DA-FR-086

DA-FR-086 is located in a primarily meadow area with small areas of forested land and the drainage area has rolling to hilly slopes with areas of channelized flow. Residential properties and driveways are located within DA-FR-086, but no new impervious area is proposed within the drainage area. The total phosphorus load reduction required for DA-FR-086 is –1.37 lb/yr. Multiple points of analysis were evaluated within DA-FR-086 to evaluate the effects on each receiving stream/channel following construction. Specifically DA-FR-086 was sub-divided into six sub-drainage areas (sub-areas A through F).

Sub-areas 086C through 086F contain both agricultural and non-agricultural areas 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. 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 Right of Way (ROW) is analyzed via VRRM; in these calculations agricultural areas are considered “Forest/Open Space”.

Sub-areas 086A and 086B are entirely agricultural within the limits of disturbance (LOD). Agricultural areas/fields that will be returned to crop production, in identical condition following 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, the provisions of water quality design criteria requirements and permanent stormwater management controls for DA-FR-086A and DA-FR-086B are exempt and no stormwater BMPs are required.

Stormwater quantity is met via the energy balance method for each of the sub-areas DA-FR-086C, DA-FR-086D, DA-FR-086E and DA-FR-086F. Agricultural areas within the study area are included in the SWM analysis, but an Improvement Factor (IF) of 1.0 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. DA-FR-086D and DA-FR-086E are greater than an acre and used an IF of 0.8. BMPs utilized in sub-area 086D included three water bars and associated soil amendments.

In addition, the Hydraflow Hydrograph’s 10-year 24-hour peak discharge results indicate a reduction in flows ranging from 0.00 to 0.35 cfs for each sub-drainage area (as seen in table below).

Sub Area	Pre Peak Flow, 10-yr Q (cfs)	Post Peak Flow, Q 10-yr (cfs)	Flow differential
DA-FR-086C	9.29	9.29	0.00
DA-FR-086D	5.51	5.48	-0.03

DA-FR-086E	5.51	5.16	-0.35
DA-FR-086F	5.05	5.05	0.00

Figures and calculations for each of the sub-areas for DA-FR-086 follow. See Appendix D of the Annual Standards and Specifications for further detail on stormwater methodology.

Note that the sub-areas 086C, 086E and 086F had time of concentration flow paths for the Post-Construction condition that accounted for a permanent water bar that is not cited within the drainage area. This permanent water bar was removed because it was cited 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-FR-086C, 086E or 086F, so the resulting changes were not made to the stormwater calculations prior to submittal.

DA-FR-086A
12.59 acres
Weighted CN = 59

DA-FR-086B
1.76 acres
Weighted CN = 58

DA-FR-086C
5.61 acres
Weighted CN = 57

DA-FR-086D
3.14 acres
Weighted CN = 56

DA-FR-086E
3.33 acres
Weighted CN = 57

DA-FR-086F
2.54 acres
Weighted CN = 58

LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Gravel	B	85	0.07	DA-FR-086A
Impervious	B	98	0.14	
Meadow - Good	B	58	12.39	
Gravel	B	85	0.002	DA-FR-086B
Meadow - Good	B	58	1.59	
Woods - Good	B	55	0.16	
Meadow - Good	B	58	4.71	DA-FR-086C
Woods - Good	B	55	0.74	
Brush	B	48	0.16	
Meadow - Good	B	58	1.41	DA-FR-086D
Woods - Good	B	55	1.73	
Meadow - Good	B	58	2.06	DA-FR-086E
Woods - Good	B	55	1.27	
Meadow - Good	B	58	2.39	DA-FR-086F
Woods - Good	B	55	0.16	

Legend

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

NAD 1983 UTM 17N (feet)

1:3,300

275 137.5 0 275 Feet

N W E S



Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Pre-Construction Drainage Area Map
DA-FR-086
Spread 11

Figure 1
Franklin County, Virginia

August, 2017

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

Document Path: P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Franklin\MVP_PCSM_DA-FR-086_Pre.mxd

DA-FR-086A
12.59 acres
Weighted CN = 59

DA-FR-086B
1.76 acres
Weighted CN = 58

DA-FR-086C
5.61 acres
Weighted CN = 57

DA-FR-086D
3.14 acres
Weighted CN = 56

DA-FR-086E
3.33 acres
Weighted CN = 56

DA-FR-086F
2.54 acres
Weighted CN = 58

DA-FR-086 Permanent ROW
4.06 acres

LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Gravel	B	85	0.07	DA-FR-086A
Impervious	B	98	0.14	
Meadow - Good	B	58	12.39	
Gravel	B	85	0.002	DA-FR-086B
Meadow - Good	B	58	1.74	
Brush	B	48	0.02	
Meadow - Good	B	58	4.93	DA-FR-086C
Woods - Good	B	55	0.46	
Brush	B	48	0.22	
Meadow - Good	B	58	1.82	DA-FR-086D
Woods - Good	B	55	0.81	
Brush	B	48	0.51	
Meadow - Good	B	58	2.56	DA-FR-086E
Woods - Good	B	55	0.32	
Brush	B	48	0.44	
Meadow - Good	B	58	2.47	DA-FR-086F
Woods - Good	B	55	0.06	
Brush	B	48	0.01	

Legend

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

NAD 1983 UTM 17N (feet)

1:3,300

N W E S

275 137.5 0 275 Feet



Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Post-Construction Drainage Area Map
DA-FR-086
Spread 11

Figure 2
Franklin County, Virginia

August, 2017

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

Document Path: P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Franklin\MVP_PCSM_DA-FR-086_Post.mxd

DA-FR-086A
12.59 acres
Weighted CN = 59

DA-FR-086B
1.76 acres
Weighted CN = 58

DA-FR-086C
5.61 acres
Weighted CN = 57

DA-FR-086D
3.14 acres
Weighted CN = 56

DA-FR-086E
3.33 acres
Weighted CN = 57

DA-FR-086F
2.54 acres
Weighted CN = 58

270.0
270.1
270.2
270.3
270.4
270.5
270.6
270.7
270.8

S-F90
S-F10
S-F9a

1000
950
1050

Board Ln

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)

N
W E
S

1:3,300

275 137.5 0 275 Feet



PRE-CONSTRUCTION TIME OF CONCENTRATION TO POI

	SHEET 1	SHEET 2	SHEET 3	SHALLOW	CHANNEL	Calculated Time of Concentration (min)
DA-FR-086A	N/A – Agricultural Exempt					
DA-FR-086B	N/A – Agricultural Exempt					
DA-FR-086C	21.72 FT @ 5.28%	16.21 FT @ 5.74%	62.06 FT @ 5.48%	712.66 FT @ 10.46%	-	18.4
DA-FR-086D	100.00 FT @ 4.99%	-	-	412.76 FT @ 12.51%	-	15.1
DA-FR-086E	100.00 FT @ 3.64%	-	-	534.90 FT @ 11.27%	-	17.4
DA-FR-086F	100.00 FT @ 7.55%	-	-	719.56 FT @ 8.58%	-	14.3

Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Pre-Construction Drainage Area and Time of Concentration
DA-FR-086
Spread 11

Figure 3
Franklin 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.

Document Path: P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Franklin\Figures 3-4\MVP_PCSM_DA-FR-086_3.mxd

DA-FR-086A
12.59 acres
Weighted CN = 59

DA-FR-086B
1.76 acres
Weighted CN = 58

DA-FR-086C
5.61 acres
Weighted CN = 57

DA-FR-086D
3.14 acres
Weighted CN = 56

DA-FR-086E
3.33 acres
Weighted CN = 56

DA-FR-086F
2.54 acres
Weighted CN = 58

270.0
270.1
270.2
270.3
270.4
270.5
270.6
270.7
270.8

S-F09
S-F10
S-F10a

1000
1050
950

Board Ln

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)

1:3,300

N
W E
S

275 137.5 0 275 Feet



POST-CONSTRUCTION TIME OF CONCENTRATION TO POI

	SHEET1	SHEET2	SHEET3	SHALLOW1	SHALLOW2	SHALLOW3	CHANNEL1	CHANNEL2	Calculated Time of Concentration (min)
DA-FR-086A	N/A – Agricultural Exempt								
DA-FR-086B	N/A – Agricultural Exempt								
DA-FR-086C	21.72 FT @ 5.28%	16.21 FT @ 5.74%	62.06 FT @ 5.48%	480.17 FT @ 9.05%	194.27 FT @ 14.66%	-	56.95 FT @ 4.55%	-	18.5
DA-FR-086D	100.00 FT @ 4.99%	-	-	412.76 FT @ 12.51%	-	-	-	-	15.1
DA-FR-086E	100.00 FT @ 3.64%	-	-	451.39 FT @ 9.97%	66.31 FT @ 18.65%	-	14.87 FT @ 5.21%	-	17.4
DA-FR-086F	100.00 FT @ 7.55%	-	-	439.17 FT @ 10.87%	49.14 FT @ 12.99%	61.66 FT @ 6.72%	28.41 FT @ 4.83%	40.15 FT @ 5.09%	13.7

Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Post-Construction Drainage Area and Time of Concentration
DA-FR-086
Spread 11

Figure 4
Franklin 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\Franklin\Figures 3-4\MVP_PCSM_DA-FR-086_4.mxd

Virginia Runoff Reduction Method New Development Worksheet - v2.8 - June 2014

Site Data Summary

Total Rainfall = 46 inches

Site Land Cover Summary

	A Soils	B Soils	C Soils	D Soils	Total	% of Total
Forest (acres)	0.00	4.06	0.00	0.00	4.06	*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*
					4.06	*100.00*

Site Rv	0.03
Post Development Treatment Volume (ft3)	442
Post Development TP Load (lb/yr)	0.30
Post Development TN Load (lb/yr)	2.13
Total TP Load Reduction Required (lb/yr)	-1.37

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)	0.30
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)	4.06	0.00	0.00	0.00	0.00	*4.06*
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*
						4.06

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-FR-086A

Table 1 – Manning's n Values for Sheet Flow

Land Surface Type	**Manning n**
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40

Note:

Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.

For Paved Road land surface types a Manning's n value 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 Channels[1]			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels[2]			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150

Notes:

[1]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 or grass channel.

[2]For the pre-developed condition (if applicable), 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

Hydraflow Table of Contents

DA-FR-086A_Hydraflow.gpw

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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-FR-086A PRE
2	SCS Runoff	DA-FR-086A DEV
3	SCS Runoff	DA-FR-086A FOR

Hydrograph Return Period Recap

Hyd. No.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)							Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	------	4.181	6.841	-------	-------	25.16	-------	-------	-------	DA-FR-086A PRE
2	SCS Runoff	------	4.181	6.841	-------	-------	25.16	-------	-------	-------	DA-FR-086A DEV
3	SCS Runoff	------	1.938	3.847	-------	-------	19.46	-------	-------	-------	DA-FR-086A FOR

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	4.181	1	726	19,069	------	------	------	DA-FR-086A PRE
2	SCS Runoff	4.181	1	726	19,069	------	------	------	DA-FR-086A DEV
3	SCS Runoff	1.938	1	727	13,006	------	------	------	DA-FR-086A FOR

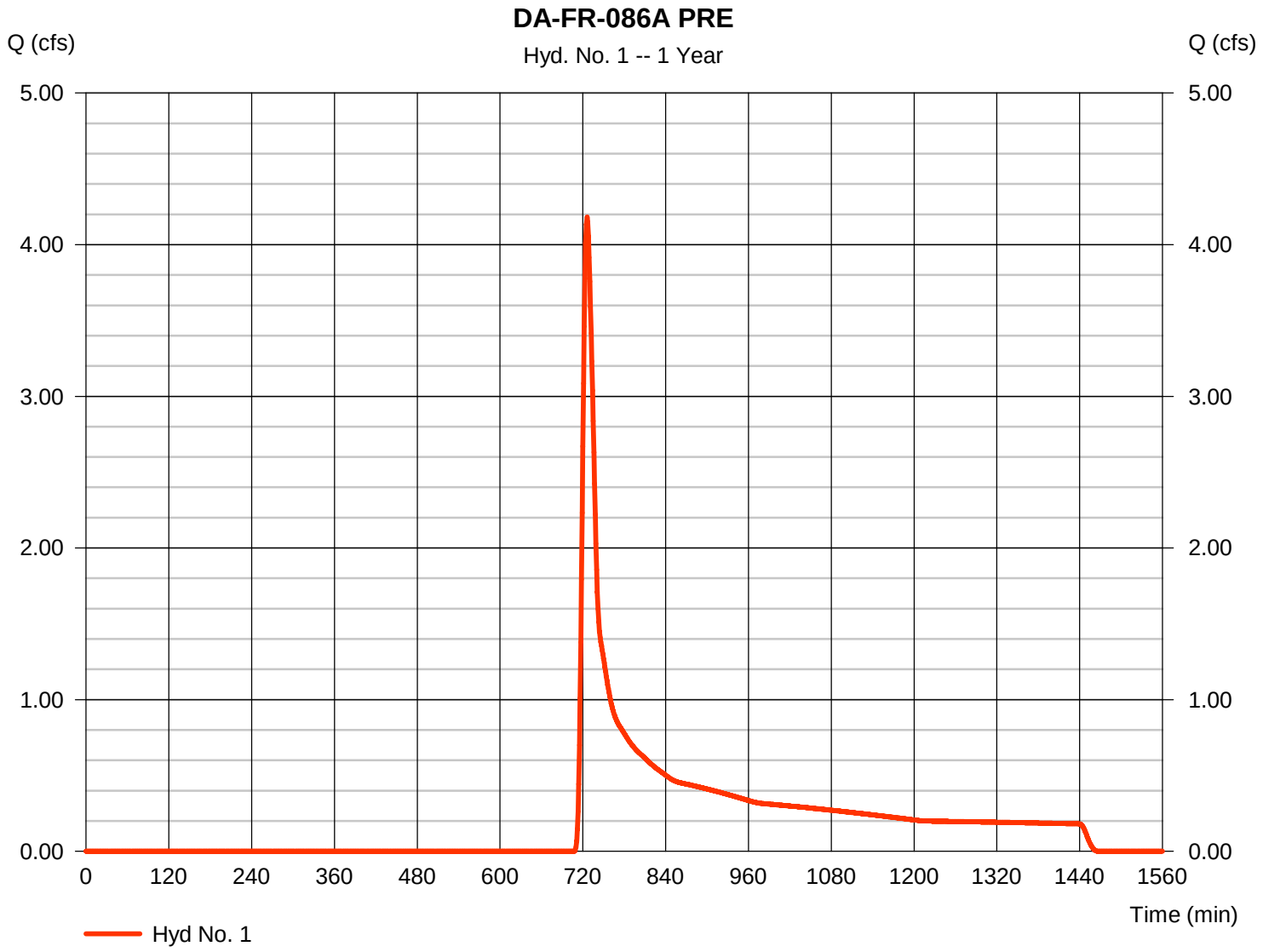
Hydrograph Report

Hyd. No. 1

DA-FR-086A PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 4.181 cfs
Storm frequency	= 1 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 19,069 cuft
Drainage area	= 12.600 ac	Curve number	= 59*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.10 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.070 x 85) + (0.140 x 98) + (12.390 x 58)] / 12.600



TR55 Tc Worksheet

Hyd. No. 1

DA-FR-086A PRE

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.011		0.400		0.011		
Flow length (ft)	= 0.0		100.0		0.0		
Two-year 24-hr precip. (in)	= 0.00		3.70		0.00		
Land slope (%)	= 0.00		8.33		0.00		
Travel Time (min)	**= 0.00**	**+**	**11.29**	**+**	**0.00**	**=**	**11.29**
Shallow Concentrated Flow							
Flow length (ft)	= 0.00		500.15		0.00		
Watercourse slope (%)	= 0.00		9.21		0.00		
Surface description	= Paved		Unpaved		Paved		
Average velocity (ft/s)	=0.00		4.90		0.00		
Travel Time (min)	**= 0.00**	**+**	**1.70**	**+**	**0.00**	**=**	**1.70**
Channel Flow							
X sectional flow area (sqft)	= 0.00		1.13		0.00		
Wetted perimeter (ft)	= 0.00		14.61		0.00		
Channel slope (%)	= 0.00		6.50		0.00		
Manning's n-value	= 0.015		0.030		0.015		
Velocity (ft/s)	=0.00		2.28		0.00		
Flow length (ft)	({0})0.0		430.6		0.0		
Travel Time (min)	**= 0.00**	**+**	**3.15**	**+**	**0.00**	**=**	**3.15**

Total Travel Time, Tc ..... 16.10 min

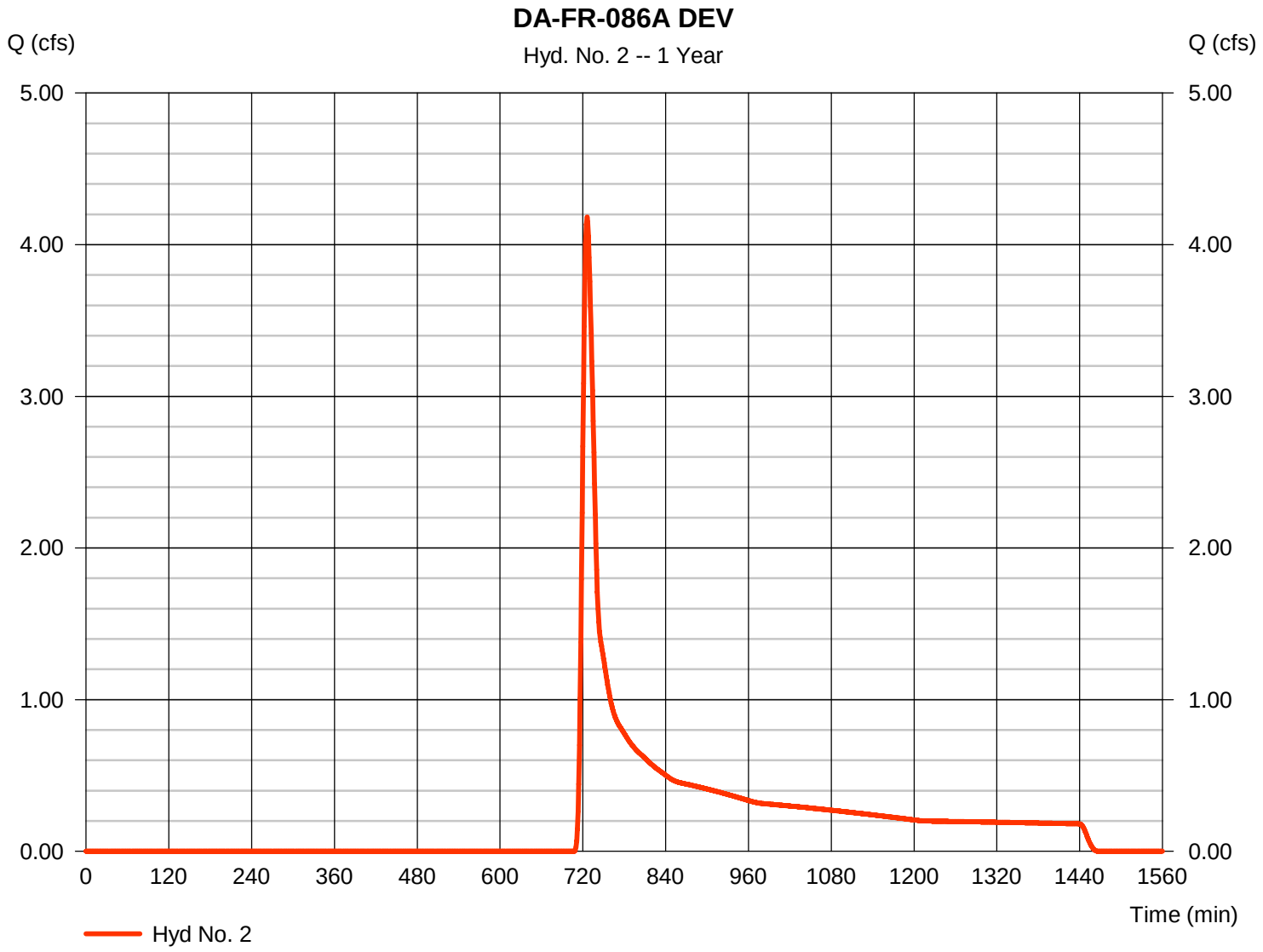
Hydrograph Report

Hyd. No. 2

DA-FR-086A DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 4.181 cfs
Storm frequency	= 1 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 19,069 cuft
Drainage area	= 12.600 ac	Curve number	= 59*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.10 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.070 x 85) + (0.140 x 98) + (12.390 x 58)] / 12.600



TR55 Tc Worksheet

Hyd. No. 2

DA-FR-086A DEV

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.011		0.400		0.011		
Flow length (ft)	= 0.0		100.0		0.0		
Two-year 24-hr precip. (in)	= 0.00		3.70		0.00		
Land slope (%)	= 0.00		8.33		0.00		
Travel Time (min)	**= 0.00**	**+**	**11.29**	**+**	**0.00**	**=**	**11.29**
Shallow Concentrated Flow							
Flow length (ft)	= 0.00		500.15		0.00		
Watercourse slope (%)	= 0.00		9.21		0.00		
Surface description	= Paved		Unpaved		Paved		
Average velocity (ft/s)	=0.00		4.90		0.00		
Travel Time (min)	**= 0.00**	**+**	**1.70**	**+**	**0.00**	**=**	**1.70**
Channel Flow							
X sectional flow area (sqft)	= 0.00		1.13		0.00		
Wetted perimeter (ft)	= 0.00		14.61		0.00		
Channel slope (%)	= 0.00		6.50		0.00		
Manning's n-value	= 0.015		0.030		0.015		
Velocity (ft/s)	=0.00		2.28		0.00		
Flow length (ft)	({0})0.0		430.6		0.0		
Travel Time (min)	**= 0.00**	**+**	**3.14**	**+**	**0.00**	**=**	**3.14**

Total Travel Time, Tc ..... 16.10 min

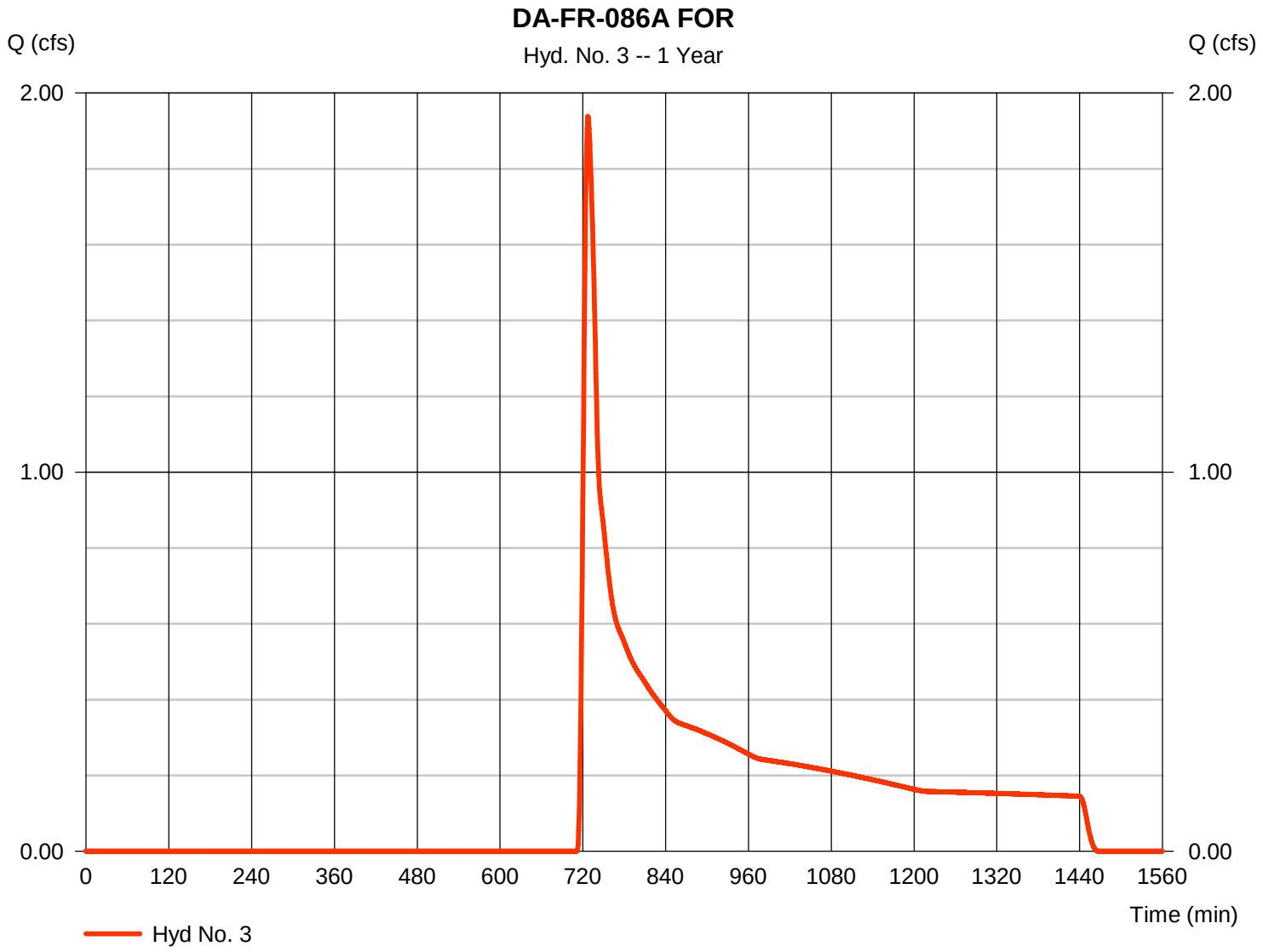
Hydrograph Report

Hyd. No. 3

DA-FR-086A FOR

Hydrograph type	=	SCS Runoff	Peak discharge	=	1.938 cfs
Storm frequency	=	1 yrs	Time to peak	=	727 min
Time interval	=	1 min	Hyd. volume	=	13,006 cuft
Drainage area	=	12.590 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	16.10 min
Total precip.	=	3.30 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.070 x 85) + (0.140 x 98) + (12.390 x 58)] / 12.590



TR55 Tc Worksheet

Hyd. No. 3

DA-FR-086A FOR

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.011		0.400		0.011		
Flow length (ft)	= 0.0		100.0		0.0		
Two-year 24-hr precip. (in)	= 0.00		3.70		0.00		
Land slope (%)	= 0.00		8.33		0.00		
Travel Time (min)	**= 0.00**	**+**	**11.29**	**+**	**0.00**	**=**	**11.29**
Shallow Concentrated Flow							
Flow length (ft)	= 0.00		500.15		0.00		
Watercourse slope (%)	= 0.00		9.21		0.00		
Surface description	= Paved		Unpaved		Paved		
Average velocity (ft/s)	=0.00		4.90		0.00		
Travel Time (min)	**= 0.00**	**+**	**1.70**	**+**	**0.00**	**=**	**1.70**
Channel Flow							
X sectional flow area (sqft)	= 0.00		1.13		0.00		
Wetted perimeter (ft)	= 0.00		14.61		0.00		
Channel slope (%)	= 0.00		6.50		0.00		
Manning's n-value	= 0.015		0.030		0.015		
Velocity (ft/s)	=0.00		2.28		0.00		
Flow length (ft)	({0})0.0		430.6		0.0		
Travel Time (min)	**= 0.00**	**+**	**3.15**	**+**	**0.00**	**=**	**3.15**

Total Travel Time, Tc ..... 16.10 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	6.841	1	725	26,692	------	------	------	DA-FR-086A PRE
2	SCS Runoff	6.841	1	725	26,692	------	------	------	DA-FR-086A DEV
3	SCS Runoff	3.847	1	726	19,230	------	------	------	DA-FR-086A FOR

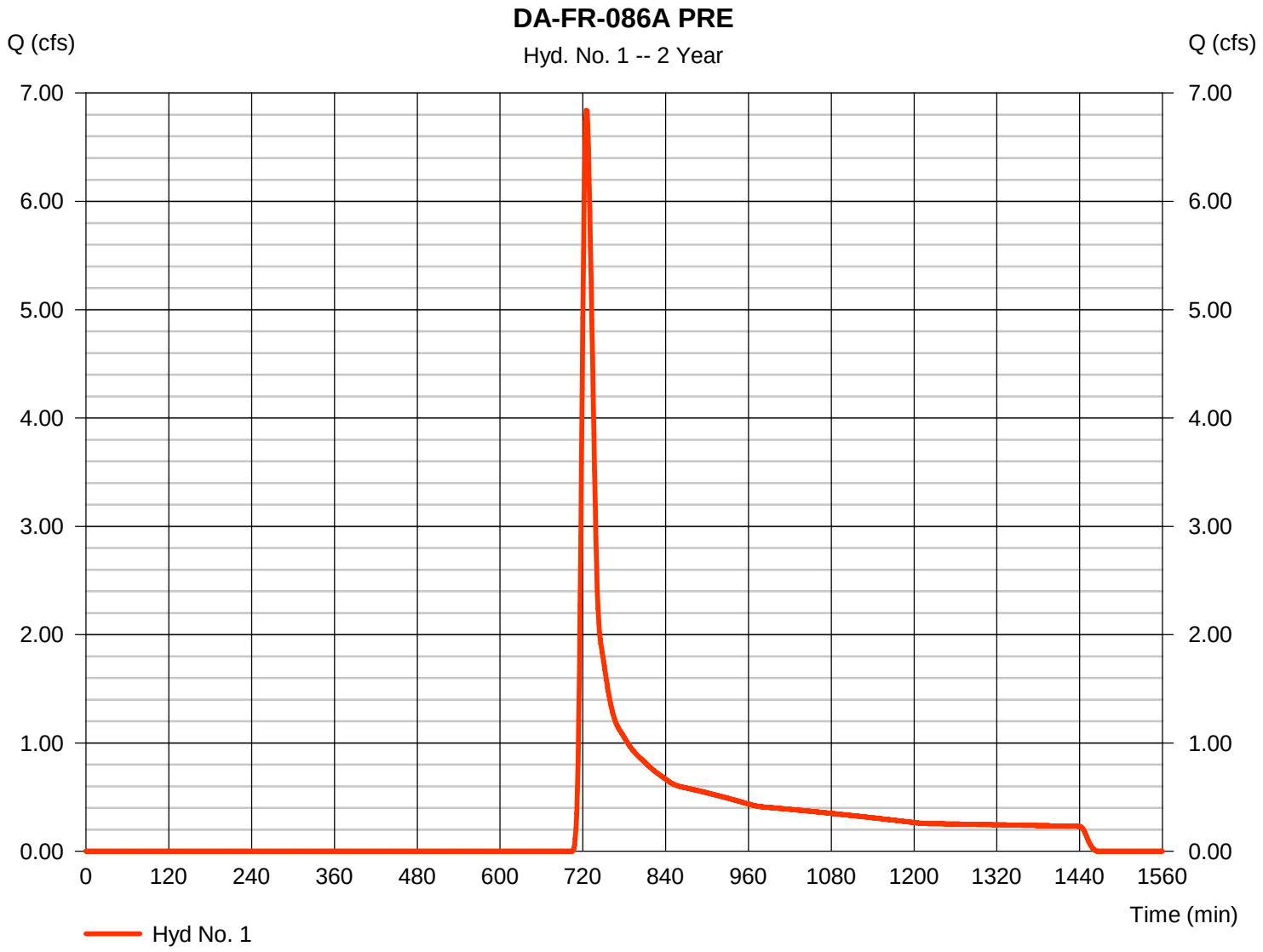
Hydrograph Report

Hyd. No. 1

DA-FR-086A PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	6.841 cfs
Storm frequency	=	2 yrs	Time to peak	=	725 min
Time interval	=	1 min	Hyd. volume	=	26,692 cuft
Drainage area	=	12.600 ac	Curve number	=	59*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	16.10 min
Total precip.	=	3.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.070 x 85) + (0.140 x 98) + (12.390 x 58)] / 12.600



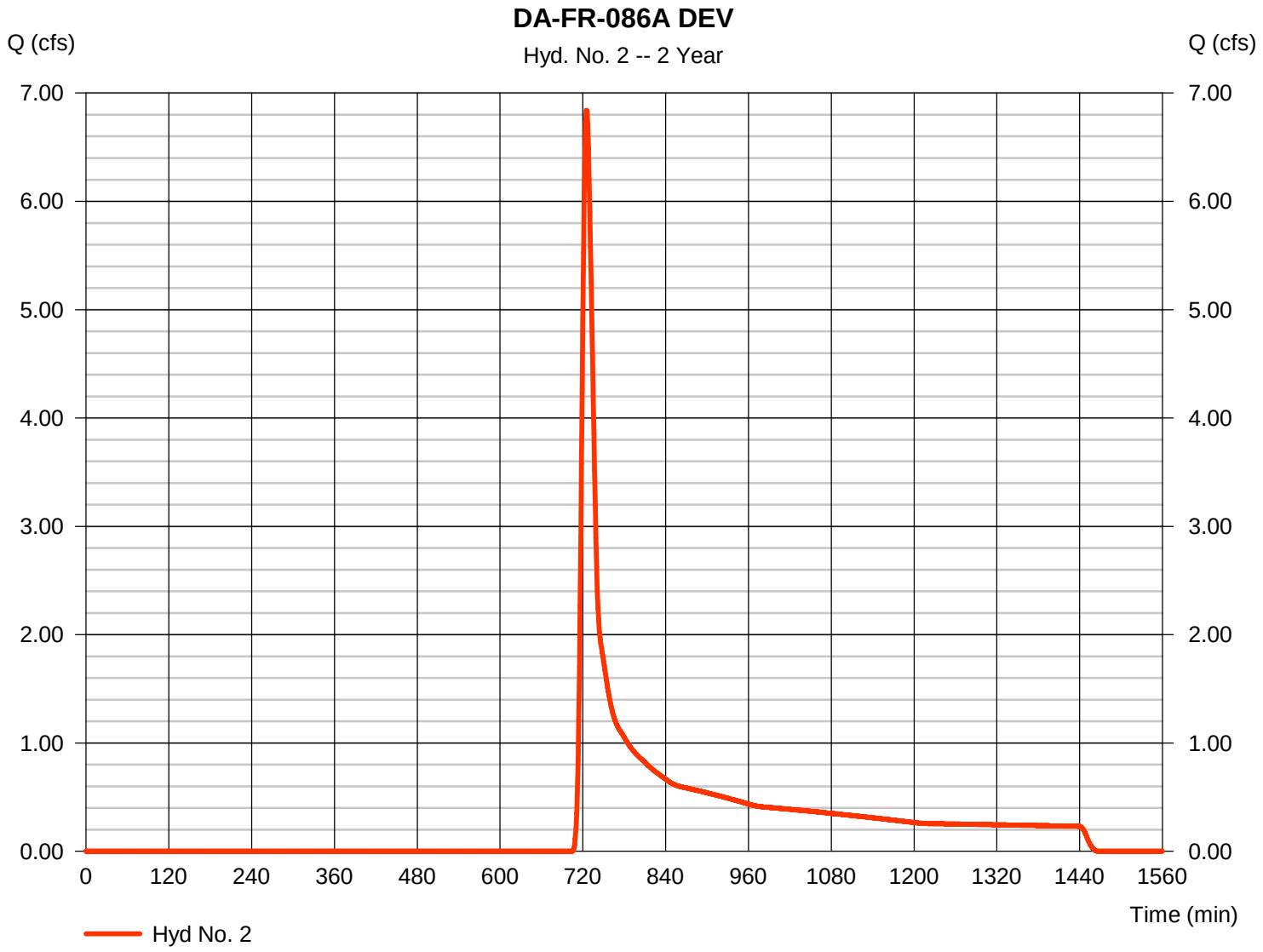
Hydrograph Report

Hyd. No. 2

DA-FR-086A DEV

Hydrograph type	=	SCS Runoff	Peak discharge	=	6.841 cfs
Storm frequency	=	2 yrs	Time to peak	=	725 min
Time interval	=	1 min	Hyd. volume	=	26,692 cuft
Drainage area	=	12.600 ac	Curve number	=	59*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	16.10 min
Total precip.	=	3.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.070 x 85) + (0.140 x 98) + (12.390 x 58)] / 12.600



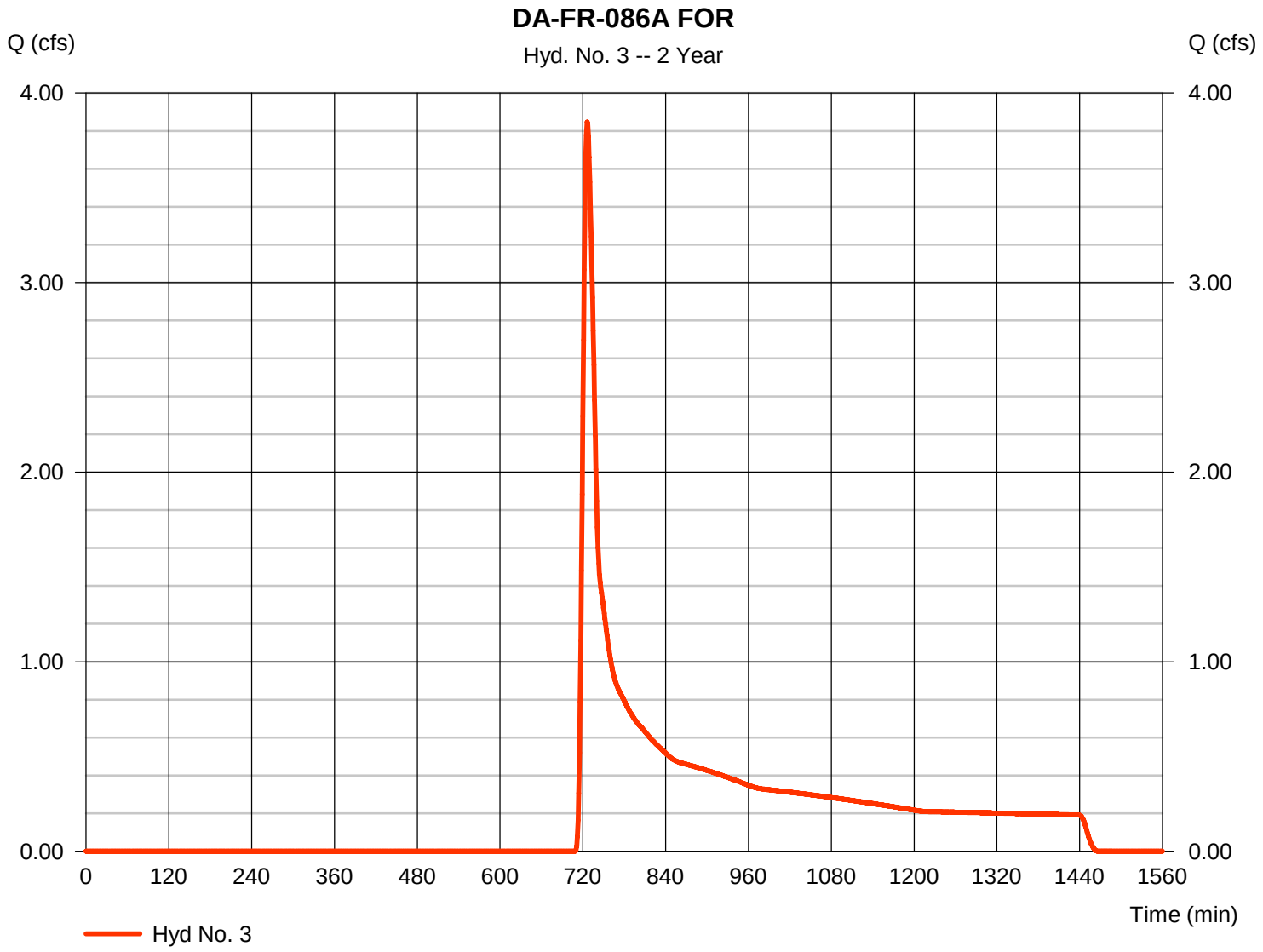
Hydrograph Report

Hyd. No. 3

DA-FR-086A FOR

Hydrograph type	=	SCS Runoff	Peak discharge	=	3.847 cfs
Storm frequency	=	2 yrs	Time to peak	=	726 min
Time interval	=	1 min	Hyd. volume	=	19,230 cuft
Drainage area	=	12.590 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	16.10 min
Total precip.	=	3.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.070 x 85) + (0.140 x 98) + (12.390 x 58)] / 12.590



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	25.16	1	724	76,410	------	------	------	DA-FR-086A PRE
2	SCS Runoff	25.16	1	724	76,410	------	------	------	DA-FR-086A DEV
3	SCS Runoff	19.46	1	724	62,399	------	------	------	DA-FR-086A FOR

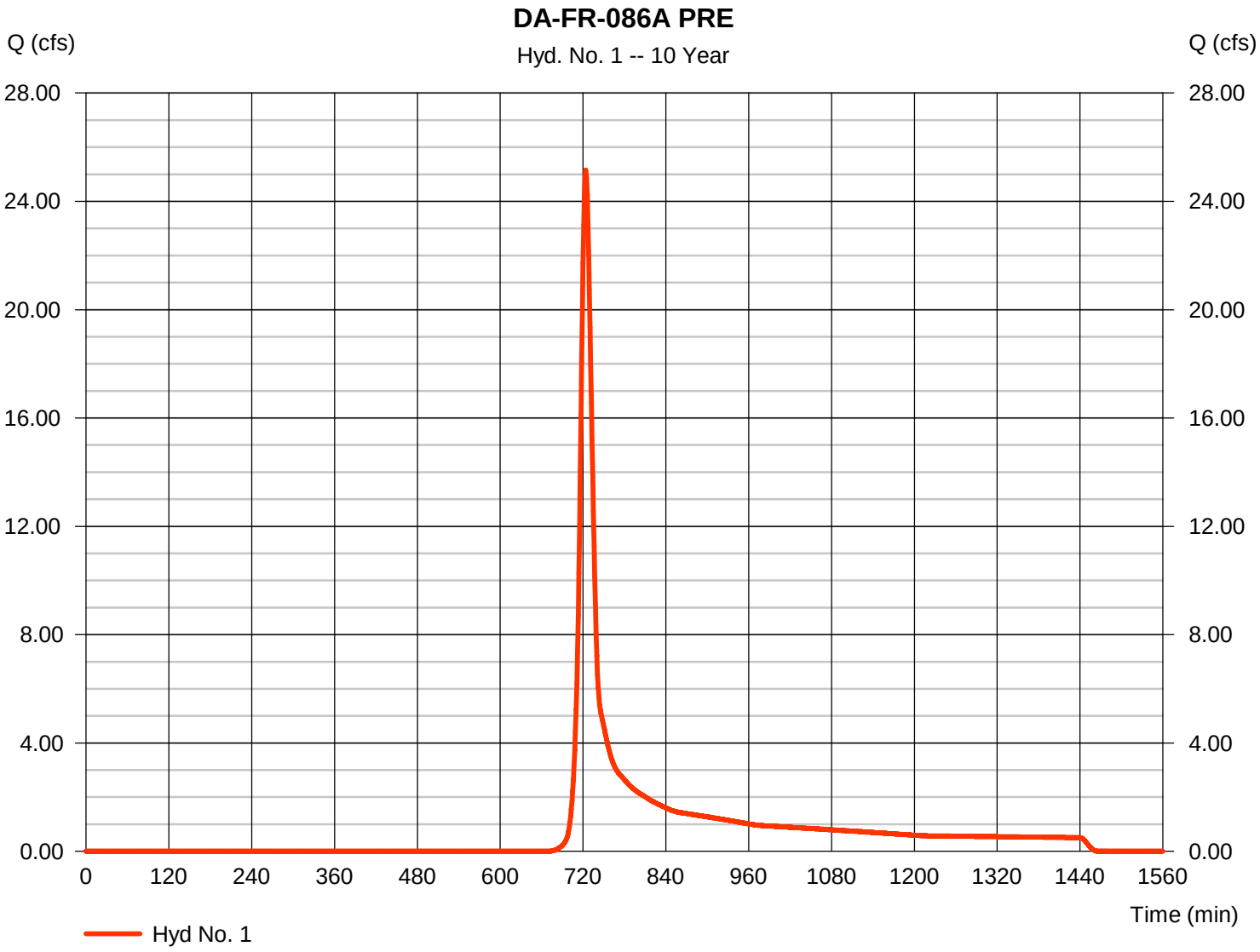
Hydrograph Report

Hyd. No. 1

DA-FR-086A PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 25.16 cfs
Storm frequency	= 10 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 76,410 cuft
Drainage area	= 12.600 ac	Curve number	= 59*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.10 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.070 x 85) + (0.140 x 98) + (12.390 x 58)] / 12.600



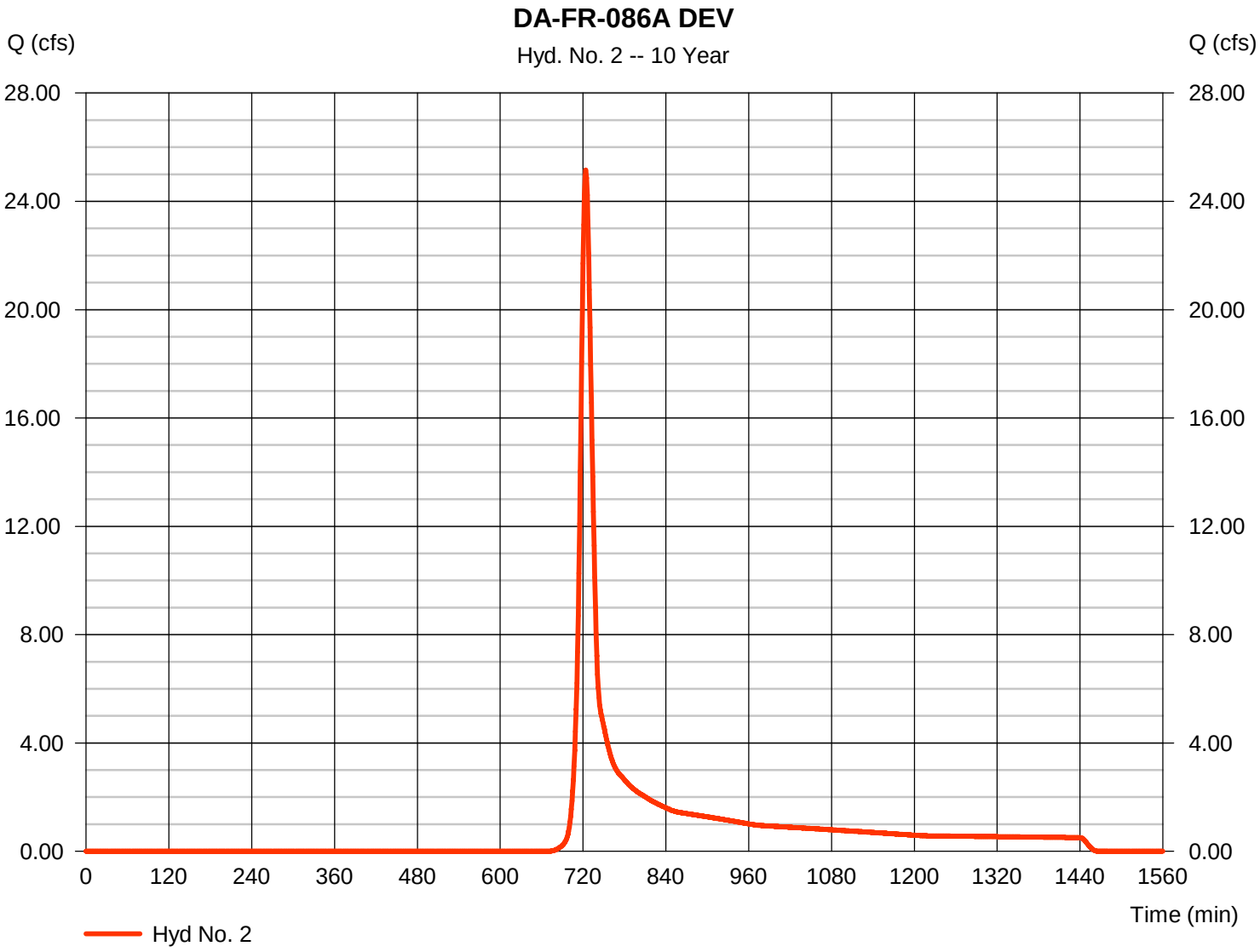
Hydrograph Report

Hyd. No. 2

DA-FR-086A DEV

Hydrograph type	=	SCS Runoff	Peak discharge	=	25.16 cfs
Storm frequency	=	10 yrs	Time to peak	=	724 min
Time interval	=	1 min	Hyd. volume	=	76,410 cuft
Drainage area	=	12.600 ac	Curve number	=	59*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	16.10 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.070 x 85) + (0.140 x 98) + (12.390 x 58)] / 12.600



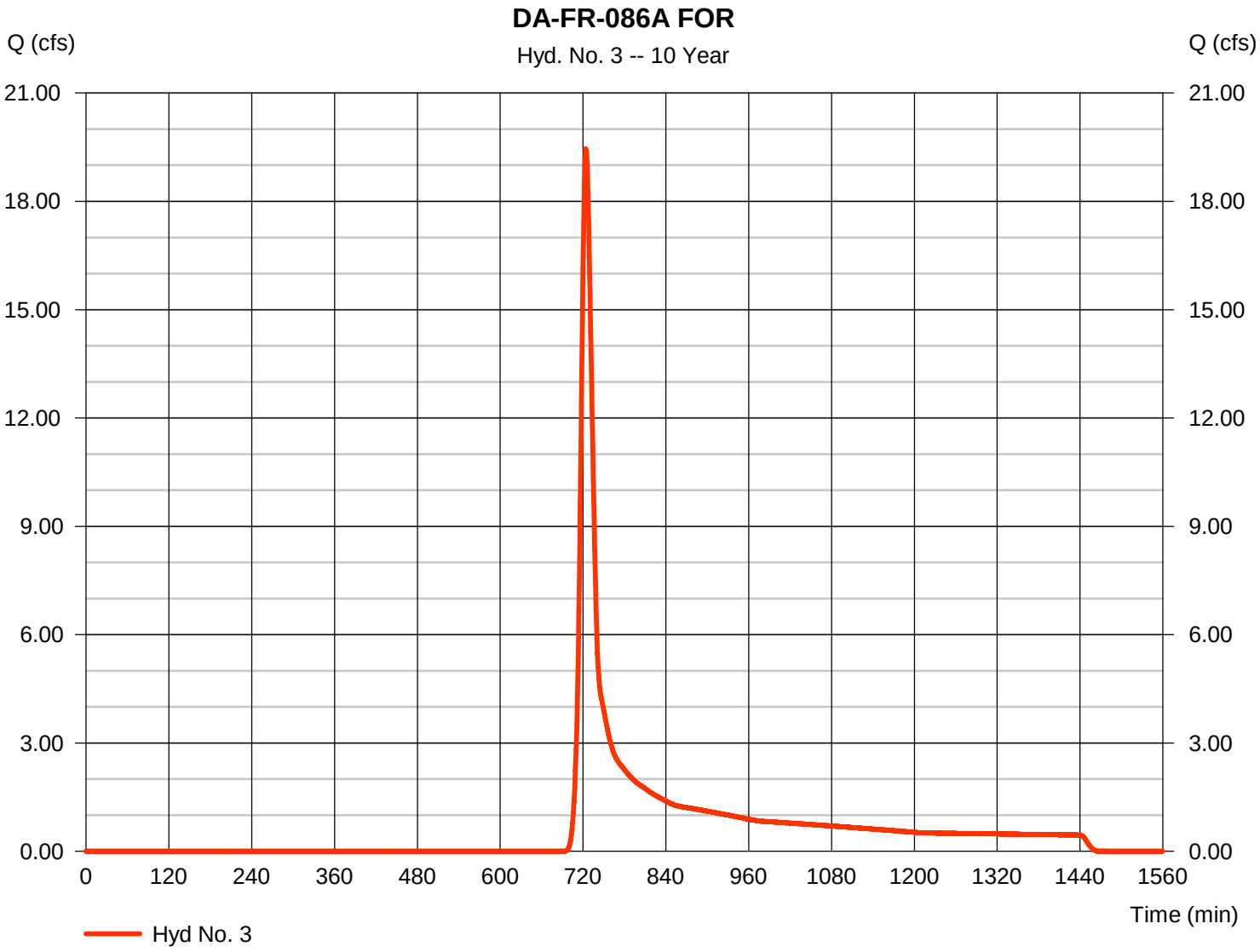
Hydrograph Report

Hyd. No. 3

DA-FR-086A FOR

Hydrograph type	=	SCS Runoff	Peak discharge	=	19.46 cfs
Storm frequency	=	10 yrs	Time to peak	=	724 min
Time interval	=	1 min	Hyd. volume	=	62,399 cuft
Drainage area	=	12.590 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	16.10 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.070 x 85) + (0.140 x 98) + (12.390 x 58)] / 12.590



Hydraflow Rainfall Report

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

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

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

Tc = time in minutes. Values may exceed 60.

ling\Franklin County\Downloaded Files\Franklin County DA Batch 4 - 046 - 058\Precipitation\Hydraflow\FranklinCo.p

Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.30	3.70	0.00	0.00	5.70	0.00	0.00	0.00
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

DA-FR-086B

Table 1 – Manning's n Values for Sheet Flow

Land Surface Type	**Manning n**
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40

Note:

Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.

For Paved Road land surface types a Manning's n value 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

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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-FR-086B PRE
2	SCS Runoff	DA-FR-086B DEV
3	SCS Runoff	DA-FR-086B FOR

Hydrograph Return Period Recap

Hyd. No.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)							Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	------	0.569	0.964	-------	-------	3.680	-------	-------	-------	DA-FR-086B PRE
2	SCS Runoff	------	0.573	0.969	-------	-------	3.701	-------	-------	-------	DA-FR-086B DEV
3	SCS Runoff	------	0.311	0.618	-------	-------	3.042	-------	-------	-------	DA-FR-086B FOR

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	724	2,357	------	------	------	DA-FR-086B PRE
2	SCS Runoff	0.573	1	724	2,371	------	------	------	DA-FR-086B DEV
3	SCS Runoff	0.311	1	725	1,758	------	------	------	DA-FR-086B FOR

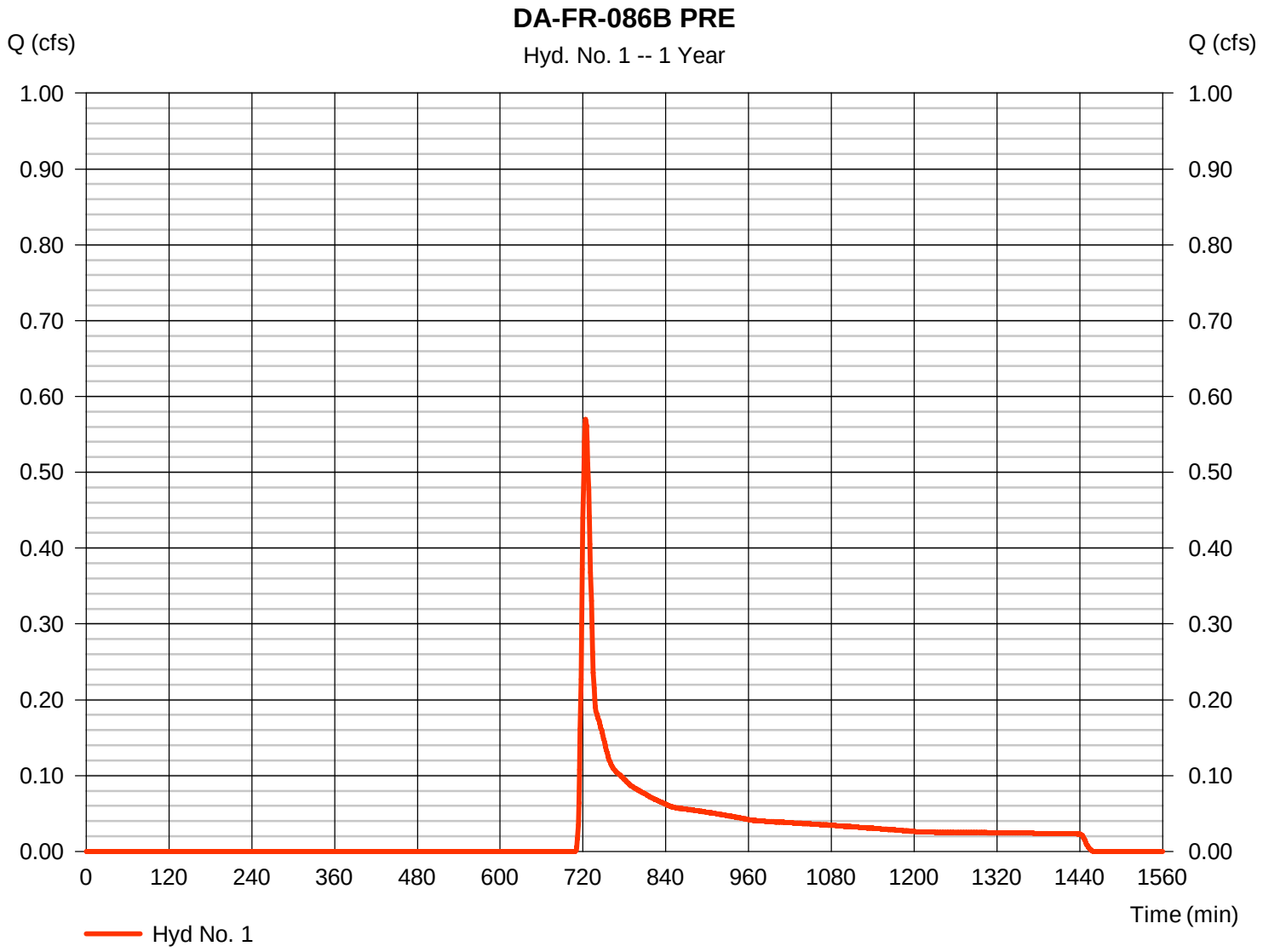
Hydrograph Report

Hyd. No. 1

DA-FR-086B PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.569 cfs
Storm frequency	=	1 yrs	Time to peak	=	724 min
Time interval	=	1 min	Hyd. volume	=	2,357 cuft
Drainage area	=	1.750 ac	Curve number	=	58*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	12.50 min
Total precip.	=	3.30 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.002 x 85) + (1.591 x 58) + (0.162 x 55)] / 1.750



TR55 Tc Worksheet

Hyd. No. 1

DA-FR-086B PRE

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 8.41		0.00		0.00		
Travel Time (min)	**= 11.24**	**+**	**0.00**	**+**	**0.00**	**=**	**11.24**
Shallow Concentrated Flow							
Flow length (ft)	= 479.02		0.00		0.00		
Watercourse slope (%)	= 15.59		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=6.37		0.00		0.00		
Travel Time (min)	**= 1.25**	**+**	**0.00**	**+**	**0.00**	**=**	**1.25**
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	= 0.015		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 ..... 12.50 min

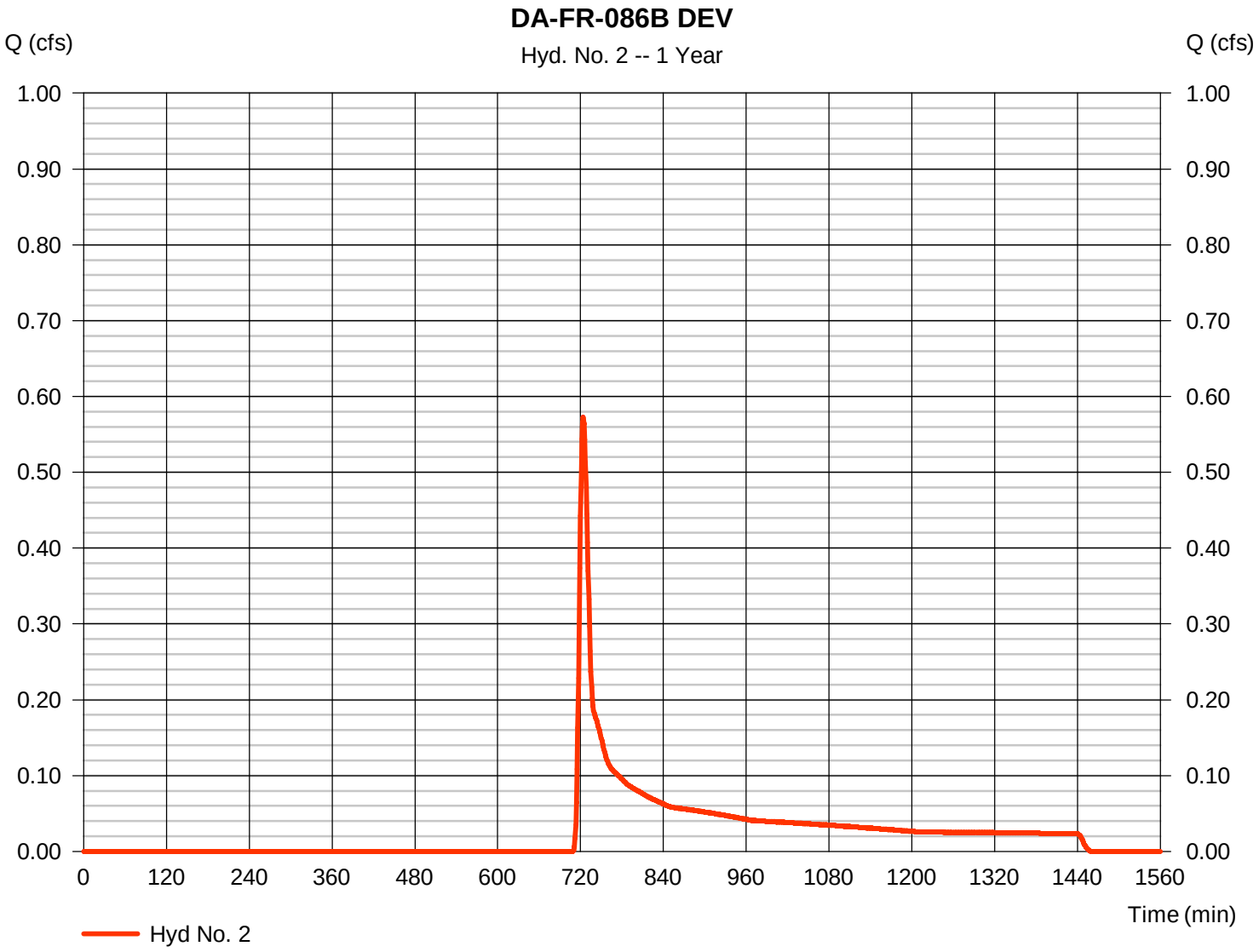
Hydrograph Report

Hyd. No. 2

DA-FR-086B DEV

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.573 cfs
Storm frequency	=	1 yrs	Time to peak	=	724 min
Time interval	=	1 min	Hyd. volume	=	2,371 cuft
Drainage area	=	1.760 ac	Curve number	=	58*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	12.50 min
Total precip.	=	3.30 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.002 x 85) + (1.736 x 58) + (0.018 x 48)] / 1.760



TR55 Tc Worksheet

Hyd. No. 2

DA-FR-086B DEV

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 8.41		0.00		0.00		
Travel Time (min)	**= 11.24**	**+**	**0.00**	**+**	**0.00**	**=**	**11.24**
Shallow Concentrated Flow							
Flow length (ft)	= 479.02		0.00		0.00		
Watercourse slope (%)	= 15.59		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=6.37		0.00		0.00		
Travel Time (min)	**= 1.25**	**+**	**0.00**	**+**	**0.00**	**=**	**1.25**
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	= 0.015		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 ..... 12.50 min

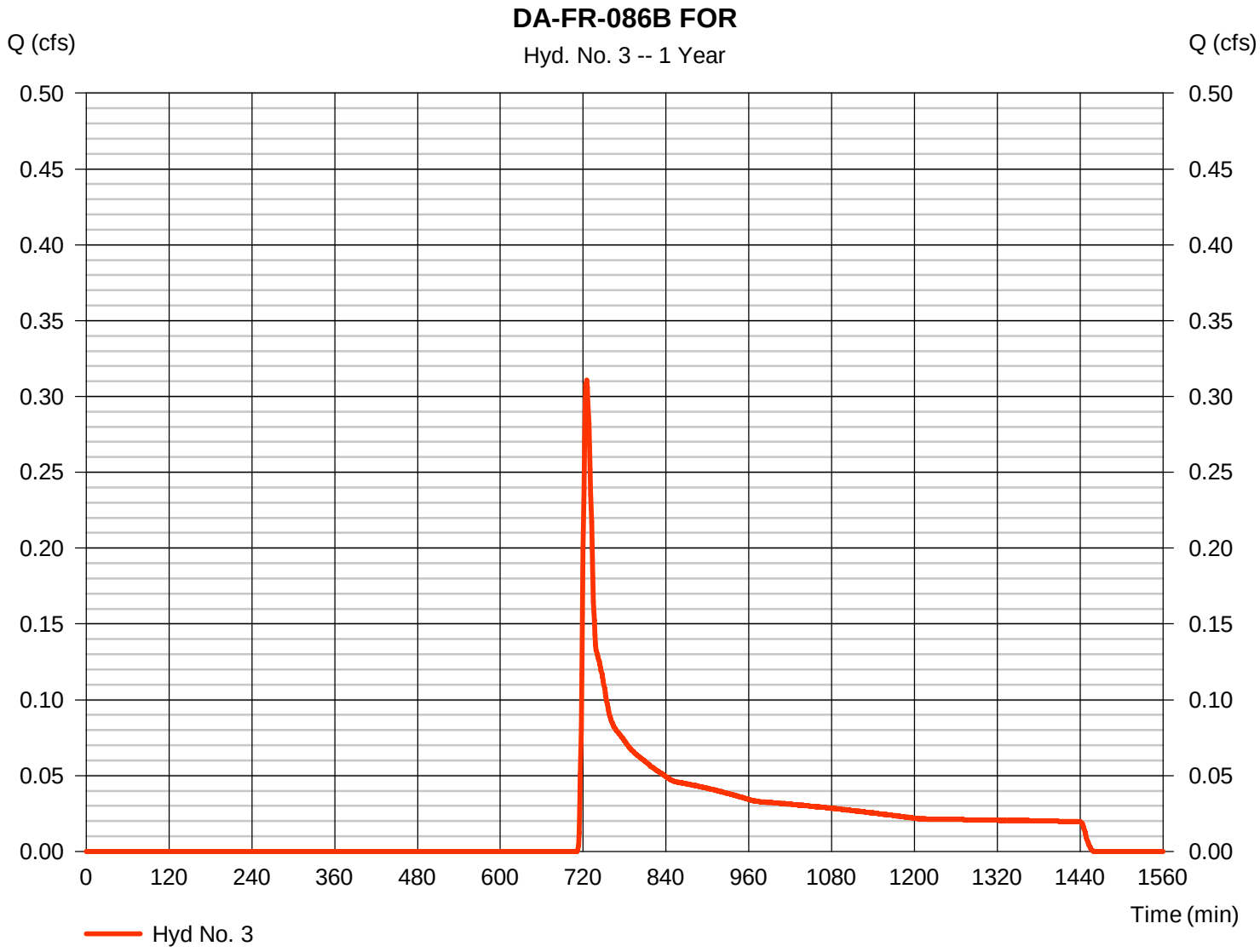
Hydrograph Report

Hyd. No. 3

DA-FR-086B FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.311 cfs
Storm frequency	= 1 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 1,758 cuft
Drainage area	= 1.750 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 12.50 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.002 x 85) + (1.591 x 58) + (0.162 x 55)] / 1.750



TR55 Tc Worksheet

Hyd. No. 3

DA-FR-086B FOR

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 8.41		0.00		0.00		
Travel Time (min)	**= 11.24**	**+**	**0.00**	**+**	**0.00**	**=**	**11.24**
Shallow Concentrated Flow							
Flow length (ft)	= 479.02		0.00		0.00		
Watercourse slope (%)	= 15.59		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=6.37		0.00		0.00		
Travel Time (min)	**= 1.25**	**+**	**0.00**	**+**	**0.00**	**=**	**1.25**
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	= 0.015		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 ..... 12.50 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	0.964	1	723	3,340	------	------	------	DA-FR-086B PRE
2	SCS Runoff	0.969	1	723	3,359	------	------	------	DA-FR-086B DEV
3	SCS Runoff	0.618	1	724	2,599	------	------	------	DA-FR-086B FOR

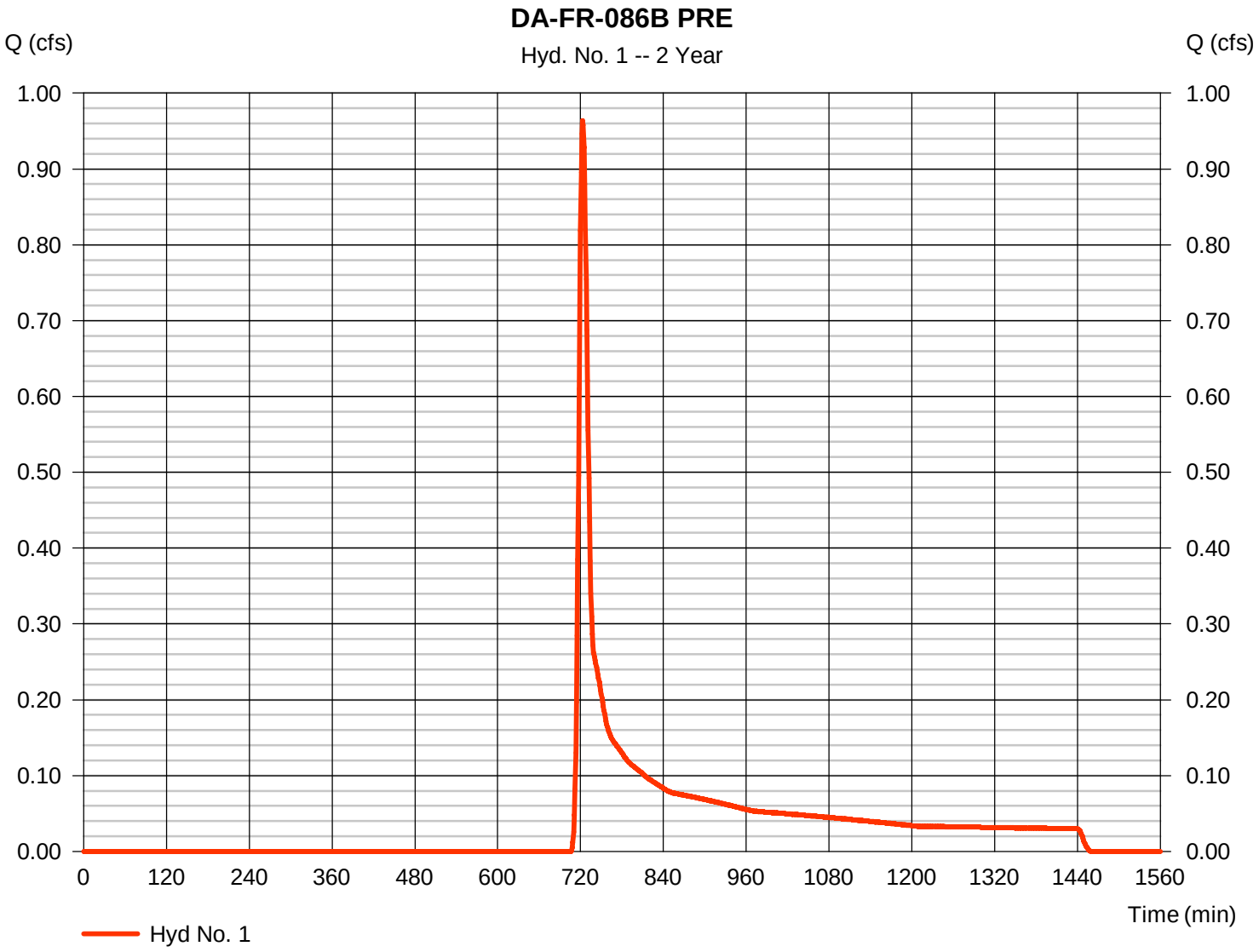
Hydrograph Report

Hyd. No. 1

DA-FR-086B PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.964 cfs
Storm frequency	= 2 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 3,340 cuft
Drainage area	= 1.750 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 12.50 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.002 x 85) + (1.591 x 58) + (0.162 x 55)] / 1.750



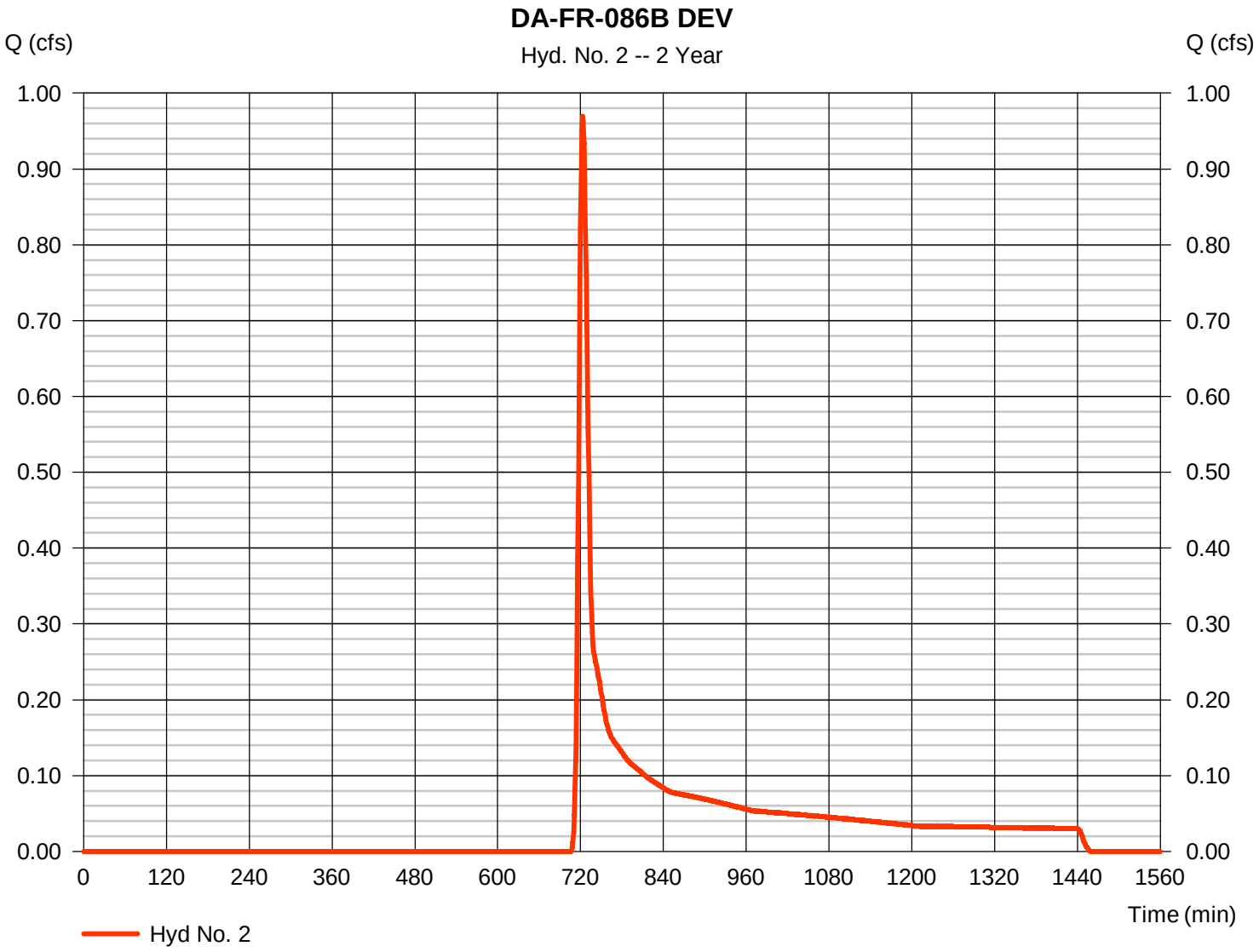
Hydrograph Report

Hyd. No. 2

DA-FR-086B DEV

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.969 cfs
Storm frequency	=	2 yrs	Time to peak	=	723 min
Time interval	=	1 min	Hyd. volume	=	3,359 cuft
Drainage area	=	1.760 ac	Curve number	=	58*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	12.50 min
Total precip.	=	3.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.002 x 85) + (1.736 x 58) + (0.018 x 48)] / 1.760



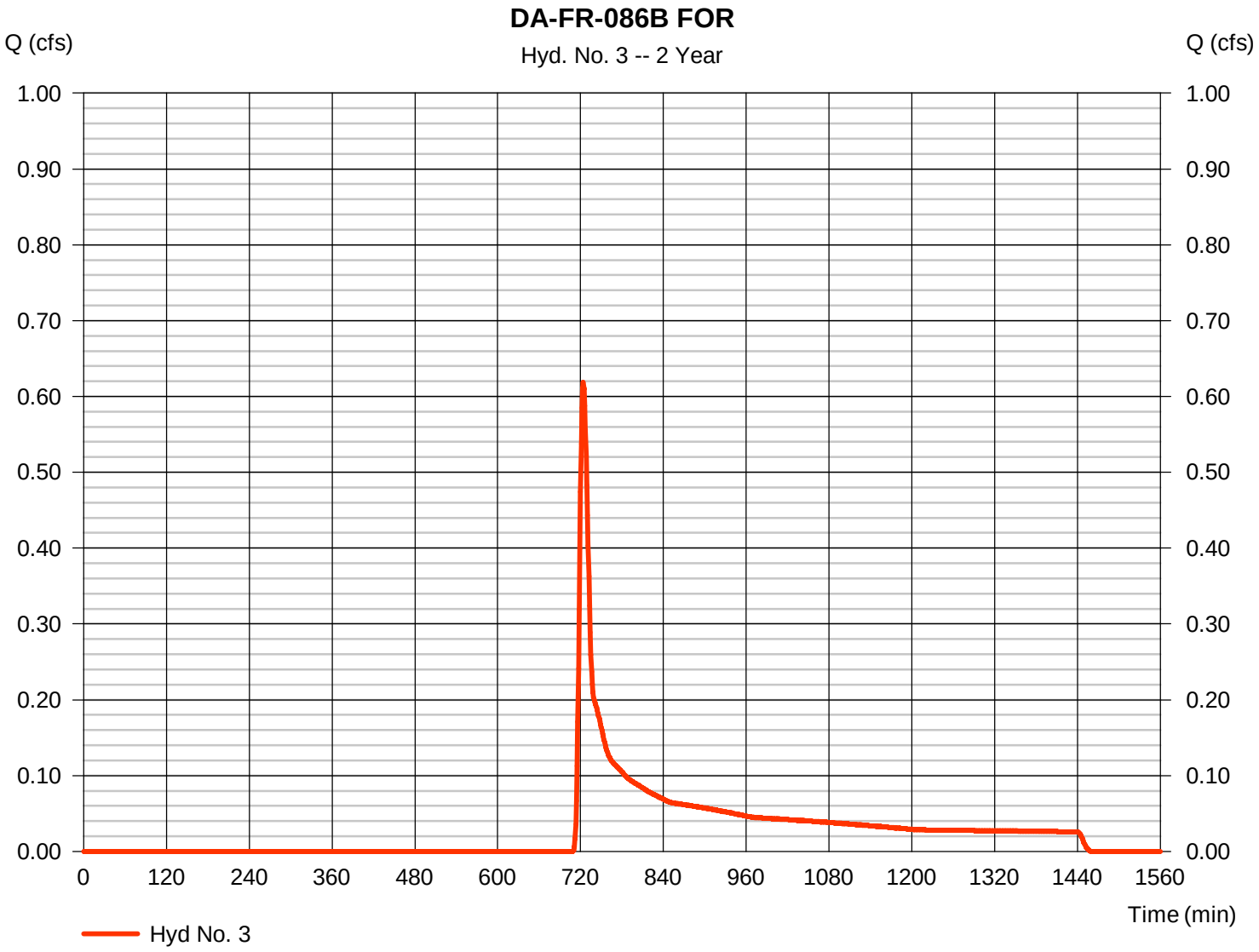
Hydrograph Report

Hyd. No. 3

DA-FR-086B FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.618 cfs
Storm frequency	= 2 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 2,599 cuft
Drainage area	= 1.750 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 12.50 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.002 x 85) + (1.591 x 58) + (0.162 x 55)] / 1.750



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	3.680	1	722	9,836	------	------	------	DA-FR-086B PRE
2	SCS Runoff	3.701	1	722	9,892	------	------	------	DA-FR-086B DEV
3	SCS Runoff	3.042	1	722	8,433	------	------	------	DA-FR-086B FOR

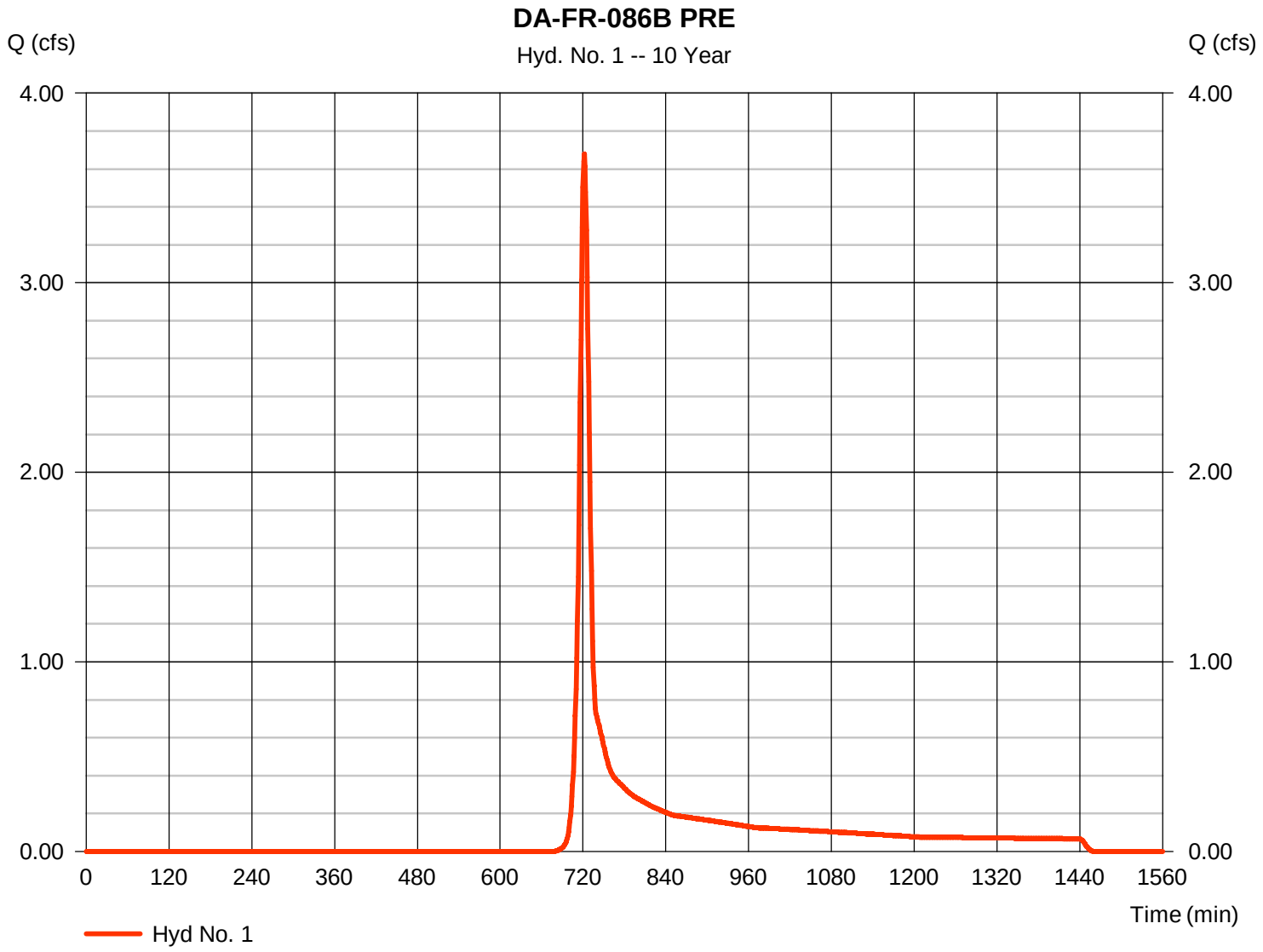
Hydrograph Report

Hyd. No. 1

DA-FR-086B PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	3.680 cfs
Storm frequency	=	10 yrs	Time to peak	=	722 min
Time interval	=	1 min	Hyd. volume	=	9,836 cuft
Drainage area	=	1.750 ac	Curve number	=	58*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	12.50 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.002 x 85) + (1.591 x 58) + (0.162 x 55)] / 1.750



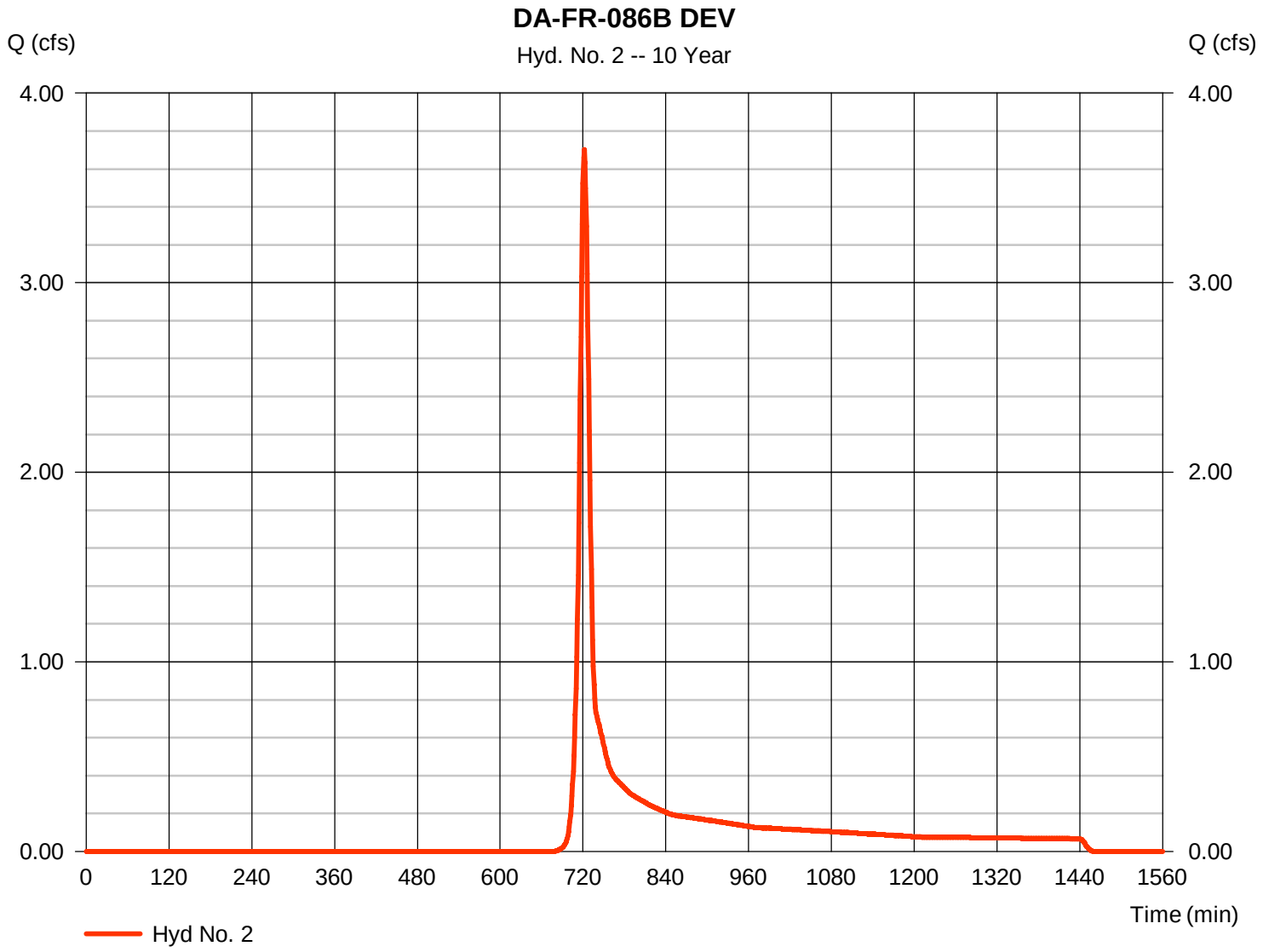
Hydrograph Report

Hyd. No. 2

DA-FR-086B DEV

Hydrograph type	=	SCS Runoff	Peak discharge	=	3.701 cfs
Storm frequency	=	10 yrs	Time to peak	=	722 min
Time interval	=	1 min	Hyd. volume	=	9,892 cuft
Drainage area	=	1.760 ac	Curve number	=	58*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	12.50 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.002 x 85) + (1.736 x 58) + (0.018 x 48)] / 1.760



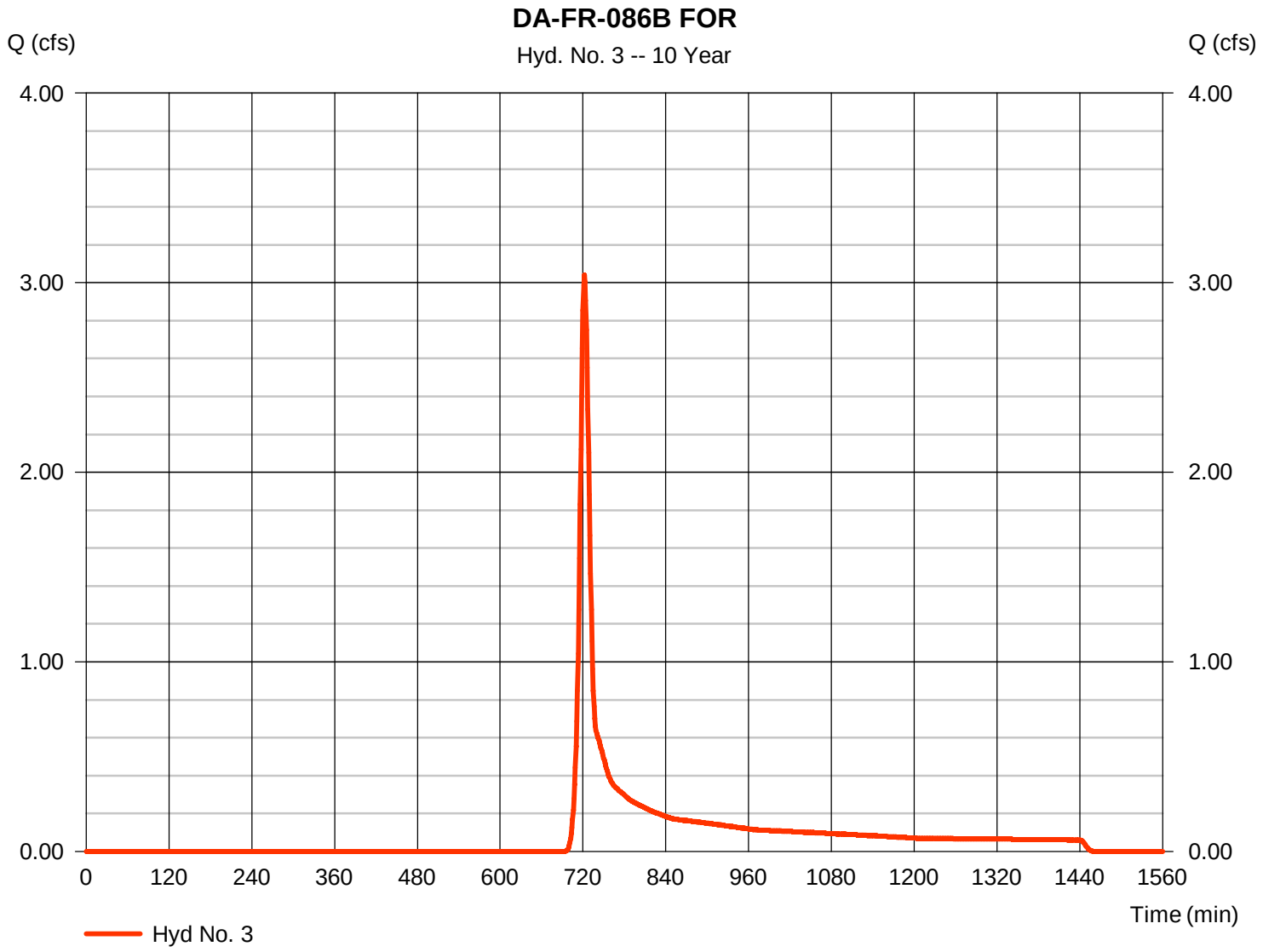
Hydrograph Report

Hyd. No. 3

DA-FR-086B FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 3.042 cfs
Storm frequency	= 10 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 8,433 cuft
Drainage area	= 1.750 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 12.50 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.002 x 85) + (1.591 x 58) + (0.162 x 55)] / 1.750



Hydraflow Rainfall Report

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

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

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

Tc = time in minutes. Values may exceed 60.

ng\Franklin County\Downloaded Files\Franklin County DA Batch 4 - 046 - 058\Precipitation\Hydraflow\FranklinCo.pc

Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.30	3.70	0.00	0.00	5.70	0.00	0.00	0.00
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

DA-FR-086C

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	1.230	6918
Developed Condition	1.230	6918
Pre-Developed (Forest) Condition	0.806	5659

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

Improvement Factor, IF = 1

Calculations:

Check #1: $Q_{developed} \leq IF \times [(Q_{pre\text{-}developed} \times RV_{pre\text{-}developed}) / RV_{developed}]$ ----------> 1.230 ≤ 1.230 OK

Check #2: $Q_{developed} \leq Q_{pre\text{-}developed}$ ----------> 1.230 ≤ 1.230 OK

Check #3: $Q_{developed}$ *shall not* be required to be ≤ $(Q_{forest} \times RV_{forest}) / RV_{developed}$ ---> 1.230 *shall not* be required to be ≤ 0.659

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

Note:

Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.

For Paved Road land surface types a Manning's n value 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 Channels[1]			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels[2]			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150

Notes:

[1]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 or grass channel.

[2]For the pre-developed condition (if applicable), 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-FR-086C PRE
2	SCS Runoff	DA-FR-086C POST
3	SCS Runoff	DA-FR-086C FOR

Hydrograph Return Period Recap

Hyd. No.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)							Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	------	1.230	2.185	-------	-------	9.289	-------	-------	-------	DA-FR-086C PRE
2	SCS Runoff	------	1.230	2.185	-------	-------	9.289	-------	-------	-------	DA-FR-086C POST
3	SCS Runoff	------	0.806	1.597	-------	-------	8.105	-------	-------	-------	DA-FR-086C FOR

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	1.230	1	728	6,918	------	------	------	DA-FR-086C PRE
2	SCS Runoff	1.230	1	728	6,918	------	------	------	DA-FR-086C POST
3	SCS Runoff	0.806	1	729	5,659	------	------	------	DA-FR-086C FOR

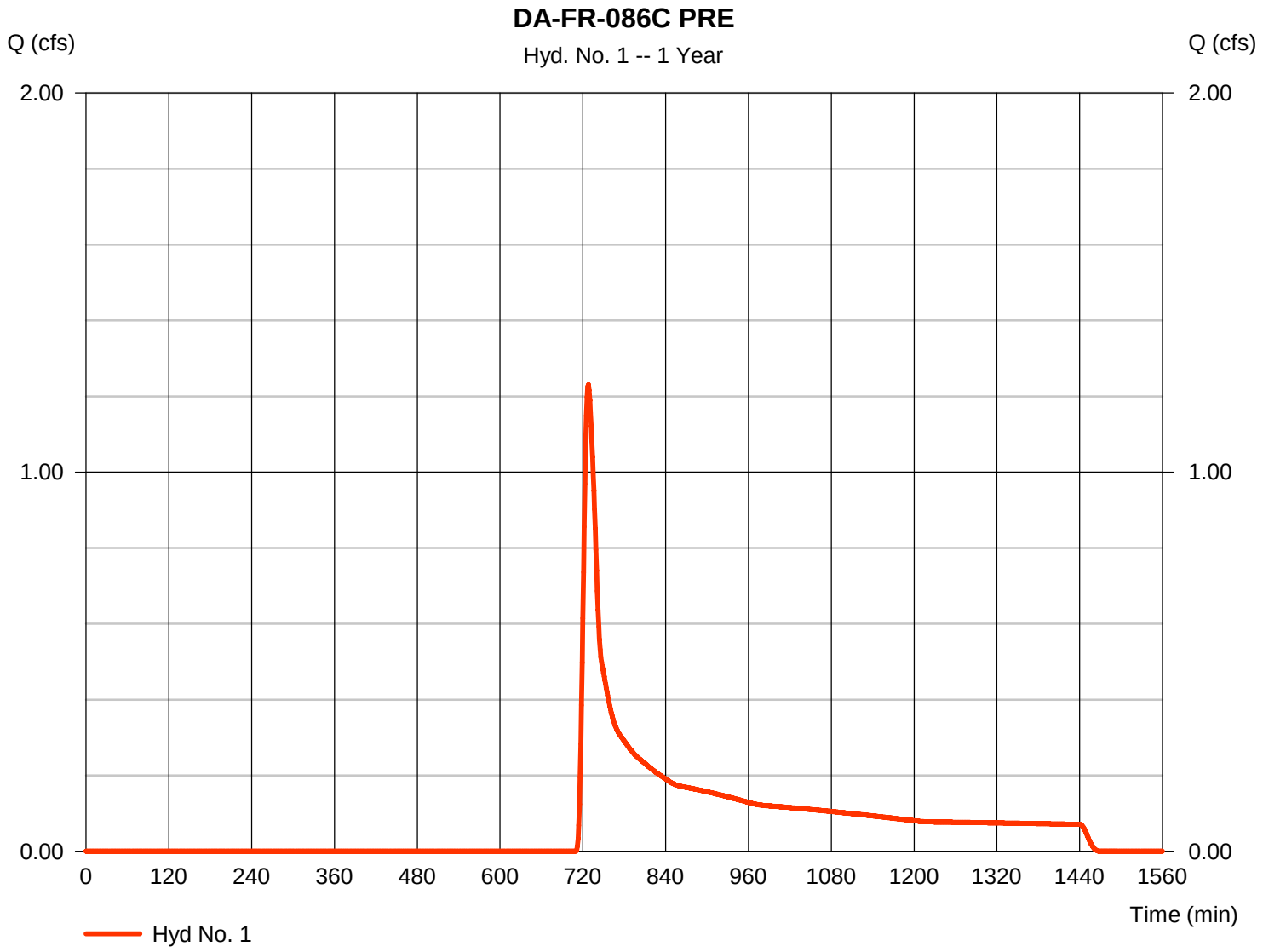
Hydrograph Report

Hyd. No. 1

DA-FR-086C PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	1.230 cfs
Storm frequency	=	1 yrs	Time to peak	=	728 min
Time interval	=	1 min	Hyd. volume	=	6,918 cuft
Drainage area	=	5.610 ac	Curve number	=	57*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	18.40 min
Total precip.	=	3.30 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = + (4.710 x 58) + (0.740 x 55) + (0.160 x 48)] / 5.610



TR55 Tc Worksheet

Hyd. No. 1

DA-FR-086C PRE

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.400		0.400		0.400		
Flow length (ft)	= 21.7		16.2		62.1		
Two-year 24-hr precip. (in)	= 3.70		3.70		3.70		
Land slope (%)	= 5.28		5.74		5.48		
Travel Time (min)	**= 3.99**	**+**	**3.06**	**+**	**9.11**	**=**	**16.16**
Shallow Concentrated Flow							
Flow length (ft)	= 0.00		0.00		712.66		
Watercourse slope (%)	= 0.00		0.00		10.46		
Surface description	= Unpaved		Paved		Unpaved		
Average velocity (ft/s)	=0.00		0.00		5.22		
Travel Time (min)	**= 0.00**	**+**	**0.00**	**+**	**2.28**	**=**	**2.28**
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	= 0.015		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

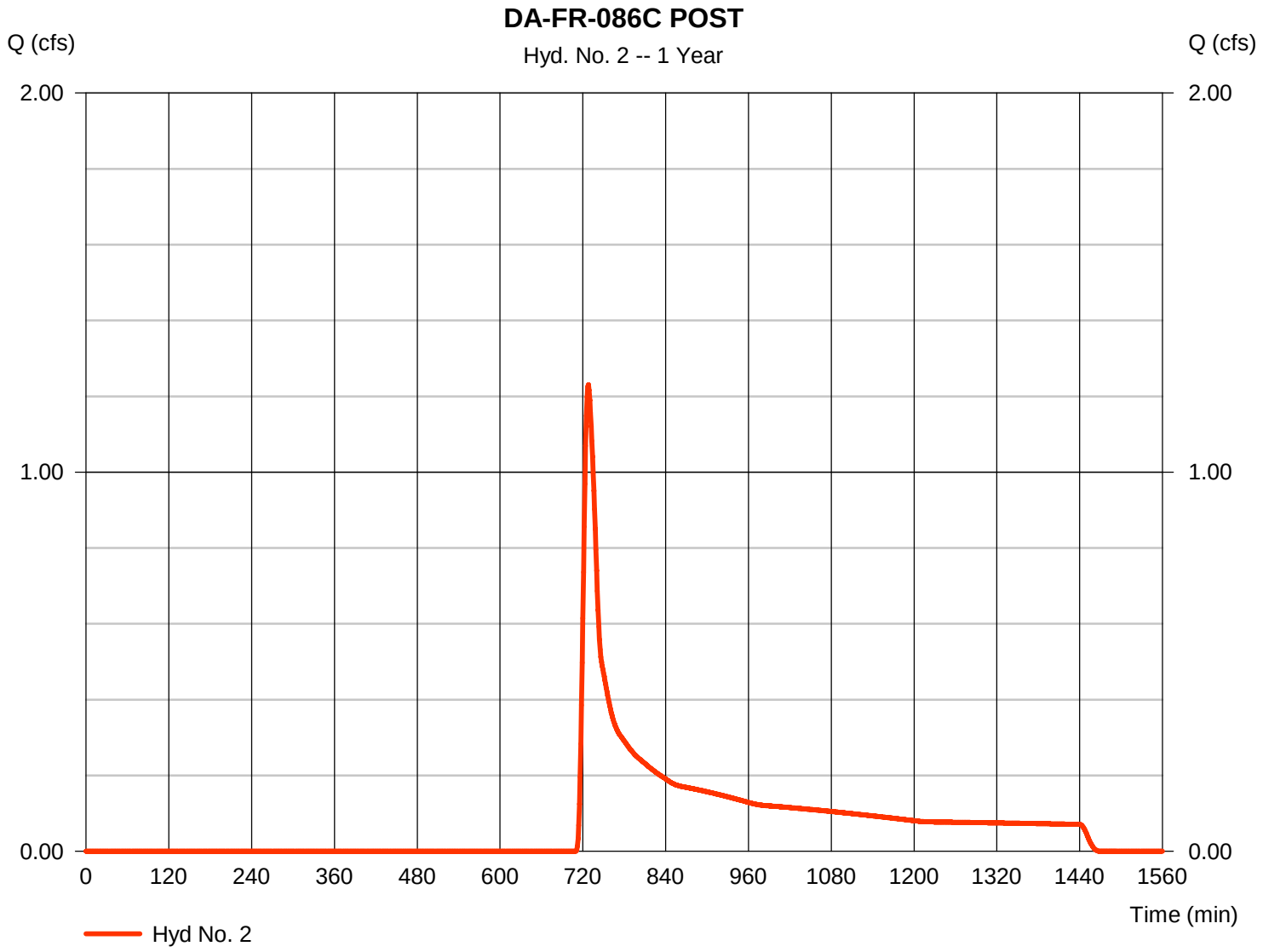
Hydrograph Report

Hyd. No. 2

DA-FR-086C POST

Hydrograph type	=	SCS Runoff	Peak discharge	=	1.230 cfs
Storm frequency	=	1 yrs	Time to peak	=	728 min
Time interval	=	1 min	Hyd. volume	=	6,918 cuft
Drainage area	=	5.610 ac	Curve number	=	57*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	18.50 min
Total precip.	=	3.30 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = + (4.931 x 58) + (0.461 x 55) + (0.220 x 48)] / 5.610



TR55 Tc Worksheet

Hyd. No. 2

DA-FR-086C POST

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.400		0.400		0.400		
Flow length (ft)	= 21.7		16.2		62.1		
Two-year 24-hr precip. (in)	= 3.70		3.70		3.70		
Land slope (%)	= 5.28		5.74		5.48		
Travel Time (min)	**= 3.99**	**+**	**3.06**	**+**	**9.11**	**=**	**16.16**
Shallow Concentrated Flow							
Flow length (ft)	= 0.00		194.27		480.17		
Watercourse slope (%)	= 0.00		14.66		9.05		
Surface description	= Paved		Unpaved		Unpaved		
Average velocity (ft/s)	=0.00		6.18		4.85		
Travel Time (min)	**= 0.00**	**+**	**0.52**	**+**	**1.65**	**=**	**2.17**
Channel Flow							
X sectional flow area (sqft)	= 0.00		0.00		2.00		
Wetted perimeter (ft)	= 0.00		0.00		4.47		
Channel slope (%)	= 0.00		0.00		5.00		
Manning's n-value	= 0.015		0.015		0.040		
Velocity (ft/s)	=0.00		0.00		4.86		
Flow length (ft)	({0})0.0		0.0		56.9		
Travel Time (min)	**= 0.00**	**+**	**0.00**	**+**	**0.20**	**=**	**0.20**

Total Travel Time, Tc ..... 18.50 min

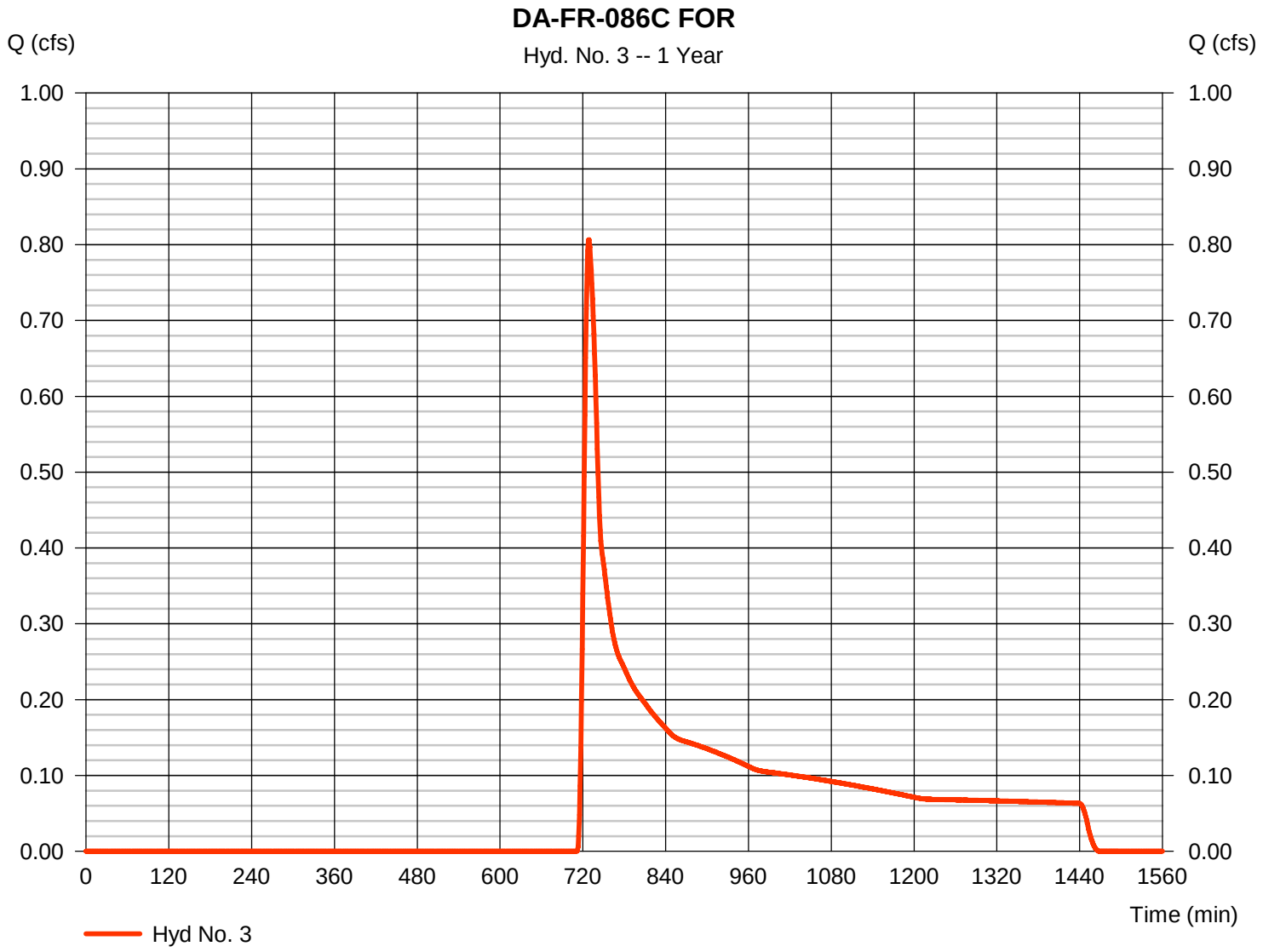
Hydrograph Report

Hyd. No. 3

DA-FR-086C FOR

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.806 cfs
Storm frequency	=	1 yrs	Time to peak	=	729 min
Time interval	=	1 min	Hyd. volume	=	5,659 cuft
Drainage area	=	5.610 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	18.40 min
Total precip.	=	3.30 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(5.610 x 55)] / 5.610



TR55 Tc Worksheet

Hyd. No. 3

DA-FR-086C FOR

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.400		0.400		0.400		
Flow length (ft)	= 21.7		16.2		62.1		
Two-year 24-hr precip. (in)	= 3.70		3.70		3.70		
Land slope (%)	= 5.28		5.74		5.48		
Travel Time (min)	**= 3.99**	**+**	**3.06**	**+**	**9.11**	**=**	**16.16**
Shallow Concentrated Flow							
Flow length (ft)	= 712.66		0.00		0.00		
Watercourse slope (%)	= 10.46		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=5.22		0.00		0.00		
Travel Time (min)	**= 2.28**	**+**	**0.00**	**+**	**0.00**	**=**	**2.28**
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	= 0.015		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 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	2.185	1	727	9,928	------	------	------	DA-FR-086C PRE
2	SCS Runoff	2.185	1	727	9,928	------	------	------	DA-FR-086C POST
3	SCS Runoff	1.597	1	727	8,367	------	------	------	DA-FR-086C FOR

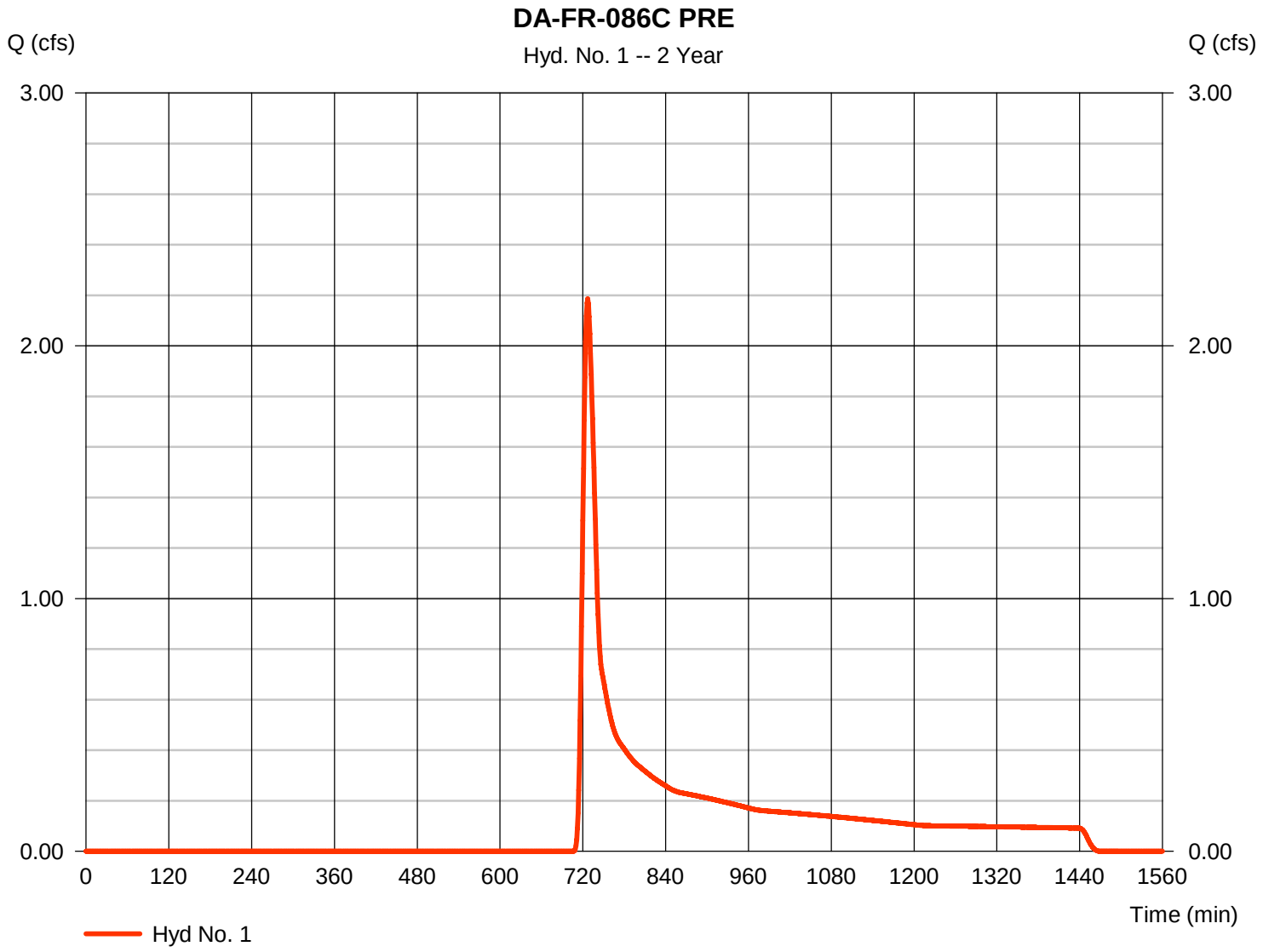
Hydrograph Report

Hyd. No. 1

DA-FR-086C PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	2.185 cfs
Storm frequency	=	2 yrs	Time to peak	=	727 min
Time interval	=	1 min	Hyd. volume	=	9,928 cuft
Drainage area	=	5.610 ac	Curve number	=	57*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	18.40 min
Total precip.	=	3.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = + (4.710 x 58) + (0.740 x 55) + (0.160 x 48)] / 5.610



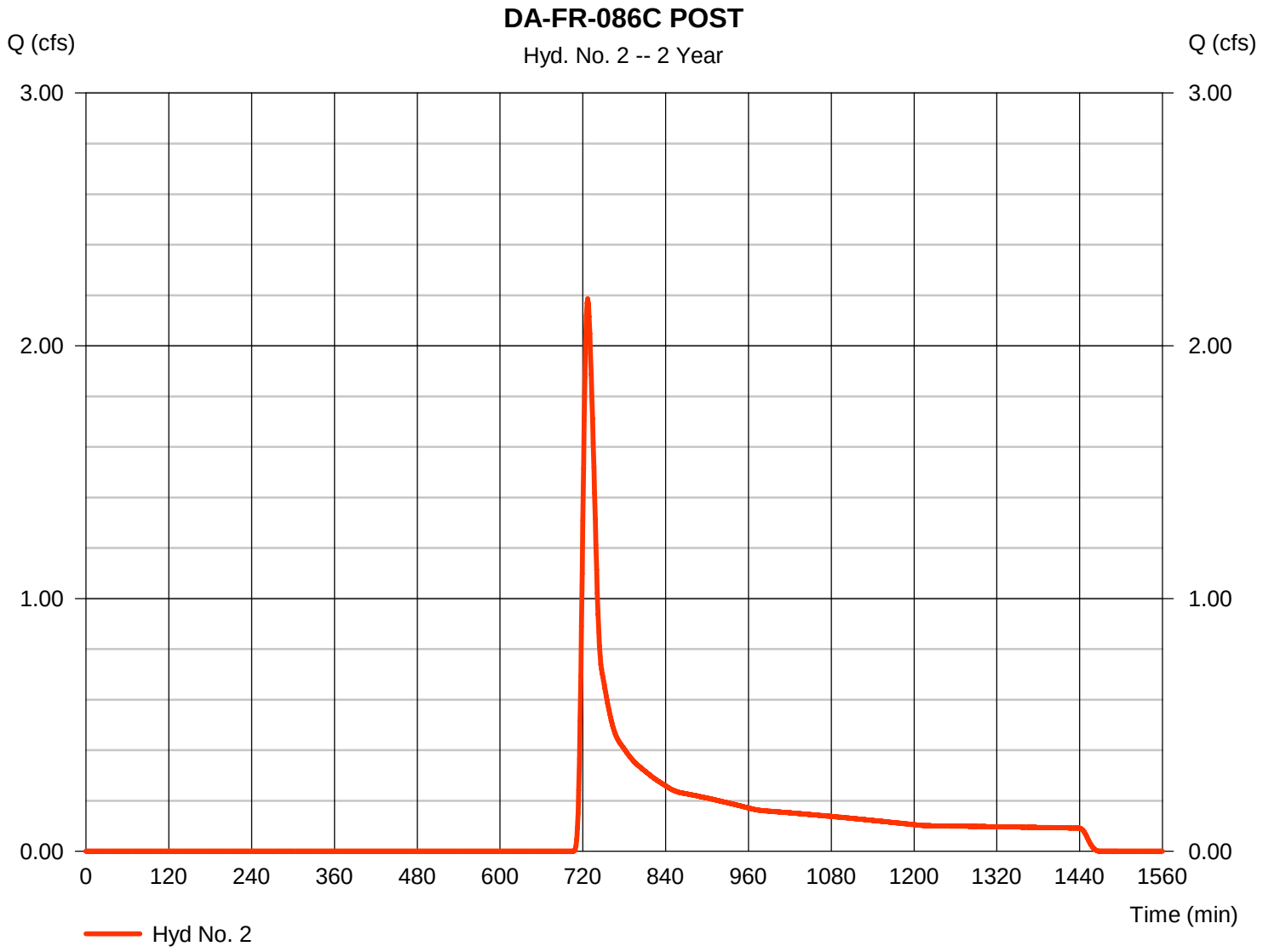
Hydrograph Report

Hyd. No. 2

DA-FR-086C POST

Hydrograph type	=	SCS Runoff	Peak discharge	=	2.185 cfs
Storm frequency	=	2 yrs	Time to peak	=	727 min
Time interval	=	1 min	Hyd. volume	=	9,928 cuft
Drainage area	=	5.610 ac	Curve number	=	57*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	18.50 min
Total precip.	=	3.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = + (4.931 x 58) + (0.461 x 55) + (0.220 x 48)] / 5.610



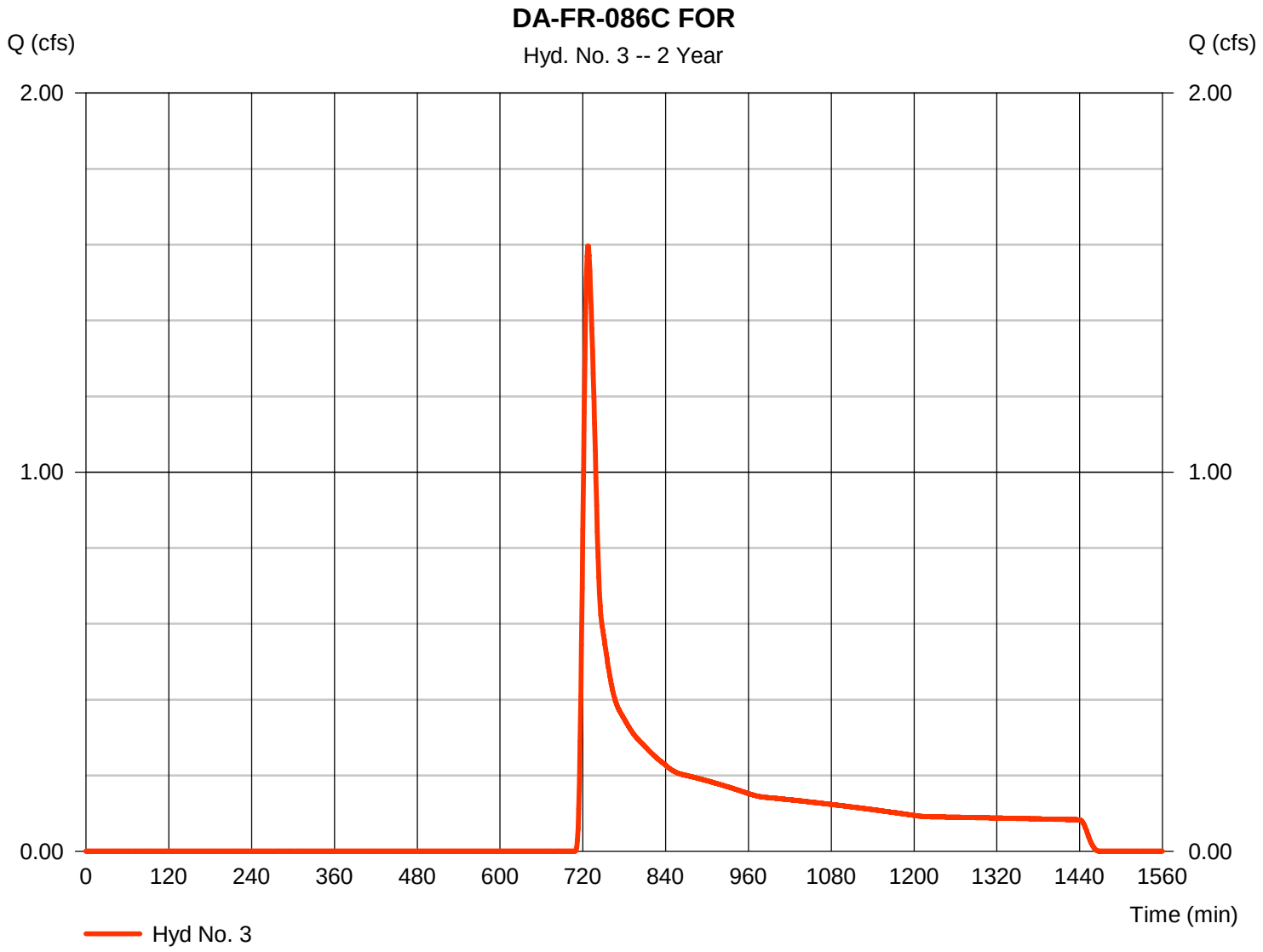
Hydrograph Report

Hyd. No. 3

DA-FR-086C FOR

Hydrograph type	=	SCS Runoff	Peak discharge	=	1.597 cfs
Storm frequency	=	2 yrs	Time to peak	=	727 min
Time interval	=	1 min	Hyd. volume	=	8,367 cuft
Drainage area	=	5.610 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	18.40 min
Total precip.	=	3.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(5.610 x 55)] / 5.610



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	9.289	1	725	30,137	------	------	------	DA-FR-086C PRE
2	SCS Runoff	9.289	1	725	30,137	------	------	------	DA-FR-086C POST
3	SCS Runoff	8.105	1	725	27,149	------	------	------	DA-FR-086C FOR

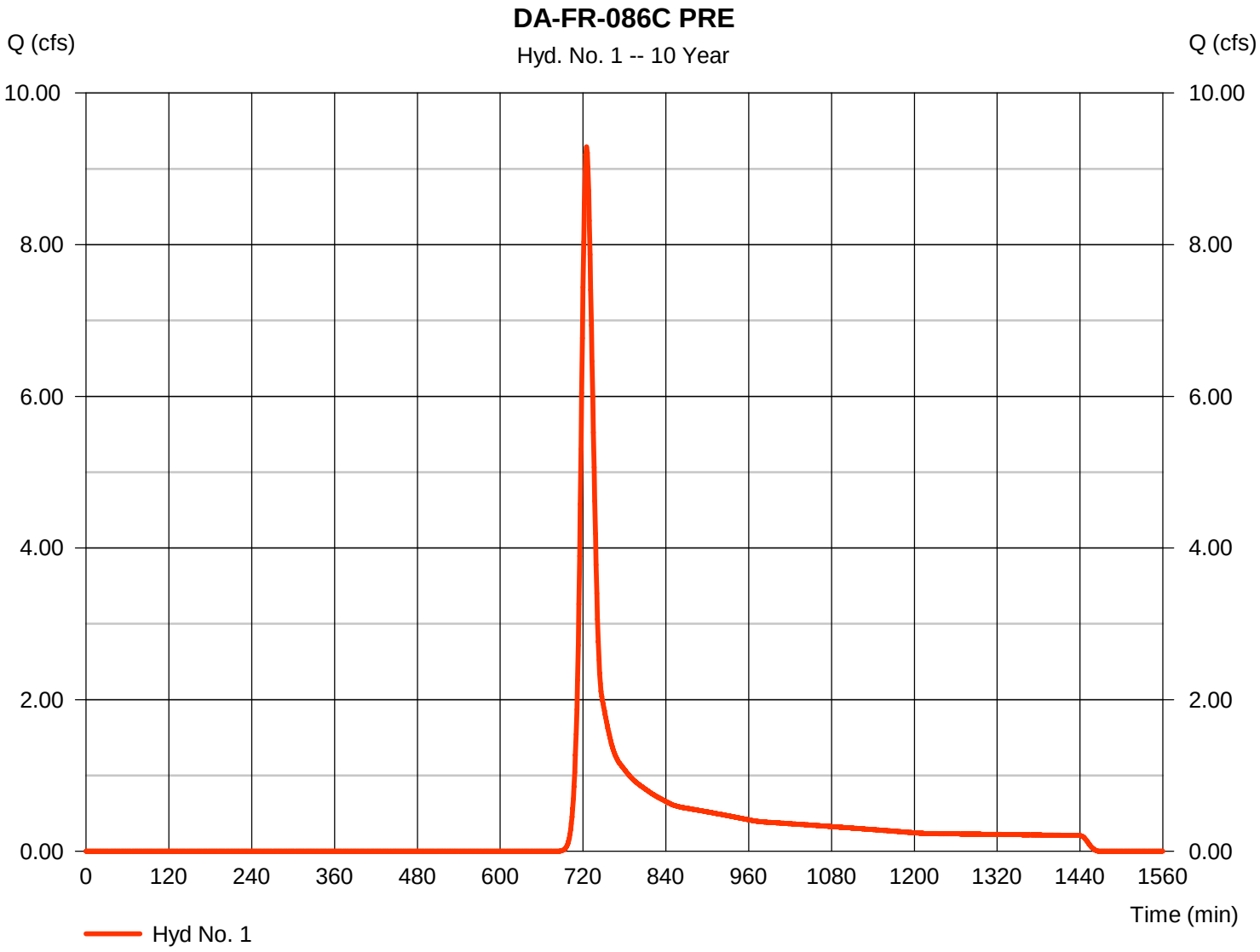
Hydrograph Report

Hyd. No. 1

DA-FR-086C PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	9.289 cfs
Storm frequency	=	10 yrs	Time to peak	=	725 min
Time interval	=	1 min	Hyd. volume	=	30,137 cuft
Drainage area	=	5.610 ac	Curve number	=	57*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	18.40 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = + (4.710 x 58) + (0.740 x 55) + (0.160 x 48)] / 5.610



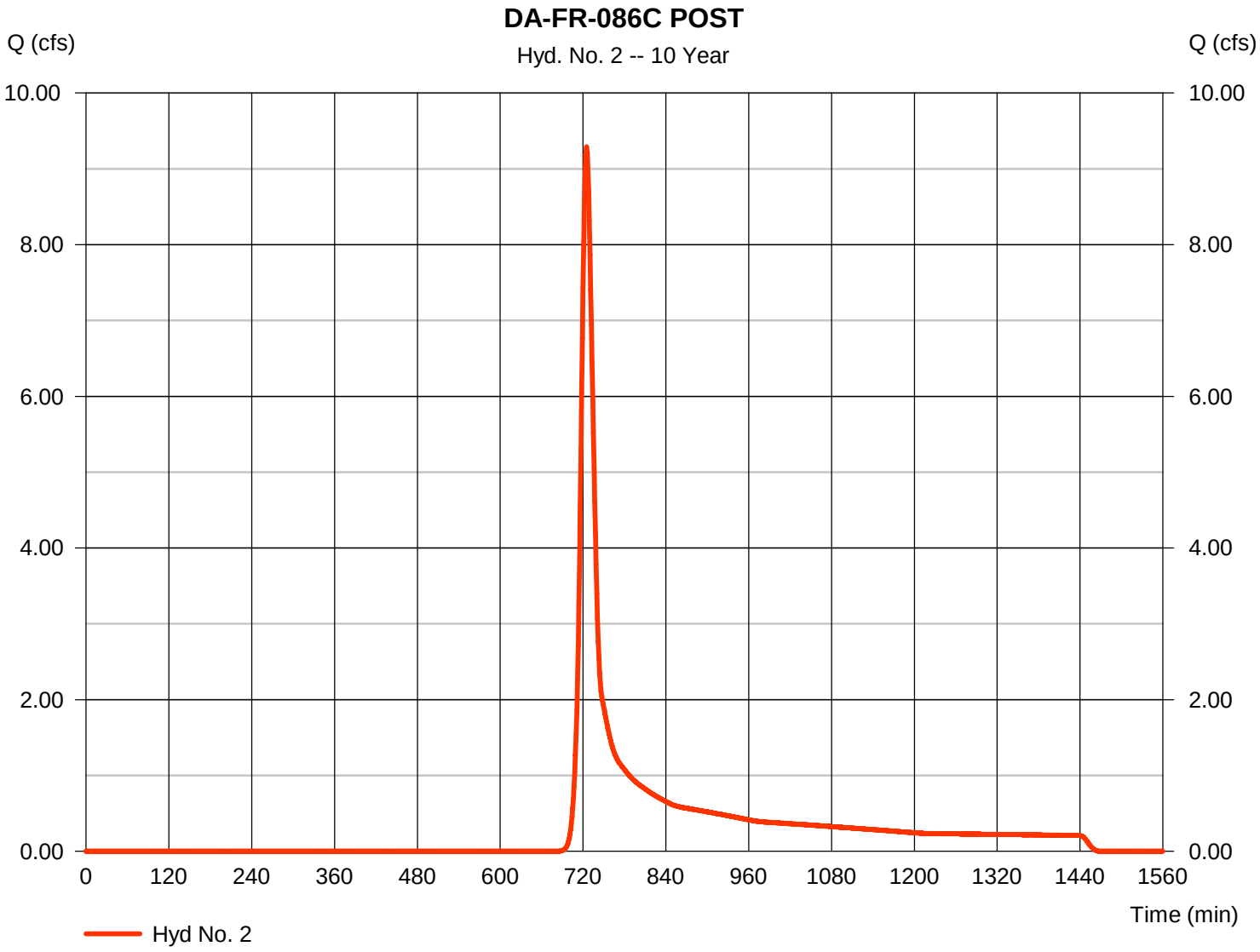
Hydrograph Report

Hyd. No. 2

DA-FR-086C POST

Hydrograph type	=	SCS Runoff	Peak discharge	=	9.289 cfs
Storm frequency	=	10 yrs	Time to peak	=	725 min
Time interval	=	1 min	Hyd. volume	=	30,137 cuft
Drainage area	=	5.610 ac	Curve number	=	57*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	18.50 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = + (4.931 x 58) + (0.461 x 55) + (0.220 x 48)] / 5.610



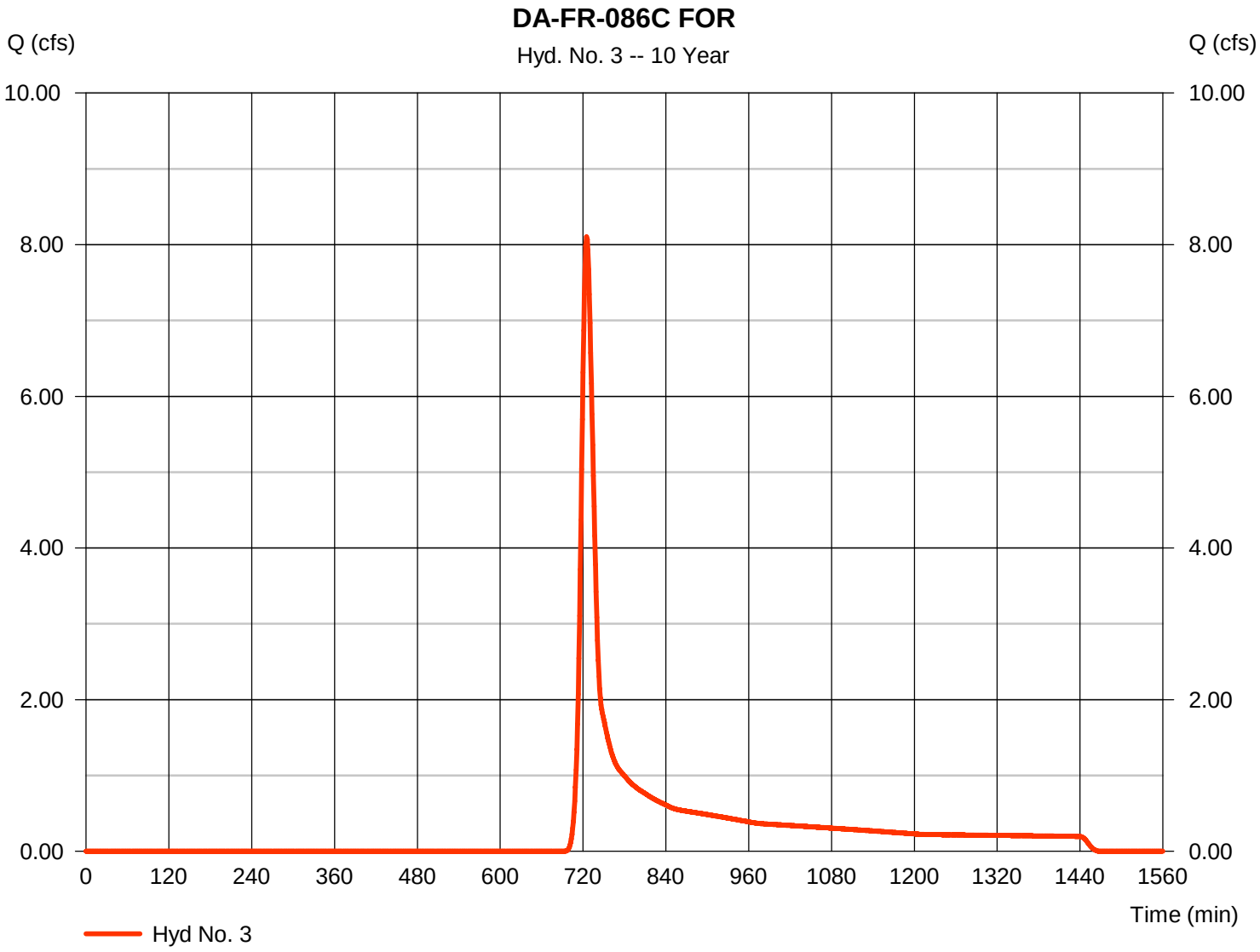
Hydrograph Report

Hyd. No. 3

DA-FR-086C FOR

Hydrograph type	=	SCS Runoff	Peak discharge	=	8.105 cfs
Storm frequency	=	10 yrs	Time to peak	=	725 min
Time interval	=	1 min	Hyd. volume	=	27,149 cuft
Drainage area	=	5.610 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	18.40 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(5.610 x 55)] / 5.610



Hydraflow Rainfall Report

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

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

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

Tc = time in minutes. Values may exceed 60.

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Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.30	3.70	0.00	0.00	5.70	0.00	0.00	0.00
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

DA-FR-086D

STORAGE VOLUME OF WATERBAR WITH SOIL COMPOST AMENDMENT AREA

Equations Used:

[1]Vgravel storage = L*W*D_{gravel}*(40/100)

[2]Vsoil storage = L*W*D_{soil}*(20/100)

[3]Vsurface storage = [W*S*D^2]+[L*S*D^2]+[W*L*D]+[((2*S*D)^2*D)/3]

[1]Equation #2b under "Volume Reduction Calculations" in Section 6.4.5 of PA BMP Manual, assuming that gravel is made up of 40% voids.

[2]Equation #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.

[3]Equation #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) =	40	Assume max. length of 50' for waterbar soil amendment areas (i.e., limited to permanent ROW)
Width of Waterbar Soil Amendment Area, W (ft) =	3	
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) =	82
Subsurface Storage Volume per BMP (cf) =	24
Total Storage Volume per BMP (cf) =	106
Total BMP Storage Volume in Drainage Area (cf) =	319
Calculated Infiltration Period per BMP (hr) =	53

Depth-Storage Data

Depth (ft)	Width (ft)	Length (ft)	Storage Volume per BMP (cf)	Storage Volume in Drainage Area (cf)
0	3	40	0	0
0.5	3	40	12	36
1	3	40	24	72
1.5	5	42	106	319
2	7	44	235	706

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.648	3552
Developed Condition	0.513	3233
Pre-Developed (Forest) Condition	0.518	3204

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

Improvement Factor, IF = 0.8

Calculations:

Check #1:	$Q_{developed} \leq IF \times [(Q_{pre\text{-}developed} \times RV_{pre\text{-}developed}) / RV_{developed}]$ ---------->	0.513	≤ OK	0.570	
Check #2:	$Q_{developed} \leq Q_{pre\text{-}developed}$ ---------->	0.513	≤ OK	0.648	
Check #3:	$Q_{developed}$ *shall not* be required to be ≤ $(Q_{forest} \times RV_{forest}) / RV_{developed}$ --->	0.513	*shall not* be required to be ≤	0.513	

Table 1 – Manning's n Values for Sheet Flow

Land Surface Type	**Manning n**
Grass:	
Average Grass Cover	0.40
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Light Turf	0.20
Dense Turf	0.17 – 0.80
Dense Grass	0.17 – 0.30
Bermuda Grass	0.30 – 0.48
Dense Shrubbery and Forest Litter	0.40
Natural:	
Short Grass Prairie	0.10 – 0.20
Poor Grass Cover, Moderately Rough Surface	0.30 – 0.40
Sparse Vegetation	0.05 – 0.13
Oak Grasslands, Open Grasslands	0.60
Dense Cover of Trees and Bushes	0.80
Rangeland:	
Typical	0.13
No Debris Cover	0.09 – 0.34
20% Debris Cover	0.05 – 0.25
Woods:	
Light Underbrush	0.40
Dense Underbrush	0.80
Rural Residential (1 – 10 acre lots, Maintenance or grazing assumed)	0.40

Note:

Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.

