Stormwater Study

Lee's Summit Water Utilities

Water Utilities Facility – SE Hamblen Road

Lee's Summit, Missouri

October 24, 2014

HDR Engineering, Inc.
3741 NE Troon Dr
Lee's Summit, MO 64064
(816) 347-1100

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1 Introduction and Analysis Criteria

HDR Engineering, Inc. was retained by the City of Lee's Summit Water Utilities Department to perform a Stormwater Study for the proposed Water Utilities Facility off of SE Hamblen Road in Lee's Summit, MO. The new facility will be located west of Hamblen Road, north of Bailey Road, and south of Highway 50, as shown in the Vicinity Map below.

Figure 0-1 – Vicinity Map

The 9.76 acre site, of which approximately 0.54 acres will be dedicated as public street right-of-way, will contain a 42,500 square foot field services building and a paved storage area to support Water Utilities activities. **Figure 1-2**, at the end of this Section, shows the watershed areas and stormwater discharge locations. **Figure 1-3** shows the same features, without the aerial map background.

The City of Lee's Summit currently follows the comprehensive control strategy for development, in accordance with Kansas City Metropolitan Chapter American Public Works Association Section 5600. Comprehensive control limits the post-development peak discharge rates on a per acre basis for the 50%, 10%, and 1% storm events and also requires extended detention for the local 90% mean annual event. Peak discharge rates from the site are limited to 0.5, 2.0, and 3.0 cfs per site acre for the 50%, 10%, and 1% storm events, respectively. Forty-hour extended detention from the local 90% mean annual event, a 1.37-inch rainfall during a 24-hour storm event, is required for water quality.

The site currently receives offsite runoff from the west and southwest. These subwatersheds contain large areas of paved parking, not currently utilized, which drain onto the site before discharging to the north or northeast. An offsite south watershed discharges to a swale in Hamblen road right-of-way, on the east side of the project site. Allowable site discharges for regulatory storm events for the project site are summarized below in **Table 1-1**.

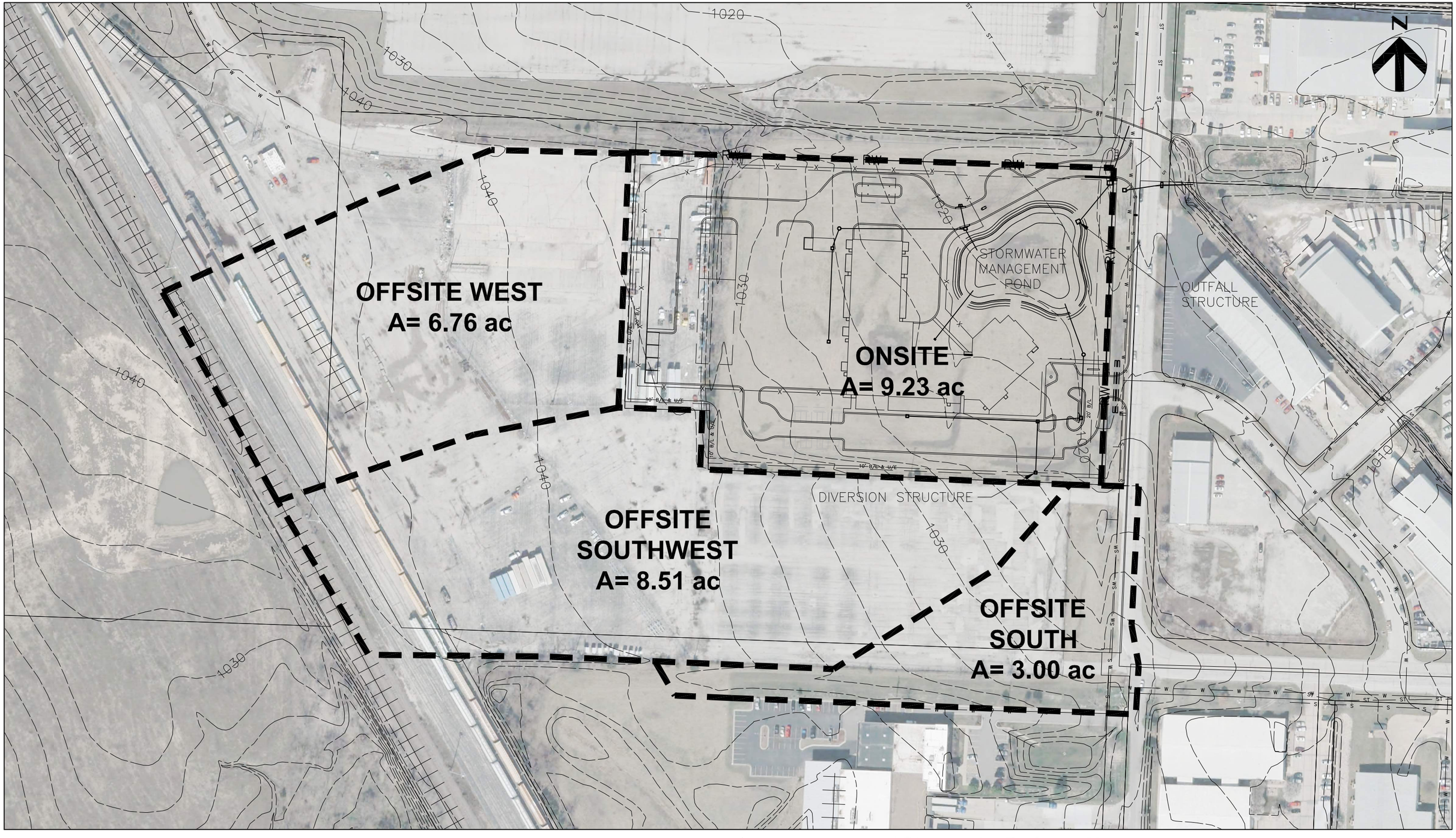
Table 1-1 – Allowable Discharge Rates

Subwatershed	Drainage Area (Ac)	Allowable 50% Storm Peak Flow (cfs)	Allowable 10% Storm Peak Flow (cfs)	Allowable 1% Storm Peak Flow (cfs)
Onsite	9.23	4.6	18.5	27.7

The extended detention volume from the local 90% mean annual event correlates to the percentage of impervious area. The impervious area, including the permanent pool for the proposed stormwater pond, is 57 percent of the site. The calculations utilize an impervious area of 60 percent, to allow for additions to impervious area in the future. The Mid-America Regional Council and American Public Works Association Manual of Best Management Practices for Stormwater Quality, October 2012 edition, includes methodology for determining the water quality volume. Utilizing the shortcut method, WQv (Water Quality Volume, inches) = P (Rainfall event, inches) x Rv (Volumetric runoff coefficient), with 1.37-inches of precipitation and 60 percent impervious area, results in 0.81-inches of runoff to be treated over the site. The water quality volumes for the Water Utilities Facility are summarized below in **Table 1-2**.

