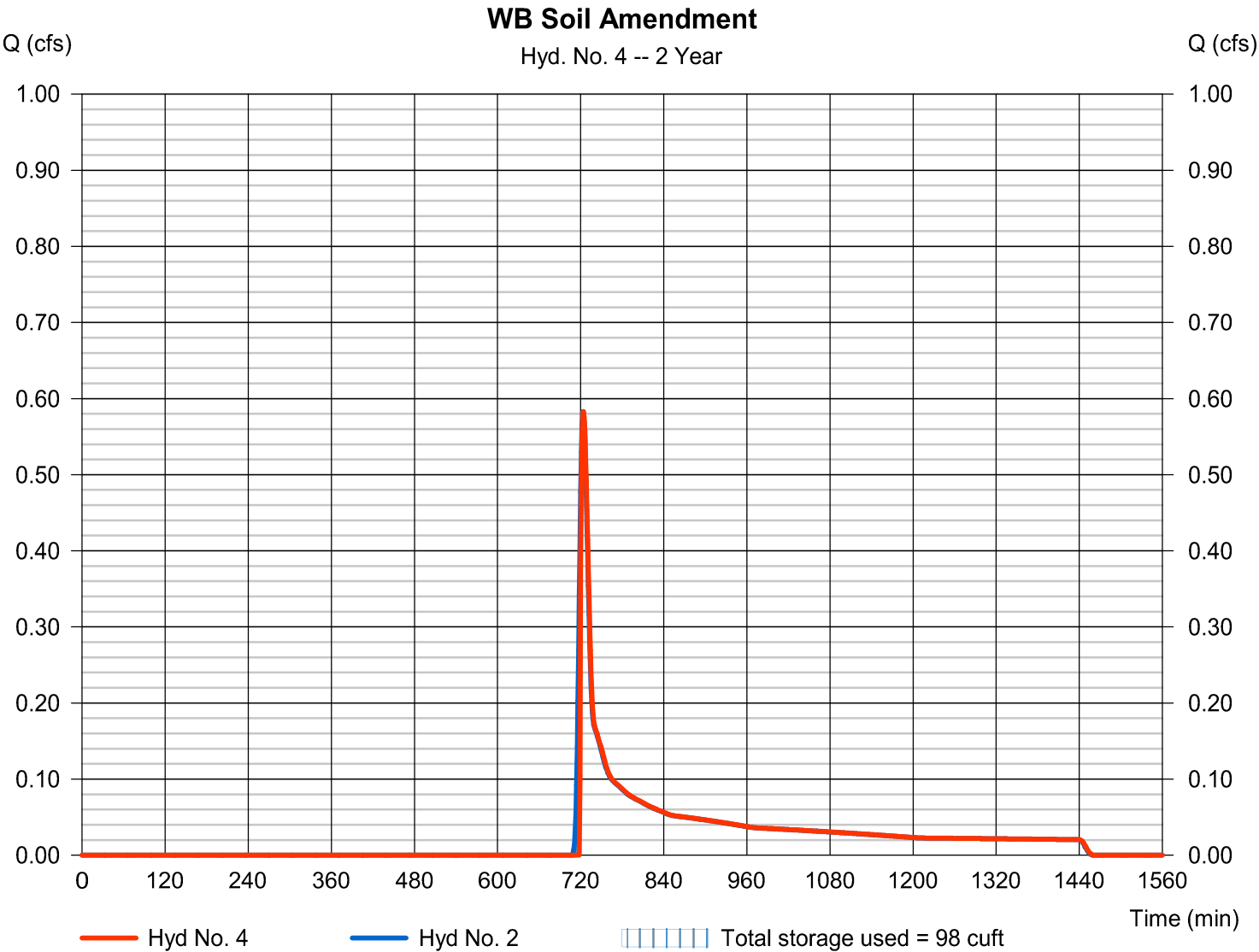
Monday, 08 / 21 / 2017

Hyd. No. 4

WB Soil Amendment

Hydrograph type	= Reservoir	Peak discharge	= 0.583 cfs
Storm frequency	= 2 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 2,113 cuft
Inflow hyd. No.	= 2 - DA-PI-031E Post	Max. Elevation	= 790.62 ft
Reservoir name	= DA-PI-031E Waterbar	Max. Storage	= 98 cuft

Storage Indication method used.



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	2.252	1	722	6,176	-----	-----	-----	DA-PI-031E Pre
2	SCS Runoff	2.252	1	722	6,176	-----	-----	-----	DA-PI-031E Post
3	SCS Runoff	1.805	1	722	5,216	-----	-----	-----	DA-PI-031E Pre-Forested
4	Reservoir	2.245	1	722	6,105	2	790.81	136	WB Soil Amendment
DA-PI-031E.gpw					Return Period: 10 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

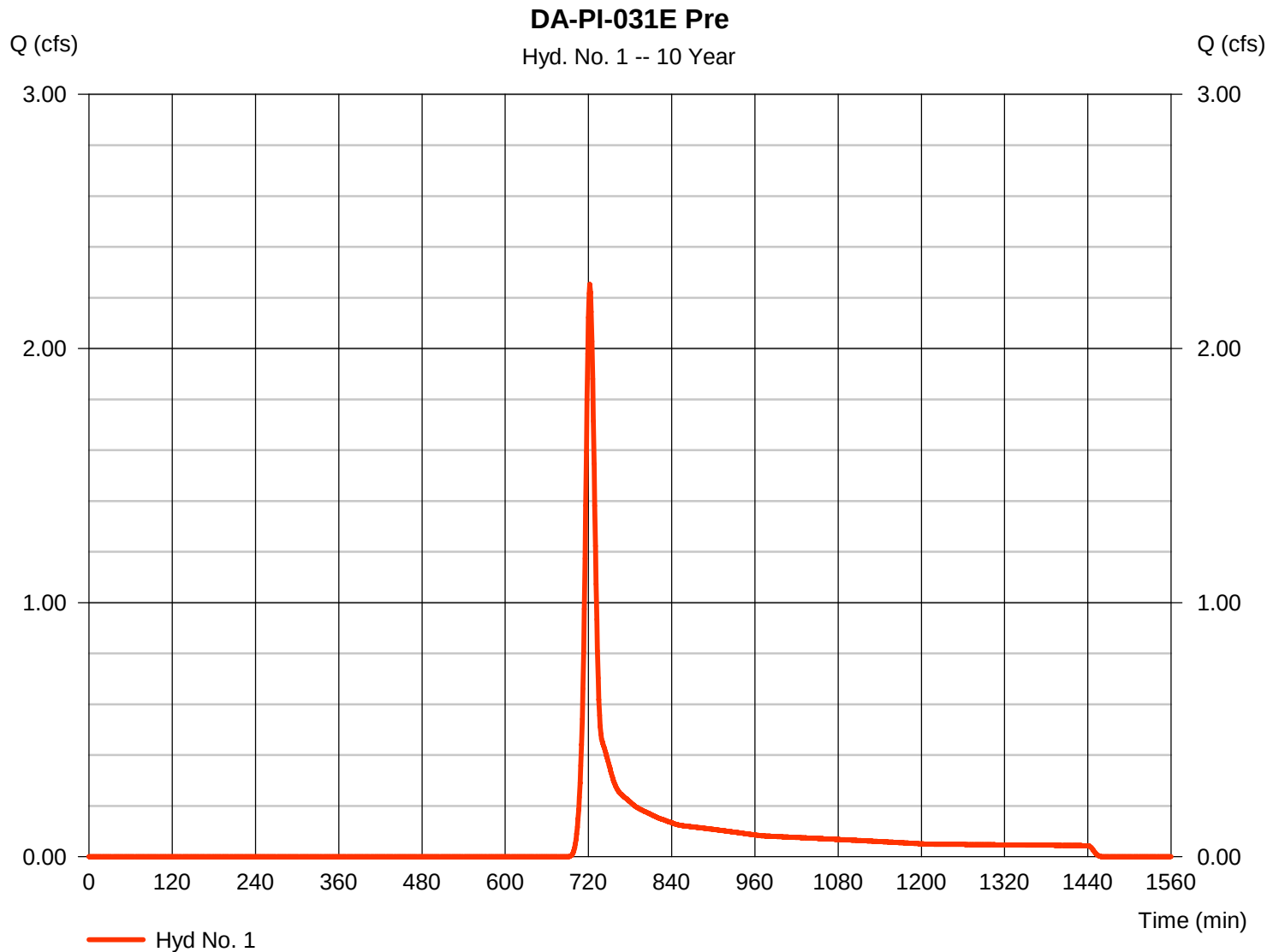
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Hyd. No. 1

DA-PI-031E Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 2.252 cfs
Storm frequency	= 10 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 6,176 cuft
Drainage area	= 1.350 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 12.30 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.120 \times 55) + (1.230 \times 58)] / 1.350$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

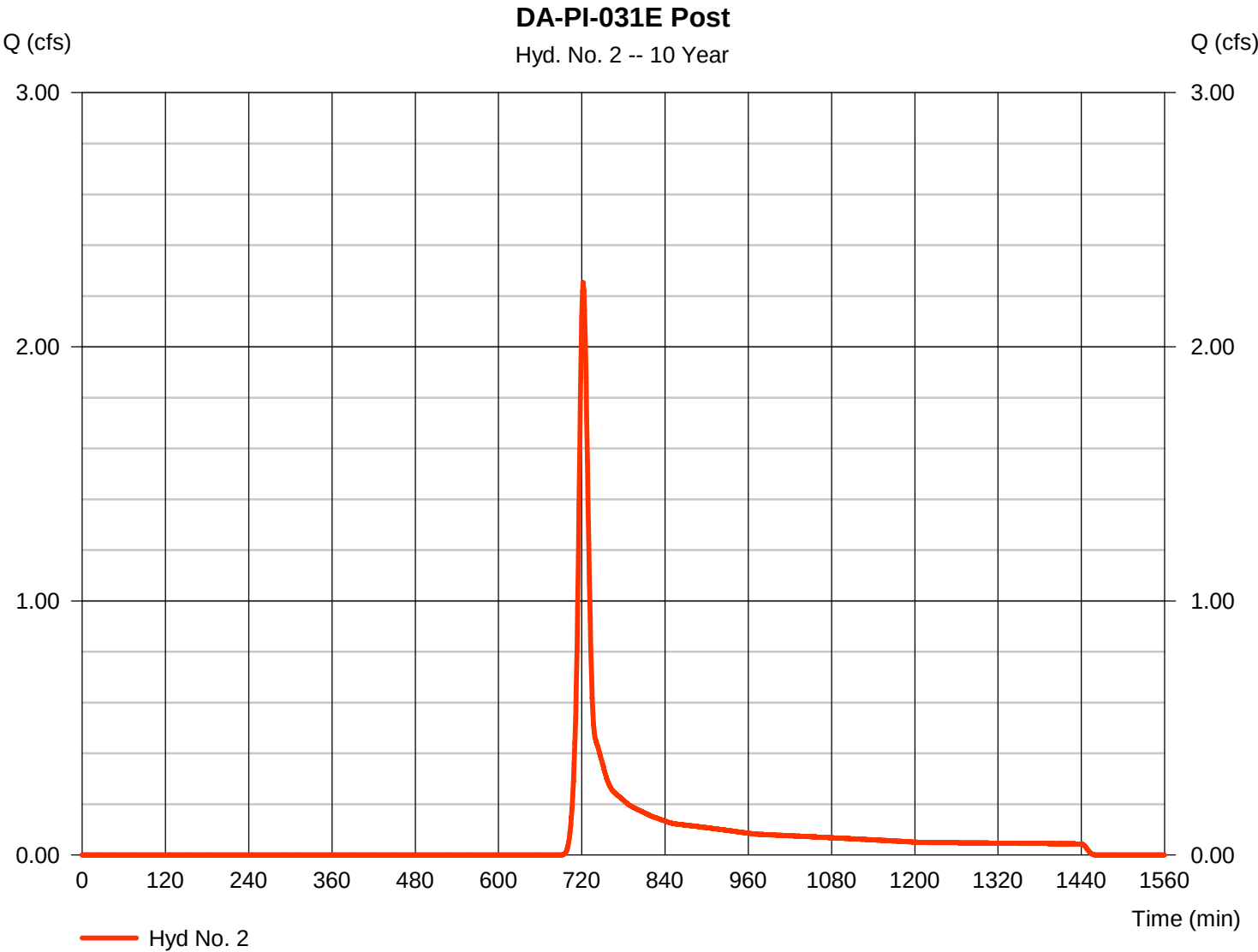
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-PI-031E Post

Hydrograph type	=	SCS Runoff	Peak discharge	=	2.252 cfs
Storm frequency	=	10 yrs	Time to peak	=	722 min
Time interval	=	1 min	Hyd. volume	=	6,176 cuft
Drainage area	=	1.350 ac	Curve number	=	58*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	12.30 min
Total precip.	=	5.20 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.010 x 55) + (1.280 x 58) + (0.060 x 48)] / 1.350



Hydrograph Report

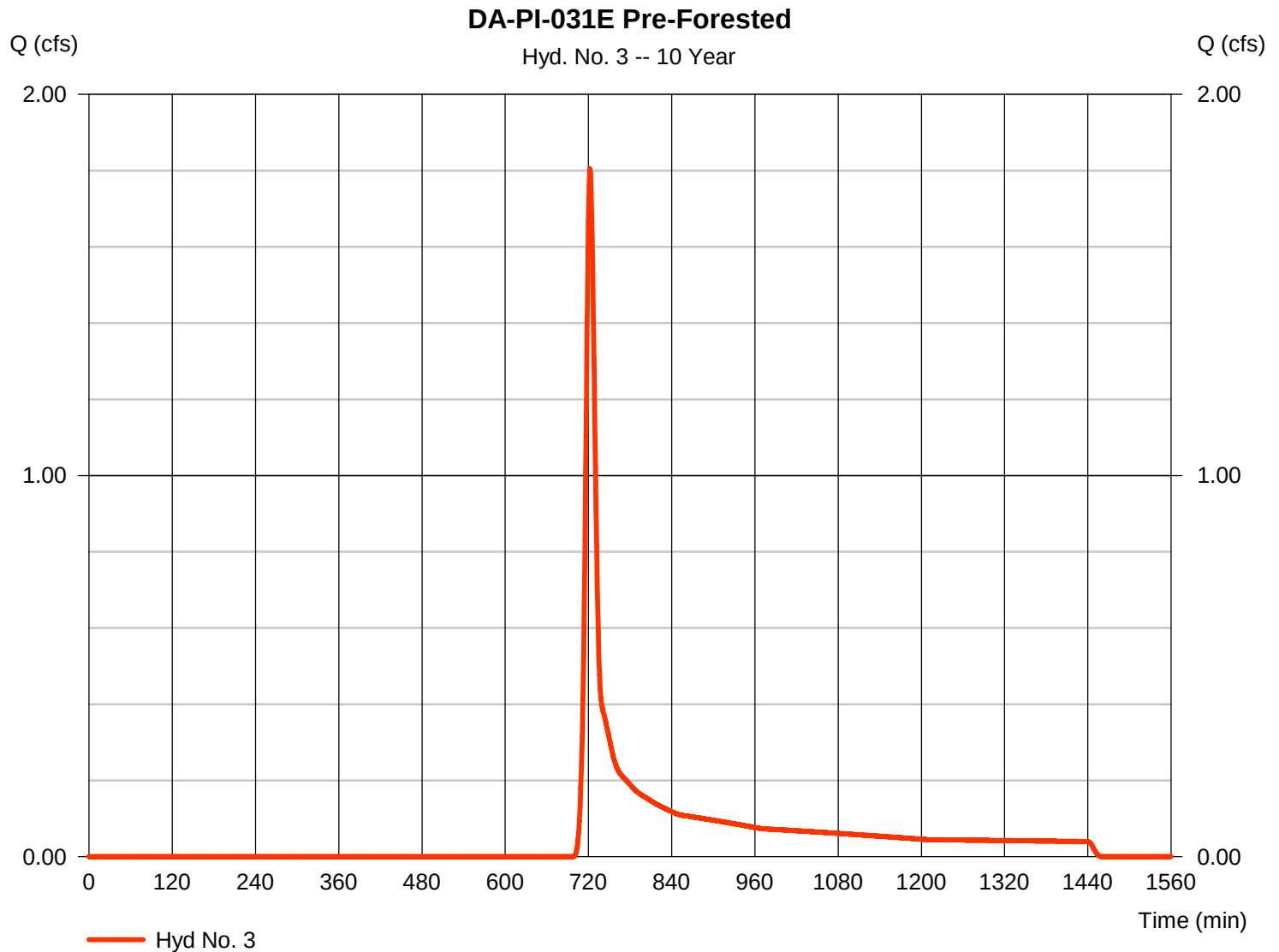
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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Hyd. No. 3

DA-PI-031E Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 1.805 cfs
Storm frequency	= 10 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 5,216 cuft
Drainage area	= 1.350 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 12.30 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.350 \times 55)] / 1.350$ 

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

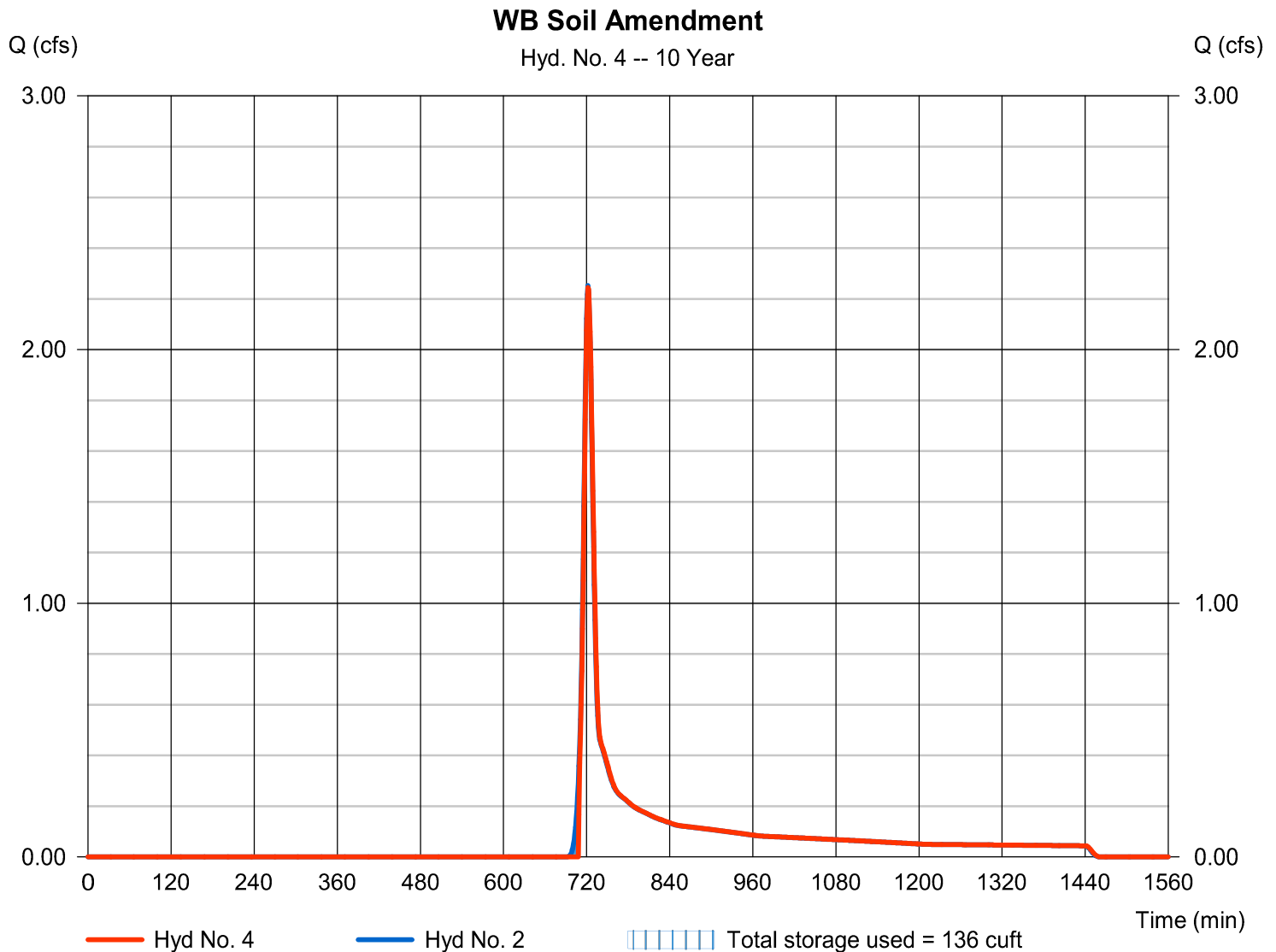
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Hyd. No. 4

WB Soil Amendment

Hydrograph type	= Reservoir	Peak discharge	= 2.245 cfs
Storm frequency	= 10 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 6,105 cuft
Inflow hyd. No.	= 2 - DA-PI-031E Post	Max. Elevation	= 790.81 ft
Reservoir name	= DA-PI-031E Waterbar	Max. Storage	= 136 cuft

Storage Indication method used.



File name: SampleFHA.idf

Return Period (Yrs)	Intensity Values (in/hr)											
	5 min	10	15	20	25	30	35	40	45	50	55	60
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	5.69	4.61	3.89	3.38	2.99	2.69	2.44	2.24	2.07	1.93	1.81	1.70
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	6.57	5.43	4.65	4.08	3.65	3.30	3.02	2.79	2.59	2.42	2.27	2.15
10	7.24	6.04	5.21	4.59	4.12	3.74	3.43	3.17	2.95	2.77	2.60	2.46
25	8.25	6.95	6.03	5.34	4.80	4.38	4.02	3.73	3.48	3.26	3.07	2.91
50	9.04	7.65	6.66	5.92	5.34	4.87	4.49	4.16	3.88	3.65	3.44	3.25
100	9.83	8.36	7.30	6.50	5.87	5.36	4.94	4.59	4.29	4.03	3.80	3.60

Precip. file name: P:\Watres\Projects\MVP\ Pittsylvania 7252017\Packages\Pittsylvania.pcp

[illegible]

DA-PI-031F

STORAGE VOLUME OF WATERBAR WITH SOIL COMPOST AMENDMENT AREA

Equations Used: ¹V_{gravel} storage = L*W*D_{gravel}*(40/100)
²V_{soil} storage = L*W*D_{soil}*(20/100)
³V_{surface} storage = [W*S*D²/2]+[L*S*D²/2]+[W*L*D]+[((2*S*D)²/3)]
¹Equation #2b under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, assuming that gravel is made up of 40% voids.
²Equation #2b under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, assuming that soil compost amendment is made up of 20% voids.
³Equation #1 under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, but calculation also takes into account surface side slopes.

Inputs:

Depth of Gravel Layer, D _{gravel} (ft) =	0	
Depth of Soil Amendment Area, D _{soil} (ft) =	1	Refer to Table 4.3 in VA DEQ Stormwater Design Specification No. 4; Note that compost amendment may not be necessary for HSG A/B soils
Length of Waterbar Soil Amendment Area, L (ft) =	14	
Width of Waterbar Soil Amendment Area, W (ft) =	2	
Inside Embankment Side Slopes, S (H:V) =	2	Assume 2H:1V surface side slopes for waterbars
Number of Perm. Waterbars in Drainage Area, n =	3	
Design Infiltration Rate, IR (in/hr) =	0.2	Min. rate of 0.30 in/hr for HSG A soils and 0.15-0.30 in/hr for HSG B soils (see Chap. 4, p. 4-30 in VA Stormwater Management Handbook Volume II (First Edition, 1999))
Surface Ponding Depth, D (ft) =	0.5	Assume 0.5' CFS height at the end of waterbars

Calculations:

Total Storage Depth per BMP (ft) =	1.5
Surface Storage Volume per BMP (cf) =	22.66666667
Subsurface Storage Volume per BMP (cf) =	5.6
Total Storage Volume per BMP (cf) =	28.26666667
Total BMP Storage Volume in Drainage Area (cf) =	84.8
Calculated Infiltration Period per BMP (hr) =	60.57142857

Depth-Storage Data				
Depth (ft)	Width (ft)	Length (ft)	Storage Volume per BMP (cf)	Storage Volume in Drainage Area (cf)
0	2	14	0	0
0.5	2	14	2.8	8.4
1	2	14	5.6	16.8
1.5	4	16	28.26666667	84.8
2	6	18	70.93333333	212.8
2.5	8	20	137.6	412.8
3	10	22	232.2666667	696.8
3.5	12	24	358.9333333	1076.8

ENERGY BALANCE METHOD

Inputs:

1-Yr Event		
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.527	1,802
Developed Condition	0.440	1,717
Pre-Developed (Forest) Condition	0.087	1,293

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1:	$Q_{\text{developed}} \leq IF \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}]$ ----->	Q (cfs)	≤	Q (cfs)
		0.440	OK	0.442
Check #2:	$Q_{\text{developed}} \leq Q_{\text{pre-developed}}$ ----->	0.440	≤	0.527
			OK	
Check #3:	$Q_{\text{developed}} \text{ shall not be required to be } \leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}}$ ---->	0.440	<u>shall not</u> be required to be ≤	0.066

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning's n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<i>Note:</i> Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted. ¹For Paved Road land surface types a Manning's n of 0.011 was used <i>Sources:</i> -USACE, 1998, HEC-1 Flood Hydrograph Package User's Manual, Hydrologic Engineering Center, Davis, CA -Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC	

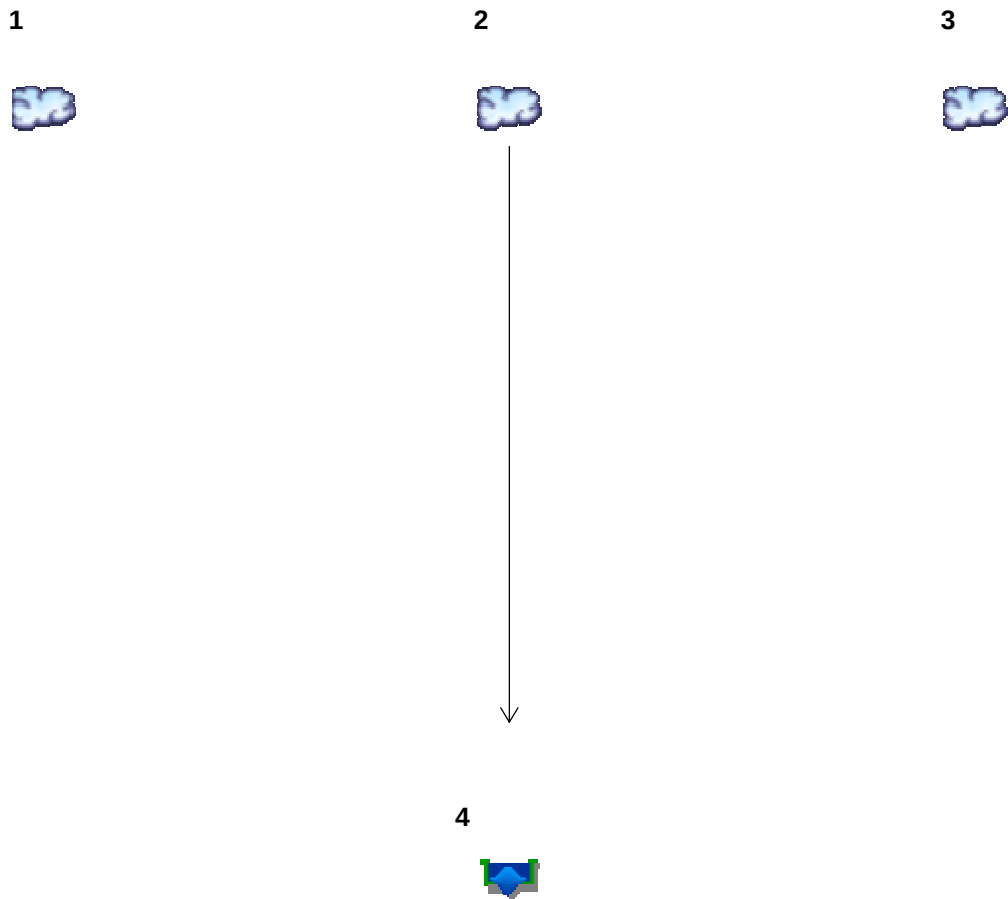
Table 2 – Manning's n Values for Open Channel Flow

Channel Type	Manning n		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹For the developed condition, a conservative Manning's n value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar, level spreader diversion, or grass channel. ²For the pre-developed condition and post-development condition, a Manning's n value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

Hyd.	Origin	Description
1	SCS Runoff	DA-PI-031F Pre
2	SCS Runoff	DA-PI-031F Post
3	SCS Runoff	DA-PI-031F Pre-Forested
4	Reservoir	WB Soil Amendment

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.527	1	718	1,802	-----	-----	-----	DA-PI-031F Pre
2	SCS Runoff	0.527	1	718	1,802	-----	-----	-----	DA-PI-031F Post
3	SCS Runoff	0.087	1	738	1,293	-----	-----	-----	DA-PI-031F Pre-Forested
4	Reservoir	0.440	1	720	1,717	2	835.58	104	WB Soil Amendment
DA-PI-031F.gpw					Return Period: 1 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

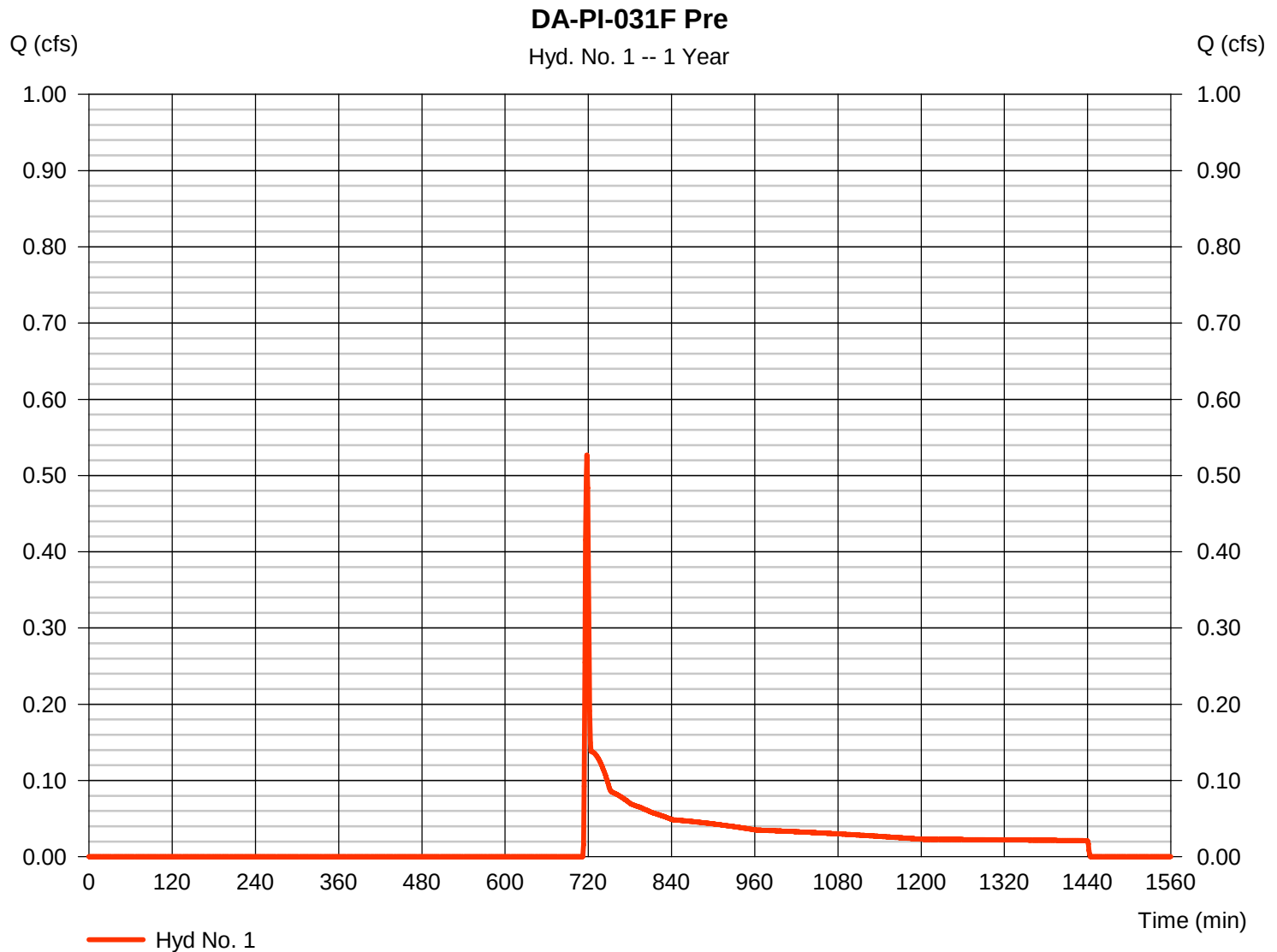
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-PI-031F Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.527 cfs
Storm frequency	= 1 yrs	Time to peak	= 718 min
Time interval	= 1 min	Hyd. volume	= 1,802 cuft
Drainage area	= 2.490 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 2.60 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.650 \times 55) + (1.730 \times 58) + (0.110 \times 85)] / 2.490$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-PI-031F Pre

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.011	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 3.31	0.00	0.00				
Travel Time (min)	= 0.95	+	0.00	+	0.00	=	0.95
Shallow Concentrated Flow							
Flow length (ft)	= 29.97	410.42	0.00				
Watercourse slope (%)	= 5.82	7.23	0.00				
Surface description	= Paved	Unpaved	Paved				
Average velocity (ft/s)	=4.90	4.34	0.00				
Travel Time (min)	= 0.10	+	1.58	+	0.00	=	1.68
Channel Flow							
X sectional flow area (sqft)	= 0.00	0.00	0.00				
Wetted perimeter (ft)	= 0.00	0.00	0.00				
Channel slope (%)	= 0.00	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	((0})0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc				2.60 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

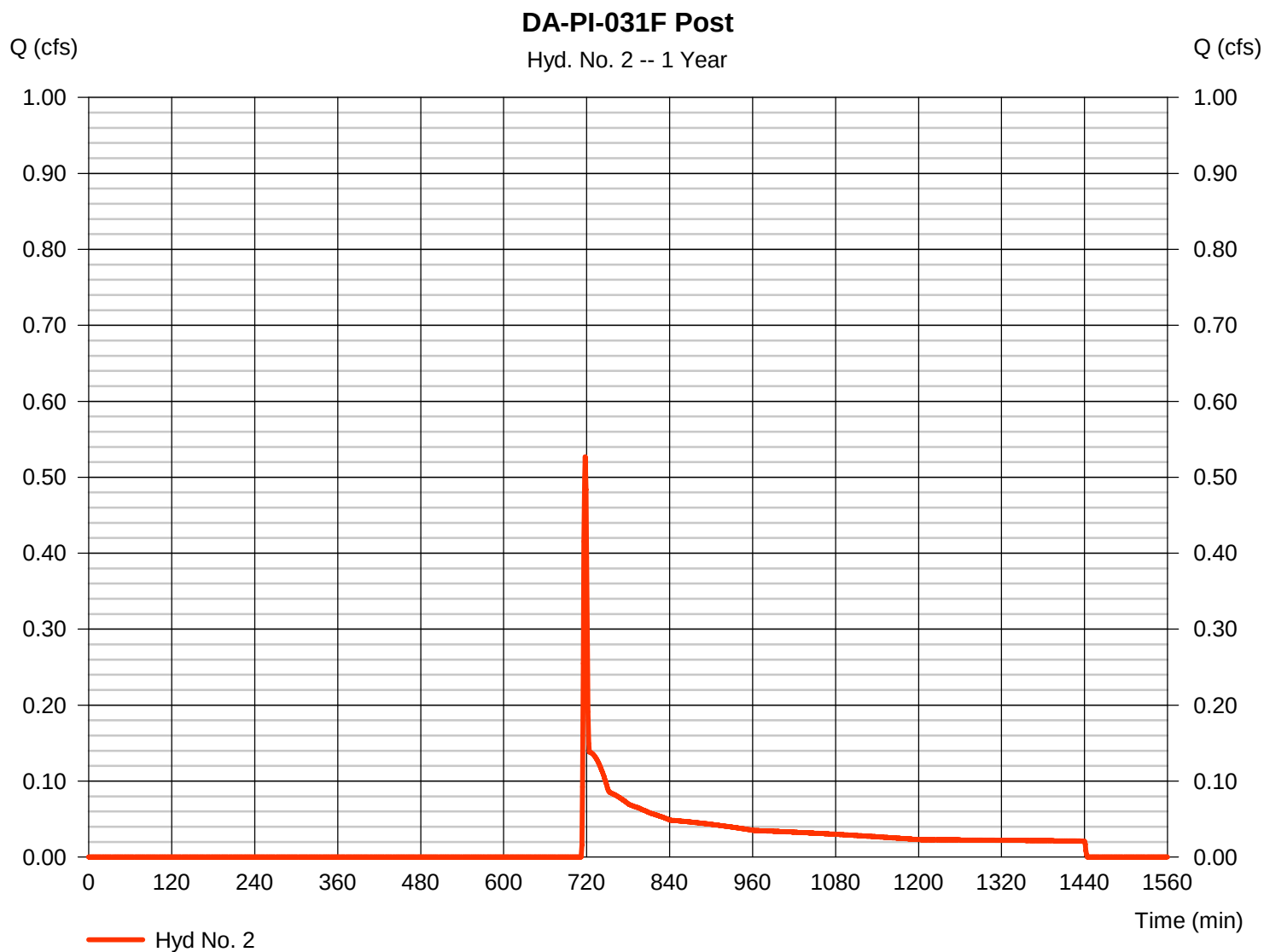
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-PI-031F Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.527 cfs
Storm frequency	= 1 yrs	Time to peak	= 718 min
Time interval	= 1 min	Hyd. volume	= 1,802 cuft
Drainage area	= 2.490 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 2.60 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.490 \times 55) + (1.760 \times 58) + (0.110 \times 85) + (0.130 \times 48)] / 2.490$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-PI-031F Post

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.011	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 3.31	0.00	0.00				
Travel Time (min)	= 0.95	+	0.00	+	0.00	=	0.95
Shallow Concentrated Flow							
Flow length (ft)	= 29.97	172.50	199.99				
Watercourse slope (%)	= 5.82	5.81	9.34				
Surface description	= Paved	Unpaved	Unpaved				
Average velocity (ft/s)	=4.90	3.89	4.93				
Travel Time (min)	= 0.10	+	0.74	+	0.68	=	1.52
Channel Flow							
X sectional flow area (sqft)	= 2.00	0.00	0.00				
Wetted perimeter (ft)	= 4.47	0.00	0.00				
Channel slope (%)	= 5.00	0.00	0.00				
Manning's n-value	= 0.040	0.015	0.015				
Velocity (ft/s)	=4.86	0.00	0.00				
Flow length (ft)	{0}33.0	0.0	0.0				
Travel Time (min)	= 0.11	+	0.00	+	0.00	=	0.11
Total Travel Time, Tc				2.60 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

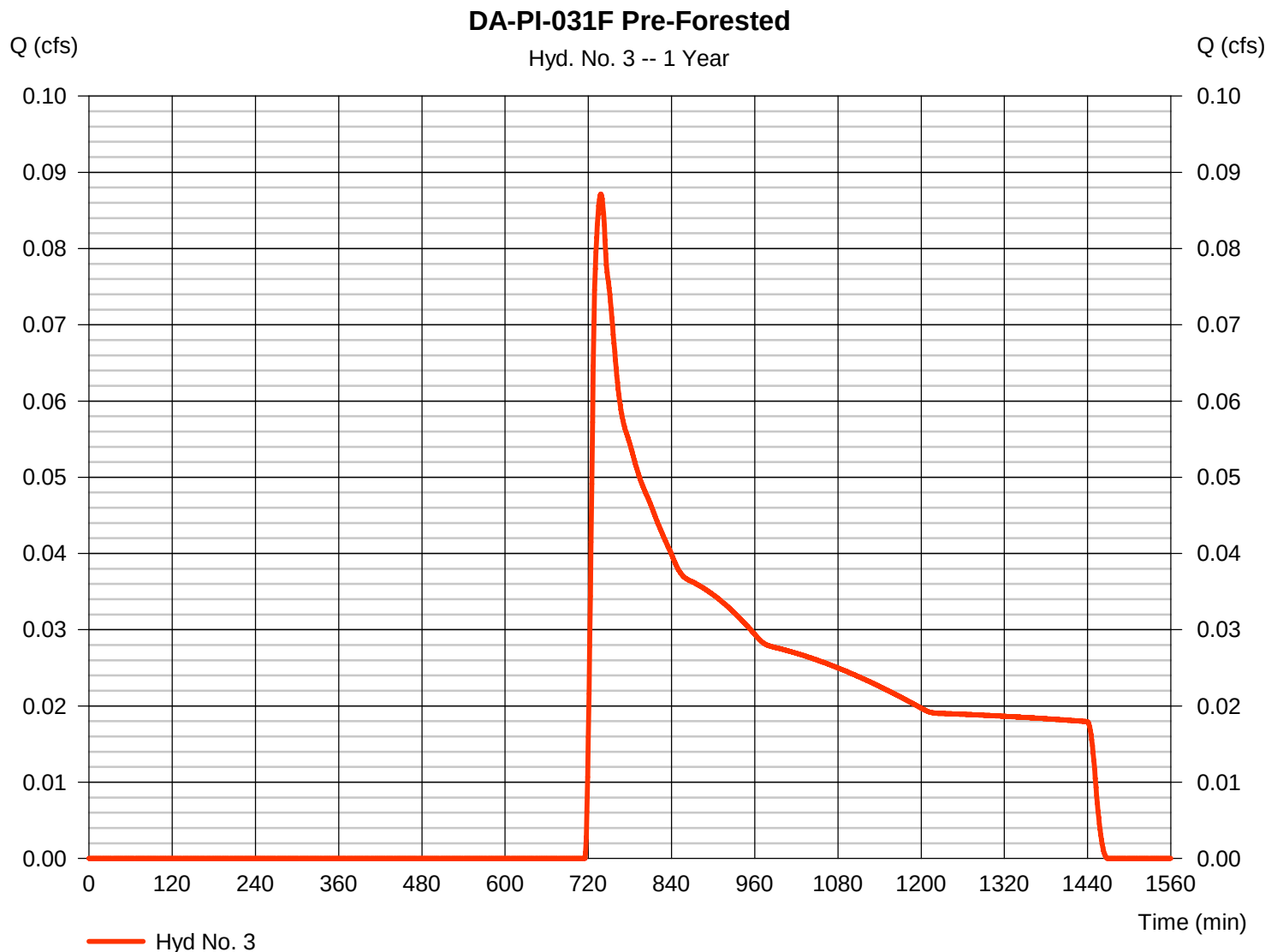
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-PI-031F Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 0.087 cfs
Storm frequency	= 1 yrs	Time to peak	= 738 min
Time interval	= 1 min	Hyd. volume	= 1,293 cuft
Drainage area	= 2.490 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.50 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(2.490 x 55)] / 2.490



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-PI-031F Pre-Forested

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 3.31	0.00	0.00				
Travel Time (min)	= 16.79	+	0.00	+	0.00	=	16.79
Shallow Concentrated Flow							
Flow length (ft)	= 29.97	410.42	0.00				
Watercourse slope (%)	= 5.82	7.23	0.00				
Surface description	= Unpaved	Unpaved	Paved				
Average velocity (ft/s)	=3.89	4.34	0.00				
Travel Time (min)	= 0.13	+	1.58	+	0.00	=	1.71
Channel Flow							
X sectional flow area (sqft)	= 0.00	0.00	0.00				
Wetted perimeter (ft)	= 0.00	0.00	0.00				
Channel slope (%)	= 0.00	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	((0})0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc				18.50 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

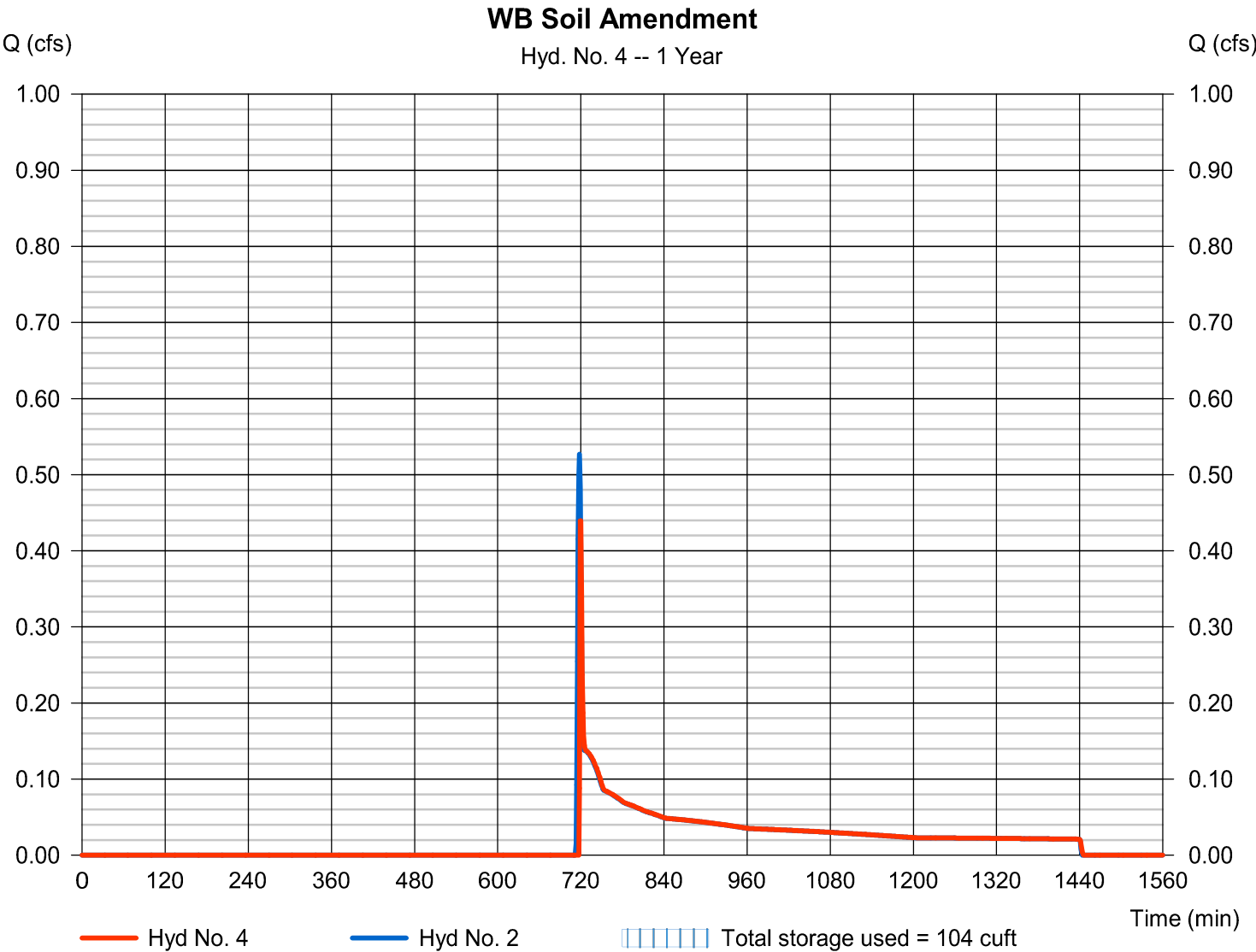
Monday, 08 / 21 / 2017

Hyd. No. 4

WB Soil Amendment

Hydrograph type	= Reservoir	Peak discharge	= 0.440 cfs
Storm frequency	= 1 yrs	Time to peak	= 720 min
Time interval	= 1 min	Hyd. volume	= 1,717 cuft
Inflow hyd. No.	= 2 - DA-PI-031F Post	Max. Elevation	= 835.58 ft
Reservoir name	= DA-PI-031F Waterbar	Max. Storage	= 104 cuft

Storage Indication method used.



Pond No. 1 - DA-PI-031F Waterbar

Pond Data

Pond storage is based on user-defined values.

Stage / Storage Table

Stage (ft)	Elevation (ft)	Contour area (sqft)	Incr. Storage (cuft)	Total storage (cuft)
0.00	834.00	n/a	0	0
0.50	834.50	n/a	8	8
1.00	835.00	n/a	8	17
1.50	835.50	n/a	68	85
2.00	836.00	n/a	128	213
2.50	836.50	n/a	200	413
3.00	837.00	n/a	284	697
3.50	837.50	n/a	380	1,077

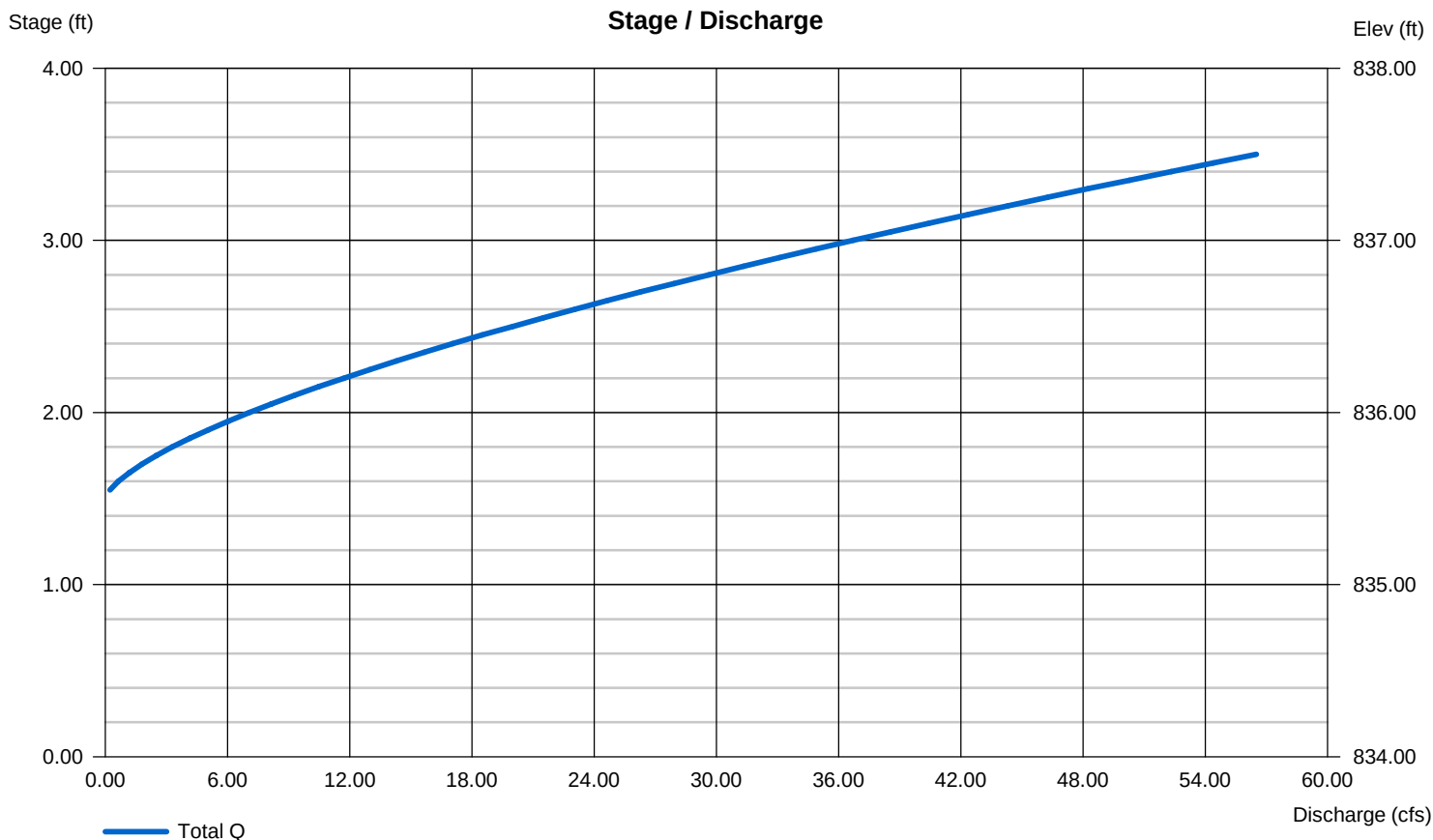
Culvert / Orifice Structures

	[A]	[B]	[C]	[PrfRsr]
Rise (in)	Inactive	0.00	0.00	0.00
Span (in)	= 0.00	0.00	0.00	0.00
No. Barrels	= 0	0	0	0
Invert El. (ft)	= 0.00	0.00	0.00	0.00
Length (ft)	= 0.00	0.00	0.00	0.00
Slope (%)	= 0.00	0.00	0.00	n/a
N-Value	= .013	.013	.013	n/a
Orifice Coeff.	= 0.60	0.60	0.60	0.60
Multi-Stage	= n/a	No	No	No

Weir Structures

	[A]	[B]	[C]	[D]
Crest Len (ft)	= 6.00	0.00	0.00	0.00
Crest El. (ft)	= 835.50	0.00	0.00	0.00
Weir Coeff.	= 3.33	3.33	3.33	3.33
Weir Type	= Rect	---	---	---
Multi-Stage	= No	No	No	No
Exfil.(in/hr)	= 0.000 (by Wet area)			
TW Elev. (ft)	= 0.00			

Note: Culvert/Orifice outflows are analyzed under inlet (ic) and outlet (oc) control. Weir risers checked for orifice conditions (ic) and submergence (s).



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	1.763	1	716	3,838	-----	-----	-----	DA-PI-031F Pre
2	SCS Runoff	1.763	1	716	3,838	-----	-----	-----	DA-PI-031F Post
3	SCS Runoff	0.522	1	728	3,090	-----	-----	-----	DA-PI-031F Pre-Forested
4	Reservoir	1.743	1	717	3,754	2	835.70	135	WB Soil Amendment
DA-PI-031F.gpw					Return Period: 2 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

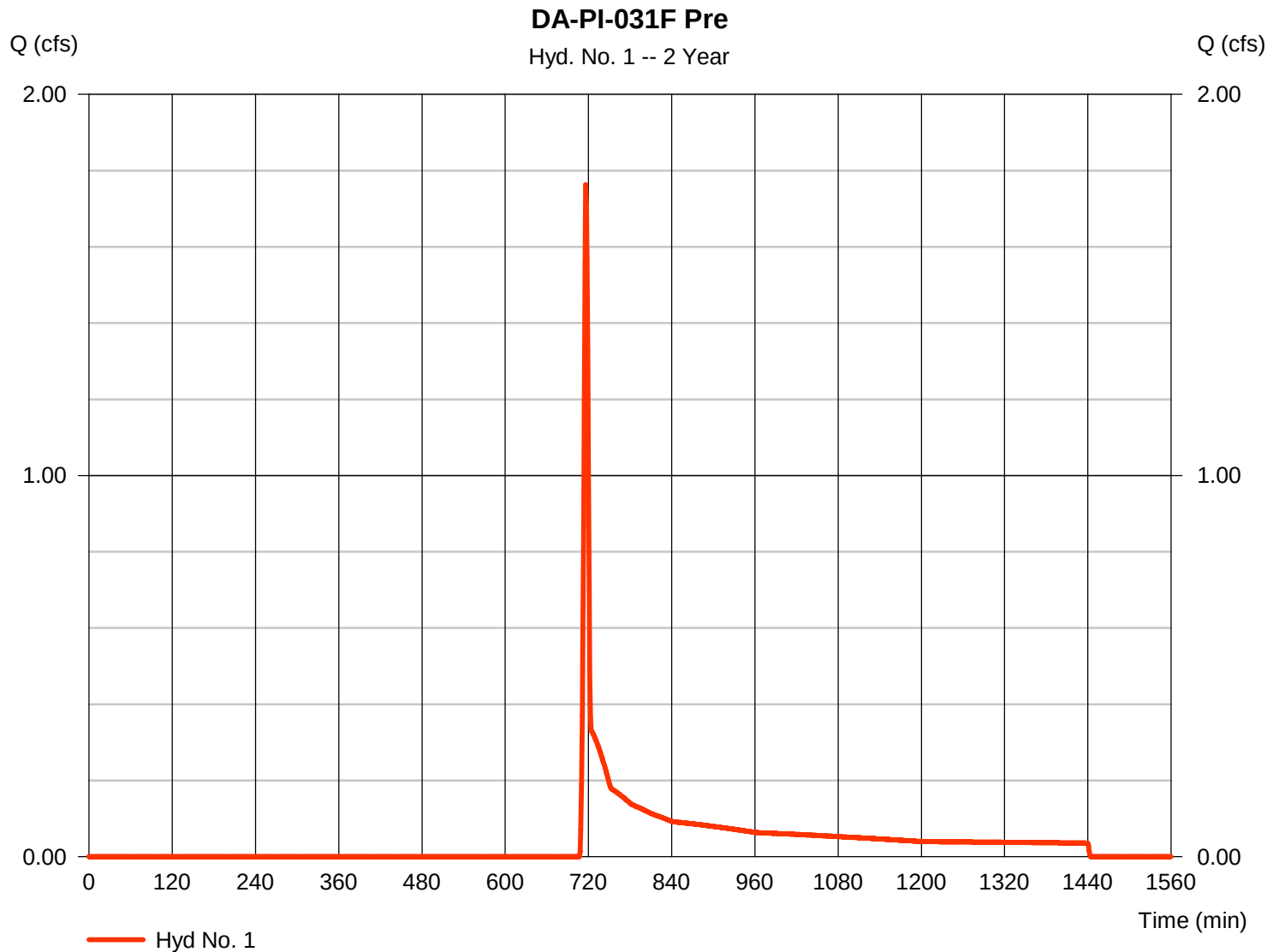
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-PI-031F Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 1.763 cfs
Storm frequency	= 2 yrs	Time to peak	= 716 min
Time interval	= 1 min	Hyd. volume	= 3,838 cuft
Drainage area	= 2.490 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 2.60 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.650 \times 55) + (1.730 \times 58) + (0.110 \times 85)] / 2.490$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

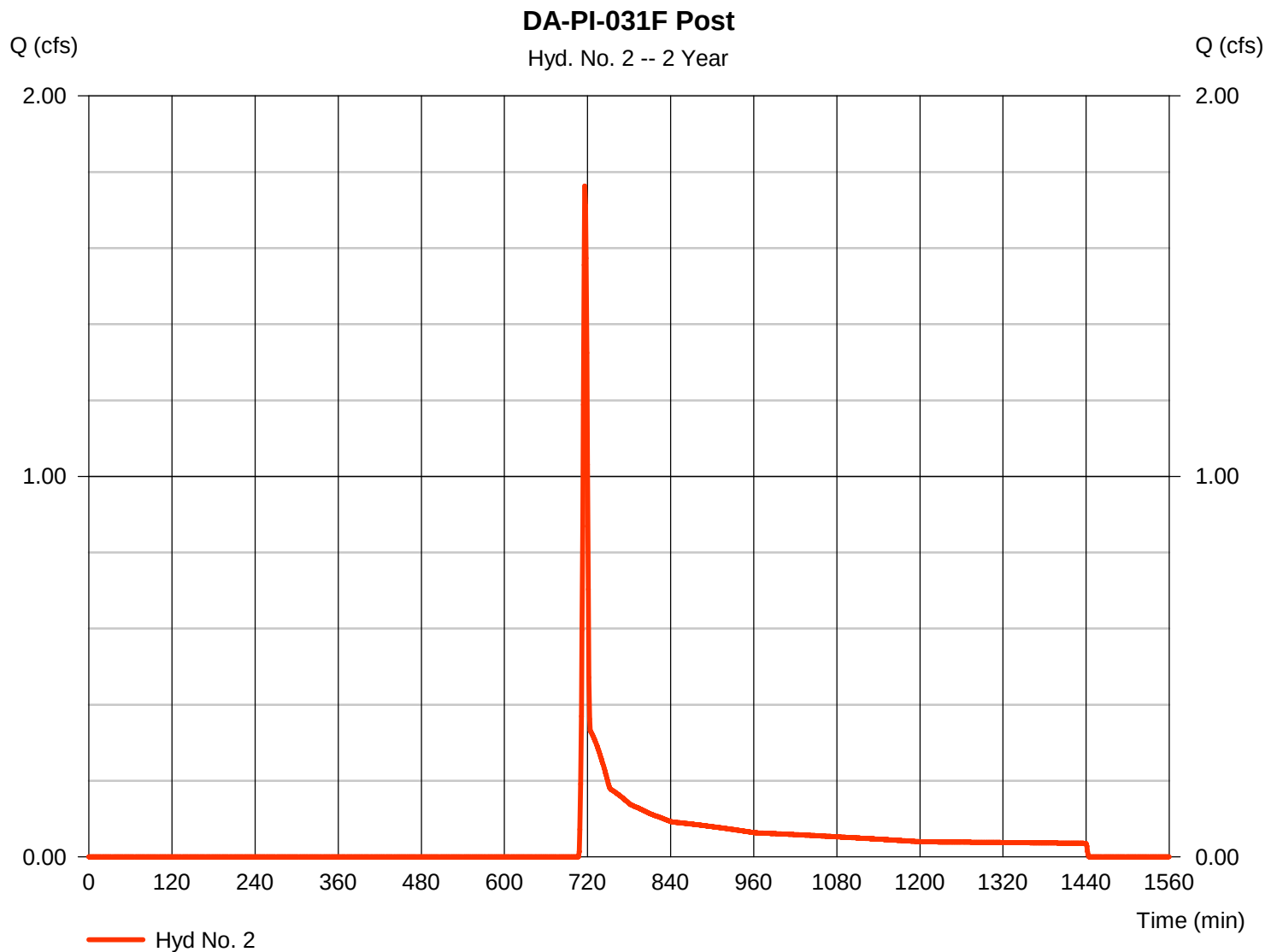
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-PI-031F Post

Hydrograph type	= SCS Runoff	Peak discharge	= 1.763 cfs
Storm frequency	= 2 yrs	Time to peak	= 716 min
Time interval	= 1 min	Hyd. volume	= 3,838 cuft
Drainage area	= 2.490 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 2.60 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.490 \times 55) + (1.760 \times 58) + (0.110 \times 85) + (0.130 \times 48)] / 2.490$



Hydrograph Report

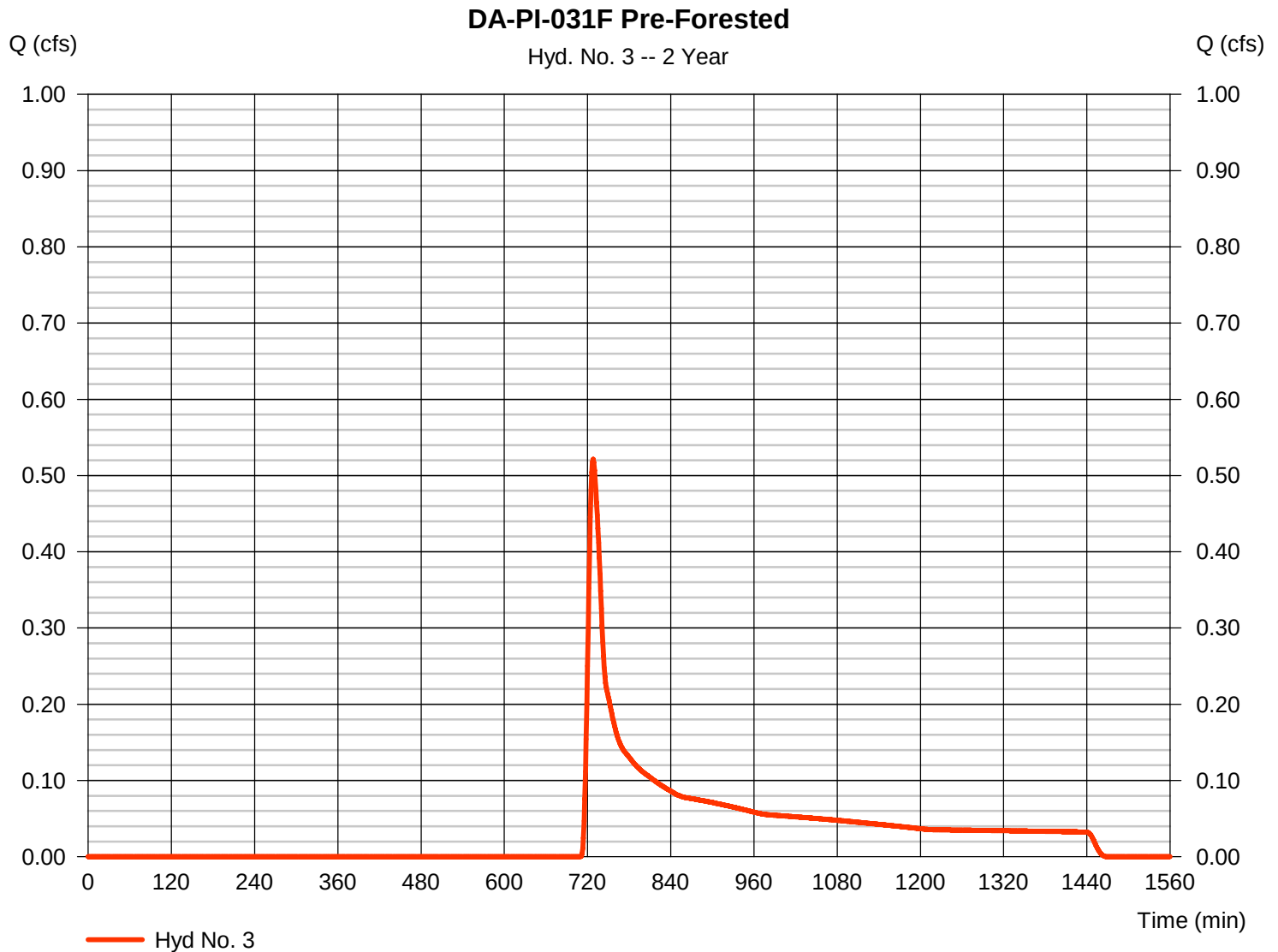
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Monday, 08 / 21 / 2017

Hyd. No. 3

DA-PI-031F Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.522 cfs
Storm frequency	=	2 yrs	Time to peak	=	728 min
Time interval	=	1 min	Hyd. volume	=	3,090 cuft
Drainage area	=	2.490 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	18.50 min
Total precip.	=	3.50 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(2.490 \times 55)] / 2.490$ 

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

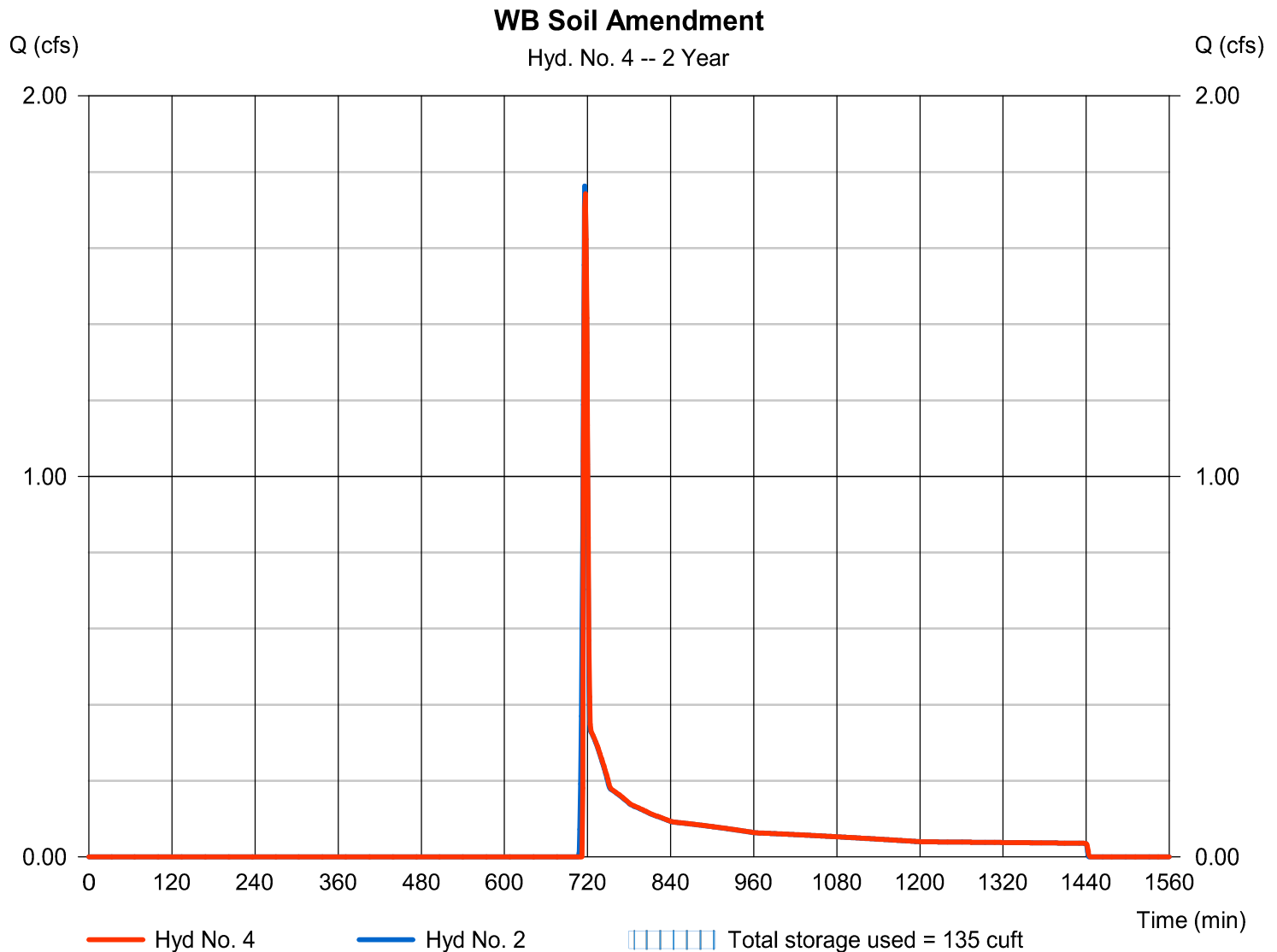
Monday, 08 / 21 / 2017

Hyd. No. 4

WB Soil Amendment

Hydrograph type	= Reservoir	Peak discharge	= 1.743 cfs
Storm frequency	= 2 yrs	Time to peak	= 717 min
Time interval	= 1 min	Hyd. volume	= 3,754 cuft
Inflow hyd. No.	= 2 - DA-PI-031F Post	Max. Elevation	= 835.70 ft
Reservoir name	= DA-PI-031F Waterbar	Max. Storage	= 135 cuft

Storage Indication method used.