For Paved Road land surface types a Manning's n value 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

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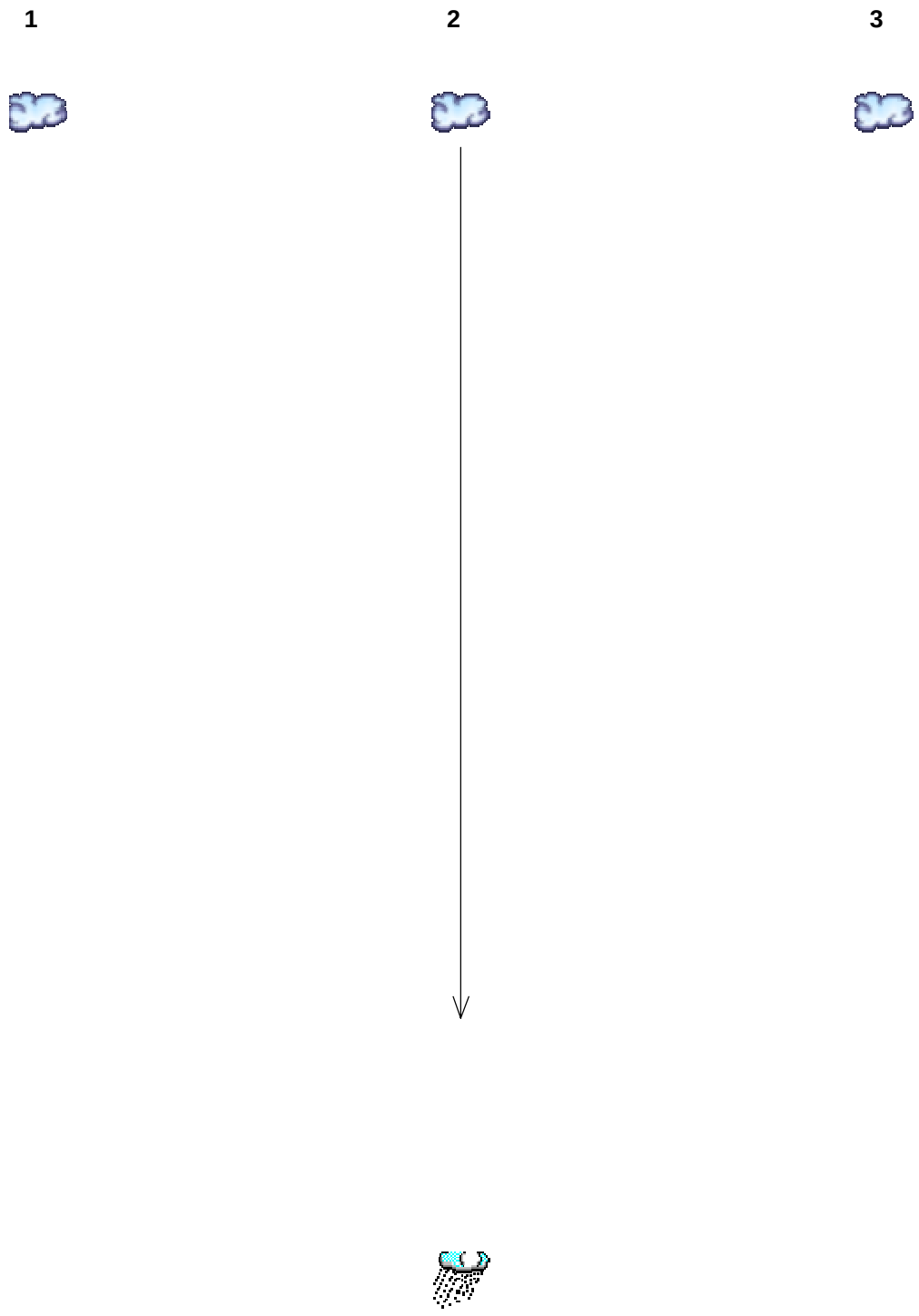
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Watershed Model Schematic

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



Legend

Hyd.	Origin	Description
1	SCS Runoff	DA-FR-086D PRE
2	SCS Runoff	DA-FR-086D DEV
3	SCS Runoff	DA-FR-086D FOR
4	Reservoir	WB Soil Amendments

Hydrograph Return Period Recap

Hyd. No.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)								Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	------	0.648	1.212	-------	-------	5.508	-------	-------	-------	DA-FR-086D PRE
2	SCS Runoff	------	0.648	1.212	-------	-------	5.508	-------	-------	-------	DA-FR-086D DEV
3	SCS Runoff	------	0.518	1.029	-------	-------	5.143	-------	-------	-------	DA-FR-086D FOR
4	Reservoir	2	0.513	1.154	-------	-------	5.475	-------	-------	-------	WB Soil Amendments

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	0.648	1	726	3,552	------	------	------	DA-FR-086D PRE
2	SCS Runoff	0.648	1	726	3,552	------	------	------	DA-FR-086D DEV
3	SCS Runoff	0.518	1	726	3,204	------	------	------	DA-FR-086D FOR
4	Reservoir	0.513	1	732	3,233	2	101.59	385	WB Soil Amendments

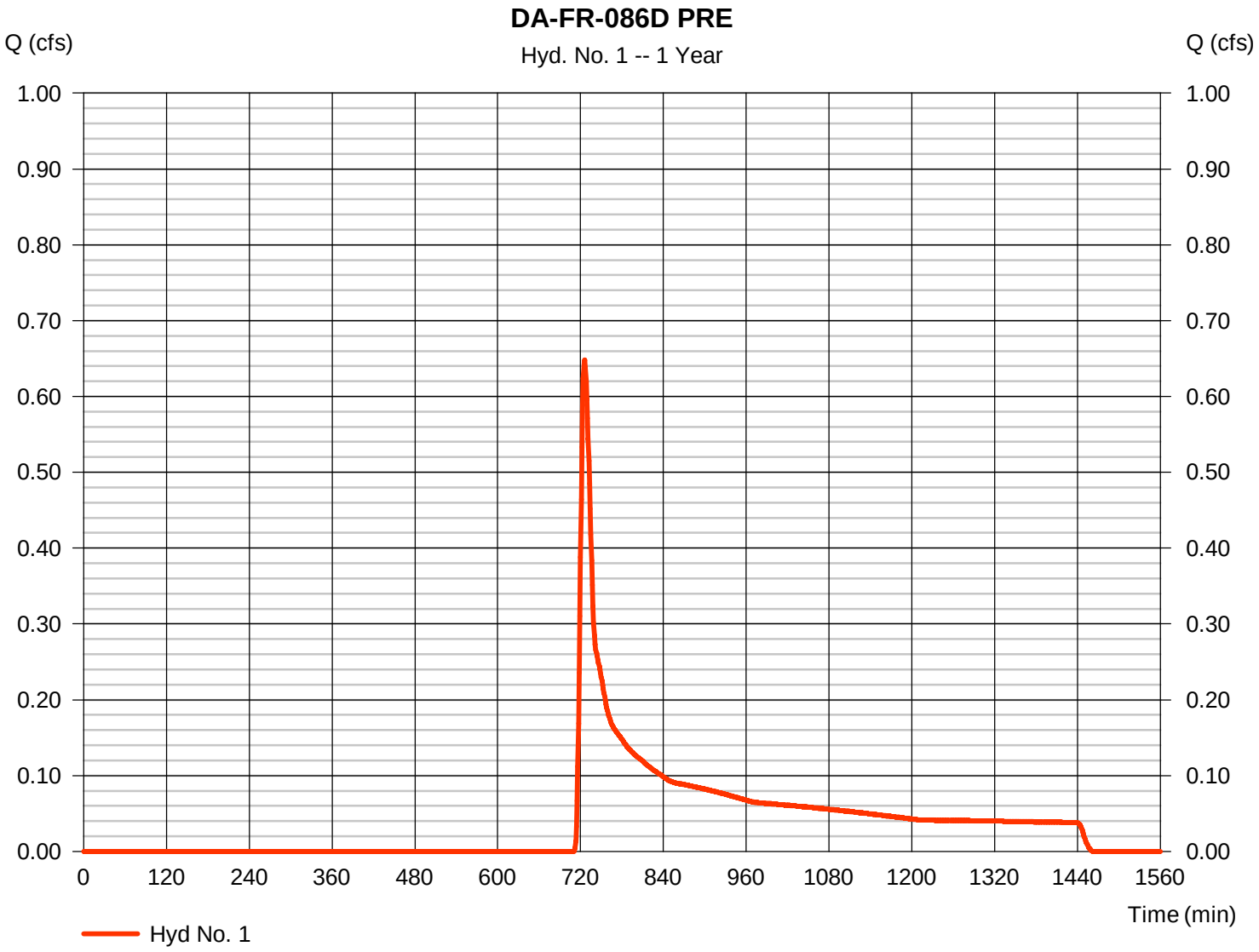
Hydrograph Report

Hyd. No. 1

DA-FR-086D PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.648 cfs
Storm frequency	= 1 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 3,552 cuft
Drainage area	= 3.140 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.10 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(1.408 x 58) + (1.730 x 55)] / 3.140



TR55 Tc Worksheet

Hyd. No. 1

DA-FR-086D PRE

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 4.99		0.00		0.00		
Travel Time (min)	**= 13.85**	**+**	**0.00**	**+**	**0.00**	**=**	**13.85**
Shallow Concentrated Flow							
Flow length (ft)	= 412.76		0.00		0.00		
Watercourse slope (%)	= 12.51		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=5.71		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	= 0.015		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							**15.10 min**

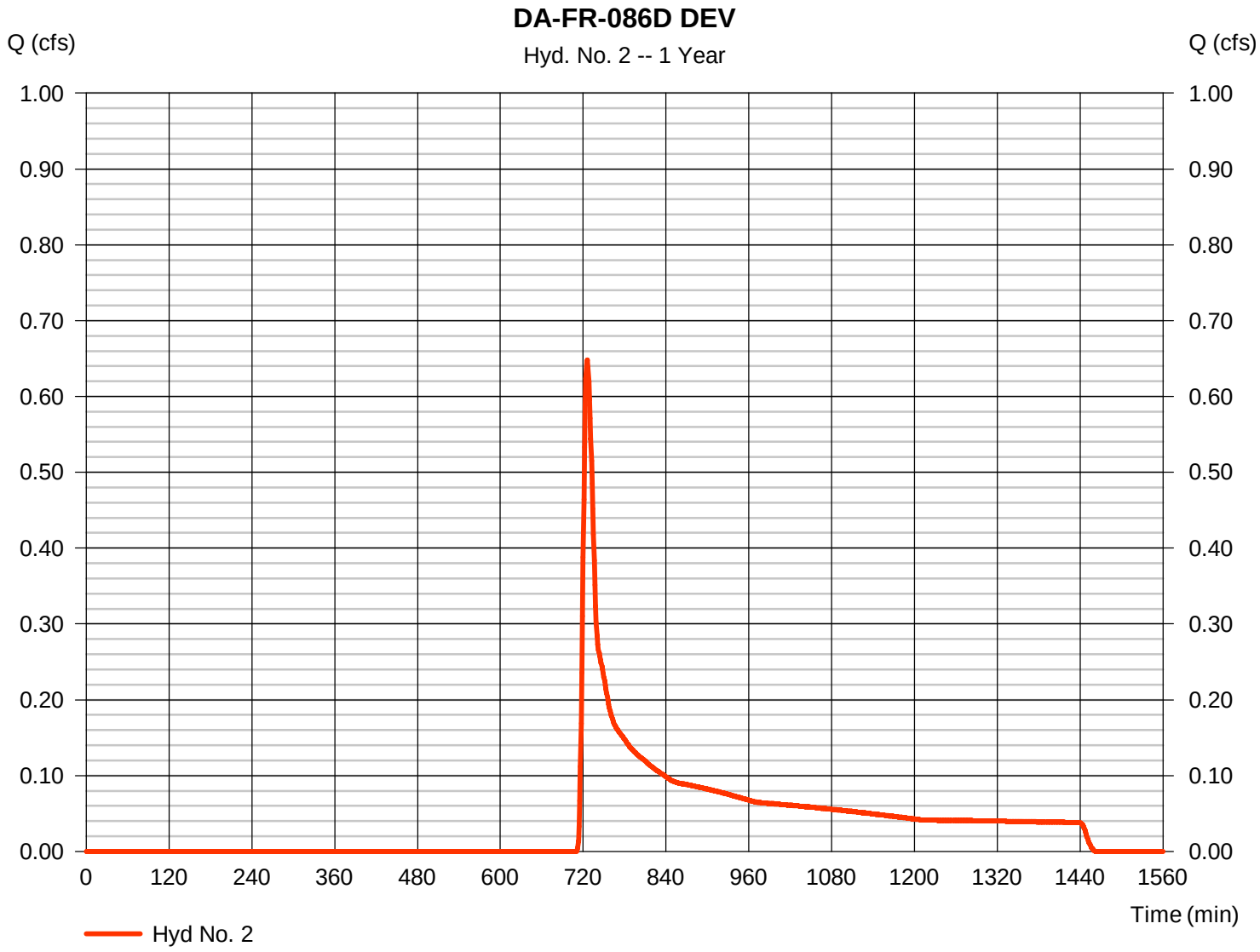
Hydrograph Report

Hyd. No. 2

DA-FR-086D DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.648 cfs
Storm frequency	= 1 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 3,552 cuft
Drainage area	= 3.140 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.10 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(1.816 x 58) + (0.811 x 55) + (0.511 x 48)] / 3.140



TR55 Tc Worksheet

Hyd. No. 2

DA-FR-086D DEV

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 4.99		0.00		0.00		
Travel Time (min)	**= 13.85**	**+**	**0.00**	**+**	**0.00**	**=**	**13.85**
Shallow Concentrated Flow							
Flow length (ft)	= 412.76		0.00		0.00		
Watercourse slope (%)	= 12.51		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=5.71		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	= 0.015		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 ..... 15.10 min

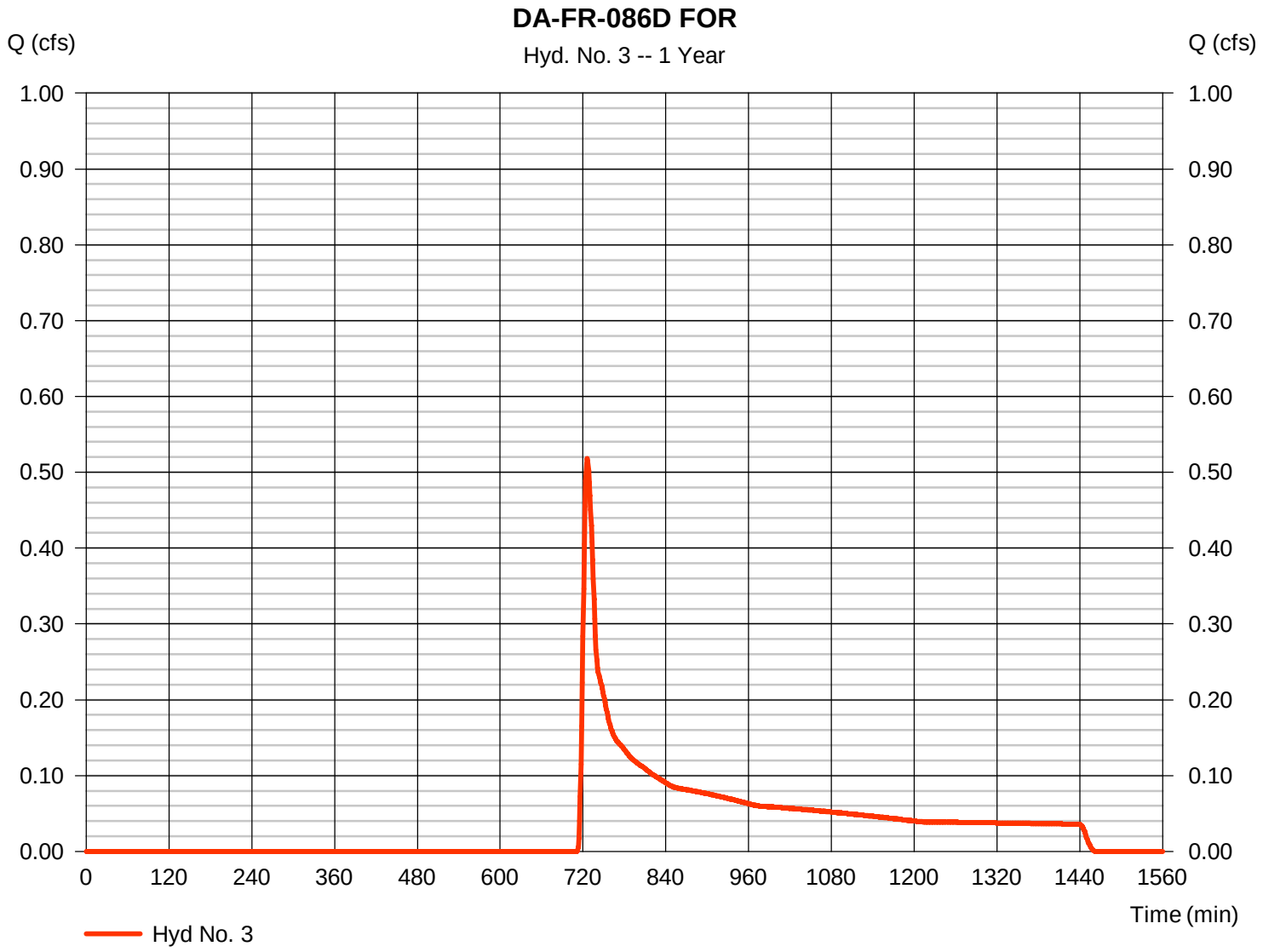
Hydrograph Report

Hyd. No. 3

DA-FR-086D FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.518 cfs
Storm frequency	= 1 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 3,204 cuft
Drainage area	= 3.140 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.10 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(3.140 x 55)] / 3.140



TR55 Tc Worksheet

Hyd. No. 3

DA-FR-086D FOR

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 4.99		0.00		0.00		
Travel Time (min)	**= 13.85**	**+**	**0.00**	**+**	**0.00**	**=**	**13.85**
Shallow Concentrated Flow							
Flow length (ft)	= 412.76		0.00		0.00		
Watercourse slope (%)	= 12.51		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=5.71		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	= 0.015		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							**15.10 min**

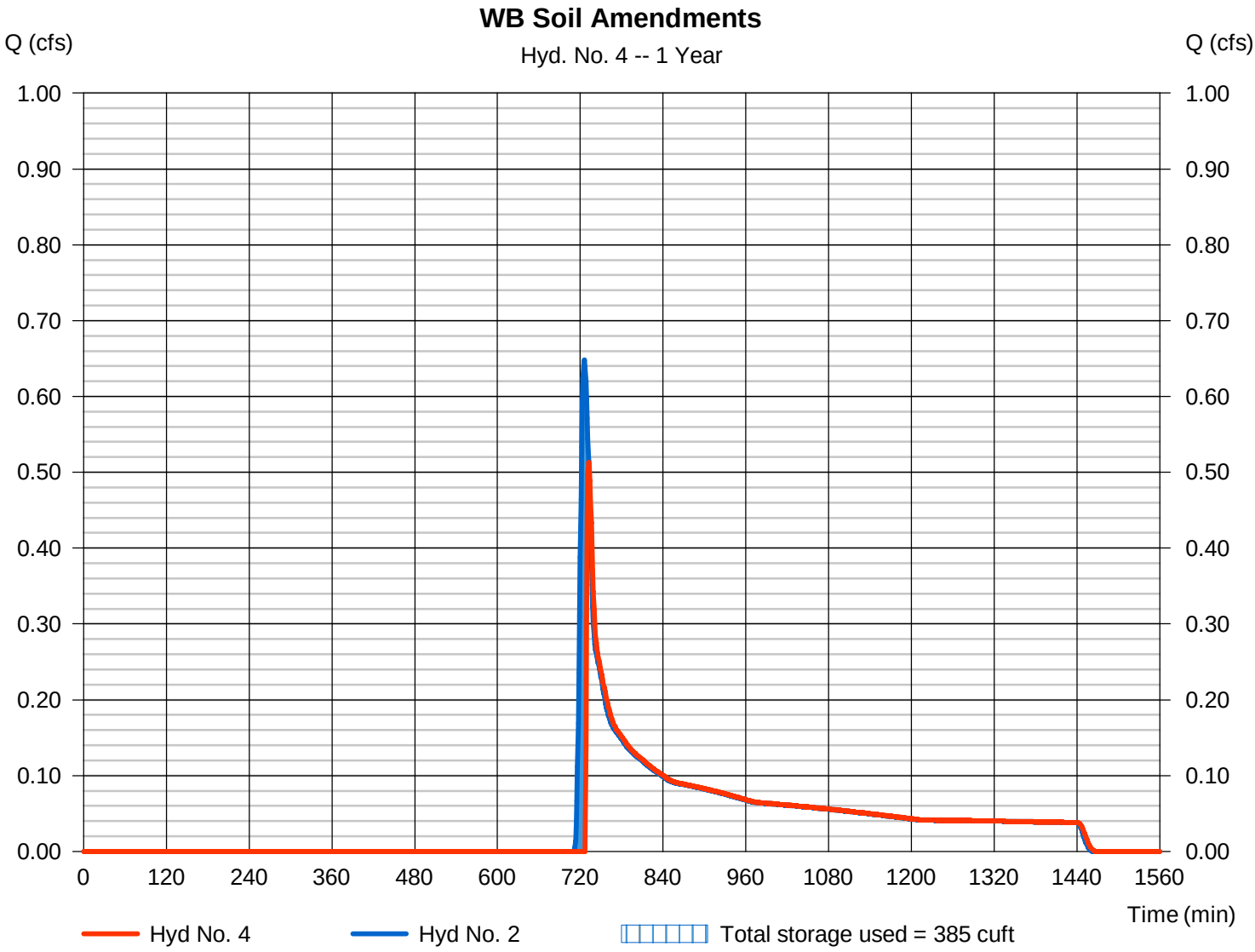
Hydrograph Report

Hyd. No. 4

WB Soil Amendments

Hydrograph type	=	Reservoir	Peak discharge	=	0.513 cfs
Storm frequency	=	1 yrs	Time to peak	=	732 min
Time interval	=	1 min	Hyd. volume	=	3,233 cuft
Inflow hyd. No.	=	2 - DA-FR-086D DEV	Max. Elevation	=	101.59 ft
Reservoir name	=	Waterbar Soil Amendments	Max. Storage	=	385 cuft

Storage Indication method used.



Pond No. 1 - Waterbar Soil Amendments

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	100.00	n/a	0	0
0.50	100.50	n/a	36	36
1.00	101.00	n/a	36	72
1.50	101.50	n/a	247	319
2.00	102.00	n/a	387	706

Culvert / Orifice Structures

	[A]	[B]	[C]	[PrfRsr]
Rise (in)	= 0.00	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)	= 101.50	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).

Stage / Storage / Discharge Table

Stage ft	Storage cuft	Elevation ft	Clv A cfs	Clv B cfs	Clv C cfs	PrfRsr cfs	Wr A cfs	Wr B cfs	Wr C cfs	Wr D cfs	Exfil cfs	User cfs	Total cfs
0.00	0	100.00	---	---	---	---	0.00	---	---	---	---	---	0.000
0.05	4	100.05	---	---	---	---	0.00	---	---	---	---	---	0.000
0.10	7	100.10	---	---	---	---	0.00	---	---	---	---	---	0.000
0.15	11	100.15	---	---	---	---	0.00	---	---	---	---	---	0.000
0.20	14	100.20	---	---	---	---	0.00	---	---	---	---	---	0.000
0.25	18	100.25	---	---	---	---	0.00	---	---	---	---	---	0.000
0.30	22	100.30	---	---	---	---	0.00	---	---	---	---	---	0.000
0.35	25	100.35	---	---	---	---	0.00	---	---	---	---	---	0.000
0.40	29	100.40	---	---	---	---	0.00	---	---	---	---	---	0.000
0.45	32	100.45	---	---	---	---	0.00	---	---	---	---	---	0.000
0.50	36	100.50	---	---	---	---	0.00	---	---	---	---	---	0.000
0.55	40	100.55	---	---	---	---	0.00	---	---	---	---	---	0.000
0.60	43	100.60	---	---	---	---	0.00	---	---	---	---	---	0.000
0.65	47	100.65	---	---	---	---	0.00	---	---	---	---	---	0.000
0.70	50	100.70	---	---	---	---	0.00	---	---	---	---	---	0.000
0.75	54	100.75	---	---	---	---	0.00	---	---	---	---	---	0.000
0.80	58	100.80	---	---	---	---	0.00	---	---	---	---	---	0.000
0.85	61	100.85	---	---	---	---	0.00	---	---	---	---	---	0.000
0.90	65	100.90	---	---	---	---	0.00	---	---	---	---	---	0.000
0.95	68	100.95	---	---	---	---	0.00	---	---	---	---	---	0.000
1.00	72	101.00	---	---	---	---	0.00	---	---	---	---	---	0.000
1.05	97	101.05	---	---	---	---	0.00	---	---	---	---	---	0.000
1.10	121	101.10	---	---	---	---	0.00	---	---	---	---	---	0.000
1.15	146	101.15	---	---	---	---	0.00	---	---	---	---	---	0.000
1.20	171	101.20	---	---	---	---	0.00	---	---	---	---	---	0.000
1.25	196	101.25	---	---	---	---	0.00	---	---	---	---	---	0.000
1.30	220	101.30	---	---	---	---	0.00	---	---	---	---	---	0.000
1.35	245	101.35	---	---	---	---	0.00	---	---	---	---	---	0.000
1.40	270	101.40	---	---	---	---	0.00	---	---	---	---	---	0.000
1.45	294	101.45	---	---	---	---	0.00	---	---	---	---	---	0.000
1.50	319	101.50	---	---	---	---	0.00	---	---	---	---	---	0.000
1.55	358	101.55	---	---	---	---	0.22	---	---	---	---	---	0.223
1.60	396	101.60	---	---	---	---	0.63	---	---	---	---	---	0.632
1.65	435	101.65	---	---	---	---	1.16	---	---	---	---	---	1.161
1.70	474	101.70	---	---	---	---	1.79	---	---	---	---	---	1.787
1.75	513	101.75	---	---	---	---	2.50	---	---	---	---	---	2.498
1.80	551	101.80	---	---	---	---	3.28	---	---	---	---	---	3.283
1.85	590	101.85	---	---	---	---	4.14	---	---	---	---	---	4.137
1.90	629	101.90	---	---	---	---	5.06	---	---	---	---	---	5.055

Continues on next page...

Waterbar Soil Amendments

Stage / Storage / Discharge Table

Stage ft	Storage cuft	Elevation ft	Clv A cfs	Clv B cfs	Clv C cfs	PrfRsr cfs	Wr A cfs	Wr B cfs	Wr C cfs	Wr D cfs	Exfil cfs	User cfs	Total cfs
1.95	667	101.95	---	---	---	---	6.03	---	---	---	---	---	6.032
2.00	706	102.00	---	---	---	---	7.06	---	---	---	---	---	7.064

...End

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	1.212	1	725	5,171	------	------	------	DA-FR-086D PRE
2	SCS Runoff	1.212	1	725	5,171	------	------	------	DA-FR-086D DEV
3	SCS Runoff	1.029	1	725	4,737	------	------	------	DA-FR-086D FOR
4	Reservoir	1.154	1	727	4,852	2	101.65	435	WB Soil Amendments

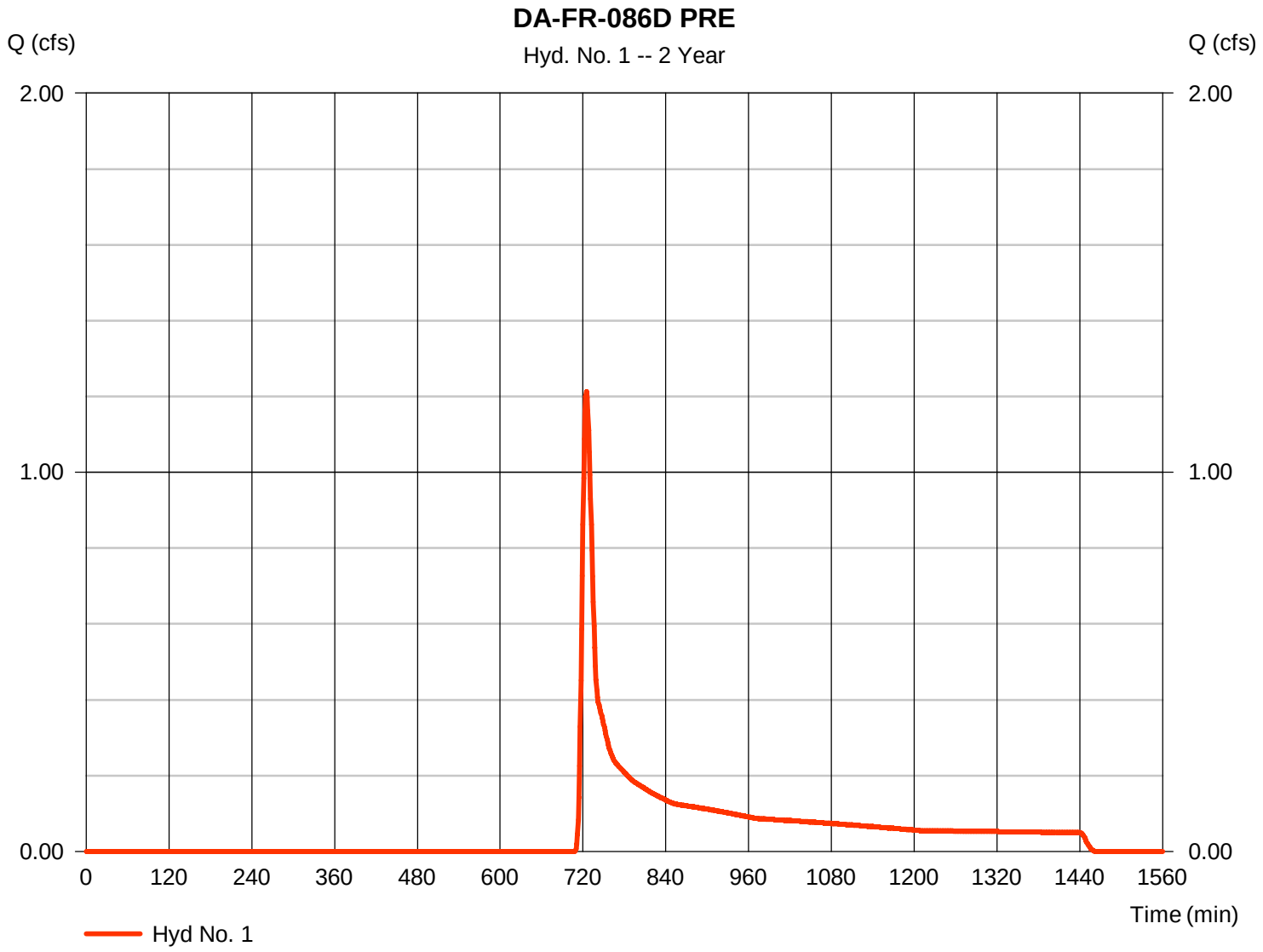
Hydrograph Report

Hyd. No. 1

DA-FR-086D PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	1.212 cfs
Storm frequency	=	2 yrs	Time to peak	=	725 min
Time interval	=	1 min	Hyd. volume	=	5,171 cuft
Drainage area	=	3.140 ac	Curve number	=	56*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	15.10 min
Total precip.	=	3.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(1.408 x 58) + (1.730 x 55)] / 3.140



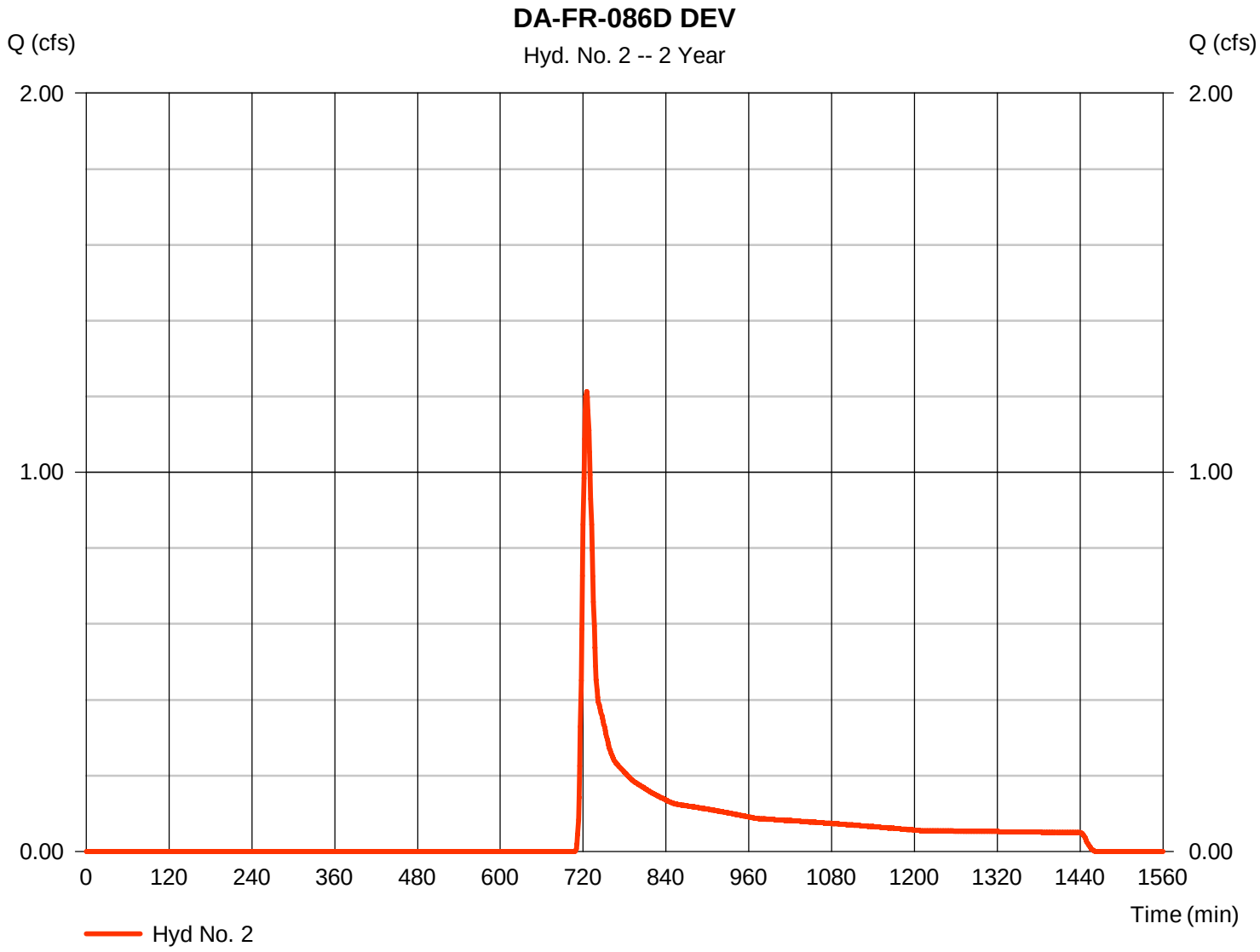
Hydrograph Report

Hyd. No. 2

DA-FR-086D DEV

Hydrograph type	=	SCS Runoff	Peak discharge	=	1.212 cfs
Storm frequency	=	2 yrs	Time to peak	=	725 min
Time interval	=	1 min	Hyd. volume	=	5,171 cuft
Drainage area	=	3.140 ac	Curve number	=	56*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	15.10 min
Total precip.	=	3.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(1.816 x 58) + (0.811 x 55) + (0.511 x 48)] / 3.140



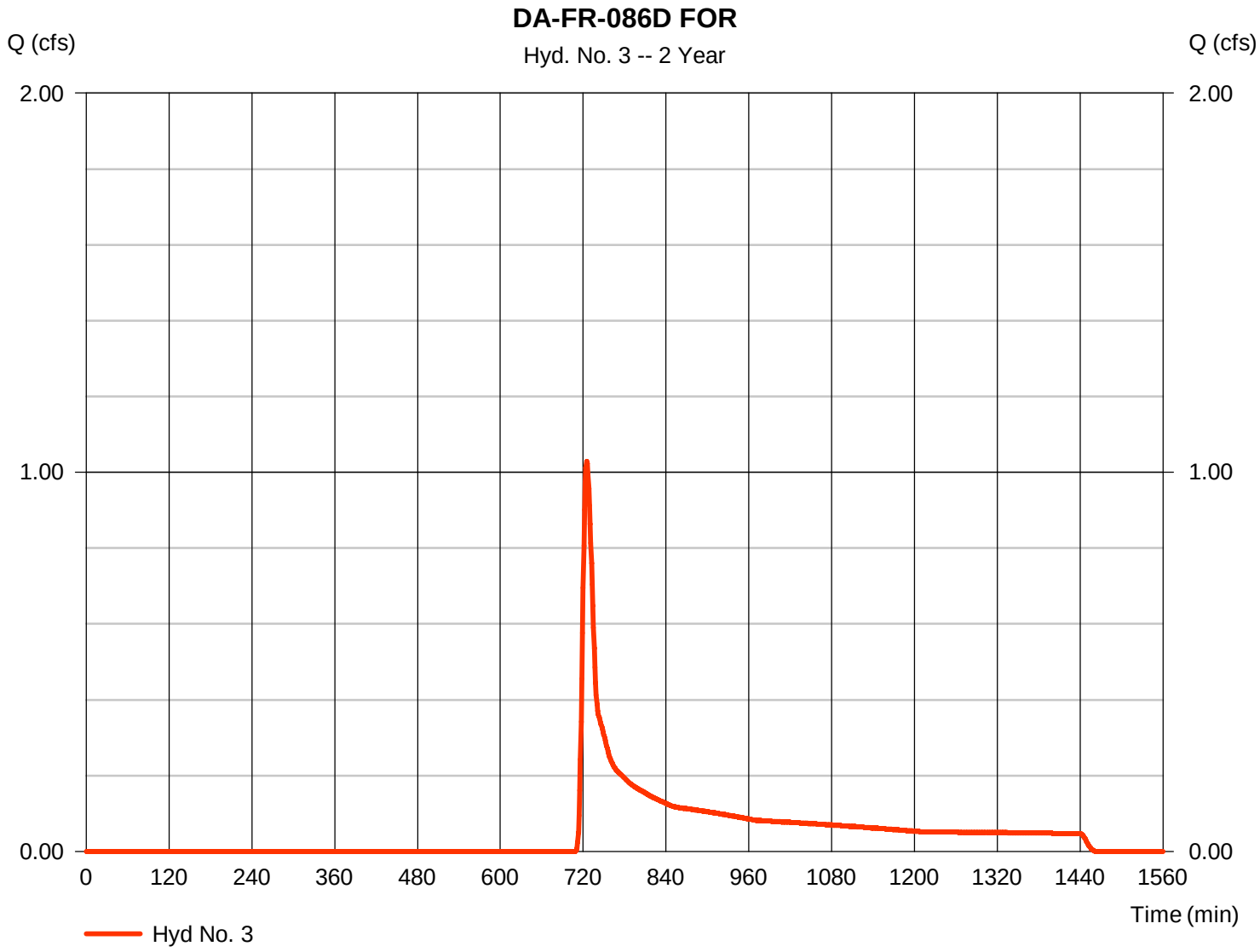
Hydrograph Report

Hyd. No. 3

DA-FR-086D FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 1.029 cfs
Storm frequency	= 2 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 4,737 cuft
Drainage area	= 3.140 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.10 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(3.140 x 55)] / 3.140



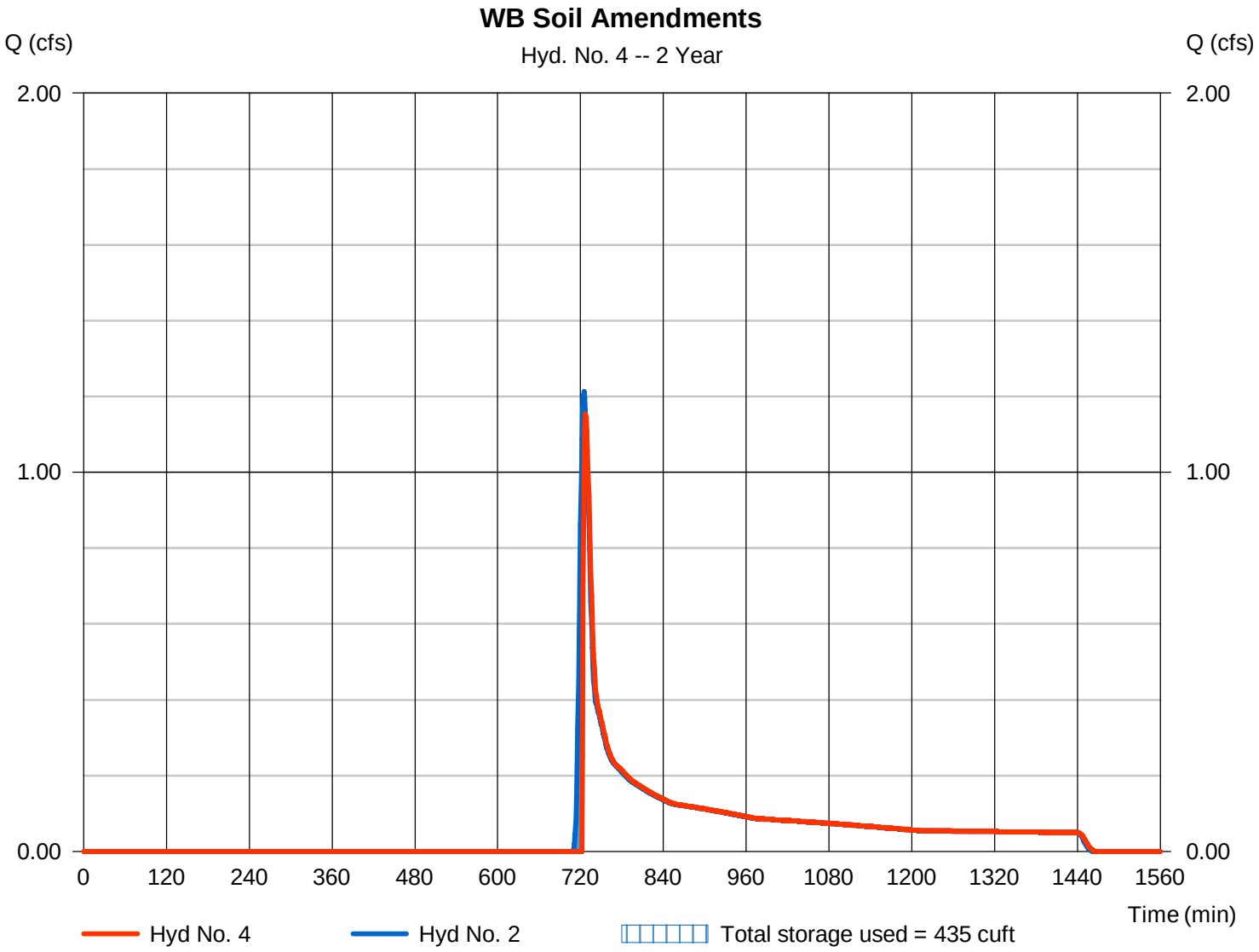
Hydrograph Report

Hyd. No. 4

WB Soil Amendments

Hydrograph type	=	Reservoir	Peak discharge	=	1.154 cfs
Storm frequency	=	2 yrs	Time to peak	=	727 min
Time interval	=	1 min	Hyd. volume	=	4,852 cuft
Inflow hyd. No.	=	2 - DA-FR-086D DEV	Max. Elevation	=	101.65 ft
Reservoir name	=	Waterbar Soil Amendments	Max. Storage	=	435 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	5.508	1	723	16,210	------	------	------	DA-FR-086D PRE
2	SCS Runoff	5.508	1	723	16,210	------	------	------	DA-FR-086D DEV
3	SCS Runoff	5.143	1	723	15,371	------	------	------	DA-FR-086D FOR
4	Reservoir	5.475	1	724	15,890	2	101.92	645	WB Soil Amendments

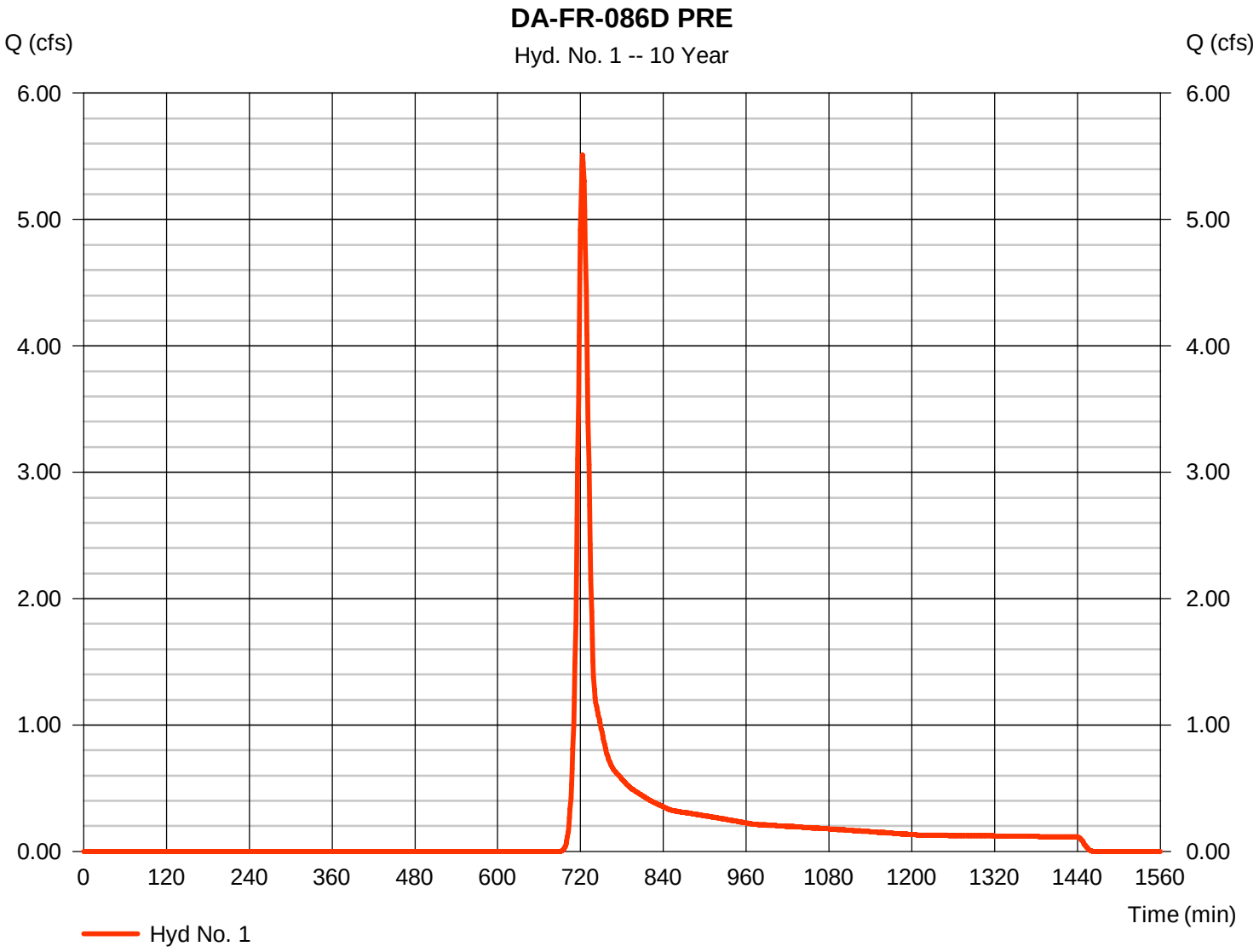
Hydrograph Report

Hyd. No. 1

DA-FR-086D PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	5.508 cfs
Storm frequency	=	10 yrs	Time to peak	=	723 min
Time interval	=	1 min	Hyd. volume	=	16,210 cuft
Drainage area	=	3.140 ac	Curve number	=	56*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	15.10 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(1.408 x 58) + (1.730 x 55)] / 3.140



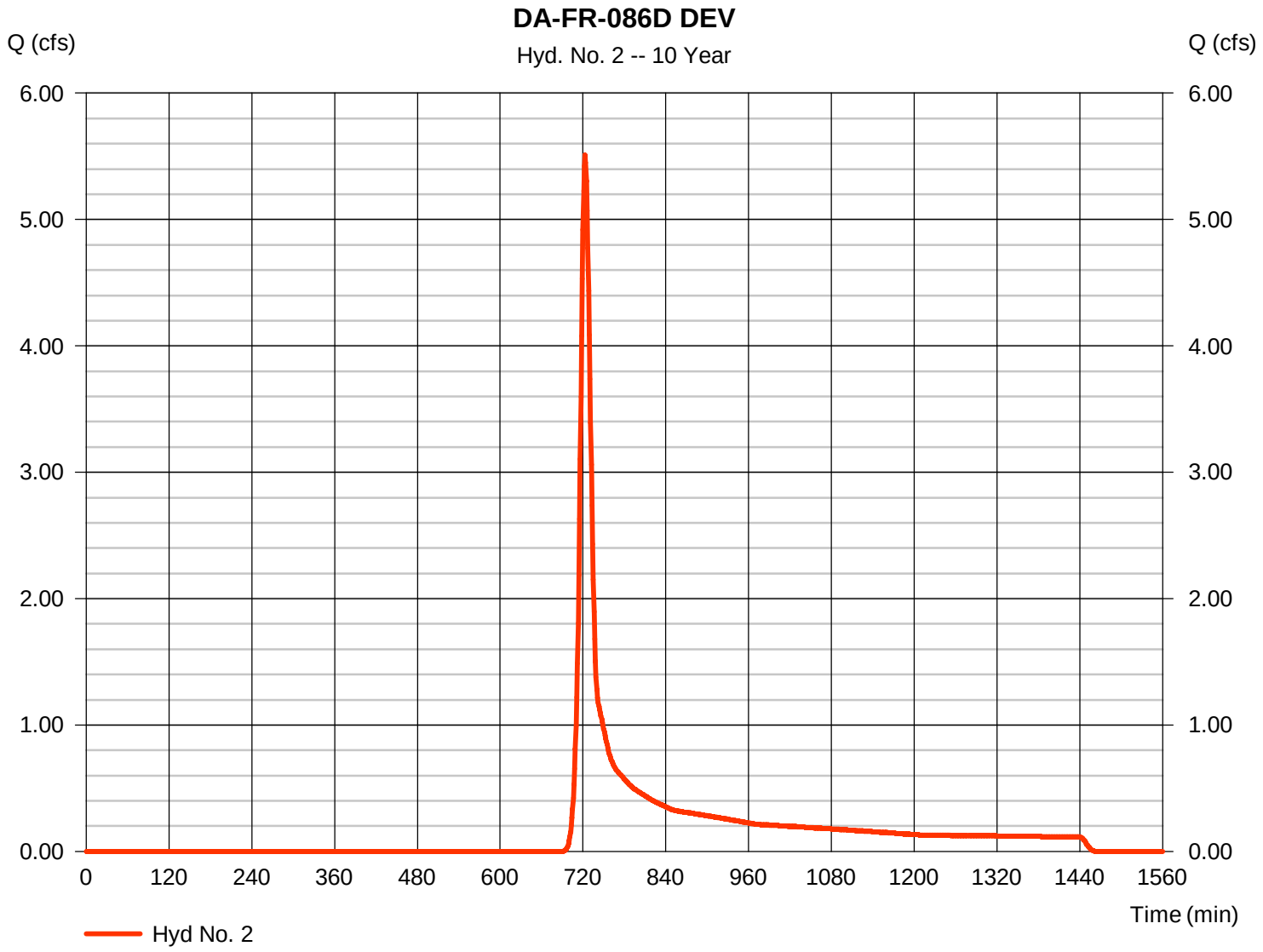
Hydrograph Report

Hyd. No. 2

DA-FR-086D DEV

Hydrograph type	=	SCS Runoff	Peak discharge	=	5.508 cfs
Storm frequency	=	10 yrs	Time to peak	=	723 min
Time interval	=	1 min	Hyd. volume	=	16,210 cuft
Drainage area	=	3.140 ac	Curve number	=	56*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	15.10 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(1.816 x 58) + (0.811 x 55) + (0.511 x 48)] / 3.140



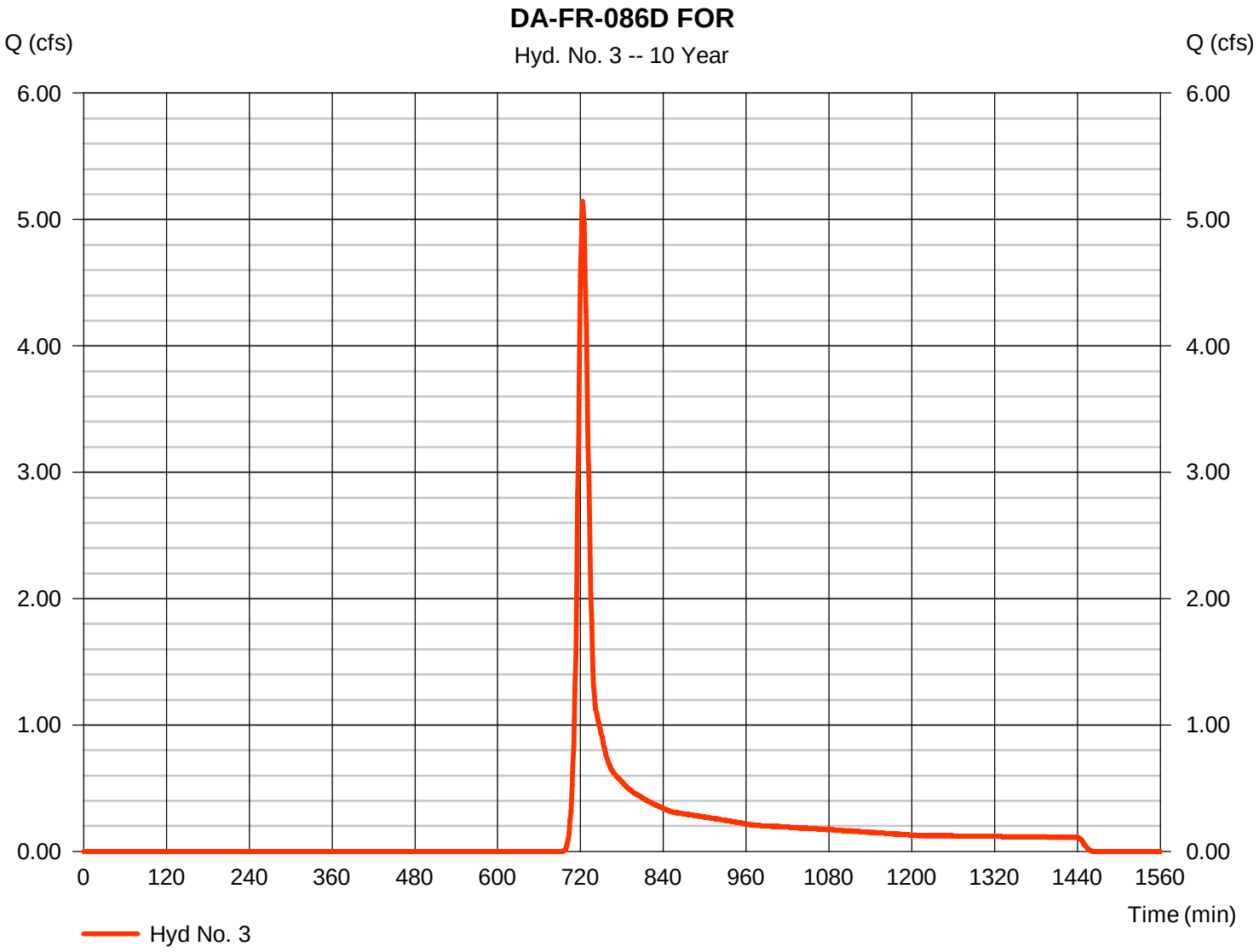
Hydrograph Report

Hyd. No. 3

DA-FR-086D FOR

Hydrograph type	=	SCS Runoff	Peak discharge	=	5.143 cfs
Storm frequency	=	10 yrs	Time to peak	=	723 min
Time interval	=	1 min	Hyd. volume	=	15,371 cuft
Drainage area	=	3.140 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	15.10 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(3.140 x 55)] / 3.140



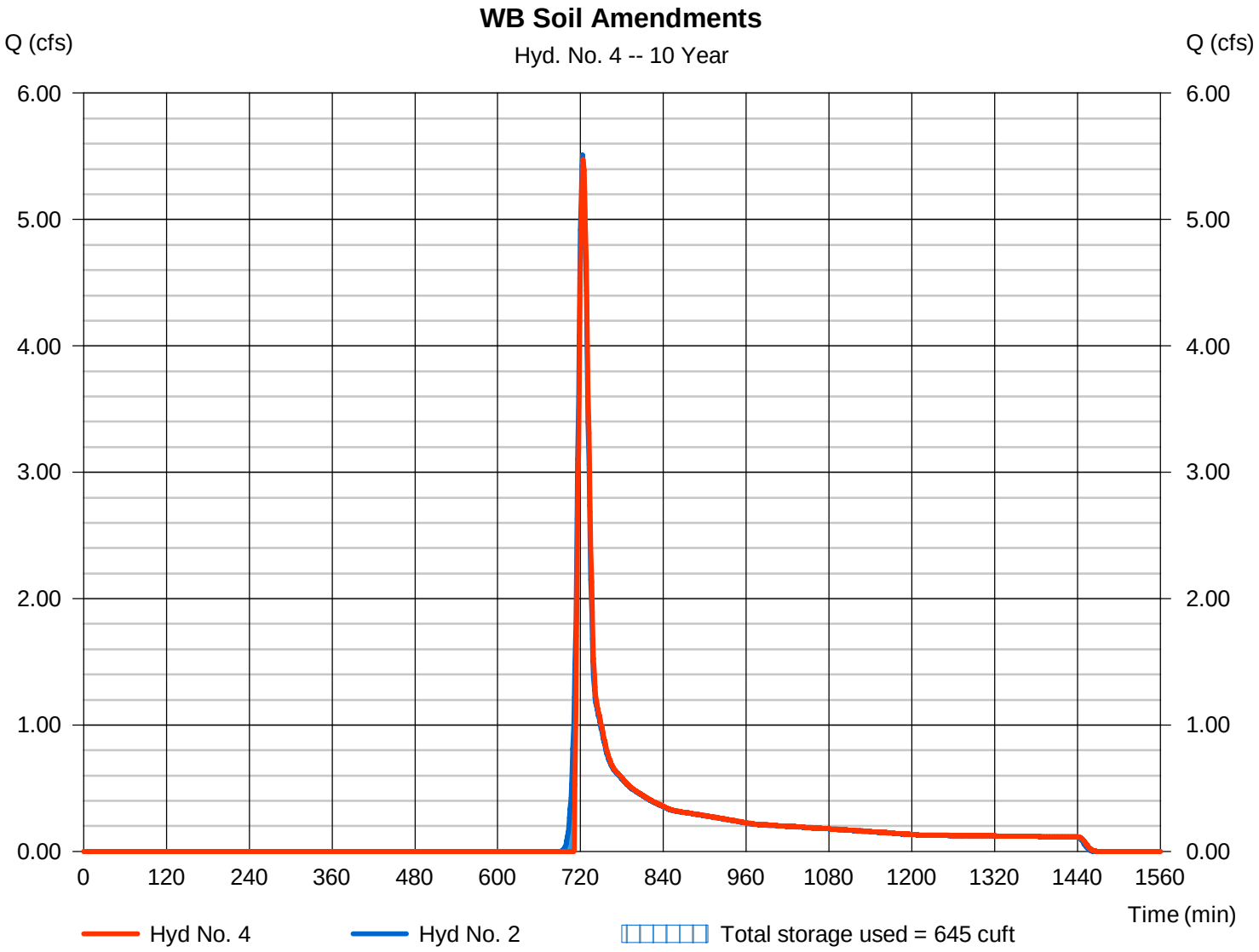
Hydrograph Report

Hyd. No. 4

WB Soil Amendments

Hydrograph type	=	Reservoir	Peak discharge	=	5.475 cfs
Storm frequency	=	10 yrs	Time to peak	=	724 min
Time interval	=	1 min	Hyd. volume	=	15,890 cuft
Inflow hyd. No.	=	2 - DA-FR-086D DEV	Max. Elevation	=	101.92 ft
Reservoir name	=	Waterbar Soil Amendments	Max. Storage	=	645 cuft

Storage Indication method used.



Hydraflow Rainfall Report

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

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

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

Tc = time in minutes. Values may exceed 60.

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Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.30	3.70	0.00	0.00	5.70	0.00	0.00	0.00
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

DA-FR-086E

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.730	4106
Developed Condition	0.599	3724
Pre-Developed (Forest) Condition	0.479	3359

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

Improvement Factor, IF = 0.8

Calculations:

Check #1: $Q_{developed} \leq IF \times [(Q_{pre\text{-}developed} \times RV_{pre\text{-}developed}) / RV_{developed}]$ ----------> 0.599 ≤ 0.644 OK

Check #2: $Q_{developed} \leq Q_{pre\text{-}developed}$ ----------> 0.599 ≤ 0.730 OK

Check #3: $Q_{developed}$ *shall not* be required to be ≤ $(Q_{forest} \times RV_{forest}) / RV_{developed}$ ---> 0.599 *shall not* be required to be ≤ 0.432

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

Note:

Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.

For Paved Road land surface types a Manning's n value 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 Channels[1]			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels[2]			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150

Notes:

[1]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 or grass channel.

[2]For the pre-developed condition (if applicable), 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-FR-086E PRE
2	SCS Runoff	DA-FR-086E DEV
3	SCS Runoff	DA-FR-086E FOR

Hydrograph Return Period Recap

Hyd. No.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)							Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	------	0.730	1.297	-------	-------	5.514	-------	-------	-------	DA-FR-086E PRE
2	SCS Runoff	------	0.599	1.118	-------	-------	5.161	-------	-------	-------	DA-FR-086E DEV
3	SCS Runoff	------	0.479	0.948	-------	-------	4.811	-------	-------	-------	DA-FR-086E FOR

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	0.730	1	728	4,106	------	------	------	DA-FR-086E PRE
2	SCS Runoff	0.599	1	728	3,724	------	------	------	DA-FR-086E DEV
3	SCS Runoff	0.479	1	729	3,359	------	------	------	DA-FR-086E FOR

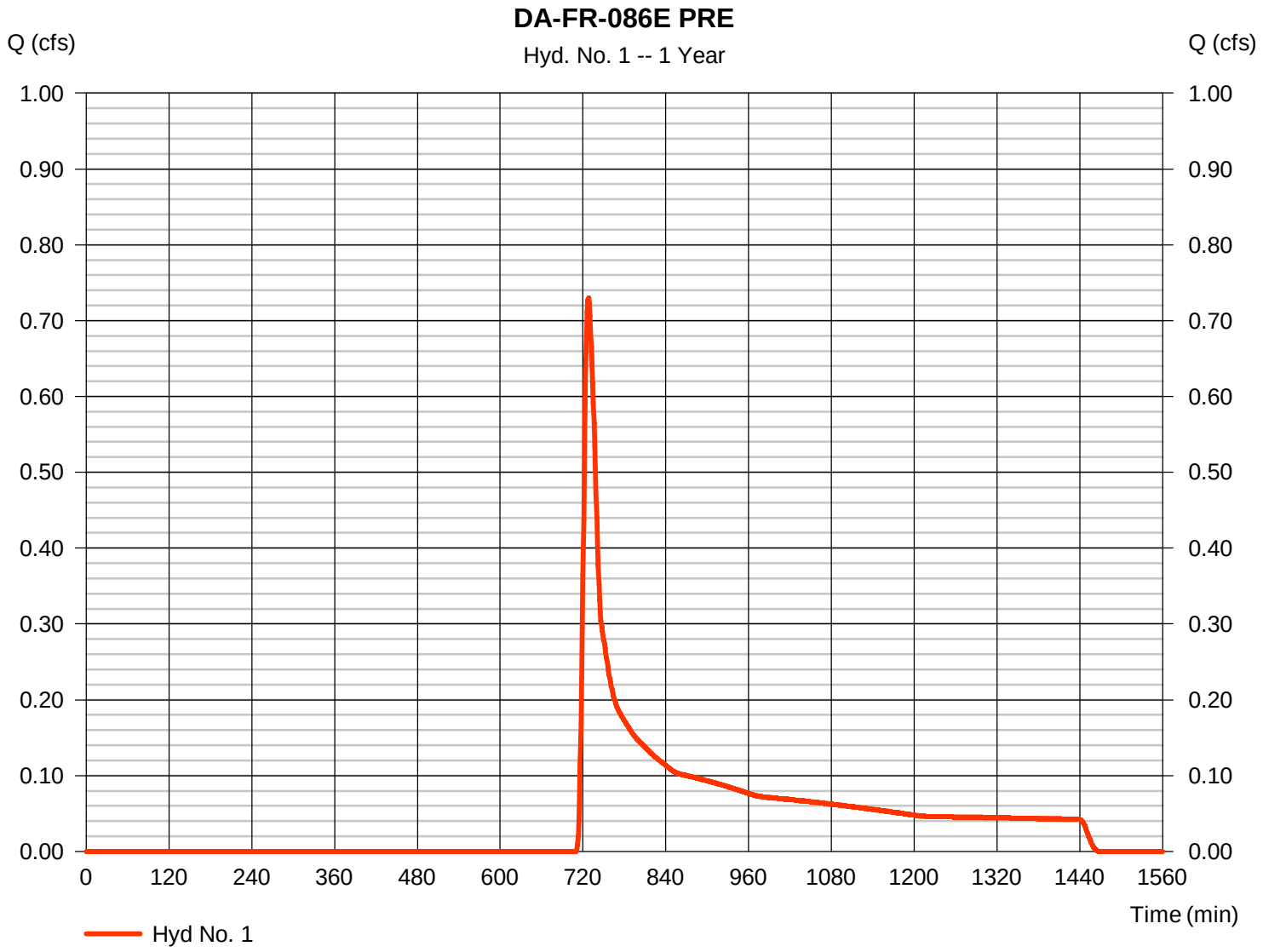
Hydrograph Report

Hyd. No. 1

DA-FR-086E PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.730 cfs
Storm frequency	= 1 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 4,106 cuft
Drainage area	= 3.330 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 17.40 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(2.059 x 58) + (1.267 x 55)] / 3.330



TR55 Tc Worksheet

Hyd. No. 1

DA-FR-086E PRE

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 3.64		0.00		0.00		
Travel Time (min)	**= 15.72**	**+**	**0.00**	**+**	**0.00**	**=**	**15.72**
Shallow Concentrated Flow							
Flow length (ft)	= 534.90		0.00		0.00		
Watercourse slope (%)	= 11.27		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=5.42		0.00		0.00		
Travel Time (min)	**= 1.65**	**+**	**0.00**	**+**	**0.00**	**=**	**1.65**
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	= 0.015		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 ..... 17.40 min

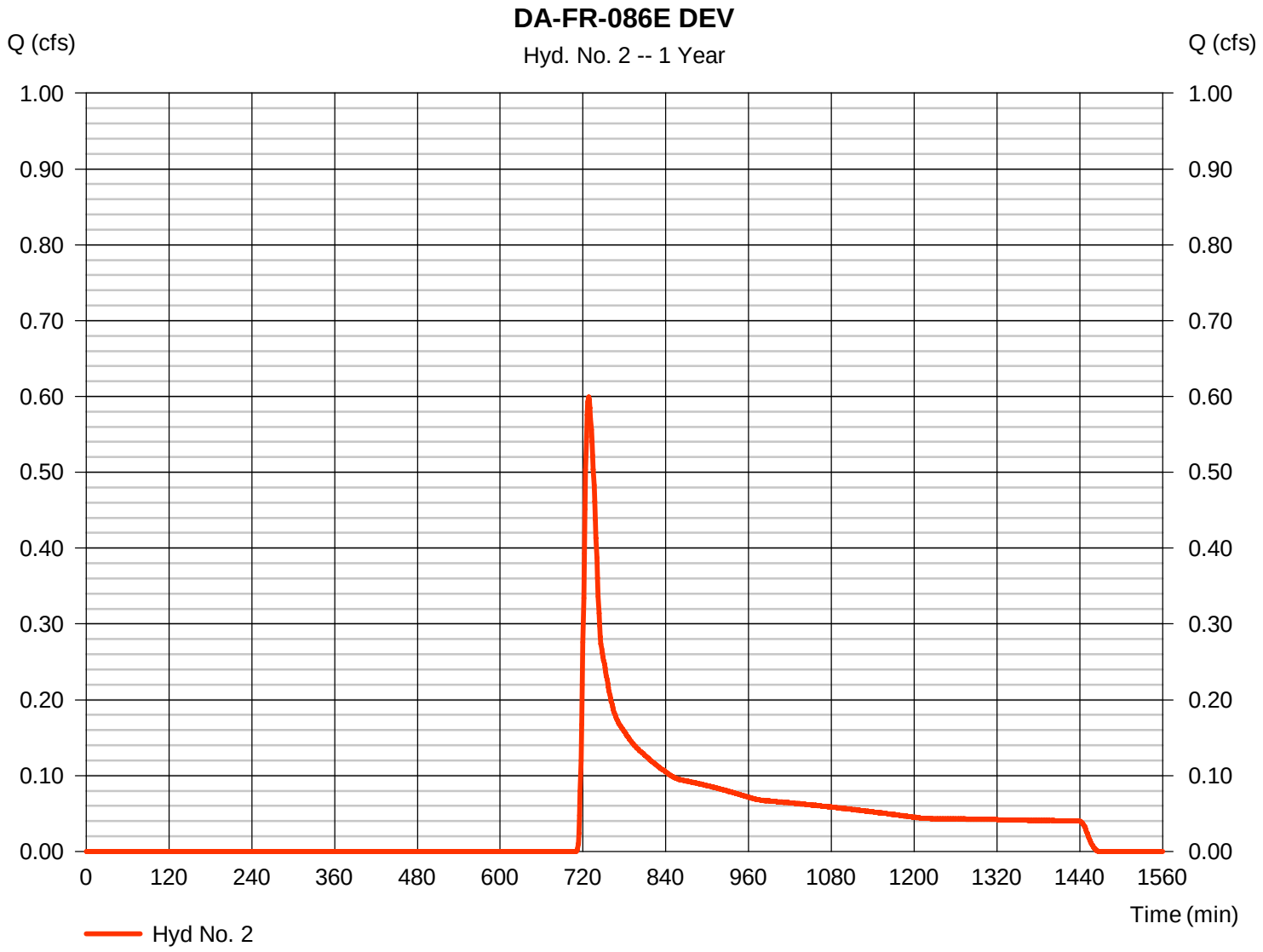
Hydrograph Report

Hyd. No. 2

DA-FR-086E DEV

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.599 cfs
Storm frequency	=	1 yrs	Time to peak	=	728 min
Time interval	=	1 min	Hyd. volume	=	3,724 cuft
Drainage area	=	3.330 ac	Curve number	=	56*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	17.40 min
Total precip.	=	3.30 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(2.564 x 58) + (0.318 x 55) + (0.444 x 48)] / 3.330



TR55 Tc Worksheet

Hyd. No. 2

DA-FR-086E DEV

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 3.64		0.00		0.00		
Travel Time (min)	**= 15.72**	**+**	**0.00**	**+**	**0.00**	**=**	**15.72**
Shallow Concentrated Flow							
Flow length (ft)	= 451.39		66.31		0.00		
Watercourse slope (%)	= 9.97		18.65		0.00		
Surface description	= Unpaved		Unpaved		Paved		
Average velocity (ft/s)	=5.09		6.97		0.00		
Travel Time (min)	**= 1.48**	**+**	**0.16**	**+**	**0.00**	**=**	**1.64**
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})14.9		0.0		0.0		
Travel Time (min)	**= 0.05**	**+**	**0.00**	**+**	**0.00**	**=**	**0.05**

Total Travel Time, Tc ..... 17.40 min

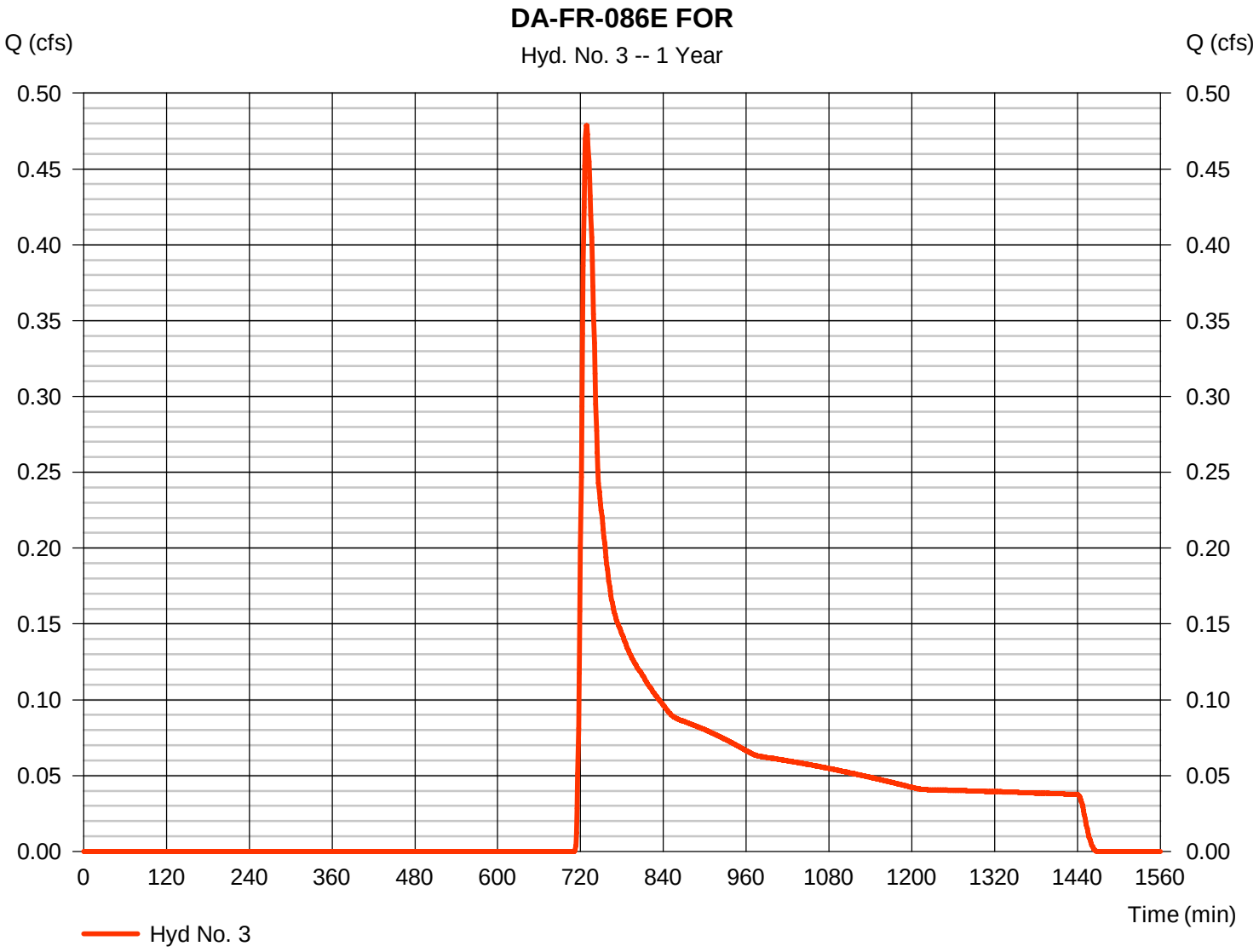
Hydrograph Report

Hyd. No. 3

DA-FR-086E FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.479 cfs
Storm frequency	= 1 yrs	Time to peak	= 729 min
Time interval	= 1 min	Hyd. volume	= 3,359 cuft
Drainage area	= 3.330 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 17.40 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(3.330 x 55)] / 3.330



TR55 Tc Worksheet

Hyd. No. 3

DA-FR-086E FOR

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 3.64		0.00		0.00		
Travel Time (min)	**= 15.72**	**+**	**0.00**	**+**	**0.00**	**=**	**15.72**
Shallow Concentrated Flow							
Flow length (ft)	= 534.90		0.00		0.00		
Watercourse slope (%)	= 11.27		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=5.42		0.00		0.00		
Travel Time (min)	**= 1.65**	**+**	**0.00**	**+**	**0.00**	**=**	**1.65**
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	= 0.015		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 ..... 17.40 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	1.297	1	727	5,893	------	------	------	DA-FR-086E PRE
2	SCS Runoff	1.118	1	727	5,422	------	------	------	DA-FR-086E DEV
3	SCS Runoff	0.948	1	727	4,966	------	------	------	DA-FR-086E FOR

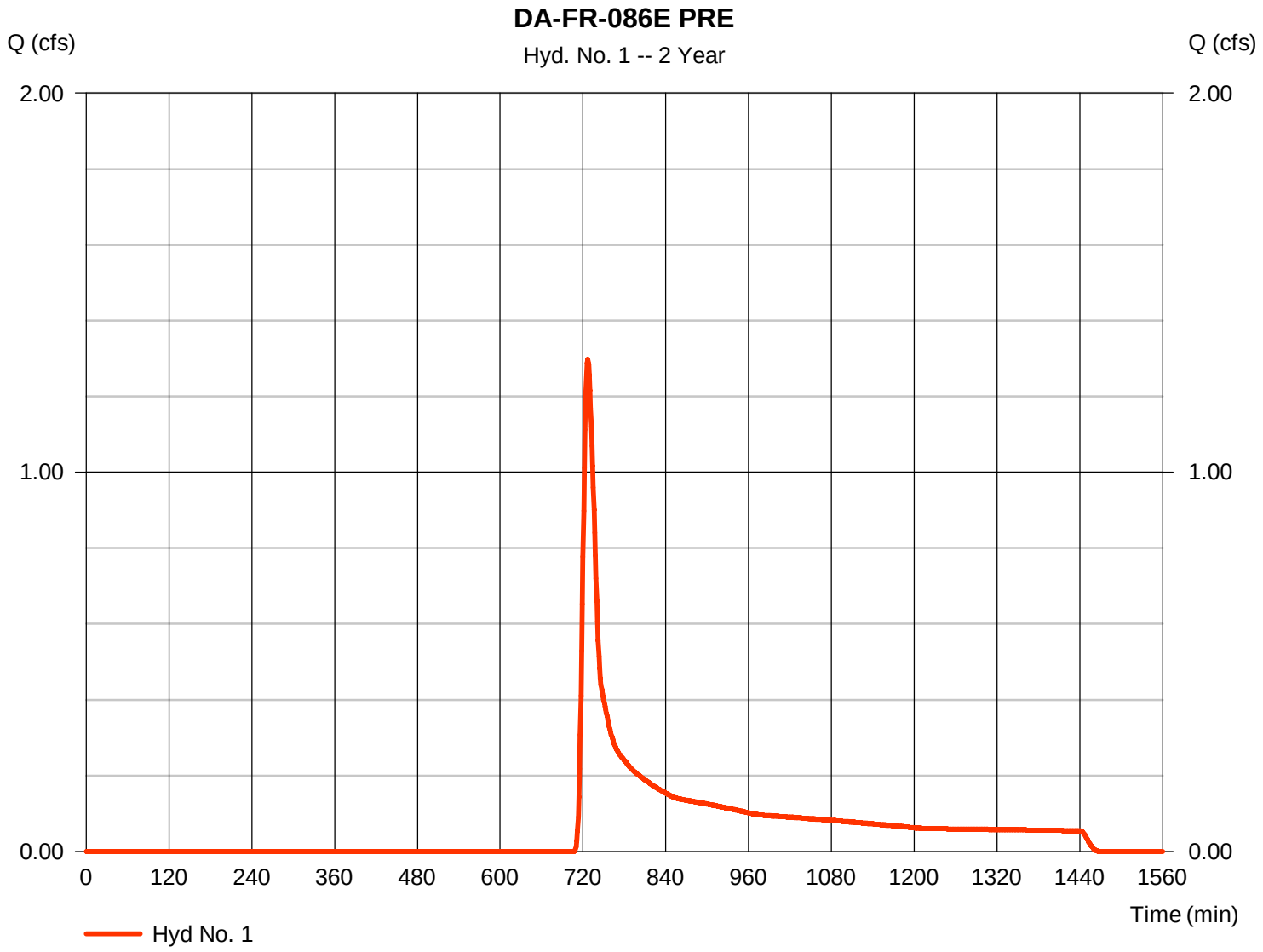
Hydrograph Report

Hyd. No. 1

DA-FR-086E PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	1.297 cfs
Storm frequency	=	2 yrs	Time to peak	=	727 min
Time interval	=	1 min	Hyd. volume	=	5,893 cuft
Drainage area	=	3.330 ac	Curve number	=	57*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	17.40 min
Total precip.	=	3.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(2.059 x 58) + (1.267 x 55)] / 3.330



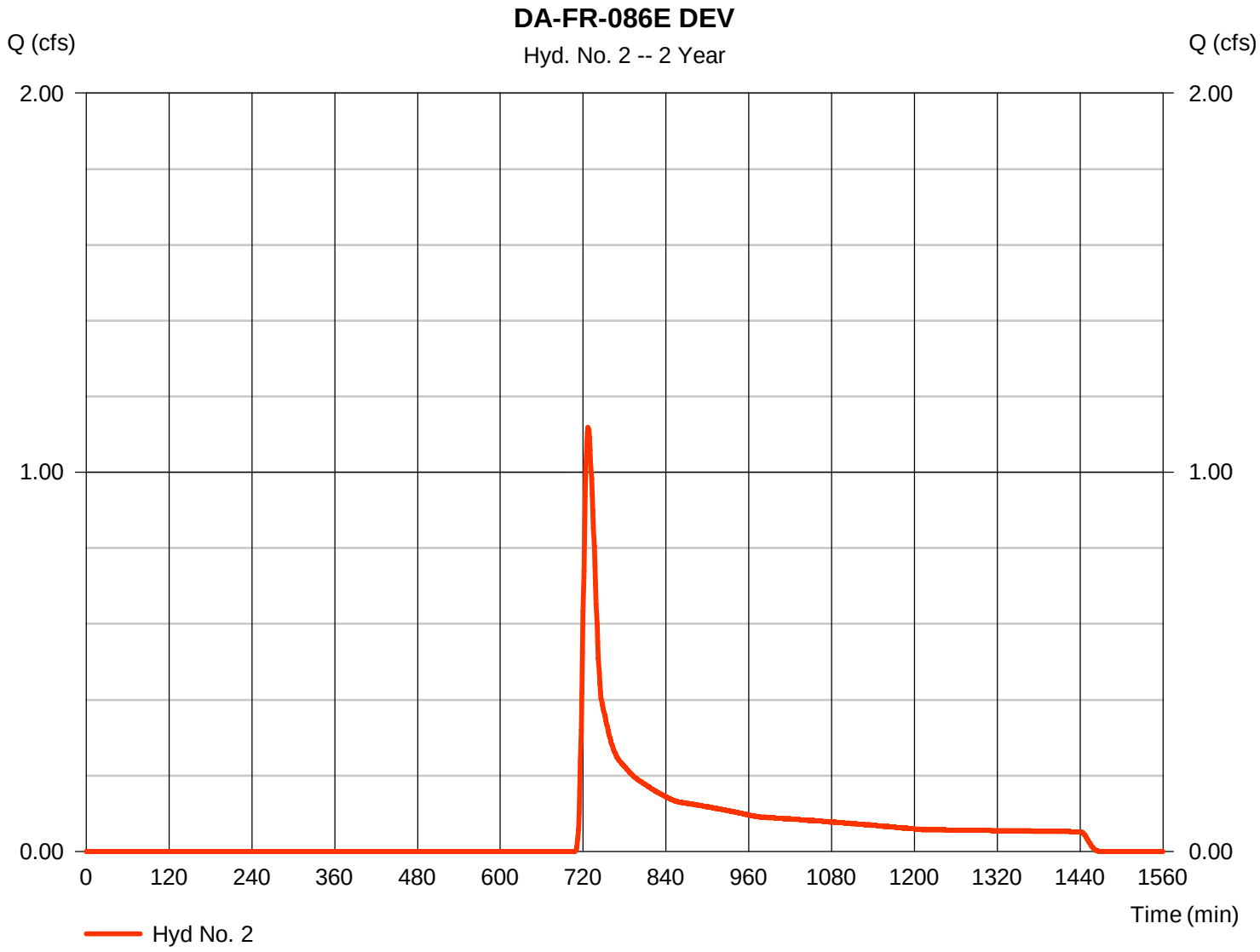
Hydrograph Report

Hyd. No. 2

DA-FR-086E DEV

Hydrograph type	=	SCS Runoff	Peak discharge	=	1.118 cfs
Storm frequency	=	2 yrs	Time to peak	=	727 min
Time interval	=	1 min	Hyd. volume	=	5,422 cuft
Drainage area	=	3.330 ac	Curve number	=	56*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	17.40 min
Total precip.	=	3.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(2.564 x 58) + (0.318 x 55) + (0.444 x 48)] / 3.330



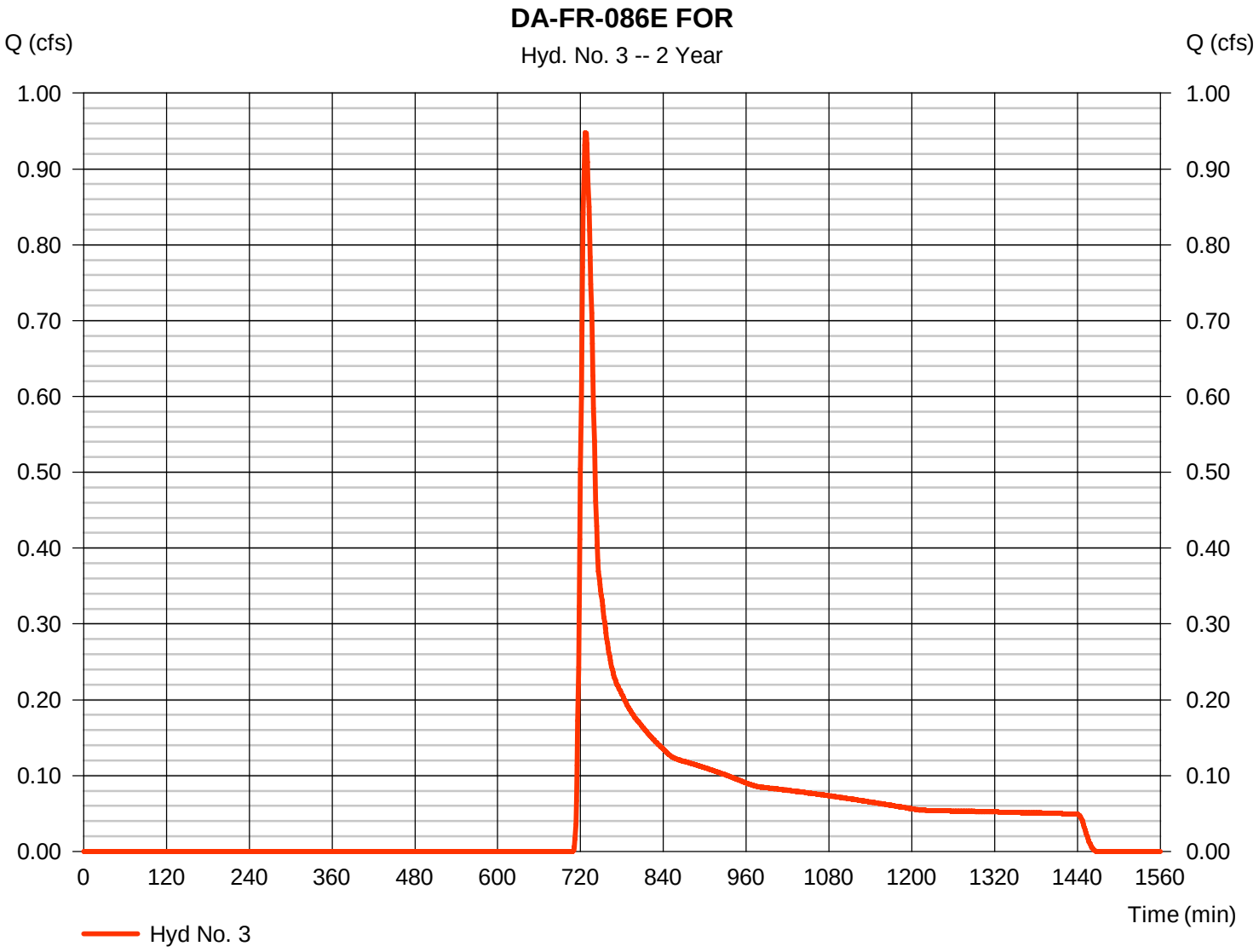
Hydrograph Report

Hyd. No. 3

DA-FR-086E FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.948 cfs
Storm frequency	= 2 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 4,966 cuft
Drainage area	= 3.330 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 17.40 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(3.330 x 55)] / 3.330



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	5.514	1	725	17,889	------	------	------	DA-FR-086E PRE
2	SCS Runoff	5.161	1	725	16,995	------	------	------	DA-FR-086E DEV
3	SCS Runoff	4.811	1	725	16,115	------	------	------	DA-FR-086E FOR

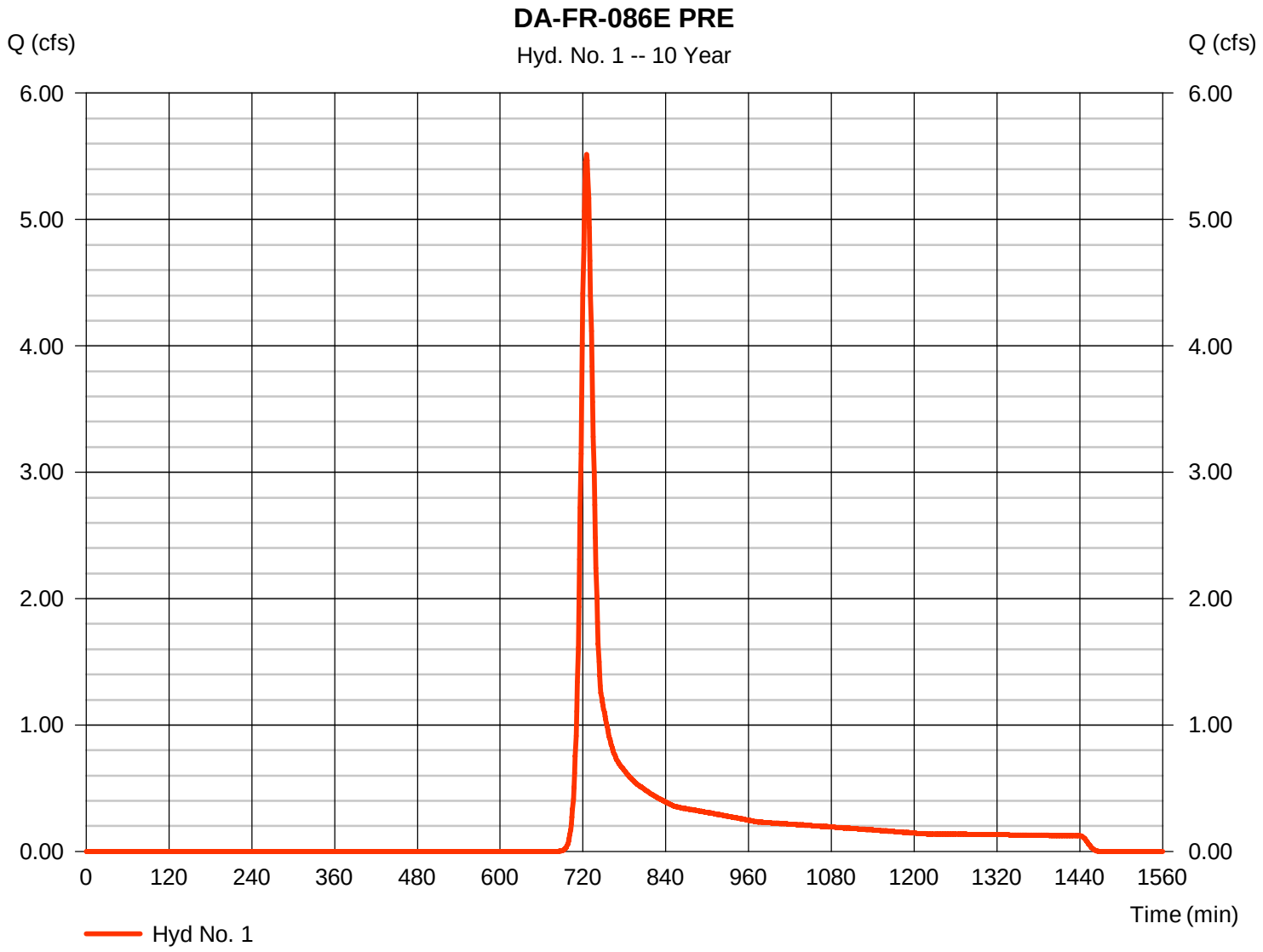
Hydrograph Report

Hyd. No. 1

DA-FR-086E PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	5.514 cfs
Storm frequency	=	10 yrs	Time to peak	=	725 min
Time interval	=	1 min	Hyd. volume	=	17,889 cuft
Drainage area	=	3.330 ac	Curve number	=	57*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	17.40 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(2.059 x 58) + (1.267 x 55)] / 3.330



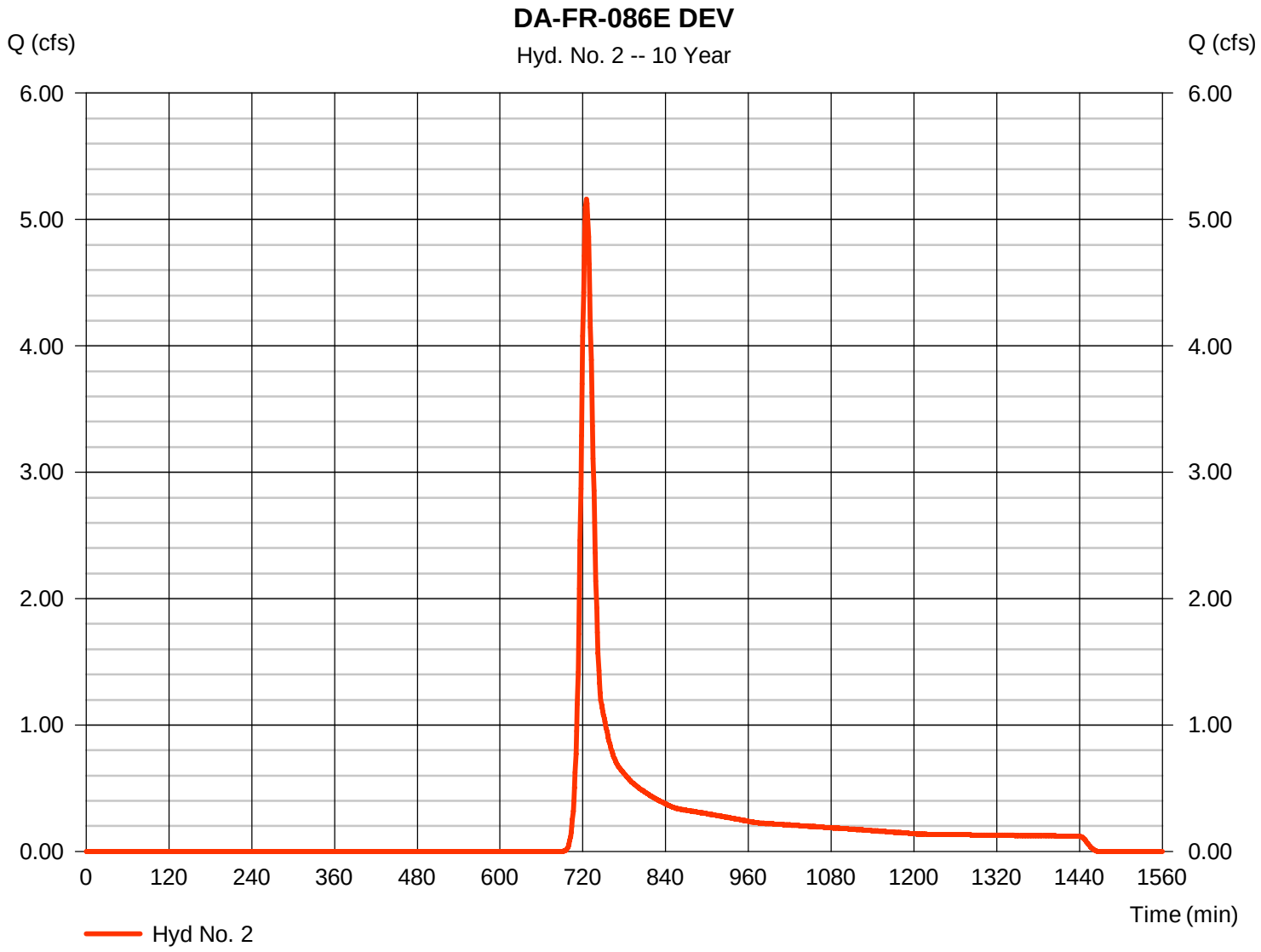
Hydrograph Report

Hyd. No. 2

DA-FR-086E DEV

Hydrograph type	=	SCS Runoff	Peak discharge	=	5.161 cfs
Storm frequency	=	10 yrs	Time to peak	=	725 min
Time interval	=	1 min	Hyd. volume	=	16,995 cuft
Drainage area	=	3.330 ac	Curve number	=	56*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	17.40 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(2.564 x 58) + (0.318 x 55) + (0.444 x 48)] / 3.330



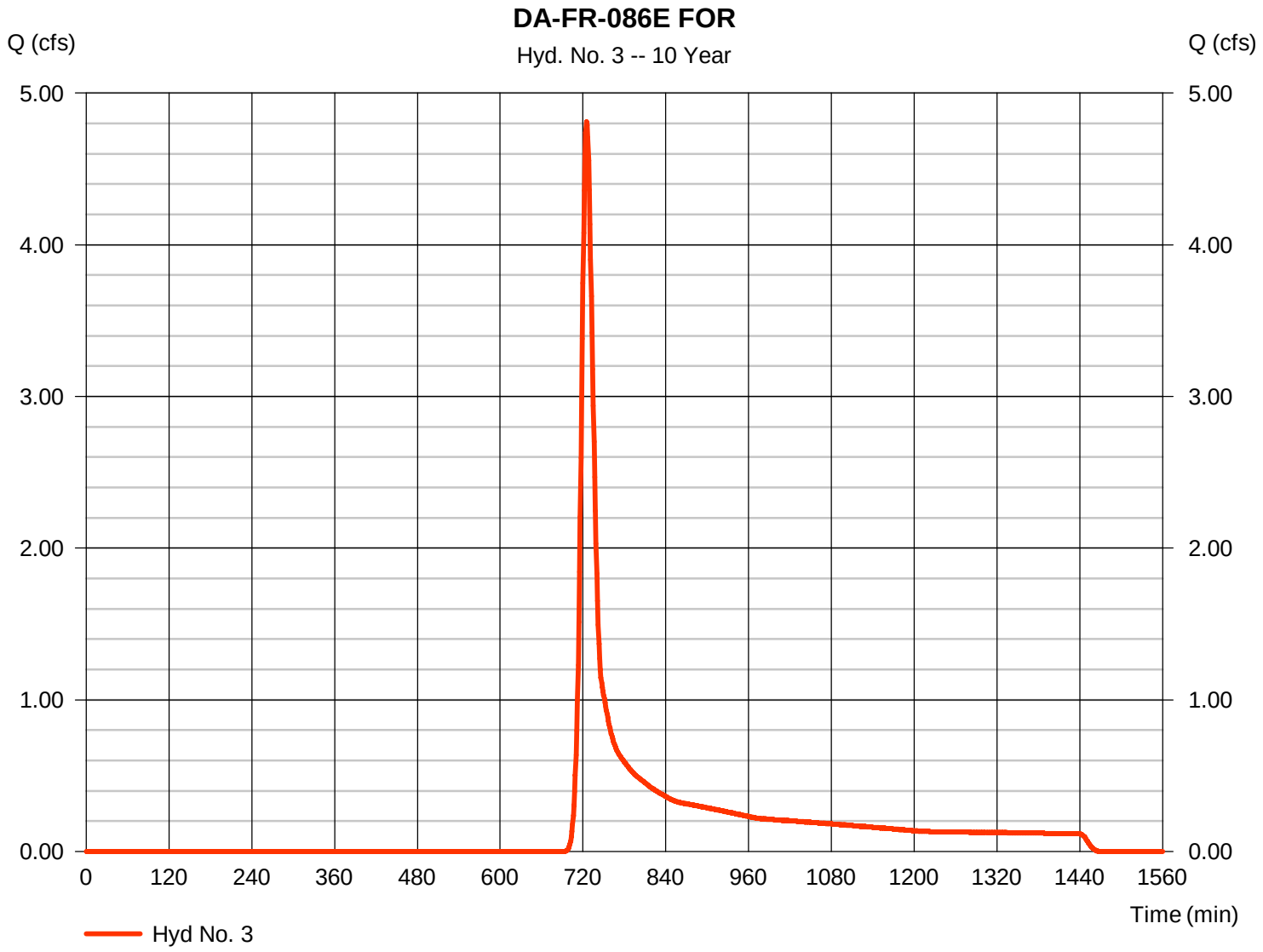
Hydrograph Report

Hyd. No. 3

DA-FR-086E FOR

Hydrograph type	=	SCS Runoff	Peak discharge	=	4.811 cfs
Storm frequency	=	10 yrs	Time to peak	=	725 min
Time interval	=	1 min	Hyd. volume	=	16,115 cuft
Drainage area	=	3.330 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	17.40 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(3.330 x 55)] / 3.330



Hydraflow Rainfall Report

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

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

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

Tc = time in minutes. Values may exceed 60.

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Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.30	3.70	0.00	0.00	5.70	0.00	0.00	0.00
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

DA-FR-086F

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.767	3476
Developed Condition	0.767	3476
Pre-Developed (Forest) Condition	0.496	2638

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

Improvement Factor, IF = 1

Calculations:

Check #1: $Q_{developed} \leq IF \times [(Q_{pre\text{-}developed} \times RV_{pre\text{-}developed}) / RV_{developed}]$ ----------> 0.767 ≤ 0.767 OK

Check #2: $Q_{developed} \leq Q_{pre\text{-}developed}$ ----------> 0.767 ≤ 0.767 OK

Check #3: $Q_{developed}$ *shall not* be required to be ≤ $(Q_{forest} \times RV_{forest}) / RV_{developed}$ ---> 0.767 *shall not* be required to be ≤ 0.376

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

Note:

Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.

For Paved Road land surface types a Manning's n value 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 Channels[1]			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels[2]			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150

Notes:

[1]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 or grass channel.

[2]For the pre-developed condition (if applicable), 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-FR-086F PRE
2	SCS Runoff	DA-FR-086F DEV
3	SCS Runoff	DA-FR-086F FOR

Hydrograph Return Period Recap

Hyd. No.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)							Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	------	0.767	1.300	-------	-------	5.052	-------	-------	-------	DA-FR-086F PRE
2	SCS Runoff	------	0.767	1.300	-------	-------	5.052	-------	-------	-------	DA-FR-086F DEV
3	SCS Runoff	------	0.496	0.989	-------	-------	4.809	-------	-------	-------	DA-FR-086F FOR

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	0.767	1	725	3,476	------	------	------	DA-FR-086F PRE
2	SCS Runoff	0.767	1	725	3,476	------	------	------	DA-FR-086F DEV
3	SCS Runoff	0.496	1	724	2,638	------	------	------	DA-FR-086F FOR

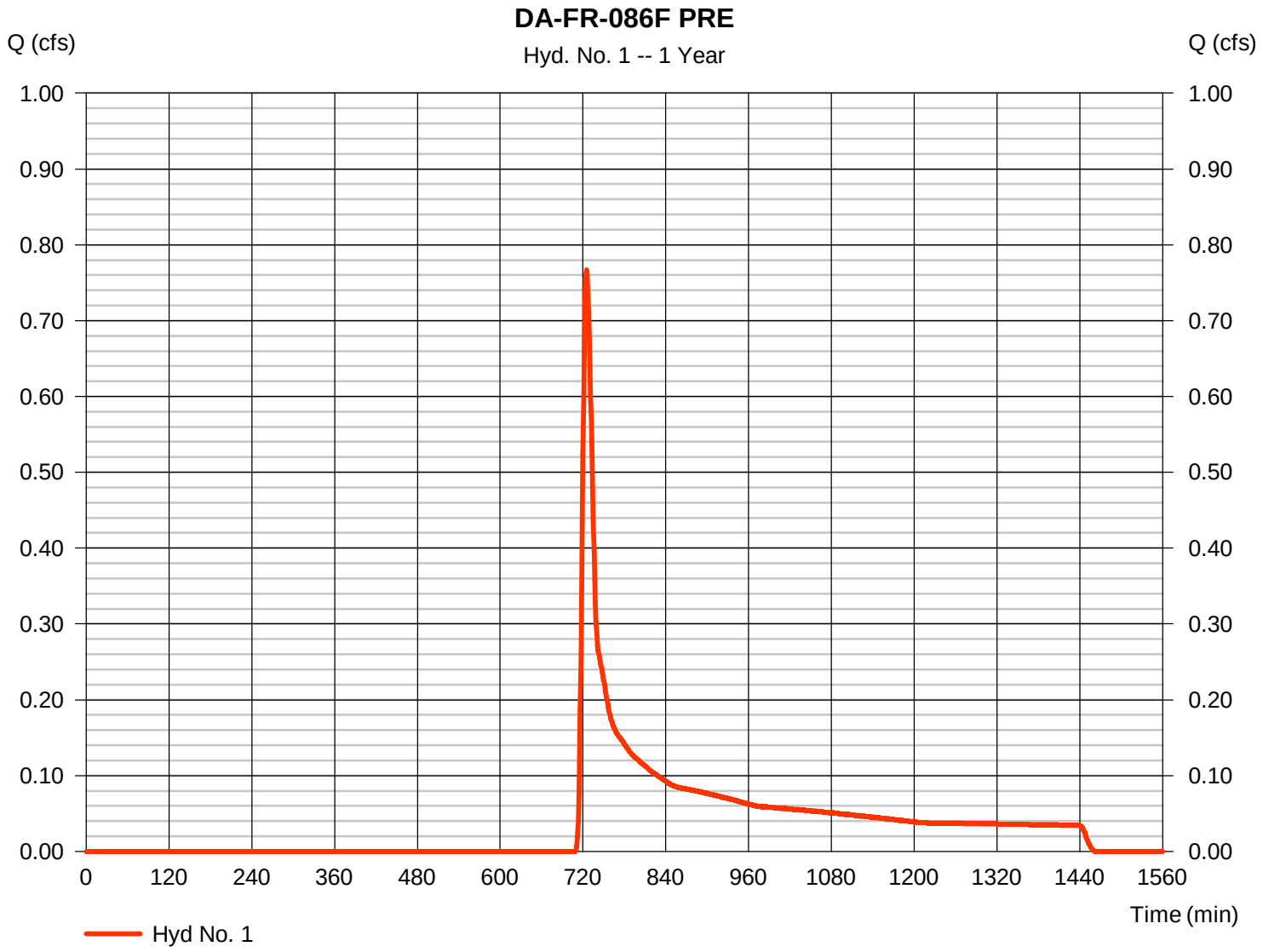
Hydrograph Report

Hyd. No. 1

DA-FR-086F PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.767 cfs
Storm frequency	=	1 yrs	Time to peak	=	725 min
Time interval	=	1 min	Hyd. volume	=	3,476 cuft
Drainage area	=	2.540 ac	Curve number	=	58*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	14.30 min
Total precip.	=	3.30 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(2.386 x 58) + (0.157 x 55)] / 2.540



TR55 Tc Worksheet

Hyd. No. 1

DA-FR-086F PRE

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 7.55		0.00		0.00		
Travel Time (min)	**= 11.74**	**+**	**0.00**	**+**	**0.00**	**=**	**11.74**
Shallow Concentrated Flow							
Flow length (ft)	= 719.56		0.00		0.00		
Watercourse slope (%)	= 8.58		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=4.73		0.00		0.00		
Travel Time (min)	**= 2.54**	**+**	**0.00**	**+**	**0.00**	**=**	**2.54**
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	= 0.015		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 ..... 14.30 min

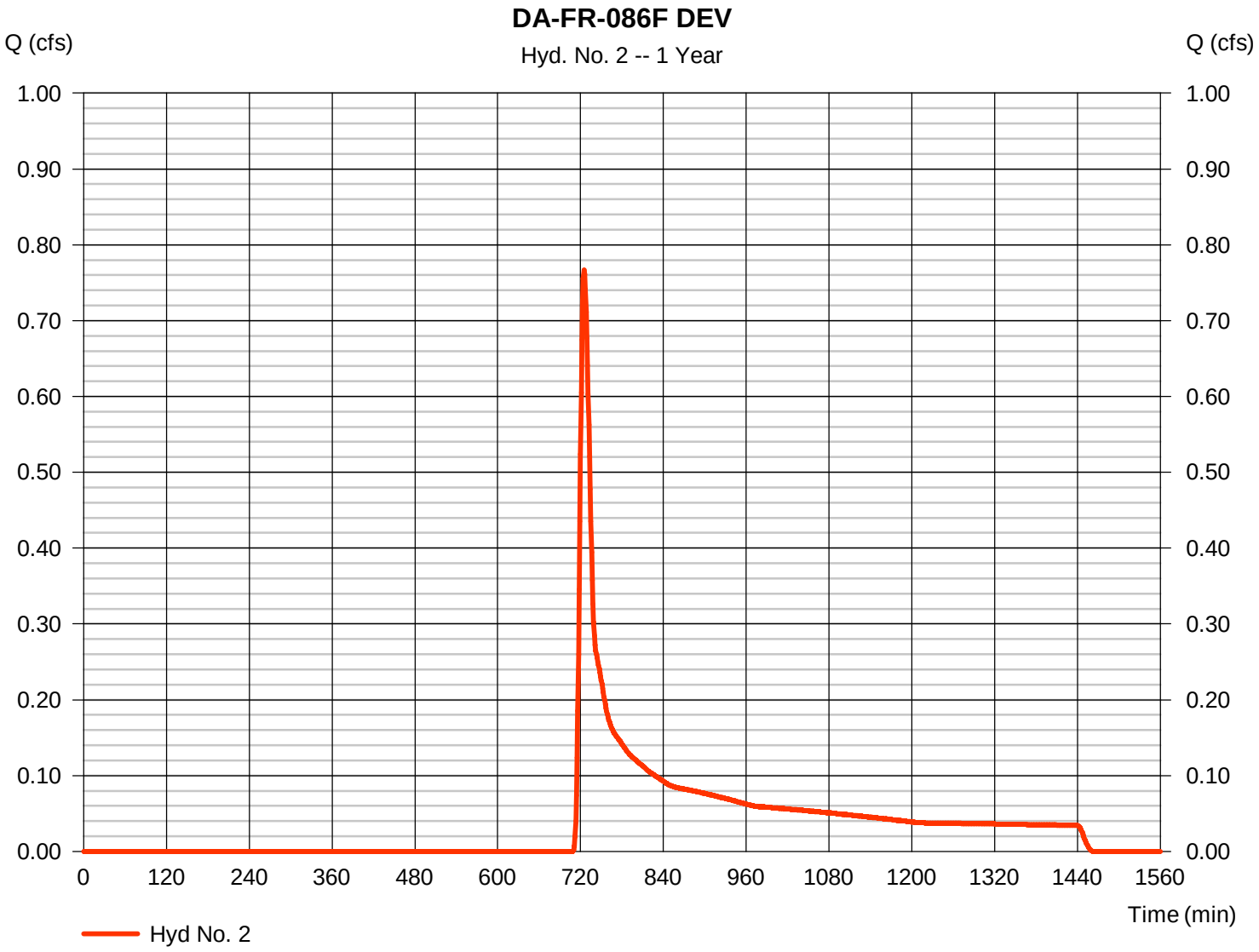
Hydrograph Report

Hyd. No. 2

DA-FR-086F DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.767 cfs
Storm frequency	= 1 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 3,476 cuft
Drainage area	= 2.540 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.70 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(2.474 x 58) + (0.061 x 55) + (0.009 x 48)] / 2.540



TR55 Tc Worksheet

Hyd. No. 2

DA-FR-086F DEV

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 7.55		0.00		0.00		
Travel Time (min)	**= 11.74**	**+**	**0.00**	**+**	**0.00**	**=**	**11.74**
Shallow Concentrated Flow							
Flow length (ft)	= 439.17		49.14		61.66		
Watercourse slope (%)	= 10.87		12.99		6.72		
Surface description	= Unpaved		Unpaved		Unpaved		
Average velocity (ft/s)	=5.32		5.82		4.18		
Travel Time (min)	**= 1.38**	**+**	**0.14**	**+**	**0.25**	**=**	**1.76**
Channel Flow							
X sectional flow area (sqft)	= 2.00		2.00		0.00		
Wetted perimeter (ft)	= 4.47		4.47		0.00		
Channel slope (%)	= 5.00		5.00		0.00		
Manning's n-value	= 0.040		0.040		0.015		
Velocity (ft/s)	=4.86						
			4.86				
					0.00		
Flow length (ft)	({0})28.4		40.1		0.0		
Travel Time (min)	**= 0.10**	**+**	**0.14**	**+**	**0.00**	**=**	**0.24**

Total Travel Time, Tc ..... 13.70 min

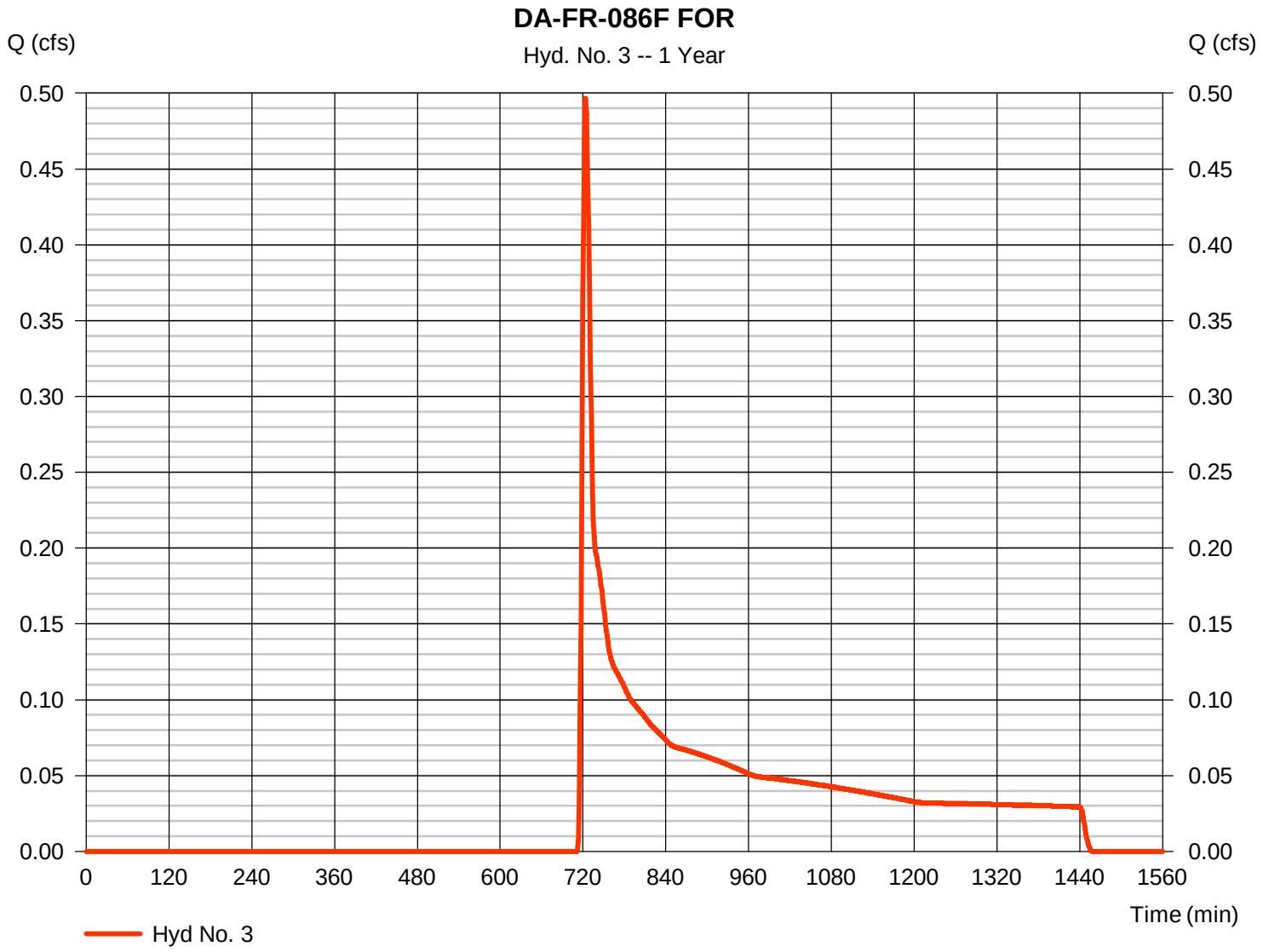
Hydrograph Report

Hyd. No. 3

DA-FR-086F FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.496 cfs
Storm frequency	= 1 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 2,638 cuft
Drainage area	= 2.540 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.70 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(2.540 x 55)] / 2.540



TR55 Tc Worksheet

Hyd. No. 3

DA-FR-086F FOR

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 7.55		0.00		0.00		
Travel Time (min)	**= 11.74**	**+**	**0.00**	**+**	**0.00**	**=**	**11.74**
Shallow Concentrated Flow							
Flow length (ft)	= 8.58		0.00		0.00		
Watercourse slope (%)	= 719.56		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=43.28		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	= 0.015		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	1.300	1	724	4,924	------	------	------	DA-FR-086F PRE
2	SCS Runoff	1.300	1	724	4,924	------	------	------	DA-FR-086F DEV
3	SCS Runoff	0.989	1	723	3,900	------	------	------	DA-FR-086F FOR

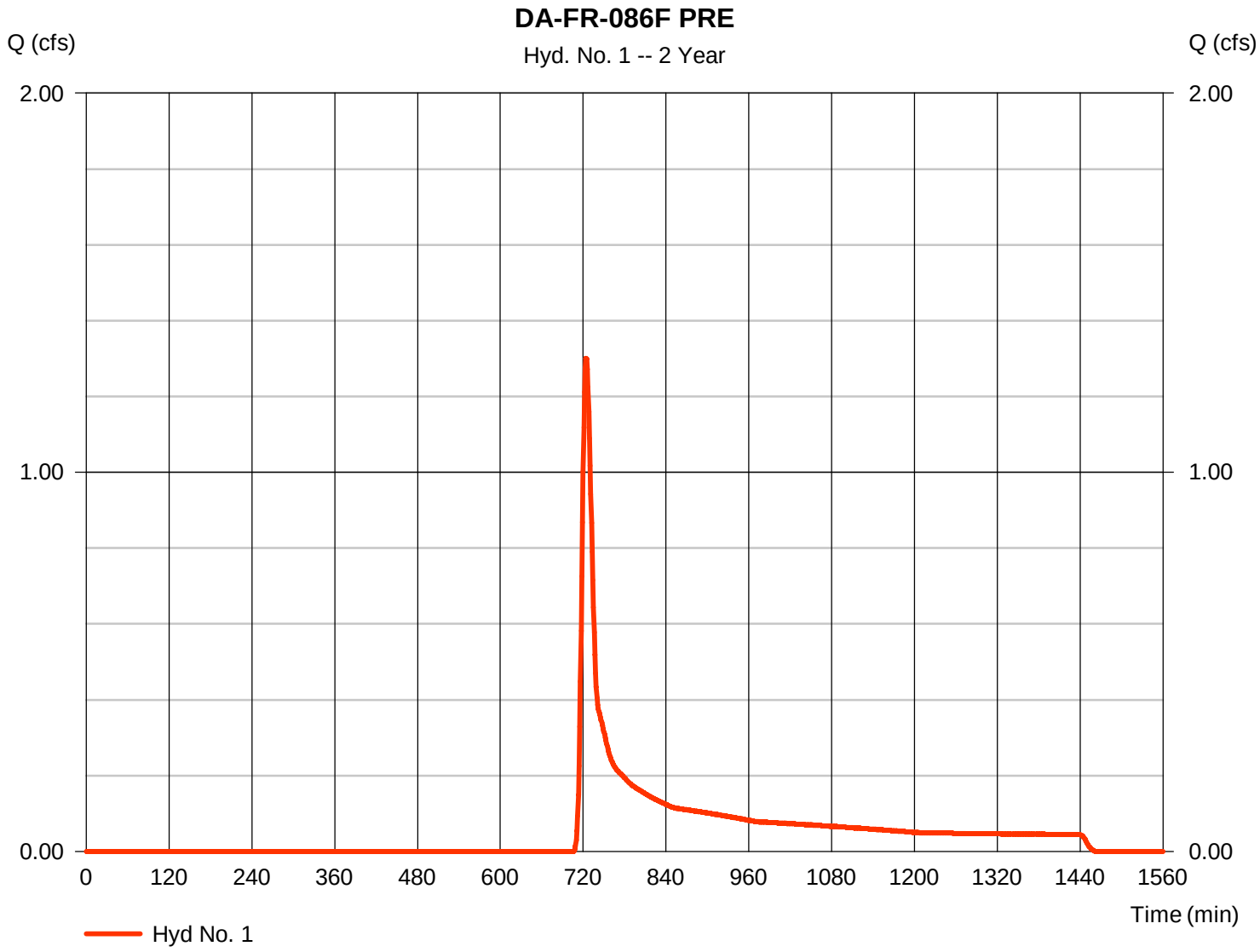
Hydrograph Report

Hyd. No. 1

DA-FR-086F PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	1.300 cfs
Storm frequency	=	2 yrs	Time to peak	=	724 min
Time interval	=	1 min	Hyd. volume	=	4,924 cuft
Drainage area	=	2.540 ac	Curve number	=	58*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	14.30 min
Total precip.	=	3.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(2.386 x 58) + (0.157 x 55)] / 2.540



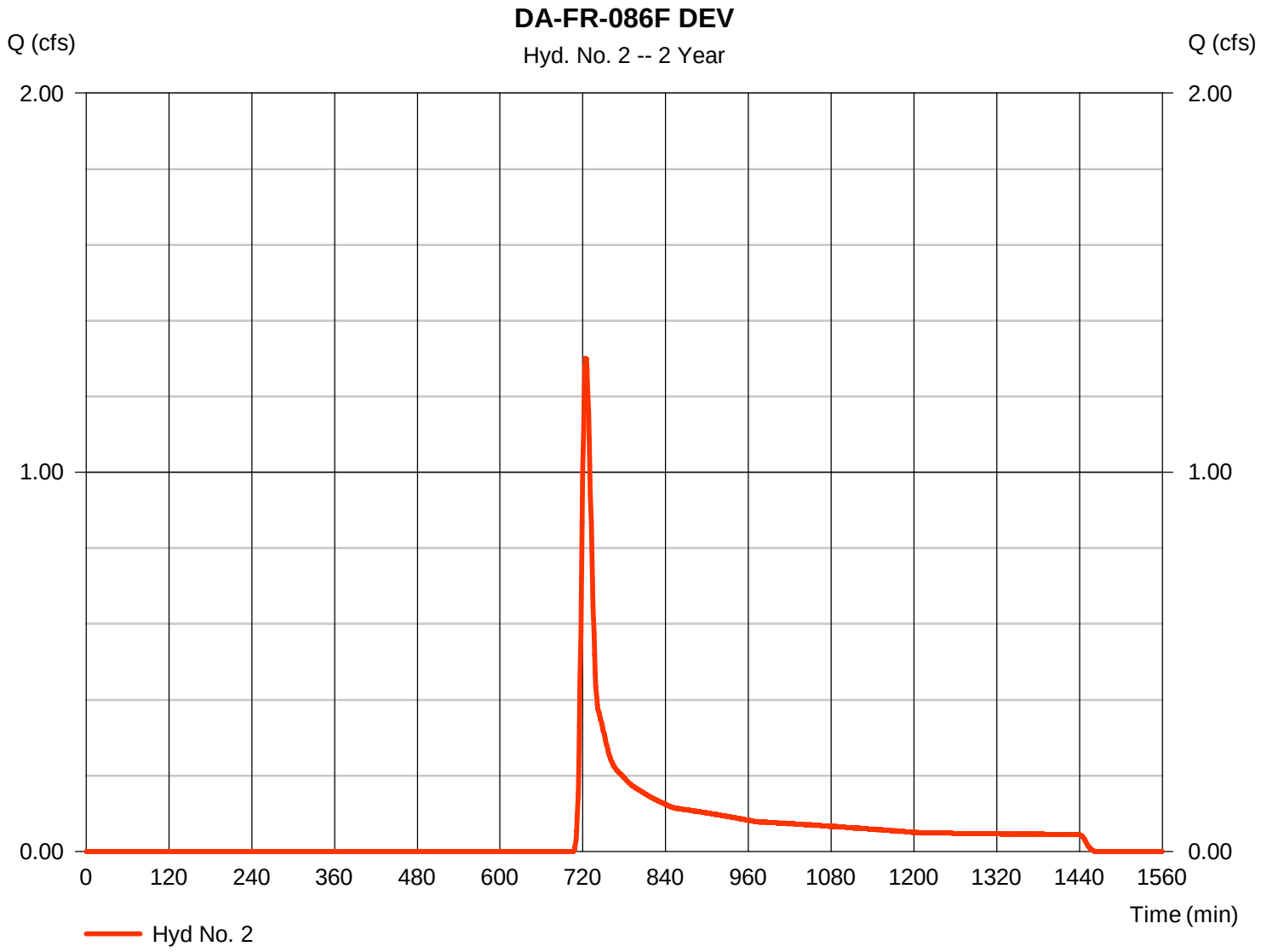
Hydrograph Report

Hyd. No. 2

DA-FR-086F DEV

Hydrograph type	=	SCS Runoff	Peak discharge	=	1.300 cfs
Storm frequency	=	2 yrs	Time to peak	=	724 min
Time interval	=	1 min	Hyd. volume	=	4,924 cuft
Drainage area	=	2.540 ac	Curve number	=	58*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	13.70 min
Total precip.	=	3.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(2.474 x 58) + (0.061 x 55) + (0.009 x 48)] / 2.540



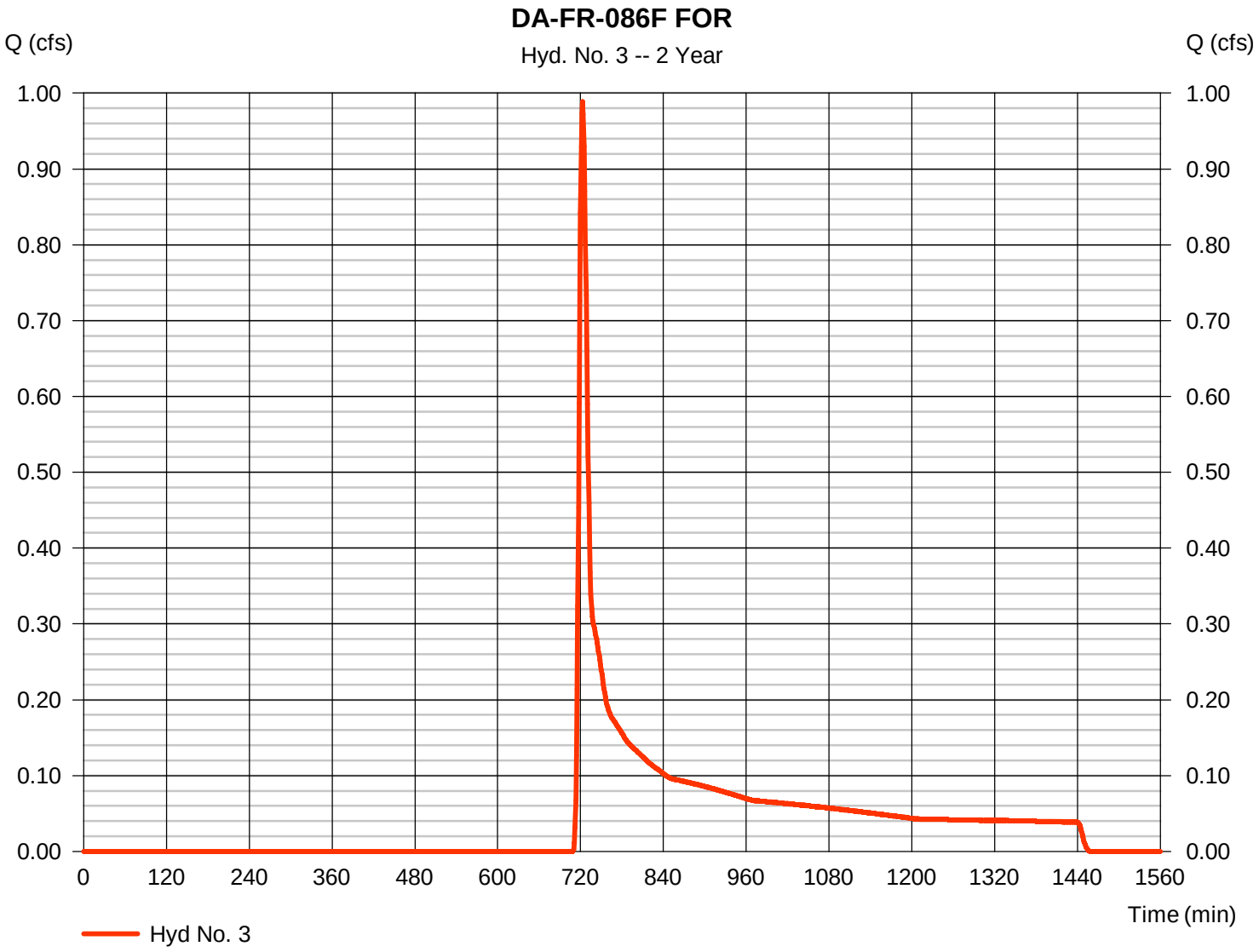
Hydrograph Report

Hyd. No. 3

DA-FR-086F FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.989 cfs
Storm frequency	= 2 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 3,900 cuft
Drainage area	= 2.540 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.70 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(2.540 x 55)] / 2.540



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	5.052	1	723	14,502	------	------	------	DA-FR-086F PRE
2	SCS Runoff	5.052	1	723	14,502	------	------	------	DA-FR-086F DEV
3	SCS Runoff	4.809	1	721	12,656	------	------	------	DA-FR-086F FOR

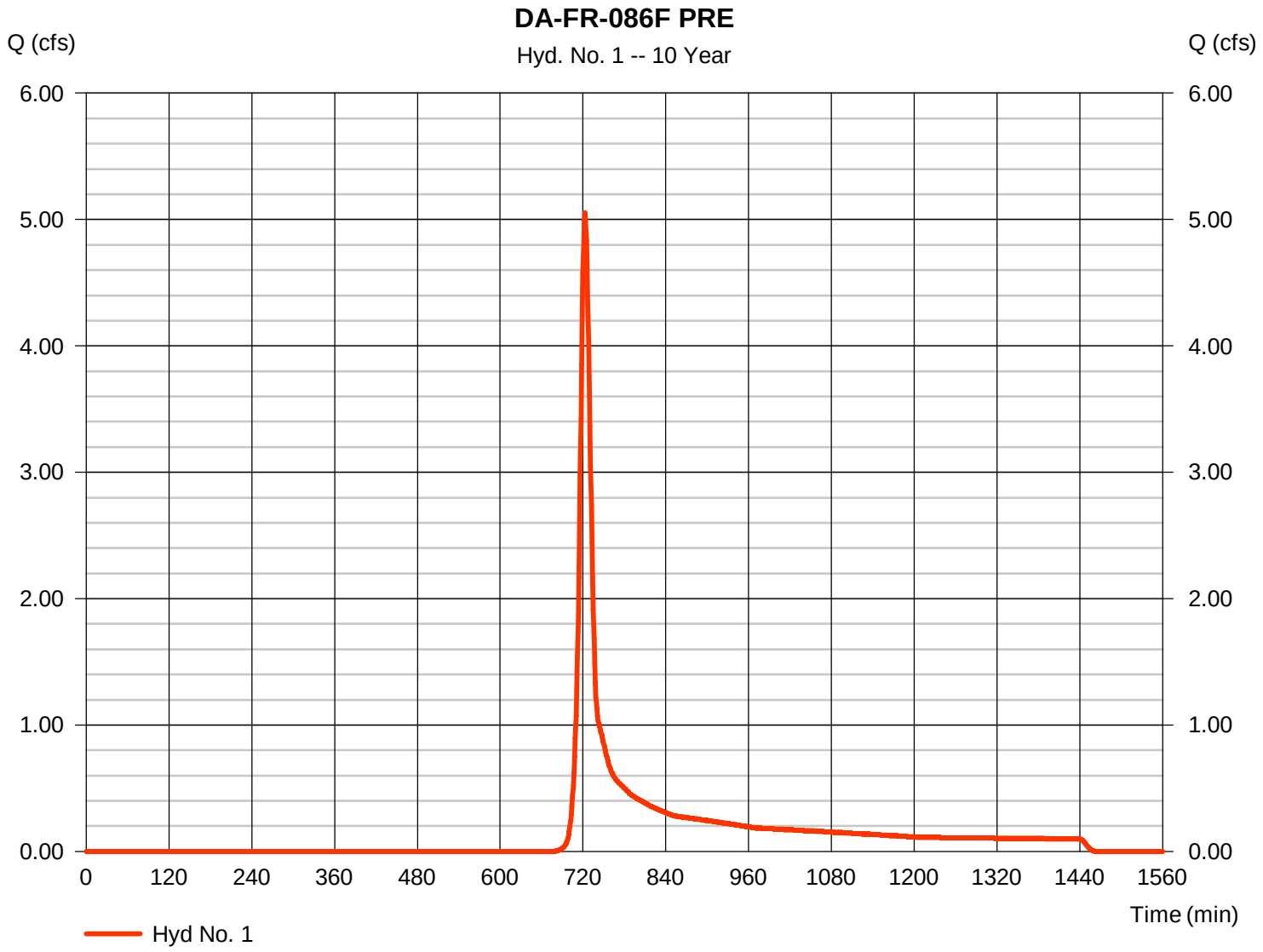
Hydrograph Report

Hyd. No. 1

DA-FR-086F PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	5.052 cfs
Storm frequency	=	10 yrs	Time to peak	=	723 min
Time interval	=	1 min	Hyd. volume	=	14,502 cuft
Drainage area	=	2.540 ac	Curve number	=	58*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	14.30 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(2.386 x 58) + (0.157 x 55)] / 2.540



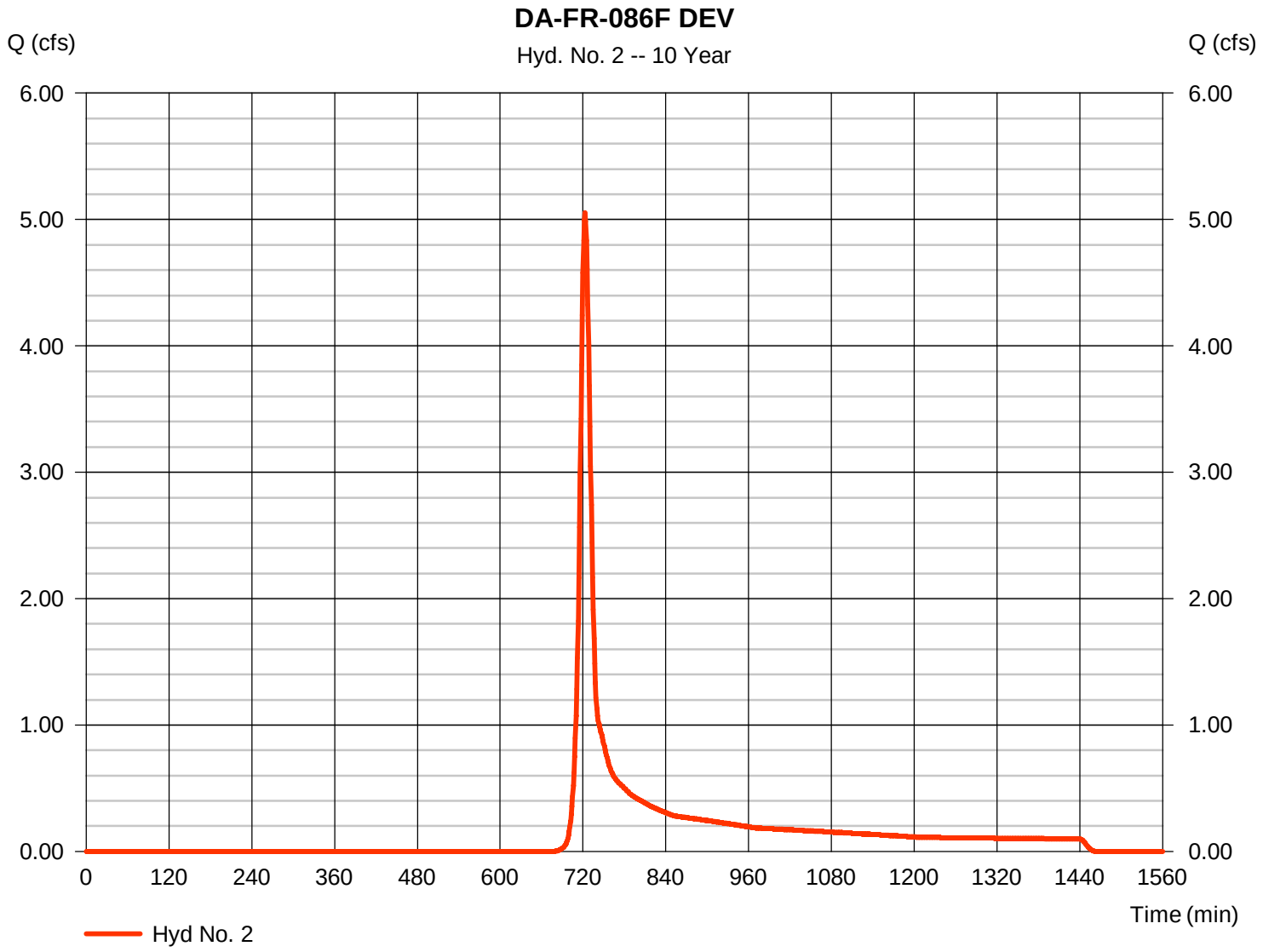
Hydrograph Report

Hyd. No. 2

DA-FR-086F DEV

Hydrograph type	=	SCS Runoff	Peak discharge	=	5.052 cfs
Storm frequency	=	10 yrs	Time to peak	=	723 min
Time interval	=	1 min	Hyd. volume	=	14,502 cuft
Drainage area	=	2.540 ac	Curve number	=	58*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	13.70 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(2.474 x 58) + (0.061 x 55) + (0.009 x 48)] / 2.540



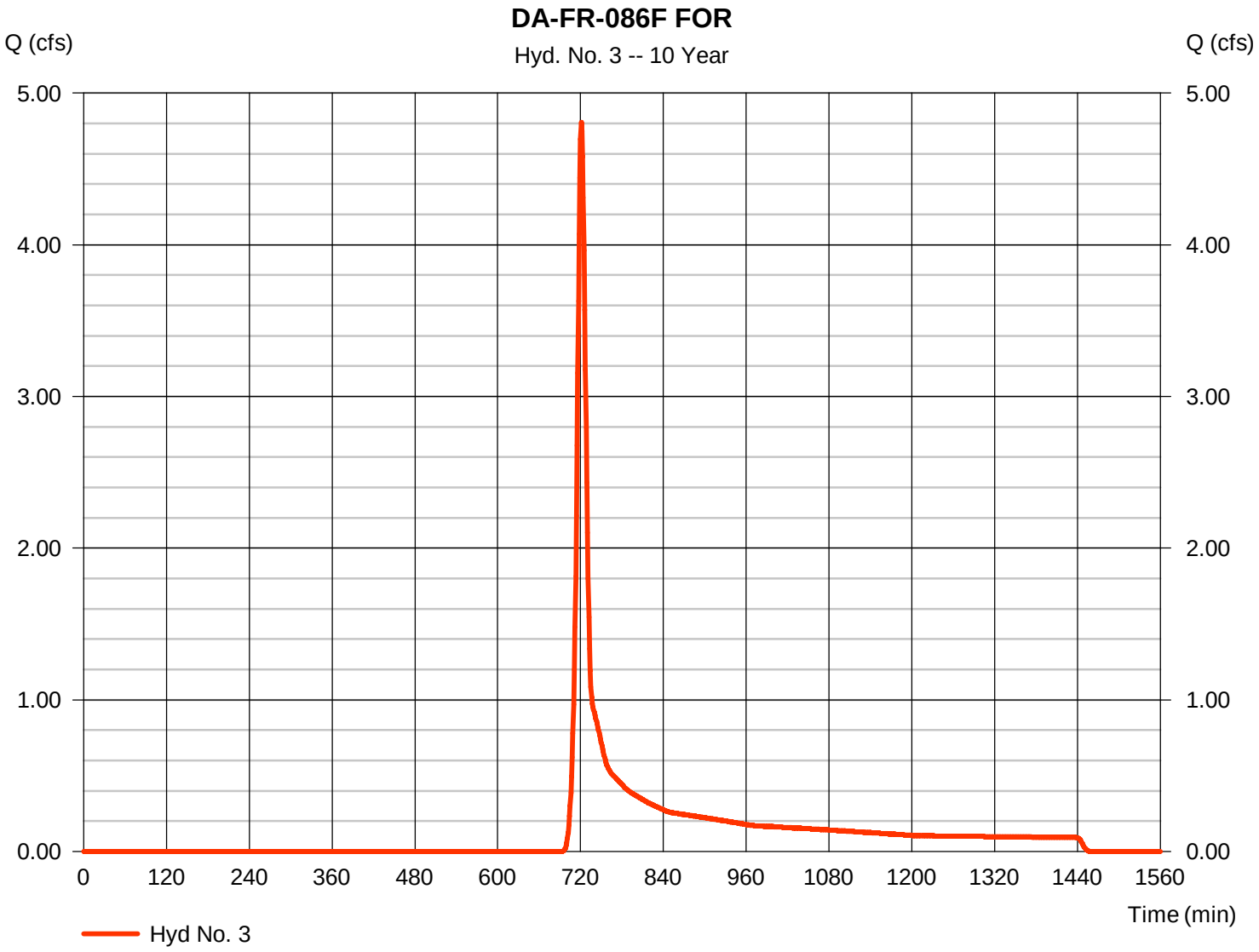
Hydrograph Report

Hyd. No. 3

DA-FR-086F FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 4.809 cfs
Storm frequency	= 10 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 12,656 cuft
Drainage area	= 2.540 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.70 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(2.540 x 55)] / 2.540



Hydraflow Rainfall Report

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

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

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

Tc = time in minutes. Values may exceed 60.

ng\Franklin County\Downloaded Files\Franklin County DA Batch 4 - 046 - 058\Precipitation\Hydraflow\FranklinCo.pc

Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.30	3.70	0.00	0.00	5.70	0.00	0.00	0.00
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

DA-FR-087

DA-FR-087 is located in meadow land use with undulating to rolling slopes. A portion of Farm View Road is located on the eastern edge of the drainage area, but no new impervious area is proposed within DA-FR-087. The total phosphorus load reduction required for DA-FR-087 is –0.29 lb/yr.

DA-FR-087 contains both agricultural and non-agricultural areas 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. 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 Right of Way (ROW) is analyzed via VRRM; in these calculations agricultural areas are considered “Forest/Open Space”.

Stormwater quantity is met via the energy balance method. In addition, the Hydraflow Hydrograph’s 10-year 24-hour peak discharge results indicate no reduction in flow for this drainage area (as seen in table below).

Drainage Area	Pre Peak Flow, 10-yr Q (cfs)	Post Peak Flow, Q 10-yr (cfs)	Flow differential
DA-FR-087	6.80	6.80	0.00

Figures and calculations for DA-FR-087 follow. See Appendix D of the Annual Standards and Specifications for further detail on stormwater methodology.

Note that the DA-FR-087 had a time of concentration flow path for the Post-Construction condition that accounted for a permanent water bar that is not cited within the drainage area. This permanent water bar was removed because it was cited 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-FR-087, so the resulting changes were not made to the stormwater calculations prior to submittal.