Table 1-2 – Water Quality Volumes

Subwatershed	Drainage Area (Ac)	Water Quality Volume (cf)	Water Quality Volume (ac-ft)
Onsite	9.23	27,082	0.62



SCALE: 1" = 150'
(11"x17")

0 1" 2"

HDR ENGINEERING, INC.
MO. STATE CERTIFICATE
OF AUTHORITY #000856

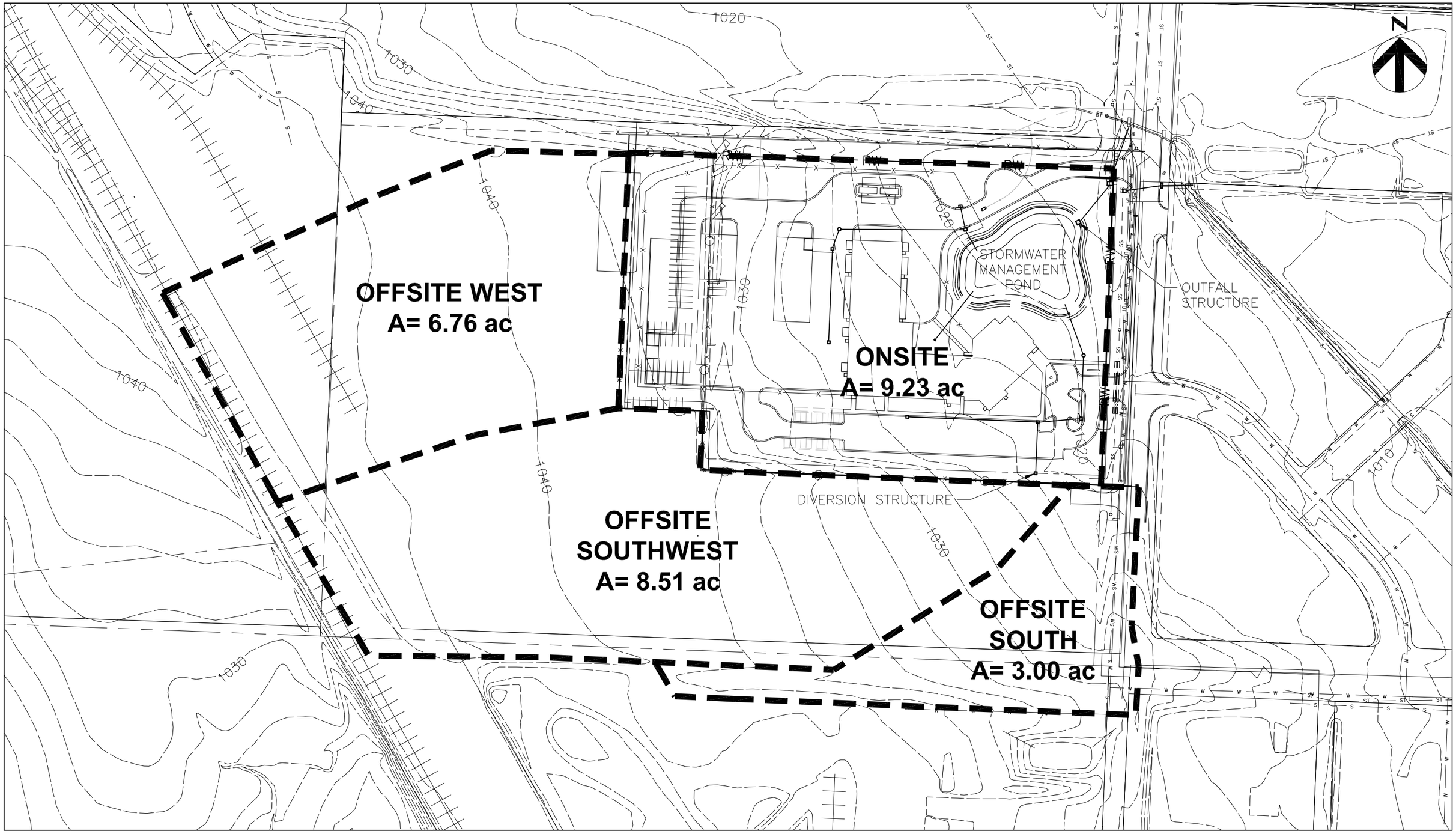
3741 NE TROON DRIVE
LEE'S SUMMIT, MO 64064-1988
816.347.1100

Stormwater Drainage Map

Lee's Summit Water Utilities Stormwater Study

DATE
Oct 2014

FIGURE
1-2



SCALE: 1" = 150'
(11"x17")

0 1" 2"

HDR ENGINEERING, INC.
MO. STATE CERTIFICATE
OF AUTHORITY #000856

3741 NE TROON DRIVE
LEE'S SUMMIT, MO 64064-1988
816.347.1100

Stormwater Drainage Map (No Aerial)

Lee's Summit Water Utilities Stormwater Study

DATE
Oct 2014

FIGURE
1–3

2 Proposed Conditions

Hydraflow Hydrographs stormwater modeling program was used to determine the drainage characteristics for the pre and post-development conditions. Hydraflow Hydrographs uses the composite curve number (CN) and time of concentration (Tc) to generate peak discharge rates and volumes for the 50%, 10%, and 1% 24-hour storm events. The software includes Technical Release 55 (TR-55) calculations to calculate the CN based on user inputs of categorized area values, which for this study is based upon both pre and post-development conditions. The Tc is calculated with TR-55 based on inputs of flow types, flow path lengths, surface types, slopes, and flow velocities. Pre and Post-development site discharges for the varying storm events, without stormwater management controls for the post-development condition, are presented below in **Tables 2-1** and **2-2**.

Table 2-1 – Site Pre-Development Discharge Rates

Subwatershed	Drainage Area (Ac)	50% Storm Peak Flow (cfs)	10% Storm Peak Flow (cfs)	1% Storm Peak Flow (cfs)
Onsite	9.23	16.2	34.7	61.9

Table 2-2 – Site Post-Development Discharge Rates (without controls)

Subwatershed	Drainage Area (Ac)	50% Storm Peak Flow (cfs)	10% Storm Peak Flow (cfs)	1% Storm Peak Flow (cfs)
Onsite	9.23	32.8	55.7	86.0

The proposed Water Utilities Facility is located on an undeveloped parcel, but it surrounded by improvements on all sides. Many of the surrounding improvements contain a very high percentage of impervious area, contributing significantly to peak discharge rates at SE Hamblen Road during large storm events. It is understood that the comprehensive strategy for stormwater management is geared toward greenfield development and development at this site might be considered redevelopment to a degree. Providing detention for the largest storm events to the comprehensive level requires significant storage volume and can restrict the total onsite impervious area. Therefore an exception to the maximum allowable release rates is sought for the 50%, 10%, and 1% storm events. The post-development discharge rates for the regulatory storm events will be restricted to pre-development rates, to maintain existing conditions. Extended 40-hour detention will be provided for water quality.

A stormwater pond, with a permanent pool, is proposed near the NE Hamblen Road frontage at the northeast corner of the site. In an effort to maintain the permanent pool elevation during relatively dry periods with minimal rainfall, a portion of the offsite southwest drainage area runoff will be intercepted by the onsite stormwater infrastructure and routed to the pond. The swale diversion structure that intercepts a fraction of the offsite flow consists of a double grate inlet that is depressed 6-inches below the flowline of the conveyance swale. The sump capacity of the grate opening regulates flow entering the onsite system, while allowing excess flow to continue to bypass the site via a perimeter swale to SE Hamblen Road right-of-way swales. The diversion flows into the site and the modified allowable pre-development discharge rates, for regulatory storm events, are presented on the following page in **Tables 2-3** and **2-4**.

Table 2-3 – Offsite Diversion Peak Discharge Rates

Subwatershed	50% Storm Peak Flow (cfs)	10% Storm Peak Flow (cfs)	1% Storm Peak Flow (cfs)
Offsite Southwest, Diversion to Onsite	13.2	14.2	11.2*

*Enclosed pipe system HGL during 1% storm, with pond elevation at 1% storm elevation, will further limit flow into the collection system. Excess flow will continue to be diverted to the right-of-way swale.

Table 2-4 – Modified Pre-Development Discharge Rate Targets

Subwatershed	50% Storm Peak Flow (cfs)	10% Storm Peak Flow (cfs)	1% Storm Peak Flow (cfs)
Onsite, with Diversion from Offsite Southwest	29.4	48.9	73.1

A retaining wall is incorporated into the interior face of the pond, to improve the aesthetics and increase the available storage volume above the permanent pool. The required water quality volume is provided above the permanent pool elevation and drawn down over a 40-hour period. An outfall structure is incorporated into the face of the retaining wall to regulate discharges to pre-development rates as described above. The additional runoff rate from the diversion swale is passed through the outfall structure, via rectangular openings on the sides. An emergency spillway is provided near the north side of the basin in the event back to back 1% storms occur or the primary outlet becomes clogged. The design detention basin stage storage table is provided below as **Table 2-5**.