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	6.103	1	716	10,850	-----	-----	-----	DA-PI-031F Pre
2	SCS Runoff	6.103	1	716	10,850	-----	-----	-----	DA-PI-031F Post
3	SCS Runoff	2.745	1	726	9,662	-----	-----	-----	DA-PI-031F Pre-Forested
4	Reservoir	6.099	1	716	10,765	2	835.95	201	WB Soil Amendment
DA-PI-031F.gpw					Return Period: 10 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

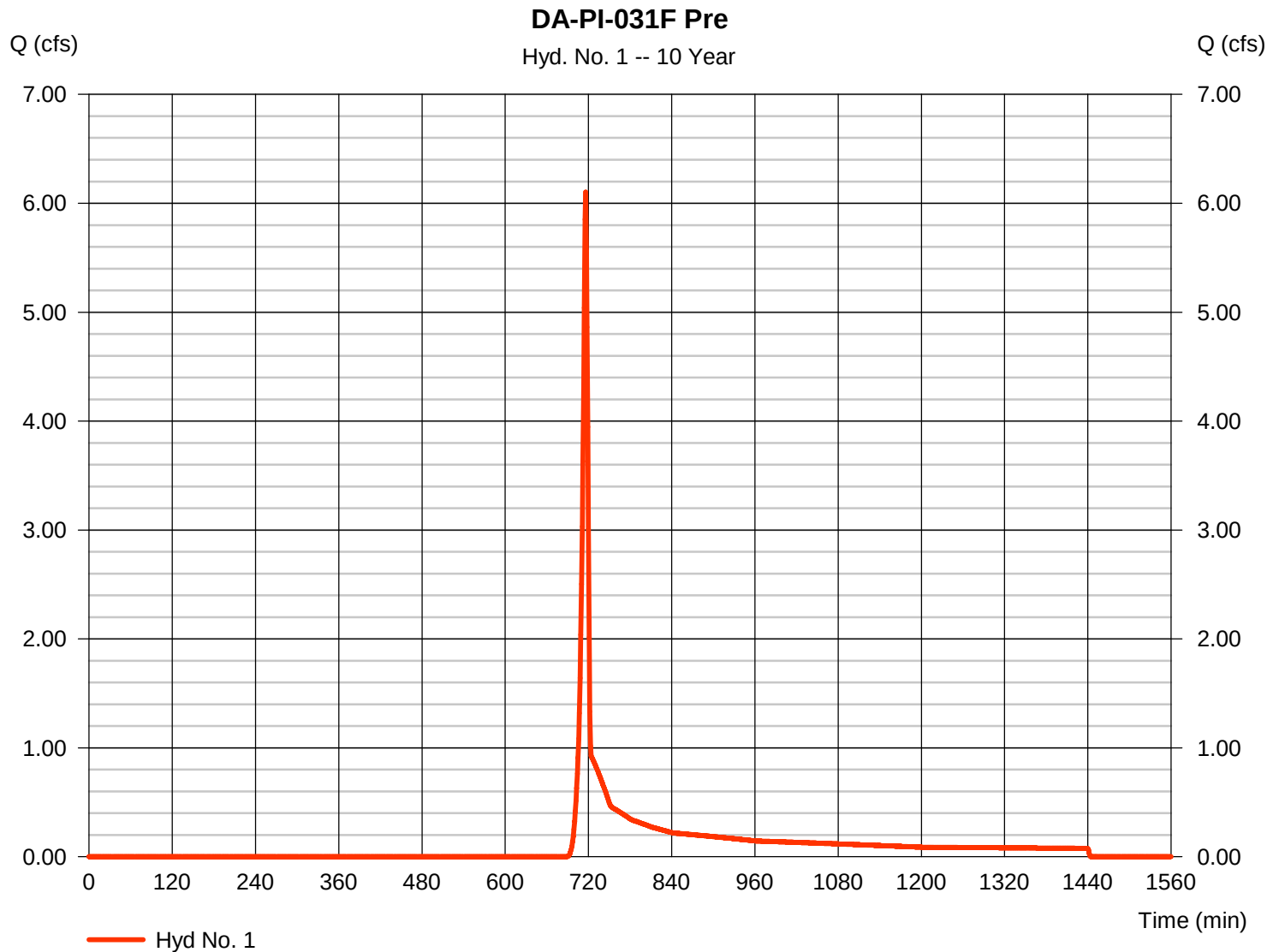
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-PI-031F Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 6.103 cfs
Storm frequency	= 10 yrs	Time to peak	= 716 min
Time interval	= 1 min	Hyd. volume	= 10,850 cuft
Drainage area	= 2.490 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 2.60 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.650 \times 55) + (1.730 \times 58) + (0.110 \times 85)] / 2.490$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

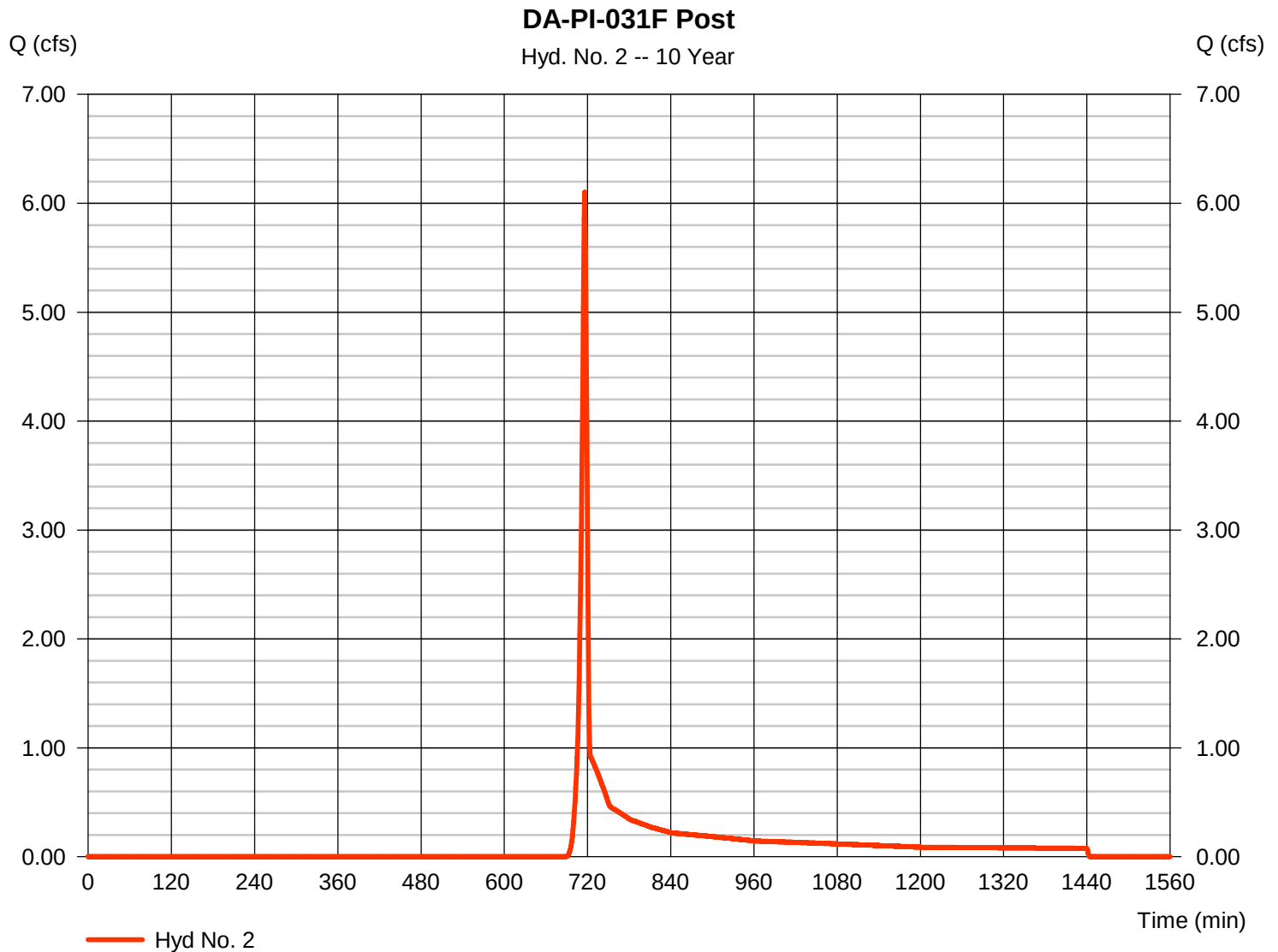
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-PI-031F Post

Hydrograph type	= SCS Runoff	Peak discharge	= 6.103 cfs
Storm frequency	= 10 yrs	Time to peak	= 716 min
Time interval	= 1 min	Hyd. volume	= 10,850 cuft
Drainage area	= 2.490 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 2.60 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.490 \times 55) + (1.760 \times 58) + (0.110 \times 85) + (0.130 \times 48)] / 2.490$



Hydrograph Report

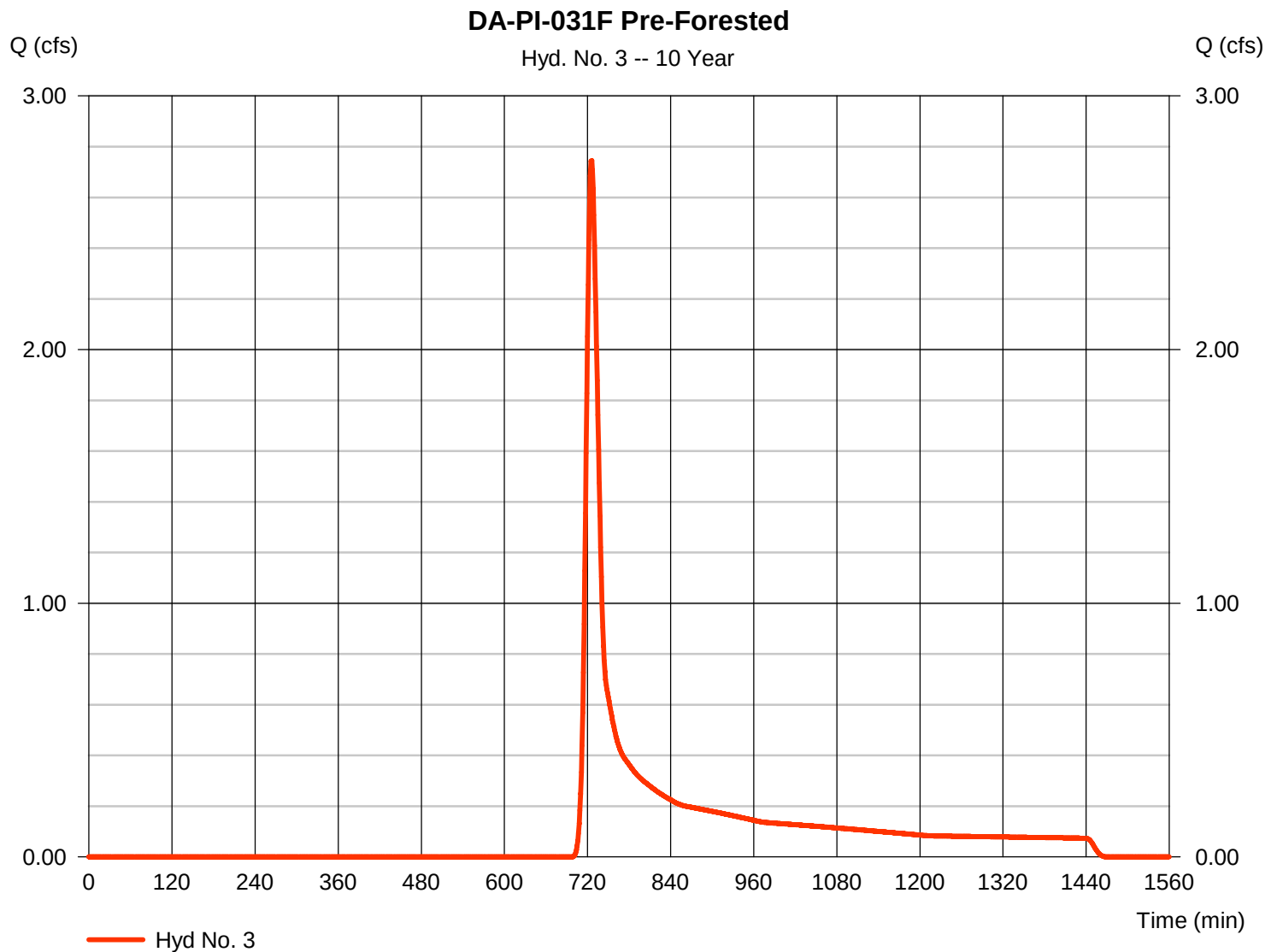
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

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Hyd. No. 3

DA-PI-031F Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	2.745 cfs
Storm frequency	=	10 yrs	Time to peak	=	726 min
Time interval	=	1 min	Hyd. volume	=	9,662 cuft
Drainage area	=	2.490 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	18.50 min
Total precip.	=	5.20 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(2.490 \times 55)] / 2.490$ 

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

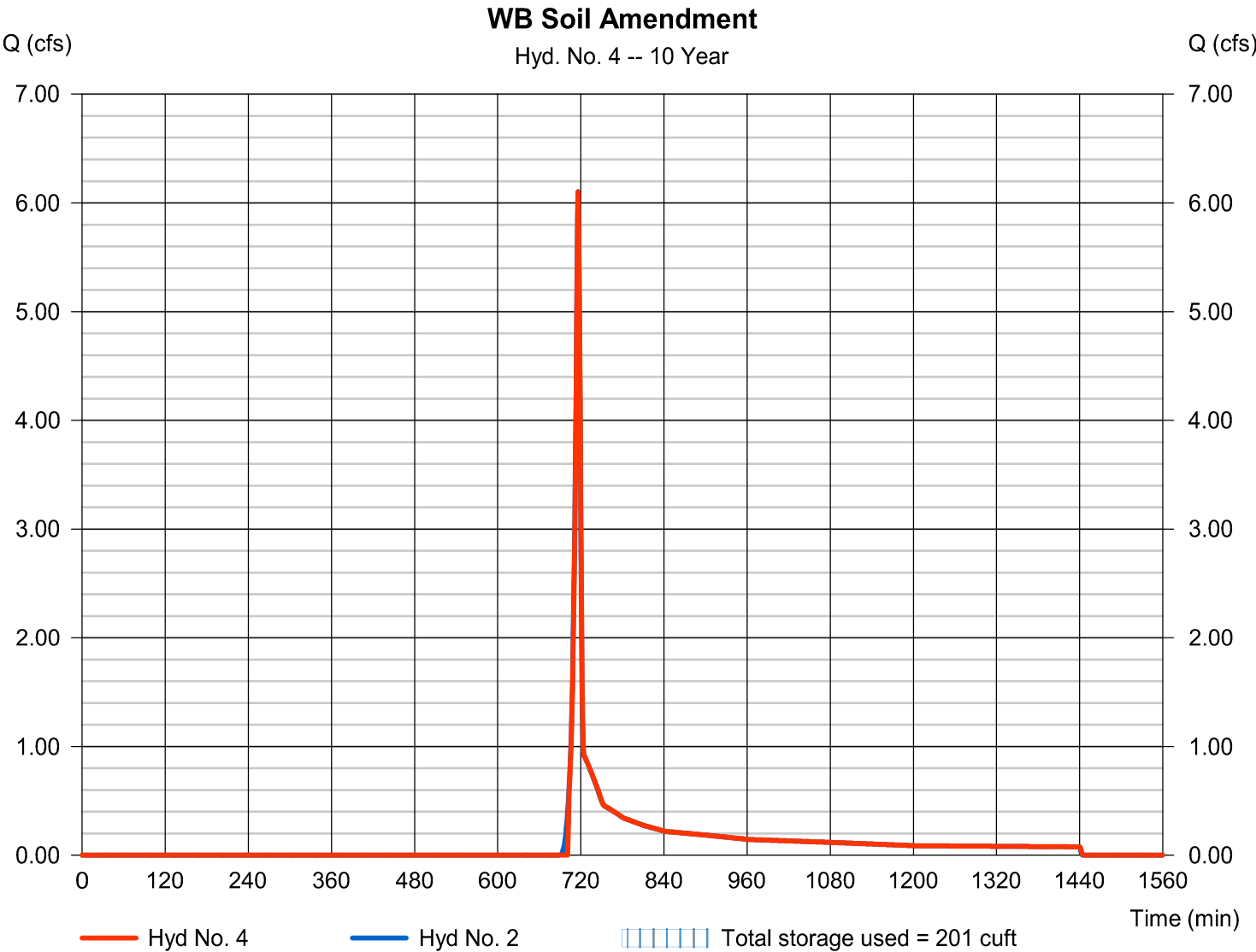
Monday, 08 / 21 / 2017

Hyd. No. 4

WB Soil Amendment

Hydrograph type	= Reservoir	Peak discharge	= 6.099 cfs
Storm frequency	= 10 yrs	Time to peak	= 716 min
Time interval	= 1 min	Hyd. volume	= 10,765 cuft
Inflow hyd. No.	= 2 - DA-PI-031F Post	Max. Elevation	= 835.95 ft
Reservoir name	= DA-PI-031F Waterbar	Max. Storage	= 201 cuft

Storage Indication method used.



DA-PI-032

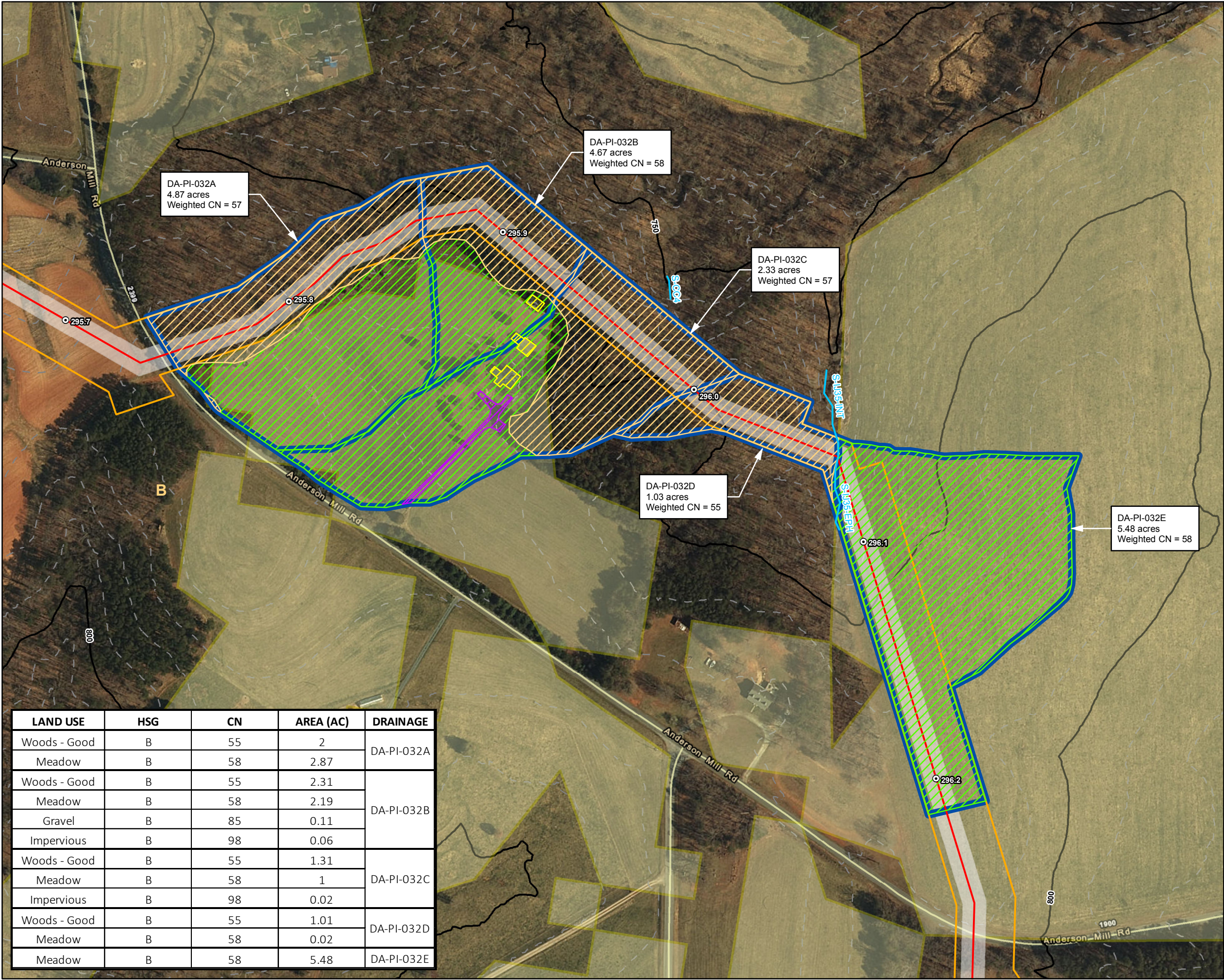
DA-PI-032 is located in a primarily meadow area with generally low slopes that steepen towards a local unnamed tributary. DA-PI-032 contains existing gravel area and impervious area that cover 1% of the overall drainage area. No new impervious areas are proposed within DA-PI-032. The total phosphorus load reduction required for DA-PI-032 is -0.96 lbs/yr. Multiple points of analysis were evaluated within DA-PI-032 to determine the effects on each receiving stream/channel following construction. Specifically DA-PI-032 was sub-divided into five sub-drainage areas (sub-areas A through E).

Stormwater quantity is met via the energy balance method for each of the sub areas - DA-PI-032A, DA-PI-032B, DA-PI-032C, and DA-PI-032D – except DA-PI-032E. Sub-area DA-PI-032E is entirely agricultural area and will be returned to crop production. Agricultural areas/fields that will be returned to crop production, in identical condition, upon completion of pipeline construction are exempt from meeting the VA water quality (9VAC25-870-63) and the VA water quantity (9VAC25-870-66) requirements per § 62.1-44.15:34 and 9VAC25-870-300. Therefore, sub-area DA-PI-032E is exempt and no stormwater BMPs are required.

The Hydraflow hydrographs 10-year 24-hour peak discharge results indicate a decrease in flow ranging from 0.00 cfs to 0.48 cfs in the remaining drainage sub-areas (as seen in table below).

Sub-area	Pre-peak Flow, 10-yr Q (cfs)	Post-peak Flow, 10-yr Q (cfs)	Flow Differential
DA-PI-032A	5.38	4.97	-0.41
DA-PI-032B	6.94	6.46	-0.48
DA-PI-032C	3.01	2.57	-0.44
DA-PI-032D	1.29	1.08	-0.21

Figures and calculations for DA-PI-032 follow. See Appendix D of the Annual Standards and Specifications for further detail on stormwater methodology.



Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Gravel
- Impervious
- Meadow
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

1:2,400

200

100

0

200

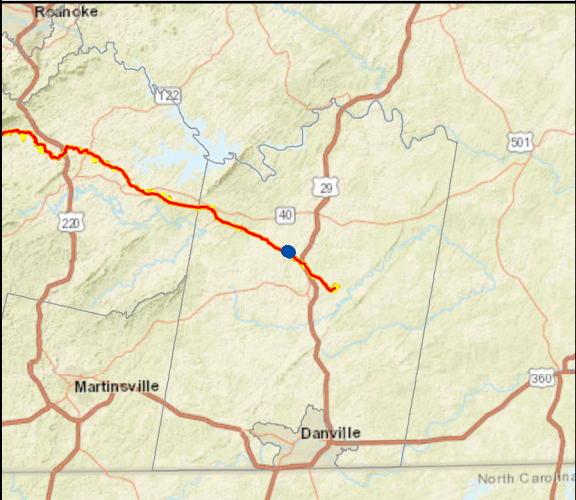
Feet

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W

E

S



LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Woods - Good	B	55	2	DA-PI-032A
Meadow	B	58	2.87	
Woods - Good	B	55	2.31	DA-PI-032B
Meadow	B	58	2.19	
Gravel	B	85	0.11	
Impervious	B	98	0.06	DA-PI-032C
Woods - Good	B	55	1.31	
Meadow	B	58	1	
Impervious	B	98	0.02	DA-PI-032D
Woods - Good	B	55	1.01	
Meadow	B	58	0.02	DA-PI-032E
Meadow	B	58	5.48	

Mountain Valley

PIPELINE

Pre-Construction Drainage Area Map

DA-PI-032

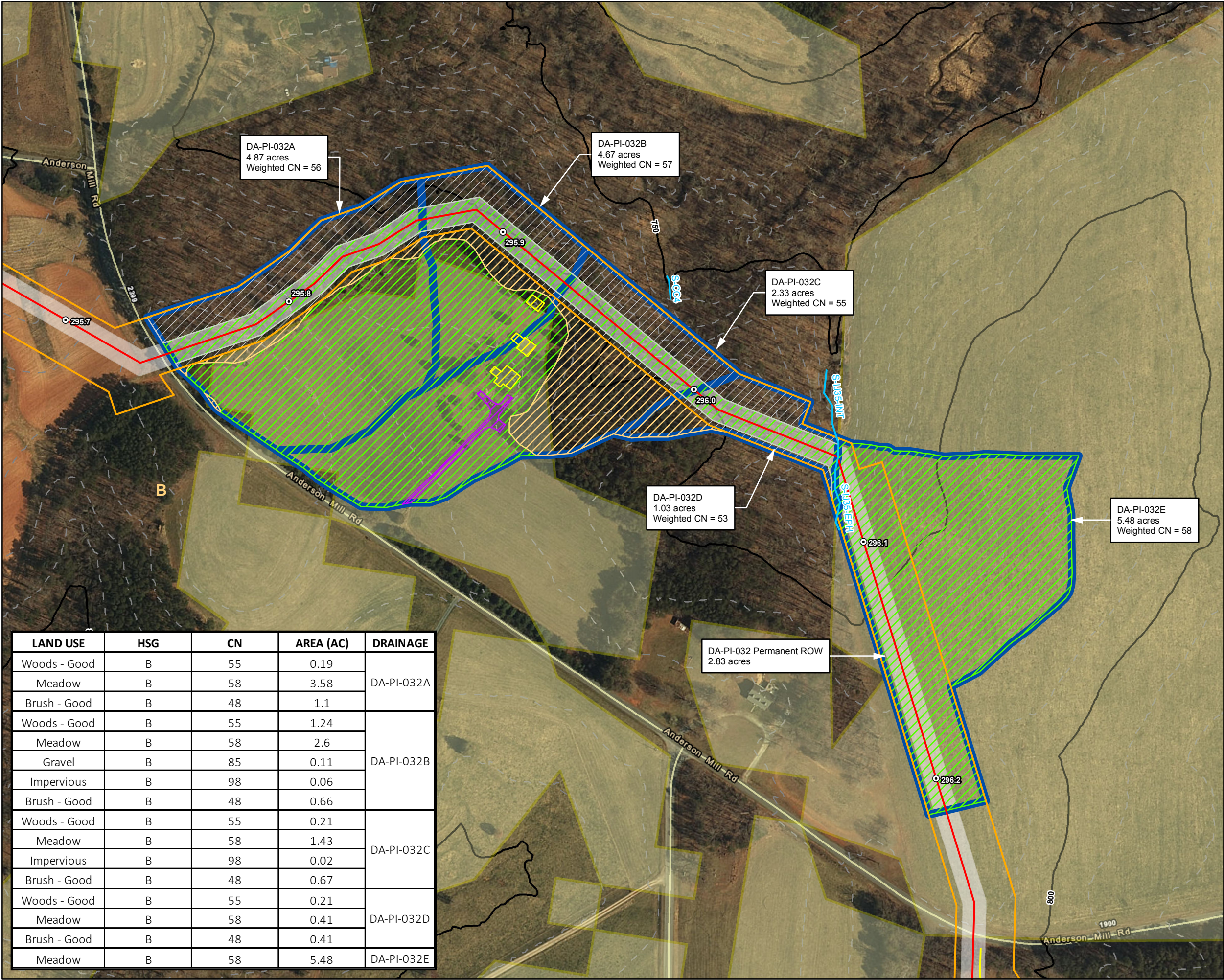
Spread 11

Figure 1

Pittsylvania County, Virginia

August, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LIDAR provided by EQT 2016, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015, Agricultural Area from National Land Cover Dataset 2011.

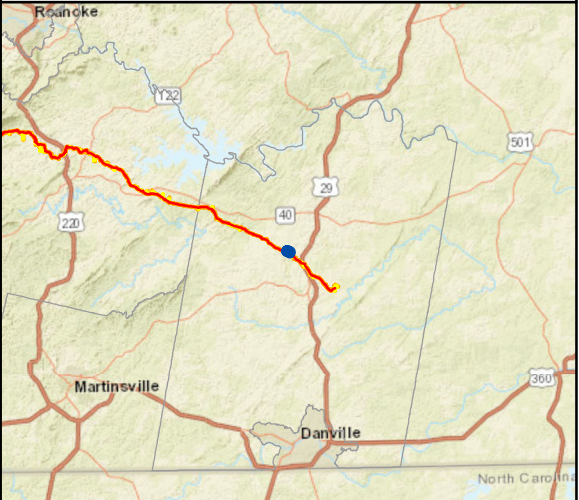
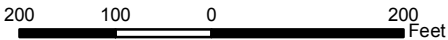


Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Brush
- Gravel
- Impervious
- Meadow
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

1:2,400



LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Woods - Good	B	55	0.19	DA-PI-032A
Meadow	B	58	3.58	
Brush - Good	B	48	1.1	
Woods - Good	B	55	1.24	DA-PI-032B
Meadow	B	58	2.6	
Gravel	B	85	0.11	
Impervious	B	98	0.06	
Brush - Good	B	48	0.66	DA-PI-032C
Woods - Good	B	55	0.21	
Meadow	B	58	1.43	
Impervious	B	98	0.02	
Brush - Good	B	48	0.67	DA-PI-032D
Woods - Good	B	55	0.21	
Meadow	B	58	0.41	
Brush - Good	B	48	0.41	DA-PI-032E
Meadow	B	58	5.48	

DA-PI-032 Permanent ROW
2.83 acres

DA-PI-032A
4.87 acres
Weighted CN = 56

DA-PI-032B
4.67 acres
Weighted CN = 57

DA-PI-032C
2.33 acres
Weighted CN = 55

DA-PI-032D
1.03 acres
Weighted CN = 53

DA-PI-032E
5.48 acres
Weighted CN = 58

Mountain Valley Pipeline Project

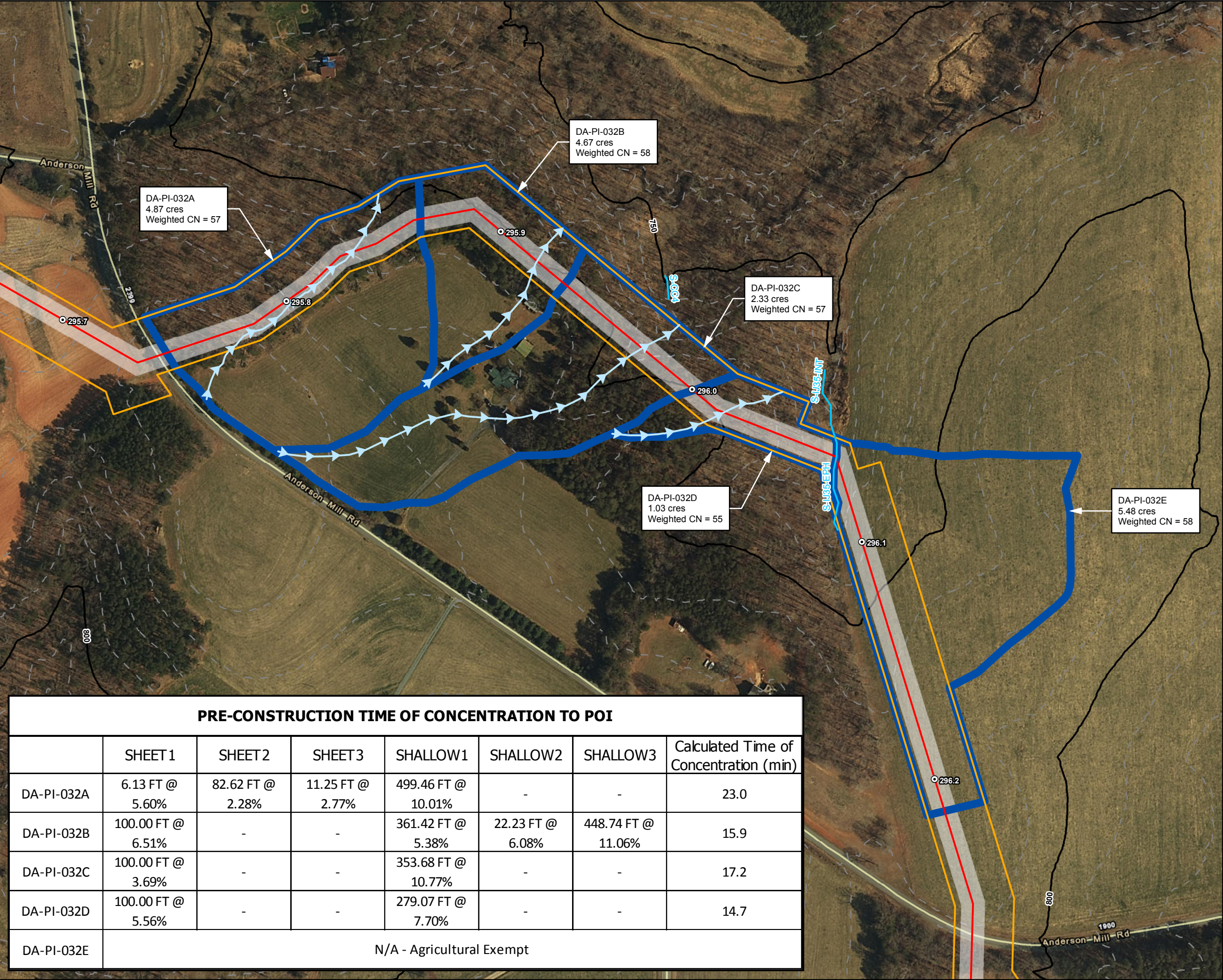


Post-Construction Drainage Area Map
DA-PI-032
Spread 11

Figure 2
Pittsylvania County, Virginia

August, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LIDAR provided by EQT 2016, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015, Agricultural Area from National Land Cover Dataset 2011.



Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:2,400

200

100

0

200

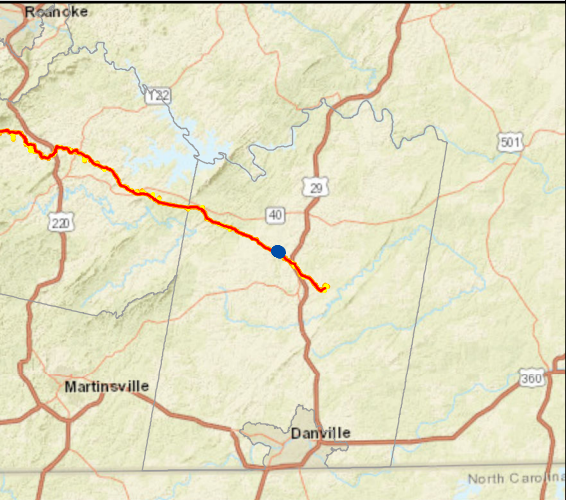
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PRE-CONSTRUCTION TIME OF CONCENTRATION TO POI							
	SHEET 1	SHEET 2	SHEET 3	SHALLOW1	SHALLOW2	SHALLOW3	Calculated Time of Concentration (min)
DA-PI-032A	6.13 FT @ 5.60%	82.62 FT @ 2.28%	11.25 FT @ 2.77%	499.46 FT @ 10.01%	-	-	23.0
DA-PI-032B	100.00 FT @ 6.51%	-	-	361.42 FT @ 5.38%	22.23 FT @ 6.08%	448.74 FT @ 11.06%	15.9
DA-PI-032C	100.00 FT @ 3.69%	-	-	353.68 FT @ 10.77%	-	-	17.2
DA-PI-032D	100.00 FT @ 5.56%	-	-	279.07 FT @ 7.70%	-	-	14.7
DA-PI-032E	N/A - Agricultural Exempt						

Mountain Valley Pipeline

Pre-Construction Drainage Area and Time of Concentration

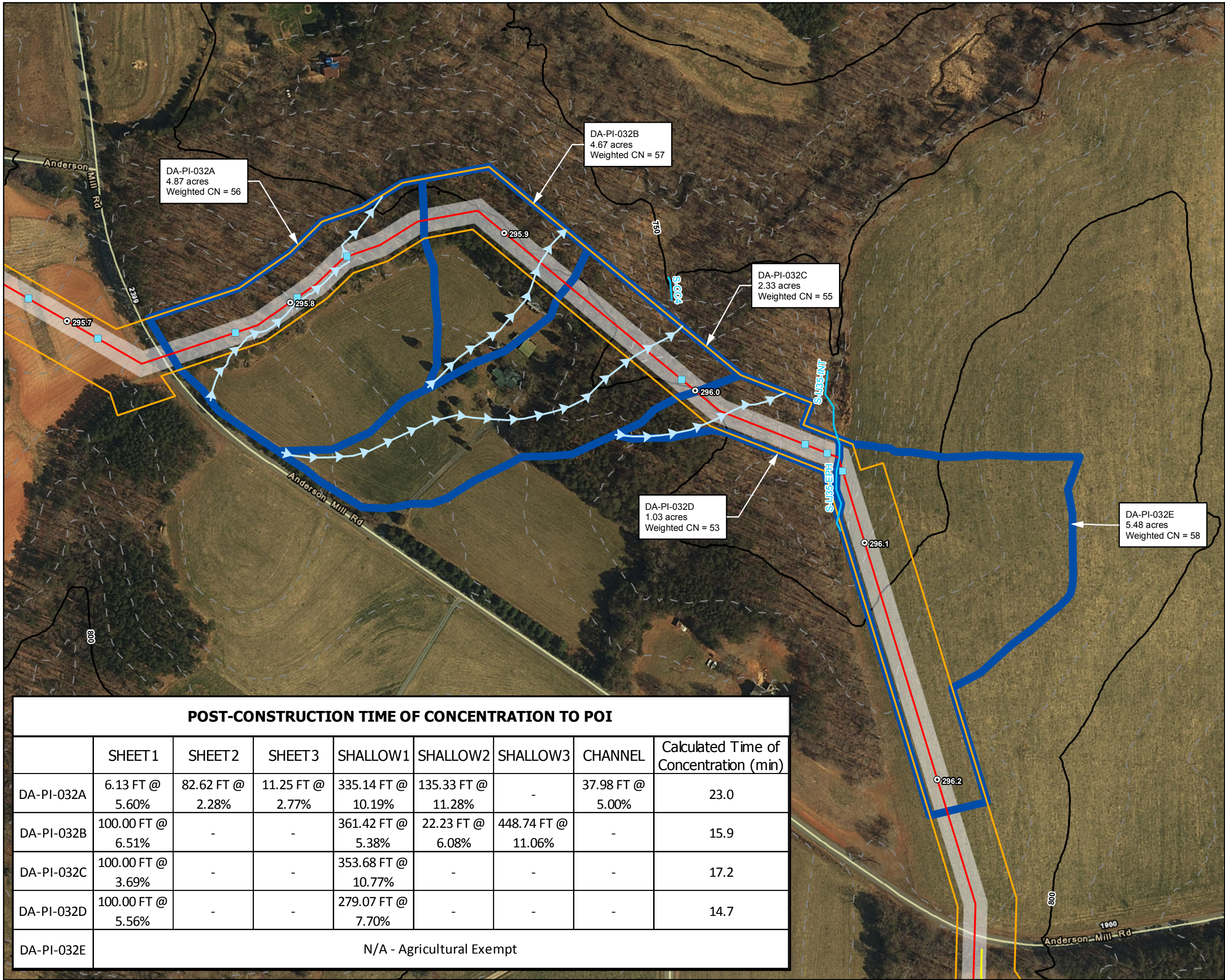
DA-PI-032 Spread 11

Figure 3

Pittsylvania County, Virginia

August, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016.



Legend

- Milepost
- Permanent Waterbars
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:2,400

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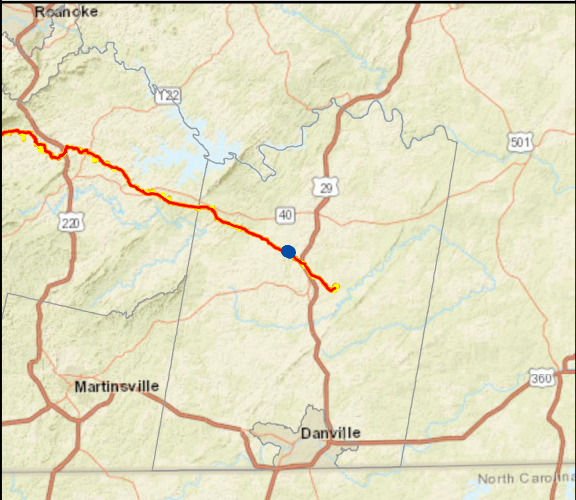
Feet

N

W

E

S



POST-CONSTRUCTION TIME OF CONCENTRATION TO POI								
	SHEET 1	SHEET 2	SHEET 3	SHALLOW1	SHALLOW2	SHALLOW3	CHANNEL	Calculated Time of Concentration (min)
DA-PI-032A	6.13 FT @ 5.60%	82.62 FT @ 2.28%	11.25 FT @ 2.77%	335.14 FT @ 10.19%	135.33 FT @ 11.28%	-	37.98 FT @ 5.00%	23.0
DA-PI-032B	100.00 FT @ 6.51%	-	-	361.42 FT @ 5.38%	22.23 FT @ 6.08%	448.74 FT @ 11.06%	-	15.9
DA-PI-032C	100.00 FT @ 3.69%	-	-	353.68 FT @ 10.77%	-	-	-	17.2
DA-PI-032D	100.00 FT @ 5.56%	-	-	279.07 FT @ 7.70%	-	-	-	14.7
DA-PI-032E	N/A - Agricultural Exempt							

Mountain Valley Pipeline

Post-Construction Drainage Area and Time of Concentration

DA-PI-032 Spread 11

Figure 4

Pittsylvania County, Virginia

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016.

Document Path: P:\GIS\EQT_MVP\MapDocs\Drainage\MVP_PCSM_DA-PI-032_Post_ToC_HH.mxd

Virginia Runoff Reduction Method New Development Worksheet - v2.8 - June 2014

Site Data Summary

Total Rainfall = 45 inches

Site Land Cover Summary

	A Soils	B Soils	C Soils	D Soils	Total	% of Total
Forest (acres)	0.00	2.83	0.00	0.00	2.83	100.00
Turf (acres)	0.00	0.00	0.00	0.00	0.00	0.00
Impervious (acres)	0.00	0.00	0.00	0.00	0.00	0.00
					2.83	100.00

Site Rv	0.03
Post Development Treatment Volume (ft3)	308
Post Development TP Load (lb/yr)	0.20
Post Development TN Load (lb/yr)	1.45
Total TP Load Reduction Required (lb/yr)	-0.96

Total Runoff Volume Reduction (ft ³)	0
Total TP Load Reduction Achieved (lb/yr)	0
Total TN Load Reduction Achieved (lb/yr)	0.00
Adjusted Post Development TP Load (lb/yr)	0.20
Remaining Phosphorous Load Reduction (Lb/yr) Required	0.00

Drainage Area Summary

	D.A. A	D.A. B	D.A. C	D.A. D	D.A. E	Total
Forest (acres)	2.83	0.00	0.00	0.00	0.00	2.83
Turf (acres)	0.00	0.00	0.00	0.00	0.00	0.00
Impervious (acres)	0.00	0.00	0.00	0.00	0.00	0.00
						2.83

Drainage Area Compliance Summary

	D.A. A	D.A. B	D.A. C	D.A. D	D.A. E	Total
TP Load Red. (lb/yr)	0.00	0.00	0.00	0.00	0.00	0.00
TN Load Red. (lb/yr)	0.00	0.00	0.00	0.00	0.00	0.00

DA-PI-032A

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.299	3,306
Developed Condition	0.223	2,910
Pre-Developed (Forest) Condition	0.163	2,536

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1:

$$Q_{\text{developed}} \leq IF \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}] \text{ ----->}$$

Q (cfs)

0.223

≤
OK

Q (cfs)

0.272

Check #2:

$$Q_{\text{developed}} \leq Q_{\text{pre-developed}} \text{ ----->}$$

0.223

≤
OK

0.299

Check #3:

$$Q_{\text{developed}} \text{ shall not be required to be } \leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}} \text{ --->}$$

0.223

shall not be required to be ≤

0.142

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning's n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<i>Note:</i> Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted. ¹For Paved Road land surface types a Manning's n of 0.011 was used <i>Sources:</i> -USACE, 1998, HEC-1 Flood Hydrograph Package User's Manual, Hydrologic Engineering Center, Davis, CA -Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC	

Table 2 – Manning's n Values for Open Channel Flow

Channel Type	Manning n		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹ For the developed condition, a conservative Manning's n value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar, level spreader diversion, or grass channel. ² For the pre-developed condition and post-development condition, a Manning's n value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

1



2



3



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-PI-032A Pre
2	SCS Runoff	DA-PI-032A Post
3	SCS Runoff	DA-PI-032A Pre-Forested

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.299	1	737	3,306	-----	-----	-----	DA-PI-032A Pre
2	SCS Runoff	0.223	1	741	2,910	-----	-----	-----	DA-PI-032A Post
3	SCS Runoff	0.163	1	745	2,536	-----	-----	-----	DA-PI-032A Pre-Forested
DA-PI-032A.gpw					Return Period: 1 Year			Thursday, 09 / 7 / 2017	

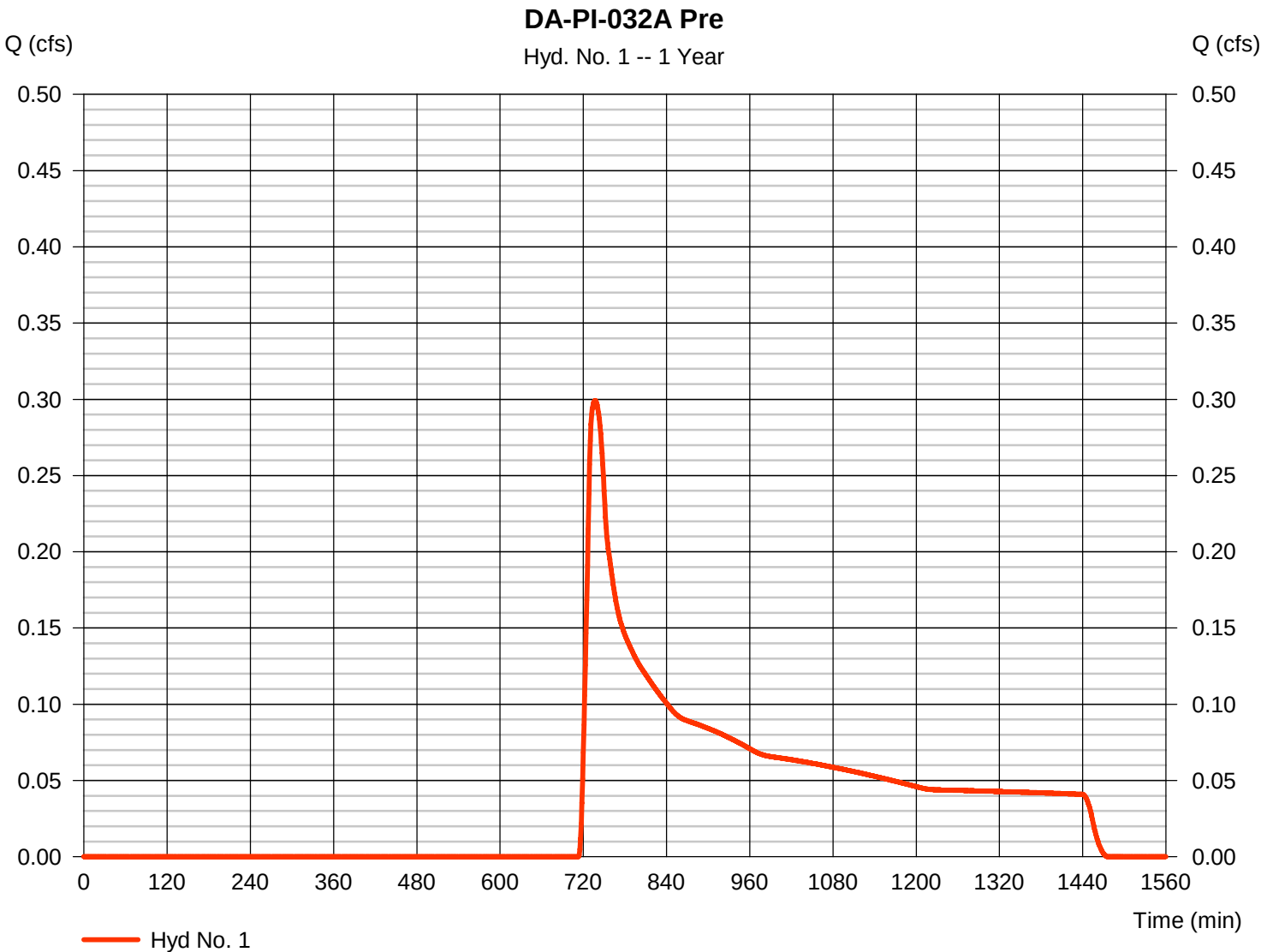
Hydrograph Report

Hyd. No. 1

DA-PI-032A Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.299 cfs
Storm frequency	= 1 yrs	Time to peak	= 737 min
Time interval	= 1 min	Hyd. volume	= 3,306 cuft
Drainage area	= 4.870 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 23.00 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(2.000 x 55) + (2.870 x 58)] / 4.870



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-PI-032A Pre

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.400	0.400				
Flow length (ft)	= 6.1	82.6	11.3				
Two-year 24-hr precip. (in)	= 3.50	3.50	3.50				
Land slope (%)	= 5.60	2.28	2.77				
Travel Time (min)	= 1.46	+	16.72	+	3.14	=	21.32
Shallow Concentrated Flow							
Flow length (ft)	= 499.46	0.00	0.00				
Watercourse slope (%)	= 10.01	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=5.10	0.00	0.00				
Travel Time (min)	= 1.63	+	0.00	+	0.00	=	1.63
Channel Flow							
X sectional flow area (sqft)	= 0.00	0.00	0.00				
Wetted perimeter (ft)	= 0.00	0.00	0.00				
Channel slope (%)	= 0.00	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	((0})0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc							23.00 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

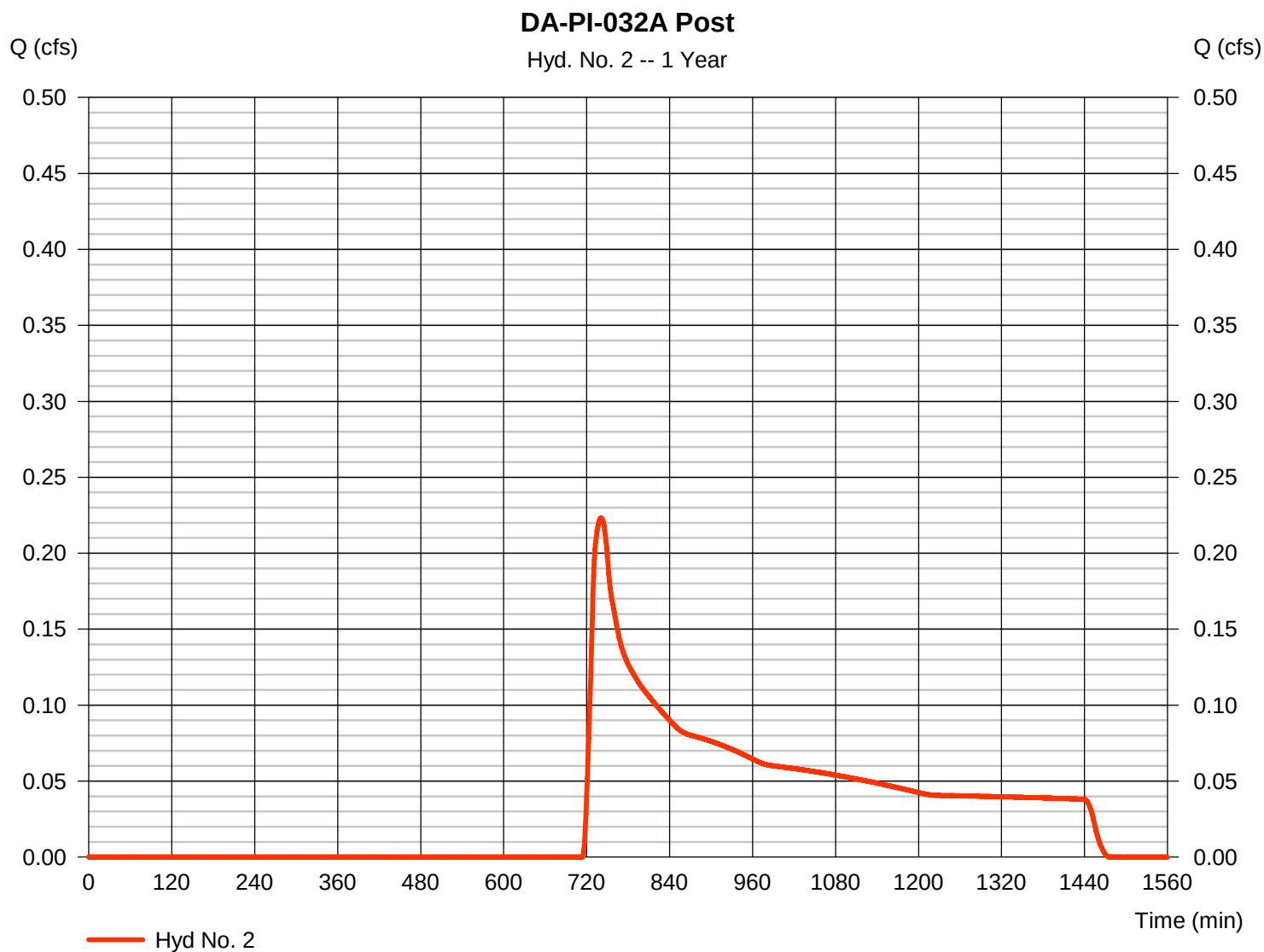
Thursday, 09 / 7 / 2017

Hyd. No. 2

DA-PI-032A Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.223 cfs
Storm frequency	= 1 yrs	Time to peak	= 741 min
Time interval	= 1 min	Hyd. volume	= 2,910 cuft
Drainage area	= 4.870 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 23.00 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.190 \times 55) + (3.580 \times 58) + (1.100 \times 48)] / 4.870$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-PI-032A Post

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.400	0.400	
Flow length (ft)	= 6.1	82.6	11.3	
Two-year 24-hr precip. (in)	= 3.50	3.50	3.50	
Land slope (%)	= 5.60	2.28	2.77	
Travel Time (min)	= 1.46	+	16.72	+
			3.14	= 21.32
Shallow Concentrated Flow				
Flow length (ft)	= 335.14	135.33	0.00	
Watercourse slope (%)	= 10.19	11.28	0.00	
Surface description	= Unpaved	Unpaved	Paved	
Average velocity (ft/s)	=5.15	5.42	0.00	
Travel Time (min)	= 1.08	+	0.42	+
			0.00	= 1.50
Channel Flow				
X sectional flow area (sqft)	= 2.00	0.00	0.00	
Wetted perimeter (ft)	= 4.47	0.00	0.00	
Channel slope (%)	= 5.00	0.00	0.00	
Manning's n-value	= 0.040	0.015	0.015	
Velocity (ft/s)	=4.86	0.00	0.00	
Flow length (ft)	({})38.0	0.0	0.0	
Travel Time (min)	= 0.13	+	0.00	+
			0.00	= 0.13
Total Travel Time, Tc				23.00 min

Hydrograph Report

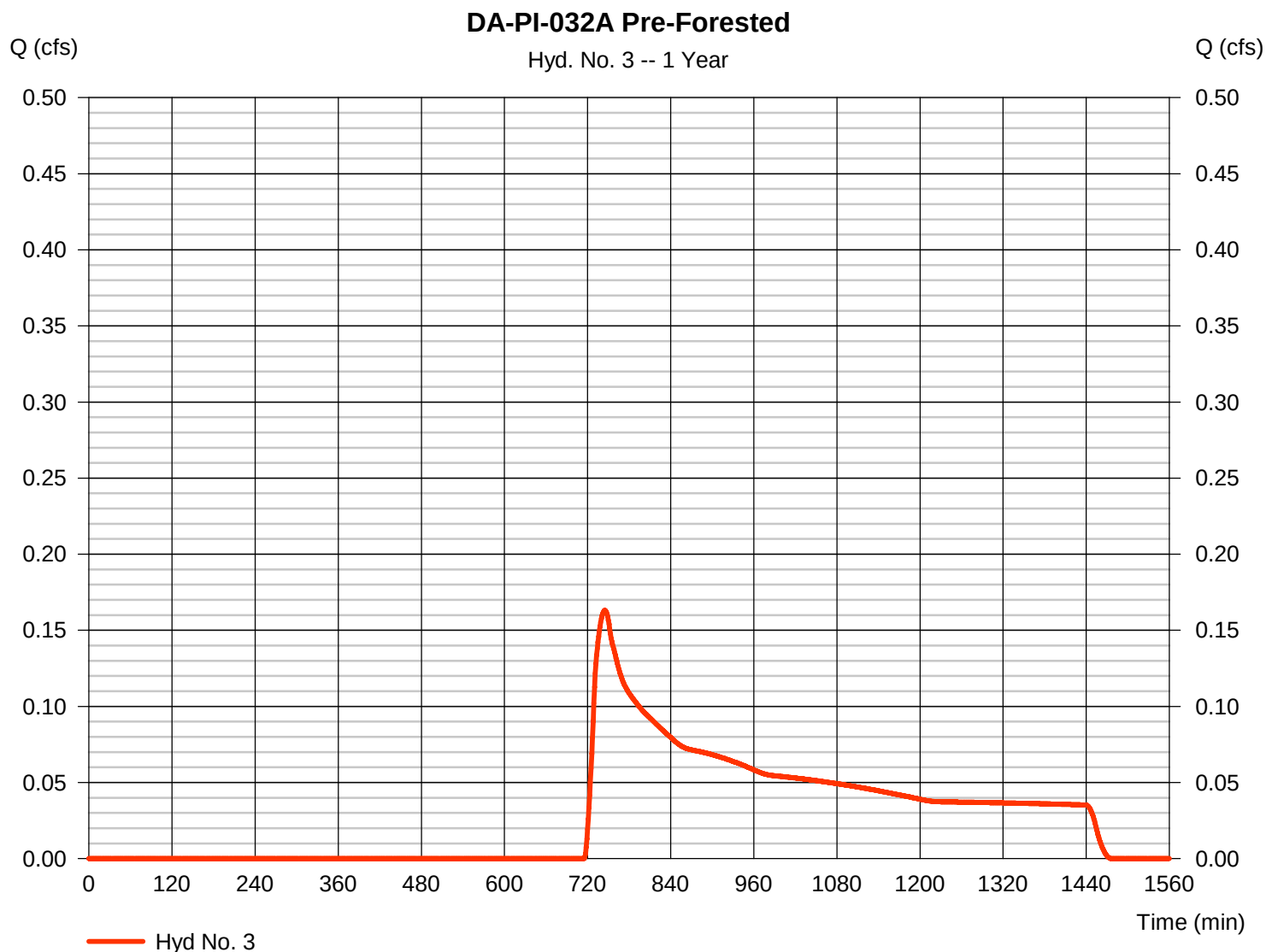
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Thursday, 09 / 7 / 2017

Hyd. No. 3

DA-PI-032A Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 0.163 cfs
Storm frequency	= 1 yrs	Time to peak	= 745 min
Time interval	= 1 min	Hyd. volume	= 2,536 cuft
Drainage area	= 4.870 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 23.00 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(4.870 \times 55)] / 4.870$ 

TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-PI-032A Pre-Forested

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.400	0.400				
Flow length (ft)	= 6.1	82.6	11.3				
Two-year 24-hr precip. (in)	= 3.50	3.50	3.50				
Land slope (%)	= 5.60	2.28	2.77				
Travel Time (min)	= 1.46	+	16.72	+	3.14	=	21.32
Shallow Concentrated Flow							
Flow length (ft)	= 499.46	0.00	0.00				
Watercourse slope (%)	= 10.01	0.00	0.00				
Surface description	= Unpaved	Unpaved	Paved				
Average velocity (ft/s)	=5.10	0.00	0.00				
Travel Time (min)	= 1.63	+	0.00	+	0.00	=	1.63
Channel Flow							
X sectional flow area (sqft)	= 0.00	0.00	0.00				
Wetted perimeter (ft)	= 0.00	0.00	0.00				
Channel slope (%)	= 0.00	0.00	0.00				
Manning's n-value	= 0.040	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	((0})0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc					23.00 min		

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	1.235	1	731	7,285	-----	-----	-----	DA-PI-032A Pre
2	SCS Runoff	1.044	1	731	6,659	-----	-----	-----	DA-PI-032A Post
3	SCS Runoff	0.866	1	731	6,057	-----	-----	-----	DA-PI-032A Pre-Forested
DA-PI-032A.gpw					Return Period: 2 Year			Thursday, 09 / 7 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

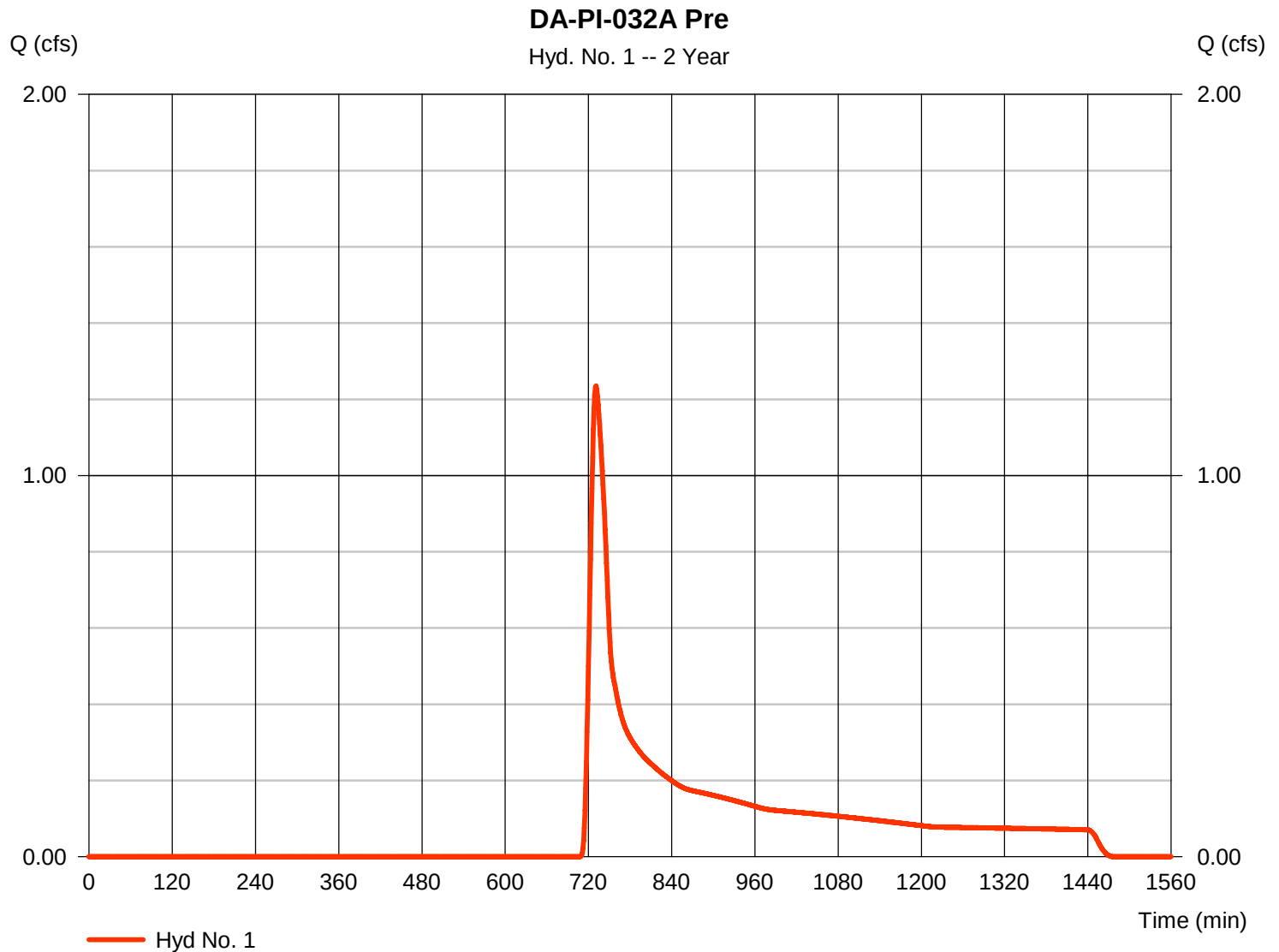
Thursday, 09 / 7 / 2017

Hyd. No. 1

DA-PI-032A Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 1.235 cfs
Storm frequency	= 2 yrs	Time to peak	= 731 min
Time interval	= 1 min	Hyd. volume	= 7,285 cuft
Drainage area	= 4.870 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 23.00 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(2.000 \times 55) + (2.870 \times 58)] / 4.870$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