DA-FR-087
4.05 acres
Weighted CN = 58

270.8

270.9

271.0

1050

B

Farm View Rd

S-GC4

LAND USE	HSG	CN	AREA (AC)
Impervious	B	98	0.04
Meadow	B	58	3.95
Woods - Good	B	55	0.06

Legend

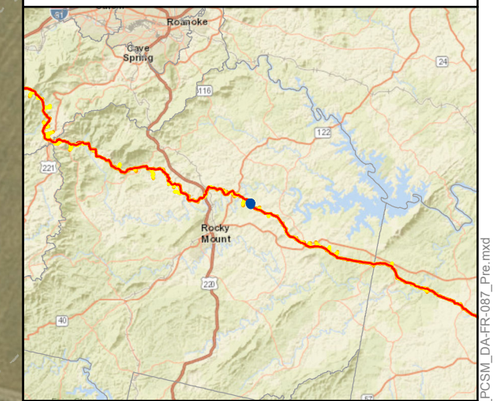
- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Impervious
- Meadow
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

1:1,500

125 62.5 0 125 Feet

N W E S



Mountain Valley Pipeline Project

Mountain Valley PIPELINE

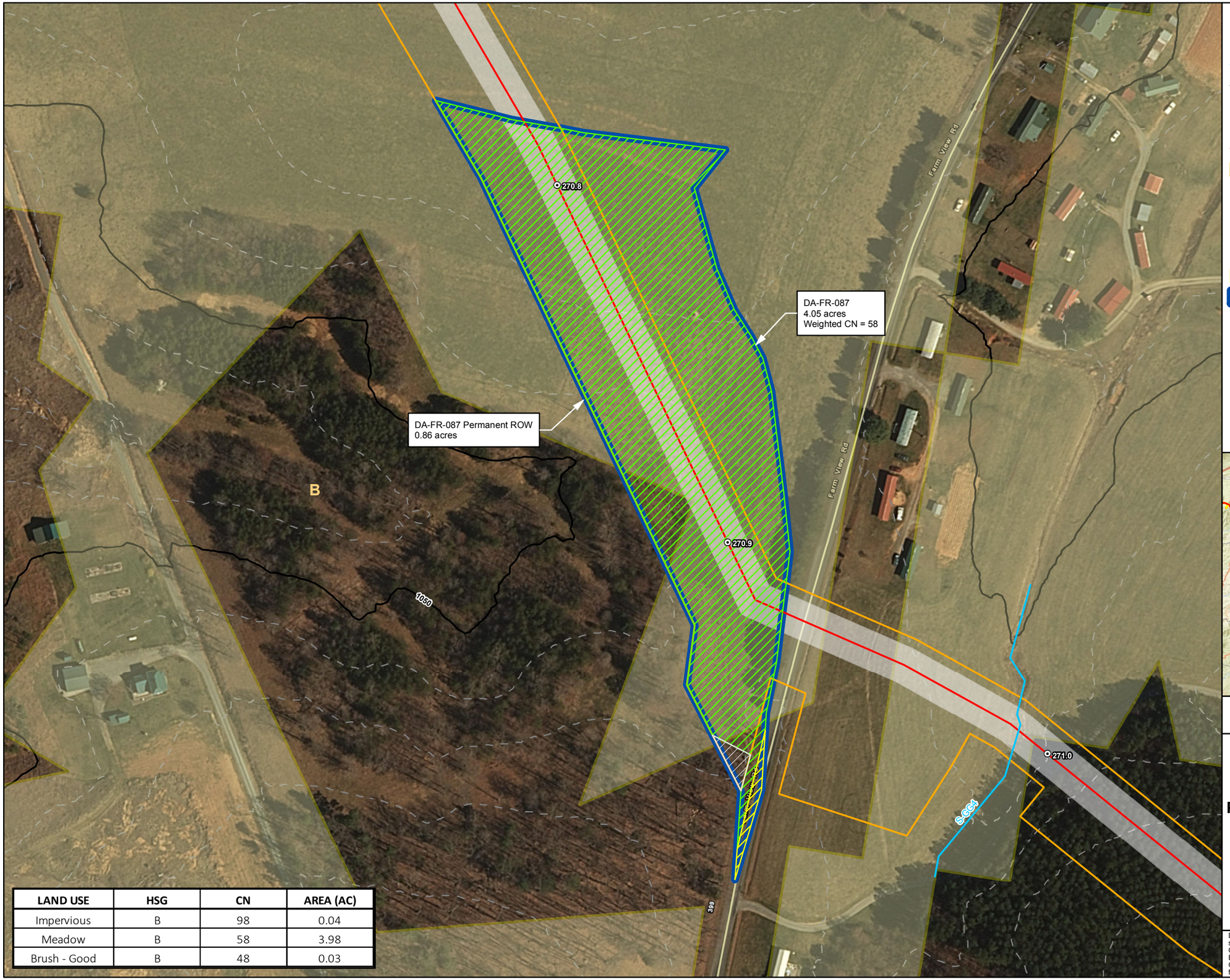
Pre-Construction Drainage Area Map
DA-FR-087
Spread 11

Figure 1
Franklin County, Virginia

August, 2017

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

Document Path: PGH P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Franklin\MVP_PCSM_DA-FR-087_Pre.mxd



LAND USE	HSG	CN	AREA (AC)
Impervious	B	98	0.04
Meadow	B	58	3.98
Brush - Good	B	48	0.03

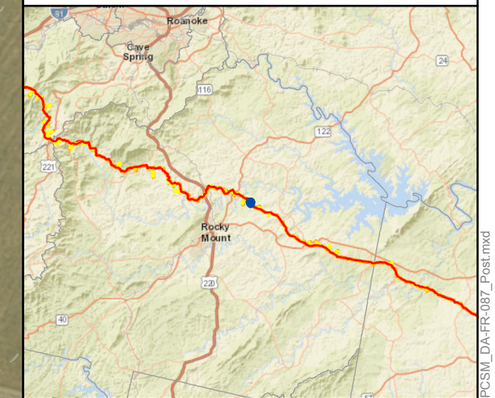
Legend

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

NAD 1983 UTM 17N (feet)

1:1,500

130 65 0 130 Feet



Mountain Valley Pipeline Project

Mountain Valley PIPELINE

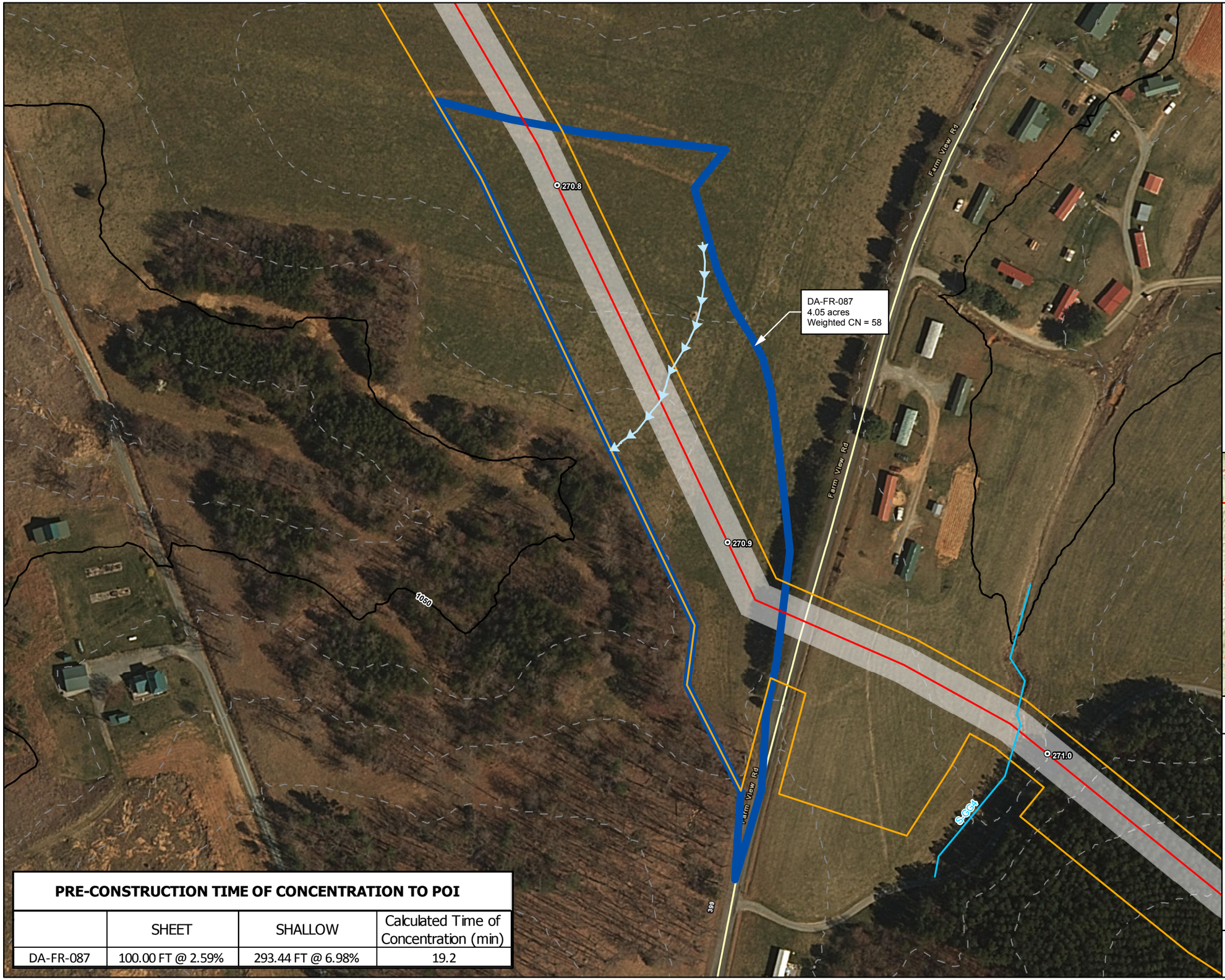
Post-Construction Drainage Area Map
DA-FR-087
Spread 11

Figure 2
Franklin County, Virginia

August, 2017

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

Document Path: P:GIS\EQT_MVP\Mapdocs\Drainage\MXD\Franklin\MVP_PCSM_DA-FR-087_Post.mxd



PRE-CONSTRUCTION TIME OF CONCENTRATION TO POI

	SHEET	SHALLOW	Calculated Time of Concentration (min)
DA-FR-087	100.00 FT @ 2.59%	293.44 FT @ 6.98%	19.2

Legend

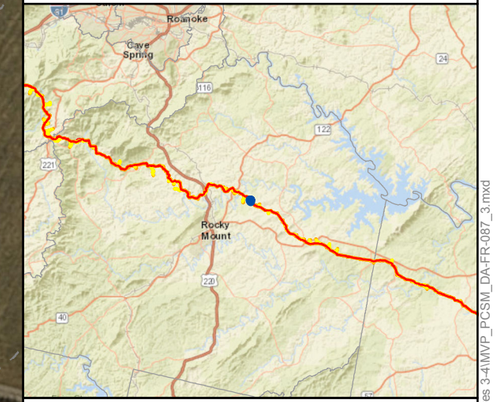
- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

N
W E
S

1:1,500

125 62.5 0 125 Feet



Mountain Valley Pipeline Project

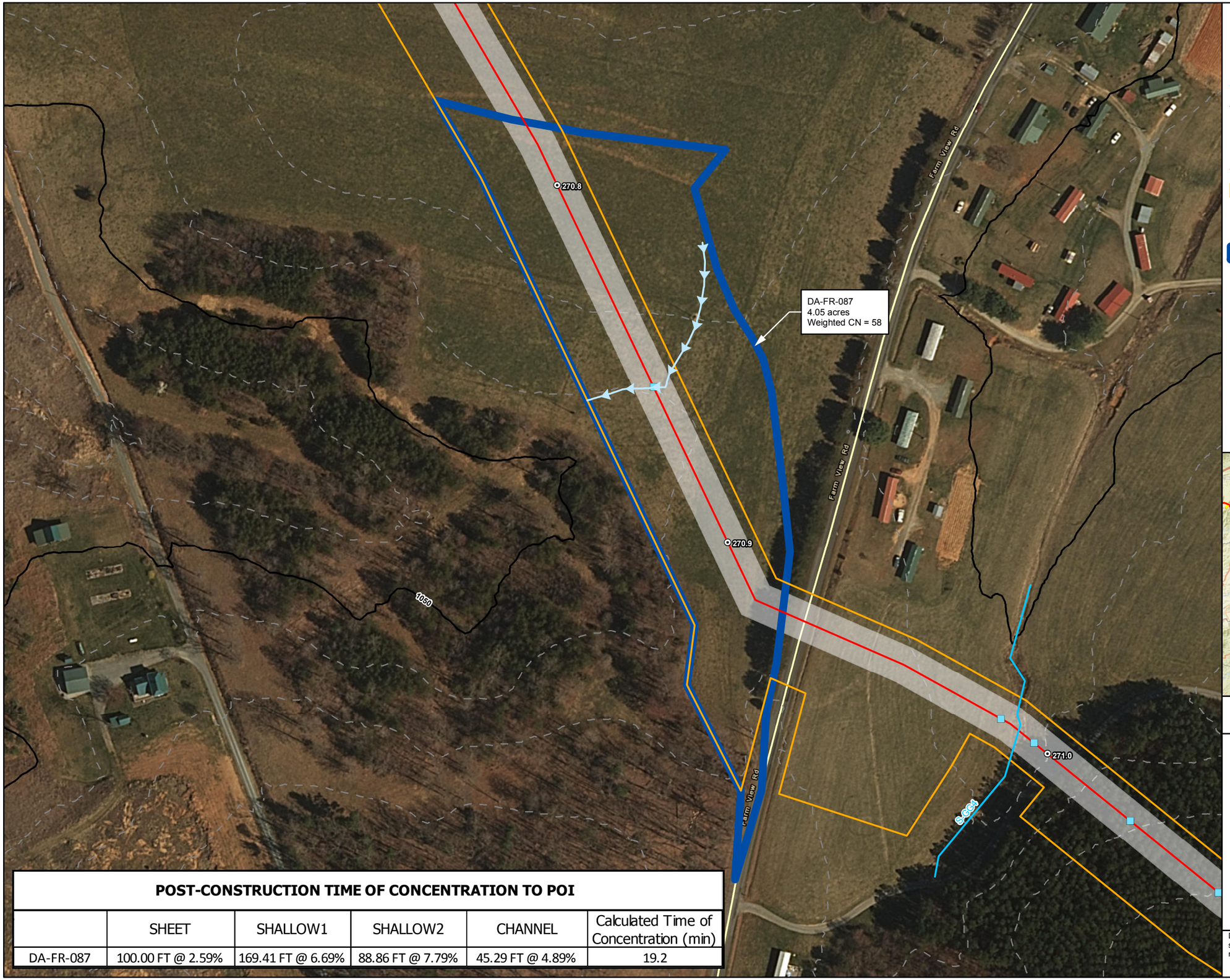
Mountain Valley PIPELINE

Pre-Construction Drainage Area and Time of Concentration
DA-FR-087
Spread 11

Figure 3
Franklin 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.

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POST-CONSTRUCTION TIME OF CONCENTRATION TO POI

	SHEET	SHALLOW1	SHALLOW2	CHANNEL	Calculated Time of Concentration (min)
DA-FR-087	100.00 FT @ 2.59%	169.41 FT @ 6.69%	88.86 FT @ 7.79%	45.29 FT @ 4.89%	19.2

Legend

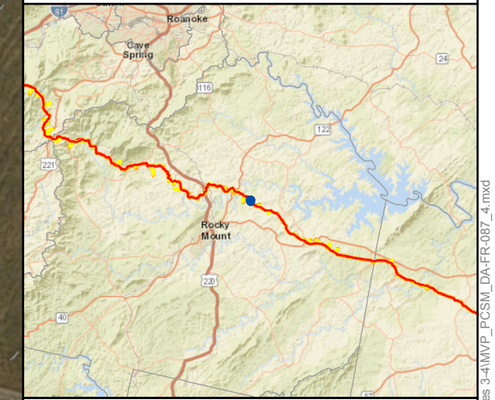
- Milepost
- Permanent Waterbars
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:1,500

N W E S

125 62.5 0 125 Feet



Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Post-Construction Drainage Area and Time of Concentration
DA-FR-087
Spread 11

Figure 4
Franklin 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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Virginia Runoff Reduction Method New Development Worksheet - v2.8 - June 2014

Site Data Summary

Total Rainfall = 46 inches

Site Land Cover Summary

	A Soils	B Soils	C Soils	D Soils	Total	% of Total
Forest (acres)	0.00	0.86	0.00	0.00	0.86	*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*
					0.86	*100.00*

Site Rv	0.03
Post Development Treatment Volume (ft3)	94
Post Development TP Load (lb/yr)	0.06
Post Development TN Load (lb/yr)	0.45
Total TP Load Reduction Required (lb/yr)	-0.29

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)	0.06
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)	0.86	0.00	0.00	0.00	0.00	*0.86*
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*
						0.86

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*

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	1.003	5542
Developed Condition	1.003	5542
Pre-Developed (Forest) Condition	0.441	4102

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

Improvement Factor, IF = 1

Calculations:

Check #1: $Q_{developed} \leq IF \times [(Q_{pre\text{-}developed} \times RV_{pre\text{-}developed}) / RV_{developed}]$ ----------> 1.003 ≤ 1.003 OK

Check #2: $Q_{developed} \leq Q_{pre\text{-}developed}$ ----------> 1.003 ≤ 1.003 OK

Check #3: $Q_{developed}$ *shall not* be required to be ≤ $(Q_{forest} \times RV_{forest}) / RV_{developed}$ ---> 1.003 *shall not* be required to be ≤ 0.326

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

Note:

Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.

For Paved Road land surface types a Manning's n value 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 Channels[1]			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels[2]			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150

Notes:

[1]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 or grass channel.

[2]For the pre-developed condition (if applicable), 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

Hydraflow Table of Contents

DA-FR-087_Hydraflow (2).gpw

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5 Tuesday, 09 / 5 / 2017

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1 - Year

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Hydrograph No. 2, SCS Runoff, DA-FR-087 DEV 6

TR-55 Tc Worksheet 7

Hydrograph No. 3, SCS Runoff, DA-FR-087 FOR 8

TR-55 Tc Worksheet 9

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Hydrograph No. 2, SCS Runoff, DA-FR-087 DEV 16

Hydrograph No. 3, SCS Runoff, DA-FR-087 FOR 17

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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-FR-087 PRE
2	SCS Runoff	DA-FR-087 DEV
3	SCS Runoff	DA-FR-087 FOR

Hydrograph Return Period Recap

Hyd. No.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)							Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	------	1.003	1.707	-------	-------	6.795	-------	-------	-------	DA-FR-087 PRE
2	SCS Runoff	------	1.003	1.707	-------	-------	6.795	-------	-------	-------	DA-FR-087 DEV
3	SCS Runoff	------	0.441	0.855	-------	-------	4.377	-------	-------	-------	DA-FR-087 FOR

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	1.003	1	729	5,542	------	------	------	DA-FR-087 PRE
2	SCS Runoff	1.003	1	729	5,542	------	------	------	DA-FR-087 DEV
3	SCS Runoff	0.441	1	737	4,102	------	------	------	DA-FR-087 FOR

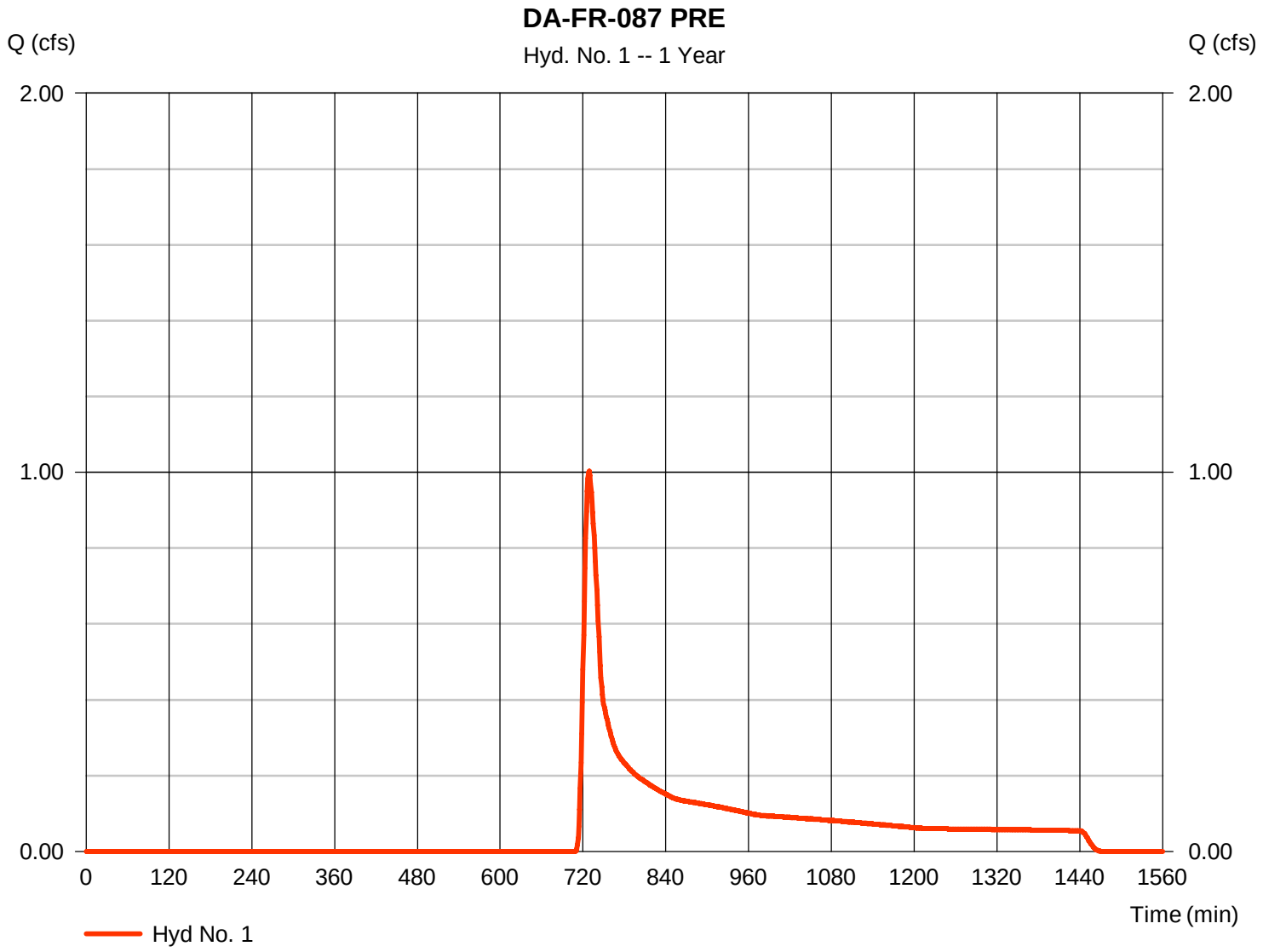
Hydrograph Report

Hyd. No. 1

DA-FR-087 PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 1.003 cfs
Storm frequency	= 1 yrs	Time to peak	= 729 min
Time interval	= 1 min	Hyd. volume	= 5,542 cuft
Drainage area	= 4.050 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 19.20 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.040 x 98) + (3.950 x 58) + (0.060 x 55)] / 4.050



TR55 Tc Worksheet

Hyd. No. 1

DA-FR-087 PRE

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 2.59		0.00		0.00		
Travel Time (min)	**= 18.01**	**+**	**0.00**	**+**	**0.00**	**=**	**18.01**
Shallow Concentrated Flow							
Flow length (ft)	= 293.44		0.00		0.00		
Watercourse slope (%)	= 6.98		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=4.26		0.00		0.00		
Travel Time (min)	**= 1.15**	**+**	**0.00**	**+**	**0.00**	**=**	**1.15**
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	= 0.015		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							**19.20 min**

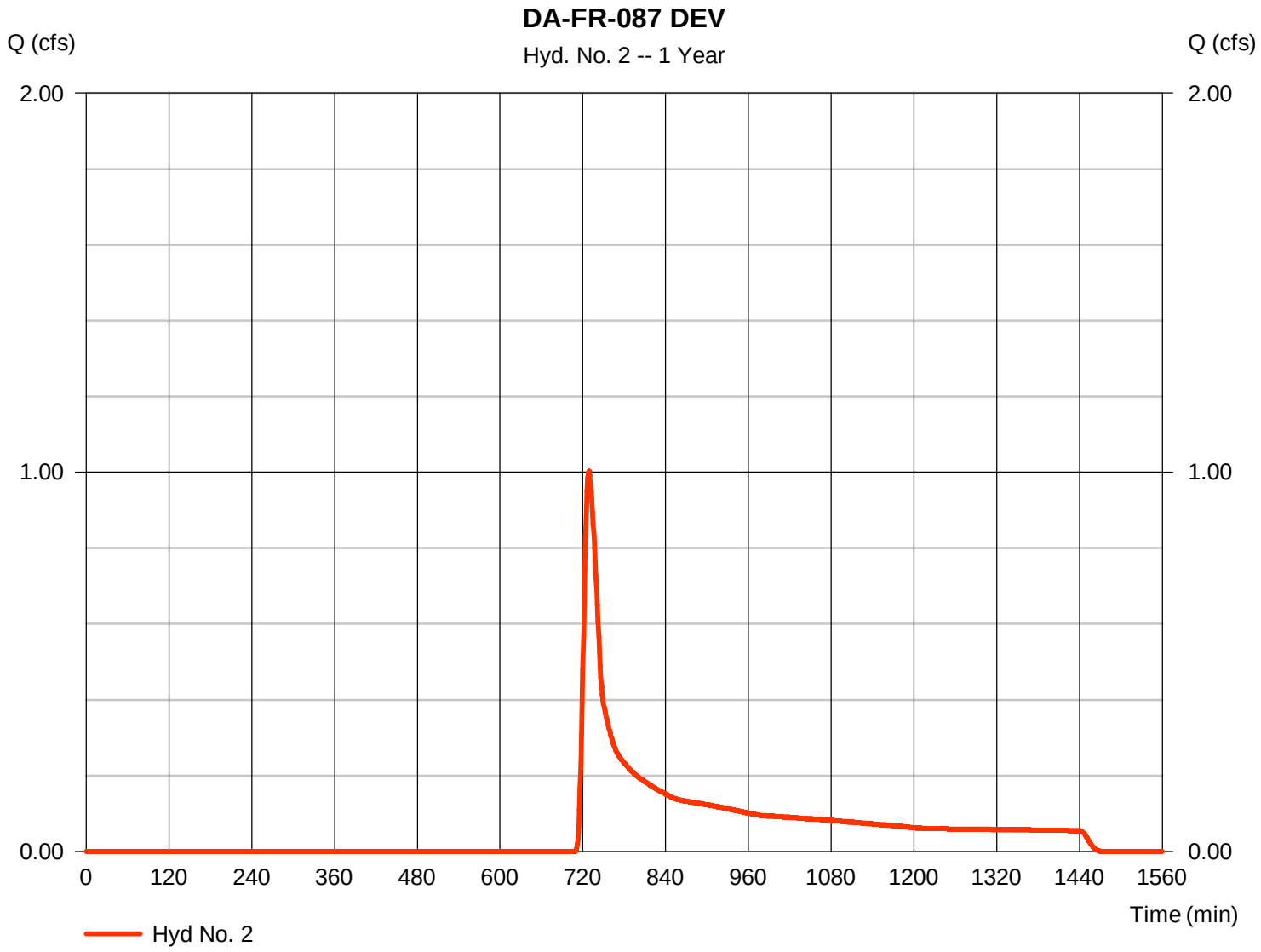
Hydrograph Report

Hyd. No. 2

DA-FR-087 DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 1.003 cfs
Storm frequency	= 1 yrs	Time to peak	= 729 min
Time interval	= 1 min	Hyd. volume	= 5,542 cuft
Drainage area	= 4.050 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 19.20 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.040 x 98) + (3.980 x 58) + (0.030 x 48)] / 4.050



TR55 Tc Worksheet

Hyd. No. 2

DA-FR-087 DEV

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 2.59		0.00		0.00		
Travel Time (min)	**= 18.01**	**+**	**0.00**	**+**	**0.00**	**=**	**18.01**
Shallow Concentrated Flow							
Flow length (ft)	= 169.41		88.86		0.00		
Watercourse slope (%)	= 6.69		7.79		0.00		
Surface description	= Unpaved		Unpaved		Paved		
Average velocity (ft/s)	=4.17		4.50		0.00		
Travel Time (min)	**= 0.68**	**+**	**0.33**	**+**	**0.00**	**=**	**1.01**
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})45.3		0.0		0.0		
Travel Time (min)	**= 0.16**	**+**	**0.00**	**+**	**0.00**	**=**	**0.16**

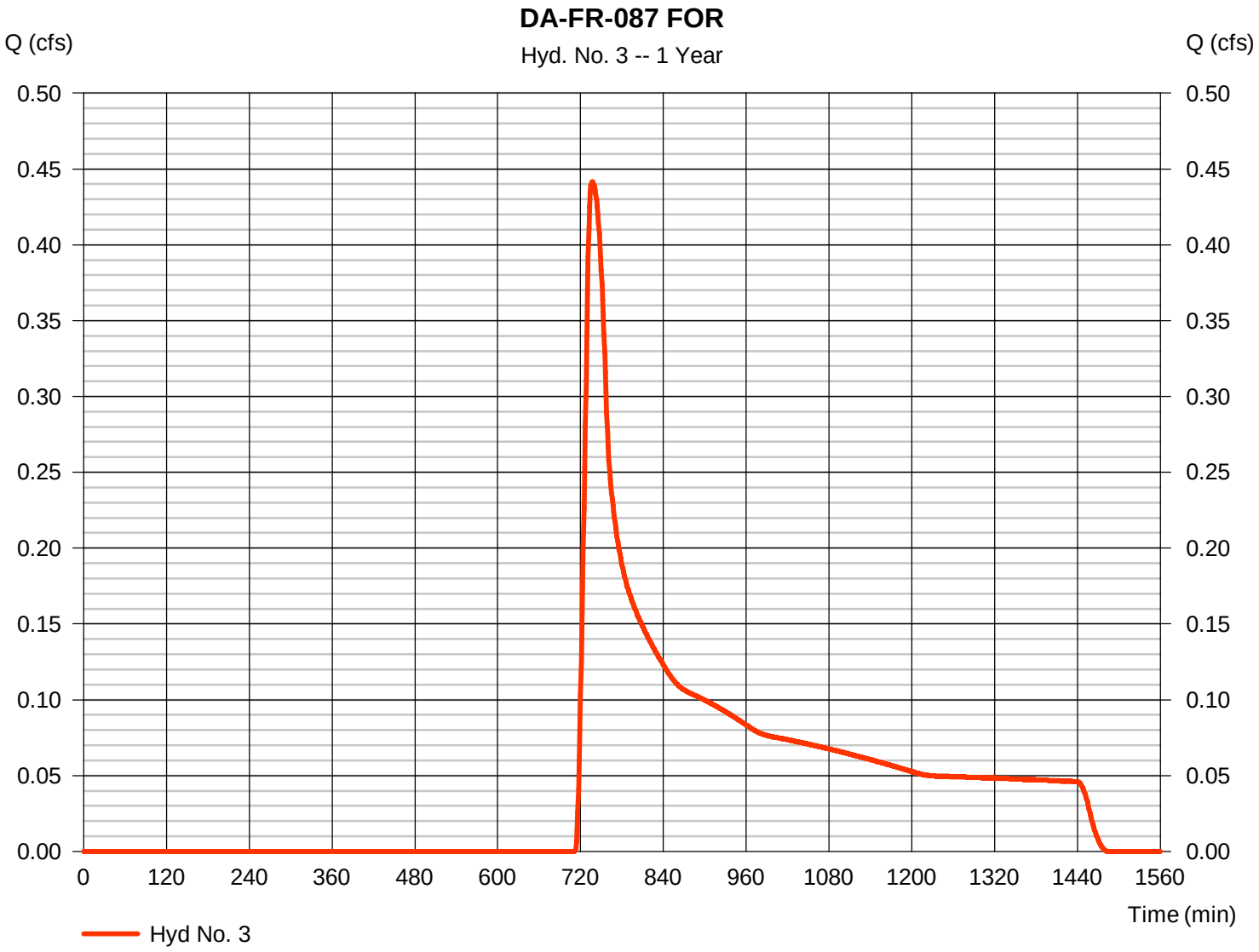
Total Travel Time, Tc ..... 19.20 min

Hydrograph Report

Hyd. No. 3

DA-FR-087 FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.441 cfs
Storm frequency	= 1 yrs	Time to peak	= 737 min
Time interval	= 1 min	Hyd. volume	= 4,102 cuft
Drainage area	= 4.050 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 28.70 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



TR55 Tc Worksheet

Hyd. No. 3

DA-FR-087 FOR

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.400		0.011		0.011		
Flow length (ft)	= 293.4		0.0		0.0		
Two-year 24-hr precip. (in)	= 3.70		0.00		0.00		
Land slope (%)	= 6.98		0.00		0.00		
Travel Time (min)	**= 28.66**	**+**	**0.00**	**+**	**0.00**	**=**	**28.66**
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	= 0.015		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 ..... 28.70 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	1.707	1	728	7,852	------	------	------	DA-FR-087 PRE
2	SCS Runoff	1.707	1	728	7,852	------	------	------	DA-FR-087 DEV
3	SCS Runoff	0.855	1	735	6,065	------	------	------	DA-FR-087 FOR

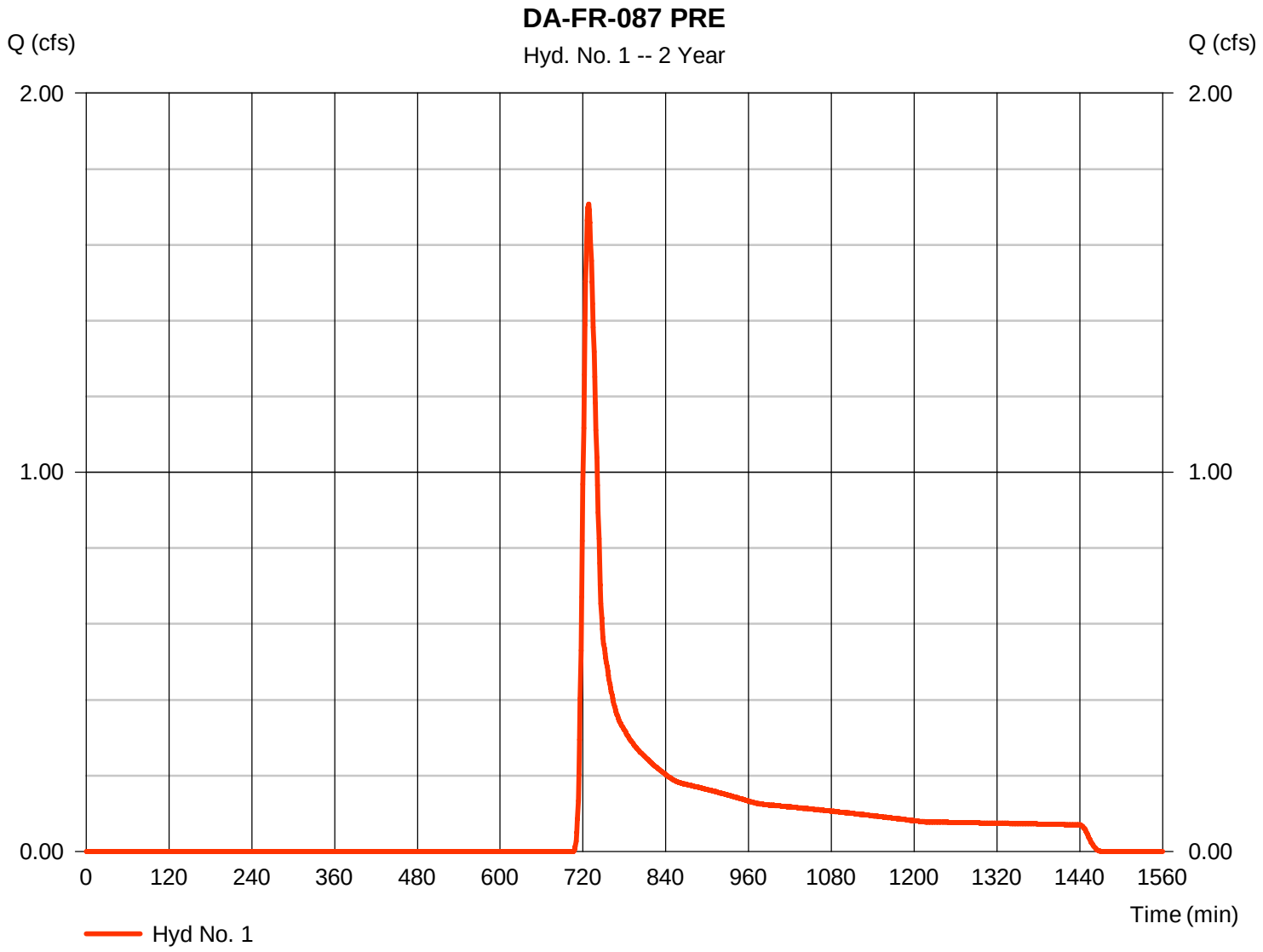
Hydrograph Report

Hyd. No. 1

DA-FR-087 PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 1.707 cfs
Storm frequency	= 2 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 7,852 cuft
Drainage area	= 4.050 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 19.20 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.040 x 98) + (3.950 x 58) + (0.060 x 55)] / 4.050



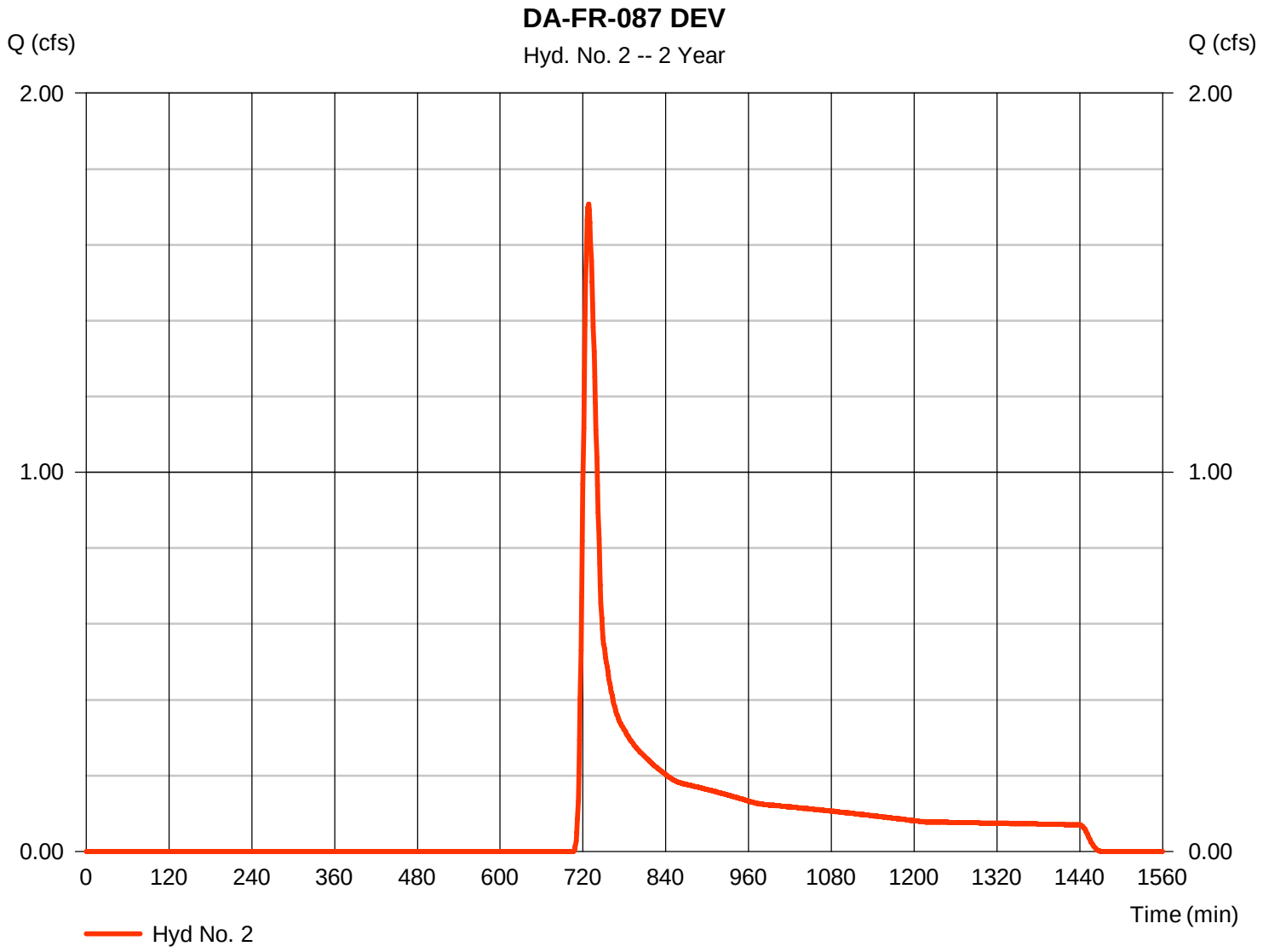
Hydrograph Report

Hyd. No. 2

DA-FR-087 DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 1.707 cfs
Storm frequency	= 2 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 7,852 cuft
Drainage area	= 4.050 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 19.20 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.040 x 98) + (3.980 x 58) + (0.030 x 48)] / 4.050

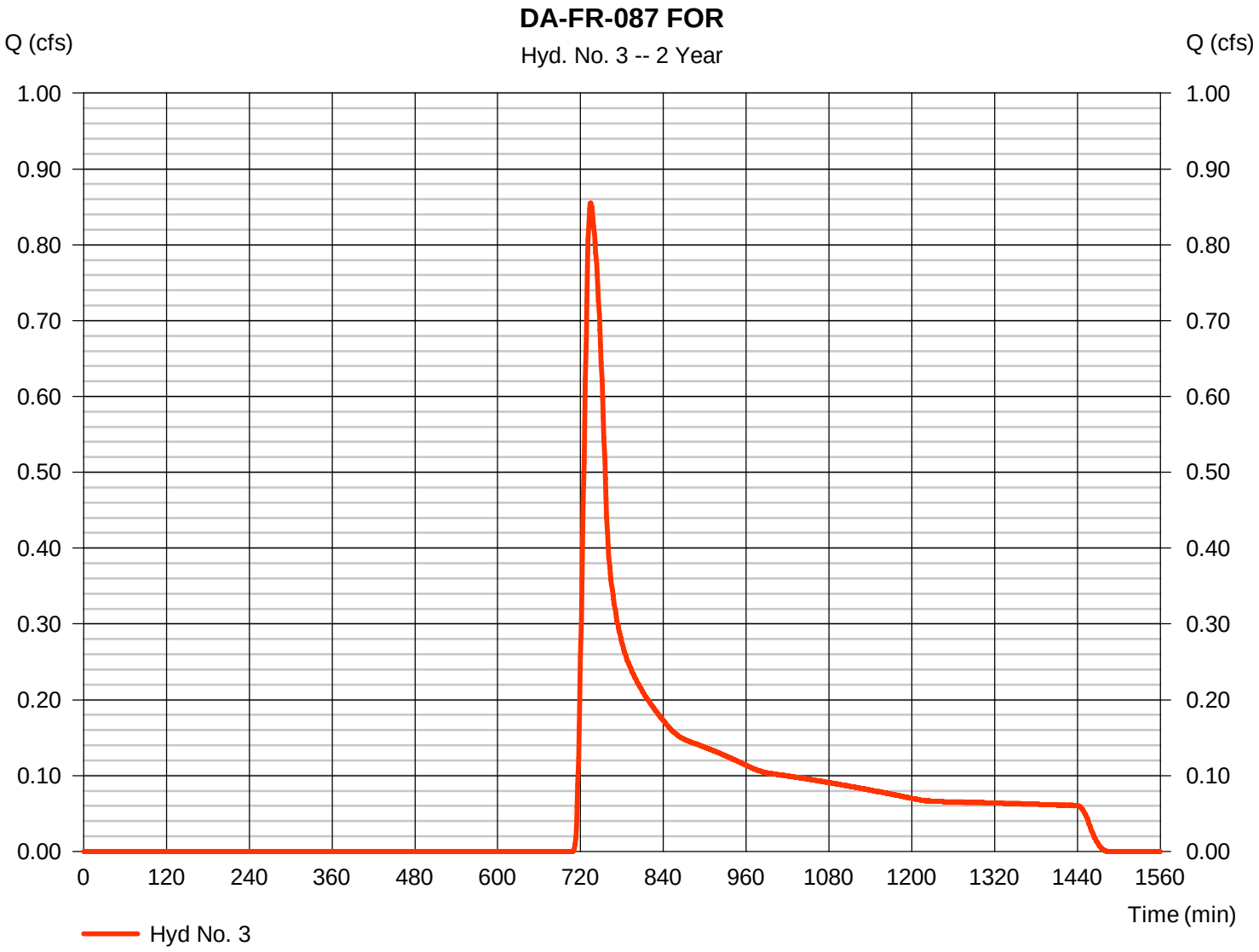


Hydrograph Report

Hyd. No. 3

DA-FR-087 FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.855 cfs
Storm frequency	= 2 yrs	Time to peak	= 735 min
Time interval	= 1 min	Hyd. volume	= 6,065 cuft
Drainage area	= 4.050 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 28.70 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



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	6.795	1	726	23,124	------	------	------	DA-FR-087 PRE
2	SCS Runoff	6.795	1	726	23,124	------	------	------	DA-FR-087 DEV
3	SCS Runoff	4.377	1	732	19,679	------	------	------	DA-FR-087 FOR

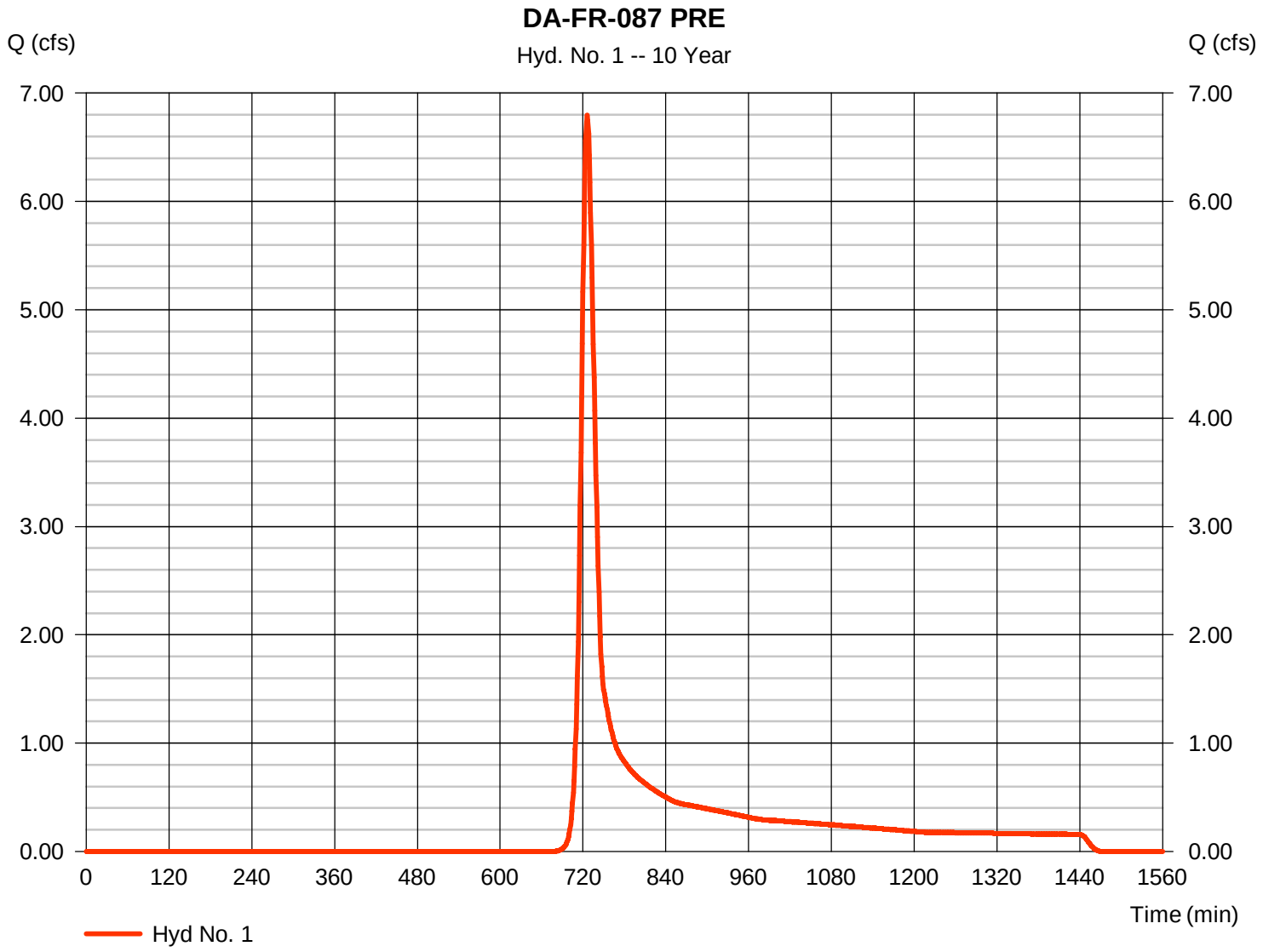
Hydrograph Report

Hyd. No. 1

DA-FR-087 PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 6.795 cfs
Storm frequency	= 10 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 23,124 cuft
Drainage area	= 4.050 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 19.20 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.040 x 98) + (3.950 x 58) + (0.060 x 55)] / 4.050



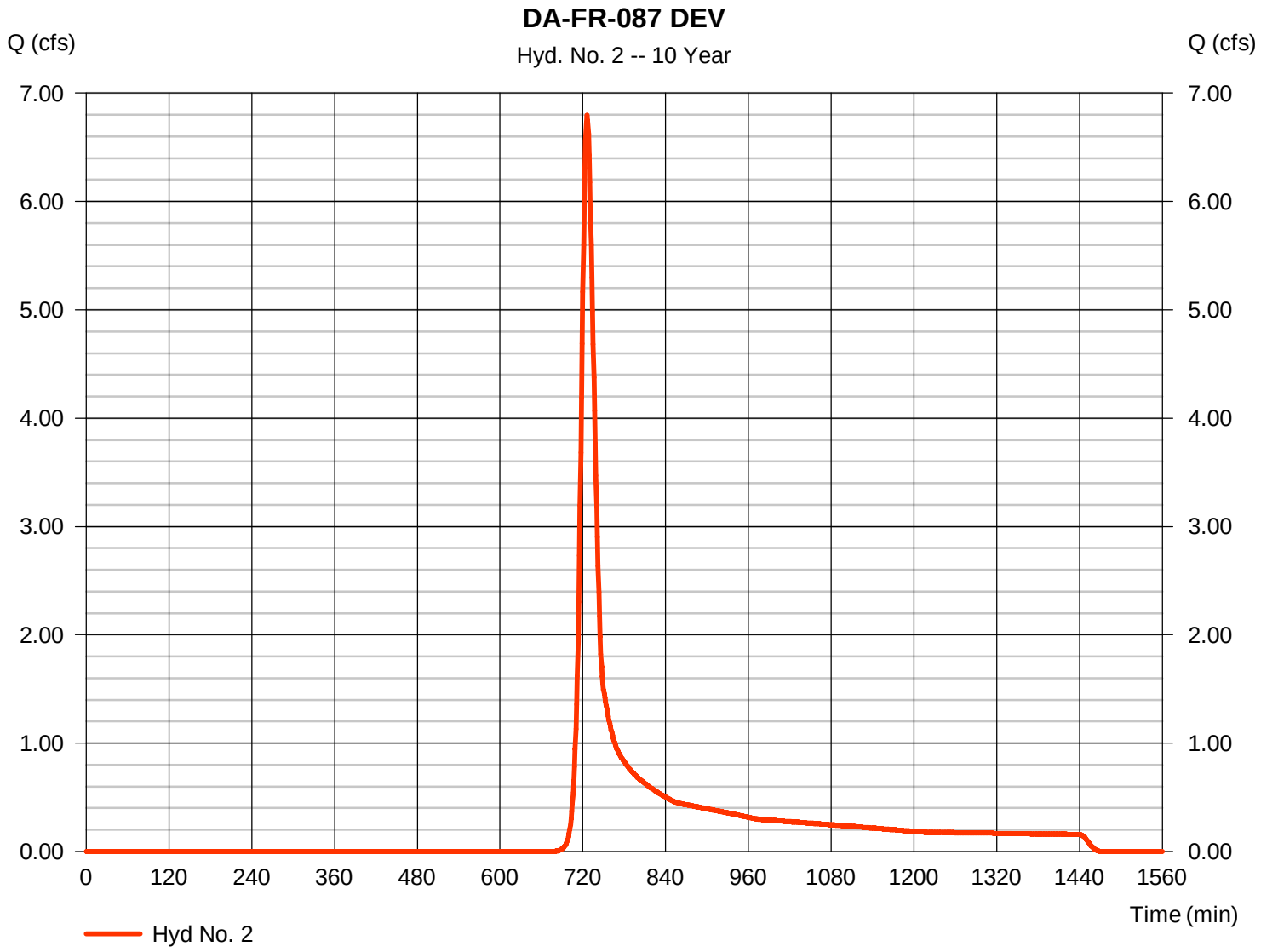
Hydrograph Report

Hyd. No. 2

DA-FR-087 DEV

Hydrograph type	=	SCS Runoff	Peak discharge	=	6.795 cfs
Storm frequency	=	10 yrs	Time to peak	=	726 min
Time interval	=	1 min	Hyd. volume	=	23,124 cuft
Drainage area	=	4.050 ac	Curve number	=	58*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	19.20 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.040 x 98) + (3.980 x 58) + (0.030 x 48)] / 4.050

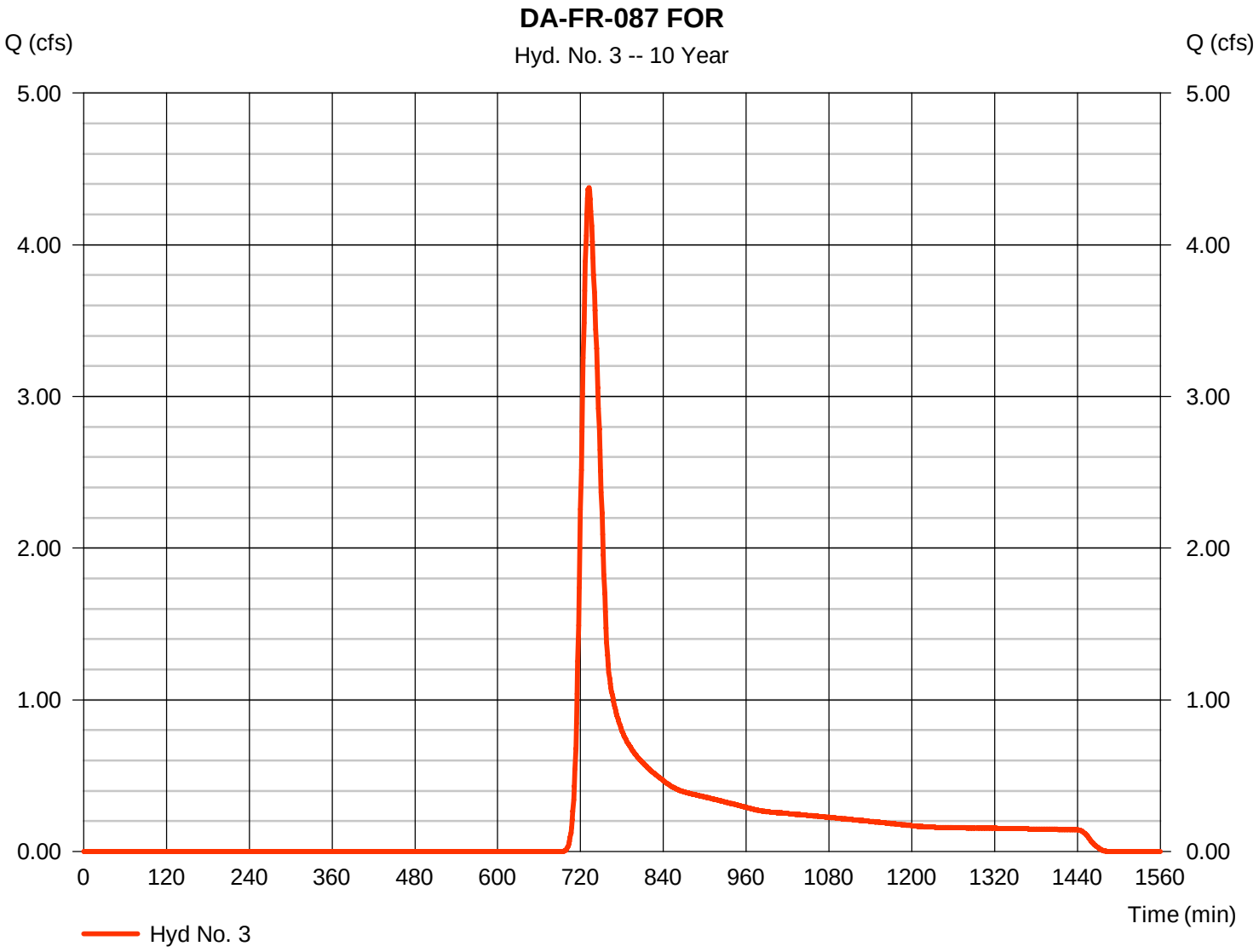


Hydrograph Report

Hyd. No. 3

DA-FR-087 FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 4.377 cfs
Storm frequency	= 10 yrs	Time to peak	= 732 min
Time interval	= 1 min	Hyd. volume	= 19,679 cuft
Drainage area	= 4.050 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 28.70 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



Hydraflow Rainfall Report

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

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

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

Tc = time in minutes. Values may exceed 60.

ng\Franklin County\Downloaded Files\Franklin County DA Batch 4 - 046 - 058\Precipitation\Hydraflow\FranklinCo.pc

Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.30	3.70	0.00	0.00	5.70	0.00	0.00	0.00
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

DA-FR-088

DA-FR-088 is located primarily within forested land use with a portion of meadow land use and has rolling to hilly slopes. A portion of Farm View Road is located on the western edge of the drainage area, driveways and residential property are located within the drainage area, but no new impervious area is proposed within DA-FR-088. The total phosphorus load reduction required for DA-FR-088 is -0.59 lb/yr. Multiple points of analysis were evaluated within DA-FR-088 to evaluate the effects on each receiving stream/channel following construction. Specifically DA-FR-088 was sub-divided into three sub-drainage areas (sub areas A through C).

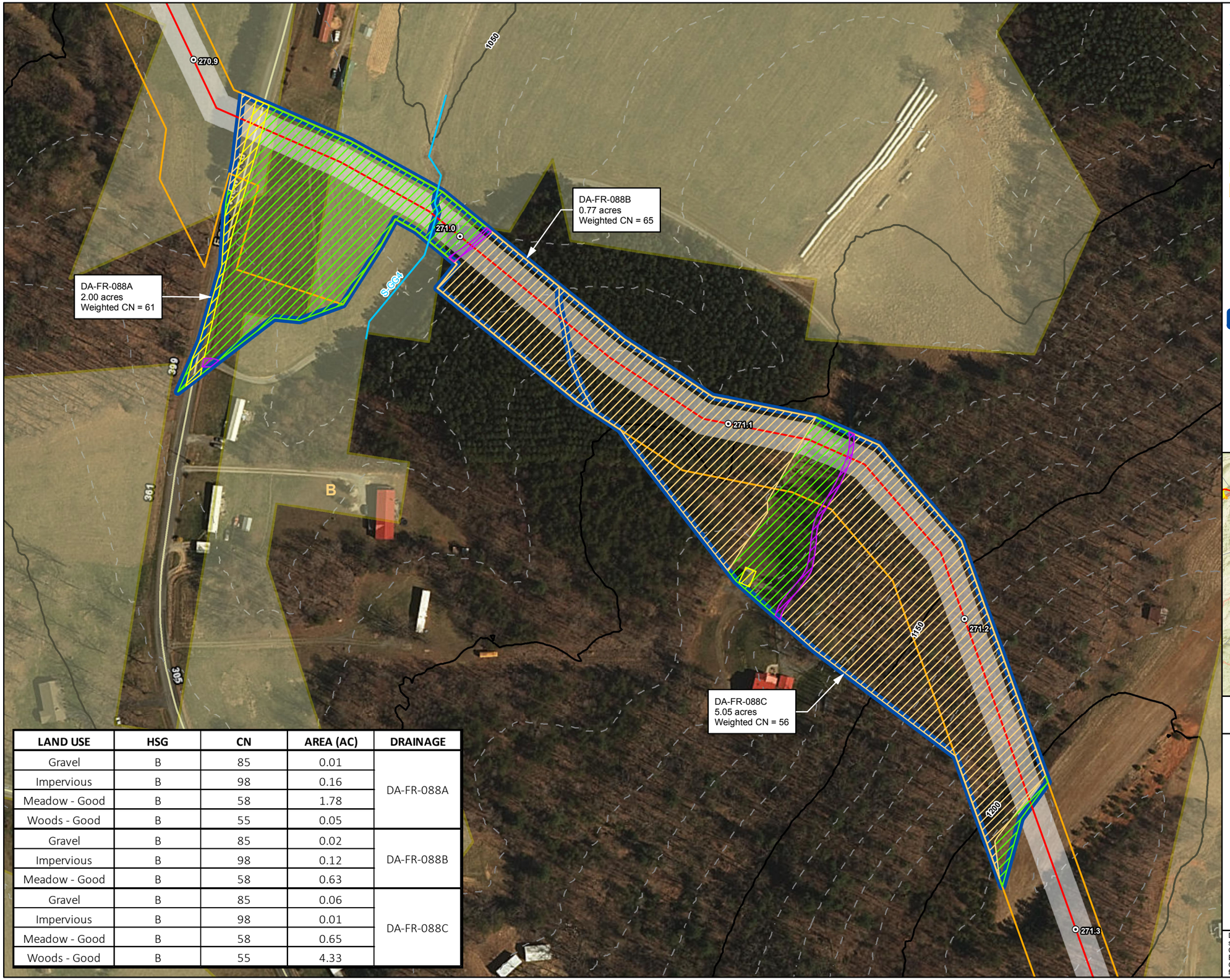
Sub-area 088A contains both agricultural and non-agricultural areas within the limits of disturbance (LOD). Pre-construction agricultural areas will be returned to agricultural land use (i.e., returned to crop production, in identical condition) following construction. In non-agricultural areas, land 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 Right of Way (ROW) is analyzed via VRRM; in these calculations agricultural areas are considered “Forest/Open Space”.

Stormwater quantity is met via the energy balance method for each of the three sub-areas DA-FR-088A, DA-FR-088B and DA-FR-088C. Agricultural areas within the study area are included in the SWM analysis, but an Improvement Factor (IF) of 1.0 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. DA-FR-088C is greater than an acre and used an IF of 0.8, and DA-FR-088B is less than an acre and used an IF of 0.9.

In addition, the Hydraflow Hydrograph’s 10-year 24-hour peak discharge results indicate a reduction in flows ranging from 0.00 to 1.43 cfs for all drainage areas (as seen in table below).

Sub Area	Pre Peak Flow, 10-yr Q (cfs)	Post Peak Flow, Q 10-yr (cfs)	Flow differential
DA-FR-088A	3.98	3.98	0.00
DA-FR-088B	2.29	0.86	-1.43
DA-FR-088C	9.39	8.17	-1.22

Figures and calculations for each of the sub-areas for DA-FR-088 follow. See Appendix D of the Annual Standards and Specifications for further detail on stormwater methodology.



LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Gravel	B	85	0.01	DA-FR-088A
Impervious	B	98	0.16	
Meadow - Good	B	58	1.78	
Woods - Good	B	55	0.05	
Gravel	B	85	0.02	DA-FR-088B
Impervious	B	98	0.12	
Meadow - Good	B	58	0.63	
Gravel	B	85	0.06	DA-FR-088C
Impervious	B	98	0.01	
Meadow - Good	B	58	0.65	
Woods - Good	B	55	4.33	

Legend

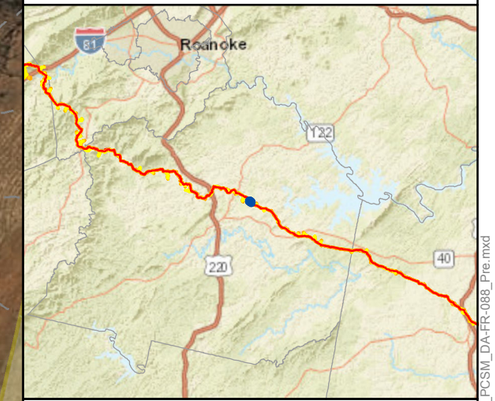
- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Agricultural Area
- Limit of Disturbance
- Permanent Right-of-Way
- Gravel
- Impervious
- Meadow
- Woods
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

1:1,800

N W E S

150 75 0 150 Feet



Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Pre-Construction Drainage Area Map
DA-FR-088
Spread 11

Figure 1
Franklin County, Virginia

August, 2017

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

Document Path: PGH P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Franklin\MVP_PCSM_DA-FR-088_Pre.mxd

DA-FR-088A
2.00 acres
Weighted CN = 61

DA-FR-088B
0.77 acres
Weighted CN = 53

DA-FR-088C
5.05 acres
Weighted CN = 54

DA-FR-088 Permanent ROW
2.04 acres

270.9
271.0
271.1
271.2
271.3
1050
1150
1200
360
361
305
S-SC4
B

LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Gravel	B	85	0.01	DA-FR-088A
Impervious	B	98	0.16	
Meadow - Good	B	58	1.83	
Woods - Good	B	55	0.00	
Gravel	B	85	0.02	DA-FR-088B
Meadow - Good	B	58	0.33	
Brush	B	48	0.42	
Gravel	B	85	0.06	DA-FR-088C
Impervious	B	98	0.01	
Meadow - Good	B	58	1.87	
Woods - Good	B	55	1.36	
Brush	B	48	1.74	

Legend

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

NAD 1983 UTM 17N (feet)

1:1,800

N
W E
S

150 75 0 150 Feet



Mountain Valley Pipeline Project

Mountain Valley PIPELINE

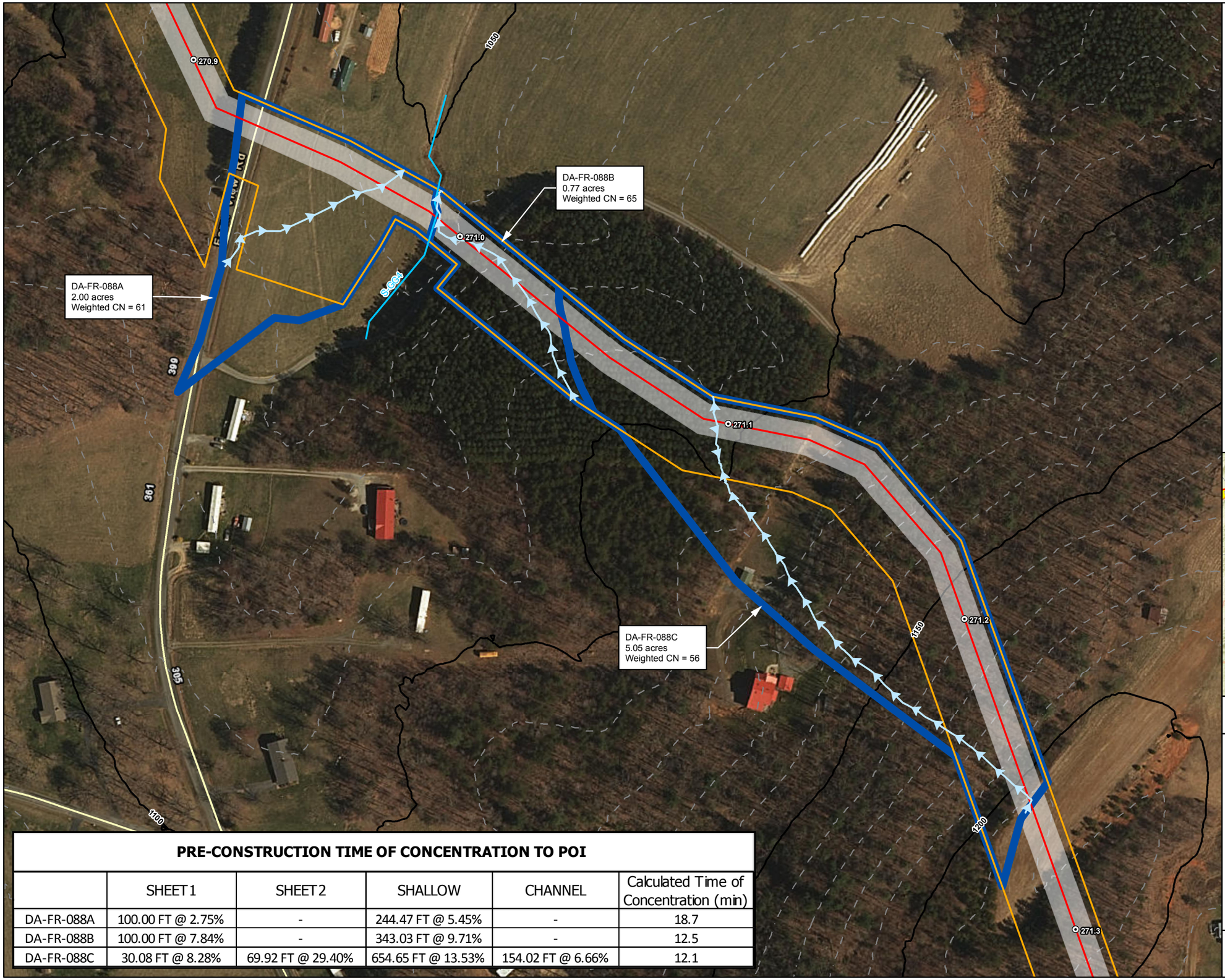
Post-Construction Drainage Area Map
DA-FR-088
Spread 11

Figure 2
Franklin County, Virginia

August, 2017

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

Document Path: PGH P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Franklin\MVP_PCSM_DA-FR-088_Post.mxd



PRE-CONSTRUCTION TIME OF CONCENTRATION TO POI

	SHEET 1	SHEET 2	SHALLOW	CHANNEL	Calculated Time of Concentration (min)
DA-FR-088A	100.00 FT @ 2.75%	-	244.47 FT @ 5.45%	-	18.7
DA-FR-088B	100.00 FT @ 7.84%	-	343.03 FT @ 9.71%	-	12.5
DA-FR-088C	30.08 FT @ 8.28%	69.92 FT @ 29.40%	654.65 FT @ 13.53%	154.02 FT @ 6.66%	12.1

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)

1:1,800

N W E S

150 75 0 150 Feet



Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Pre-Construction Drainage Area and Time of Concentration
DA-FR-088
Spread 11

Figure 3
Franklin 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.

Document Path: P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Franklin\Figures 3-4\MVP_PCSM_DA-FR-088_3.mxd

DA-FR-088A
2.00 acres
Weighted CN = 61

DA-FR-088B
0.77 acres
Weighted CN = 53

DA-FR-088C
5.05 acres
Weighted CN = 54

270.9
271.0
271.1
271.2
271.3
1050
1150
1200
1100
Sec4
399
361
305

POST-CONSTRUCTION TIME OF CONCENTRATION TO POI

	SHEET 1	SHEET 2	SHALLOW1	SHALLOW2	CHANNEL	Calculated Time of Concentration (min)
DA-FR-088A	100.00 FT @ 2.75%	-	244.47 FT @ 5.45%		-	18.7
DA-FR-088B	100.00 FT @ 7.84%	-	86.44 FT @ 9.63%	215.40 FT @ 10.84%	32.80 FT @ 4.92%	20.6
DA-FR-088C	84.70 FT @ 23.72%	15.30 FT @ 19.32%	654.65 FT @ 13.53%		154.02 FT @ 6.66%	12.3

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)

1:1,800

150 75 0 150 Feet

N W E S



Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Post-Construction Drainage Area and Time of Concentration
DA-FR-088
Spread 11

Figure 4
Franklin 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\Franklin\Figures 3-4\MVP_PCSM_DA-FR-088_4.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:	**2.04**

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	1.99	0.00	0.00	1.99	98
Managed Turf (acres)	0.00	0.00	0.00	0.00	0.00	0
Impervious Cover (acres)	0.00	0.05	0.00	0.00	0.05	2
					2.04	100

Post-ReDevelopment Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	% of Total	
Forest/Open (acres)	0.00	1.99	0.00	0.00	1.99	98	*
Managed Turf (acres)	0.00	0.00	0.00	0.00	0.00	0	
Impervious Cover (acres)	0.00	0.05	0.00	0.00	0.05	2	
					2.04	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)	389	389	--	389
TP Load (lb/yr)	0.24	0.24	--	0.24

Baseline TP Load (lb/yr): 0.8364* **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)
0.12	**0.12**	**0.12**

Total TP Load Reduction Required (lb/yr)	**-0.59**	N/A***	N/A***

******This is a linear development project***

	Final Post-Development Load (Post-ReDevelopment & New Impervious)	Pre-ReDevelopment
TN Load (lb/yr)	1.75	1.75

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 0.84 lb/yr (0.41 lb/ac/yr)*
[Post-Dev Reduction Requirement = Post-Dev TP load - baseline load of 0.84 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)	0.24
Remaining TP Load Reduction (lb/yr) Required	**0.00**

**** TARGET TP REDUCTION EXCEEDED BY 0.59 LB/YEAR ****

**Reduction below new development load limitation not required*

DA-FR-088A

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.776	3525
Developed Condition	0.776	3525
Pre-Developed (Forest) Condition	0.272	2041

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

Improvement Factor, IF = 1

Calculations:

Check #1: $Q_{developed} \leq IF \times [(Q_{pre\text{-}developed} \times RV_{pre\text{-}developed}) / RV_{developed}]$ ----------> 0.776 ≤ 0.776 OK

Check #2: $Q_{developed} \leq Q_{pre\text{-}developed}$ ----------> 0.776 ≤ 0.776 OK

Check #3: $Q_{developed}$ *shall not* be required to be ≤ $(Q_{forest} \times RV_{forest}) / RV_{developed}$ ---> 0.776 *shall not* be required to be ≤ 0.157

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

Note:

Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.

For Paved Road land surface types a Manning's n value 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

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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-FR-088A PRE
2	SCS Runoff	DA-FR-088A DEV
3	SCS Runoff	DA-FR-088A FOR

Hydrograph Return Period Recap

Hyd. No.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)							Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	------	0.776	1.199	-------	-------	3.980	-------	-------	-------	DA-FR-088A PRE
2	SCS Runoff	------	0.776	1.199	-------	-------	3.980	-------	-------	-------	DA-FR-088A DEV
3	SCS Runoff	------	0.272	0.538	-------	-------	2.743	-------	-------	-------	DA-FR-088A FOR

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	0.776	1	728	3,525	------	------	------	DA-FR-088A PRE
2	SCS Runoff	0.776	1	728	3,525	------	------	------	DA-FR-088A DEV
3	SCS Runoff	0.272	1	730	2,041	------	------	------	DA-FR-088A FOR

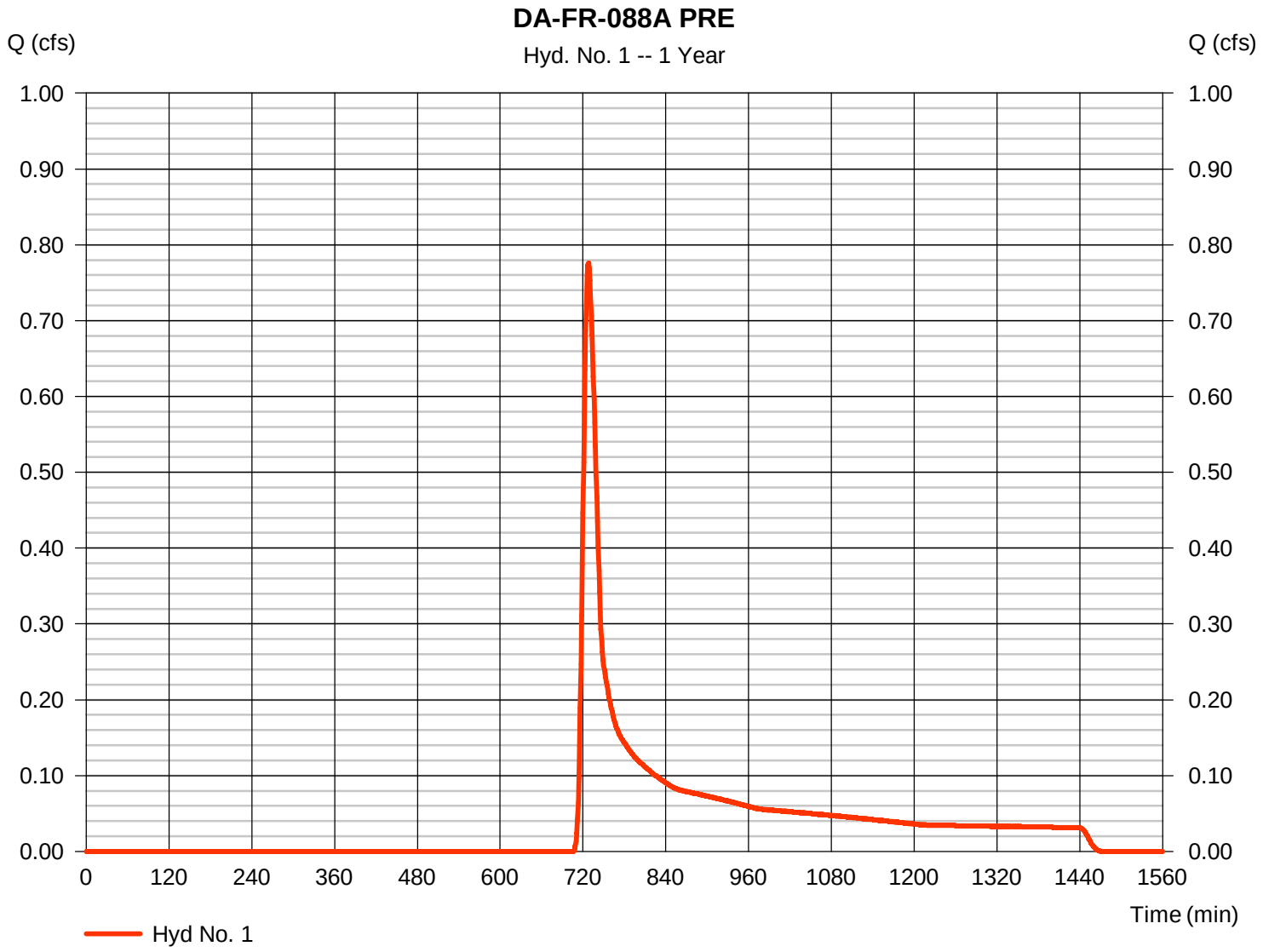
Hydrograph Report

Hyd. No. 1

DA-FR-088A PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.776 cfs
Storm frequency	= 1 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 3,525 cuft
Drainage area	= 2.000 ac	Curve number	= 61*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.70 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.006 x 85) + (0.162 x 98) + (1.782 x 58) + (0.049 x 55)] / 2.000



TR55 Tc Worksheet

Hyd. No. 1

DA-FR-088A PRE

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 2.75		0.00		0.00		
Travel Time (min)	**= 17.58**	**+**	**0.00**	**+**	**0.00**	**=**	**17.58**
Shallow Concentrated Flow							
Flow length (ft)	= 244.47		0.00		0.00		
Watercourse slope (%)	= 5.45		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=3.77		0.00		0.00		
Travel Time (min)	**= 1.08**	**+**	**0.00**	**+**	**0.00**	**=**	**1.08**
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	= 0.015		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 ..... 18.70 min

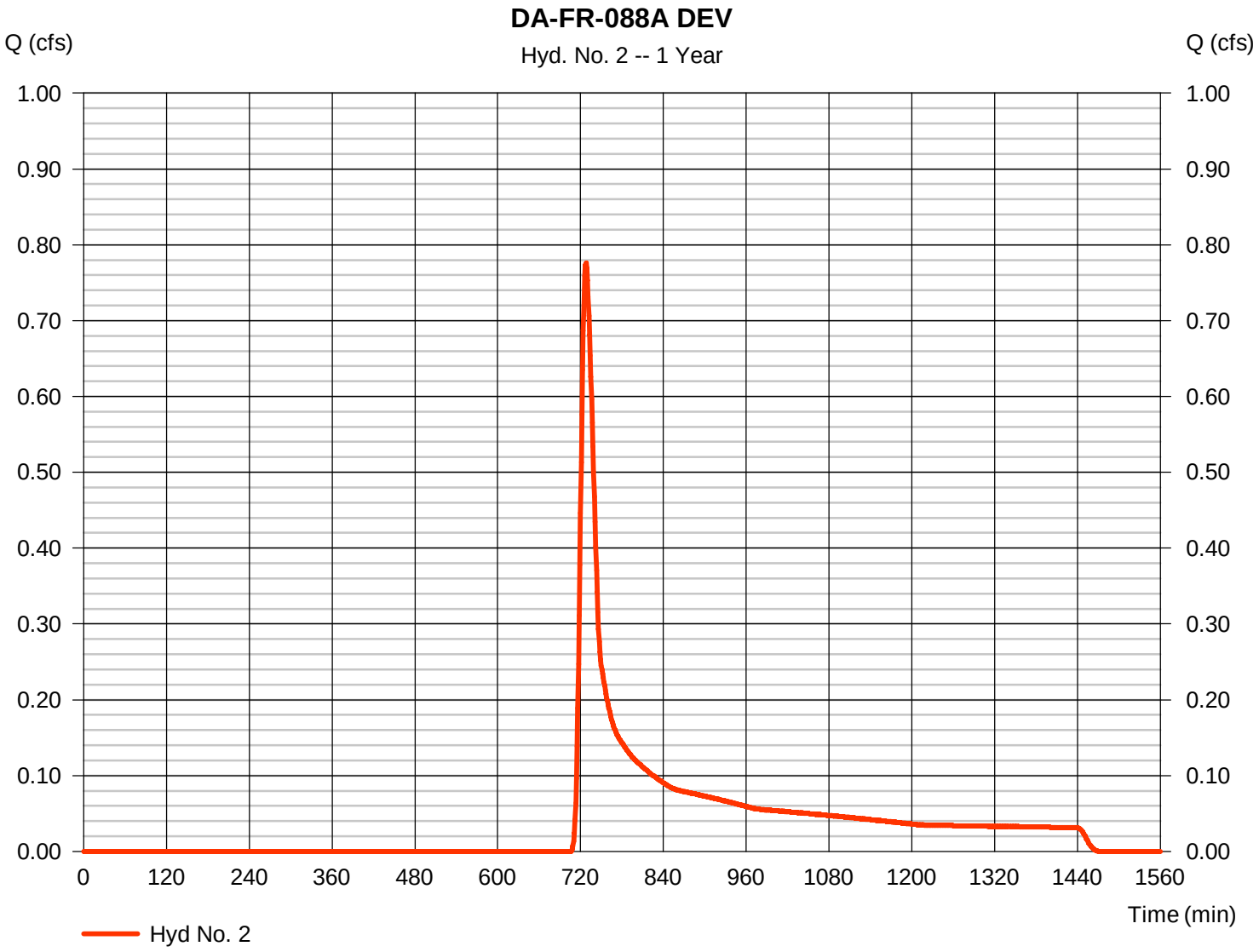
Hydrograph Report

Hyd. No. 2

DA-FR-088A DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.776 cfs
Storm frequency	= 1 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 3,525 cuft
Drainage area	= 2.000 ac	Curve number	= 61*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.70 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.006 x 85) + (0.162 x 98) + (1.827 x 58) + (0.004 x 55)] / 2.000



TR55 Tc Worksheet

Hyd. No. 2

DA-FR-088A DEV

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 2.75		0.00		0.00		
Travel Time (min)	**= 17.58**	**+**	**0.00**	**+**	**0.00**	**=**	**17.58**
Shallow Concentrated Flow							
Flow length (ft)	= 244.47		0.00		0.00		
Watercourse slope (%)	= 5.45		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=3.77		0.00		0.00		
Travel Time (min)	**= 1.08**	**+**	**0.00**	**+**	**0.00**	**=**	**1.08**
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	= 0.015		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**

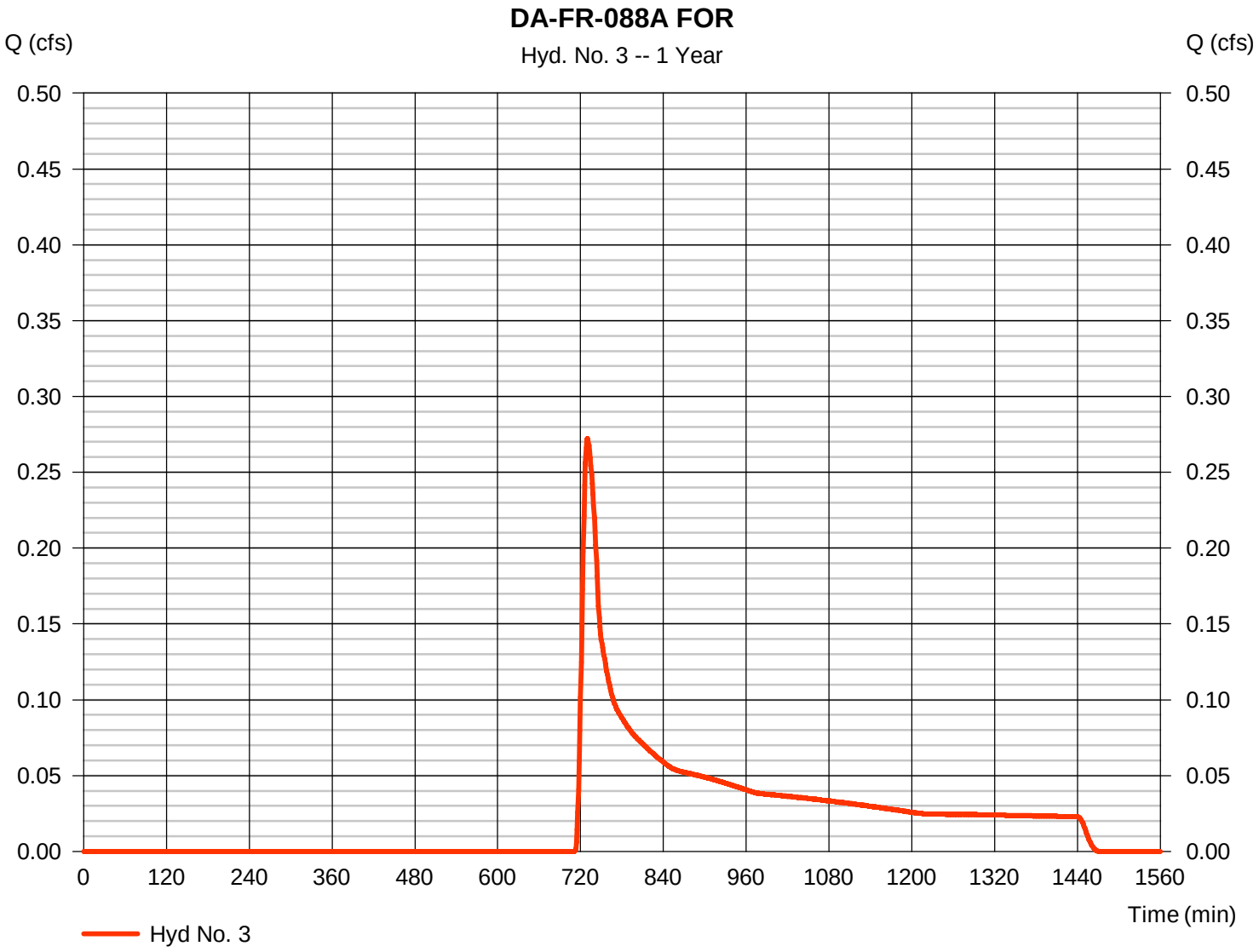
Total Travel Time, Tc ..... 18.70 min

Hydrograph Report

Hyd. No. 3

DA-FR-088A FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.272 cfs
Storm frequency	= 1 yrs	Time to peak	= 730 min
Time interval	= 1 min	Hyd. volume	= 2,041 cuft
Drainage area	= 2.000 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.70 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



TR55 Tc Worksheet

Hyd. No. 3

DA-FR-088A FOR

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 2.75		0.00		0.00		
Travel Time (min)	**= 17.58**	**+**	**0.00**	**+**	**0.00**	**=**	**17.58**
Shallow Concentrated Flow							
Flow length (ft)	= 244.47		0.00		0.00		
Watercourse slope (%)	= 5.45		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=3.77		0.00		0.00		
Travel Time (min)	**= 1.08**	**+**	**0.00**	**+**	**0.00**	**=**	**1.08**
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	= 0.015		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 ..... 18.70 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	1.199	1	727	4,829	------	------	------	DA-FR-088A PRE
2	SCS Runoff	1.199	1	727	4,829	------	------	------	DA-FR-088A DEV
3	SCS Runoff	0.538	1	729	3,017	------	------	------	DA-FR-088A FOR

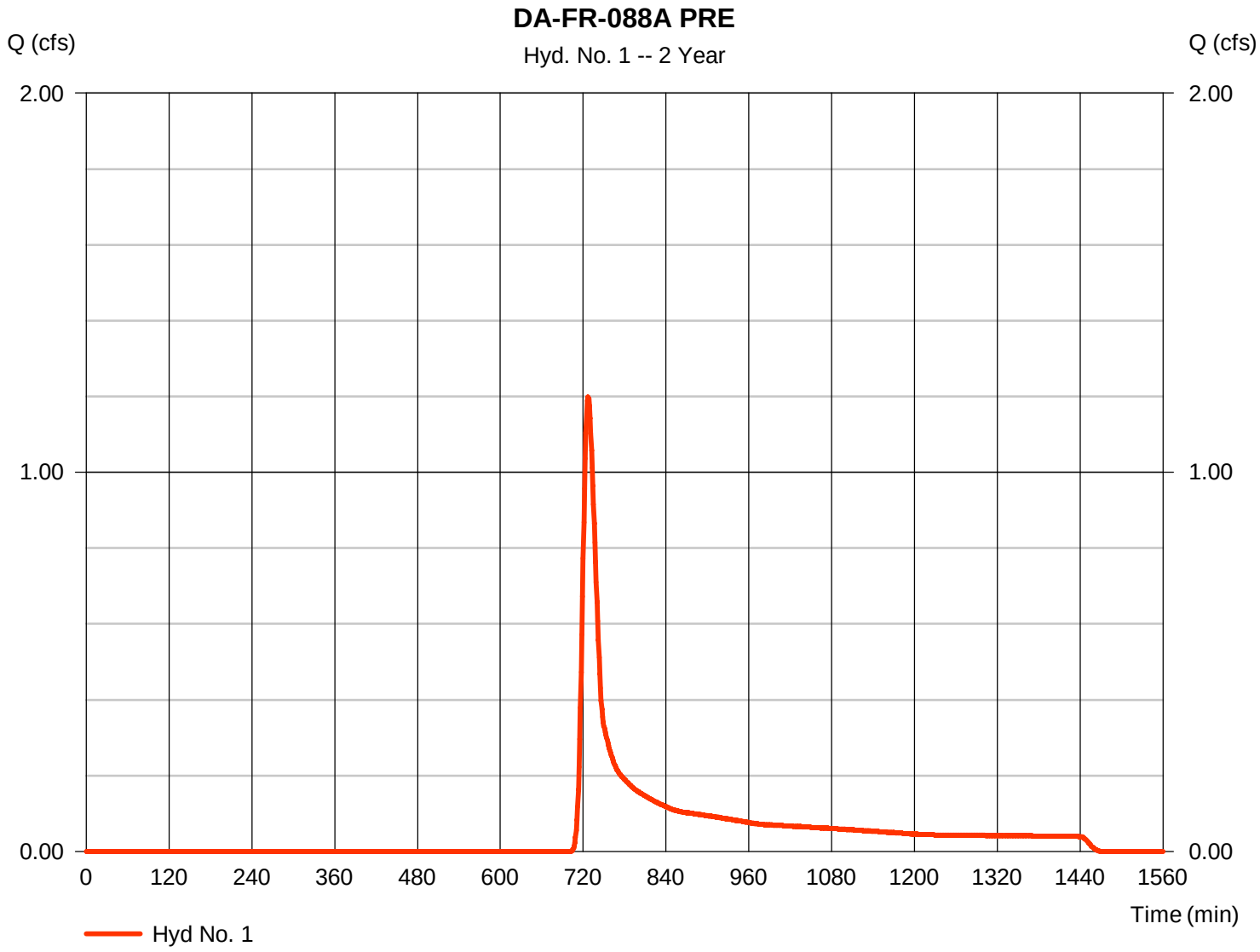
Hydrograph Report

Hyd. No. 1

DA-FR-088A PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	1.199 cfs
Storm frequency	=	2 yrs	Time to peak	=	727 min
Time interval	=	1 min	Hyd. volume	=	4,829 cuft
Drainage area	=	2.000 ac	Curve number	=	61*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	18.70 min
Total precip.	=	3.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.006 x 85) + (0.162 x 98) + (1.782 x 58) + (0.049 x 55)] / 2.000



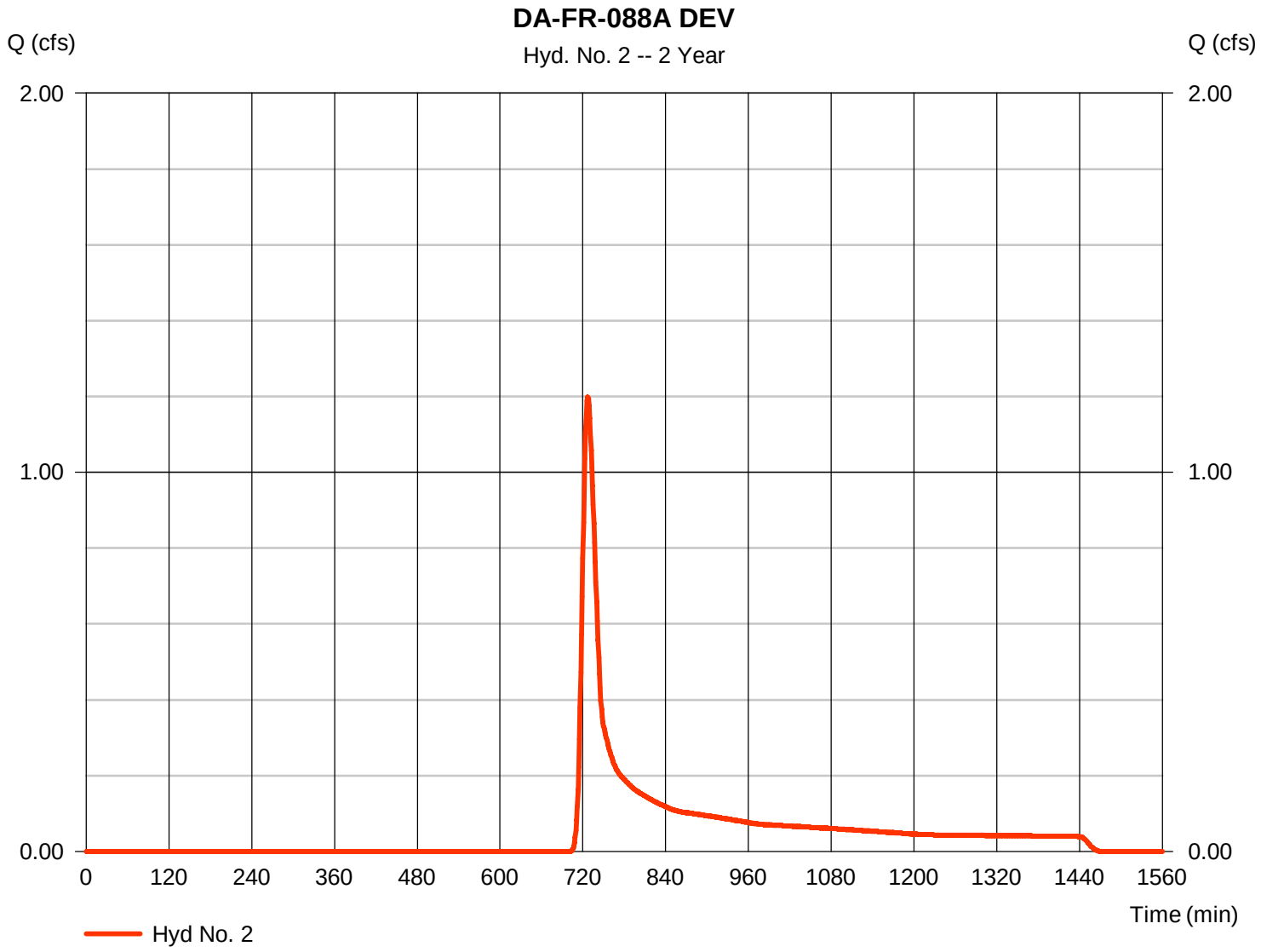
Hydrograph Report

Hyd. No. 2

DA-FR-088A DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 1.199 cfs
Storm frequency	= 2 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 4,829 cuft
Drainage area	= 2.000 ac	Curve number	= 61*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.70 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.006 x 85) + (0.162 x 98) + (1.827 x 58) + (0.004 x 55)] / 2.000

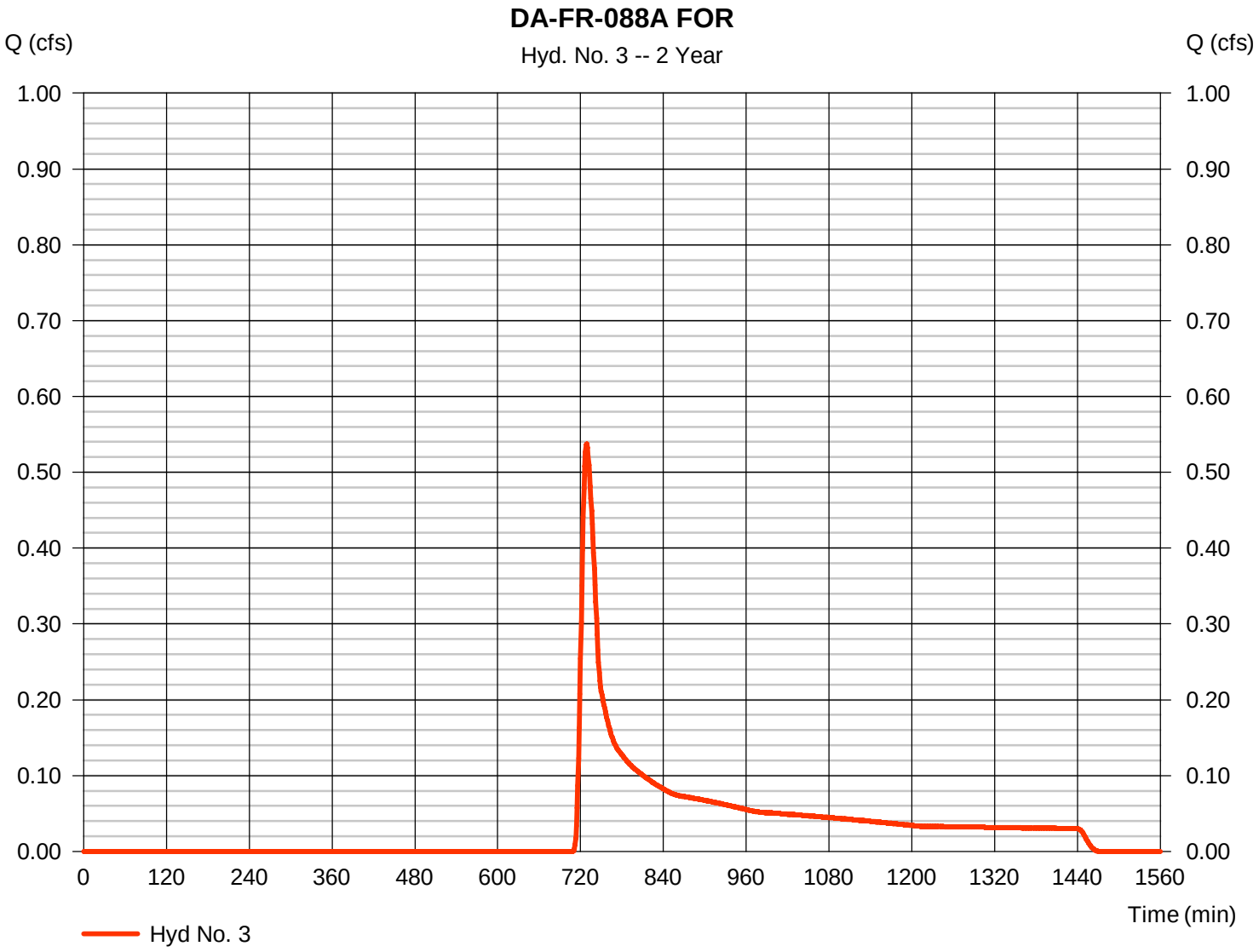


Hydrograph Report

Hyd. No. 3

DA-FR-088A FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.538 cfs
Storm frequency	= 2 yrs	Time to peak	= 729 min
Time interval	= 1 min	Hyd. volume	= 3,017 cuft
Drainage area	= 2.000 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.70 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



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	3.980	1	726	13,123	------	------	------	DA-FR-088A PRE
2	SCS Runoff	3.980	1	726	13,123	------	------	------	DA-FR-088A DEV
3	SCS Runoff	2.743	1	726	9,790	------	------	------	DA-FR-088A FOR

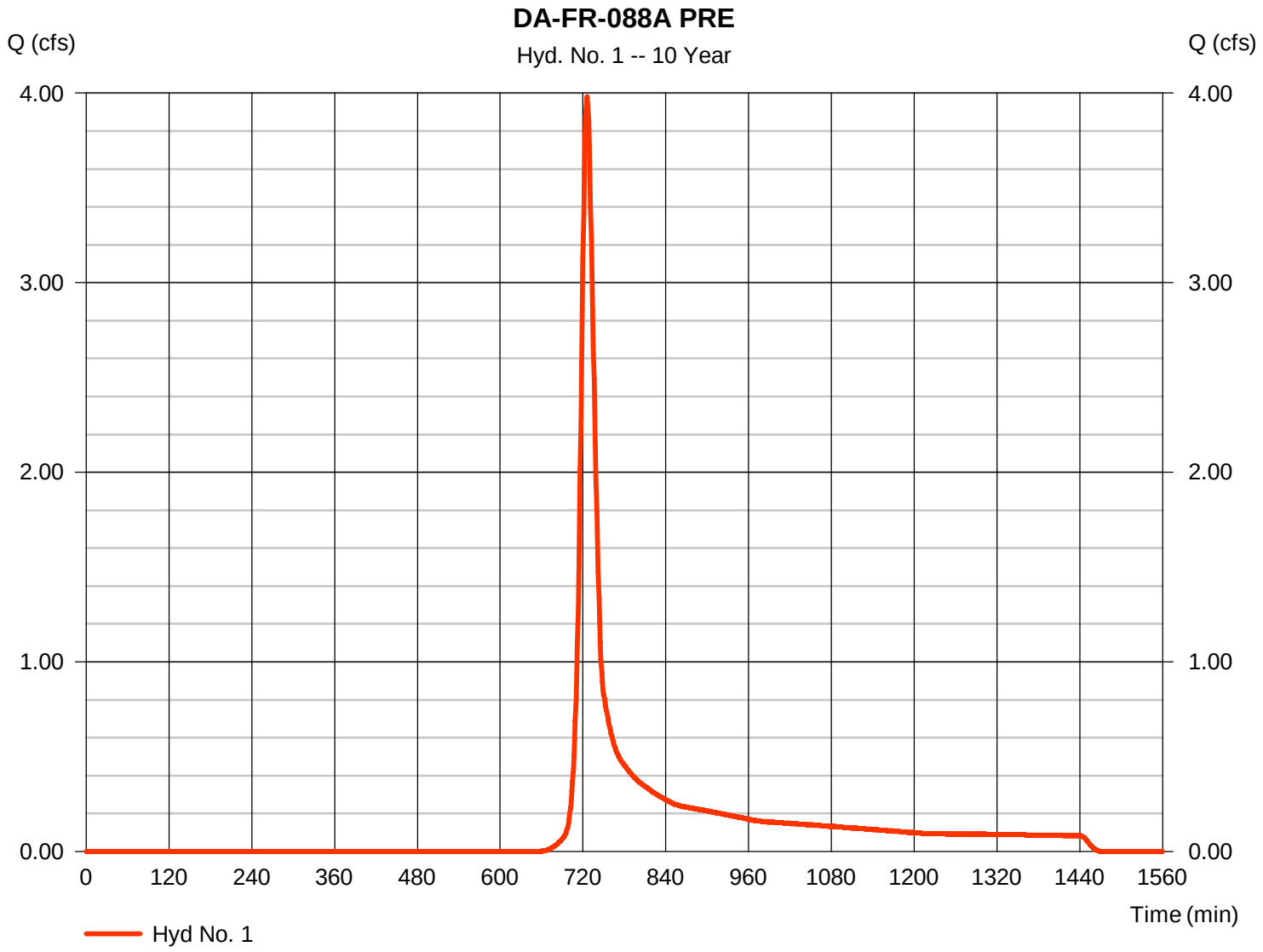
Hydrograph Report

Hyd. No. 1

DA-FR-088A PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	3.980 cfs
Storm frequency	=	10 yrs	Time to peak	=	726 min
Time interval	=	1 min	Hyd. volume	=	13,123 cuft
Drainage area	=	2.000 ac	Curve number	=	61*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	18.70 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.006 x 85) + (0.162 x 98) + (1.782 x 58) + (0.049 x 55)] / 2.000



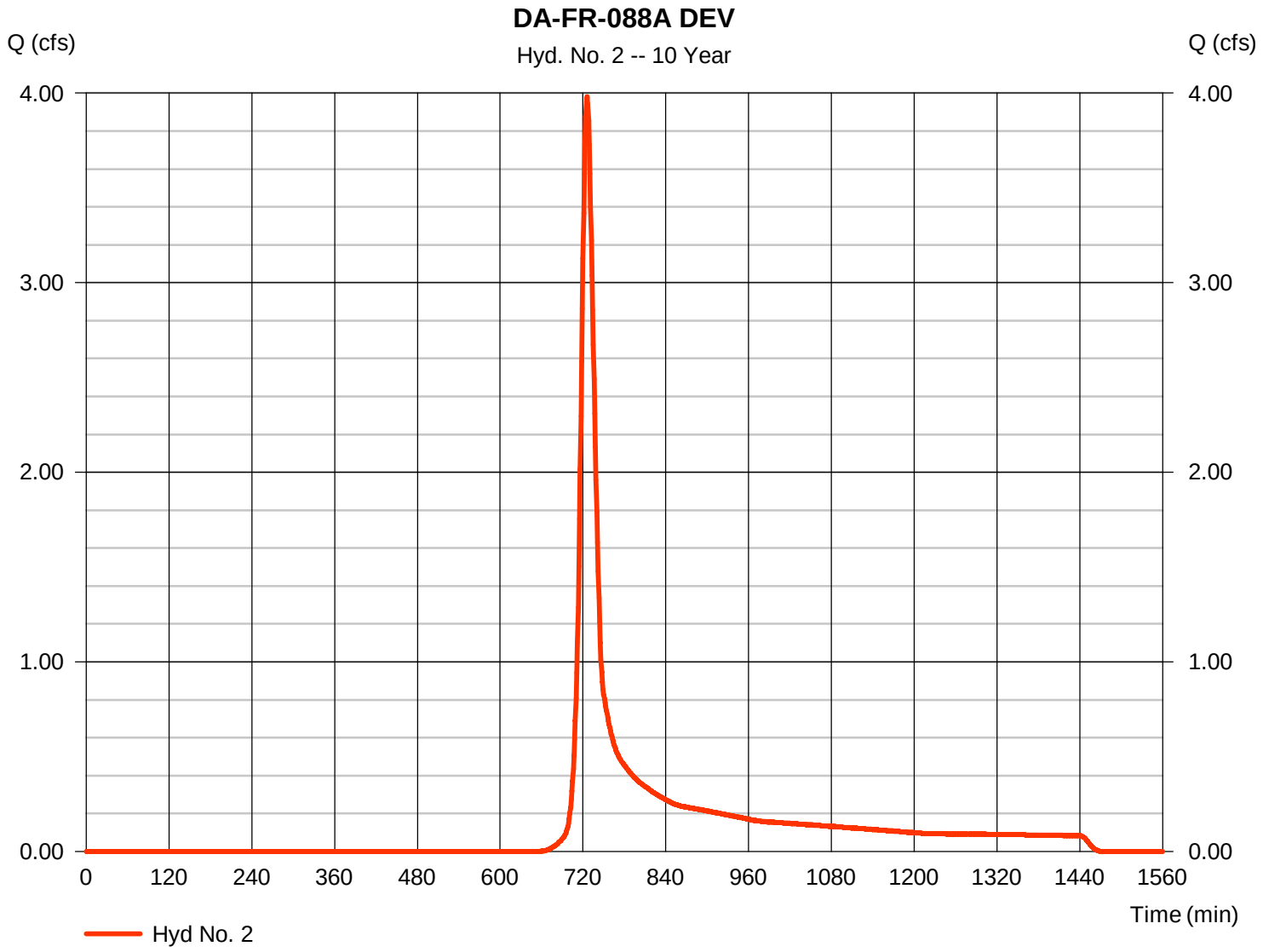
Hydrograph Report

Hyd. No. 2

DA-FR-088A DEV

Hydrograph type	=	SCS Runoff	Peak discharge	=	3.980 cfs
Storm frequency	=	10 yrs	Time to peak	=	726 min
Time interval	=	1 min	Hyd. volume	=	13,123 cuft
Drainage area	=	2.000 ac	Curve number	=	61*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	18.70 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.006 x 85) + (0.162 x 98) + (1.827 x 58) + (0.004 x 55)] / 2.000

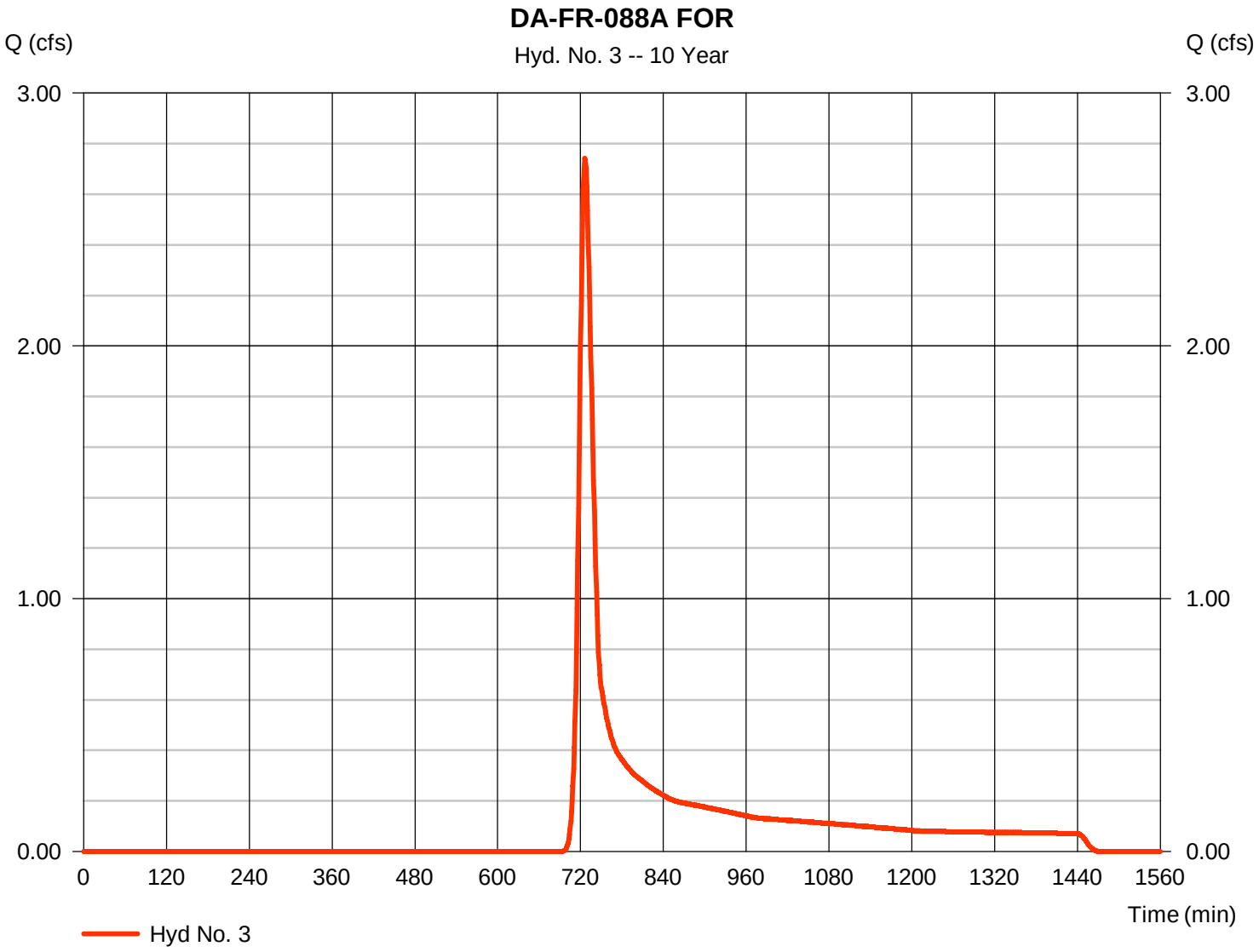


Hydrograph Report

Hyd. No. 3

DA-FR-088A FOR

Hydrograph type	=	SCS Runoff	Peak discharge	=	2.743 cfs
Storm frequency	=	10 yrs	Time to peak	=	726 min
Time interval	=	1 min	Hyd. volume	=	9,790 cuft
Drainage area	=	2.000 ac	Curve number	=	55
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	18.70 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484



Hydraflow Rainfall Report

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

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

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

Tc = time in minutes. Values may exceed 60.

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Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.30	3.70	0.00	0.00	5.70	0.00	0.00	0.00
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

DA-FR-088B

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.605	1787
Developed Condition	0.059	663
Pre-Developed (Forest) Condition	0.137	773

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

Improvement Factor, IF = 0.9

Calculations:

Check #1:	$Q_{developed} \leq IF \times [(Q_{pre\text{-}developed} \times RV_{pre\text{-}developed}) / RV_{developed}]$ ---------->	0.059	≤ OK	1.468
Check #2:	$Q_{developed} \leq Q_{pre\text{-}developed}$ ---------->	0.059	≤ OK	0.605
Check #3:	$Q_{developed}$ *shall not* be required to be ≤ $(Q_{forest} \times RV_{forest}) / RV_{developed}$ --->	0.059	*shall not* be required to be ≤	0.160

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

Note:

Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.

For Paved Road land surface types a Manning's n value 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 Channels[1]			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels[2]			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150

Notes:

[1]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 or grass channel.

[2]For the pre-developed condition (if applicable), 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-FR-088B PRE
2	SCS Runoff	DA-FR-088B DEV
3	SCS Runoff	DA-FR-088B FOR

Hydrograph Return Period Recap

Hyd. No.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)							Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	------	0.605	0.848	-------	-------	2.291	-------	-------	-------	DA-FR-088B PRE
2	SCS Runoff	------	0.059	0.134	-------	-------	0.858	-------	-------	-------	DA-FR-088B DEV
3	SCS Runoff	------	0.137	0.272	-------	-------	1.338	-------	-------	-------	DA-FR-088B FOR

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	0.605	1	722	1,787	------	------	------	DA-FR-088B PRE
2	SCS Runoff	0.059	1	735	633	------	------	------	DA-FR-088B DEV
3	SCS Runoff	0.137	1	725	773	------	------	------	DA-FR-088B FOR

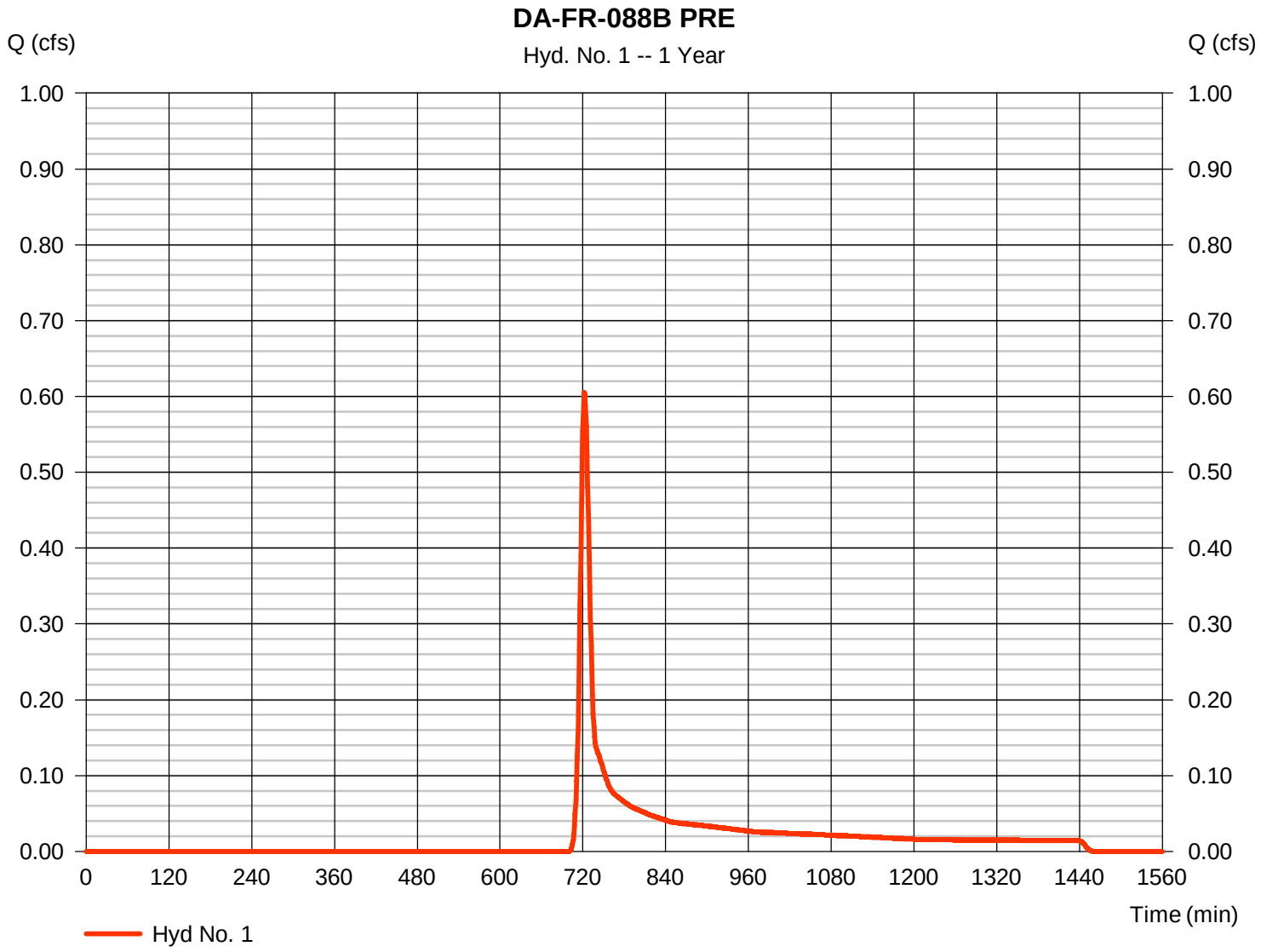
Hydrograph Report

Hyd. No. 1

DA-FR-088B PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.605 cfs
Storm frequency	= 1 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 1,787 cuft
Drainage area	= 0.770 ac	Curve number	= 65*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 12.50 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.017 x 85) + (0.120 x 98) + (0.634 x 58)] / 0.770



TR55 Tc Worksheet

Hyd. No. 1

DA-FR-088B PRE

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 7.84		0.00		0.00		
Travel Time (min)	**= 11.56**	**+**	**0.00**	**+**	**0.00**	**=**	**11.56**
Shallow Concentrated Flow							
Flow length (ft)	= 293.44		0.00		0.00		
Watercourse slope (%)	= 9.71		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=5.03		0.00		0.00		
Travel Time (min)	**= 0.97**	**+**	**0.00**	**+**	**0.00**	**=**	**0.97**
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	= 0.015		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 ..... 12.50 min

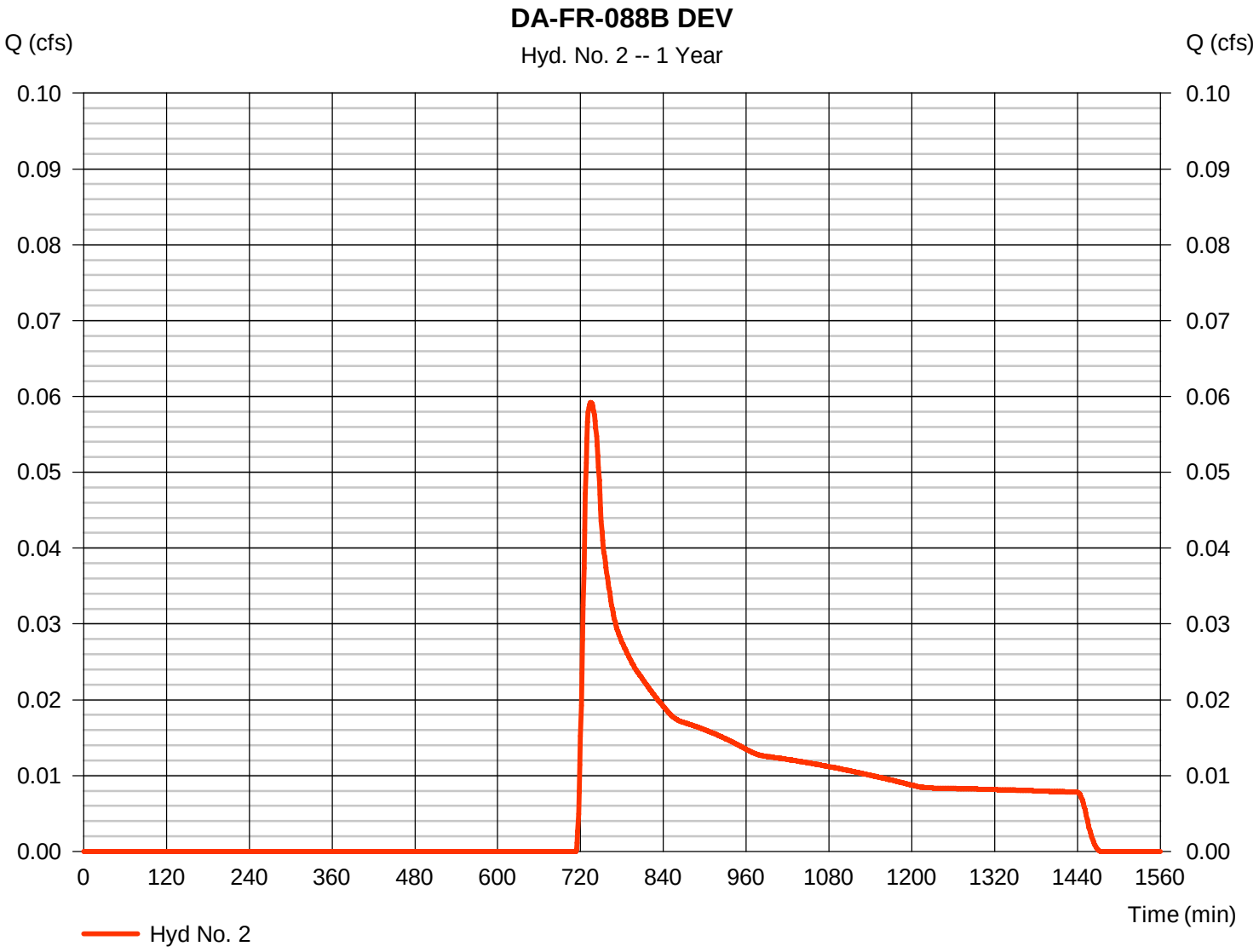
Hydrograph Report

Hyd. No. 2

DA-FR-088B DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.059 cfs
Storm frequency	= 1 yrs	Time to peak	= 735 min
Time interval	= 1 min	Hyd. volume	= 633 cuft
Drainage area	= 0.770 ac	Curve number	= 53*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 20.60 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.017 x 85) + (0.332 x 58) + (0.423 x 48)] / 0.770



TR55 Tc Worksheet

Hyd. No. 2

DA-FR-088B DEV

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.800		0.011		0.011		
Flow length (ft)	= 100.0		0.0		0.0		
Two-year 24-hr precip. (in)	= 3.70		0.00		0.00		
Land slope (%)	= 7.84		0.00		0.00		
Travel Time (min)	**= 20.13**	**+**	**0.00**	**+**	**0.00**	**=**	**20.13**
Shallow Concentrated Flow							
Flow length (ft)	= 86.44		0.00		0.00		
Watercourse slope (%)	= 9.63		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=5.01		0.00		0.00		
Travel Time (min)	**= 0.29**	**+**	**0.00**	**+**	**0.00**	**=**	**0.29**
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		
Flow length (ft)	({0})45.3		0.0		0.0		
Travel Time (min)	**= 0.16**	**+**	**0.00**	**+**	**0.00**	**=**	**0.16**

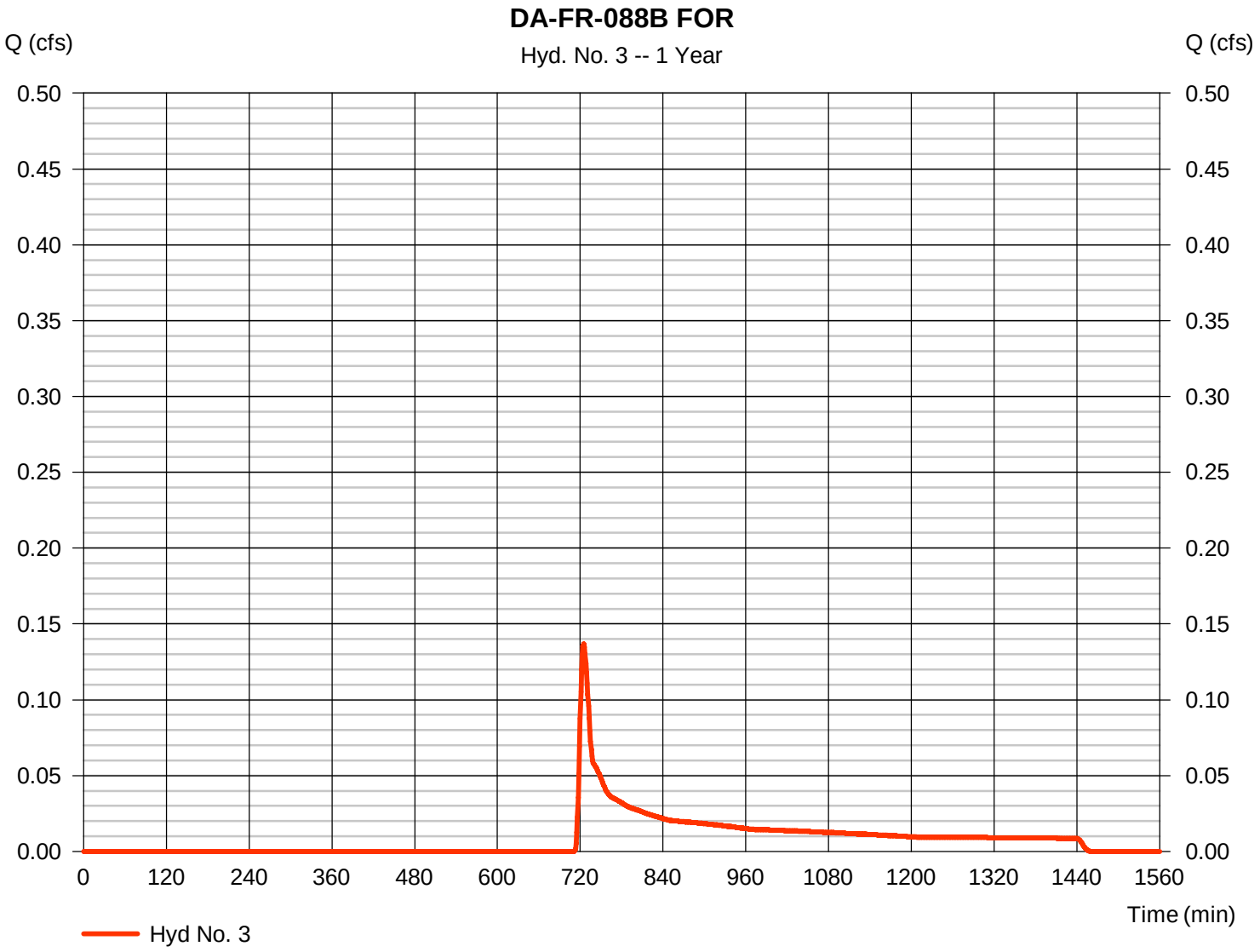
Total Travel Time, Tc ..... 20.60 min

Hydrograph Report

Hyd. No. 3

DA-FR-088B FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.137 cfs
Storm frequency	= 1 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 773 cuft
Drainage area	= 0.770 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 12.70 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



TR55 Tc Worksheet

Hyd. No. 3

DA-FR-088B FOR

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 7.84		0.00		0.00		
Travel Time (min)	**= 11.56**	**+**	**0.00**	**+**	**0.00**	**=**	**11.56**
Shallow Concentrated Flow							
Flow length (ft)	= 343.03		0.00		0.00		
Watercourse slope (%)	= 9.71		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=5.03		0.00		0.00		
Travel Time (min)	**= 1.14**	**+**	**0.00**	**+**	**0.00**	**=**	**1.14**
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	= 0.015		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 ..... 12.70 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	0.848	1	722	2,364	------	------	------	DA-FR-088B PRE
2	SCS Runoff	0.134	1	731	970	------	------	------	DA-FR-088B DEV
3	SCS Runoff	0.272	1	724	1,143	------	------	------	DA-FR-088B FOR

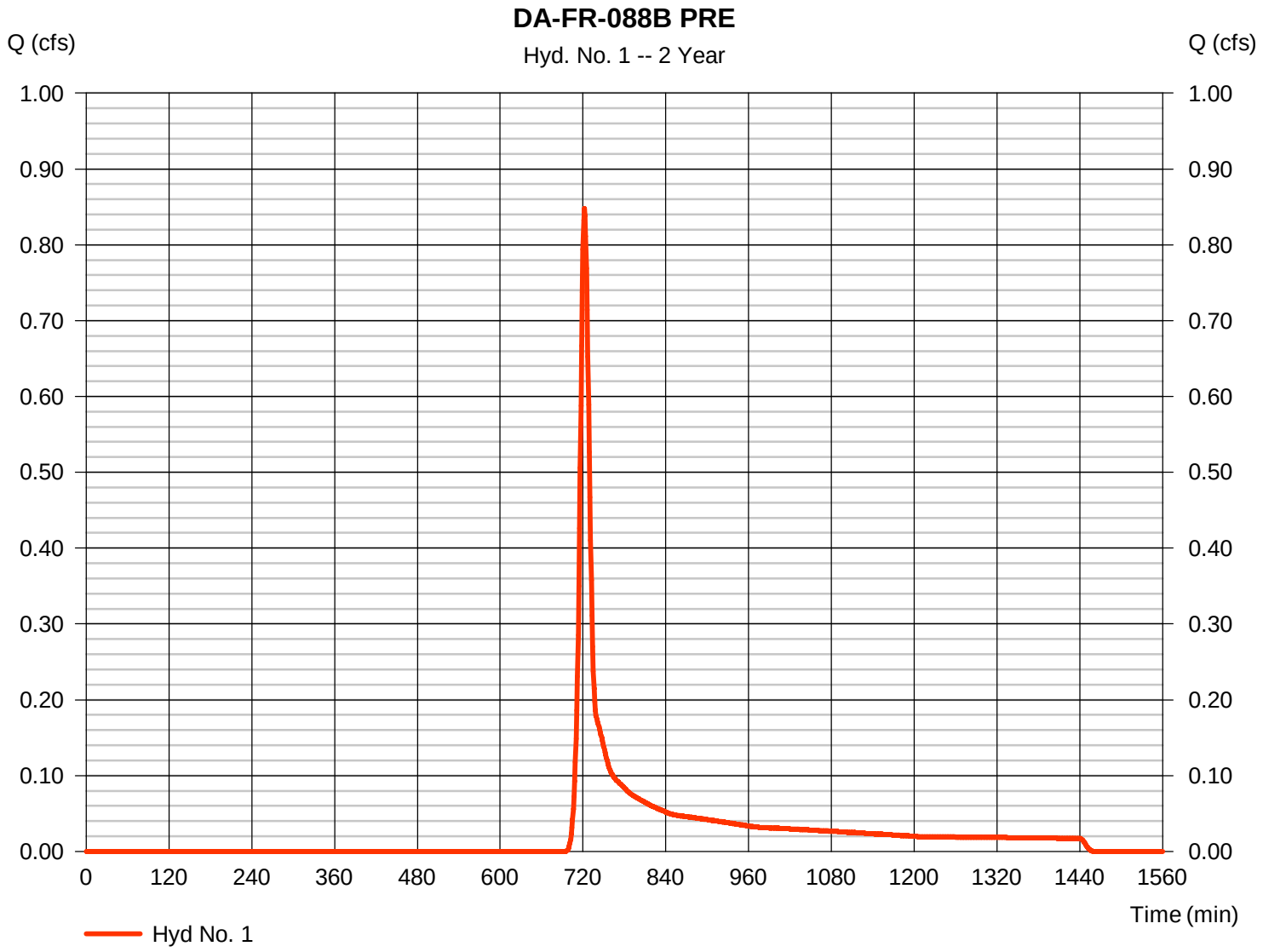
Hydrograph Report

Hyd. No. 1

DA-FR-088B PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.848 cfs
Storm frequency	= 2 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 2,364 cuft
Drainage area	= 0.770 ac	Curve number	= 65*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 12.50 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.017 x 85) + (0.120 x 98) + (0.634 x 58)] / 0.770



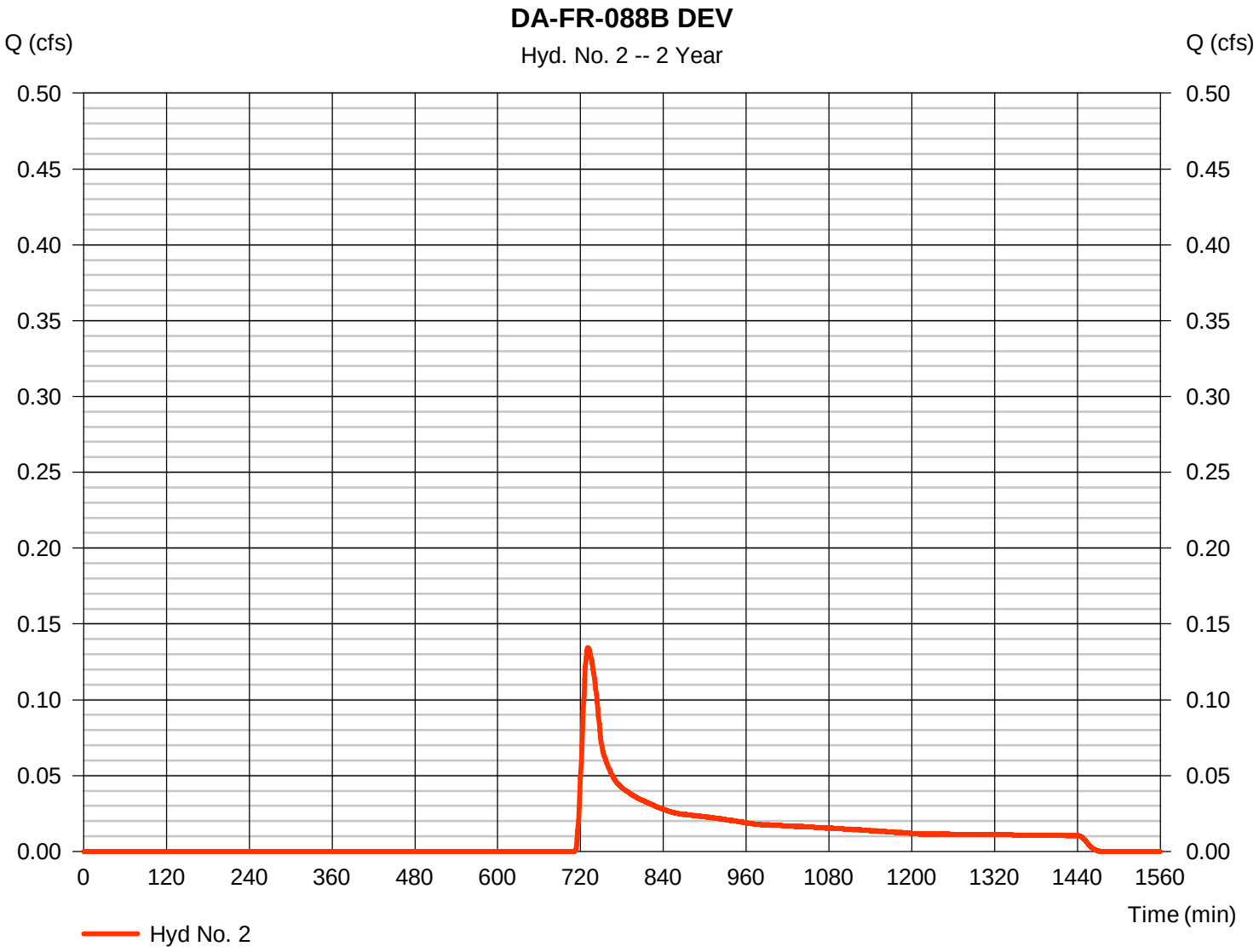
Hydrograph Report

Hyd. No. 2

DA-FR-088B DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.134 cfs
Storm frequency	= 2 yrs	Time to peak	= 731 min
Time interval	= 1 min	Hyd. volume	= 970 cuft
Drainage area	= 0.770 ac	Curve number	= 53*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 20.60 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.017 x 85) + (0.332 x 58) + (0.423 x 48)] / 0.770

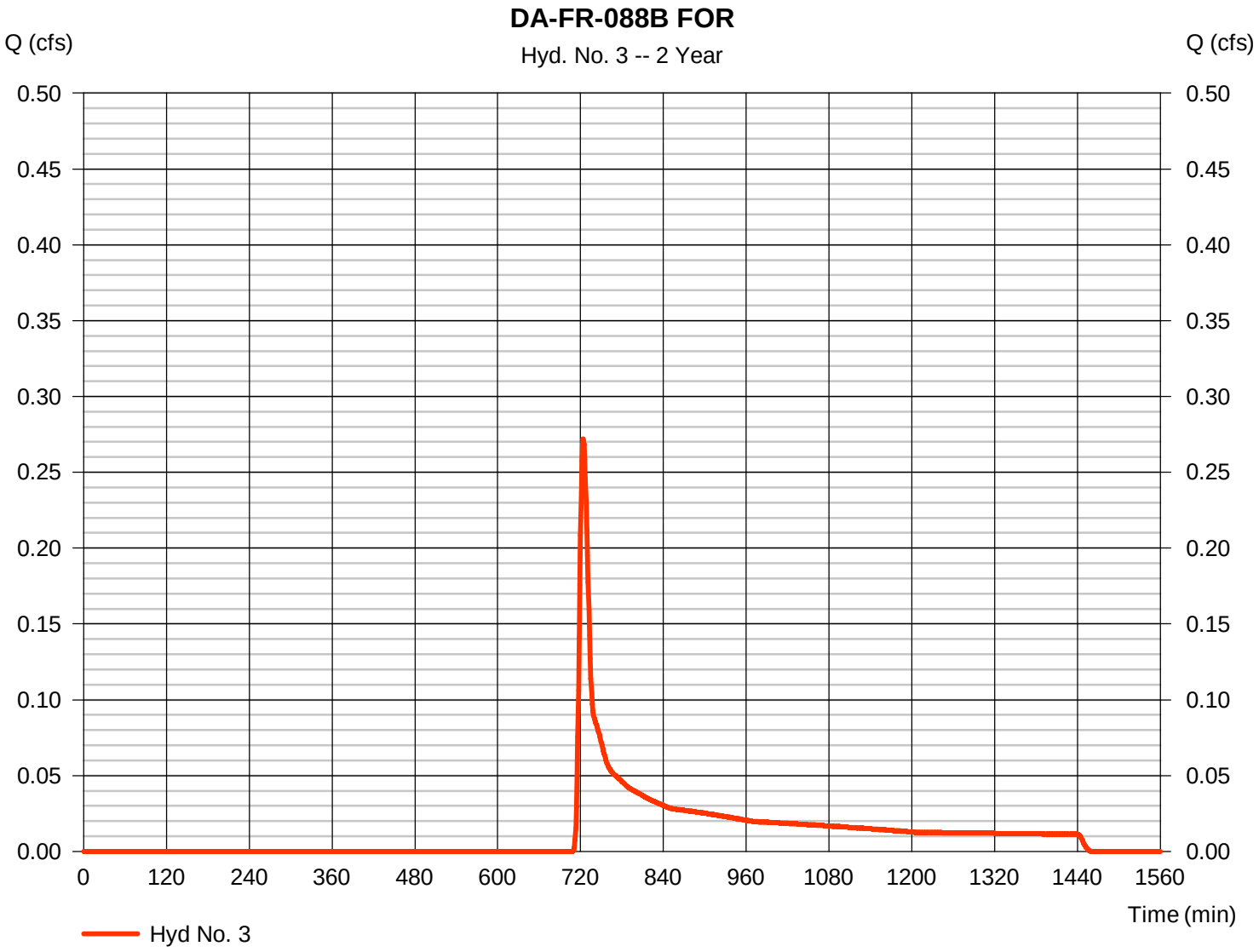


Hydrograph Report

Hyd. No. 3

DA-FR-088B FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.272 cfs
Storm frequency	= 2 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 1,143 cuft
Drainage area	= 0.770 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 12.70 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



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	2.291	1	722	5,876	------	------	------	DA-FR-088B PRE
2	SCS Runoff	0.858	1	728	3,400	------	------	------	DA-FR-088B DEV
3	SCS Runoff	1.338	1	722	3,710	------	------	------	DA-FR-088B FOR

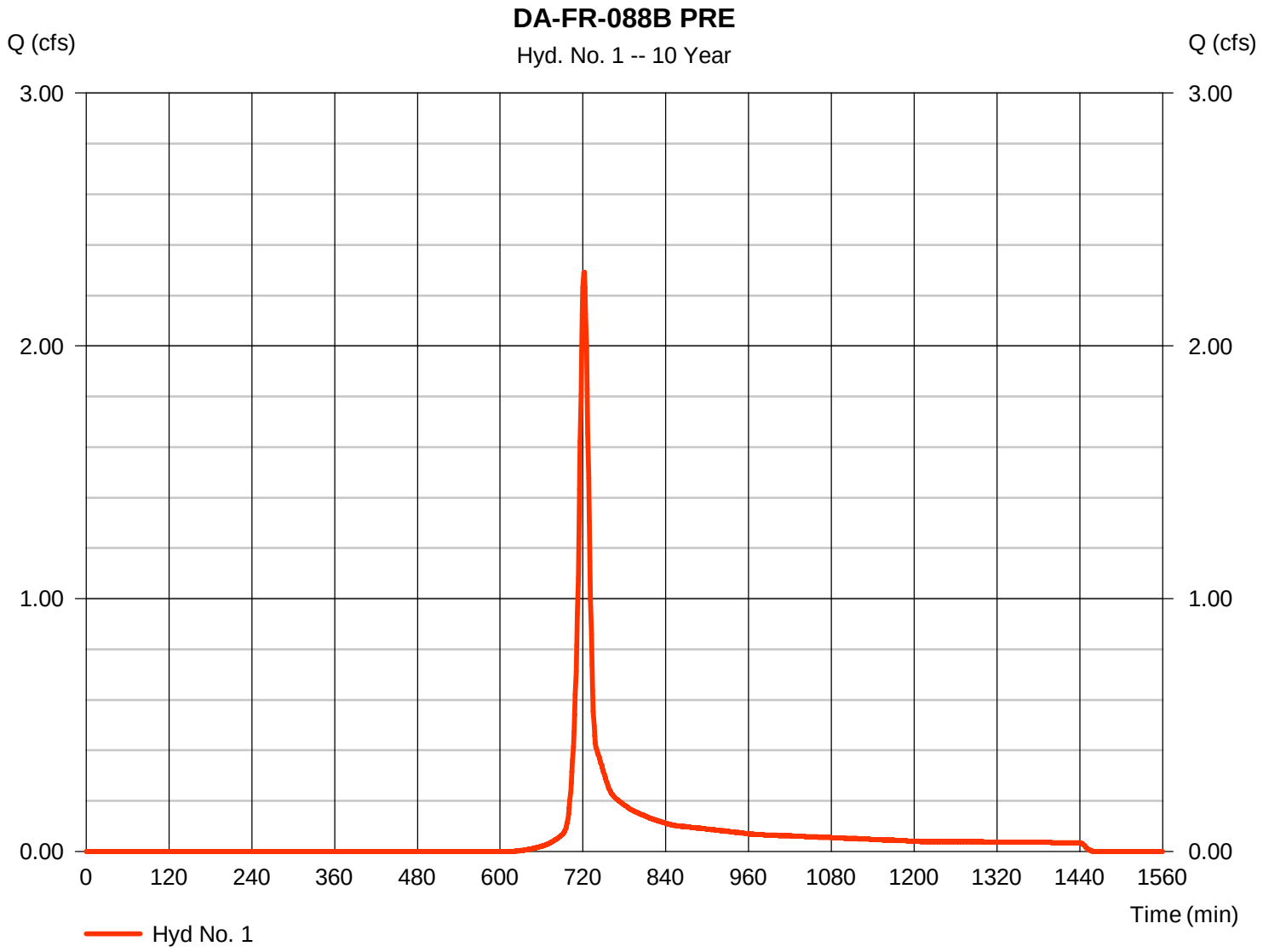
Hydrograph Report

Hyd. No. 1

DA-FR-088B PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	2.291 cfs
Storm frequency	=	10 yrs	Time to peak	=	722 min
Time interval	=	1 min	Hyd. volume	=	5,876 cuft
Drainage area	=	0.770 ac	Curve number	=	65*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	12.50 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.017 x 85) + (0.120 x 98) + (0.634 x 58)] / 0.770



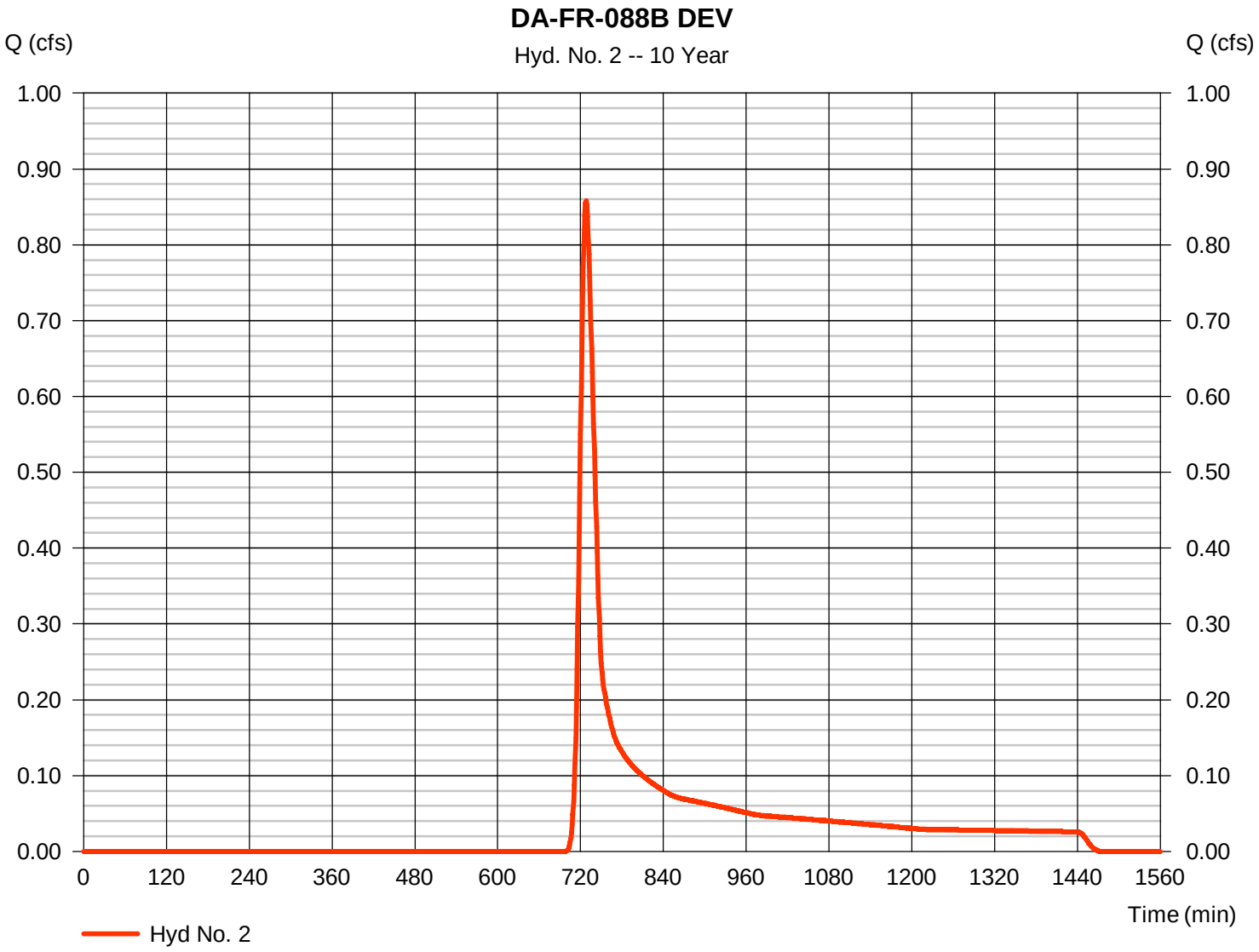
Hydrograph Report

Hyd. No. 2

DA-FR-088B DEV

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.858 cfs
Storm frequency	=	10 yrs	Time to peak	=	728 min
Time interval	=	1 min	Hyd. volume	=	3,400 cuft
Drainage area	=	0.770 ac	Curve number	=	53*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	20.60 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.017 x 85) + (0.332 x 58) + (0.423 x 48)] / 0.770

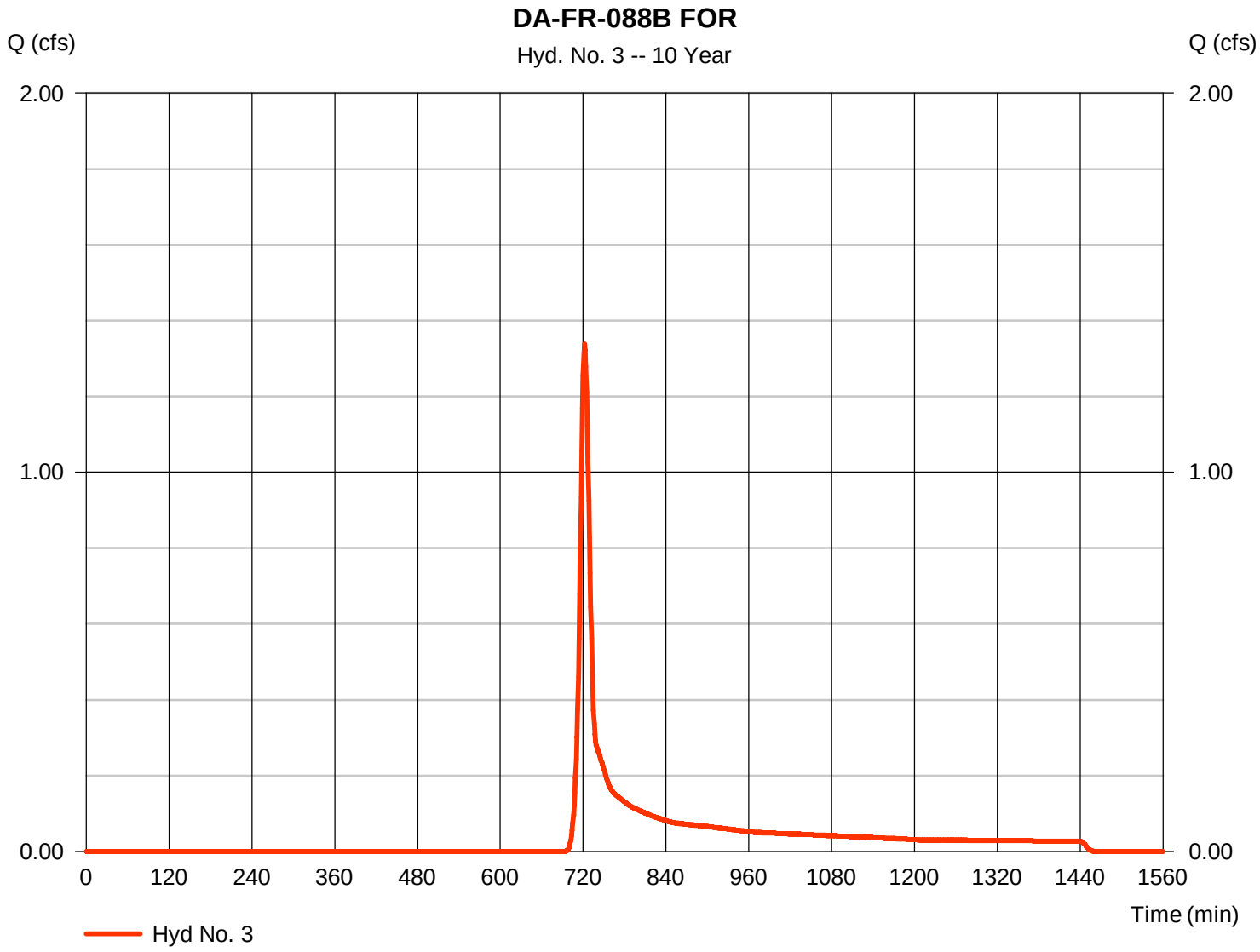


Hydrograph Report

Hyd. No. 3

DA-FR-088B FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 1.338 cfs
Storm frequency	= 10 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 3,710 cuft
Drainage area	= 0.770 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 12.70 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



Hydraflow Rainfall Report

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

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

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

Tc = time in minutes. Values may exceed 60.

ng\Franklin County\Downloaded Files\Franklin County DA Batch 4 - 046 - 058\Precipitation\Hydraflow\FranklinCo.pc

Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.30	3.70	0.00	0.00	5.70	0.00	0.00	0.00
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

DA-FR-088C

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	1.121	5624
Developed Condition	0.692	4546
Pre-Developed (Forest) Condition	1.121	5624

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

Improvement Factor, IF = 0.8

Calculations:

Check #1:	$Q_{developed} \leq IF \times [(Q_{pre\text{-}developed} \times RV_{pre\text{-}developed}) / RV_{developed}]$ ---------->	0.692	≤ N/A - See Check #3	1.109
Check #2:	$Q_{developed} \leq Q_{pre\text{-}developed}$ ---------->	0.692	≤ N/A - See Check #3	1.121
Check #3:	$Q_{developed}$ *shall not* be required to be ≤ $(Q_{forest} \times RV_{forest}) / RV_{developed}$ --->	0.692	*shall not* be required to be ≤	1.387

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

Note:

Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.