Table 2-5 – Detention Basin Stage Storage

Elevation (ft)	Area (ft^2)	Area (ac)	Avg. Area (ft^2)	Depth (ft)	Incremental Volume (ft^3)	Cumulative Volume (ft^3)	Cumulative Volume (ac-ft)	Notes
1008.0	12,653	0.291			0	0	0	Bottom of Pond
			17,043	5.5				
1013.5	21,433	0.492			93,736	93,736	2.15	
			24,348	1.5				
1015.0	27,264	0.626			36,523	130,259	2.99	
			27,264	1				
1016.0	27,264	0.626			27,264	157,523	3.62	Permanent Pool Elev.
			27,264	1				
1017.0	27,264	0.626			27,264	184,787	4.24	
			27,264	0.25				
1017.25	27,264	0.626			6,816	191,603	4.40	Water Quality Elev.
			27,264	0.75				
1018.0	27,264	0.626			20,448	212,051	4.87	
			27,264	1				
1019.0	27,264	0.626			27,264	239,315	5.49	
			27,264	1				
1020.0	27,264	0.626			27,264	266,579	6.12	Emergency Spillway Elev. & Top of Retaining Wall
			29,422	1				
1021.0	31,581	0.725			29,422	296,001	6.80	
			32,975	1				
1022.0	34,369	0.789			32,975	328,976	7.55	Top of Bank

In the existing condition, the offsite west subwatershed drains onto the site and discharges north via a swale to the existing detention basin located on the adjacent property (vacant Adessa property). In order to reduce the pass through flow in the proposed stormwater basin, this offsite area will continue to be bypassed around the site in the post-development condition. A stormwater swale will be located adjacent to the west property line and convey the flow to the concrete spillway into the adjacent detention basin.

Similarly most flow from the offsite southwest subwatershed will be routed east to the SE Hamblen Road right-of-way via a swale. Currently the properties frontage along SE Hamblen Road is not improved with curb and gutter and an enclosed storm sewer system. Curb will be installed along the frontage, but flumes will provide the drainage to the right-of-way swale. The swale will promote water quality while also increasing conveyance capacity during significant storm events.

Discharge from the southwest, south, and onsite areas currently discharge to an existing 36-inch CMP at the northeast corner of the water utilities facility parcel. Any surcharge that's experienced during large storm events likely ponds on the undeveloped land until the hydraulic grade lines subside. To improve regional stormwater hydraulics, a new outfall will be provided from the SE Hamblen Road right-of-way swale east across SE Hamblen Road to the downstream channel. Flow from the proposed stormwater basin will continue to flow to the existing outfall location, with a modification to the existing curb inlet structure sidewall to increase its depth to accept a larger pipe diameter.

3 Summary

The proposed stormwater basin will provide water quality treatment and detention to pre-development release rates for all regulatory storm events. Runoff from the site will be routed to the stormwater management facility and offsite flows will be diverted around the site. A new stormwater outfall location will be provided for the adjacent offsite drainage to improve hydraulic characteristics of the existing storm water system. The detention basin will limit release rates as summarized below in **Table 3-1**.

Table 3-1 – Summary of Onsite Discharge Rates

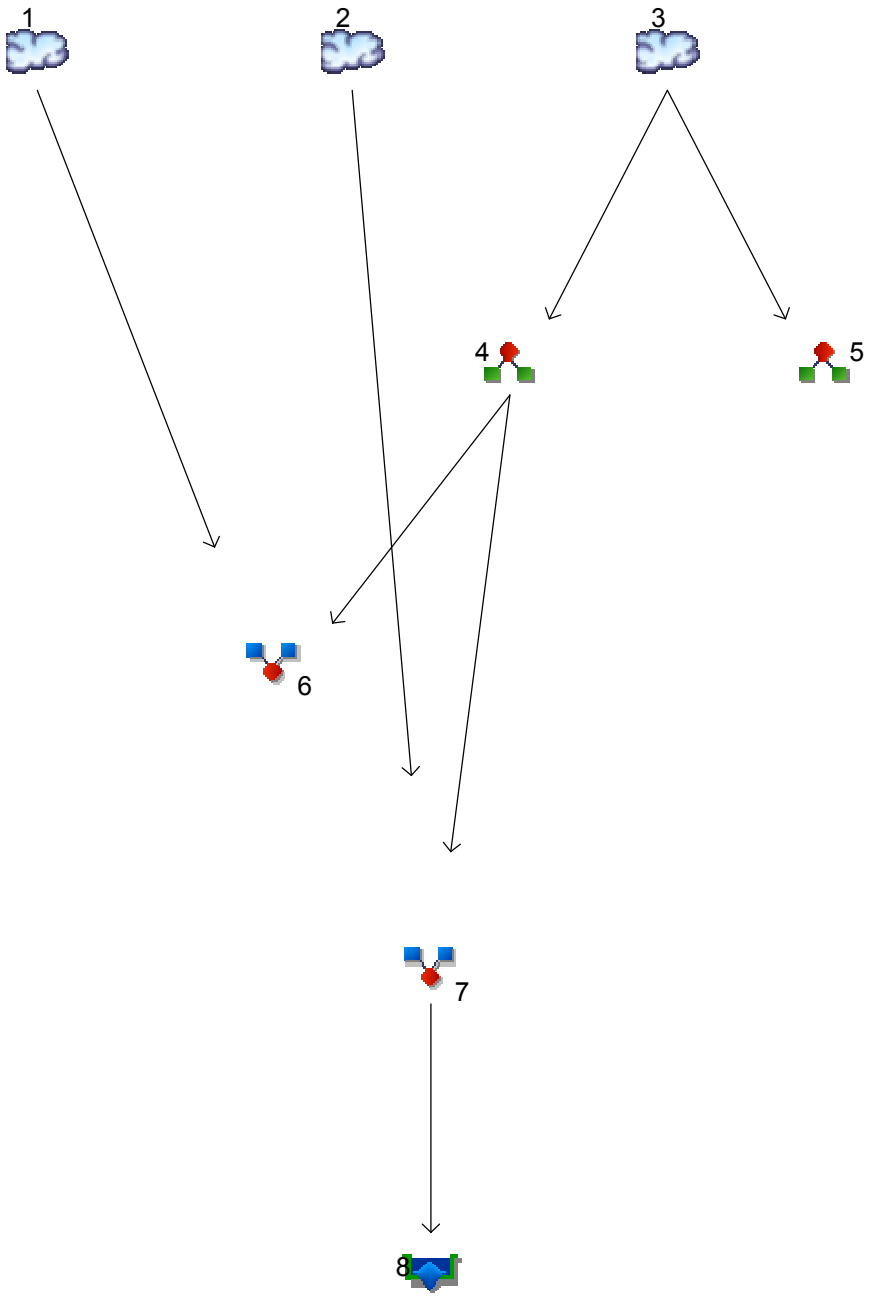
Storm Event	Comprehensive Allowable Peak Flow (cfs)	Onsite Pre-Development Peak Flow (cfs)	Swale Diversion Peak Flow (cfs)	Modified Pre-Development Peak Flow Target (cfs)	Maximum Proposed Post-Development Peak Flow (cfs)	Basin Water Surface Elevation (ft)
50%	4.6	16.2	13.2	29.4	25.5	1018.23
10%	18.5	34.7	14.2	48.9	43.4	1018.86
1%	27.7	61.9	11.2	73.1	67.8	1019.37

As shown by **Table 3-1**, the project will not increase peak discharges from the site from modified pre-development conditions for all regulatory storm events.