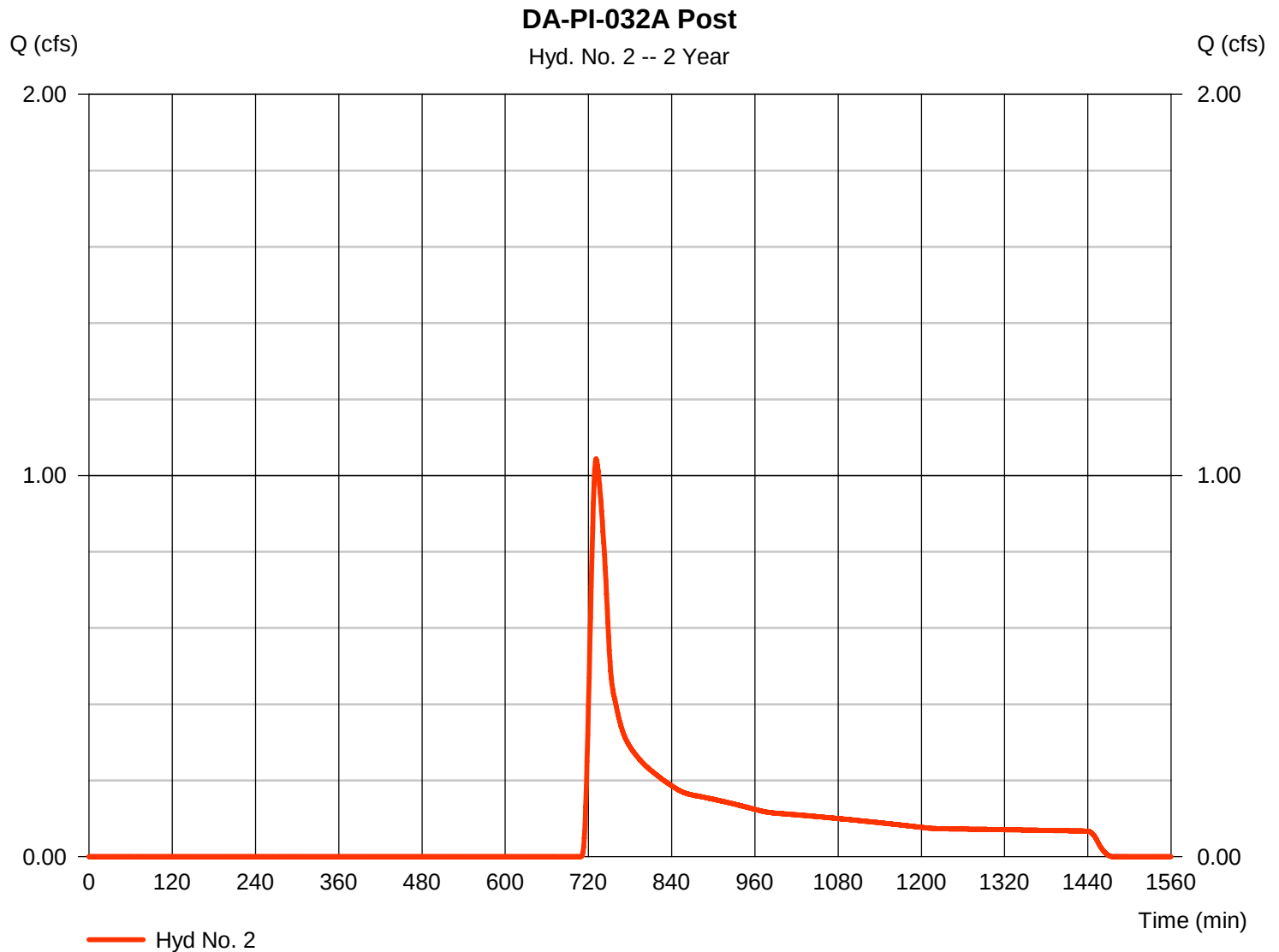
Thursday, 09 / 7 / 2017

Hyd. No. 2

DA-PI-032A Post

Hydrograph type	= SCS Runoff	Peak discharge	= 1.044 cfs
Storm frequency	= 2 yrs	Time to peak	= 731 min
Time interval	= 1 min	Hyd. volume	= 6,659 cuft
Drainage area	= 4.870 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 23.00 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.190 \times 55) + (3.580 \times 58) + (1.100 \times 48)] / 4.870$



Hydrograph Report

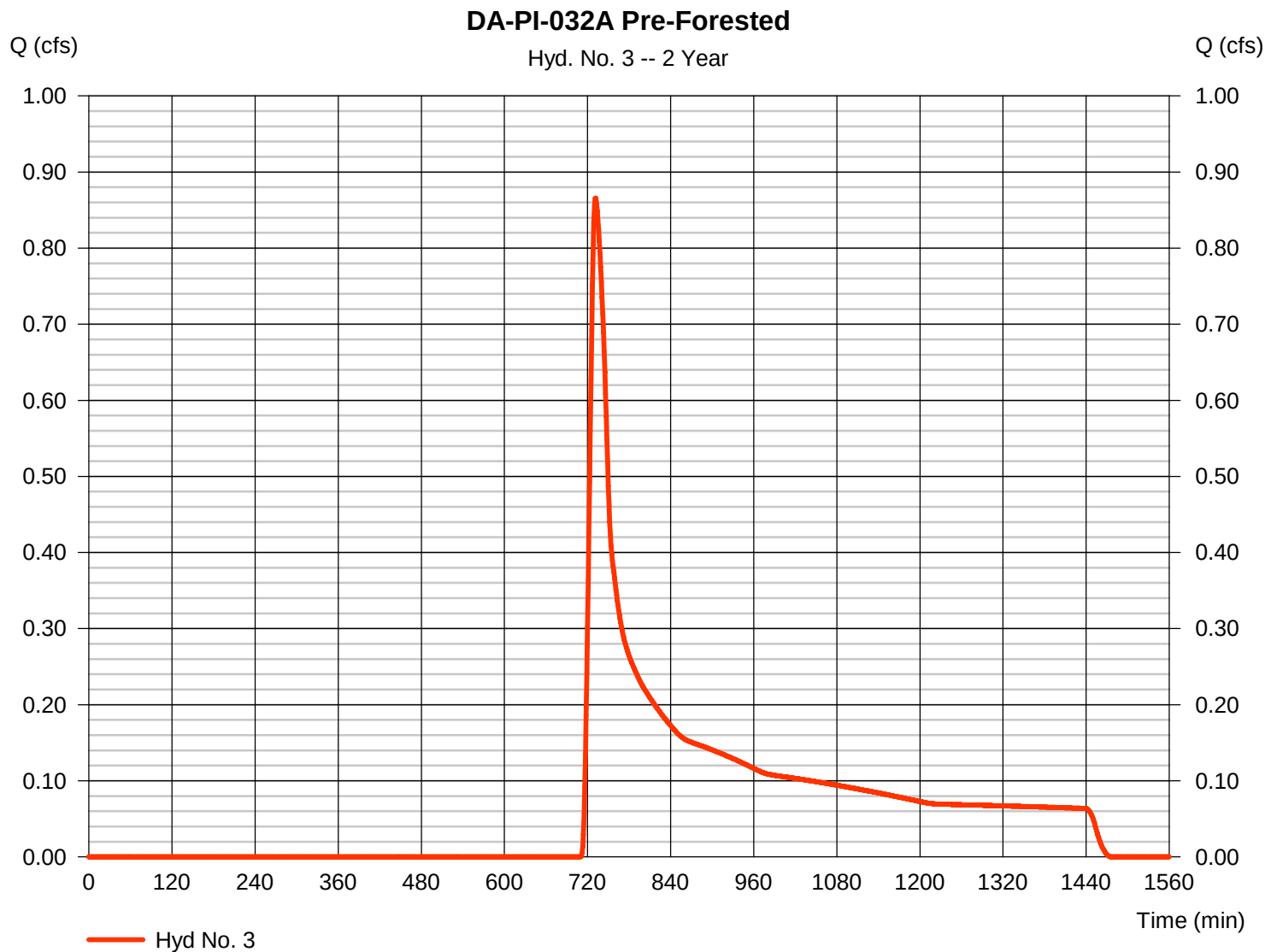
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Thursday, 09 / 7 / 2017

Hyd. No. 3

DA-PI-032A Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 0.866 cfs
Storm frequency	= 2 yrs	Time to peak	= 731 min
Time interval	= 1 min	Hyd. volume	= 6,057 cuft
Drainage area	= 4.870 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 23.00 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(4.870 \times 55)] / 4.870$ 

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	5.377	1	729	21,247	-----	-----	-----	DA-PI-032A Pre
2	SCS Runoff	4.973	1	729	20,084	-----	-----	-----	DA-PI-032A Post
3	SCS Runoff	4.574	1	729	18,943	-----	-----	-----	DA-PI-032A Pre-Forested
DA-PI-032A.gpw					Return Period: 10 Year			Thursday, 09 / 7 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

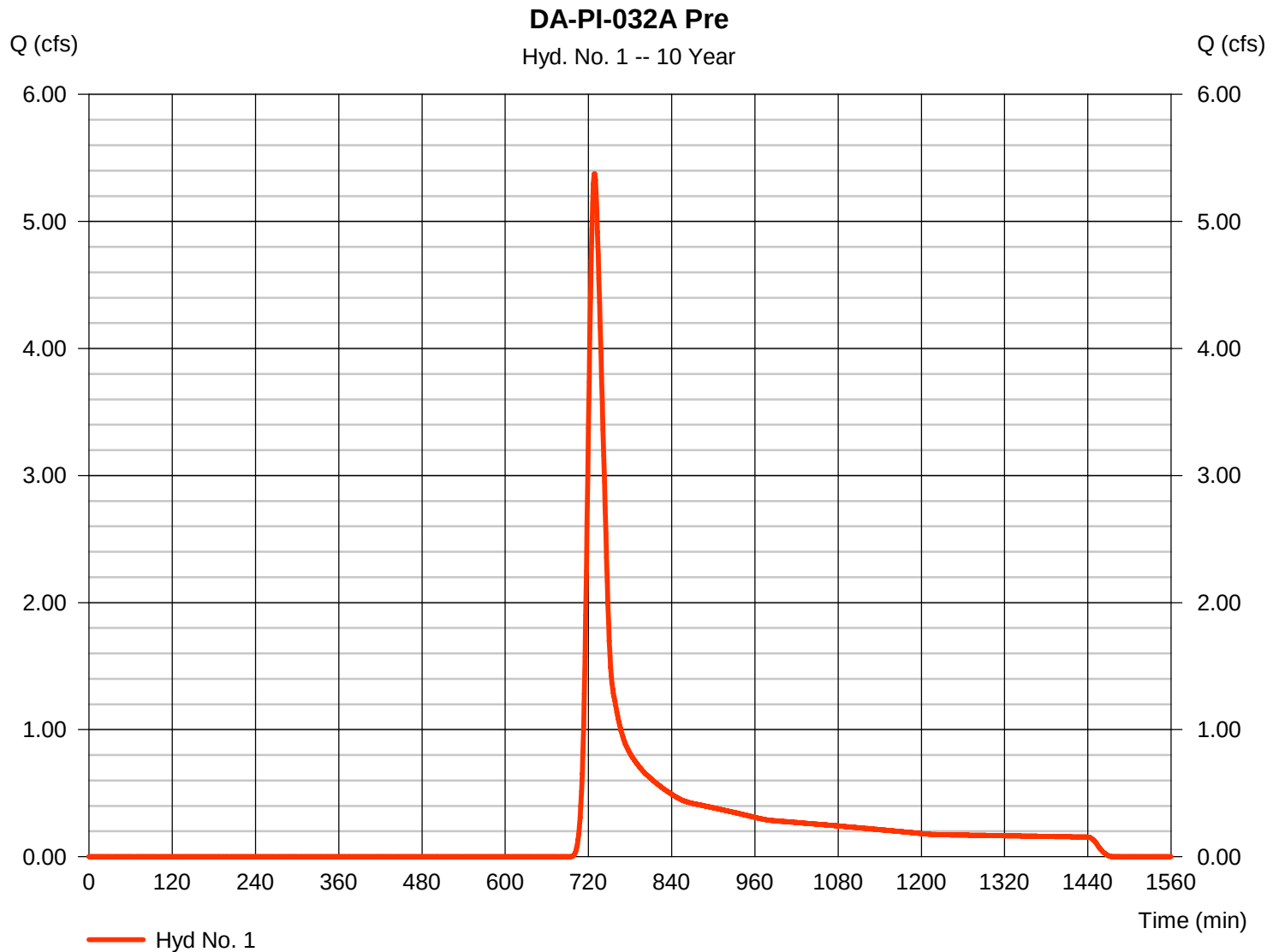
Thursday, 09 / 7 / 2017

Hyd. No. 1

DA-PI-032A Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 5.377 cfs
Storm frequency	= 10 yrs	Time to peak	= 729 min
Time interval	= 1 min	Hyd. volume	= 21,247 cuft
Drainage area	= 4.870 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 23.00 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(2.000 \times 55) + (2.870 \times 58)] / 4.870$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

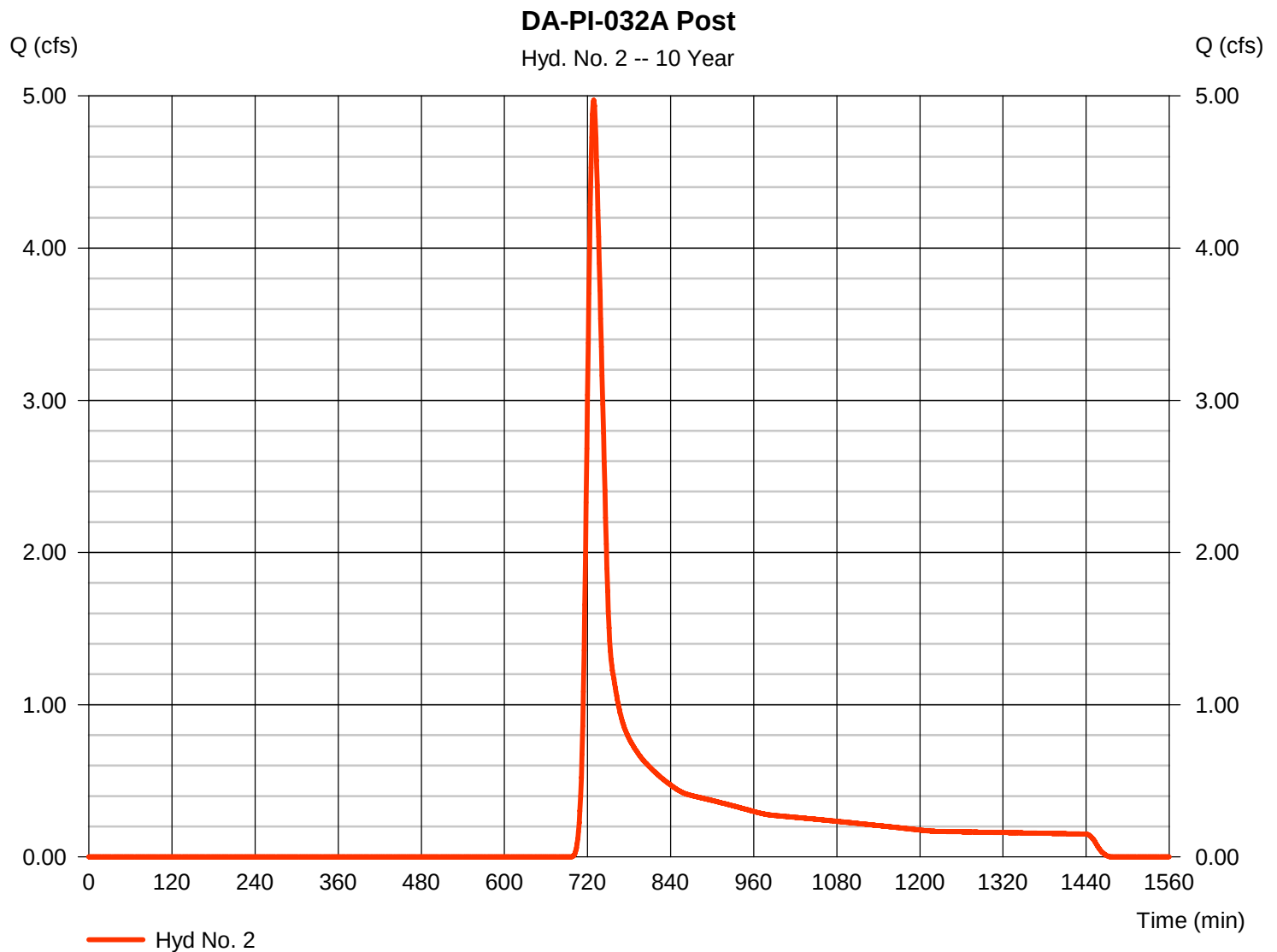
Thursday, 09 / 7 / 2017

Hyd. No. 2

DA-PI-032A Post

Hydrograph type	= SCS Runoff	Peak discharge	= 4.973 cfs
Storm frequency	= 10 yrs	Time to peak	= 729 min
Time interval	= 1 min	Hyd. volume	= 20,084 cuft
Drainage area	= 4.870 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 23.00 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.190 \times 55) + (3.580 \times 58) + (1.100 \times 48)] / 4.870$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

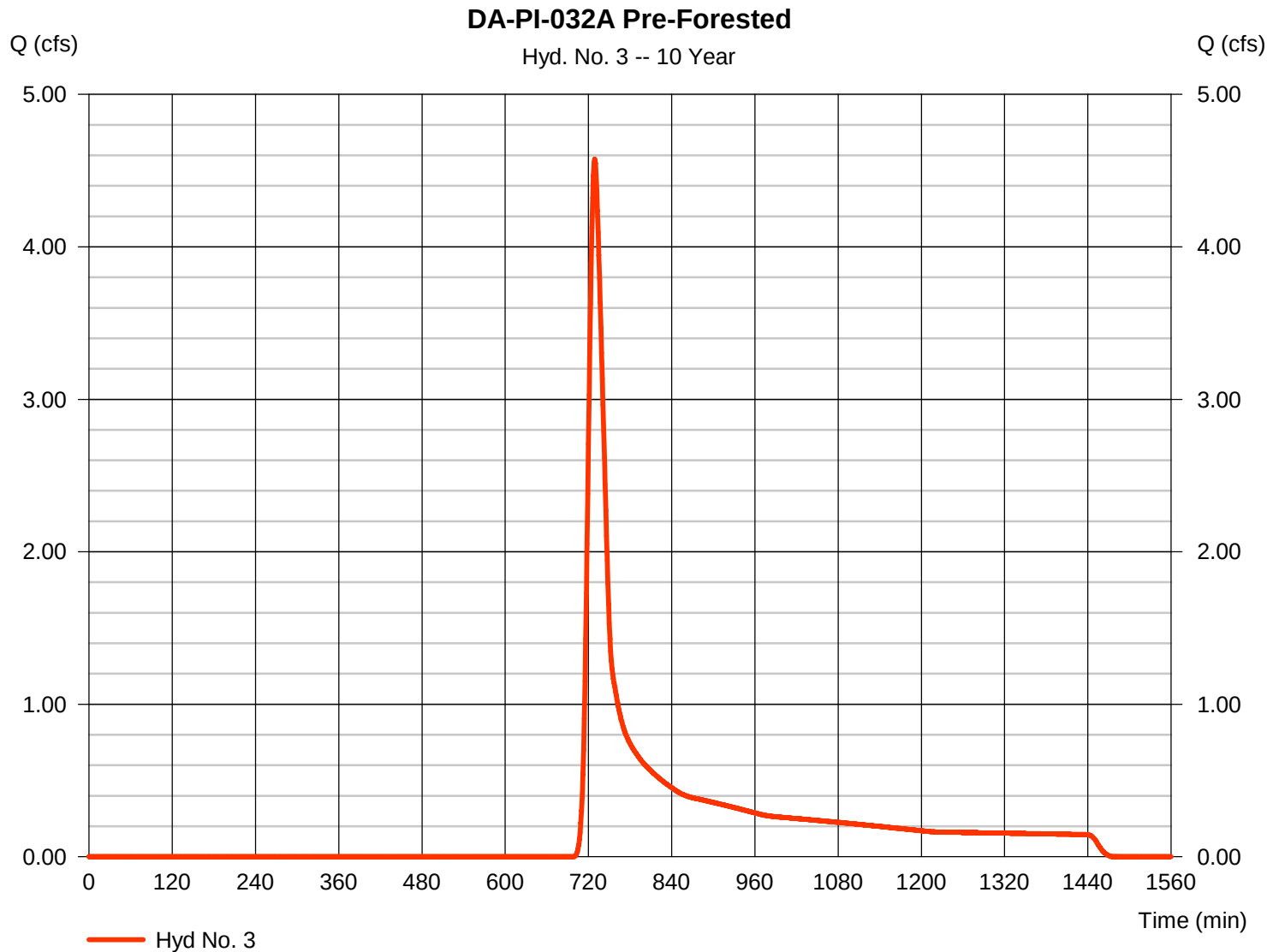
Thursday, 09 / 7 / 2017

Hyd. No. 3

DA-PI-032A Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 4.574 cfs
Storm frequency	= 10 yrs	Time to peak	= 729 min
Time interval	= 1 min	Hyd. volume	= 18,943 cuft
Drainage area	= 4.870 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 23.00 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(4.870 x 55)] / 4.870



DA-PI-032B

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.467	3,649
Developed Condition	0.346	3,239
Pre-Developed (Forest) Condition	0.170	2,484

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1:

$$Q_{\text{developed}} \leq IF \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}] \text{ ----->}$$

Q (cfs)

0.346

≤
OK

Q (cfs)

0.421

Check #2:

$$Q_{\text{developed}} \leq Q_{\text{pre-developed}} \text{ ----->}$$

0.346

≤
OK

0.467

Check #3:

$$Q_{\text{developed}} \text{ shall not be required to be } \leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}} \text{ --->}$$

0.346

shall not be required to be ≤

0.130

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning's n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<i>Note:</i> Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted. ¹For Paved Road land surface types a Manning's n of 0.011 was used <i>Sources:</i> -USACE, 1998, HEC-1 Flood Hydrograph Package User's Manual, Hydrologic Engineering Center, Davis, CA -Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC	

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

1



2



3



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-PI-032B Pre
2	SCS Runoff	DA-PI-032B Post
3	SCS Runoff	DA-PI-032B Pre-Forested

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.467	1	728	3,649	-----	-----	-----	DA-PI-032B Pre
2	SCS Runoff	0.346	1	729	3,239	-----	-----	-----	DA-PI-032B Post
3	SCS Runoff	0.170	1	736	2,484	-----	-----	-----	DA-PI-032B Pre-Forested
DA-PI-032B.gpw					Return Period: 1 Year			Saturday, 08 / 19 / 2017	

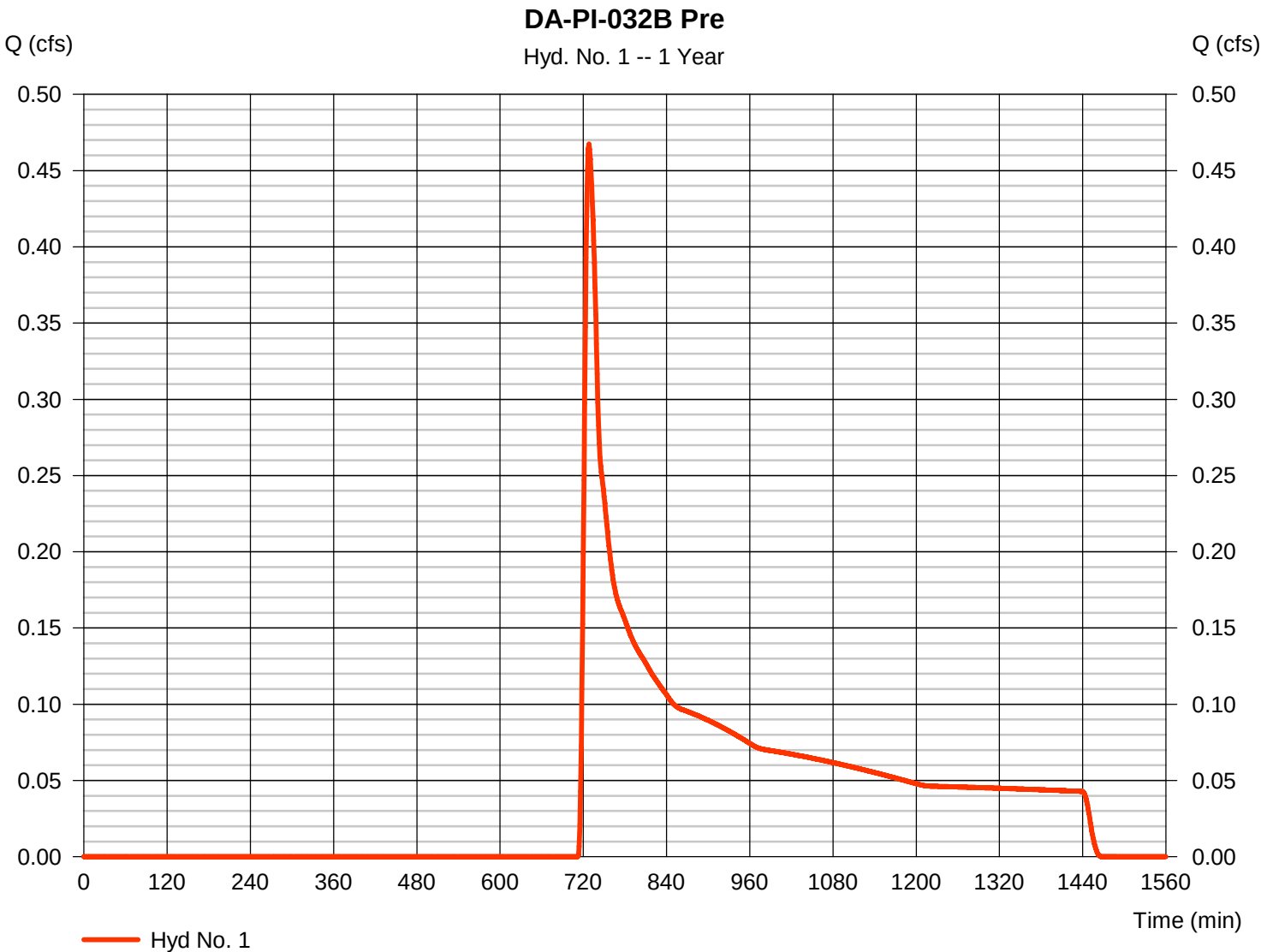
Hydrograph Report

Hyd. No. 1

DA-PI-032B Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.467 cfs
Storm frequency	= 1 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 3,649 cuft
Drainage area	= 4.670 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.90 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(2.310 x 55) + (2.190 x 58) + (0.110 x 85) + (0.060 x 98)] / 4.670



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-PI-032B Pre

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 6.51	0.00	0.00				
Travel Time (min)	= 12.81	+	0.00	+	0.00	=	12.81
Shallow Concentrated Flow							
Flow length (ft)	= 361.42	22.23	448.73				
Watercourse slope (%)	= 5.38	6.08	11.06				
Surface description	= Unpaved	Paved	Unpaved				
Average velocity (ft/s)	=3.74	5.01	5.37				
Travel Time (min)	= 1.61	+	0.07	+	1.39	=	3.08
Channel Flow							
X sectional flow area (sqft)	= 0.00	0.00	0.00				
Wetted perimeter (ft)	= 0.00	0.00	0.00				
Channel slope (%)	= 0.00	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	(0)0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc				15.90 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

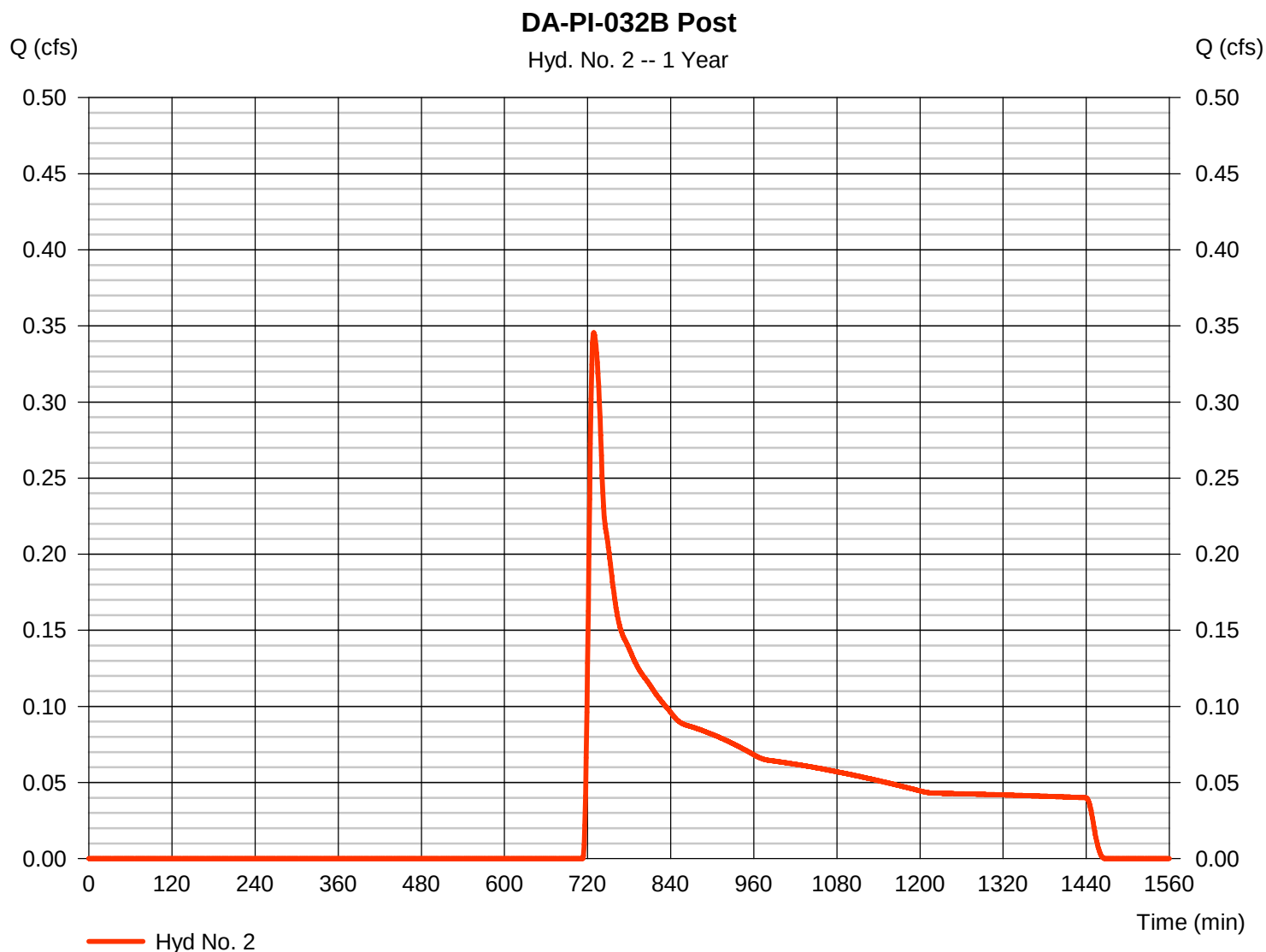
Saturday, 08 / 19 / 2017

Hyd. No. 2

DA-PI-032B Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.346 cfs
Storm frequency	= 1 yrs	Time to peak	= 729 min
Time interval	= 1 min	Hyd. volume	= 3,239 cuft
Drainage area	= 4.670 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.90 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.240 \times 55) + (2.600 \times 58) + (0.110 \times 85) + (0.060 \times 98) + (0.660 \times 48)] / 4.670$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-PI-032B Post

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 6.51	0.00	0.00				
Travel Time (min)	= 12.81	+	0.00	+	0.00	=	12.81
Shallow Concentrated Flow							
Flow length (ft)	= 361.42	22.23	448.73				
Watercourse slope (%)	= 5.38	6.08	11.06				
Surface description	= Unpaved	Paved	Unpaved				
Average velocity (ft/s)	=3.74	5.01	5.37				
Travel Time (min)	= 1.61	+	0.07	+	1.39	=	3.08
Channel Flow							
X sectional flow area (sqft)	= 0.00	0.00	0.00				
Wetted perimeter (ft)	= 0.00	0.00	0.00				
Channel slope (%)	= 0.00	0.00	0.00				
Manning's n-value	= 0.040	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	((0))0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc				15.90 min			

Hydrograph Report

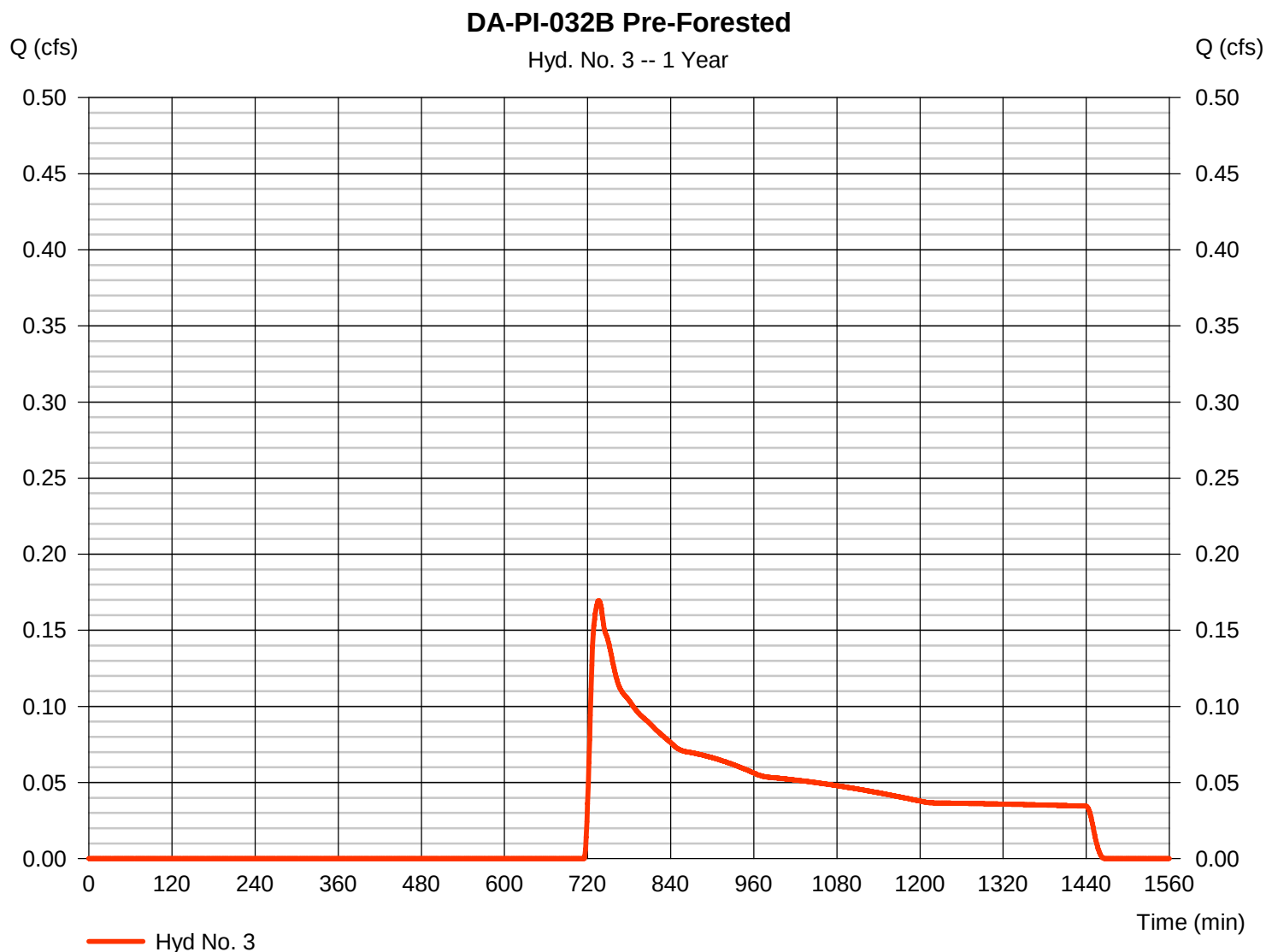
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Saturday, 08 / 19 / 2017

Hyd. No. 3

DA-PI-032B Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 0.170 cfs
Storm frequency	= 1 yrs	Time to peak	= 736 min
Time interval	= 1 min	Hyd. volume	= 2,484 cuft
Drainage area	= 4.670 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.90 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(4.670 \times 55)] / 4.670$ 

TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-PI-032B Pre-Forested

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 6.51	0.00	0.00				
Travel Time (min)	= 12.81	+	0.00	+	0.00	=	12.81
Shallow Concentrated Flow							
Flow length (ft)	= 361.42	22.23	448.73				
Watercourse slope (%)	= 5.38	6.08	11.06				
Surface description	= Unpaved	Unpaved	Unpaved				
Average velocity (ft/s)	=3.74	3.98	5.37				
Travel Time (min)	= 1.61	+	0.09	+	1.39	=	3.10
Channel Flow							
X sectional flow area (sqft)	= 0.00	0.00	0.00				
Wetted perimeter (ft)	= 0.00	0.00	0.00				
Channel slope (%)	= 0.00	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	((0})0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc				15.90 min			

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	1.755	1	726	7,775	-----	-----	-----	DA-PI-032B Pre
2	SCS Runoff	1.502	1	726	7,137	-----	-----	-----	DA-PI-032B Post
3	SCS Runoff	1.049	1	727	5,934	-----	-----	-----	DA-PI-032B Pre-Forested
DA-PI-032B.gpw					Return Period: 2 Year			Saturday, 08 / 19 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

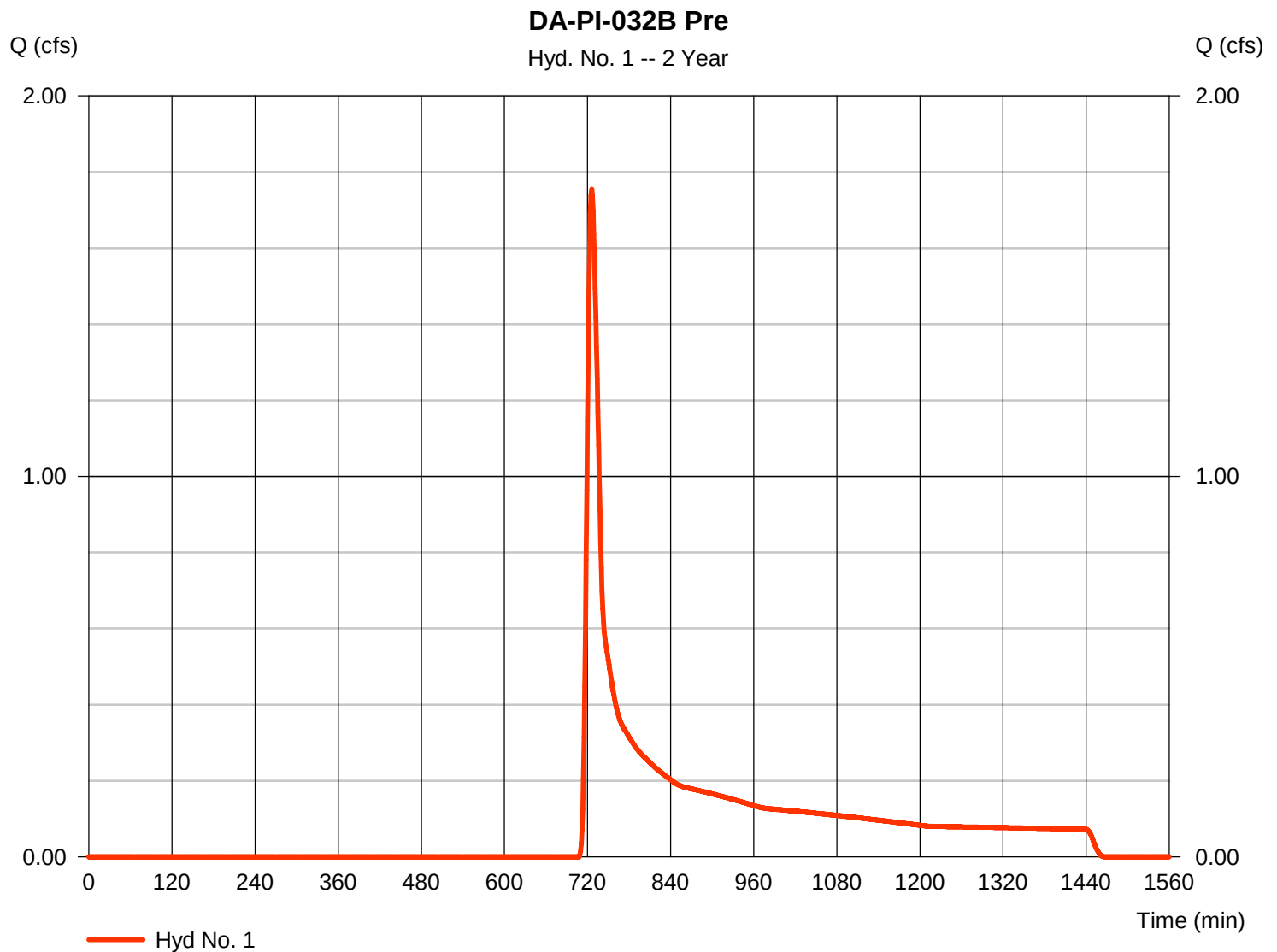
Saturday, 08 / 19 / 2017

Hyd. No. 1

DA-PI-032B Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 1.755 cfs
Storm frequency	= 2 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 7,775 cuft
Drainage area	= 4.670 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.90 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(2.310 \times 55) + (2.190 \times 58) + (0.110 \times 85) + (0.060 \times 98)] / 4.670$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

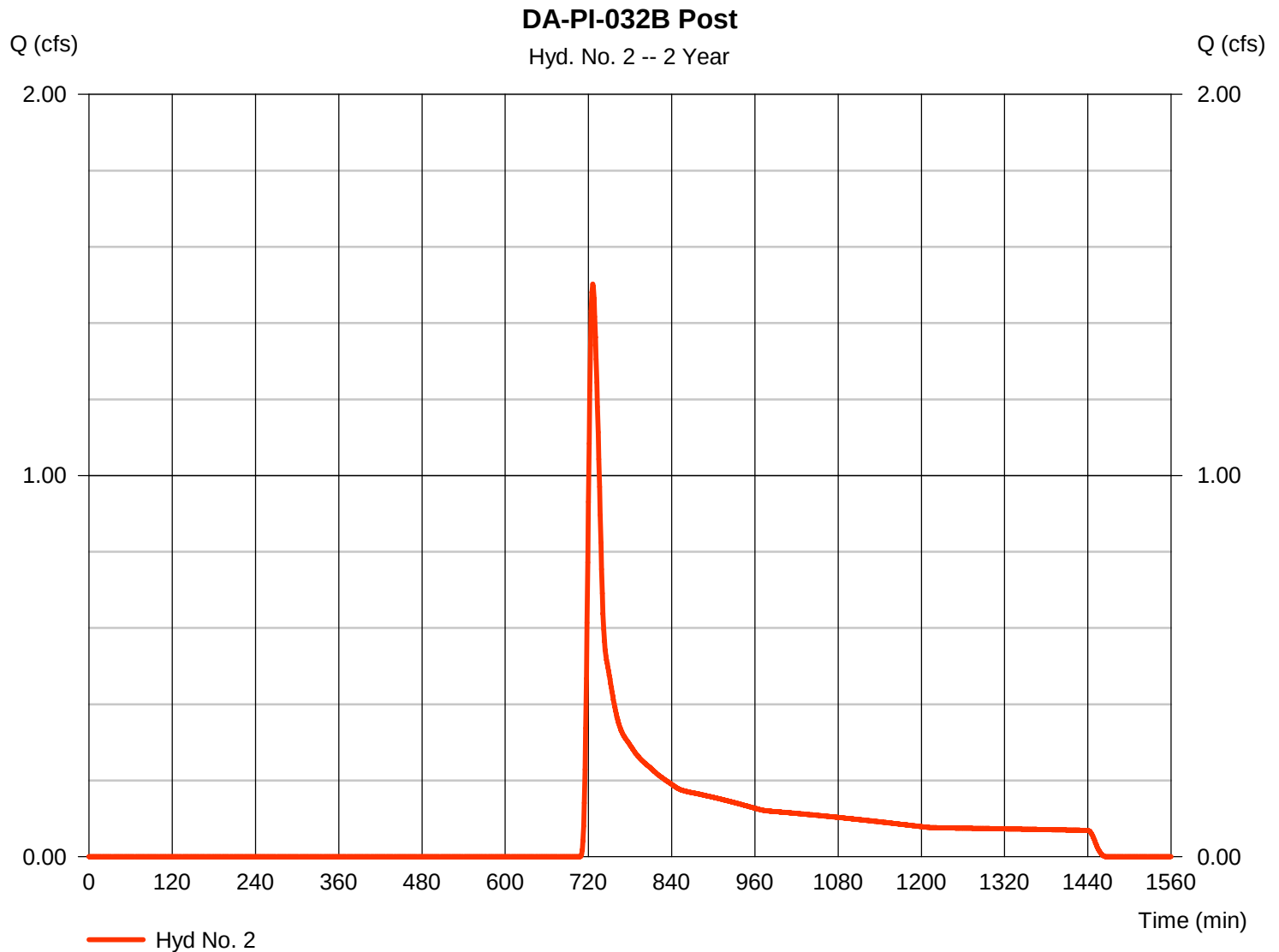
Saturday, 08 / 19 / 2017

Hyd. No. 2

DA-PI-032B Post

Hydrograph type	= SCS Runoff	Peak discharge	= 1.502 cfs
Storm frequency	= 2 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 7,137 cuft
Drainage area	= 4.670 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.90 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.240 \times 55) + (2.600 \times 58) + (0.110 \times 85) + (0.060 \times 98) + (0.660 \times 48)] / 4.670$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

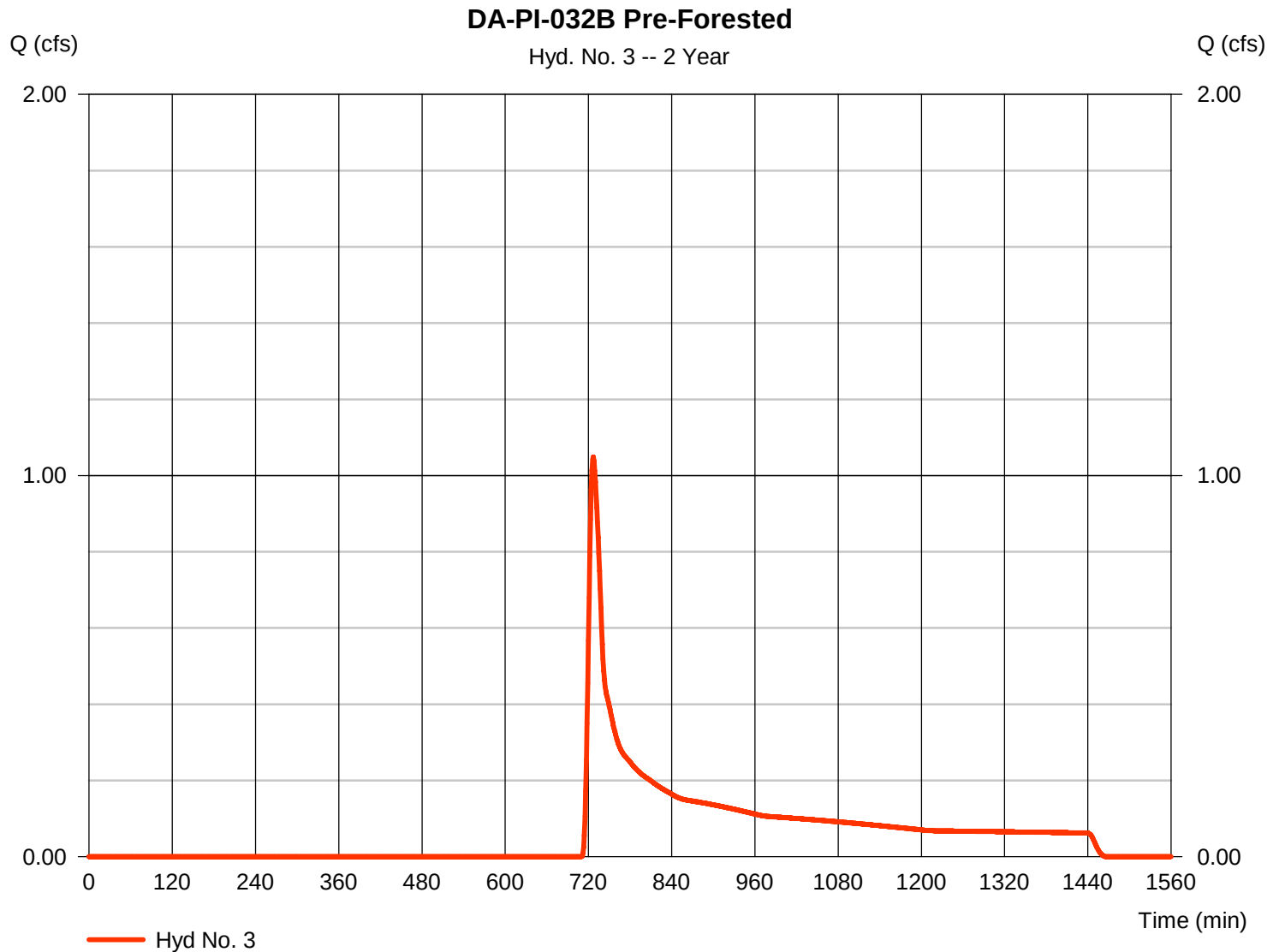
Saturday, 08 / 19 / 2017

Hyd. No. 3

DA-PI-032B Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 1.049 cfs
Storm frequency	= 2 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 5,934 cuft
Drainage area	= 4.670 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.90 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(4.670 x 55)] / 4.670



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	6.940	1	724	21,977	-----	-----	-----	DA-PI-032B Pre
2	SCS Runoff	6.459	1	724	20,815	-----	-----	-----	DA-PI-032B Post
3	SCS Runoff	5.513	1	725	18,558	-----	-----	-----	DA-PI-032B Pre-Forested
DA-PI-032B.gpw					Return Period: 10 Year			Saturday, 08 / 19 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

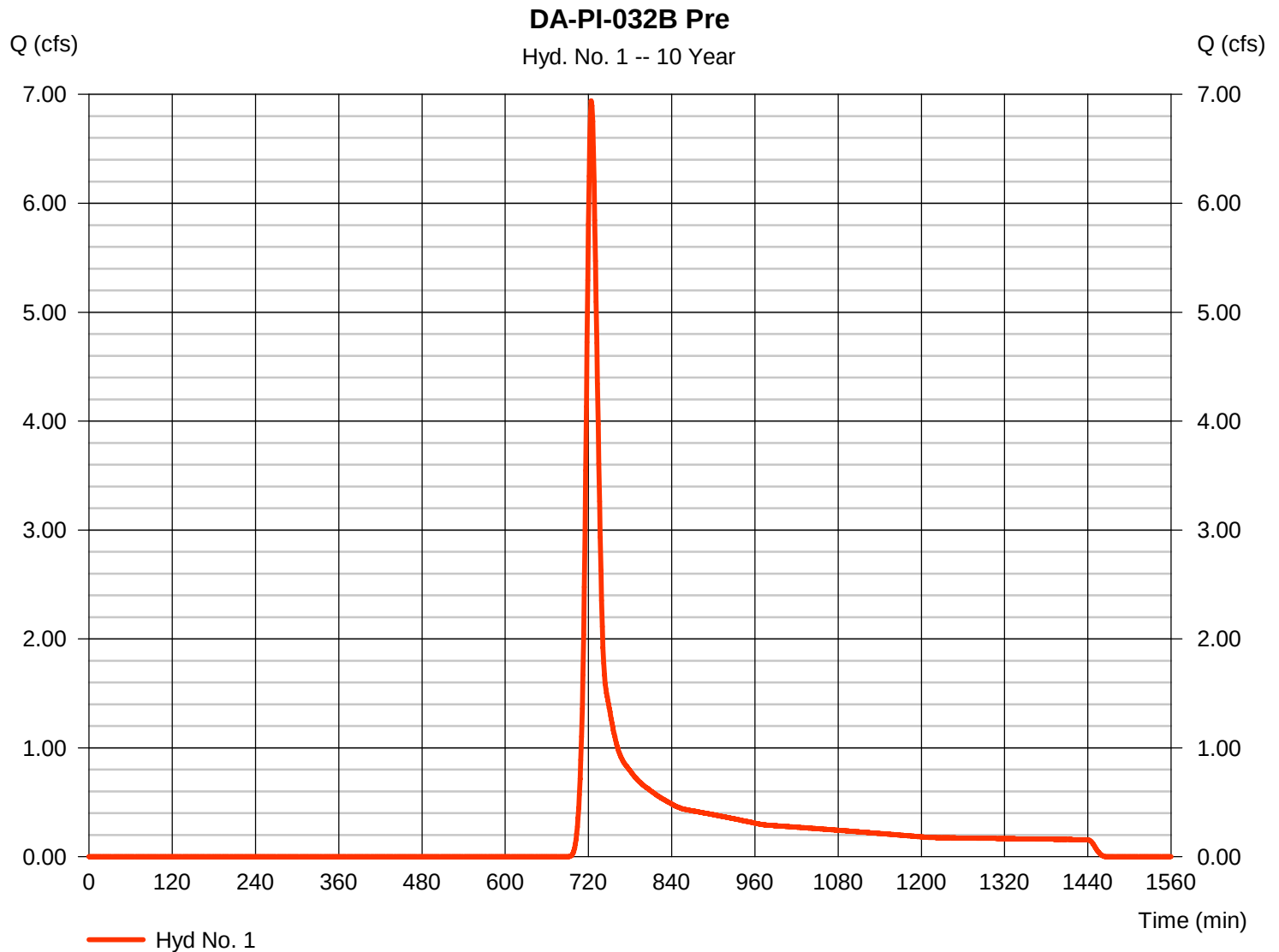
Saturday, 08 / 19 / 2017

Hyd. No. 1

DA-PI-032B Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 6.940 cfs
Storm frequency	= 10 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 21,977 cuft
Drainage area	= 4.670 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.90 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(2.310 \times 55) + (2.190 \times 58) + (0.110 \times 85) + (0.060 \times 98)] / 4.670$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

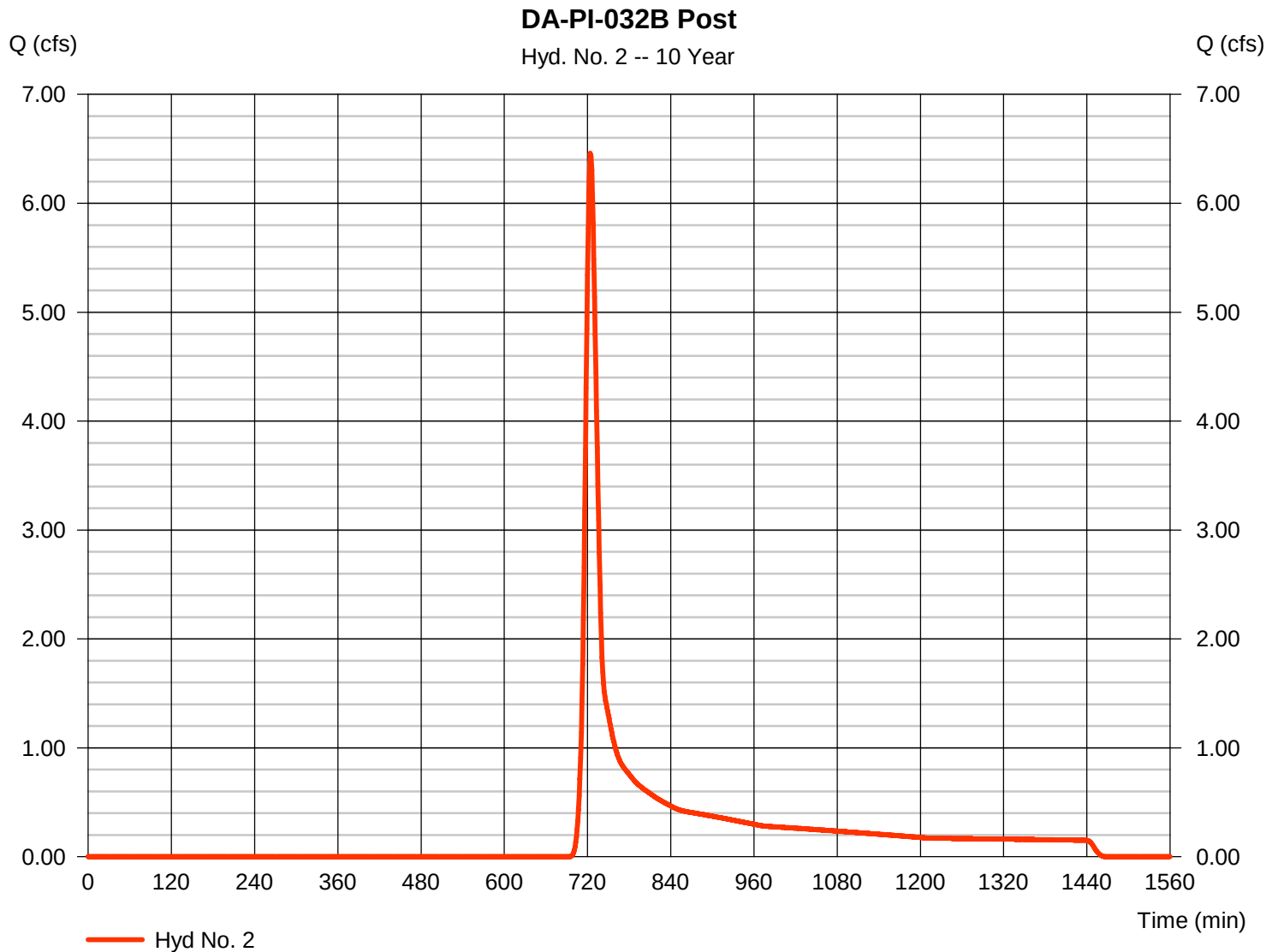
Saturday, 08 / 19 / 2017

Hyd. No. 2

DA-PI-032B Post

Hydrograph type	= SCS Runoff	Peak discharge	= 6.459 cfs
Storm frequency	= 10 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 20,815 cuft
Drainage area	= 4.670 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.90 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.240 \times 55) + (2.600 \times 58) + (0.110 \times 85) + (0.060 \times 98) + (0.660 \times 48)] / 4.670$



Hydrograph Report

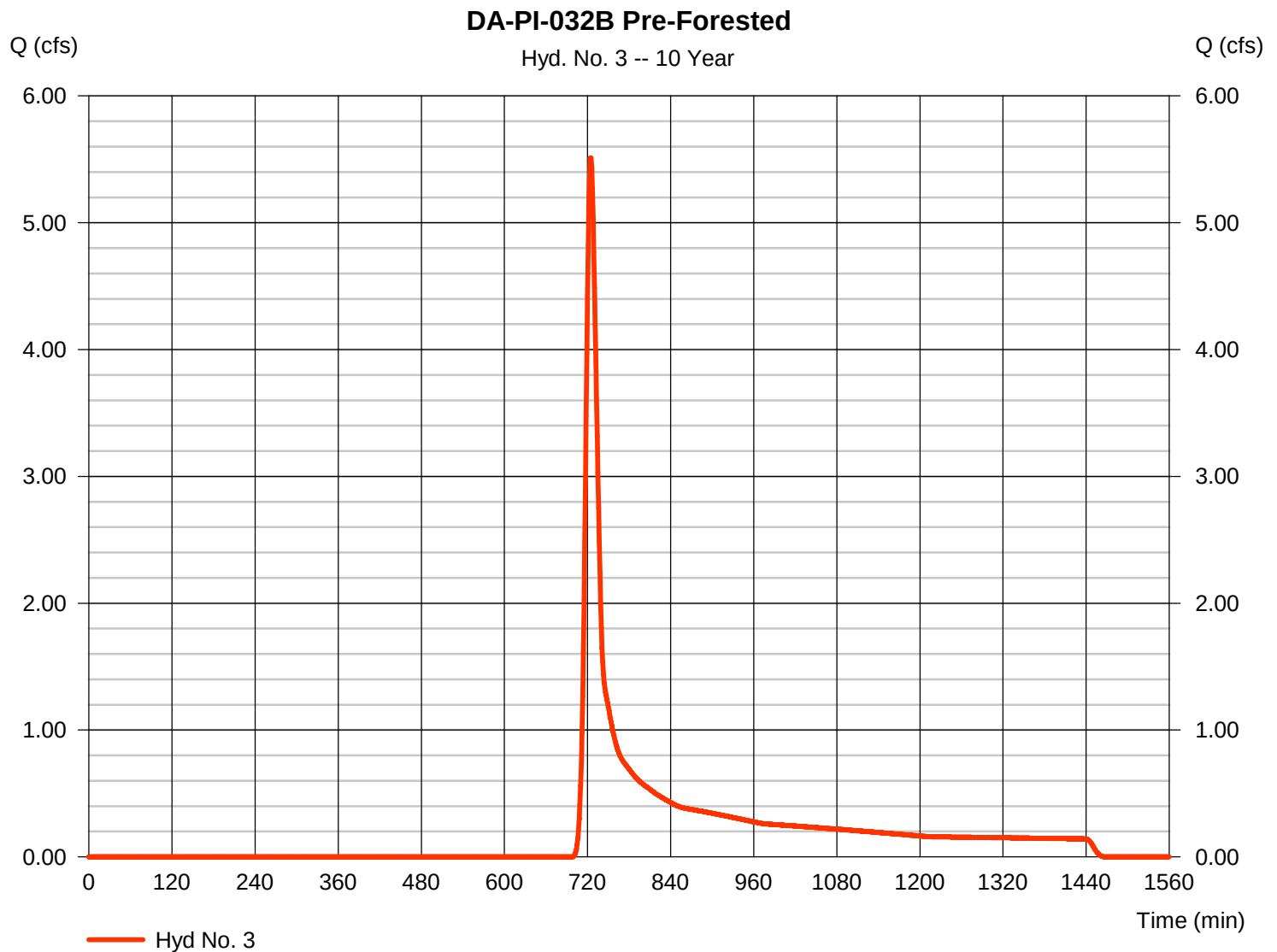
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Saturday, 08 / 19 / 2017

Hyd. No. 3

DA-PI-032B Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 5.513 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 18,558 cuft
Drainage area	= 4.670 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.90 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(4.670 \times 55)] / 4.670$ 

DA-PI-032C

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.162	1,578
Developed Condition	0.082	1,210
Pre-Developed (Forest) Condition	0.082	1,210

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1:

$$Q_{\text{developed}} \leq IF \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}] \text{ ----->}$$

Q (cfs)

0.082

≤
OK

Q (cfs)

0.169

Check #2:

$$Q_{\text{developed}} \leq Q_{\text{pre-developed}} \text{ ----->}$$

0.082

≤
OK

0.162

Check #3:

$$Q_{\text{developed}} \text{ shall not be required to be } \leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}} \text{ --->}$$

0.082

shall not be required to be ≤

0.082

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning's n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<i>Note:</i> Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted. ¹For Paved Road land surface types a Manning's n of 0.011 was used <i>Sources:</i> -USACE, 1998, HEC-1 Flood Hydrograph Package User's Manual, Hydrologic Engineering Center, Davis, CA -Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC	

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

1



2



3



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-PI-032C Pre
2	SCS Runoff	DA-PI-032C Post
3	SCS Runoff	DA-PI-032C Pre-Forested

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.162	1	730	1,578	-----	-----	-----	DA-PI-032C Pre
2	SCS Runoff	0.082	1	738	1,210	-----	-----	-----	DA-PI-032C Post
3	SCS Runoff	0.082	1	738	1,210	-----	-----	-----	DA-PI-032C Pre-Forested
DA-PI-032C.gpw					Return Period: 1 Year			Saturday, 08 / 19 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

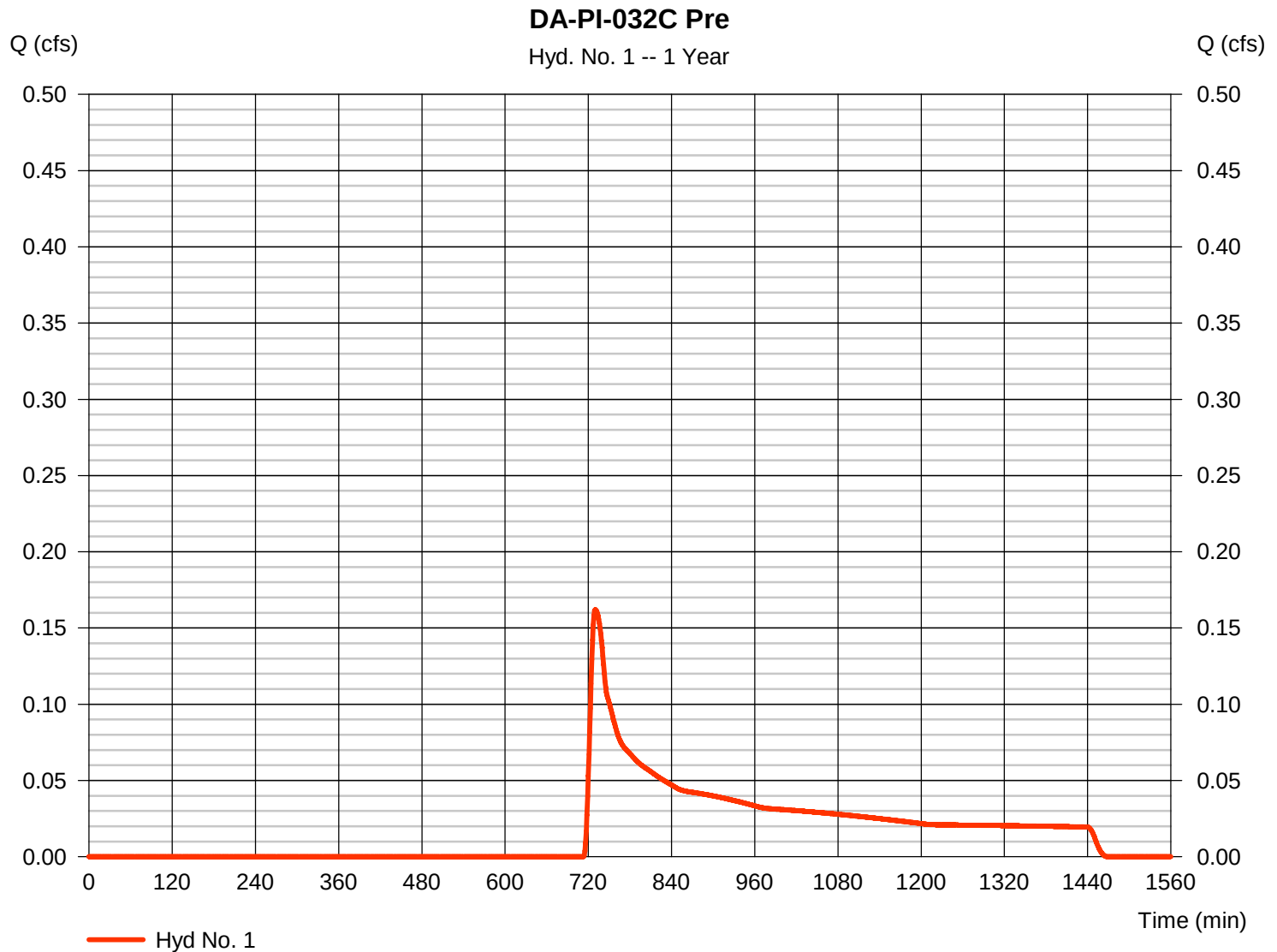
Saturday, 08 / 19 / 2017

Hyd. No. 1

DA-PI-032C Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.162 cfs
Storm frequency	= 1 yrs	Time to peak	= 730 min
Time interval	= 1 min	Hyd. volume	= 1,578 cuft
Drainage area	= 2.330 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 17.20 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.310 \times 55) + (1.000 \times 58) + (0.020 \times 98)] / 2.330$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-PI-032C Pre