For Paved Road land surface types a Manning's n value 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 Channels[1]			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels[2]			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150

Notes:

[1]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 or grass channel.

[2]For the pre-developed condition (if applicable), 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-FR-088C PRE
2	SCS Runoff	DA-FR-088C DEV
3	SCS Runoff	DA-FR-088C FOR

Hydrograph Return Period Recap

Hyd. No.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)							Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	------	1.121	2.097	-------	-------	9.388	-------	-------	-------	DA-FR-088C PRE
2	SCS Runoff	------	0.692	1.488	-------	-------	8.171	-------	-------	-------	DA-FR-088C DEV
3	SCS Runoff	------	1.121	2.097	-------	-------	9.388	-------	-------	-------	DA-FR-088C FOR

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	1.121	1	725	5,624	------	------	------	DA-FR-088C PRE
2	SCS Runoff	0.692	1	725	4,546	------	------	------	DA-FR-088C DEV
3	SCS Runoff	1.121	1	725	5,624	------	------	------	DA-FR-088C FOR

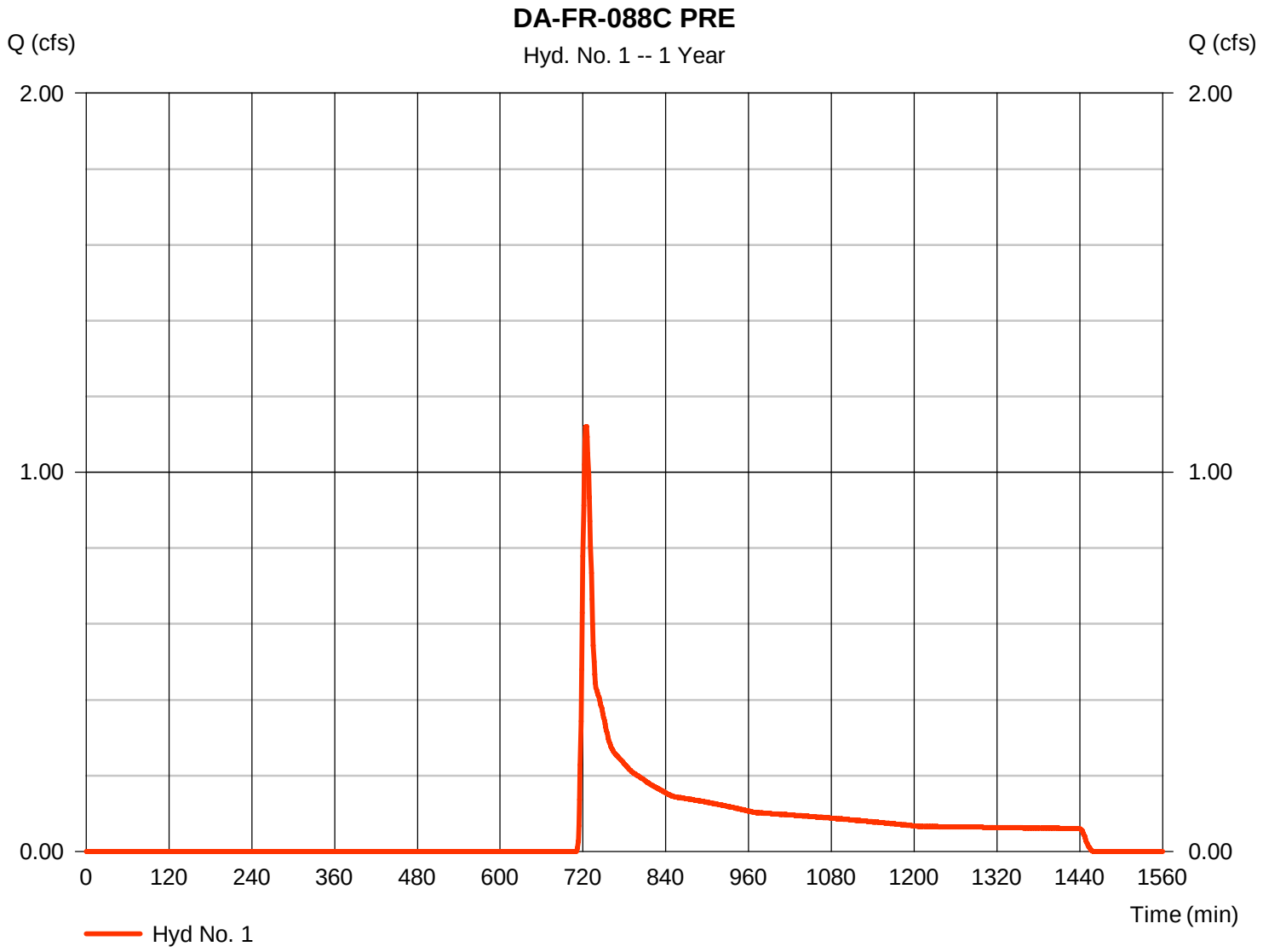
Hydrograph Report

Hyd. No. 1

DA-FR-088C PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 1.121 cfs
Storm frequency	= 1 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 5,624 cuft
Drainage area	= 5.050 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 12.10 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.061 x 85) + (0.011 x 98) + (0.650 x 58) + (4.329 x 55)] / 5.050



TR55 Tc Worksheet

Hyd. No. 1

DA-FR-088C PRE

Description	A	B	C	Totals
Sheet Flow				
Manning's n-value	= 0.400	0.400	0.011	
Flow length (ft)	= 30.1	69.9	0.0	
Two-year 24-hr precip. (in)	= 3.70	3.70	0.00	
Land slope (%)	= 8.28	29.40	0.00	
Travel Time (min)	**= 4.33**	**+ 5.12**	**+ 0.00**	**= 9.45**
Shallow Concentrated Flow				
Flow length (ft)	= 0.00	654.65	0.00	
Watercourse slope (%)	= 0.00	13.53	0.00	
Surface description	= Unpaved	Unpaved	Paved	
Average velocity (ft/s)	=0.00	5.93	0.00	
Travel Time (min)	**= 0.00**	**+ 1.84**	**+ 0.00**	**= 1.84**
Channel Flow				
X sectional flow area (sqft)	= 0.00	1.44	0.00	
Wetted perimeter (ft)	= 0.00	11.71	0.00	
Channel slope (%)	= 0.00	6.66	0.00	
Manning's n-value	= 0.015	0.030	0.015	
Velocity (ft/s)	=0.00	3.15	0.00	
Flow length (ft)	({0})0.0	154.0	0.0	
Travel Time (min)	**= 0.00**	**+ 0.82**	**+ 0.00**	**= 0.82**

Total Travel Time, Tc ..... 12.10 min

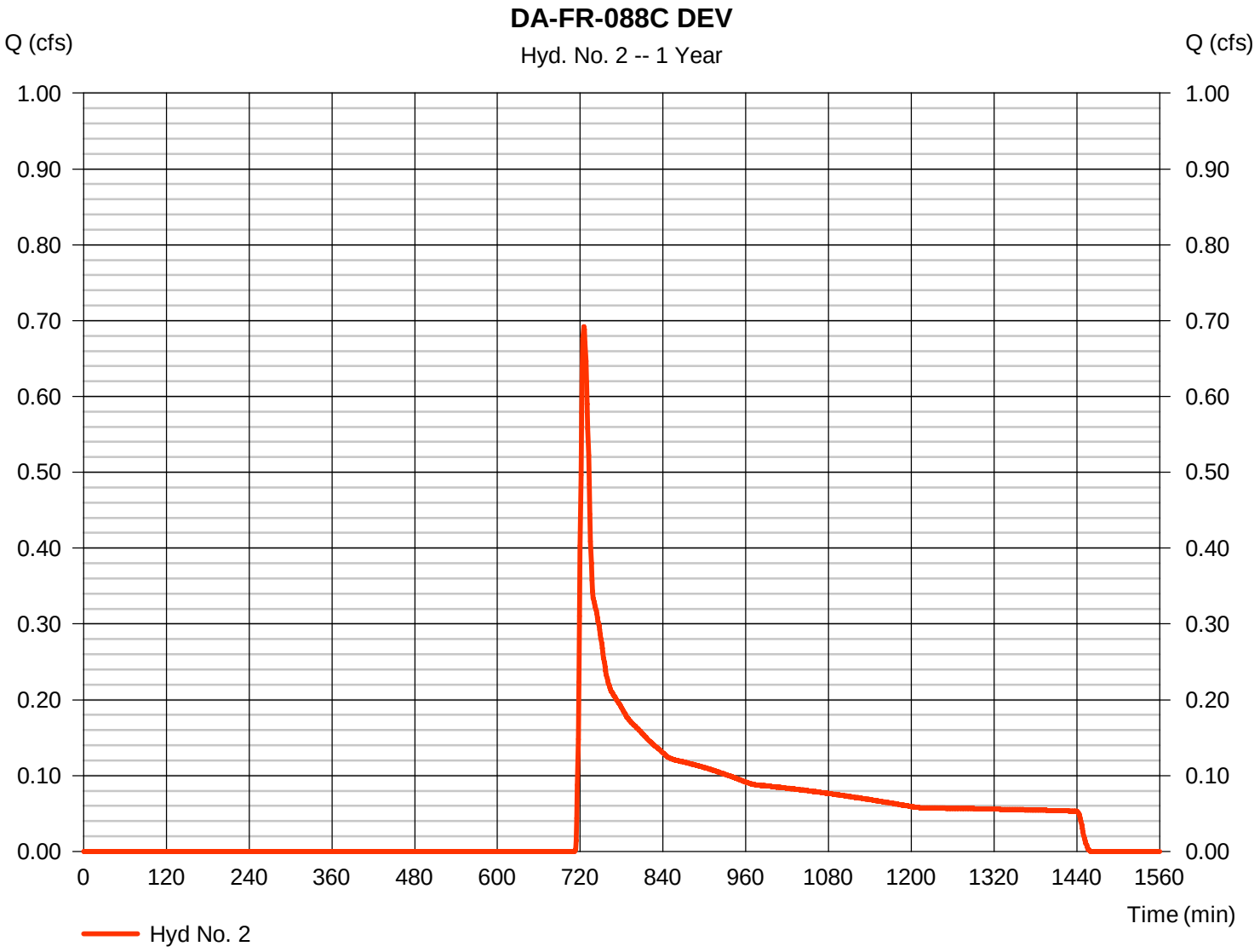
Hydrograph Report

Hyd. No. 2

DA-FR-088C DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.692 cfs
Storm frequency	= 1 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 4,546 cuft
Drainage area	= 5.050 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 12.30 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.061 x 85) + (0.011 x 98) + (1.874 x 58) + (1.364 x 55) + (1.741 x 48)] / 5.050



TR55 Tc Worksheet

Hyd. No. 2

DA-FR-088C DEV

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.400		0.800		0.011		
Flow length (ft)	= 84.7		15.3		0.0		
Two-year 24-hr precip. (in)	= 3.70		3.70		0.00		
Land slope (%)	= 23.72		19.32		0.00		
Travel Time (min)	**= 6.50**	**+**	**3.13**	**+**	**0.00**	**=**	**9.63**
Shallow Concentrated Flow							
Flow length (ft)	= 0.00		654.65		0.00		
Watercourse slope (%)	= 0.00		13.53		0.00		
Surface description	= Unpaved		Unpaved		Paved		
Average velocity (ft/s)	=0.00		5.93		0.00		
Travel Time (min)	**= 0.00**	**+**	**1.84**	**+**	**0.00**	**=**	**1.84**
Channel Flow							
X sectional flow area (sqft)	= 0.00		1.44		0.00		
Wetted perimeter (ft)	= 0.00		11.71		0.00		
Channel slope (%)	= 0.00		6.66		0.00		
Manning's n-value	= 0.015		0.030		0.015		
Velocity (ft/s)	=0.00		3.15		0.00		
Flow length (ft)	({0})0.0		154.0		0.0		
Travel Time (min)	**= 0.00**	**+**	**0.82**	**+**	**0.00**	**=**	**0.82**

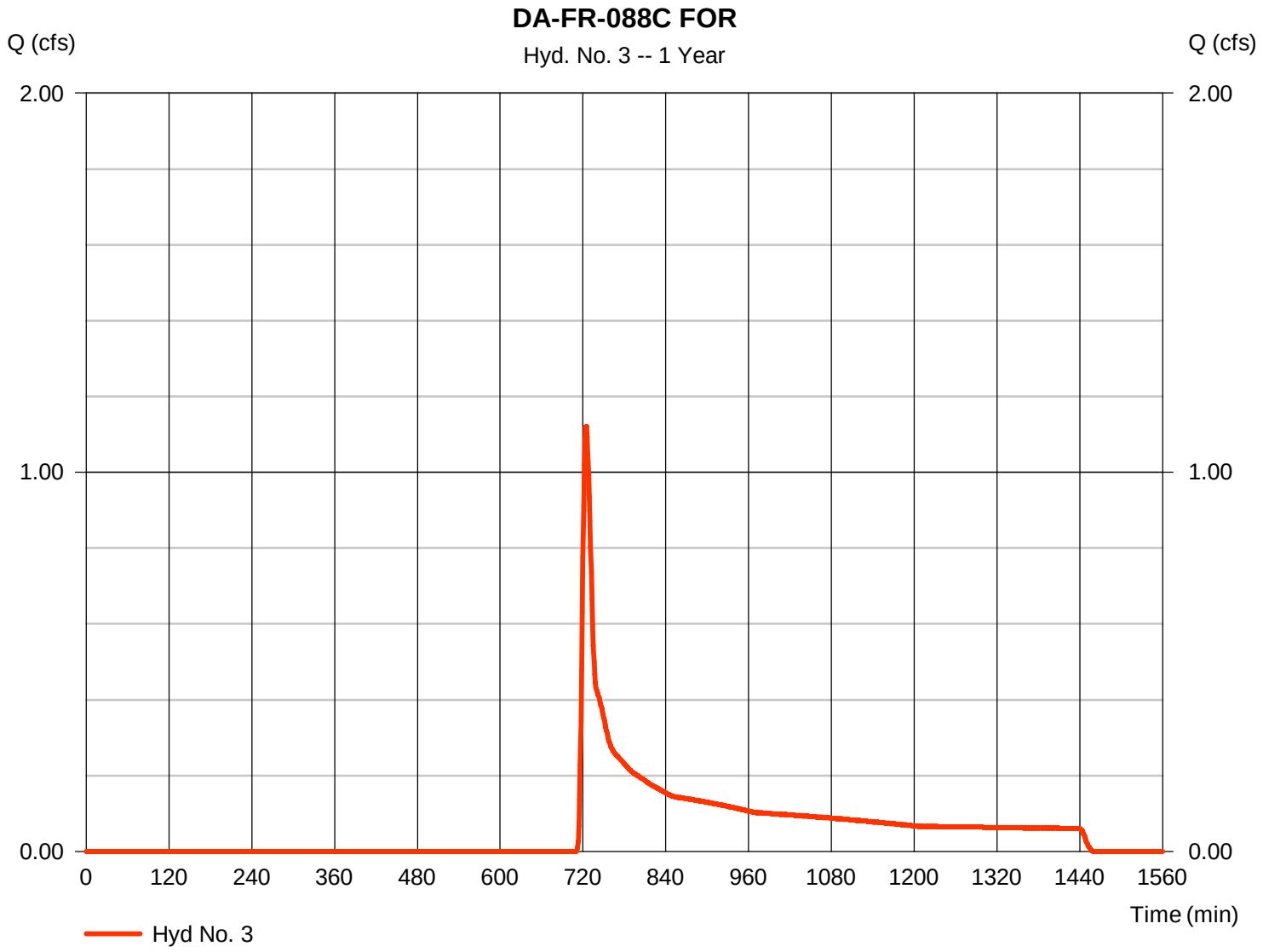
Total Travel Time, Tc ..... 12.30 min

Hydrograph Report

Hyd. No. 3

DA-FR-088C FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 1.121 cfs
Storm frequency	= 1 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 5,624 cuft
Drainage area	= 5.050 ac	Curve number	= 56
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 12.10 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



TR55 Tc Worksheet

Hyd. No. 3

DA-FR-088C FOR

Description	A	B	C	Totals
Sheet Flow				
Manning's n-value	= 0.400	0.400	0.011	
Flow length (ft)	= 30.1	69.9	0.0	
Two-year 24-hr precip. (in)	= 3.70	3.70	0.00	
Land slope (%)	= 8.28	29.40	0.00	
Travel Time (min)	**= 4.33**	**+ 5.12**	**+ 0.00**	**= 9.45**
Shallow Concentrated Flow				
Flow length (ft)	= 0.00	654.65	0.00	
Watercourse slope (%)	= 0.00	13.53	0.00	
Surface description	= Unpaved	Unpaved	Unpaved	
Average velocity (ft/s)	=0.00	5.93	0.00	
Travel Time (min)	**= 0.00**	**+ 1.84**	**+ 0.00**	**= 1.84**
Channel Flow				
X sectional flow area (sqft)	= 0.00	1.44	0.00	
Wetted perimeter (ft)	= 0.00	11.71	0.00	
Channel slope (%)	= 0.00	6.66	0.00	
Manning's n-value	= 0.015	0.030	0.015	
Velocity (ft/s)	=0.00	3.15	0.00	
Flow length (ft)	({0})0.0	154.0	0.0	
Travel Time (min)	**= 0.00**	**+ 0.82**	**+ 0.00**	**= 0.82**

Total Travel Time, Tc ..... 12.10 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	2.097	1	724	8,186	------	------	------	DA-FR-088C PRE
2	SCS Runoff	1.488	1	724	6,837	------	------	------	DA-FR-088C DEV
3	SCS Runoff	2.097	1	724	8,186	------	------	------	DA-FR-088C FOR

Hydrograph Report

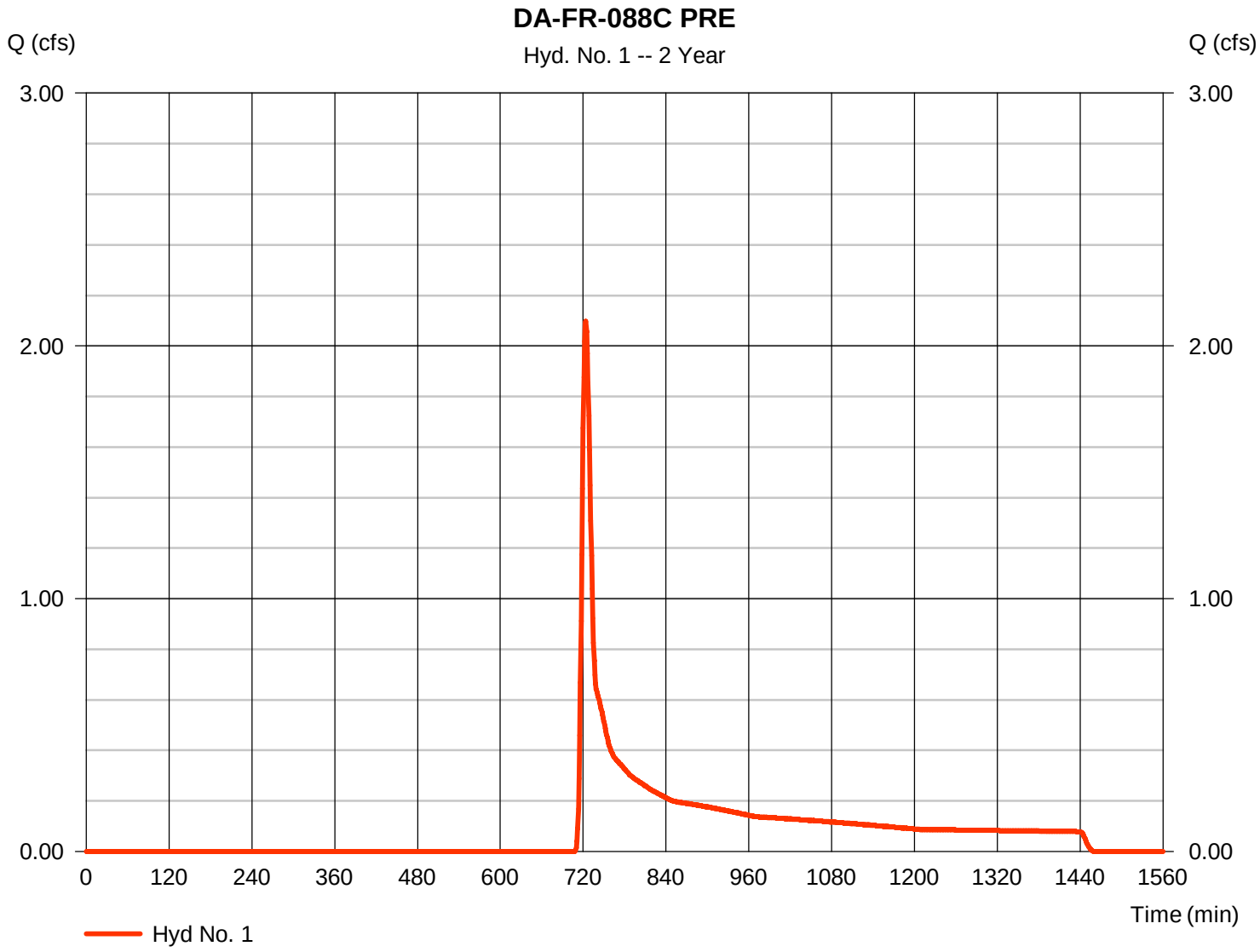
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5 Tuesday, 08 / 15 / 2017

Hyd. No. 1

DA-FR-088C PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	2.097 cfs
Storm frequency	=	2 yrs	Time to peak	=	724 min
Time interval	=	1 min	Hyd. volume	=	8,186 cuft
Drainage area	=	5.050 ac	Curve number	=	56*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	12.10 min
Total precip.	=	3.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.061 x 85) + (0.011 x 98) + (0.650 x 58) + (4.329 x 55)] / 5.050



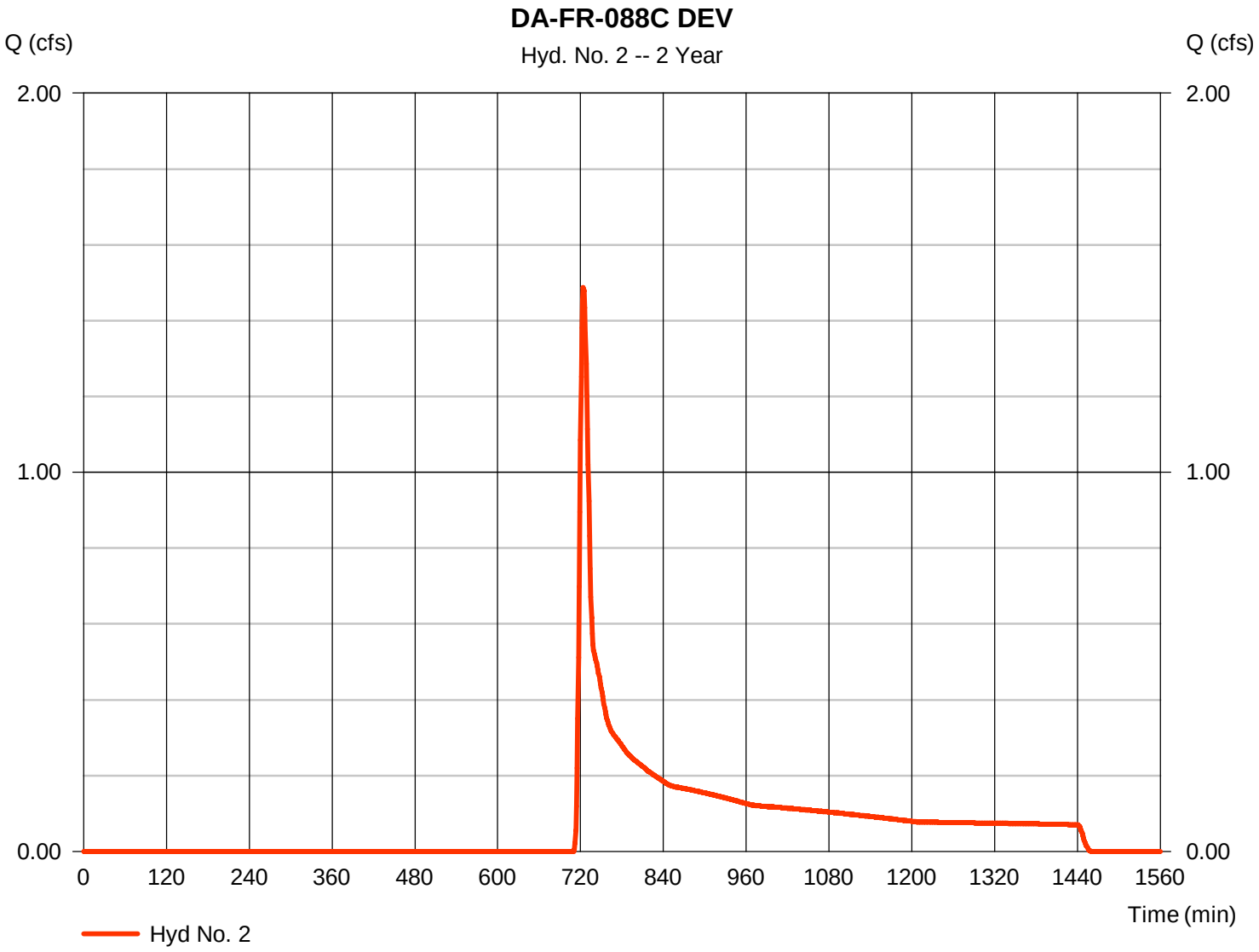
Hydrograph Report

Hyd. No. 2

DA-FR-088C DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 1.488 cfs
Storm frequency	= 2 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 6,837 cuft
Drainage area	= 5.050 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 12.30 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.061 x 85) + (0.011 x 98) + (1.874 x 58) + (1.364 x 55) + (1.741 x 48)] / 5.050

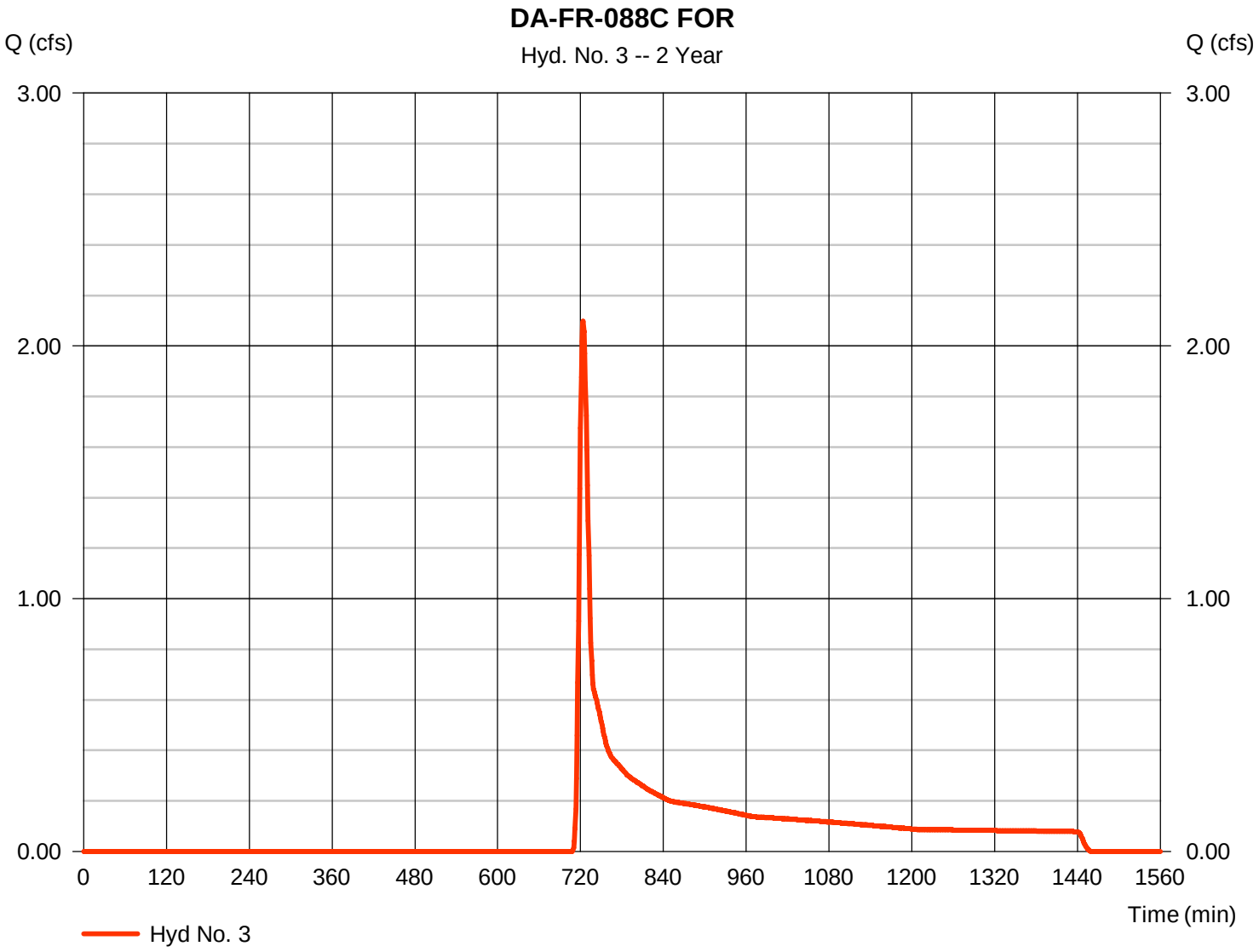


Hydrograph Report

Hyd. No. 3

DA-FR-088C FOR

Hydrograph type	=	SCS Runoff	Peak discharge	=	2.097 cfs
Storm frequency	=	2 yrs	Time to peak	=	724 min
Time interval	=	1 min	Hyd. volume	=	8,186 cuft
Drainage area	=	5.050 ac	Curve number	=	56
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	12.10 min
Total precip.	=	3.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484



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	9.388	1	722	25,662	------	------	------	DA-FR-088C PRE
2	SCS Runoff	8.171	1	722	23,027	------	------	------	DA-FR-088C DEV
3	SCS Runoff	9.388	1	722	25,662	------	------	------	DA-FR-088C FOR

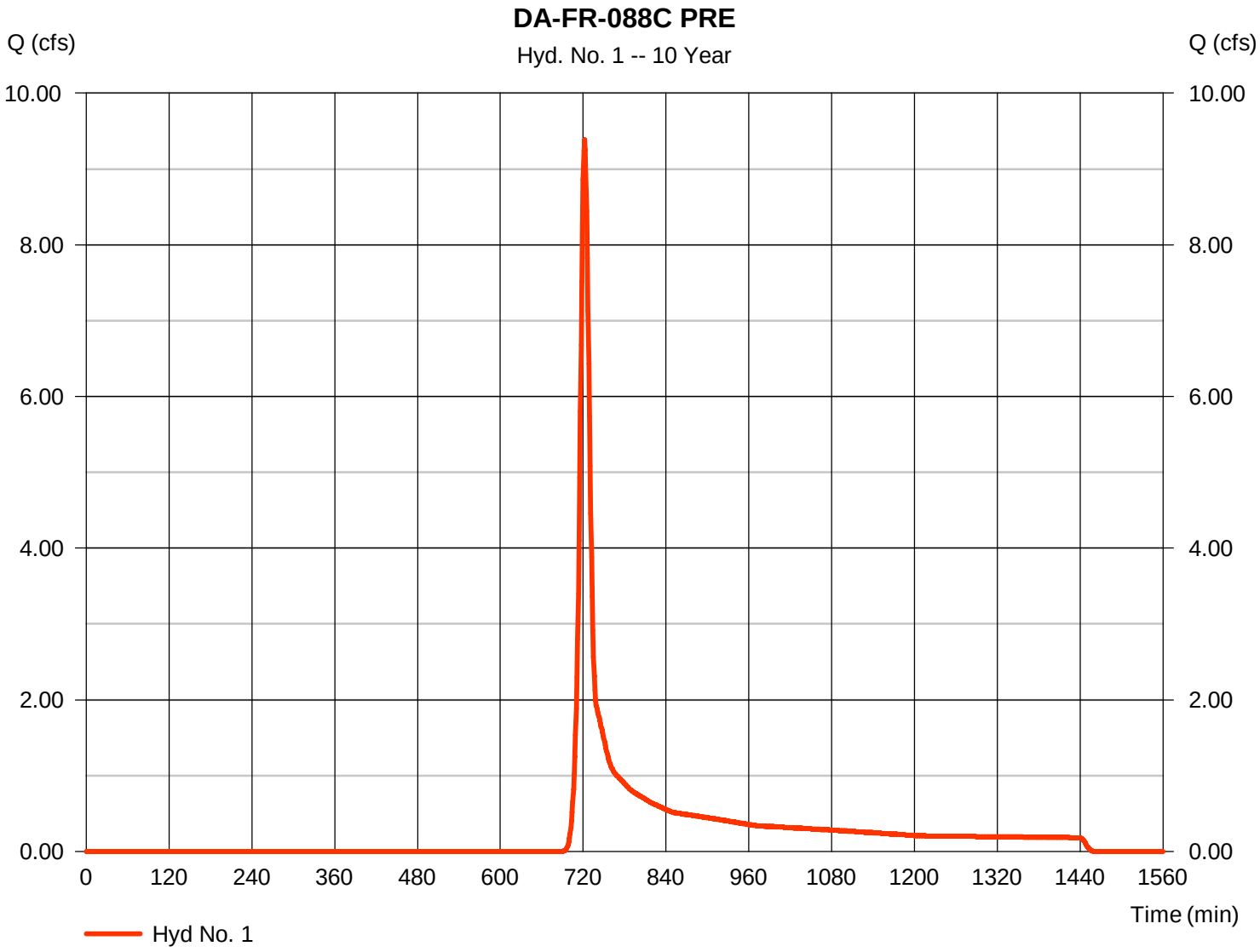
Hydrograph Report

Hyd. No. 1

DA-FR-088C PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	9.388 cfs
Storm frequency	=	10 yrs	Time to peak	=	722 min
Time interval	=	1 min	Hyd. volume	=	25,662 cuft
Drainage area	=	5.050 ac	Curve number	=	56*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	12.10 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.061 x 85) + (0.011 x 98) + (0.650 x 58) + (4.329 x 55)] / 5.050



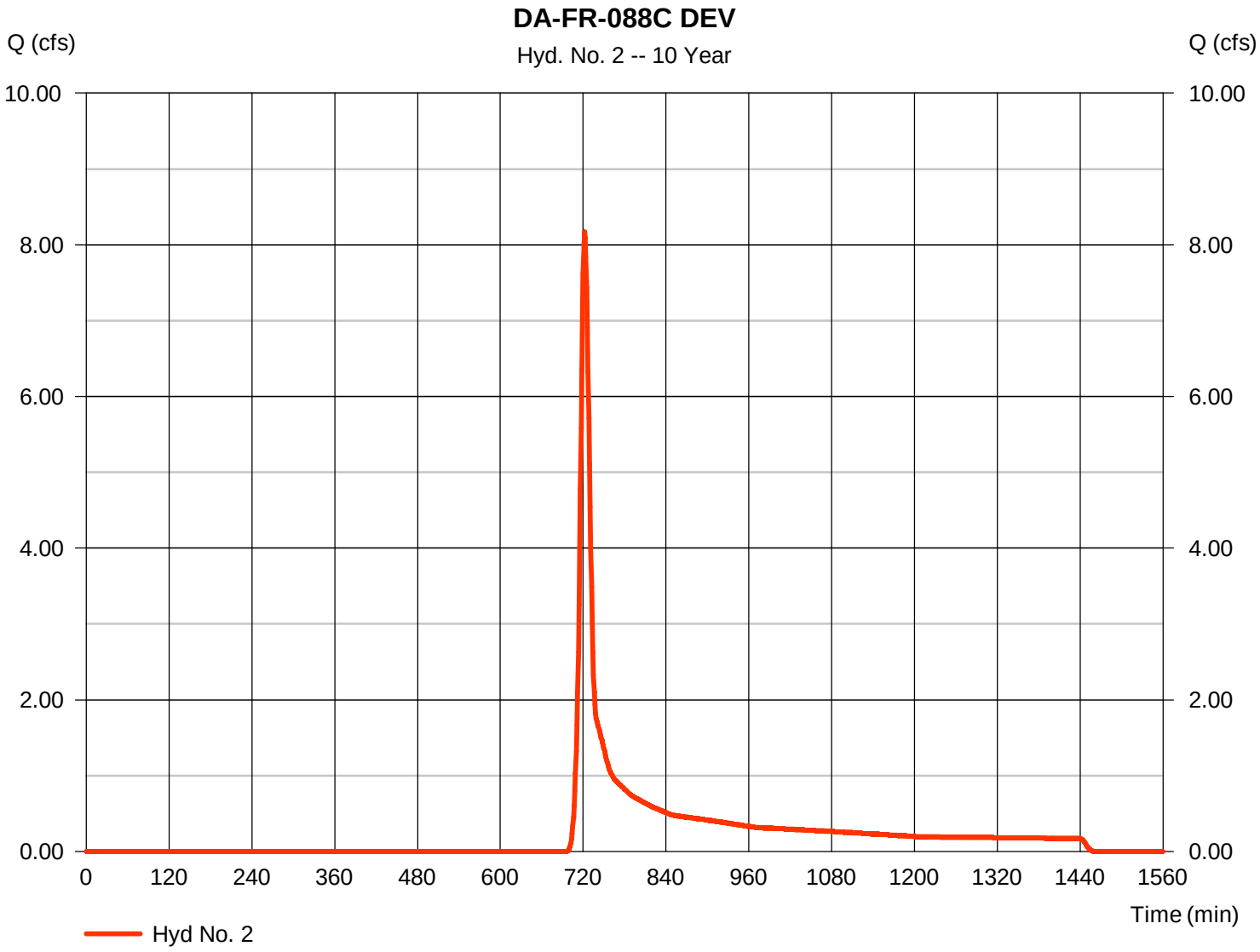
Hydrograph Report

Hyd. No. 2

DA-FR-088C DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 8.171 cfs
Storm frequency	= 10 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 23,027 cuft
Drainage area	= 5.050 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 12.30 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.061 x 85) + (0.011 x 98) + (1.874 x 58) + (1.364 x 55) + (1.741 x 48)] / 5.050

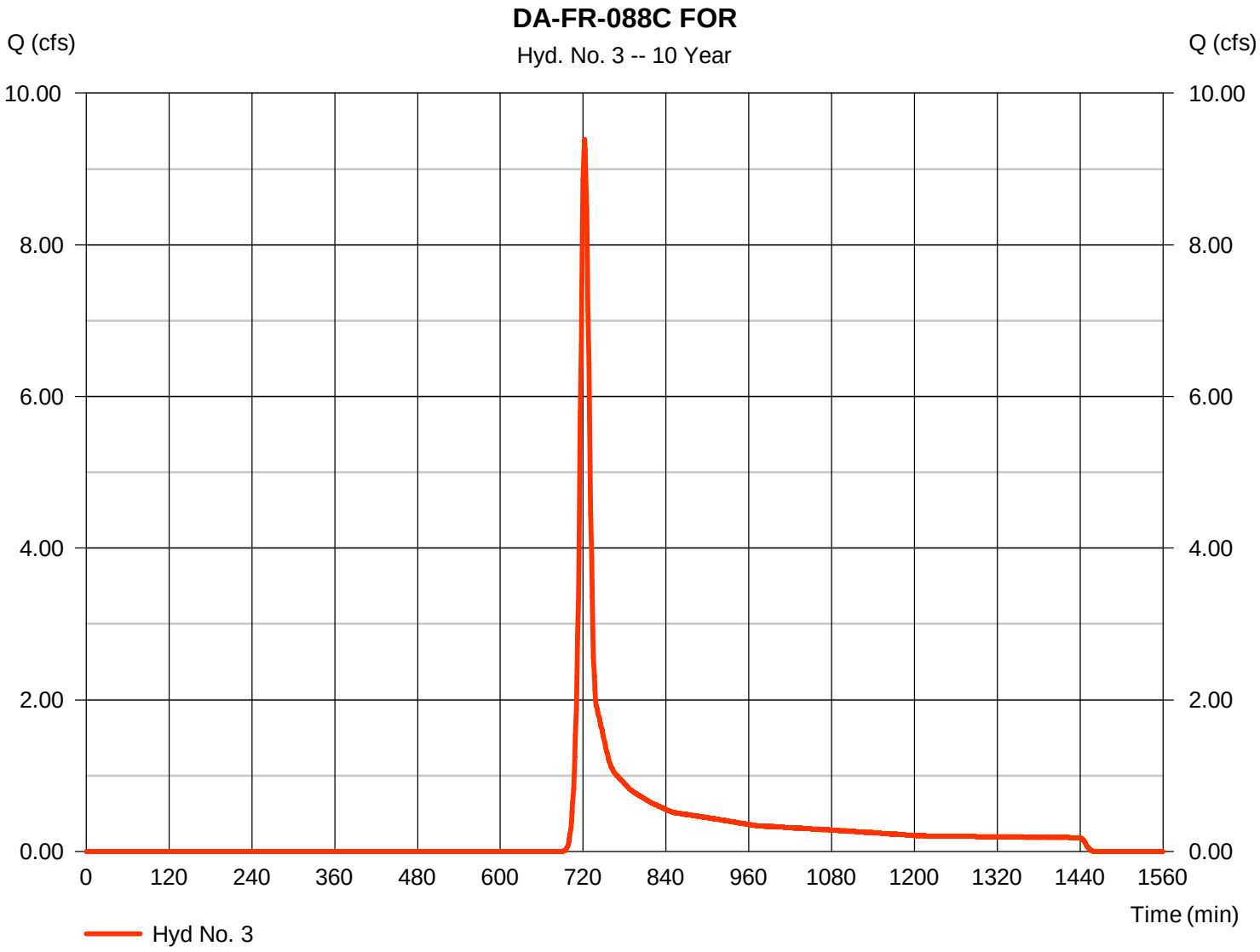


Hydrograph Report

Hyd. No. 3

DA-FR-088C FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 9.388 cfs
Storm frequency	= 10 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 25,662 cuft
Drainage area	= 5.050 ac	Curve number	= 56
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 12.10 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



Hydraflow Rainfall Report

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

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

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

Tc = time in minutes. Values may exceed 60.

ng\Franklin County\Downloaded Files\Franklin County DA Batch 4 - 046 - 058\Precipitation\Hydraflow\FranklinCo.pc

Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.30	3.70	0.00	0.00	5.70	0.00	0.00	0.00
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

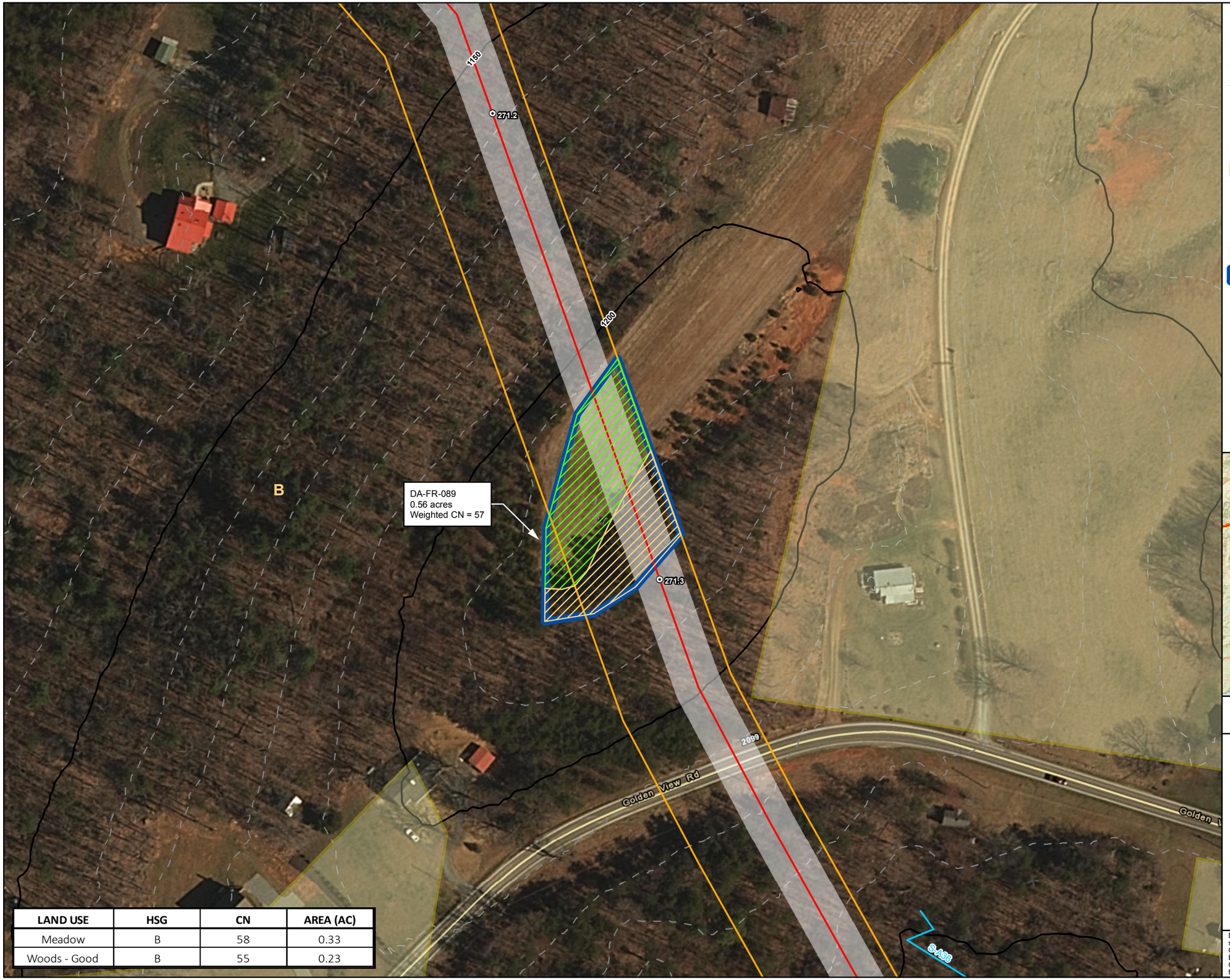
DA-FR-089

DA-FR-089 is located in a primarily meadow area with a portion of forest land and has rolling to hilly slopes. No impervious area is found within the drainage area and no new impervious area is proposed within DA-FR-089. The total phosphorus load reduction required for DA-FR-089 is -0.07 lb/yr.

Stormwater quantity is met via the energy balance method. In addition, the Hydraflow Hydrograph's 10-year 24-hour peak discharge results indicate a reduction in flow of 0.06 cfs for this drainage area (as seen in table below).

Drainage Area	Pre Peak Flow, 10-yr Q (cfs)	Post Peak Flow, Q 10-yr (cfs)	Flow differential
DA-FR-089	0.93	0.87	-0.06

Figures and calculations for DA-FR-089 follow. See Appendix D of the Annual Standards and Specifications for further detail on stormwater methodology.



LAND USE	HSG	CN	AREA (AC)
Meadow	B	58	0.33
Woods - Good	B	55	0.23

Legend

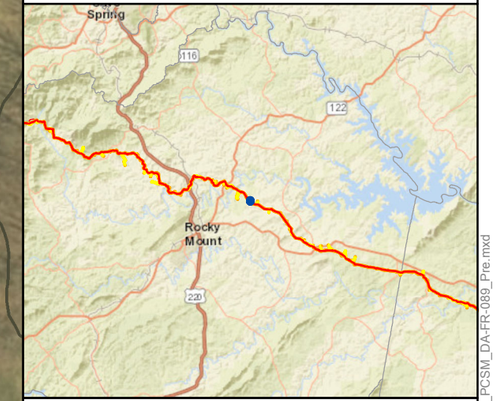
- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Meadow
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

N
W E
S

1:1,200

100 50 0 100 Feet



Mountain Valley Pipeline Project

Mountain Valley PIPELINE

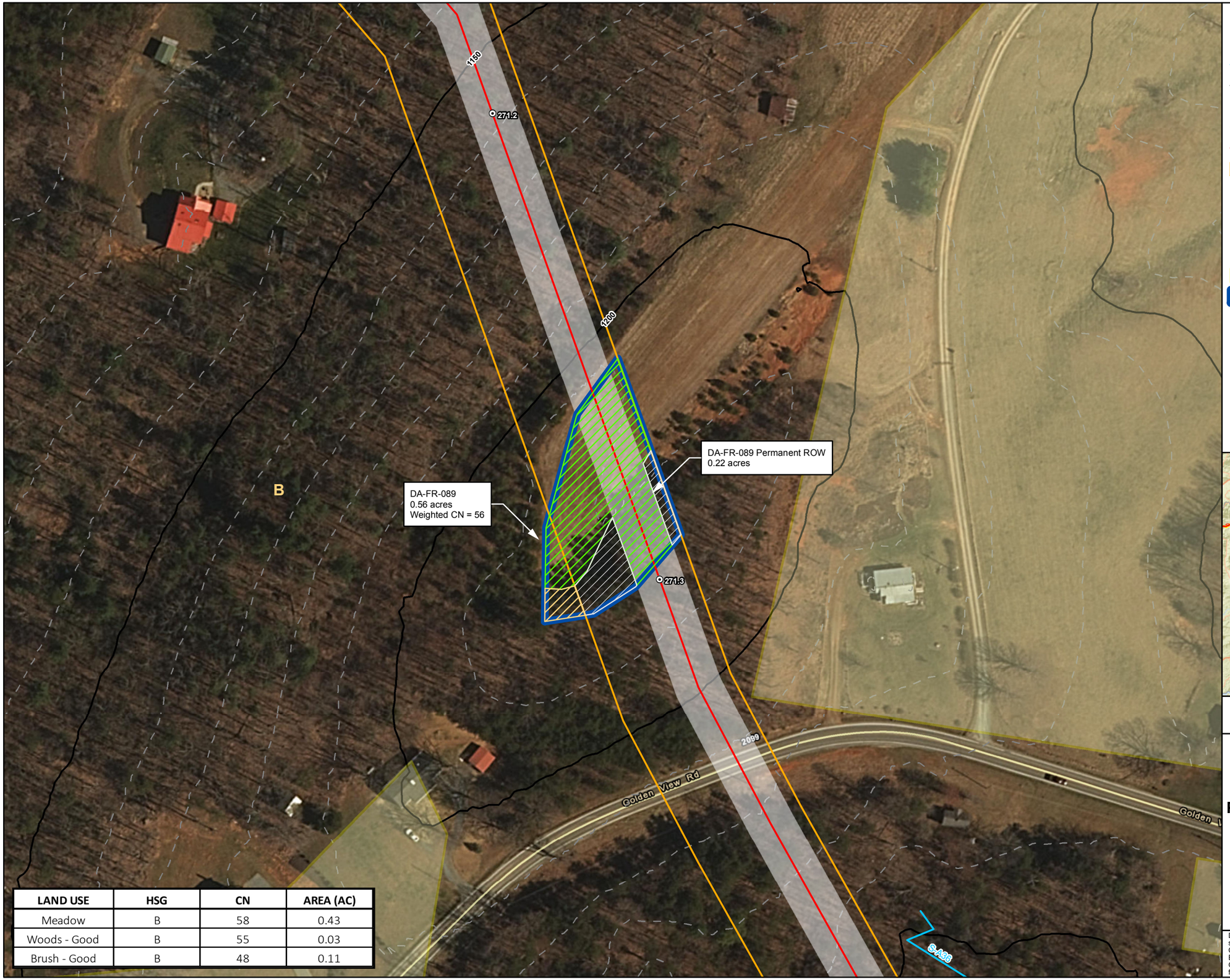
Pre-Construction Drainage Area Map
DA-FR-089
Spread 11

Figure 1
Franklin County, Virginia

August, 2017

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

Document Path: PGH P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Franklin\MVP_PCSM_DA-FR-089_Pre.mxd



LAND USE	HSG	CN	AREA (AC)
Meadow	B	58	0.43
Woods - Good	B	55	0.03
Brush - Good	B	48	0.11

Legend

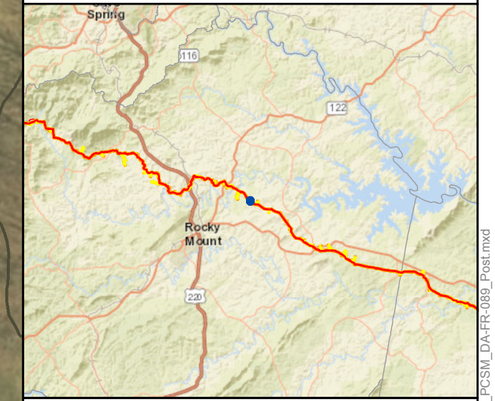
- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Brush
- Meadow
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

N
W E
S

1:1,200

100 50 0 100 Feet



Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Post-Construction Drainage Area Map
DA-FR-089
Spread 11

Figure 2
Franklin County, Virginia

August, 2017

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

Document Path: PGH P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Franklin\MVP_PCSM_DA-FR-089_Post.mxd



PRE-CONSTRUCTION TIME OF CONCENTRATION TO POI

	SHEET 1	SHEET 2	SHALLOW1	SHALLOW2	Calculated Time of Concentration (min)
DA-FR-089	28.11 FT @ 12.40%	71.89 FT @ 2.53%	110.33 FT @ 2.16%	11.54 FT @ 2.75%	18.3

Legend

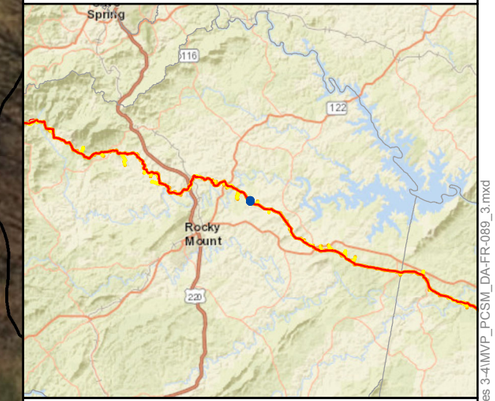
- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:1,200

N W E S

100 50 0 100 Feet



Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Pre-Construction Drainage Area and Time of Concentration
DA-FR-089
Spread 11

Figure 3
Franklin 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.

Document Path: PGH P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Franklin\Figures 3-4\MVP_PCSM_DA-FR-089_3.mxd



POST-CONSTRUCTION TIME OF CONCENTRATION TO POI

	SHEET 1	SHEET 2	SHALLOW1	SHALLOW2	Calculated Time of Concentration (min)
DA-FR-089	28.11 FT @ 12.40%	71.89 FT @ 2.53%	110.33 FT @ 2.16%	11.54 FT @ 2.75%	18.3

Legend

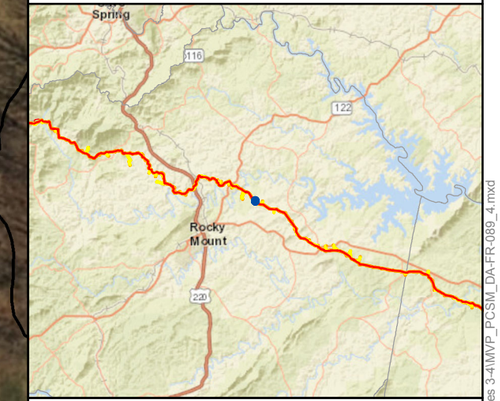
- Milepost
- Permanent Waterbars
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

N
W E
S

1:1,200

100 50 0 100 Feet



Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Post-Construction Drainage Area and Time of Concentration
DA-FR-089
Spread 11

Figure 4
Franklin 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\Franklin\Figures 3-4\MVP_PCSM_DA-FR-089_4.mxd

Virginia Runoff Reduction Method New Development Worksheet - v2.8 - June 2014

Site Data Summary

Total Rainfall = 46 inches

Site Land Cover Summary

	A Soils	B Soils	C Soils	D Soils	Total	% of Total
Forest (acres)	0.00	0.22	0.00	0.00	0.22	*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*
					0.22	*100.00*

Site Rv	0.03
Post Development Treatment Volume (ft3)	24
Post Development TP Load (lb/yr)	0.02
Post Development TN Load (lb/yr)	0.12
Total TP Load Reduction Required (lb/yr)	-0.07

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)	0.02
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)	0.22	0.00	0.00	0.00	0.00	*0.22*
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*
						0.22

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*

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.123	691
Developed Condition	0.101	626
Pre-Developed (Forest) Condition	0.080	565

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

Improvement Factor, IF = 0.9

Calculations:

			Q (cfs)		Q (cfs)
Check #1:	$Q_{developed} \leq IF \times [(Q_{pre\text{-}developed} \times RV_{pre\text{-}developed}) / RV_{developed}]$ ---------->		0.101	≤ OK	0.122
Check #2:	$Q_{developed} \leq Q_{pre\text{-}developed}$ ---------->		0.101	≤ OK	0.123
Check #3:	$Q_{developed}$ *shall not* be required to be ≤ $(Q_{forest} \times RV_{forest}) / RV_{developed}$ --->		0.101	*shall not* be required to be ≤	0.072

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

Note:

Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.

For Paved Road land surface types a Manning's n value 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

Hydraflow Table of Contents

DA-FR-089_Hydraflow.gpw

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5 Tuesday, 08 / 15 / 2017

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TR-55 Tc Worksheet 5

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Hydrograph No. 3, SCS Runoff, DA-FR-089 FOR 17

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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-FR-089 PRE
2	SCS Runoff	DA-FR-089 DEV
3	SCS Runoff	DA-FR-089 FOR

Hydrograph Return Period Recap

Hyd. No.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)							Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	------	0.123	0.218	-------	-------	0.927	-------	-------	-------	DA-FR-089 PRE
2	SCS Runoff	------	0.101	0.188	-------	-------	0.868	-------	-------	-------	DA-FR-089 DEV
3	SCS Runoff	------	0.080	0.159	-------	-------	0.809	-------	-------	-------	DA-FR-089 FOR

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	0.123	1	728	691	------	------	------	DA-FR-089 PRE
2	SCS Runoff	0.101	1	728	626	------	------	------	DA-FR-089 DEV
3	SCS Runoff	0.080	1	729	565	------	------	------	DA-FR-089 FOR

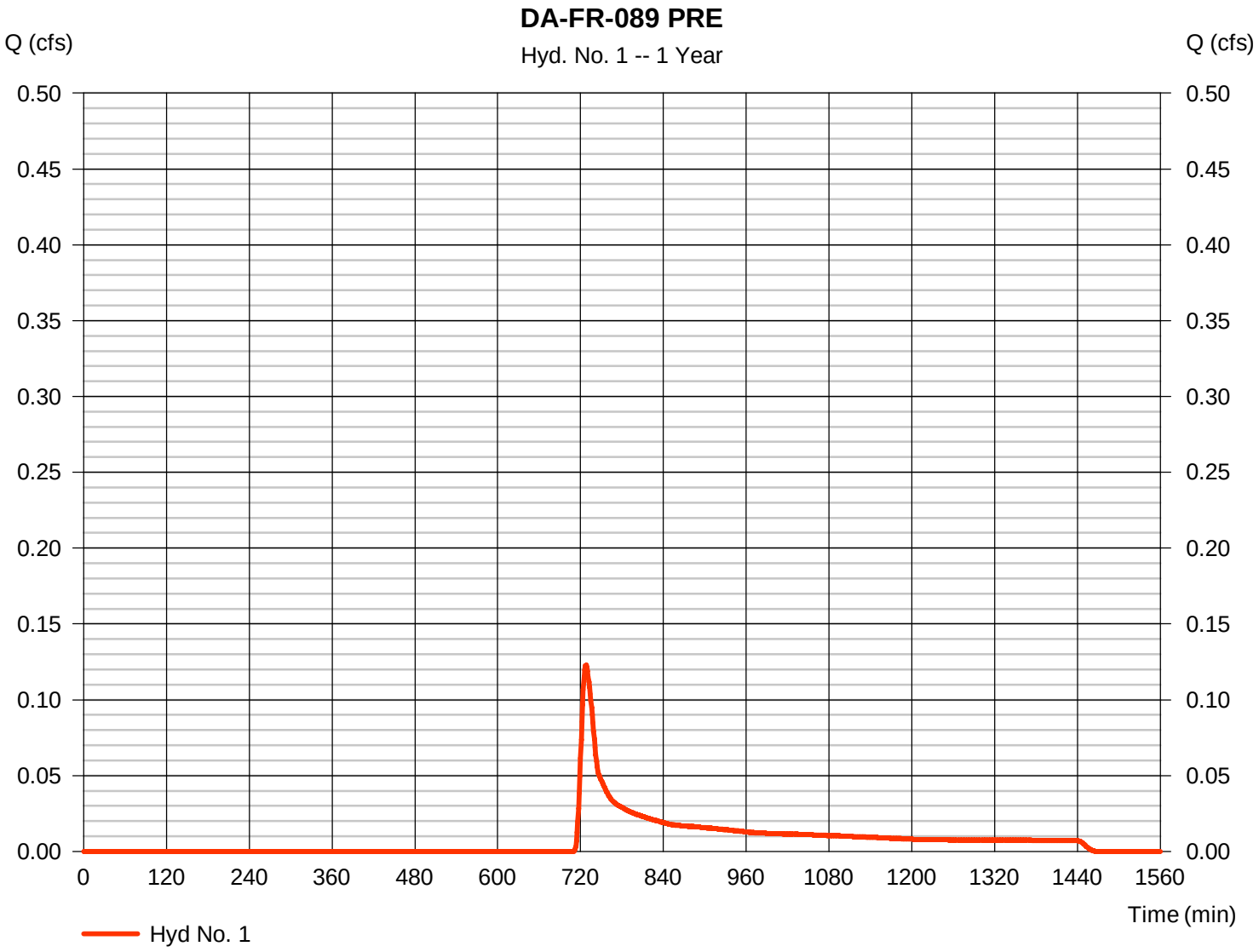
Hydrograph Report

Hyd. No. 1

DA-FR-089 PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.123 cfs
Storm frequency	= 1 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 691 cuft
Drainage area	= 0.560 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.30 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.332 x 58) + (0.231 x 55)] / 0.560



TR55 Tc Worksheet

Hyd. No. 1

DA-FR-089 PRE

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.400		0.400		0.011		
Flow length (ft)	= 28.1		71.9		0.0		
Two-year 24-hr precip. (in)	= 3.70		3.70		3.70		
Land slope (%)	= 12.40		2.53		0.00		
Travel Time (min)	**= 3.49**	**+**	**13.96**	**+**	**0.00**	**=**	**17.45**
Shallow Concentrated Flow							
Flow length (ft)	= 110.33		11.54		0.00		
Watercourse slope (%)	= 2.16		2.75		0.00		
Surface description	= Unpaved		Unpaved		Paved		
Average velocity (ft/s)	=2.37		2.68		0.00		
Travel Time (min)	**= 0.78**	**+**	**0.07**	**+**	**0.00**	**=**	**0.85**
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	= 0.015		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 ..... 18.30 min

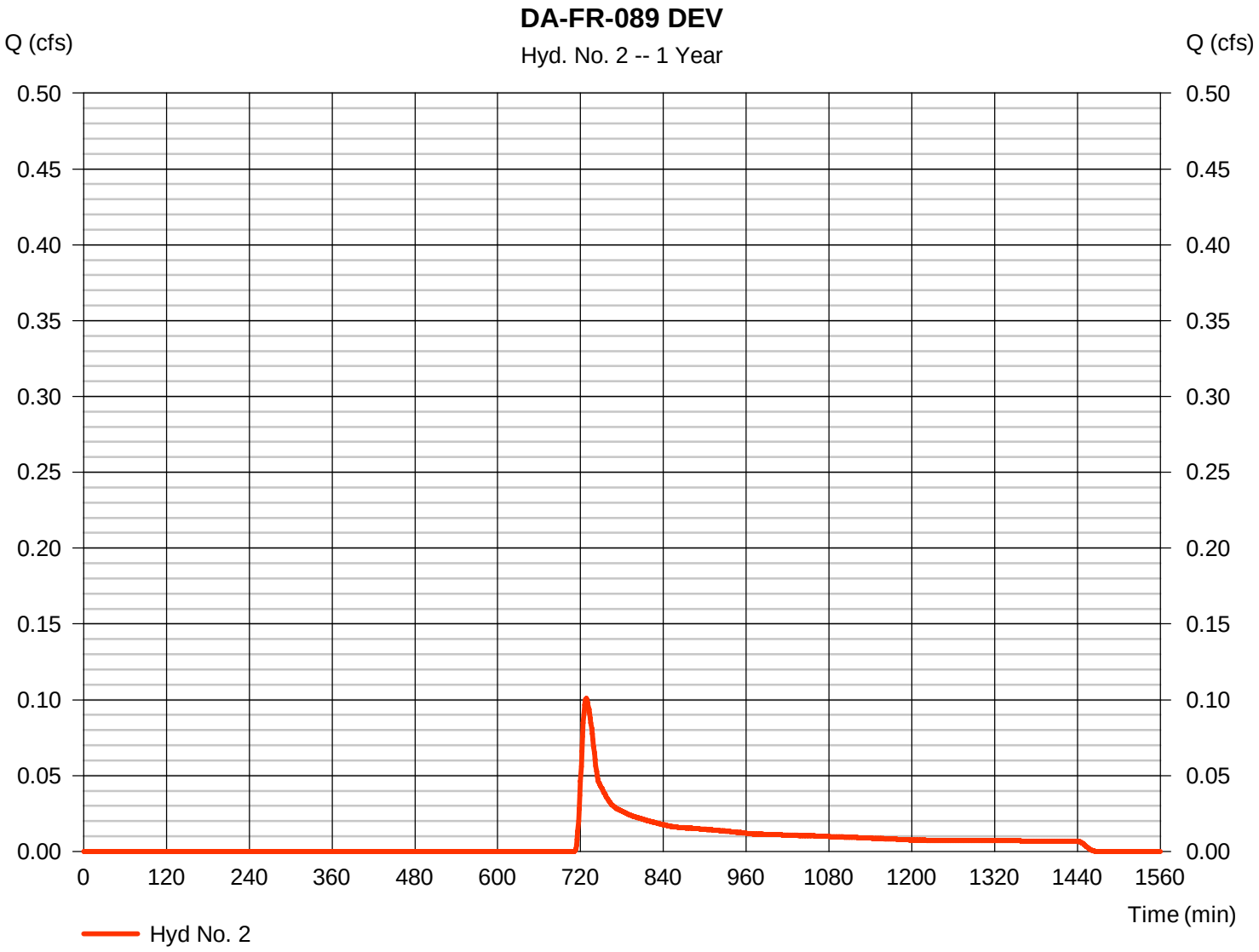
Hydrograph Report

Hyd. No. 2

DA-FR-089 DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.101 cfs
Storm frequency	= 1 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 626 cuft
Drainage area	= 0.560 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.30 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.430 x 58) + (0.028 x 55) + (0.105 x 48)] / 0.560



TR55 Tc Worksheet

Hyd. No. 2

DA-FR-089 DEV

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.400		0.400		0.011		
Flow length (ft)	= 28.1		71.9		0.0		
Two-year 24-hr precip. (in)	= 3.70		3.70		0.00		
Land slope (%)	= 12.40		2.53		0.00		
Travel Time (min)	**= 3.49**	**+**	**13.96**	**+**	**0.00**	**=**	**17.45**
Shallow Concentrated Flow							
Flow length (ft)	= 110.33		11.54		0.00		
Watercourse slope (%)	= 2.16		2.75		0.00		
Surface description	= Unpaved		Unpaved		Paved		
Average velocity (ft/s)	=2.37		2.68		0.00		
Travel Time (min)	**= 0.78**	**+**	**0.07**	**+**	**0.00**	**=**	**0.85**
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	= 0.015		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**

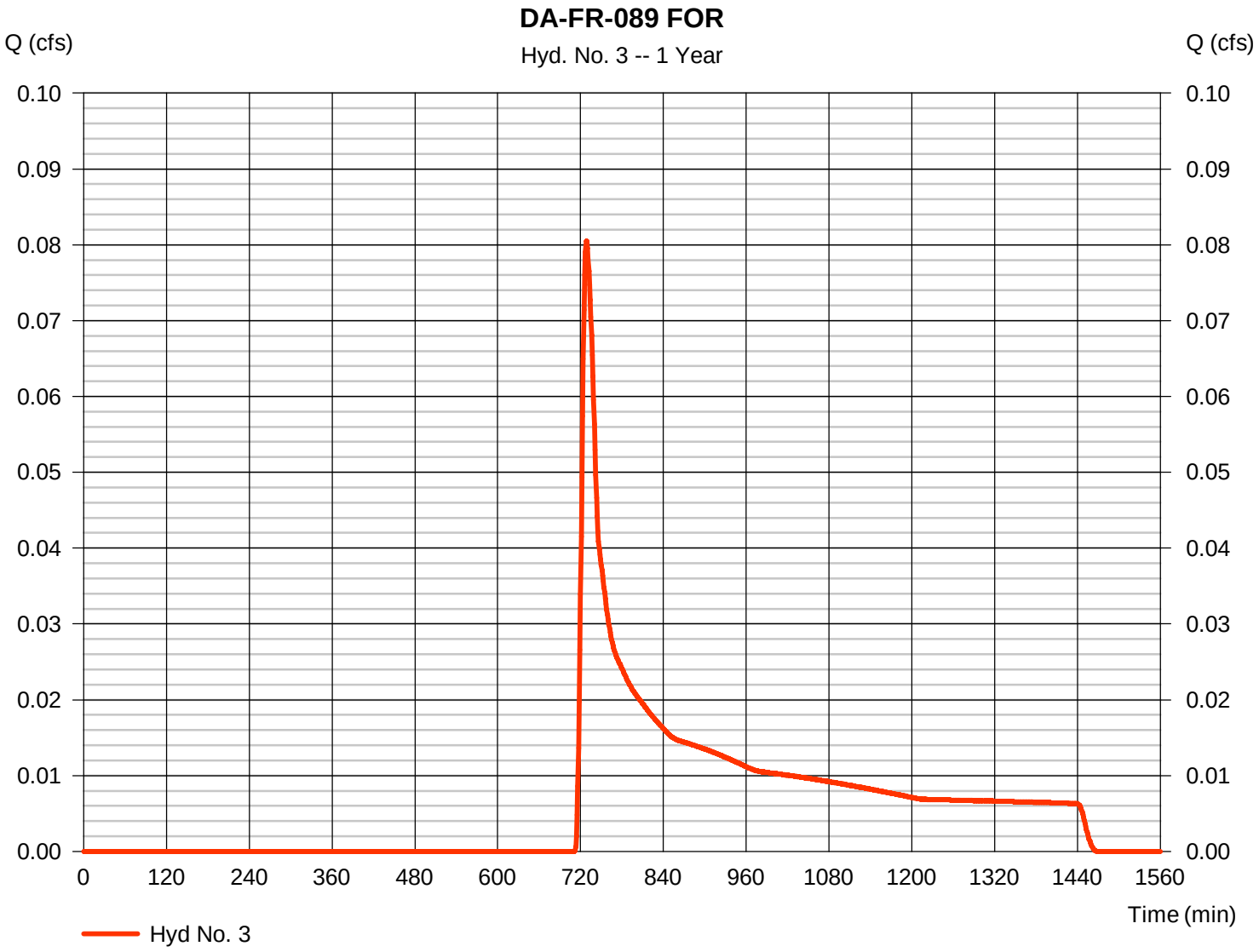
Total Travel Time, Tc ..... 18.30 min

Hydrograph Report

Hyd. No. 3

DA-FR-089 FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.080 cfs
Storm frequency	= 1 yrs	Time to peak	= 729 min
Time interval	= 1 min	Hyd. volume	= 565 cuft
Drainage area	= 0.560 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.30 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



TR55 Tc Worksheet

Hyd. No. 3

DA-FR-089 FOR

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.400		0.400		0.011		
Flow length (ft)	= 28.1		71.9		0.0		
Two-year 24-hr precip. (in)	= 3.70		3.70		3.70		
Land slope (%)	= 12.40		2.53		0.00		
Travel Time (min)	**= 3.49**	**+**	**13.96**	**+**	**0.00**	**=**	**17.45**
Shallow Concentrated Flow							
Flow length (ft)	= 110.33		11.54		0.00		
Watercourse slope (%)	= 2.16		2.75		0.00		
Surface description	= Unpaved		Unpaved		Paved		
Average velocity (ft/s)	=2.37		2.68		0.00		
Travel Time (min)	**= 0.78**	**+**	**0.07**	**+**	**0.00**	**=**	**0.85**
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	= 0.015		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 ..... 18.30 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	0.218	1	727	991	------	------	------	DA-FR-089 PRE
2	SCS Runoff	0.188	1	727	912	------	------	------	DA-FR-089 DEV
3	SCS Runoff	0.159	1	727	835	------	------	------	DA-FR-089 FOR

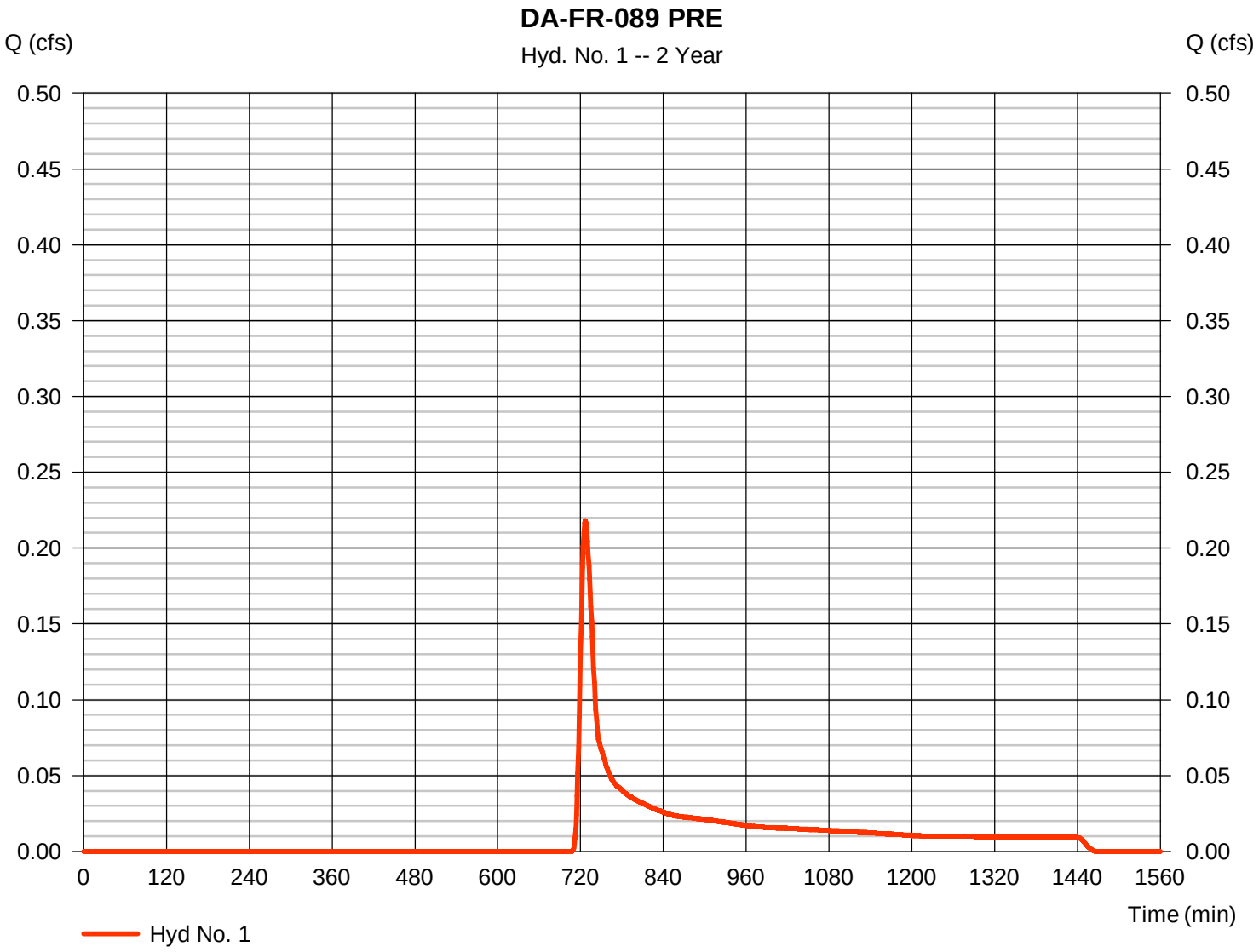
Hydrograph Report

Hyd. No. 1

DA-FR-089 PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.218 cfs
Storm frequency	= 2 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 991 cuft
Drainage area	= 0.560 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.30 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.332 x 58) + (0.231 x 55)] / 0.560



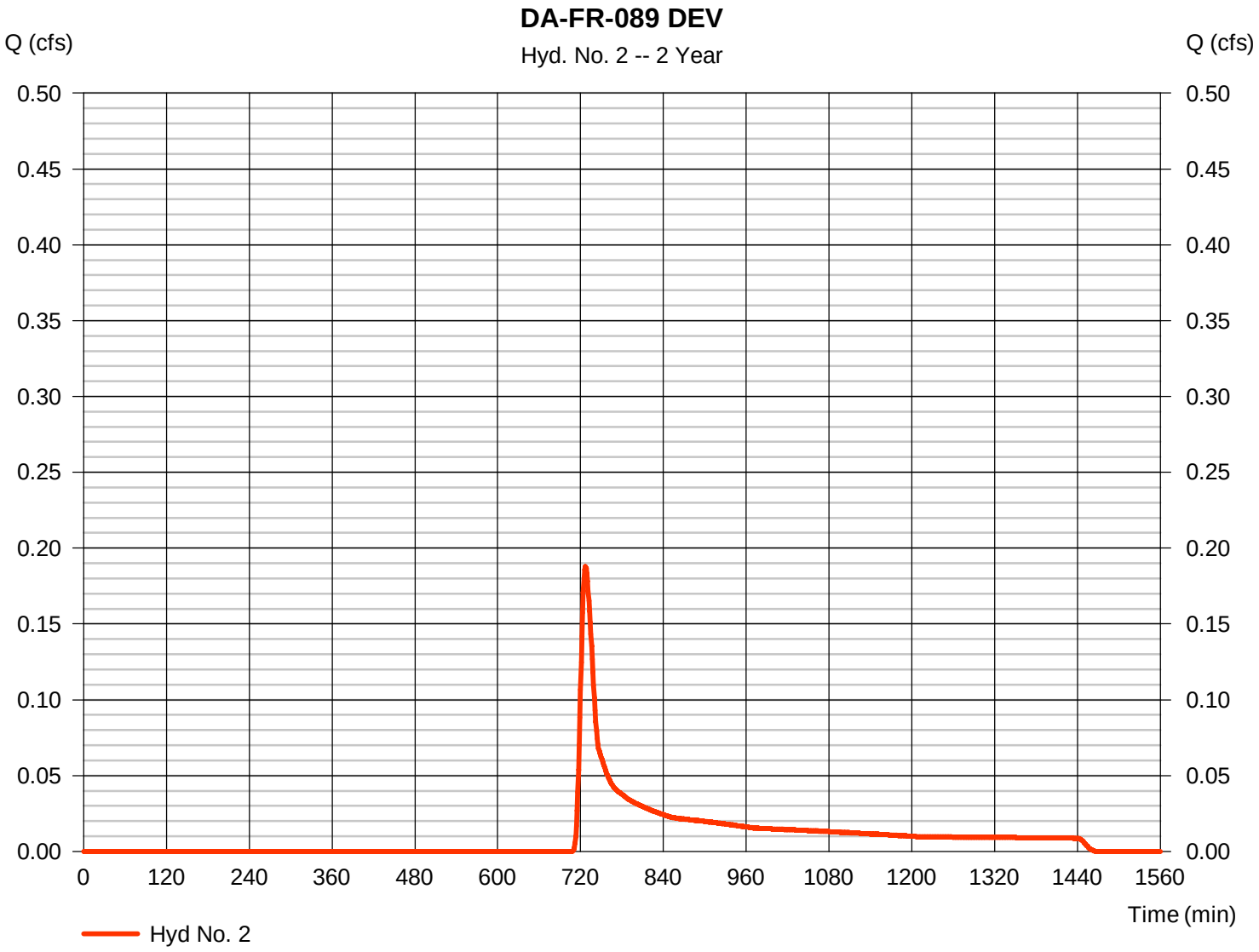
Hydrograph Report

Hyd. No. 2

DA-FR-089 DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.188 cfs
Storm frequency	= 2 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 912 cuft
Drainage area	= 0.560 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.30 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.430 x 58) + (0.028 x 55) + (0.105 x 48)] / 0.560

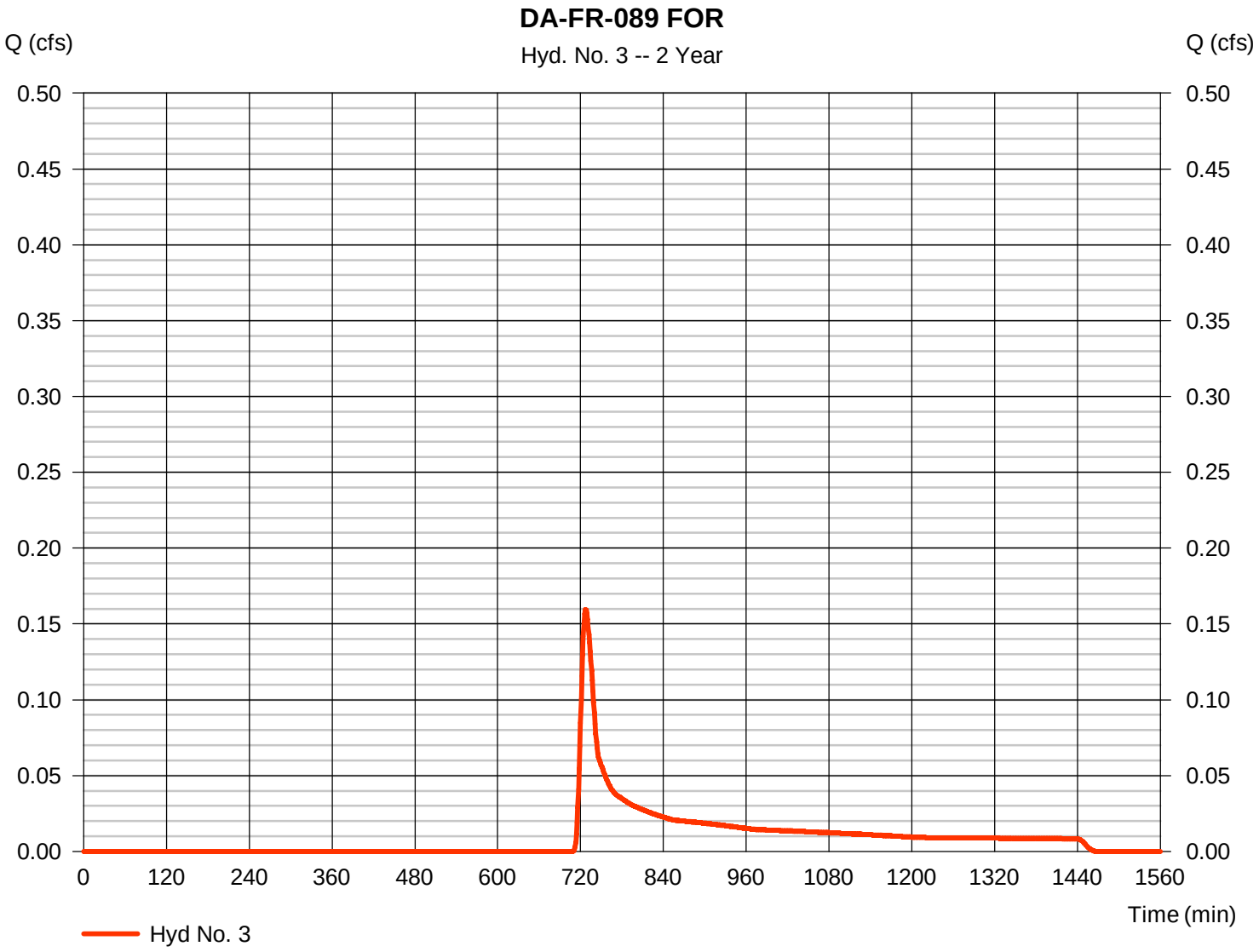


Hydrograph Report

Hyd. No. 3

DA-FR-089 FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.159 cfs
Storm frequency	= 2 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 835 cuft
Drainage area	= 0.560 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.30 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



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	0.927	1	725	3,008	------	------	------	DA-FR-089 PRE
2	SCS Runoff	0.868	1	725	2,858	------	------	------	DA-FR-089 DEV
3	SCS Runoff	0.809	1	725	2,710	------	------	------	DA-FR-089 FOR

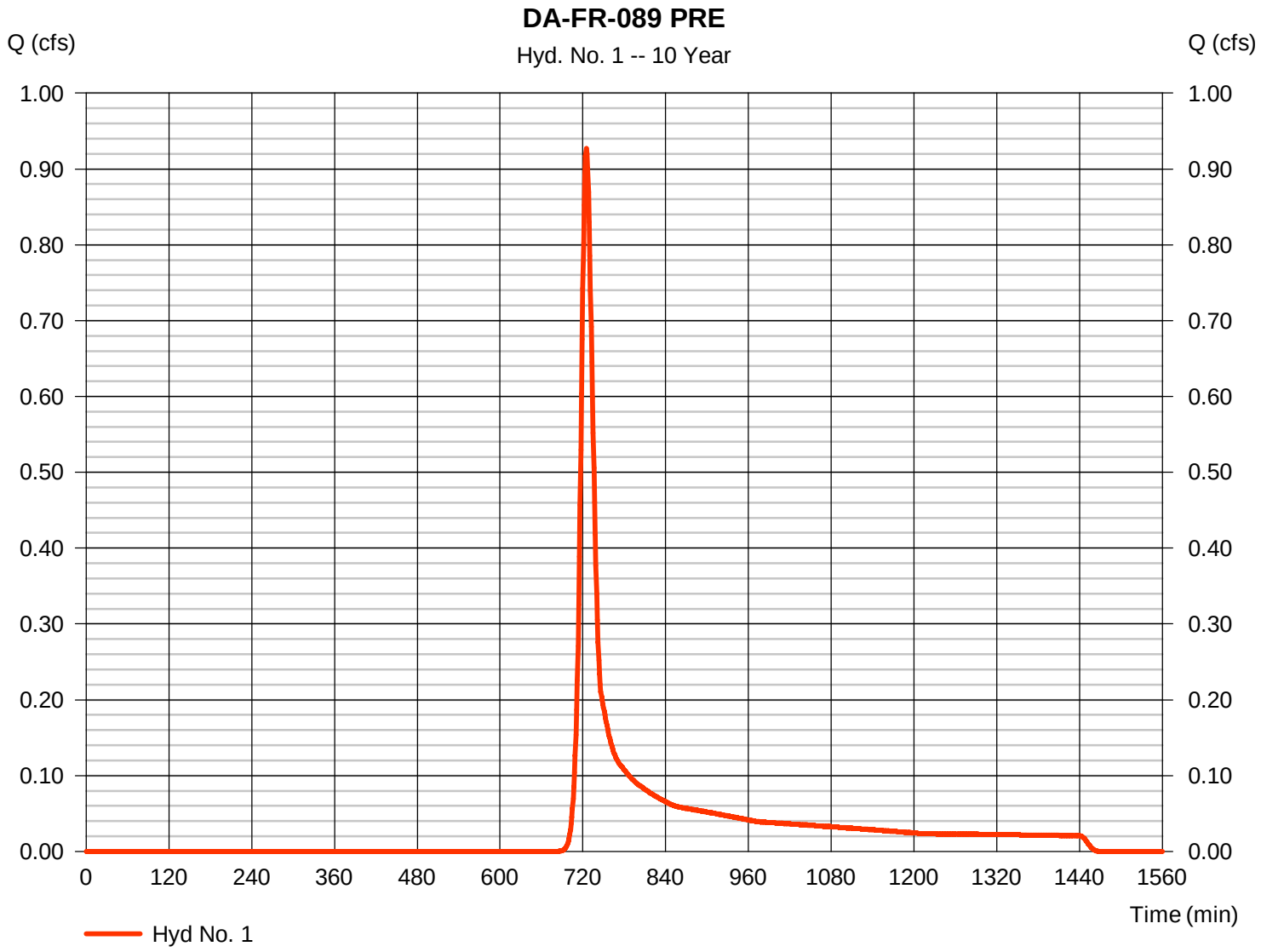
Hydrograph Report

Hyd. No. 1

DA-FR-089 PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.927 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 3,008 cuft
Drainage area	= 0.560 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.30 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.332 x 58) + (0.231 x 55)] / 0.560



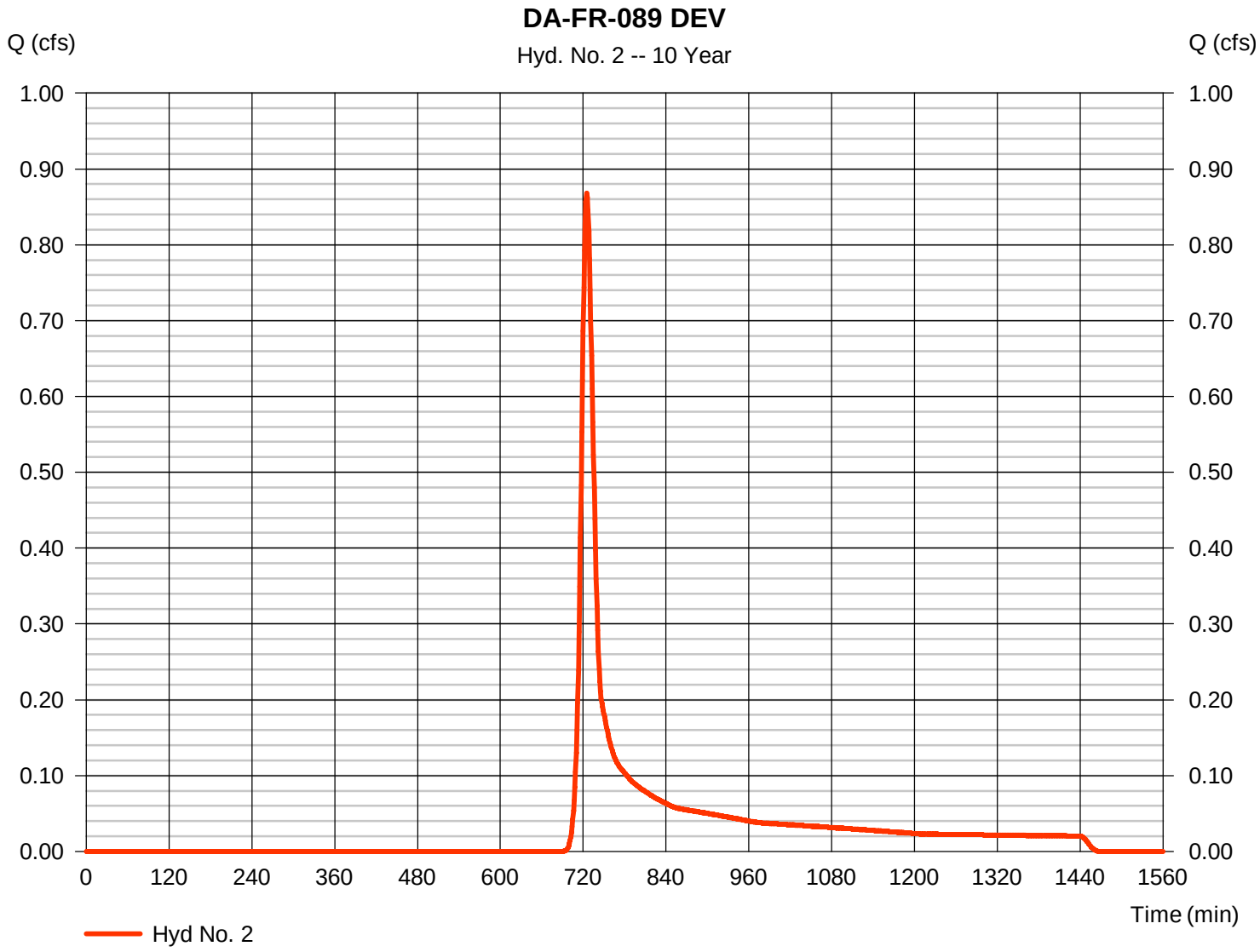
Hydrograph Report

Hyd. No. 2

DA-FR-089 DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.868 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 2,858 cuft
Drainage area	= 0.560 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.30 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.430 x 58) + (0.028 x 55) + (0.105 x 48)] / 0.560

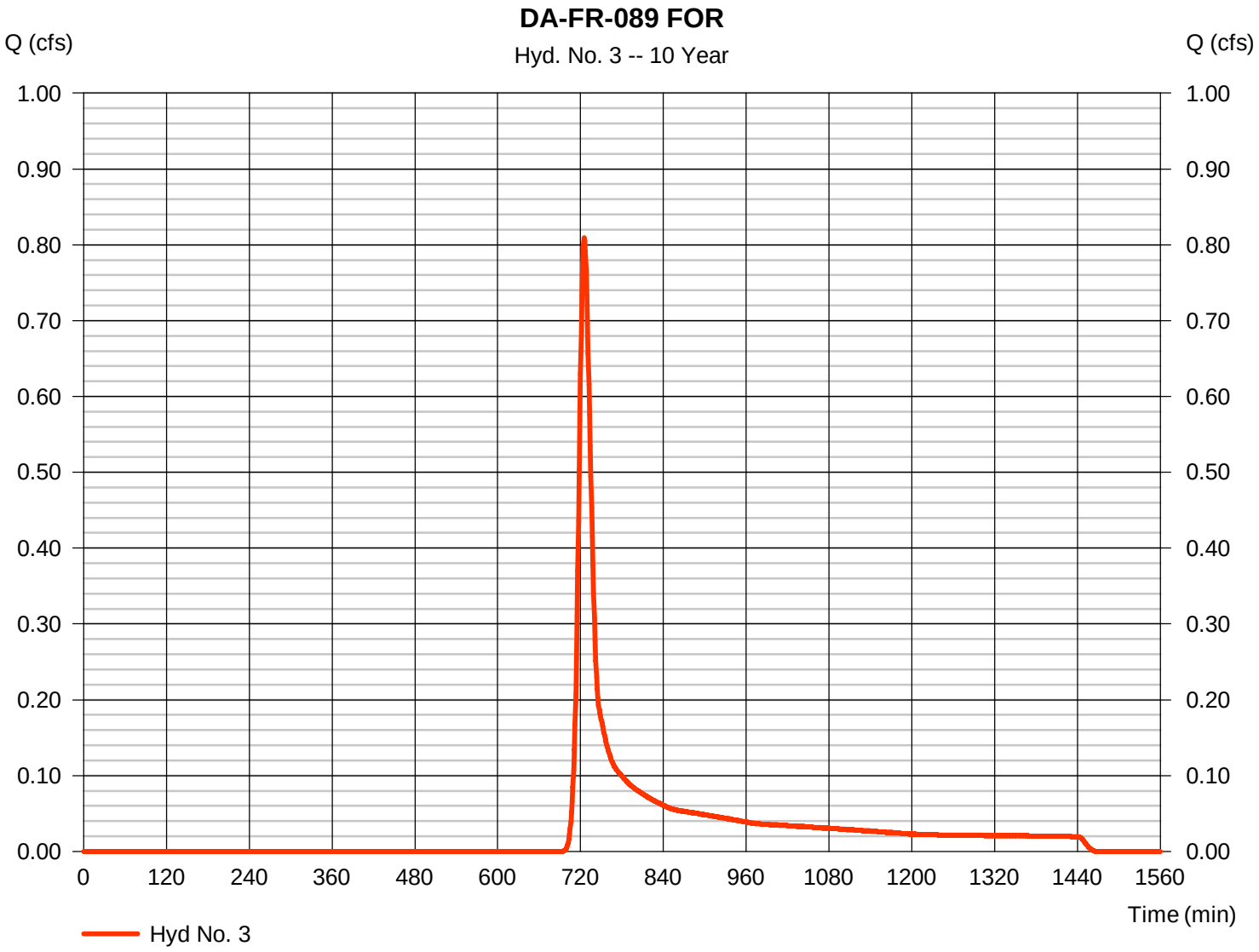


Hydrograph Report

Hyd. No. 3

DA-FR-089 FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.809 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 2,710 cuft
Drainage area	= 0.560 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.30 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



Hydraflow Rainfall Report

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

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

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

Tc = time in minutes. Values may exceed 60.

ng\Franklin County\Downloaded Files\Franklin County DA Batch 4 - 046 - 058\Precipitation\Hydraflow\FranklinCo.pc

Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.30	3.70	0.00	0.00	5.70	0.00	0.00	0.00
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

DA-FR-090

DA-FR-090 is located primarily within forested land use with a portion of meadow and has rolling slopes. Golden View Road crosses the drainage area and residential property is located within the drainage area, but no new impervious area is proposed within DA-FR-090. The total phosphorus load reduction required for DA-FR-090 is -0.44 lb/yr. Multiple points of analysis were evaluated within DA-FR-090 to evaluate the effects on each receiving stream/channel following construction. Specifically DA-FR-090 was sub-divided into three sub-drainage areas (sub areas A through C).

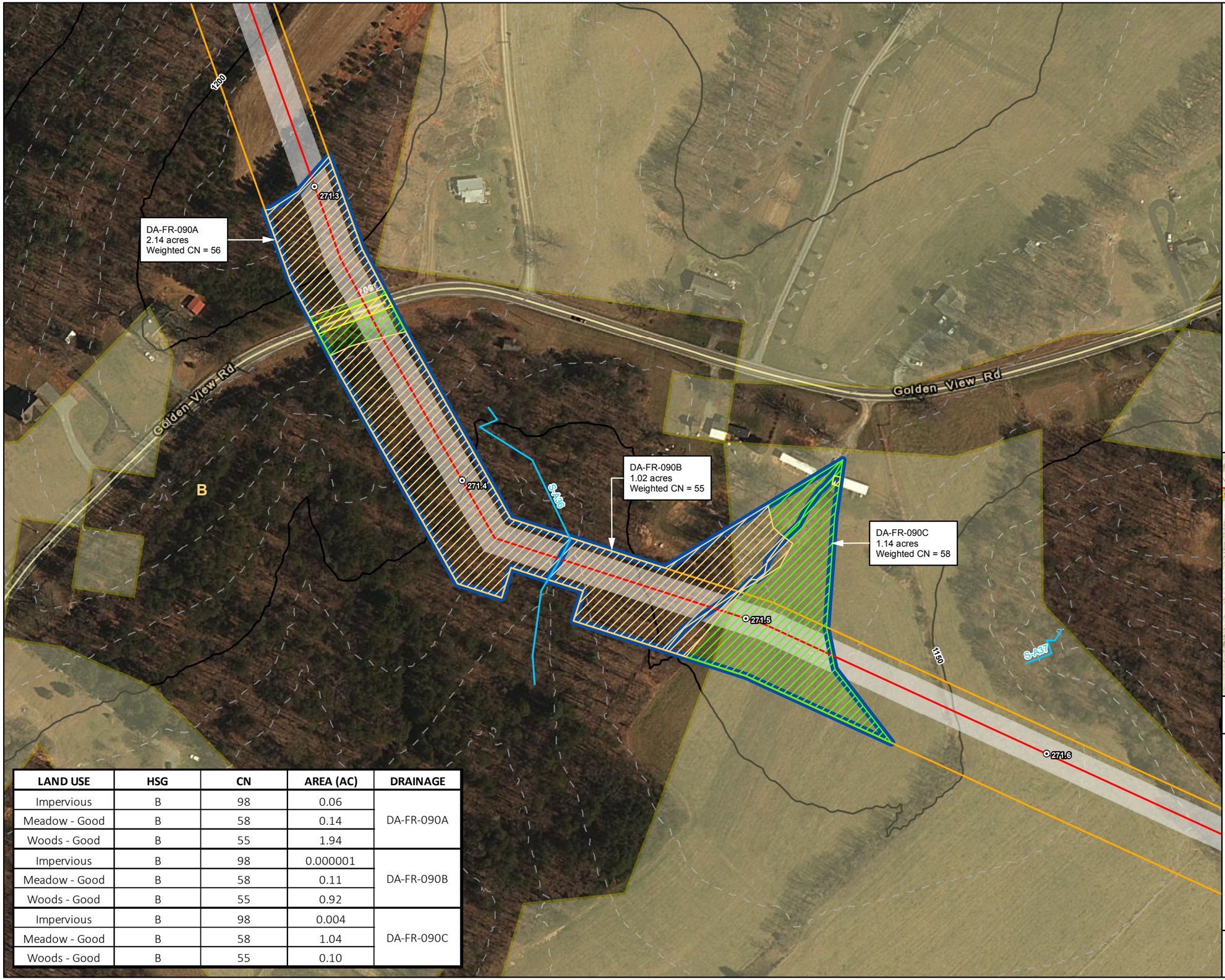
Sub-areas 090B and 090C contain both agricultural and non-agricultural areas within the limits of disturbance (LOD). Pre-construction agricultural areas will be returned to agricultural land use (i.e., returned to crop production, in identical condition) following construction. In non-agricultural areas, 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 Right of Way (ROW) is analyzed via VRRM; in these calculations agricultural areas are considered “Forest/Open Space”.

Stormwater quantity is met via the energy balance method for each of the three sub-areas – DA-FR-090A, DA-FR-090B and DA-FR-090C. Agricultural areas within the study area are included in the SWM analysis, but an Improvement Factor (IF) of 1.0 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 Hydrograph’s 10-year 24-hour peak discharge results indicate a reduction in flows ranging from 0.00 to 0.94 cfs for all drainage areas (as seen in table below).

Sub Area	Pre Peak Flow, 10-yr Q (cfs)	Post Peak Flow, Q 10-yr (cfs)	Flow differential
DA-FR-090A	5.72	4.78	-0.94
DA-FR-090B	1.67	1.55	-0.12
DA-FR-090C	2.15	2.15	0.00

Figures and calculations for each of the sub-areas for DA-FR-090 follow. See Appendix D of the Annual Standards and Specifications for further detail on stormwater methodology.



LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Impervious	B	98	0.06	DA-FR-090A
Meadow - Good	B	58	0.14	
Woods - Good	B	55	1.94	
Impervious	B	98	0.000001	DA-FR-090B
Meadow - Good	B	58	0.11	
Woods - Good	B	55	0.92	
Impervious	B	98	0.004	DA-FR-090C
Meadow - Good	B	58	1.04	
Woods - Good	B	55	0.10	

Legend

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

NAD 1983 UTM 17N (feet)

1:1,800

N W E S

150 75 0 150 Feet



Mountain Valley Pipeline Project

Mountain Valley PIPELINE

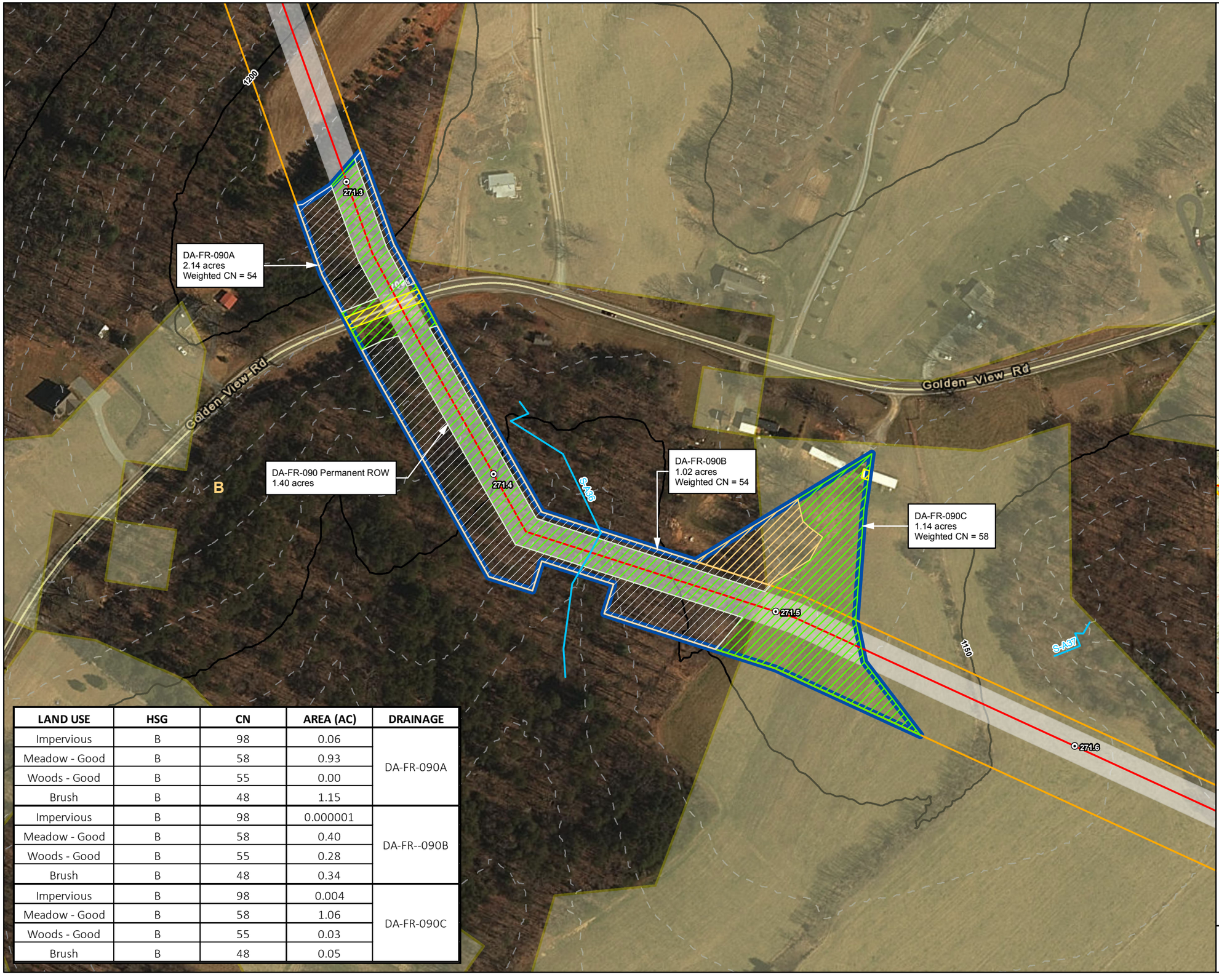
Pre-Construction Drainage Area Map
DA-FR-090
Spread 11

Figure 1
Franklin County, Virginia

August, 2017

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

Document Path: PGH P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\FranklinIMVP_PCSM_DA-FR-090_Pre.mxd



LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Impervious	B	98	0.06	DA-FR-090A
Meadow - Good	B	58	0.93	
Woods - Good	B	55	0.00	
Brush	B	48	1.15	
Impervious	B	98	0.000001	DA-FR--090B
Meadow - Good	B	58	0.40	
Woods - Good	B	55	0.28	
Brush	B	48	0.34	
Impervious	B	98	0.004	DA-FR-090C
Meadow - Good	B	58	1.06	
Woods - Good	B	55	0.03	
Brush	B	48	0.05	

Legend

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

NAD 1983 UTM 17N (feet)

N
W E
S

1:1,800

150 75 0 150 Feet



Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Post-Construction Drainage Area Map
DA-FR-090
Spread 11

Figure 2
Franklin County, Virginia

August, 2017

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

Document Path: P:\GIS\EQT_MVP\Mapdocs\DrainageMXD\Franklin\MVP_PCSM_DA-FR-090_Post.mxd

DA-FR-090A
2.14 acres
Weighted CN = 56

DA-FR-090B
1.02 acres
Weighted CN = 55

DA-FR-090C
1.14 acres
Weighted CN = 58

Golden View Rd

Golden View Rd

271.3

271.4

271.5

271.6

1200

1150

S-A90

S-A97

PRE-CONSTRUCTION TIME OF CONCENTRATION TO POI

	SHEET	SHALLOW	Calculated Time of Concentration (min)
DA-FR-090A	30.05 FT @ 43.09%	482.22 FT @ 11.94%	3.7
DA-FR-090B	100.00 FT @ 5.77%	232.71 FT @ 7.08%	14.0
DA-FR-090C	100.00 FT @ 3.80%	283.33 FT @ 4.97%	16.8

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)

1:1,800

150 75 0 150 Feet

N W E S



Mountain Valley Pipeline Project

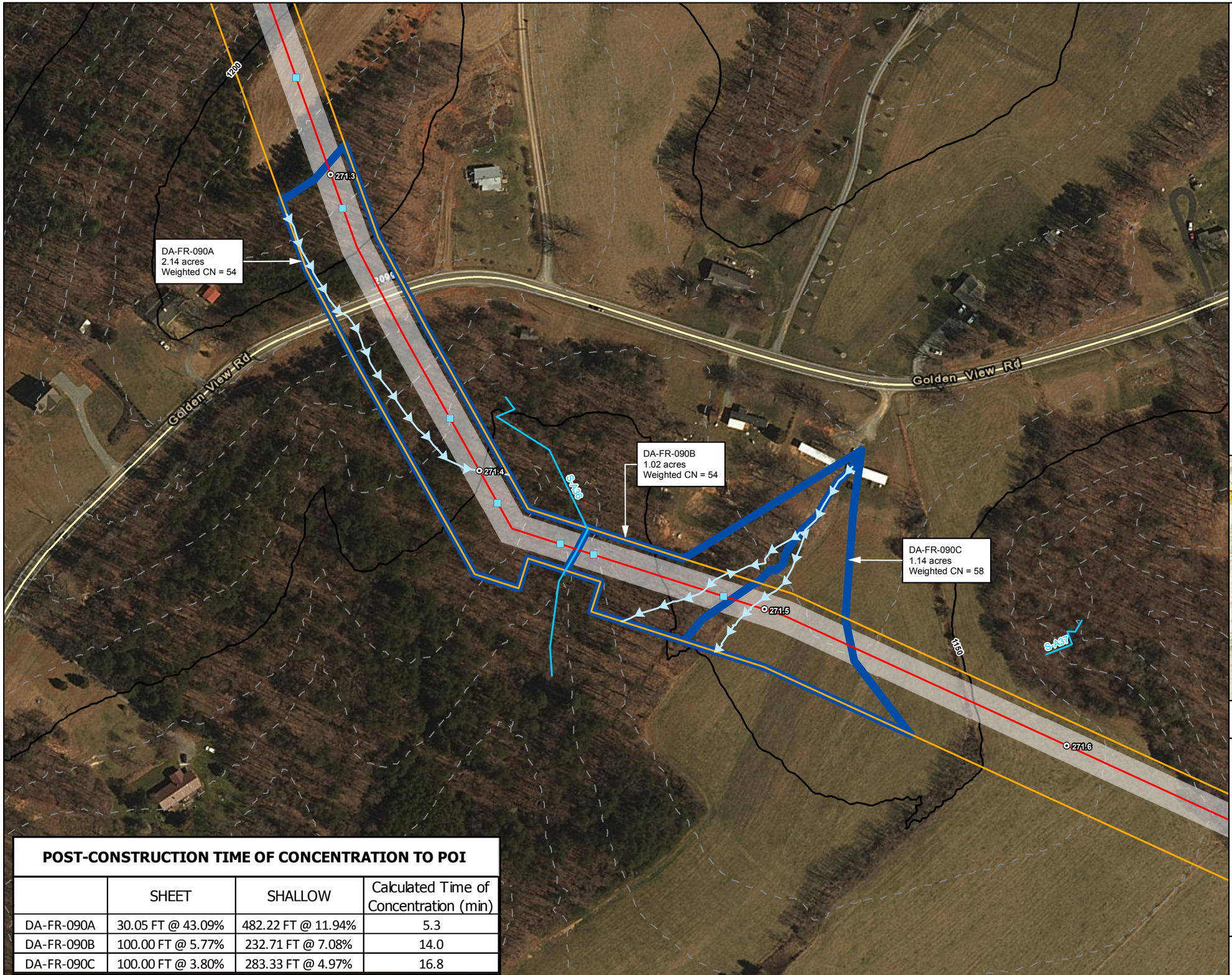
Mountain Valley PIPELINE

Pre-Construction Drainage Area and Time of Concentration
DA-FR-090
Spread 11

Figure 3
Franklin 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.

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POST-CONSTRUCTION TIME OF CONCENTRATION TO POI

	SHEET	SHALLOW	Calculated Time of Concentration (min)
DA-FR-090A	30.05 FT @ 43.09%	482.22 FT @ 11.94%	5.3
DA-FR-090B	100.00 FT @ 5.77%	232.71 FT @ 7.08%	14.0
DA-FR-090C	100.00 FT @ 3.80%	283.33 FT @ 4.97%	16.8

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)

1:1,800

150 75 0 150 Feet



Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Post-Construction Drainage Area and Time of Concentration
DA-FR-090
Spread 11

Figure 4
Franklin 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: PGH P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Franklin\Figures 3-4\MVP_PCSM_DA-FR-090_4.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:	**1.40**

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	1.38	0.00	0.00	1.38	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
					1.40	100

Post-ReDevelopment Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	% of Total	
Forest/Open (acres)	0.00	1.38	0.00	0.00	1.38	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	
					1.40	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)	219	219	--	219
TP Load (lb/yr)	0.14	0.14	--	0.14

Baseline TP Load (lb/yr): 0.574* **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	**0.10**	**0.10**

Total TP Load Reduction Required (lb/yr)	**-0.44**	N/A***	N/A***

******This is a linear development project***

	Final Post-Development Load (Post-ReDevelopment & New Impervious)	Pre-ReDevelopment
TN Load (lb/yr)	0.99	0.99

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 0.57 lb/yr (0.41 lb/ac/yr)*
[Post-Dev Reduction Requirement = Post-Dev TP load - baseline load of 0.57 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)	0.14
Remaining TP Load Reduction (lb/yr) Required	**0.00**

**** TARGET TP REDUCTION EXCEEDED BY 0.44 LB/YEAR ****

**Reduction below new development load limitation not required*

DA-FR-090A

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.805	2421
Developed Condition	0.454	2018
Pre-Developed (Forest) Condition	0.658	2184

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

Improvement Factor, IF = 0.8

Calculations:

Check #1: $Q_{developed} \leq IF \times [(Q_{pre\text{-}developed} \times RV_{pre\text{-}developed}) / RV_{developed}]$ ----------> 0.454 ≤ 0.773 OK

Check #2: $Q_{developed} \leq Q_{pre\text{-}developed}$ ----------> 0.454 ≤ 0.805 OK

Check #3: $Q_{developed}$ *shall not* be required to be ≤ $(Q_{forest} \times RV_{forest}) / RV_{developed}$ ---> 0.454 *shall not* be required to be ≤ 0.712

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

Note:

Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.