Appendix

Watershed Model Schematic

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2011 by Autodesk, Inc. v8



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2011 by Autodesk, Inc. v8

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	16.18	2	722	42,841	------	------	------	Onsite - Pre
2	SCS Runoff	32.77	2	718	76,012	------	------	------	Onsite - Post
3	SCS Runoff	38.43	2	718	100,787	------	------	------	Offsite Southwest
4	Diversion1	13.20	2	714	83,223	3	------	------	To Basin
5	Diversion2	25.23	2	718	17,564	3	------	------	To ROW
6	Combine	29.38	2	722	126,064	1, 4,	------	------	Target Release
7	Combine	45.97	2	718	159,235	2, 4,	------	------	Diverted to Basin
8	Reservoir	22.93	2	728	159,097	7	1018.23	60,714	Basin Discharge

Hydrograph Report

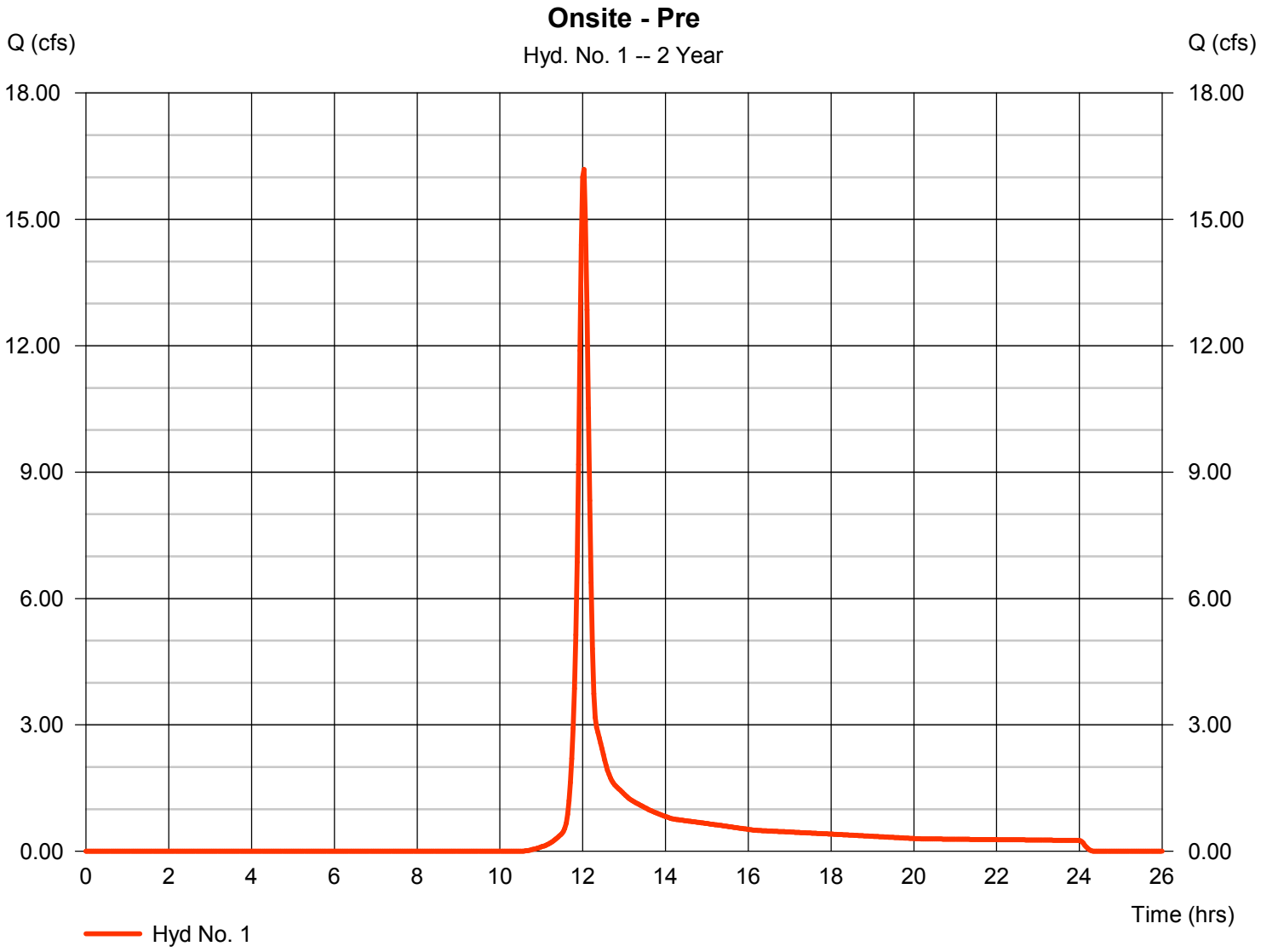
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2011 by Autodesk, Inc. v8 Friday, Oct 24, 2014

Hyd. No. 1

Onsite - Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 16.18 cfs
Storm frequency	= 2 yrs	Time to peak	= 12.03 hrs
Time interval	= 2 min	Hyd. volume	= 42,841 cuft
Drainage area	= 9.230 ac	Curve number	= 74*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.60 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(5.540 x 98) + (3.690 x 74)] / 9.230



TR55 Tc Worksheet

Hyd. No. 1

Onsite - Pre

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.150		0.011		0.011		
Flow length (ft)	= 100.0		0.0		0.0		
Two-year 24-hr precip. (in)	= 3.50		0.00		0.00		
Land slope (%)	= 2.00		0.00		0.00		
Travel Time (min)	**= 9.37**	**+**	**0.00**	**+**	**0.00**	**=**	**9.37**
Shallow Concentrated Flow							
Flow length (ft)	= 320.00		0.00		0.00		
Watercourse slope (%)	= 3.00		0.00		0.00		
Surface description	= Unpaved		Paved		Paved		
Average velocity (ft/s)	=2.79		0.00		0.00		
Travel Time (min)	**= 1.91**	**+**	**0.00**	**+**	**0.00**	**=**	**1.91**
Channel Flow							
X sectional flow area (sqft)	= 20.00		0.00		0.00		
Wetted perimeter (ft)	= 15.00		0.00		0.00		
Channel slope (%)	= 1.75		0.00		0.00		
Manning's n-value	= 0.015		0.015		0.015		
Velocity (ft/s)	=15.93						
			0.00				
					0.00		
Flow length (ft)	({0})345.0		0.0		0.0		
Travel Time (min)	**= 0.36**	**+**	**0.00**	**+**	**0.00**	**=**	**0.36**