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.011	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 3.69	0.00	0.00				
Travel Time (min)	= 16.07	+	0.00	+	0.00	=	16.07
Shallow Concentrated Flow							
Flow length (ft)	= 353.67	0.00	0.00				
Watercourse slope (%)	= 10.77	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=5.29	0.00	0.00				
Travel Time (min)	= 1.11	+	0.00	+	0.00	=	1.11
Channel Flow							
X sectional flow area (sqft)	= 0.00	0.00	0.00				
Wetted perimeter (ft)	= 0.00	0.00	0.00				
Channel slope (%)	= 0.00	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	(0)0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc				17.20 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

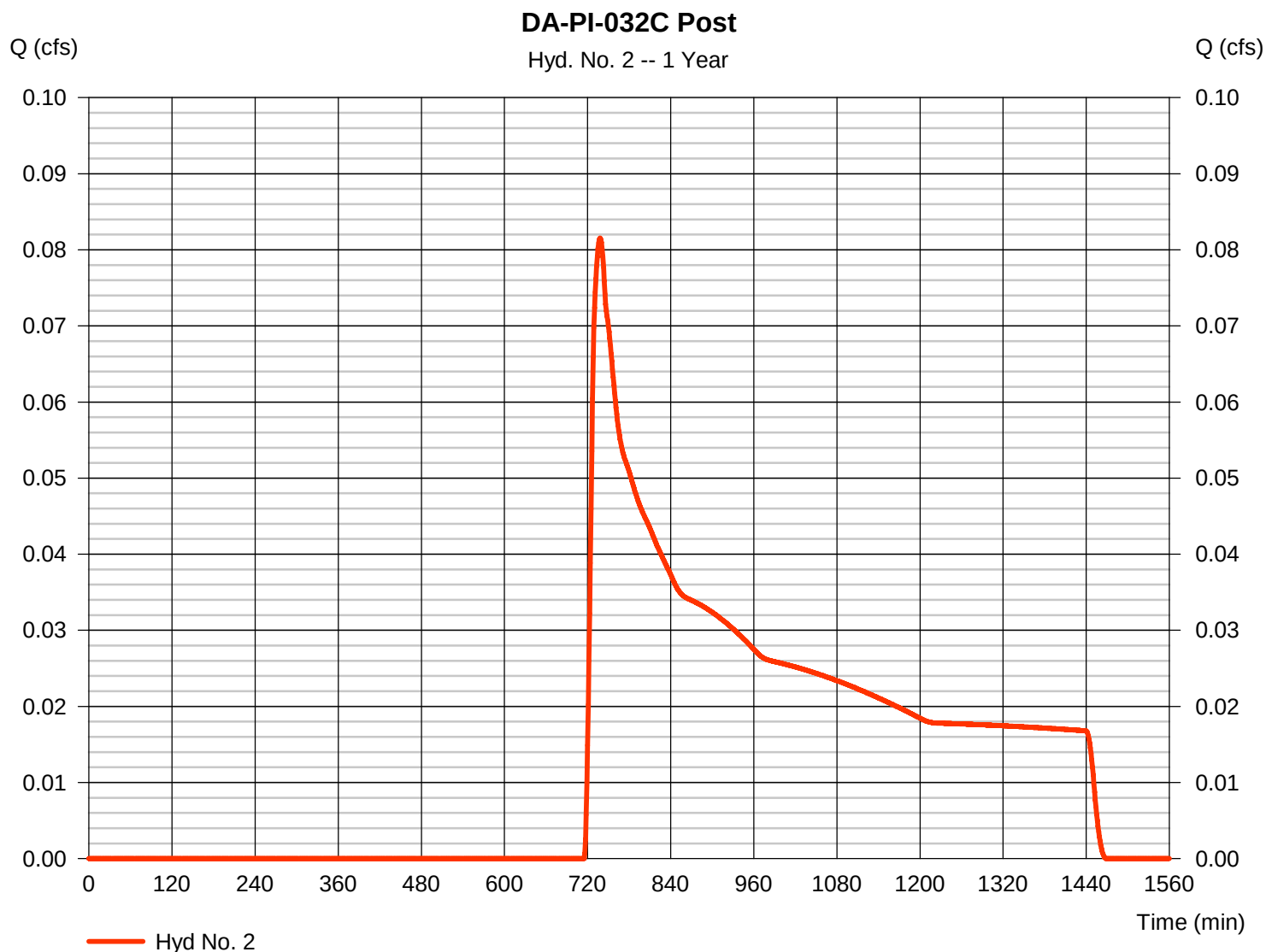
Saturday, 08 / 19 / 2017

Hyd. No. 2

DA-PI-032C Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.082 cfs
Storm frequency	= 1 yrs	Time to peak	= 738 min
Time interval	= 1 min	Hyd. volume	= 1,210 cuft
Drainage area	= 2.330 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 17.20 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.210 \times 55) + (1.430 \times 58) + (0.020 \times 98) + (0.670 \times 48)] / 2.330$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-PI-032C Post

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00	
Land slope (%)	= 3.69	0.00	0.00	
Travel Time (min)	= 16.07	+ 0.00	+ 0.00	= 16.07
Shallow Concentrated Flow				
Flow length (ft)	= 353.67	0.00	0.00	
Watercourse slope (%)	= 10.77	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=5.29	0.00	0.00	
Travel Time (min)	= 1.11	+ 0.00	+ 0.00	= 1.11
Channel Flow				
X sectional flow area (sqft)	= 0.00	0.00	0.00	
Wetted perimeter (ft)	= 0.00	0.00	0.00	
Channel slope (%)	= 0.00	0.00	0.00	
Manning's n-value	= 0.040	0.015	0.015	
Velocity (ft/s)	=0.00	0.00	0.00	
Flow length (ft)	(0)0.0	0.0	0.0	
Travel Time (min)	= 0.00	+ 0.00	+ 0.00	= 0.00
Total Travel Time, Tc				17.20 min

Hydrograph Report

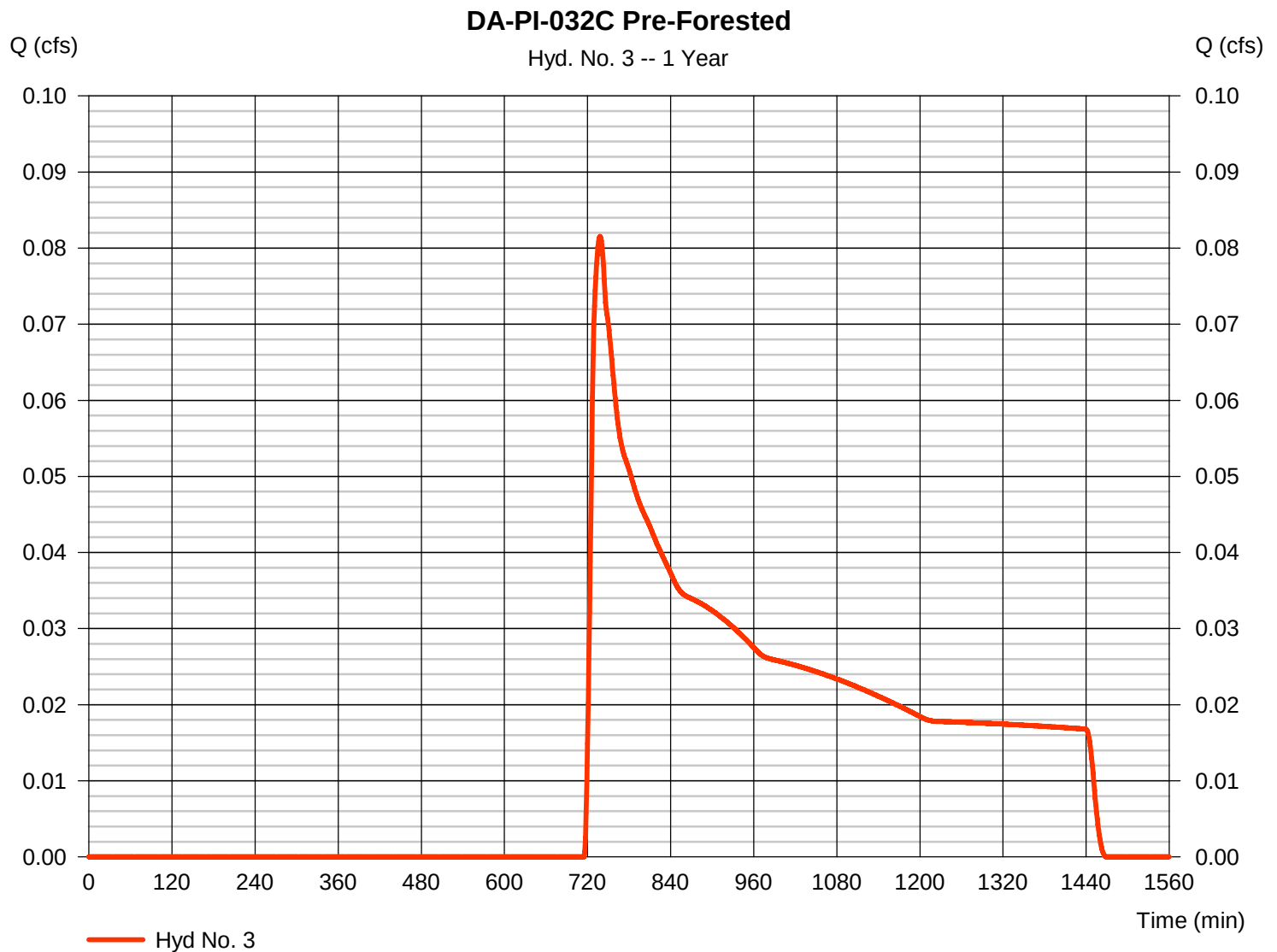
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Saturday, 08 / 19 / 2017

Hyd. No. 3

DA-PI-032C Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 0.082 cfs
Storm frequency	= 1 yrs	Time to peak	= 738 min
Time interval	= 1 min	Hyd. volume	= 1,210 cuft
Drainage area	= 2.330 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 17.20 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(2.330 \times 55)] / 2.330$ 

TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-PI-032C Pre-Forested

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00	
Land slope (%)	= 3.69	0.00	0.00	
Travel Time (min)	= 16.07	+ 0.00	+ 0.00	= 16.07
Shallow Concentrated Flow				
Flow length (ft)	= 353.67	0.00	0.00	
Watercourse slope (%)	= 10.77	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=5.29	0.00	0.00	
Travel Time (min)	= 1.11	+ 0.00	+ 0.00	= 1.11
Channel Flow				
X sectional flow area (sqft)	= 0.00	0.00	0.00	
Wetted perimeter (ft)	= 0.00	0.00	0.00	
Channel slope (%)	= 0.00	0.00	0.00	
Manning's n-value	= 0.030	0.015	0.015	
Velocity (ft/s)	=0.00	0.00	0.00	
Flow length (ft)	(0)0.0	0.0	0.0	
Travel Time (min)	= 0.00	+ 0.00	+ 0.00	= 0.00
Total Travel Time, Tc				17.20 min

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.698	1	727	3,477	-----	-----	-----	DA-PI-032C Pre
2	SCS Runoff	0.488	1	728	2,891	-----	-----	-----	DA-PI-032C Post
3	SCS Runoff	0.488	1	728	2,891	-----	-----	-----	DA-PI-032C Pre-Forested
DA-PI-032C.gpw					Return Period: 2 Year			Saturday, 08 / 19 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

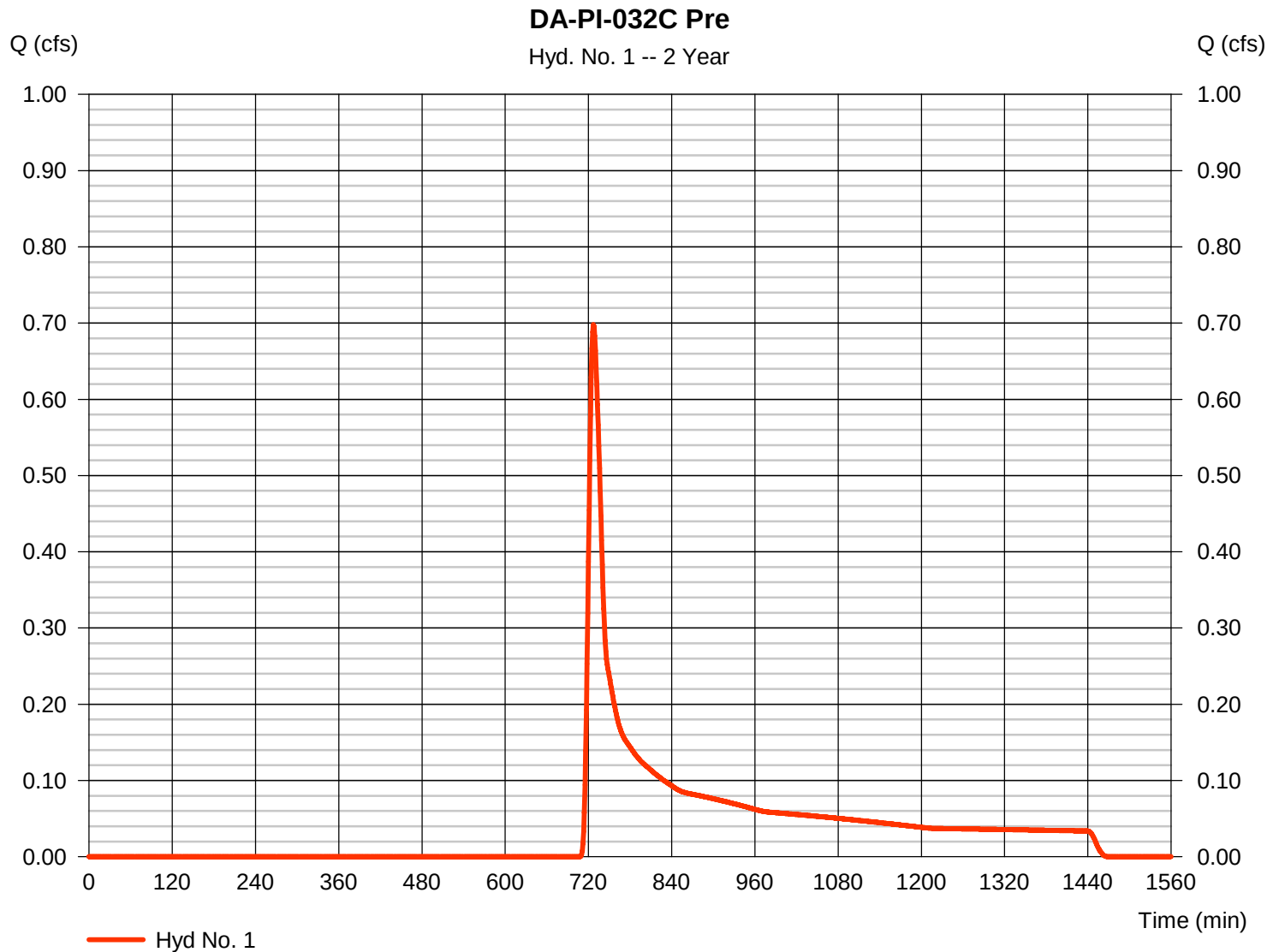
Saturday, 08 / 19 / 2017

Hyd. No. 1

DA-PI-032C Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.698 cfs
Storm frequency	= 2 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 3,477 cuft
Drainage area	= 2.330 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 17.20 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.310 \times 55) + (1.000 \times 58) + (0.020 \times 98)] / 2.330$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

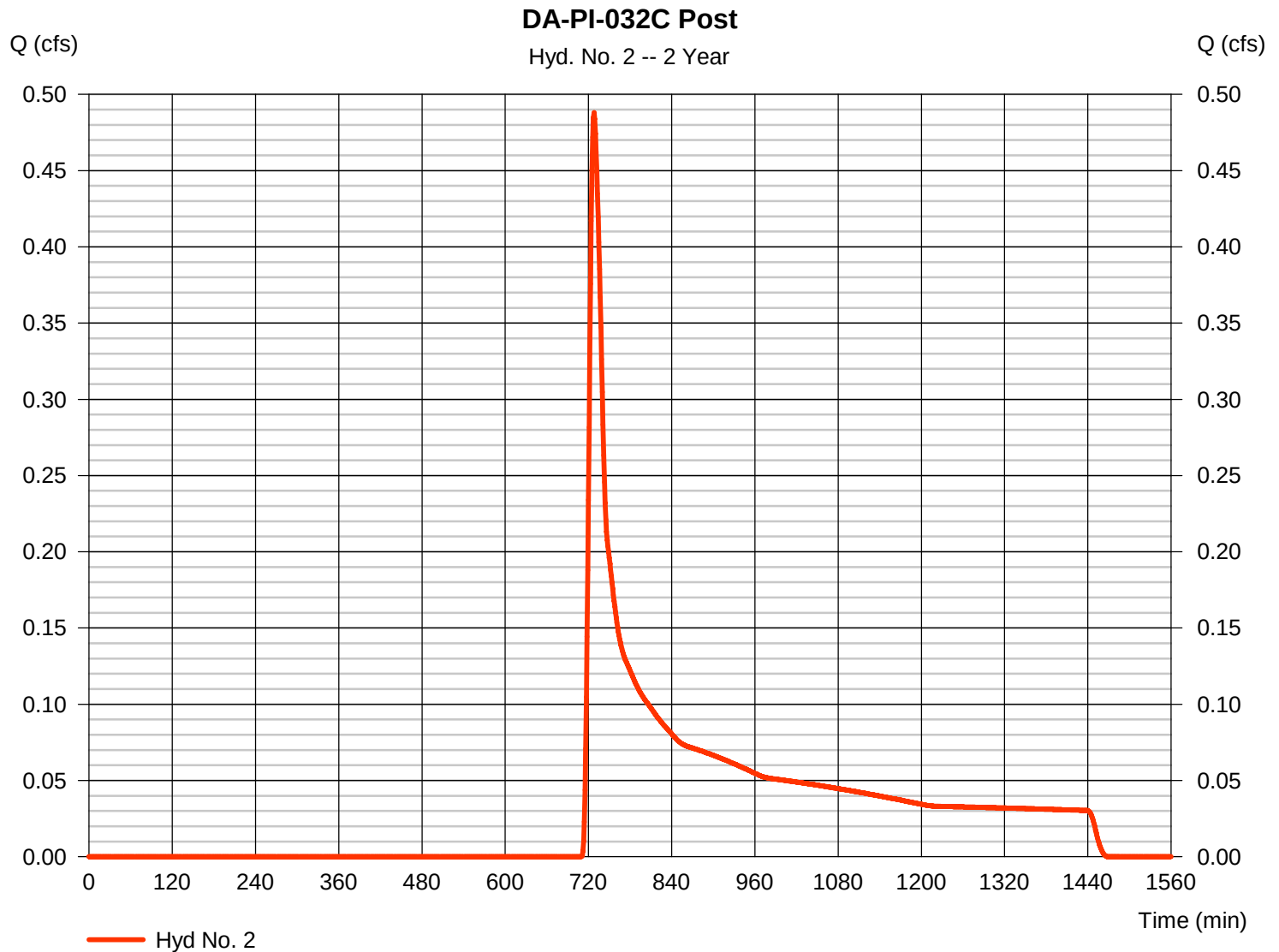
Saturday, 08 / 19 / 2017

Hyd. No. 2

DA-PI-032C Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.488 cfs
Storm frequency	= 2 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 2,891 cuft
Drainage area	= 2.330 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 17.20 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.210 \times 55) + (1.430 \times 58) + (0.020 \times 98) + (0.670 \times 48)] / 2.330$



Hydrograph Report

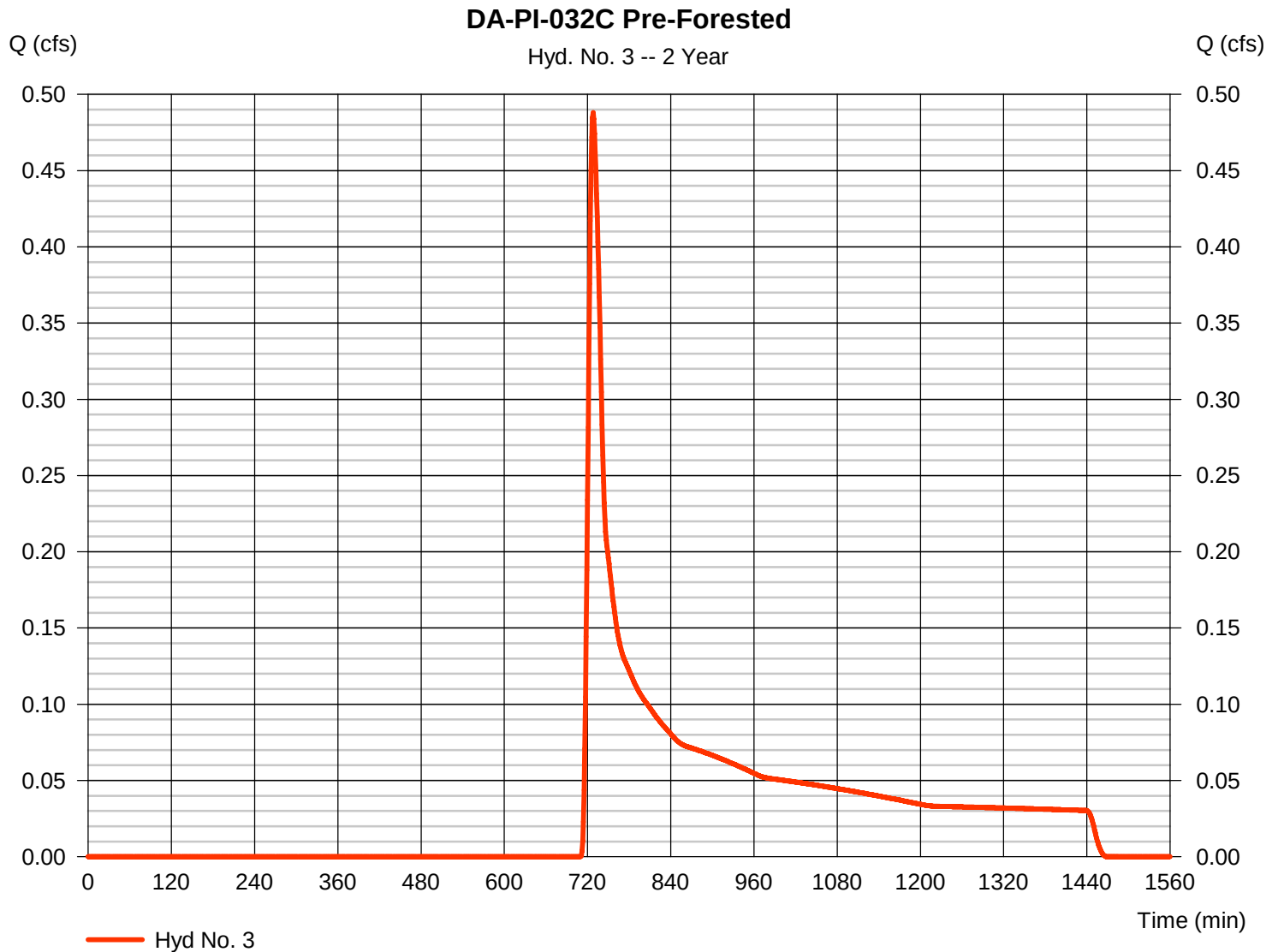
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Saturday, 08 / 19 / 2017

Hyd. No. 3

DA-PI-032C Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 0.488 cfs
Storm frequency	= 2 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 2,891 cuft
Drainage area	= 2.330 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 17.20 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(2.330 \times 55)] / 2.330$ 

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	3.012	1	725	10,141	-----	-----	-----	DA-PI-032C Pre
2	SCS Runoff	2.568	1	726	9,041	-----	-----	-----	DA-PI-032C Post
3	SCS Runoff	2.568	1	726	9,041	-----	-----	-----	DA-PI-032C Pre-Forested
DA-PI-032C.gpw					Return Period: 10 Year			Saturday, 08 / 19 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

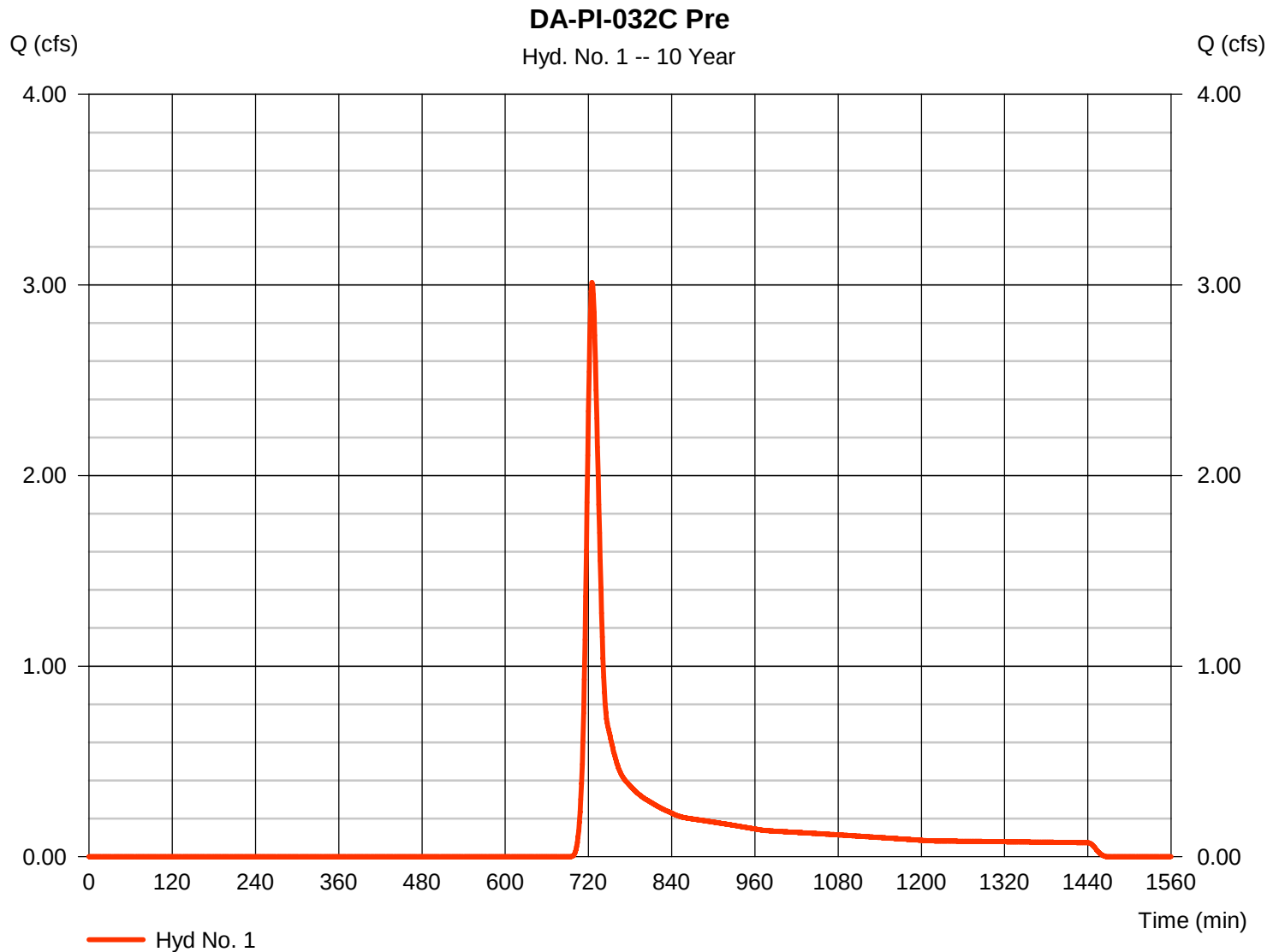
Saturday, 08 / 19 / 2017

Hyd. No. 1

DA-PI-032C Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 3.012 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 10,141 cuft
Drainage area	= 2.330 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 17.20 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.310 \times 55) + (1.000 \times 58) + (0.020 \times 98)] / 2.330$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

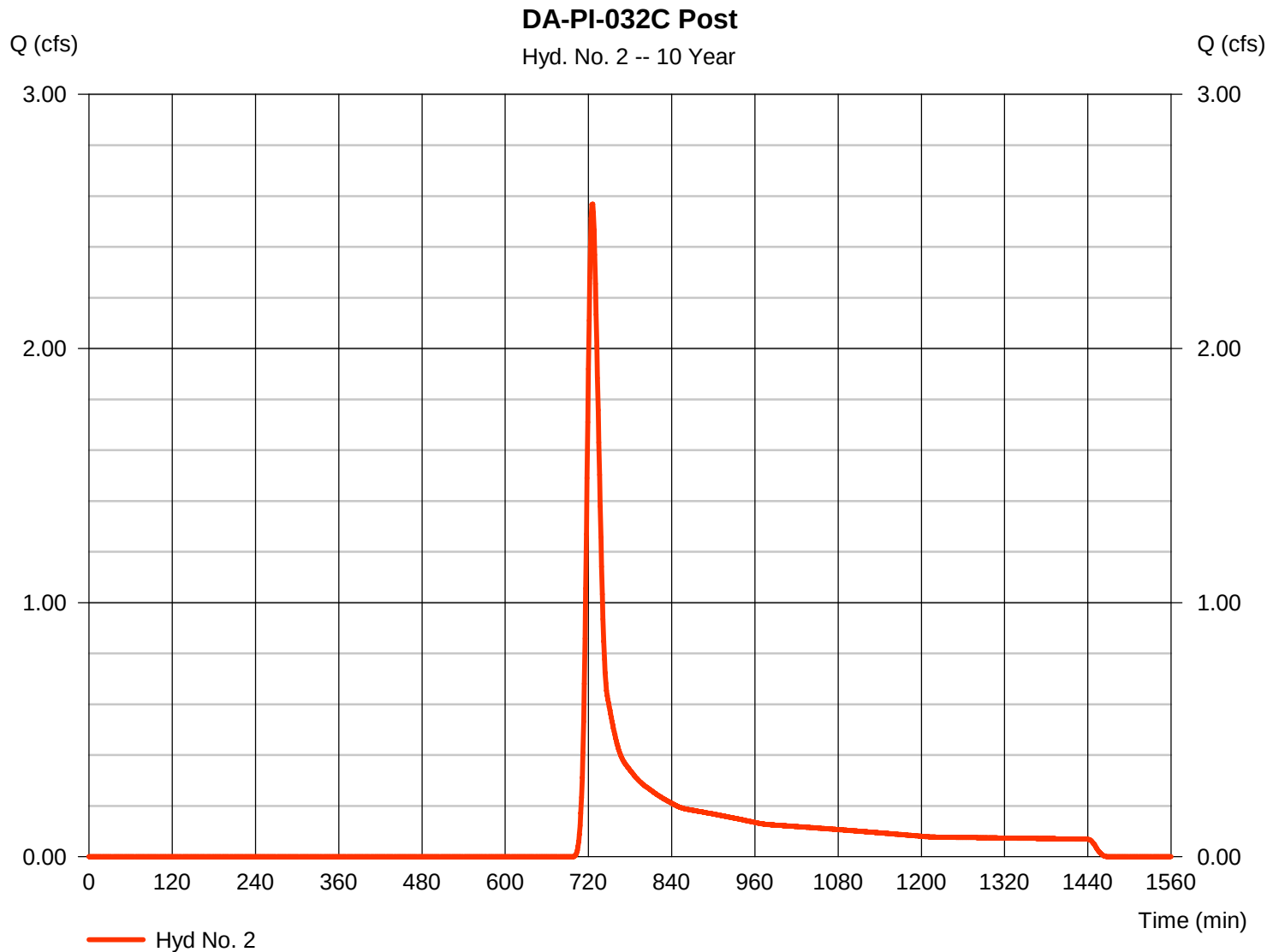
Saturday, 08 / 19 / 2017

Hyd. No. 2

DA-PI-032C Post

Hydrograph type	= SCS Runoff	Peak discharge	= 2.568 cfs
Storm frequency	= 10 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 9,041 cuft
Drainage area	= 2.330 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 17.20 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.210 \times 55) + (1.430 \times 58) + (0.020 \times 98) + (0.670 \times 48)] / 2.330$



Hydrograph Report

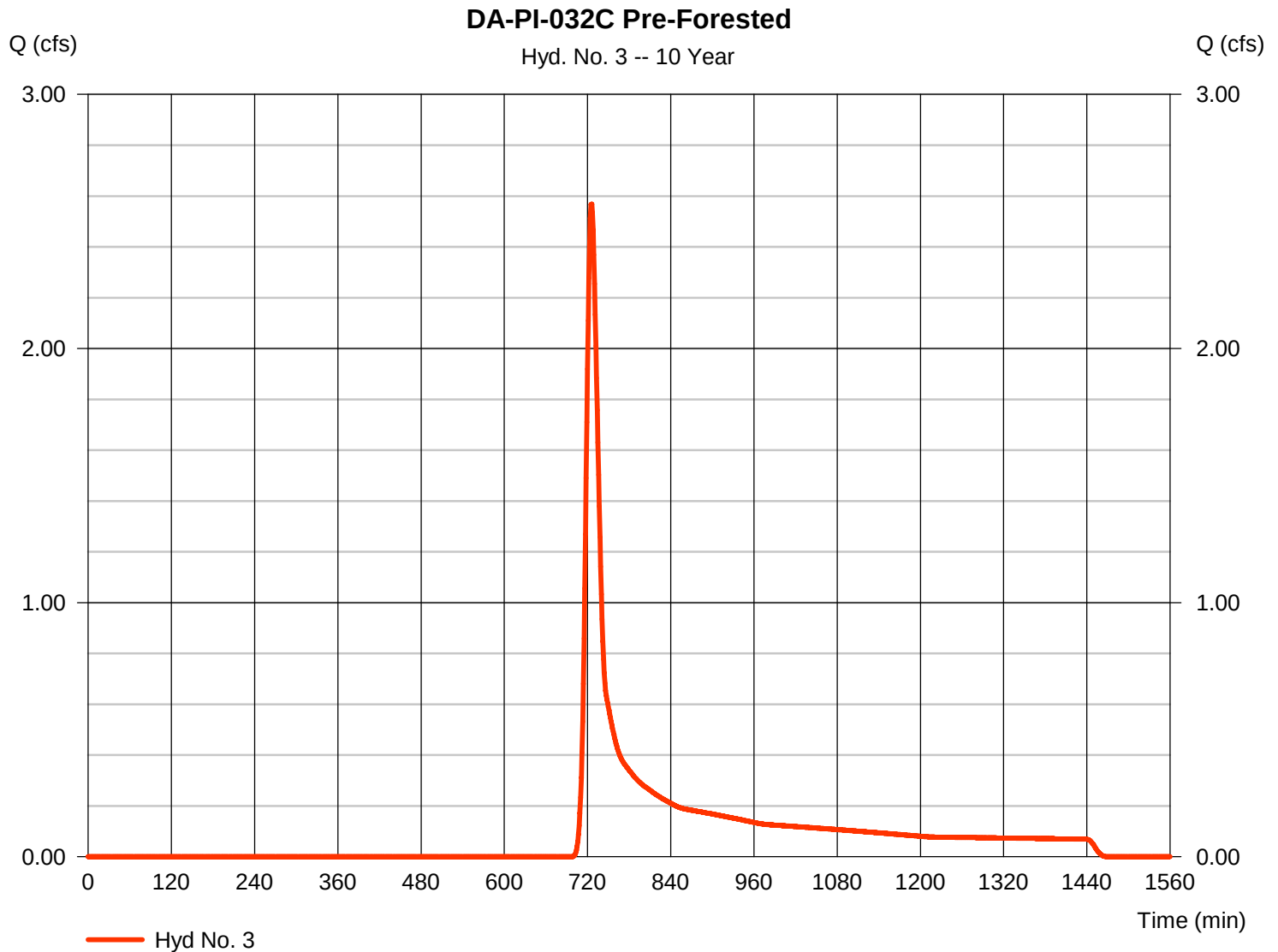
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Saturday, 08 / 19 / 2017

Hyd. No. 3

DA-PI-032C Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	2.568 cfs
Storm frequency	=	10 yrs	Time to peak	=	726 min
Time interval	=	1 min	Hyd. volume	=	9,041 cuft
Drainage area	=	2.330 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	17.20 min
Total precip.	=	5.20 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(2.330 \times 55)] / 2.330$ 

DA-PI-032D

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.038	541
Developed Condition	0.018	398
Pre-Developed (Forest) Condition	0.038	541

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1:

$$Q_{\text{developed}} \leq IF \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}] \text{ ----->}$$

Q (cfs)

0.018

≤

Q (cfs)

0.041

N/A - See Check #3

Check #2:

$$Q_{\text{developed}} \leq Q_{\text{pre-developed}} \text{ ----->}$$

0.018

≤

0.038

N/A - See Check #3

Check #3:

$$Q_{\text{developed}} \text{ shall not be required to be } \leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}} \text{ --->}$$

0.018

shall not be required to be ≤

0.052

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning's n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<i>Note:</i> Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted. ¹For Paved Road land surface types a Manning's n of 0.011 was used <i>Sources:</i> -USACE, 1998, HEC-1 Flood Hydrograph Package User's Manual, Hydrologic Engineering Center, Davis, CA -Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC	

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

1



2



3



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-PI-032D Pre
2	SCS Runoff	DA-PI-032D Post
3	SCS Runoff	DA-PI-032D Pre-Forested

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.038	1	733	541	-----	-----	-----	DA-PI-032D Pre
2	SCS Runoff	0.018	1	748	398	-----	-----	-----	DA-PI-032D Post
3	SCS Runoff	0.038	1	733	541	-----	-----	-----	DA-PI-032D Pre-Forested
DA-PI-032D.gpw					Return Period: 1 Year			Sunday, 08 / 20 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

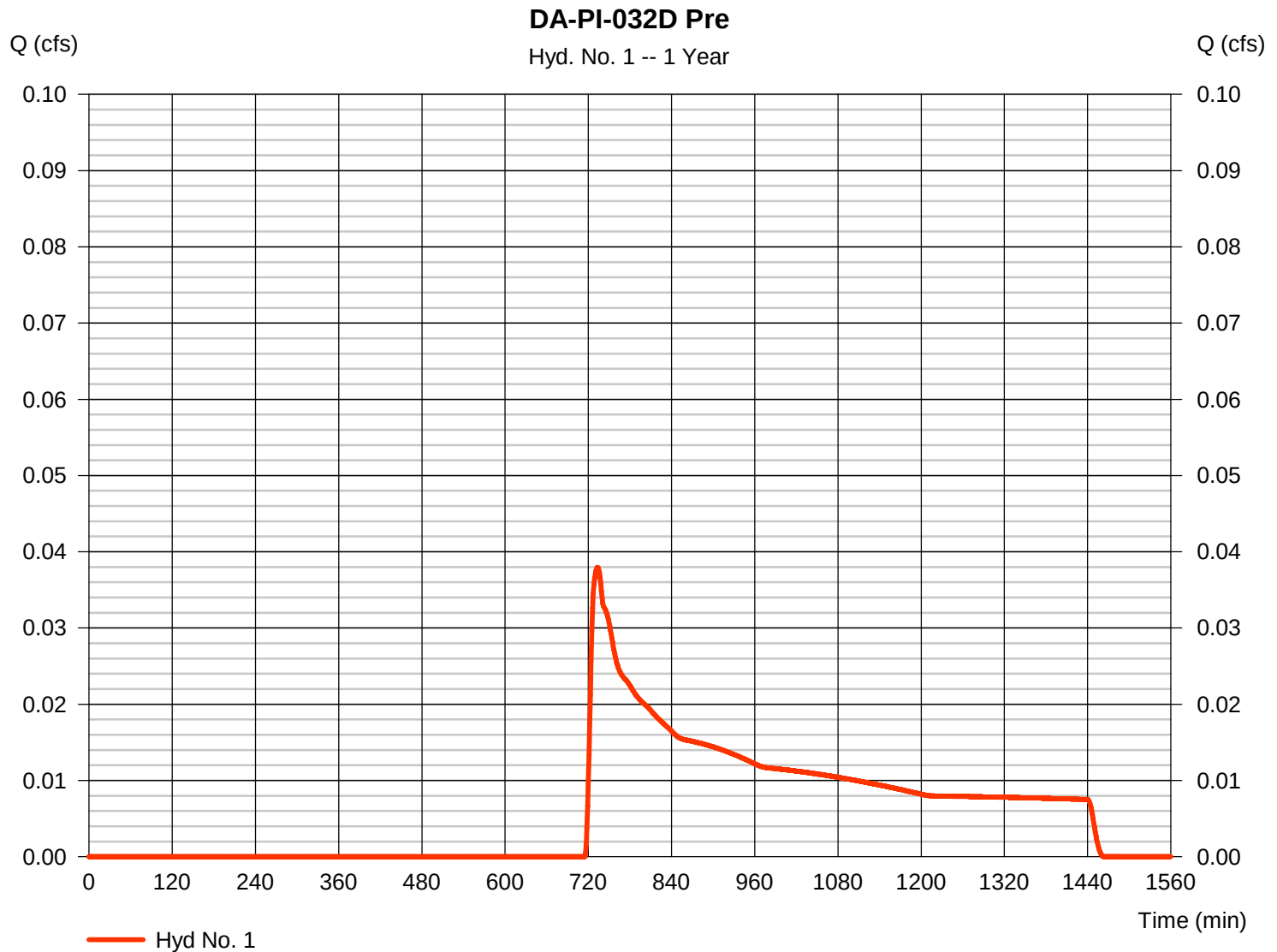
Sunday, 08 / 20 / 2017

Hyd. No. 1

DA-PI-032D Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.038 cfs
Storm frequency	= 1 yrs	Time to peak	= 733 min
Time interval	= 1 min	Hyd. volume	= 541 cuft
Drainage area	= 1.030 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.70 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.010 \times 55) + (0.020 \times 58)] / 1.030$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-PI-032D Pre

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00	
Land slope (%)	= 5.56	0.00	0.00	
Travel Time (min)	= 13.64	+	0.00	+
			0.00	= 13.64
Shallow Concentrated Flow				
Flow length (ft)	= 279.07	0.00	0.00	
Watercourse slope (%)	= 7.70	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=4.48	0.00	0.00	
Travel Time (min)	= 1.04	+	0.00	+
			0.00	= 1.04
Channel Flow				
X sectional flow area (sqft)	= 0.00	0.00	0.00	
Wetted perimeter (ft)	= 0.00	0.00	0.00	
Channel slope (%)	= 0.00	0.00	0.00	
Manning's n-value	= 0.030	0.015	0.015	
Velocity (ft/s)	=0.00	0.00	0.00	
Flow length (ft)	(0)0.0	0.0	0.0	
Travel Time (min)	= 0.00	+	0.00	+
			0.00	= 0.00
Total Travel Time, Tc				14.70 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

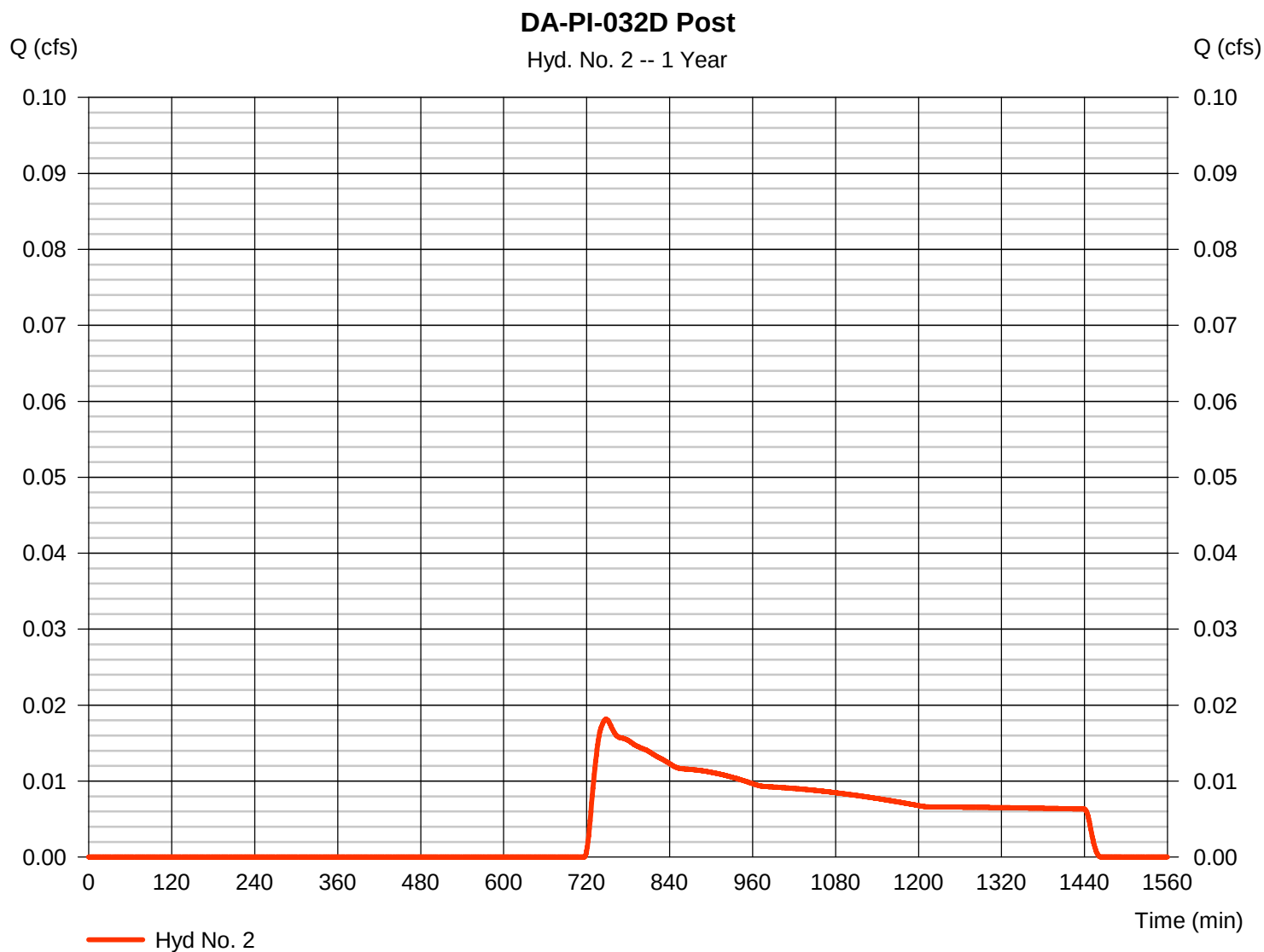
Sunday, 08 / 20 / 2017

Hyd. No. 2

DA-PI-032D Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.018 cfs
Storm frequency	= 1 yrs	Time to peak	= 748 min
Time interval	= 1 min	Hyd. volume	= 398 cuft
Drainage area	= 1.030 ac	Curve number	= 53*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.70 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.210 \times 55) + (0.410 \times 58) + (0.410 \times 48)] / 1.030$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-PI-032D Post

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00	
Land slope (%)	= 5.56	0.00	0.00	
Travel Time (min)	= 13.64	+	0.00	+
			0.00	= 13.64
Shallow Concentrated Flow				
Flow length (ft)	= 279.07	0.00	0.00	
Watercourse slope (%)	= 7.70	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=4.48	0.00	0.00	
Travel Time (min)	= 1.04	+	0.00	+
			0.00	= 1.04
Channel Flow				
X sectional flow area (sqft)	= 0.00	0.00	0.00	
Wetted perimeter (ft)	= 0.00	0.00	0.00	
Channel slope (%)	= 0.00	0.00	0.00	
Manning's n-value	= 0.040	0.015	0.015	
Velocity (ft/s)	=0.00	0.00	0.00	
Flow length (ft)	(0)0.0	0.0	0.0	
Travel Time (min)	= 0.00	+	0.00	+
			0.00	= 0.00
Total Travel Time, Tc				14.70 min

Hydrograph Report

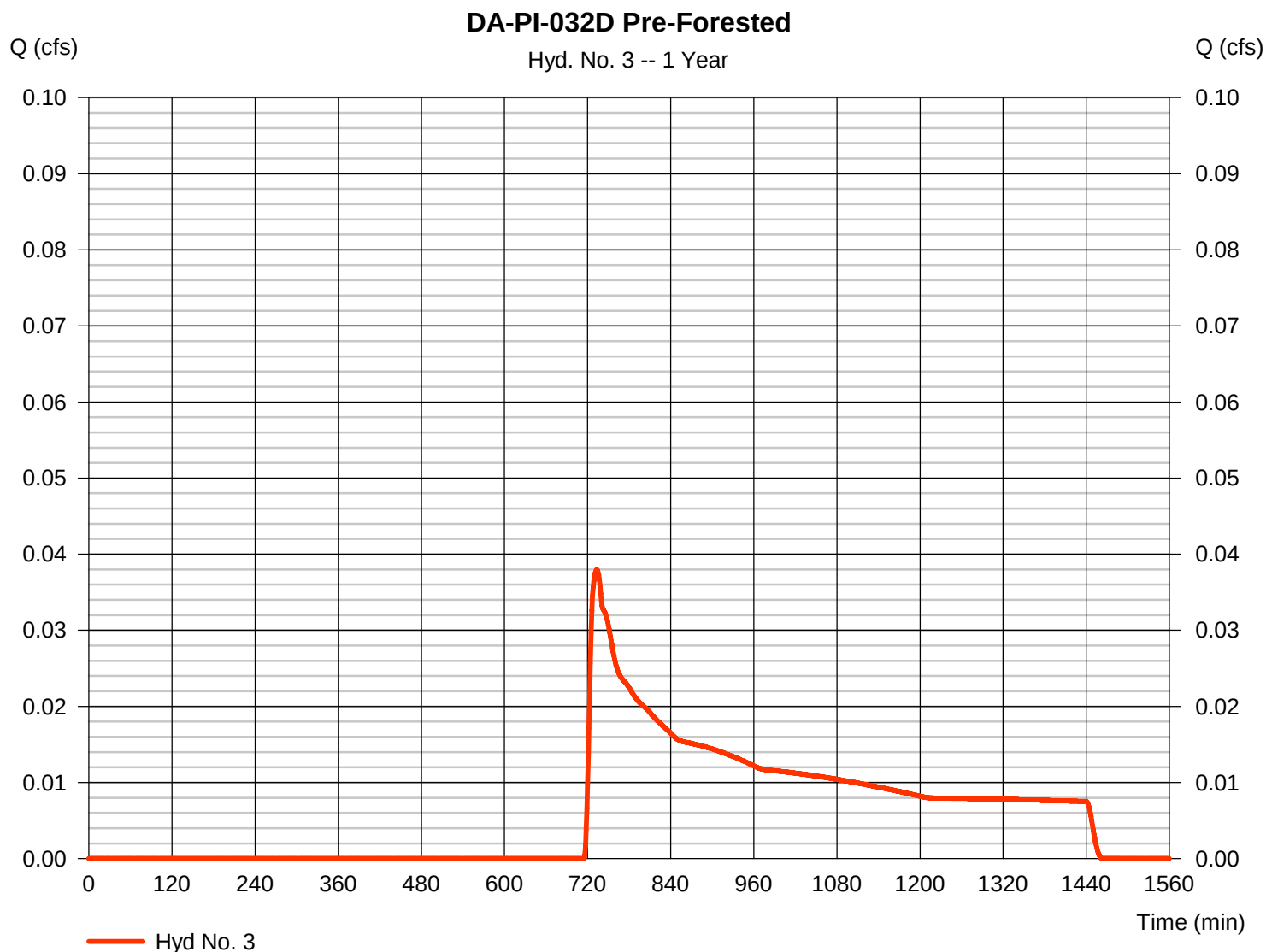
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Sunday, 08 / 20 / 2017

Hyd. No. 3

DA-PI-032D Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 0.038 cfs
Storm frequency	= 1 yrs	Time to peak	= 733 min
Time interval	= 1 min	Hyd. volume	= 541 cuft
Drainage area	= 1.030 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.70 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.030 \times 55)] / 1.030$ 

TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-PI-032D Pre-Forested

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.011	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00	
Land slope (%)	= 5.56	0.00	0.00	
Travel Time (min)	= 13.64	+ 0.00	+ 0.00	= 13.64
Shallow Concentrated Flow				
Flow length (ft)	= 279.07	0.00	0.00	
Watercourse slope (%)	= 7.70	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=4.48	0.00	0.00	
Travel Time (min)	= 1.04	+ 0.00	+ 0.00	= 1.04
Channel Flow				
X sectional flow area (sqft)	= 0.00	0.00	0.00	
Wetted perimeter (ft)	= 0.00	0.00	0.00	
Channel slope (%)	= 0.00	0.00	0.00	
Manning's n-value	= 0.030	0.015	0.015	
Velocity (ft/s)	=0.00	0.00	0.00	
Flow length (ft)	(0)0.0	0.0	0.0	
Travel Time (min)	= 0.00	+ 0.00	+ 0.00	= 0.00
Total Travel Time, Tc				14.70 min

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.247	1	726	1,293	-----	-----	-----	DA-PI-032D Pre
2	SCS Runoff	0.157	1	726	1,052	-----	-----	-----	DA-PI-032D Post
3	SCS Runoff	0.247	1	726	1,293	-----	-----	-----	DA-PI-032D Pre-Forested
DA-PI-032D.gpw					Return Period: 2 Year			Sunday, 08 / 20 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

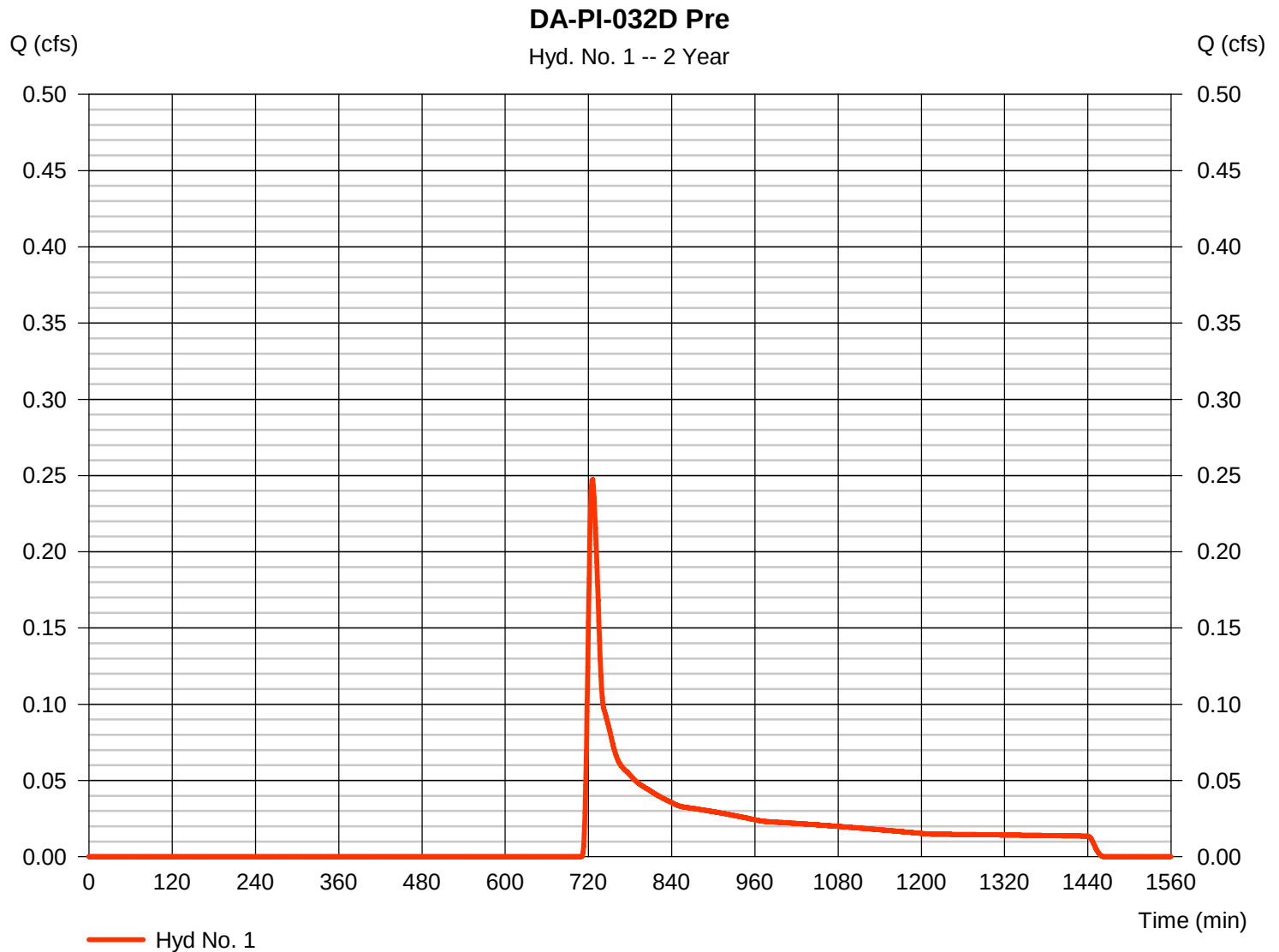
Sunday, 08 / 20 / 2017

Hyd. No. 1

DA-PI-032D Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.247 cfs
Storm frequency	= 2 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 1,293 cuft
Drainage area	= 1.030 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.70 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.010 \times 55) + (0.020 \times 58)] / 1.030$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

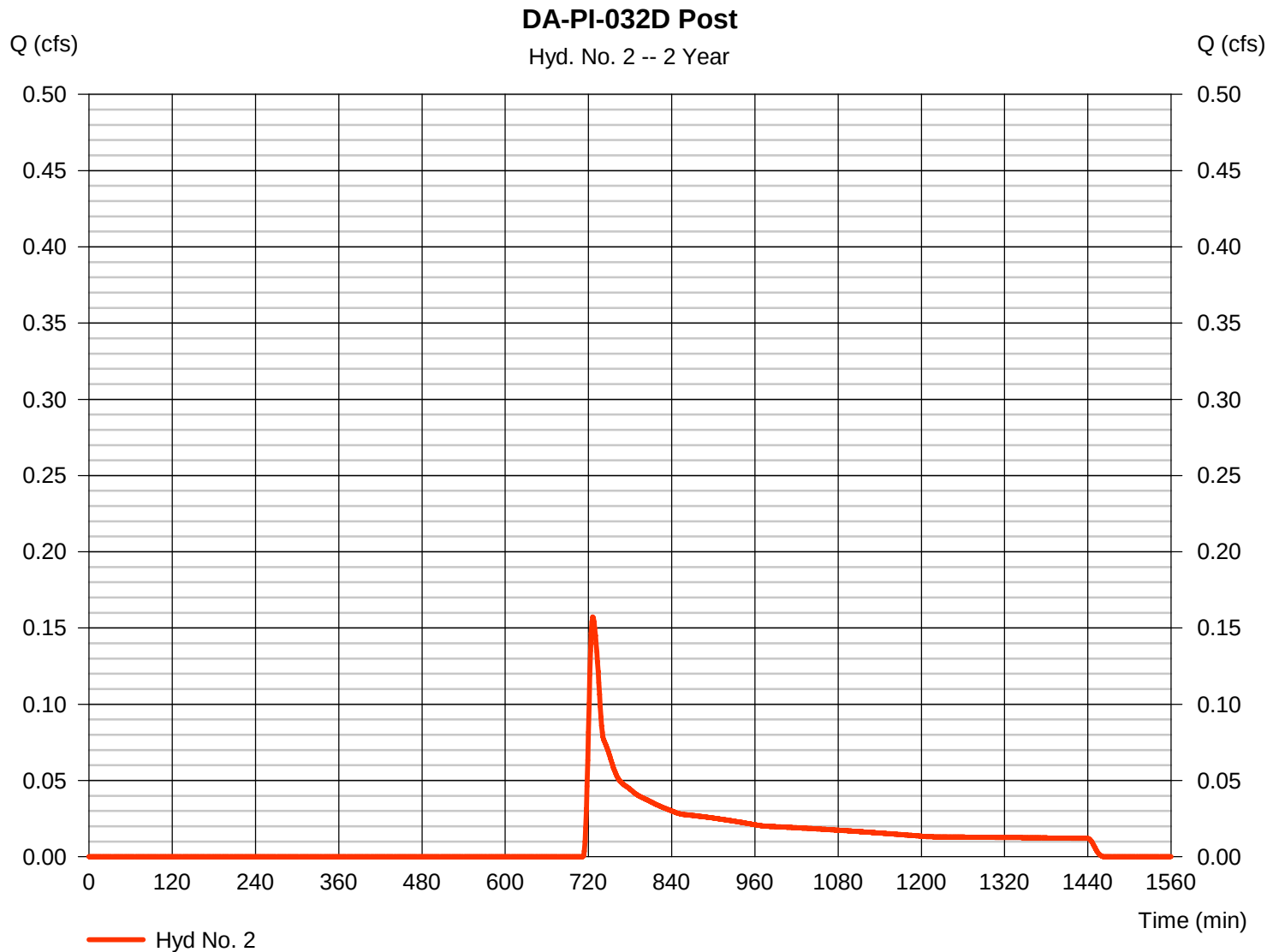
Sunday, 08 / 20 / 2017

Hyd. No. 2

DA-PI-032D Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.157 cfs
Storm frequency	= 2 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 1,052 cuft
Drainage area	= 1.030 ac	Curve number	= 53*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.70 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.210 \times 55) + (0.410 \times 58) + (0.410 \times 48)] / 1.030$



Hydrograph Report

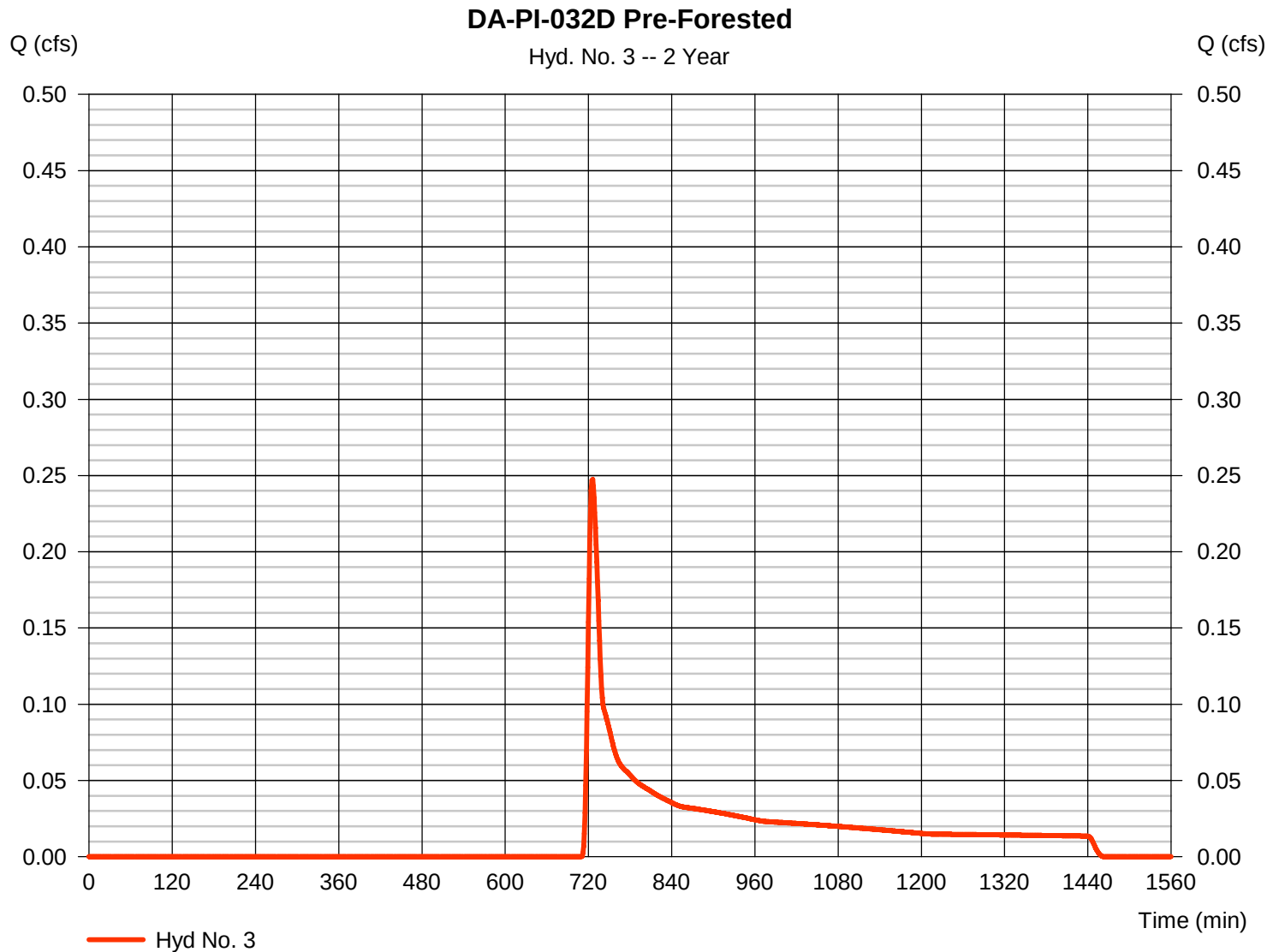
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Sunday, 08 / 20 / 2017

Hyd. No. 3

DA-PI-032D Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.247 cfs
Storm frequency	=	2 yrs	Time to peak	=	726 min
Time interval	=	1 min	Hyd. volume	=	1,293 cuft
Drainage area	=	1.030 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	14.70 min
Total precip.	=	3.50 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(1.030 \times 55)] / 1.030$ 

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	1.293	1	723	4,043	-----	-----	-----	DA-PI-032D Pre
2	SCS Runoff	1.083	1	724	3,570	-----	-----	-----	DA-PI-032D Post
3	SCS Runoff	1.293	1	723	4,043	-----	-----	-----	DA-PI-032D Pre-Forested
DA-PI-032D.gpw					Return Period: 10 Year			Sunday, 08 / 20 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