For Paved Road land surface types a Manning's n value 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

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DA-FR-090A_Hydraflow.gpw

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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-FR-090A PRE
2	SCS Runoff	DA-FR-090A DEV
3	SCS Runoff	DA-FR-090A FOR

Hydrograph Return Period Recap

Hyd. No.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)							Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	------	0.805	1.424	-------	-------	5.718	-------	-------	-------	DA-FR-090A PRE
2	SCS Runoff	------	0.454	0.964	-------	-------	4.775	-------	-------	-------	DA-FR-090A DEV
3	SCS Runoff	------	0.658	1.232	-------	-------	5.375	-------	-------	-------	DA-FR-090A FOR

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	0.805	1	719	2,421	------	------	------	DA-FR-090A PRE
2	SCS Runoff	0.454	1	721	2,018	------	------	------	DA-FR-090A DEV
3	SCS Runoff	0.658	1	719	2,184	------	------	------	DA-FR-090A FOR

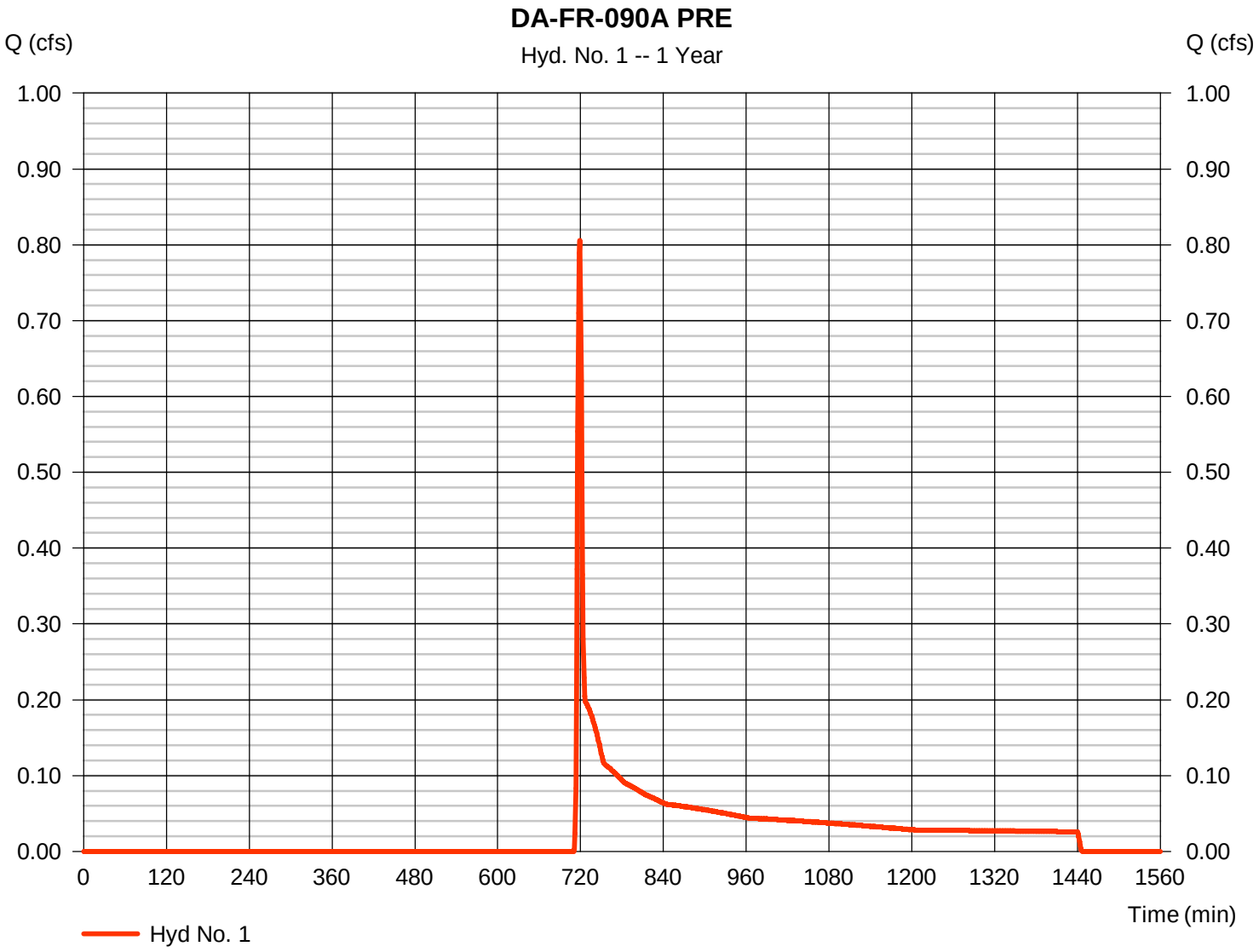
Hydrograph Report

Hyd. No. 1

DA-FR-090A PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.805 cfs
Storm frequency	= 1 yrs	Time to peak	= 719 min
Time interval	= 1 min	Hyd. volume	= 2,421 cuft
Drainage area	= 2.140 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 3.70 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.060 x 98) + (0.144 x 58) + (1.937 x 55)] / 2.140



TR55 Tc Worksheet

Hyd. No. 1

DA-FR-090A PRE

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.400		0.011		0.011		
Flow length (ft)	= 30.0		0.0		0.0		
Two-year 24-hr precip. (in)	= 3.70		0.00		0.00		
Land slope (%)	= 43.09		0.00		0.00		
Travel Time (min)	**= 2.23**	**+**	**0.00**	**+**	**0.00**	**=**	**2.23**
Shallow Concentrated Flow							
Flow length (ft)	= 482.22		0.00		0.00		
Watercourse slope (%)	= 11.94		0.00		0.00		
Surface description	= Unpaved		Unpaved		Paved		
Average velocity (ft/s)	=5.58		0.00		0.00		
Travel Time (min)	**= 1.44**	**+**	**0.00**	**+**	**0.00**	**=**	**1.44**
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	= 0.015		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 ..... 3.70 min

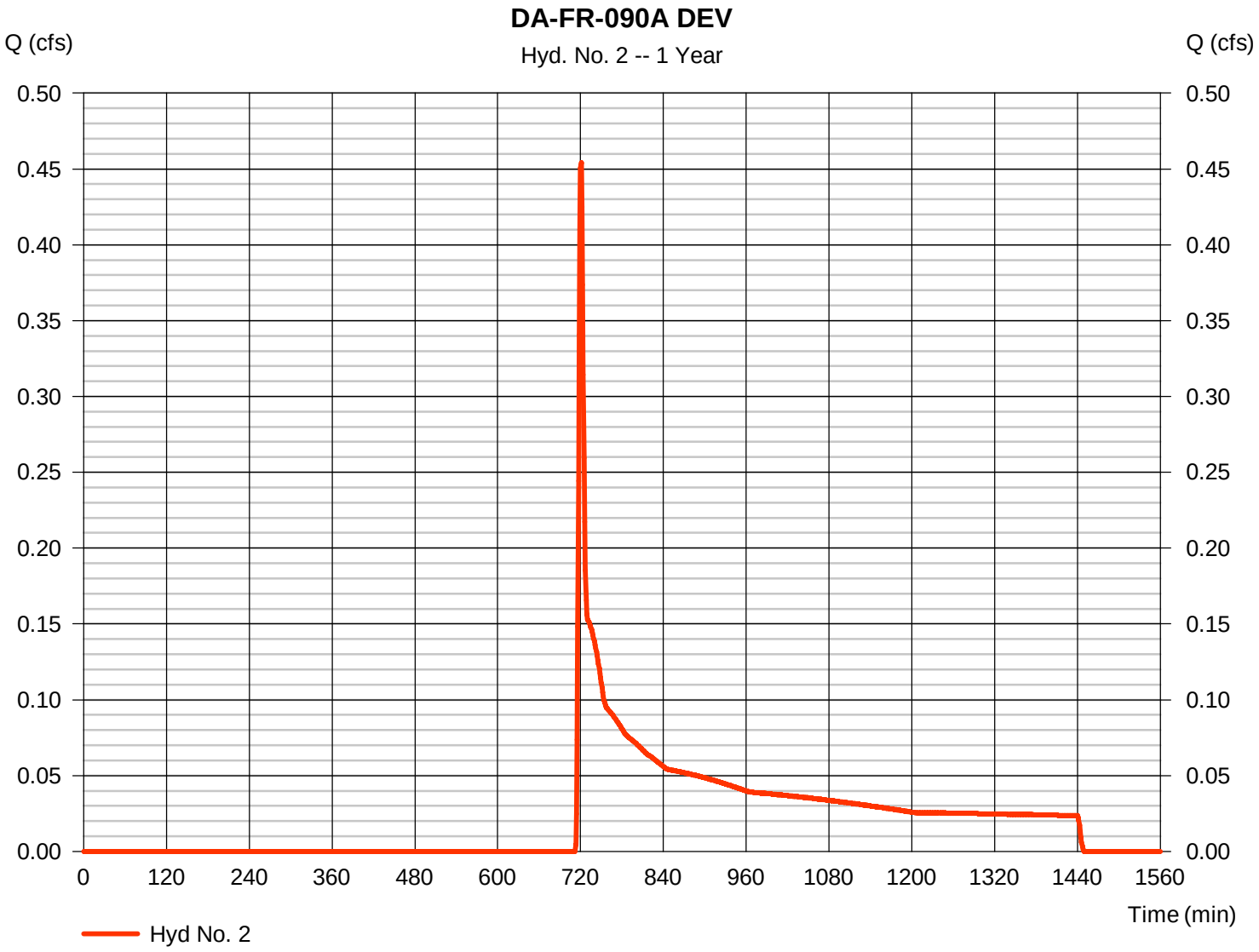
Hydrograph Report

Hyd. No. 2

DA-FR-090A DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.454 cfs
Storm frequency	= 1 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 2,018 cuft
Drainage area	= 2.140 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 5.30 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.060 x 98) + (0.932 x 58) + (1.149 x 48)] / 2.140



TR55 Tc Worksheet

Hyd. No. 2

DA-FR-090A DEV

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.800		0.011		0.011		
Flow length (ft)	= 30.0		0.0		0.0		
Two-year 24-hr precip. (in)	= 3.70		0.00		0.00		
Land slope (%)	= 43.09		0.00		0.00		
Travel Time (min)	**= 3.89**	**+**	**0.00**	**+**	**0.00**	**=**	**3.89**
Shallow Concentrated Flow							
Flow length (ft)	= 482.22		0.00		0.00		
Watercourse slope (%)	= 11.94		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=5.58		0.00		0.00		
Travel Time (min)	**= 1.44**	**+**	**0.00**	**+**	**0.00**	**=**	**1.44**
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	= 0.015		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**

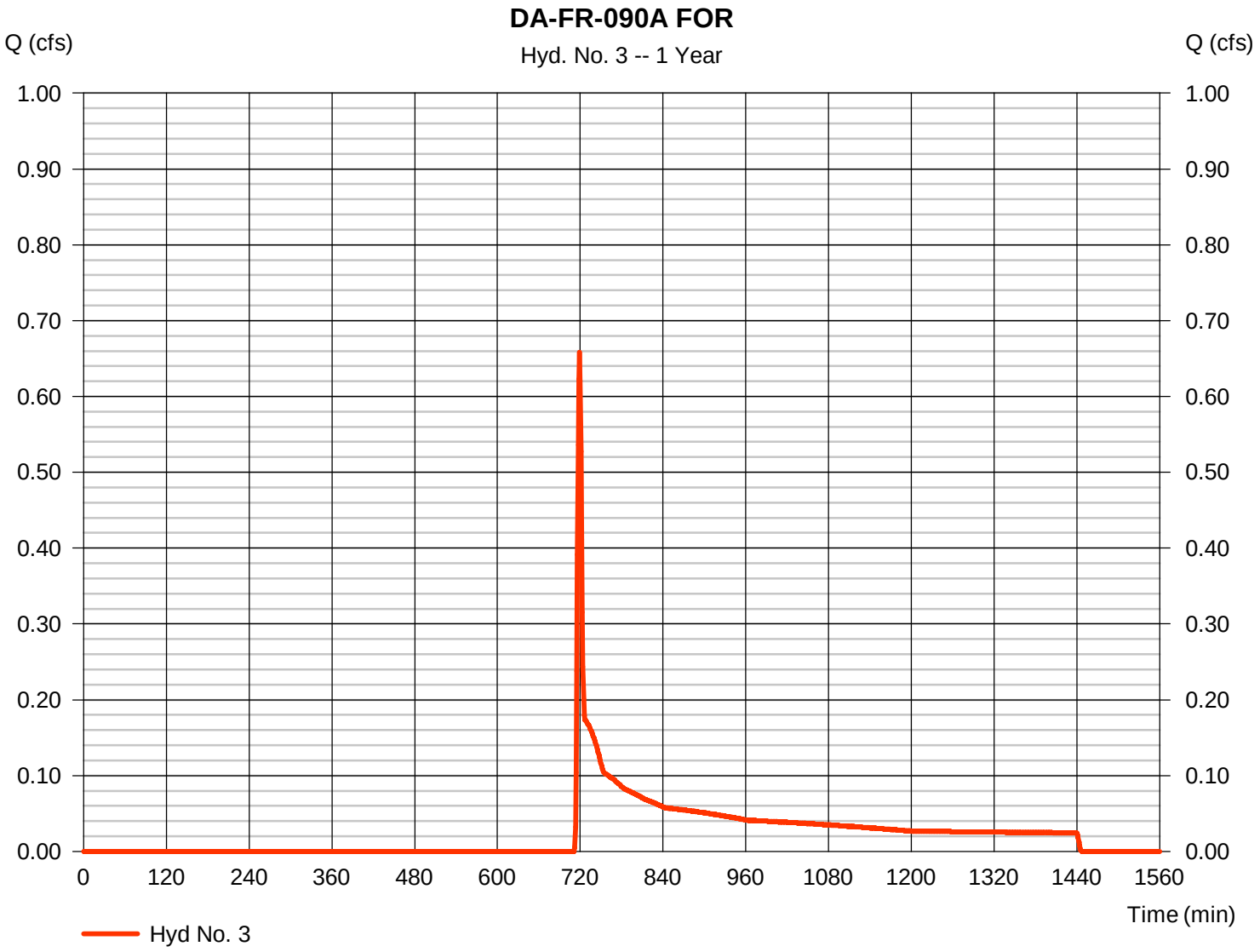
Total Travel Time, Tc ..... 5.30 min

Hydrograph Report

Hyd. No. 3

DA-FR-090A FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.658 cfs
Storm frequency	= 1 yrs	Time to peak	= 719 min
Time interval	= 1 min	Hyd. volume	= 2,184 cuft
Drainage area	= 2.140 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 3.40 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



TR55 Tc Worksheet

Hyd. No. 3

DA-FR-090A FOR

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.400		0.011		0.011		
Flow length (ft)	= 30.0		0.0		0.0		
Two-year 24-hr precip. (in)	= 3.70		0.00		0.00		
Land slope (%)	= 43.09		0.00		0.00		
Travel Time (min)	**= 2.23**	**+**	**0.00**	**+**	**0.00**	**=**	**2.23**
Shallow Concentrated Flow							
Flow length (ft)	= 482.22		0.00		0.00		
Watercourse slope (%)	= 11.94		0.00		0.00		
Surface description	= Paved		Paved		Paved		
Average velocity (ft/s)	=7.02		0.00		0.00		
Travel Time (min)	**= 1.14**	**+**	**0.00**	**+**	**0.00**	**=**	**1.14**
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	= 0.015		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 ..... 3.40 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	1.424	1	718	3,524	------	------	------	DA-FR-090A PRE
2	SCS Runoff	0.964	1	720	3,035	------	------	------	DA-FR-090A DEV
3	SCS Runoff	1.232	1	718	3,228	------	------	------	DA-FR-090A FOR

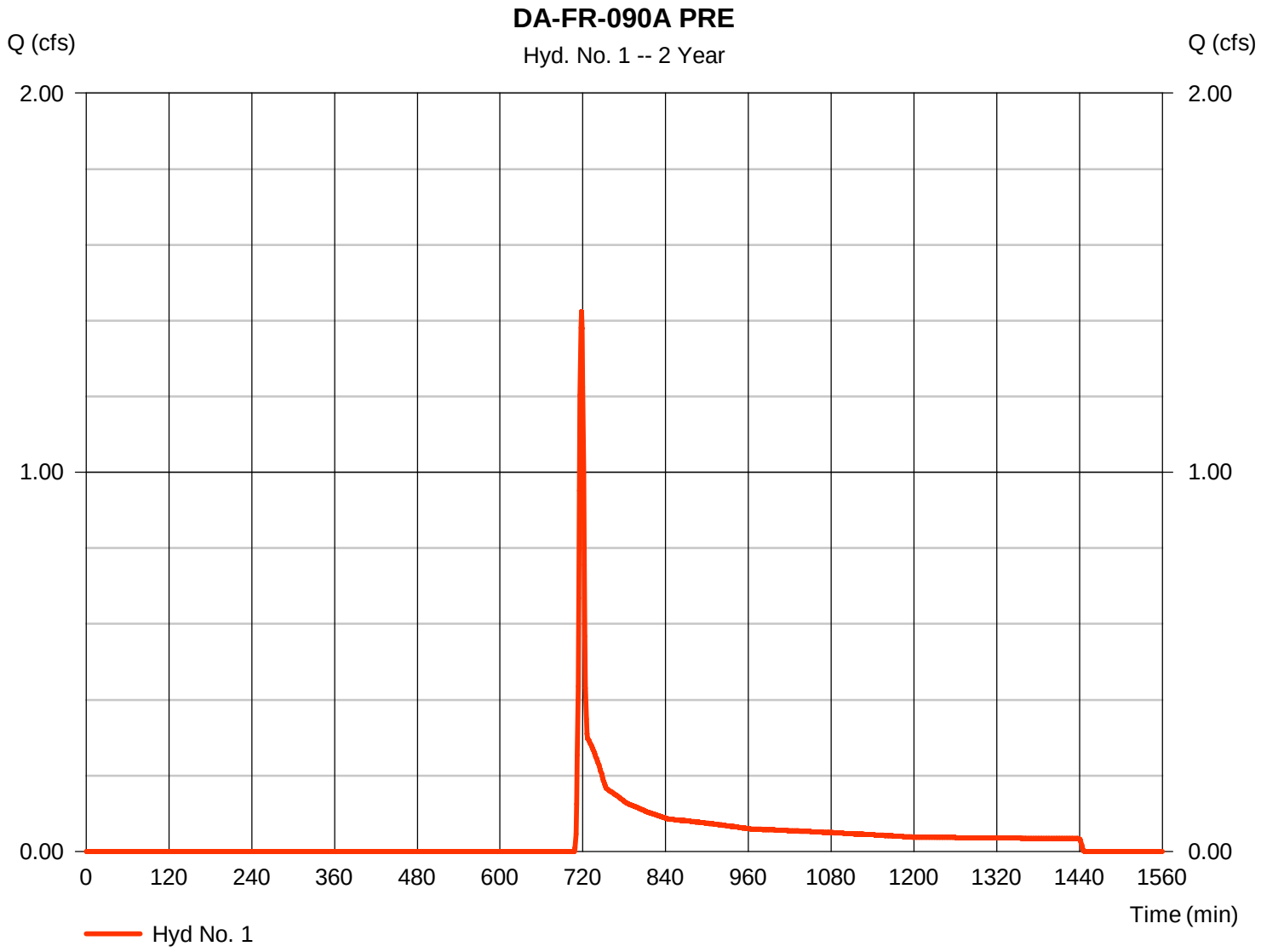
Hydrograph Report

Hyd. No. 1

DA-FR-090A PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	1.424 cfs
Storm frequency	=	2 yrs	Time to peak	=	718 min
Time interval	=	1 min	Hyd. volume	=	3,524 cuft
Drainage area	=	2.140 ac	Curve number	=	56*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	3.70 min
Total precip.	=	3.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.060 x 98) + (0.144 x 58) + (1.937 x 55)] / 2.140



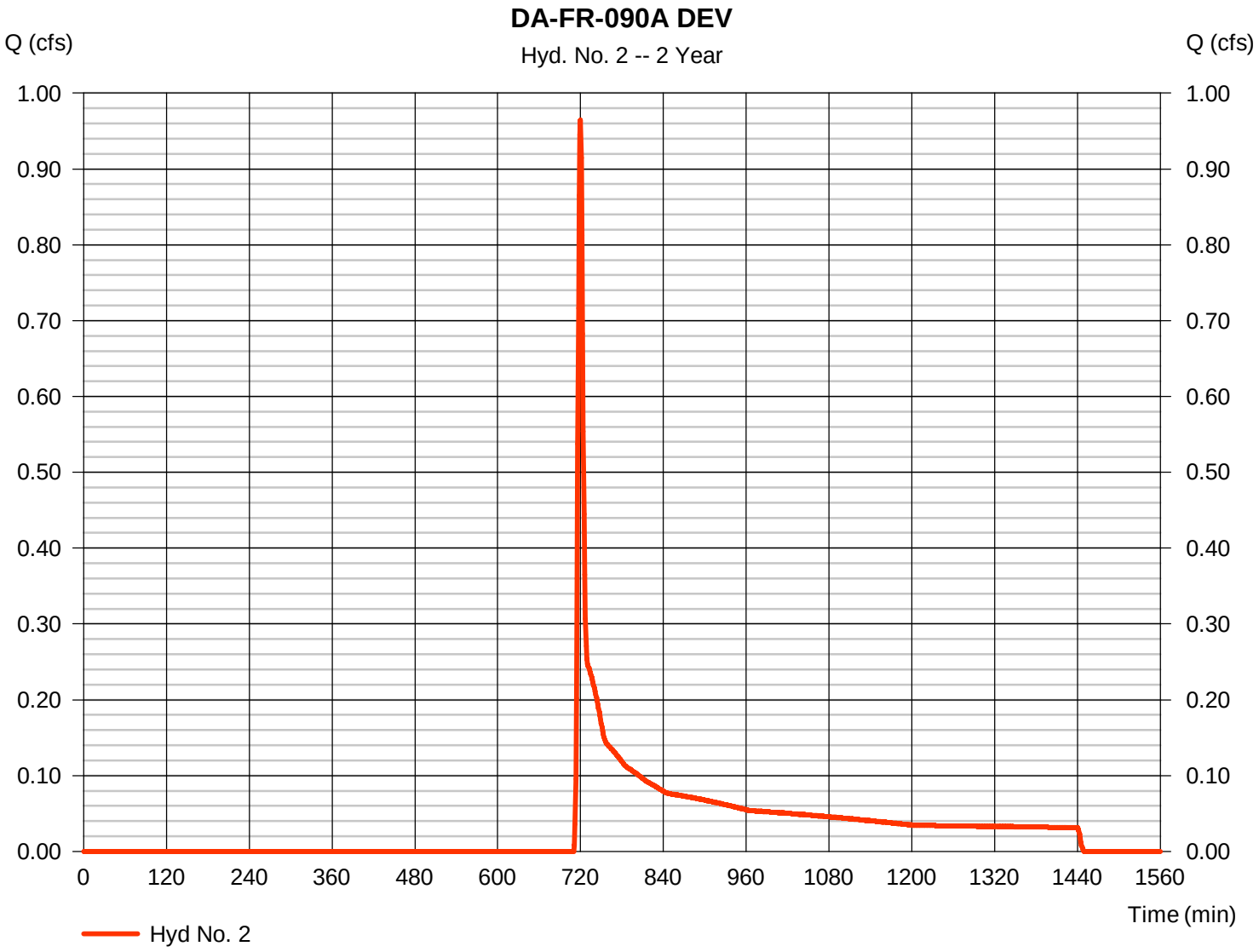
Hydrograph Report

Hyd. No. 2

DA-FR-090A DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.964 cfs
Storm frequency	= 2 yrs	Time to peak	= 720 min
Time interval	= 1 min	Hyd. volume	= 3,035 cuft
Drainage area	= 2.140 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 5.30 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.060 x 98) + (0.932 x 58) + (1.149 x 48)] / 2.140

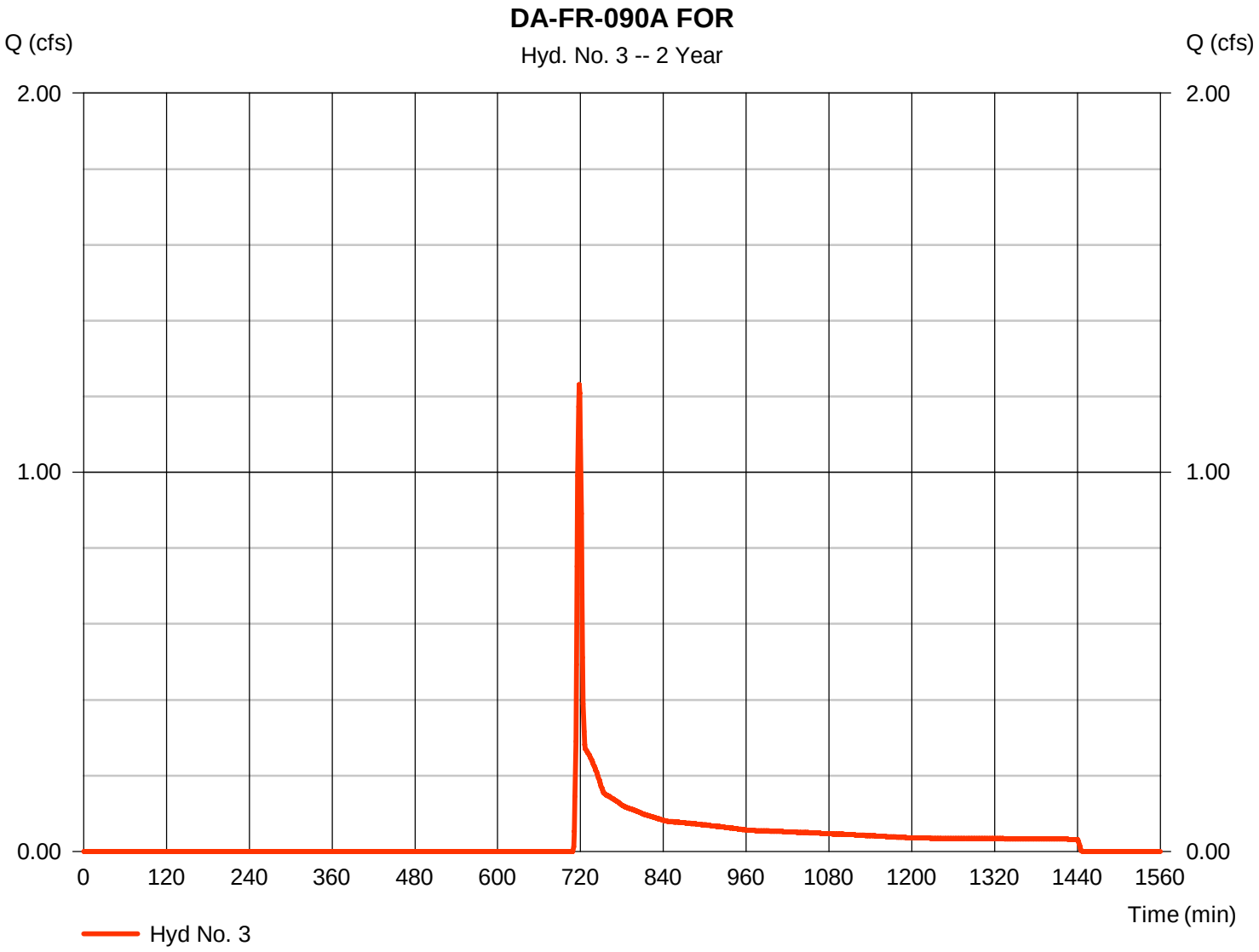


Hydrograph Report

Hyd. No. 3

DA-FR-090A FOR

Hydrograph type	=	SCS Runoff	Peak discharge	=	1.232 cfs
Storm frequency	=	2 yrs	Time to peak	=	718 min
Time interval	=	1 min	Hyd. volume	=	3,228 cuft
Drainage area	=	2.140 ac	Curve number	=	55
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	3.40 min
Total precip.	=	3.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484



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	5.718	1	717	11,047	------	------	------	DA-FR-090A PRE
2	SCS Runoff	4.775	1	718	10,223	------	------	------	DA-FR-090A DEV
3	SCS Runoff	5.375	1	717	10,475	------	------	------	DA-FR-090A FOR

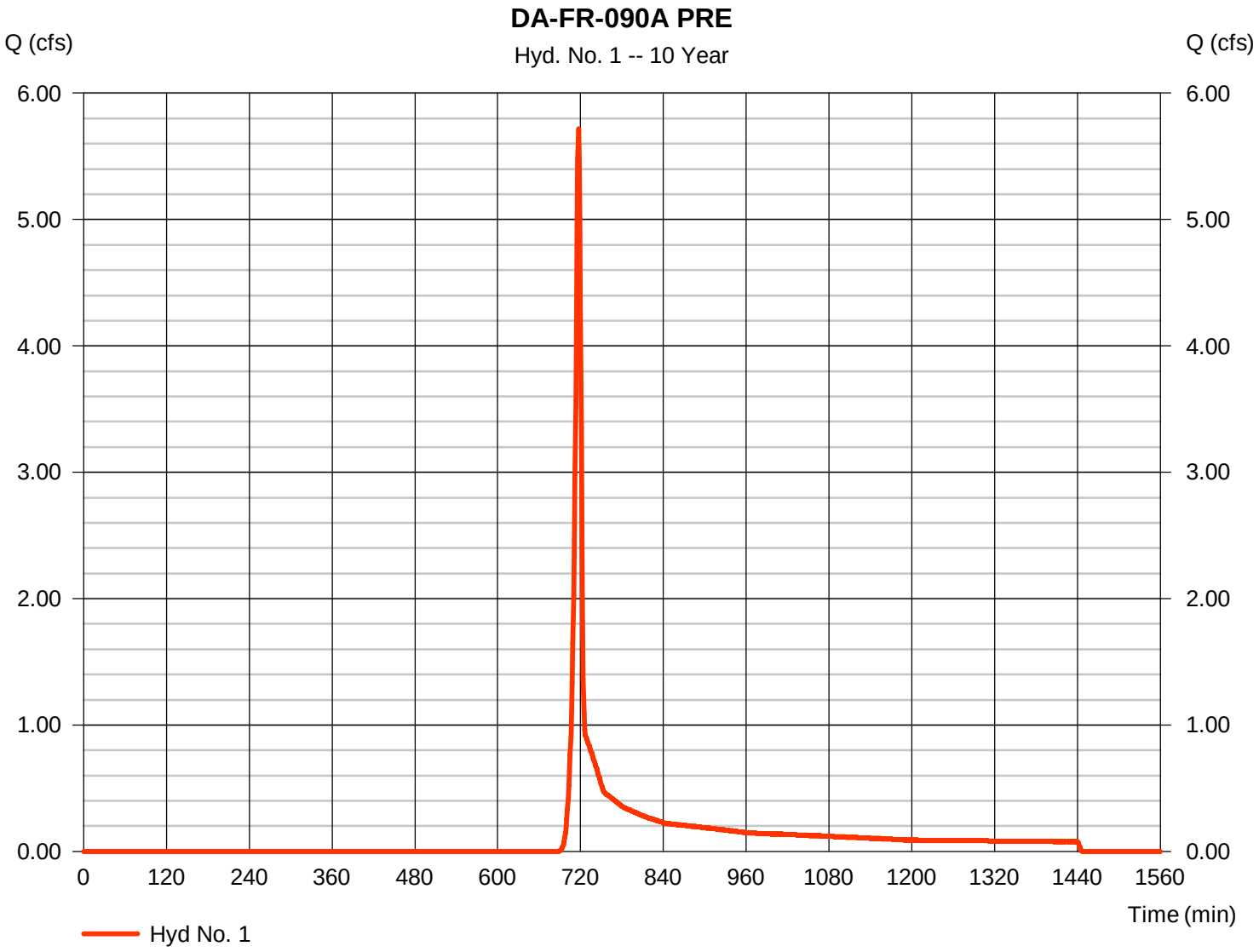
Hydrograph Report

Hyd. No. 1

DA-FR-090A PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	5.718 cfs
Storm frequency	=	10 yrs	Time to peak	=	717 min
Time interval	=	1 min	Hyd. volume	=	11,047 cuft
Drainage area	=	2.140 ac	Curve number	=	56*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	3.70 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.060 x 98) + (0.144 x 58) + (1.937 x 55)] / 2.140



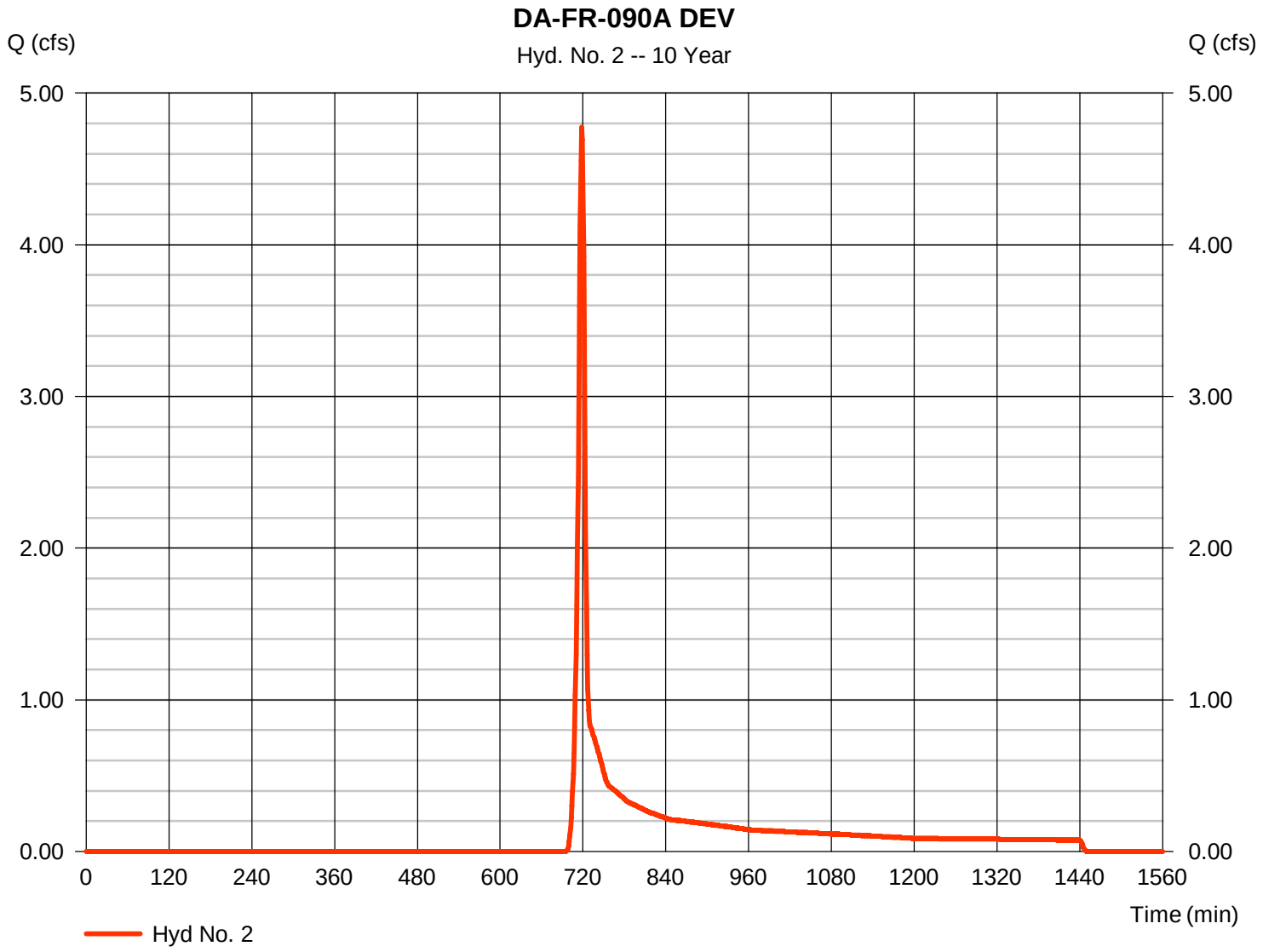
Hydrograph Report

Hyd. No. 2

DA-FR-090A DEV

Hydrograph type	=	SCS Runoff	Peak discharge	=	4.775 cfs
Storm frequency	=	10 yrs	Time to peak	=	718 min
Time interval	=	1 min	Hyd. volume	=	10,223 cuft
Drainage area	=	2.140 ac	Curve number	=	54*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	5.30 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.060 x 98) + (0.932 x 58) + (1.149 x 48)] / 2.140

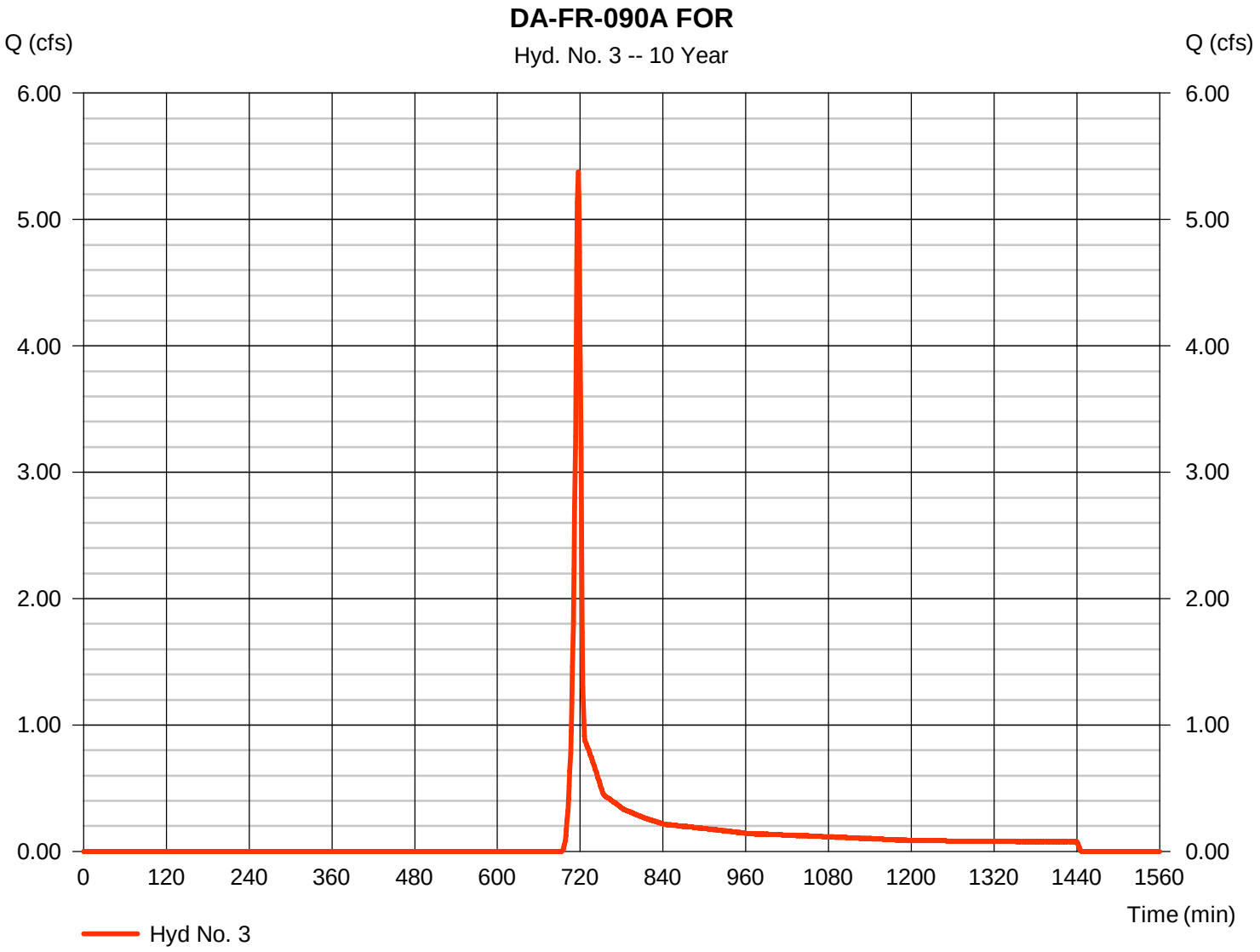


Hydrograph Report

Hyd. No. 3

DA-FR-090A FOR

Hydrograph type	=	SCS Runoff	Peak discharge	=	5.375 cfs
Storm frequency	=	10 yrs	Time to peak	=	717 min
Time interval	=	1 min	Hyd. volume	=	10,475 cuft
Drainage area	=	2.140 ac	Curve number	=	55
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	3.40 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484



Hydraflow Rainfall Report

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

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

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

Tc = time in minutes. Values may exceed 60.

ng\Franklin County\Downloaded Files\Franklin County DA Batch 4 - 046 - 058\Precipitation\Hydraflow\FranklinCo.pc

Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.30	3.70	0.00	0.00	5.70	0.00	0.00	0.00
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

DA-FR-090B

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.168	1041
Developed Condition	0.130	933
Pre-Developed (Forest) Condition	0.168	1041

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

Improvement Factor, IF = 0.8

Calculations:

Check #1:	$Q_{developed} \leq IF \times [(Q_{pre\text{-}developed} \times RV_{pre\text{-}developed}) / RV_{developed}]$ ---------->	0.130	≤ N/A - See Check #3	0.150
Check #2:	$Q_{developed} \leq Q_{pre\text{-}developed}$ ---------->	0.130	≤ N/A - See Check #3	0.168
Check #3:	$Q_{developed}$ *shall not* be required to be ≤ $(Q_{forest} \times RV_{forest}) / RV_{developed}$ --->	0.130	*shall not* be required to be ≤	0.187

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

Note:

Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.

For Paved Road land surface types a Manning's n value 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

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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-FR-090B PRE
2	SCS Runoff	DA-FR-090B DEV
3	SCS Runoff	DA-FR-090B FOR

Hydrograph Return Period Recap

Hyd. No.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)							Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	------	0.168	0.334	-------	-------	1.671	-------	-------	-------	DA-FR-090B PRE
2	SCS Runoff	------	0.130	0.278	-------	-------	1.553	-------	-------	-------	DA-FR-090B DEV
3	SCS Runoff	------	0.168	0.334	-------	-------	1.671	-------	-------	-------	DA-FR-090B FOR

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	0.168	1	726	1,041	------	------	------	DA-FR-090B PRE
2	SCS Runoff	0.130	1	727	933	------	------	------	DA-FR-090B DEV
3	SCS Runoff	0.168	1	726	1,041	------	------	------	DA-FR-090B FOR

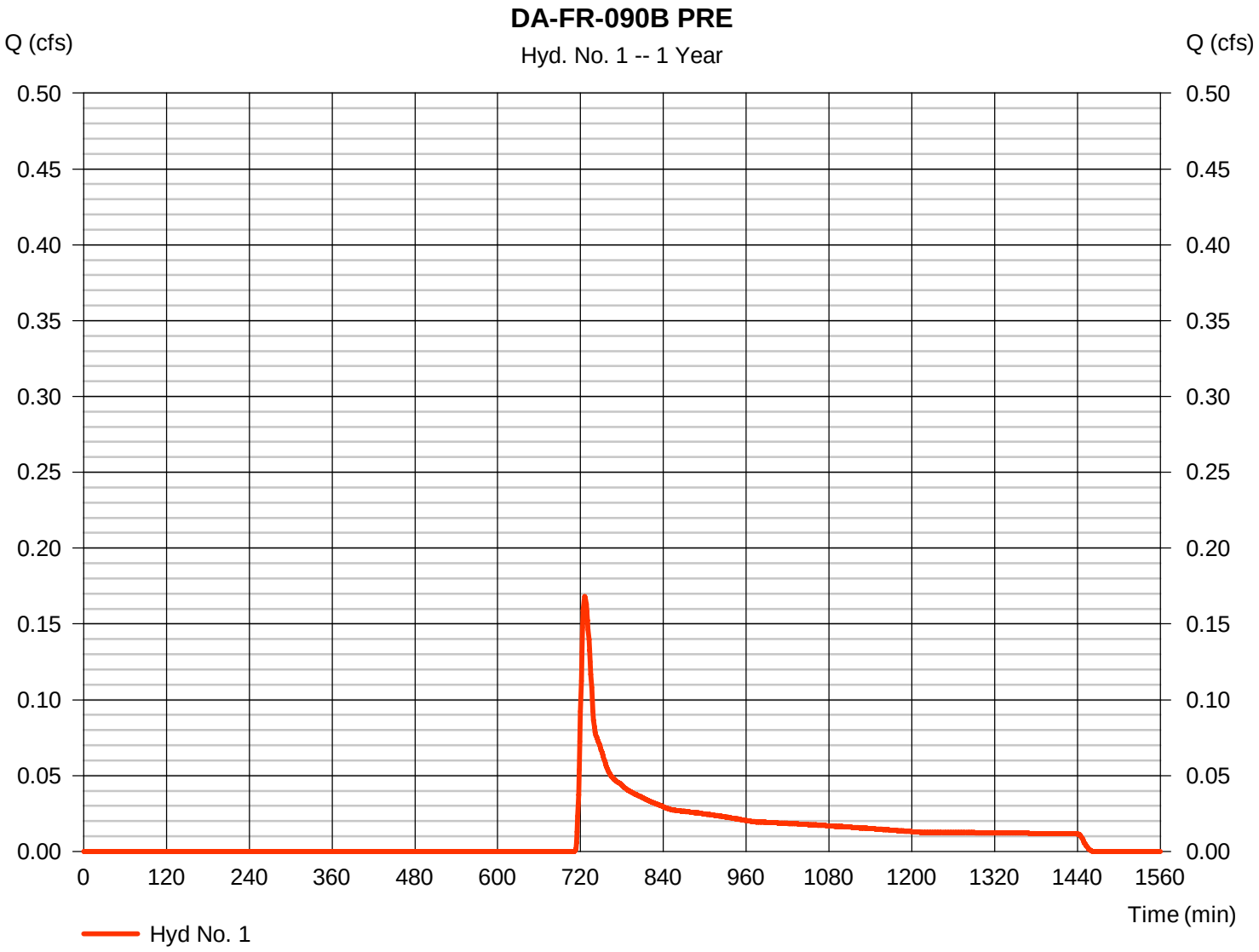
Hydrograph Report

Hyd. No. 1

DA-FR-090B PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.168 cfs
Storm frequency	=	1 yrs	Time to peak	=	726 min
Time interval	=	1 min	Hyd. volume	=	1,041 cuft
Drainage area	=	1.020 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	14.00 min
Total precip.	=	3.30 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = + (0.107 x 58) + (0.917 x 55)] / 1.020



TR55 Tc Worksheet

Hyd. No. 1

DA-FR-090B PRE

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 5.77		0.00		0.00		
Travel Time (min)	**= 13.07**	**+**	**0.00**	**+**	**0.00**	**=**	**13.07**
Shallow Concentrated Flow							
Flow length (ft)	= 232.71		0.00		0.00		
Watercourse slope (%)	= 7.08		0.00		0.00		
Surface description	= Unpaved		Unpaved		Unpaved		
Average velocity (ft/s)	=4.29		0.00		0.00		
Travel Time (min)	**= 0.90**	**+**	**0.00**	**+**	**0.00**	**=**	**0.90**
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	= 0.015		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 ..... 14.00 min

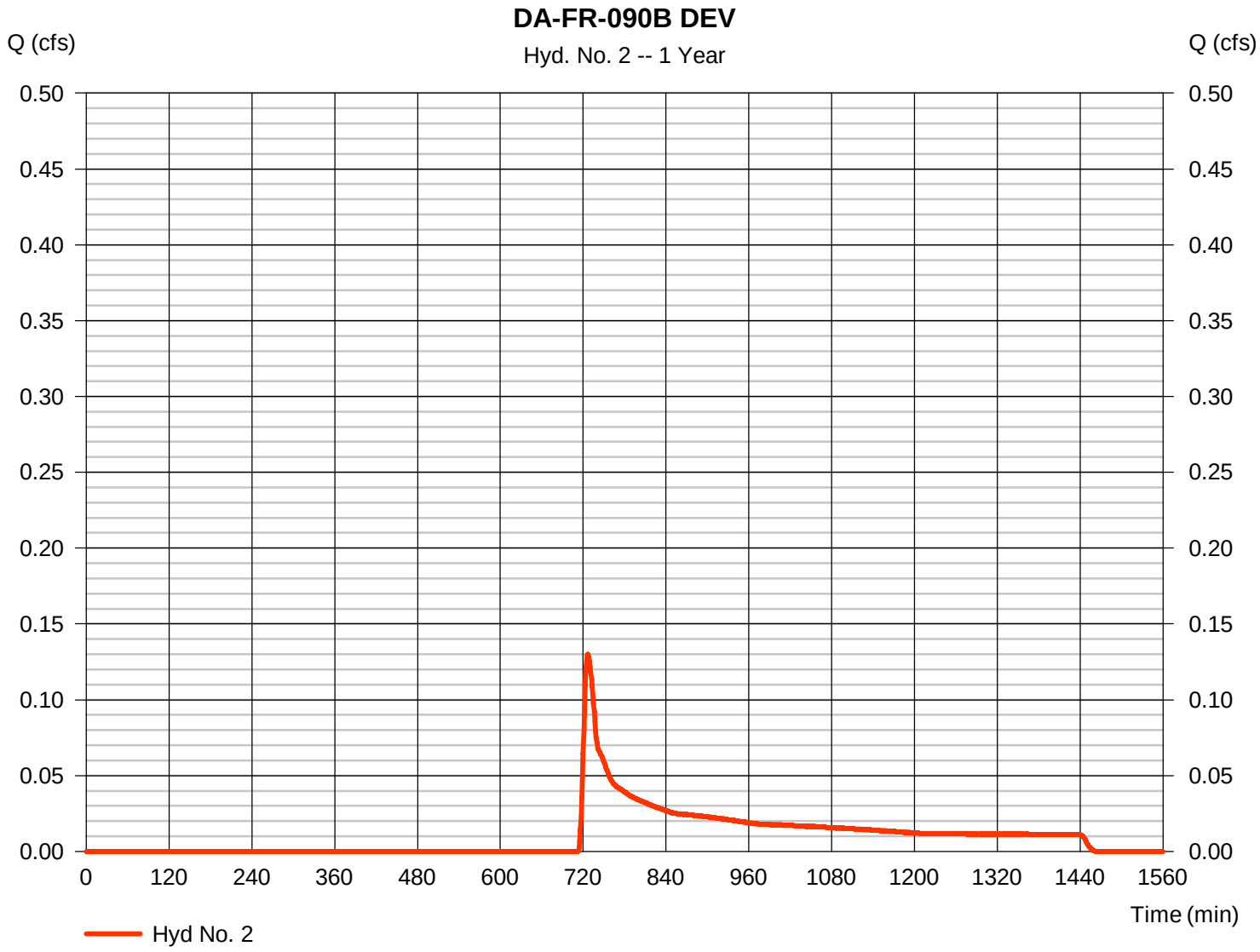
Hydrograph Report

Hyd. No. 2

DA-FR-090B DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.130 cfs
Storm frequency	= 1 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 933 cuft
Drainage area	= 1.020 ac	Curve number	= 54*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.00 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.403 x 58) + (0.282 x 55) + (0.338 x 48)] / 1.020



TR55 Tc Worksheet

Hyd. No. 2

DA-FR-090B DEV

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 5.77		0.00		0.00		
Travel Time (min)	**= 13.07**	**+**	**0.00**	**+**	**0.00**	**=**	**13.07**
Shallow Concentrated Flow							
Flow length (ft)	= 232.71		0.00		0.00		
Watercourse slope (%)	= 7.08		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=4.29		0.00		0.00		
Travel Time (min)	**= 0.90**	**+**	**0.00**	**+**	**0.00**	**=**	**0.90**
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	= 0.015		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**

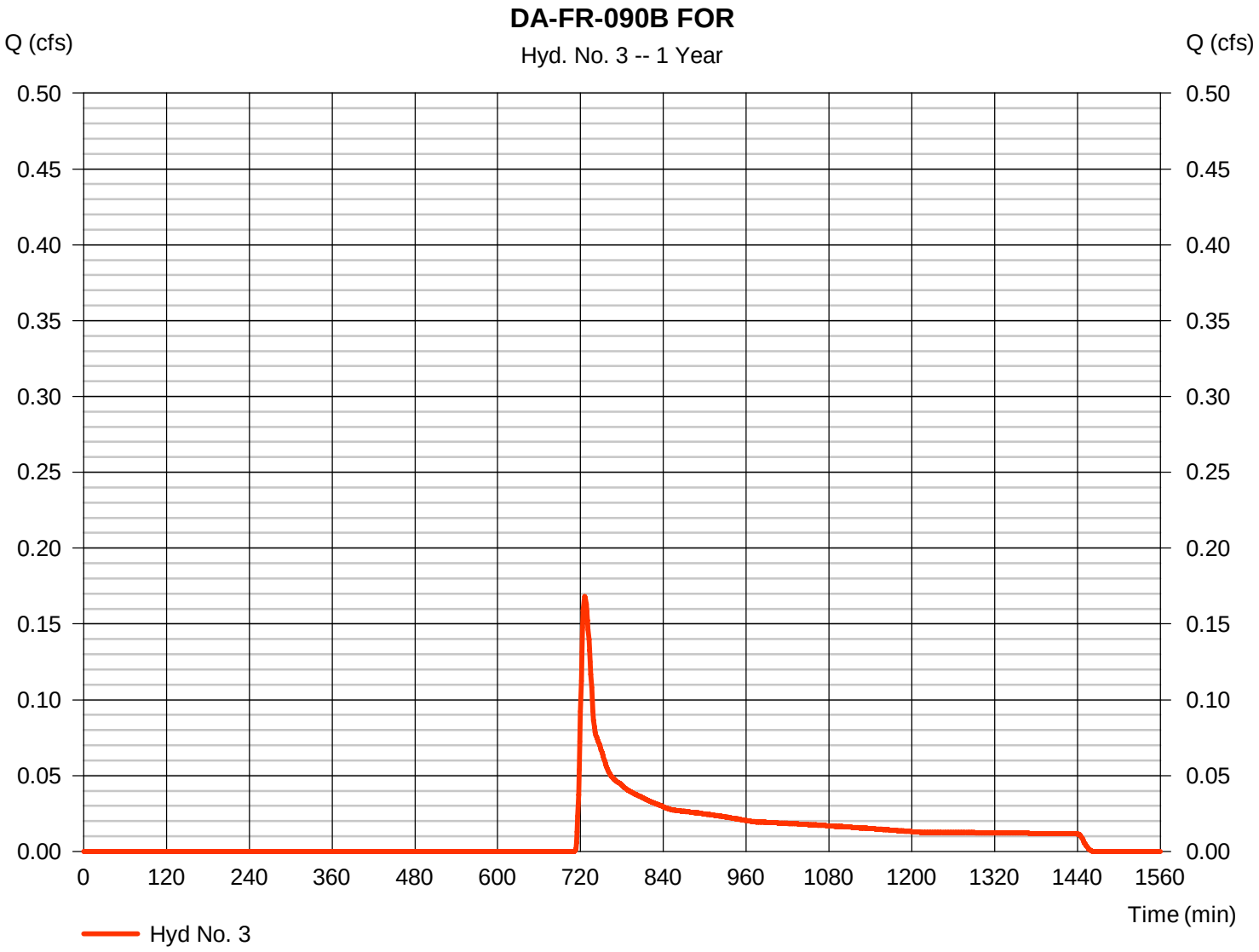
Total Travel Time, Tc ..... 14.00 min

Hydrograph Report

Hyd. No. 3

DA-FR-090B FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.168 cfs
Storm frequency	= 1 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 1,041 cuft
Drainage area	= 1.020 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.00 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



TR55 Tc Worksheet

Hyd. No. 3

DA-FR-090B FOR

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 5.77		0.00		0.00		
Travel Time (min)	**= 13.07**	**+**	**0.00**	**+**	**0.00**	**=**	**13.07**
Shallow Concentrated Flow							
Flow length (ft)	= 232.71		0.00		0.00		
Watercourse slope (%)	= 7.08		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=4.29		0.00		0.00		
Travel Time (min)	**= 0.90**	**+**	**0.00**	**+**	**0.00**	**=**	**0.90**
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	= 0.015		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 ..... 14.00 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	0.334	1	725	1,539	------	------	------	DA-FR-090B PRE
2	SCS Runoff	0.278	1	725	1,403	------	------	------	DA-FR-090B DEV
3	SCS Runoff	0.334	1	725	1,539	------	------	------	DA-FR-090B FOR

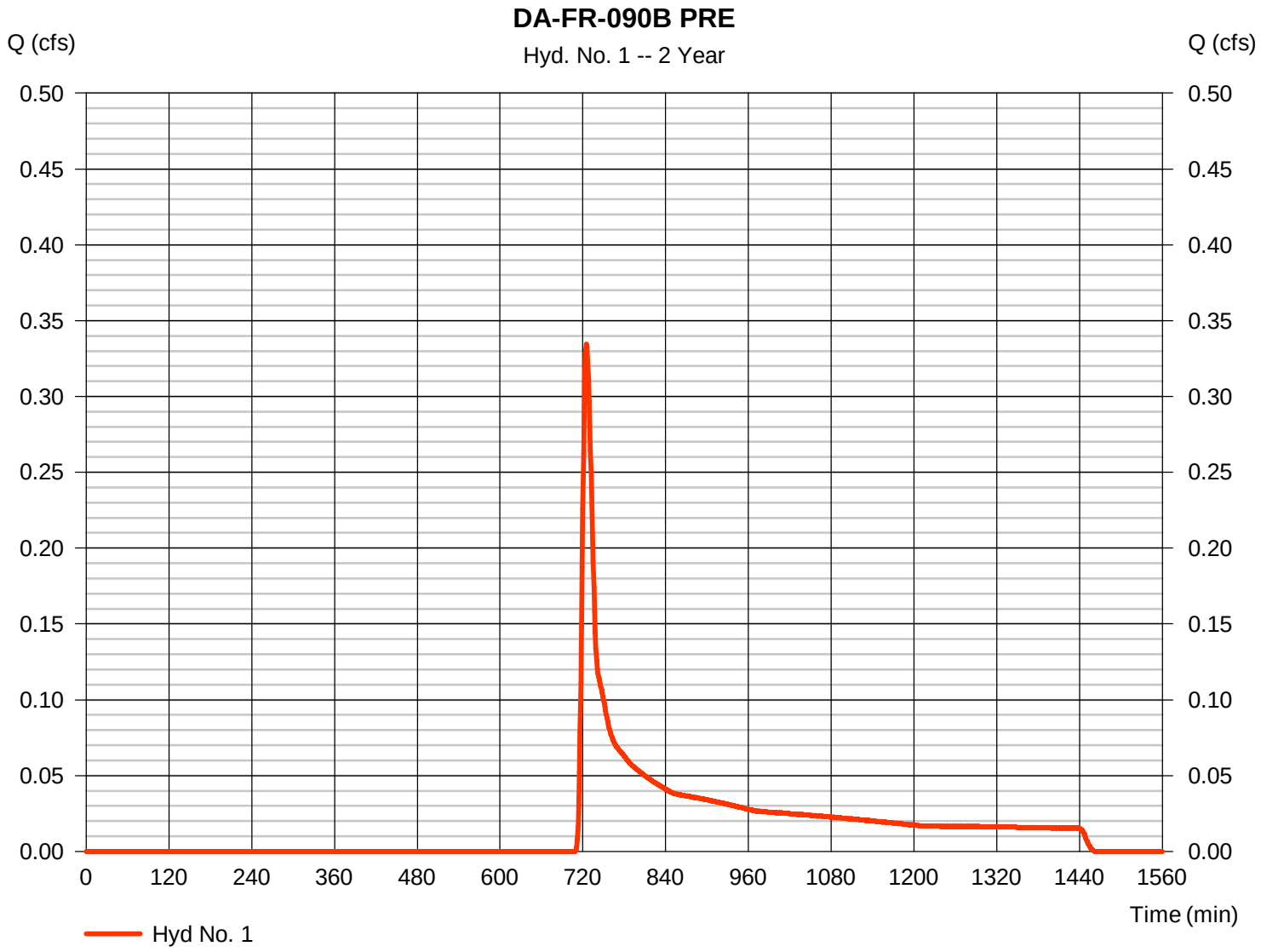
Hydrograph Report

Hyd. No. 1

DA-FR-090B PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.334 cfs
Storm frequency	= 2 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 1,539 cuft
Drainage area	= 1.020 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.00 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = + (0.107 x 58) + (0.917 x 55)] / 1.020



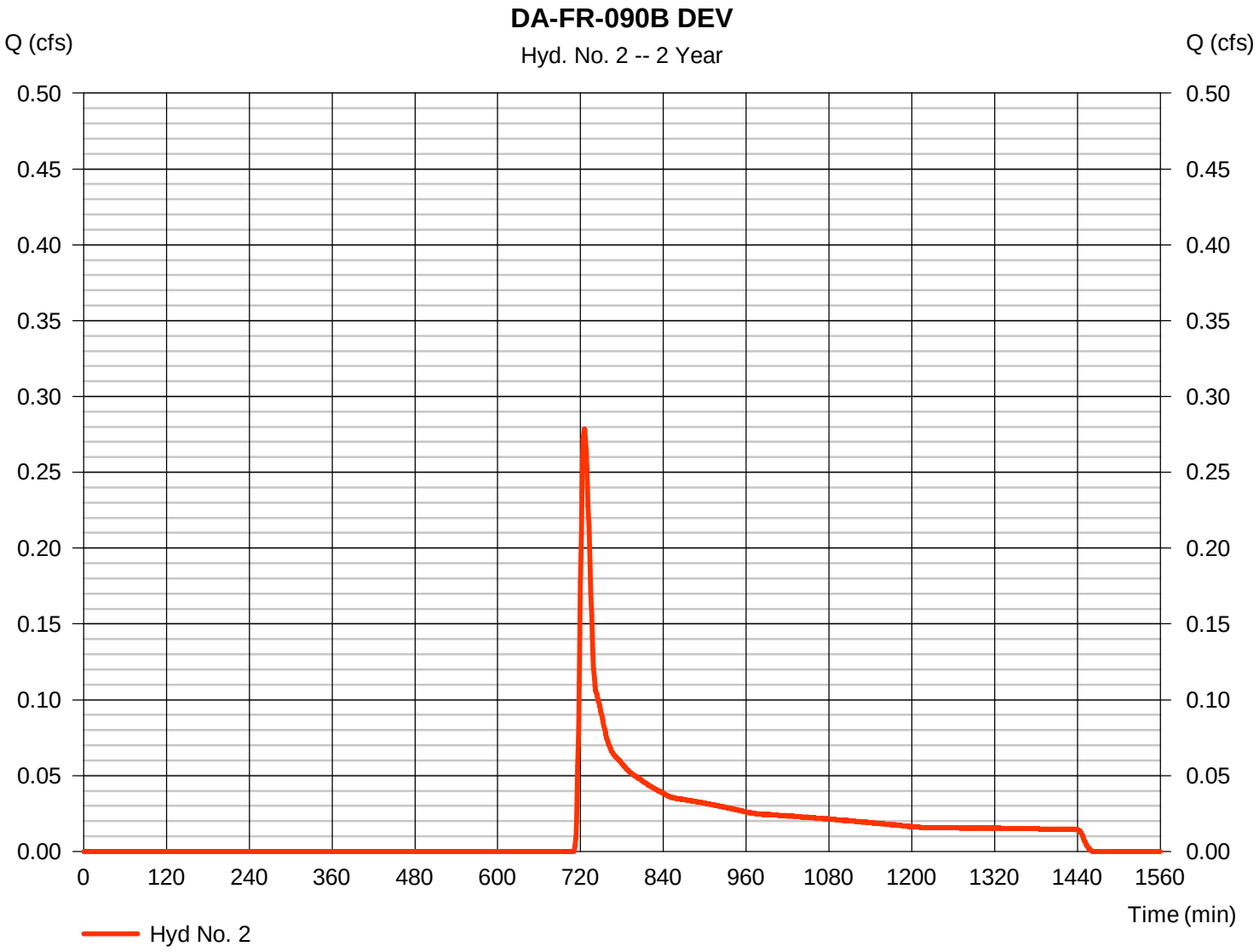
Hydrograph Report

Hyd. No. 2

DA-FR-090B DEV

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.278 cfs
Storm frequency	=	2 yrs	Time to peak	=	725 min
Time interval	=	1 min	Hyd. volume	=	1,403 cuft
Drainage area	=	1.020 ac	Curve number	=	54*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	14.00 min
Total precip.	=	3.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.403 x 58) + (0.282 x 55) + (0.338 x 48)] / 1.020

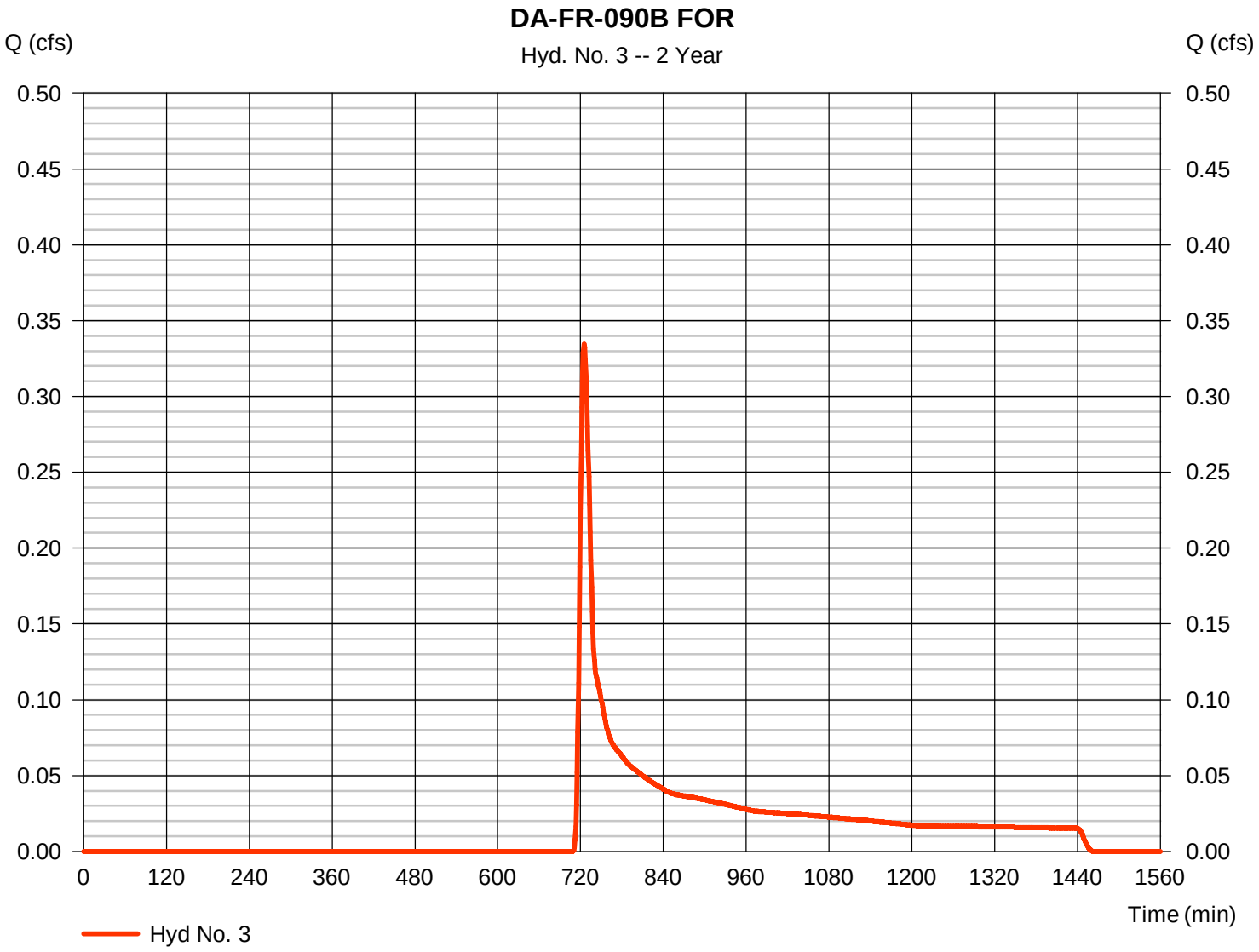


Hydrograph Report

Hyd. No. 3

DA-FR-090B FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.334 cfs
Storm frequency	= 2 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 1,539 cuft
Drainage area	= 1.020 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.00 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



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	1.671	1	723	4,993	------	------	------	DA-FR-090B PRE
2	SCS Runoff	1.553	1	723	4,725	------	------	------	DA-FR-090B DEV
3	SCS Runoff	1.671	1	723	4,993	------	------	------	DA-FR-090B FOR

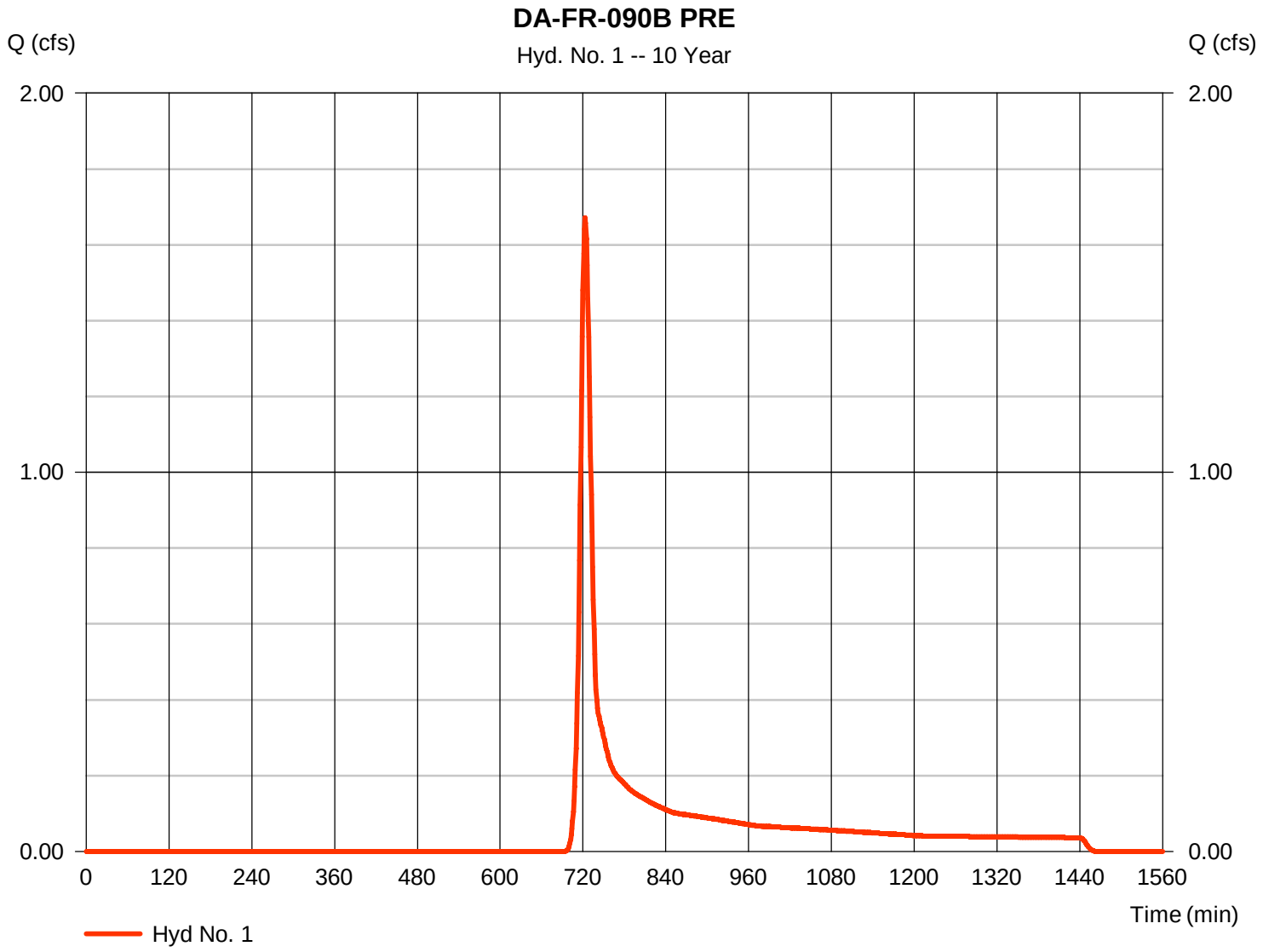
Hydrograph Report

Hyd. No. 1

DA-FR-090B PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	1.671 cfs
Storm frequency	=	10 yrs	Time to peak	=	723 min
Time interval	=	1 min	Hyd. volume	=	4,993 cuft
Drainage area	=	1.020 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	14.00 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = + (0.107 x 58) + (0.917 x 55)] / 1.020



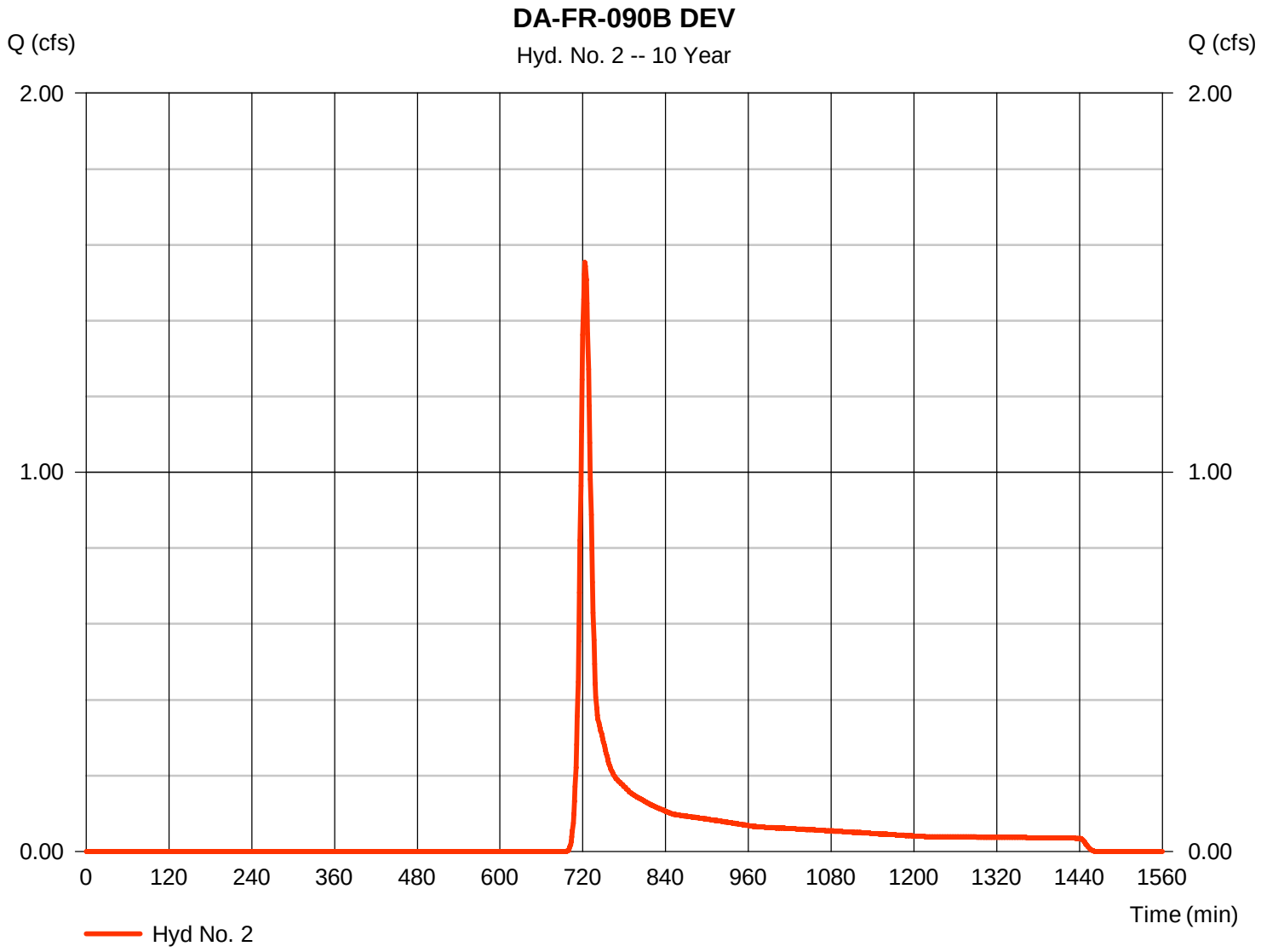
Hydrograph Report

Hyd. No. 2

DA-FR-090B DEV

Hydrograph type	=	SCS Runoff	Peak discharge	=	1.553 cfs
Storm frequency	=	10 yrs	Time to peak	=	723 min
Time interval	=	1 min	Hyd. volume	=	4,725 cuft
Drainage area	=	1.020 ac	Curve number	=	54*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	14.00 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.403 x 58) + (0.282 x 55) + (0.338 x 48)] / 1.020

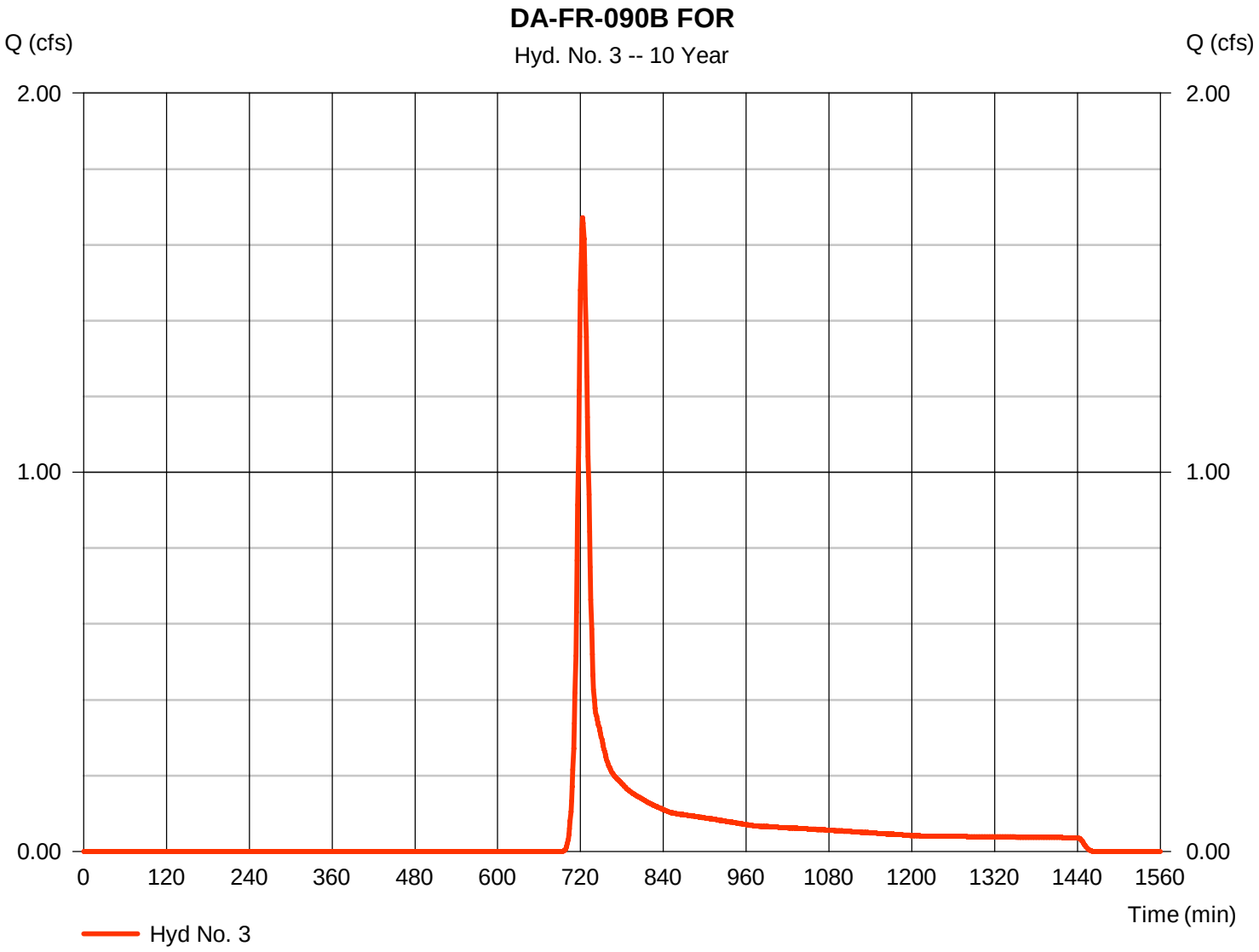


Hydrograph Report

Hyd. No. 3

DA-FR-090B FOR

Hydrograph type	=	SCS Runoff	Peak discharge	=	1.671 cfs
Storm frequency	=	10 yrs	Time to peak	=	723 min
Time interval	=	1 min	Hyd. volume	=	4,993 cuft
Drainage area	=	1.020 ac	Curve number	=	55
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	14.00 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484



Hydraflow Rainfall Report

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

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

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

Tc = time in minutes. Values may exceed 60.

ng\Franklin County\Downloaded Files\Franklin County DA Batch 4 - 046 - 058\Precipitation\Hydraflow\FranklinCo.pc

Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.30	3.70	0.00	0.00	5.70	0.00	0.00	0.00
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

DA-FR-090C

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.321	1580
Developed Condition	0.321	1580
Pre-Developed (Forest) Condition	0.175	1178

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

Improvement Factor, IF = 1

Calculations:

Check #1: $Q_{developed} \leq IF \times [(Q_{pre\text{-}developed} \times RV_{pre\text{-}developed}) / RV_{developed}]$ ----------> 0.321 ≤ 0.321 OK

Check #2: $Q_{developed} \leq Q_{pre\text{-}developed}$ ----------> 0.321 ≤ 0.321 OK

Check #3: $Q_{developed}$ *shall not* be required to be ≤ $(Q_{forest} \times RV_{forest}) / RV_{developed}$ ---> 0.321 *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

Note:

Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.

For Paved Road land surface types a Manning's n value 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

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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-FR-090C PRE
2	SCS Runoff	DA-FR-090C DEV
3	SCS Runoff	DA-FR-090C FOR

Hydrograph Return Period Recap

Hyd. No.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)							Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	------	0.321	0.546	-------	-------	2.146	-------	-------	-------	DA-FR-090C PRE
2	SCS Runoff	------	0.321	0.546	-------	-------	2.146	-------	-------	-------	DA-FR-090C DEV
3	SCS Runoff	------	0.175	0.348	-------	-------	1.762	-------	-------	-------	DA-FR-090C FOR

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	1,580	------	------	------	DA-FR-090C PRE
2	SCS Runoff	0.321	1	726	1,580	------	------	------	DA-FR-090C DEV
3	SCS Runoff	0.175	1	727	1,178	------	------	------	DA-FR-090C FOR

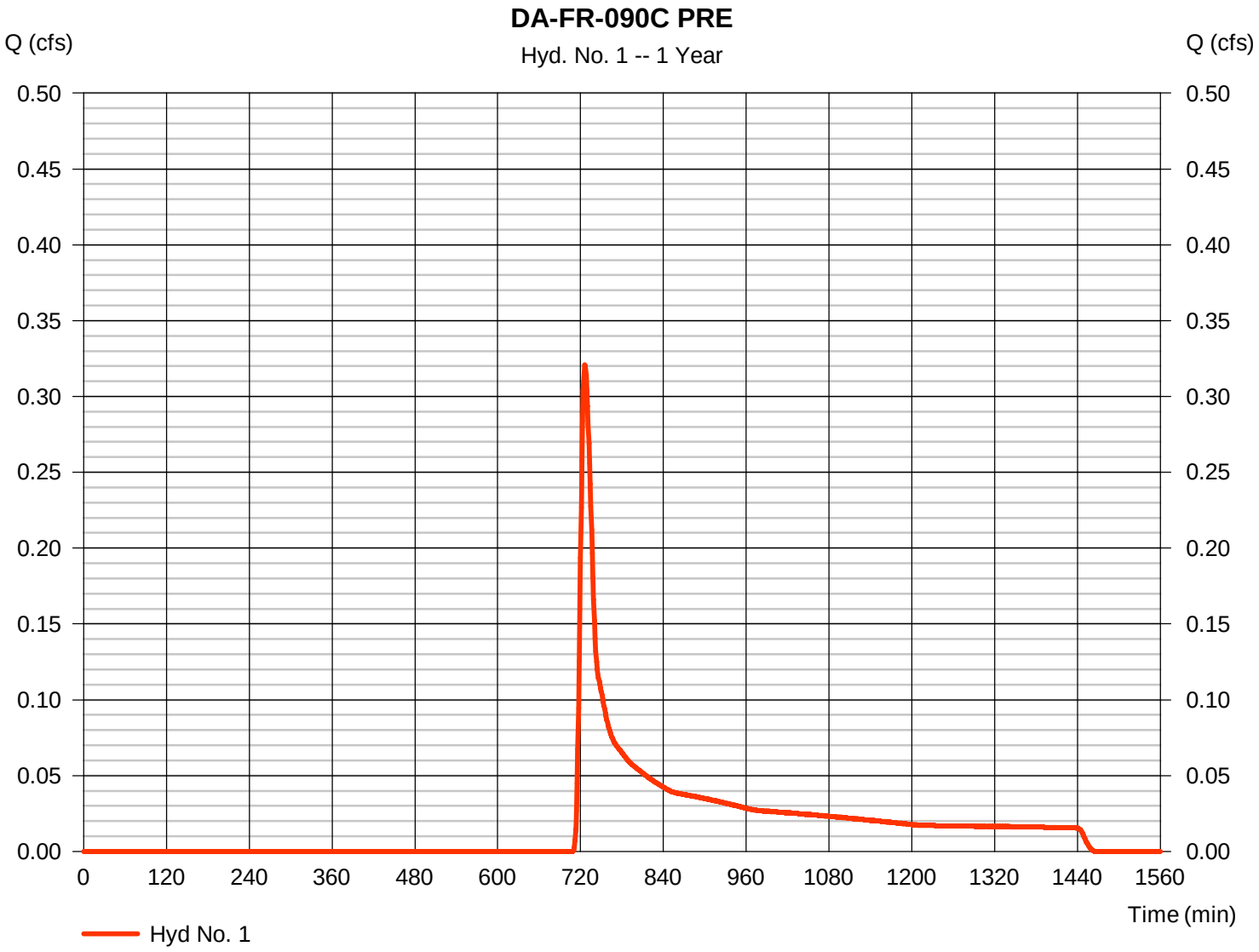
Hydrograph Report

Hyd. No. 1

DA-FR-090C 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	= 1,580 cuft
Drainage area	= 1.140 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.80 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.004 x 98) + (1.037 x 58) + (0.098 x 55)] / 1.140



TR55 Tc Worksheet

Hyd. No. 1

DA-FR-090C PRE

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 3.80		0.00		0.00		
Travel Time (min)	**= 15.45**	**+**	**0.00**	**+**	**0.00**	**=**	**15.45**
Shallow Concentrated Flow							
Flow length (ft)	= 283.33		0.00		0.00		
Watercourse slope (%)	= 4.97		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=3.60		0.00		0.00		
Travel Time (min)	**= 1.31**	**+**	**0.00**	**+**	**0.00**	**=**	**1.31**
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	= 0.015		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							**16.80 min**

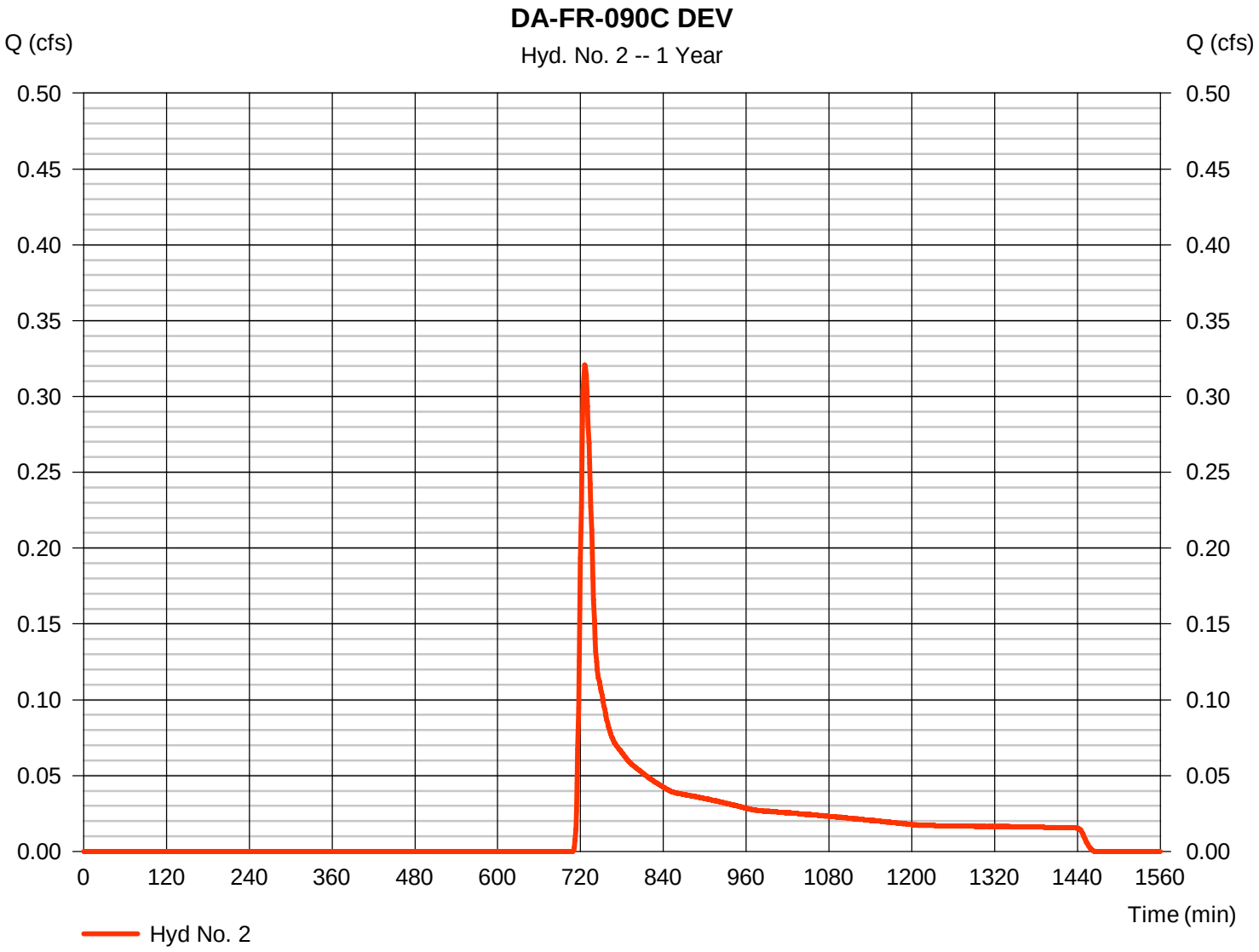
Hydrograph Report

Hyd. No. 2

DA-FR-090C DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.321 cfs
Storm frequency	= 1 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 1,580 cuft
Drainage area	= 1.140 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.80 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.004 x 98) + (1.057 x 58) + (0.030 x 55) + (0.050 x 48)] / 1.140



TR55 Tc Worksheet

Hyd. No. 2

DA-FR-090C DEV

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 3.80		0.00		0.00		
Travel Time (min)	**= 15.45**	**+**	**0.00**	**+**	**0.00**	**=**	**15.45**
Shallow Concentrated Flow							
Flow length (ft)	= 283.33		0.00		0.00		
Watercourse slope (%)	= 4.97		0.00		0.00		
Surface description	= Unpaved		Unpaved		Unpaved		
Average velocity (ft/s)	=3.60		0.00		0.00		
Travel Time (min)	**= 1.31**	**+**	**0.00**	**+**	**0.00**	**=**	**1.31**
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	= 0.015		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**

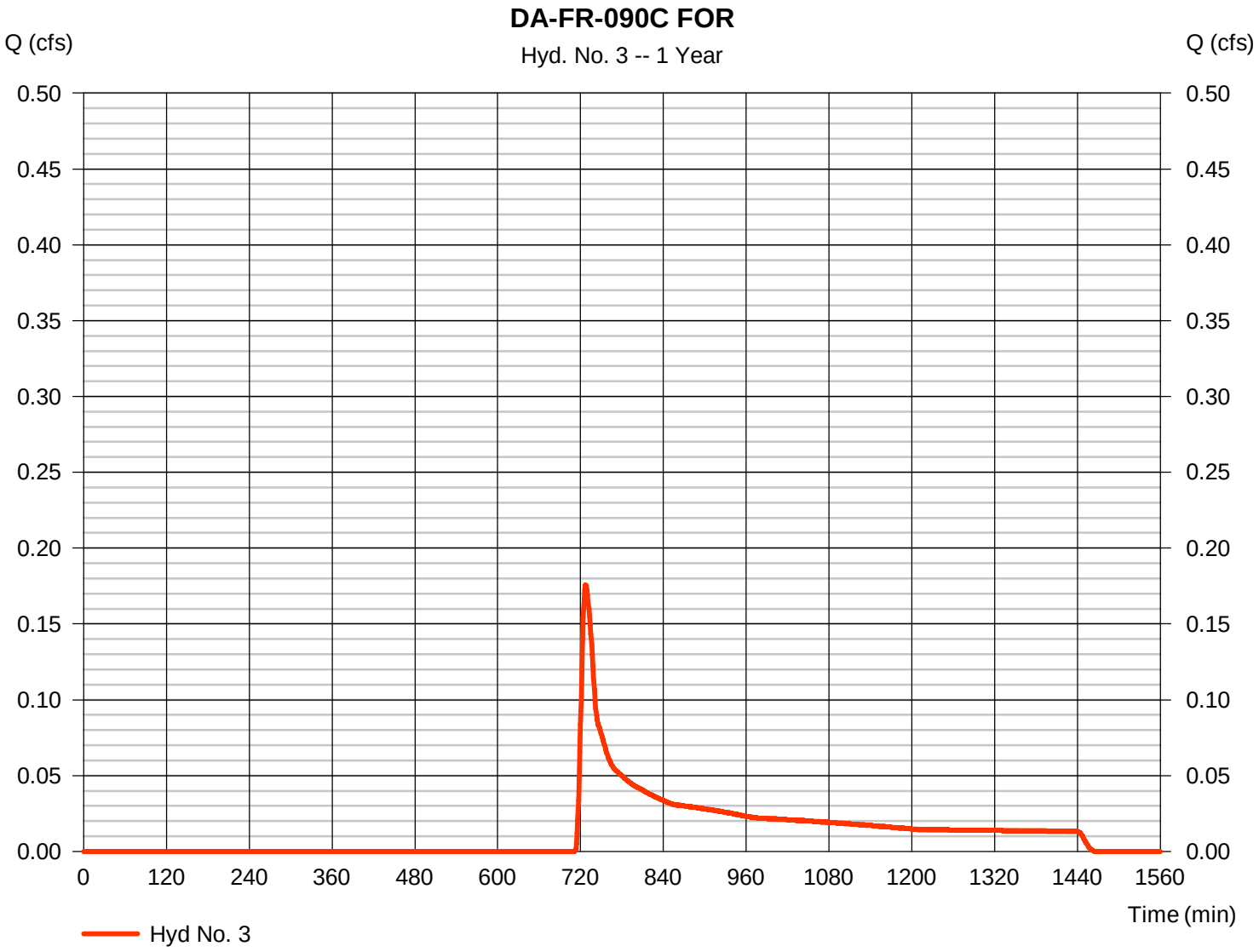
Total Travel Time, Tc ..... 16.80 min

Hydrograph Report

Hyd. No. 3

DA-FR-090C FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.175 cfs
Storm frequency	= 1 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 1,178 cuft
Drainage area	= 1.140 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.80 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



TR55 Tc Worksheet

Hyd. No. 3

DA-FR-090C FOR

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 3.80		0.00		0.00		
Travel Time (min)	**= 15.45**	**+**	**0.00**	**+**	**0.00**	**=**	**15.45**
Shallow Concentrated Flow							
Flow length (ft)	= 283.33		0.00		0.00		
Watercourse slope (%)	= 4.97		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=3.60		0.00		0.00		
Travel Time (min)	**= 1.31**	**+**	**0.00**	**+**	**0.00**	**=**	**1.31**
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	= 0.015		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							**16.80 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	0.546	1	726	2,238	------	------	------	DA-FR-090C PRE
2	SCS Runoff	0.546	1	726	2,238	------	------	------	DA-FR-090C DEV
3	SCS Runoff	0.348	1	726	1,741	------	------	------	DA-FR-090C FOR

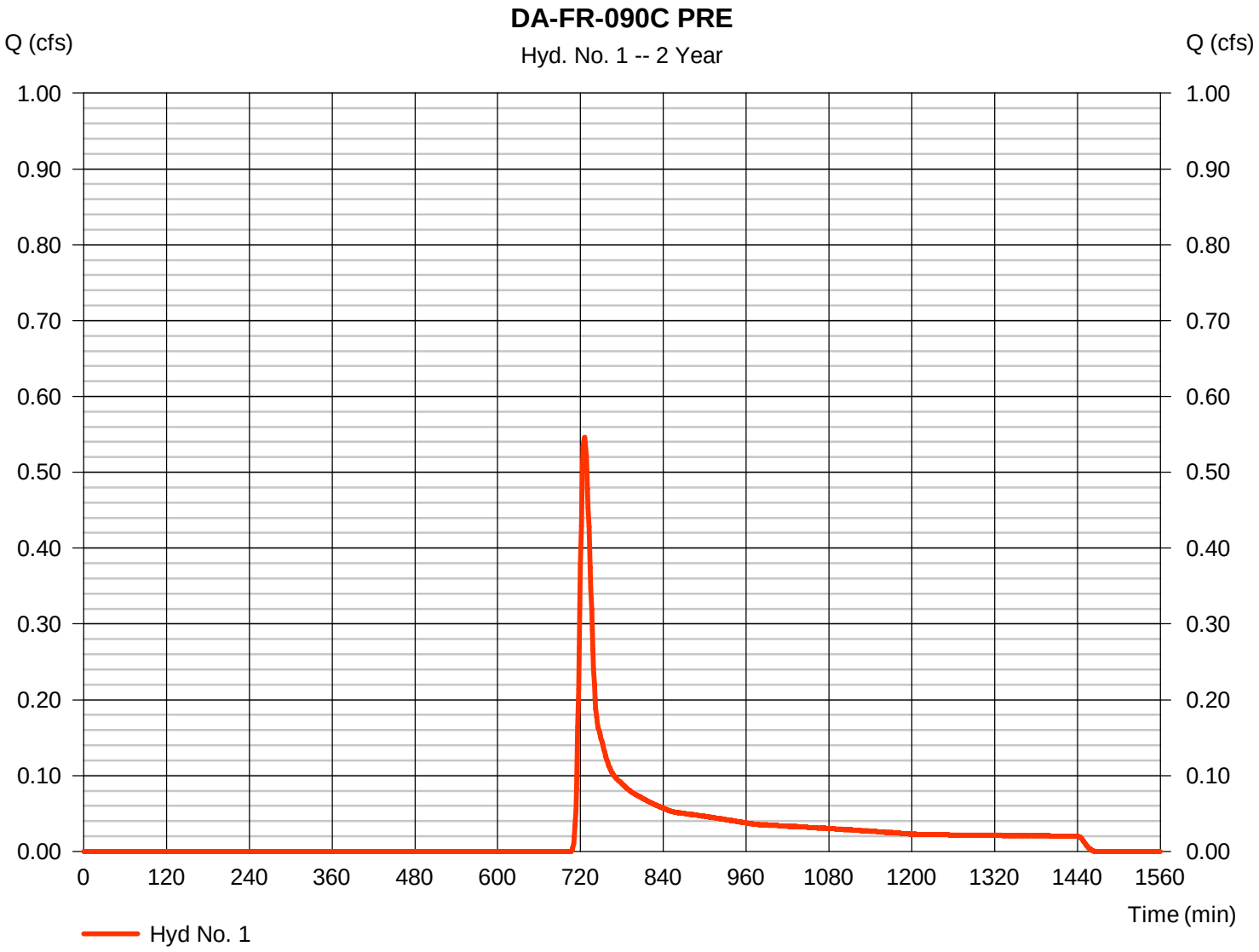
Hydrograph Report

Hyd. No. 1

DA-FR-090C PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.546 cfs
Storm frequency	= 2 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 2,238 cuft
Drainage area	= 1.140 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.80 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.004 x 98) + (1.037 x 58) + (0.098 x 55)] / 1.140



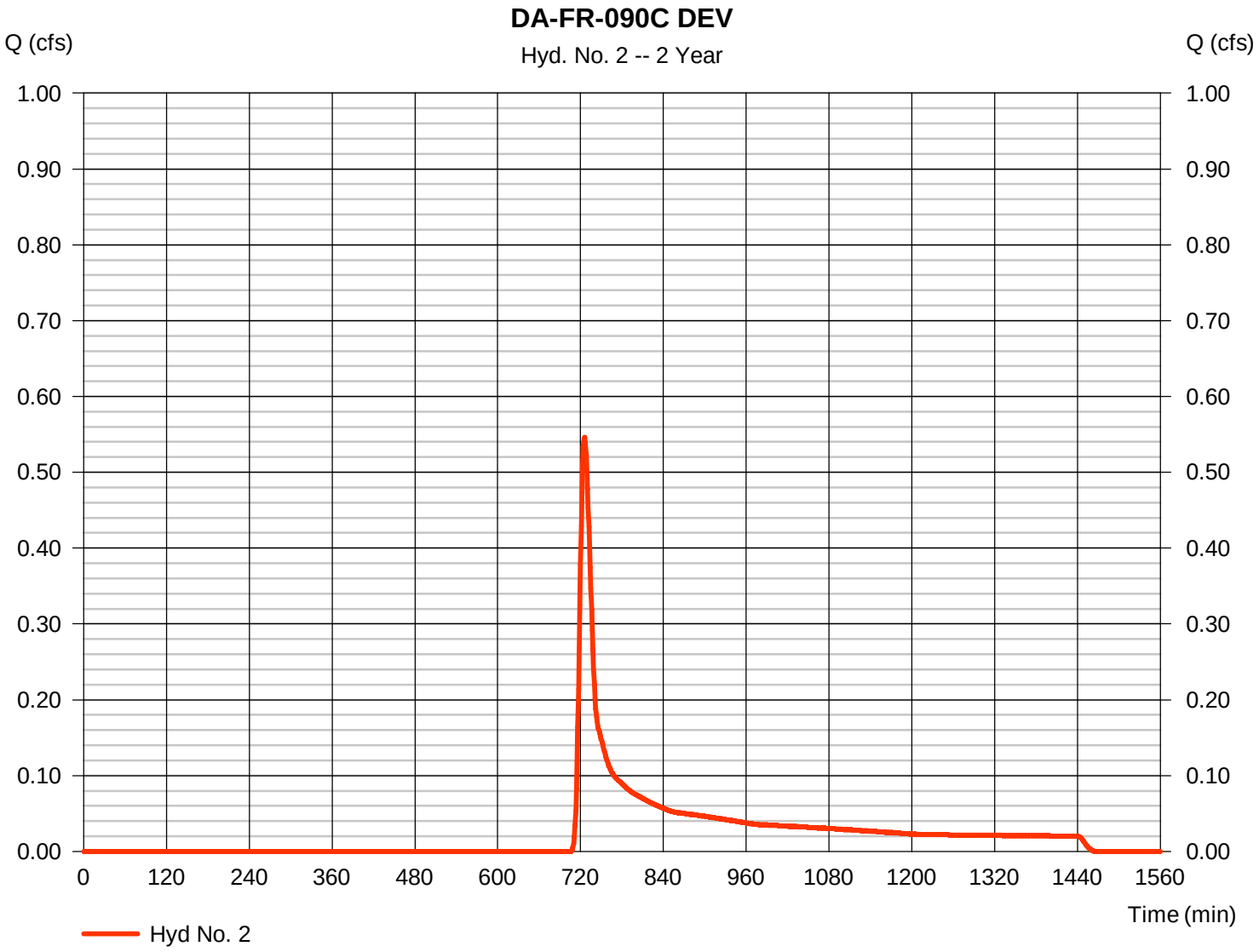
Hydrograph Report

Hyd. No. 2

DA-FR-090C DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.546 cfs
Storm frequency	= 2 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 2,238 cuft
Drainage area	= 1.140 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.80 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.004 x 98) + (1.057 x 58) + (0.030 x 55) + (0.050 x 48)] / 1.140

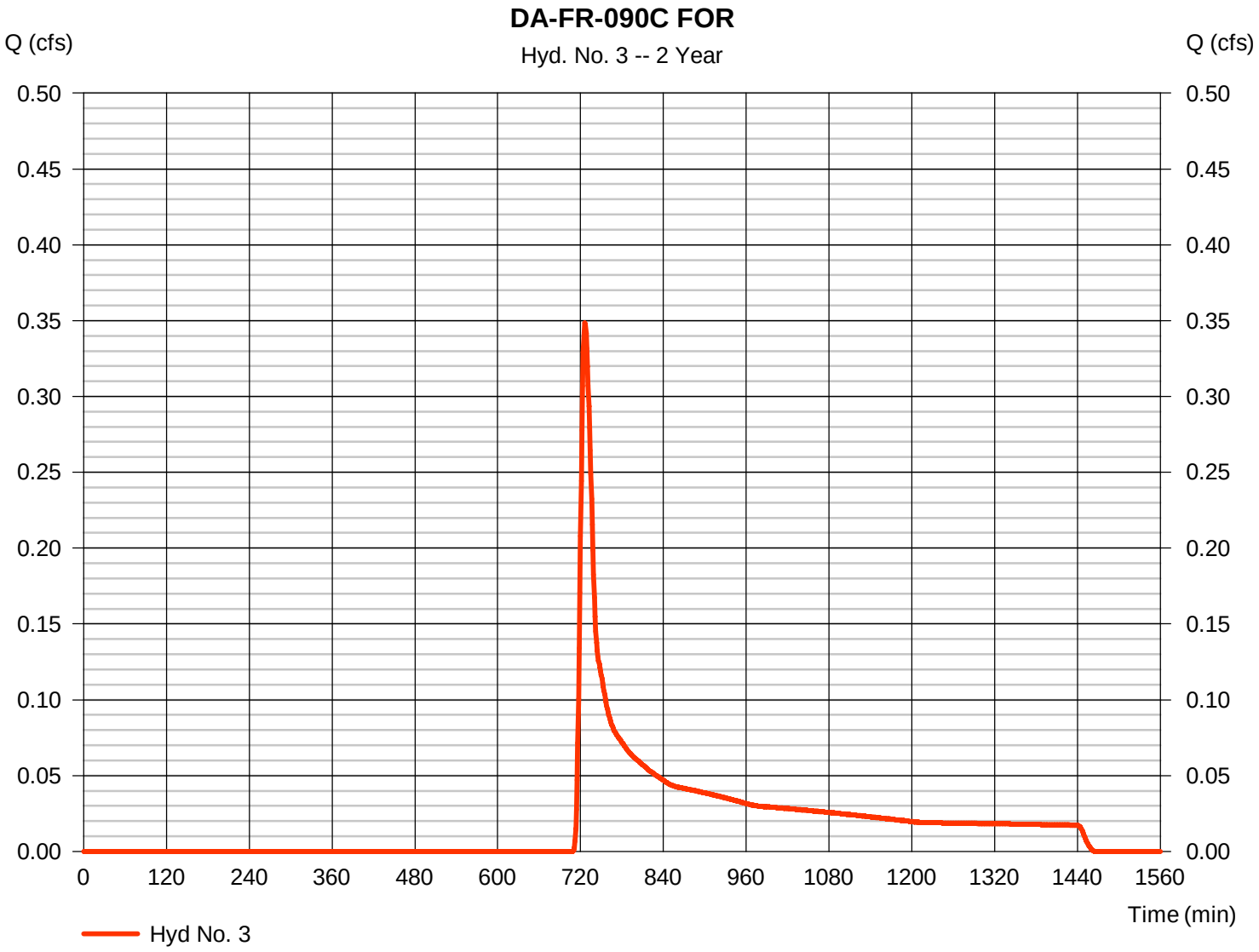


Hydrograph Report

Hyd. No. 3

DA-FR-090C FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.348 cfs
Storm frequency	= 2 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 1,741 cuft
Drainage area	= 1.140 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.80 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



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	2.146	1	724	6,590	------	------	------	DA-FR-090C PRE
2	SCS Runoff	2.146	1	724	6,590	------	------	------	DA-FR-090C DEV
3	SCS Runoff	1.762	1	724	5,650	------	------	------	DA-FR-090C FOR

Hydrograph Report

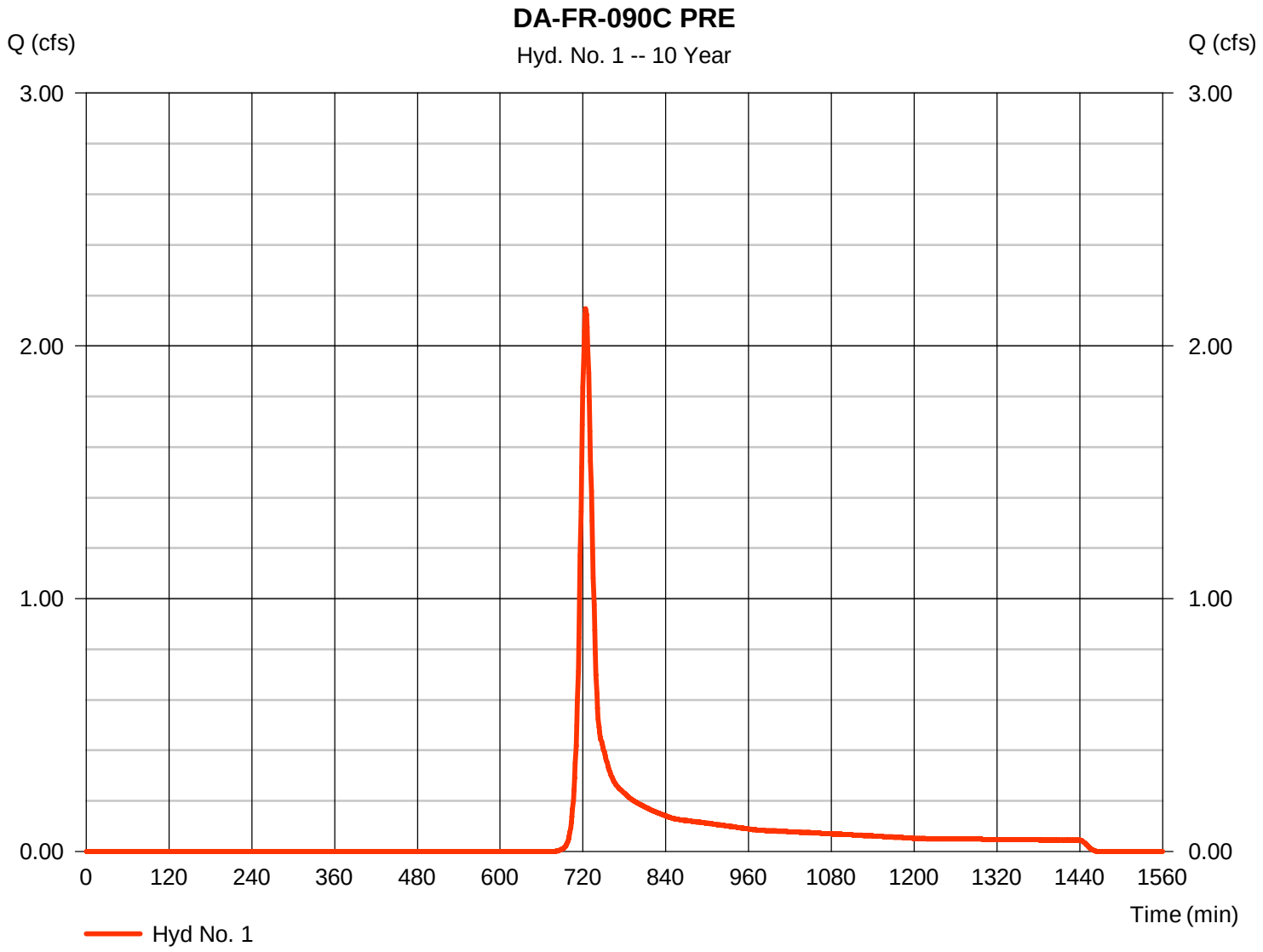
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5 Tuesday, 08 / 15 / 2017

Hyd. No. 1

DA-FR-090C PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	2.146 cfs
Storm frequency	=	10 yrs	Time to peak	=	724 min
Time interval	=	1 min	Hyd. volume	=	6,590 cuft
Drainage area	=	1.140 ac	Curve number	=	58*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	16.80 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.004 x 98) + (1.037 x 58) + (0.098 x 55)] / 1.140



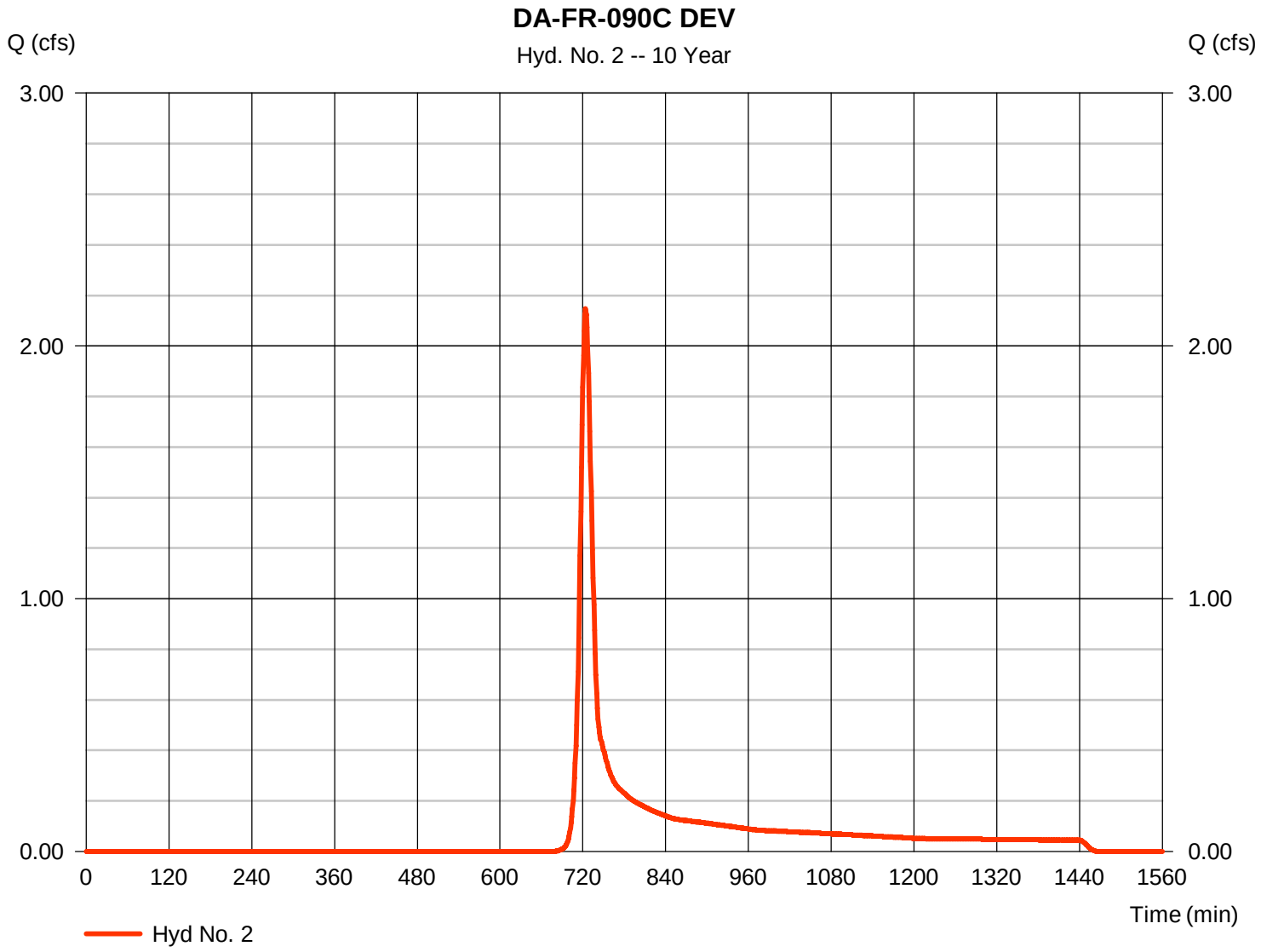
Hydrograph Report

Hyd. No. 2

DA-FR-090C DEV

Hydrograph type	=	SCS Runoff	Peak discharge	=	2.146 cfs
Storm frequency	=	10 yrs	Time to peak	=	724 min
Time interval	=	1 min	Hyd. volume	=	6,590 cuft
Drainage area	=	1.140 ac	Curve number	=	58*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	16.80 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.004 x 98) + (1.057 x 58) + (0.030 x 55) + (0.050 x 48)] / 1.140

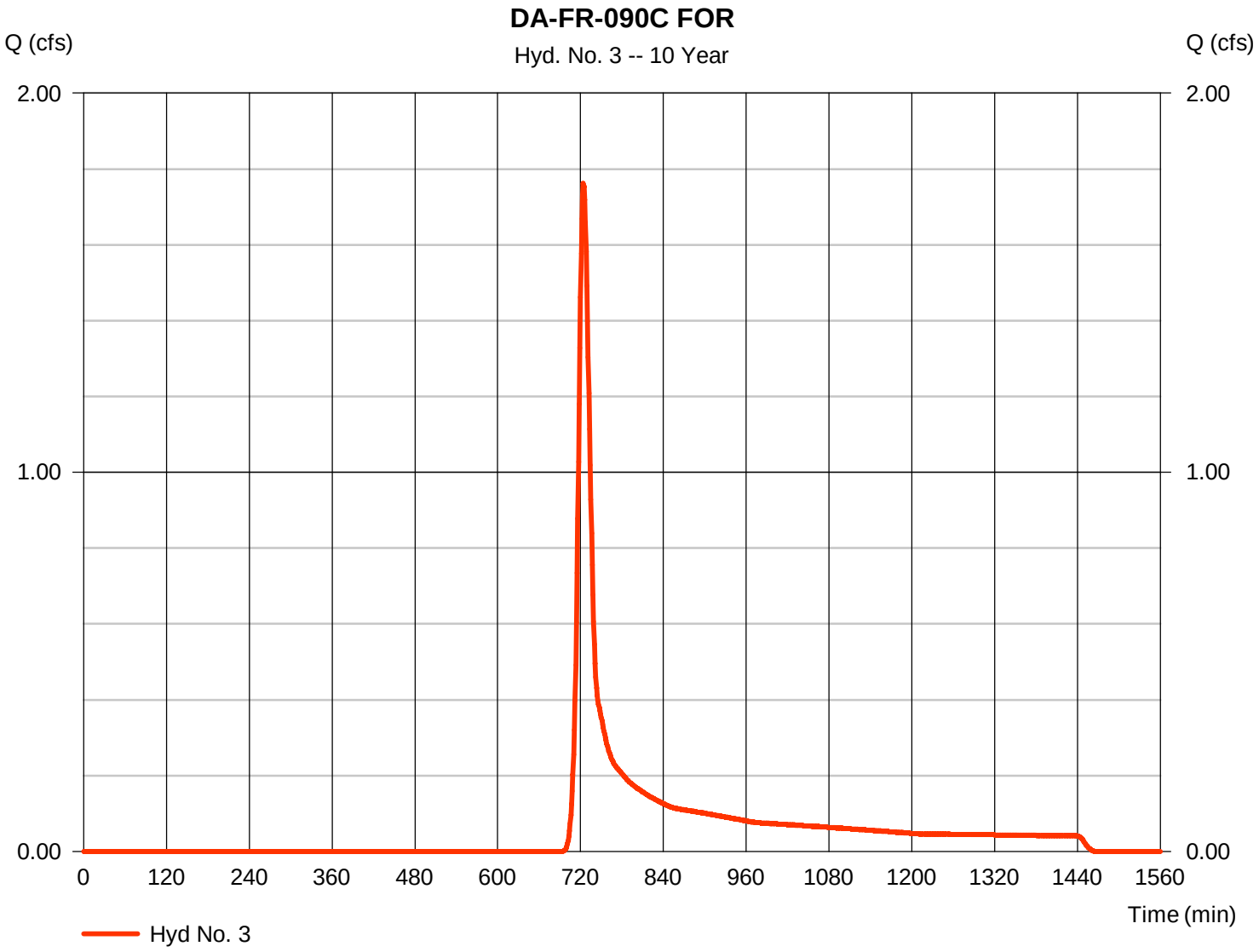


Hydrograph Report

Hyd. No. 3

DA-FR-090C FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 1.762 cfs
Storm frequency	= 10 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 5,650 cuft
Drainage area	= 1.140 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.80 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



Hydraflow Rainfall Report

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

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

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

Tc = time in minutes. Values may exceed 60.

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Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.30	3.70	0.00	0.00	5.70	0.00	0.00	0.00
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

DA-FR-091

DA-FR-091 is located primarily within meadow land use with portions of forested land use and has undulating to hilly slopes. An existing dirt road and two small graveled areas are located within the drainage area, but no new impervious area is proposed within DA-FR-091. The total phosphorus load reduction required for DA-FR-091 is -0.77 lb/yr. Multiple points of analysis were evaluated within DA-FR-091 to evaluate the effects on each receiving stream/channel following construction. Specifically DA-FR-091 was sub-divided into three sub-drainage areas (sub areas A through C).

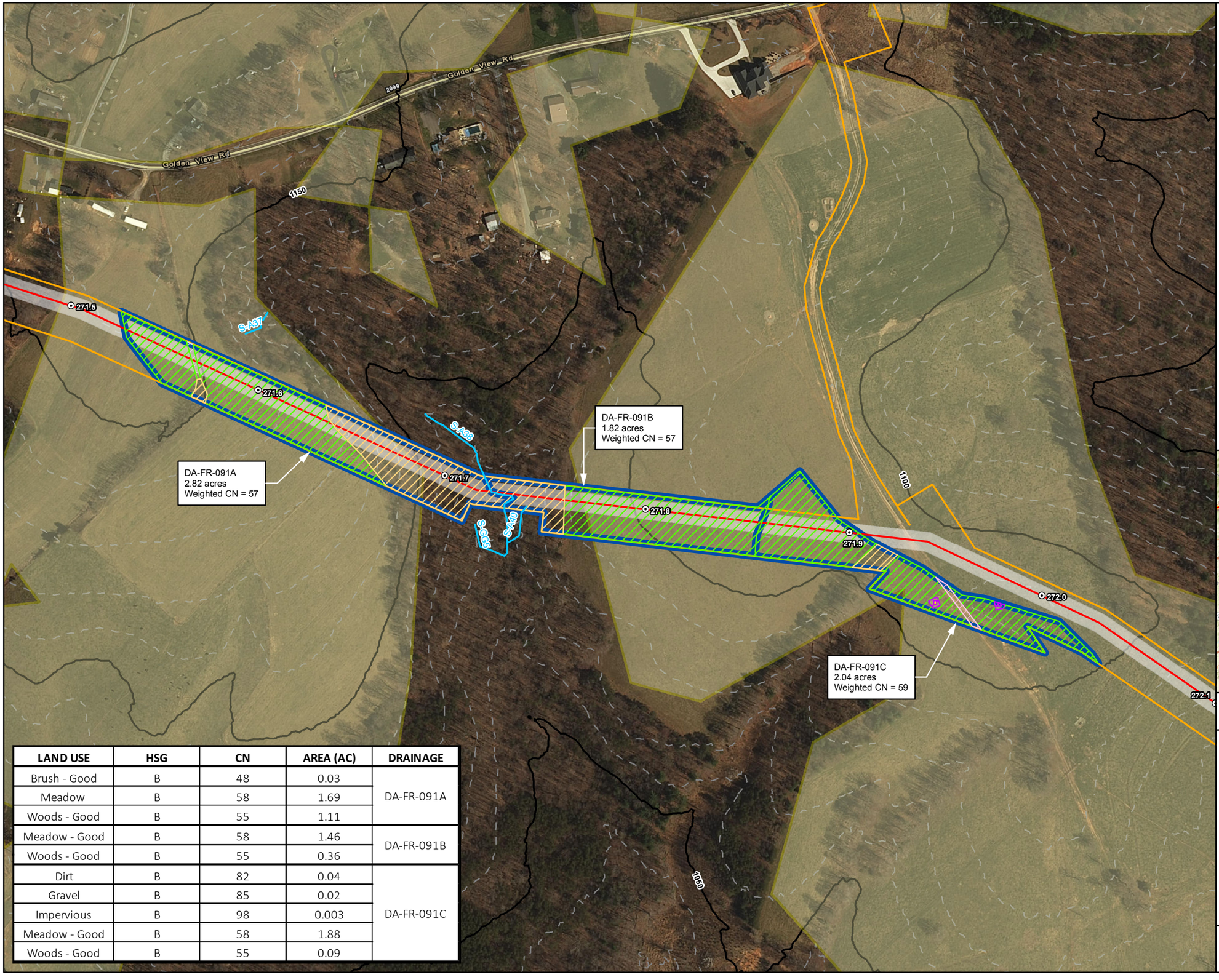
Sub-areas 091A, 091B and 091C contain both agricultural and non-agricultural areas within the limits of disturbance (LOD). Pre-construction agricultural areas will be returned to agricultural land use (i.e., returned to crop production, in identical condition) following construction. In non-agricultural 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 Right of Way (ROW) is analyzed via VRRM; in these calculations agricultural areas are considered “Forest/Open Space”.

Stormwater quantity is met via the energy balance method for each of the three sub-areas DA-FR-091A, DA-FR-091B and DA-FR-091C. Agricultural areas within the study area are included in the SWM analysis, but an Improvement Factor (IF) of 1.0 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 Hydrograph’s 10-year 24-hour peak discharge results indicate a reduction in flows ranging from 0.00 to 0.86 cfs for all drainage areas (as seen in table below).

Sub Area	Pre Peak Flow, 10-yr Q (cfs)	Post Peak Flow, Q 10-yr (cfs)	Flow differential
DA-FR-091A	4.44	3.58	-0.86
DA-FR-091B	3.41	3.41	0.00
DA-FR-091C	3.62	3.41	-0.21

Figures and calculations for each of the sub-areas for DA-FR-091 follow. See Appendix D of the Annual Standards and Specifications for further detail on stormwater methodology.



LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Brush - Good	B	48	0.03	DA-FR-091A
Meadow	B	58	1.69	
Woods - Good	B	55	1.11	
Meadow - Good	B	58	1.46	DA-FR-091B
Woods - Good	B	55	0.36	
Dirt	B	82	0.04	DA-FR-091C
Gravel	B	85	0.02	
Impervious	B	98	0.003	
Meadow - Good	B	58	1.88	
Woods - Good	B	55	0.09	

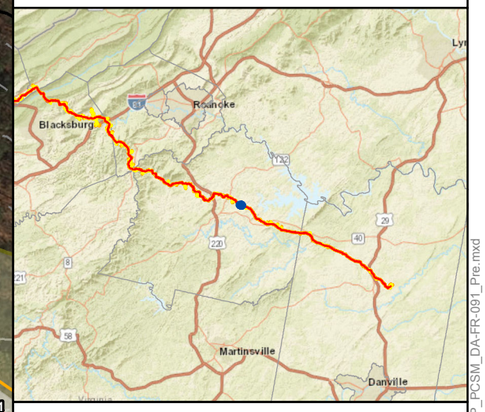
Legend

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

NAD 1983 UTM 17N (feet)

1:2,880

240 120 0 240 Feet



Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Pre-Construction Drainage Area Map
DA-FR-091
Spread 11

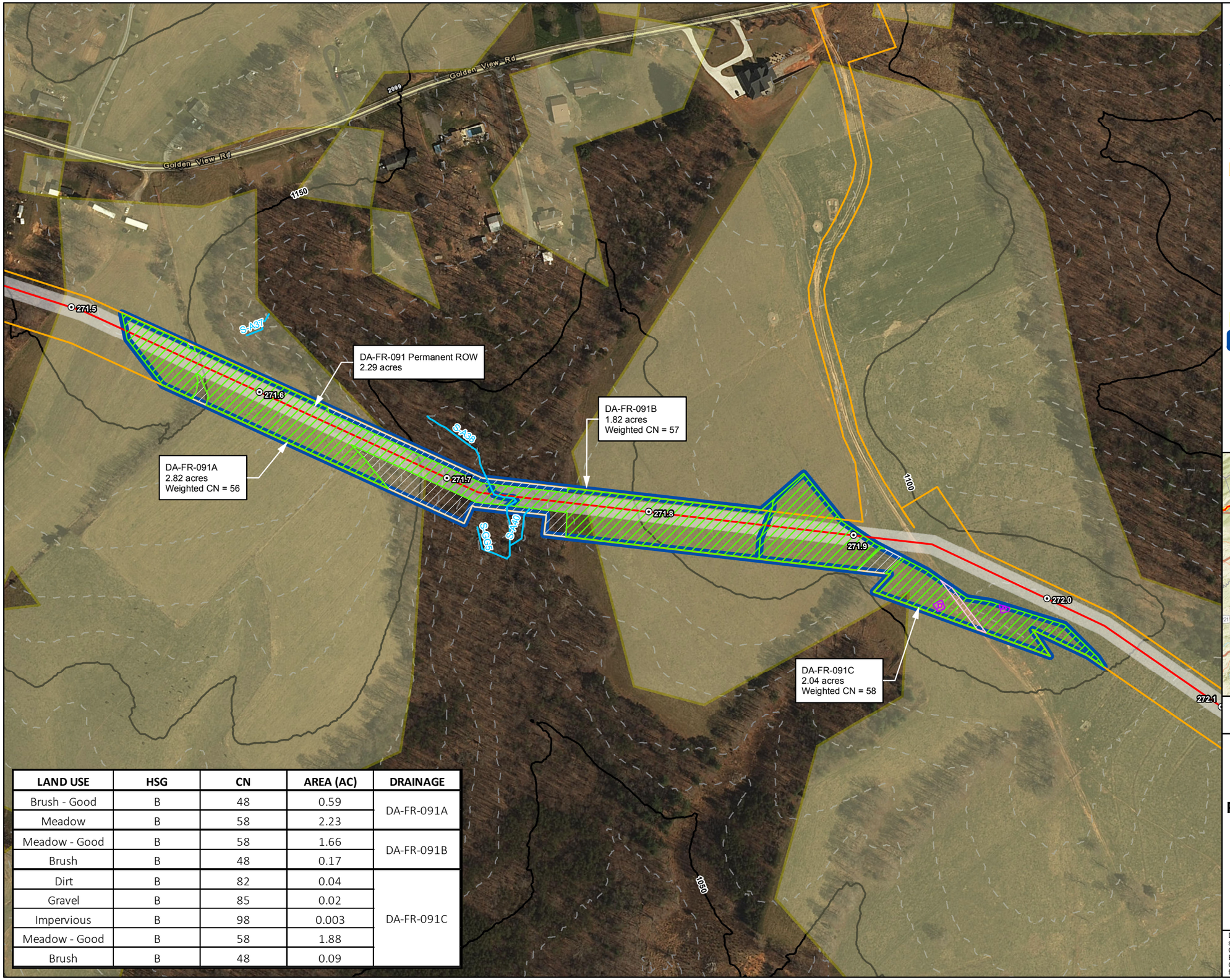
Figure 1

Franklin County, Virginia

August, 2017

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

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LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Brush - Good	B	48	0.59	DA-FR-091A
Meadow	B	58	2.23	
Meadow - Good	B	58	1.66	DA-FR-091B
Brush	B	48	0.17	
Dirt	B	82	0.04	DA-FR-091C
Gravel	B	85	0.02	
Impervious	B	98	0.003	
Meadow - Good	B	58	1.88	
Brush	B	48	0.09	

Legend

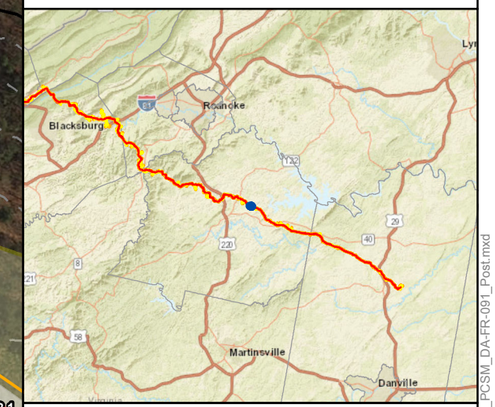
- Milepost
- Delineated Stream
- Existing 50' Contour
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- Road Centerline
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Brush
- Dirt Road
- Gravel
- Impervious
- Meadow
- Agricultural Area
- Drainage Area
- Hydrologic Soil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

NAD 1983 UTM 17N (feet)

N W E S

1:2,880

240 120 0 240 Feet



Mountain Valley Pipeline Project

Mountain Valley PIPELINE

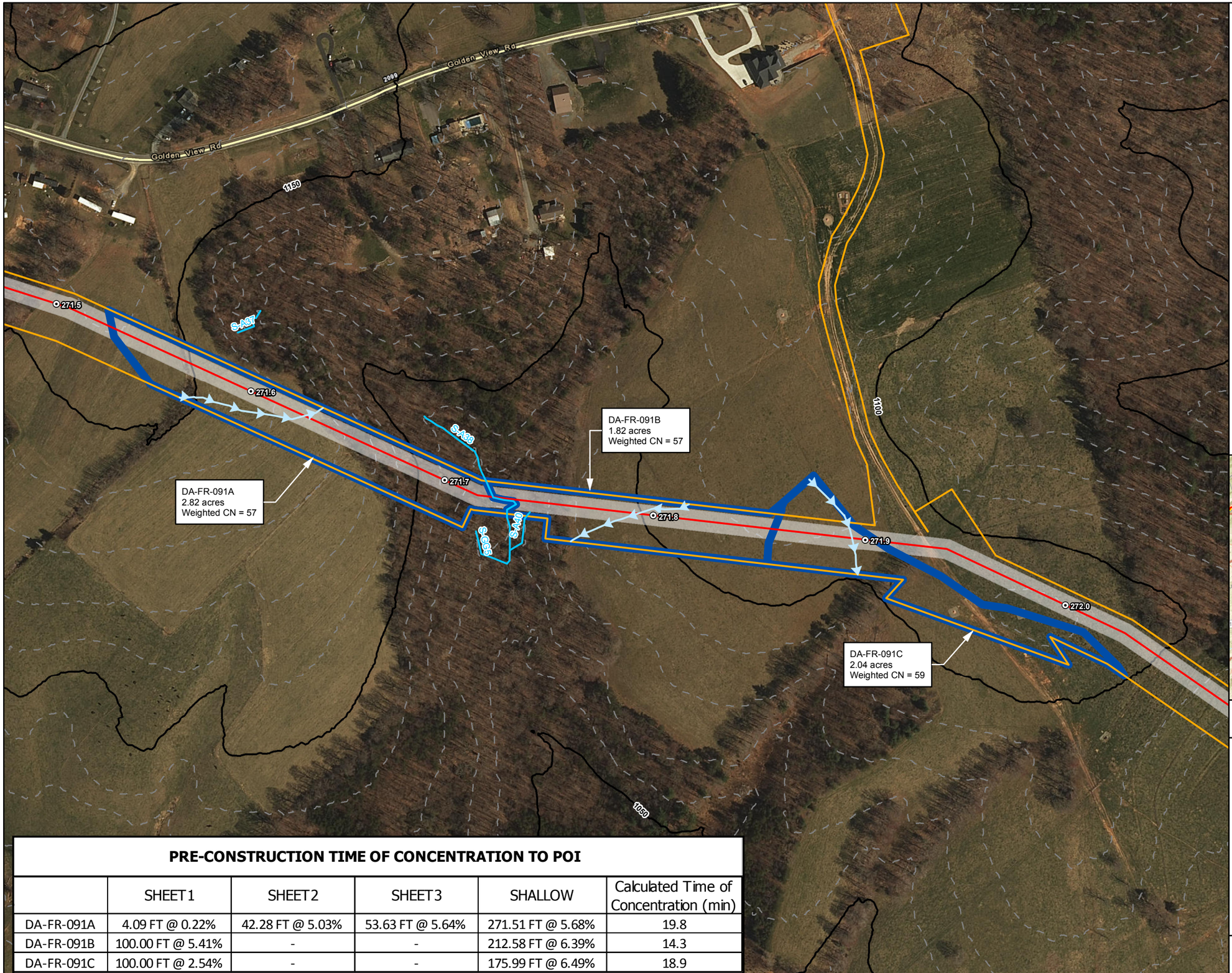
Post-Construction Drainage Area Map
DA-FR-091
Spread 11

Figure 2
Franklin County, Virginia

September, 2017

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

Document Path: PGH P:\GIS\EOT_MVP\Mapdocs\DrainageIMXD\FranklinMVP_PCSM_DA-FR-091_Post.mxd



PRE-CONSTRUCTION TIME OF CONCENTRATION TO POI

	SHEET1	SHEET2	SHEET3	SHALLOW	Calculated Time of Concentration (min)
DA-FR-091A	4.09 FT @ 0.22%	42.28 FT @ 5.03%	53.63 FT @ 5.64%	271.51 FT @ 5.68%	19.8
DA-FR-091B	100.00 FT @ 5.41%	-	-	212.58 FT @ 6.39%	14.3
DA-FR-091C	100.00 FT @ 2.54%	-	-	175.99 FT @ 6.49%	18.9

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)

1:2,800

240 120 0 240 Feet



Mountain Valley Pipeline Project

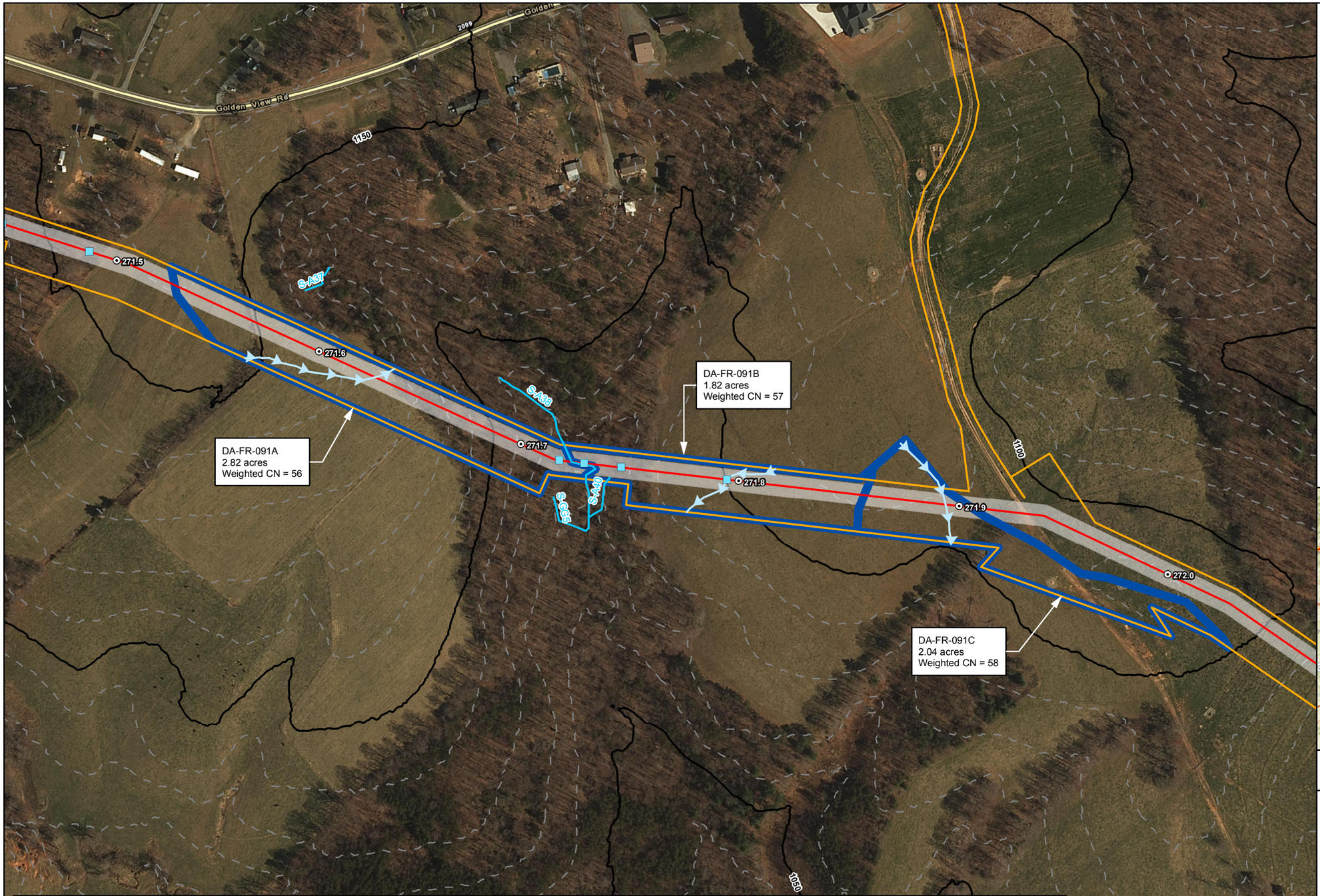
Mountain Valley PIPELINE

Pre-Construction Drainage Area and Time of Concentration
DA-FR-091
Spread 11

Figure 3
Franklin 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.

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POST-CONSTRUCTION TIME OF CONCENTRATION TO POI

	SHEET1	SHEET2	SHEET3	SHALLOW1	SHALLOW2	CHANNEL	Calculated Time of Concentration (min)
DA-FR-091A	4.09 FT @ 0.22%	42.28 FT @ 5.03%	53.63 FT @ 5.64%	271.51 FT @ 5.68%	-	-	25.0
DA-FR-091B	100.00 FT @ 5.41%	-	-	17.90 FT @ 7.93%	100.73 FT @ 6.00%	32.47 FT @ 4.85%	14.0
DA-FR-091C	100.00 FT @ 2.54%	-	-	175.99 FT @ 6.49%	-	-	18.9

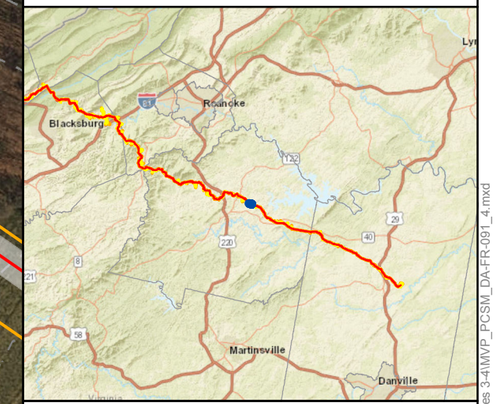
Legend

- 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)

1:2,880

240 120 0 240 Feet



Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Post-Construction Drainage Area and Time of Concentration
DA-FR-091
Spread 11

Figure 4
Franklin 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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Virginia Runoff Reduction Method New Development Worksheet - v2.8 - June 2014

Site Data Summary

Total Rainfall = 46 inches

Site Land Cover Summary

	A Soils	B Soils	C Soils	D Soils	Total	% of Total
Forest (acres)	0.00	2.29	0.00	0.00	2.29	*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*
					2.29	*100.00*

Site Rv	0.03
Post Development Treatment Volume (ft3)	249
Post Development TP Load (lb/yr)	0.17
Post Development TN Load (lb/yr)	1.20
Total TP Load Reduction Required (lb/yr)	-0.77

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)	0.17
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)	2.29	0.00	0.00	0.00	0.00	*2.29*
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*
						2.29

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-FR-091A

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.584	3517
Developed Condition	0.413	3190
Pre-Developed (Forest) Condition	0.384	2877

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

Improvement Factor, IF = 1

Calculations:

Check #1: $Q_{developed} \leq IF \times [(Q_{pre\text{-}developed} \times RV_{pre\text{-}developed}) / RV_{developed}]$ ----------> 0.413 ≤ 0.644 OK

Check #2: $Q_{developed} \leq Q_{pre\text{-}developed}$ ----------> 0.413 ≤ 0.584 OK

Check #3: $Q_{developed}$ *shall not* be required to be $\leq (Q_{forest} \times RV_{forest}) / RV_{developed}$ ---> 0.413 *shall not* be required to be ≤ 0.346

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

Note:

Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.