Total Travel Time, Tc ..... 11.60 min

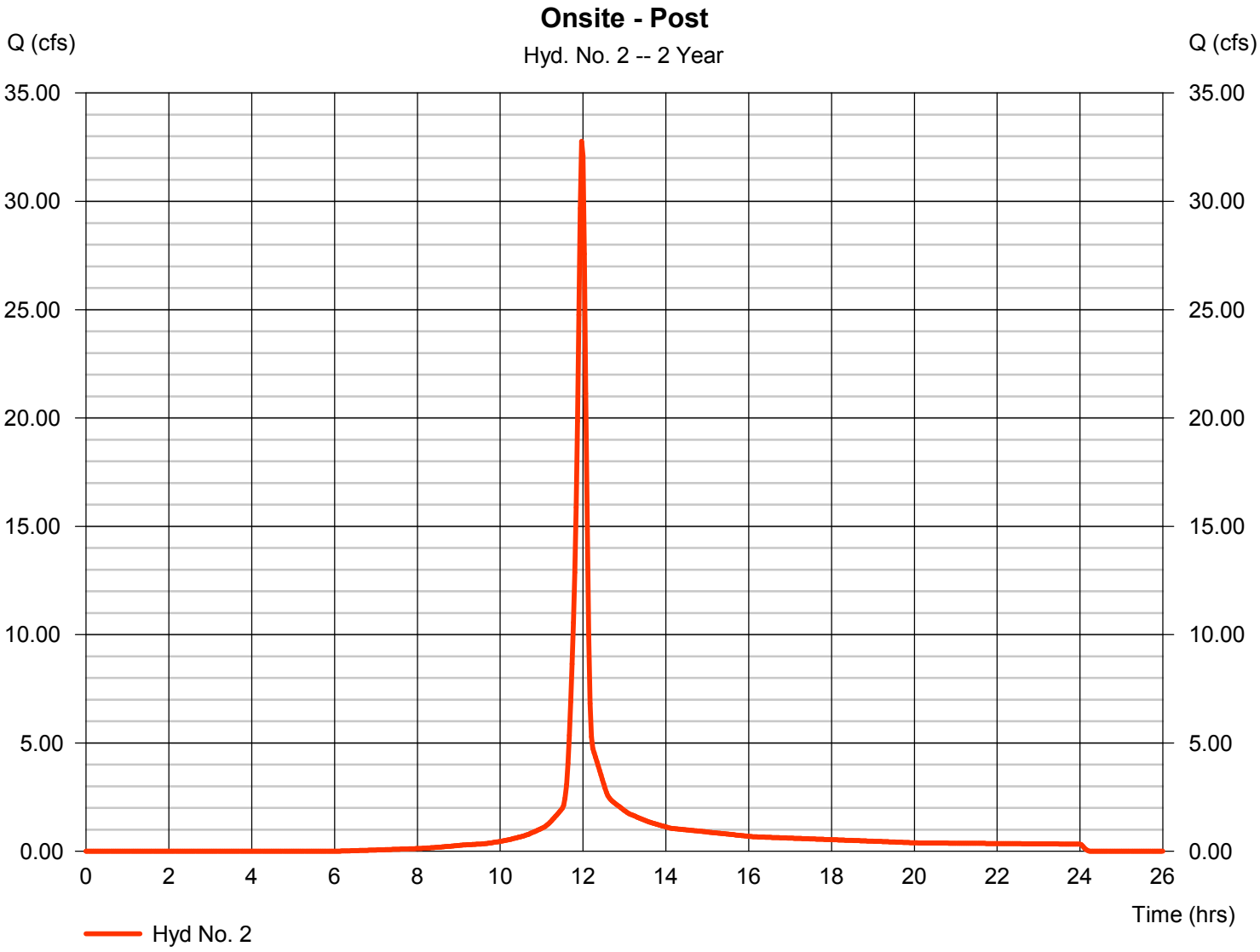
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2011 by Autodesk, Inc. v8 Friday, Oct 24, 2014

Hyd. No. 2

Onsite - Post

Hydrograph type	= SCS Runoff	Peak discharge	= 32.77 cfs
Storm frequency	= 2 yrs	Time to peak	= 11.97 hrs
Time interval	= 2 min	Hyd. volume	= 76,012 cuft
Drainage area	= 9.230 ac	Curve number	= 88
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.00 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



TR55 Tc Worksheet

Hyd. No. 2

Onsite - Post

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.240		0.011		0.011		
Flow length (ft)	= 60.0		0.0		0.0		
Two-year 24-hr precip. (in)	= 3.50		0.00		0.00		
Land slope (%)	= 6.50		0.00		0.00		
Travel Time (min)	**= 5.66**	**+**	**0.00**	**+**	**0.00**	**=**	**5.66**
Shallow Concentrated Flow							
Flow length (ft)	= 175.00		0.00		0.00		
Watercourse slope (%)	= 2.00		0.00		0.00		
Surface description	= Paved		Unpaved		Paved		
Average velocity (ft/s)	=2.87		0.00		0.00		
Travel Time (min)	**= 1.01**	**+**	**0.00**	**+**	**0.00**	**=**	**1.01**
Channel Flow							
X sectional flow area (sqft)	= 3.14		0.00		0.00		
Wetted perimeter (ft)	= 6.28		0.00		0.00		
Channel slope (%)	= 1.50		0.00		0.00		
Manning's n-value	= 0.015		0.015		0.015		
Velocity (ft/s)	=7.65						
			0.00				
					0.00		
Flow length (ft)	({0})590.0		0.0		0.0		
Travel Time (min)	**= 1.29**	**+**	**0.00**	**+**	**0.00**	**=**	**1.29**

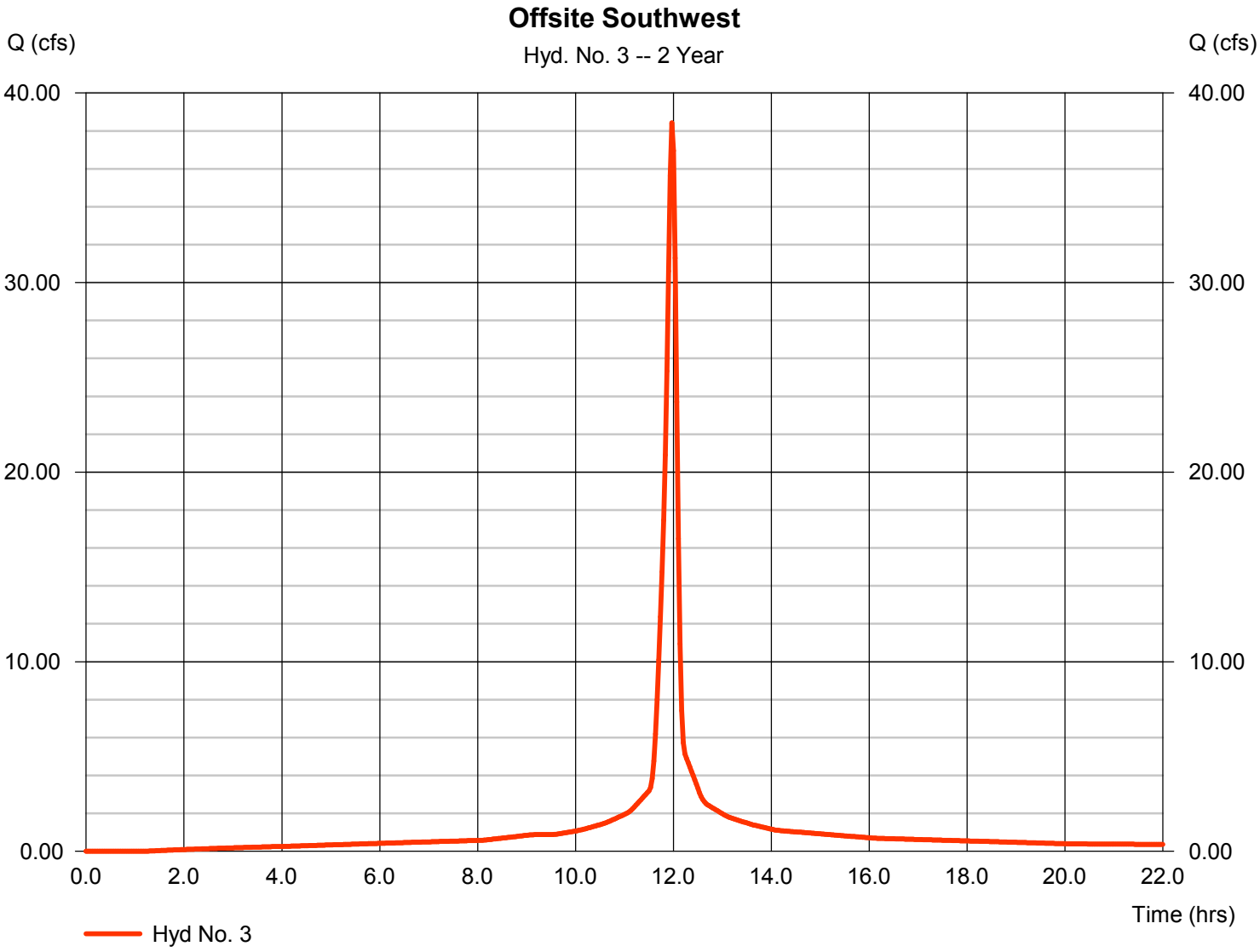
Total Travel Time, Tc ..... 8.00 min

Hydrograph Report

Hyd. No. 3

Offsite Southwest

Hydrograph type	= SCS Runoff	Peak discharge	= 38.43 cfs
Storm frequency	= 2 yrs	Time to peak	= 11.97 hrs
Time interval	= 2 min	Hyd. volume	= 100,787 cuft
Drainage area	= 8.500 ac	Curve number	= 98
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 7.10 min
Total precip.	= 3.50 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