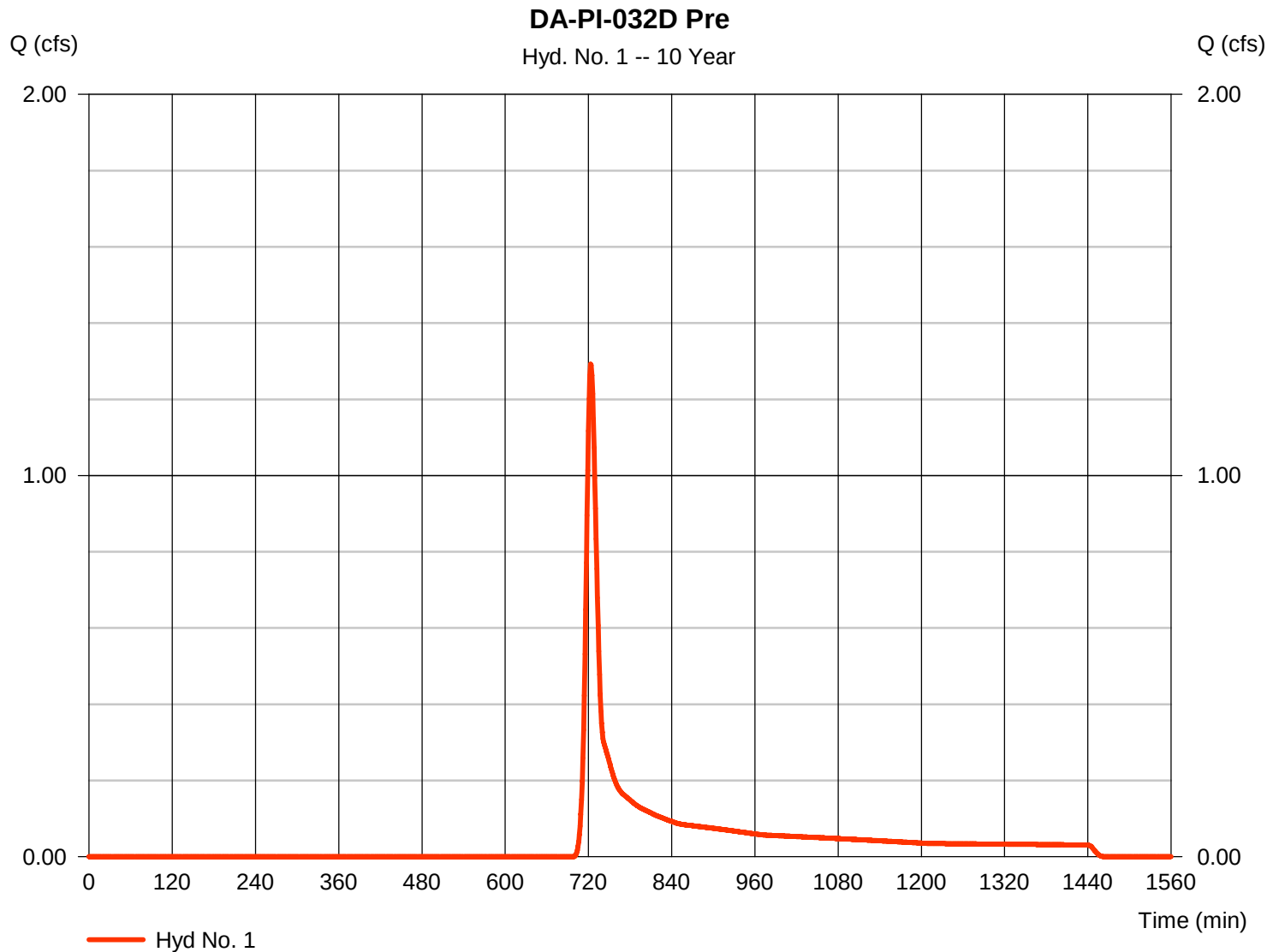
Sunday, 08 / 20 / 2017

Hyd. No. 1

DA-PI-032D Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 1.293 cfs
Storm frequency	= 10 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 4,043 cuft
Drainage area	= 1.030 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.70 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.010 \times 55) + (0.020 \times 58)] / 1.030$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

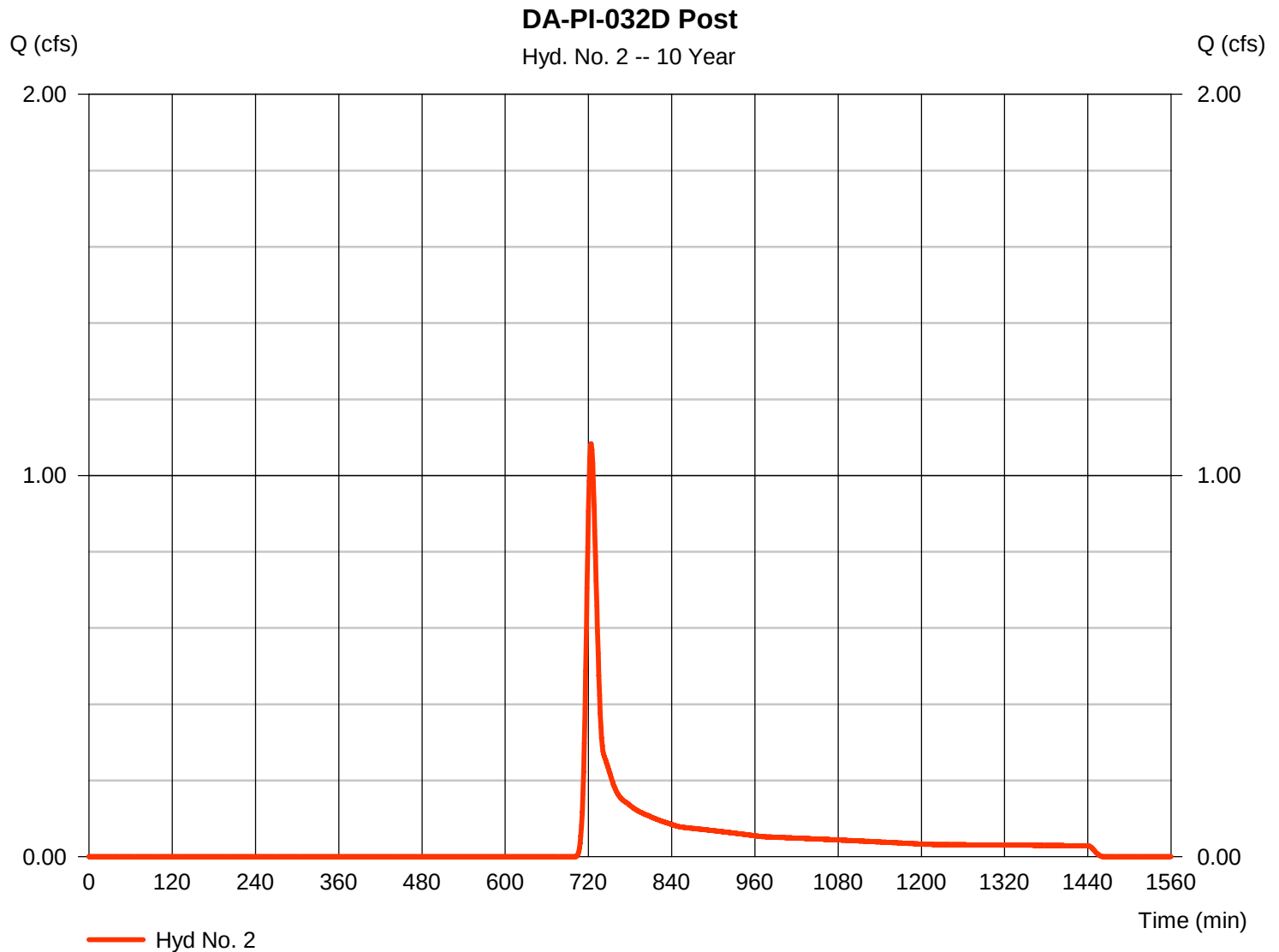
Sunday, 08 / 20 / 2017

Hyd. No. 2

DA-PI-032D Post

Hydrograph type	= SCS Runoff	Peak discharge	= 1.083 cfs
Storm frequency	= 10 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 3,570 cuft
Drainage area	= 1.030 ac	Curve number	= 53*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.70 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.210 \times 55) + (0.410 \times 58) + (0.410 \times 48)] / 1.030$



Hydrograph Report

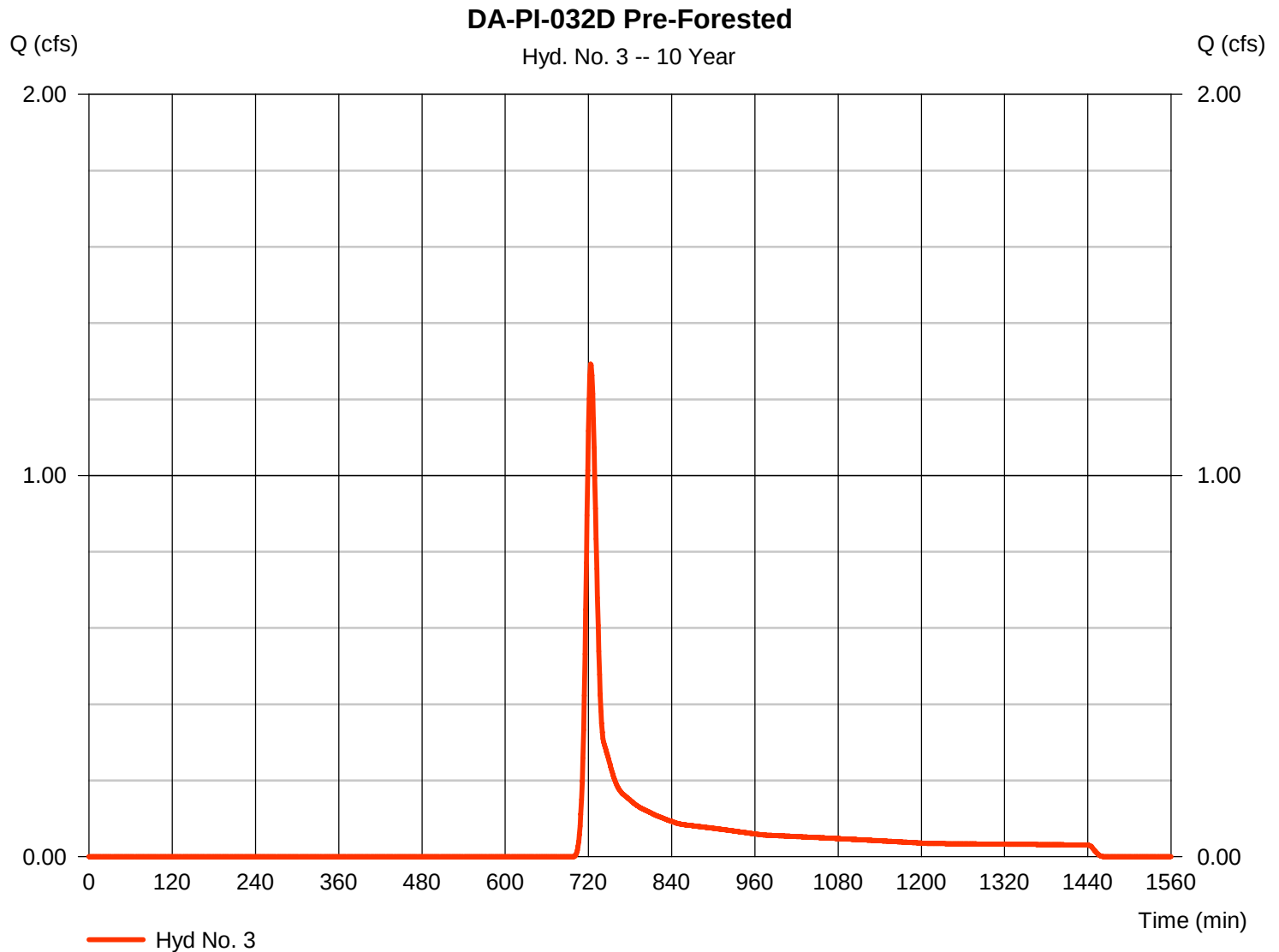
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Sunday, 08 / 20 / 2017

Hyd. No. 3

DA-PI-032D Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 1.293 cfs
Storm frequency	= 10 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 4,043 cuft
Drainage area	= 1.030 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.70 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(1.030 \times 55)] / 1.030$ 

DA-PI-033

DA-PI-033 is located in a meadow and forested area with undulating slopes. DA-PI-033 is bisected by Pole Bridge Branch and contains existing gravel area, including Anderson Mill Road. New gravel area is proposed at the northern portion of the drainage area within DA-PI-033 where there is a Mainline Valve (MLV) site. There is also a gravel area that serves as a permanent access road to the MLV site leading from the existing Anderson Mill Road. Total post-project gravel area will cover less than 2% of the overall drainage area. Multiple points of analysis were evaluated within DA-PI-033 to determine the effects on each receiving stream/channel following construction. Specifically, DA-PI-033 was sub-divided into five sub-drainage areas (sub-areas A through E). Sub-area DA-PI-033A and DA-PI-033E contain agricultural area within the limits of disturbance (LOD).

Pre-construction agricultural areas will be returned to agricultural land use (i.e., returned to crop production, in identical condition) following construction, but in non-agricultural areas, land use will be restored following construction as noted in the Stormwater Management (SWM) Narrative and the Annual Standards and Specifications. Agricultural areas within the LOD are included in the SWM quality analysis and the total permanent ROW is analyzed via VRRM; in these calculations agricultural areas are considered "Forest/Open Space". The total phosphorus load reduction required for DA-PI-033 is -0.68 lbs/yr.

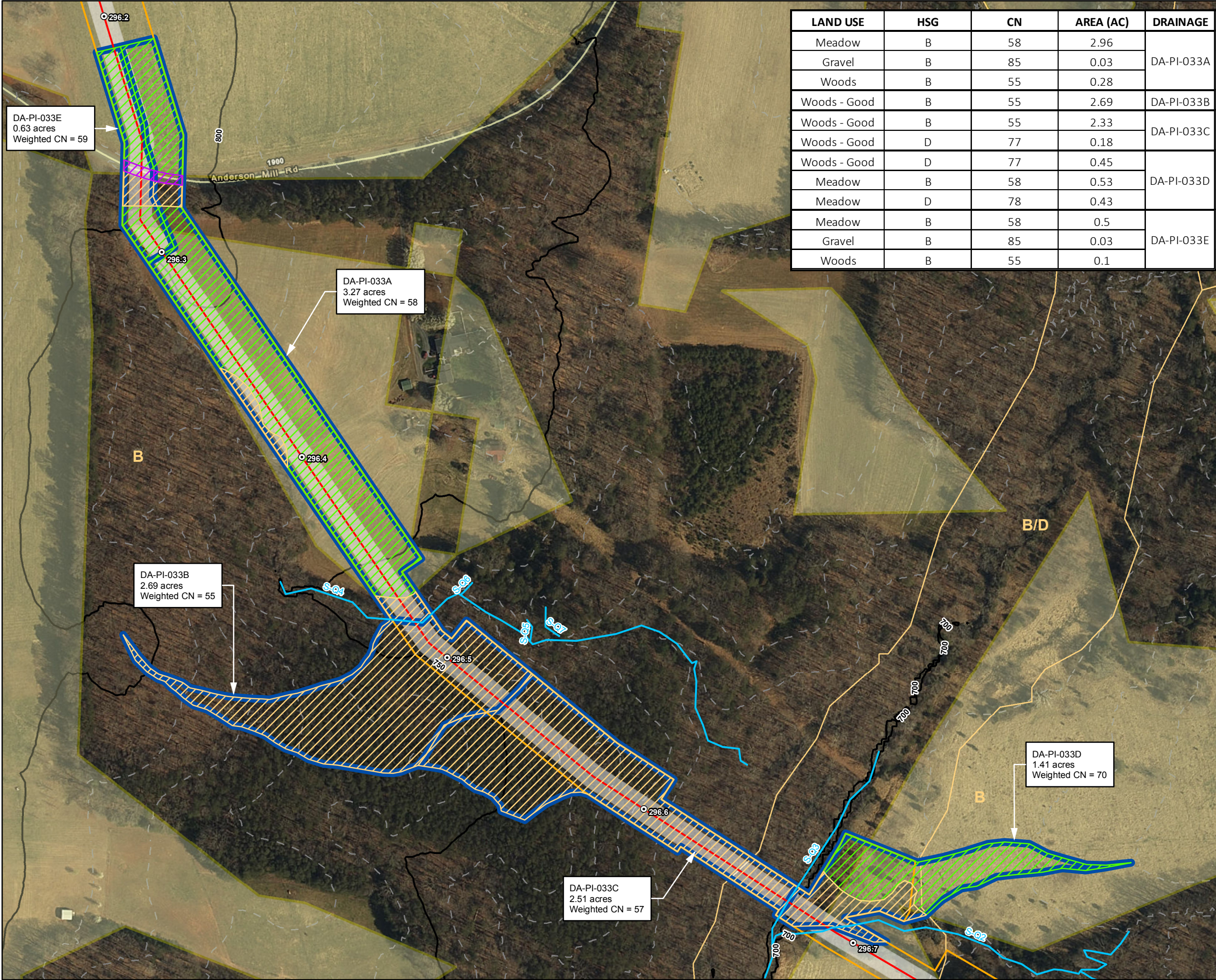
Stormwater quantity is met via the energy balance method for each of the sub-areas - DA-PI-033A, DA-PI-033B, DA-PI-033C, and DA-PI-033D – and a 48 ft by 48 ft gap graded gravel area in sub-area DA-PI-033E (see General Detail MVP-ES33 for a full schedule). Agricultural areas within the study area are included in the SWM quantity analysis, but an improvement factor of 1.00 is used when applying the energy balance method. This improvement factor is used to account for the exemption of agricultural areas (§ 62.1- 44.15:34 and 9VAC25-870-300) since such areas will be returned to agricultural land use (i.e., returned to crop production, in identical condition) following construction.

In addition, the Hydraflow hydrographs 10-year 24-hour peak discharge results indicate a 0.25 cfs increase in flows in sub-area DA-PI-033E and an overall decrease in flows ranging from 0.00 cfs to 0.55 cfs for the remaining drainage sub-areas (as seen in table below). The increase in 10-yr peak flow in sub-area DA-PI-033E will have little/no impact on flood stage in the downstream channel.

Sub-area	Pre-peak Flow, 10-yr Q (cfs)	Post-peak Flow, 10-yr Q (cfs)	Flow Differential
DA-PI-033A	4.55	4.55	0.00
DA-PI-033B	3.18	2.91	-0.27

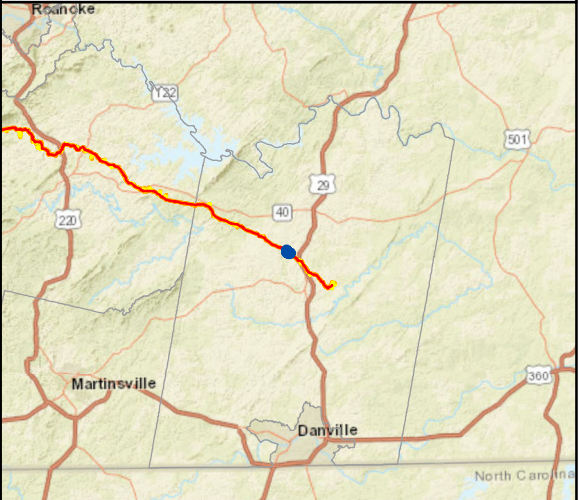
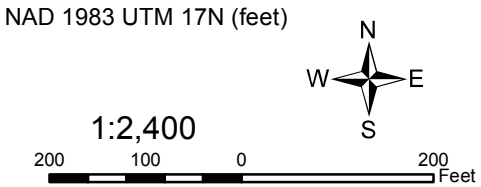
DA-PI-033C	3.91	3.36	-0.55
DA-PI-033D	3.69	3.54	-0.15
DA-PI-033E	0.80	1.05	0.25

Figures and calculations for DA-PI-033 follow. See Appendix D of the Annual Standards and Specifications for further detail on stormwater methodology.



LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Meadow	B	58	2.96	DA-PI-033A
Gravel	B	85	0.03	
Woods	B	55	0.28	
Woods - Good	B	55	2.69	DA-PI-033B
Woods - Good	B	55	2.33	DA-PI-033C
Woods - Good	D	77	0.18	
Woods - Good	D	77	0.45	DA-PI-033D
Meadow	B	58	0.53	
Meadow	D	78	0.43	
Meadow	B	58	0.5	DA-PI-033E
Gravel	B	85	0.03	
Woods	B	55	0.1	

- Legend**
- Milepost
 - Delineated Stream
 - Existing 50' Contour
 - - Existing 10' Contour
 - Road Centerline
 - Alignment Centerline
 - Limit of Disturbance
 - Gravel
 - Meadow
 - Woods
 - Agricultural Area
 - Drainage Area
 - Permanent Right-of-Way
 - Hydrologic Soil Groups



Mountain Valley Pipeline Project

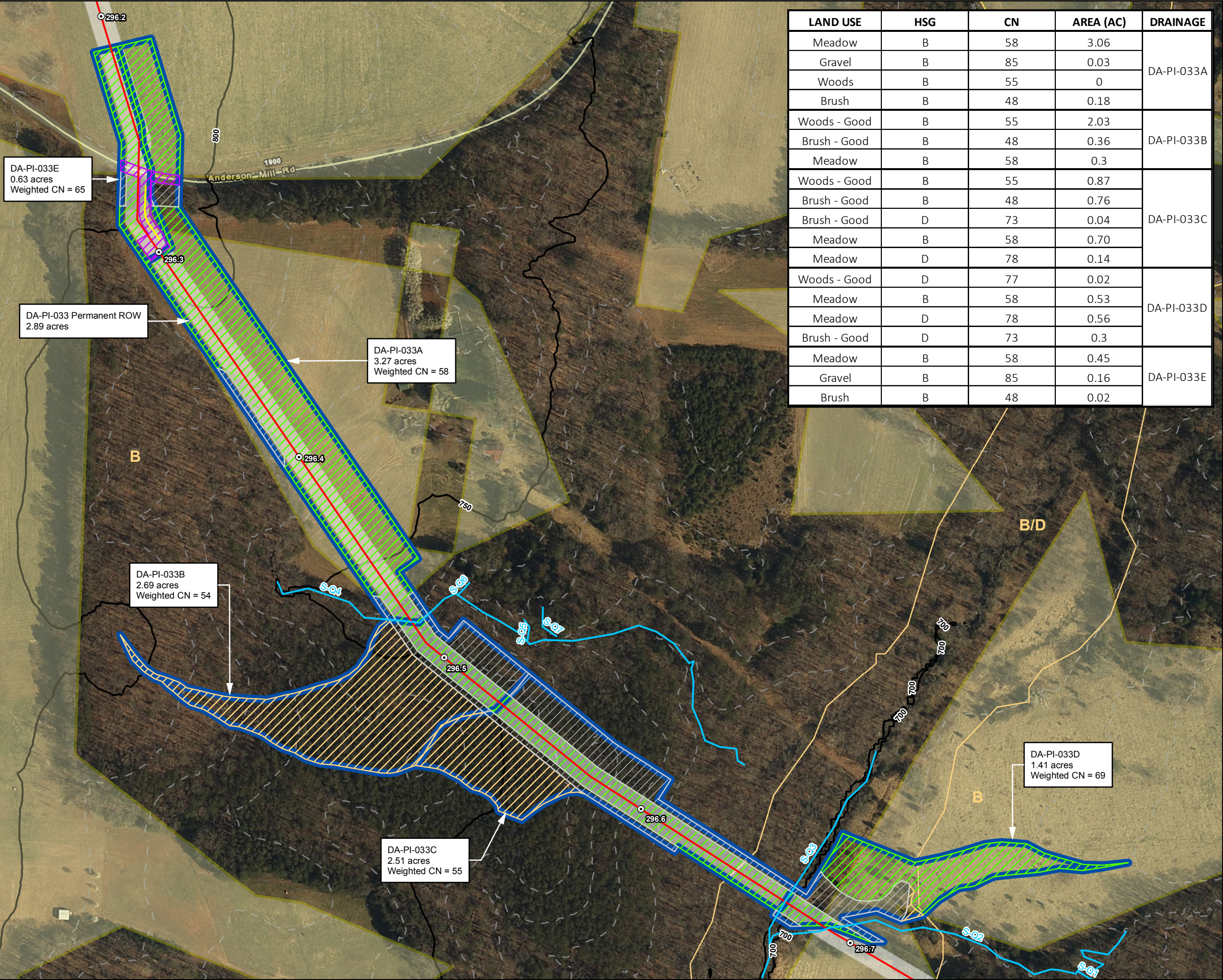


**Pre-Construction Drainage Area Map
DA-PI-033
Spread 11**

Figure 1
Pittsylvania County, Virginia

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LIDAR provided by EQT 2016, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015, Agricultural Area from National Land Cover Dataset 2011.



LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Meadow	B	58	3.06	DA-PI-033A
Gravel	B	85	0.03	
Woods	B	55	0	
Brush	B	48	0.18	
Woods - Good	B	55	2.03	DA-PI-033B
Brush - Good	B	48	0.36	
Meadow	B	58	0.3	
Woods - Good	B	55	0.87	
Brush - Good	B	48	0.76	DA-PI-033C
Brush - Good	D	73	0.04	
Meadow	B	58	0.70	
Meadow	D	78	0.14	
Woods - Good	D	77	0.02	DA-PI-033D
Meadow	B	58	0.53	
Meadow	D	78	0.56	
Brush - Good	D	73	0.3	
Meadow	B	58	0.45	DA-PI-033E
Gravel	B	85	0.16	
Brush	B	48	0.02	

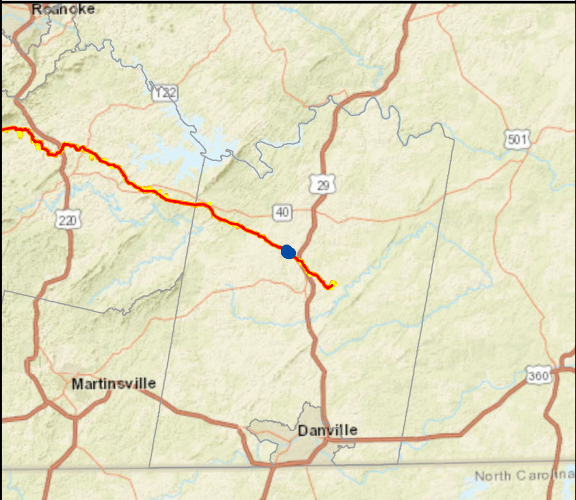
Legend

- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Permanent Right-of-Way
- Brush
- Gravel
- Meadow
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

1:2,400

200 100 0 200 Feet



Mountain Valley Pipeline Project



Post-Construction Drainage Area Map
DA-PI-033
Spread 11

Figure 2
Pittsylvania County, Virginia

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LIDAR provided by EQT 2016, Soils from NRCS Gridded Soil Survey Geographic (SSURGO) database 2014, Land Use digitized from ESRI World Imagery 2015, Agricultural Area from National Land Cover Dataset 2011.

PRE-CONSTRUCTION TIME OF CONCENTRATION TO POI					
	SHEET	SHALLOW1	SHALLOW2	SHALLOW3	Calculated Time of Concentration (min)
DA-PI-033A	100.00 FT @ 4.00%	724.80 FT @ 6.62%	-	-	15.5
DA-PI-033B	100.00 FT @ 5.36%	628.97 FT @ 8.95%	-	-	16.0
DA-PI-033C	100.00 FT @ 11.17%	770.34 FT @ 7.89%	-	-	13.2
DA-PI-033D	100.00 FT @ 4.26%	577.16 FT @ 3.99%	-	-	18.2
DA-PI-033E	100.00 FT @ 2.00%	163.56 FT @ 4.35%	23.46 FT @ 3.75%	163.98 FT @ 5.33%	18.2

Legend

Milepost

Delineated Stream

Existing 50' Contour

Existing 10' Contour

Road Centerline

Alignment Centerline

Limit of Disturbance

Permanent Right-of-Way

Time of Concentration

Drainage Area

NAD 1983 UTM 17N (feet)

1:2,400

200

100

0

200

Feet

N

W

E

S

Mountain Valley Pipeline Project

Mountain Valley

PIPELINE

Pre-Construction Drainage Area and Time of Concentration

DA-PI-033

Spread 11

Figure 3

Pittsylvania County, Virginia

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016.

Document Path: P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Pittsylvania\MVP_PCSM_DA-PI-033_Pre_ToC_HH.mxd

POST-CONSTRUCTION TIME OF CONCENTRATION TO POI							
	SHEET 1	SHEET 2	SHEET 3	SHALLOW1	SHALLOW2	CHANNEL	Calculated Time of Concentration (min)
DA-PI-033A	100.00 FT @ 4.00%	724.80 FT @ 6.62%	5.59 FT @ 5.72%	658.21 FT @ 6.13%	-	-	18.5
DA-PI-033B	100.00 FT @ 5.36%	-	-	628.97 FT @ 8.95%	-	-	16.0
DA-PI-033C	100.00 FT @ 11.17%	-	-	329.64 FT @ 9.19%	450.56 FT @ 6.51%	24.31 FT @ 5.00%	13.3
DA-PI-033D	100.00 FT @ 4.26%	-	-	577.16 FT @ 3.99%	-	-	18.2
DA-PI-033E	100.00 FT @ 2.00%	-	-	163.56 FT @ 4.35%	187.44 FT @ 5.13%	-	22.0

Legend

- Milepost
- Permanent Waterbars
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:2,400

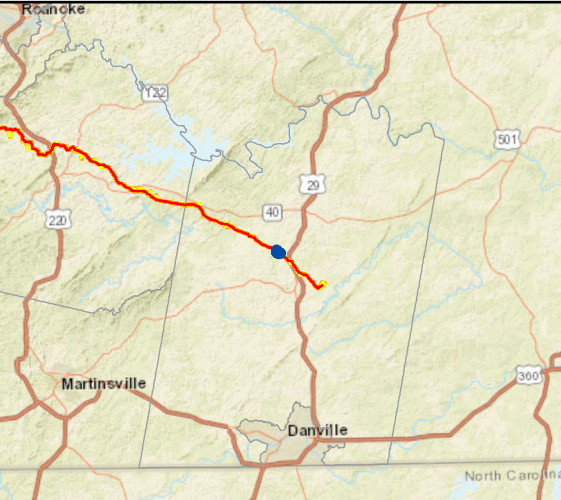
200 100 0 200 Feet

N

W

E

S



Mountain Valley Pipeline Project

Mountain Valley
PIPELINE

Post-Construction Drainage Area and Time of Concentration

DA-PI-033

Spread 11

Figure 4

Pittsylvania County, Virginia

September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Delineated streams surveyed by Tetra Tech Inc. 2014 to 2017, Transportation data from VITA map layer 2016, Elevation data derived from LiDAR provided by EQT 2016.

DA-PI-033E
0.63 acres
Weighted CN = 65

DA-PI-033A
3.27 acres
Weighted CN = 58

DA-PI-033B
2.69 acres
Weighted CN = 54

DA-PI-033D
1.41 acres
Weighted CN = 69

DA-PI-033C
2.51 acres
Weighted CN = 55

DEQ Virginia Runoff Reduction Method Re-Development Compliance Spreadsheet - Version 3.0

BMP Design Specifications List: 2013 Draft Stds & Specs

Site Summary - Linear Development Project***

Total Rainfall (in):	43
Total Disturbed Acreage:	2.89

Site Land Cover Summary

Pre-ReDevelopment Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	% of Total
Forest/Open (acres)	0.00	2.59	0.00	0.27	2.86	99
Managed Turf (acres)	0.00	0.00	0.00	0.00	0.00	0
Impervious Cover (acres)	0.00	0.03	0.00	0.00	0.03	1
					2.89	100

Post-ReDevelopment Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	% of Total
Forest/Open (acres)	0.00	2.48	0.00	0.27	2.75	95
Managed Turf (acres)	0.00	0.00	0.00	0.00	0.00	0
Impervious Cover (acres)	0.00	0.14	0.00	0.00	0.14	5
					2.89	100

* Forest/Open Space areas must be protected in accordance with the Virginia Runoff Reduction Method

Site Tv and Land Cover Nutrient Loads

	Final Post-Development (Post-ReDevelopment & New Impervious)	Post- ReDevelopment	Post- Development (New Impervious)	Adjusted Pre- ReDevelopment
Site Rv	0.08	0.04	0.95	0.04
Treatment Volume (ft ³)	802	423	379	423
TP Load (lb/yr)	0.50	0.27	0.24	0.27

Baseline TP Load (lb/yr): 1.1398* *Reduction below new development load limitation not required

Pre- ReDevelopment TP Load per acre (lb/acre/yr)	Final Post-Development TP Load per acre (lb/acre/yr)	Post-ReDevelopment TP Load per acre (lb/acre/yr)
0.10	0.17	0.10

Total TP Load Reduction Required (lb/yr)	-0.68	N/A***	N/A***
--	-------	--------	--------

***This is a linear development project

	Final Post-Development Load (Post-ReDevelopment & New Impervious)	Pre- ReDevelopment
TN Load (lb/yr)	3.60	1.95

Site Compliance Summary - ***Linear Development Project

Maximum % Reduction Required Below Pre-ReDevelopment Load	20%
--	-----

* Note: % Reduction will reduce post-development TP load to less than or equal to baseline load of 1.14 lb/yr (0.41 lb/ac/yr)
 [Post-Dev Reduction Requirement = Post-Dev TP load - baseline load of 1.14 lb/yr], baseline load = site area x 0.41 lb/ac/yr

Total Runoff Volume Reduction (ft ³)	0
Total TP Load Reduction Achieved (lb/yr)	0.00
Total TN Load Reduction Achieved (lb/yr)	0.00
Remaining Post Development TP Load (lb/yr)	0.50
Remaining TP Load Reduction (lb/yr) Required	0.00

**** TARGET TP REDUCTION EXCEEDED BY 0.68 LB/YEAR ****

**Reduction below new development load limitation not required*

DA-PI-033A

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.306	2,495
Developed Condition	0.306	2,495
Pre-Developed (Forest) Condition	0.114	1,699

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 1

Calculations:

Check #1:

$$Q_{\text{developed}} \leq \text{IF} \times [(Q_{\text{pre-developed}} \times \text{RV}_{\text{pre-developed}}) / \text{RV}_{\text{developed}}] \text{ ----->}$$

Q (cfs)

0.306

≤

OK

Q (cfs)

0.306

Check #2:

$$Q_{\text{developed}} \leq Q_{\text{pre-developed}} \text{ ----->}$$

0.306

≤

OK

0.306

Check #3:

$$Q_{\text{developed}} \text{ shall not be required to be } \leq (Q_{\text{forest}} \times \text{RV}_{\text{forest}}) / \text{RV}_{\text{developed}} \text{ --->}$$

0.306

shall not be required to be ≤

0.078

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning's n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<i>Note:</i> Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted. ¹For Paved Road land surface types a Manning's n of 0.011 was used <i>Sources:</i> -USACE, 1998, HEC-1 Flood Hydrograph Package User's Manual, Hydrologic Engineering Center, Davis, CA -Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC	

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

1



2



3



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-PI-033A Pre
2	SCS Runoff	DA-PI-033A Post
3	SCS Runoff	DA-PI-032D Pre-Forested

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.306	1	729	2,495	-----	-----	-----	DA-PI-033A Pre
2	SCS Runoff	0.306	1	729	2,495	-----	-----	-----	DA-PI-033A Post
3	SCS Runoff	0.114	1	738	1,699	-----	-----	-----	DA-PI-032D Pre-Forested
DA-PI-033A.gpw					Return Period: 1 Year			Wednesday, 09 / 6 / 2017	

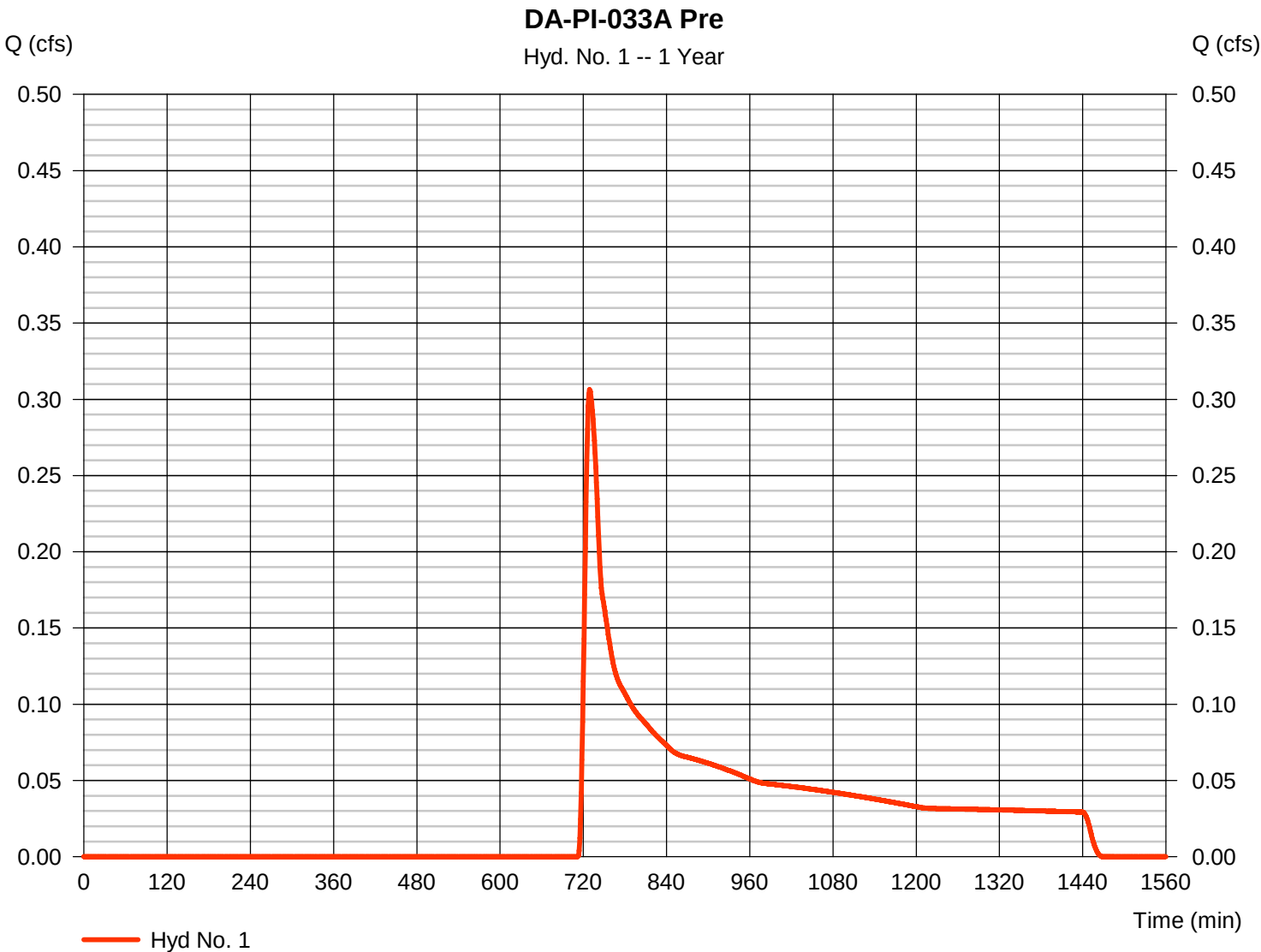
Hydrograph Report

Hyd. No. 1

DA-PI-033A Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.306 cfs
Storm frequency	= 1 yrs	Time to peak	= 729 min
Time interval	= 1 min	Hyd. volume	= 2,495 cuft
Drainage area	= 3.270 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.50 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(2.960 x 58) + (0.030 x 85) + (0.280 x 55)] / 3.270



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-PI-033A Pre

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.400	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 4.00	0.00	0.00				
Travel Time (min)	= 15.56	+	0.00	+	0.00	=	15.56
Shallow Concentrated Flow							
Flow length (ft)	= 724.80	0.00	0.00				
Watercourse slope (%)	= 6.62	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=4.15	0.00	0.00				
Travel Time (min)	= 2.91	+	0.00	+	0.00	=	2.91
Channel Flow							
X sectional flow area (sqft)	= 0.00	0.00	0.00				
Wetted perimeter (ft)	= 0.00	0.00	0.00				
Channel slope (%)	= 0.00	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	((0})0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc				18.50 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Wednesday, 09 / 6 / 2017

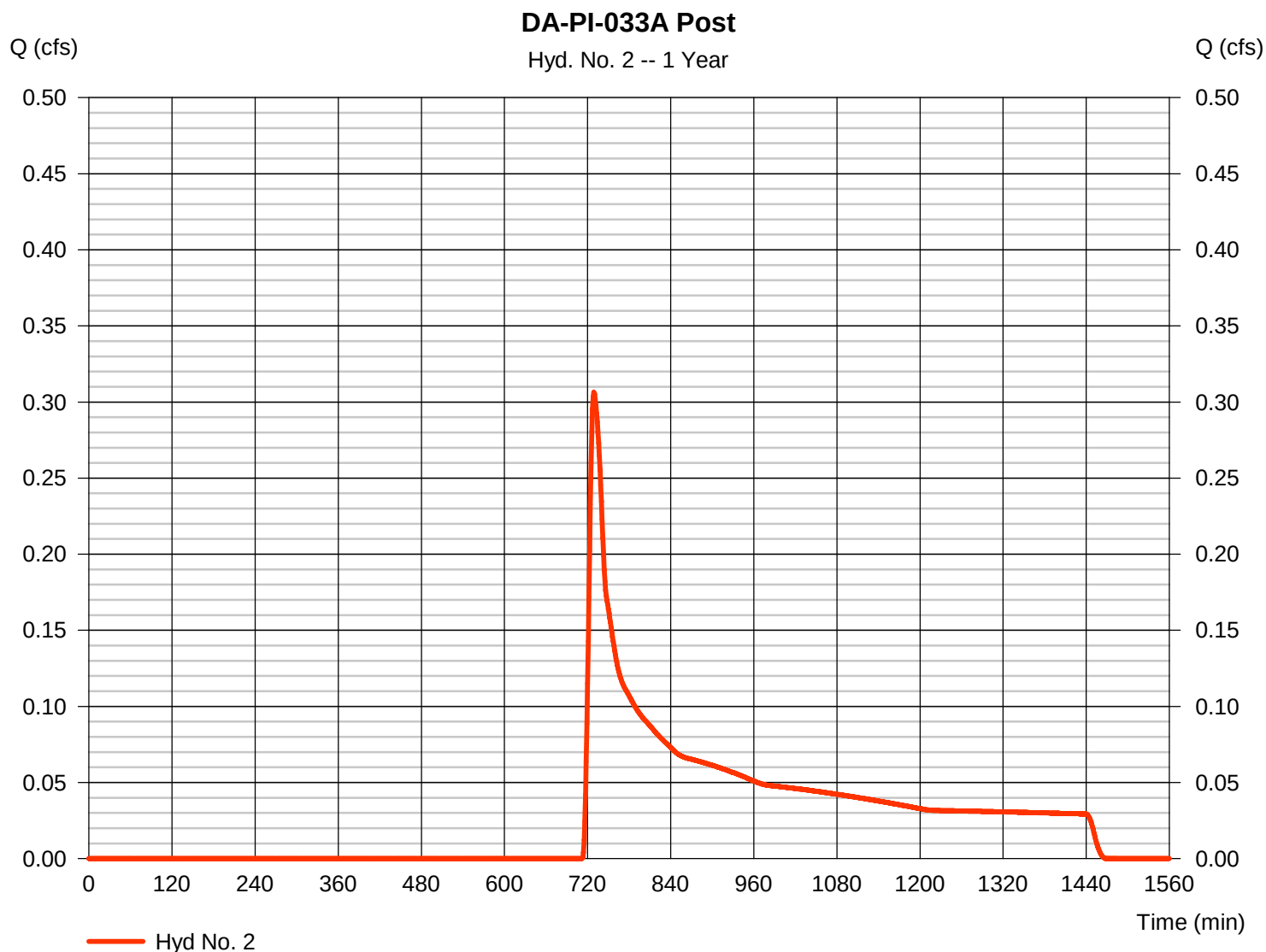
Hyd. No. 2

DA-PI-033A Post

Hydrograph type = SCS Runoff
 Storm frequency = 1 yrs
 Time interval = 1 min
 Drainage area = 3.270 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 2.80 in
 Storm duration = 24 hrs

Peak discharge = 0.306 cfs
 Time to peak = 729 min
 Hyd. volume = 2,495 cuft
 Curve number = 58*
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 18.50 min
 Distribution = Type II
 Shape factor = 484

* Composite (Area/CN) = $[(3.060 \times 58) + (0.030 \times 85) + (0.180 \times 48)] / 3.270$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-PI-033A Post

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.400	0.800	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00	
Land slope (%)	= 4.00	0.00	0.00	
Travel Time (min)	= 15.56	+	0.00	+
			0.00	= 15.56
Shallow Concentrated Flow				
Flow length (ft)	= 724.80	0.00	0.00	
Watercourse slope (%)	= 6.62	0.00	0.00	
Surface description	= Unpaved	Unpaved	Paved	
Average velocity (ft/s)	=4.15	0.00	0.00	
Travel Time (min)	= 2.91	+	0.00	+
			0.00	= 2.91
Channel Flow				
X sectional flow area (sqft)	= 0.00	0.00	0.00	
Wetted perimeter (ft)	= 0.00	0.00	0.00	
Channel slope (%)	= 0.00	0.00	0.00	
Manning's n-value	= 0.040	0.015	0.015	
Velocity (ft/s)	=0.00	0.00	0.00	
Flow length (ft)	(0)0.0	0.0	0.0	
Travel Time (min)	= 0.00	+	0.00	+
			0.00	= 0.00
Total Travel Time, Tc				18.50 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Wednesday, 09 / 6 / 2017

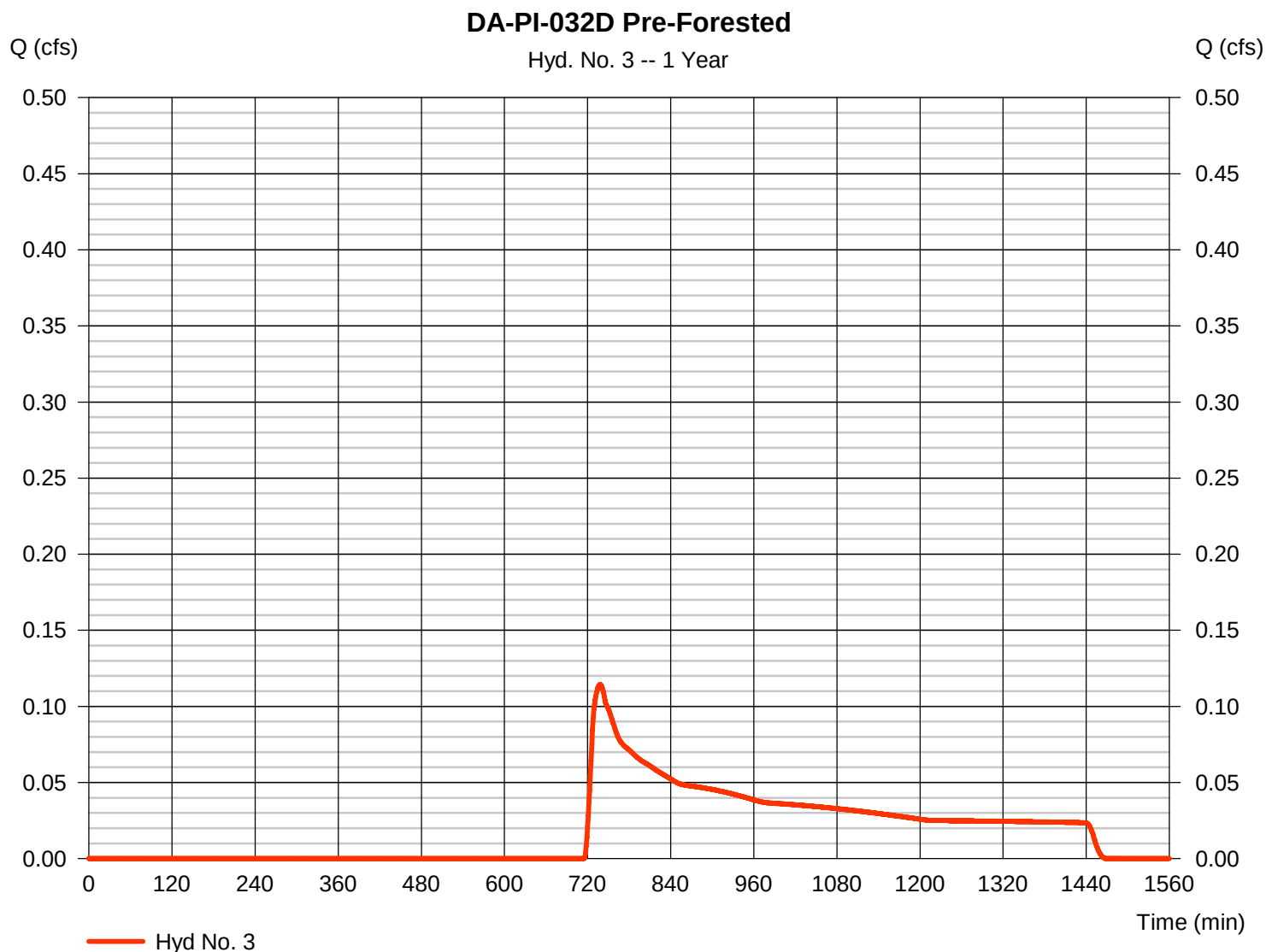
Hyd. No. 3

DA-PI-032D Pre-Forested

Hydrograph type = SCS Runoff
 Storm frequency = 1 yrs
 Time interval = 1 min
 Drainage area = 3.270 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 2.80 in
 Storm duration = 24 hrs

Peak discharge = 0.114 cfs
 Time to peak = 738 min
 Hyd. volume = 1,699 cuft
 Curve number = 55*
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 18.50 min
 Distribution = Type II
 Shape factor = 484

* Composite (Area/CN) = $[(3.270 \times 55)] / 3.270$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-PI-032D Pre-Forested

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.400	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00	
Land slope (%)	= 4.00	0.00	0.00	
Travel Time (min)	= 15.56	+	0.00	+
			0.00	= 15.56
Shallow Concentrated Flow				
Flow length (ft)	= 724.80	0.00	0.00	
Watercourse slope (%)	= 6.62	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=4.15	0.00	0.00	
Travel Time (min)	= 2.91	+	0.00	+
			0.00	= 2.91
Channel Flow				
X sectional flow area (sqft)	= 0.00	0.00	0.00	
Wetted perimeter (ft)	= 0.00	0.00	0.00	
Channel slope (%)	= 0.00	0.00	0.00	
Manning's n-value	= 0.030	0.015	0.015	
Velocity (ft/s)	=0.00	0.00	0.00	
Flow length (ft)	(0)0.0	0.0	0.0	
Travel Time (min)	= 0.00	+	0.00	+
			0.00	= 0.00
Total Travel Time, Tc				18.50 min

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	1.144	1	727	5,316	-----	-----	-----	DA-PI-033A Pre
2	SCS Runoff	1.144	1	727	5,316	-----	-----	-----	DA-PI-033A Post
3	SCS Runoff	0.685	1	728	4,057	-----	-----	-----	DA-PI-032D Pre-Forested
DA-PI-033A.gpw					Return Period: 2 Year			Wednesday, 09 / 6 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

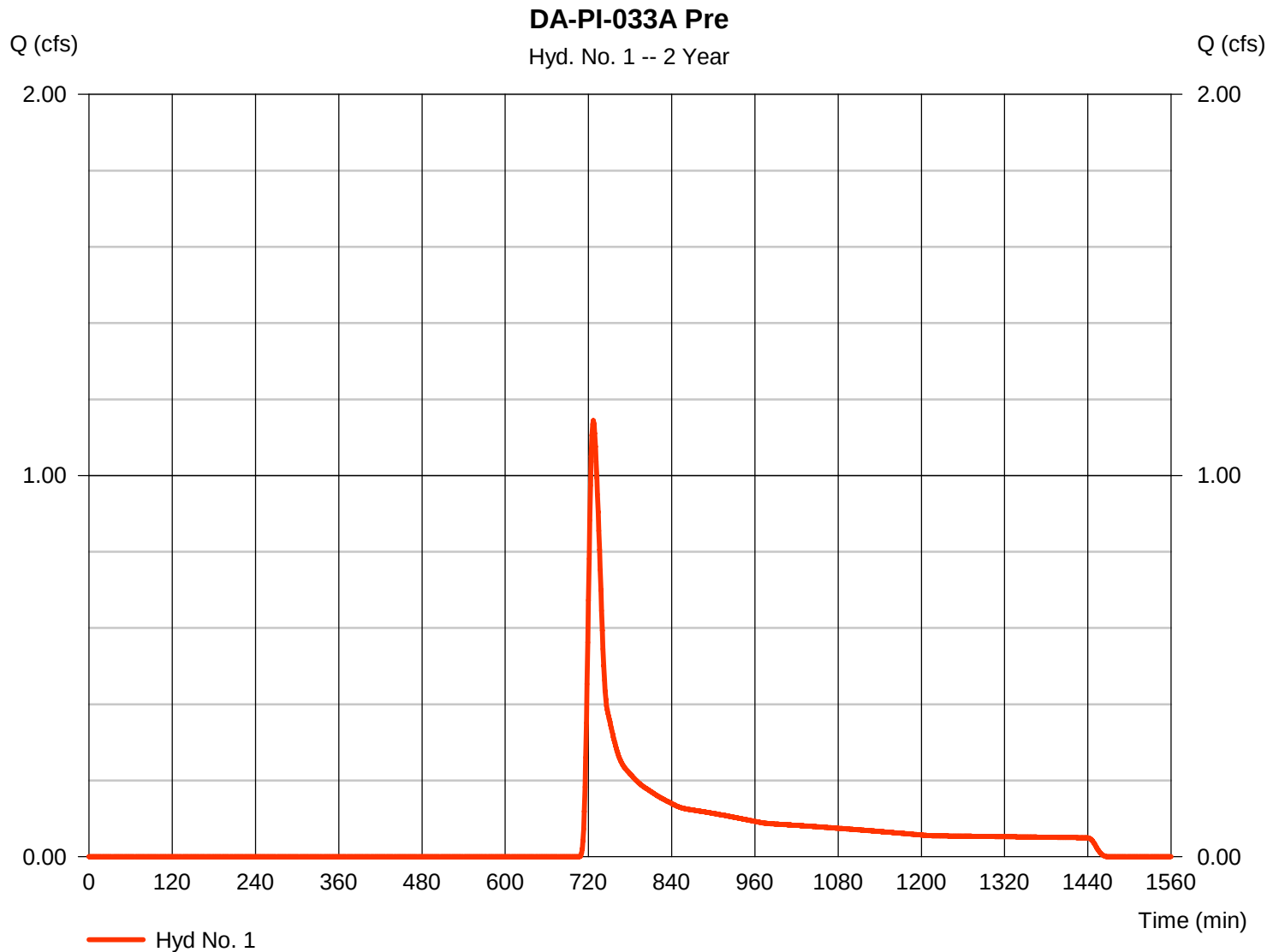
Wednesday, 09 / 6 / 2017

Hyd. No. 1

DA-PI-033A Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 1.144 cfs
Storm frequency	= 2 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 5,316 cuft
Drainage area	= 3.270 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.50 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(2.960 \times 58) + (0.030 \times 85) + (0.280 \times 55)] / 3.270$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

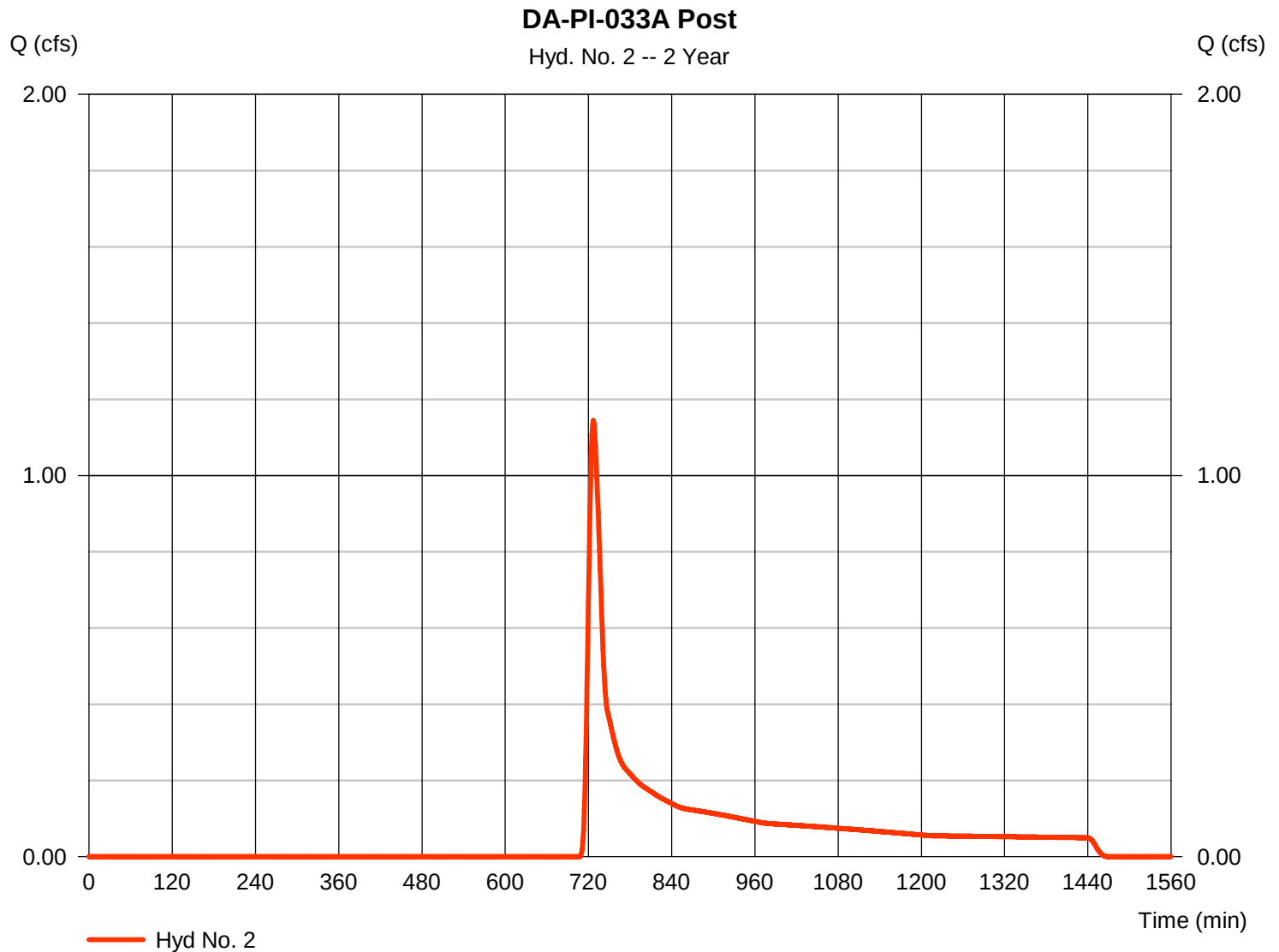
Wednesday, 09 / 6 / 2017

Hyd. No. 2

DA-PI-033A Post

Hydrograph type	= SCS Runoff	Peak discharge	= 1.144 cfs
Storm frequency	= 2 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 5,316 cuft
Drainage area	= 3.270 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.50 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(3.060 \times 58) + (0.030 \times 85) + (0.180 \times 48)] / 3.270$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

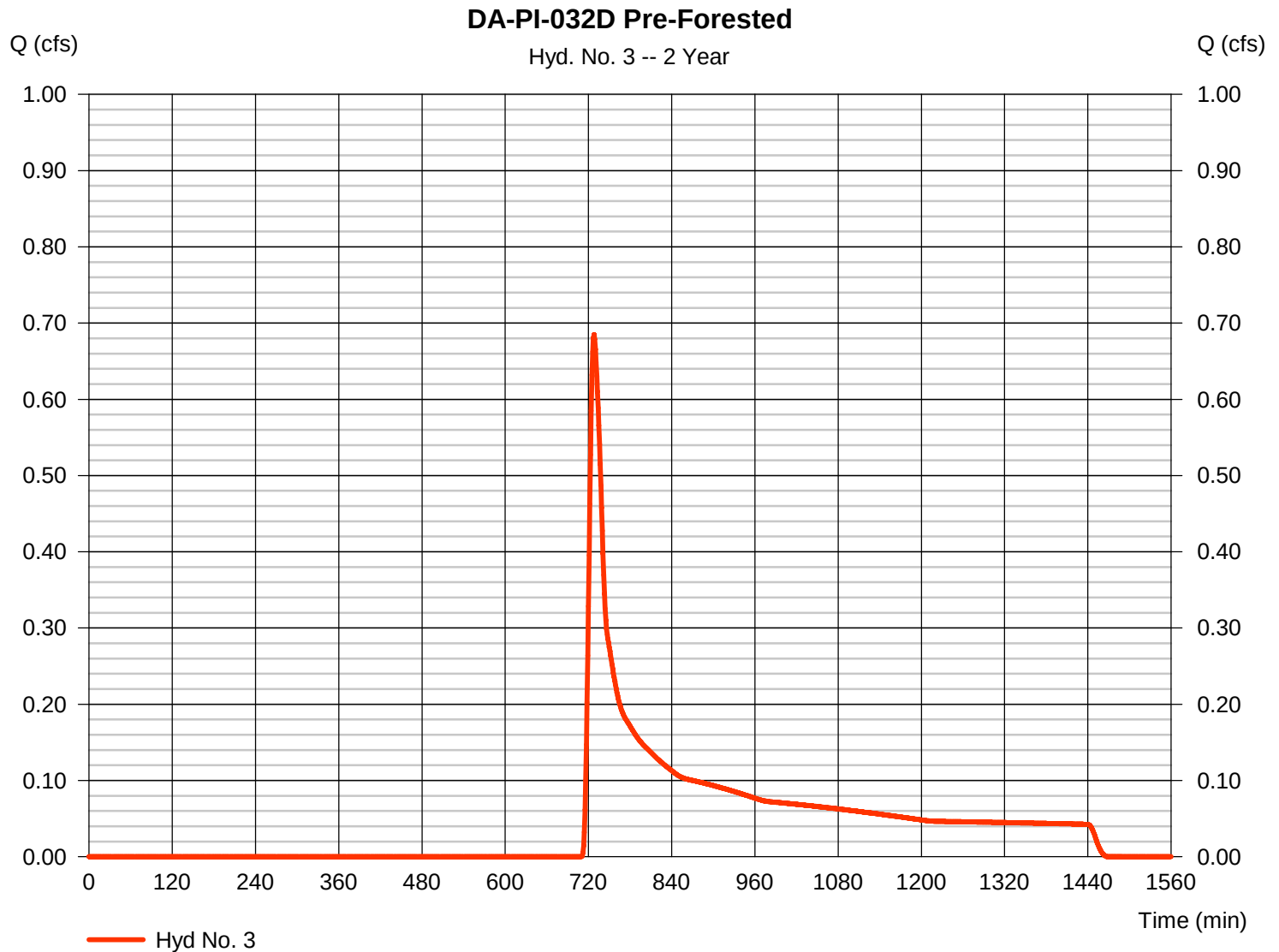
Wednesday, 09 / 6 / 2017

Hyd. No. 3

DA-PI-032D Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 0.685 cfs
Storm frequency	= 2 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 4,057 cuft
Drainage area	= 3.270 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.50 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(3.270 x 55)] / 3.270



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	4.545	1	725	15,026	-----	-----	-----	DA-PI-033A Pre
2	SCS Runoff	4.545	1	725	15,026	-----	-----	-----	DA-PI-033A Post
3	SCS Runoff	3.604	1	726	12,688	-----	-----	-----	DA-PI-032D Pre-Forested
DA-PI-033A.gpw					Return Period: 10 Year			Wednesday, 09 / 6 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

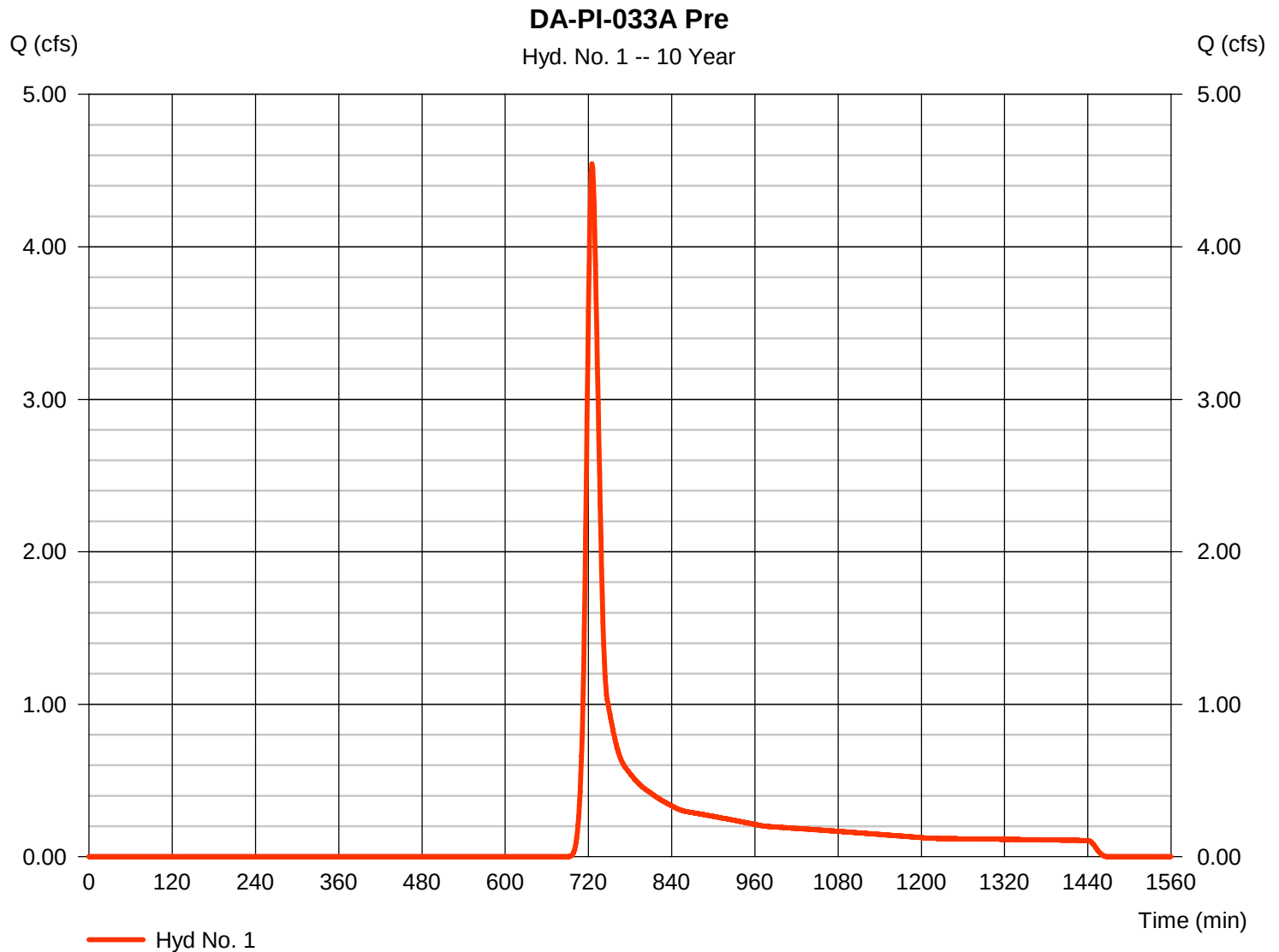
Wednesday, 09 / 6 / 2017

Hyd. No. 1

DA-PI-033A Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 4.545 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 15,026 cuft
Drainage area	= 3.270 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.50 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(2.960 \times 58) + (0.030 \times 85) + (0.280 \times 55)] / 3.270$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