For Paved Road land surface types a Manning's n value 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

Hydraflow Table of Contents

DA-FR-091A_Hydraflow.gpw

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5 Tuesday, 08 / 15 / 2017

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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-FR-091A PRE
2	SCS Runoff	DA-FR-091A DEV
3	SCS Runoff	DA-FR-091A FOR

Hydrograph Return Period Recap

Hyd. No.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)							Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	------	0.584	1.036	-------	-------	4.441	-------	-------	-------	DA-FR-091A PRE
2	SCS Runoff	------	0.413	0.764	-------	-------	3.579	-------	-------	-------	DA-FR-091A DEV
3	SCS Runoff	------	0.384	0.758	-------	-------	3.867	-------	-------	-------	DA-FR-091A FOR

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	0.584	1	729	3,517	------	------	------	DA-FR-091A PRE
2	SCS Runoff	0.413	1	733	3,190	------	------	------	DA-FR-091A DEV
3	SCS Runoff	0.384	1	730	2,877	------	------	------	DA-FR-091A FOR

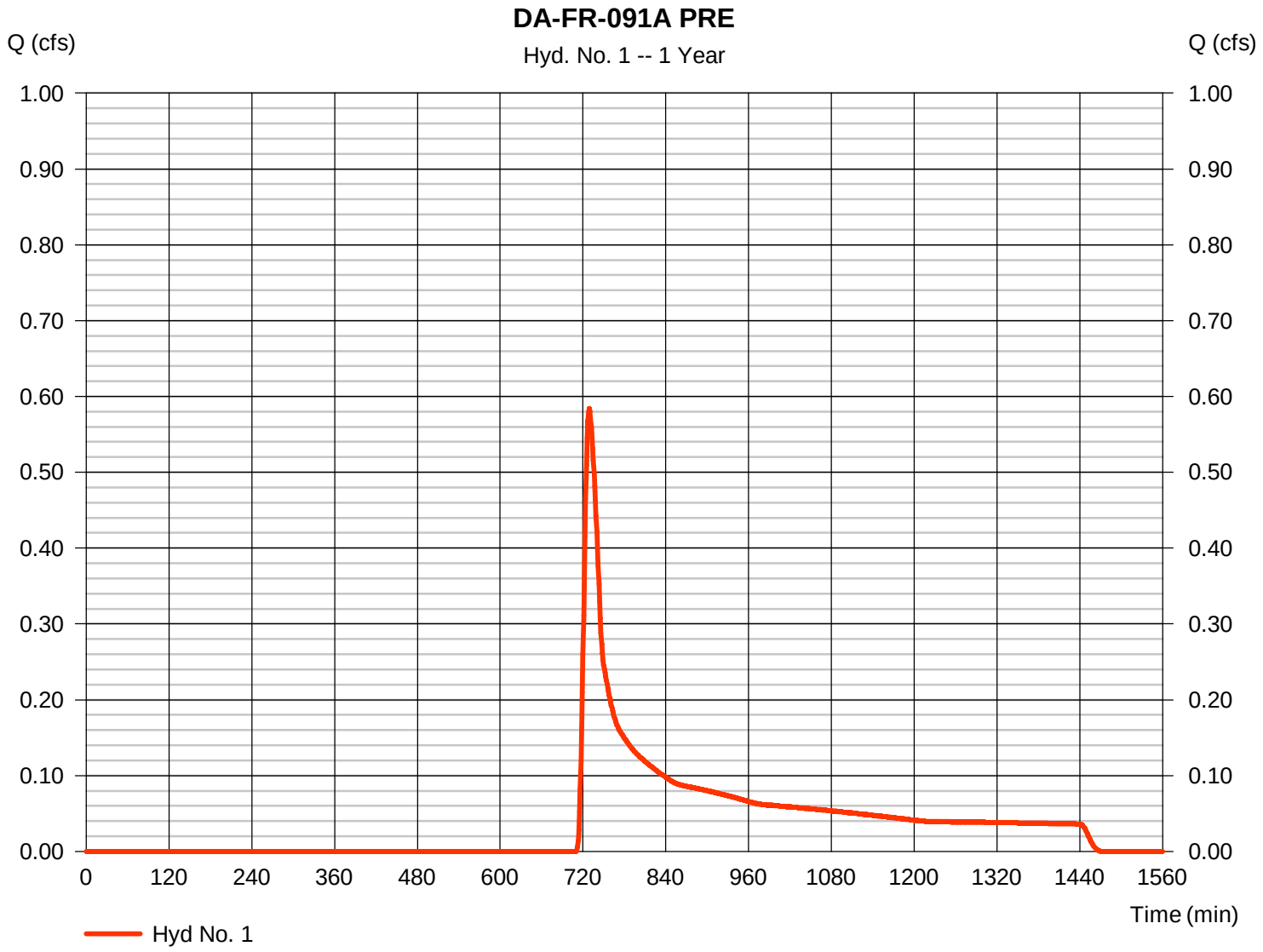
Hydrograph Report

Hyd. No. 1

DA-FR-091A PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.584 cfs
Storm frequency	= 1 yrs	Time to peak	= 729 min
Time interval	= 1 min	Hyd. volume	= 3,517 cuft
Drainage area	= 2.820 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 19.80 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.026 x 48) + (1.687 x 58) + (1.108 x 55)] / 2.820



TR55 Tc Worksheet

Hyd. No. 1

DA-FR-091A PRE

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.400		0.400		0.400		
Flow length (ft)	= 4.1		42.3		53.0		
Two-year 24-hr precip. (in)	= 3.70		3.70		3.70		
Land slope (%)	= 0.22		5.03		5.64		
Travel Time (min)	**= 3.74**	**+**	**6.94**	**+**	**7.94**	**=**	**18.62**
Shallow Concentrated Flow							
Flow length (ft)	= 0.00		0.00		271.51		
Watercourse slope (%)	= 0.00		0.00		5.68		
Surface description	= Unpaved		Unpaved		Unpaved		
Average velocity (ft/s)	=0.00		0.00		3.85		
Travel Time (min)	**= 0.00**	**+**	**0.00**	**+**	**1.18**	**=**	**1.18**
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	= 0.015		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 ..... 19.80 min

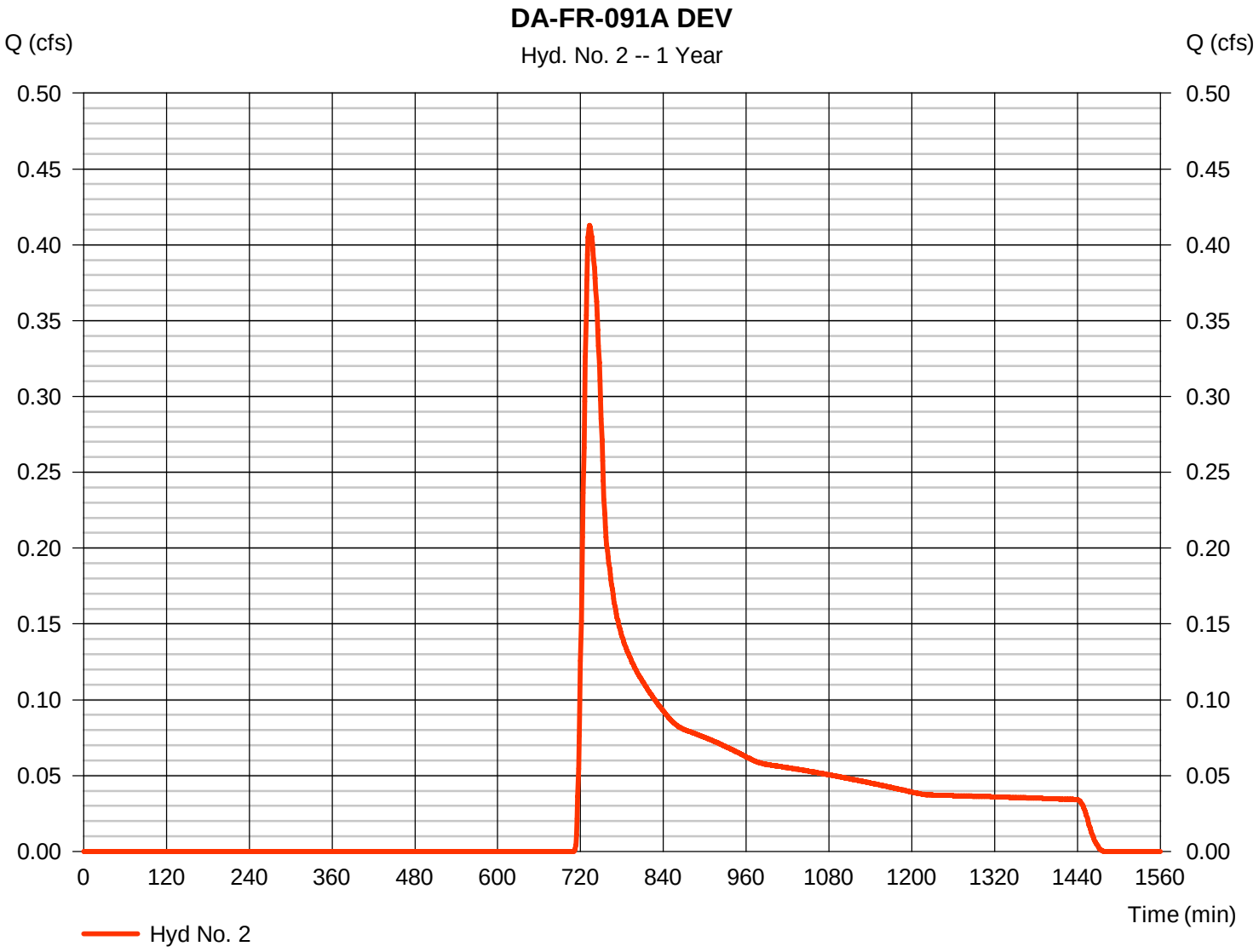
Hydrograph Report

Hyd. No. 2

DA-FR-091A DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.413 cfs
Storm frequency	= 1 yrs	Time to peak	= 733 min
Time interval	= 1 min	Hyd. volume	= 3,190 cuft
Drainage area	= 2.820 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 25.00 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.590 x 48) + (2.232 x 58)] / 2.820



TR55 Tc Worksheet

Hyd. No. 2

DA-FR-091A DEV

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.400		0.800		0.400		
Flow length (ft)	= 4.1		42.3		53.6		
Two-year 24-hr precip. (in)	= 3.70		3.70		3.70		
Land slope (%)	= 0.22		5.03		5.64		
Travel Time (min)	**= 3.74**	**+**	**12.08**	**+**	**8.01**	**=**	**23.83**
Shallow Concentrated Flow							
Flow length (ft)	= 271.51		0.00		0.00		
Watercourse slope (%)	= 5.68		0.00		0.00		
Surface description	= Unpaved		Unpaved		Unpaved		
Average velocity (ft/s)	=3.85		0.00		0.00		
Travel Time (min)	**= 1.18**	**+**	**0.00**	**+**	**0.00**	**=**	**1.18**
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	= 0.015		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 ..... 25.00 min

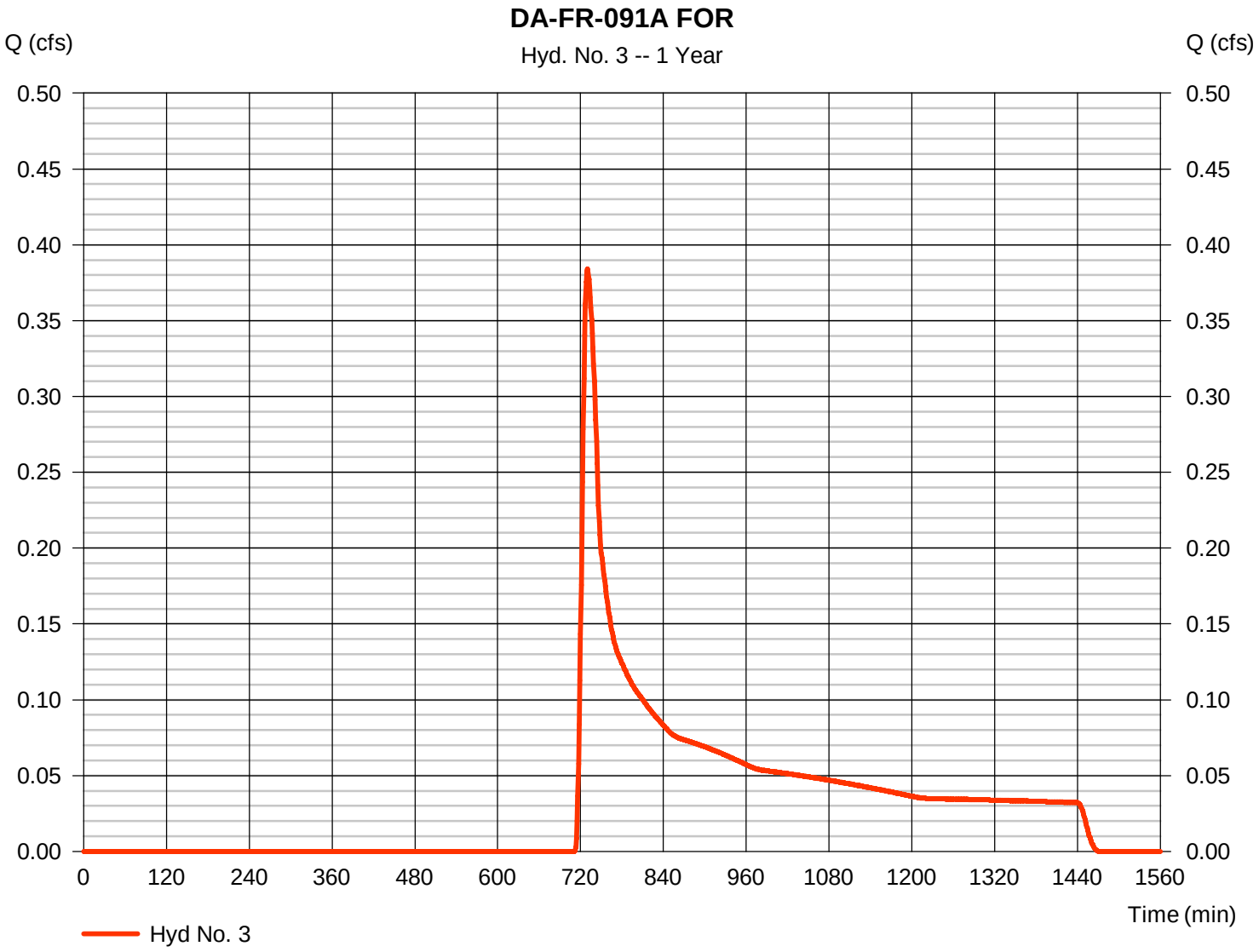
Hydrograph Report

Hyd. No. 3

DA-FR-091A FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.384 cfs
Storm frequency	= 1 yrs	Time to peak	= 730 min
Time interval	= 1 min	Hyd. volume	= 2,877 cuft
Drainage area	= 2.820 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 19.80 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.026 x 48) + (1.687 x 58) + (1.108 x 55)] / 2.820



TR55 Tc Worksheet

Hyd. No. 3

DA-FR-091A FOR

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.400		0.400		0.400		
Flow length (ft)	= 4.1		42.3		53.0		
Two-year 24-hr precip. (in)	= 3.70		3.70		3.70		
Land slope (%)	= 0.22		5.03		5.64		
Travel Time (min)	**= 3.74**	**+**	**6.94**	**+**	**7.94**	**=**	**18.62**
Shallow Concentrated Flow							
Flow length (ft)	= 0.00		0.00		271.51		
Watercourse slope (%)	= 0.00		0.00		5.68		
Surface description	= Unpaved		Unpaved		Unpaved		
Average velocity (ft/s)	=0.00		0.00		3.85		
Travel Time (min)	**= 0.00**	**+**	**0.00**	**+**	**1.18**	**=**	**1.18**
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	= 0.015		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 ..... 19.80 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	1.036	1	728	5,048	------	------	------	DA-FR-091A PRE
2	SCS Runoff	0.764	1	732	4,644	------	------	------	DA-FR-091A DEV
3	SCS Runoff	0.758	1	729	4,254	------	------	------	DA-FR-091A FOR

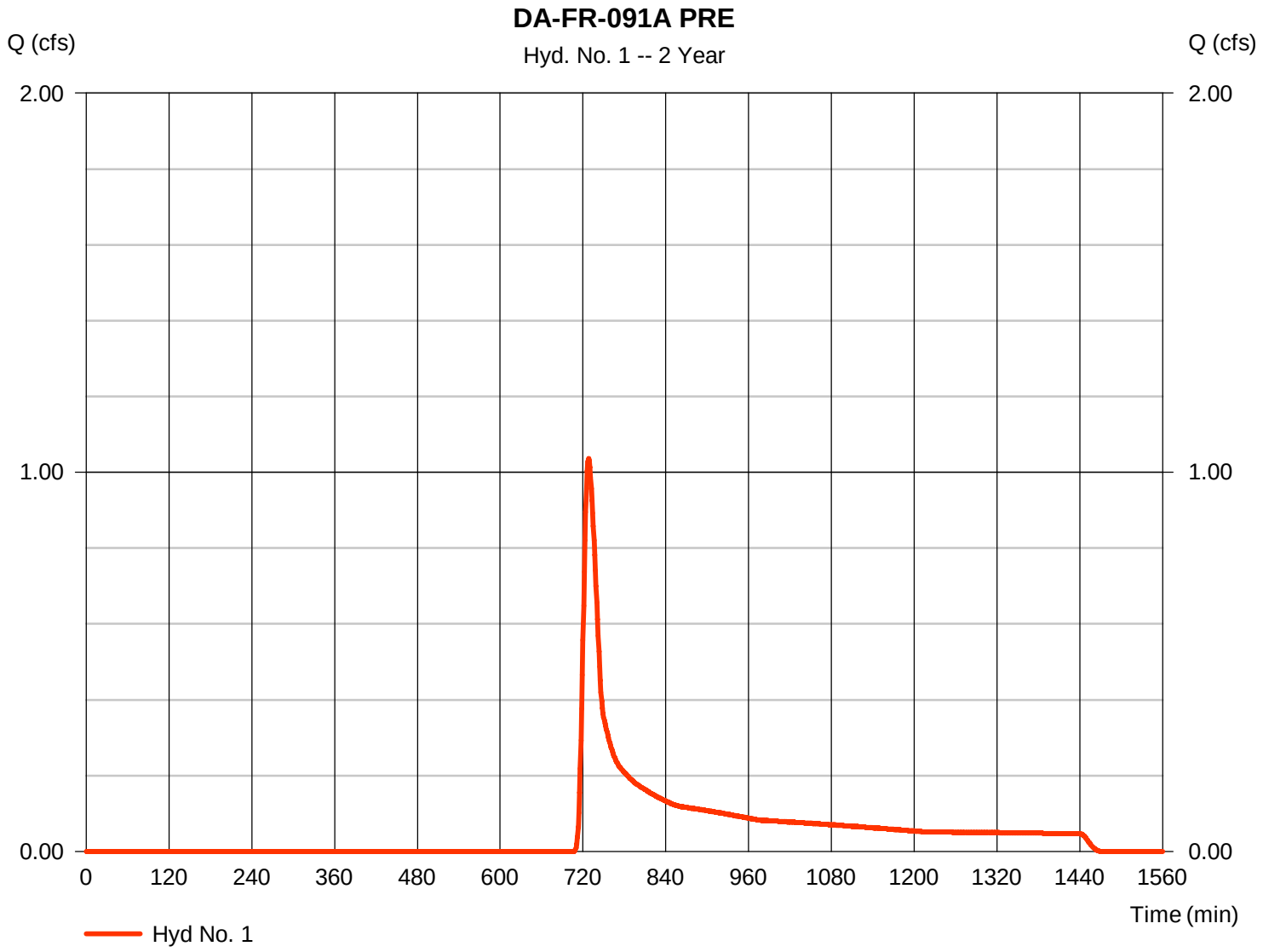
Hydrograph Report

Hyd. No. 1

DA-FR-091A PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	1.036 cfs
Storm frequency	=	2 yrs	Time to peak	=	728 min
Time interval	=	1 min	Hyd. volume	=	5,048 cuft
Drainage area	=	2.820 ac	Curve number	=	57*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	19.80 min
Total precip.	=	3.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.026 x 48) + (1.687 x 58) + (1.108 x 55)] / 2.820



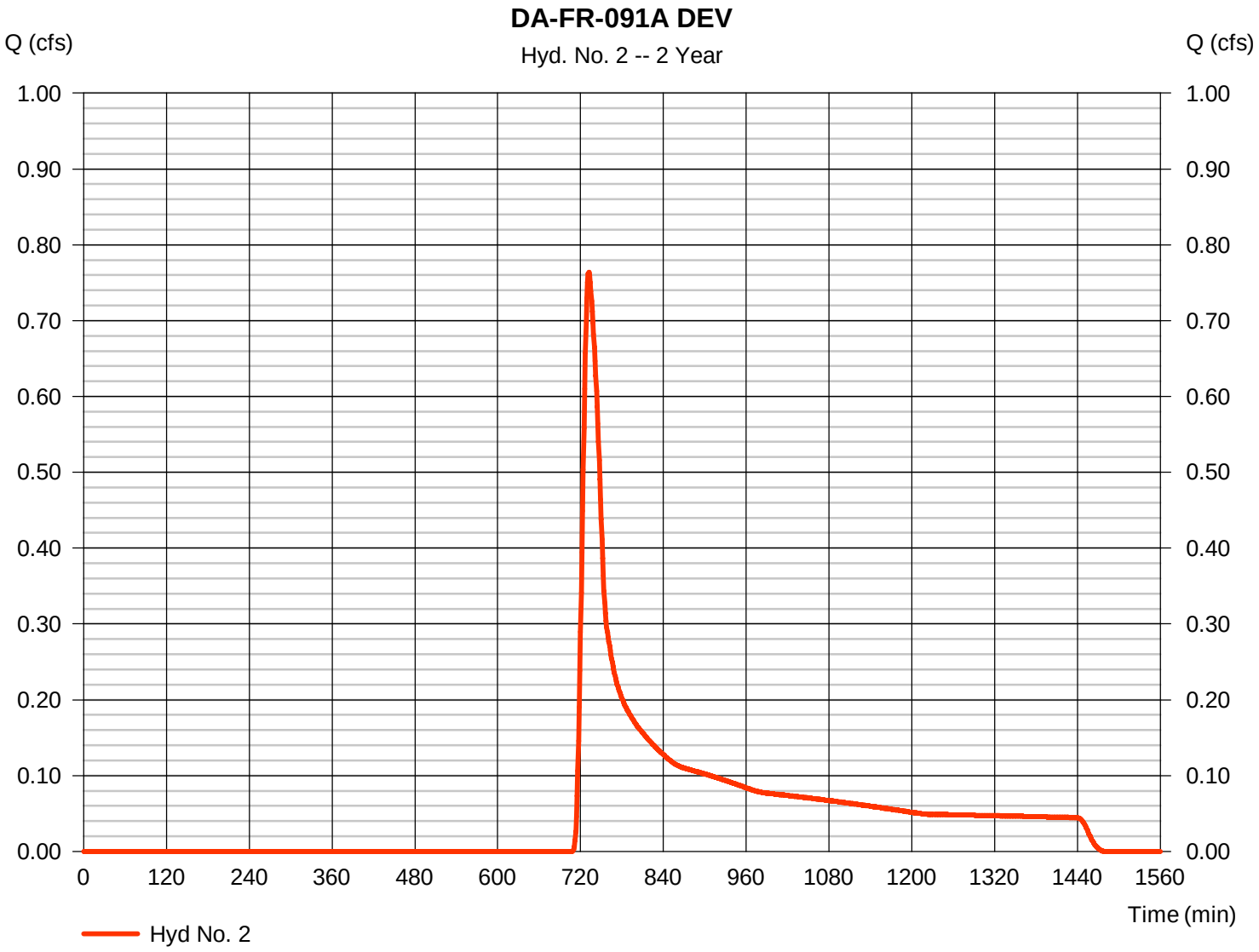
Hydrograph Report

Hyd. No. 2

DA-FR-091A DEV

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.764 cfs
Storm frequency	=	2 yrs	Time to peak	=	732 min
Time interval	=	1 min	Hyd. volume	=	4,644 cuft
Drainage area	=	2.820 ac	Curve number	=	56*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	25.00 min
Total precip.	=	3.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.590 x 48) + (2.232 x 58)] / 2.820



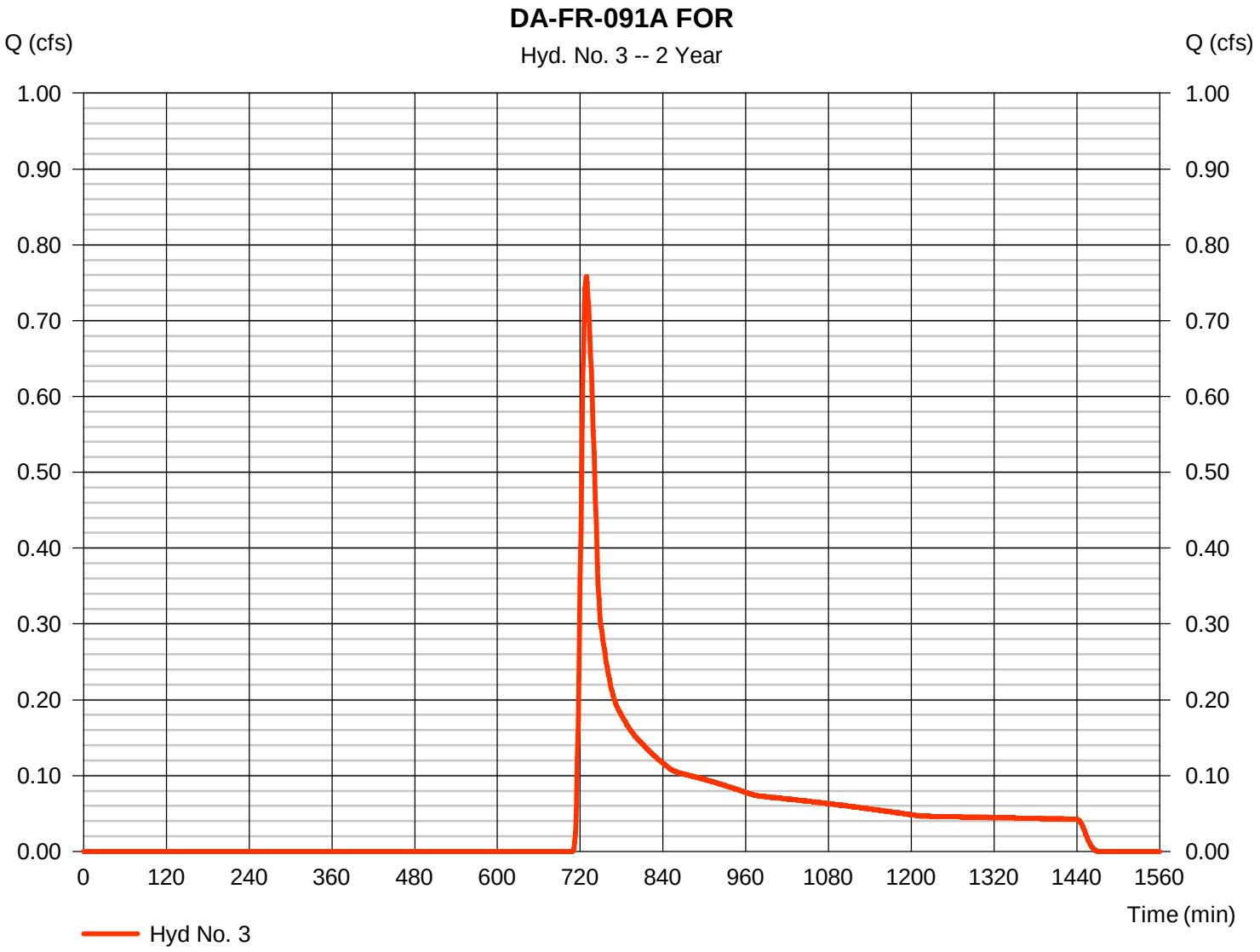
Hydrograph Report

Hyd. No. 3

DA-FR-091A FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.758 cfs
Storm frequency	= 2 yrs	Time to peak	= 729 min
Time interval	= 1 min	Hyd. volume	= 4,254 cuft
Drainage area	= 2.820 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 19.80 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.026 x 48) + (1.687 x 58) + (1.108 x 55)] / 2.820



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	4.441	1	726	15,323	------	------	------	DA-FR-091A PRE
2	SCS Runoff	3.579	1	729	14,558	------	------	------	DA-FR-091A DEV
3	SCS Runoff	3.867	1	726	13,804	------	------	------	DA-FR-091A FOR

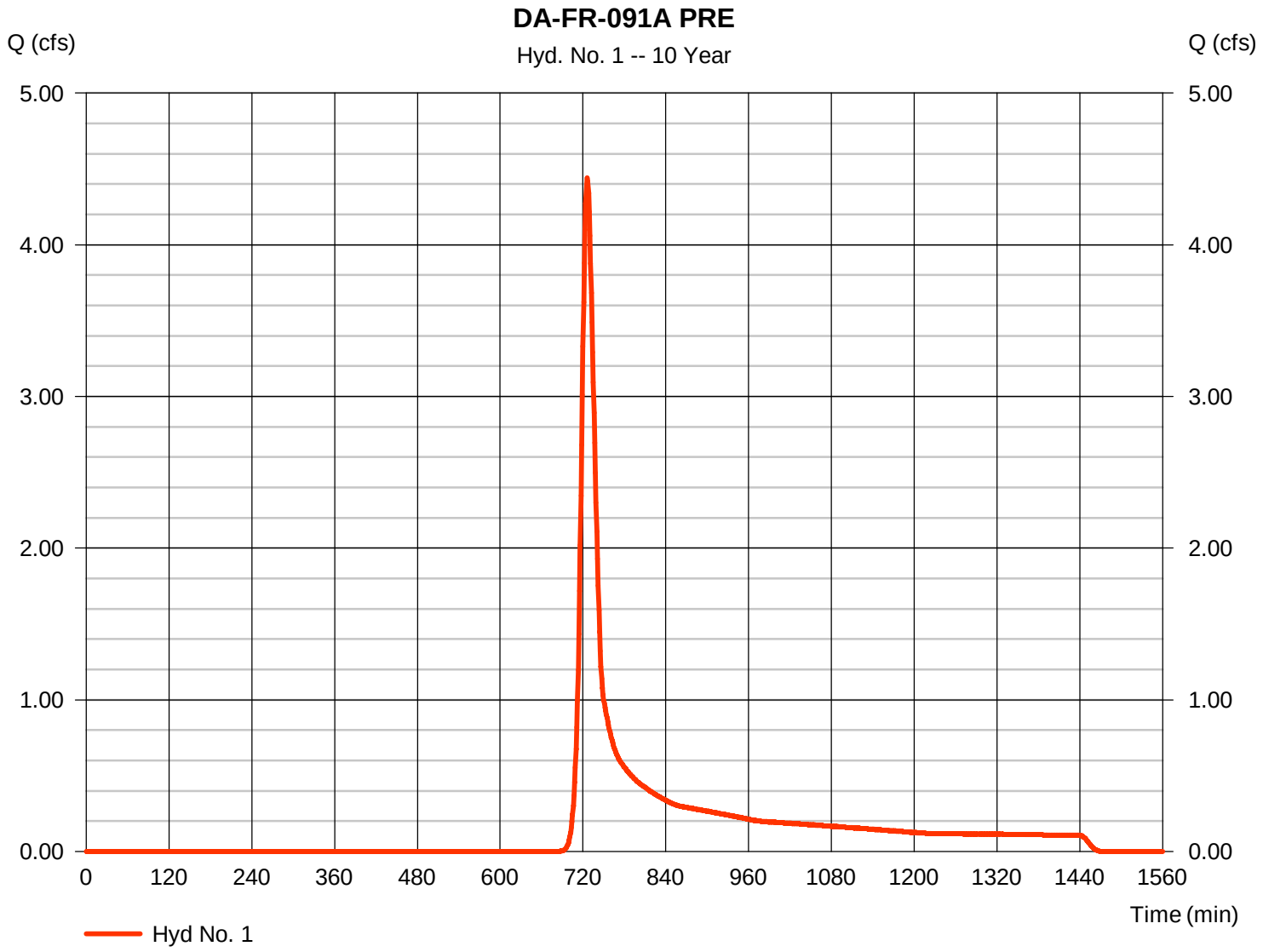
Hydrograph Report

Hyd. No. 1

DA-FR-091A PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	4.441 cfs
Storm frequency	=	10 yrs	Time to peak	=	726 min
Time interval	=	1 min	Hyd. volume	=	15,323 cuft
Drainage area	=	2.820 ac	Curve number	=	57*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	19.80 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.026 x 48) + (1.687 x 58) + (1.108 x 55)] / 2.820



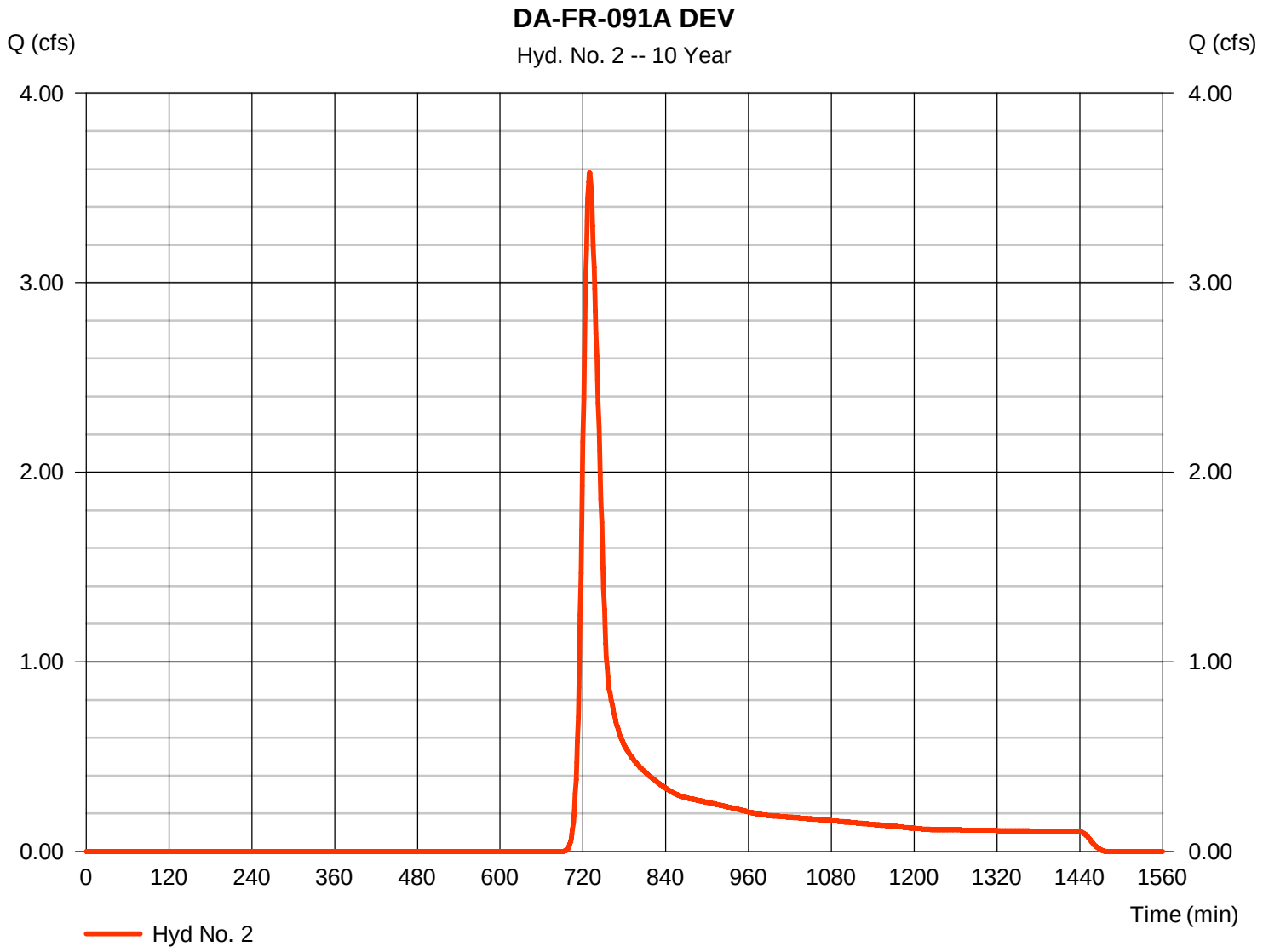
Hydrograph Report

Hyd. No. 2

DA-FR-091A DEV

Hydrograph type	=	SCS Runoff	Peak discharge	=	3.579 cfs
Storm frequency	=	10 yrs	Time to peak	=	729 min
Time interval	=	1 min	Hyd. volume	=	14,558 cuft
Drainage area	=	2.820 ac	Curve number	=	56*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	25.00 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.590 x 48) + (2.232 x 58)] / 2.820



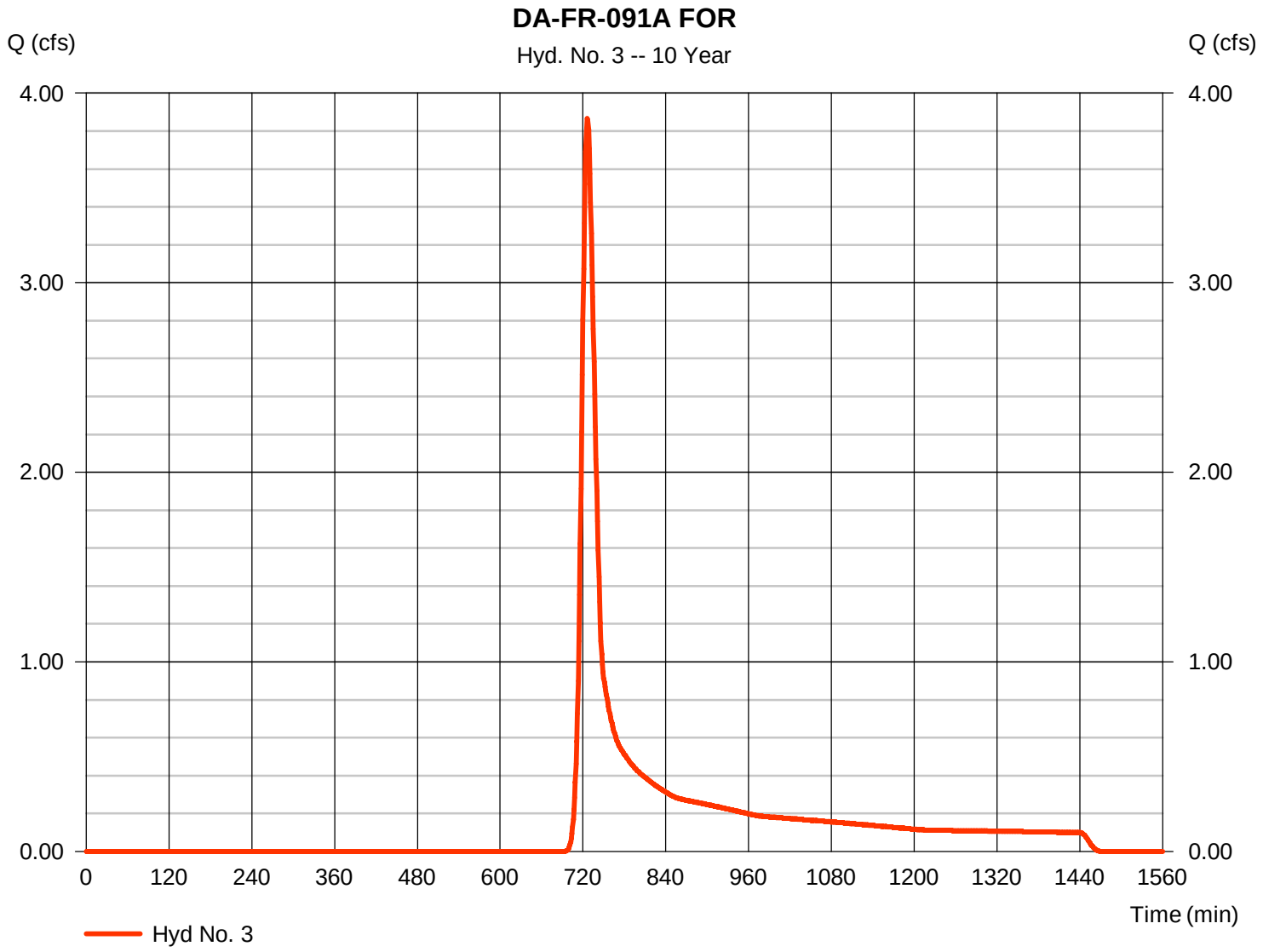
Hydrograph Report

Hyd. No. 3

DA-FR-091A FOR

Hydrograph type	=	SCS Runoff	Peak discharge	=	3.867 cfs
Storm frequency	=	10 yrs	Time to peak	=	726 min
Time interval	=	1 min	Hyd. volume	=	13,804 cuft
Drainage area	=	2.820 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	19.80 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.026 x 48) + (1.687 x 58) + (1.108 x 55)] / 2.820



Hydraflow Rainfall Report

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

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

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

Tc = time in minutes. Values may exceed 60.

ng\Franklin County\Downloaded Files\Franklin County DA Batch 4 - 046 - 058\Precipitation\Hydraflow\FranklinCo.pc

Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.30	3.70	0.00	0.00	5.70	0.00	0.00	0.00
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

DA-FR-091B

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.458	2270
Developed Condition	0.458	2270
Pre-Developed (Forest) Condition	0.300	1857

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

Improvement Factor, IF = 1

Calculations:

Check #1: $Q_{developed} \leq IF \times [(Q_{pre\text{-}developed} \times RV_{pre\text{-}developed}) / RV_{developed}]$ ----------> 0.458 ≤ 0.458 OK

Check #2: $Q_{developed} \leq Q_{pre\text{-}developed}$ ----------> 0.458 ≤ 0.458 OK

Check #3: $Q_{developed}$ *shall not* be required to be ≤ $(Q_{forest} \times RV_{forest}) / RV_{developed}$ ---> 0.458 *shall not* be required to be ≤ 0.245

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

Note:

Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.

For Paved Road land surface types a Manning's n value 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 Channels[1]			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels[2]			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150

Notes:

[1]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 or grass channel.

[2]For the pre-developed condition (if applicable), 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-FR-091B PRE
2	SCS Runoff	DA-FR-091B DEV
3	SCS Runoff	DA-FR-091B FOR

Hydrograph Return Period Recap

Hyd. No.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)							Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	------	0.458	0.814	-------	-------	3.406	-------	-------	-------	DA-FR-091B PRE
2	SCS Runoff	------	0.458	0.814	-------	-------	3.406	-------	-------	-------	DA-FR-091B DEV
3	SCS Runoff	------	0.300	0.597	-------	-------	2.981	-------	-------	-------	DA-FR-091B FOR

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	0.458	1	725	2,270	------	------	------	DA-FR-091B PRE
2	SCS Runoff	0.458	1	725	2,270	------	------	------	DA-FR-091B DEV
3	SCS Runoff	0.300	1	726	1,857	------	------	------	DA-FR-091B FOR

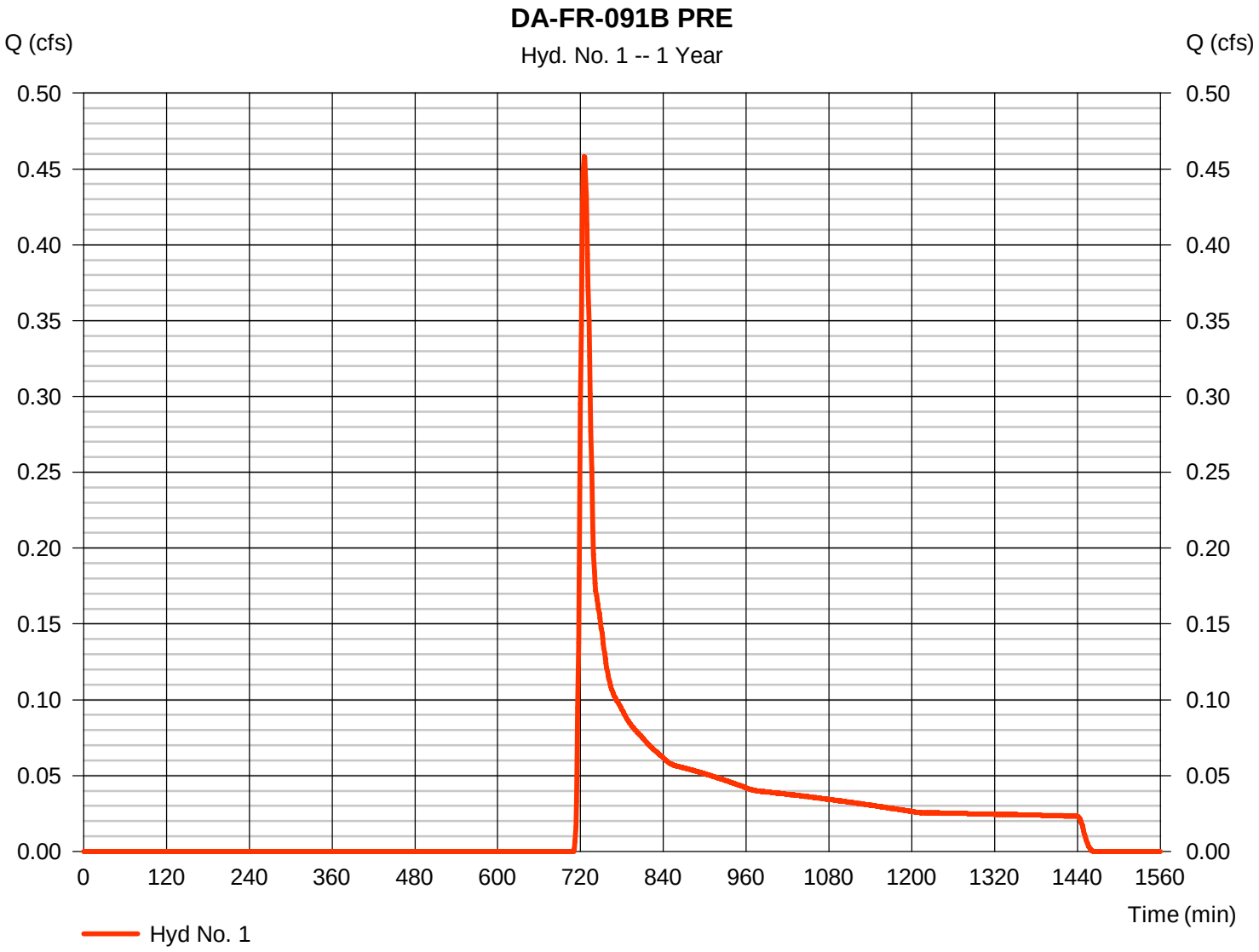
Hydrograph Report

Hyd. No. 1

DA-FR-091B PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.458 cfs
Storm frequency	= 1 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 2,270 cuft
Drainage area	= 1.820 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.30 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(1.461 x 58) + (0.361 x 55)] / 1.820



TR55 Tc Worksheet

Hyd. No. 1

DA-FR-091B PRE

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 5.41		0.00		0.00		
Travel Time (min)	**= 13.41**	**+**	**0.00**	**+**	**0.00**	**=**	**13.41**
Shallow Concentrated Flow							
Flow length (ft)	= 212.58		0.00		0.00		
Watercourse slope (%)	= 6.39		0.00		0.00		
Surface description	= Unpaved		Unpaved		Unpaved		
Average velocity (ft/s)	=4.08		0.00		0.00		
Travel Time (min)	**= 0.87**	**+**	**0.00**	**+**	**0.00**	**=**	**0.87**
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	= 0.015		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 ..... 14.30 min

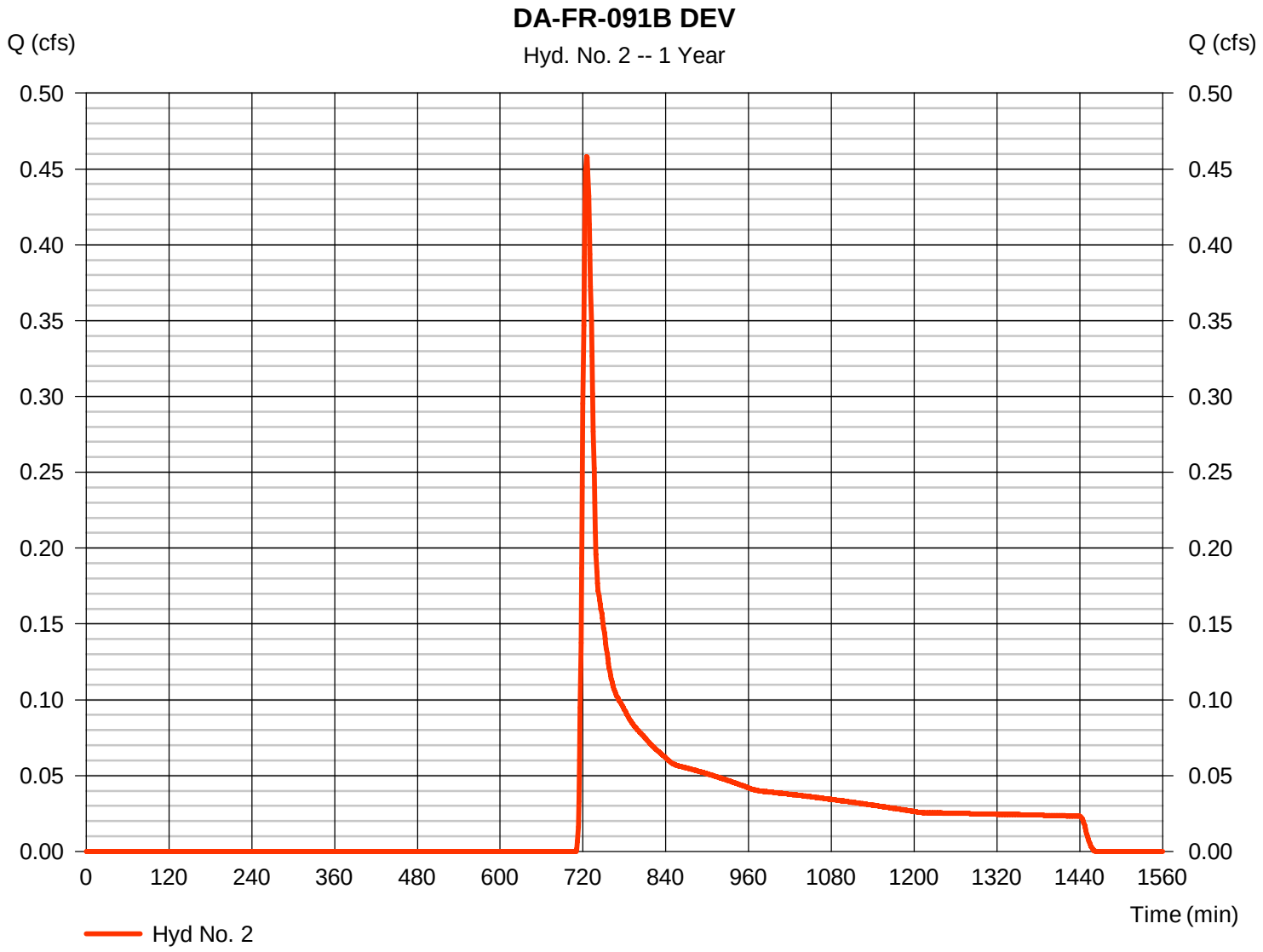
Hydrograph Report

Hyd. No. 2

DA-FR-091B DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.458 cfs
Storm frequency	= 1 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 2,270 cuft
Drainage area	= 1.820 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.00 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(1.657 x 58) + (0.165 x 48)] / 1.820



TR55 Tc Worksheet

Hyd. No. 2

DA-FR-091B DEV

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 5.41		0.00		0.00		
Travel Time (min)	**= 13.41**	**+**	**0.00**	**+**	**0.00**	**=**	**13.41**
Shallow Concentrated Flow							
Flow length (ft)	= 17.90		100.73		0.00		
Watercourse slope (%)	= 7.93		6.00		0.00		
Surface description	= Unpaved		Unpaved		Unpaved		
Average velocity (ft/s)	=4.54		3.95		0.00		
Travel Time (min)	**= 0.07**	**+**	**0.42**	**+**	**0.00**	**=**	**0.49**
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})32.5		0.0		0.0		
Travel Time (min)	**= 0.11**	**+**	**0.00**	**+**	**0.00**	**=**	**0.11**

Total Travel Time, Tc ..... 14.00 min

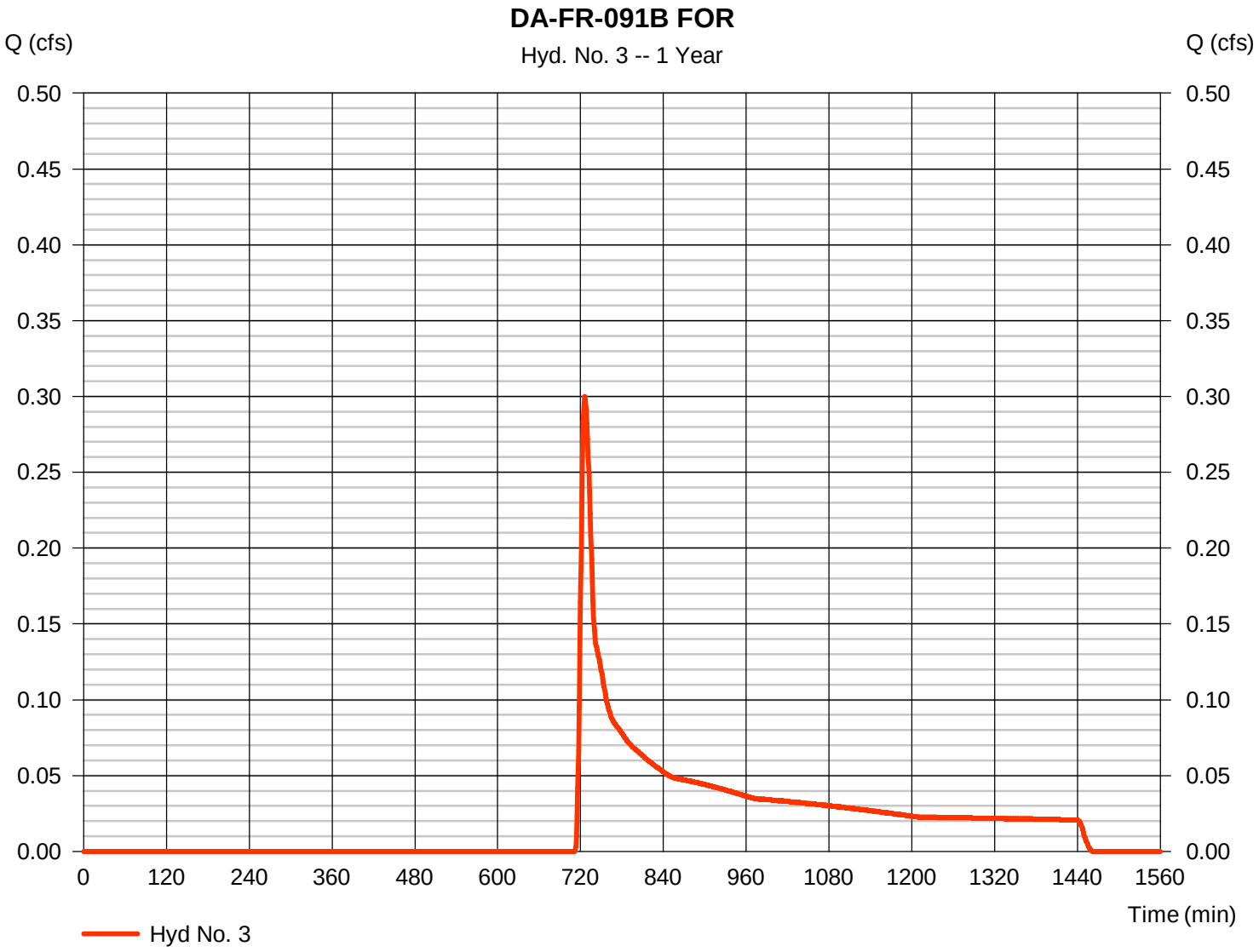
Hydrograph Report

Hyd. No. 3

DA-FR-091B FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.300 cfs
Storm frequency	= 1 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 1,857 cuft
Drainage area	= 1.820 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.30 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(1.461 x 58) + (0.361 x 55)] / 1.820



TR55 Tc Worksheet

Hyd. No. 3

DA-FR-091B FOR

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 5.41		0.00		0.00		
Travel Time (min)	**= 13.41**	**+**	**0.00**	**+**	**0.00**	**=**	**13.41**
Shallow Concentrated Flow							
Flow length (ft)	= 212.58		0.00		0.00		
Watercourse slope (%)	= 6.39		0.00		0.00		
Surface description	= Unpaved		Unpaved		Unpaved		
Average velocity (ft/s)	=4.08		0.00		0.00		
Travel Time (min)	**= 0.87**	**+**	**0.00**	**+**	**0.00**	**=**	**0.87**
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	= 0.015		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 ..... 14.30 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	0.814	1	725	3,258	------	------	------	DA-FR-091B PRE
2	SCS Runoff	0.814	1	725	3,258	------	------	------	DA-FR-091B DEV
3	SCS Runoff	0.597	1	725	2,746	------	------	------	DA-FR-091B FOR

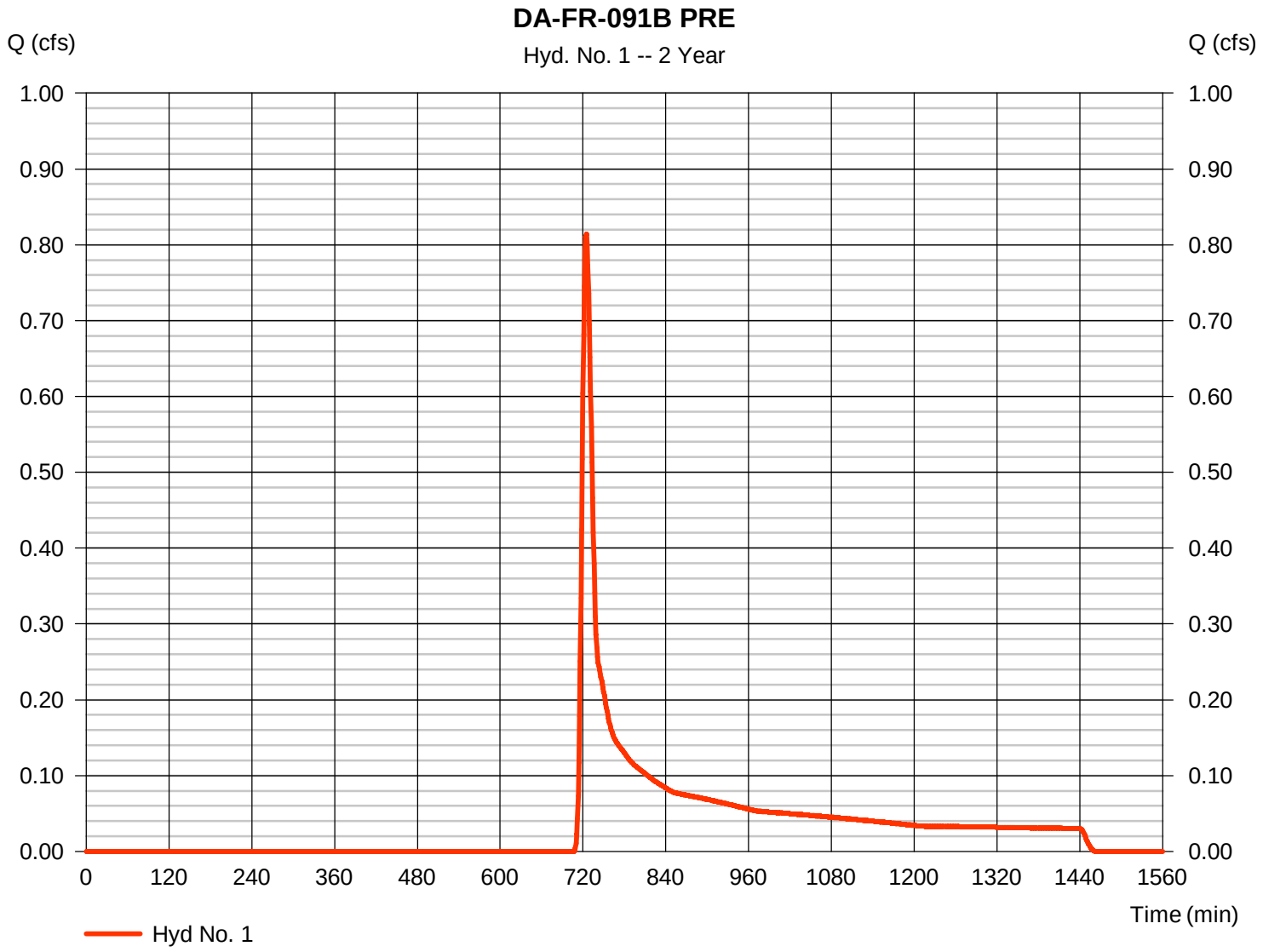
Hydrograph Report

Hyd. No. 1

DA-FR-091B PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.814 cfs
Storm frequency	=	2 yrs	Time to peak	=	725 min
Time interval	=	1 min	Hyd. volume	=	3,258 cuft
Drainage area	=	1.820 ac	Curve number	=	57*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	14.30 min
Total precip.	=	3.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(1.461 x 58) + (0.361 x 55)] / 1.820



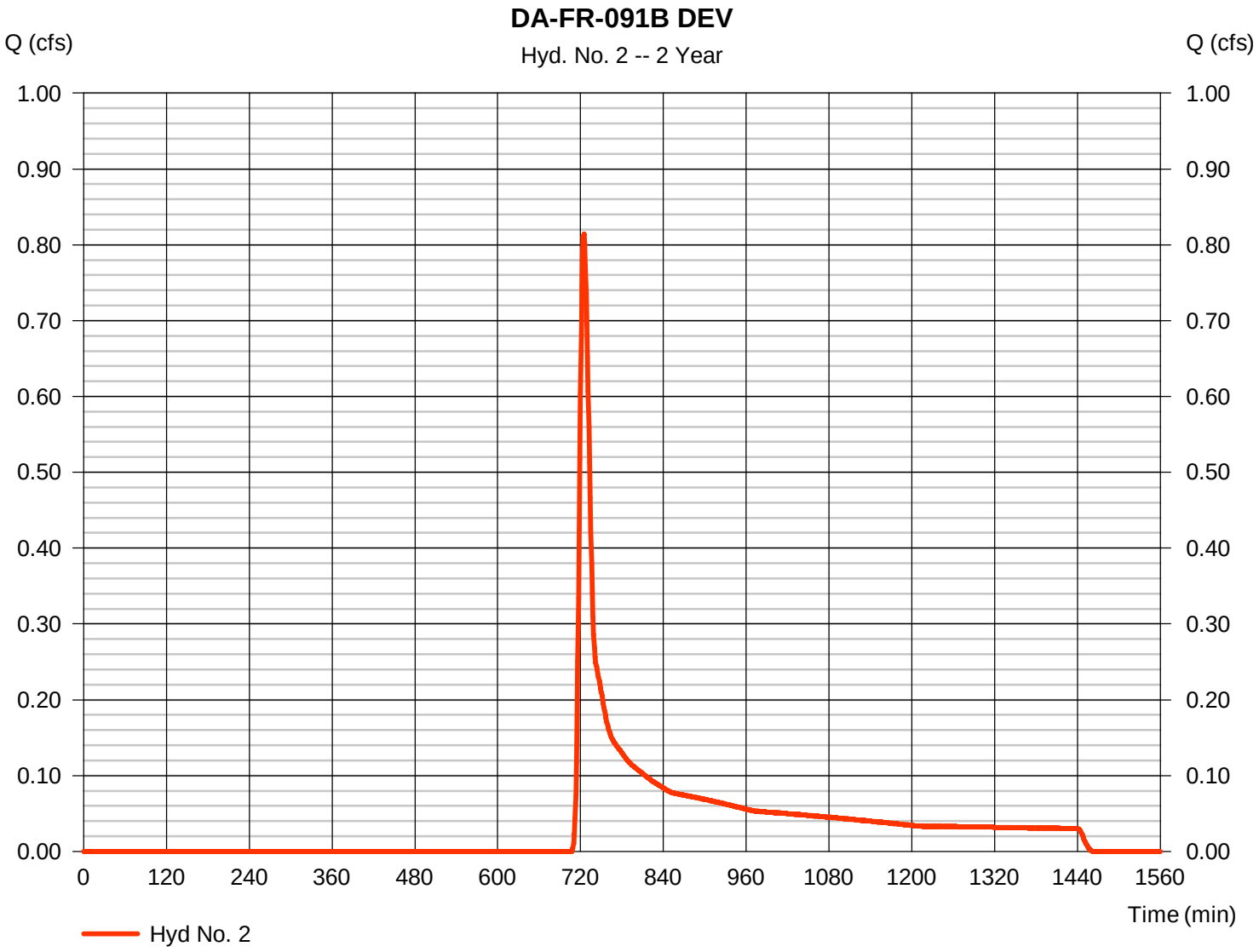
Hydrograph Report

Hyd. No. 2

DA-FR-091B DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.814 cfs
Storm frequency	= 2 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 3,258 cuft
Drainage area	= 1.820 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.00 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(1.657 x 58) + (0.165 x 48)] / 1.820



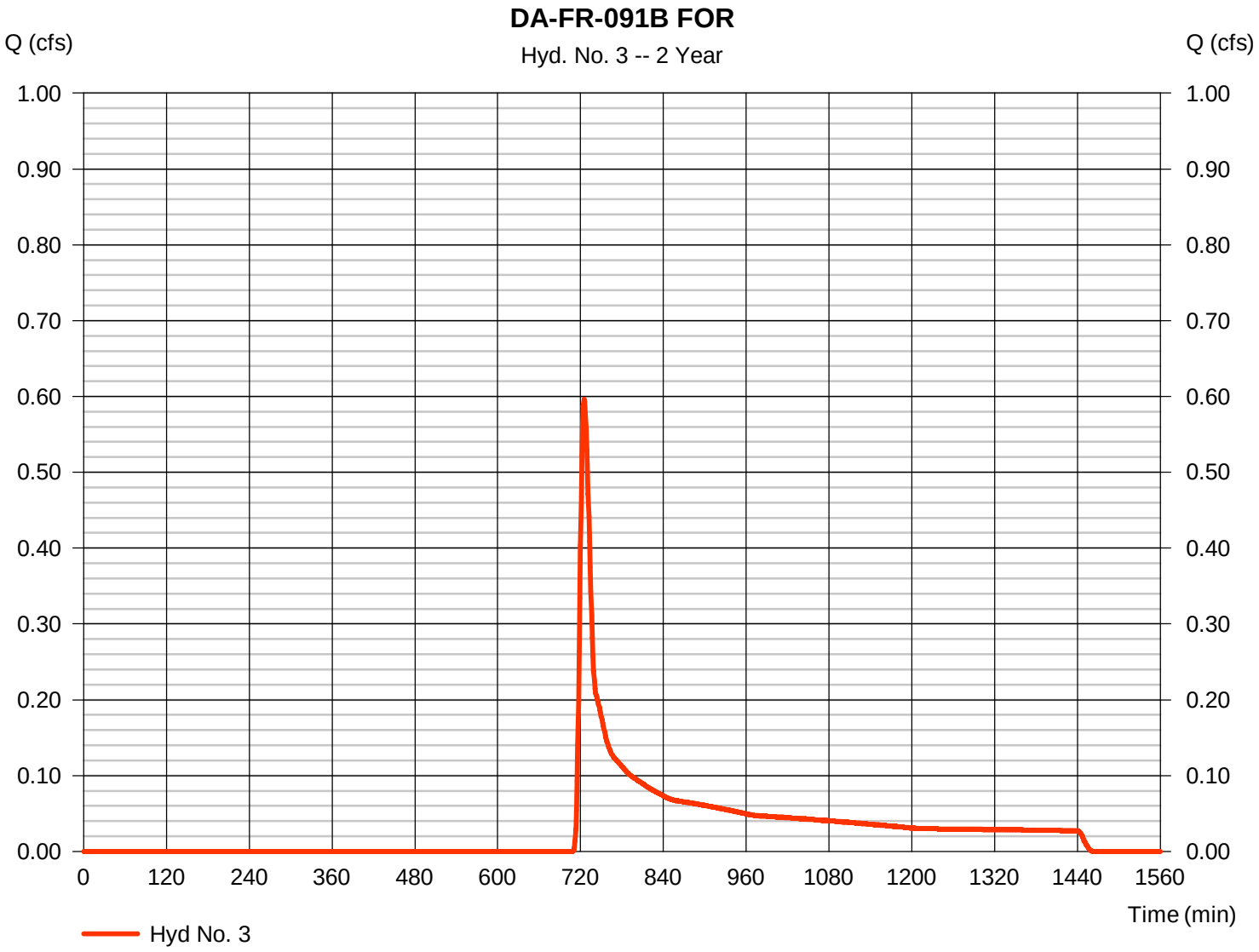
Hydrograph Report

Hyd. No. 3

DA-FR-091B FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.597 cfs
Storm frequency	= 2 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 2,746 cuft
Drainage area	= 1.820 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 14.30 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(1.461 x 58) + (0.361 x 55)] / 1.820



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	3.406	1	723	9,889	------	------	------	DA-FR-091B PRE
2	SCS Runoff	3.406	1	723	9,889	------	------	------	DA-FR-091B DEV
3	SCS Runoff	2.981	1	723	8,909	------	------	------	DA-FR-091B FOR

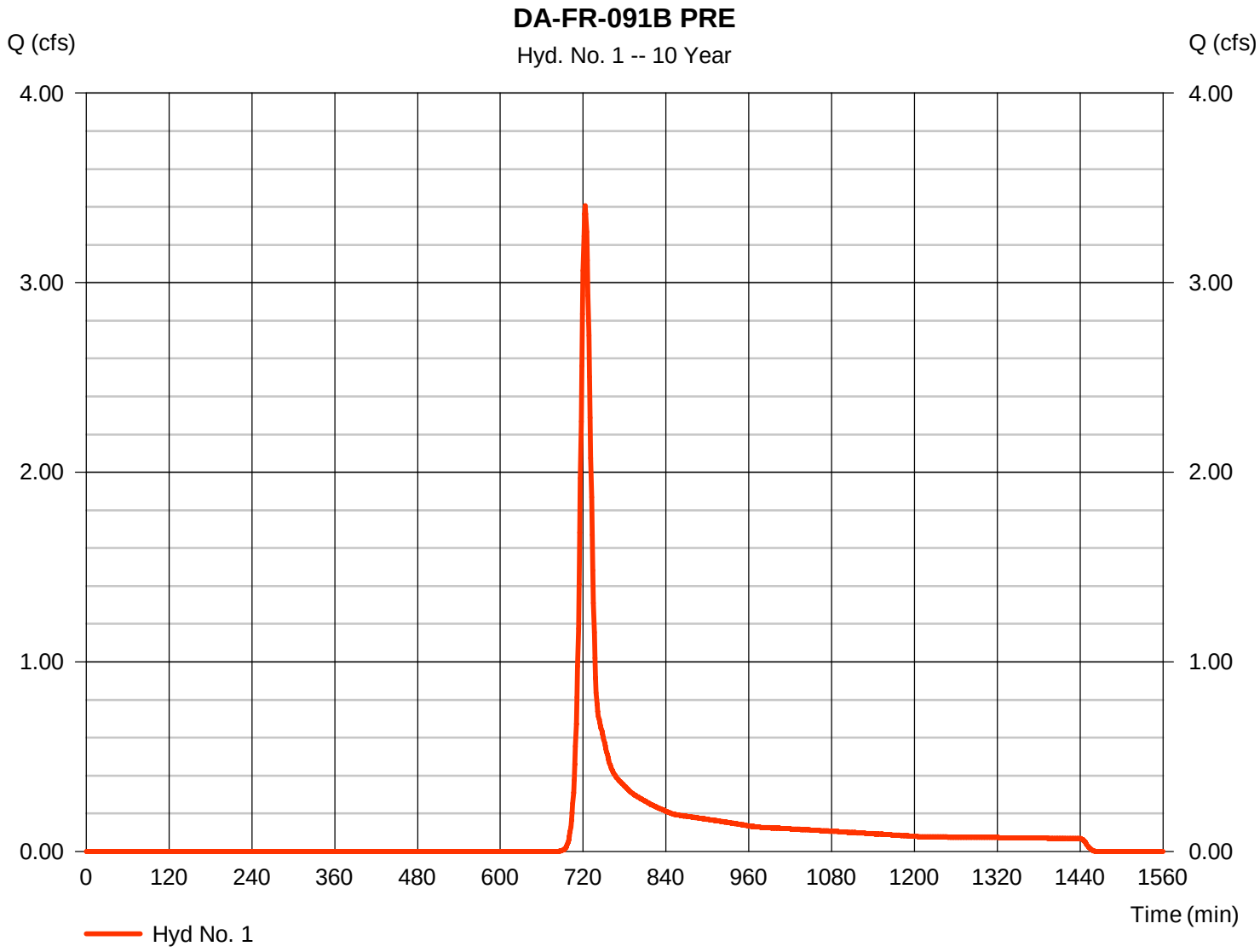
Hydrograph Report

Hyd. No. 1

DA-FR-091B PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	3.406 cfs
Storm frequency	=	10 yrs	Time to peak	=	723 min
Time interval	=	1 min	Hyd. volume	=	9,889 cuft
Drainage area	=	1.820 ac	Curve number	=	57*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	14.30 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(1.461 x 58) + (0.361 x 55)] / 1.820



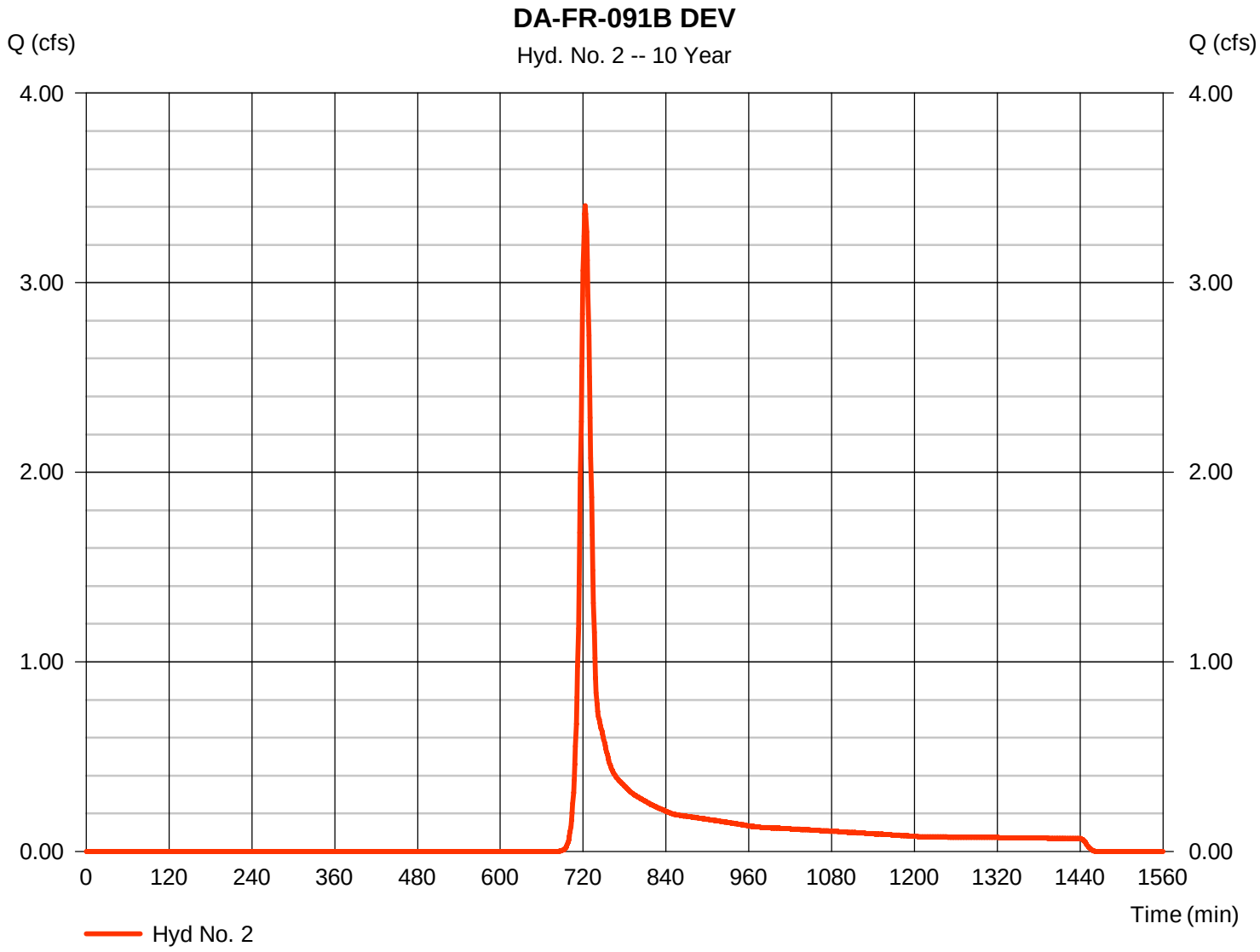
Hydrograph Report

Hyd. No. 2

DA-FR-091B DEV

Hydrograph type	=	SCS Runoff	Peak discharge	=	3.406 cfs
Storm frequency	=	10 yrs	Time to peak	=	723 min
Time interval	=	1 min	Hyd. volume	=	9,889 cuft
Drainage area	=	1.820 ac	Curve number	=	57*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	14.00 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(1.657 x 58) + (0.165 x 48)] / 1.820



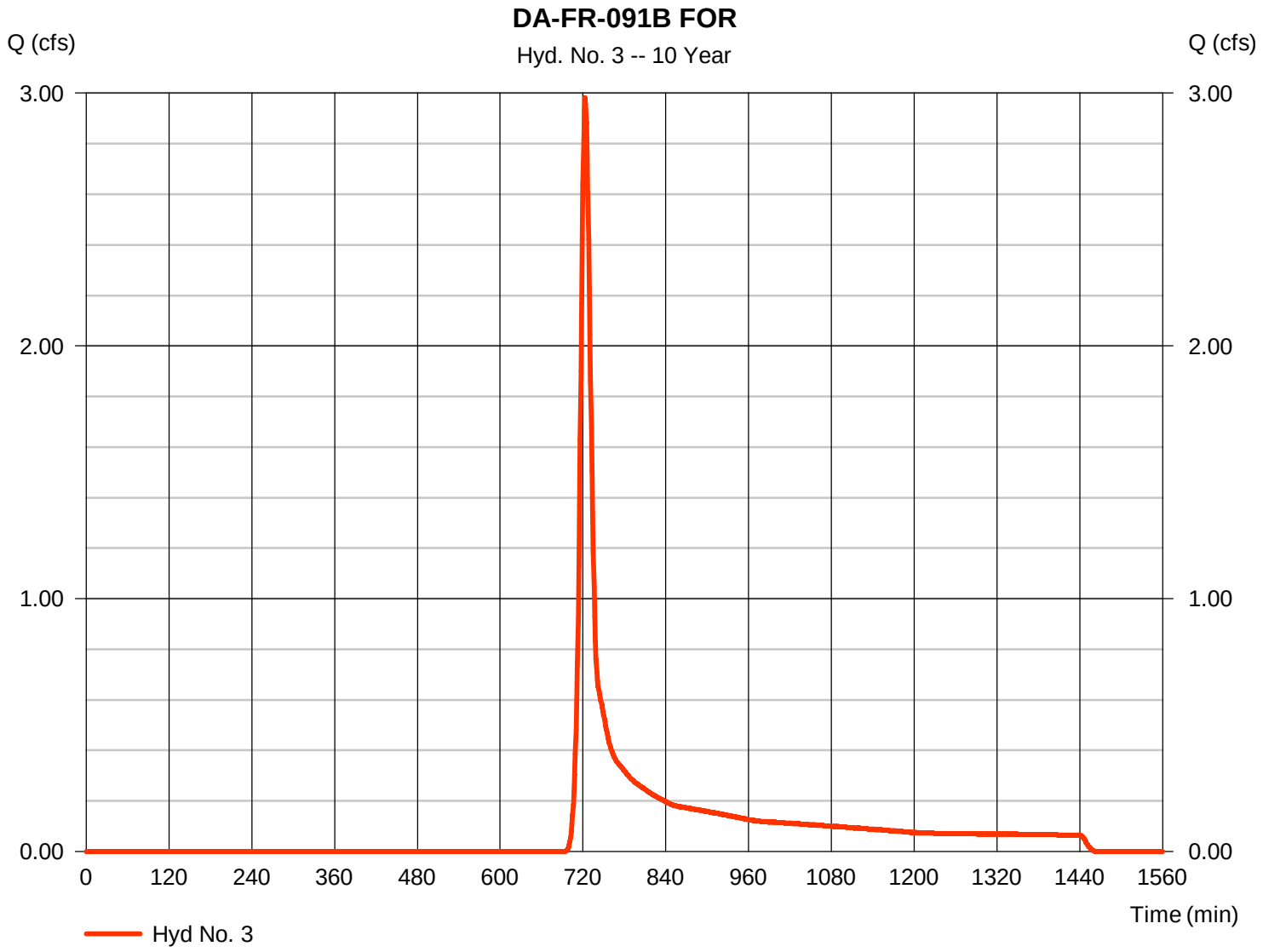
Hydrograph Report

Hyd. No. 3

DA-FR-091B FOR

Hydrograph type	=	SCS Runoff	Peak discharge	=	2.981 cfs
Storm frequency	=	10 yrs	Time to peak	=	723 min
Time interval	=	1 min	Hyd. volume	=	8,909 cuft
Drainage area	=	1.820 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	14.30 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(1.461 x 58) + (0.361 x 55)] / 1.820



Hydraflow Rainfall Report

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

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

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

Tc = time in minutes. Values may exceed 60.

ng\Franklin County\Downloaded Files\Franklin County DA Batch 4 - 046 - 058\Precipitation\Hydraflow\FranklinCo.pc

Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.30	3.70	0.00	0.00	5.70	0.00	0.00	0.00
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

DA-FR-091C

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.592	3034
Developed Condition	0.503	2778
Pre-Developed (Forest) Condition	0.277	2071

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

Improvement Factor, IF = 1

Calculations:

Check #1: $Q_{developed} \leq IF \times [(Q_{pre\text{-}developed} \times RV_{pre\text{-}developed}) / RV_{developed}]$ ----------> 0.503 ≤ 0.647 OK

Check #2: $Q_{developed} \leq Q_{pre\text{-}developed}$ ----------> 0.503 ≤ 0.592 OK

Check #3: $Q_{developed}$ *shall not* be required to be ≤ $(Q_{forest} \times RV_{forest}) / RV_{developed}$ ---> 0.503 *shall not* be required to be ≤ 0.207

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

Note:

Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.

For Paved Road land surface types a Manning's n value 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

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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-FR-091C PRE
2	SCS Runoff	DA-FR-091C DEV
3	SCS Runoff	DA-FR-091C FOR

Hydrograph Return Period Recap

Hyd. No.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)							Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	------	0.592	0.970	-------	-------	3.616	-------	-------	-------	DA-FR-091C PRE
2	SCS Runoff	------	0.503	0.856	-------	-------	3.406	-------	-------	-------	DA-FR-091C DEV
3	SCS Runoff	------	0.277	0.546	-------	-------	2.784	-------	-------	-------	DA-FR-091C FOR

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	0.592	1	728	3,034	------	------	------	DA-FR-091C PRE
2	SCS Runoff	0.503	1	729	2,778	------	------	------	DA-FR-091C DEV
3	SCS Runoff	0.277	1	730	2,071	------	------	------	DA-FR-091C FOR

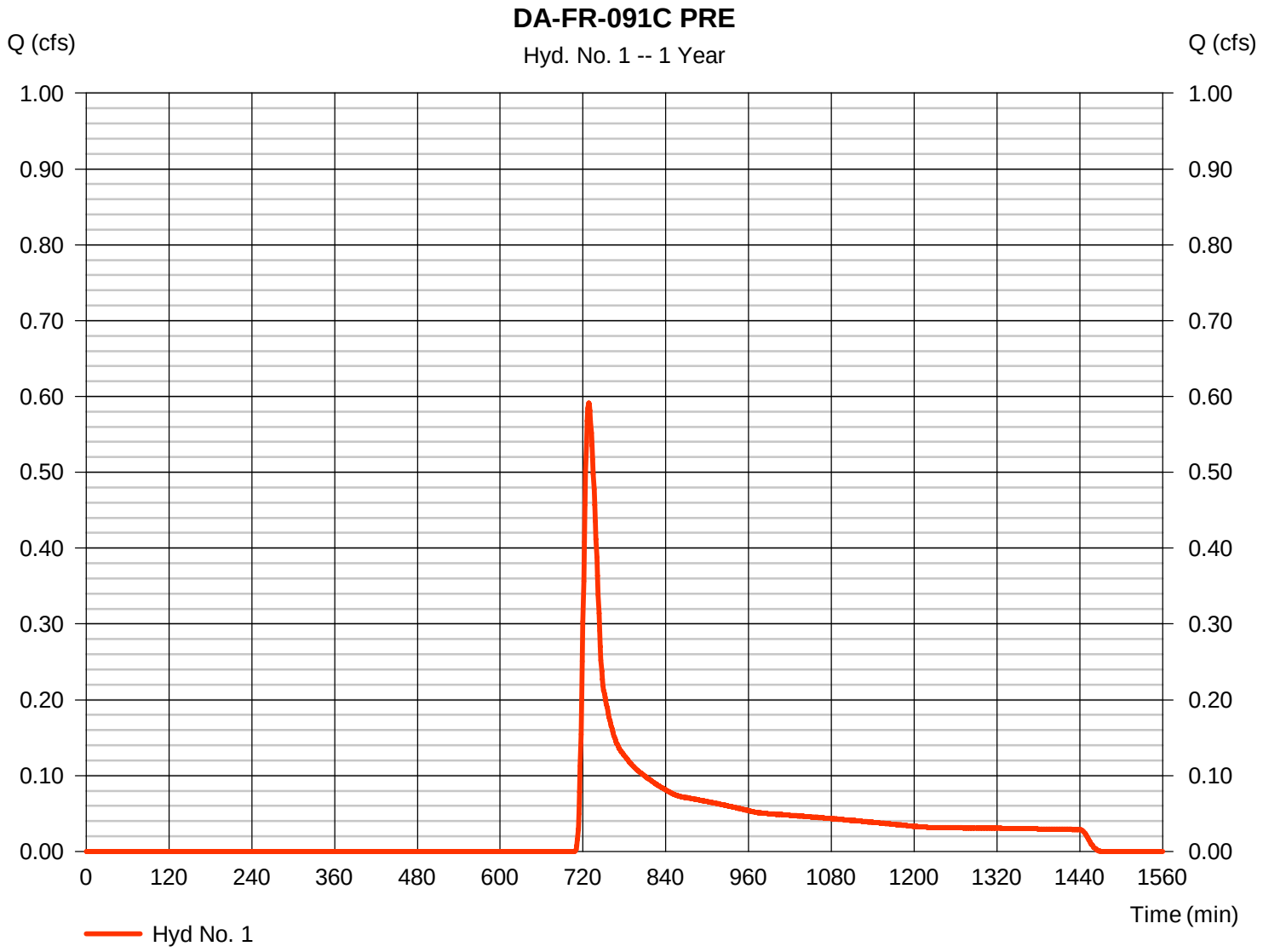
Hydrograph Report

Hyd. No. 1

DA-FR-091C PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.592 cfs
Storm frequency	= 1 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 3,034 cuft
Drainage area	= 2.030 ac	Curve number	= 59*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.90 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.040 x 82) + (0.020 x 85) + (1.880 x 58) + (0.090 x 55)] / 2.030



TR55 Tc Worksheet

Hyd. No. 1

DA-FR-091C PRE

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 2.54		0.00		0.00		
Travel Time (min)	**= 18.15**	**+**	**0.00**	**+**	**0.00**	**=**	**18.15**
Shallow Concentrated Flow							
Flow length (ft)	= 175.99		0.00		0.00		
Watercourse slope (%)	= 6.49		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=4.11		0.00		0.00		
Travel Time (min)	**= 0.71**	**+**	**0.00**	**+**	**0.00**	**=**	**0.71**
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	= 0.015		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 ..... 18.90 min

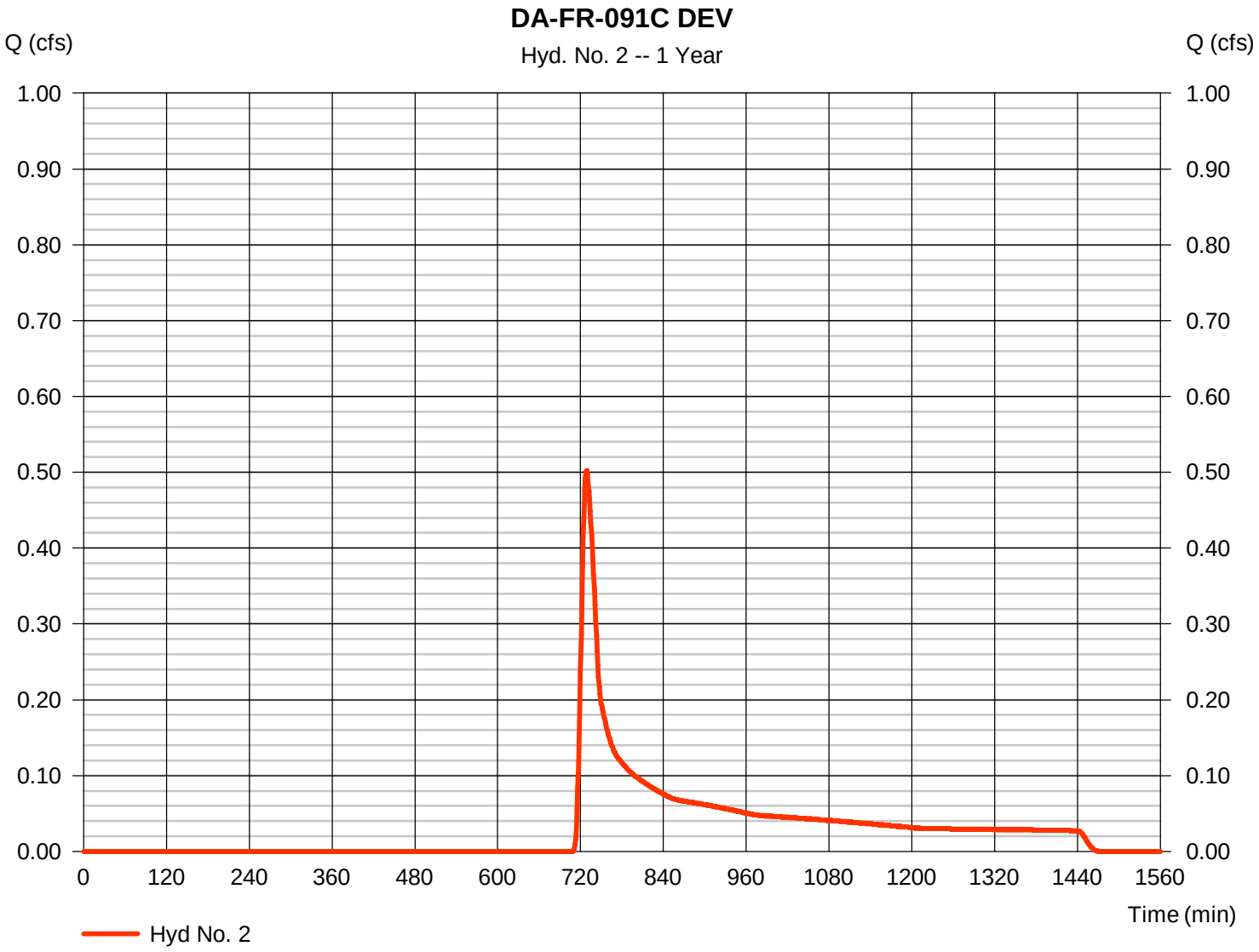
Hydrograph Report

Hyd. No. 2

DA-FR-091C DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.503 cfs
Storm frequency	= 1 yrs	Time to peak	= 729 min
Time interval	= 1 min	Hyd. volume	= 2,778 cuft
Drainage area	= 2.030 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.90 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.040 x 82) + (0.017 x 85) + (0.003 x 98) + (1.881 x 58) + (0.092 x 48)] / 2.030



TR55 Tc Worksheet

Hyd. No. 2

DA-FR-091C DEV

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 2.54		0.00		0.00		
Travel Time (min)	**= 18.15**	**+**	**0.00**	**+**	**0.00**	**=**	**18.15**
Shallow Concentrated Flow							
Flow length (ft)	= 175.99		0.00		0.00		
Watercourse slope (%)	= 6.49		0.00		0.00		
Surface description	= Unpaved		Unpaved		Unpaved		
Average velocity (ft/s)	=4.11		0.00		0.00		
Travel Time (min)	**= 0.71**	**+**	**0.00**	**+**	**0.00**	**=**	**0.71**
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	= 0.015		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 ..... 18.90 min

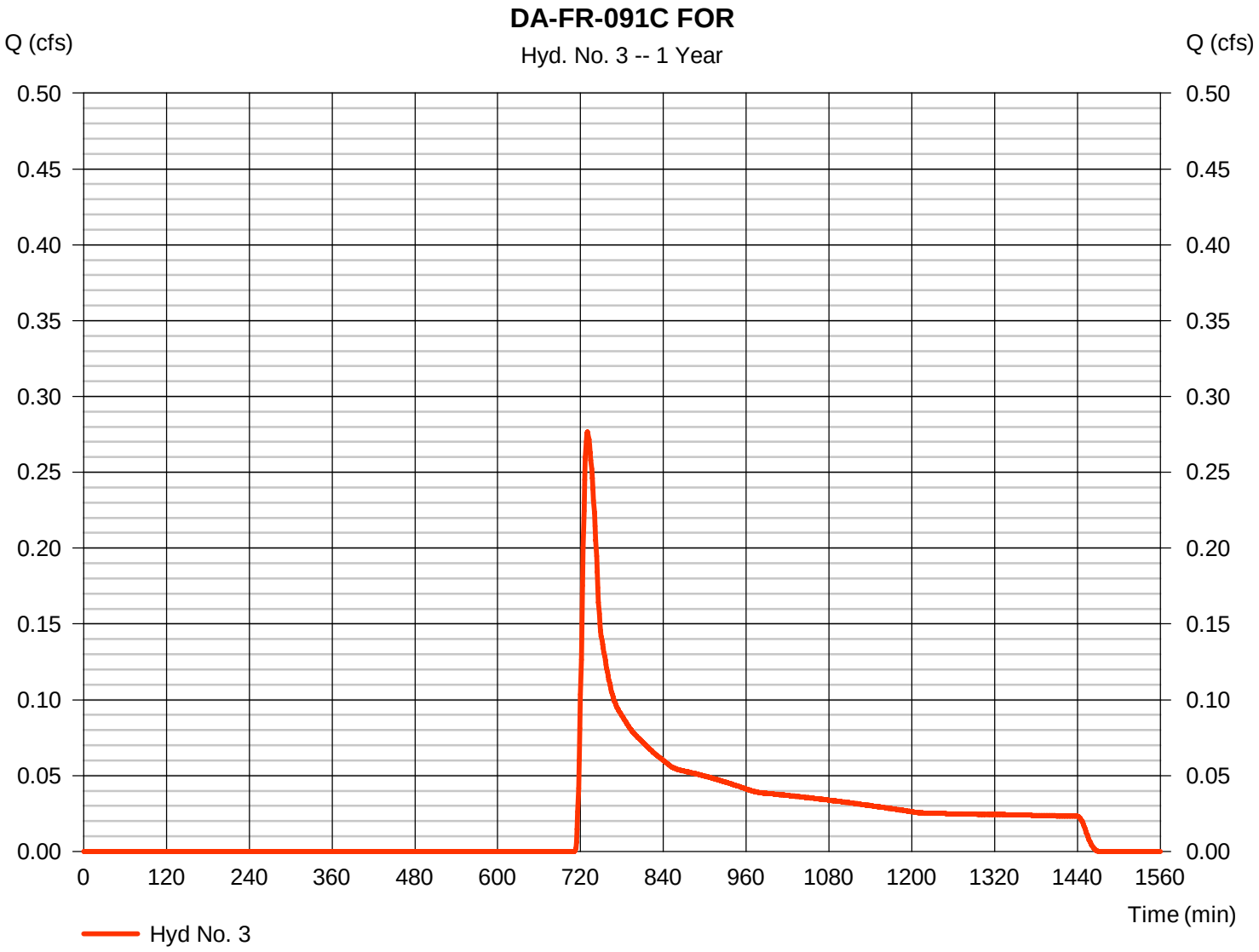
Hydrograph Report

Hyd. No. 3

DA-FR-091C FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.277 cfs
Storm frequency	= 1 yrs	Time to peak	= 730 min
Time interval	= 1 min	Hyd. volume	= 2,071 cuft
Drainage area	= 2.030 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.90 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.040 x 82) + (0.020 x 85) + (1.880 x 58) + (0.090 x 55)] / 2.030



TR55 Tc Worksheet

Hyd. No. 3

DA-FR-091C FOR

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 2.54		0.00		0.00		
Travel Time (min)	**= 18.15**	**+**	**0.00**	**+**	**0.00**	**=**	**18.15**
Shallow Concentrated Flow							
Flow length (ft)	= 175.99		0.00		0.00		
Watercourse slope (%)	= 6.49		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=4.11		0.00		0.00		
Travel Time (min)	**= 0.71**	**+**	**0.00**	**+**	**0.00**	**=**	**0.71**
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	= 0.015		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 ..... 18.90 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	0.970	1	728	4,247	------	------	------	DA-FR-091C PRE
2	SCS Runoff	0.856	1	728	3,935	------	------	------	DA-FR-091C DEV
3	SCS Runoff	0.546	1	729	3,062	------	------	------	DA-FR-091C FOR

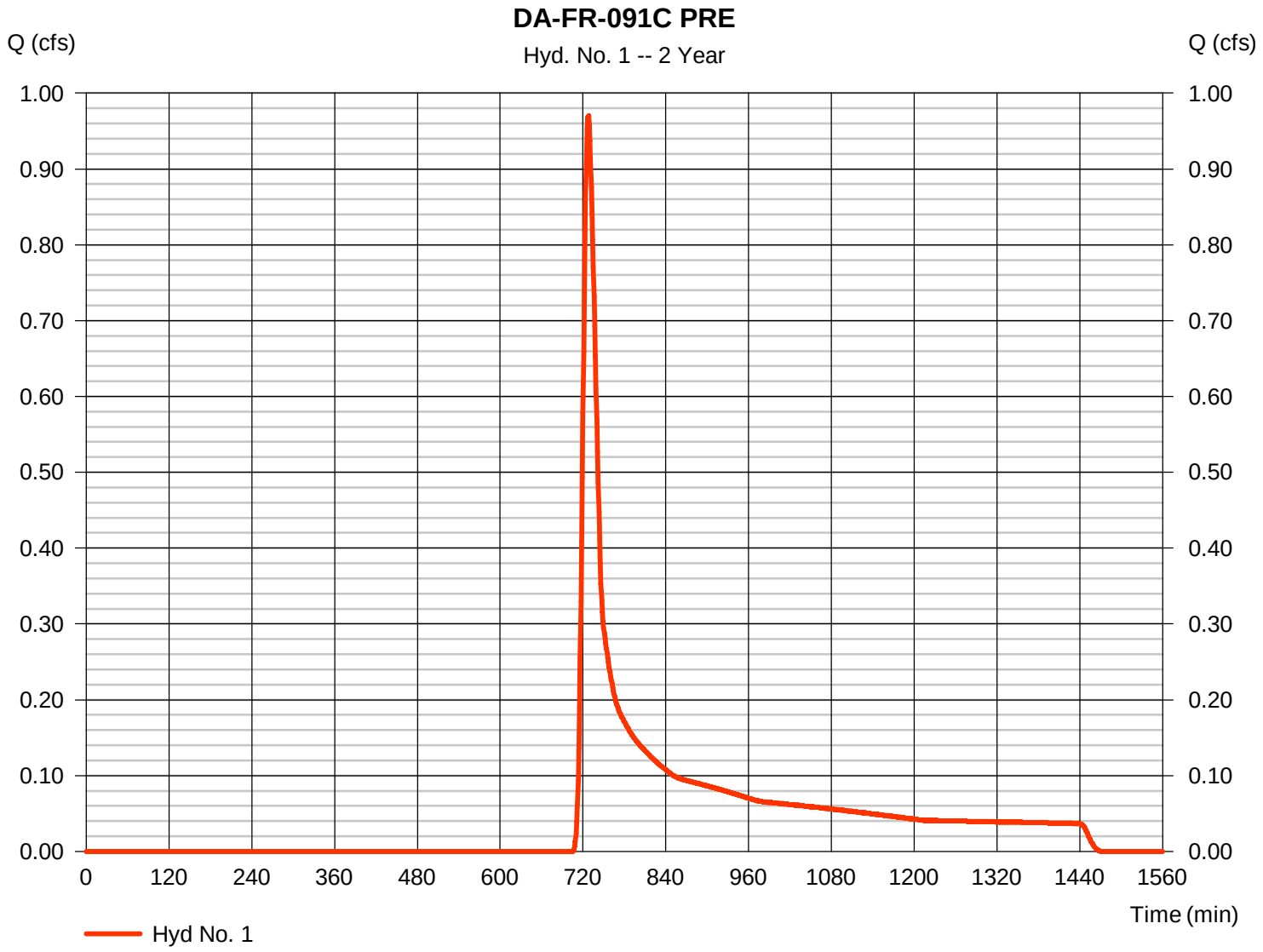
Hydrograph Report

Hyd. No. 1

DA-FR-091C PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.970 cfs
Storm frequency	= 2 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 4,247 cuft
Drainage area	= 2.030 ac	Curve number	= 59*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.90 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.040 x 82) + (0.020 x 85) + (1.880 x 58) + (0.090 x 55)] / 2.030



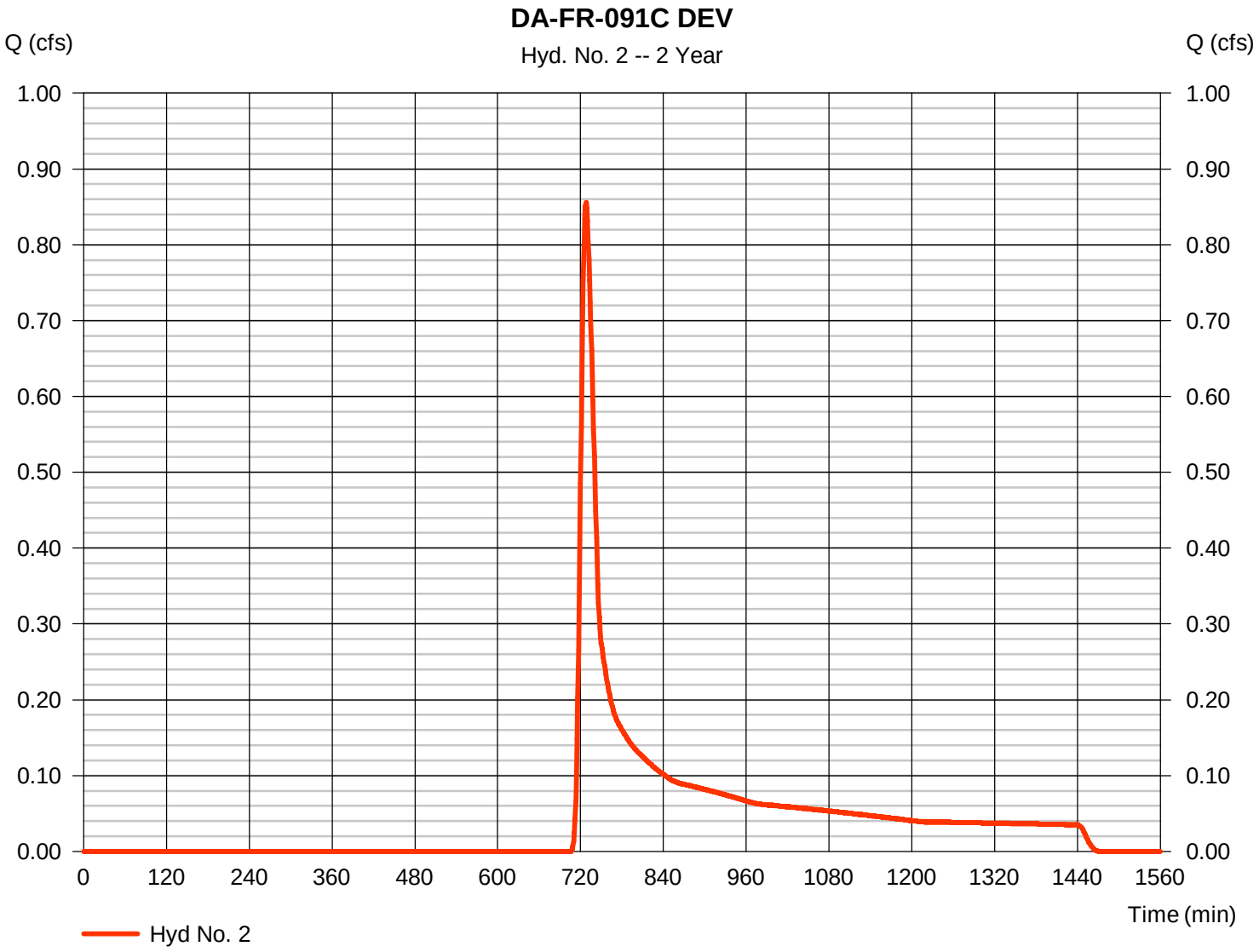
Hydrograph Report

Hyd. No. 2

DA-FR-091C DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.856 cfs
Storm frequency	= 2 yrs	Time to peak	= 728 min
Time interval	= 1 min	Hyd. volume	= 3,935 cuft
Drainage area	= 2.030 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.90 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.040 x 82) + (0.017 x 85) + (0.003 x 98) + (1.881 x 58) + (0.092 x 48)] / 2.030



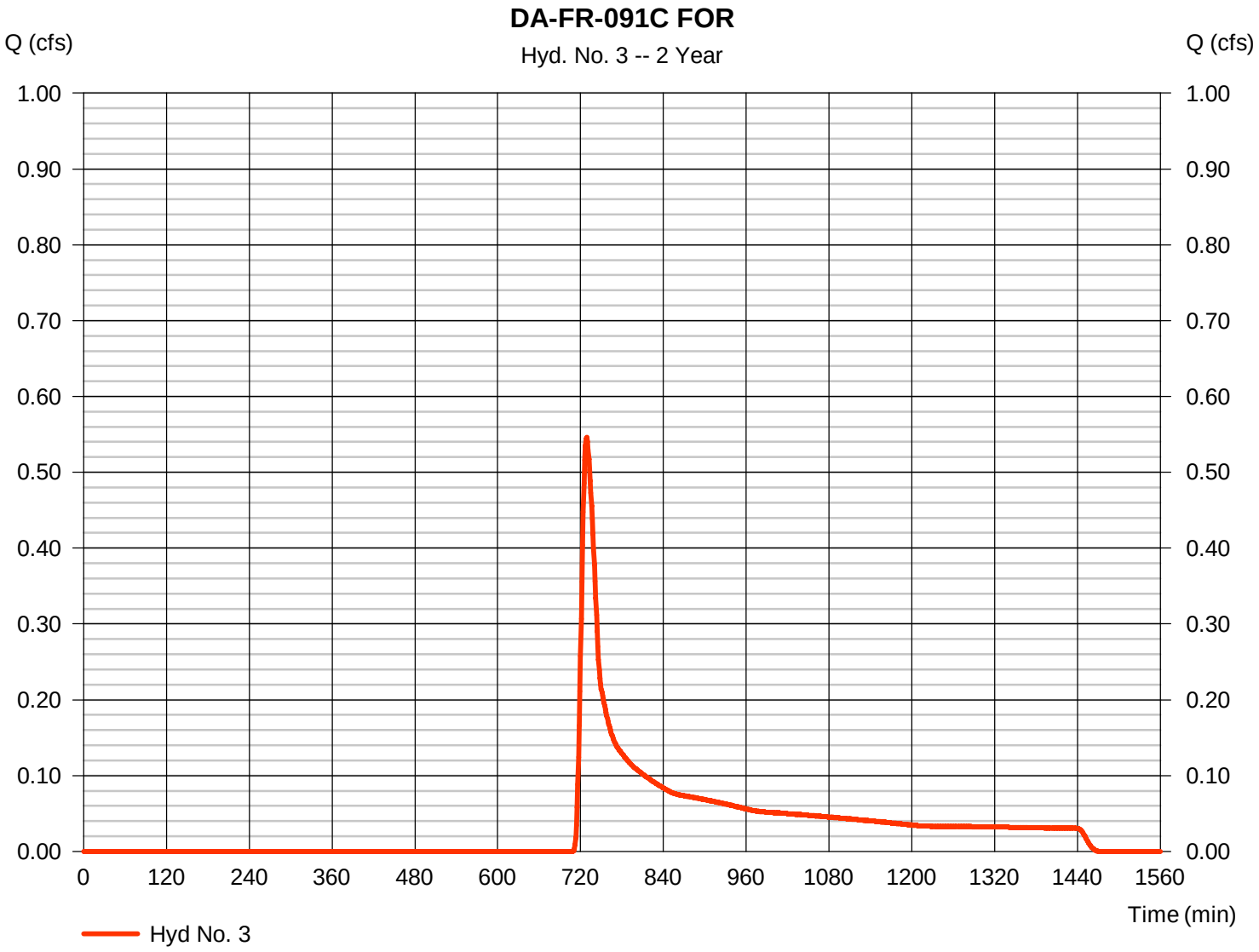
Hydrograph Report

Hyd. No. 3

DA-FR-091C FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.546 cfs
Storm frequency	= 2 yrs	Time to peak	= 729 min
Time interval	= 1 min	Hyd. volume	= 3,062 cuft
Drainage area	= 2.030 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.90 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.040 x 82) + (0.020 x 85) + (1.880 x 58) + (0.090 x 55)] / 2.030



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	3.616	1	726	12,158	------	------	------	DA-FR-091C PRE
2	SCS Runoff	3.406	1	726	11,590	------	------	------	DA-FR-091C DEV
3	SCS Runoff	2.784	1	726	9,937	------	------	------	DA-FR-091C FOR

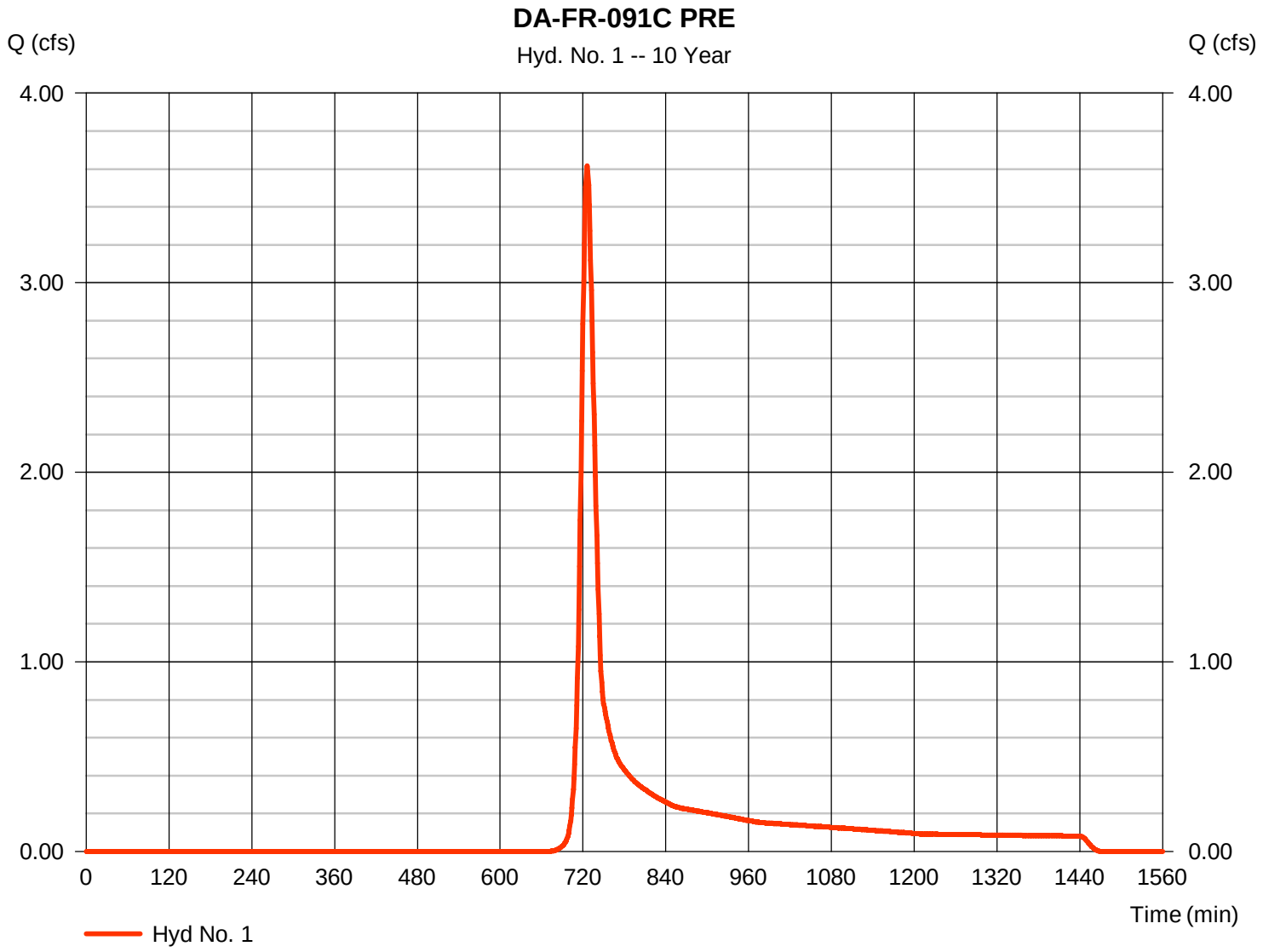
Hydrograph Report

Hyd. No. 1

DA-FR-091C PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	3.616 cfs
Storm frequency	=	10 yrs	Time to peak	=	726 min
Time interval	=	1 min	Hyd. volume	=	12,158 cuft
Drainage area	=	2.030 ac	Curve number	=	59*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	18.90 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.040 x 82) + (0.020 x 85) + (1.880 x 58) + (0.090 x 55)] / 2.030



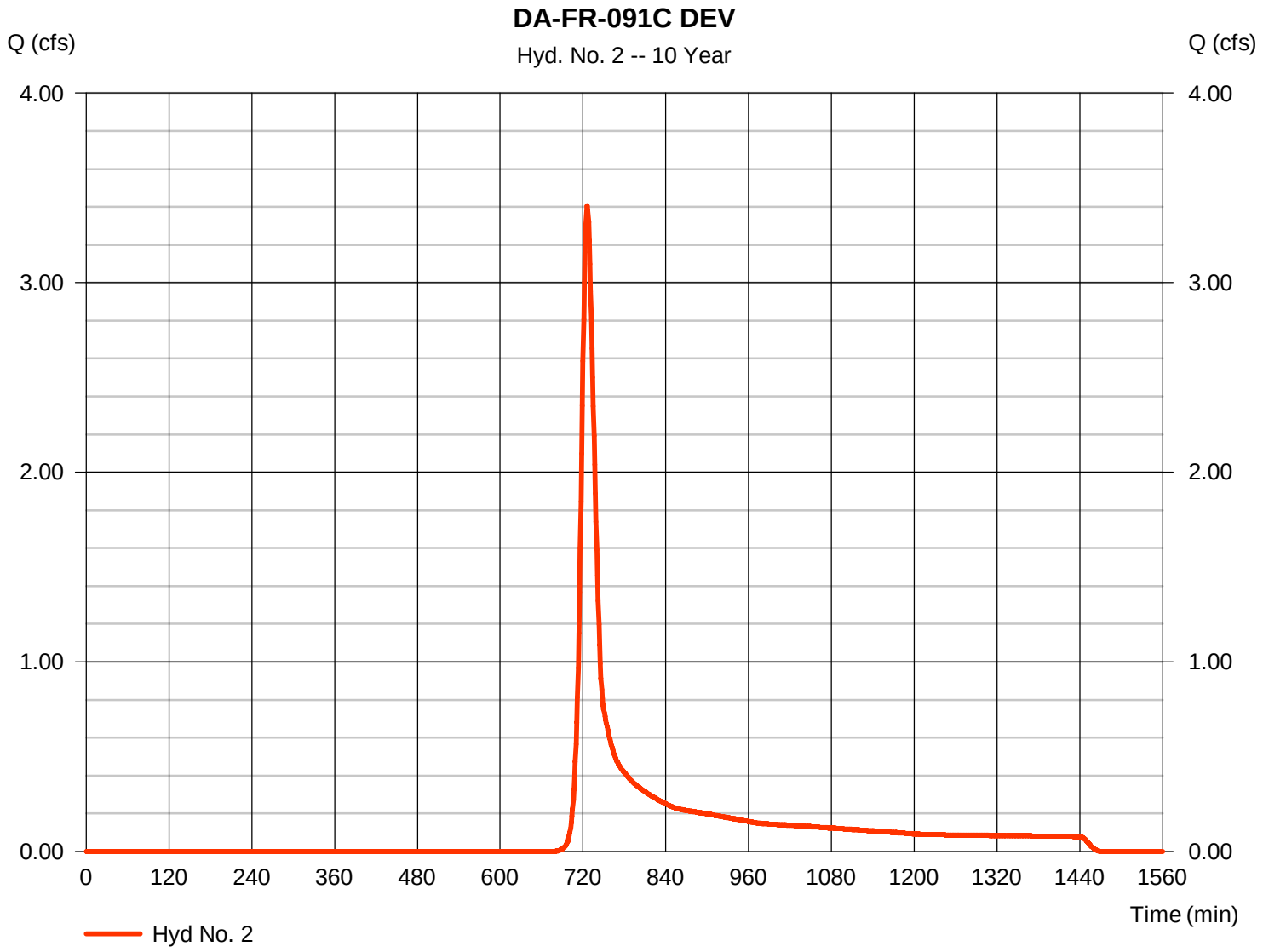
Hydrograph Report

Hyd. No. 2

DA-FR-091C DEV

Hydrograph type	=	SCS Runoff	Peak discharge	=	3.406 cfs
Storm frequency	=	10 yrs	Time to peak	=	726 min
Time interval	=	1 min	Hyd. volume	=	11,590 cuft
Drainage area	=	2.030 ac	Curve number	=	58*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	18.90 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.040 x 82) + (0.017 x 85) + (0.003 x 98) + (1.881 x 58) + (0.092 x 48)] / 2.030



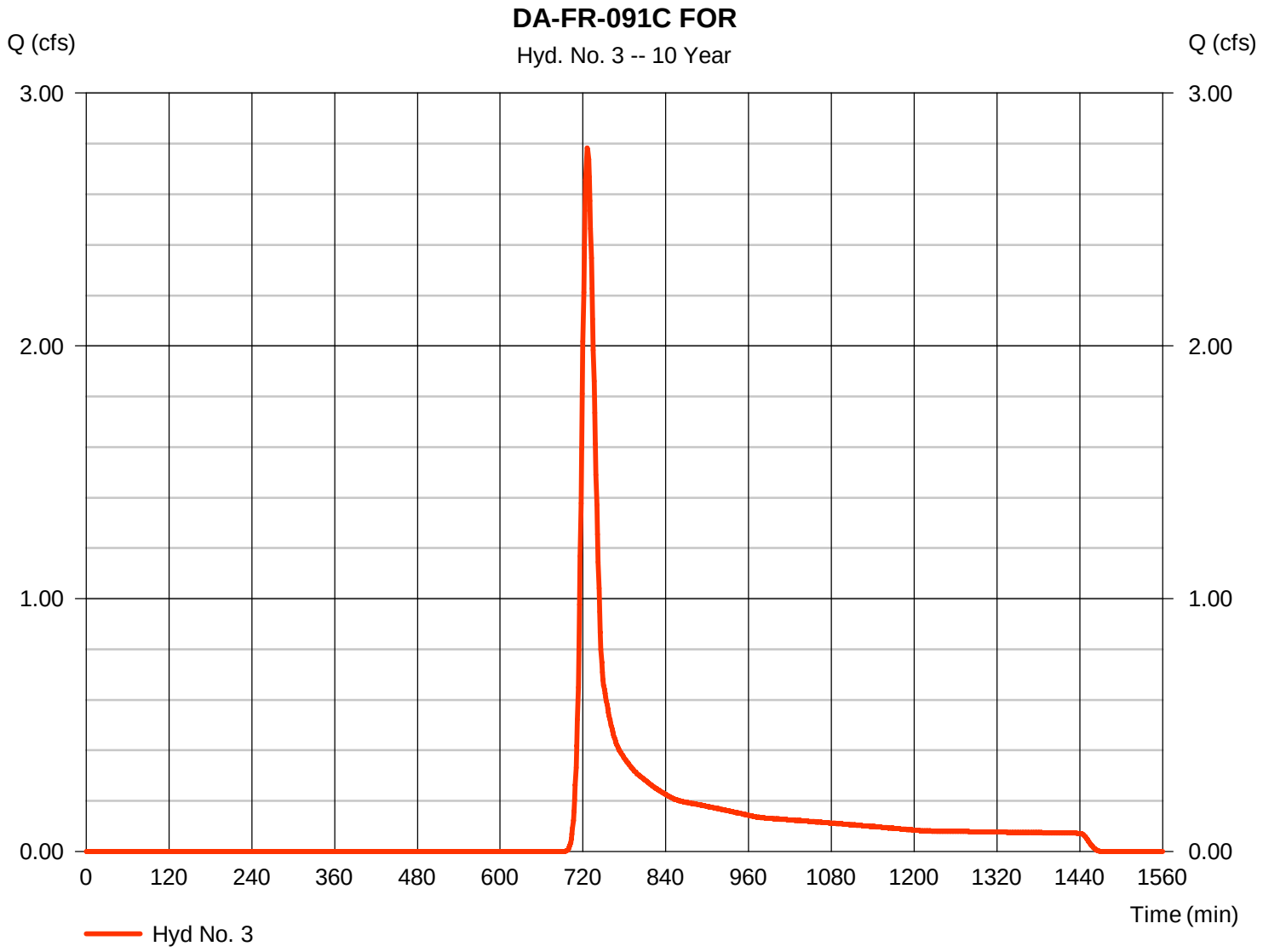
Hydrograph Report

Hyd. No. 3

DA-FR-091C FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 2.784 cfs
Storm frequency	= 10 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 9,937 cuft
Drainage area	= 2.030 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.90 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.040 x 82) + (0.020 x 85) + (1.880 x 58) + (0.090 x 55)] / 2.030



Hydraflow Rainfall Report

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

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

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

Tc = time in minutes. Values may exceed 60.

ng\Franklin County\Downloaded Files\Franklin County DA Batch 4 - 046 - 058\Precipitation\Hydraflow\FranklinCo.pc

Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.30	3.70	0.00	0.00	5.70	0.00	0.00	0.00
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

DA-FR-092

DA-FR-092 is located primarily within agricultural use land with a very small portion of forest land and has undulating slopes. An existing dirt road and a small graveled area are located within the drainage area, but no new impervious area is proposed within DA-FR-092. The total phosphorus load reduction required for DA-FR-092 is -0.18 lb/yr.

DA-FR-092 is an agricultural area/field that will be returned to crop production, in identical condition following pipeline construction, and is 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, the provisions of water quality design criteria requirements and permanent stormwater management controls for DA-FR-092 are exempt and no stormwater BMPs are required.

Figures for DA-FR-092 are presented in following pages. See Appendix D of the Annual Standards and Specifications for further detail on stormwater methodology.

DA-FR-092
1.58 acres
Weighted CN = 59

1050

1100

2719

272.0

272.1

B

LAND USE	HSG	CN	AREA (AC)
Dirt Road	B	82	0.06
Gravel	B	85	0.005
Impervious	B	98	0.000007
Meadow	B	58	1.46
Woods - Good	B	55	0.05

Legend

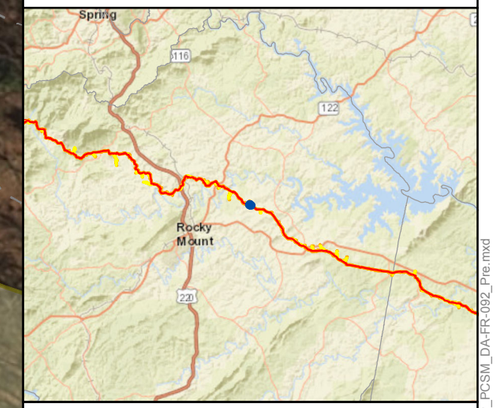
- Milepost
- Existing 50' Contour
- Existing 10' Contour
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Dirt Road
- Gravel
- Impervious
- Meadow
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

1:1,200

N
W E
S

100 50 0 100 Feet



Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Pre-Construction Drainage Area Map
DA-FR-092
Spread 11

Figure 1
Franklin County, Virginia

August, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Agricultural Area from National Land Cover Database (NLCD) 2011, 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.

Document Path: P:\GIS\EQT_MVP\MapdocsDrainage\MXD\Franklin\MVP_PCSM_DA-FR-092_Pre.mxd

DA-FR-092
1.58 acres
Weighted CN = 59

DA-FR-092 Permanent ROW
0.64 acres

1050

1100

271.9

272.0

272.1

B

LAND USE	HSG	CN	AREA (AC)
Dirt Road	B	82	0.06
Gravel	B	85	0.005
Impervious	B	98	0.000007
Meadow	B	58	1.50
Brush - Good	B	48	0.01

Legend

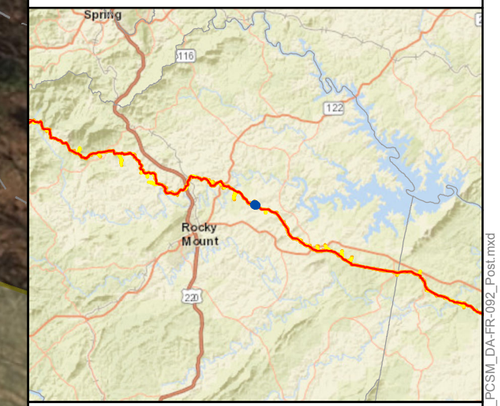
- Milepost
- Existing 50' Contour
- Existing 10' Contour
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Brush
- Dirt Road
- Gravel
- Impervious
- Meadow
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

N
W E
S

1:1,200

100 50 0 100 Feet



Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Post-Construction Drainage Area Map
DA-FR-092
Spread 11

Figure 2
Franklin County, Virginia

August, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Agricultural Area from National Land Cover Database (NLCD) 2011, 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.

Document Path: PGH P:\GIS\EQT_MVP\Mapdocs\DrainageMXD\Franklin\MVP_PCSM_DA-FR-092_Post.mxd

DA-FR-092
1.58 acres
Weighted CN = 59

271.9
272.0
272.1
1050
1100

PRE-CONSTRUCTION TIME OF CONCENTRATION TO POI

	SHEET	SHALLOW	Calculated Time of Concentration (min)
DA-FR-092	100.00 FT @ 3.64%	123.57 FT @ 7.12%	16.2

Legend

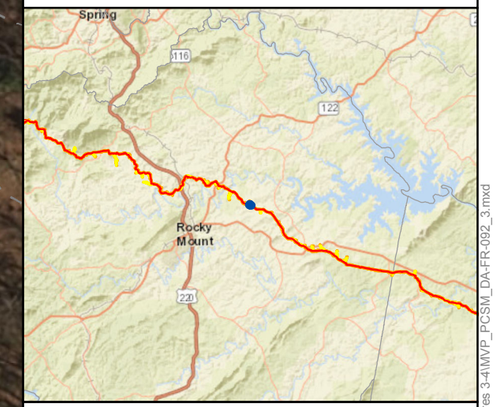
- Milepost
- Existing 50' Contour
- Existing 10' Contour
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:1,200

N
W E
S

100 50 0 100 Feet



Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Pre-Construction Drainage Area and Time of Concentration
DA-FR-092
Spread 11

Figure 3
Franklin County, Virginia
August, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Elevation data derived from LiDAR provided by EQT 2016.

Document Path: P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Franklin\Figures 3-4\MVP_PCSM_DA-FR-092_3.mxd

DA-FR-092
1.58 acres
Weighted CN = 59

1050
1100
271.9
272.0
272.1

POST-CONSTRUCTION TIME OF CONCENTRATION TO POI

	SHEET	SHALLOW1	SHALLOW2	CHANNEL	Calculated Time of Concentration (min)
DA-FR-092	100.00 FT @ 3.64%	33.67 FT @ 4.95%	53.70 FT @ 8.2%	42.39 FT @ 1.94%	16.3

Legend

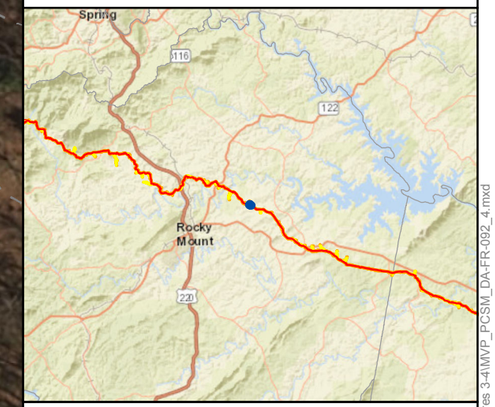
- Milepost
- Existing 50' Contour
- Existing 10' Contour
- Alignment Centerline
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

N
W E
S

1:1,200

100 50 0 100 Feet



Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Post-Construction Drainage Area and Time of Concentration
DA-FR-092
Spread 11

Figure 4
Franklin County, Virginia
September, 2017

Data Sources: Imagery from ESRI Streaming Data 2014, Elevation data derived from LiDAR provided by EQT 2016.

Document Path: PGH P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Franklin\Figures 3-4\MVP_PCSM_DA-FR-092_4.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:	**0.65**

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	0.63	0.00	0.00	0.63	97
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	3
					0.65	100

Post-ReDevelopment Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	% of Total	
Forest/Open (acres)	0.00	0.63	0.00	0.00	0.63	97	*
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	3	
					0.65	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	0.06	0.06	--	0.06
Treatment Volume (ft^3)	138	138	--	138
TP Load (lb/yr)	0.09	0.09	--	0.09

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)
0.13	**0.13**	**0.13**

Baseline TP Load (lb/yr): 0.2665* **Reduction below new development load limitation not required*

Total TP Load Reduction Required (lb/yr)	**-0.18**	N/A***	N/A***

******This is a linear development project***

	Final Post-Development Load (Post-ReDevelopment & New Impervious)	Pre-ReDevelopment
TN Load (lb/yr)	0.62	0.62

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 0.27 lb/yr (0.41 lb/ac/yr)*
[Post-Dev Reduction Requirement = Post-Dev TP load - baseline load of 0.27 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)	0.09
Remaining TP Load Reduction (lb/yr) Required	**0.00**

**** TARGET TP REDUCTION EXCEEDED BY 0.18 LB/YEAR ****

**Reduction below new development load limitation not required*

DA-FR-093

DA-FR-093 is located primarily within meadow land use with portions of forest land and has rolling slopes. An existing dirt road and unnamed tributary are located within the drainage area; no new impervious area is proposed within DA-FR-093. The total phosphorus load reduction required for DA-FR-093 is -1.62 lb/yr. Multiple points of analysis were evaluated within DA-FR-093 to evaluate the effects on each receiving stream/channel following construction. Specifically, DA-FR-093 was sub-divided into three sub-drainage areas (sub areas A through C).

Sub-areas 093A, 093B and 093C contain both agricultural and non-agricultural areas 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. 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 Right of Way (ROW) is analyzed via VRRM; in these calculations agricultural areas are considered “Forest/Open Space”.

Stormwater quantity is met via the energy balance method for each of the three sub-areas DA-FR-093A, DA-FR-093B and DA-FR-093C. Agricultural areas within the study area are included in the SWM analysis, but an Improvement Factor (IF) of 1.0 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 Hydrograph’s 10-year 24-hour peak discharge results indicate a reduction in flows ranging from 0.00 to 1.03 cfs for all drainage areas (as seen in table below).

Sub Area	Pre Peak Flow, 10-yr Q (cfs)	Post Peak Flow, Q 10-yr (cfs)	Flow differential
DA-FR-093A	15.34	15.34	0.00
DA-FR-093B	5.52	5.52	0.00
DA-FR-093C	16.76	15.73	-1.03

Figures and calculations for each of the sub-areas for DA-FR-093 follow. See Appendix D of the Annual Standards and Specifications for further detail on stormwater methodology.

Note that the sub-areas 093A and 093B had time of concentration flow paths for the Post-Construction condition that accounted for a permanent water bar that is not cited within the drainage area. This permanent water bar was removed because it was cited 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-FR-093A or 093B, so the resulting changes were not made to the stormwater calculations prior to submittal.

DA-FR-093A
8.67 acres
Weighted CN = 57

DA-FR-093B
2.93 acres
Weighted CN = 58

DA-FR-093C
8.46 acres
Weighted CN = 57

LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Meadow	B	58	6.86	DA-FR-093A
Woods - Good	B	55	1.80	
Brush - Good	B	48	0.06	DA-FR-093B
Meadow	B	58	2.85	
Waterbody	B	100	0.02	
Brush - Good	B	48	0.10	DA-FR-093C
Dirt Road	B	82	0.06	
Meadow	B	58	3.89	
Waterbody	B	100	0.01	
Woods - Good	B	55	4.41	

Legend

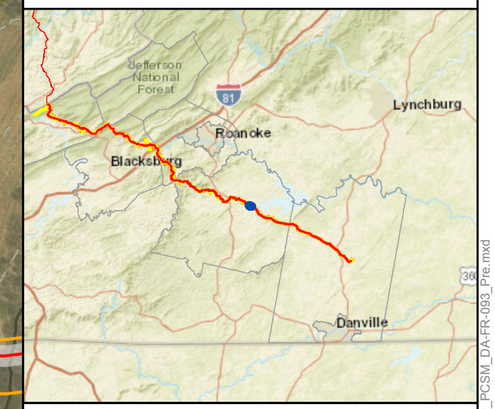
- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Brush
- Dirt Road
- Meadow
- Waterbody
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

1:4,200

350 175 0 350 Feet

N W E S



Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Pre-Construction Drainage Area Map
DA-FR-093
Spread 11

Figure 1
Franklin County, Virginia

August, 2017

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

Document Path: PGH P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Franklin\MVP_PCSM_DA-FR-093_Pre.mxd

DA-FR-093A
8.67 acres
Weighted CN = 57

DA-FR-093B
2.93 acres
Weighted CN = 58

DA-FR-093 Permanent ROW
4.81 acres

DA-FR-093C
8.46 acres
Weighted CN = 56

LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Brush - Good	B	48	0.01	DA-FR-093A
Meadow	B	58	6.86	
Woods - Good	B	55	1.79	
Brush - Good	B	48	0.06	DA-FR-093B
Meadow	B	58	2.85	
Waterbody	B	100	0.02	
Brush - Good	B	48	1.46	DA-FR-093C
Dirt Road	B	82	0.06	
Meadow	B	58	4.64	
Waterbody	B	100	0.01	
Woods - Good	B	55	2.30	

Legend

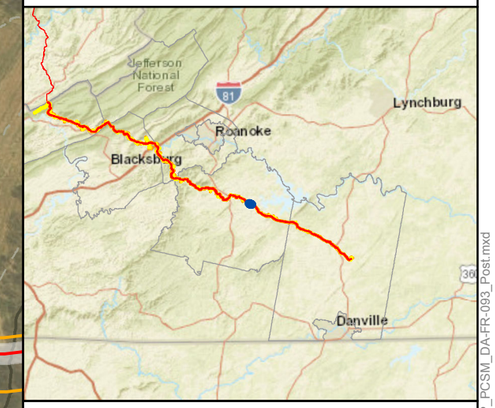
- Milepost
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Brush
- Dirt Road
- Meadow
- Waterbody
- Woods
- Agricultural Area
- Drainage Area
- Hydrologic Soil Groups

NAD 1983 UTM 17N (feet)

1:4,200

N W E S

350 175 0 350 Feet



Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Post-Construction Drainage Area Map
DA-FR-093
Spread 11

Figure 2
Franklin County, Virginia

August, 2017

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

Document Path: P:\GIS\EQT_MVP\MapdocsDrainage\MXD\Franklin\MVP_PCSM_DA-FR-093_Post.mxd

DA-FR-093A
8.67 acres
Weighted CN = 57

DA-FR-093B
2.93 acres
Weighted CN = 58

DA-FR-093C
8.46 acres
Weighted CN = 57

272.0
272.1
272.2
272.3
272.4
272.5
272.6
272.7
272.8

1100
1050
1000
950

S-M1
S-M2

Poplar Court Ln
Holland Farm Ln

PRE-CONSTRUCTION TIME OF CONCENTRATION TO POI

	SHEET 1	SHEET 2	SHALLOW	Calculated Time of Concentration (min)
DA-FR-093A	82.64 FT @ 5.87%	17.36 FT @ 8.08%	463.80 FT @ 7.94%	15.7
DA-FR-093B	100.00 FT @ 4.27%	-	573.19 FT @ 9.67%	16.6
DA-FR-093C	100.00 FT @ 9.64%	-	400.99 FT @ 11.78%	11.9

Legend

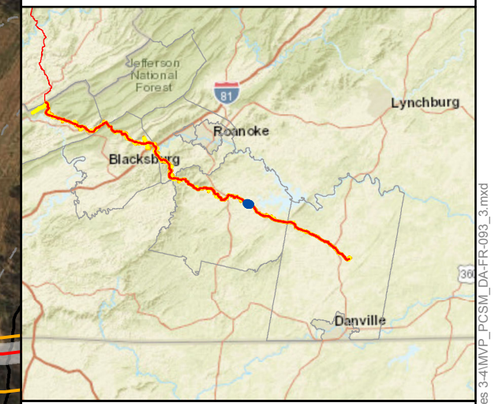
- Milepost
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:4,200

N
W E
S

350 175 0 350
Feet



Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Pre-Construction Drainage Area and Time of Concentration
DA-FR-093
Spread 11

Figure 3
Franklin 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.

Document Path: P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\FranklinIN\Figures 3-4\MVP_PCSM_DA-FR-093_3.mxd

DA-FR-093A
8.67 acres
Weighted CN = 57

DA-FR-093B
2.93 acres
Weighted CN = 58

DA-FR-093C
8.46 acres
Weighted CN = 56

S-M2

S-M1

Poplar Court Ln

Holland Farm Ln

POST-CONSTRUCTION TIME OF CONCENTRATION TO POI

	SHEET 1	SHEET 2	SHALLOW1	SHALLOW2	CHANNEL	Calculated Time of Concentration (min)
DA-FR-093A	82.64 FT @ 5.87%	17.36 FT @ 8.08%	66.31 FT @ 8.42%	367.31 FT @ 7.91%	46.41 FT @ 4.76%	15.7
DA-FR-093B	100.00 FT @ 4.27%	-	333.84 FT @ 6.55%	333.68 FT @ 9.73%	24.01 FT @ 4.64%	16.2
DA-FR-093C	100.00 FT @ 9.64%	-	400.99 FT @ 11.78%	-	-	11.9

Legend

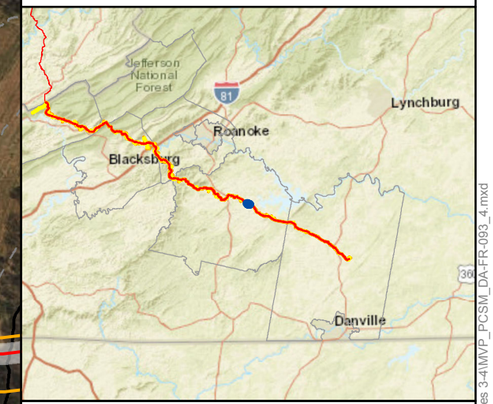
- Milepost
- Permanent Waterbars
- Delineated Stream
- Existing 50' Contour
- Existing 10' Contour
- Road Centerline
- Alignment Centerline
- Permanent Access Road
- Limit of Disturbance
- Permanent Right-of-Way
- Time of Concentration
- Drainage Area

NAD 1983 UTM 17N (feet)

1:4,200

350 175 0 350 Feet

N W E S



Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Post-Construction Drainage Area and Time of Concentration
DA-FR-093
Spread 11

Figure 4
Franklin 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\Franklin\Figures 3-4\MVP_PCSM_DA-FR-093_4.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:	**4.81**

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	4.80	0.00	0.00	4.80	100
Managed Turf (acres)	0.00	0.00	0.00	0.00	0.00	0
Impervious Cover (acres)	0.00	0.01	0.00	0.00	0.01	0
					4.81	100

Post-ReDevelopment Land Cover (acres)

	A soils	B Soils	C Soils	D Soils	Totals	% of Total	
Forest/Open (acres)	0.00	4.80	0.00	0.00	4.80	100	*
Managed Turf (acres)	0.00	0.00	0.00	0.00	0.00	0	
Impervious Cover (acres)	0.00	0.01	0.00	0.00	0.01	0	
					4.81	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	0.03	0.03	--	0.03
Treatment Volume (ft^3)	557	557	--	557
TP Load (lb/yr)	0.35	0.35	--	0.35

Baseline TP Load (lb/yr): 1.9721* **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)
0.07	**0.07**	**0.07**

Total TP Load Reduction Required (lb/yr)	**-1.62**	N/A***	N/A***

******This is a linear development project***

	Final Post-Development Load (Post-ReDevelopment & New Impervious)	Pre-ReDevelopment
TN Load (lb/yr)	2.50	2.50

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 1.97 lb/yr (0.41 lb/ac/yr)*
[Post-Dev Reduction Requirement = Post-Dev TP load - baseline load of 1.97 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)	0.35
Remaining TP Load Reduction (lb/yr) Required	**0.00**

**** TARGET TP REDUCTION EXCEEDED BY 1.62 LB/YEAR ****

**Reduction below new development load limitation not required*

DA-FR-093A

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	2.039	10949
Developed Condition	2.039	10949
Pre-Developed (Forest) Condition	1.335	8957

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

Improvement Factor, IF = 1

Calculations:

Check #1: $Q_{developed} \leq IF \times [(Q_{pre\text{-}developed} \times RV_{pre\text{-}developed}) / RV_{developed}]$ ----------> 2.039 ≤ 2.039 OK

Check #2: $Q_{developed} \leq Q_{pre\text{-}developed}$ ----------> 2.039 ≤ 2.039 OK

Check #3: $Q_{developed}$ *shall not* be required to be ≤ $(Q_{forest} \times RV_{forest}) / RV_{developed}$ ---> 2.039 *shall not* be required to be ≤ 1.092

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

Note:

Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.

For Paved Road land surface types a Manning's n value 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 Channels[1]			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels[2]			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150

Notes:

[1]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 or grass channel.