TR55 Tc Worksheet

Hyd. No. 3

Offsite Southwest

Description	A		B		C		Totals
Sheet Flow							
Manning's n-value	= 0.011		0.011		0.011		
Flow length (ft)	= 300.0		0.0		0.0		
Two-year 24-hr precip. (in)	= 3.50		0.00		0.00		
Land slope (%)	= 2.00		0.00		0.00		
Travel Time (min)	**= 2.79**	**+**	**0.00**	**+**	**0.00**	**=**	**2.79**
Shallow Concentrated Flow							
Flow length (ft)	= 670.00		0.00		0.00		
Watercourse slope (%)	= 1.65		0.00		0.00		
Surface description	= Paved		Paved		Paved		
Average velocity (ft/s)	=2.61		0.00		0.00		
Travel Time (min)	**= 4.28**	**+**	**0.00**	**+**	**0.00**	**=**	**4.28**
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 ..... 7.10 min

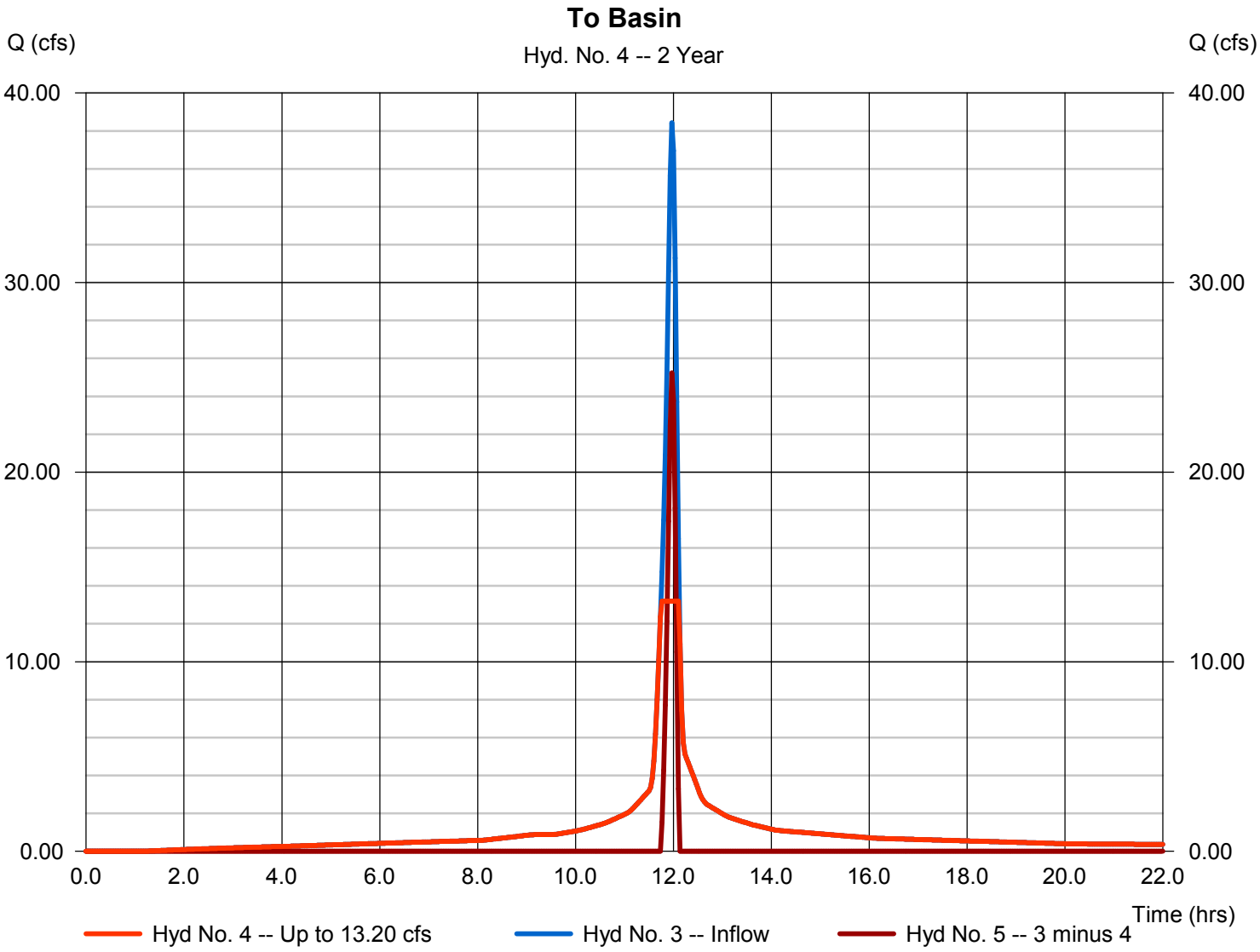
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2011 by Autodesk, Inc. v8 Friday, Oct 24, 2014

Hyd. No. 4

To Basin

Hydrograph type	= Diversion1	Peak discharge	= 13.20 cfs
Storm frequency	= 2 yrs	Time to peak	= 11.90 hrs
Time interval	= 2 min	Hyd. volume	= 83,223 cuft
Inflow hydrograph	= 3 - Offsite Southwest	2nd diverted hyd.	= 5
Diversion method	= Constant Q	Constant Q	= 13.20 cfs