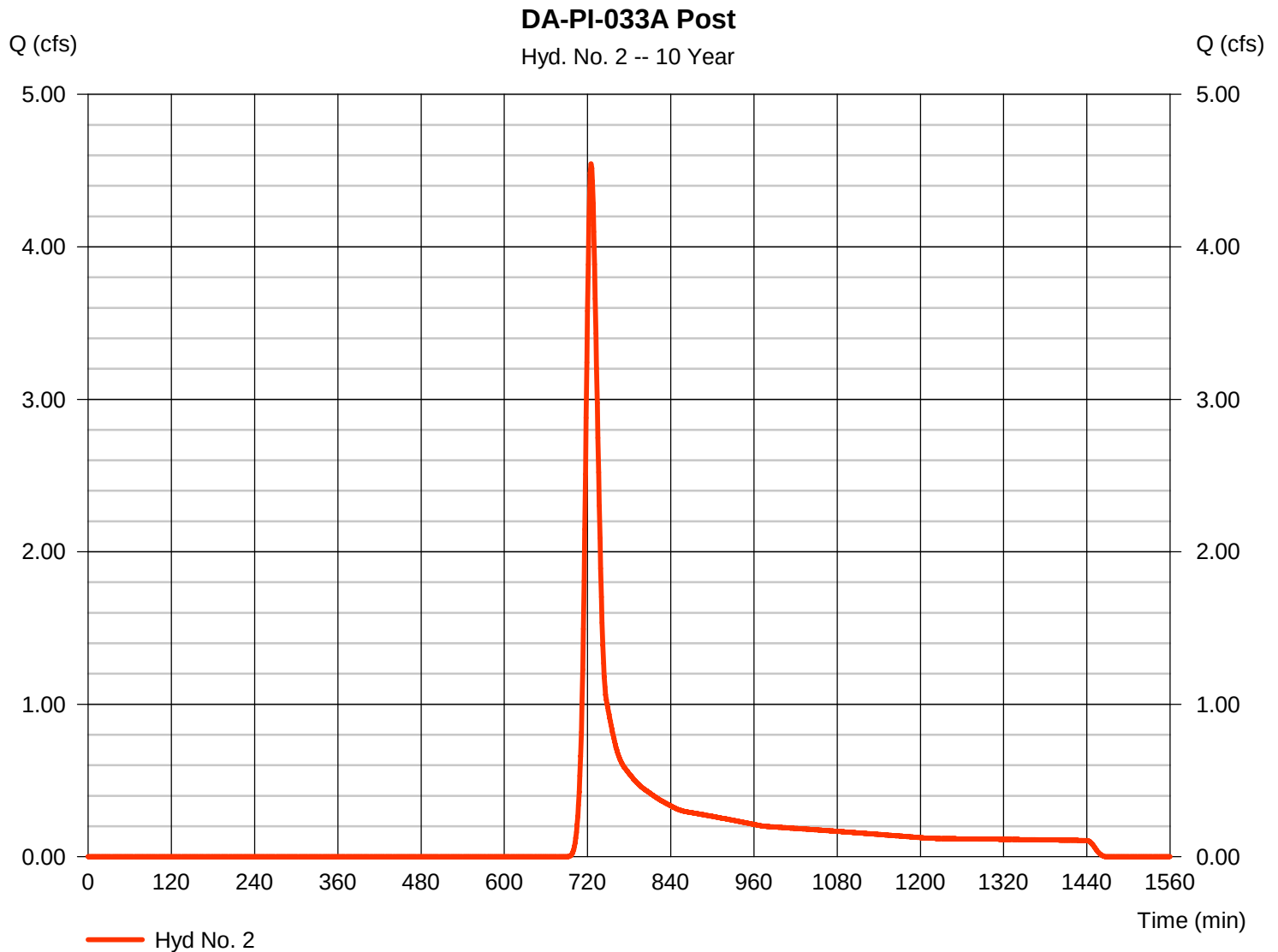
Wednesday, 09 / 6 / 2017

Hyd. No. 2

DA-PI-033A Post

Hydrograph type	= SCS Runoff	Peak discharge	= 4.545 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 15,026 cuft
Drainage area	= 3.270 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.50 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(3.060 \times 58) + (0.030 \times 85) + (0.180 \times 48)] / 3.270$



Hydrograph Report

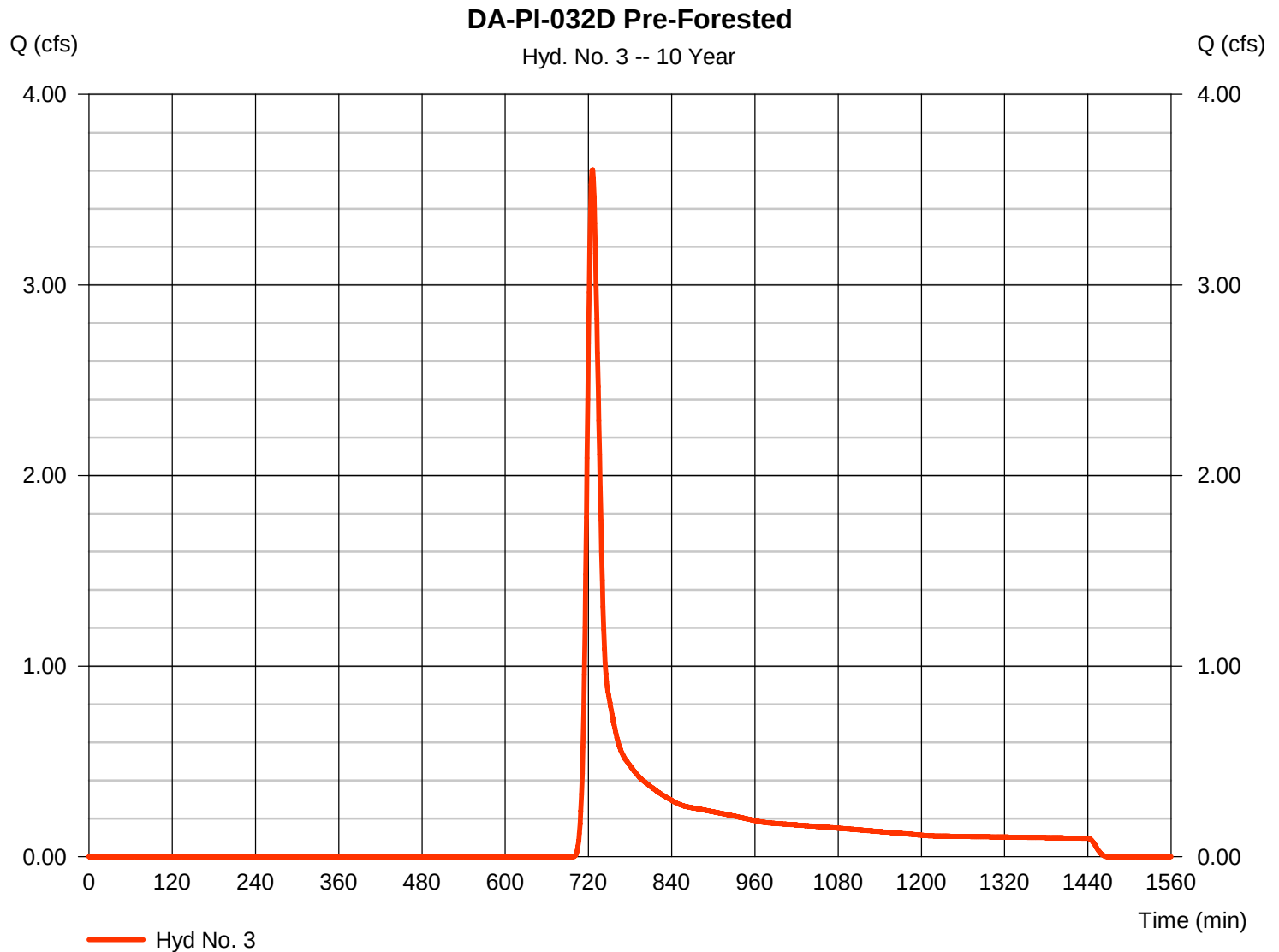
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Wednesday, 09 / 6 / 2017

Hyd. No. 3

DA-PI-032D Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	3.604 cfs
Storm frequency	=	10 yrs	Time to peak	=	726 min
Time interval	=	1 min	Hyd. volume	=	12,688 cuft
Drainage area	=	3.270 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	18.50 min
Total precip.	=	5.20 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(3.270 \times 55)] / 3.270$ 

DA-PI-033B

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.098	1,431
Developed Condition	0.068	1,235
Pre-Developed (Forest) Condition	0.098	1,431

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1:

$$Q_{\text{developed}} \leq IF \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}] \text{ ----->}$$

Q (cfs)

0.068

≤

Q (cfs)

0.091

N/A - See Check #3

Check #2:

$$Q_{\text{developed}} \leq Q_{\text{pre-developed}} \text{ ----->}$$

0.068

≤

0.098

N/A - See Check #3

Check #3:

$$Q_{\text{developed}} \text{ shall not be required to be } \leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}} \text{ --->}$$

0.068

shall not be required to be ≤

0.114

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning's n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<i>Note:</i> Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted. ¹For Paved Road land surface types a Manning's n of 0.011 was used <i>Sources:</i> -USACE, 1998, HEC-1 Flood Hydrograph Package User's Manual, Hydrologic Engineering Center, Davis, CA -Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC	

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

1



2



3



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-PI-033B Pre
2	SCS Runoff	DA-PI-033B Post
3	SCS Runoff	DA-PI-033B Pre-Forested

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.098	1	736	1,431	-----	-----	-----	DA-PI-033B Pre
2	SCS Runoff	0.068	1	741	1,235	-----	-----	-----	DA-PI-033B Post
3	SCS Runoff	0.098	1	736	1,431	-----	-----	-----	DA-PI-033B Pre-Forested
DA-PI-033B.gpw					Return Period: 1 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Monday, 08 / 21 / 2017

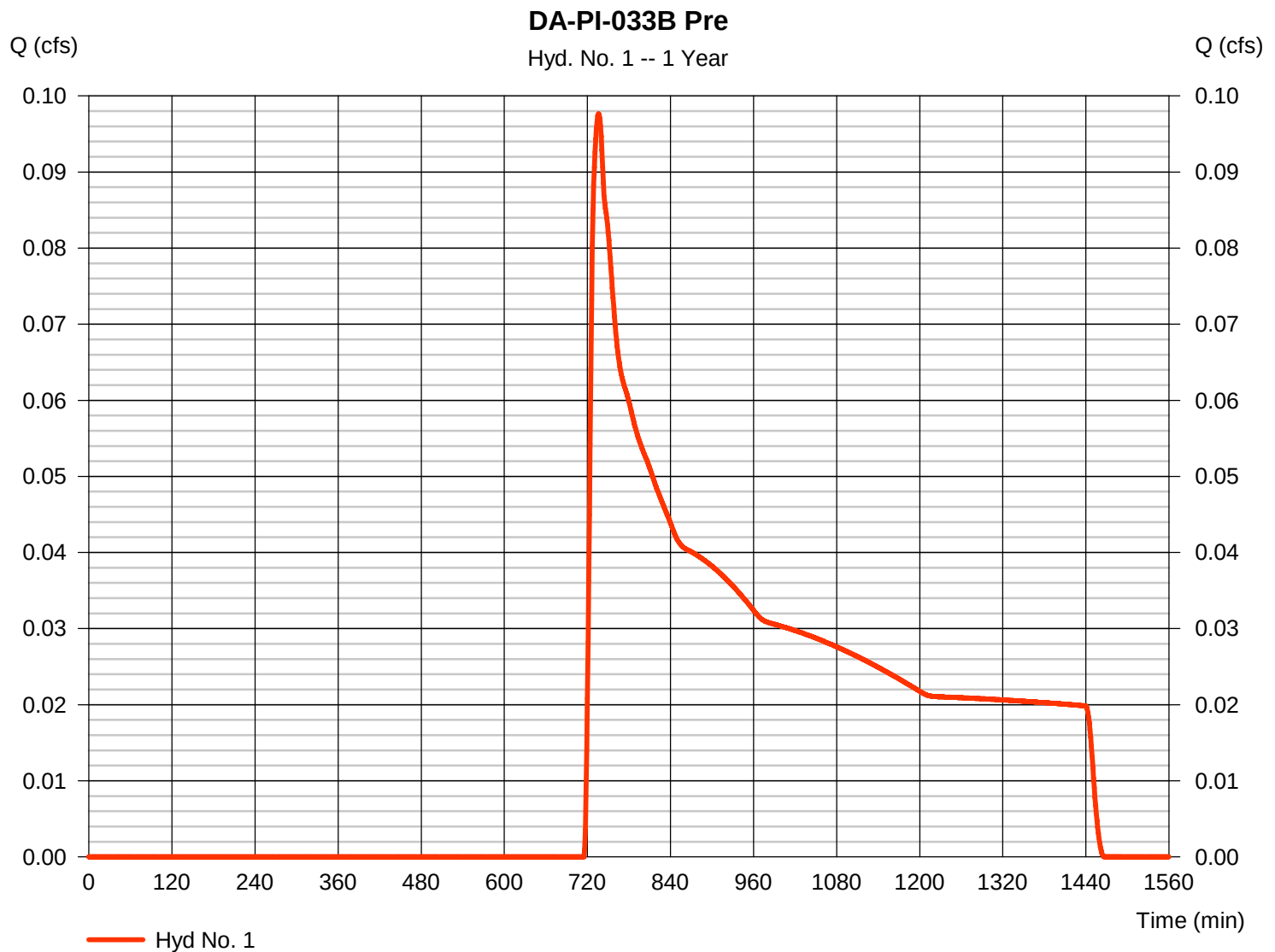
Hyd. No. 1

DA-PI-033B Pre

Hydrograph type = SCS Runoff
 Storm frequency = 1 yrs
 Time interval = 1 min
 Drainage area = 2.690 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 2.80 in
 Storm duration = 24 hrs

Peak discharge = 0.098 cfs
 Time to peak = 736 min
 Hyd. volume = 1,431 cuft
 Curve number = 55*
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 16.00 min
 Distribution = Type II
 Shape factor = 484

* Composite (Area/CN) = $[(2.690 \times 55)] / 2.690$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-PI-033B Pre

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.400	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 5.36	0.00	0.00				
Travel Time (min)	= 13.84	+	0.00	+	0.00	=	13.84
Shallow Concentrated Flow							
Flow length (ft)	= 628.97	0.00	0.00				
Watercourse slope (%)	= 8.95	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=4.83	0.00	0.00				
Travel Time (min)	= 2.17	+	0.00	+	0.00	=	2.17
Channel Flow							
X sectional flow area (sqft)	= 0.00	0.00	0.00				
Wetted perimeter (ft)	= 0.00	0.00	0.00				
Channel slope (%)	= 0.00	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	(0)0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc				16.00 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

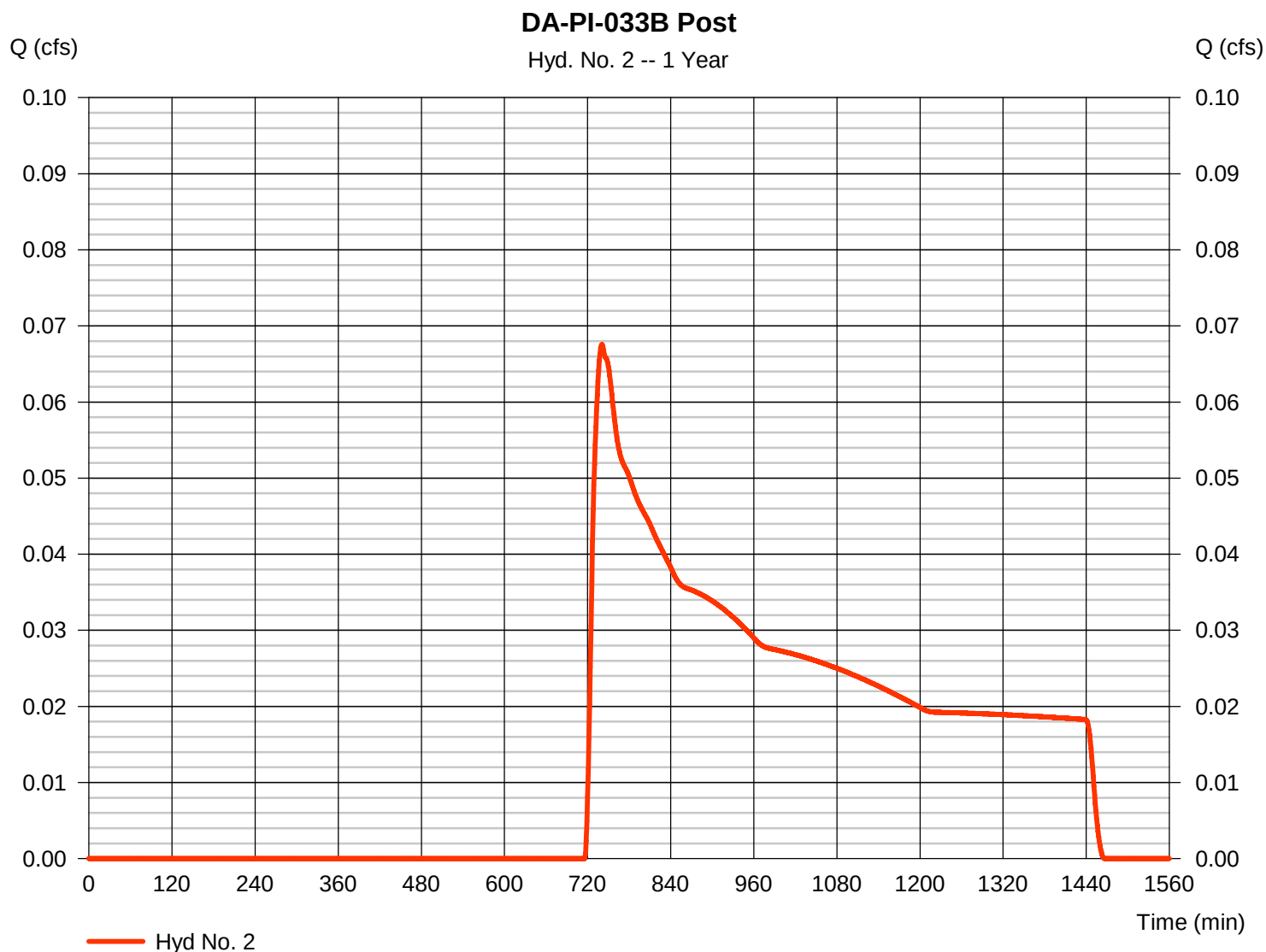
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-PI-033B Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.068 cfs
Storm frequency	= 1 yrs	Time to peak	= 741 min
Time interval	= 1 min	Hyd. volume	= 1,235 cuft
Drainage area	= 2.690 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.00 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(2.030 \times 55) + (0.360 \times 48) + (0.300 \times 58)] / 2.690$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-PI-033B Post

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.400	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00	
Land slope (%)	= 5.36	0.00	0.00	
Travel Time (min)	= 13.84	+	0.00	+
			0.00	= 13.84
Shallow Concentrated Flow				
Flow length (ft)	= 628.97	0.00	0.00	
Watercourse slope (%)	= 8.95	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=4.83	0.00	0.00	
Travel Time (min)	= 2.17	+	0.00	+
			0.00	= 2.17
Channel Flow				
X sectional flow area (sqft)	= 0.00	0.00	0.00	
Wetted perimeter (ft)	= 0.00	0.00	0.00	
Channel slope (%)	= 0.00	0.00	0.00	
Manning's n-value	= 0.040	0.015	0.015	
Velocity (ft/s)	=0.00	0.00	0.00	
Flow length (ft)	(0)0.0	0.0	0.0	
Travel Time (min)	= 0.00	+	0.00	+
			0.00	= 0.00
Total Travel Time, Tc				16.00 min

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Monday, 08 / 21 / 2017

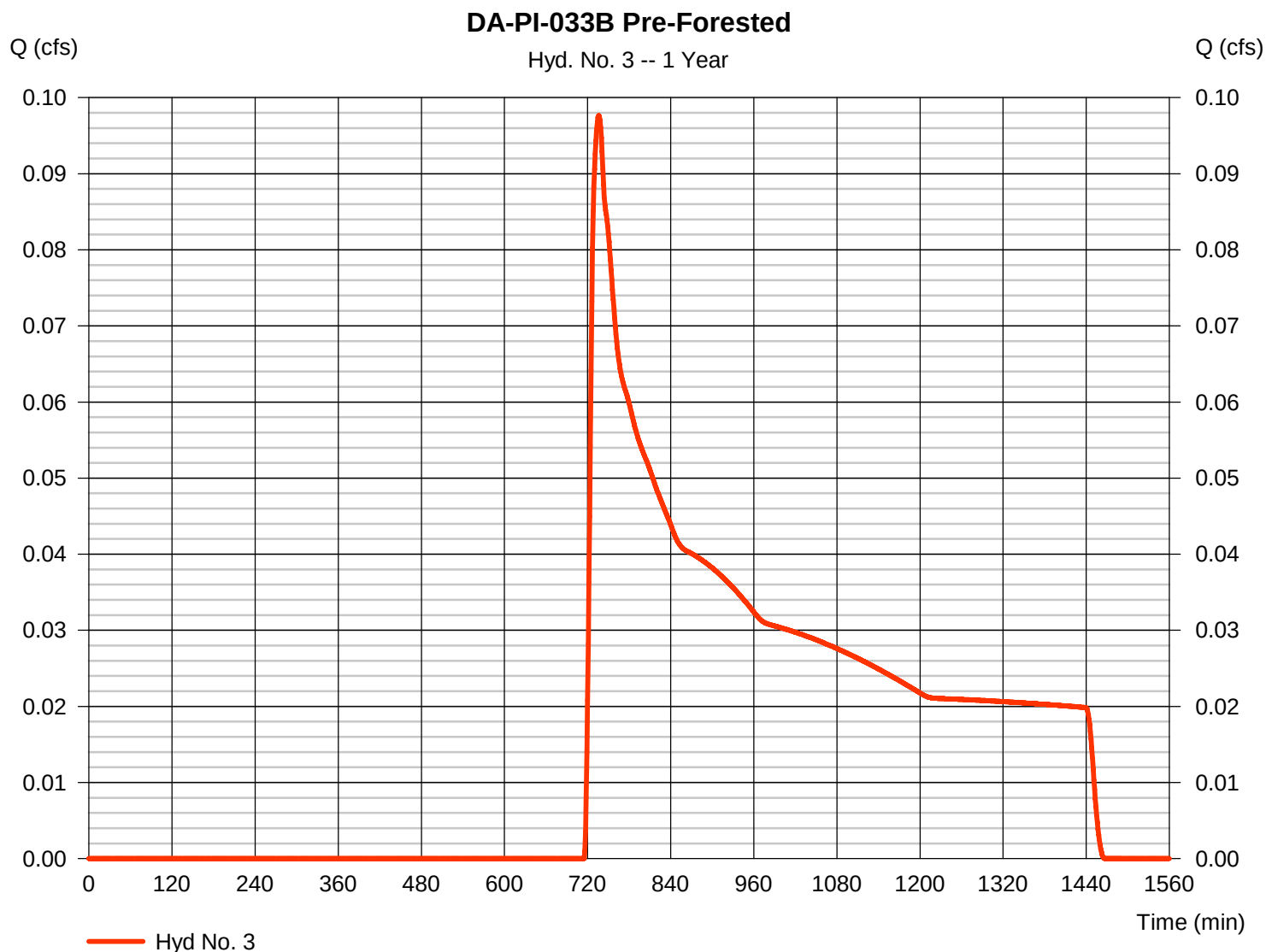
Hyd. No. 3

DA-PI-033B Pre-Forested

Hydrograph type = SCS Runoff
 Storm frequency = 1 yrs
 Time interval = 1 min
 Drainage area = 2.690 ac
 Basin Slope = 0.0 %
 Tc method = TR55
 Total precip. = 2.80 in
 Storm duration = 24 hrs

Peak discharge = 0.098 cfs
 Time to peak = 736 min
 Hyd. volume = 1,431 cuft
 Curve number = 55*
 Hydraulic length = 0 ft
 Time of conc. (Tc) = 16.00 min
 Distribution = Type II
 Shape factor = 484

* Composite (Area/CN) = $[(2.690 \times 55)] / 2.690$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-PI-033B Pre-Forested

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.400	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 5.36	0.00	0.00				
Travel Time (min)	= 13.84	+	0.00	+	0.00	=	13.84
Shallow Concentrated Flow							
Flow length (ft)	= 628.97	0.00	0.00				
Watercourse slope (%)	= 8.95	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=4.83	0.00	0.00				
Travel Time (min)	= 2.17	+	0.00	+	0.00	=	2.17
Channel Flow							
X sectional flow area (sqft)	= 0.00	0.00	0.00				
Wetted perimeter (ft)	= 0.00	0.00	0.00				
Channel slope (%)	= 0.00	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	((0})0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc				16.00 min			

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.604	1	727	3,418	-----	-----	-----	DA-PI-033B Pre
2	SCS Runoff	0.489	1	727	3,093	-----	-----	-----	DA-PI-033B Post
3	SCS Runoff	0.604	1	727	3,418	-----	-----	-----	DA-PI-033B Pre-Forested
DA-PI-033B.gpw					Return Period: 2 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

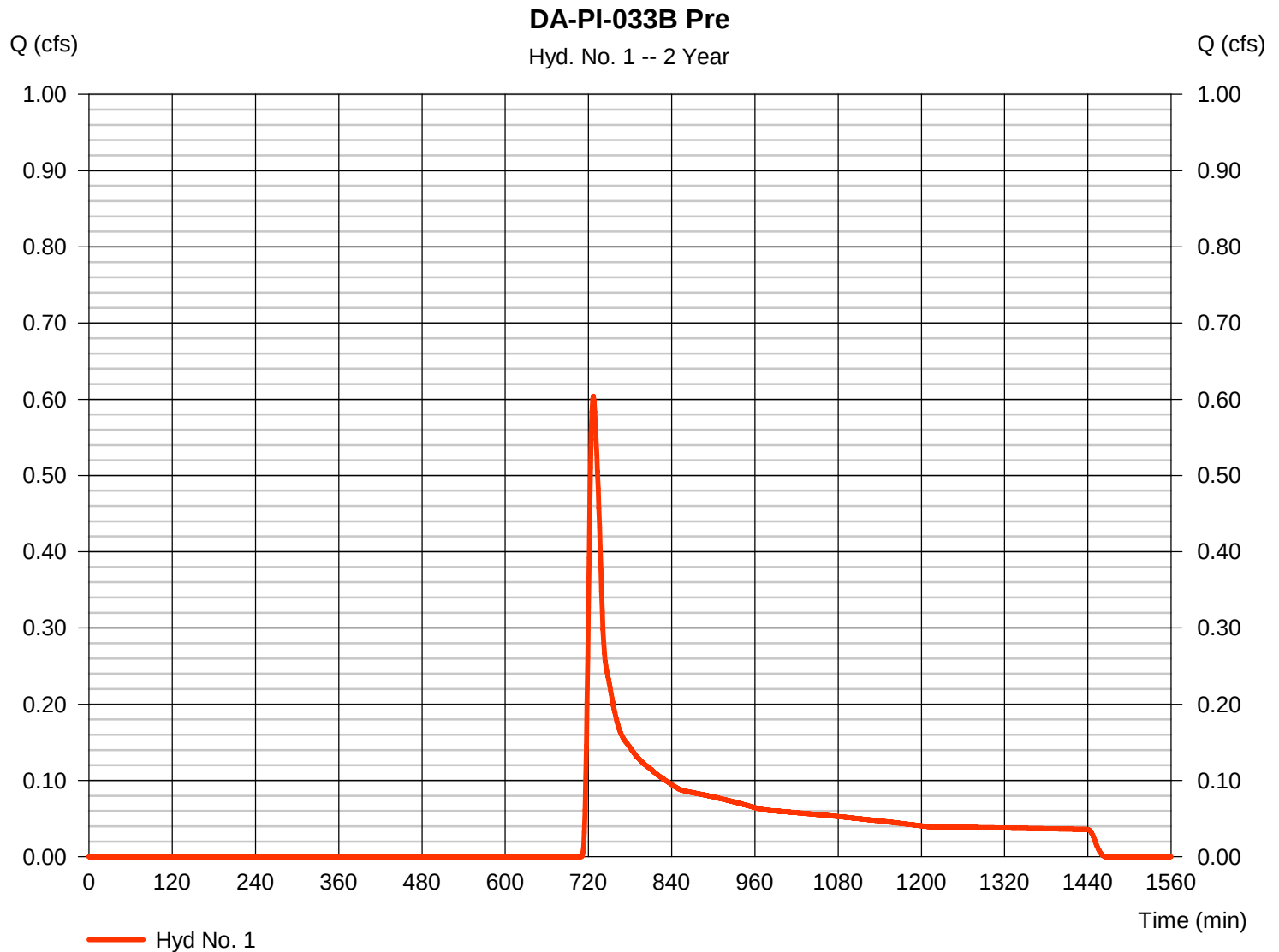
Monday, 08 / 21 / 2017

Hyd. No. 1

DA-PI-033B Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.604 cfs
Storm frequency	= 2 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 3,418 cuft
Drainage area	= 2.690 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.00 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(2.690 x 55)] / 2.690



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

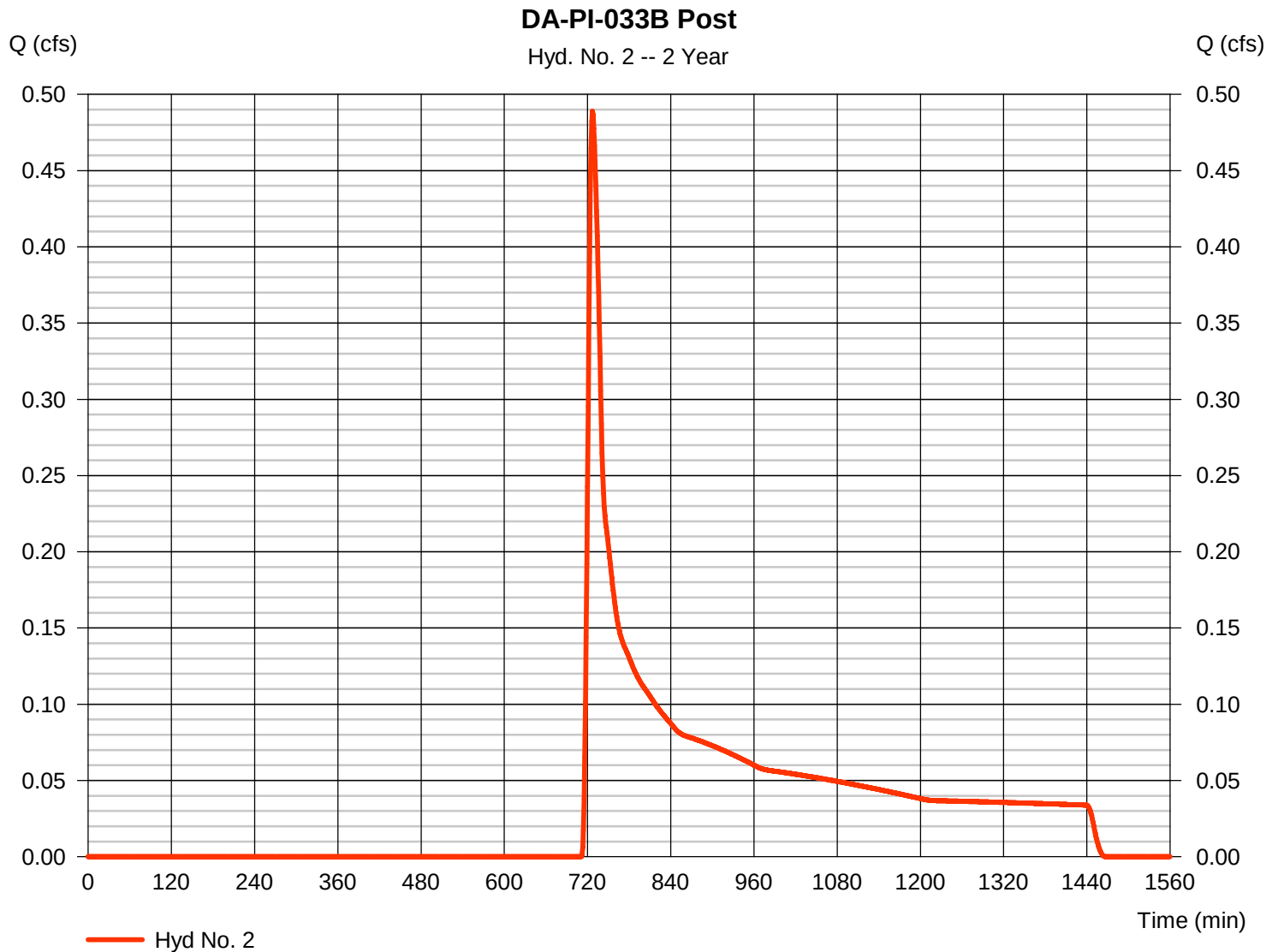
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-PI-033B Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.489 cfs
Storm frequency	= 2 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 3,093 cuft
Drainage area	= 2.690 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.00 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(2.030 \times 55) + (0.360 \times 48) + (0.300 \times 58)] / 2.690$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

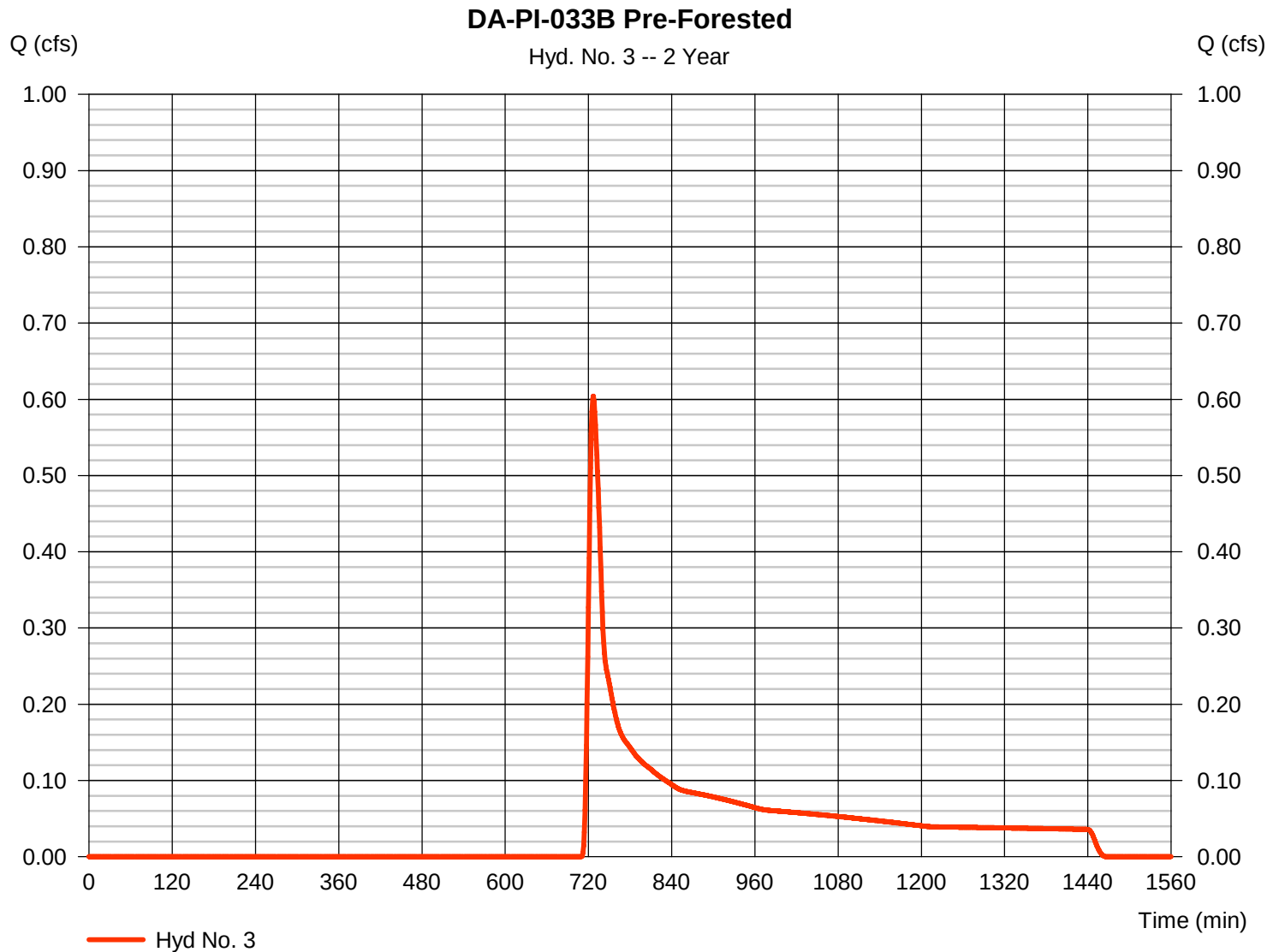
Monday, 08 / 21 / 2017

Hyd. No. 3

DA-PI-033B Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 0.604 cfs
Storm frequency	= 2 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 3,418 cuft
Drainage area	= 2.690 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.00 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(2.690 x 55)] / 2.690



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	3.175	1	725	10,690	-----	-----	-----	DA-PI-033B Pre
2	SCS Runoff	2.914	1	725	10,059	-----	-----	-----	DA-PI-033B Post
3	SCS Runoff	3.175	1	725	10,690	-----	-----	-----	DA-PI-033B Pre-Forested
DA-PI-033B.gpw					Return Period: 10 Year			Monday, 08 / 21 / 2017	

Hydrograph Report

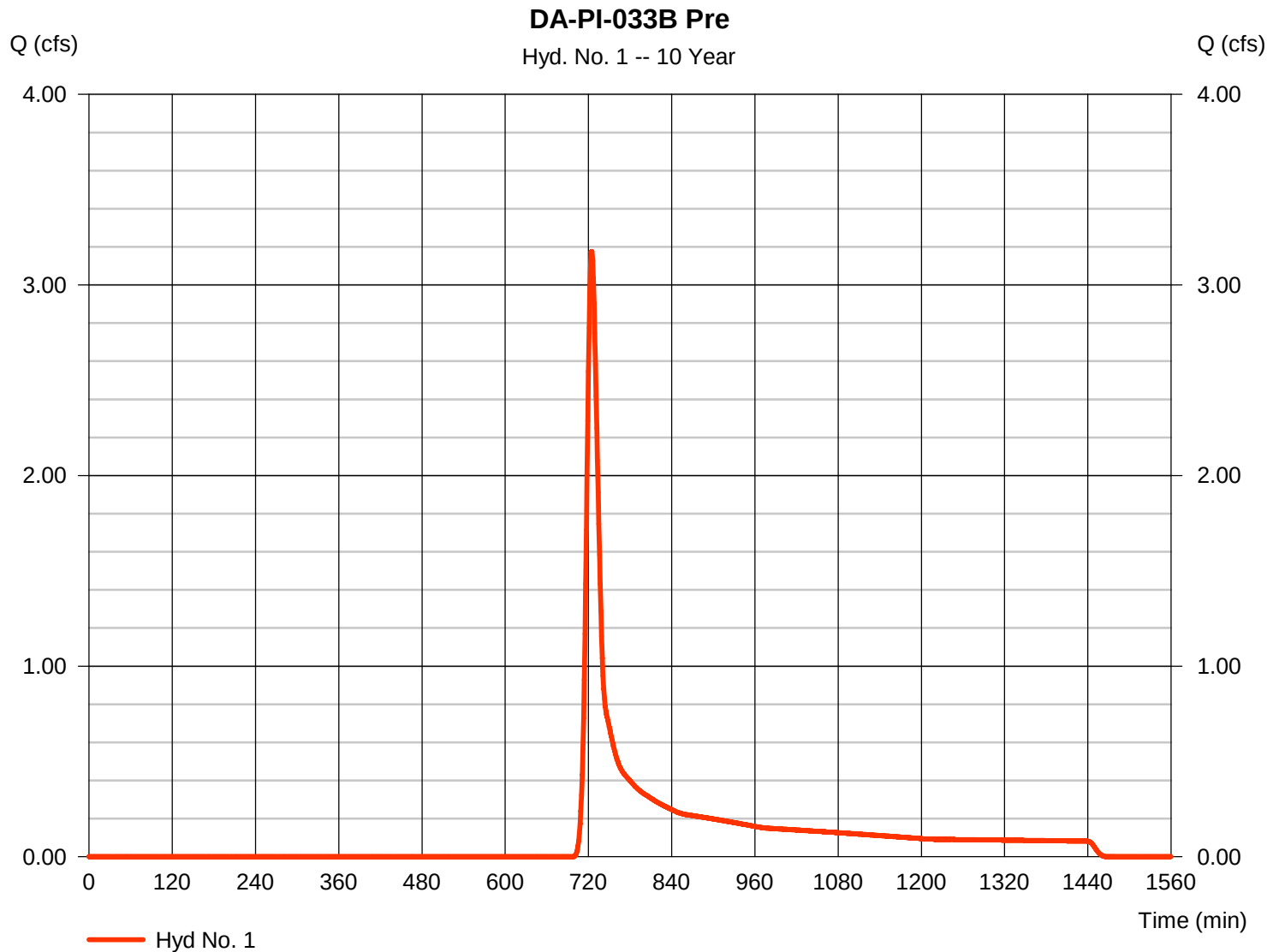
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Monday, 08 / 21 / 2017

Hyd. No. 1

DA-PI-033B Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 3.175 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 10,690 cuft
Drainage area	= 2.690 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.00 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(2.690 \times 55)] / 2.690$ 

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

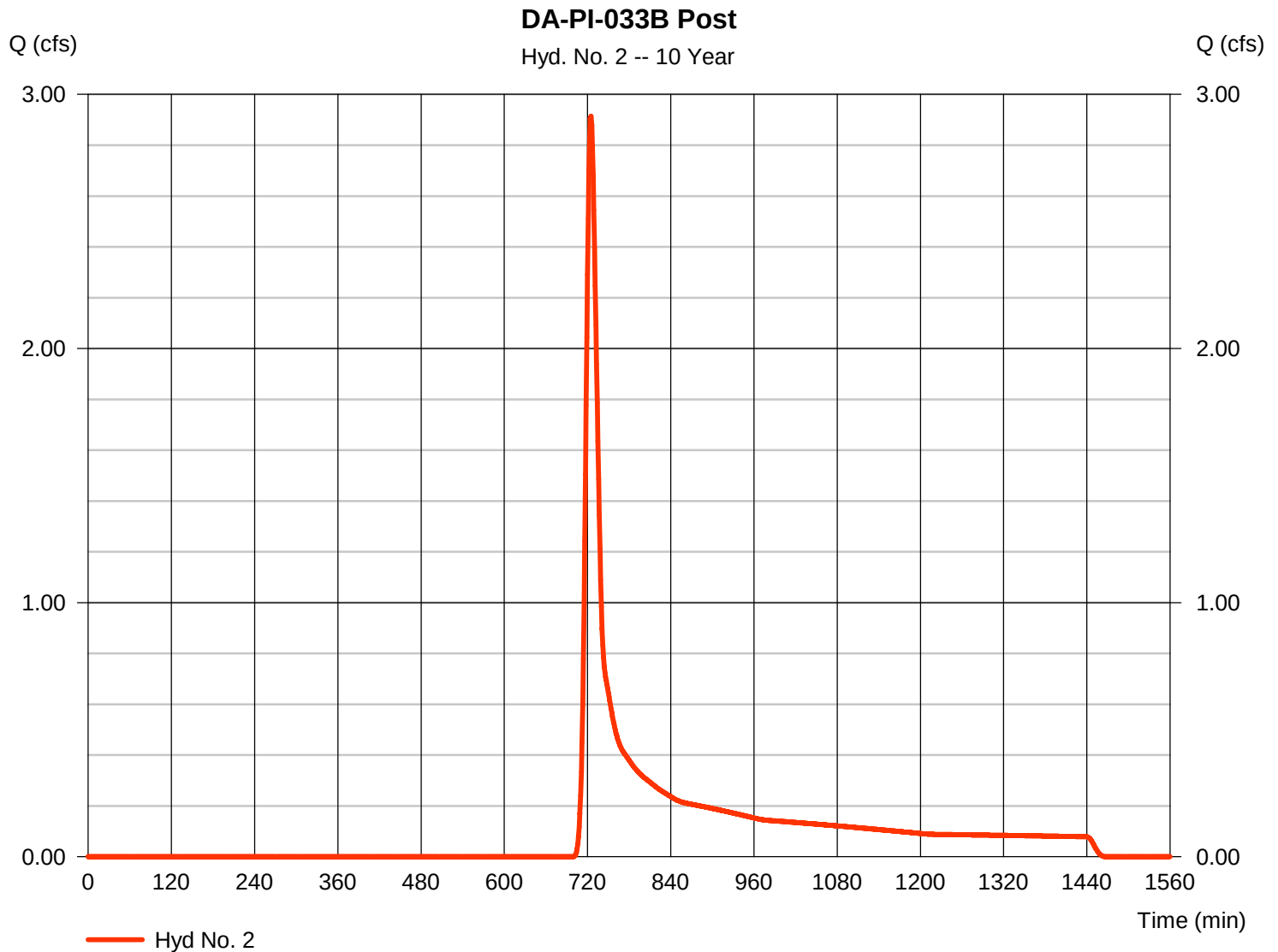
Monday, 08 / 21 / 2017

Hyd. No. 2

DA-PI-033B Post

Hydrograph type	=	SCS Runoff	Peak discharge	=	2.914 cfs
Storm frequency	=	10 yrs	Time to peak	=	725 min
Time interval	=	1 min	Hyd. volume	=	10,059 cuft
Drainage area	=	2.690 ac	Curve number	=	54*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	16.00 min
Total precip.	=	5.20 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(2.030 \times 55) + (0.360 \times 48) + (0.300 \times 58)] / 2.690$



Hydrograph Report

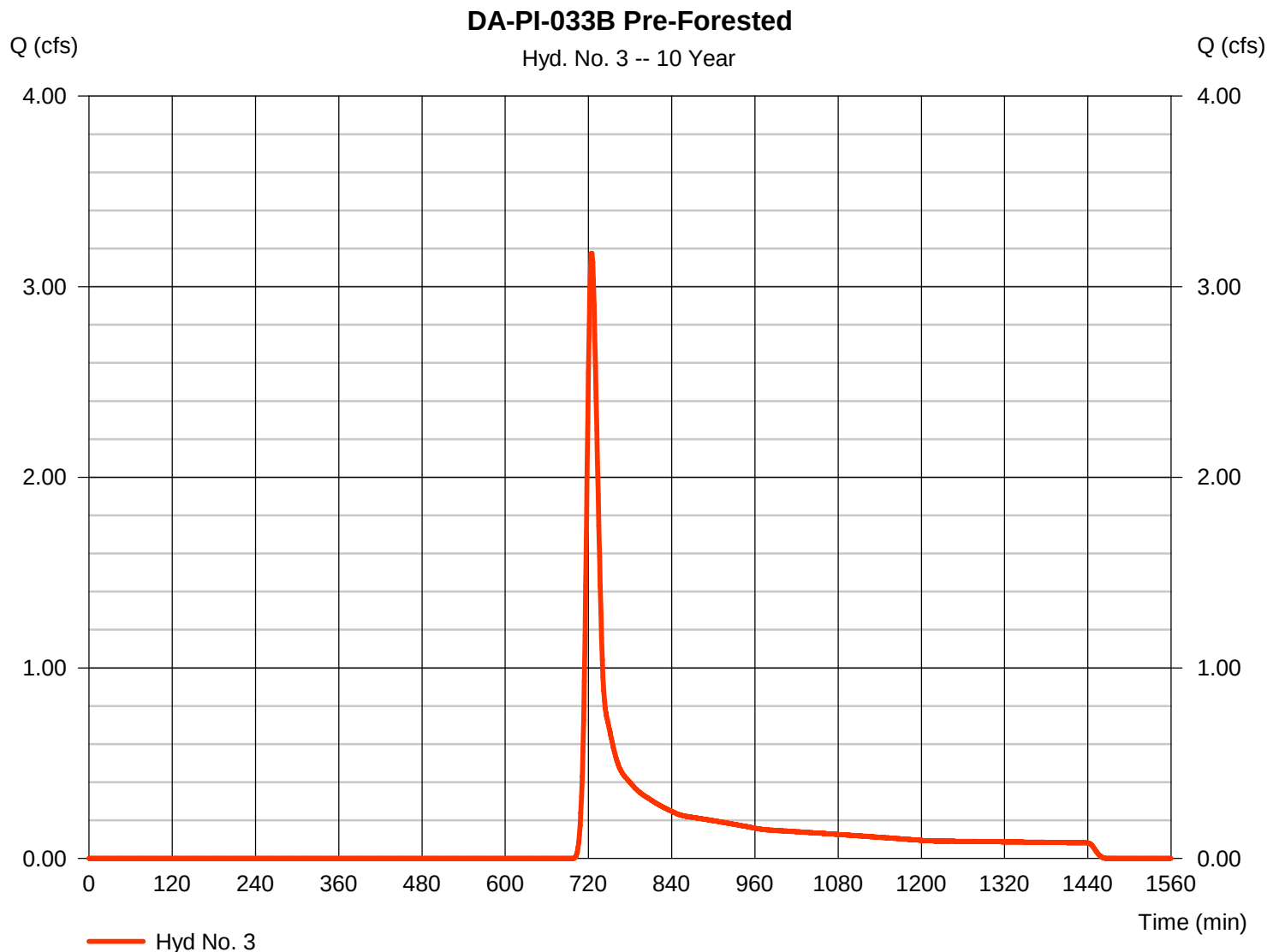
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Monday, 08 / 21 / 2017

Hyd. No. 3

DA-PI-033B Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	3.175 cfs
Storm frequency	=	10 yrs	Time to peak	=	725 min
Time interval	=	1 min	Hyd. volume	=	10,690 cuft
Drainage area	=	2.690 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	16.00 min
Total precip.	=	5.20 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(2.690 \times 55)] / 2.690$ 

DA-PI-033C

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.212	1,693
Developed Condition	0.095	1,298
Pre-Developed (Forest) Condition	0.212	1,693

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 0.8

Calculations:

Check #1:

$$Q_{\text{developed}} \leq \text{IF} \times [(Q_{\text{pre-developed}} \times \text{RV}_{\text{pre-developed}}) / \text{RV}_{\text{developed}}] \text{ ----->}$$

Q (cfs)

0.095

≤

Q (cfs)

0.221

N/A - See Check #3

Check #2:

$$Q_{\text{developed}} \leq Q_{\text{pre-developed}} \text{ ----->}$$

0.095

≤

0.212

N/A - See Check #3

Check #3:

$$Q_{\text{developed}} \text{ shall not be required to be } \leq (Q_{\text{forest}} \times \text{RV}_{\text{forest}}) / \text{RV}_{\text{developed}} \text{ --->}$$

0.095

shall not be required to be ≤

0.277

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning's n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<i>Note:</i> Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted. ¹For Paved Road land surface types a Manning's n of 0.011 was used <i>Sources:</i> -USACE, 1998, HEC-1 Flood Hydrograph Package User's Manual, Hydrologic Engineering Center, Davis, CA -Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC	

Table 2 – Manning's n Values for Open Channel Flow

Channel Type	Manning n		
	Min.	Normal	Max.
1. Excavated or Dredged Channels¹			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels²			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
Notes: ¹For the developed condition, a conservative Manning's n value of 0.040 was used in Hydraflow Hydrographs for open channel flow through the permanent waterbar, level spreader diversion, or grass channel. ²For the pre-developed condition and post-development condition, a Manning's n value of 0.030 was used in Hydraflow Hydrographs. Sources: -ASCE, (1982), Gravity Sanitary Sewer Design and Construction, ASCE Manual of Practice No. 60, New York, NY -Chow, V.T., (1959), Open Channel Hydraulics, McGraw-Hill, New York, NY			

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

1



2



3



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-PI-033C Pre
2	SCS Runoff	DA-PI-033C Post
3	SCS Runoff	DA-PI-033C Pre-Forested

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.212	1	726	1,693	-----	-----	-----	DA-PI-033C Pre
2	SCS Runoff	0.095	1	730	1,298	-----	-----	-----	DA-PI-033C Post
3	SCS Runoff	0.212	1	726	1,693	-----	-----	-----	DA-PI-033C Pre-Forested
DA-PI-033C.gpw					Return Period: 1 Year			Tuesday, 08 / 22 / 2017	

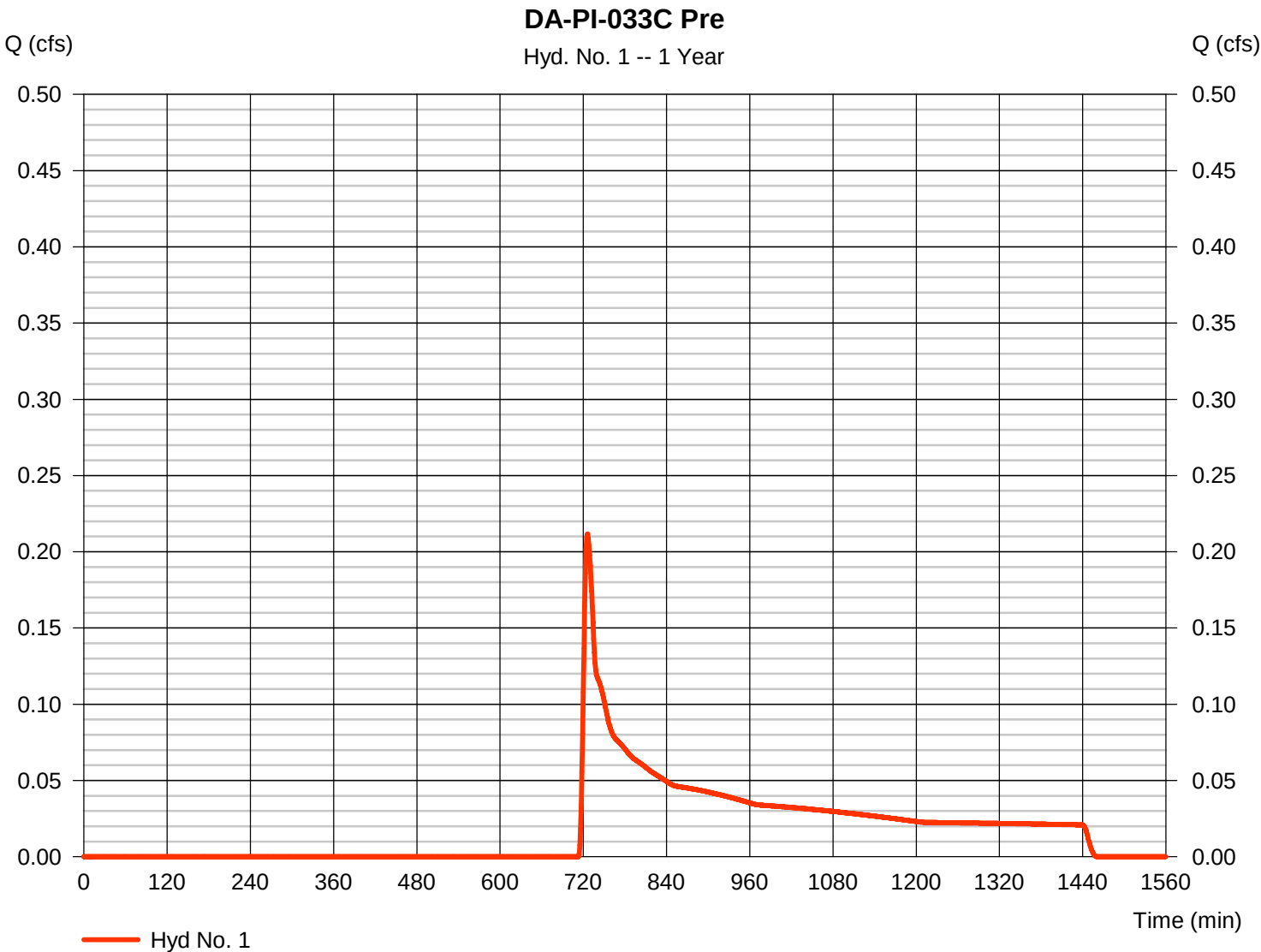
Hydrograph Report

Hyd. No. 1

DA-PI-033C Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.212 cfs
Storm frequency	= 1 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 1,693 cuft
Drainage area	= 2.510 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.20 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(2.330 x 55) + (0.180 x 77)] / 2.510



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-PI-033C Pre

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.400	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 11.17	0.00	0.00				
Travel Time (min)	= 10.32	+	0.00	+	0.00	=	10.32
Shallow Concentrated Flow							
Flow length (ft)	= 770.34	0.00	0.00				
Watercourse slope (%)	= 7.89	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=4.53	0.00	0.00				
Travel Time (min)	= 2.83	+	0.00	+	0.00	=	2.83
Channel Flow							
X sectional flow area (sqft)	= 0.00	0.00	0.00				
Wetted perimeter (ft)	= 0.00	0.00	0.00				
Channel slope (%)	= 0.00	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	((0))0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc				13.20 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

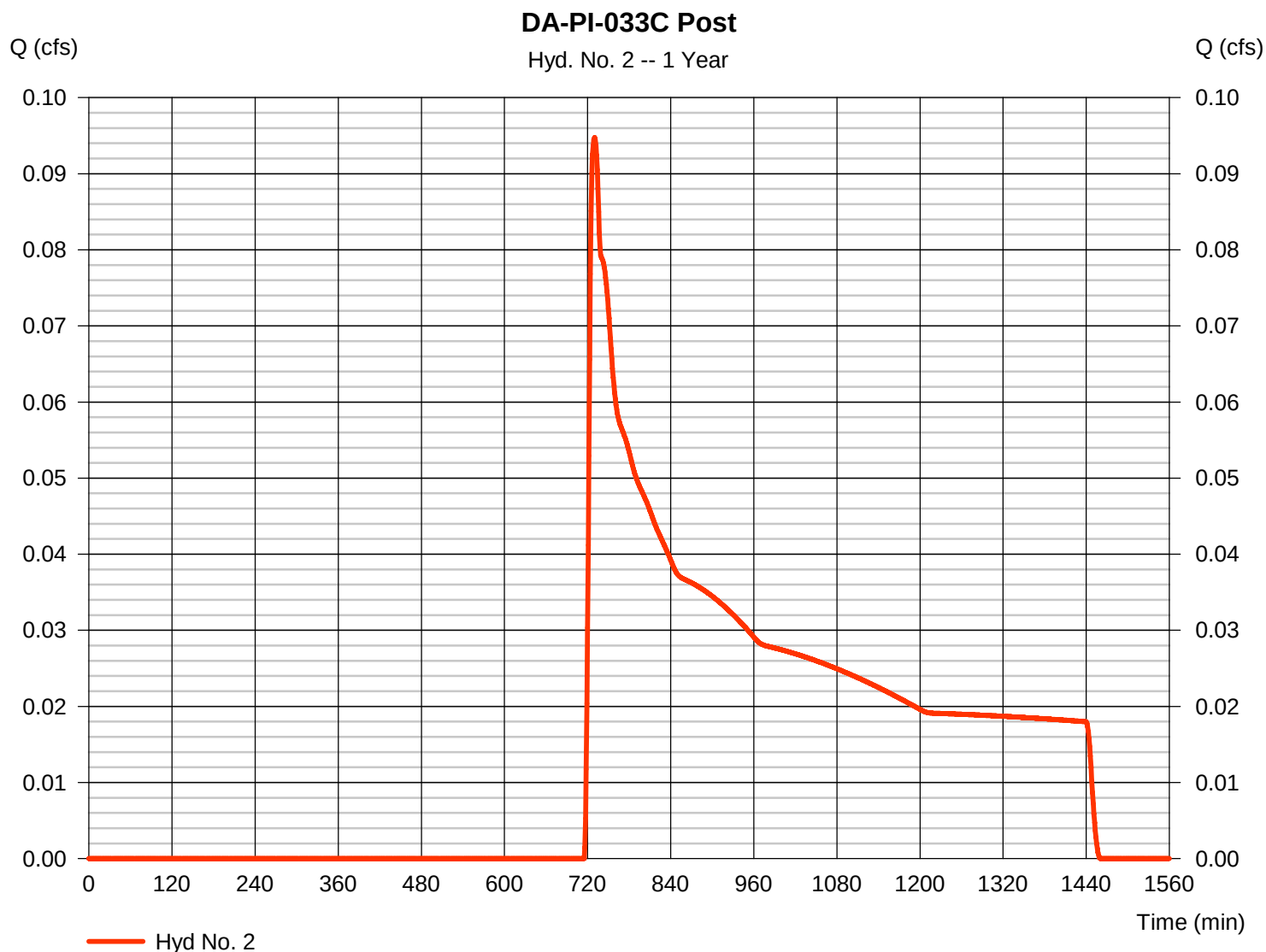
Tuesday, 08 / 22 / 2017

Hyd. No. 2

DA-PI-033C Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.095 cfs
Storm frequency	= 1 yrs	Time to peak	= 730 min
Time interval	= 1 min	Hyd. volume	= 1,298 cuft
Drainage area	= 2.510 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.30 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.870 \times 55) + (0.760 \times 48) + (0.040 \times 73) + (0.700 \times 58) + (0.140 \times 78)] / 2.510$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-PI-033C Post

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.400	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 11.17	0.00	0.00				
Travel Time (min)	= 10.32	+	0.00	+	0.00	=	10.32
Shallow Concentrated Flow							
Flow length (ft)	= 329.64	450.56	0.00				
Watercourse slope (%)	= 9.19	6.51	0.00				
Surface description	= Unpaved	Unpaved	Paved				
Average velocity (ft/s)	=4.89	4.12	0.00				
Travel Time (min)	= 1.12	+	1.82	+	0.00	=	2.95
Channel Flow							
X sectional flow area (sqft)	= 2.00	0.00	0.00				
Wetted perimeter (ft)	= 4.47	0.00	0.00				
Channel slope (%)	= 5.00	0.00	0.00				
Manning's n-value	= 0.040	0.015	0.015				
Velocity (ft/s)	=4.86	0.00	0.00				
Flow length (ft)	((0))24.3	0.0	0.0				
Travel Time (min)	= 0.08	+	0.00	+	0.00	=	0.08
Total Travel Time, Tc				13.30 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

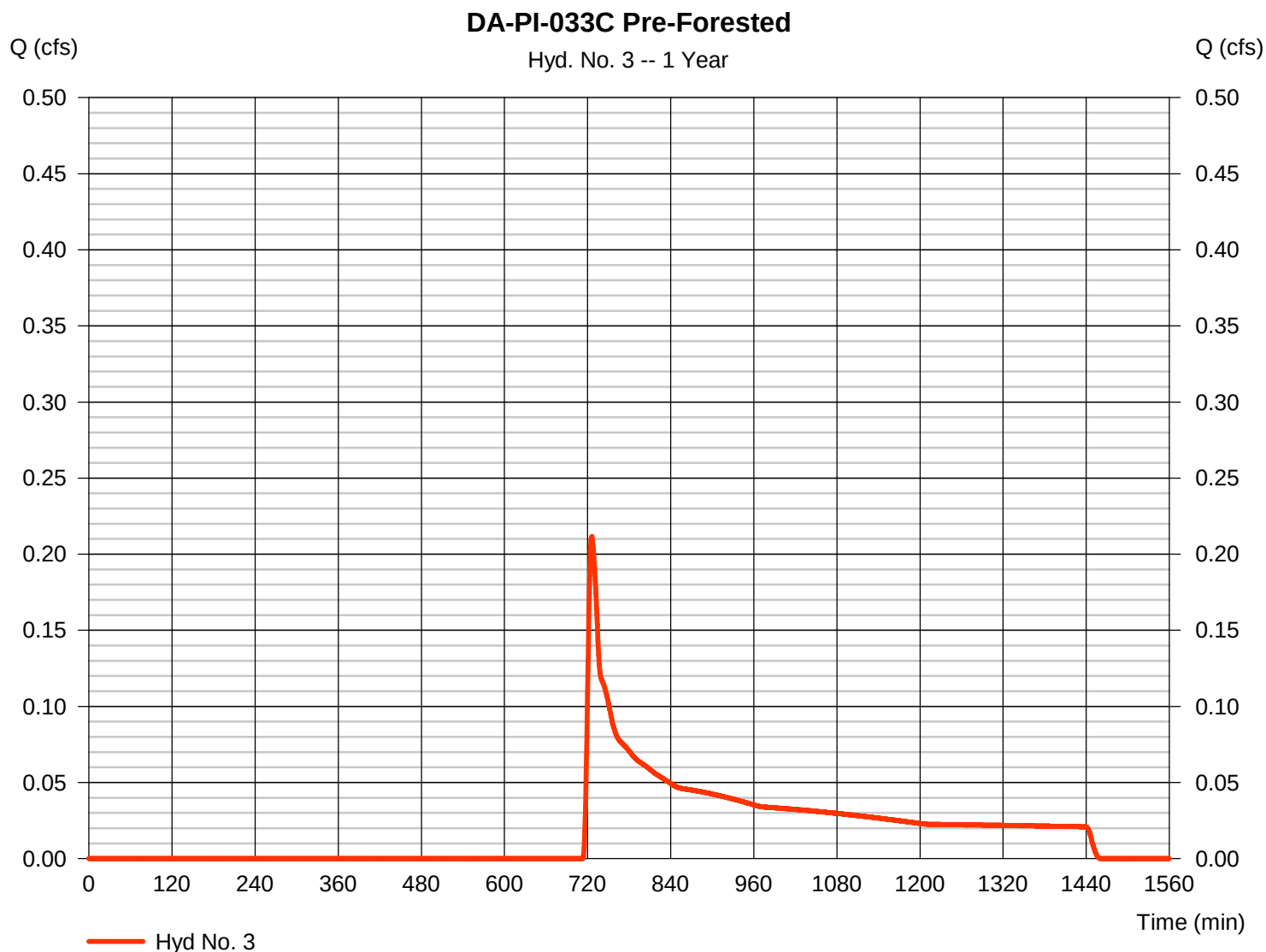
Tuesday, 08 / 22 / 2017

Hyd. No. 3

DA-PI-033C Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 0.212 cfs
Storm frequency	= 1 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 1,693 cuft
Drainage area	= 2.510 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.20 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(2.330 \times 55) + (0.180 \times 77)] / 2.510$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-PI-033C Pre-Forested

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.400	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00	
Land slope (%)	= 11.17	0.00	0.00	
Travel Time (min)	= 10.32	+ 0.00	+ 0.00	= 10.32
Shallow Concentrated Flow				
Flow length (ft)	= 770.34	0.00	0.00	
Watercourse slope (%)	= 7.89	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=4.53	0.00	0.00	
Travel Time (min)	= 2.83	+ 0.00	+ 0.00	= 2.83
Channel Flow				
X sectional flow area (sqft)	= 0.00	0.00	0.00	
Wetted perimeter (ft)	= 0.00	0.00	0.00	
Channel slope (%)	= 0.00	0.00	0.00	
Manning's n-value	= 0.030	0.015	0.015	
Velocity (ft/s)	=0.00	0.00	0.00	
Flow length (ft)	(0)0.0	0.0	0.0	
Travel Time (min)	= 0.00	+ 0.00	+ 0.00	= 0.00
Total Travel Time, Tc				13.20 min

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.932	1	724	3,730	-----	-----	-----	DA-PI-033C Pre
2	SCS Runoff	0.650	1	724	3,101	-----	-----	-----	DA-PI-033C Post
3	SCS Runoff	0.932	1	724	3,730	-----	-----	-----	DA-PI-033C Pre-Forested
DA-PI-033C.gpw					Return Period: 2 Year			Tuesday, 08 / 22 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