[2]For the pre-developed condition (if applicable), 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

Hydraflow Table of Contents

DA-FR-093A_Hydraflow.gpw

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5 Wednesday, 08 / 30 / 2017

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Hydrograph No. 2, SCS Runoff, DA-FR-093A DEV 6

TR-55 Tc Worksheet 7

Hydrograph No. 3, SCS Runoff, DA-FR-093A FOR 8

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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-FR-093A PRE
2	SCS Runoff	DA-FR-093A DEV
3	SCS Runoff	DA-FR-093A FOR

Hydrograph Return Period Recap

Hyd. No.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)							Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	------	2.039	3.626	-------	-------	15.34	-------	-------	-------	DA-FR-093A PRE
2	SCS Runoff	------	2.039	3.626	-------	-------	15.34	-------	-------	-------	DA-FR-093A DEV
3	SCS Runoff	------	1.335	2.649	-------	-------	13.40	-------	-------	-------	DA-FR-093A FOR

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	2.039	1	727	10,949	------	------	------	DA-FR-093A PRE
2	SCS Runoff	2.039	1	727	10,949	------	------	------	DA-FR-093A DEV
3	SCS Runoff	1.335	1	727	8,957	------	------	------	DA-FR-093A FOR

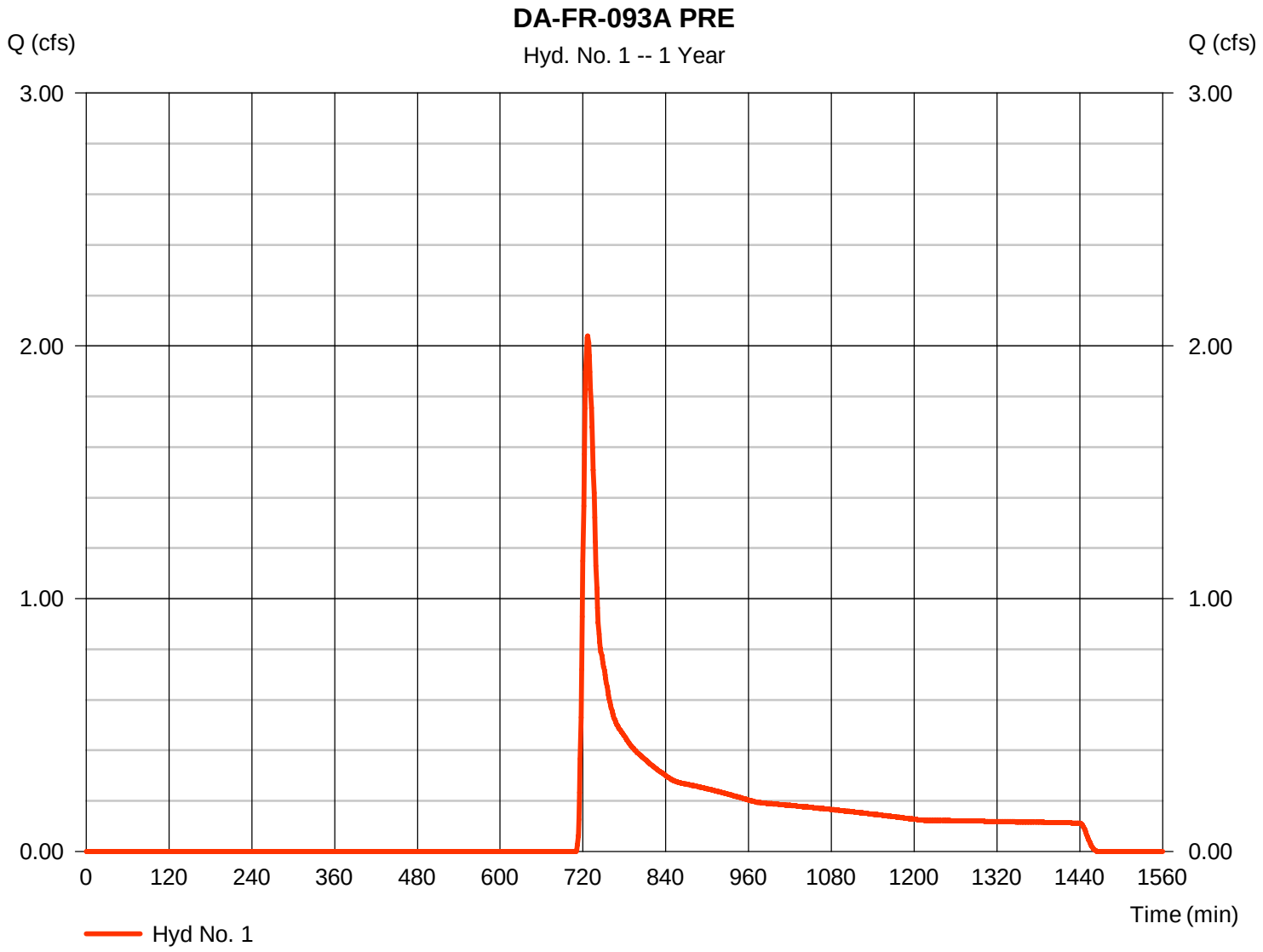
Hydrograph Report

Hyd. No. 1

DA-FR-093A PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 2.039 cfs
Storm frequency	= 1 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 10,949 cuft
Drainage area	= 8.670 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.70 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(6.865 x 58) + (1.801 x 55)] / 8.670



TR55 Tc Worksheet

Hyd. No. 1

DA-FR-093A PRE

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.400		0.400		0.011		
Flow length (ft)	= 82.6		17.4		0.0		
Two-year 24-hr precip. (in)	= 3.70		3.70		0.00		
Land slope (%)	= 5.87		8.08		0.00		
Travel Time (min)	**= 11.15**	**+**	**2.81**	**+**	**0.00**	**=**	**13.96**
Shallow Concentrated Flow							
Flow length (ft)	= 463.80		0.00		0.00		
Watercourse slope (%)	= 7.94		0.00		0.00		
Surface description	= Unpaved		Unpaved		Paved		
Average velocity (ft/s)	=4.55		0.00		0.00		
Travel Time (min)	**= 1.70**	**+**	**0.00**	**+**	**0.00**	**=**	**1.70**
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	= 0.015		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 ..... 15.70 min

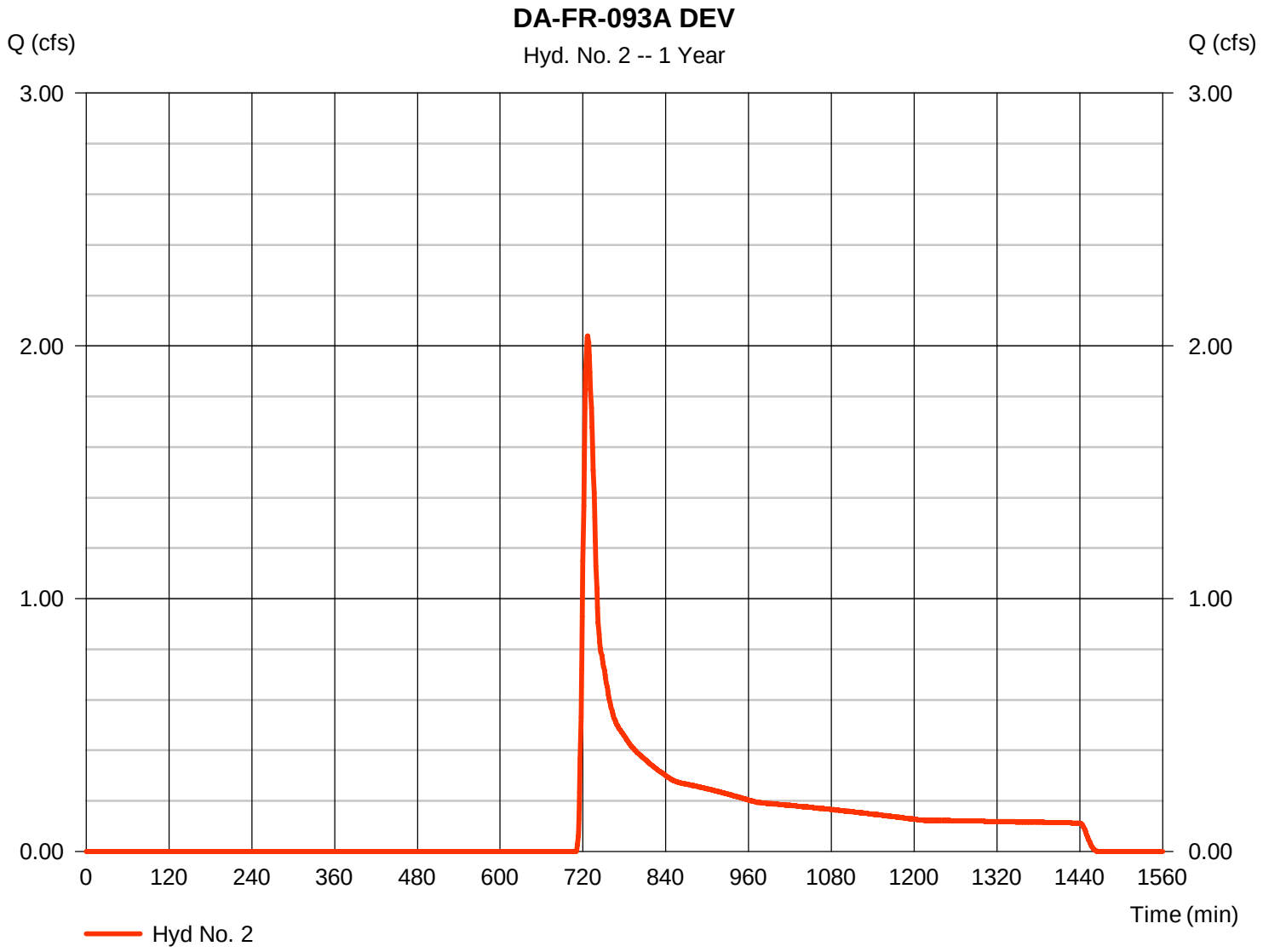
Hydrograph Report

Hyd. No. 2

DA-FR-093A DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 2.039 cfs
Storm frequency	= 1 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 10,949 cuft
Drainage area	= 8.670 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.70 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.007 x 48) + (6.865 x 58) + (1.794 x 55)] / 8.670



TR55 Tc Worksheet

Hyd. No. 2

DA-FR-093A DEV

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.400		0.400		0.011		
Flow length (ft)	= 82.6		17.4		0.0		
Two-year 24-hr precip. (in)	= 3.70		3.70		0.00		
Land slope (%)	= 5.87		8.08		0.00		
Travel Time (min)	**= 11.15**	**+**	**2.81**	**+**	**0.00**	**=**	**13.96**
Shallow Concentrated Flow							
Flow length (ft)	= 66.31		367.31		0.00		
Watercourse slope (%)	= 8.42		7.91		0.00		
Surface description	= Unpaved		Unpaved		Paved		
Average velocity (ft/s)	=4.68		4.54		0.00		
Travel Time (min)	**= 0.24**	**+**	**1.35**	**+**	**0.00**	**=**	**1.59**
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})46.4		0.0		0.0		
Travel Time (min)	**= 0.16**	**+**	**0.00**	**+**	**0.00**	**=**	**0.16**

Total Travel Time, Tc ..... 15.70 min

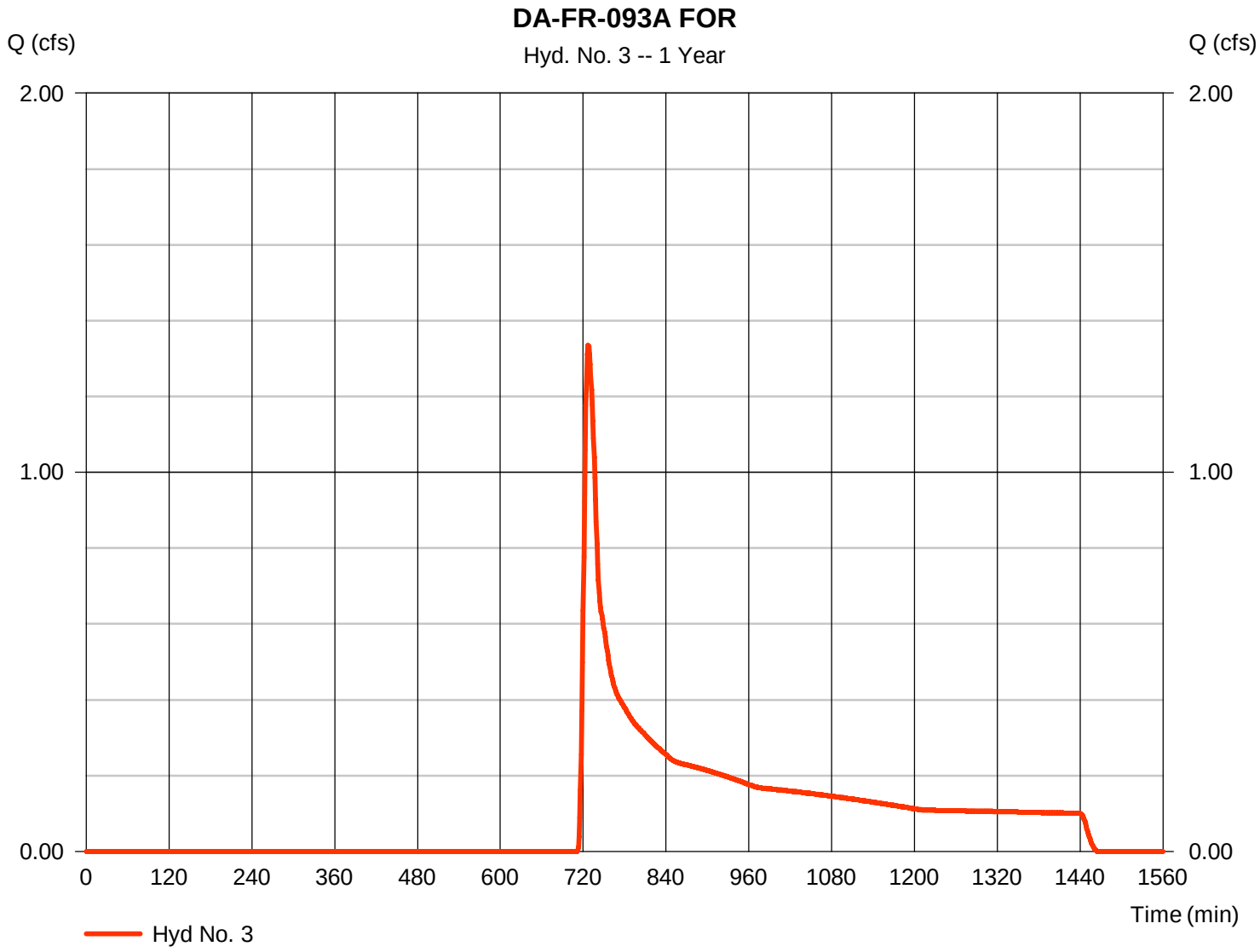
Hydrograph Report

Hyd. No. 3

DA-FR-093A FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 1.335 cfs
Storm frequency	= 1 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 8,957 cuft
Drainage area	= 8.670 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.70 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(6.865 x 58) + (1.800 x 55)] / 8.670



TR55 Tc Worksheet

Hyd. No. 3

DA-FR-093A FOR

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.400		0.400		0.011		
Flow length (ft)	= 82.6		17.4		0.0		
Two-year 24-hr precip. (in)	= 3.70		3.70		0.00		
Land slope (%)	= 5.87		8.08		0.00		
Travel Time (min)	**= 11.15**	**+**	**2.81**	**+**	**0.00**	**=**	**13.96**
Shallow Concentrated Flow							
Flow length (ft)	= 463.80		0.00		0.00		
Watercourse slope (%)	= 7.94		0.00		0.00		
Surface description	= Unpaved		Unpaved		Paved		
Average velocity (ft/s)	=4.55		0.00		0.00		
Travel Time (min)	**= 1.70**	**+**	**0.00**	**+**	**0.00**	**=**	**1.70**
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	= 0.015		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 ..... 15.70 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	3.626	1	726	15,714	------	------	------	DA-FR-093A PRE
2	SCS Runoff	3.626	1	726	15,714	------	------	------	DA-FR-093A DEV
3	SCS Runoff	2.649	1	726	13,243	------	------	------	DA-FR-093A FOR

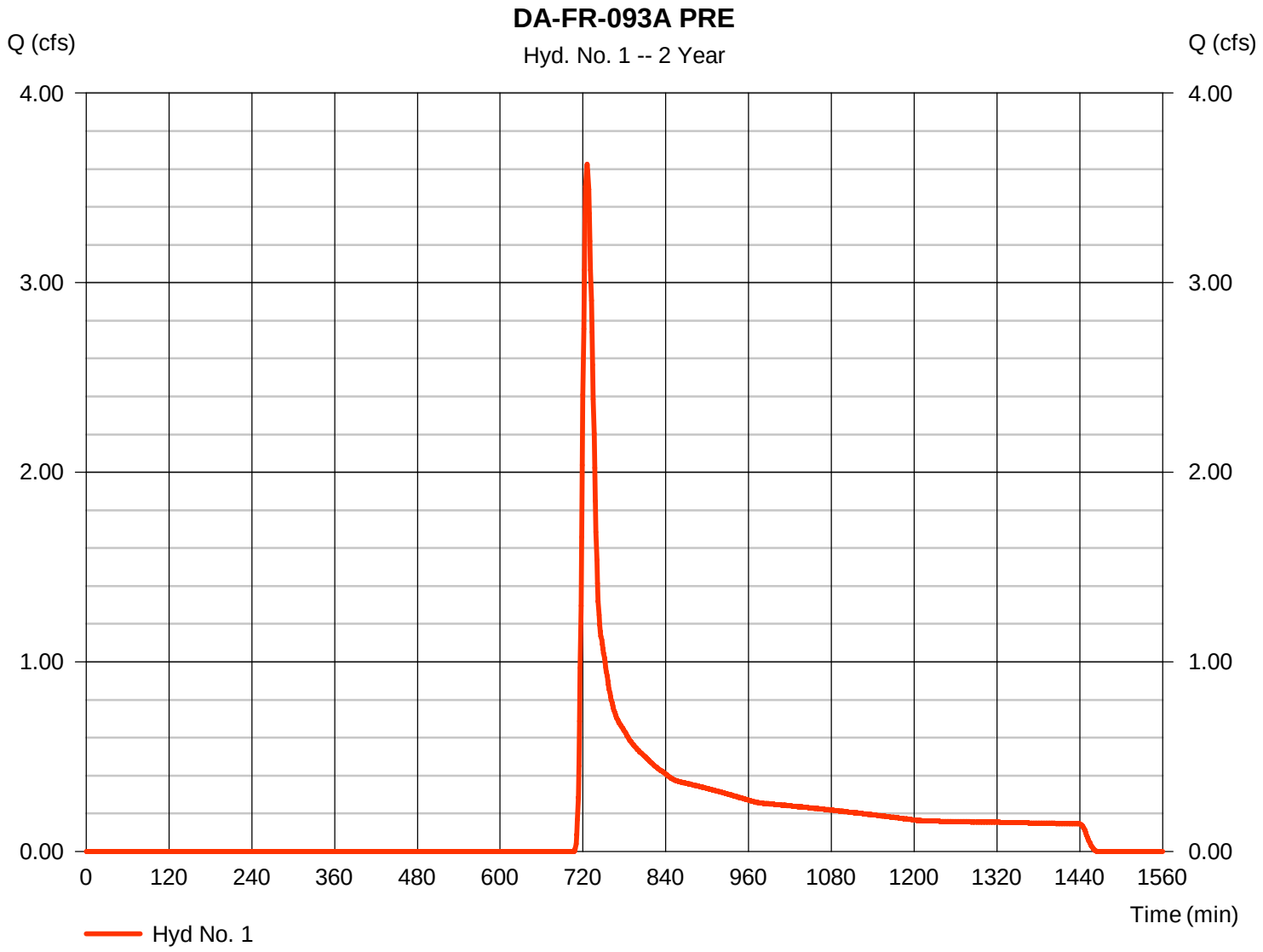
Hydrograph Report

Hyd. No. 1

DA-FR-093A PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	3.626 cfs
Storm frequency	=	2 yrs	Time to peak	=	726 min
Time interval	=	1 min	Hyd. volume	=	15,714 cuft
Drainage area	=	8.670 ac	Curve number	=	57*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	15.70 min
Total precip.	=	3.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(6.865 x 58) + (1.801 x 55)] / 8.670



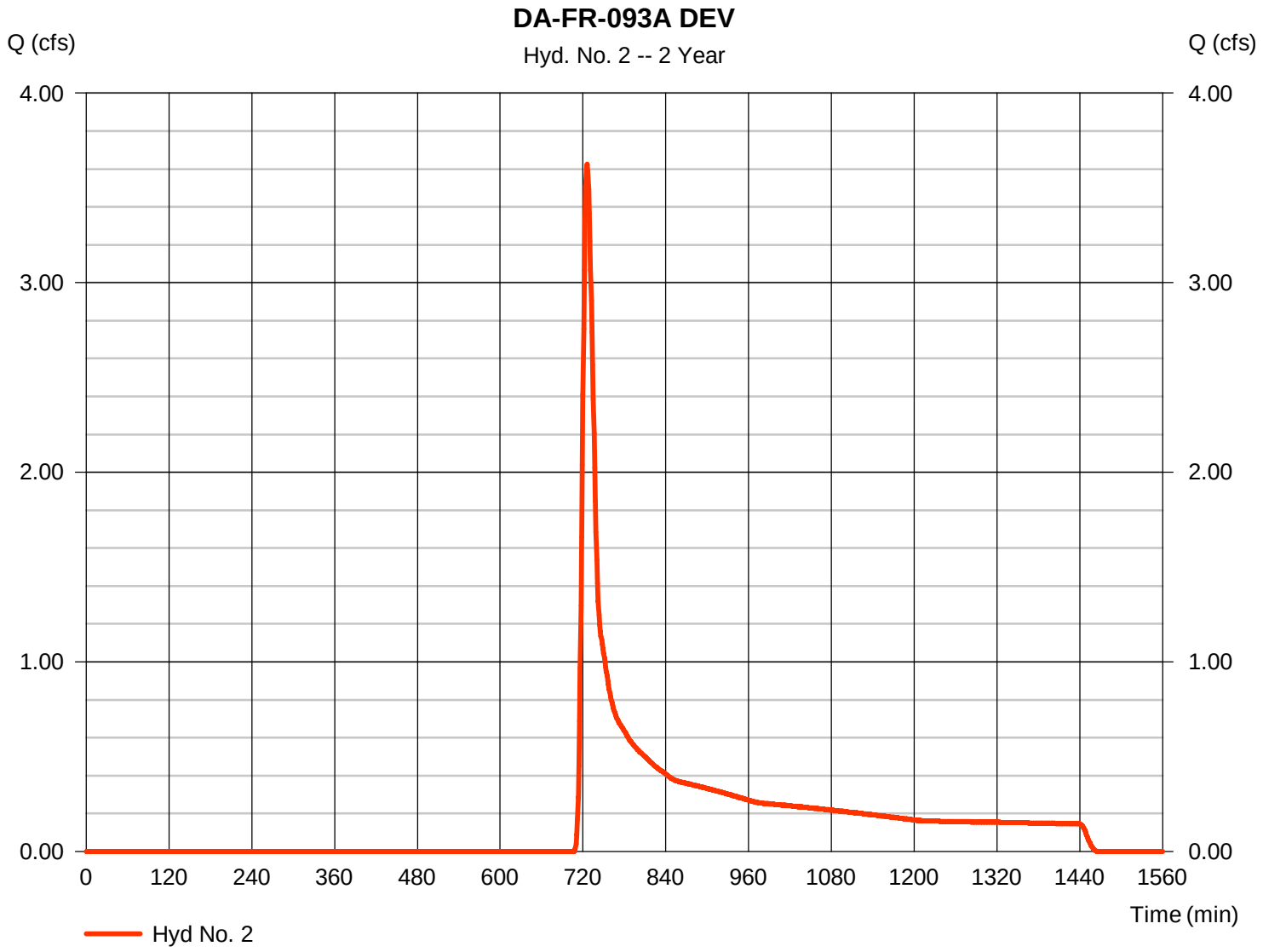
Hydrograph Report

Hyd. No. 2

DA-FR-093A DEV

Hydrograph type	=	SCS Runoff	Peak discharge	=	3.626 cfs
Storm frequency	=	2 yrs	Time to peak	=	726 min
Time interval	=	1 min	Hyd. volume	=	15,714 cuft
Drainage area	=	8.670 ac	Curve number	=	57*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	15.70 min
Total precip.	=	3.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.007 x 48) + (6.865 x 58) + (1.794 x 55)] / 8.670



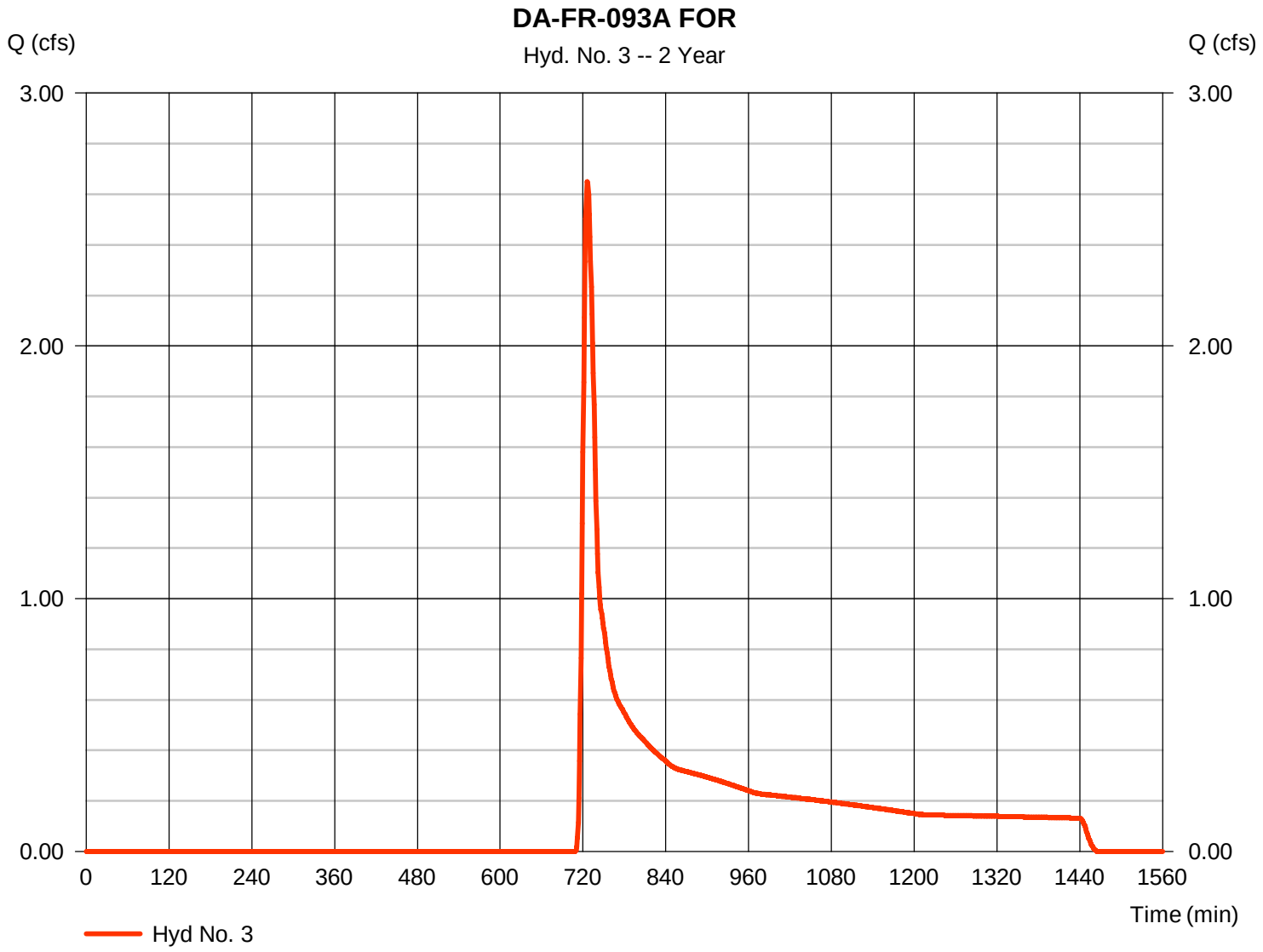
Hydrograph Report

Hyd. No. 3

DA-FR-093A FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 2.649 cfs
Storm frequency	= 2 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 13,243 cuft
Drainage area	= 8.670 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.70 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(6.865 x 58) + (1.800 x 55)] / 8.670



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	15.34	1	724	47,700	------	------	------	DA-FR-093A PRE
2	SCS Runoff	15.34	1	724	47,700	------	------	------	DA-FR-093A DEV
3	SCS Runoff	13.40	1	724	42,971	------	------	------	DA-FR-093A FOR

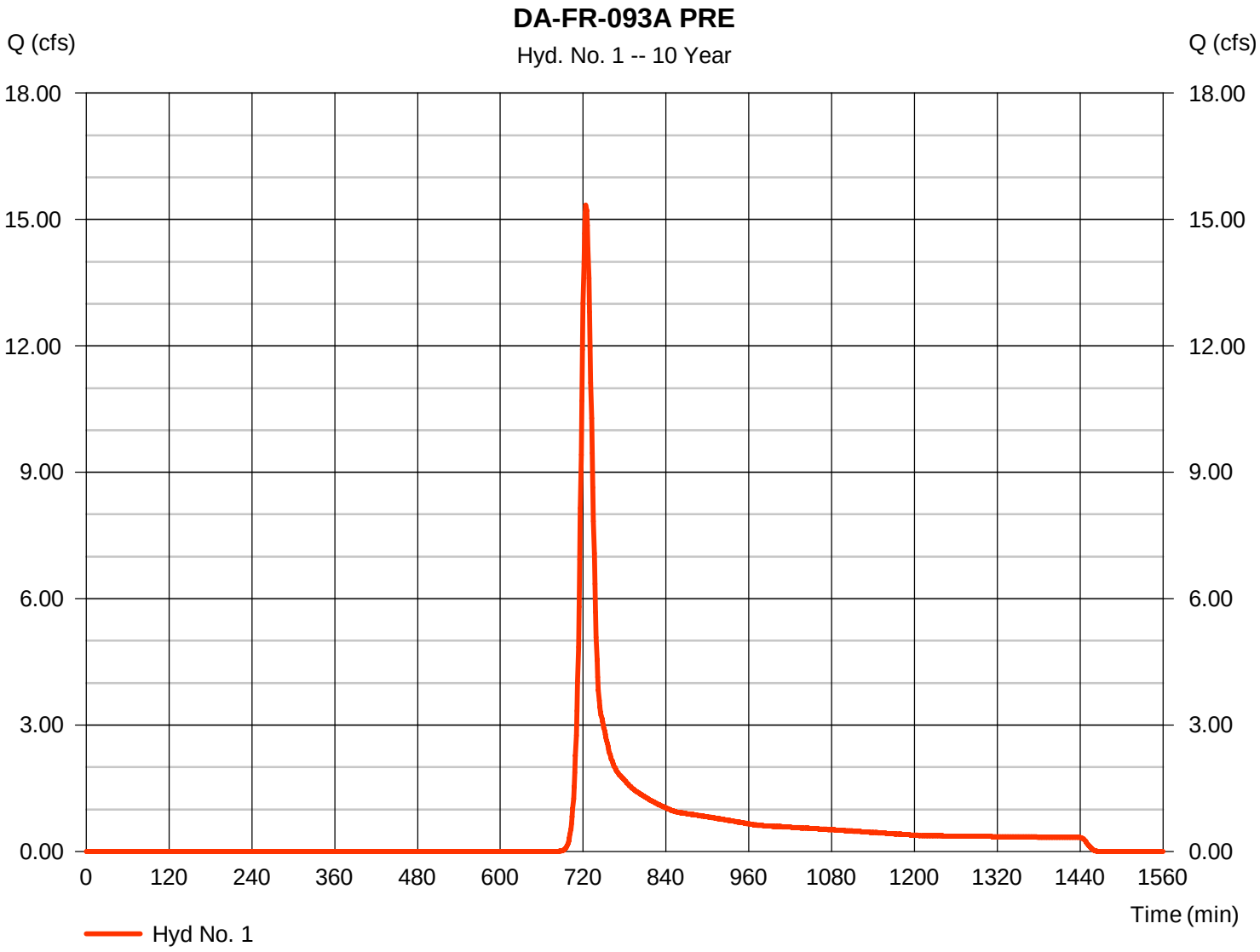
Hydrograph Report

Hyd. No. 1

DA-FR-093A PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 15.34 cfs
Storm frequency	= 10 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 47,700 cuft
Drainage area	= 8.670 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.70 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(6.865 x 58) + (1.801 x 55)] / 8.670



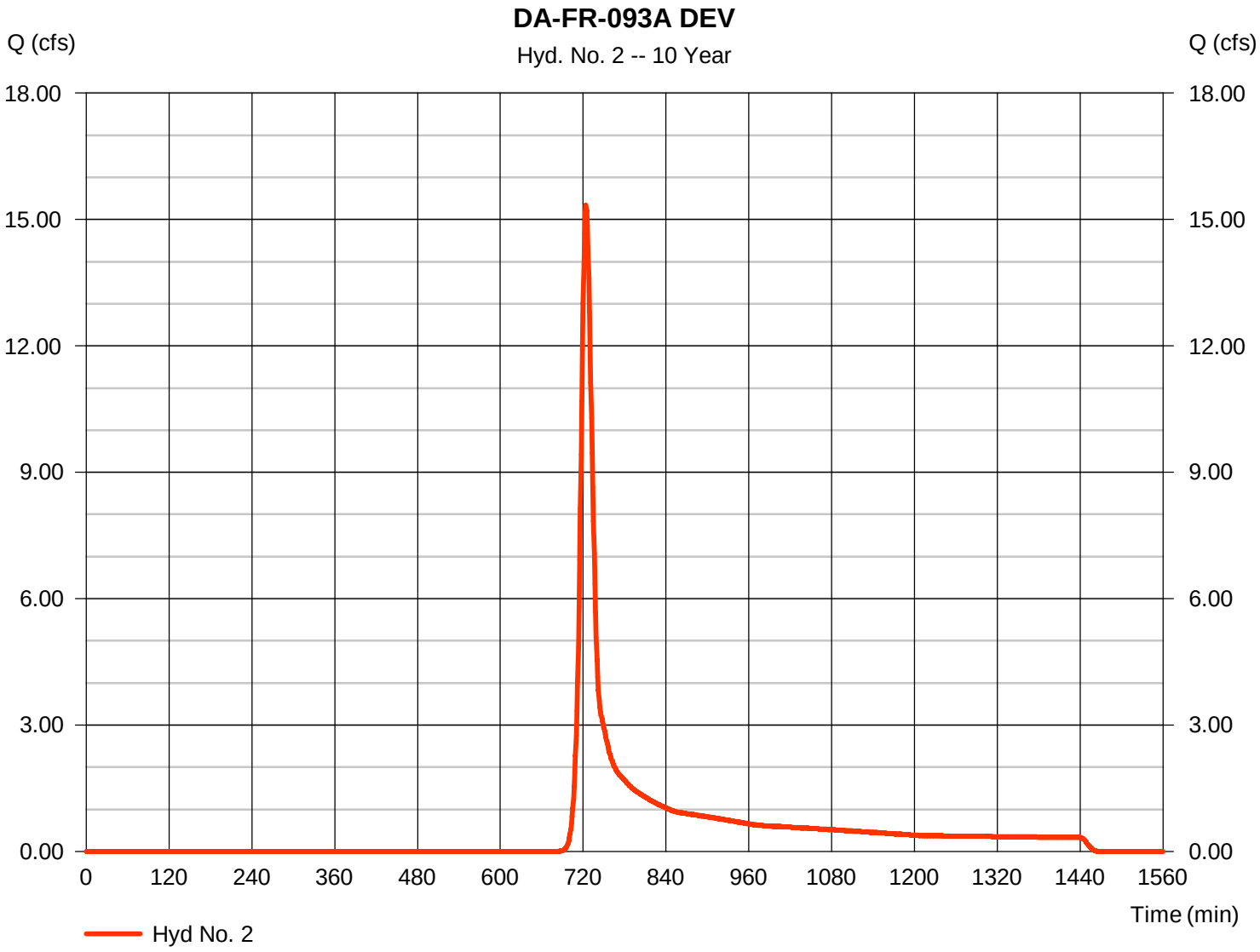
Hydrograph Report

Hyd. No. 2

DA-FR-093A DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 15.34 cfs
Storm frequency	= 10 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 47,700 cuft
Drainage area	= 8.670 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.70 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.007 x 48) + (6.865 x 58) + (1.794 x 55)] / 8.670



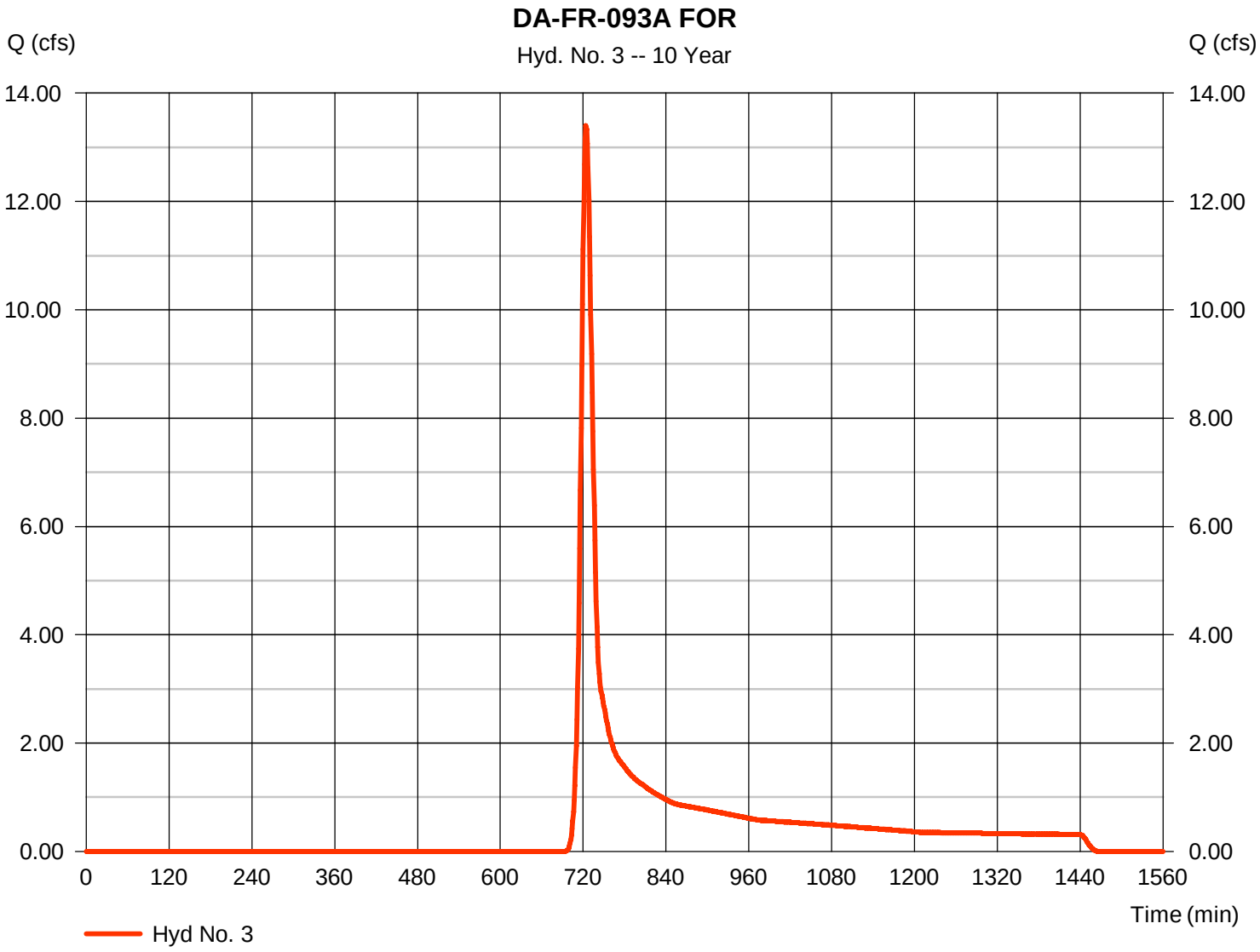
Hydrograph Report

Hyd. No. 3

DA-FR-093A FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 13.40 cfs
Storm frequency	= 10 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 42,971 cuft
Drainage area	= 8.670 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.70 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(6.865 x 58) + (1.800 x 55)] / 8.670



Hydraflow Rainfall Report

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

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

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

Tc = time in minutes. Values may exceed 60.

ng\Franklin County\Downloaded Files\Franklin County DA Batch 4 - 046 - 058\Precipitation\Hydraflow\FranklinCo.pc

Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.30	3.70	0.00	0.00	5.70	0.00	0.00	0.00
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

DA-FR-093B

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.825	4060
Developed Condition	0.825	4060
Pre-Developed (Forest) Condition	0.451	3027

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

Improvement Factor, IF = 1

Calculations:

Check #1: $Q_{developed} \leq IF \times [(Q_{pre\text{-}developed} \times RV_{pre\text{-}developed}) / RV_{developed}]$ ----------> 0.825 ≤ 0.825 OK

Check #2: $Q_{developed} \leq Q_{pre\text{-}developed}$ ----------> 0.825 ≤ 0.825 OK

Check #3: $Q_{developed}$ *shall not* be required to be $\leq (Q_{forest} \times RV_{forest}) / RV_{developed}$ ---> 0.825 *shall not* be required to be ≤ 0.336

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

Note:

Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.

For Paved Road land surface types a Manning's n value 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 Channels[1]			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels[2]			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150

Notes:

[1]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 or grass channel.

[2]For the pre-developed condition (if applicable), 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-FR-093B PRE
2	SCS Runoff	DA-FR-093B DEV
3	SCS Runoff	DA-FR-093B FOR

Hydrograph Return Period Recap

Hyd. No.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)							Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	------	0.825	1.403	-------	-------	5.516	-------	-------	-------	DA-FR-093B PRE
2	SCS Runoff	------	0.825	1.403	-------	-------	5.516	-------	-------	-------	DA-FR-093B DEV
3	SCS Runoff	------	0.451	0.895	-------	-------	4.528	-------	-------	-------	DA-FR-093B FOR

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	0.825	1	726	4,060	------	------	------	DA-FR-093B PRE
2	SCS Runoff	0.825	1	726	4,060	------	------	------	DA-FR-093B DEV
3	SCS Runoff	0.451	1	727	3,027	------	------	------	DA-FR-093B FOR

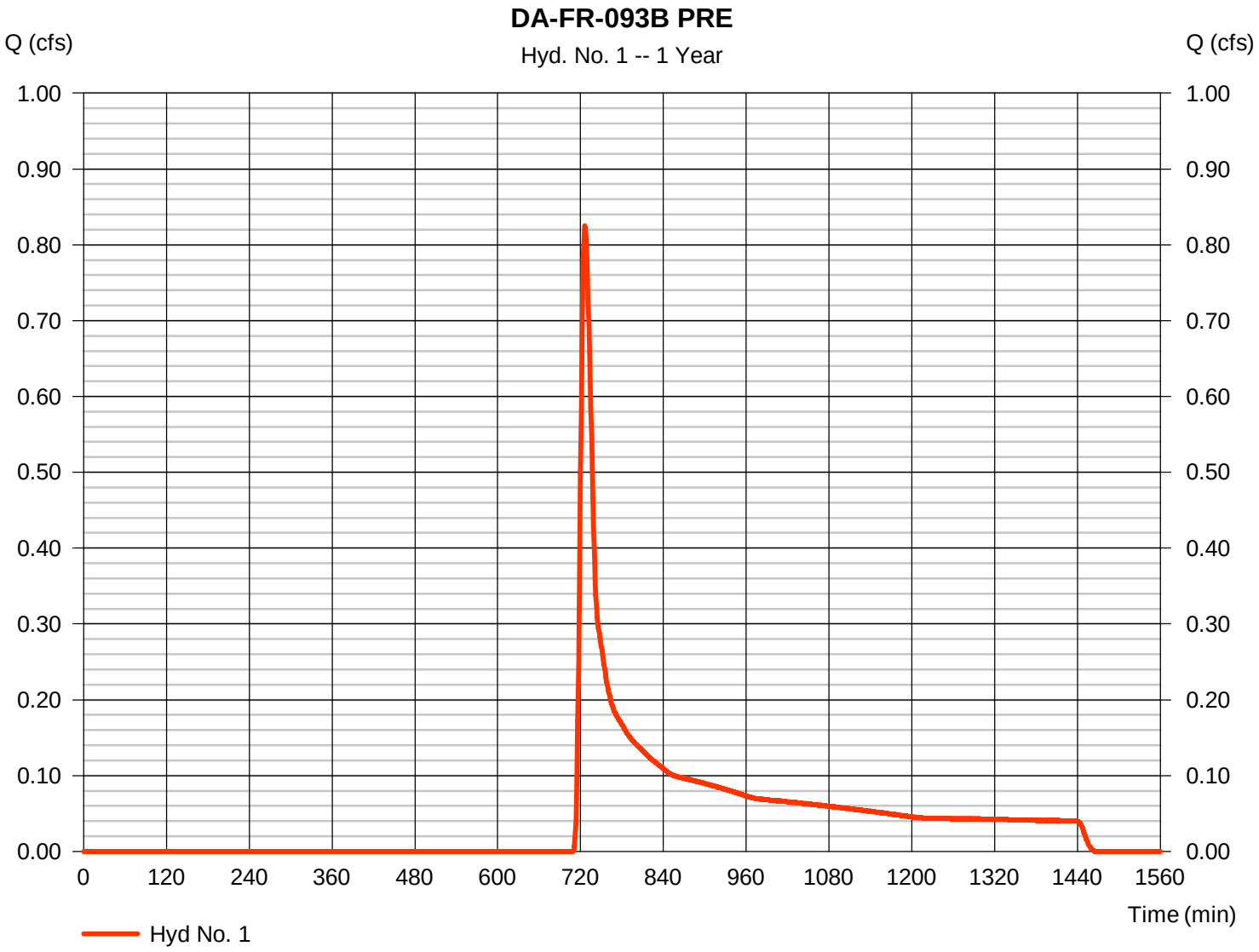
Hydrograph Report

Hyd. No. 1

DA-FR-093B PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.825 cfs
Storm frequency	= 1 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 4,060 cuft
Drainage area	= 2.930 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.60 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.065 x 48) + (2.850 x 58) + (0.018 x 100)] / 2.930



TR55 Tc Worksheet

Hyd. No. 1

DA-FR-093B PRE

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 4.27		0.00		0.00		
Travel Time (min)	**= 14.74**	**+**	**0.00**	**+**	**0.00**	**=**	**14.74**
Shallow Concentrated Flow							
Flow length (ft)	= 573.19		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)	**= 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	= 0.015		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							**16.60 min**

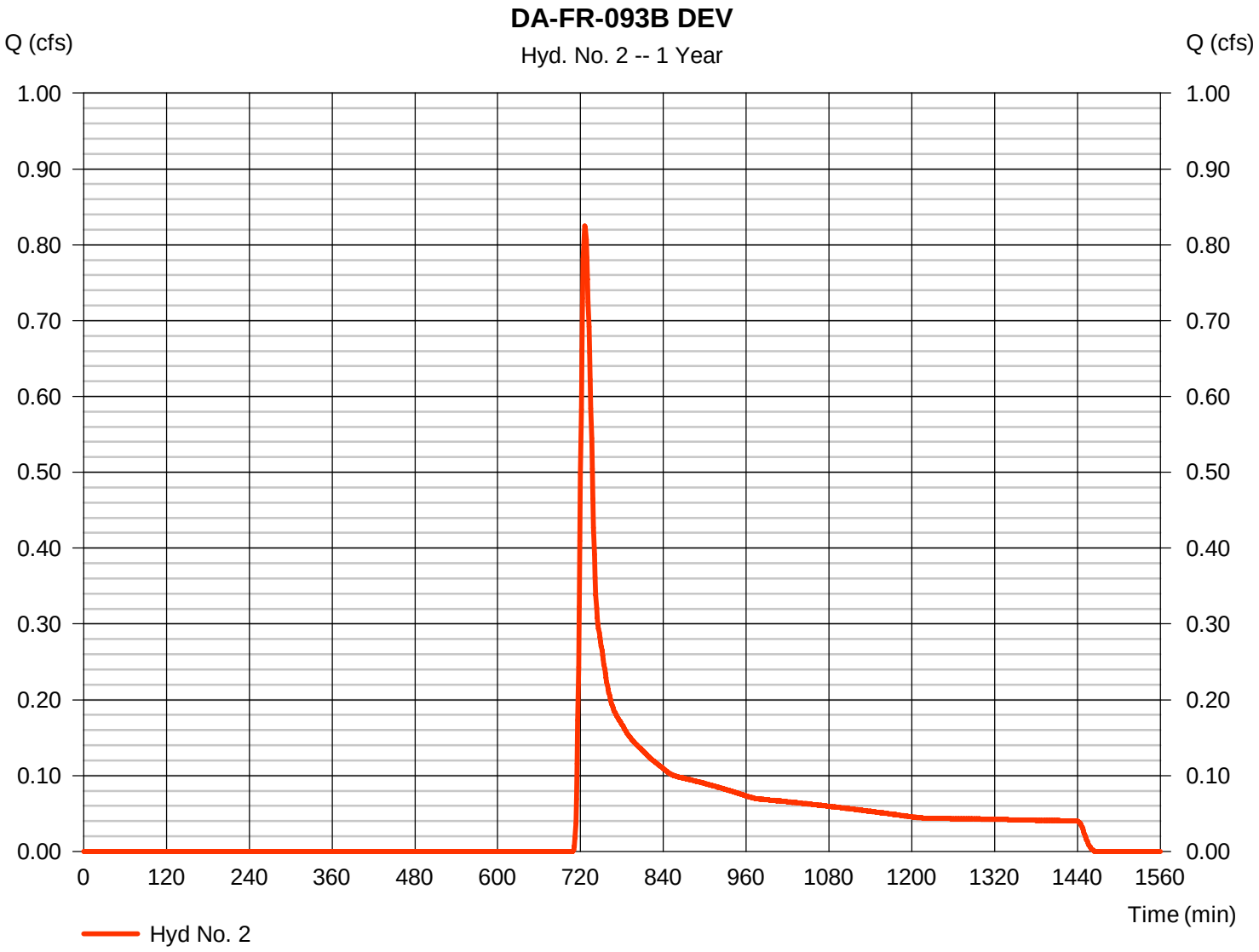
Hydrograph Report

Hyd. No. 2

DA-FR-093B DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.825 cfs
Storm frequency	= 1 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 4,060 cuft
Drainage area	= 2.930 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.20 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.065 x 48) + (2.850 x 58) + (0.018 x 100)] / 2.930



TR55 Tc Worksheet

Hyd. No. 2

DA-FR-093B DEV

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 4.27		0.00		0.00		
Travel Time (min)	**= 14.74**	**+**	**0.00**	**+**	**0.00**	**=**	**14.74**
Shallow Concentrated Flow							
Flow length (ft)	= 333.84		0.00		0.00		
Watercourse slope (%)	= 6.55		0.00		0.00		
Surface description	= Unpaved		Unpaved		Unpaved		
Average velocity (ft/s)	=4.13		0.00		0.00		
Travel Time (min)	**= 1.35**	**+**	**0.00**	**+**	**0.00**	**=**	**1.35**
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})24.0		0.0		0.0		
Travel Time (min)	**= 0.08**	**+**	**0.00**	**+**	**0.00**	**=**	**0.08**

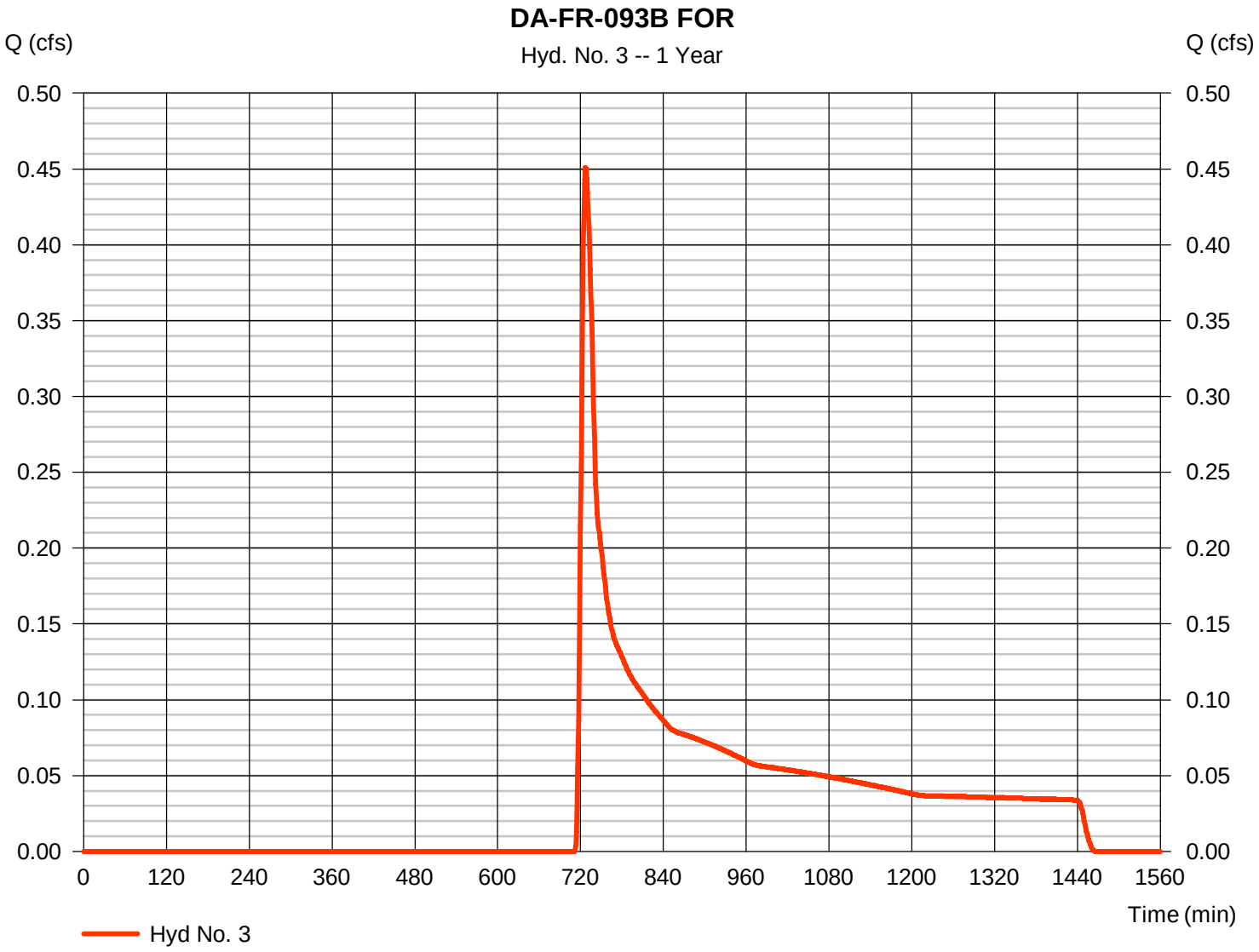
Total Travel Time, Tc ..... 16.20 min

Hydrograph Report

Hyd. No. 3

DA-FR-093B FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.451 cfs
Storm frequency	= 1 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 3,027 cuft
Drainage area	= 2.930 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.60 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



TR55 Tc Worksheet

Hyd. No. 3

DA-FR-093B FOR

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 4.27		0.00		0.00		
Travel Time (min)	**= 14.74**	**+**	**0.00**	**+**	**0.00**	**=**	**14.74**
Shallow Concentrated Flow							
Flow length (ft)	= 573.19		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)	**= 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	= 0.015		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							**16.60 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	1.403	1	726	5,751	------	------	------	DA-FR-093B PRE
2	SCS Runoff	1.403	1	726	5,751	------	------	------	DA-FR-093B DEV
3	SCS Runoff	0.895	1	726	4,475	------	------	------	DA-FR-093B FOR

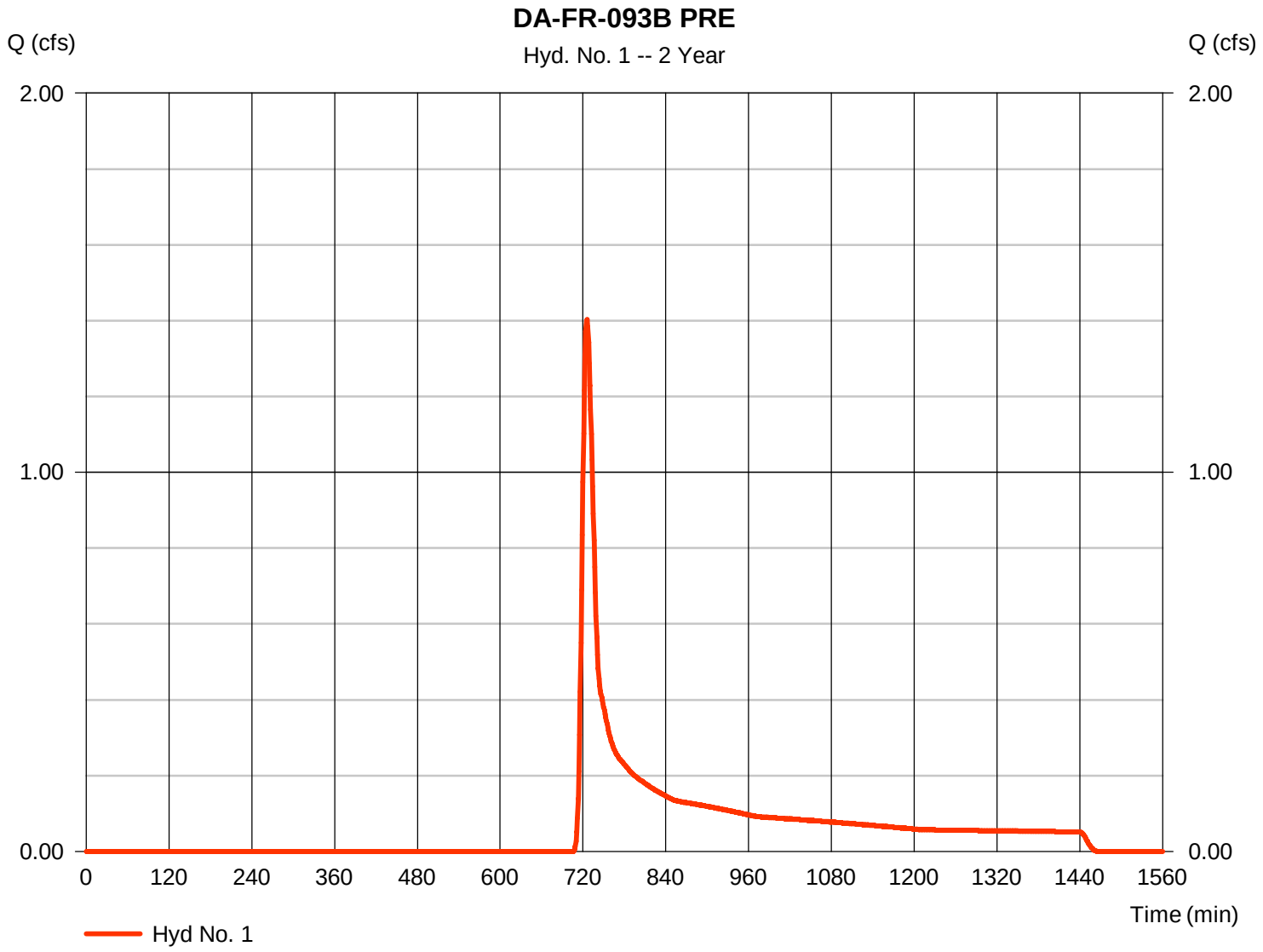
Hydrograph Report

Hyd. No. 1

DA-FR-093B PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 1.403 cfs
Storm frequency	= 2 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 5,751 cuft
Drainage area	= 2.930 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.60 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.065 x 48) + (2.850 x 58) + (0.018 x 100)] / 2.930



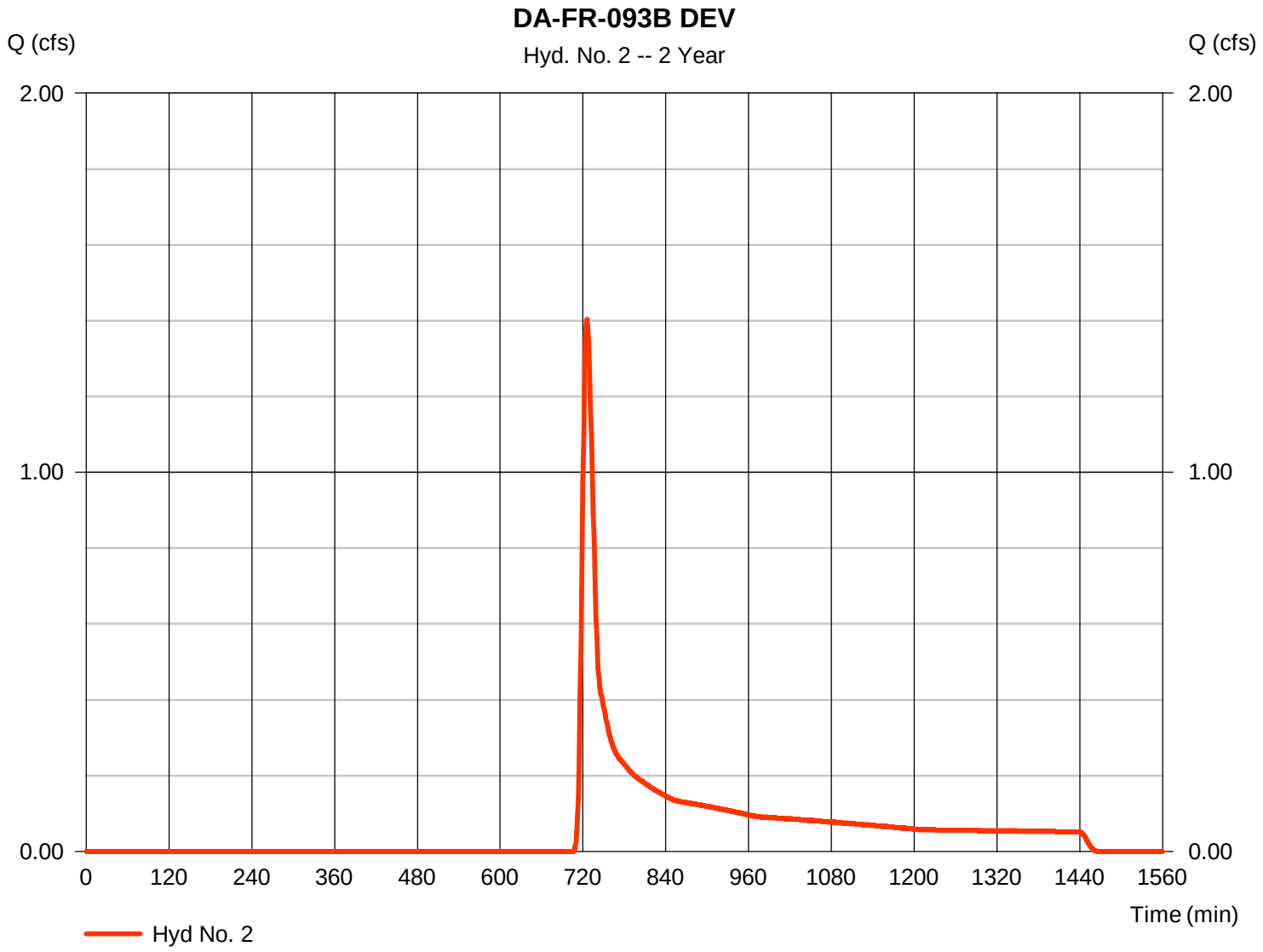
Hydrograph Report

Hyd. No. 2

DA-FR-093B DEV

Hydrograph type	=	SCS Runoff	Peak discharge	=	1.403 cfs
Storm frequency	=	2 yrs	Time to peak	=	726 min
Time interval	=	1 min	Hyd. volume	=	5,751 cuft
Drainage area	=	2.930 ac	Curve number	=	58*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	16.20 min
Total precip.	=	3.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.065 x 48) + (2.850 x 58) + (0.018 x 100)] / 2.930

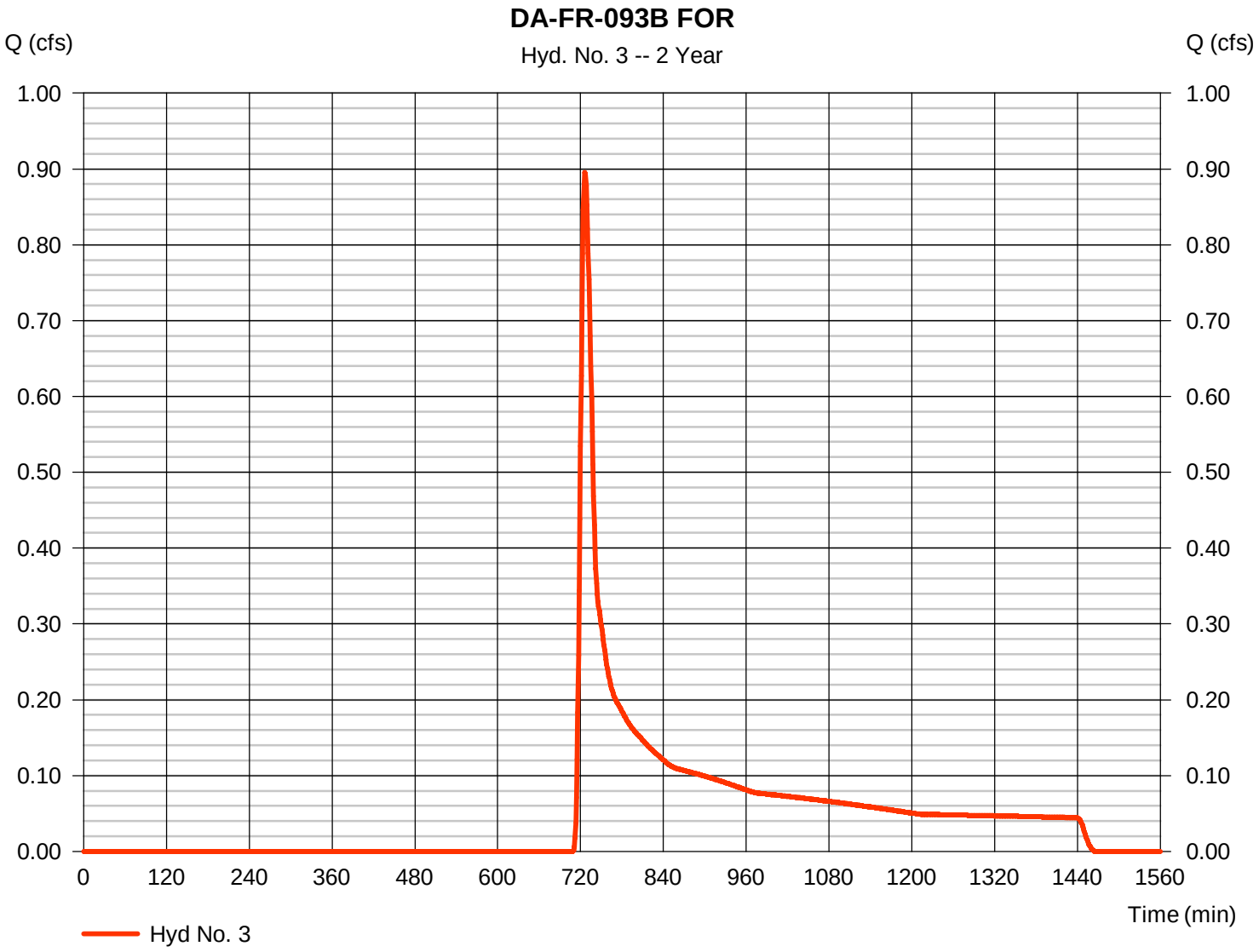


Hydrograph Report

Hyd. No. 3

DA-FR-093B FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.895 cfs
Storm frequency	= 2 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 4,475 cuft
Drainage area	= 2.930 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.60 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



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	5.516	1	724	16,938	------	------	------	DA-FR-093B PRE
2	SCS Runoff	5.516	1	724	16,938	------	------	------	DA-FR-093B DEV
3	SCS Runoff	4.528	1	724	14,522	------	------	------	DA-FR-093B FOR

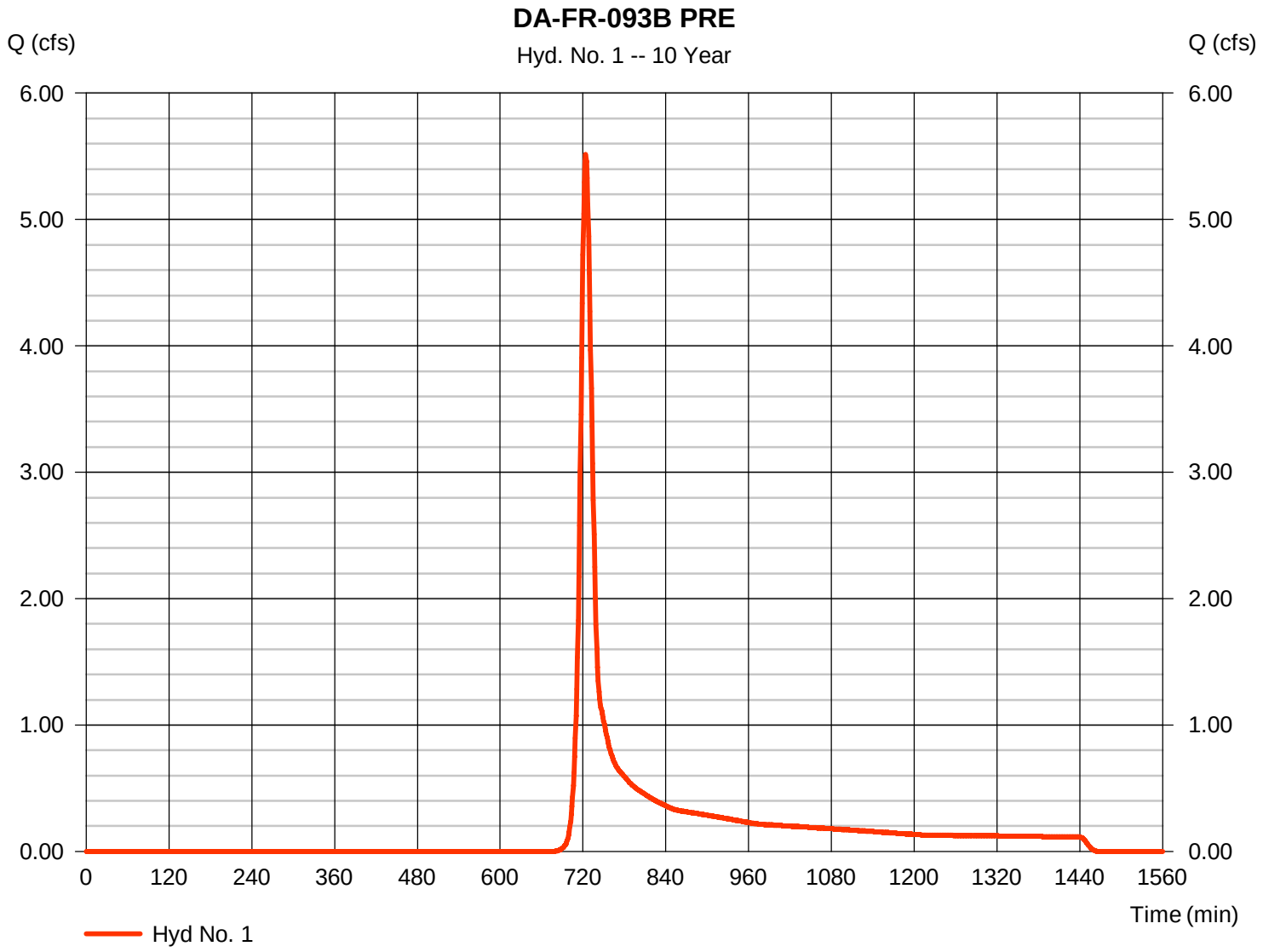
Hydrograph Report

Hyd. No. 1

DA-FR-093B PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 5.516 cfs
Storm frequency	= 10 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 16,938 cuft
Drainage area	= 2.930 ac	Curve number	= 58*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.60 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.065 x 48) + (2.850 x 58) + (0.018 x 100)] / 2.930



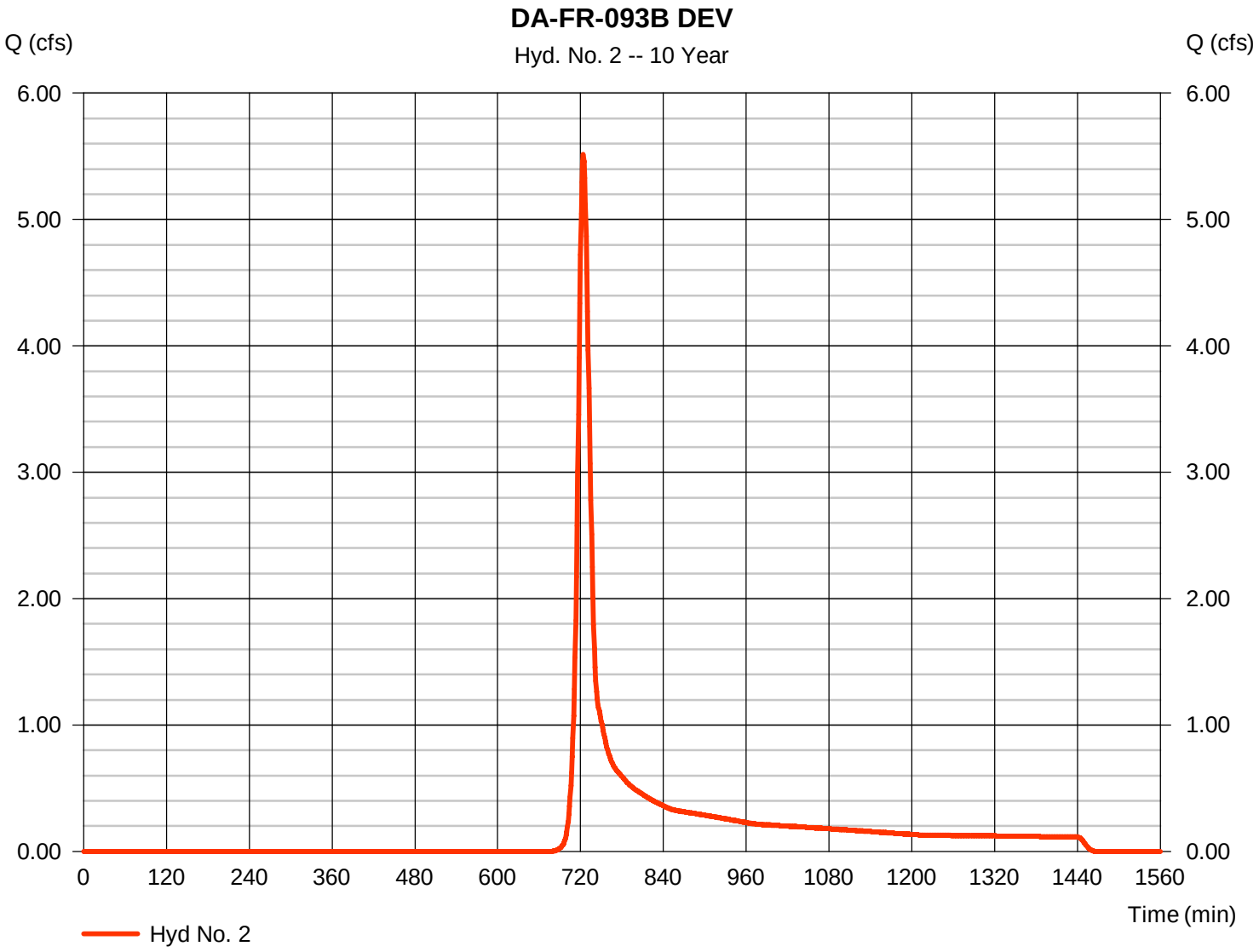
Hydrograph Report

Hyd. No. 2

DA-FR-093B DEV

Hydrograph type	=	SCS Runoff	Peak discharge	=	5.516 cfs
Storm frequency	=	10 yrs	Time to peak	=	724 min
Time interval	=	1 min	Hyd. volume	=	16,938 cuft
Drainage area	=	2.930 ac	Curve number	=	58*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	16.20 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.065 x 48) + (2.850 x 58) + (0.018 x 100)] / 2.930

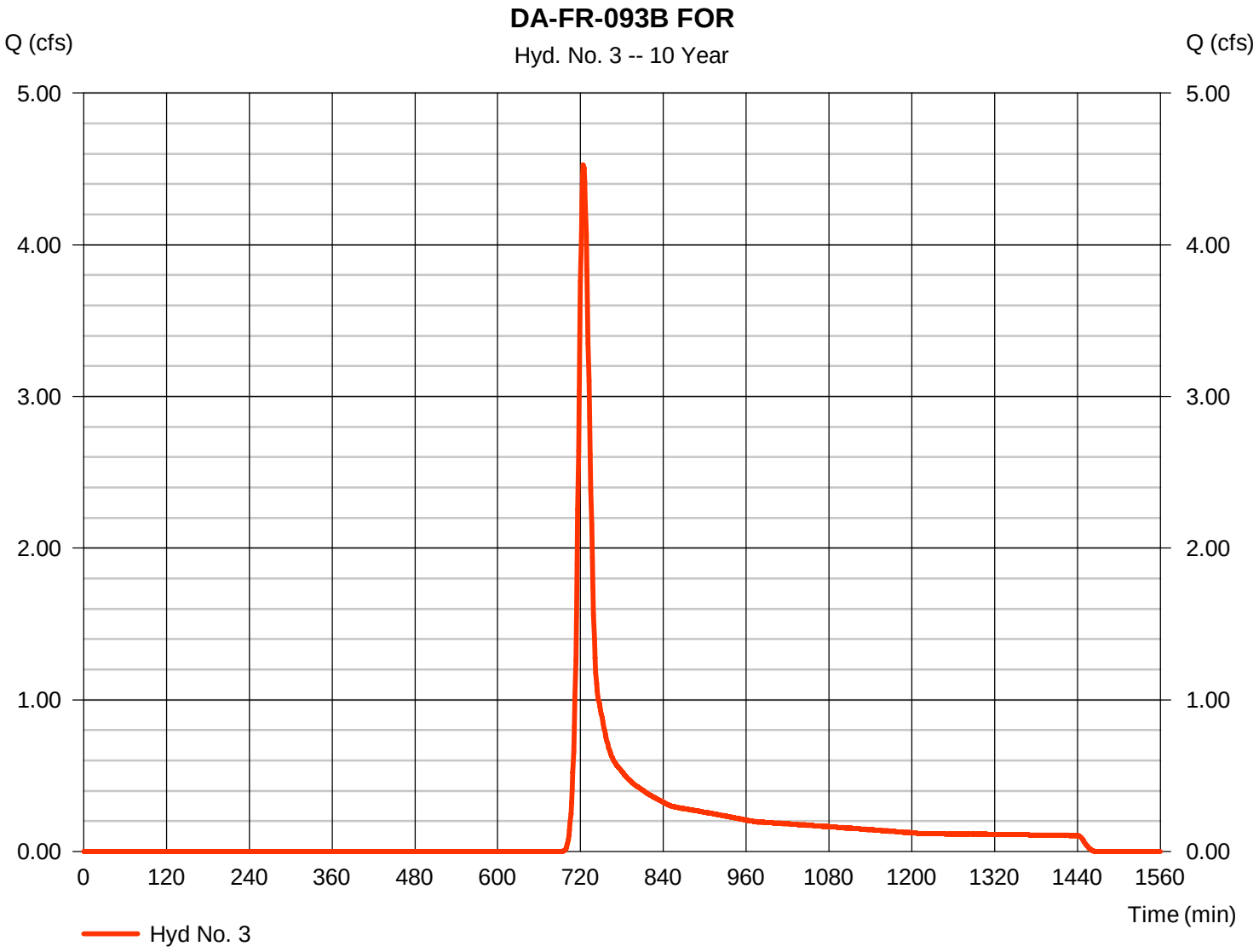


Hydrograph Report

Hyd. No. 3

DA-FR-093B FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 4.528 cfs
Storm frequency	= 10 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 14,522 cuft
Drainage area	= 2.930 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 16.60 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



Hydraflow Rainfall Report

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

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

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

Tc = time in minutes. Values may exceed 60.

ng\Franklin County\Downloaded Files\Franklin County DA Batch 4 - 046 - 058\Precipitation\Hydraflow\FranklinCo.pc

Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.30	3.70	0.00	0.00	5.70	0.00	0.00	0.00
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

DA-FR-093C

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	2.299	10387
Developed Condition	1.877	9421
Pre-Developed (Forest) Condition	1.502	8497

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

Improvement Factor, IF = 1

Calculations:

Check #1: $Q_{developed} \leq IF \times [(Q_{pre\text{-}developed} \times RV_{pre\text{-}developed}) / RV_{developed}]$ ----------> 1.877 ≤ 2.535 OK

Check #2: $Q_{developed} \leq Q_{pre\text{-}developed}$ ----------> 1.877 ≤ 2.299 OK

Check #3: $Q_{developed}$ *shall not* be required to be ≤ $(Q_{forest} \times RV_{forest}) / RV_{developed}$ ---> 1.877 *shall not* be required to be ≤ 1.355

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

Note:

Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.

For Paved Road land surface types a Manning's n value 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

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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-FR-093C PRE
2	SCS Runoff	DA-FR-093B DEV
3	SCS Runoff	DA-FR-093C FOR

Hydrograph Return Period Recap

Hyd. No.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)							Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	------	2.299	4.063	-------	-------	16.76	-------	-------	-------	DA-FR-093C PRE
2	SCS Runoff	------	1.877	3.514	-------	-------	15.73	-------	-------	-------	DA-FR-093B DEV
3	SCS Runoff	------	1.502	2.990	-------	-------	14.71	-------	-------	-------	DA-FR-093C FOR

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	2.299	1	724	10,387	------	------	------	DA-FR-093C PRE
2	SCS Runoff	1.877	1	725	9,421	------	------	------	DA-FR-093B DEV
3	SCS Runoff	1.502	1	725	8,497	------	------	------	DA-FR-093C FOR

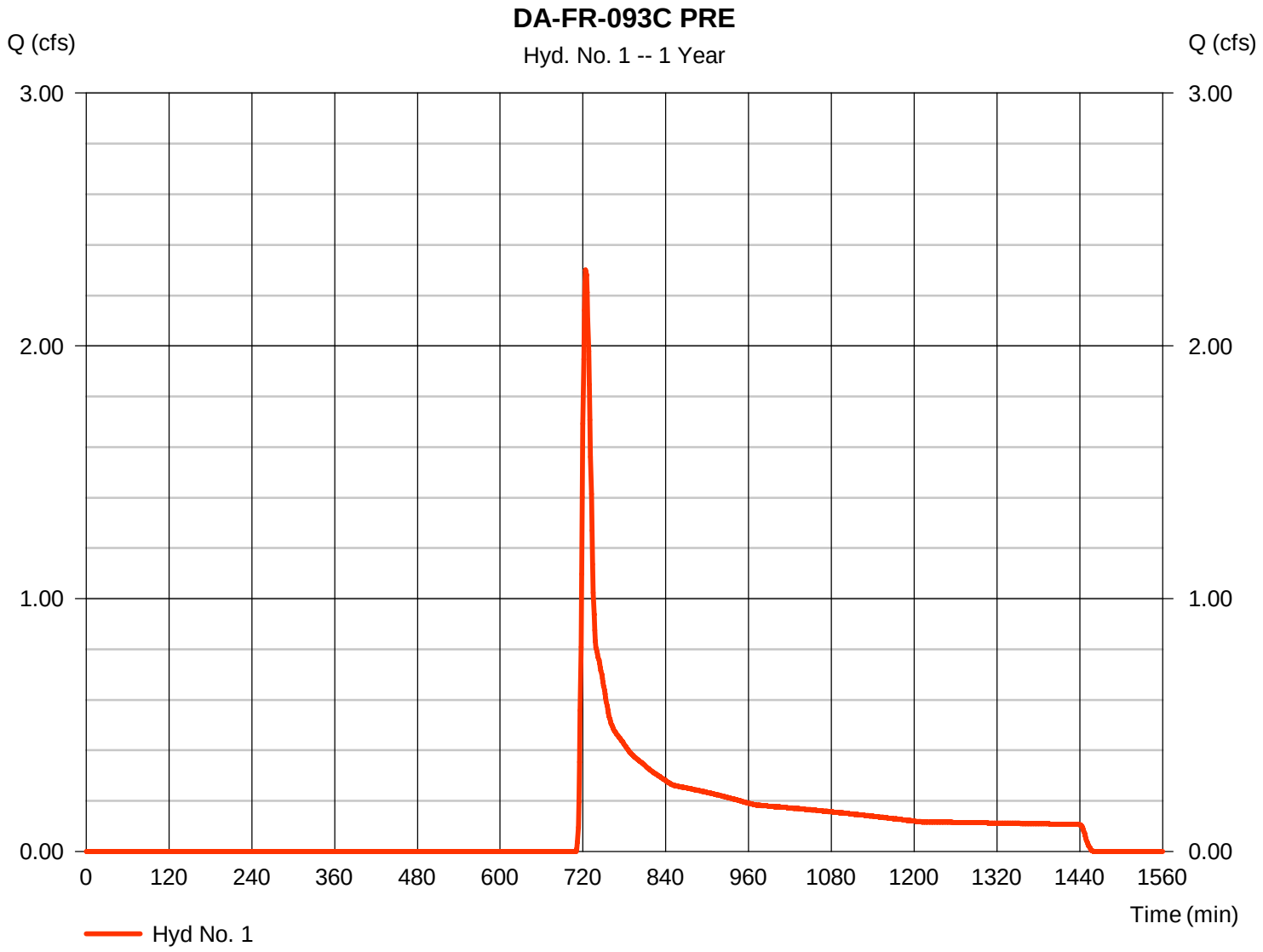
Hydrograph Report

Hyd. No. 1

DA-FR-093C PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 2.299 cfs
Storm frequency	= 1 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 10,387 cuft
Drainage area	= 8.460 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.90 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.095 x 48) + (0.056 x 82) + (3.895 x 58) + (0.007 x 100) + (4.408 x 55)] / 8.460



TR55 Tc Worksheet

Hyd. No. 1

DA-FR-093C PRE

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 9.64		0.00		0.00		
Travel Time (min)	**= 10.65**	**+**	**0.00**	**+**	**0.00**	**=**	**10.65**
Shallow Concentrated Flow							
Flow length (ft)	= 400.99		0.00		0.00		
Watercourse slope (%)	= 11.78		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=5.54		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	= 0.015		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 ..... 11.90 min

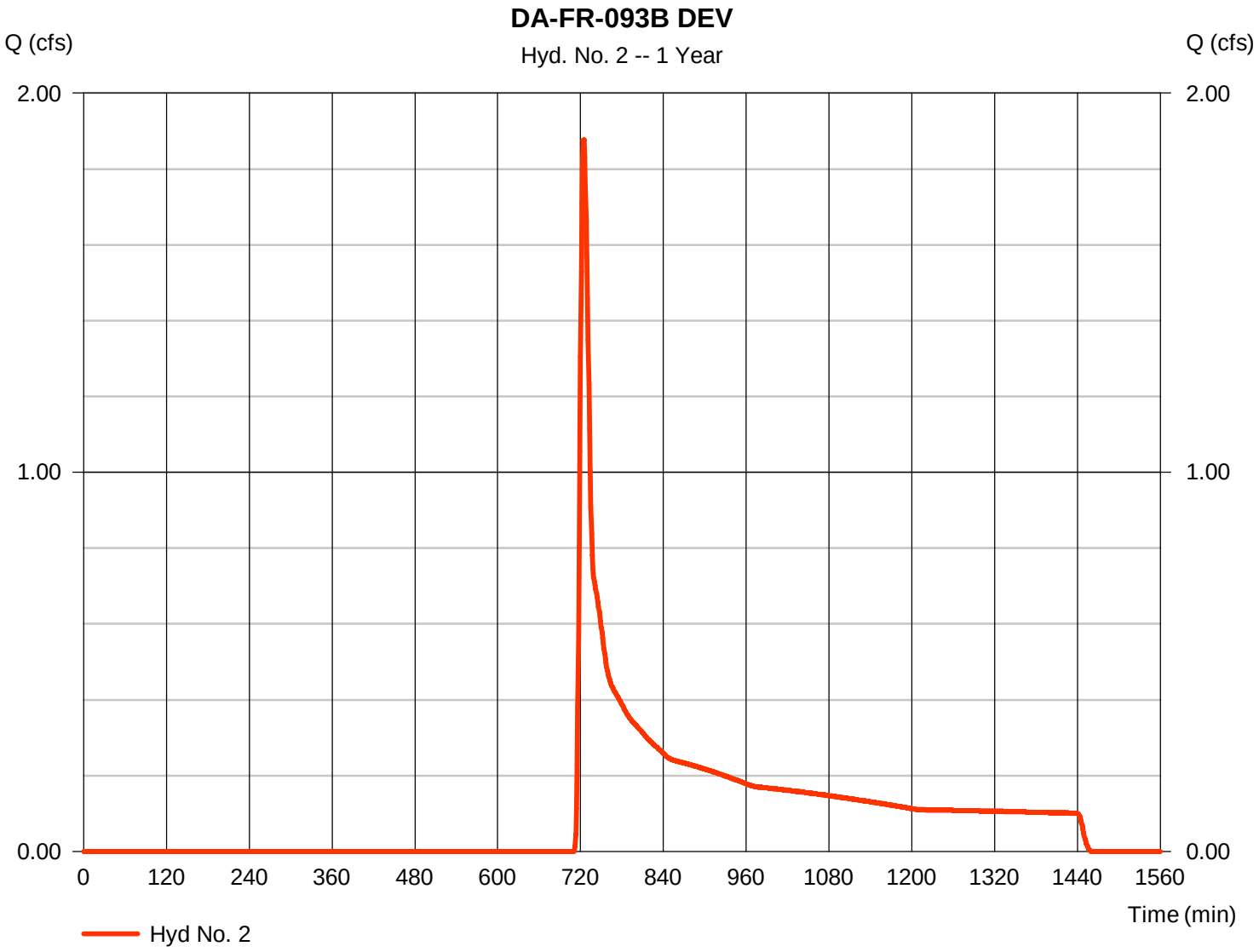
Hydrograph Report

Hyd. No. 2

DA-FR-093B DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 1.877 cfs
Storm frequency	= 1 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 9,421 cuft
Drainage area	= 8.460 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.90 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(1.461 x 48) + (0.056 x 82) + (4.635 x 58) + (0.007 x 100) + (2.302 x 55)] / 8.460



TR55 Tc Worksheet

Hyd. No. 2

DA-FR-093B DEV

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 9.64		0.00		0.00		
Travel Time (min)	**= 10.65**	**+**	**0.00**	**+**	**0.00**	**=**	**10.65**
Shallow Concentrated Flow							
Flow length (ft)	= 400.99		0.00		0.00		
Watercourse slope (%)	= 11.78		0.00		0.00		
Surface description	= Unpaved		Unpaved		Unpaved		
Average velocity (ft/s)	=5.54		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	= 0.015		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**

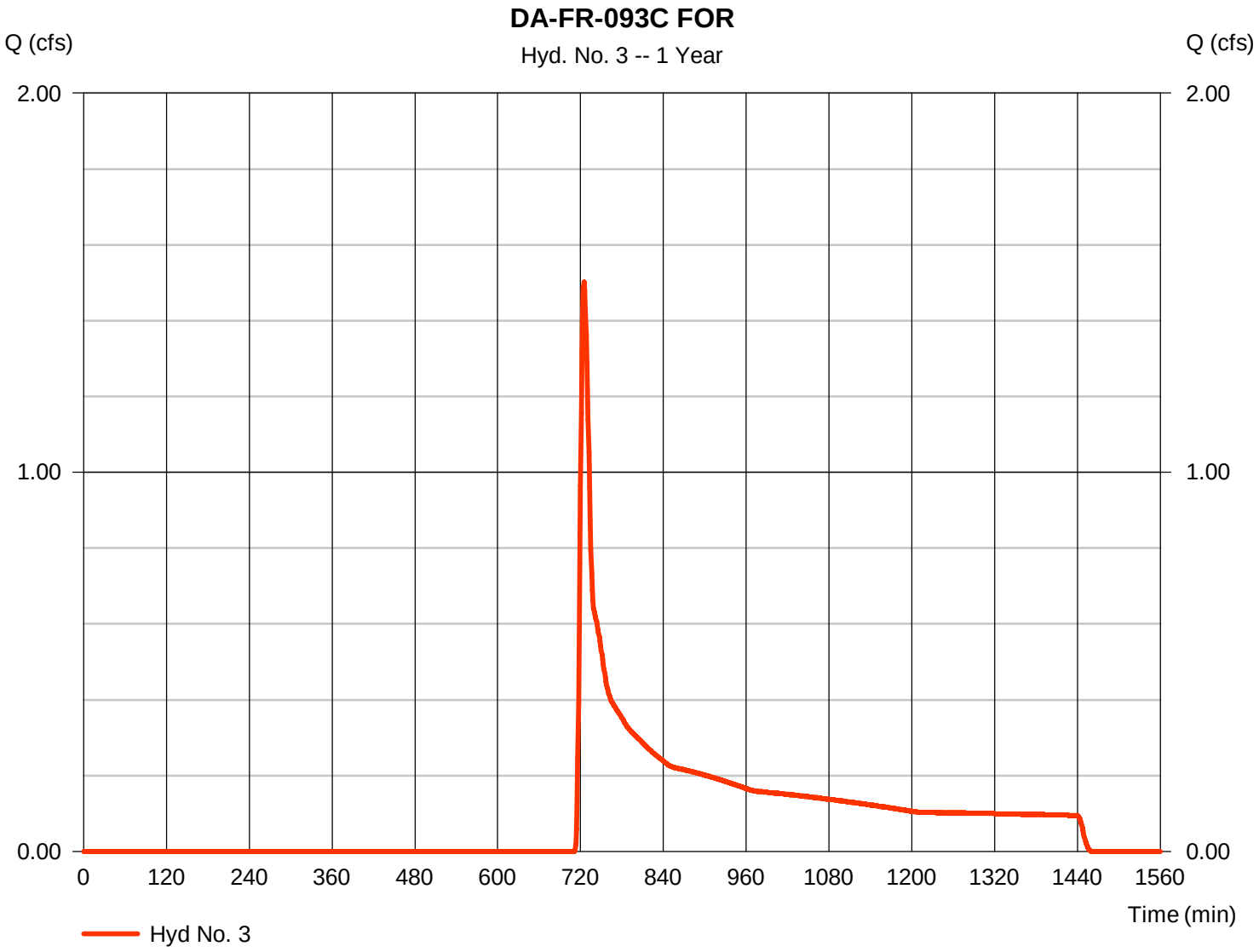
Total Travel Time, Tc ..... 11.90 min

Hydrograph Report

Hyd. No. 3

DA-FR-093C FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 1.502 cfs
Storm frequency	= 1 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 8,497 cuft
Drainage area	= 8.460 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.90 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



TR55 Tc Worksheet

Hyd. No. 3

DA-FR-093C FOR

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 9.64		0.00		0.00		
Travel Time (min)	**= 10.65**	**+**	**0.00**	**+**	**0.00**	**=**	**10.65**
Shallow Concentrated Flow							
Flow length (ft)	= 400.99		0.00		0.00		
Watercourse slope (%)	= 11.78		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=5.54		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	= 0.015		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 ..... 11.90 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	4.063	1	723	14,908	------	------	------	DA-FR-093C PRE
2	SCS Runoff	3.514	1	724	13,714	------	------	------	DA-FR-093B DEV
3	SCS Runoff	2.990	1	724	12,563	------	------	------	DA-FR-093C FOR

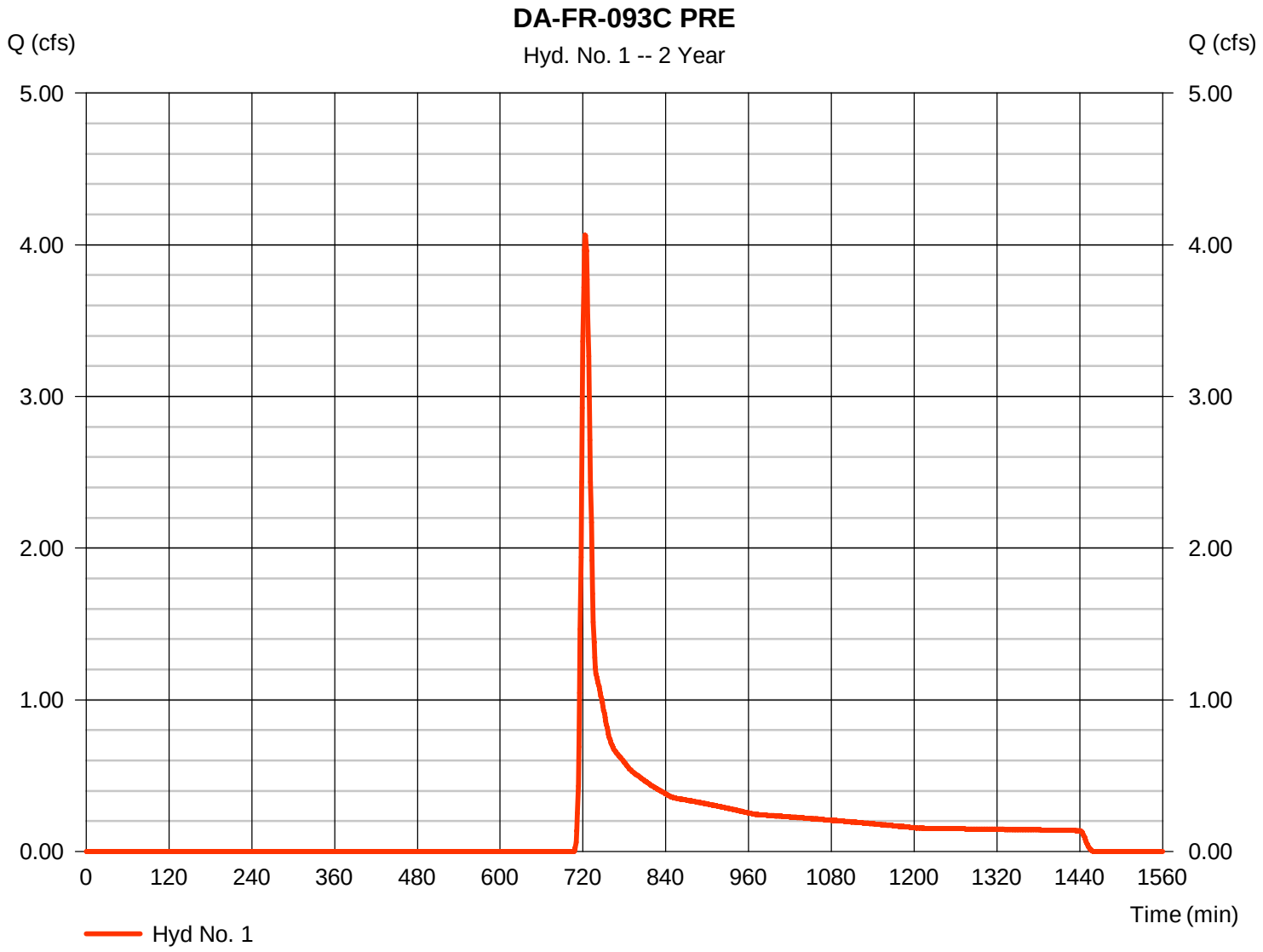
Hydrograph Report

Hyd. No. 1

DA-FR-093C PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 4.063 cfs
Storm frequency	= 2 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 14,908 cuft
Drainage area	= 8.460 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.90 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.095 x 48) + (0.056 x 82) + (3.895 x 58) + (0.007 x 100) + (4.408 x 55)] / 8.460



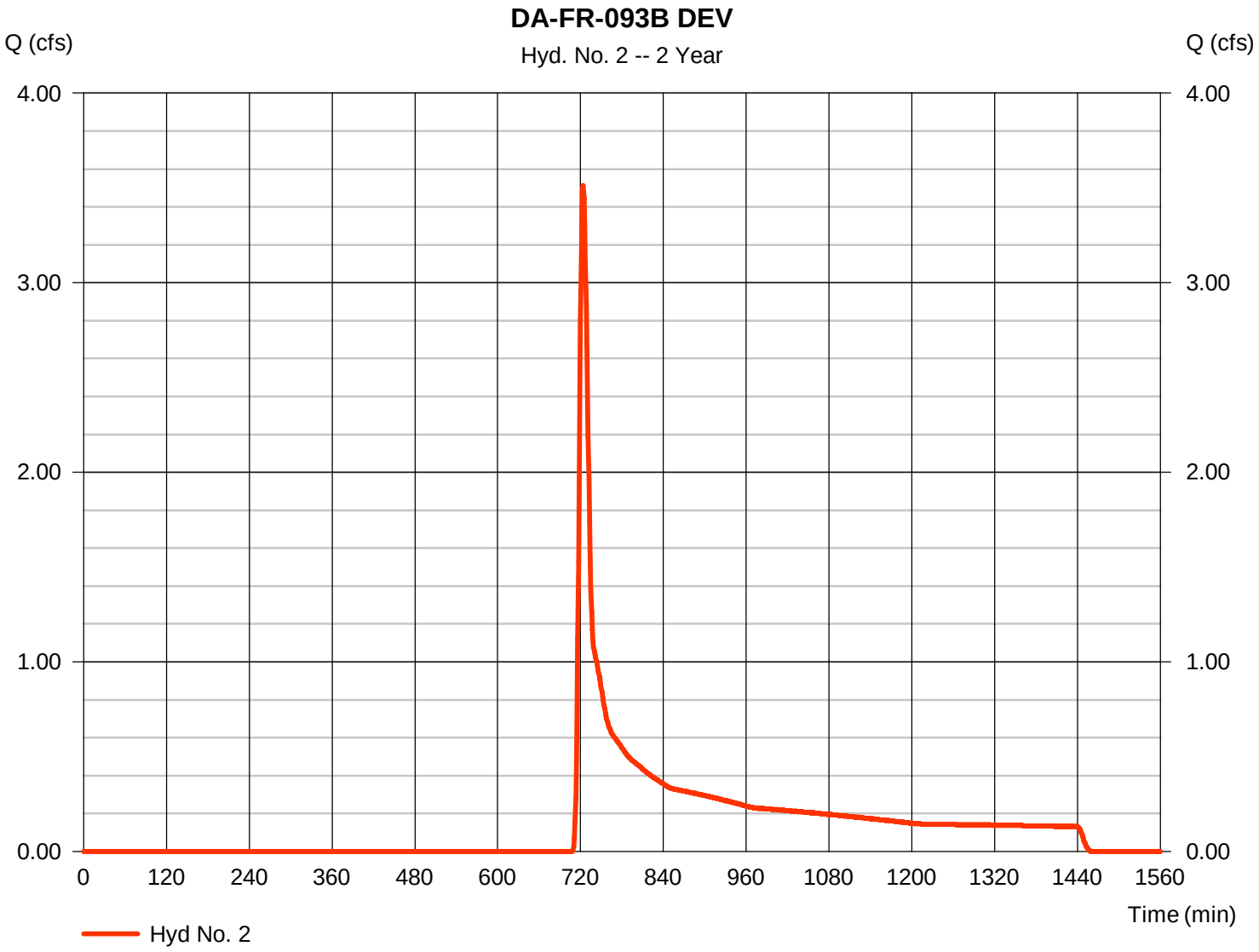
Hydrograph Report

Hyd. No. 2

DA-FR-093B DEV

Hydrograph type	=	SCS Runoff	Peak discharge	=	3.514 cfs
Storm frequency	=	2 yrs	Time to peak	=	724 min
Time interval	=	1 min	Hyd. volume	=	13,714 cuft
Drainage area	=	8.460 ac	Curve number	=	56*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	11.90 min
Total precip.	=	3.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(1.461 x 48) + (0.056 x 82) + (4.635 x 58) + (0.007 x 100) + (2.302 x 55)] / 8.460

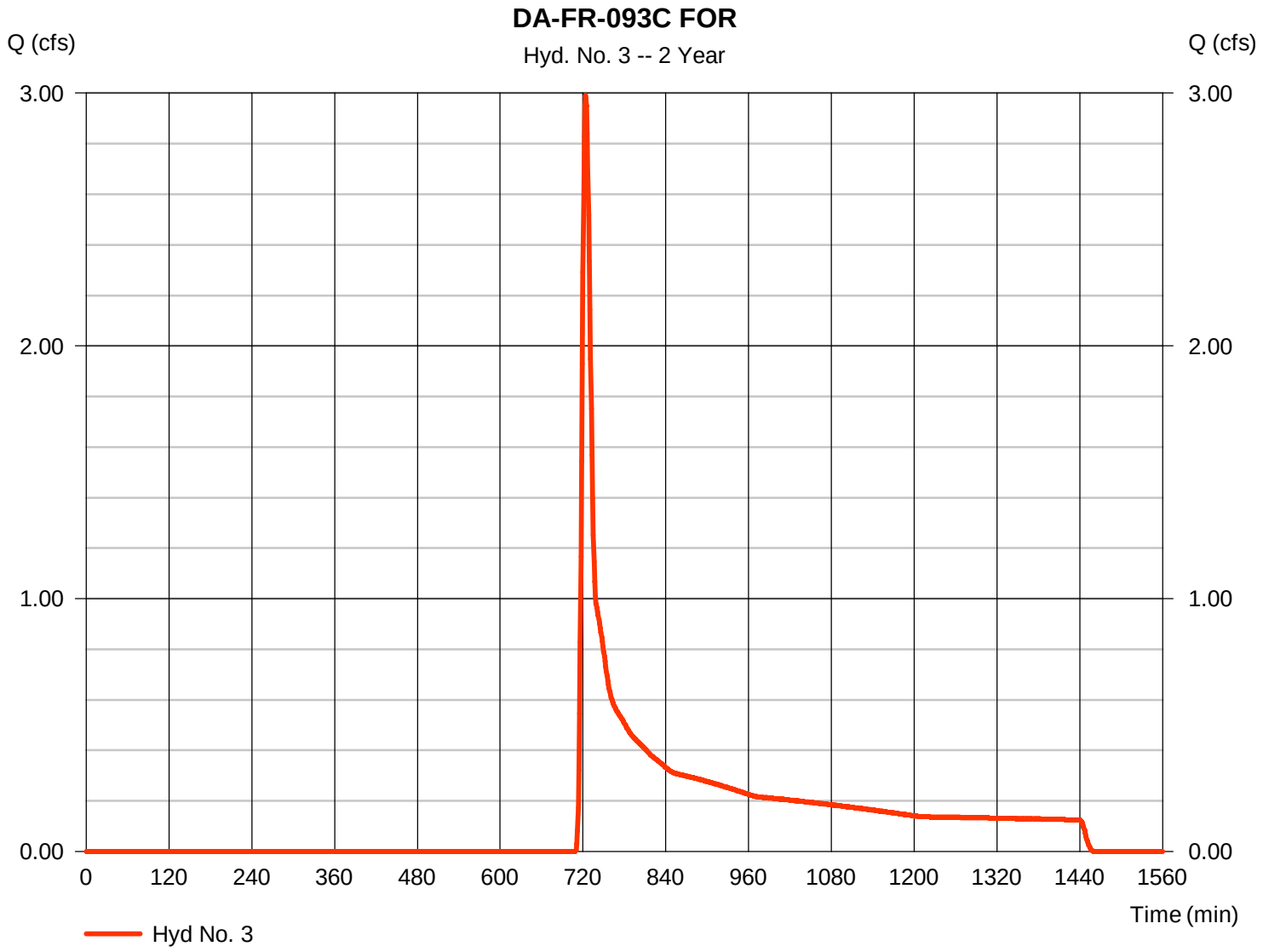


Hydrograph Report

Hyd. No. 3

DA-FR-093C FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 2.990 cfs
Storm frequency	= 2 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 12,563 cuft
Drainage area	= 8.460 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.90 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



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	16.76	1	722	45,252	------	------	------	DA-FR-093C PRE
2	SCS Runoff	15.73	1	722	42,991	------	------	------	DA-FR-093B DEV
3	SCS Runoff	14.71	1	722	40,765	------	------	------	DA-FR-093C FOR

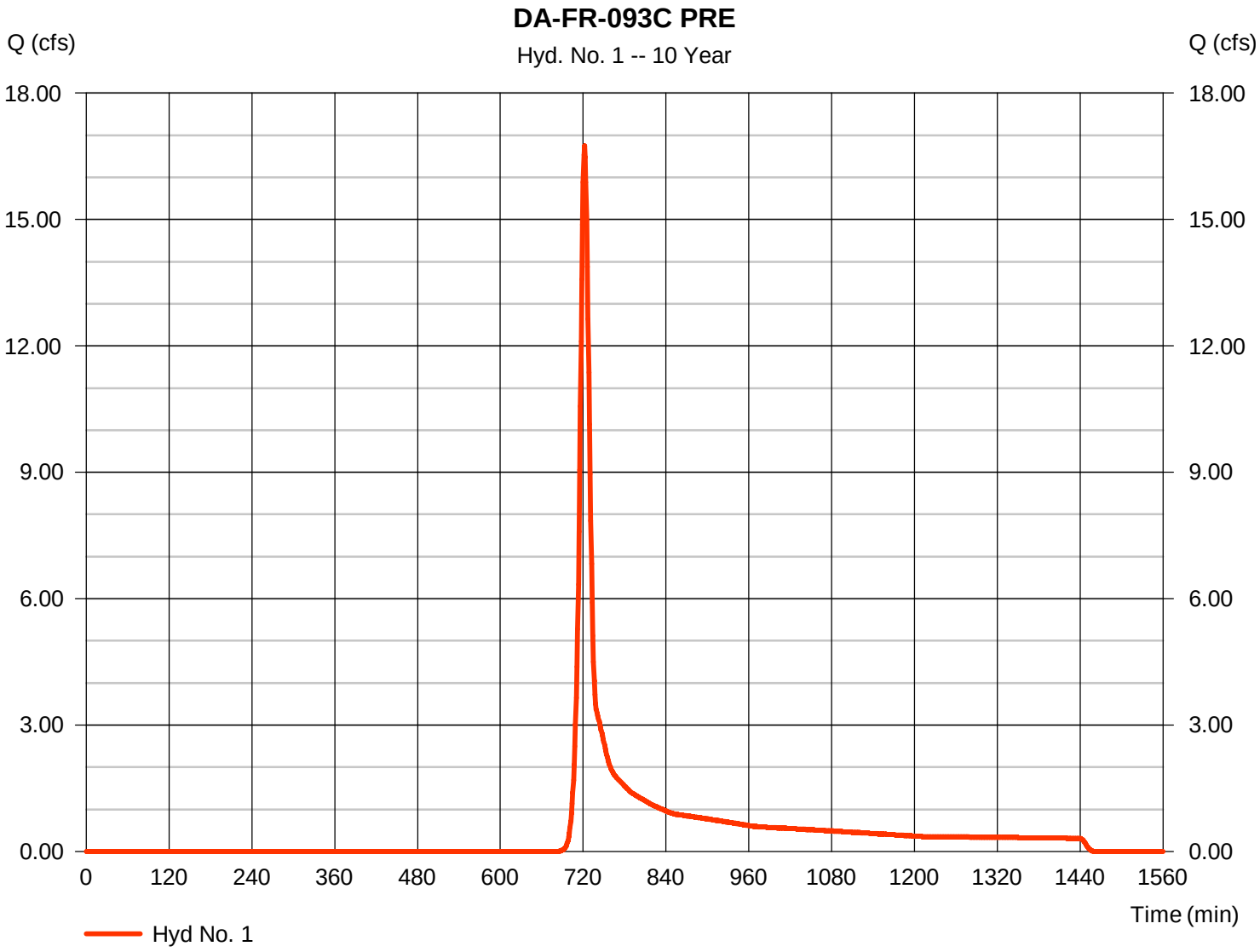
Hydrograph Report

Hyd. No. 1

DA-FR-093C PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	16.76 cfs
Storm frequency	=	10 yrs	Time to peak	=	722 min
Time interval	=	1 min	Hyd. volume	=	45,252 cuft
Drainage area	=	8.460 ac	Curve number	=	57*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	11.90 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.095 x 48) + (0.056 x 82) + (3.895 x 58) + (0.007 x 100) + (4.408 x 55)] / 8.460



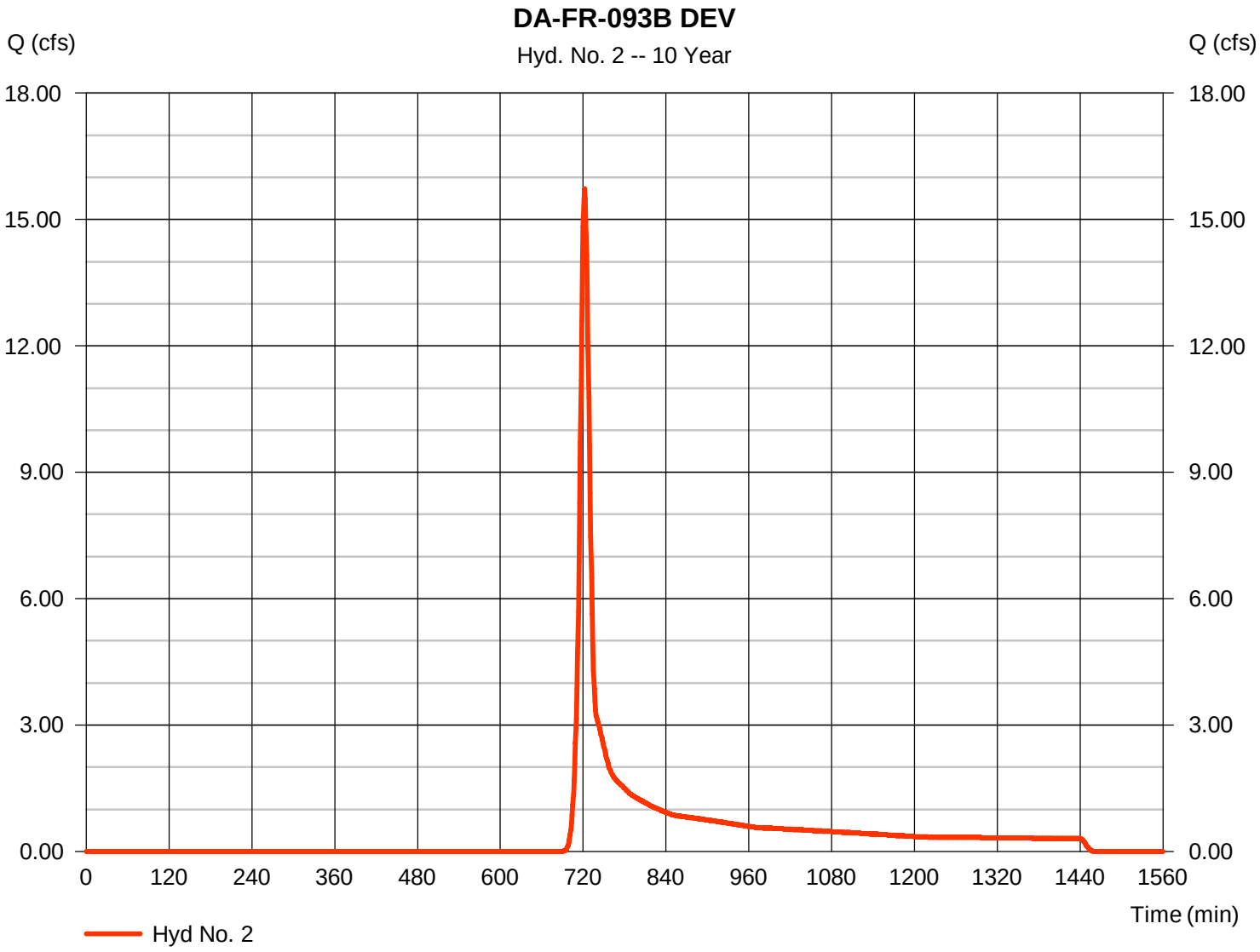
Hydrograph Report

Hyd. No. 2

DA-FR-093B DEV

Hydrograph type	=	SCS Runoff	Peak discharge	=	15.73 cfs
Storm frequency	=	10 yrs	Time to peak	=	722 min
Time interval	=	1 min	Hyd. volume	=	42,991 cuft
Drainage area	=	8.460 ac	Curve number	=	56*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	11.90 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(1.461 x 48) + (0.056 x 82) + (4.635 x 58) + (0.007 x 100) + (2.302 x 55)] / 8.460

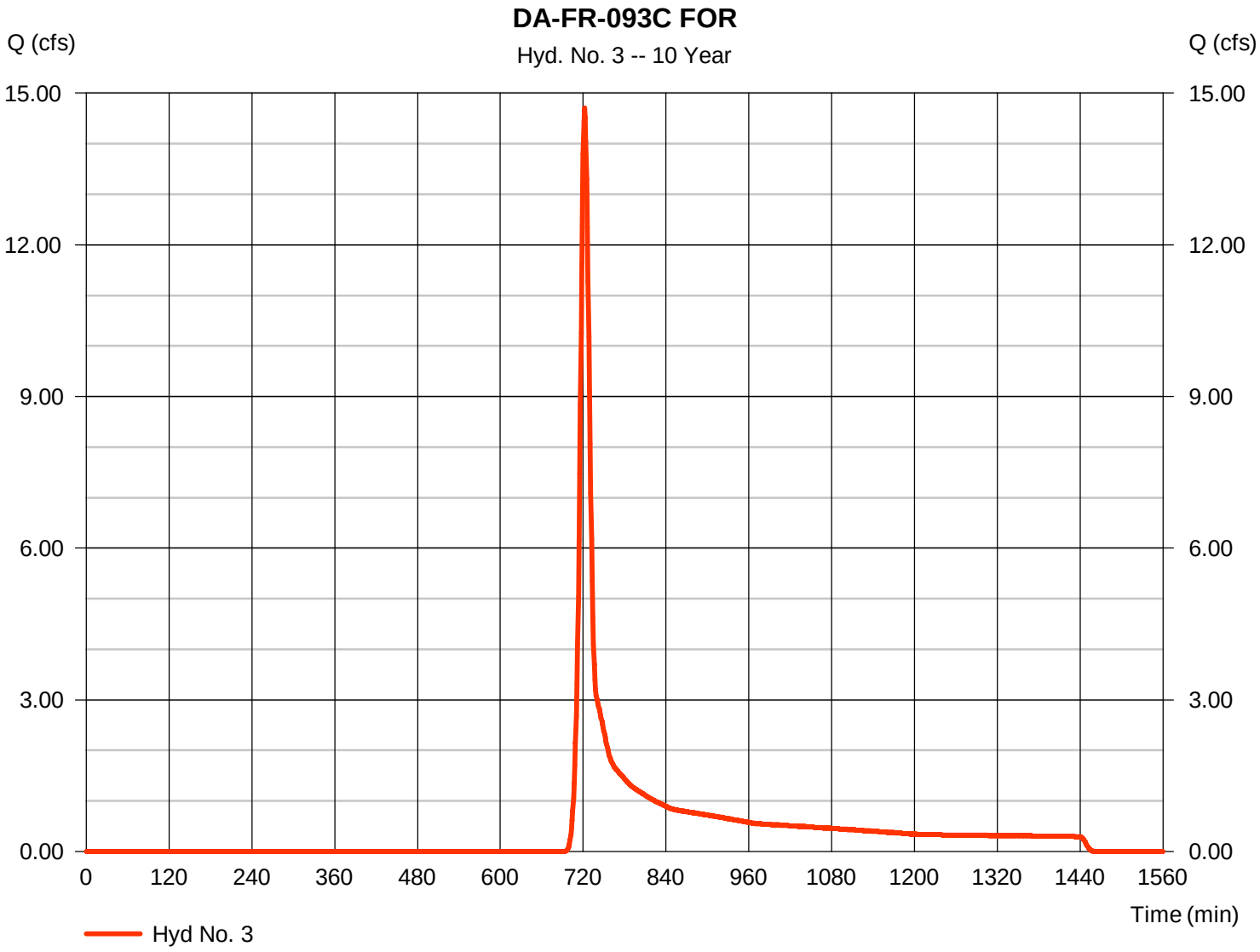


Hydrograph Report

Hyd. No. 3

DA-FR-093C FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 14.71 cfs
Storm frequency	= 10 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 40,765 cuft
Drainage area	= 8.460 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.90 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



Hydraflow Rainfall Report

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

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

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

Tc = time in minutes. Values may exceed 60.

ng\Franklin County\Downloaded Files\Franklin County DA Batch 4 - 046 - 058\Precipitation\Hydraflow\FranklinCo.pc

Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.30	3.70	0.00	0.00	5.70	0.00	0.00	0.00
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

DA-FR-094

DA-FR-094 is located primarily within forested land use with a portion of meadow land use and has hilly slopes. Three unnamed tributaries cross the drainage area. A gravel access road (total area 0.0928 acres) is proposed, but no new impervious area is proposed within DA-FR-094. The total phosphorus load reduction required for DA-FR-094 is -0.74 lb/yr. Multiple points of analysis were evaluated within DA-FR-094 to evaluate the effects on each receiving stream/channel following construction. Specifically DA-FR-094 was sub-divided into four sub-drainage areas (sub-areas A through D).

Sub-area 094A contains both agricultural and non-agricultural areas 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. 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 Right of Way (ROW) is analyzed via VRRM; in these calculations agricultural areas are considered “Forest/Open Space”.

Stormwater quantity is met via the energy balance method for each of the four sub-areas DA-FR-094A, DA-FR-094B, DA-FR-094C and DA-FR-094D. Agricultural areas within the study area are included in the SWM analysis, but an Improvement Factor (IF) of 1.0 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. DA-FR-094B and DA-FR-094C are less than an acre in size and used an IF of 0.9, and DA-FR-094D is more than an acre and used an IF of 0.8.

In addition, the Hydraflow Hydrograph’s 10-year 24-hour peak discharge results indicate a reduction in flows ranging from 0.06 to 1.23 cfs for all drainage areas (as seen in table below).

Sub Area	Pre Peak Flow, 10-yr Q (cfs)	Post Peak Flow, Q 10-yr (cfs)	Flow differential
DA-FR-094A	9.55	8.50	-1.05
DA-FR-094B	0.18	0.11	-0.07
DA-FR-094C	0.45	0.39	-0.06
DA-FR-094D	2.87	1.64	-1.23

Figures and calculations for each of the sub-areas for DA-FR-094 follow. See Appendix D of the Annual Standards and Specifications for further detail on stormwater methodology.

Note that the sub-area 094A had a time of concentration flow path for the Post-Construction condition that accounted for a permanent water bar that is not cited within the drainage area. This permanent water bar was removed because it was cited 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-FR-094A, so the resulting changes were not made to the stormwater calculations prior to submittal.

DA-FR-094A
5.77 acres
Weighted CN = 57

DA-FR-094B
0.08 acres
Weighted CN = 59

DA-FR-094C
0.21 acres
Weighted CN = 57

DA-FR-094D
1.86 acres
Weighted CN = 55

272.8
272.9
273.0
273.1
1000
1050
299
S-GH36
S-GH37
S-GH38
S-KL17
S-GH39
B

LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Dirt Road	B	82	0.003	DA-FR-094A
Meadow	B	58	3.31	
Waterbody	B	100	0.003	
Woods - Good	B	55	2.45	
Waterbody	B	100	0.01	DA-FR-094B
Woods - Good	B	55	0.07	
Waterbody	B	100	0.01	DA-FR-094C
Woods - Good	B	55	0.20	
Waterbody	B	100	0.004	DA-FR-094D
Woods - Good	B	55	1.85	

Legend

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

NAD 1983 UTM 17N (feet)

1:1,800

N W E S

150 75 0 150 Feet



Mountain Valley Pipeline Project

Mountain Valley PIPELINE

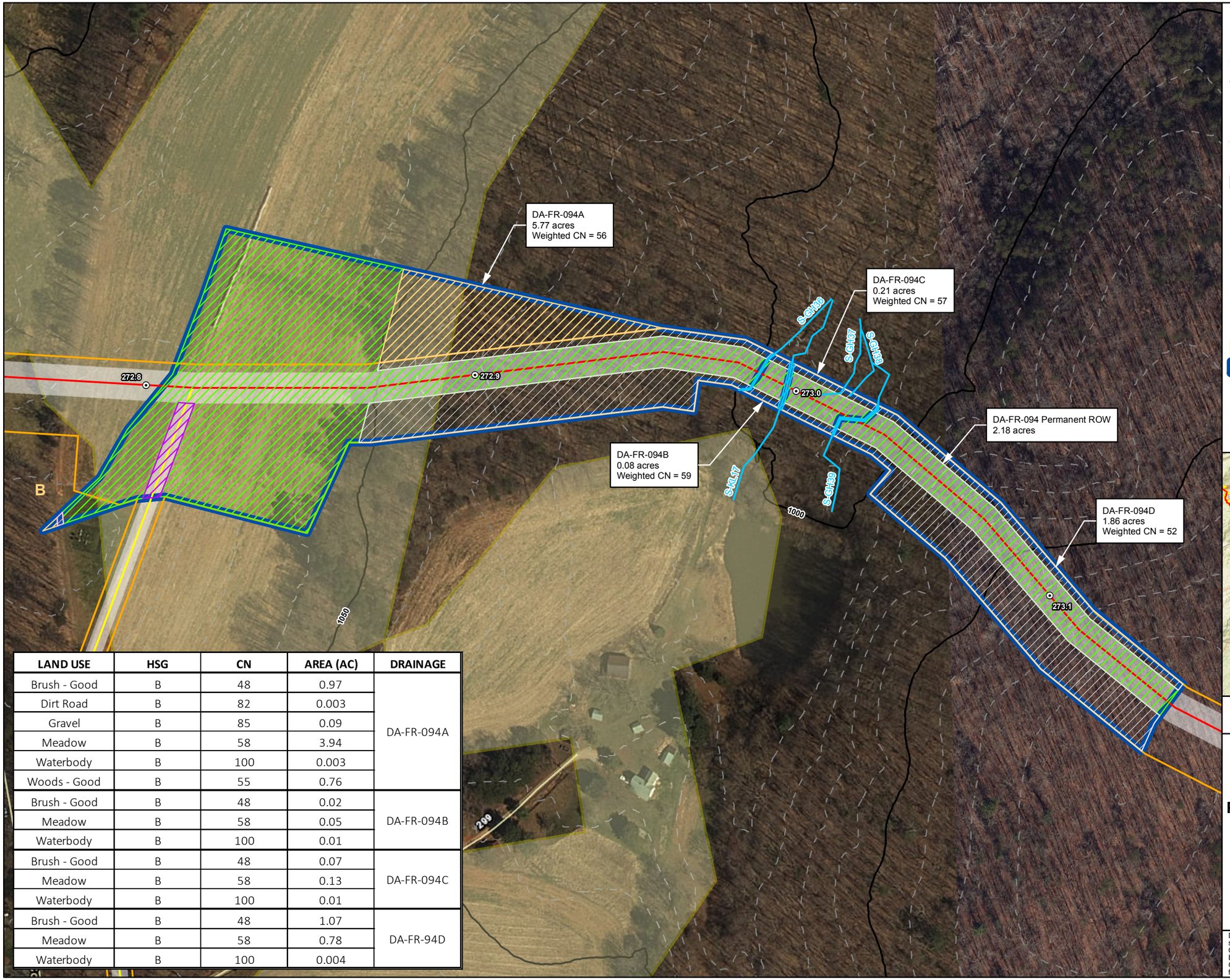
Pre-Construction Drainage Area Map
DA-FR-094
Spread 11

Figure 1
Franklin County, Virginia

August, 2017

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

Document Path: P:\GIS\EQT_MVP\MapdocsIDrainage\MXD\FranklinIMVP_PCSM_DA-FR-094_Pre.mxd



LAND USE	HSG	CN	AREA (AC)	DRAINAGE
Brush - Good	B	48	0.97	DA-FR-094A
Dirt Road	B	82	0.003	
Gravel	B	85	0.09	
Meadow	B	58	3.94	
Waterbody	B	100	0.003	
Woods - Good	B	55	0.76	
Brush - Good	B	48	0.02	DA-FR-094B
Meadow	B	58	0.05	
Waterbody	B	100	0.01	
Brush - Good	B	48	0.07	DA-FR-094C
Meadow	B	58	0.13	
Waterbody	B	100	0.01	
Brush - Good	B	48	1.07	DA-FR-94D
Meadow	B	58	0.78	
Waterbody	B	100	0.004	

Legend

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

NAD 1983 UTM 17N (feet)

1:1,800

150 75 0 150 Feet

N W E S



Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Post-Construction Drainage Area Map
DA-FR-094
Spread 11

Figure 2
Franklin County, Virginia

September, 2017

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

Document Path: PGH P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Franklin\MVP_PCSM_DA-FR-094_Post.mxd

DA-FR-094A
5.77 acres
Weighted CN = 57

DA-FR-094B
0.08 acres
Weighted CN = 59

DA-FR-094C
0.21 acres
Weighted CN = 57

DA-FR-094D
1.86 acres
Weighted CN = 55

272.8
272.9
273.0
273.1
1000
1050
S-CH36
S-CH37
S-CH38
S-CH39
S-CH40
S-CH41
S-CH42
S-CH43
S-CH44
S-CH45
S-CH46
S-CH47

PRE-CONSTRUCTION TIME OF CONCENTRATION TO POI

	SHEET	SHALLOW	CHANNEL	Calculated Time of Concentration (min)
DA-FR-094A	100.00 FT @ 4.18%	738.42 FT @ 8.70%	325.48 FT @ 6.19%	18.1
DA-FR-094B	89.21 FT @ 4.68%	-	-	13.0
DA-FR-094C	100.00 FT @ 9.01%	4.23 FT @ 0.09%	-	11.1
DA-FR-094D	100.00 FT @ 4.69%	629.39 FT @ 15.50%	-	15.9

Legend

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

NAD 1983 UTM 17N (feet)

1:1,800

N W E S

150 75 0 150 Feet



Mountain Valley Pipeline Project

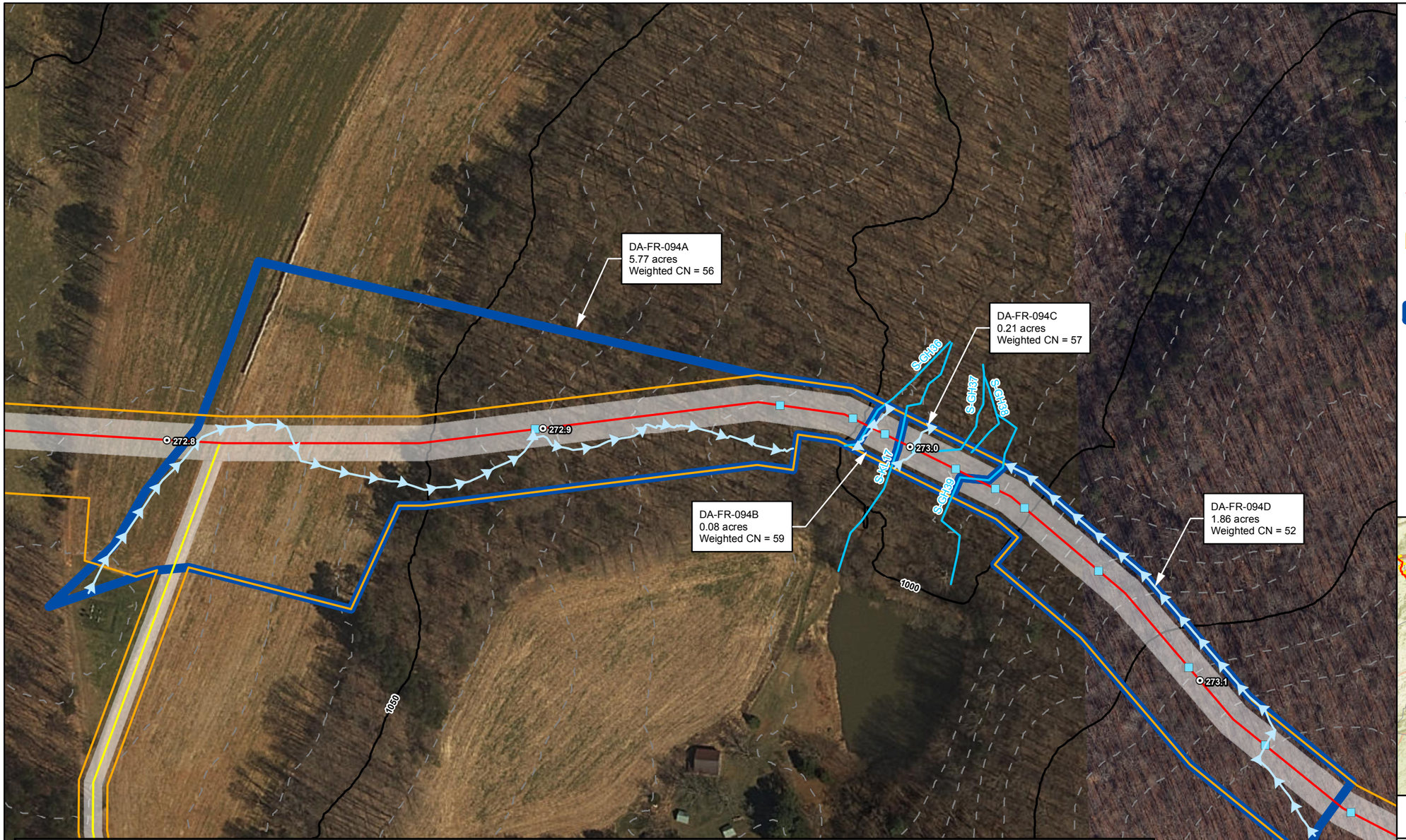
Mountain Valley PIPELINE

Pre-Construction Drainage Area and Time of Concentration
DA-FR-094
Spread 11

Figure 3
Franklin 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.

Document Path: P:\GIS\EQT_MVP\Mapdocs\Drainage\MXD\Franklin\Figures 3-4\MVP_PCSM_DA-FR-094_3.mxd



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)

1:1,800

N W E S

150 75 0 150 Feet



POST-CONSTRUCTION TIME OF CONCENTRATION TO POI

	SHEET1	SHEET2	SHEET3	SHALLOW1	SHALLOW2	SHALLOW3	CHANNEL1	CHANNEL2	CHANNEL3	Calculated Time of Concentration (min)
DA-FR-094A	100.00 FT @ 4.18%	-	-	293.85 FT @ 4.99%	372.93 FT @ 10.63%	143.65 FT @ 8.81%	52.54 FT @ 5.01%	17.69 FT @ 5.24%	231.14 FT @ 6.01%	18.6
DA-FR-094B	16.88 FT @ 0.30%	58.10 FT @ 4.04%	14.23 FT @ 12.46%	-	-	-	-	-	-	31.2
DA-FR-094C	13.20 FT @ 5.18%	25.16 FT @ 6.16%	16.65 FT @ 7.63%	-	-	-	29.42 FT @ 5.01%	-	-	13.9
DA-FR-094D	100.00 FT @ 4.69%	-	-	34.25 FT @ 9.47%	540.57 FT @ 17.01%	-	47.37 FT @ 4.93%	-	-	26.4

Mountain Valley Pipeline Project

Mountain Valley PIPELINE

Post-Construction Drainage Area and Time of Concentration
DA-FR-094
Spread 11

Figure 4
Franklin 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\Franklin\Figures 3-4\MVP_PCSM_DA-FR-094_4.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	2.18	0.00	0.00	2.18	*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*
					2.18	*100.00*

Site Rv	0.03
Post Development Treatment Volume (ft3)	237
Post Development TP Load (lb/yr)	0.16
Post Development TN Load (lb/yr)	1.12
Total TP Load Reduction Required (lb/yr)	-0.74

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)	0.16
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)	2.18	0.00	0.00	0.00	0.00	*2.18*
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*
						2.18

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-FR-094A

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	1.266	7115
Developed Condition	0.980	6527
Pre-Developed (Forest) Condition	0.829	5820

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

Improvement Factor, IF = 1

Calculations:

Check #1: $Q_{developed} \leq IF \times [(Q_{pre\text{-}developed} \times RV_{pre\text{-}developed}) / RV_{developed}]$ ----------> 0.980 ≤ 1.380 OK

Check #2: $Q_{developed} \leq Q_{pre\text{-}developed}$ ----------> 0.980 ≤ 1.266 OK

Check #3: $Q_{developed}$ *shall not* be required to be ≤ $(Q_{forest} \times RV_{forest}) / RV_{developed}$ ---> 0.980 *shall not* be required to be ≤ 0.739

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

Note:

Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.

For Paved Road land surface types a Manning's n value 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 Channels[1]			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels[2]			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150

Notes:

[1]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 or grass channel.

[2]For the pre-developed condition (if applicable), 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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Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5 Tuesday, 08 / 15 / 2017

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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-FR-094A PRE
2	SCS Runoff	DA-FR-094A DEV
3	SCS Runoff	DA-FR-094A FOR

Hydrograph Return Period Recap

Hyd. No.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)							Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	------	1.266	2.247	-------	-------	9.554	-------	-------	-------	DA-FR-094A PRE
2	SCS Runoff	------	0.980	1.826	-------	-------	8.498	-------	-------	-------	DA-FR-094A DEV
3	SCS Runoff	------	0.829	1.642	-------	-------	8.336	-------	-------	-------	DA-FR-094A FOR

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	1.266	1	728	7,115	------	------	------	DA-FR-094A PRE
2	SCS Runoff	0.980	1	729	6,527	------	------	------	DA-FR-094A DEV
3	SCS Runoff	0.829	1	729	5,820	------	------	------	DA-FR-094A FOR

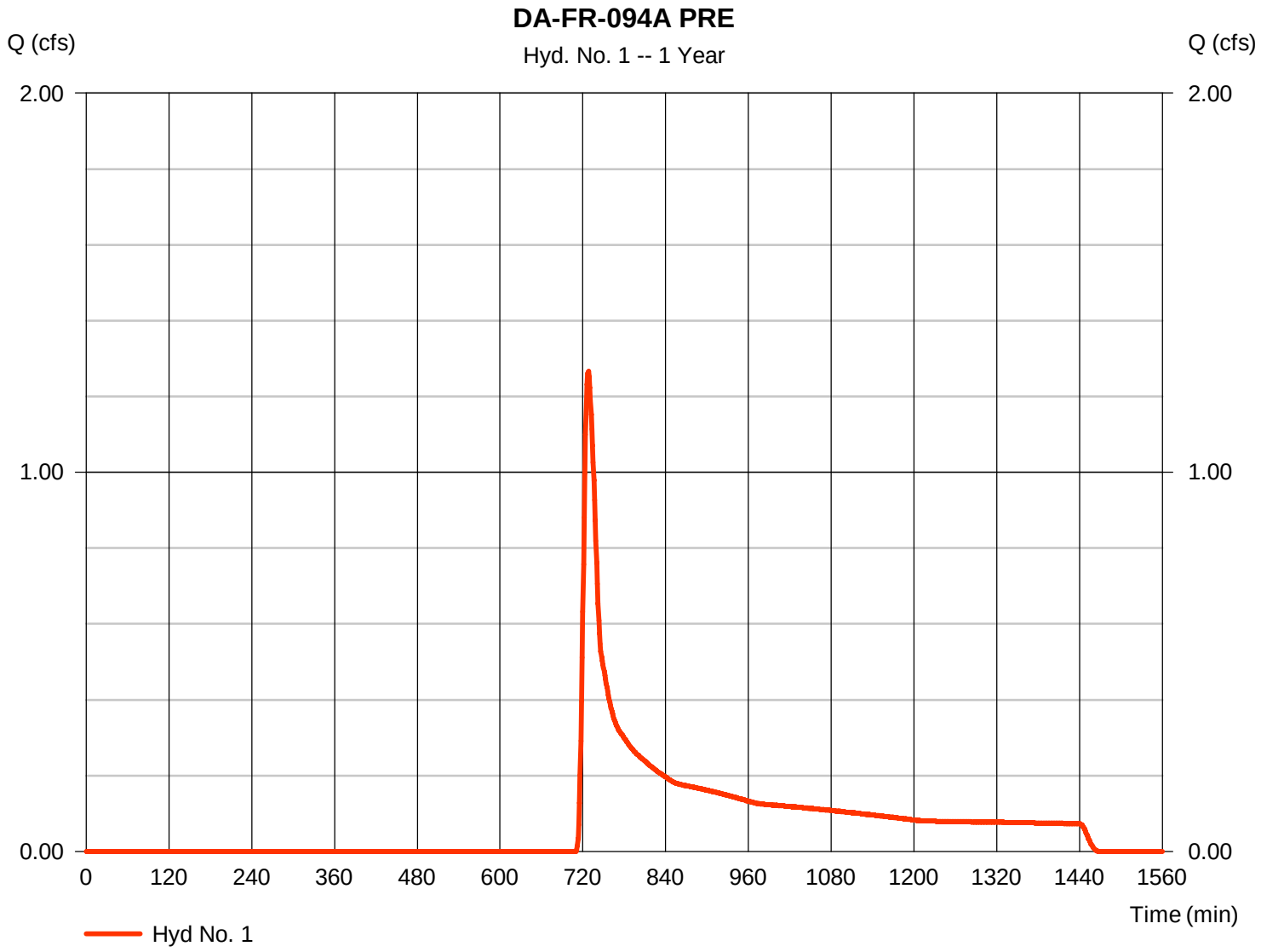
Hydrograph Report

Hyd. No. 1

DA-FR-094A PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	1.266 cfs
Storm frequency	=	1 yrs	Time to peak	=	728 min
Time interval	=	1 min	Hyd. volume	=	7,115 cuft
Drainage area	=	5.770 ac	Curve number	=	57*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	18.10 min
Total precip.	=	3.30 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.003 x 82) + (3.311 x 58) + (0.003 x 100) + (2.452 x 55)] / 5.770



TR55 Tc Worksheet

Hyd. No. 1

DA-FR-094A PRE

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 4.18		0.00		0.00		
Travel Time (min)	**= 14.87**	**+**	**0.00**	**+**	**0.00**	**=**	**14.87**
Shallow Concentrated Flow							
Flow length (ft)	= 738.42		0.00		0.00		
Watercourse slope (%)	= 8.70		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=4.76		0.00		0.00		
Travel Time (min)	**= 2.59**	**+**	**0.00**	**+**	**0.00**	**=**	**2.59**
Channel Flow							
X sectional flow area (sqft)	= 8.96		0.00		0.00		
Wetted perimeter (ft)	= 17.45		0.00		0.00		
Channel slope (%)	= 6.19		0.00		0.00		
Manning's n-value	= 0.030		0.015		0.015		
Velocity (ft/s)	=7.91						
			0.00				
					0.00		
Flow length (ft)	({0})325.5		0.0		0.0		
Travel Time (min)	**= 0.69**	**+**	**0.00**	**+**	**0.00**	**=**	**0.69**

Total Travel Time, Tc ..... 18.10 min

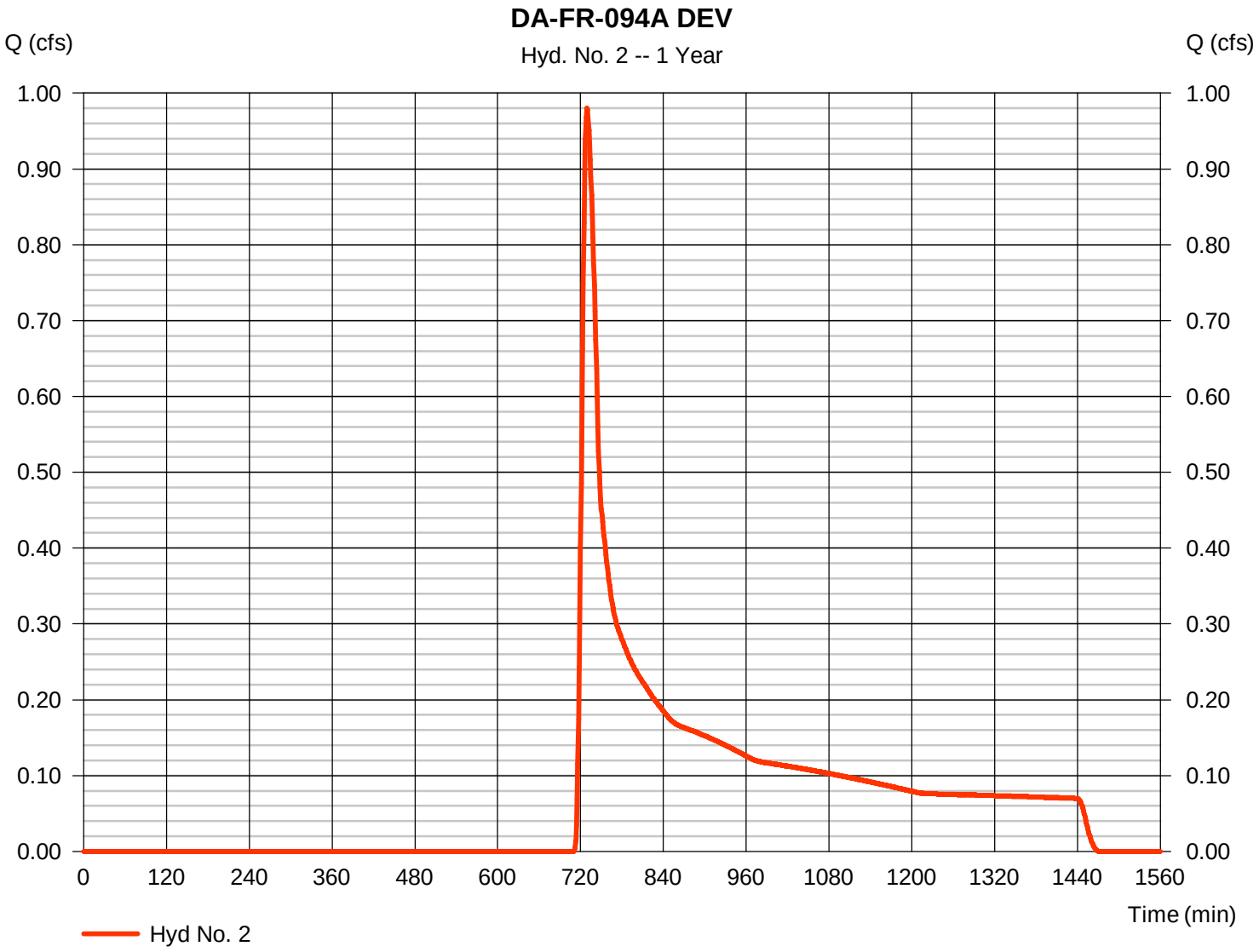
Hydrograph Report

Hyd. No. 2

DA-FR-094A DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.980 cfs
Storm frequency	= 1 yrs	Time to peak	= 729 min
Time interval	= 1 min	Hyd. volume	= 6,527 cuft
Drainage area	= 5.770 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.60 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.975 x 48) + (0.003 x 82) + (0.093 x 85) + (3.937 x 58) + (0.003 x 100) + (0.759 x 55)] / 5.770



TR55 Tc Worksheet

Hyd. No. 2

DA-FR-094A DEV

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 4.18		0.00		0.00		
Travel Time (min)	**= 14.87**	**+**	**0.00**	**+**	**0.00**	**=**	**14.87**
Shallow Concentrated Flow							
Flow length (ft)	= 293.85		372.93		143.65		
Watercourse slope (%)	= 4.99		10.63		8.81		
Surface description	= Unpaved		Unpaved		Unpaved		
Average velocity (ft/s)	=3.60		5.26		4.79		
Travel Time (min)	**= 1.36**	**+**	**1.18**	**+**	**0.50**	**=**	**3.04**
Channel Flow							
X sectional flow area (sqft)	= 2.00		2.00		8.96		
Wetted perimeter (ft)	= 4.47		4.47		17.45		
Channel slope (%)	= 5.00		5.00		6.01		
Manning's n-value	= 0.040		0.040		0.030		
Velocity (ft/s)	=4.86						
			4.86				
					7.79		
Flow length (ft)	({0})52.5		17.7		231.1		
Travel Time (min)	**= 0.18**	**+**	**0.06**	**+**	**0.49**	**=**	**0.74**

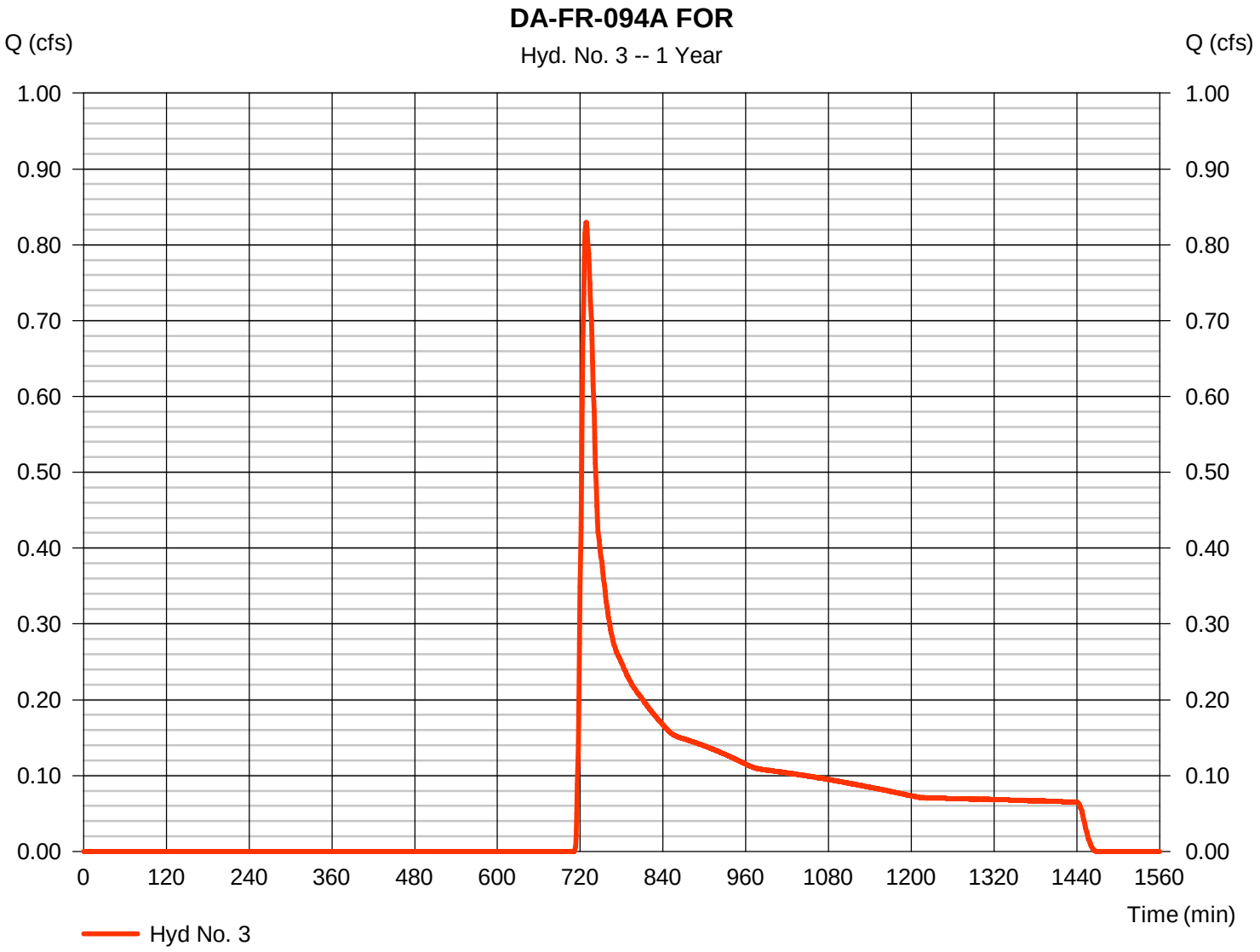
Total Travel Time, Tc ..... 18.60 min

Hydrograph Report

Hyd. No. 3

DA-FR-094A FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.829 cfs
Storm frequency	= 1 yrs	Time to peak	= 729 min
Time interval	= 1 min	Hyd. volume	= 5,820 cuft
Drainage area	= 5.770 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.10 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



TR55 Tc Worksheet

Hyd. No. 3

DA-FR-094A FOR

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 4.18		0.00		0.00		
Travel Time (min)	**= 14.87**	**+**	**0.00**	**+**	**0.00**	**=**	**14.87**
Shallow Concentrated Flow							
Flow length (ft)	= 738.85		0.00		0.00		
Watercourse slope (%)	= 8.70		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=4.76		0.00		0.00		
Travel Time (min)	**= 2.59**	**+**	**0.00**	**+**	**0.00**	**=**	**2.59**
Channel Flow							
X sectional flow area (sqft)	= 8.96		0.00		0.00		
Wetted perimeter (ft)	= 17.45		0.00		0.00		
Channel slope (%)	= 6.19		0.00		0.00		
Manning's n-value	= 0.030		0.015		0.015		
Velocity (ft/s)	=7.91						
			0.00				
					0.00		
Flow length (ft)	({0})325.5		0.0		0.0		
Travel Time (min)	**= 0.69**	**+**	**0.00**	**+**	**0.00**	**=**	**0.69**

Total Travel Time, Tc ..... 18.10 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	2.247	1	727	10,211	------	------	------	DA-FR-094A PRE
2	SCS Runoff	1.826	1	728	9,502	------	------	------	DA-FR-094A DEV
3	SCS Runoff	1.642	1	727	8,605	------	------	------	DA-FR-094A FOR

Hydrograph Report

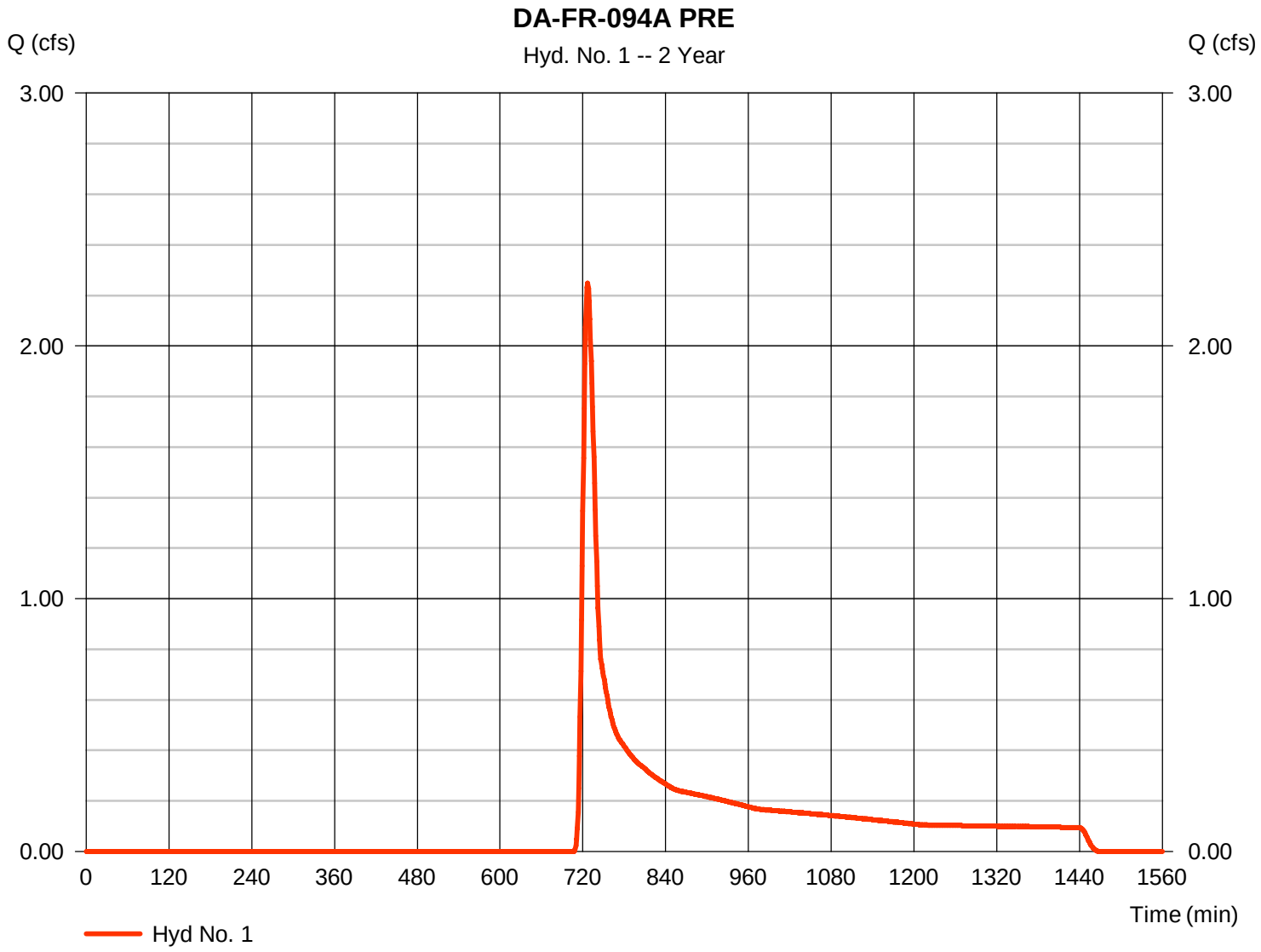
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2016 by Autodesk, Inc. v10.5 Tuesday, 08 / 15 / 2017

Hyd. No. 1

DA-FR-094A PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	2.247 cfs
Storm frequency	=	2 yrs	Time to peak	=	727 min
Time interval	=	1 min	Hyd. volume	=	10,211 cuft
Drainage area	=	5.770 ac	Curve number	=	57*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	18.10 min
Total precip.	=	3.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.003 x 82) + (3.311 x 58) + (0.003 x 100) + (2.452 x 55)] / 5.770



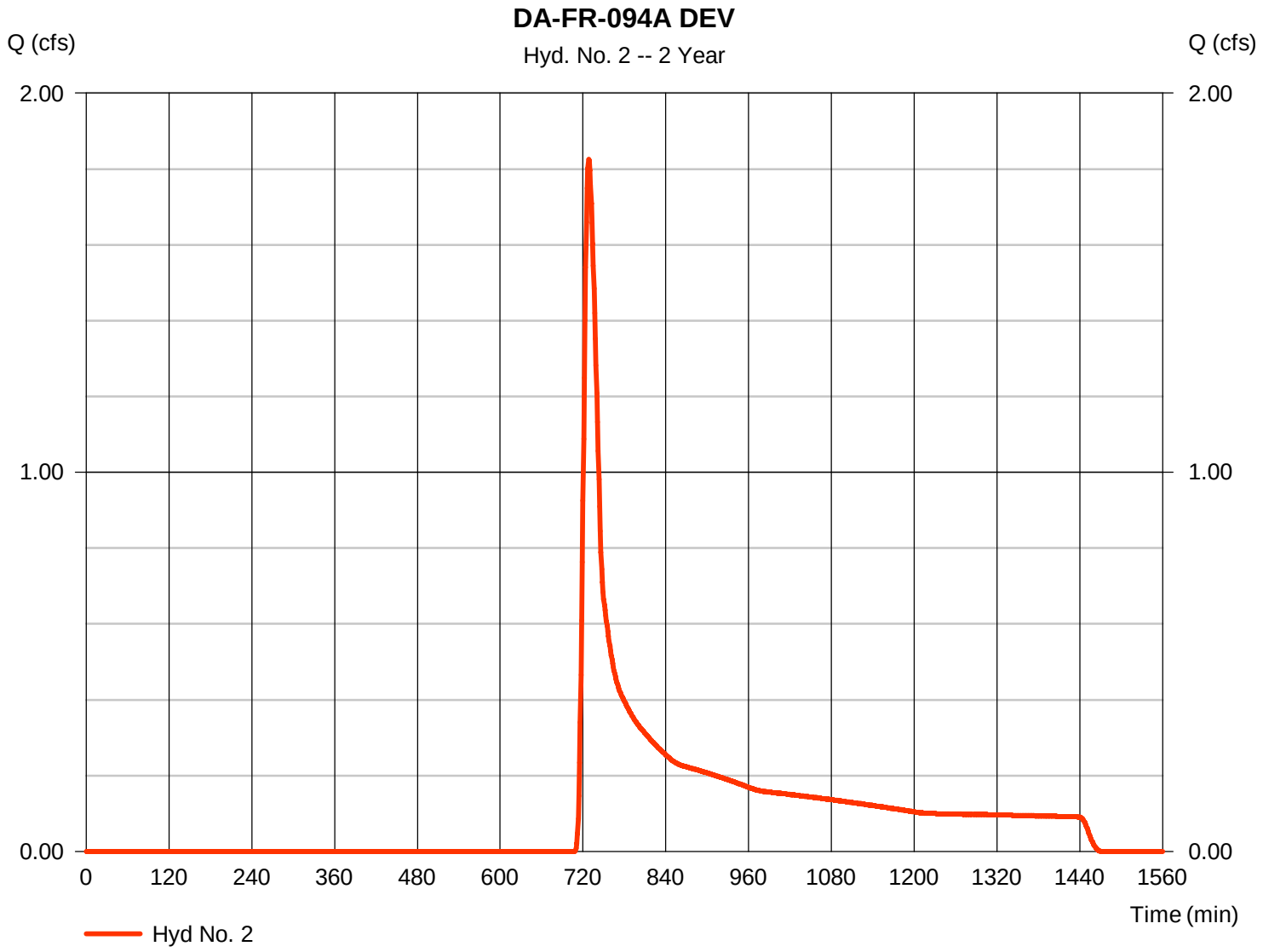
Hydrograph Report

Hyd. No. 2

DA-FR-094A DEV

Hydrograph type	=	SCS Runoff	Peak discharge	=	1.826 cfs
Storm frequency	=	2 yrs	Time to peak	=	728 min
Time interval	=	1 min	Hyd. volume	=	9,502 cuft
Drainage area	=	5.770 ac	Curve number	=	56*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	18.60 min
Total precip.	=	3.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.975 x 48) + (0.003 x 82) + (0.093 x 85) + (3.937 x 58) + (0.003 x 100) + (0.759 x 55)] / 5.770

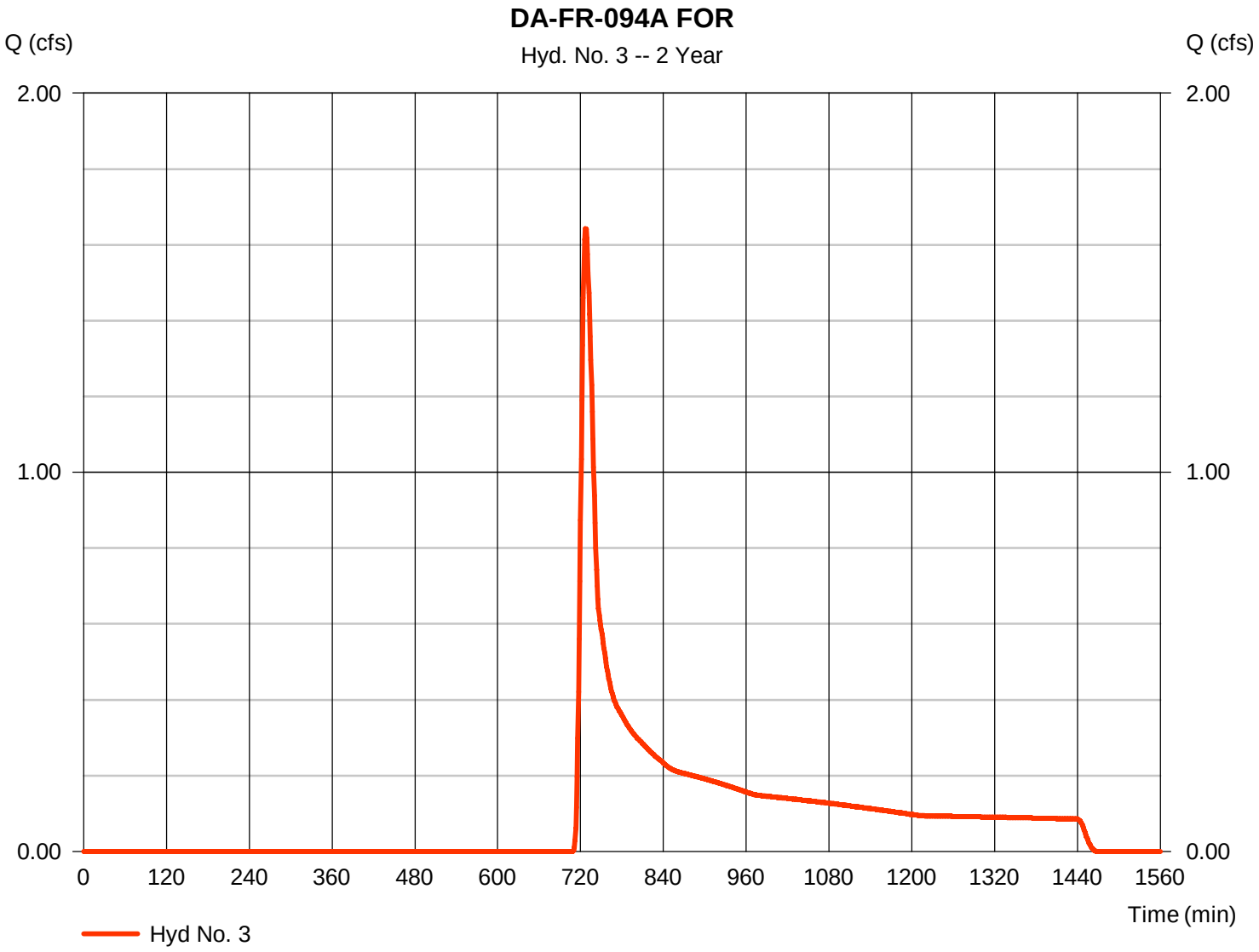


Hydrograph Report

Hyd. No. 3

DA-FR-094A FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 1.642 cfs
Storm frequency	= 2 yrs	Time to peak	= 727 min
Time interval	= 1 min	Hyd. volume	= 8,605 cuft
Drainage area	= 5.770 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.10 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



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	9.554	1	725	30,997	------	------	------	DA-FR-094A PRE
2	SCS Runoff	8.498	1	726	29,786	------	------	------	DA-FR-094A DEV
3	SCS Runoff	8.336	1	725	27,924	------	------	------	DA-FR-094A FOR

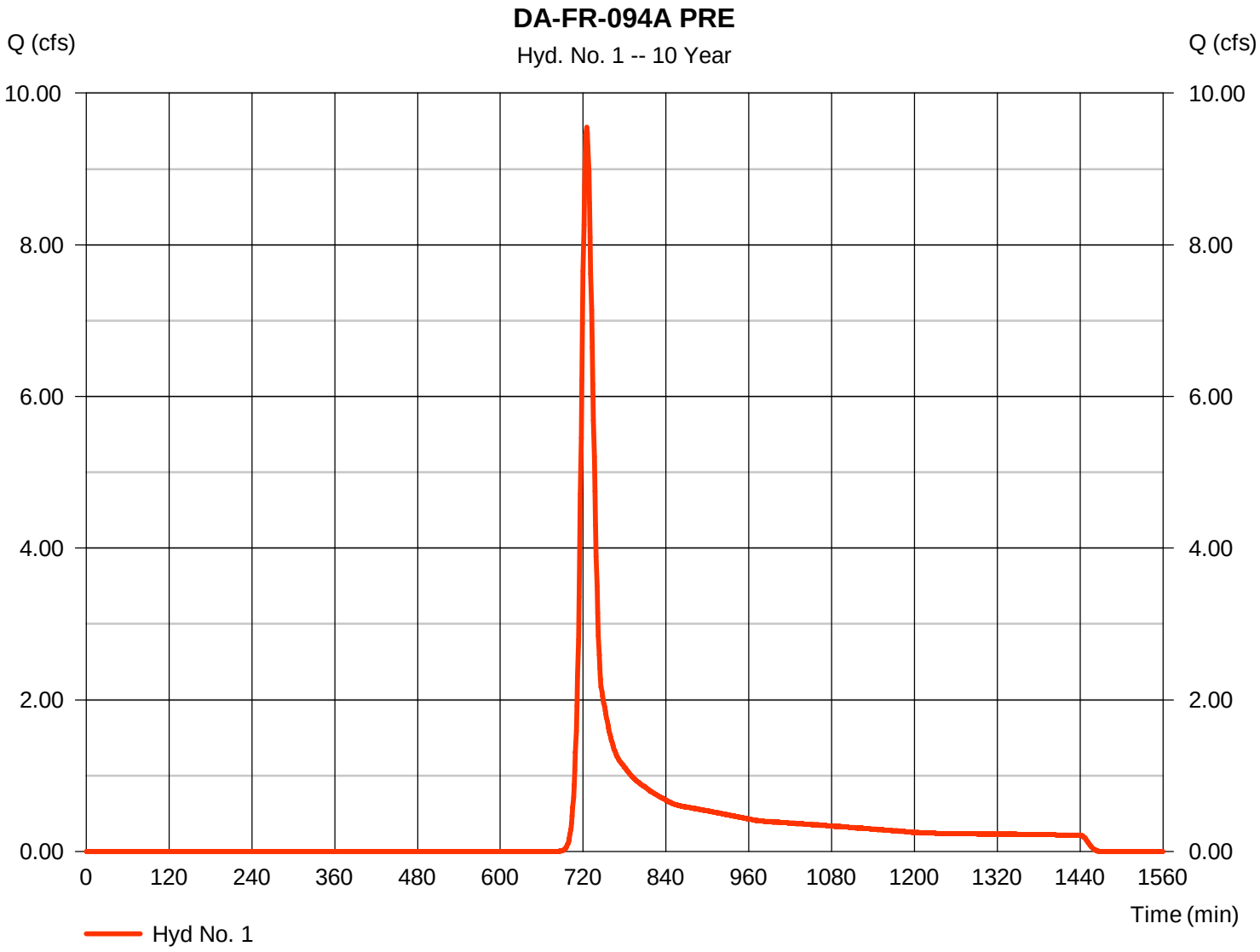
Hydrograph Report

Hyd. No. 1

DA-FR-094A PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	9.554 cfs
Storm frequency	=	10 yrs	Time to peak	=	725 min
Time interval	=	1 min	Hyd. volume	=	30,997 cuft
Drainage area	=	5.770 ac	Curve number	=	57*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	18.10 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.003 x 82) + (3.311 x 58) + (0.003 x 100) + (2.452 x 55)] / 5.770



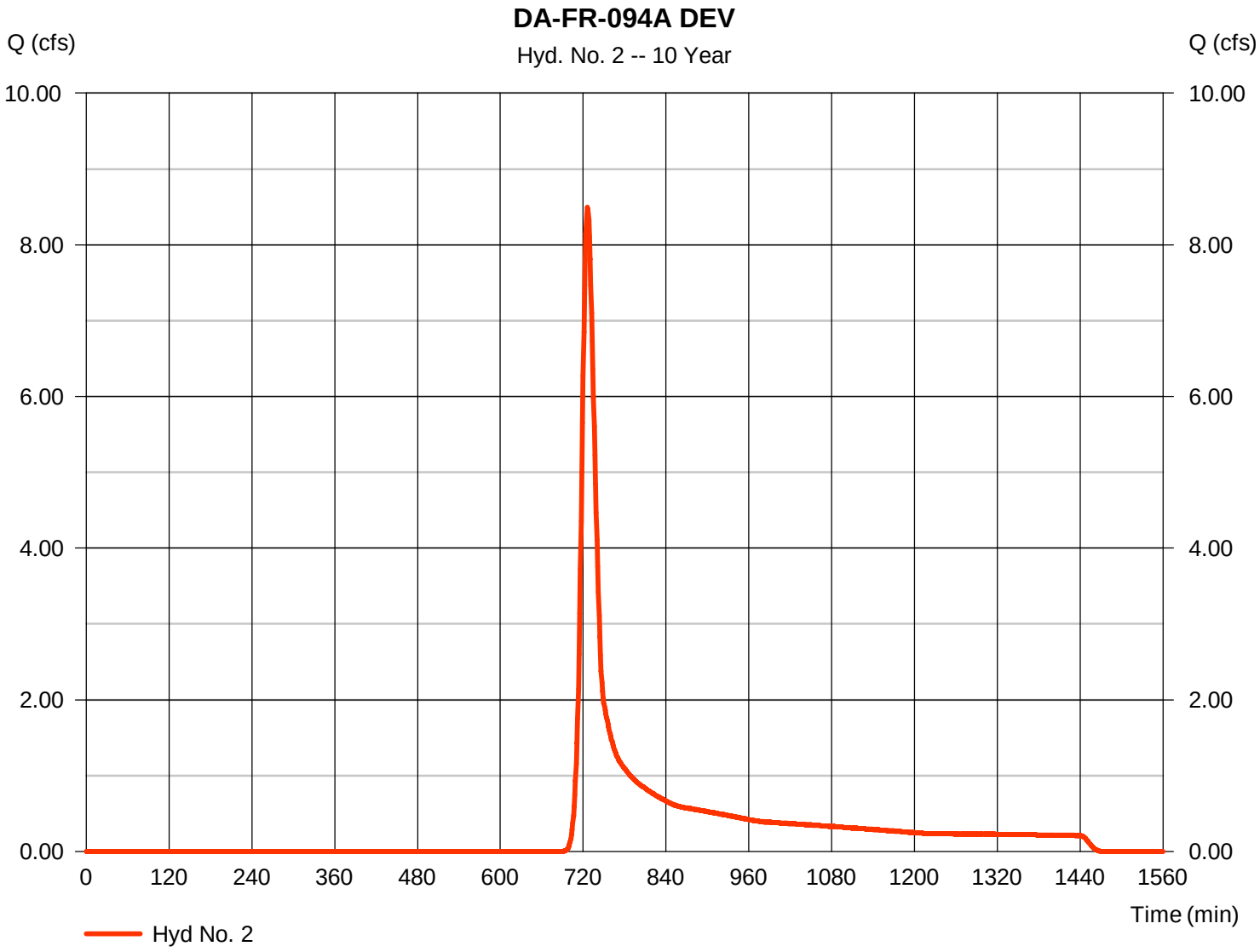
Hydrograph Report

Hyd. No. 2

DA-FR-094A DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 8.498 cfs
Storm frequency	= 10 yrs	Time to peak	= 726 min
Time interval	= 1 min	Hyd. volume	= 29,786 cuft
Drainage area	= 5.770 ac	Curve number	= 56*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.60 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.975 x 48) + (0.003 x 82) + (0.093 x 85) + (3.937 x 58) + (0.003 x 100) + (0.759 x 55)] / 5.770

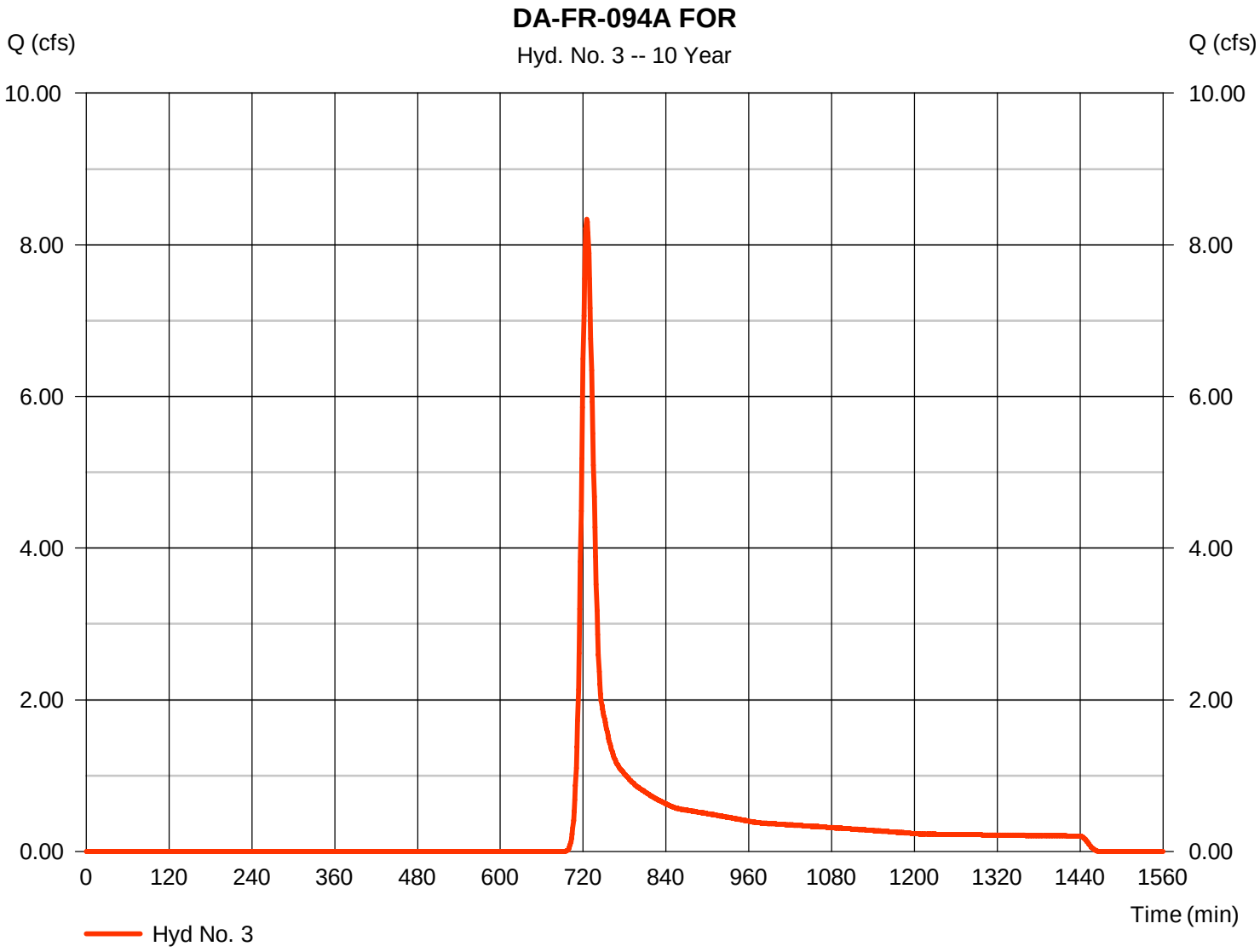


Hydrograph Report

Hyd. No. 3

DA-FR-094A FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 8.336 cfs
Storm frequency	= 10 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 27,924 cuft
Drainage area	= 5.770 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 18.10 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



Hydraflow Rainfall Report

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

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

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

Tc = time in minutes. Values may exceed 60.

ng\Franklin County\Downloaded Files\Franklin County DA Batch 4 - 046 - 058\Precipitation\Hydraflow\FranklinCo.pc

Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.30	3.70	0.00	0.00	5.70	0.00	0.00	0.00
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

DA-FR-094B

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.031	118
Developed Condition	0.017	120
Pre-Developed (Forest) Condition	0.010	80.9

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

Improvement Factor, IF = 0.9

Calculations:

Check #1: $Q_{developed} \leq IF \times [(Q_{pre\text{-}developed} \times RV_{pre\text{-}developed}) / RV_{developed}]$ ----------> 0.017 ≤ 0.027 OK

Check #2: $Q_{developed} \leq Q_{pre\text{-}developed}$ ----------> 0.017 ≤ 0.031 OK

Check #3: $Q_{developed}$ *shall not* be required to be $\leq (Q_{forest} \times RV_{forest}) / RV_{developed}$ ---> 0.017 *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

Note:

Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.