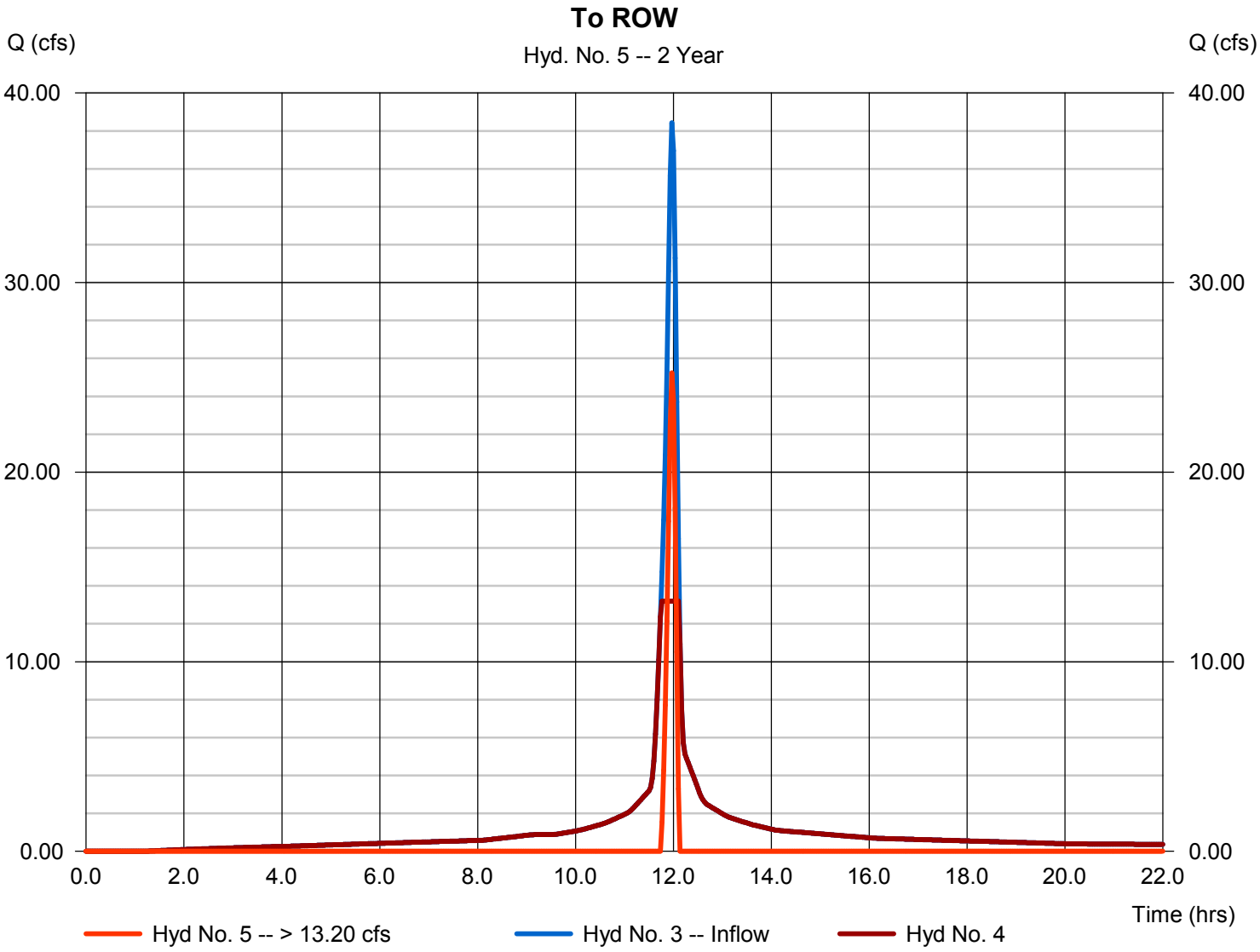


Hydrograph Report

Hyd. No. 5

To ROW

Hydrograph type	= Diversion2	Peak discharge	= 25.23 cfs
Storm frequency	= 2 yrs	Time to peak	= 11.97 hrs
Time interval	= 2 min	Hyd. volume	= 17,564 cuft
Inflow hydrograph	= 3 - Offsite Southwest	2nd diverted hyd.	= 4
Diversion method	= Constant Q	Constant Q	= 13.20 cfs



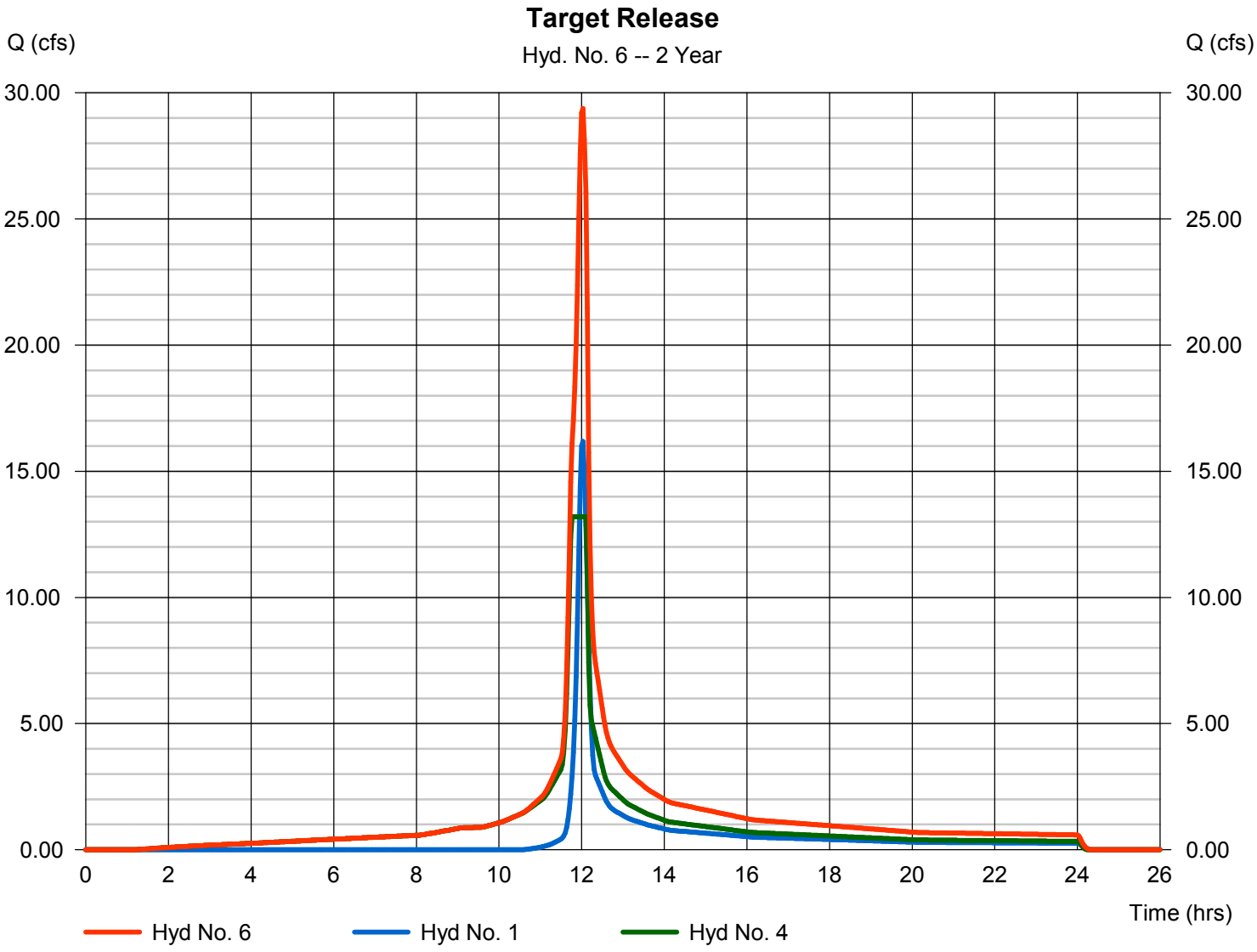
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2011 by Autodesk, Inc. v8 Friday, Oct 24, 2014

Hyd. No. 6

Target Release

Hydrograph type	= Combine	Peak discharge	= 29.38 cfs
Storm frequency	= 2 yrs	Time to peak	= 12.03 hrs
Time interval	= 2 min	Hyd. volume	= 126,064 cuft
Inflow hyds.	= 1, 4	Contrib. drain. area	= 9.230 ac