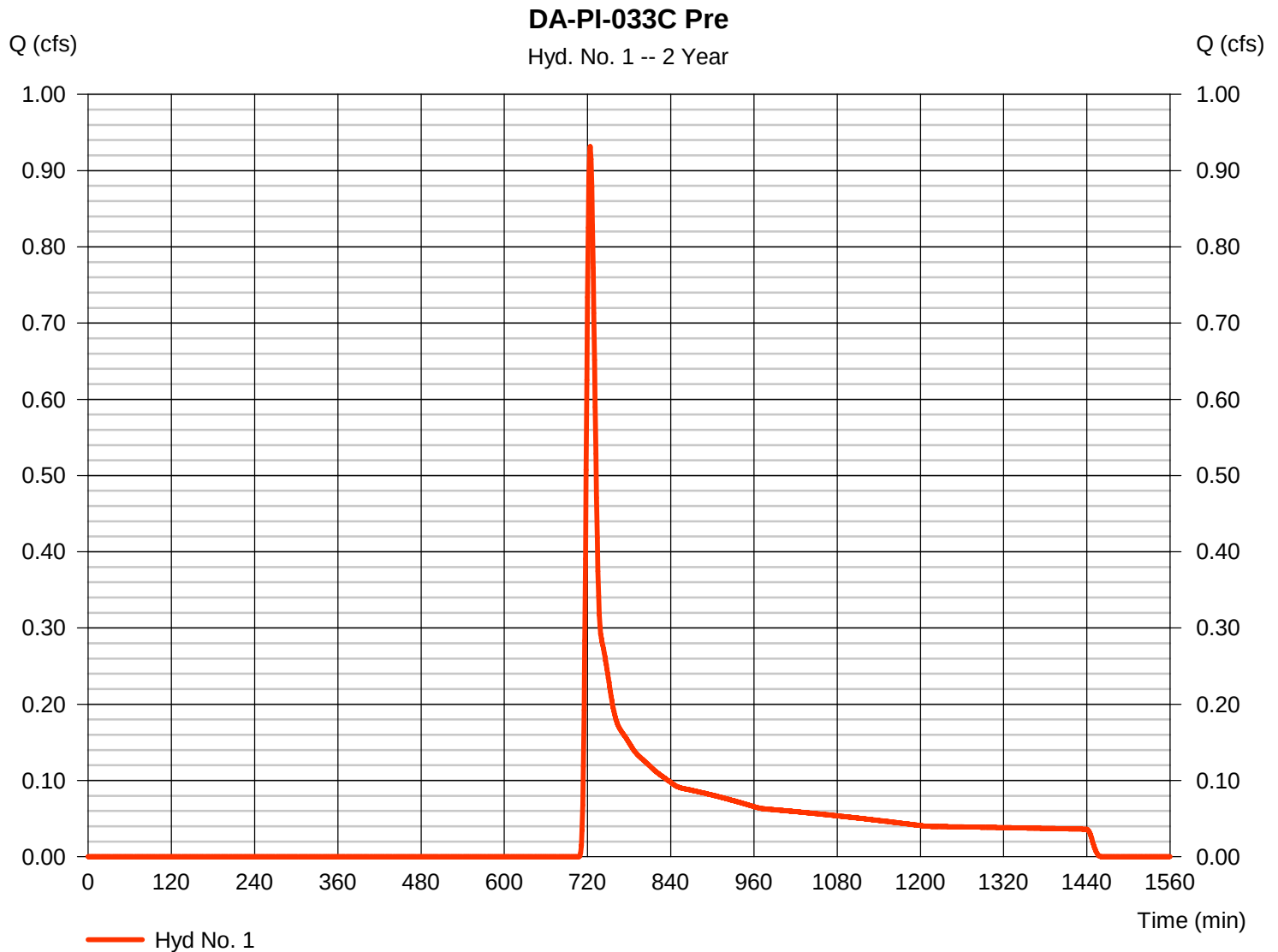
Tuesday, 08 / 22 / 2017

Hyd. No. 1

DA-PI-033C Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.932 cfs
Storm frequency	= 2 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 3,730 cuft
Drainage area	= 2.510 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.20 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(2.330 \times 55) + (0.180 \times 77)] / 2.510$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

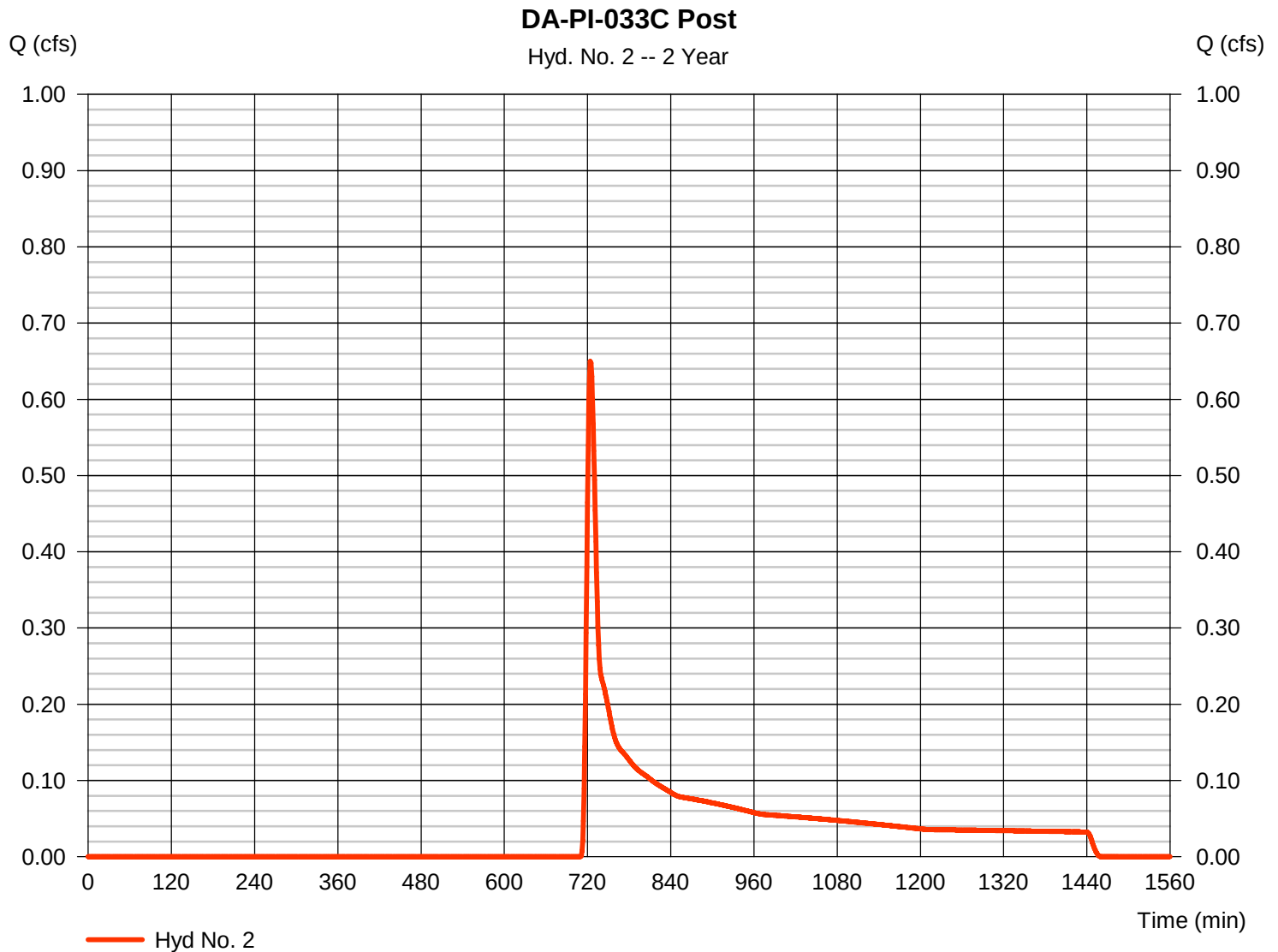
Tuesday, 08 / 22 / 2017

Hyd. No. 2

DA-PI-033C Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.650 cfs
Storm frequency	= 2 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 3,101 cuft
Drainage area	= 2.510 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.30 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.870 \times 55) + (0.760 \times 48) + (0.040 \times 73) + (0.700 \times 58) + (0.140 \times 78)] / 2.510$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

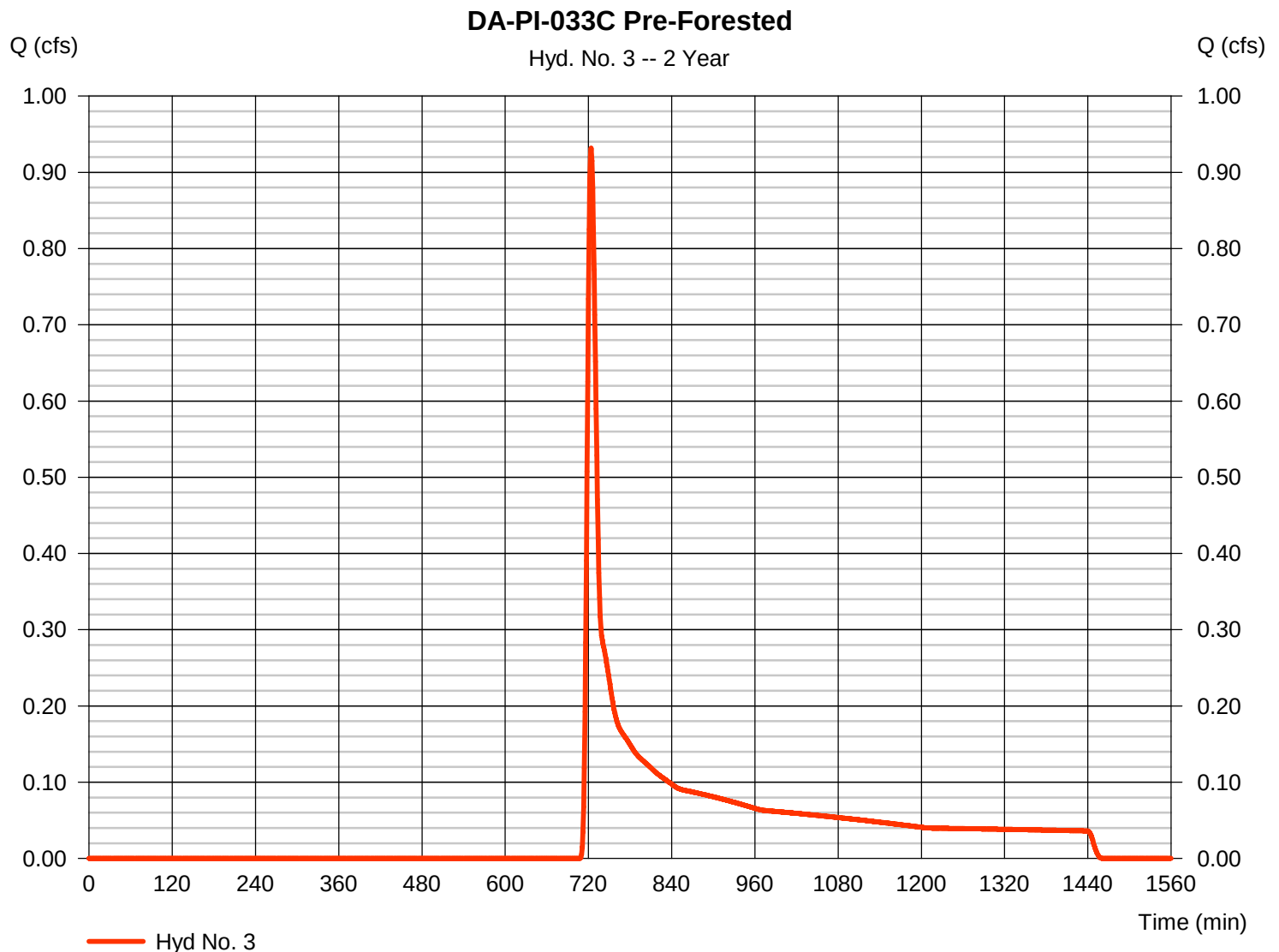
Tuesday, 08 / 22 / 2017

Hyd. No. 3

DA-PI-033C Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 0.932 cfs
Storm frequency	= 2 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 3,730 cuft
Drainage area	= 2.510 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.20 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(2.330 \times 55) + (0.180 \times 77)] / 2.510$



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	3.908	1	722	10,877	-----	-----	-----	DA-PI-033C Pre
2	SCS Runoff	3.355	1	722	9,697	-----	-----	-----	DA-PI-033C Post
3	SCS Runoff	3.908	1	722	10,877	-----	-----	-----	DA-PI-033C Pre-Forested
DA-PI-033C.gpw					Return Period: 10 Year			Tuesday, 08 / 22 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

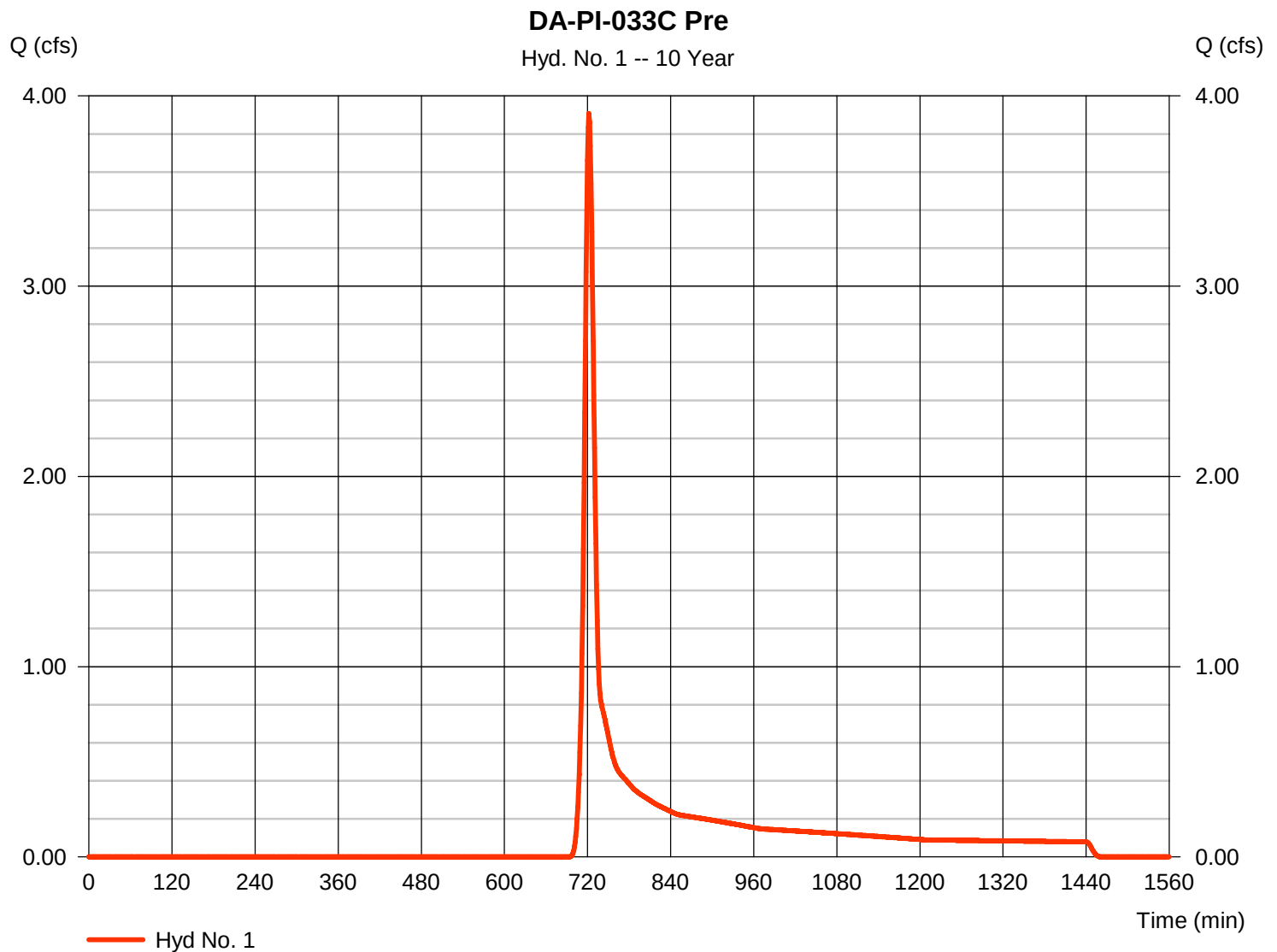
Tuesday, 08 / 22 / 2017

Hyd. No. 1

DA-PI-033C Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 3.908 cfs
Storm frequency	= 10 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 10,877 cuft
Drainage area	= 2.510 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.20 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(2.330 \times 55) + (0.180 \times 77)] / 2.510$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

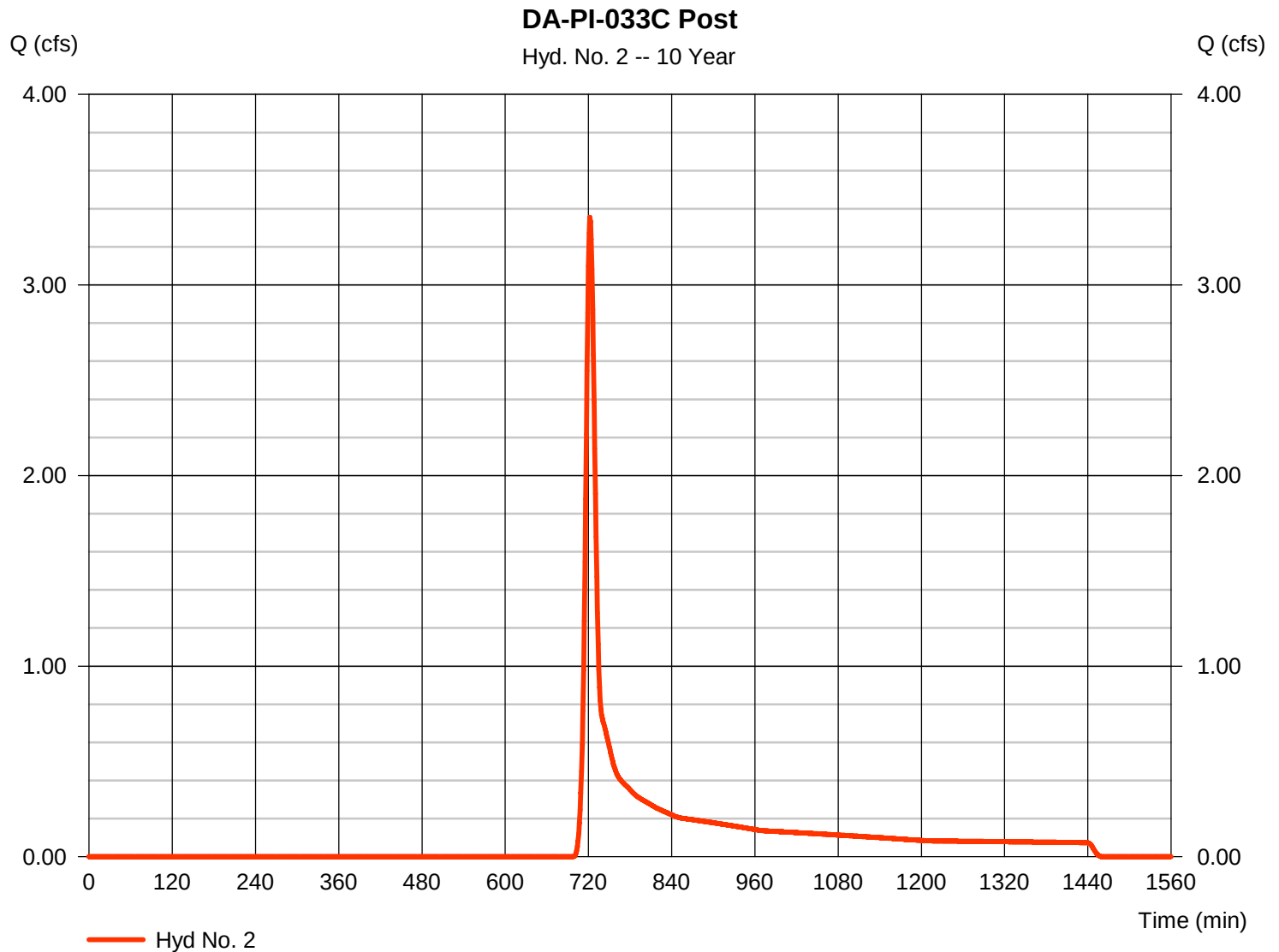
Tuesday, 08 / 22 / 2017

Hyd. No. 2

DA-PI-033C Post

Hydrograph type	= SCS Runoff	Peak discharge	= 3.355 cfs
Storm frequency	= 10 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 9,697 cuft
Drainage area	= 2.510 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.30 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.870 \times 55) + (0.760 \times 48) + (0.040 \times 73) + (0.700 \times 58) + (0.140 \times 78)] / 2.510$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

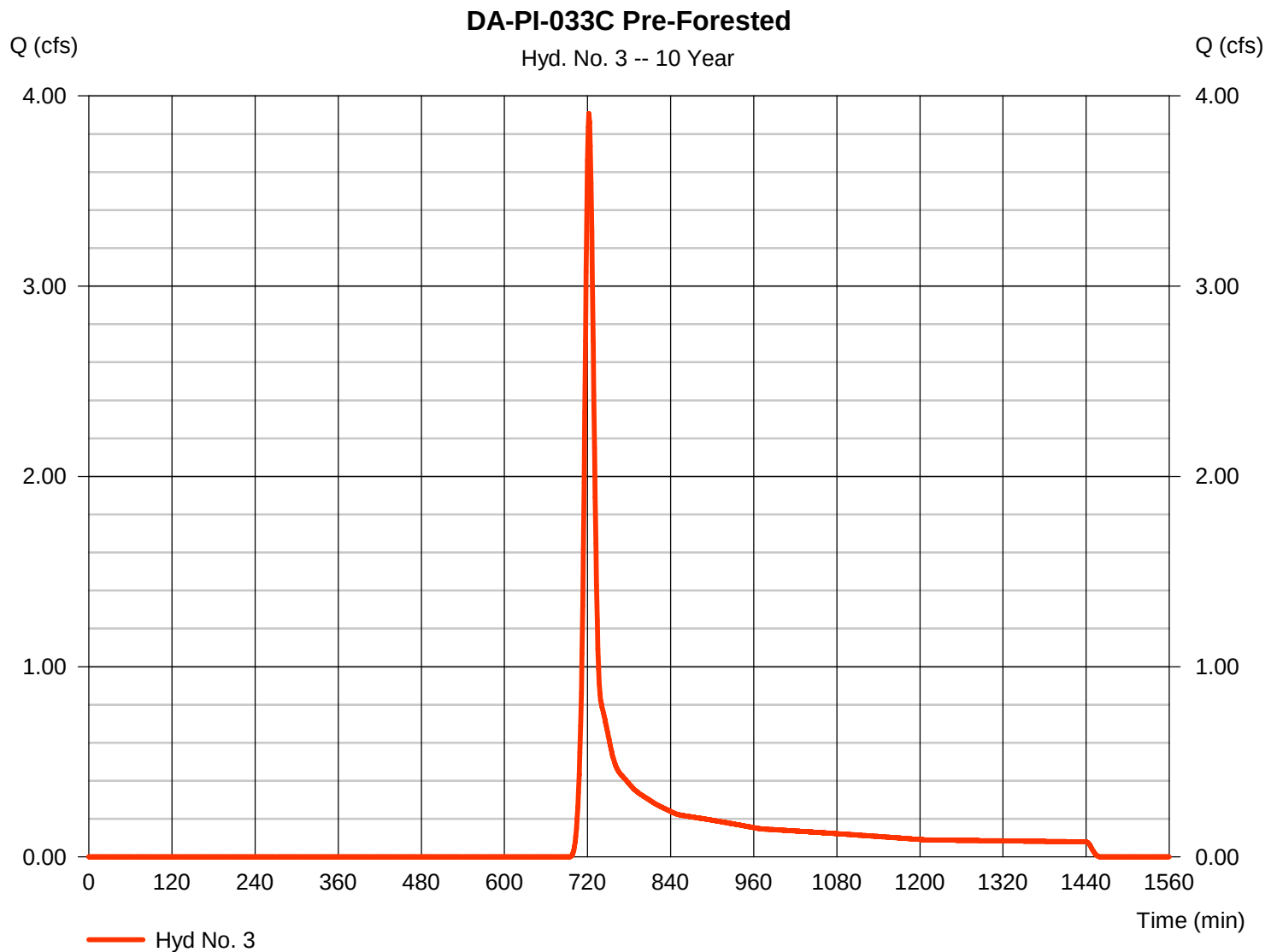
Tuesday, 08 / 22 / 2017

Hyd. No. 3

DA-PI-033C Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	3.908 cfs
Storm frequency	=	10 yrs	Time to peak	=	722 min
Time interval	=	1 min	Hyd. volume	=	10,877 cuft
Drainage area	=	2.510 ac	Curve number	=	57*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	13.20 min
Total precip.	=	5.20 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(2.330 \times 55) + (0.180 \times 77)] / 2.510$



DA-PI-033D

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.886	3,067
Developed Condition	0.803	2,861
Pre-Developed (Forest) Condition	0.886	2,861

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 1

Calculations:

Check #1:

$$Q_{\text{developed}} \leq IF \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}] \text{ ----->}$$

Q (cfs)

0.803

≤

OK

Q (cfs)

0.950

Check #2:

$$Q_{\text{developed}} \leq Q_{\text{pre-developed}} \text{ ----->}$$

0.803

≤

OK

0.886

Check #3:

$$Q_{\text{developed}} \text{ shall not be required to be } \leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}} \text{ --->}$$

0.803

shall not be required to be ≤

0.886

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

Table 1 – Manning's n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<i>Note:</i> <i>Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.</i> ¹<i>For Paved Road land surface types a Manning's n of 0.011 was used</i> <i>Sources:</i> <i>-USACE, 1998, HEC-1 Flood Hydrograph Package User's Manual, Hydrologic Engineering Center, Davis, CA</i> <i>-Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC</i>	

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

1



2



3



Legend

<u>Hyd.</u>	<u>Origin</u>	<u>Description</u>
1	SCS Runoff	DA-PI-033D Pre
2	SCS Runoff	DA-PI-033D Post
3	SCS Runoff	DA-PI-033D Pre-Forested

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.886	1	725	3,067	-----	-----	-----	DA-PI-033D Pre
2	SCS Runoff	0.803	1	726	2,861	-----	-----	-----	DA-PI-033D Post
3	SCS Runoff	0.803	1	726	2,861	-----	-----	-----	DA-PI-033D Pre-Forested
DA-PI-033D.gpw					Return Period: 1 Year			Tuesday, 08 / 22 / 2017	

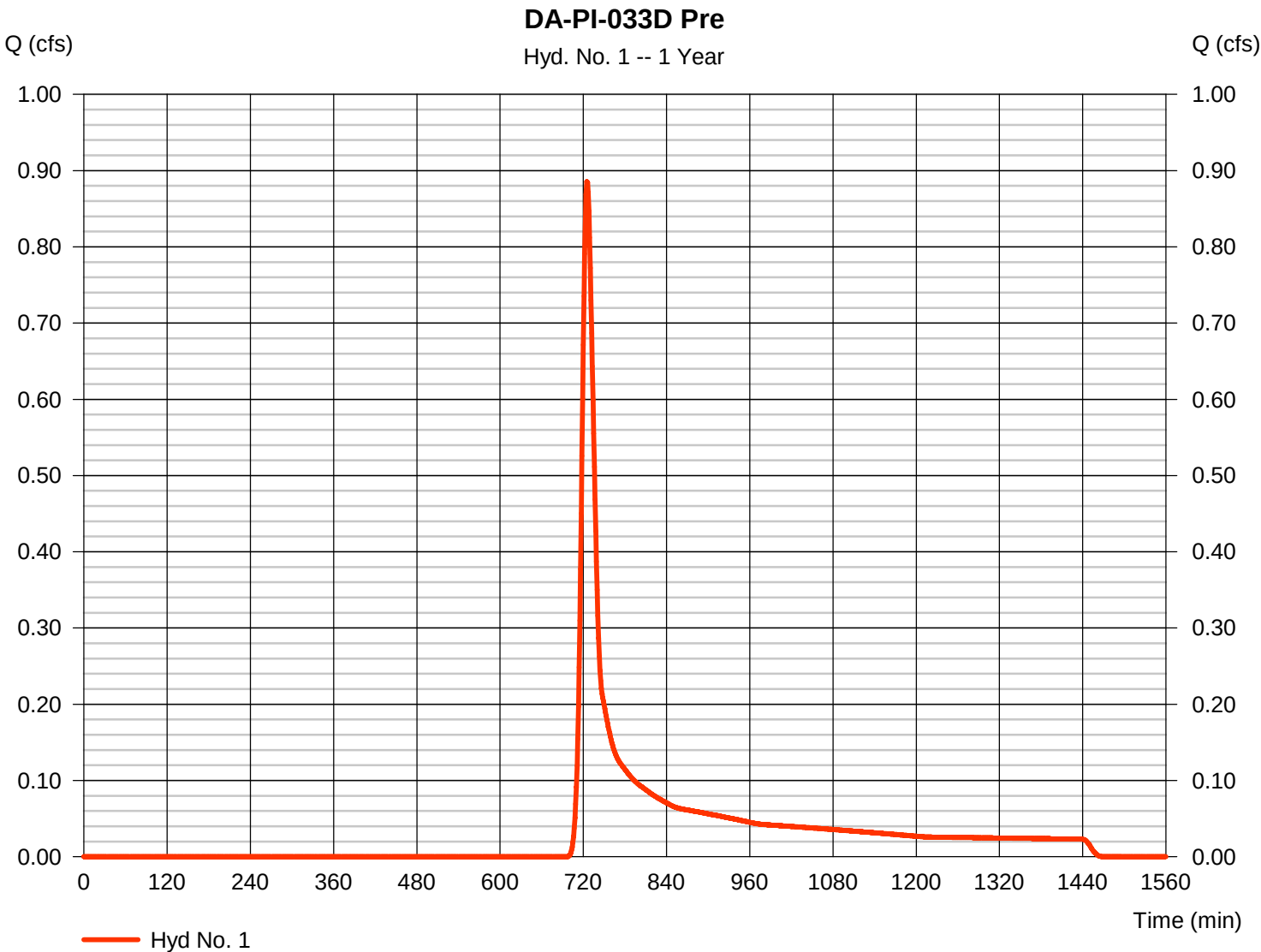
Hydrograph Report

Hyd. No. 1

DA-PI-033D Pre

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.886 cfs
Storm frequency	=	1 yrs	Time to peak	=	725 min
Time interval	=	1 min	Hyd. volume	=	3,067 cuft
Drainage area	=	1.410 ac	Curve number	=	70*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	18.20 min
Total precip.	=	2.80 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.450 x 77) + (0.530 x 58) + (0.430 x 78)] / 1.410



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-PI-033D Pre

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.400	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 4.26	0.00	0.00				
Travel Time (min)	= 15.17	+	0.00	+	0.00	=	15.17
Shallow Concentrated Flow							
Flow length (ft)	= 577.16	0.00	0.00				
Watercourse slope (%)	= 3.99	0.00	0.00				
Surface description	= Unpaved	Paved	Paved				
Average velocity (ft/s)	=3.22	0.00	0.00				
Travel Time (min)	= 2.98	+	0.00	+	0.00	=	2.98
Channel Flow							
X sectional flow area (sqft)	= 0.00	0.00	0.00				
Wetted perimeter (ft)	= 0.00	0.00	0.00				
Channel slope (%)	= 0.00	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	((0})0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc				18.20 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

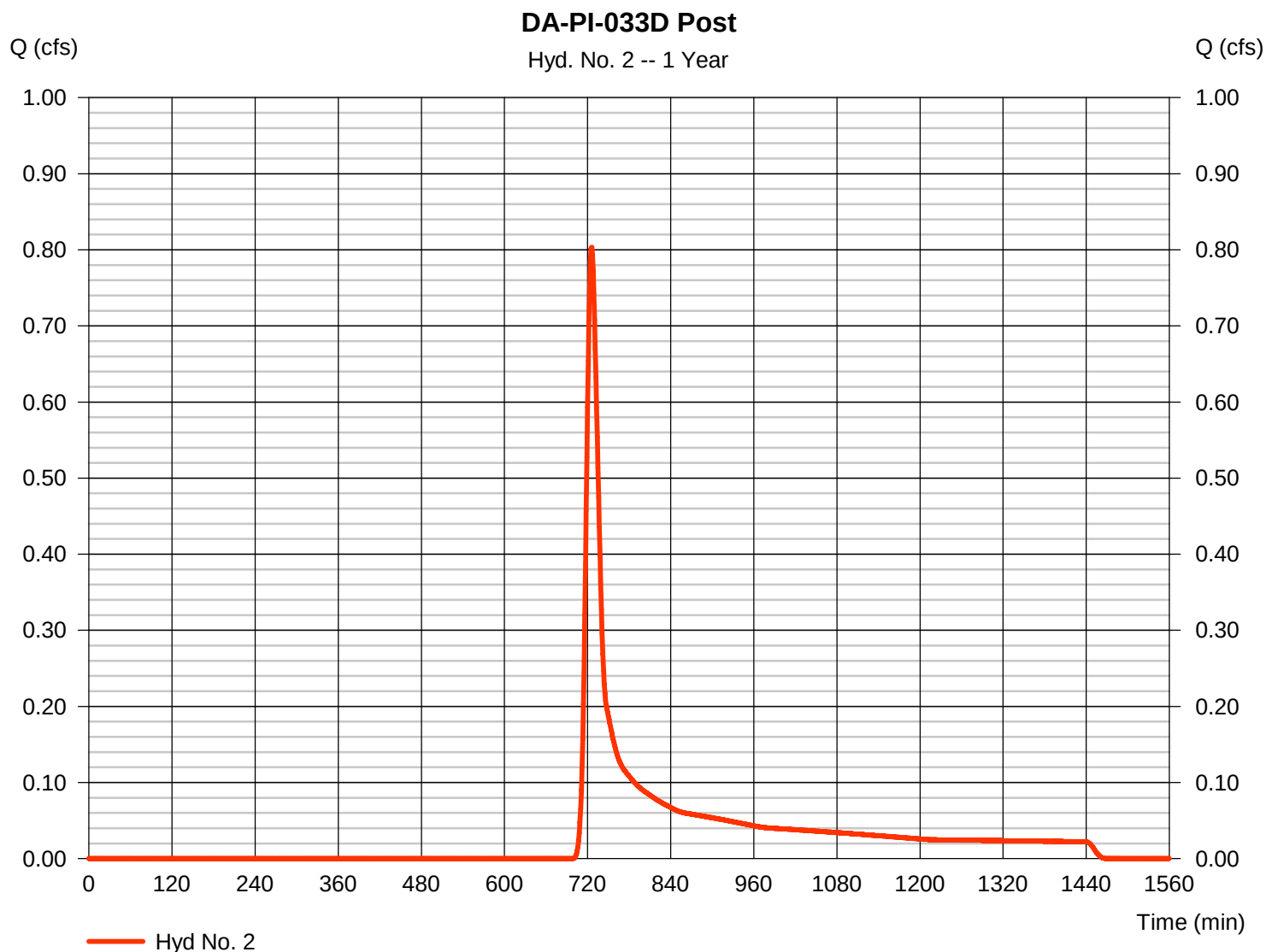
Tuesday, 08 / 22 / 2017

Hyd. No. 2

DA-PI-033D Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.803 cfs
Storm frequency	= 1 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 2,861 cuft
Drainage area	= 1.410 ac	Curve number	= 69*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.20 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.020 \times 77) + (0.530 \times 58) + (0.560 \times 78) + (0.300 \times 73)] / 1.410$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-PI-033D Post

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.400	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 4.26	0.00	0.00				
Travel Time (min)	= 15.17	+	0.00	+	0.00	=	15.17
Shallow Concentrated Flow							
Flow length (ft)	= 577.16	0.00	0.00				
Watercourse slope (%)	= 3.99	0.00	0.00				
Surface description	= Unpaved	Unpaved	Paved				
Average velocity (ft/s)	=3.22	0.00	0.00				
Travel Time (min)	= 2.98	+	0.00	+	0.00	=	2.98
Channel Flow							
X sectional flow area (sqft)	= 0.00	0.00	0.00				
Wetted perimeter (ft)	= 0.00	0.00	0.00				
Channel slope (%)	= 0.00	0.00	0.00				
Manning's n-value	= 0.040	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc				18.20 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

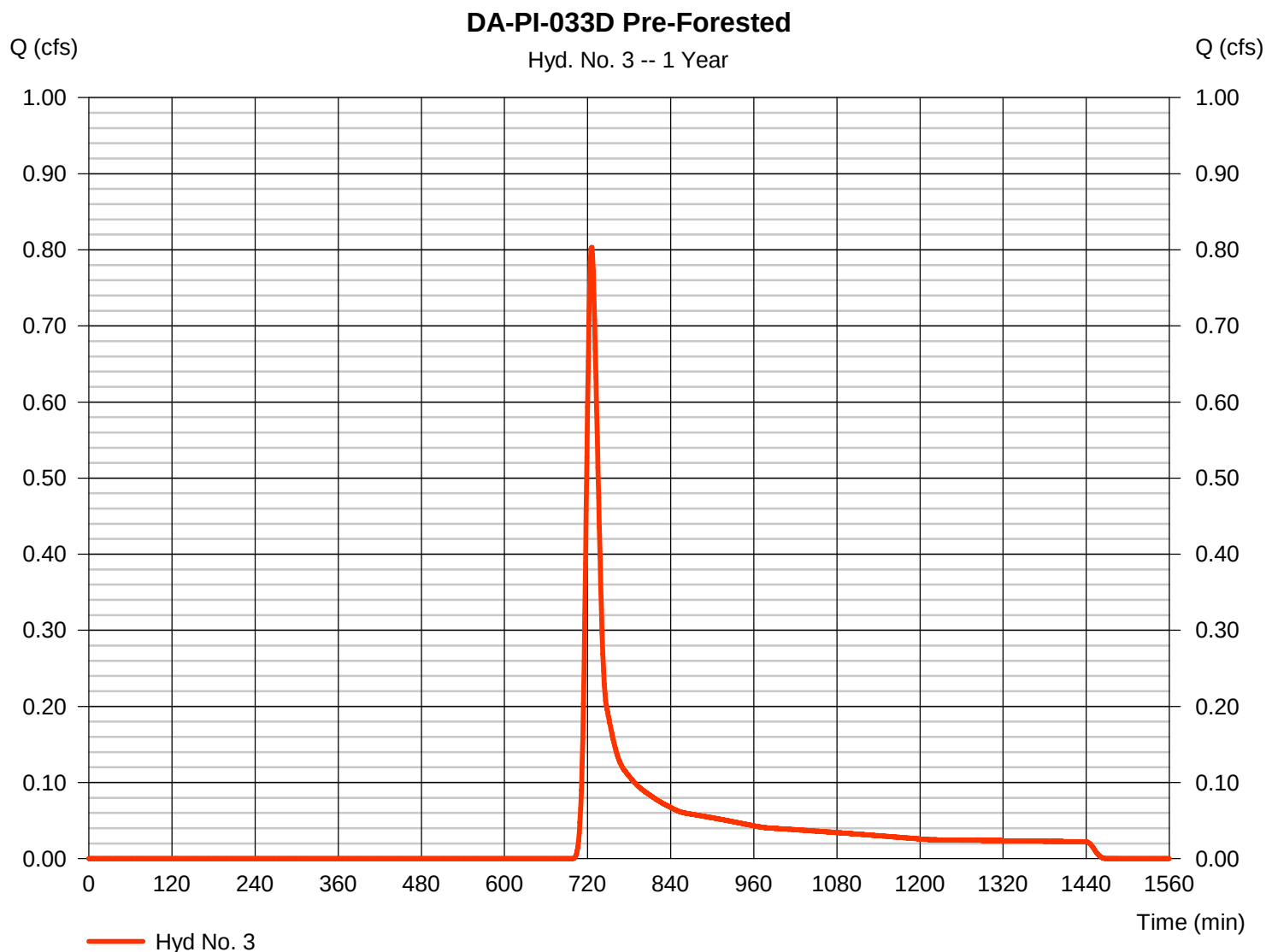
Tuesday, 08 / 22 / 2017

Hyd. No. 3

DA-PI-033D Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 0.803 cfs
Storm frequency	= 1 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 2,861 cuft
Drainage area	= 1.410 ac	Curve number	= 69*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.20 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.530 \times 55) + (0.880 \times 77)] / 1.410$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-PI-033D Pre-Forested

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.400	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00	
Land slope (%)	= 4.26	0.00	0.00	
Travel Time (min)	= 15.17	+ 0.00	+ 0.00	= 15.17
Shallow Concentrated Flow				
Flow length (ft)	= 577.16	0.00	0.00	
Watercourse slope (%)	= 3.99	0.00	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=3.22	0.00	0.00	
Travel Time (min)	= 2.98	+ 0.00	+ 0.00	= 2.98
Channel Flow				
X sectional flow area (sqft)	= 0.00	0.00	0.00	
Wetted perimeter (ft)	= 0.00	0.00	0.00	
Channel slope (%)	= 0.00	0.00	0.00	
Manning's n-value	= 0.030	0.015	0.015	
Velocity (ft/s)	=0.00	0.00	0.00	
Flow length (ft)	(0)0.0	0.0	0.0	
Travel Time (min)	= 0.00	+ 0.00	+ 0.00	= 0.00
Total Travel Time, Tc				18.20 min

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	1.609	1	725	5,101	-----	-----	-----	DA-PI-033D Pre
2	SCS Runoff	1.502	1	725	4,827	-----	-----	-----	DA-PI-033D Post
3	SCS Runoff	1.502	1	725	4,827	-----	-----	-----	DA-PI-033D Pre-Forested
DA-PI-033D.gpw					Return Period: 2 Year			Tuesday, 08 / 22 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

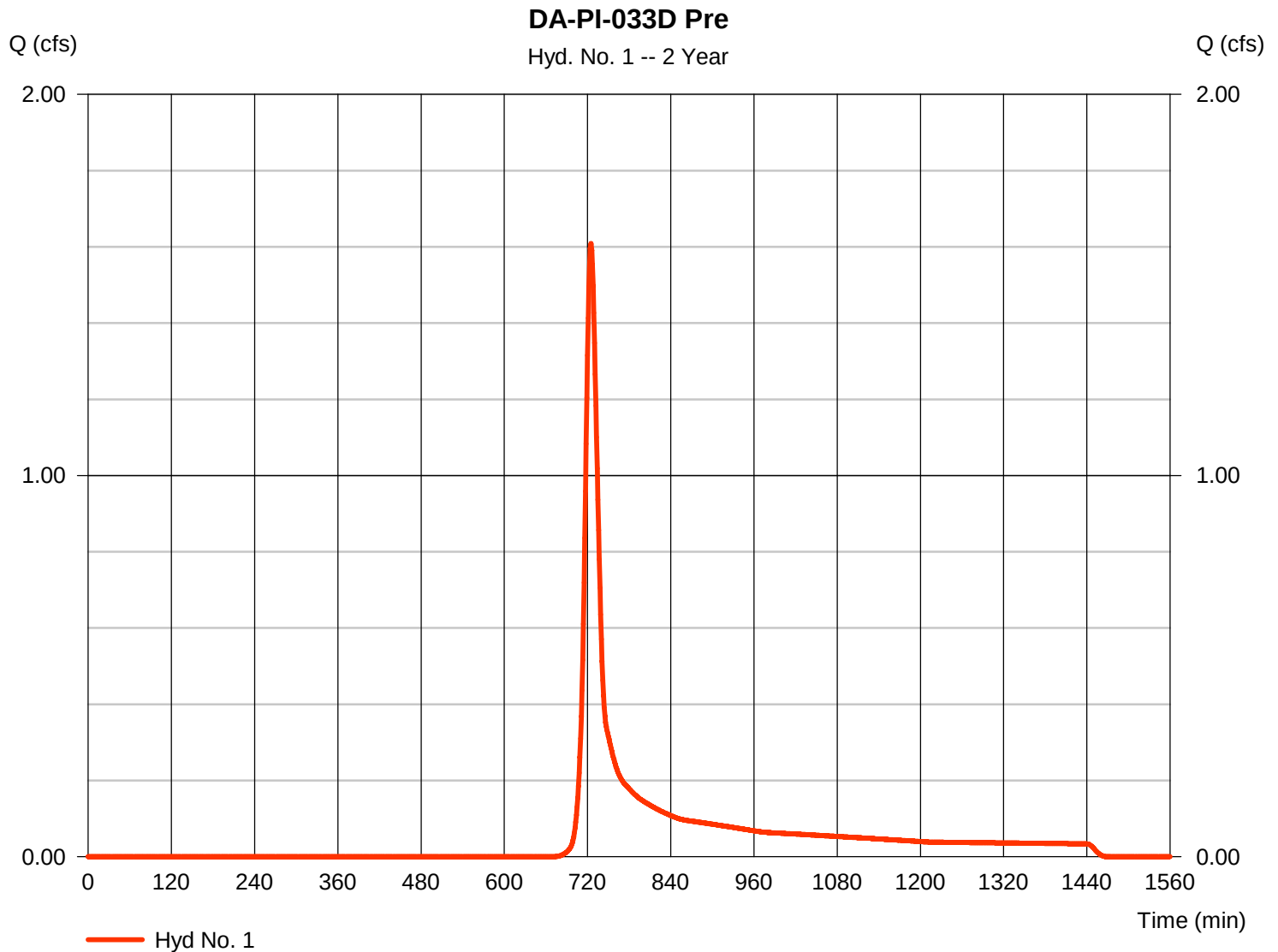
Tuesday, 08 / 22 / 2017

Hyd. No. 1

DA-PI-033D Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 1.609 cfs
Storm frequency	= 2 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 5,101 cuft
Drainage area	= 1.410 ac	Curve number	= 70*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.20 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.450 \times 77) + (0.530 \times 58) + (0.430 \times 78)] / 1.410$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

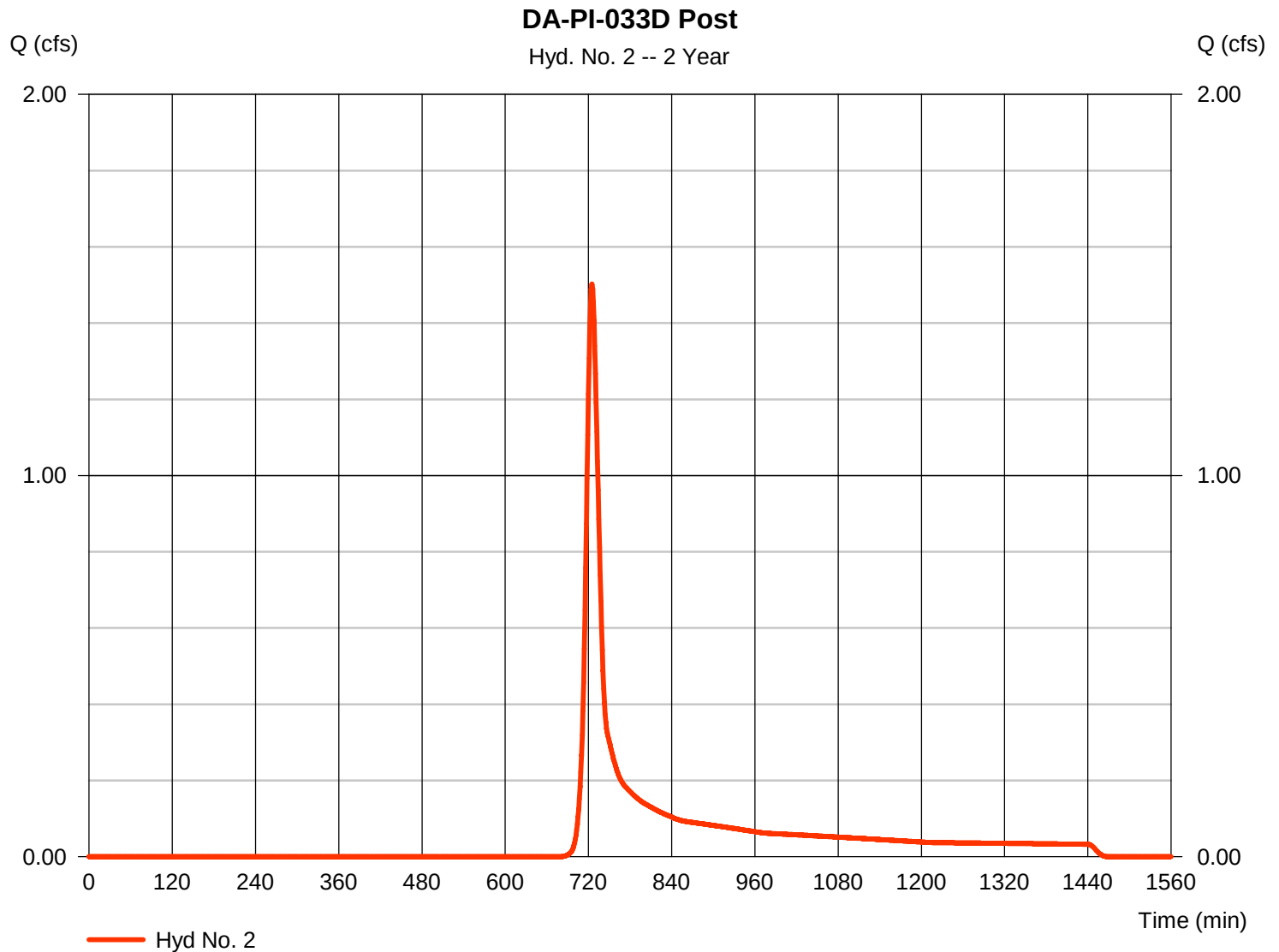
Tuesday, 08 / 22 / 2017

Hyd. No. 2

DA-PI-033D Post

Hydrograph type	= SCS Runoff	Peak discharge	= 1.502 cfs
Storm frequency	= 2 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 4,827 cuft
Drainage area	= 1.410 ac	Curve number	= 69*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.20 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.020 \times 77) + (0.530 \times 58) + (0.560 \times 78) + (0.300 \times 73)] / 1.410$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

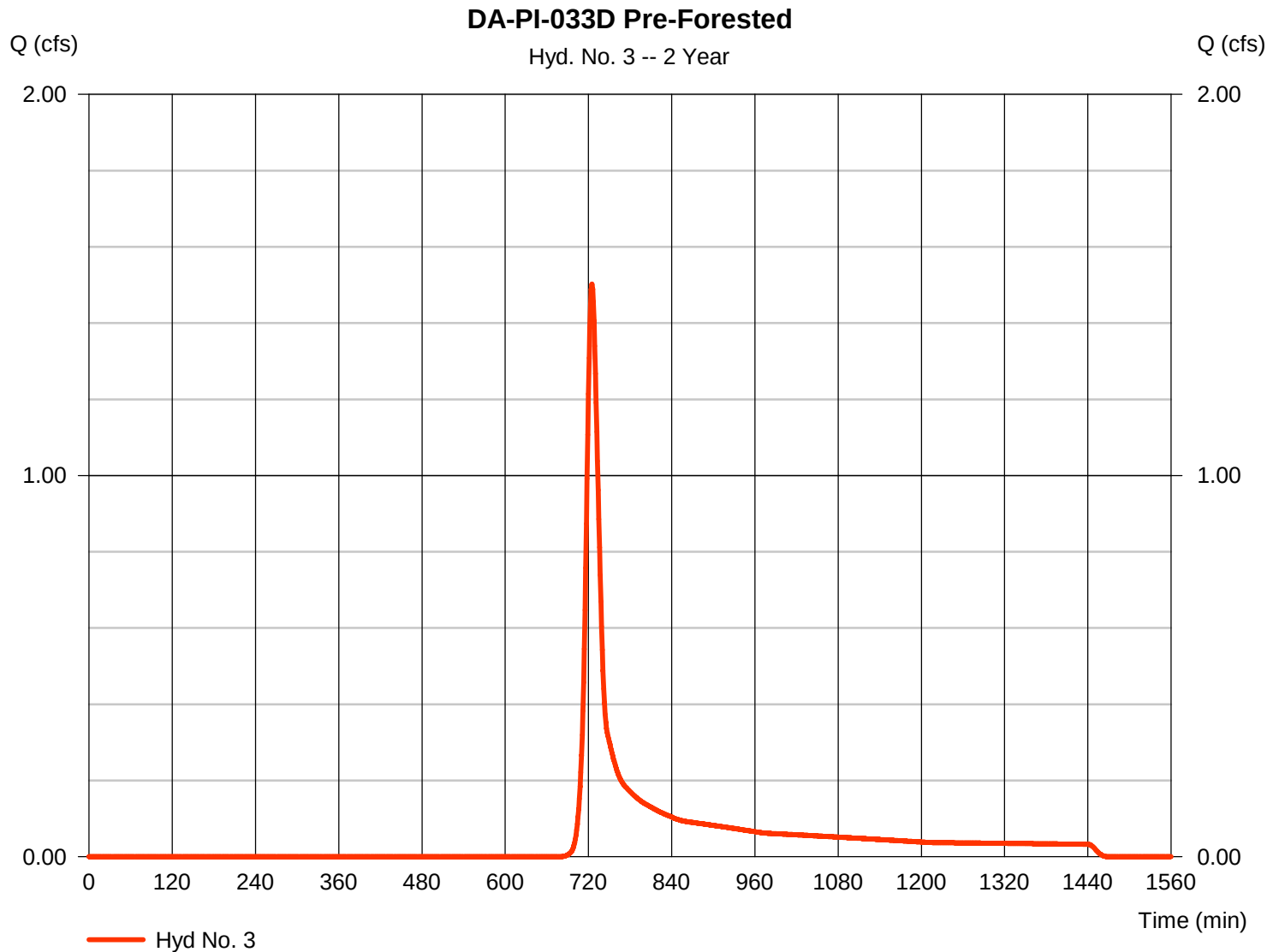
Tuesday, 08 / 22 / 2017

Hyd. No. 3

DA-PI-033D Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 1.502 cfs
Storm frequency	= 2 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 4,827 cuft
Drainage area	= 1.410 ac	Curve number	= 69*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.20 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.530 \times 55) + (0.880 \times 77)] / 1.410$



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	3.691	1	724	11,060	-----	-----	-----	DA-PI-033D Pre
2	SCS Runoff	3.539	1	724	10,646	-----	-----	-----	DA-PI-033D Post
3	SCS Runoff	3.539	1	724	10,646	-----	-----	-----	DA-PI-033D Pre-Forested
DA-PI-033D.gpw					Return Period: 10 Year			Tuesday, 08 / 22 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

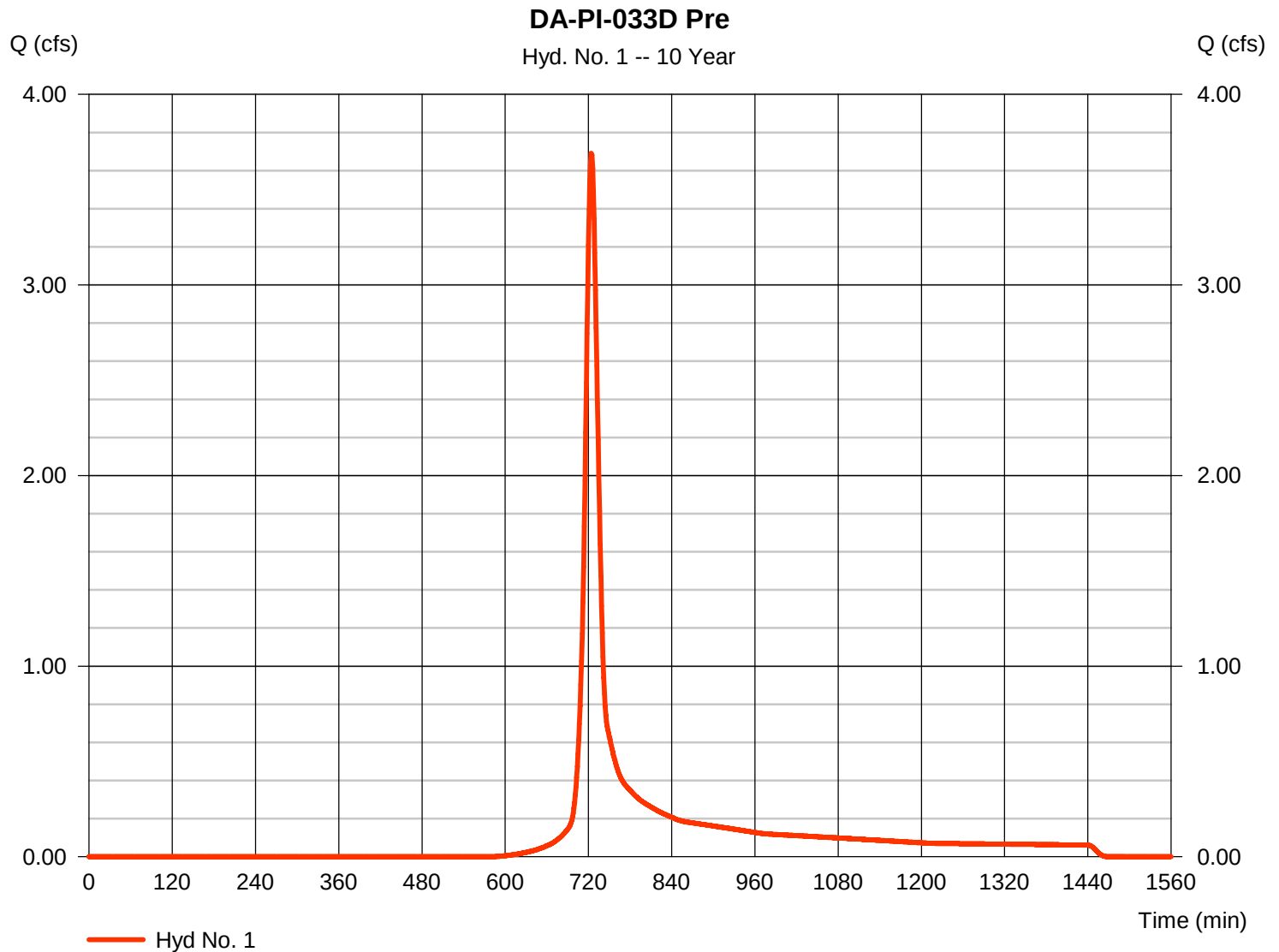
Tuesday, 08 / 22 / 2017

Hyd. No. 1

DA-PI-033D Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 3.691 cfs
Storm frequency	= 10 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 11,060 cuft
Drainage area	= 1.410 ac	Curve number	= 70*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.20 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.450 \times 77) + (0.530 \times 58) + (0.430 \times 78)] / 1.410$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

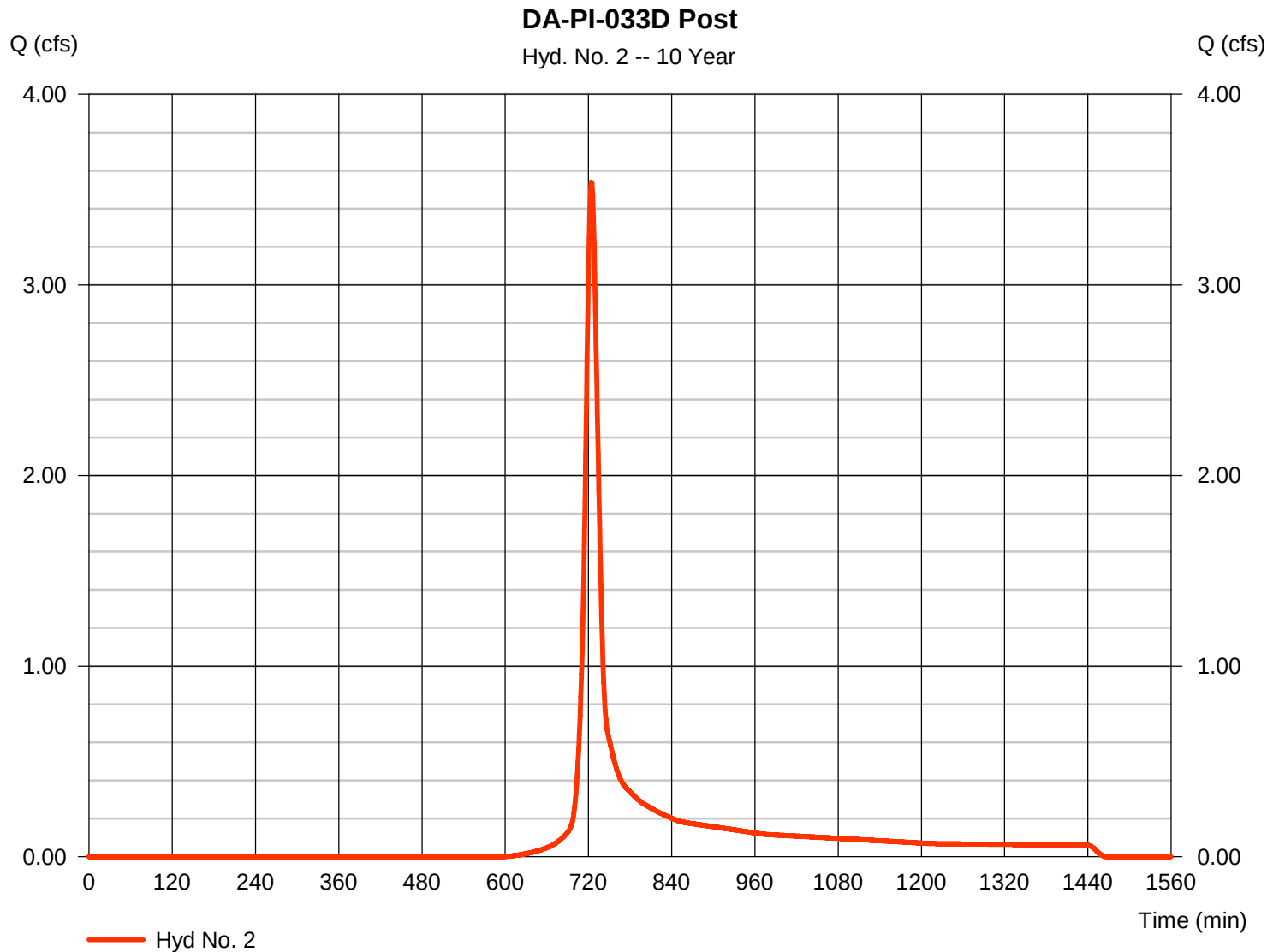
Tuesday, 08 / 22 / 2017

Hyd. No. 2

DA-PI-033D Post

Hydrograph type	= SCS Runoff	Peak discharge	= 3.539 cfs
Storm frequency	= 10 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 10,646 cuft
Drainage area	= 1.410 ac	Curve number	= 69*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.20 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.020 \times 77) + (0.530 \times 58) + (0.560 \times 78) + (0.300 \times 73)] / 1.410$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

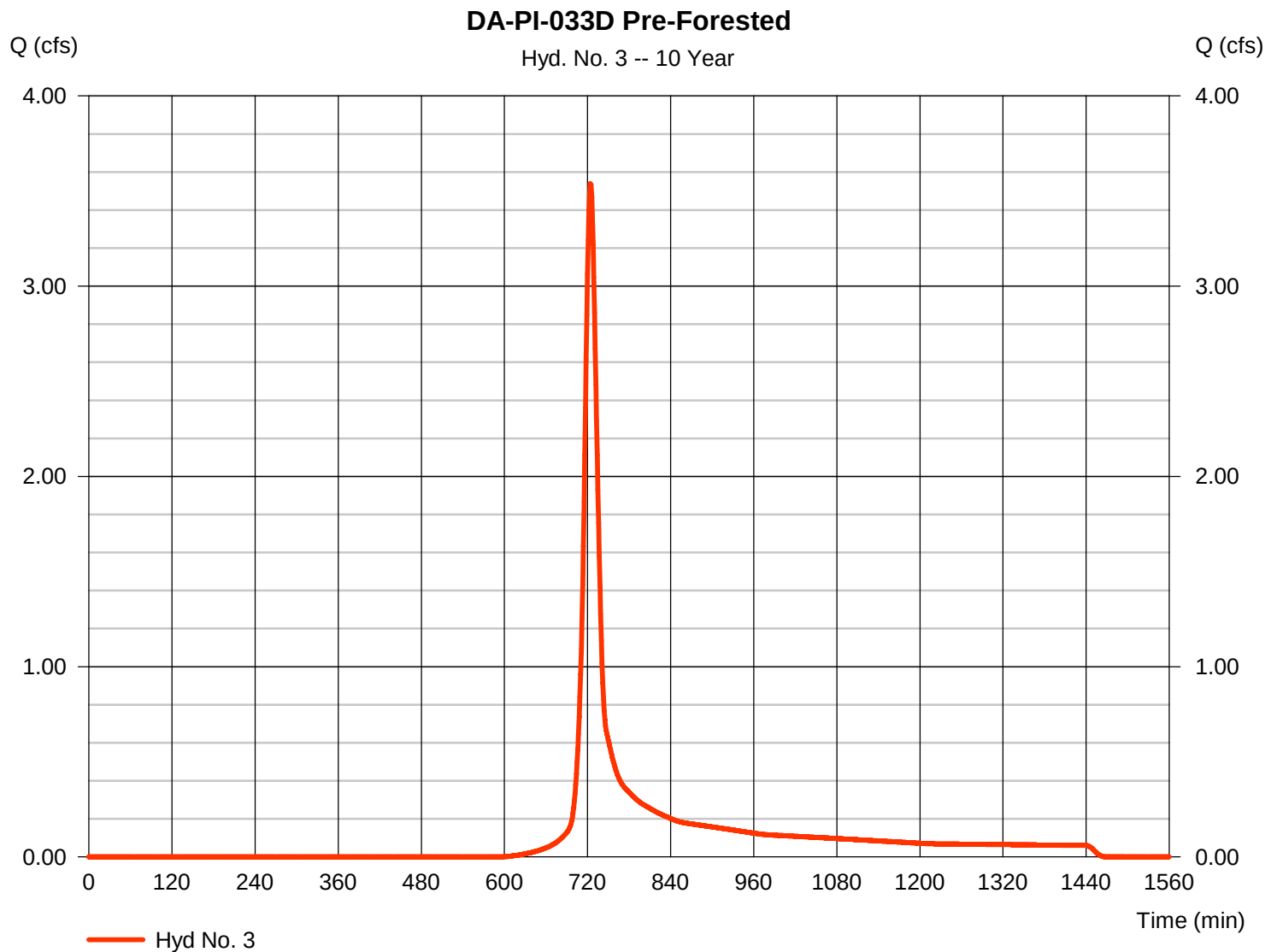
Tuesday, 08 / 22 / 2017

Hyd. No. 3

DA-PI-033D Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	3.539 cfs
Storm frequency	=	10 yrs	Time to peak	=	724 min
Time interval	=	1 min	Hyd. volume	=	10,646 cuft
Drainage area	=	1.410 ac	Curve number	=	69*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	18.20 min
Total precip.	=	5.20 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(0.530 \times 55) + (0.880 \times 77)] / 1.410$



DA-PI-033E

STORAGE VOLUME OF PAD AREA (DA-PI-033E)

Equations Used: $V_{\text{pad gravel storage}} = L_{\text{pad}} \times W_{\text{pad}} \times D_{\text{gravel}} \times (40/100)$

¹Equation #2b under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, assuming that gravel is made up of 40% voids.