For Paved Road land surface types a Manning's n value 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

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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-FR-094B PRE
2	SCS Runoff	DA-FR-094B dev
3	SCS Runoff	DA-FR-094B FOR

Hydrograph Return Period Recap

Hyd. No.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)							Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	------	0.031	0.050	-------	-------	0.178	-------	-------	-------	DA-FR-094B PRE
2	SCS Runoff	------	0.017	0.028	-------	-------	0.105	-------	-------	-------	DA-FR-094B dev
3	SCS Runoff	------	0.010	0.019	-------	-------	0.099	-------	-------	-------	DA-FR-094B FOR

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	0.031	1	724	118	------	------	------	DA-FR-094B PRE
2	SCS Runoff	0.017	1	736	120	------	------	------	DA-FR-094B dev
3	SCS Runoff	0.010	1	732	81	------	------	------	DA-FR-094B FOR

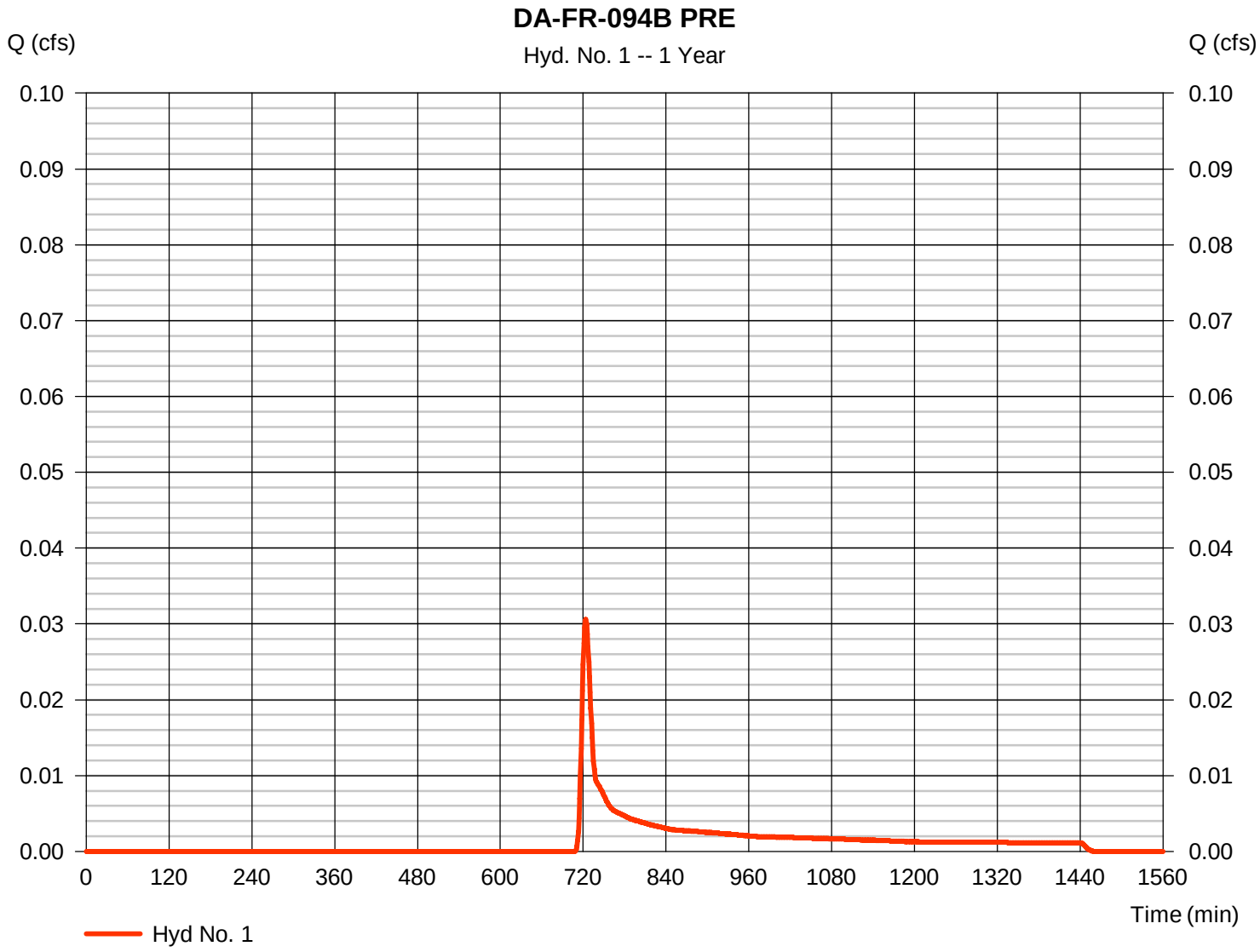
Hydrograph Report

Hyd. No. 1

DA-FR-094B PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.031 cfs
Storm frequency	= 1 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 118 cuft
Drainage area	= 0.080 ac	Curve number	= 59*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.00 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.008 x 100) + (0.074 x 55)] / 0.080



TR55 Tc Worksheet

Hyd. No. 1

DA-FR-094B PRE

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.400		0.011		0.011		
Flow length (ft)	= 89.2		0.0		0.0		
Two-year 24-hr precip. (in)	= 3.70		0.00		0.00		
Land slope (%)	= 4.68		0.00		0.00		
Travel Time (min)	**= 12.97**	**+**	**0.00**	**+**	**0.00**	**=**	**12.97**
Shallow Concentrated Flow							
Flow length (ft)	= 0.00		0.00		0.00		
Watercourse slope (%)	= 0.00		0.00		0.00		
Surface description	= Paved		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	= 0.015		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 ..... 13.00 min

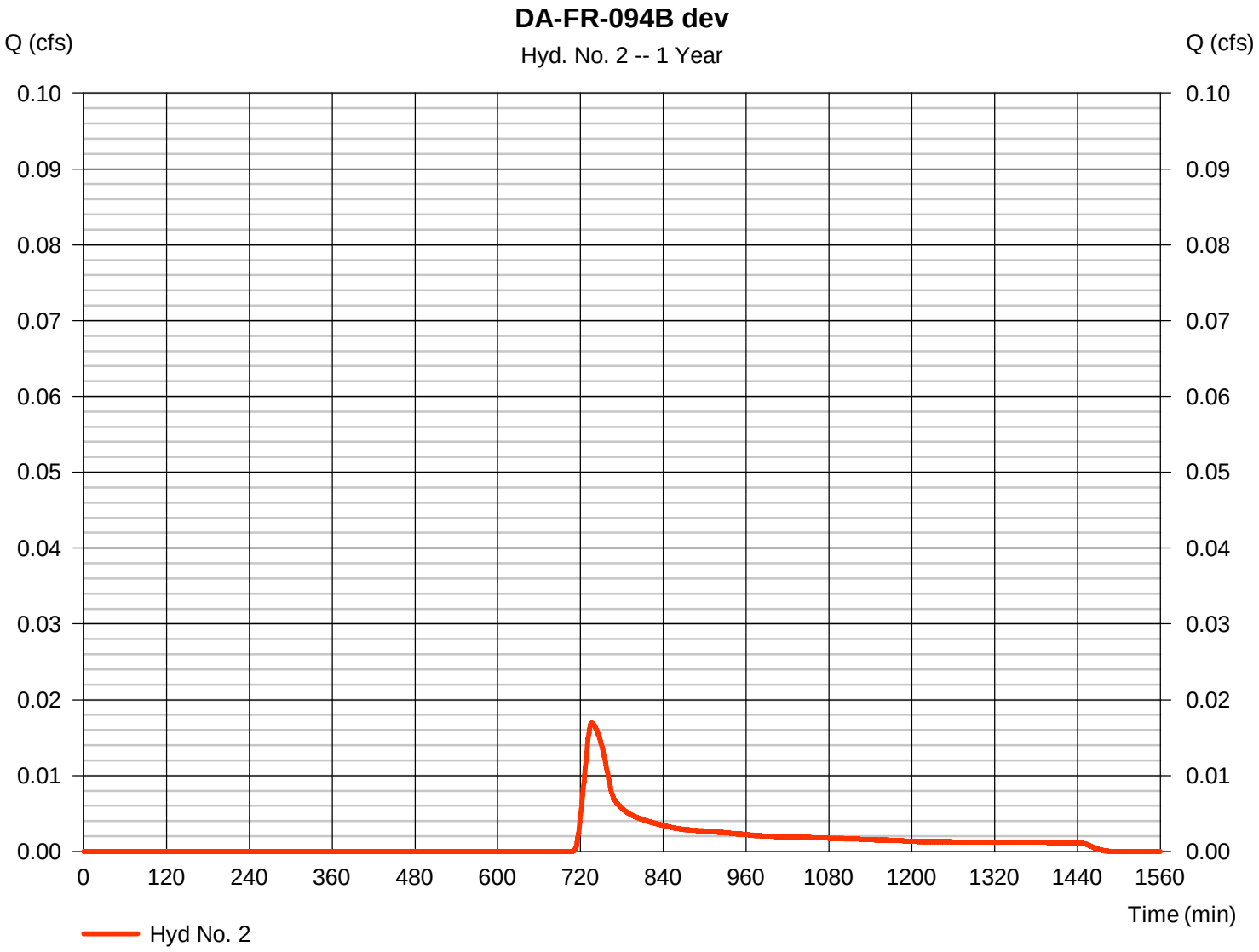
Hydrograph Report

Hyd. No. 2

DA-FR-094B dev

Hydrograph type	= SCS Runoff	Peak discharge	= 0.017 cfs
Storm frequency	= 1 yrs	Time to peak	= 736 min
Time interval	= 1 min	Hyd. volume	= 120 cuft
Drainage area	= 0.080 ac	Curve number	= 59*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 31.20 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.024 x 48) + (0.050 x 58) + (0.008 x 100)] / 0.080



TR55 Tc Worksheet

Hyd. No. 2

DA-FR-094B dev

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.800		0.400		0.800		
Flow length (ft)	= 16.9		58.1		14.2		
Two-year 24-hr precip. (in)	= 3.70		3.70		3.70		
Land slope (%)	= 0.30		4.04		12.46		
Travel Time (min)	**= 17.89**	**+**	**9.76**	**+**	**3.52**	**=**	**31.17**
Shallow Concentrated Flow							
Flow length (ft)	= 0.00		0.00		0.00		
Watercourse slope (%)	= 0.00		0.00		0.00		
Surface description	= Unpaved		Unpaved		Unpaved		
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	= 0.015		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**

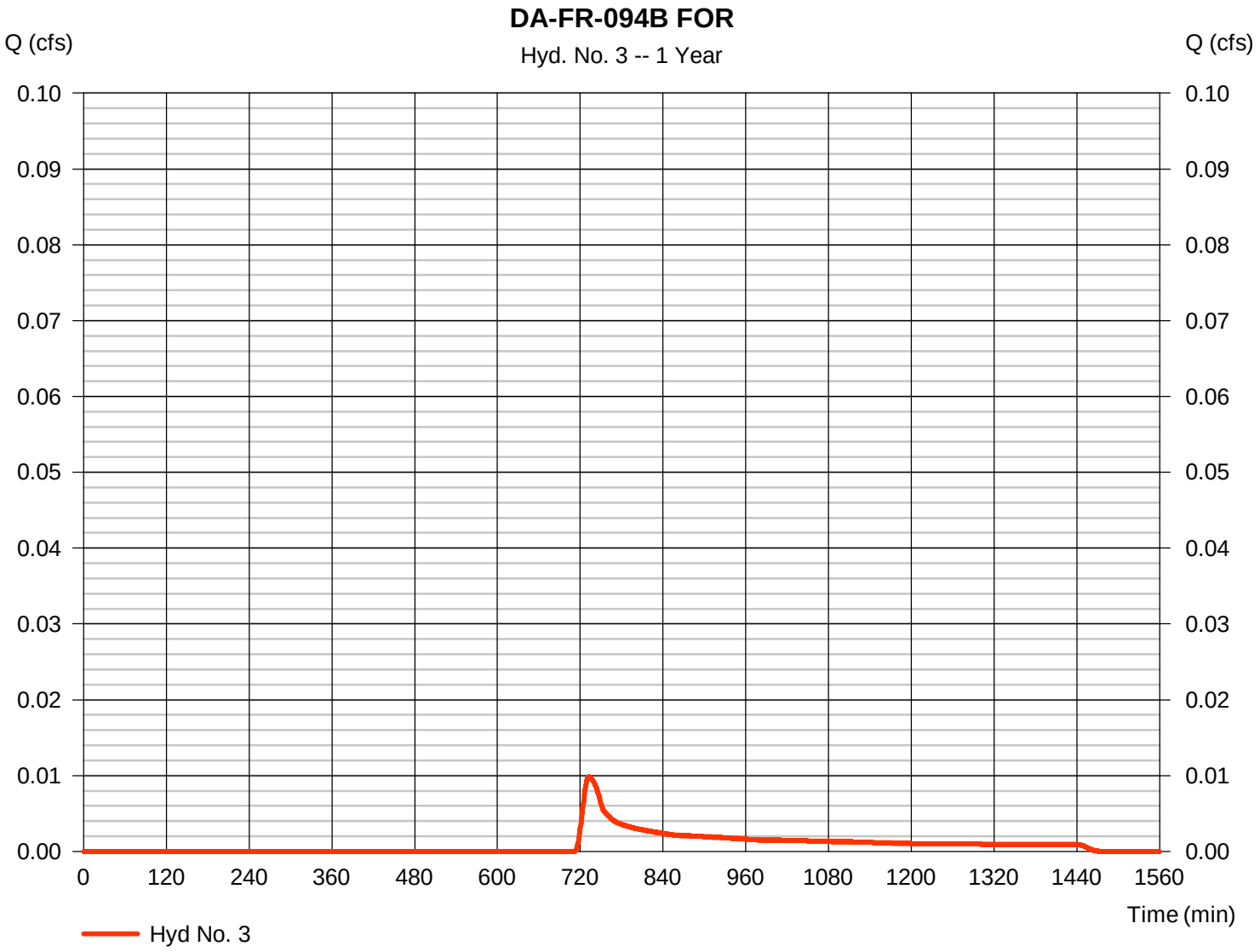
Total Travel Time, Tc ..... 31.20 min

Hydrograph Report

Hyd. No. 3

DA-FR-094B FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.010 cfs
Storm frequency	= 1 yrs	Time to peak	= 732 min
Time interval	= 1 min	Hyd. volume	= 81 cuft
Drainage area	= 0.080 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 22.60 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



TR55 Tc Worksheet

Hyd. No. 3

DA-FR-094B FOR

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.800		0.011		0.011		
Flow length (ft)	= 89.2		0.0		0.0		
Two-year 24-hr precip. (in)	= 3.70		0.00		0.00		
Land slope (%)	= 4.68		0.00		0.00		
Travel Time (min)	**= 22.59**	**+**	**0.00**	**+**	**0.00**	**=**	**22.59**
Shallow Concentrated Flow							
Flow length (ft)	= 0.00		0.00		0.00		
Watercourse slope (%)	= 0.00		0.00		0.00		
Surface description	= Paved		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	= 0.015		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 ..... 22.60 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	0.050	1	723	165	------	------	------	DA-FR-094B PRE
2	SCS Runoff	0.028	1	736	168	------	------	------	DA-FR-094B dev
3	SCS Runoff	0.019	1	731	120	------	------	------	DA-FR-094B FOR

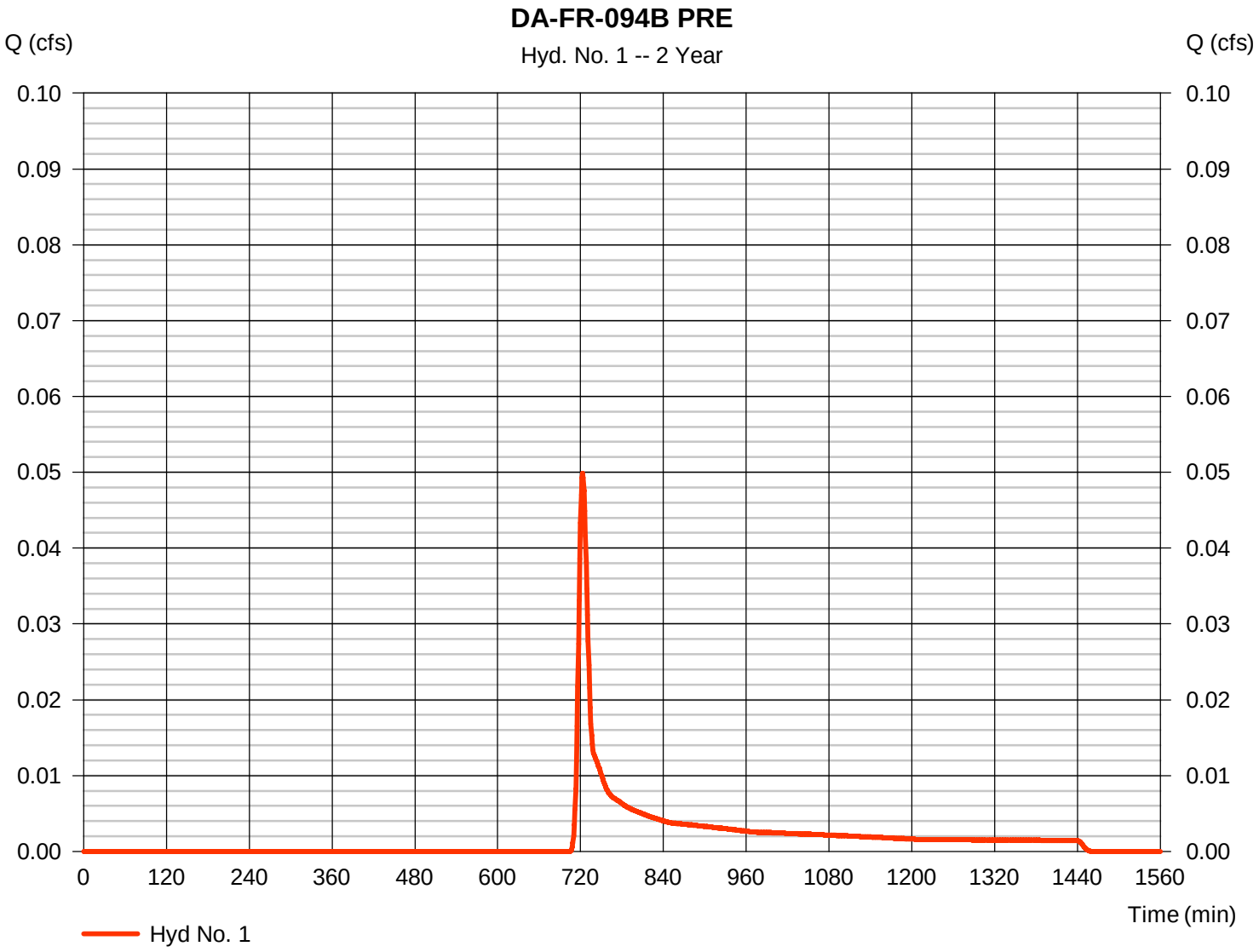
Hydrograph Report

Hyd. No. 1

DA-FR-094B PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.050 cfs
Storm frequency	= 2 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 165 cuft
Drainage area	= 0.080 ac	Curve number	= 59*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.00 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.008 x 100) + (0.074 x 55)] / 0.080



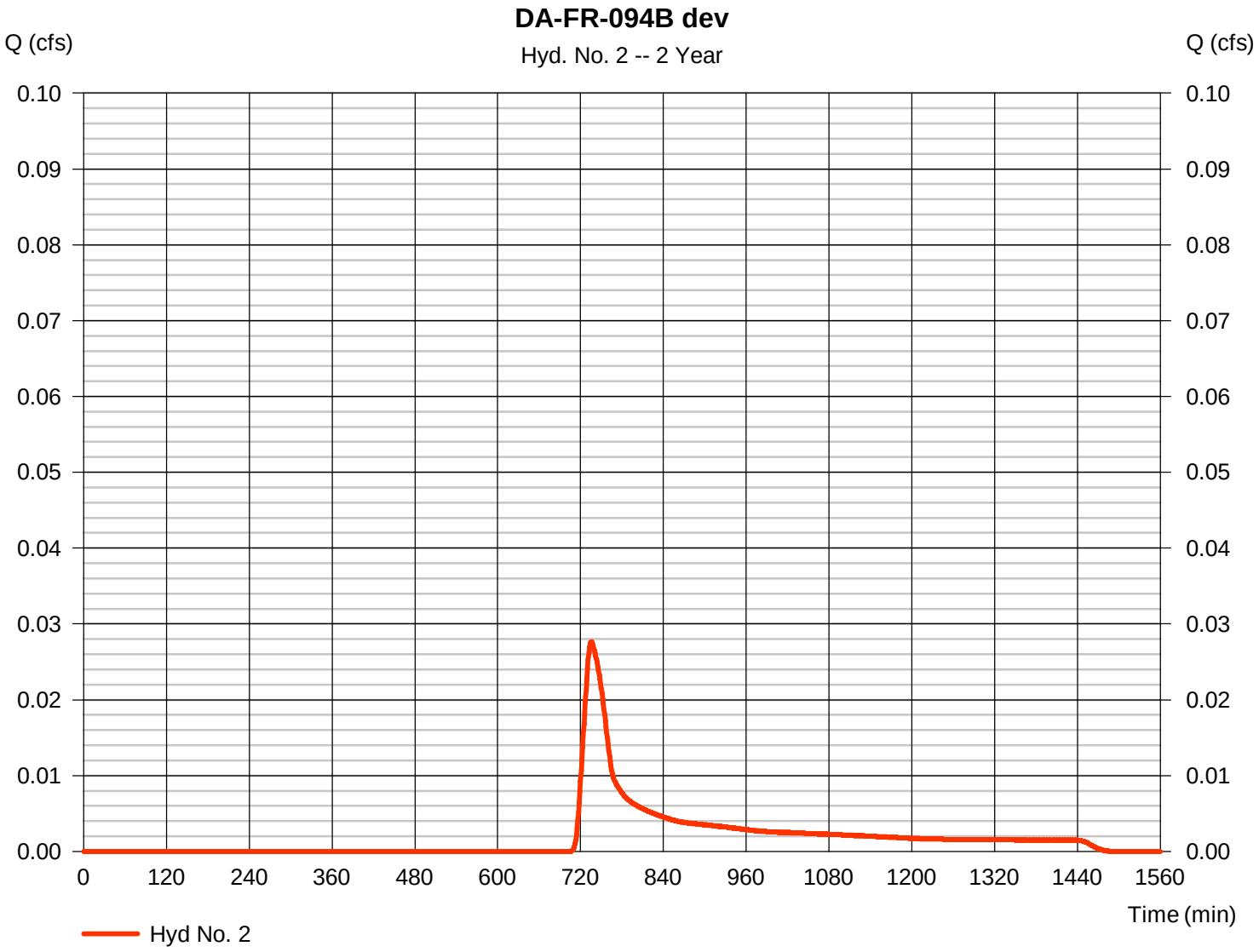
Hydrograph Report

Hyd. No. 2

DA-FR-094B dev

Hydrograph type	= SCS Runoff	Peak discharge	= 0.028 cfs
Storm frequency	= 2 yrs	Time to peak	= 736 min
Time interval	= 1 min	Hyd. volume	= 168 cuft
Drainage area	= 0.080 ac	Curve number	= 59*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 31.20 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.024 x 48) + (0.050 x 58) + (0.008 x 100)] / 0.080

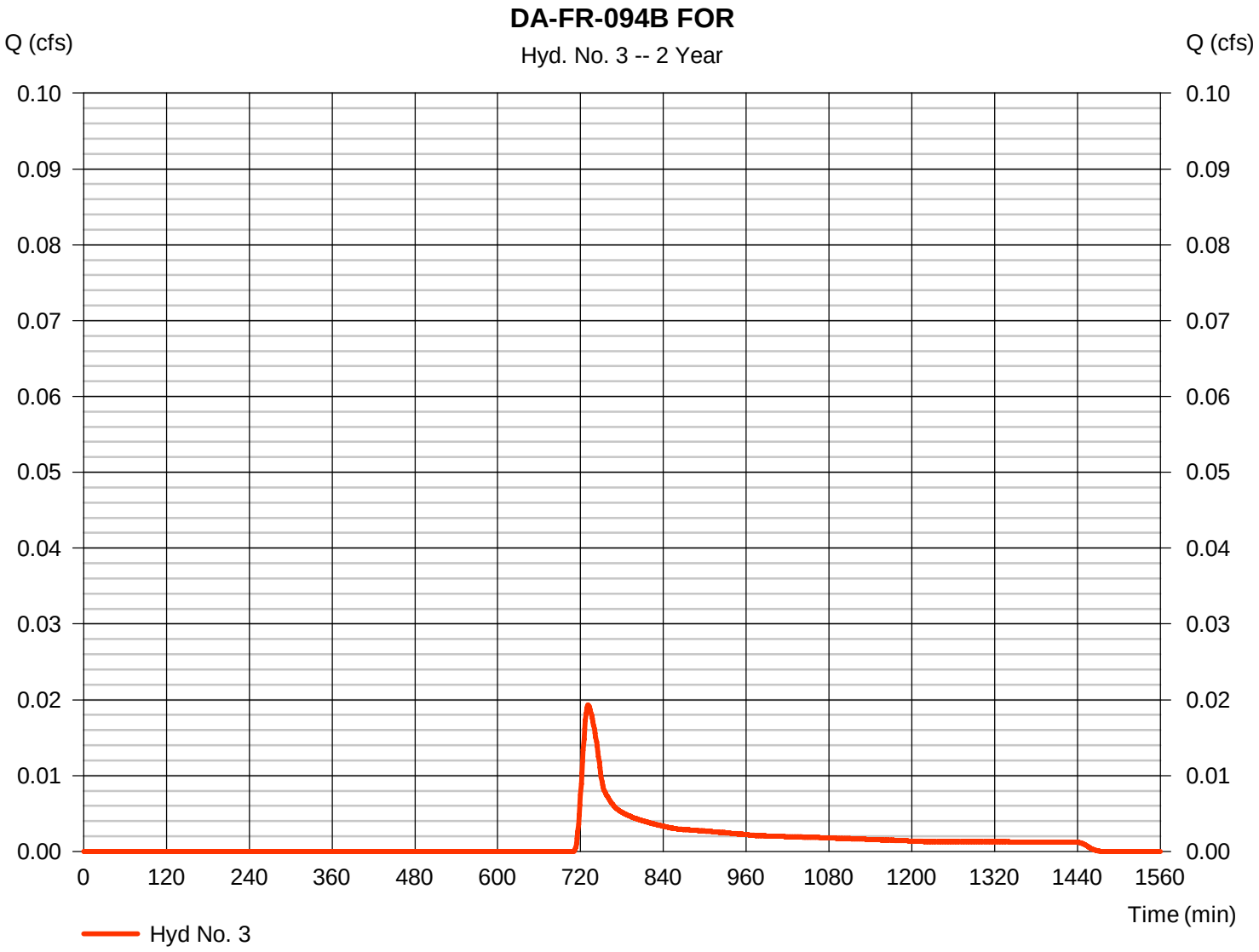


Hydrograph Report

Hyd. No. 3

DA-FR-094B FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.019 cfs
Storm frequency	= 2 yrs	Time to peak	= 731 min
Time interval	= 1 min	Hyd. volume	= 120 cuft
Drainage area	= 0.080 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 22.60 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



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	0.178	1	722	472	------	------	------	DA-FR-094B PRE
2	SCS Runoff	0.105	1	733	482	------	------	------	DA-FR-094B dev
3	SCS Runoff	0.099	1	728	388	------	------	------	DA-FR-094B FOR

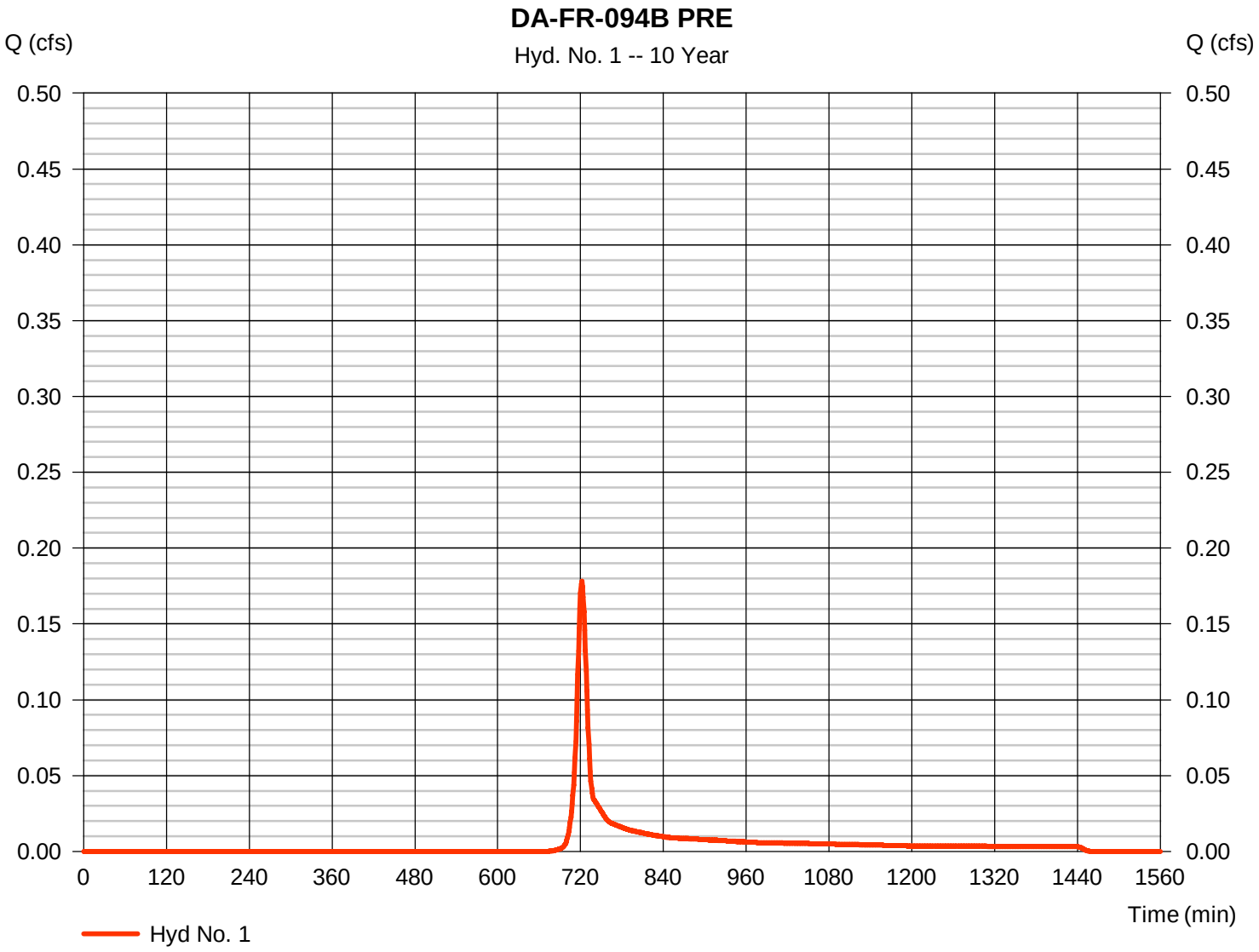
Hydrograph Report

Hyd. No. 1

DA-FR-094B PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.178 cfs
Storm frequency	=	10 yrs	Time to peak	=	722 min
Time interval	=	1 min	Hyd. volume	=	472 cuft
Drainage area	=	0.080 ac	Curve number	=	59*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	13.00 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.008 x 100) + (0.074 x 55)] / 0.080



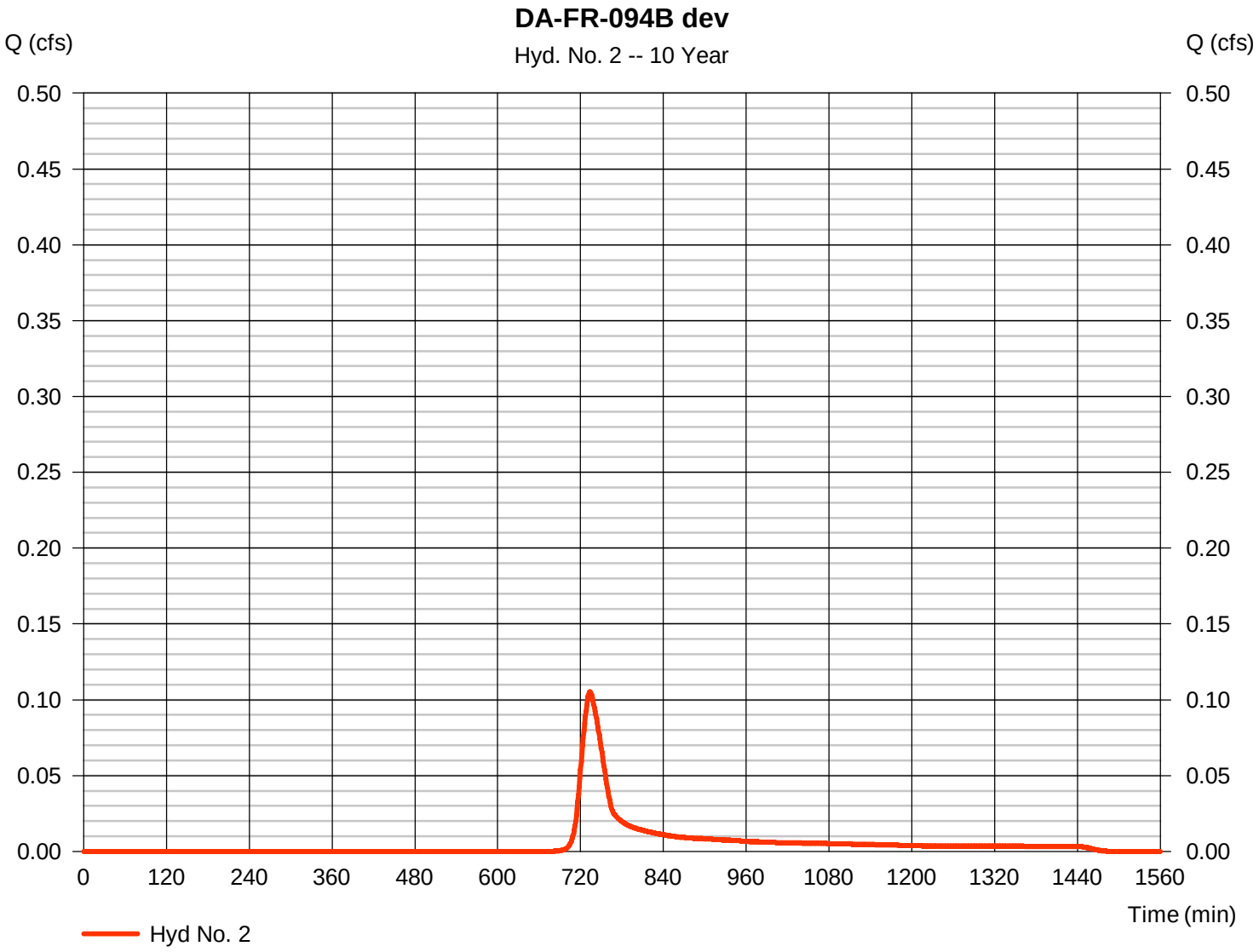
Hydrograph Report

Hyd. No. 2

DA-FR-094B dev

Hydrograph type	= SCS Runoff	Peak discharge	= 0.105 cfs
Storm frequency	= 10 yrs	Time to peak	= 733 min
Time interval	= 1 min	Hyd. volume	= 482 cuft
Drainage area	= 0.080 ac	Curve number	= 59*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 31.20 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.024 x 48) + (0.050 x 58) + (0.008 x 100)] / 0.080

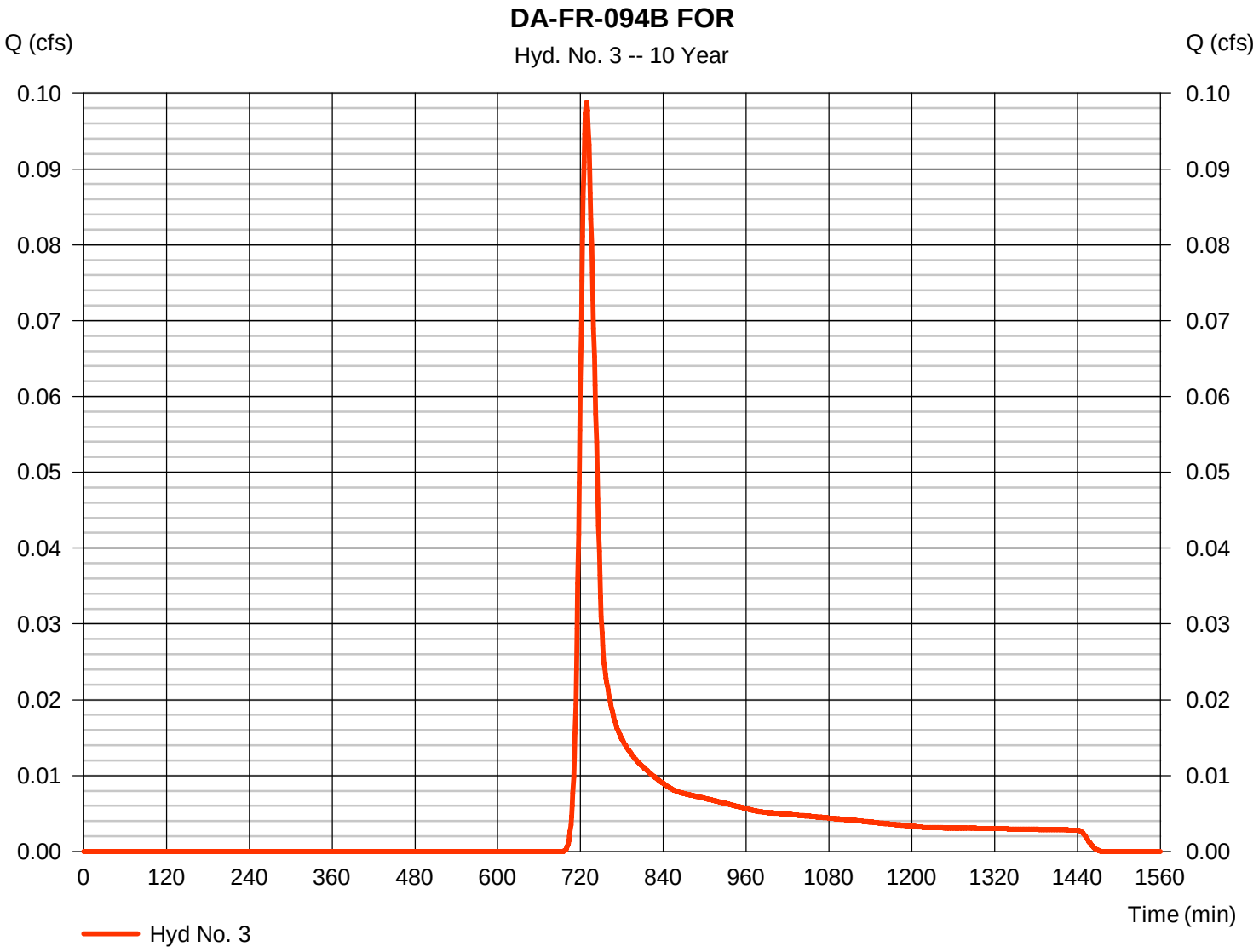


Hydrograph Report

Hyd. No. 3

DA-FR-094B FOR

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.099 cfs
Storm frequency	=	10 yrs	Time to peak	=	728 min
Time interval	=	1 min	Hyd. volume	=	388 cuft
Drainage area	=	0.080 ac	Curve number	=	55
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	22.60 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484



Hydraflow Rainfall Report

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

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

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

Tc = time in minutes. Values may exceed 60.

ng\Franklin County\Downloaded Files\Franklin County DA Batch 4 - 046 - 058\Precipitation\Hydraflow\FranklinCo.pc

Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.30	3.70	0.00	0.00	5.70	0.00	0.00	0.00
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

DA-FR-094C

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.063	267
Developed Condition	0.053	262
Pre-Developed (Forest) Condition	0.041	218

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

Improvement Factor, IF = 0.9

Calculations:

Check #1: $Q_{developed} \leq IF \times [(Q_{pre\text{-}developed} \times RV_{pre\text{-}developed}) / RV_{developed}]$ ----------> 0.053 ≤ 0.058 OK

Check #2: $Q_{developed} \leq Q_{pre\text{-}developed}$ ----------> 0.053 ≤ 0.063 OK

Check #3: $Q_{developed}$ *shall not* be required to be ≤ $(Q_{forest} \times RV_{forest}) / RV_{developed}$ ---> 0.053 *shall not* be required to be ≤ 0.034

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

Note:

Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.

For Paved Road land surface types a Manning's n value 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 Channels[1]			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels[2]			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150

Notes:

[1]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 or grass channel.

[2]For the pre-developed condition (if applicable), 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-FR-094C PRE
2	SCS Runoff	DA-FR-094C DEV
3	SCS Runoff	DA-FR-094C FOR

Hydrograph Return Period Recap

Hyd. No.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)							Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	------	0.063	0.111	-------	-------	0.453	-------	-------	-------	DA-FR-094C PRE
2	SCS Runoff	------	0.053	0.094	-------	-------	0.393	-------	-------	-------	DA-FR-094C DEV
3	SCS Runoff	------	0.041	0.082	-------	-------	0.398	-------	-------	-------	DA-FR-094C FOR

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	0.063	1	723	267	------	------	------	DA-FR-094C PRE
2	SCS Runoff	0.053	1	725	262	------	------	------	DA-FR-094C DEV
3	SCS Runoff	0.041	1	724	218	------	------	------	DA-FR-094C FOR

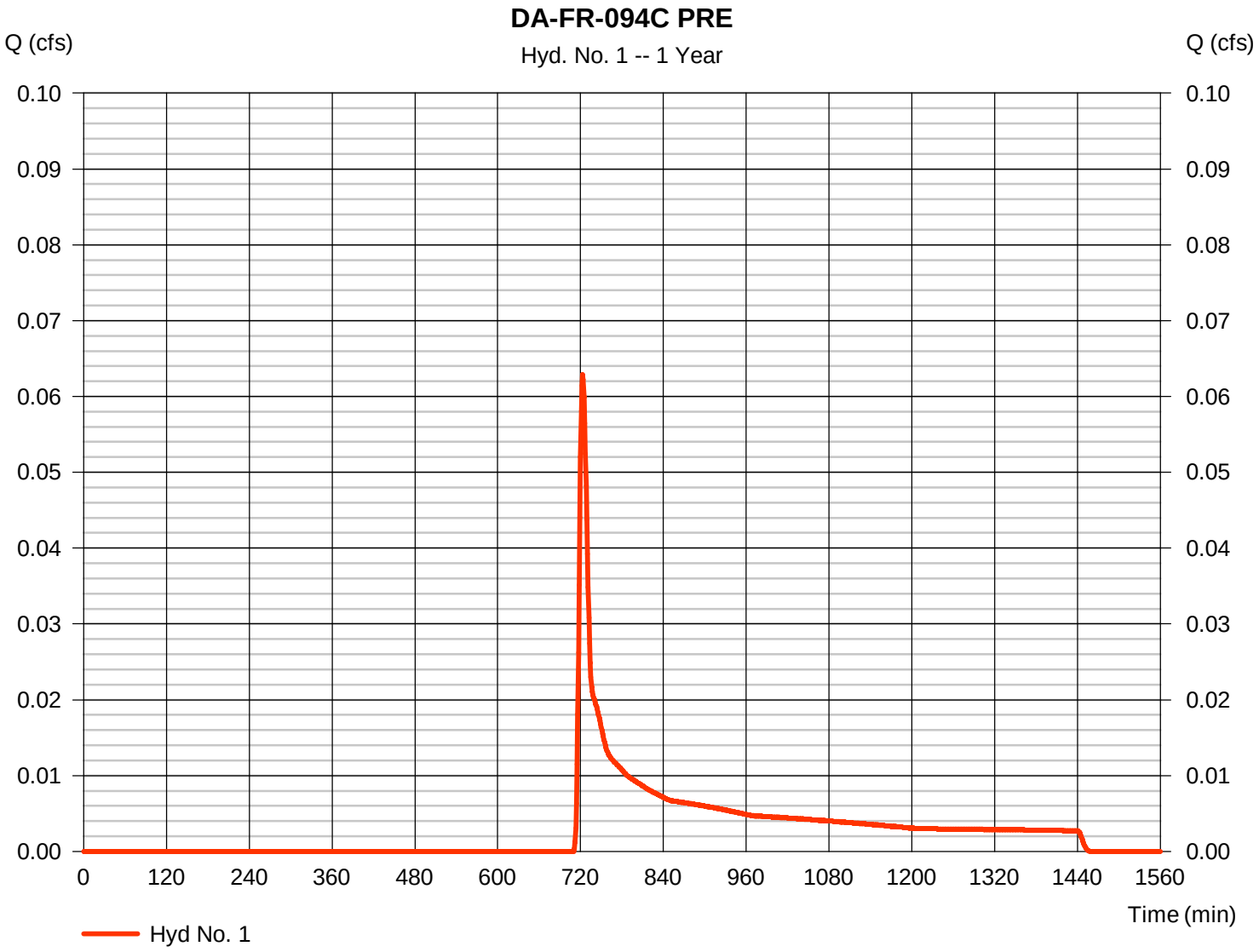
Hydrograph Report

Hyd. No. 1

DA-FR-094C PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.063 cfs
Storm frequency	= 1 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 267 cuft
Drainage area	= 0.210 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.10 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.011 x 100) + (0.198 x 55)] / 0.210



TR55 Tc Worksheet

Hyd. No. 1

DA-FR-094C PRE

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 9.01		0.00		0.00		
Travel Time (min)	**= 10.94**	**+**	**0.00**	**+**	**0.00**	**=**	**10.94**
Shallow Concentrated Flow							
Flow length (ft)	= 4.23		0.00		0.00		
Watercourse slope (%)	= 0.09		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=0.48		0.00		0.00		
Travel Time (min)	**= 0.15**	**+**	**0.00**	**+**	**0.00**	**=**	**0.15**
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	= 0.015		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							**11.10 min**

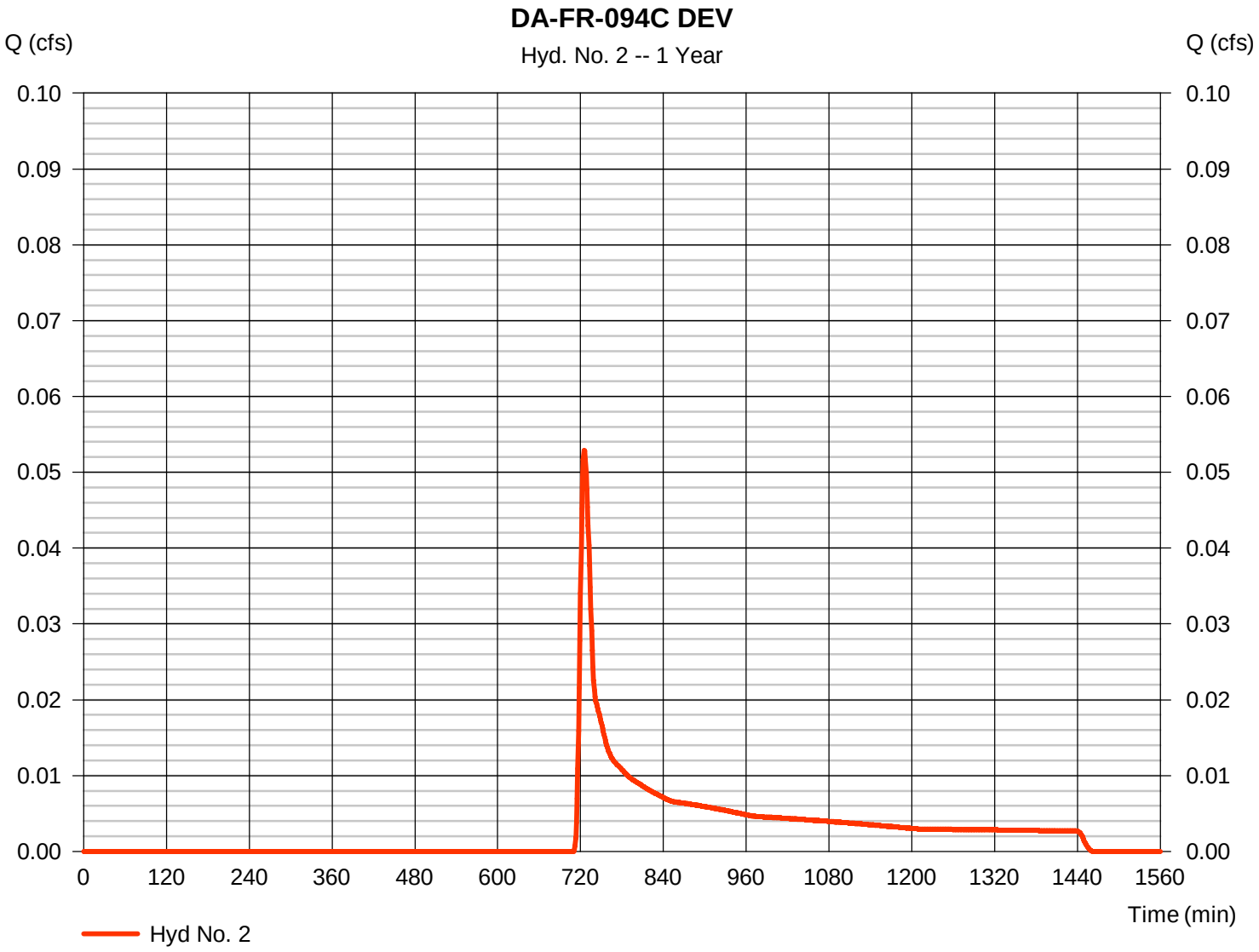
Hydrograph Report

Hyd. No. 2

DA-FR-094C DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.053 cfs
Storm frequency	= 1 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 262 cuft
Drainage area	= 0.210 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.90 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.068 x 48) + (0.130 x 58) + (0.011 x 100)] / 0.210



TR55 Tc Worksheet

Hyd. No. 2

DA-FR-094C DEV

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.800		0.400		0.800		
Flow length (ft)	= 13.2		25.2		16.7		
Two-year 24-hr precip. (in)	= 3.70		3.70		3.70		
Land slope (%)	= 5.18		6.16		7.63		
Travel Time (min)	**= 4.70**	**+**	**4.22**	**+**	**4.85**	**=**	**13.78**
Shallow Concentrated Flow							
Flow length (ft)	= 0.00		0.00		0.00		
Watercourse slope (%)	= 0.00		0.00		0.00		
Surface description	= Unpaved		Unpaved		Unpaved		
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)	= 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})29.4		0.0		0.0		
Travel Time (min)	**= 0.10**	**+**	**0.00**	**+**	**0.00**	**=**	**0.10**

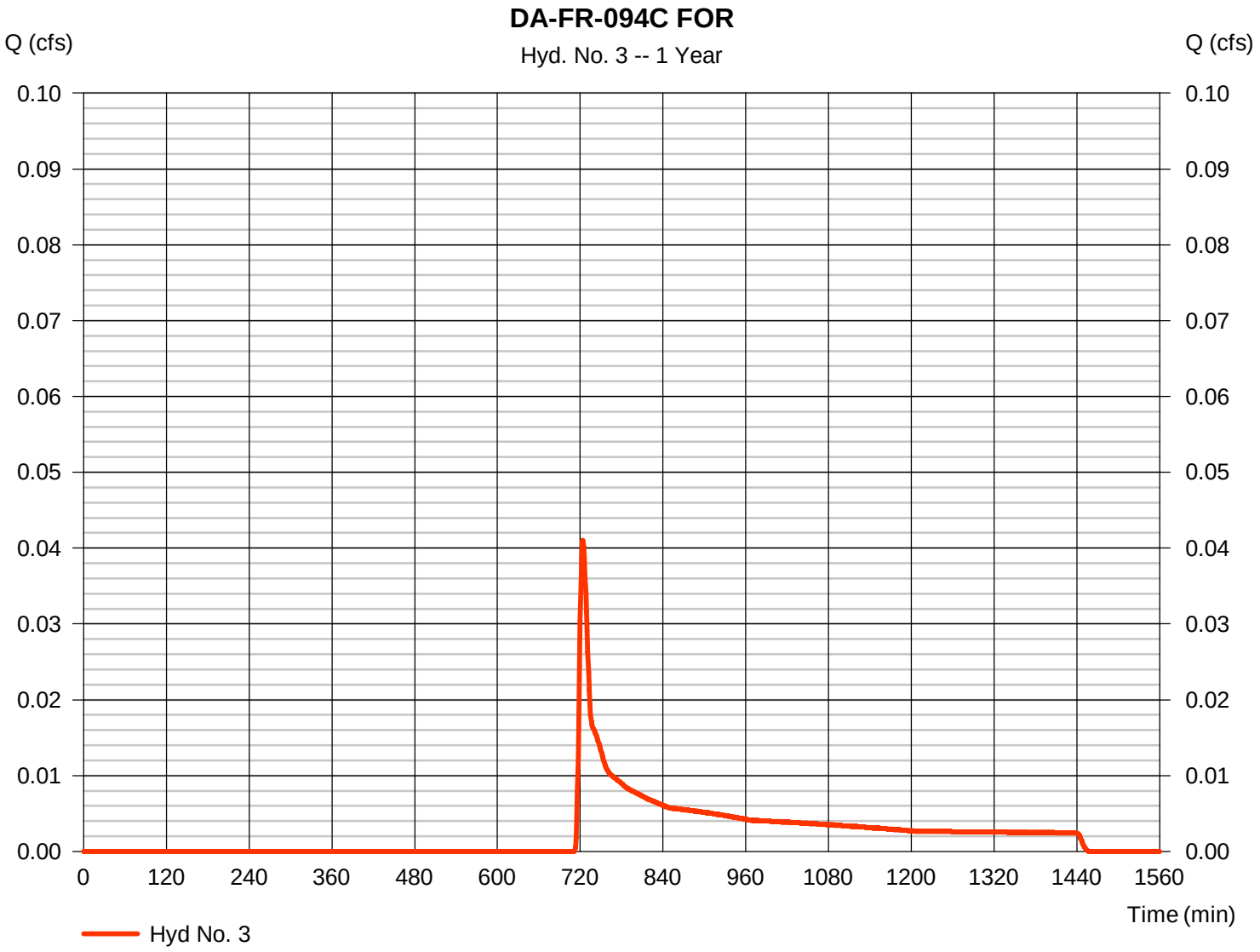
Total Travel Time, Tc ..... 13.90 min

Hydrograph Report

Hyd. No. 3

DA-FR-094C FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.041 cfs
Storm frequency	= 1 yrs	Time to peak	= 724 min
Time interval	= 1 min	Hyd. volume	= 218 cuft
Drainage area	= 0.210 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.10 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



TR55 Tc Worksheet

Hyd. No. 3

DA-FR-094C FOR

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 9.01		0.00		0.00		
Travel Time (min)	**= 10.94**	**+**	**0.00**	**+**	**0.00**	**=**	**10.94**
Shallow Concentrated Flow							
Flow length (ft)	= 4.23		0.00		0.00		
Watercourse slope (%)	= 0.09		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=0.48		0.00		0.00		
Travel Time (min)	**= 0.15**	**+**	**0.00**	**+**	**0.00**	**=**	**0.15**
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	= 0.015		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 ..... 11.10 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	0.111	1	722	383	------	------	------	DA-FR-094C PRE
2	SCS Runoff	0.094	1	725	376	------	------	------	DA-FR-094C DEV
3	SCS Runoff	0.082	1	723	322	------	------	------	DA-FR-094C FOR

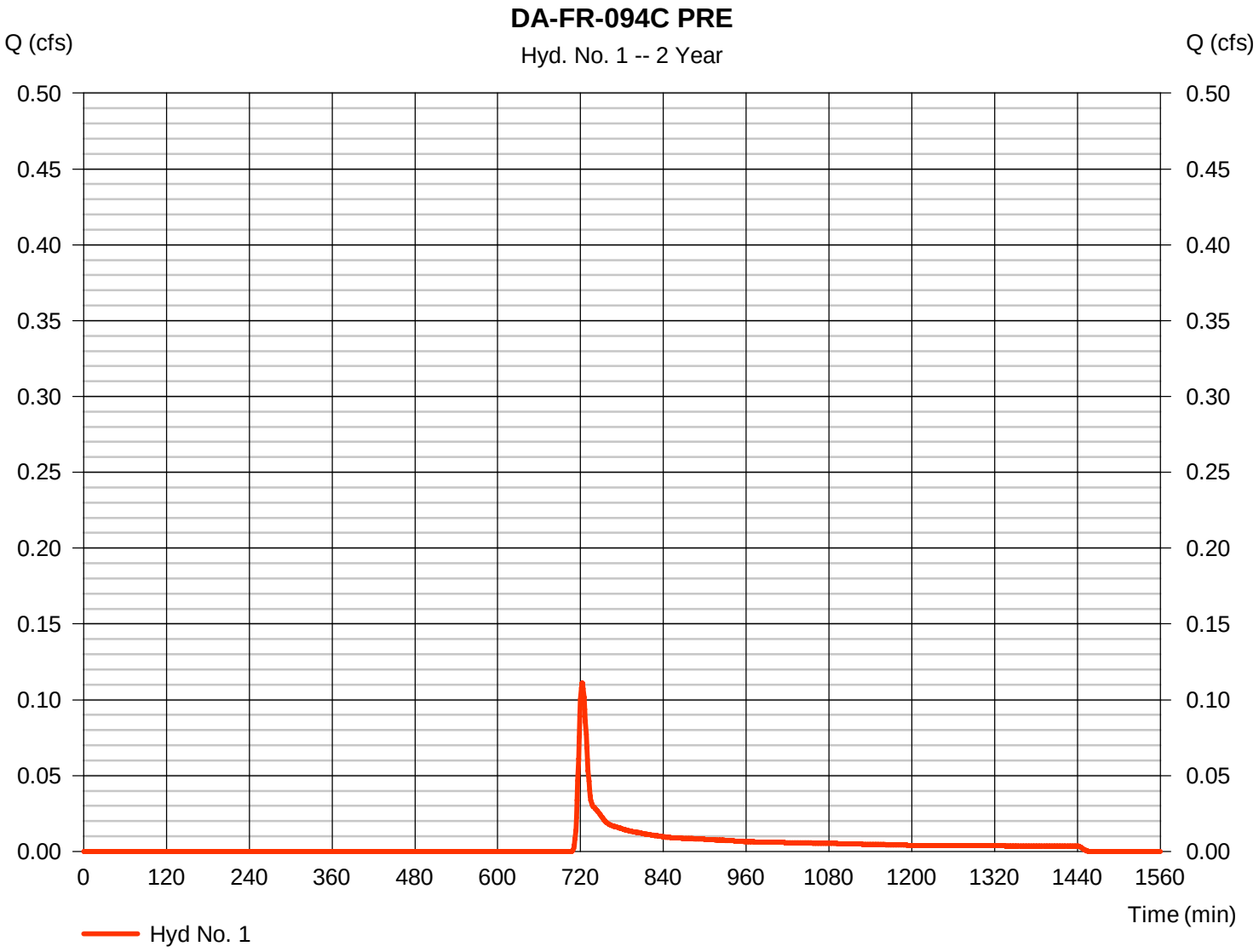
Hydrograph Report

Hyd. No. 1

DA-FR-094C PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.111 cfs
Storm frequency	= 2 yrs	Time to peak	= 722 min
Time interval	= 1 min	Hyd. volume	= 383 cuft
Drainage area	= 0.210 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.10 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.011 x 100) + (0.198 x 55)] / 0.210



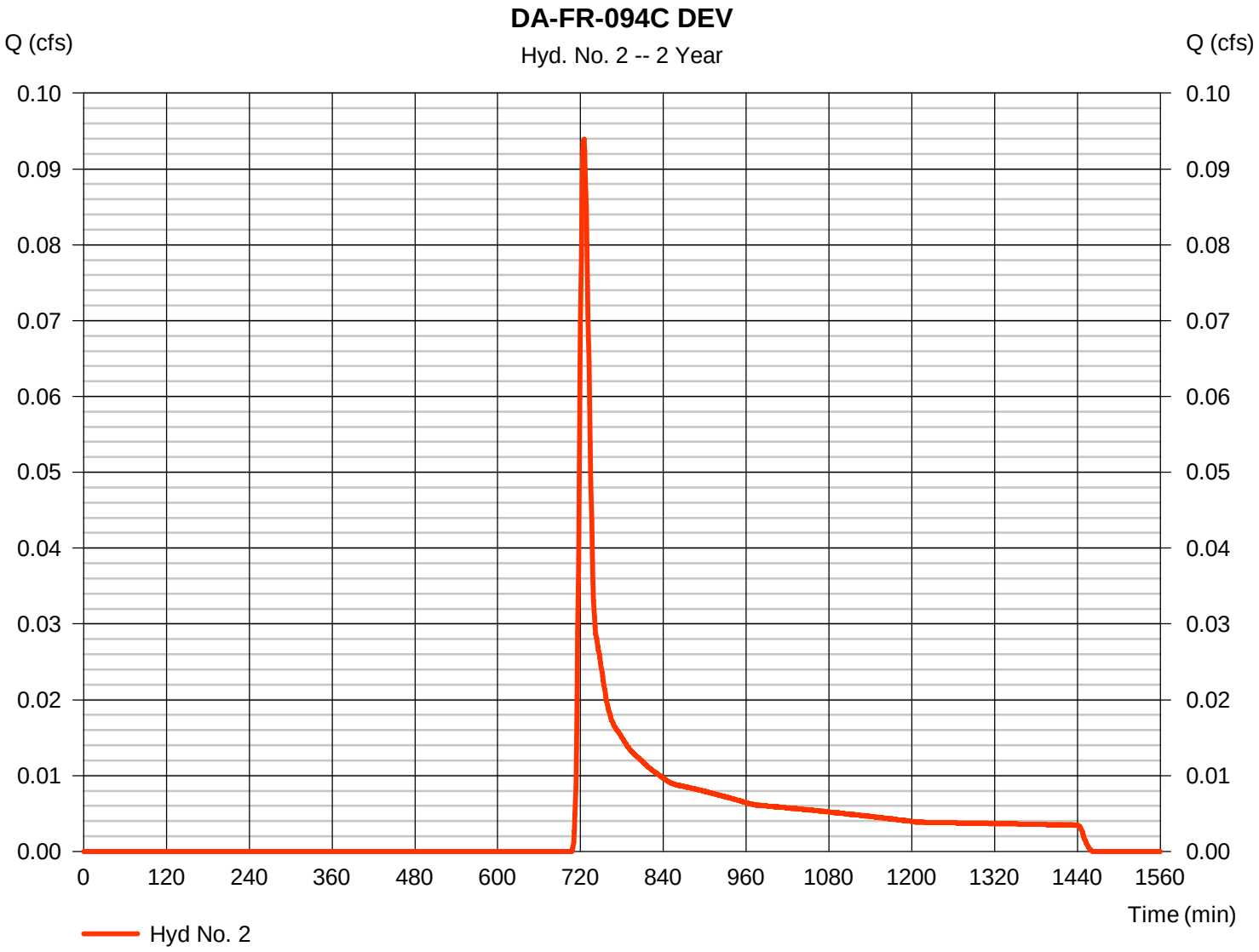
Hydrograph Report

Hyd. No. 2

DA-FR-094C DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.094 cfs
Storm frequency	= 2 yrs	Time to peak	= 725 min
Time interval	= 1 min	Hyd. volume	= 376 cuft
Drainage area	= 0.210 ac	Curve number	= 57*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 13.90 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.068 x 48) + (0.130 x 58) + (0.011 x 100)] / 0.210

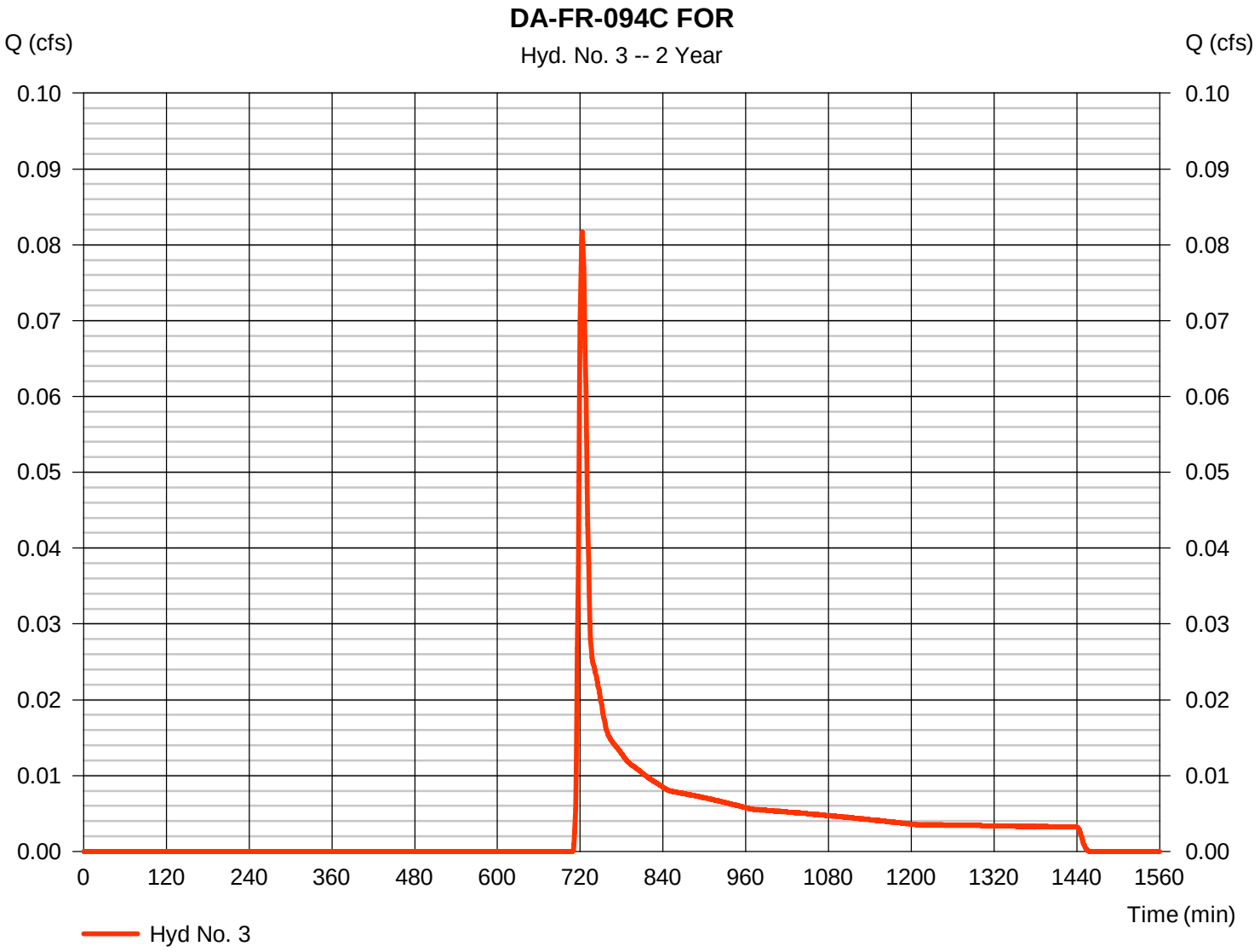


Hydrograph Report

Hyd. No. 3

DA-FR-094C FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.082 cfs
Storm frequency	= 2 yrs	Time to peak	= 723 min
Time interval	= 1 min	Hyd. volume	= 322 cuft
Drainage area	= 0.210 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.10 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



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	0.453	1	721	1,161	------	------	------	DA-FR-094C PRE
2	SCS Runoff	0.393	1	723	1,141	------	------	------	DA-FR-094C DEV
3	SCS Runoff	0.398	1	721	1,046	------	------	------	DA-FR-094C FOR

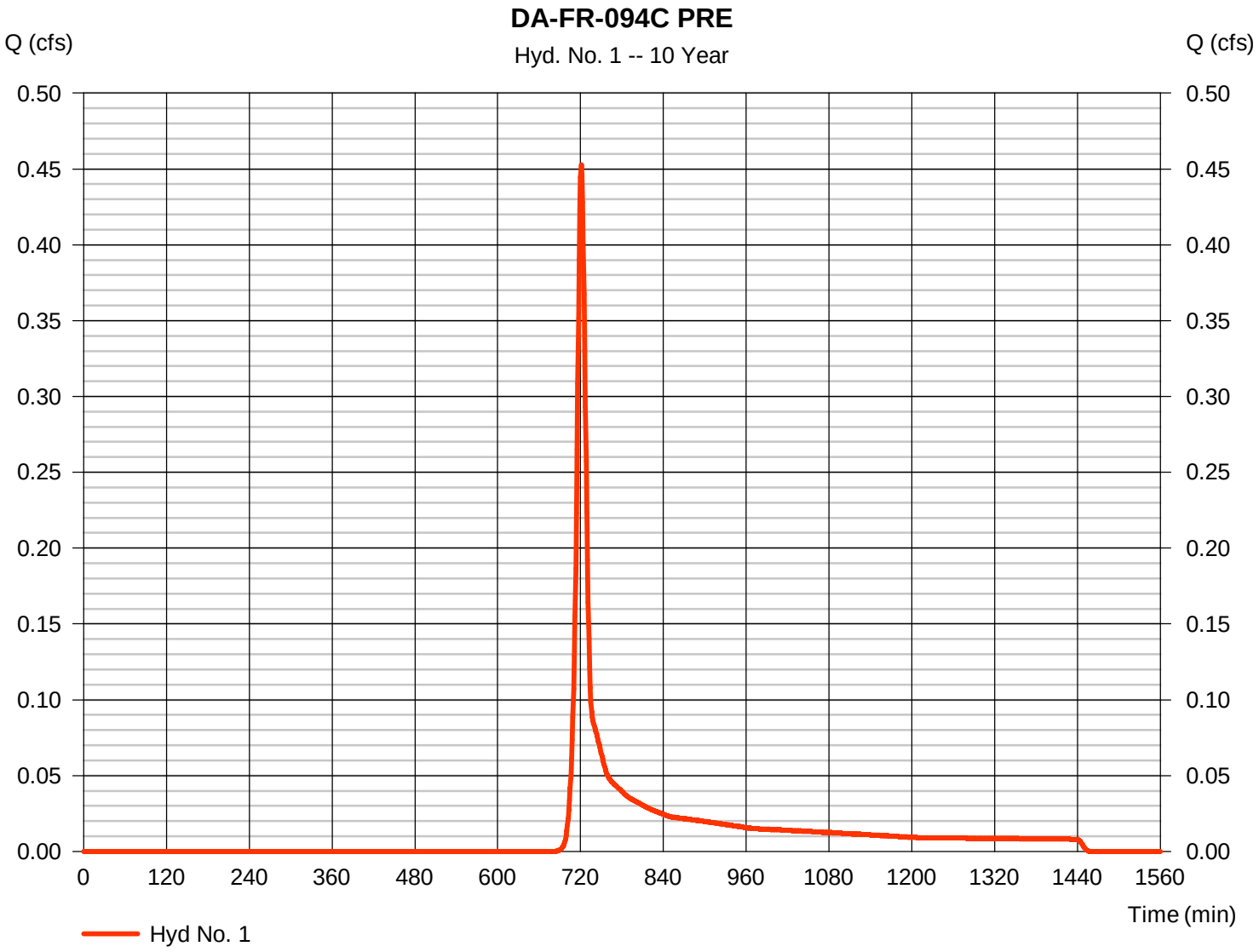
Hydrograph Report

Hyd. No. 1

DA-FR-094C PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.453 cfs
Storm frequency	=	10 yrs	Time to peak	=	721 min
Time interval	=	1 min	Hyd. volume	=	1,161 cuft
Drainage area	=	0.210 ac	Curve number	=	57*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	11.10 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.011 x 100) + (0.198 x 55)] / 0.210



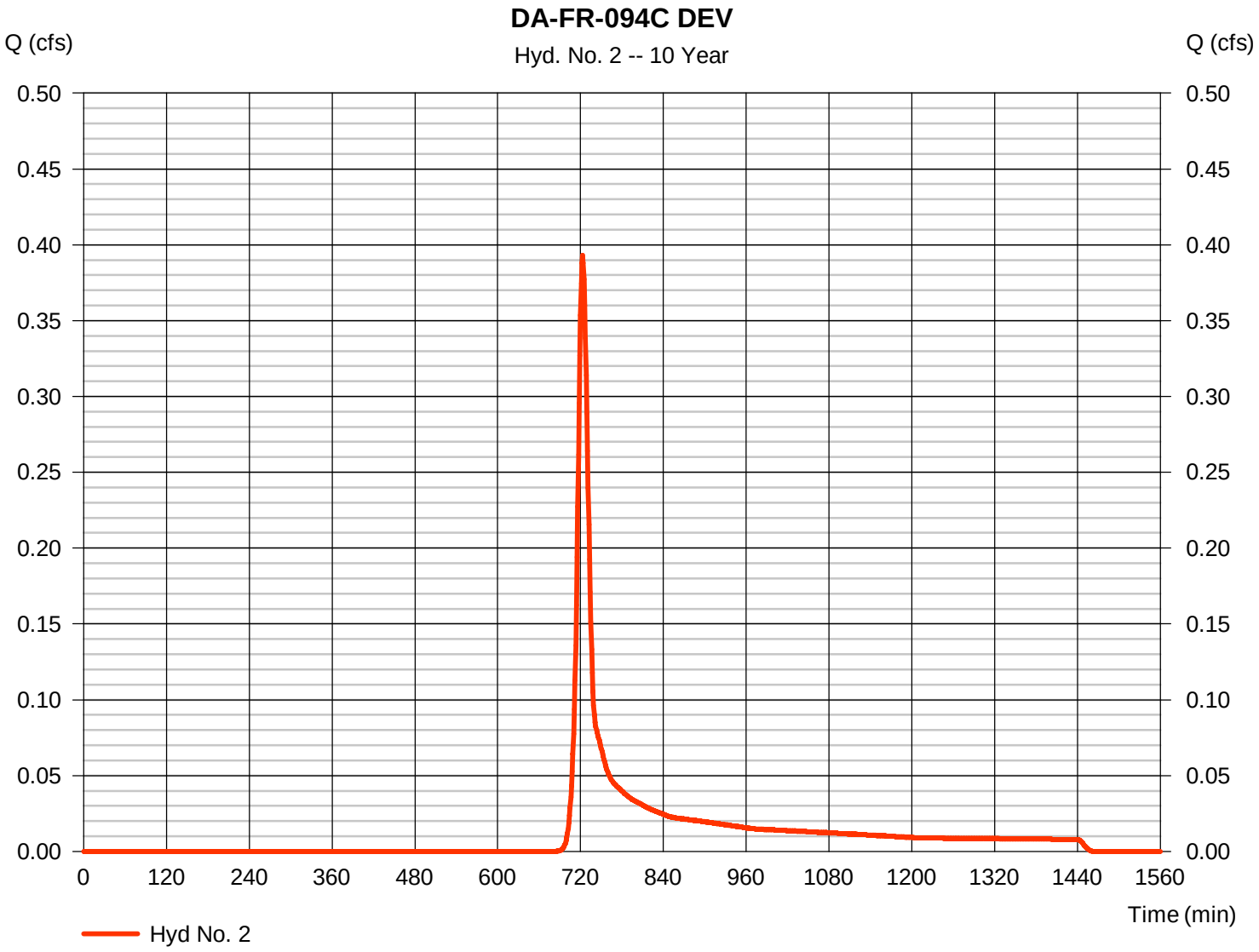
Hydrograph Report

Hyd. No. 2

DA-FR-094C DEV

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.393 cfs
Storm frequency	=	10 yrs	Time to peak	=	723 min
Time interval	=	1 min	Hyd. volume	=	1,141 cuft
Drainage area	=	0.210 ac	Curve number	=	57*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	13.90 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.068 x 48) + (0.130 x 58) + (0.011 x 100)] / 0.210

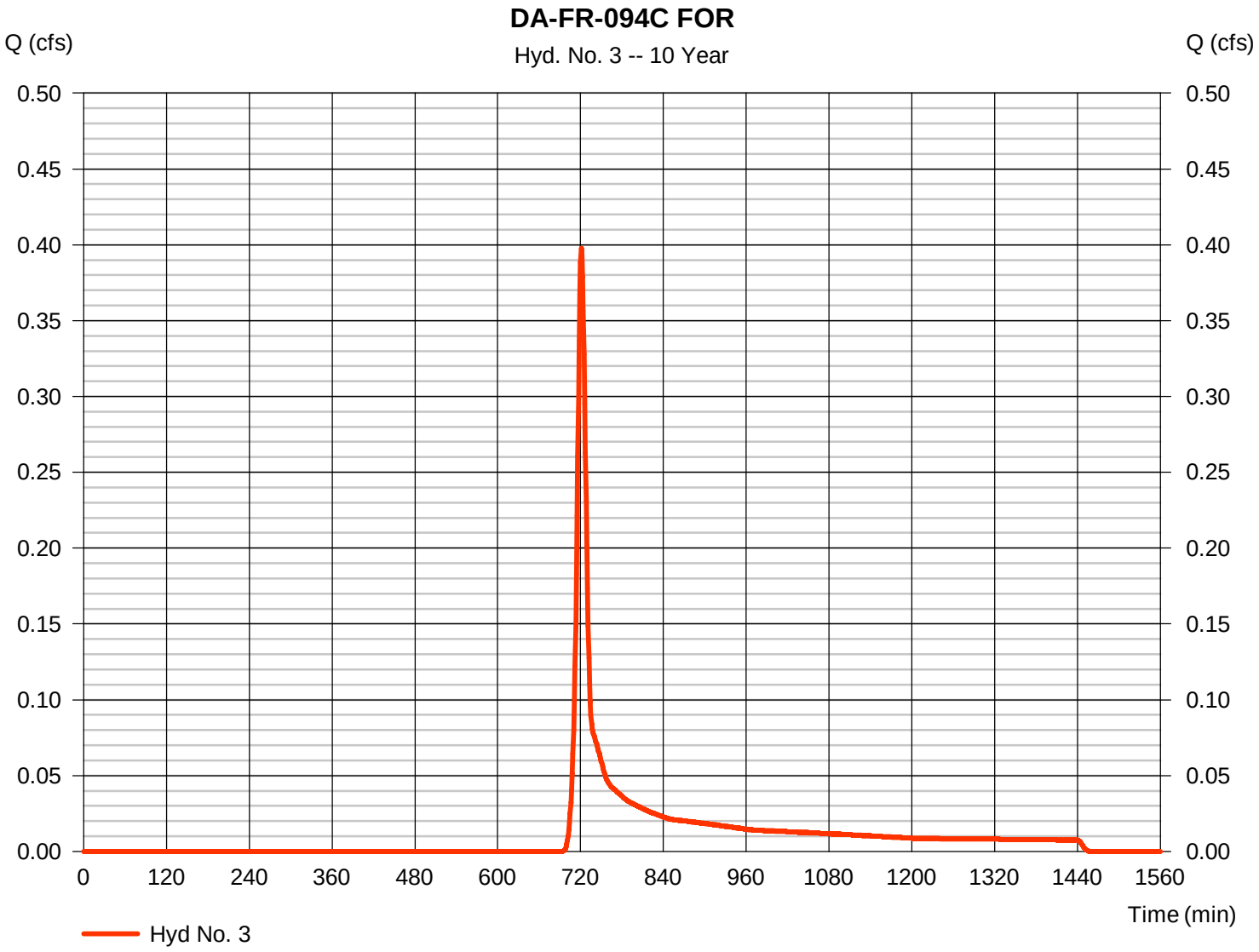


Hydrograph Report

Hyd. No. 3

DA-FR-094C FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.398 cfs
Storm frequency	= 10 yrs	Time to peak	= 721 min
Time interval	= 1 min	Hyd. volume	= 1,046 cuft
Drainage area	= 0.210 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.10 min
Total precip.	= 5.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



Hydraflow Rainfall Report

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

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

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

Tc = time in minutes. Values may exceed 60.

ng\Franklin County\Downloaded Files\Franklin County DA Batch 4 - 046 - 058\Precipitation\Hydraflow\FranklinCo.pc

Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.30	3.70	0.00	0.00	5.70	0.00	0.00	0.00
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

DA-FR-094D

ENERGY BALANCE METHOD

Inputs:

	1-Yr Event	
	Peak Flow, Q (cfs)	Runoff Volume, RV (cf)
Pre-Developed Condition	0.286	1922
Developed Condition	0.099	1346
Pre-Developed (Forest) Condition	0.286	1922

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

Improvement Factor, IF = 0.8

Calculations:

Check #1:	$Q_{developed} \leq IF \times [(Q_{pre\text{-}developed} \times RV_{pre\text{-}developed}) / RV_{developed}]$ ---------->	0.099	≤ N/A - See Check #3	0.327
Check #2:	$Q_{developed} \leq Q_{pre\text{-}developed}$ ---------->	0.099	≤ N/A - See Check #3	0.286
Check #3:	$Q_{developed}$ *shall not* be required to be ≤ $(Q_{forest} \times RV_{forest}) / RV_{developed}$ --->	0.099	*shall not* be required to be ≤	0.408

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

Note:

Manning's n values for sheet flow that are used in Hydraflow Hydrographs are highlighted.

For Paved Road land surface types a Manning's n value 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 Channels[1]			
a. Earth, Straight, and Uniform:			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.018	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
b. Earth Winding and Sluggish:			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-Excavated or Dredged:			
No vegetation	0.025	0.028	0.033
Light brush on banks	0.035	0.050	0.060
d. Rock Cuts:			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
e. Channels not Maintained, Weeds and Brush Uncut:			
Dense weeds, high as flow depth	0.050	0.080	0.120
Clean bottom, brush on sides	0.040	0.050	0.080
Same as above, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140
2. Main Channels[2]			
a. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective	0.040	0.048	0.055
f. Same as (d) with more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150

Notes:

[1]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 or grass channel.

[2]For the pre-developed condition (if applicable), 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-FR-094D PRE
2	SCS Runoff	DA-FR-094D DEV
3	SCS Runoff	DA-FR-094D FOR

Hydrograph Return Period Recap

Hyd. No.	Hydrograph type (origin)	Inflow hyd(s)	Peak Outflow (cfs)							Hydrograph Description
			1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr	
1	SCS Runoff	------	0.286	0.568	-------	-------	2.874	-------	-------	-------	DA-FR-094D PRE
2	SCS Runoff	------	0.099	0.228	-------	-------	1.641	-------	-------	-------	DA-FR-094D DEV
3	SCS Runoff	------	0.286	0.568	-------	-------	2.874	-------	-------	-------	DA-FR-094D FOR

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	0.286	1	727	1,922	------	------	------	DA-FR-094D PRE
2	SCS Runoff	0.099	1	745	1,346	------	------	------	DA-FR-094D DEV
3	SCS Runoff	0.286	1	727	1,922	------	------	------	DA-FR-094D FOR

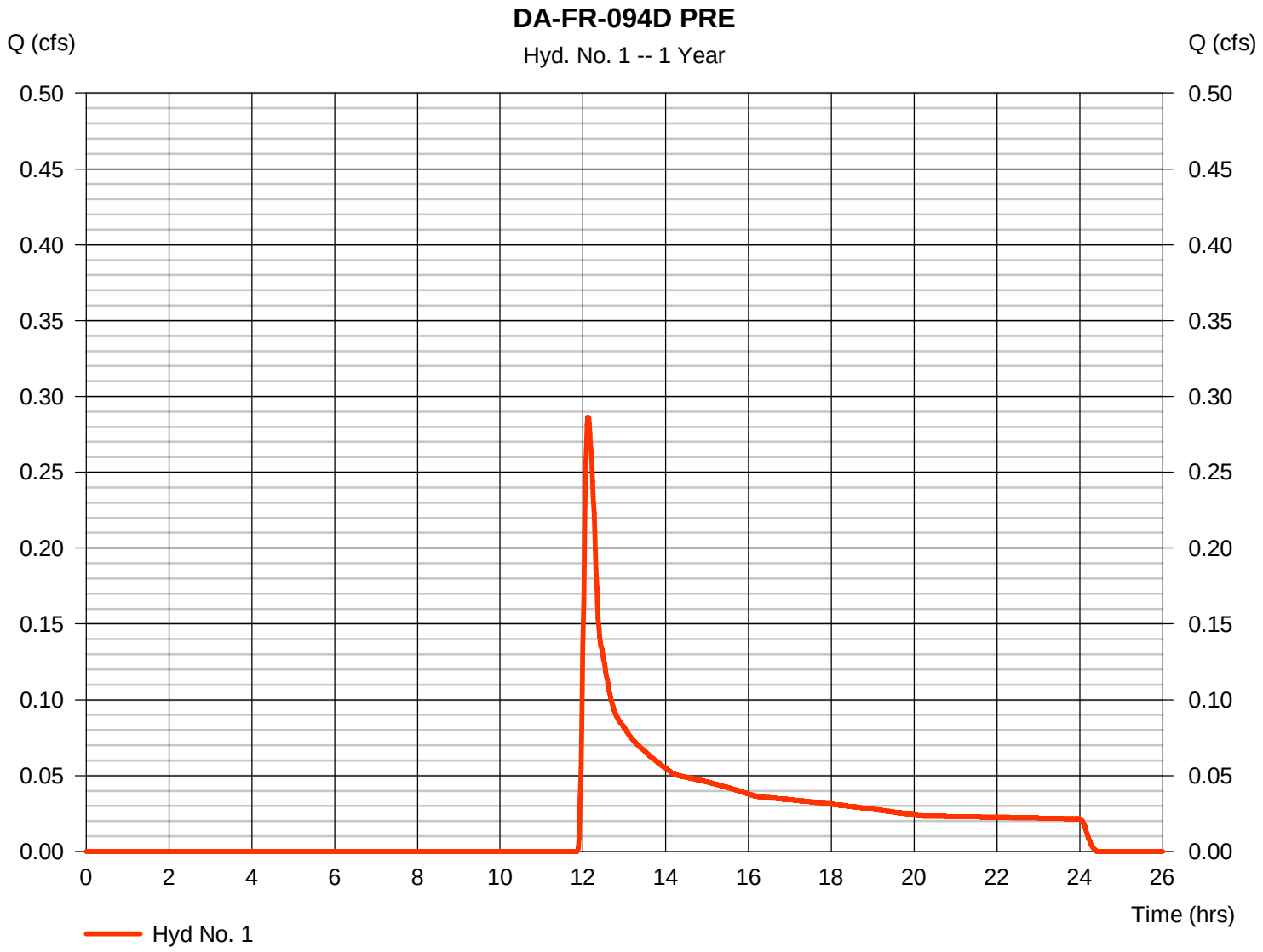
Hydrograph Report

Hyd. No. 1

DA-FR-094D PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.286 cfs
Storm frequency	= 1 yrs	Time to peak	= 12.12 hrs
Time interval	= 1 min	Hyd. volume	= 1,922 cuft
Drainage area	= 1.860 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.90 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.004 x 100) + (1.853 x 55)] / 1.860



TR55 Tc Worksheet

Hyd. No. 1

DA-FR-094D PRE

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 4.69		0.00		0.00		
Travel Time (min)	**= 14.20**	**+**	**0.00**	**+**	**0.00**	**=**	**14.20**
Shallow Concentrated Flow							
Flow length (ft)	= 629.39		0.00		0.00		
Watercourse slope (%)	= 15.50		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=6.35		0.00		0.00		
Travel Time (min)	**= 1.65**	**+**	**0.00**	**+**	**0.00**	**=**	**1.65**
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	= 0.015		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

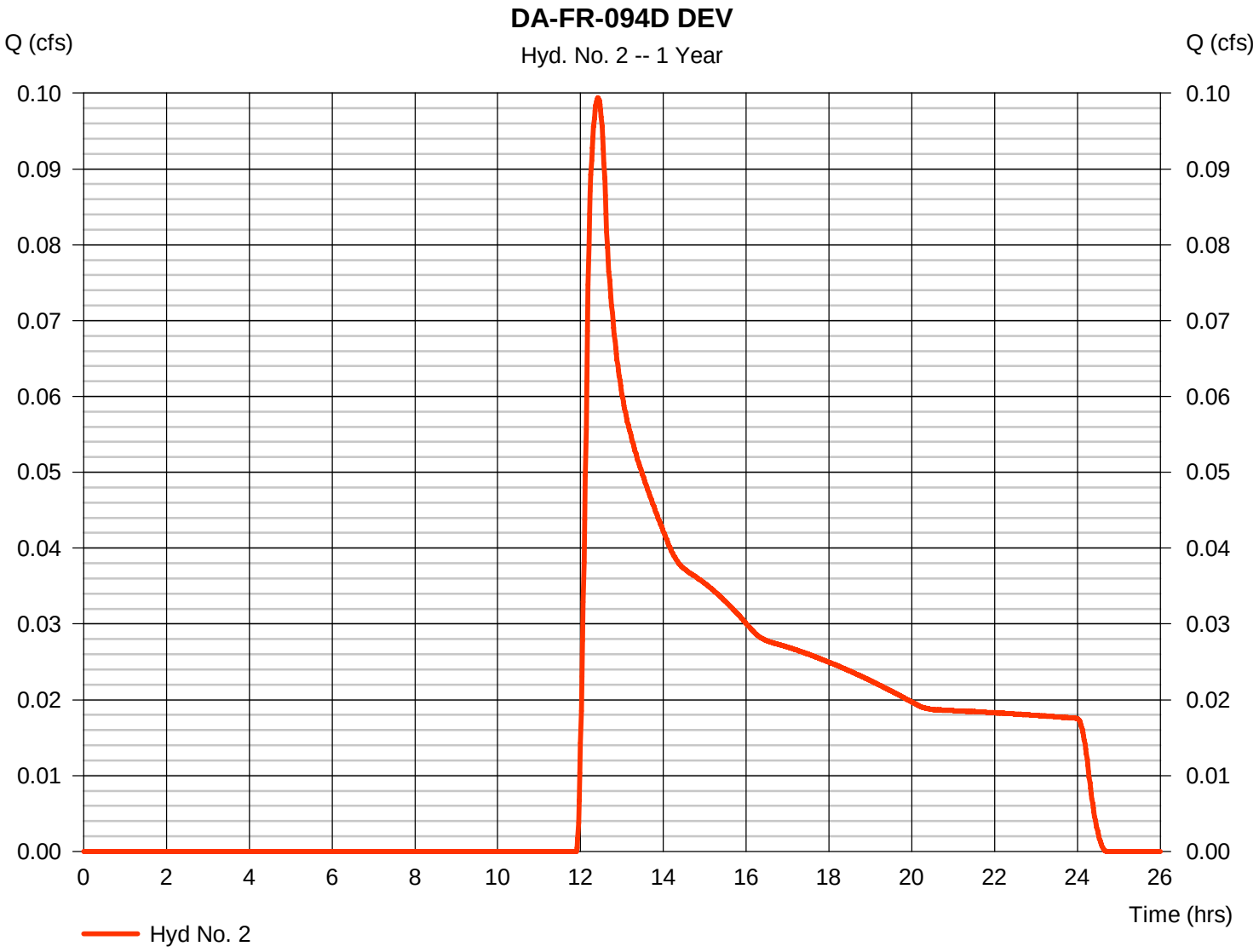
Hydrograph Report

Hyd. No. 2

DA-FR-094D DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.099 cfs
Storm frequency	= 1 yrs	Time to peak	= 12.42 hrs
Time interval	= 1 min	Hyd. volume	= 1,346 cuft
Drainage area	= 1.860 ac	Curve number	= 52*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 26.40 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(1.073 x 48) + (0.781 x 58) + (0.004 x 100)] / 1.860



TR55 Tc Worksheet

Hyd. No. 2

DA-FR-094D DEV

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.800		0.011		0.011		
Flow length (ft)	= 100.0		0.0		0.0		
Two-year 24-hr precip. (in)	= 3.70		0.00		0.00		
Land slope (%)	= 4.69		0.00		0.00		
Travel Time (min)	**= 24.73**	**+**	**0.00**	**+**	**0.00**	**=**	**24.73**
Shallow Concentrated Flow							
Flow length (ft)	= 34.25		540.57		0.00		
Watercourse slope (%)	= 9.47		17.01		0.00		
Surface description	= Unpaved		Unpaved		Paved		
Average velocity (ft/s)	=4.97		6.65		0.00		
Travel Time (min)	**= 0.11**	**+**	**1.35**	**+**	**0.00**	**=**	**1.47**
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})47.4		0.0		0.0		
Travel Time (min)	**= 0.16**	**+**	**0.00**	**+**	**0.00**	**=**	**0.16**

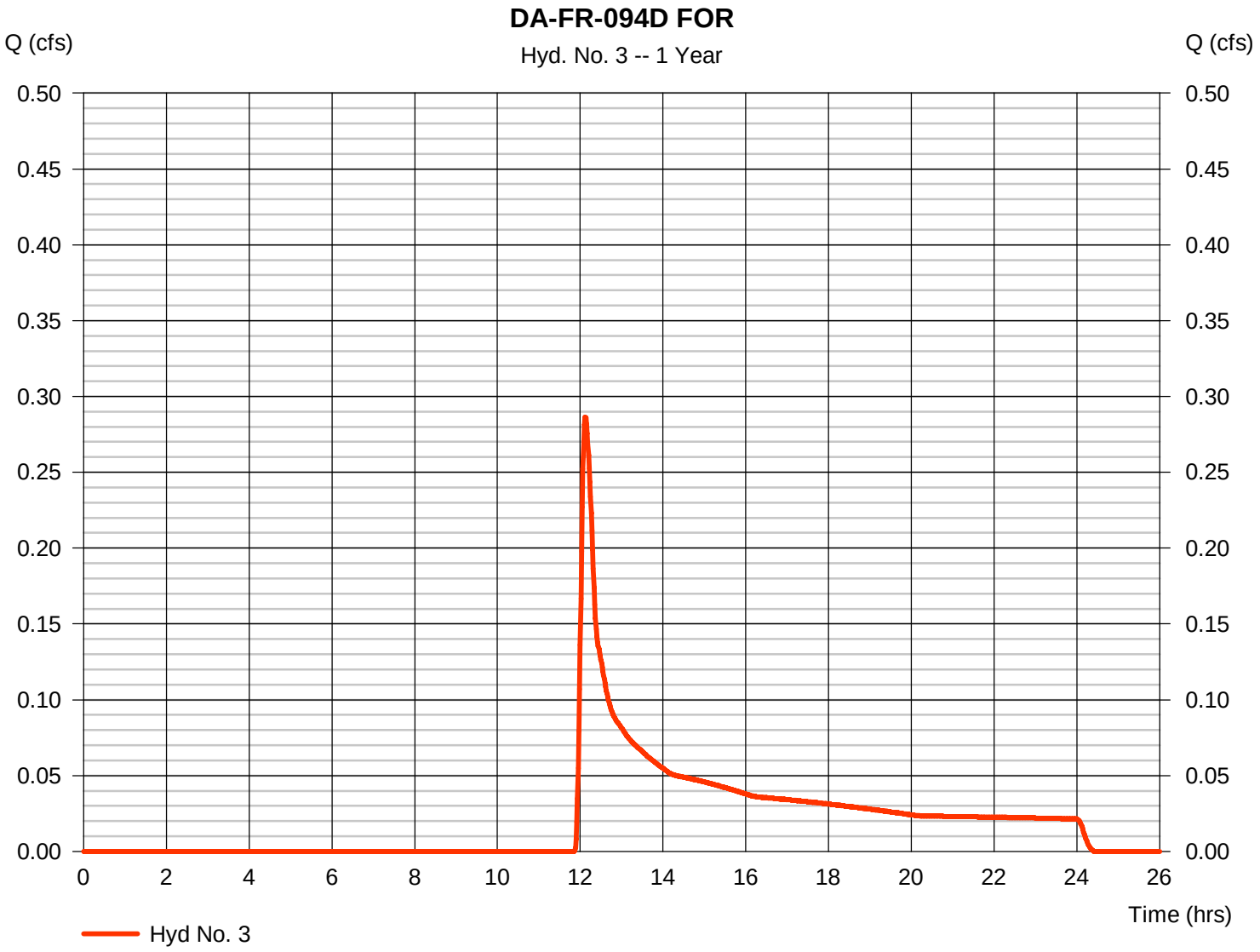
Total Travel Time, Tc ..... 26.40 min

Hydrograph Report

Hyd. No. 3

DA-FR-094D FOR

Hydrograph type	= SCS Runoff	Peak discharge	= 0.286 cfs
Storm frequency	= 1 yrs	Time to peak	= 12.12 hrs
Time interval	= 1 min	Hyd. volume	= 1,922 cuft
Drainage area	= 1.860 ac	Curve number	= 55
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.90 min
Total precip.	= 3.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



TR55 Tc Worksheet

Hyd. No. 3

DA-FR-094D FOR

Description	A		B		C		Totals
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)	= 3.70		0.00		0.00		
Land slope (%)	= 4.69		0.00		0.00		
Travel Time (min)	**= 14.20**	**+**	**0.00**	**+**	**0.00**	**=**	**14.20**
Shallow Concentrated Flow							
Flow length (ft)	= 629.39		0.00		0.00		
Watercourse slope (%)	= 15.50		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=6.35		0.00		0.00		
Travel Time (min)	**= 1.65**	**+**	**0.00**	**+**	**0.00**	**=**	**1.65**
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	= 0.015		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	0.568	1	726	2,841	------	------	------	DA-FR-094D PRE
2	SCS Runoff	0.228	1	736	2,109	------	------	------	DA-FR-094D DEV
3	SCS Runoff	0.568	1	726	2,841	------	------	------	DA-FR-094D FOR

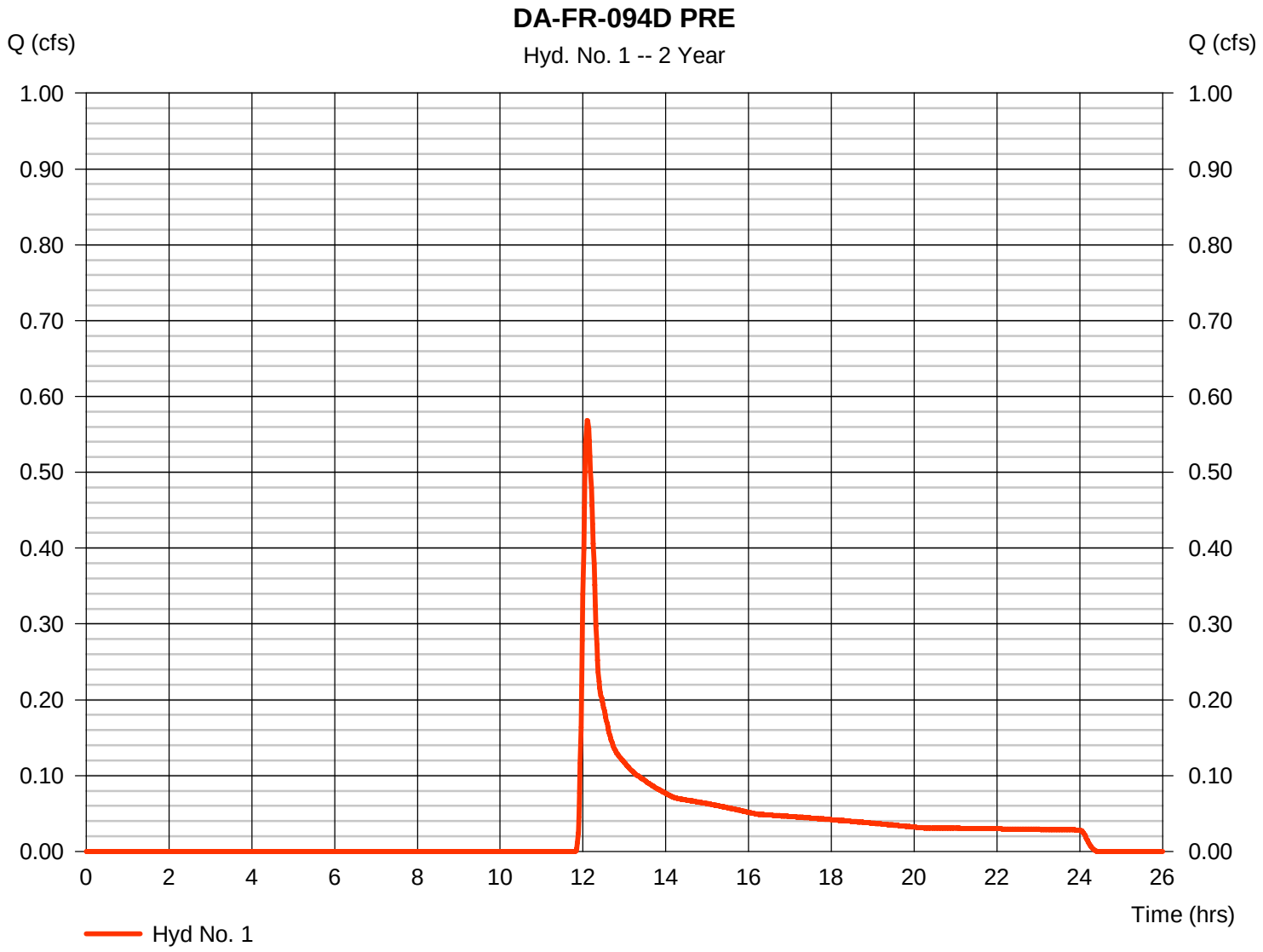
Hydrograph Report

Hyd. No. 1

DA-FR-094D PRE

Hydrograph type	= SCS Runoff	Peak discharge	= 0.568 cfs
Storm frequency	= 2 yrs	Time to peak	= 12.10 hrs
Time interval	= 1 min	Hyd. volume	= 2,841 cuft
Drainage area	= 1.860 ac	Curve number	= 55*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 15.90 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(0.004 x 100) + (1.853 x 55)] / 1.860



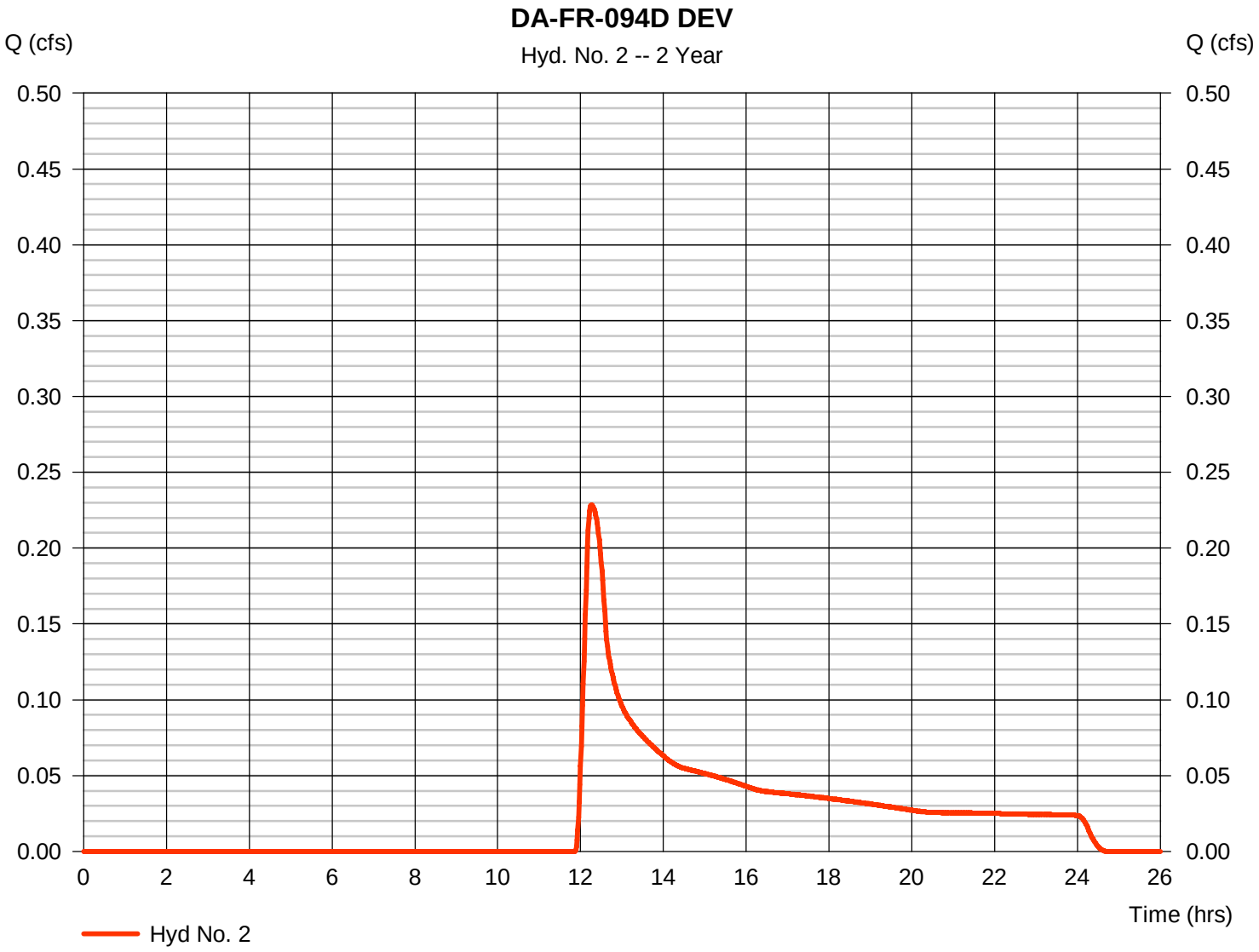
Hydrograph Report

Hyd. No. 2

DA-FR-094D DEV

Hydrograph type	= SCS Runoff	Peak discharge	= 0.228 cfs
Storm frequency	= 2 yrs	Time to peak	= 12.27 hrs
Time interval	= 1 min	Hyd. volume	= 2,109 cuft
Drainage area	= 1.860 ac	Curve number	= 52*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 26.40 min
Total precip.	= 3.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(1.073 x 48) + (0.781 x 58) + (0.004 x 100)] / 1.860

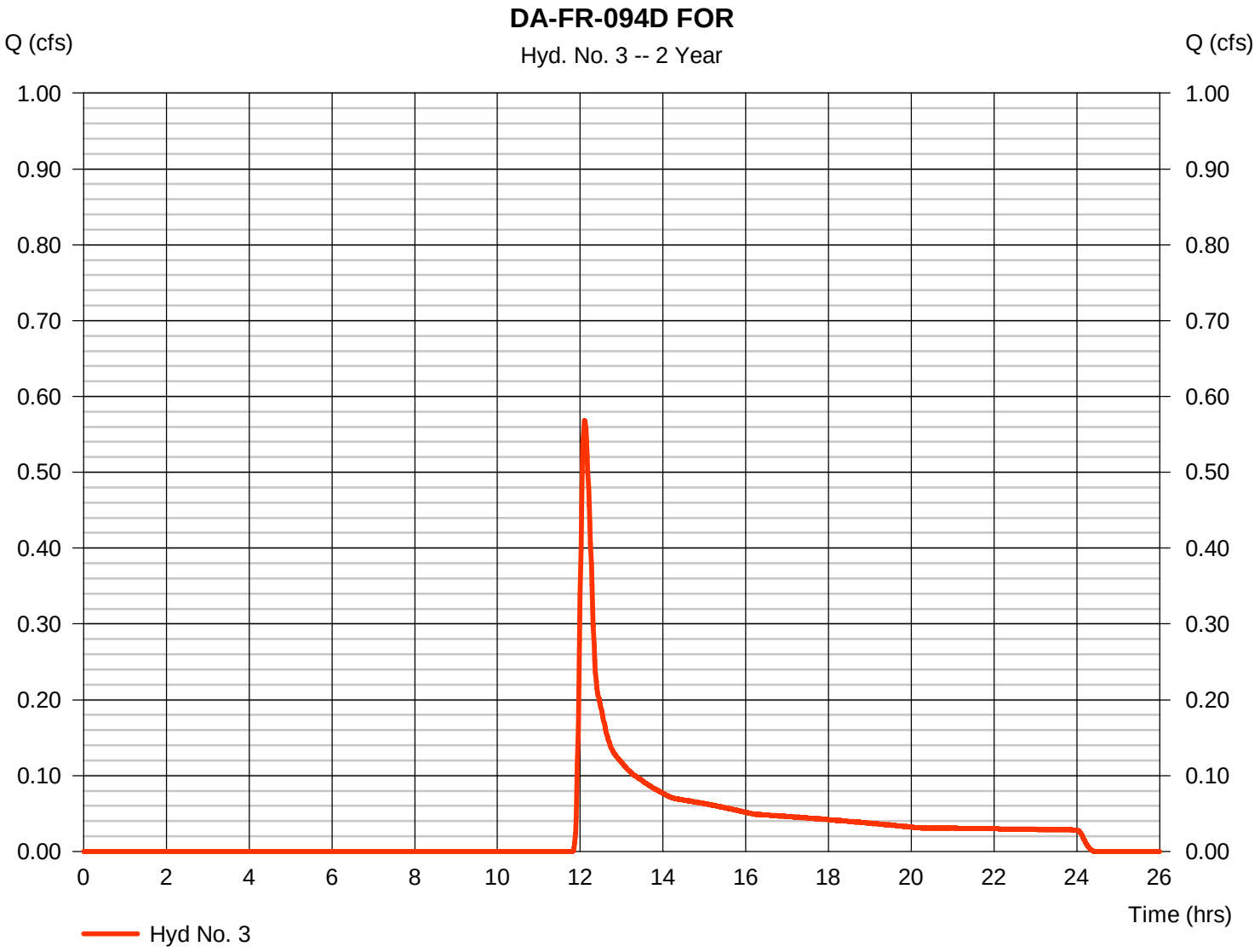


Hydrograph Report

Hyd. No. 3

DA-FR-094D FOR

Hydrograph type	=	SCS Runoff	Peak discharge	=	0.568 cfs
Storm frequency	=	2 yrs	Time to peak	=	12.10 hrs
Time interval	=	1 min	Hyd. volume	=	2,841 cuft
Drainage area	=	1.860 ac	Curve number	=	55
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	15.90 min
Total precip.	=	3.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484



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	2.874	1	724	9,219	------	------	------	DA-FR-094D PRE
2	SCS Runoff	1.641	1	731	7,723	------	------	------	DA-FR-094D DEV
3	SCS Runoff	2.874	1	724	9,219	------	------	------	DA-FR-094D FOR

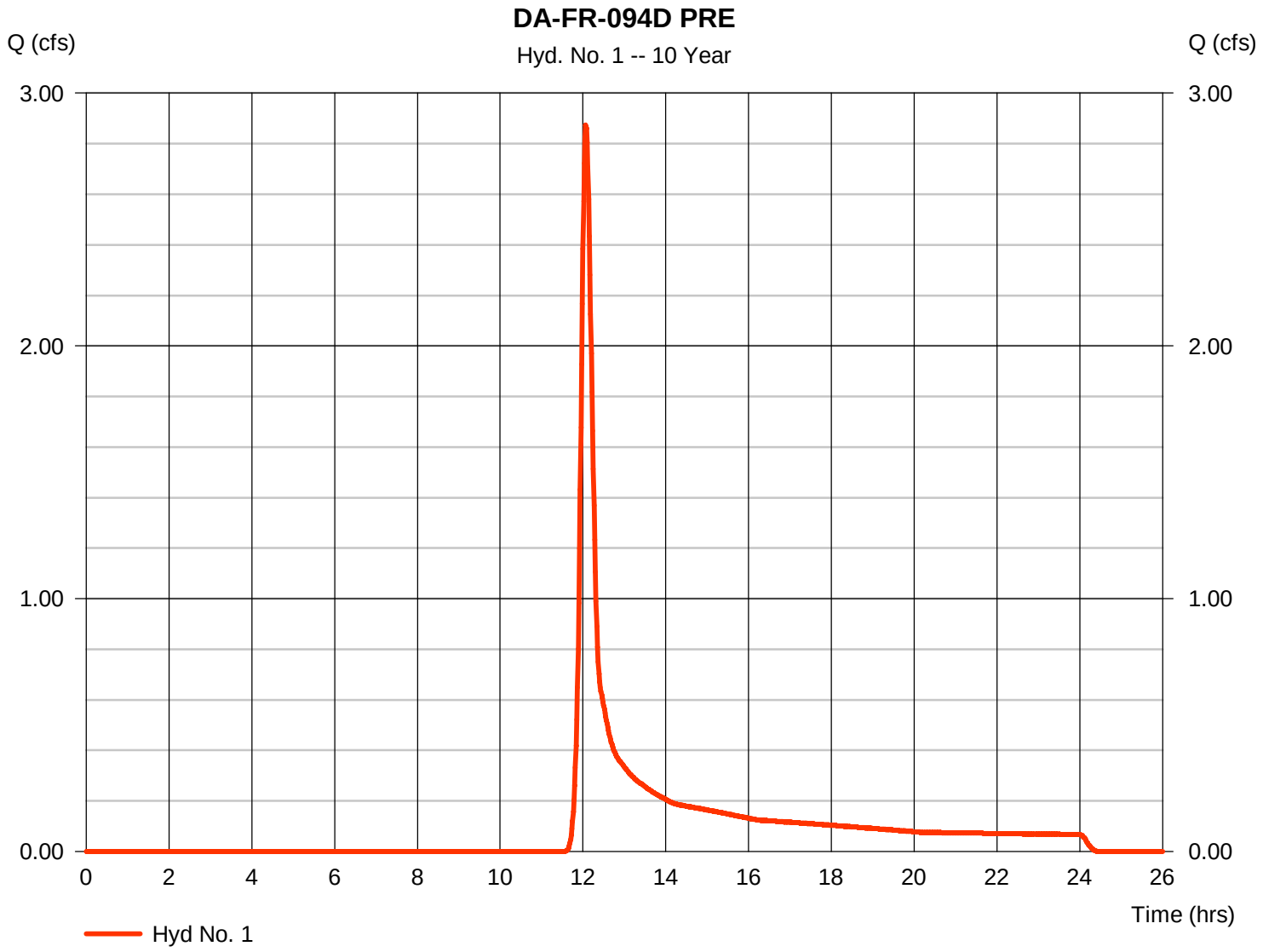
Hydrograph Report

Hyd. No. 1

DA-FR-094D PRE

Hydrograph type	=	SCS Runoff	Peak discharge	=	2.874 cfs
Storm frequency	=	10 yrs	Time to peak	=	12.07 hrs
Time interval	=	1 min	Hyd. volume	=	9,219 cuft
Drainage area	=	1.860 ac	Curve number	=	55*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	15.90 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(0.004 x 100) + (1.853 x 55)] / 1.860



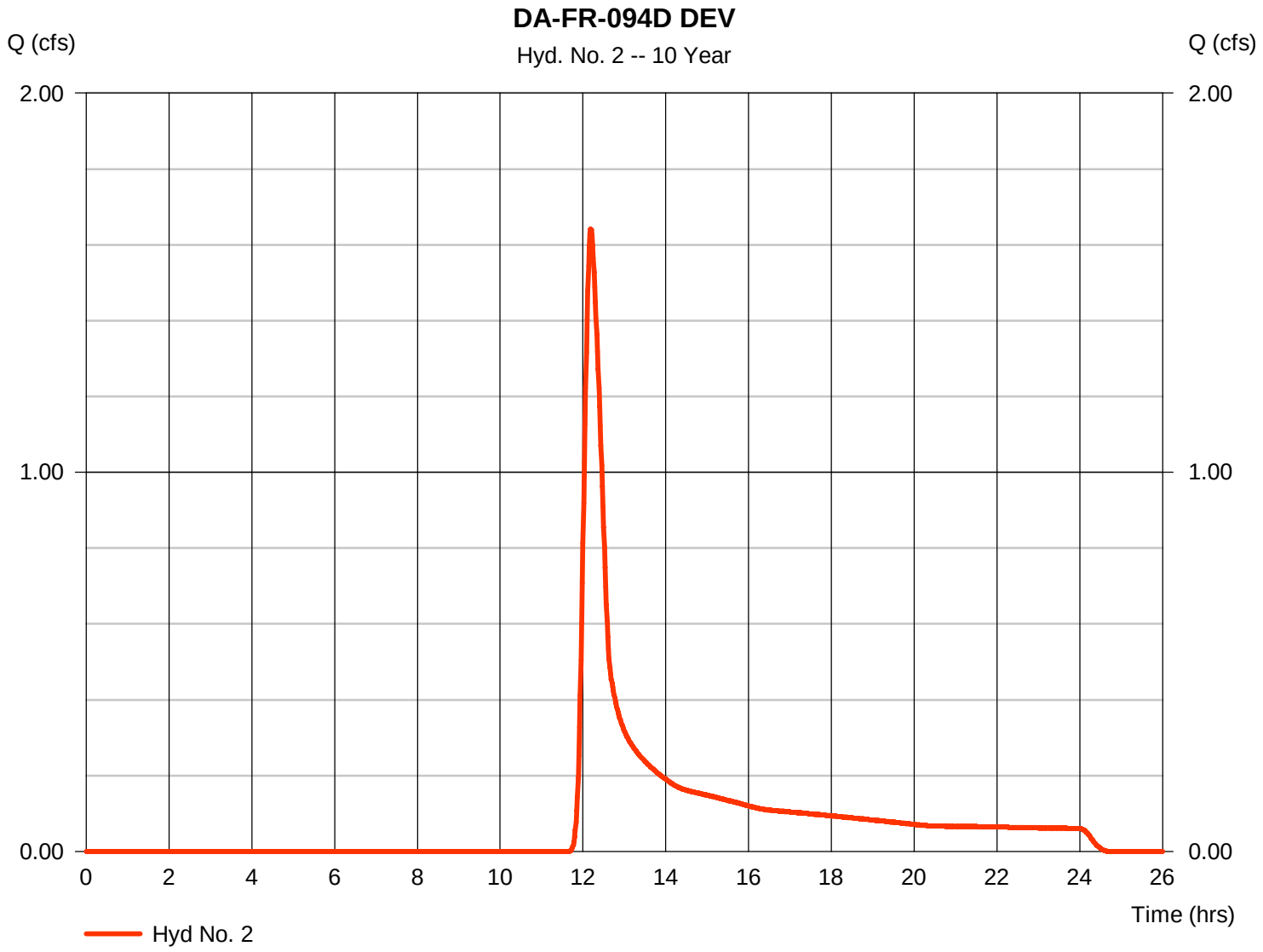
Hydrograph Report

Hyd. No. 2

DA-FR-094D DEV

Hydrograph type	=	SCS Runoff	Peak discharge	=	1.641 cfs
Storm frequency	=	10 yrs	Time to peak	=	12.18 hrs
Time interval	=	1 min	Hyd. volume	=	7,723 cuft
Drainage area	=	1.860 ac	Curve number	=	52*
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	26.40 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484

* Composite (Area/CN) = [(1.073 x 48) + (0.781 x 58) + (0.004 x 100)] / 1.860

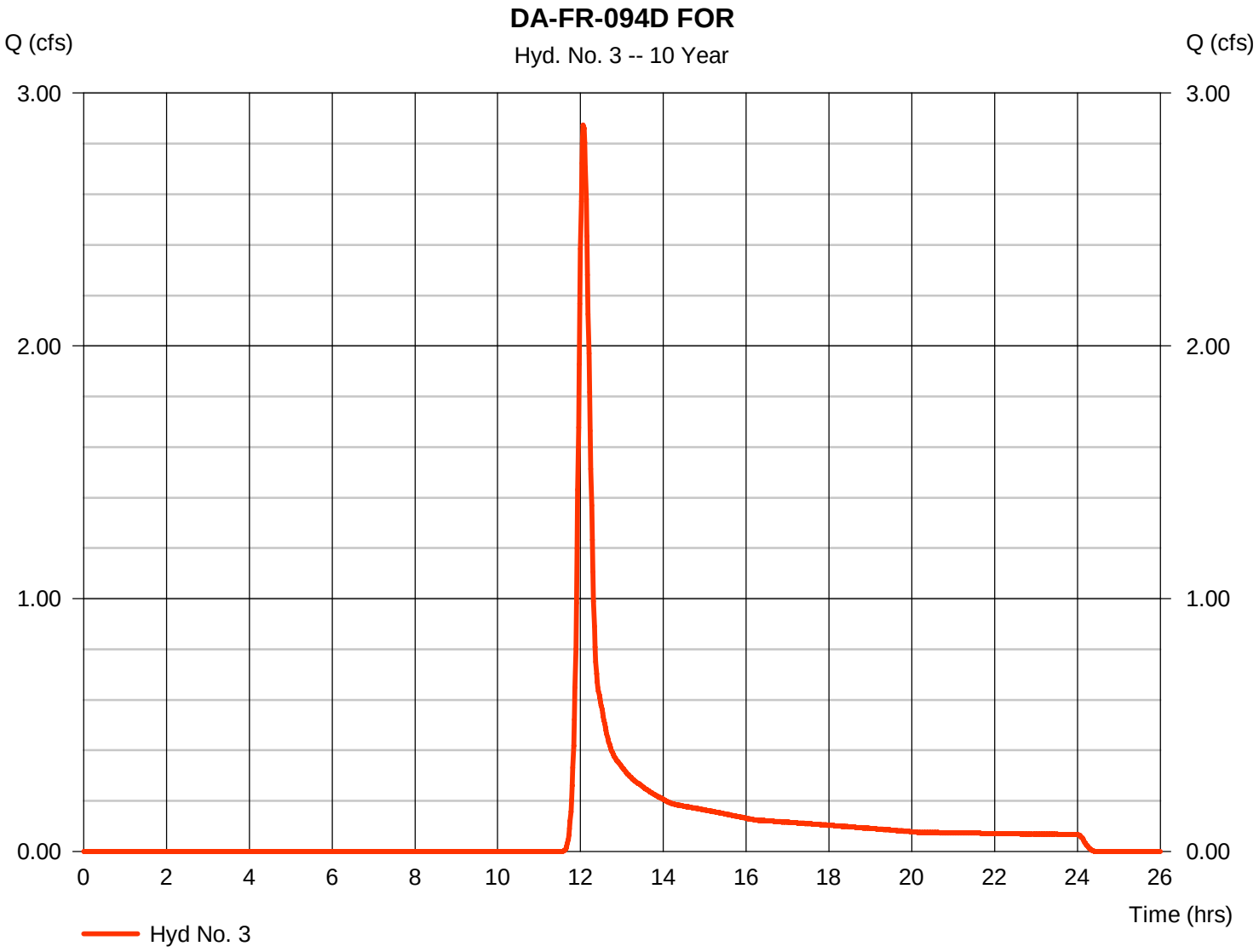


Hydrograph Report

Hyd. No. 3

DA-FR-094D FOR

Hydrograph type	=	SCS Runoff	Peak discharge	=	2.874 cfs
Storm frequency	=	10 yrs	Time to peak	=	12.07 hrs
Time interval	=	1 min	Hyd. volume	=	9,219 cuft
Drainage area	=	1.860 ac	Curve number	=	55
Basin Slope	=	0.0 %	Hydraulic length	=	0 ft
Tc method	=	TR55	Time of conc. (Tc)	=	15.90 min
Total precip.	=	5.70 in	Distribution	=	Type II
Storm duration	=	24 hrs	Shape factor	=	484



Hydraflow Rainfall Report

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

File name: SampleFHA.idf

Intensity = B / (Tc + D)^E

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

Tc = time in minutes. Values may exceed 60.

ng\Franklin County\Downloaded Files\Franklin County DA Batch 4 - 046 - 058\Precipitation\Hydraflow\FranklinCo.pc

Storm Distribution	Rainfall Precipitation Table (in)							
	1-yr	2-yr	3-yr	5-yr	10-yr	25-yr	50-yr	100-yr
SCS 24-hour	3.30	3.70	0.00	0.00	5.70	0.00	0.00	0.00
SCS 6-Hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-1st	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-2nd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-3rd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-4th	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Huff-Indy	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Custom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00