Inputs:

Depth of Gravel Layer, D_{gravel} (ft) =	1
Length of Pad, L_{pad} (ft) =	48
Width of Pad, W_{pad} (ft) =	48

Calculations:

Depth-Storage Data			
Depth (ft)	Width (ft)	Length (ft)	Storage Volume (cf)
0	48	48	0
0.5	48	48	460.8
1	48	48	921.6
1.5	48	48	2073.6

ENERGY BALANCE METHOD

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.065	539
Developed Condition	0.008	25
Pre-Developed (Forest) Condition	0.021	328

*Peak Flow and Runoff Volume inputs taken from Hydraflow Hydrographs model

Improvement Factor, IF = 1

Calculations:			Q (cfs)		Q (cfs)
Check #1:	$Q_{\text{developed}} \leq IF \times [(Q_{\text{pre-developed}} \times RV_{\text{pre-developed}}) / RV_{\text{developed}}]$ ----->		0.008	$\leq$	1.396
				OK	
Check #2:	$Q_{\text{developed}} \leq Q_{\text{pre-developed}}$ ----->		0.008	$\leq$	0.065
				N/A - See Check #3	
Check #3:	$Q_{\text{developed}}$ <u>shall not</u> be required to be $\leq (Q_{\text{forest}} \times RV_{\text{forest}}) / RV_{\text{developed}}$ --->		0.008	<u>shall not</u> be required to be $\leq$	0.274

STORMWATER QUANTITY REQUIREMENTS ARE SATISFIED

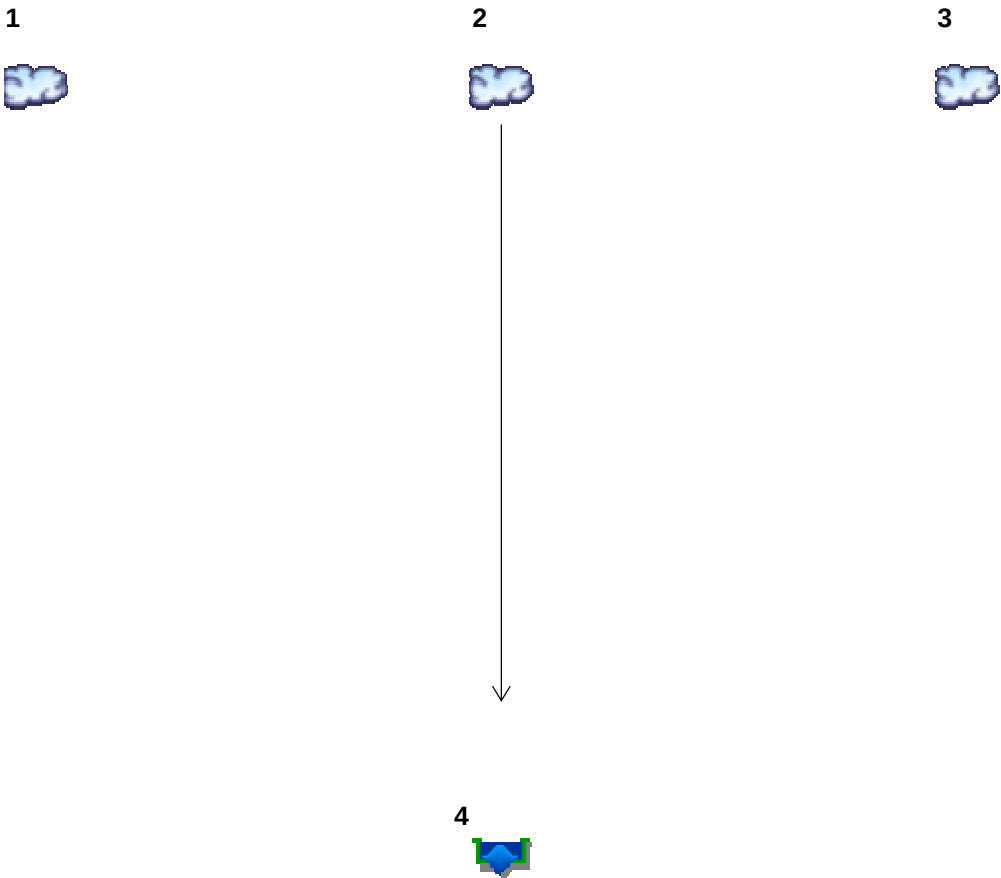
Table 1 – Manning's n Values for Sheet Flow

Land Surface Type	Manning n
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40
<i>Note:</i> Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted. ¹For Paved Road land surface types a Manning's n of 0.011 was used <i>Sources:</i> -USACE, 1998, HEC-1 Flood Hydrograph Package User's Manual, Hydrologic Engineering Center, Davis, CA -Soil Conservation Service, 1986, Urban Hydrology for Small Watersheds, Technical Release 55, U.S. Department of Agriculture, Washington, DC	

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Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5



Legend

Hyd.	Origin	Description
1	SCS Runoff	DA-PI-033E Pre
2	SCS Runoff	DA-PI-033E Post
3	SCS Runoff	DA-PI-033E Pre-Forested
4	Reservoir	DA-PI-033E Pad Storage

Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.065	1	732	539	-----	-----	-----	DA-PI-033E Pre
2	SCS Runoff	0.190	1	730	947	-----	-----	-----	DA-PI-033E Post
3	SCS Runoff	0.021	1	745	328	-----	-----	-----	DA-PI-033E Pre-Forested
4	Reservoir	0.008	1	1414	25	2	802.00	922	DA-PI-033E Pad Storage
DA-PI-033E.gpw					Return Period: 1 Year			Wednesday, 09 / 6 / 2017	

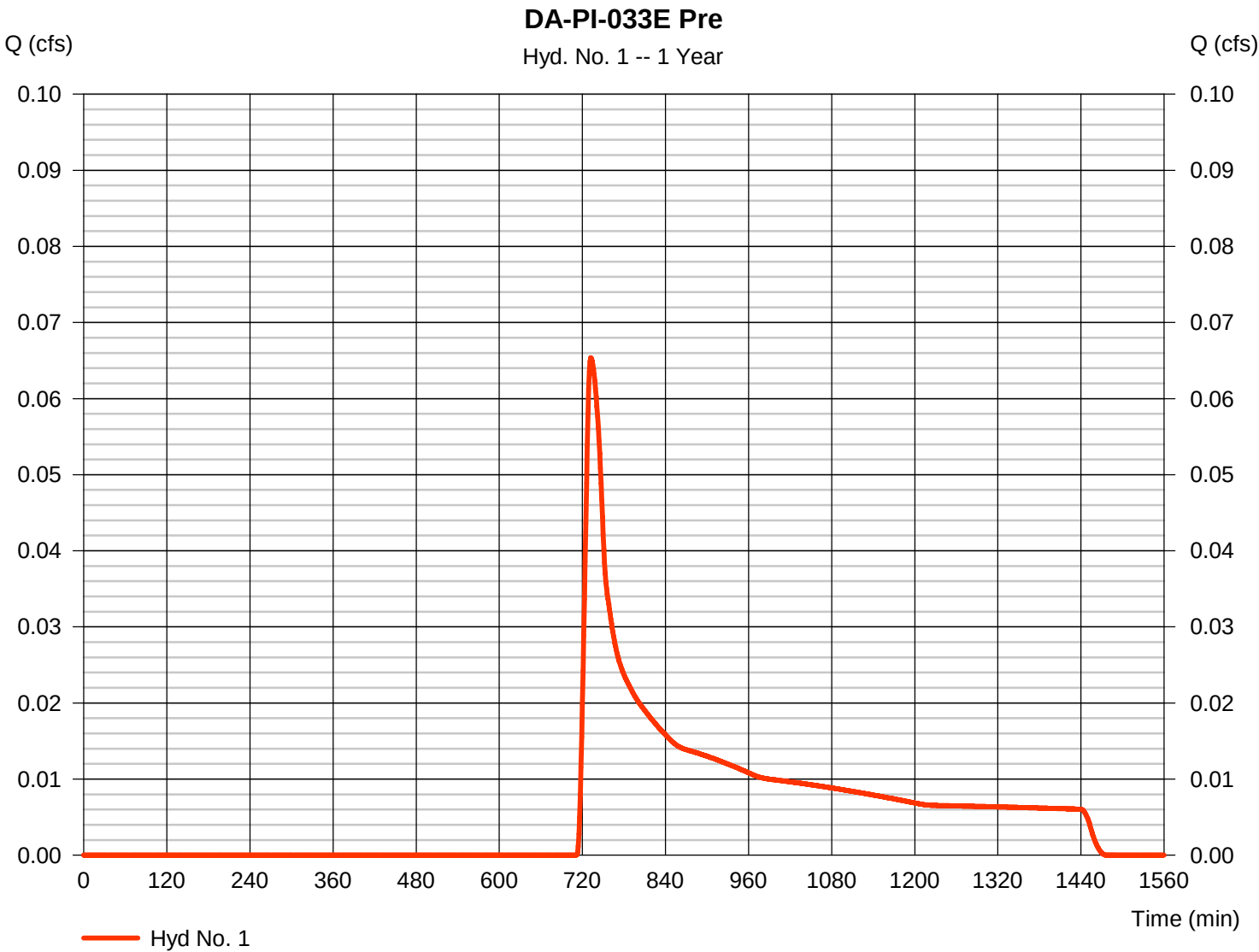
Hydrograph Report

Hyd. No. 1

DA-PI-033E Pre

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.065 cfs
Storm frequency	=	1 yrs	Time to peak	=	732 min
Time interval	=	1 min	Hyd. volume	=	539 cuft
Drainage area	=	0.630 ac	Curve number	=	59*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	22.20 min
Total precip.	=	2.80 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.500 x 58) + (0.030 x 85) + (0.100 x 55)] / 0.630



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 1

DA-PI-033E Pre

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.400	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 2.00	0.00	0.00				
Travel Time (min)	= 20.53	+	0.00	+	0.00	=	20.53
Shallow Concentrated Flow							
Flow length (ft)	= 163.56	23.46	163.98				
Watercourse slope (%)	= 4.35	3.75	5.33				
Surface description	= Unpaved	Paved	Unpaved				
Average velocity (ft/s)	=3.37	3.94	3.72				
Travel Time (min)	= 0.81	+	0.10	+	0.73	=	1.64
Channel Flow							
X sectional flow area (sqft)	= 0.00	0.00	0.00				
Wetted perimeter (ft)	= 0.00	0.00	0.00				
Channel slope (%)	= 0.00	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	((0})0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc				22.20 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

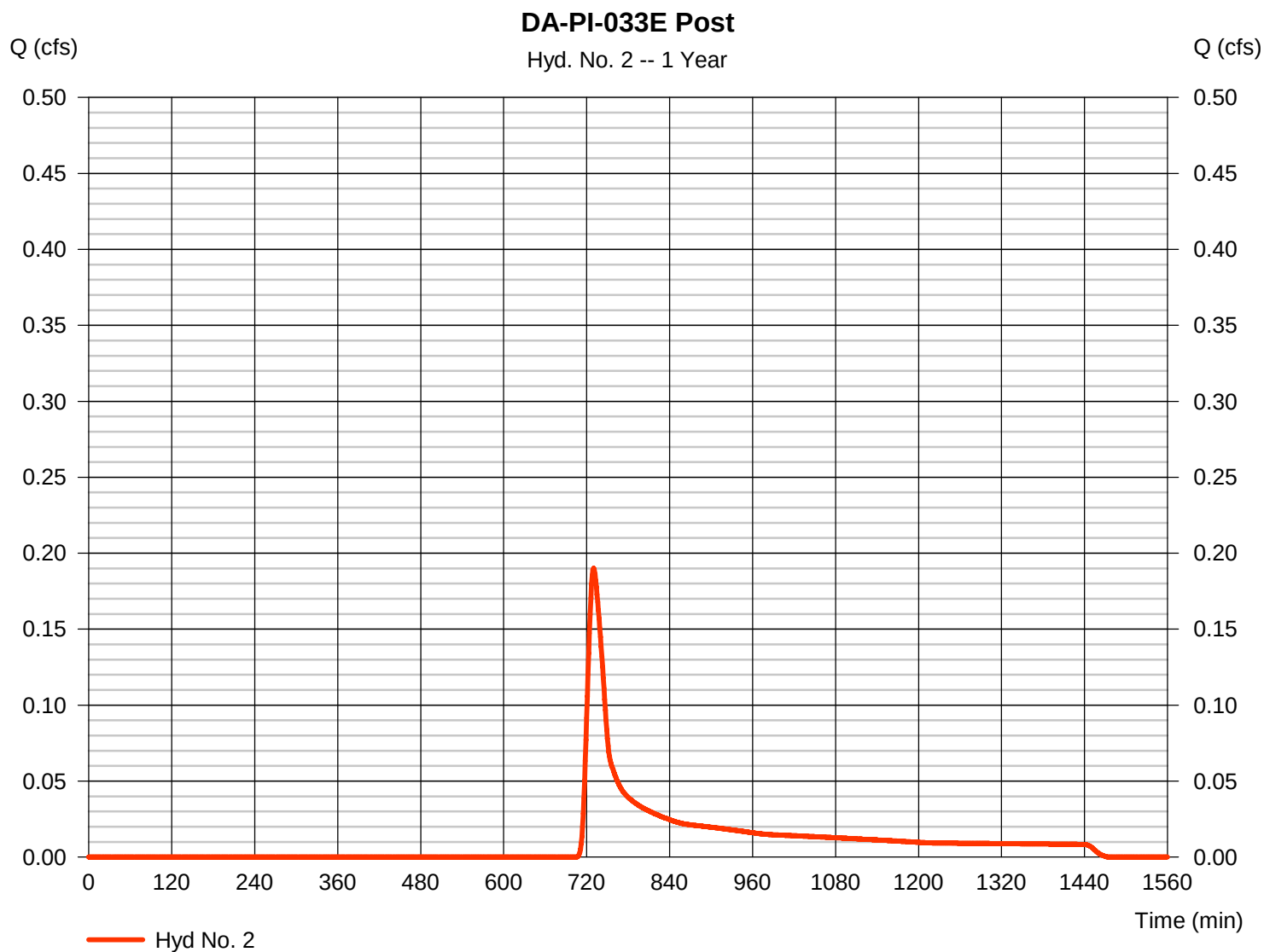
Wednesday, 09 / 6 / 2017

Hyd. No. 2

DA-PI-033E Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.190 cfs
Storm frequency	= 1 yrs	Time to peak	= 730 min
Time interval	= 1 min	Hyd. volume	= 947 cuft
Drainage area	= 0.630 ac	Curve number	= 65*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 22.00 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.450 \times 58) + (0.160 \times 85) + (0.020 \times 48)] / 0.630$



TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 2

DA-PI-033E Post

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>
Sheet Flow				
Manning's n-value	= 0.400	0.400	0.011	
Flow length (ft)	= 100.0	0.0	0.0	
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00	
Land slope (%)	= 2.00	0.00	0.00	
Travel Time (min)	= 20.53	+	0.00	+
			0.00	= 20.53
Shallow Concentrated Flow				
Flow length (ft)	= 163.56	187.44	0.00	
Watercourse slope (%)	= 4.35	5.13	0.00	
Surface description	= Unpaved	Paved	Paved	
Average velocity (ft/s)	=3.37	4.60	0.00	
Travel Time (min)	= 0.81	+	0.68	+
			0.00	= 1.49
Channel Flow				
X sectional flow area (sqft)	= 0.00	0.00	0.00	
Wetted perimeter (ft)	= 0.00	0.00	0.00	
Channel slope (%)	= 0.00	0.00	0.00	
Manning's n-value	= 0.040	0.015	0.015	
Velocity (ft/s)	=0.00	0.00	0.00	
Flow length (ft)	(0)0.0	0.0	0.0	
Travel Time (min)	= 0.00	+	0.00	+
			0.00	= 0.00
Total Travel Time, Tc				22.00 min

Hydrograph Report

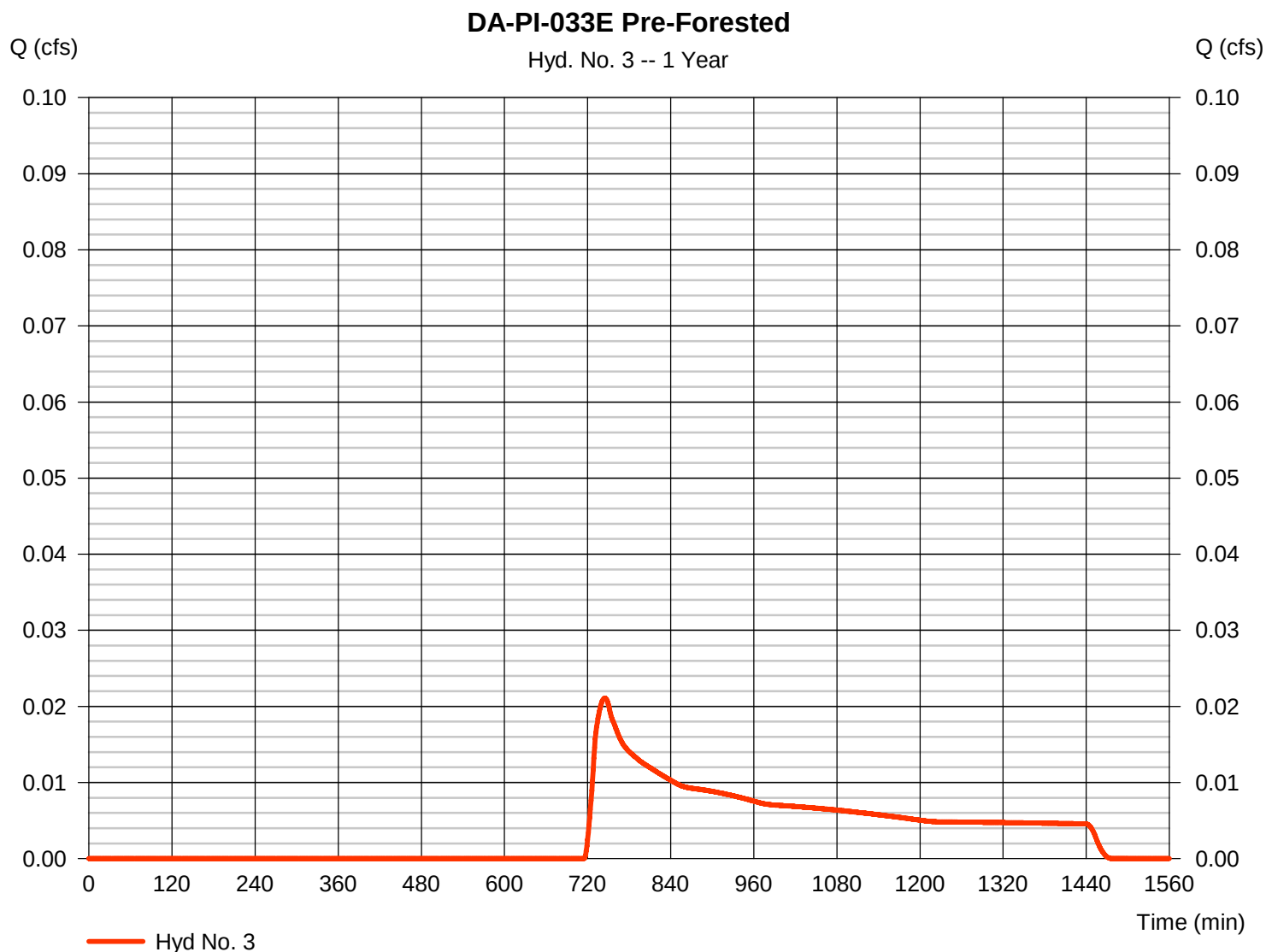
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Wednesday, 09 / 6 / 2017

Hyd. No. 3

DA-PI-033E Pre-Forested

Hydrograph type	= SCS Runoff	Peak discharge	= 0.021 cfs
Storm frequency	= 1 yrs	Time to peak	= 745 min
Time interval	= 1 min	Hyd. volume	= 328 cuft
Drainage area	= 0.630 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 22.20 min
Total precip.	= 2.80 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.630 \times 55)] / 0.630$ 

TR55 Tc Worksheet

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No. 3

DA-PI-033E Pre-Forested

<u>Description</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>Totals</u>			
Sheet Flow							
Manning's n-value	= 0.400	0.400	0.011				
Flow length (ft)	= 100.0	0.0	0.0				
Two-year 24-hr precip. (in)	= 3.50	0.00	0.00				
Land slope (%)	= 2.00	0.00	0.00				
Travel Time (min)	= 20.53	+	0.00	+	0.00	=	20.53
Shallow Concentrated Flow							
Flow length (ft)	= 163.56	23.46	163.98				
Watercourse slope (%)	= 4.35	3.75	5.33				
Surface description	= Unpaved	Unpaved	Unpaved				
Average velocity (ft/s)	=3.37	3.12	3.72				
Travel Time (min)	= 0.81	+	0.13	+	0.73	=	1.67
Channel Flow							
X sectional flow area (sqft)	= 0.00	0.00	0.00				
Wetted perimeter (ft)	= 0.00	0.00	0.00				
Channel slope (%)	= 0.00	0.00	0.00				
Manning's n-value	= 0.030	0.015	0.015				
Velocity (ft/s)	=0.00	0.00	0.00				
Flow length (ft)	((0})0.0	0.0	0.0				
Travel Time (min)	= 0.00	+	0.00	+	0.00	=	0.00
Total Travel Time, Tc				22.20 min			

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

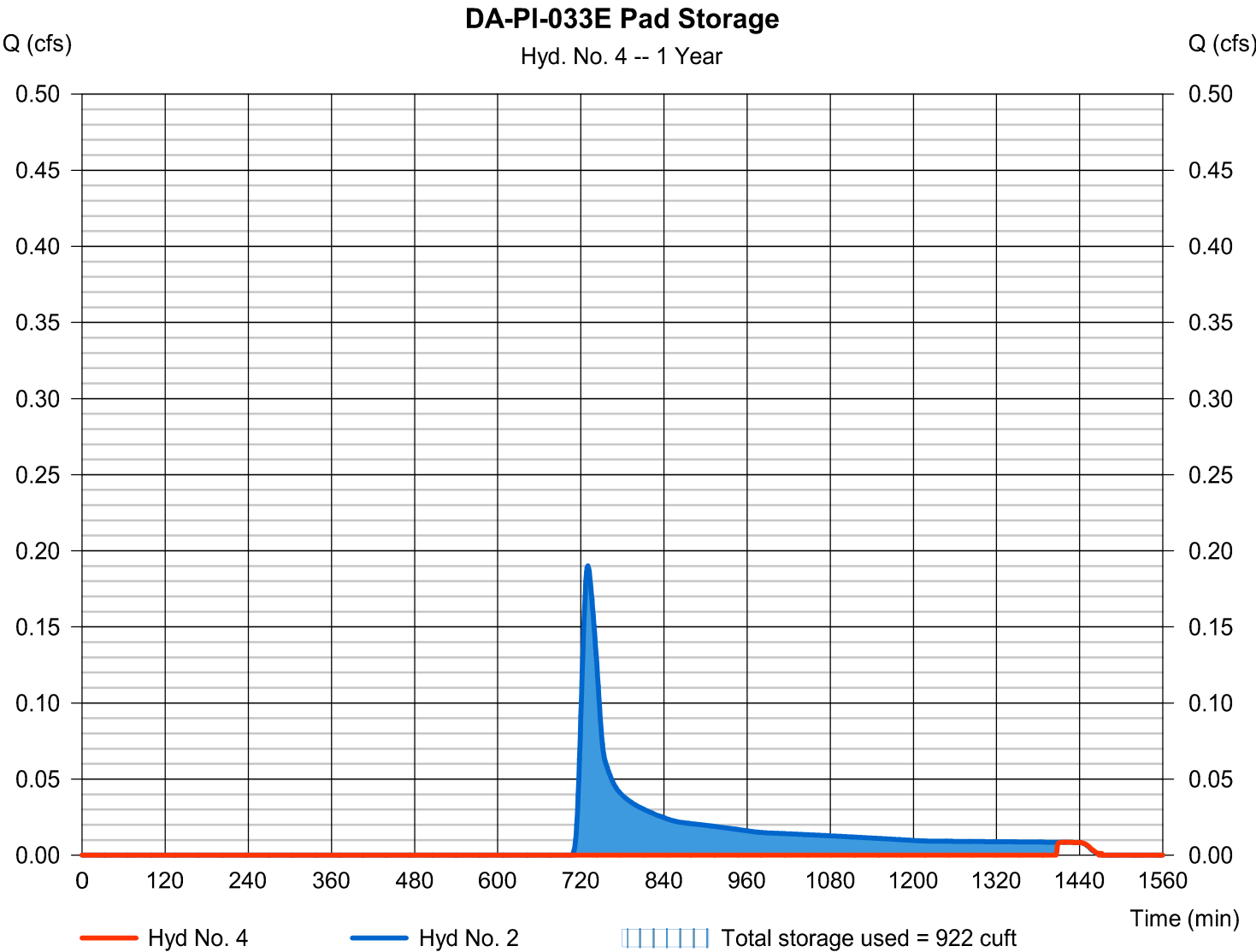
Wednesday, 09 / 6 / 2017

Hyd. No. 4

DA-PI-033E Pad Storage

Hydrograph type	= Reservoir	Peak discharge	= 0.008 cfs
Storm frequency	= 1 yrs	Time to peak	= 1414 min
Time interval	= 1 min	Hyd. volume	= 25 cuft
Inflow hyd. No.	= 2 - DA-PI-033E Post	Max. Elevation	= 802.00 ft
Reservoir name	= DA-PI-033E Pad Storage	Max. Storage	= 922 cuft

Storage Indication method used.



Pond No. 1 - DA-PI-033E Pad Storage

Pond Data

Pond storage is based on user-defined values.

Stage / Storage Table

Stage (ft)	Elevation (ft)	Contour area (sqft)	Incr. Storage (cuft)	Total storage (cuft)
0.00	801.00	n/a	0	0
0.50	801.50	n/a	461	461
1.00	802.00	n/a	461	922
1.50	802.50	n/a	1,152	2,074

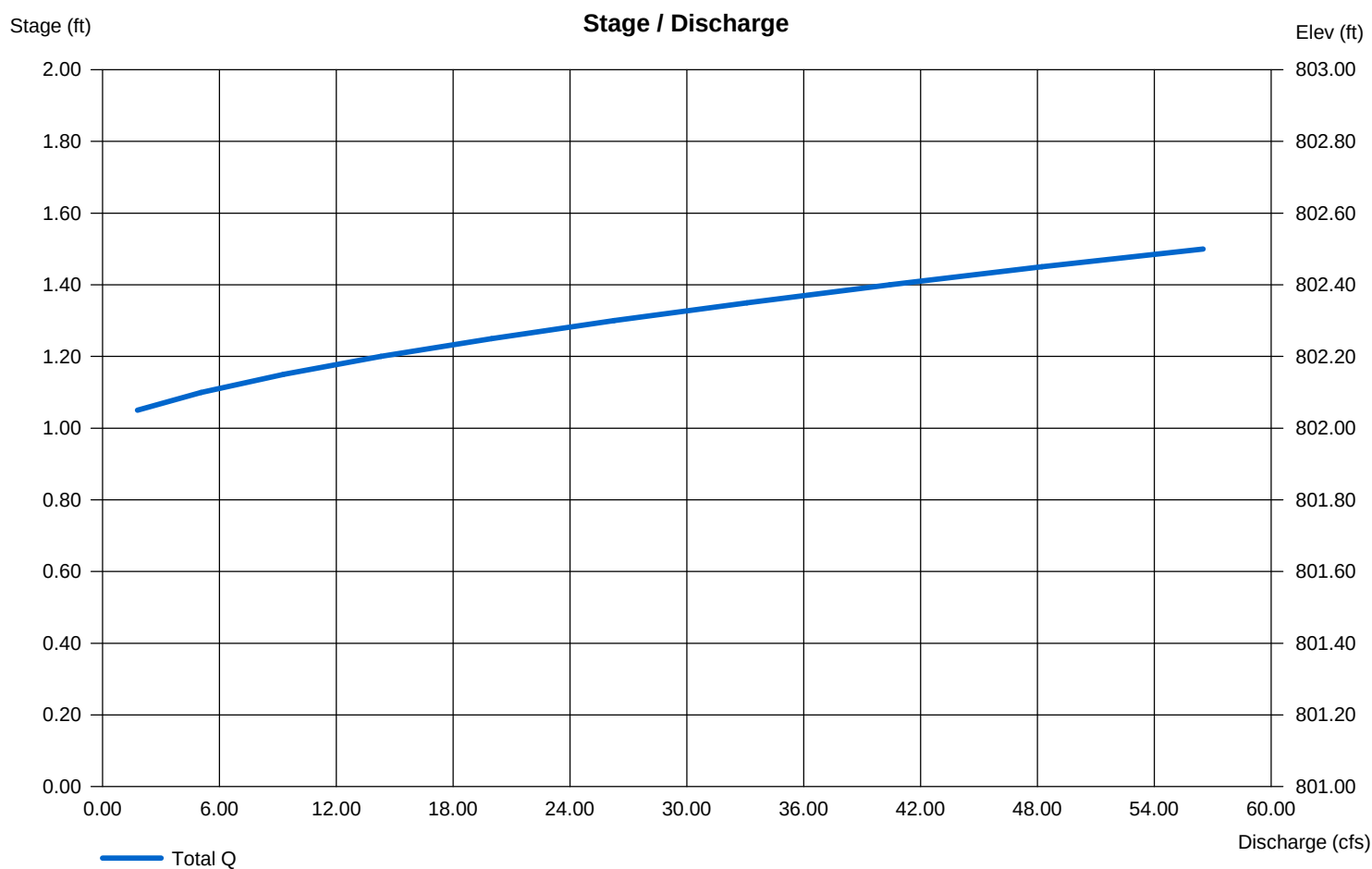
Culvert / Orifice Structures

	[A]	[B]	[C]	[PrfRsr]
Rise (in)	Inactive	0.00	0.00	0.00
Span (in)	= 0.00	0.00	0.00	0.00
No. Barrels	= 0	0	0	0
Invert El. (ft)	= 0.00	0.00	0.00	0.00
Length (ft)	= 0.00	0.00	0.00	0.00
Slope (%)	= 0.00	0.00	0.00	n/a
N-Value	= .013	.013	.013	n/a
Orifice Coeff.	= 0.60	0.60	0.60	0.60
Multi-Stage	= n/a	No	No	No

Weir Structures

	[A]	[B]	[C]	[D]
Crest Len (ft)	= 48.00	0.00	0.00	0.00
Crest El. (ft)	= 802.00	0.00	0.00	0.00
Weir Coeff.	= 3.33	3.33	3.33	3.33
Weir Type	= Rect	---	---	---
Multi-Stage	= No	No	No	No
Exfil.(in/hr)	= 0.000 (by Wet area)			
TW Elev. (ft)	= 0.00			

Note: Culvert/Orifice outflows are analyzed under inlet (ic) and outlet (oc) control. Weir risers checked for orifice conditions (ic) and submergence (s).



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.215	1	730	1,114	-----	-----	-----	DA-PI-033E Pre
2	SCS Runoff	0.417	1	729	1,704	-----	-----	-----	DA-PI-033E Post
3	SCS Runoff	0.112	1	731	784	-----	-----	-----	DA-PI-033E Pre-Forested
4	Reservoir	0.045	1	824	783	2	802.00	925	DA-PI-033E Pad Storage
DA-PI-033E.gpw					Return Period: 2 Year			Wednesday, 09 / 6 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

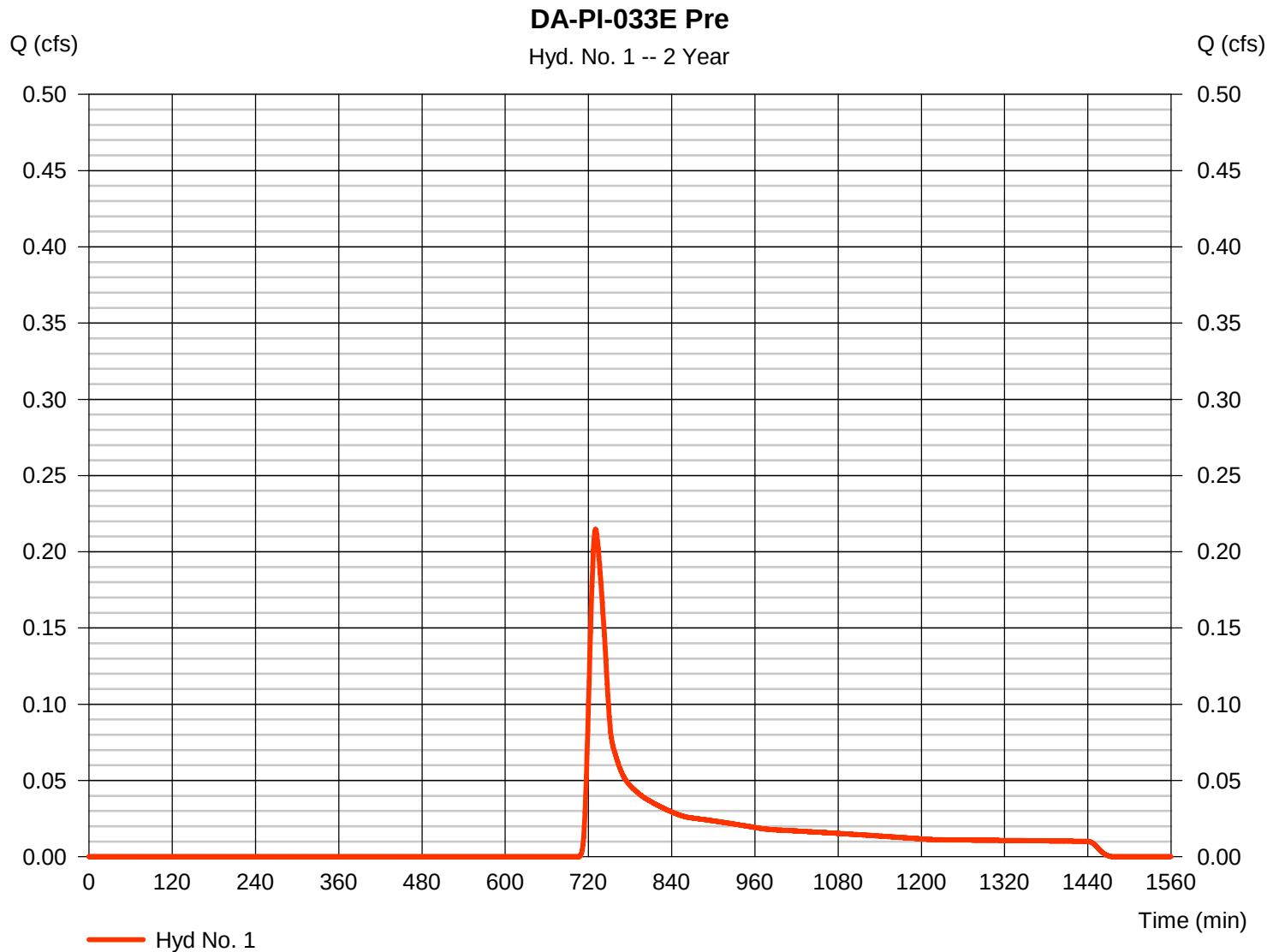
Wednesday, 09 / 6 / 2017

Hyd. No. 1

DA-PI-033E Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.215 cfs
Storm frequency	= 2 yrs	Time to peak	= 730 min
Time interval	= 1 min	Hyd. volume	= 1,114 cuft
Drainage area	= 0.630 ac	Curve number	= 59*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 22.20 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.500 \times 58) + (0.030 \times 85) + (0.100 \times 55)] / 0.630$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

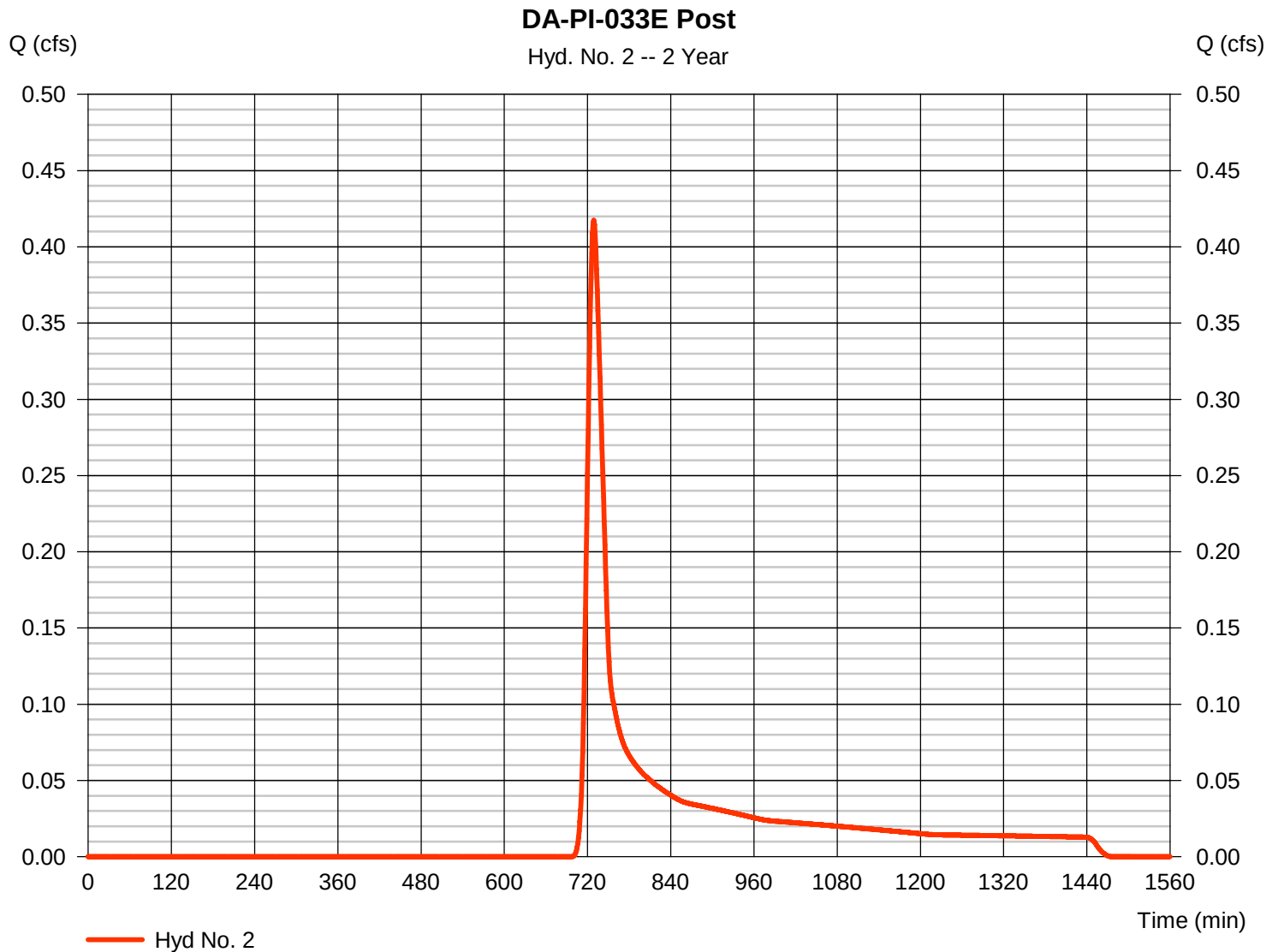
Wednesday, 09 / 6 / 2017

Hyd. No. 2

DA-PI-033E Post

Hydrograph type	= SCS Runoff	Peak discharge	= 0.417 cfs
Storm frequency	= 2 yrs	Time to peak	= 729 min
Time interval	= 1 min	Hyd. volume	= 1,704 cuft
Drainage area	= 0.630 ac	Curve number	= 65*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 22.00 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.450 \times 58) + (0.160 \times 85) + (0.020 \times 48)] / 0.630$



Hydrograph Report

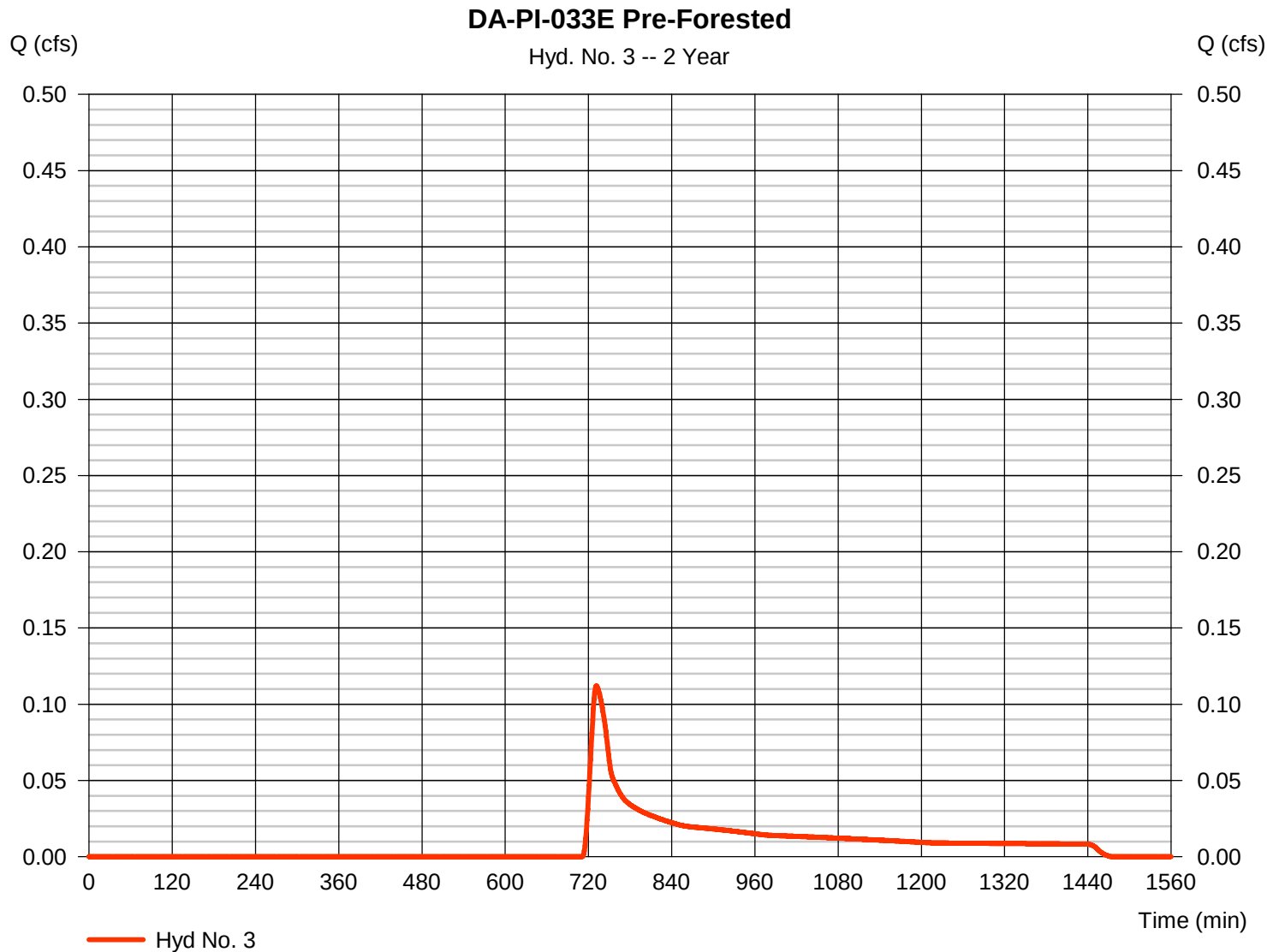
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Wednesday, 09 / 6 / 2017

Hyd. No. 3

DA-PI-033E Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.112 cfs
Storm frequency	=	2 yrs	Time to peak	=	731 min
Time interval	=	1 min	Hyd. volume	=	784 cuft
Drainage area	=	0.630 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	22.20 min
Total precip.	=	3.50 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(0.630 \times 55)] / 0.630$ 

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

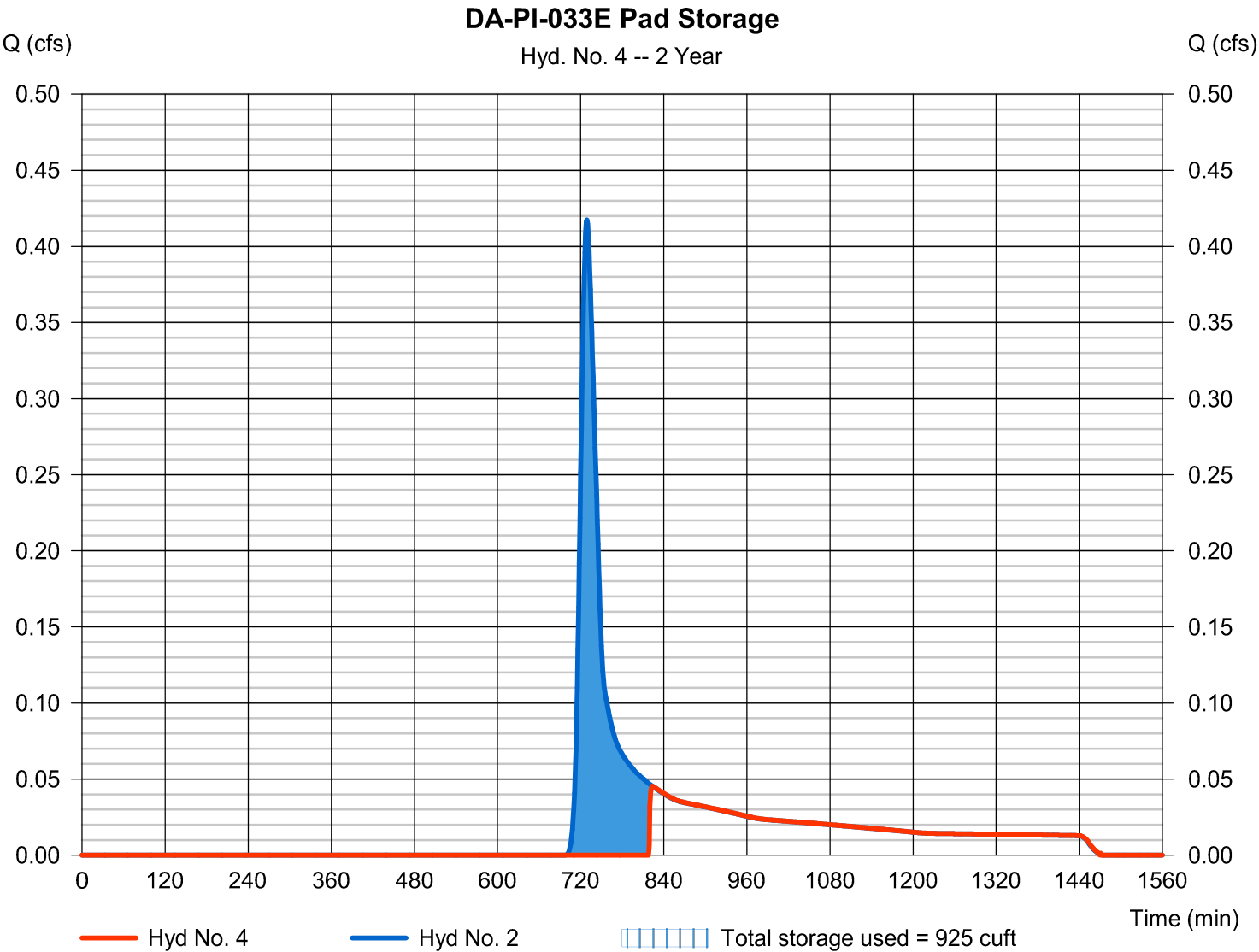
Wednesday, 09 / 6 / 2017

Hyd. No. 4

DA-PI-033E Pad Storage

Hydrograph type	= Reservoir	Peak discharge	= 0.045 cfs
Storm frequency	= 2 yrs	Time to peak	= 824 min
Time interval	= 1 min	Hyd. volume	= 783 cuft
Inflow hyd. No.	= 2 - DA-PI-033E Post	Max. Elevation	= 802.00 ft
Reservoir name	= DA-PI-033E Pad Storage	Max. Storage	= 925 cuft

Storage Indication method used.



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Hyd. No.	Hydrograph type (origin)	Peak flow (cfs)	Time interval (min)	Time to Peak (min)	Hyd. volume (cuft)	Inflow hyd(s)	Maximum elevation (ft)	Total strge used (cuft)	Hydrograph Description
1	SCS Runoff	0.804	1	728	3,058	-----	-----	-----	DA-PI-033E Pre
2	SCS Runoff	1.141	1	728	4,052	-----	-----	-----	DA-PI-033E Post
3	SCS Runoff	0.592	1	729	2,451	-----	-----	-----	DA-PI-033E Pre-Forested
4	Reservoir	1.048	1	732	3,131	2	802.03	989	DA-PI-033E Pad Storage
DA-PI-033E.gpw					Return Period: 10 Year			Wednesday, 09 / 6 / 2017	

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

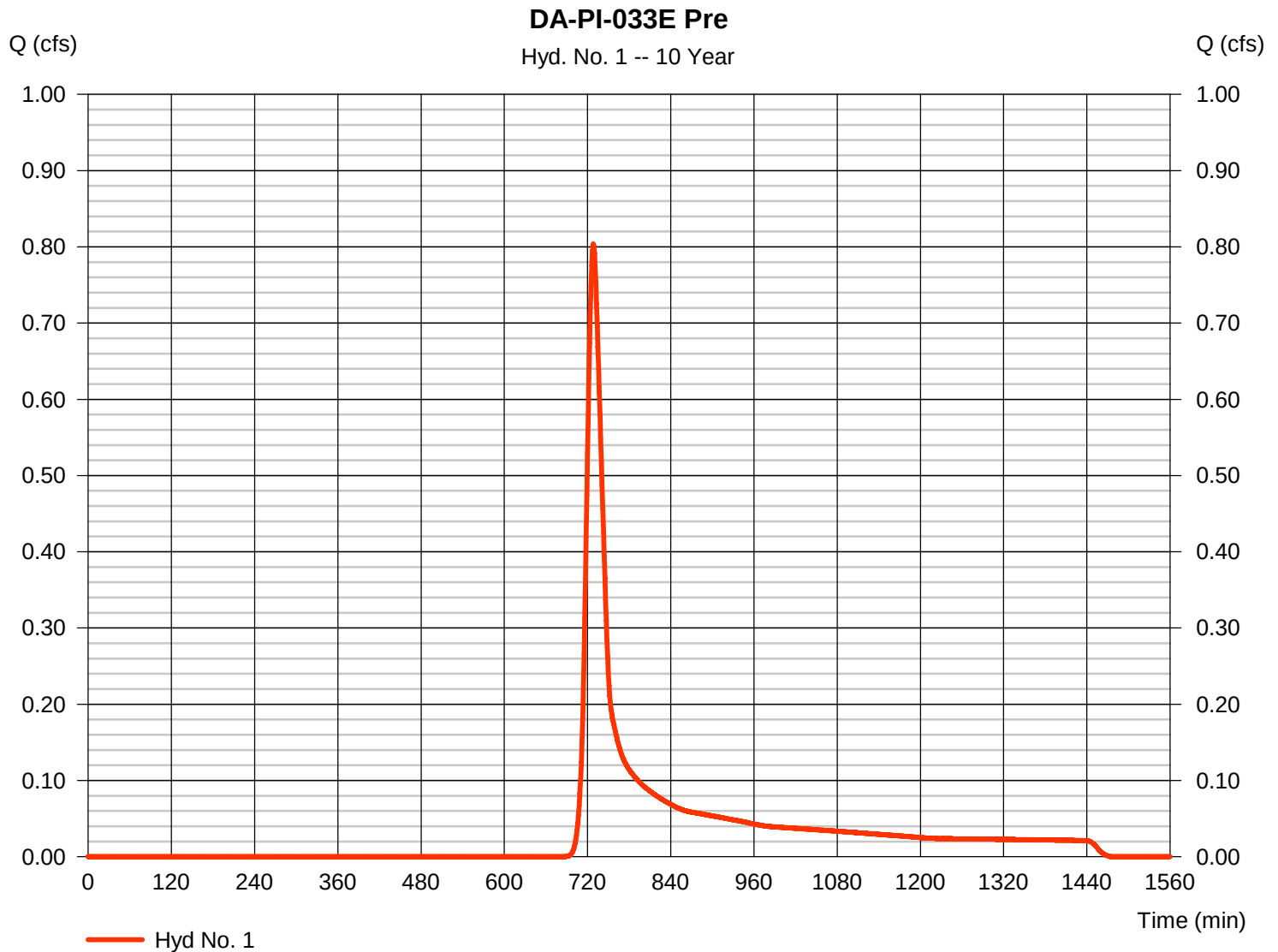
Wednesday, 09 / 6 / 2017

Hyd. No. 1

DA-PI-033E Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 0.804 cfs
Storm frequency	= 10 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 3,058 cuft
Drainage area	= 0.630 ac	Curve number	= 59*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 22.20 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.500 \times 58) + (0.030 \times 85) + (0.100 \times 55)] / 0.630$



Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

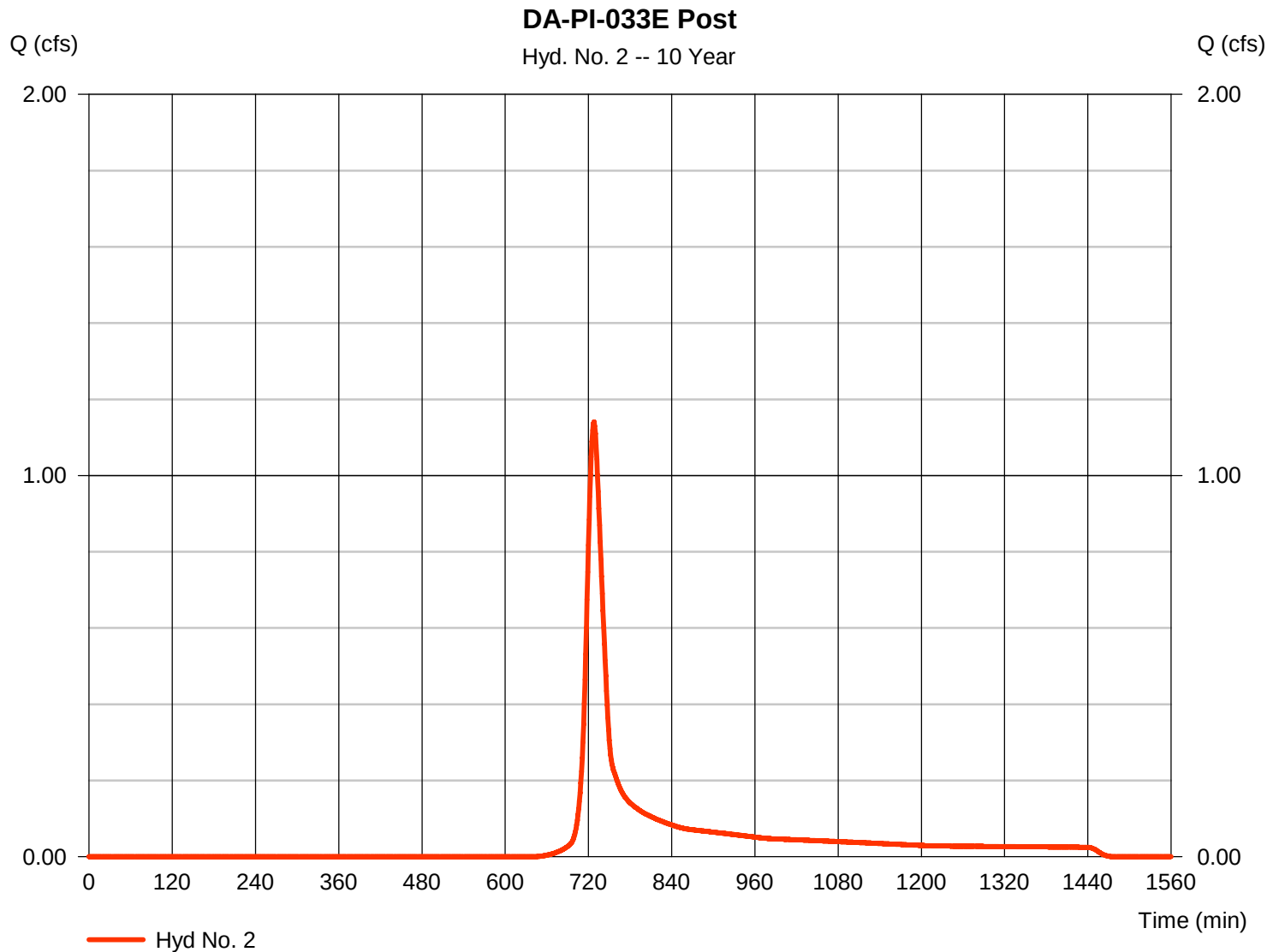
Wednesday, 09 / 6 / 2017

Hyd. No. 2

DA-PI-033E Post

Hydrograph type	= SCS Runoff	Peak discharge	= 1.141 cfs
Storm frequency	= 10 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 4,052 cuft
Drainage area	= 0.630 ac	Curve number	= 65*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 22.00 min
Total precip.	= 5.20 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = $[(0.450 \times 58) + (0.160 \times 85) + (0.020 \times 48)] / 0.630$



Hydrograph Report

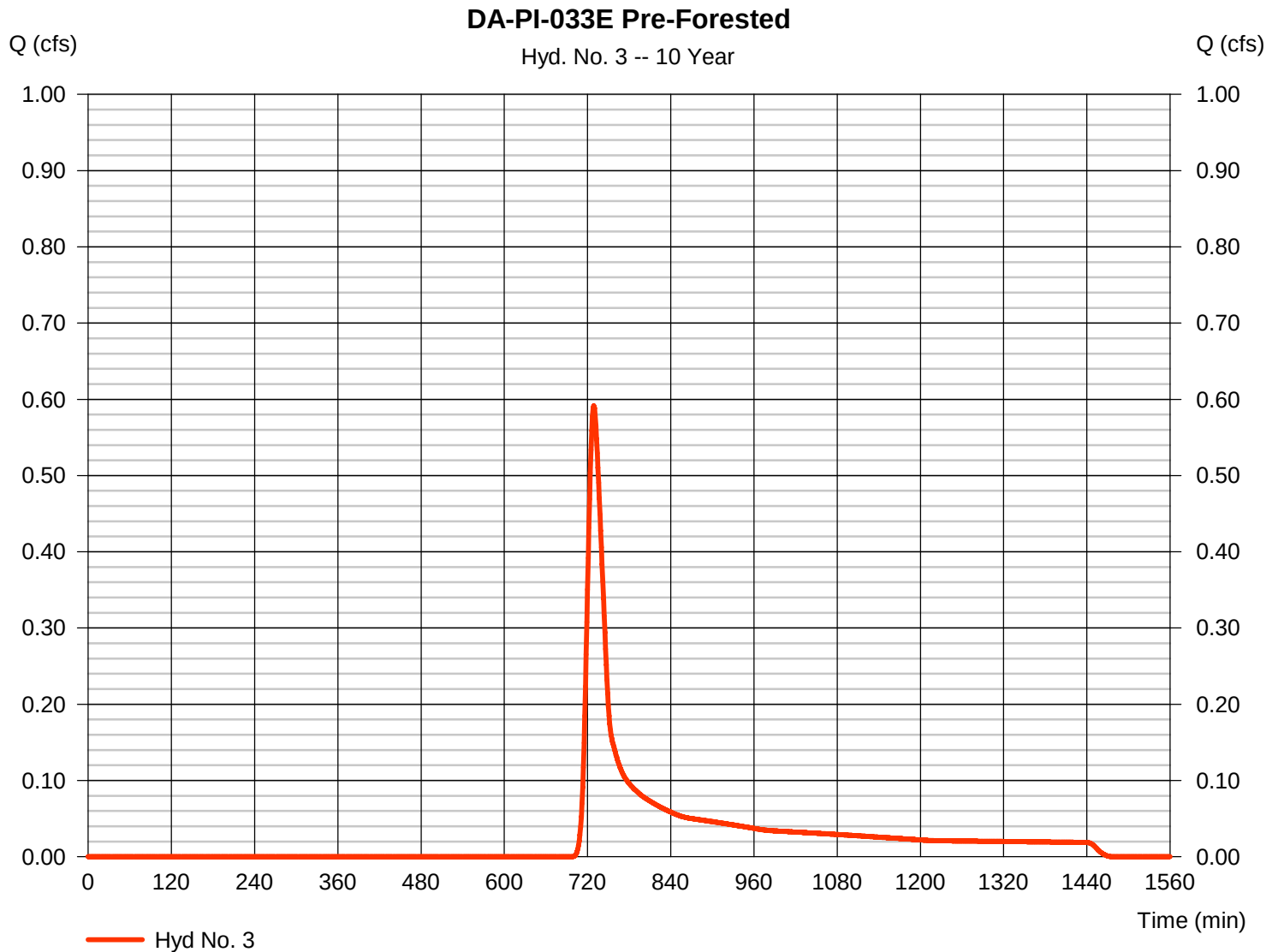
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

Wednesday, 09 / 6 / 2017

Hyd. No. 3

DA-PI-033E Pre-Forested

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.592 cfs
Storm frequency	=	10 yrs	Time to peak	=	729 min
Time interval	=	1 min	Hyd. volume	=	2,451 cuft
Drainage area	=	0.630 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	22.20 min
Total precip.	=	5.20 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = $[(0.630 \times 55)] / 0.630$ 

Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5

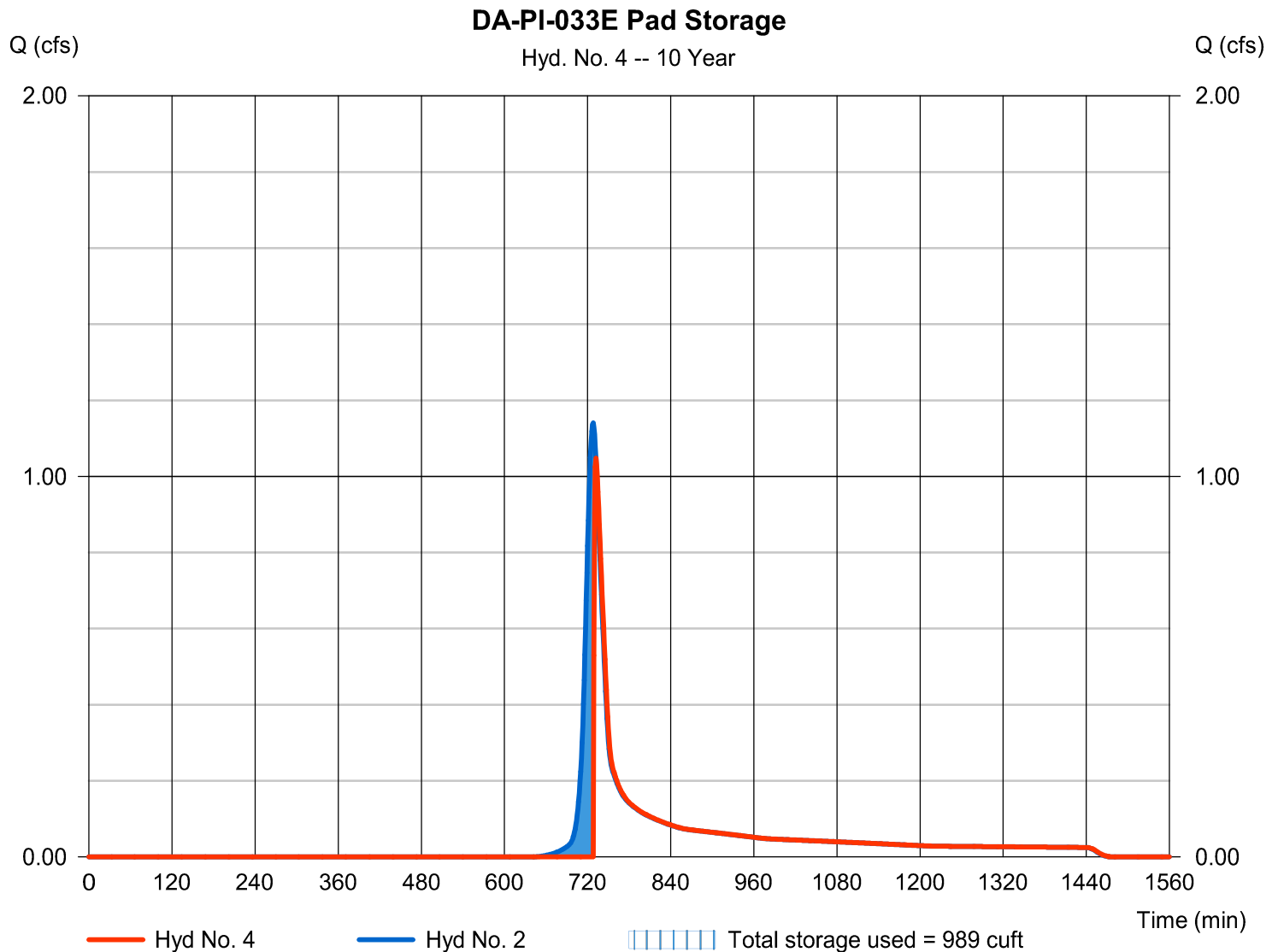
Wednesday, 09 / 6 / 2017

Hyd. No. 4

DA-PI-033E Pad Storage

Hydrograph type	= Reservoir	Peak discharge	= 1.048 cfs
Storm frequency	= 10 yrs	Time to peak	= 732 min
Time interval	= 1 min	Hyd. volume	= 3,131 cuft
Inflow hyd. No.	= 2 - DA-PI-033E Post	Max. Elevation	= 802.03 ft
Reservoir name	= DA-PI-033E Pad Storage	Max. Storage	= 989 cuft

Storage Indication method used.



Return Period (Yrs)	Intensity-Duration-Frequency Equation Coefficients (FHA)			
	B	D	E	(N/A)
1	0.0000	0.0000	0.0000	-----
2	69.8703	13.1000	0.8658	-----
3	0.0000	0.0000	0.0000	-----
5	79.2597	14.6000	0.8369	-----
10	88.2351	15.5000	0.8279	-----
25	102.6072	16.5000	0.8217	-----
50	114.8193	17.2000	0.8199	-----
100	127.1596	17.8000	0.8186	-----

File name: SampleFHA.idf

$$\text{Intensity} = B / (T_c + D)^E$$

Return Period (Yrs)	Intensity Values (in/hr)											
	5 min	10	15	20	25	30	35	40	45	50	55	60
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	5.69	4.61	3.89	3.38	2.99	2.69	2.44	2.24	2.07	1.93	1.81	1.70
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	6.57	5.43	4.65	4.08	3.65	3.30	3.02	2.79	2.59	2.42	2.27	2.15
10	7.24	6.04	5.21	4.59	4.12	3.74	3.43	3.17	2.95	2.77	2.60	2.46
25	8.25	6.95	6.03	5.34	4.80	4.38	4.02	3.73	3.48	3.26	3.07	2.91
50	9.04	7.65	6.66	5.92	5.34	4.87	4.49	4.16	3.88	3.65	3.44	3.25
100	9.83	8.36	7.30	6.50	5.87	5.36	4.94	4.59	4.29	4.03	3.80	3.60

Tc = time in minutes. Values may exceed 60.

Precip. file name: P:\Watres\Projects\MVP\ Pittsylvania_7252017\ Packages\Pittsylvania.pcp

[illegible]

DA-PI-033D	3.69	3.54	-0.15
DA-PI-033E	0.80	1.05	0.25

Figures and calculations for DA-PI-033 follow. See Appendix D of the Annual Standards and Specifications for further detail on stormwater methodology.