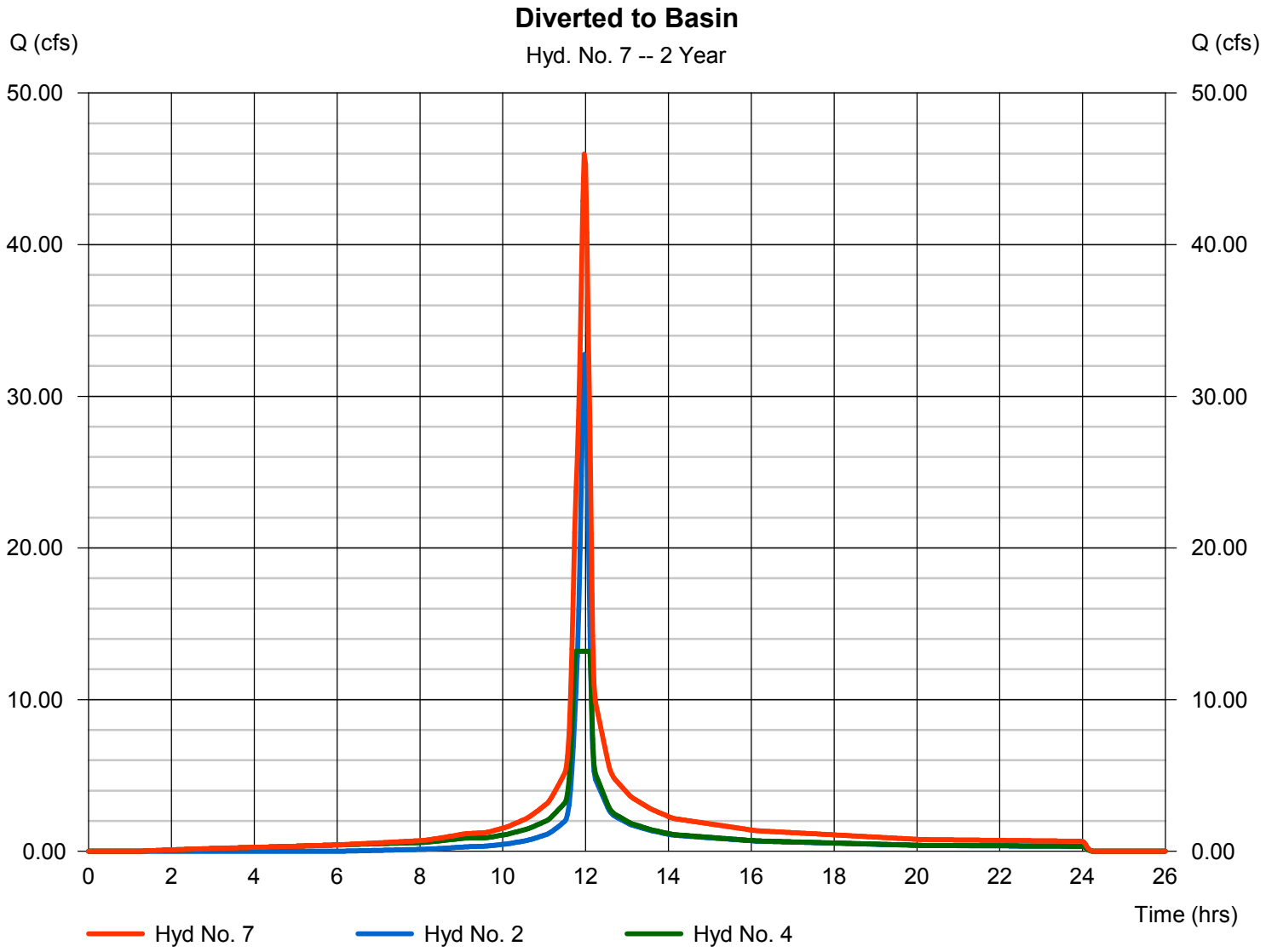
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2011 by Autodesk, Inc. v8 Friday, Oct 24, 2014

Hyd. No. 7

Diverted to Basin

Hydrograph type	= Combine	Peak discharge	= 45.97 cfs
Storm frequency	= 2 yrs	Time to peak	= 11.97 hrs
Time interval	= 2 min	Hyd. volume	= 159,235 cuft
Inflow hyds.	= 2, 4	Contrib. drain. area	= 9.230 ac



Hydrograph Report

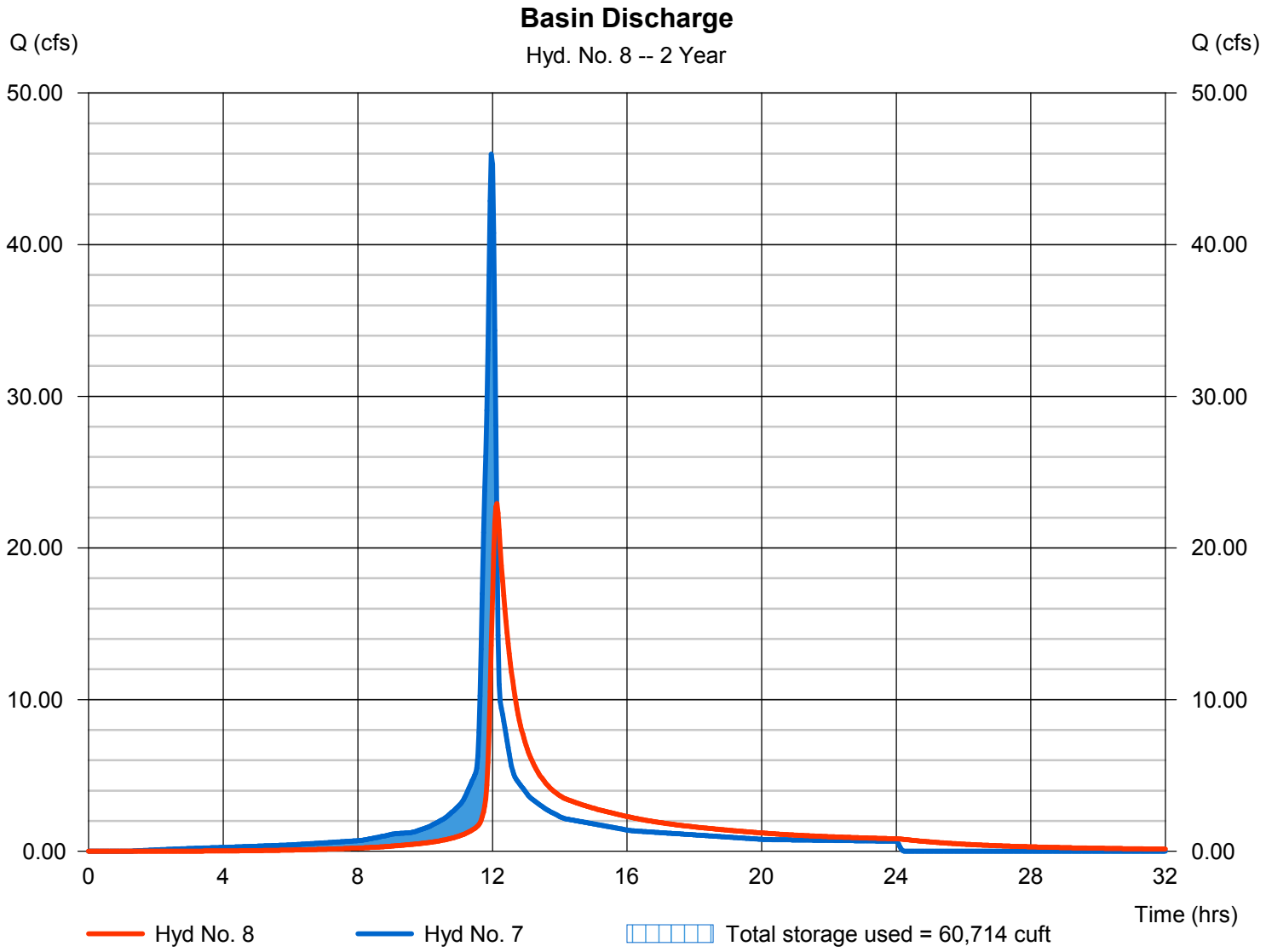
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2011 by Autodesk, Inc. v8 Friday, Oct 24, 2014

Hyd. No. 8

Basin Discharge

Hydrograph type	= Reservoir	Peak discharge	= 22.93 cfs
Storm frequency	= 2 yrs	Time to peak	= 12.13 hrs
Time interval	= 2 min	Hyd. volume	= 159,097 cuft
Inflow hyd. No.	= 7 - Diverted to Basin	Max. Elevation	= 1018.23 ft
Reservoir name	= Detention Basin	Max. Storage	= 60,714 cuft

Storage Indication method used.



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2011 by Autodesk, Inc. v8

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	34.68	2	720	90,035	------	------	------	Onsite - Pre
2	SCS Runoff	55.67	2	718	132,498	------	------	------	Onsite - Post
3	SCS Runoff	58.54	2	718	156,210	------	------	------	Offsite Southwest
4	Diversion1	14.20	2	710	120,579	3	------	------	To Basin
5	Diversion2	44.34	2	718	35,631	3	------	------	To ROW
6	Combine	48.88	2	720	210,615	1, 4,	------	------	Target Release
7	Combine	69.87	2	718	253,077	2, 4,	------	------	Diverted to Basin
8	Reservoir	43.39	2	726	252,933	7	1018.86	77,818	Basin Discharge

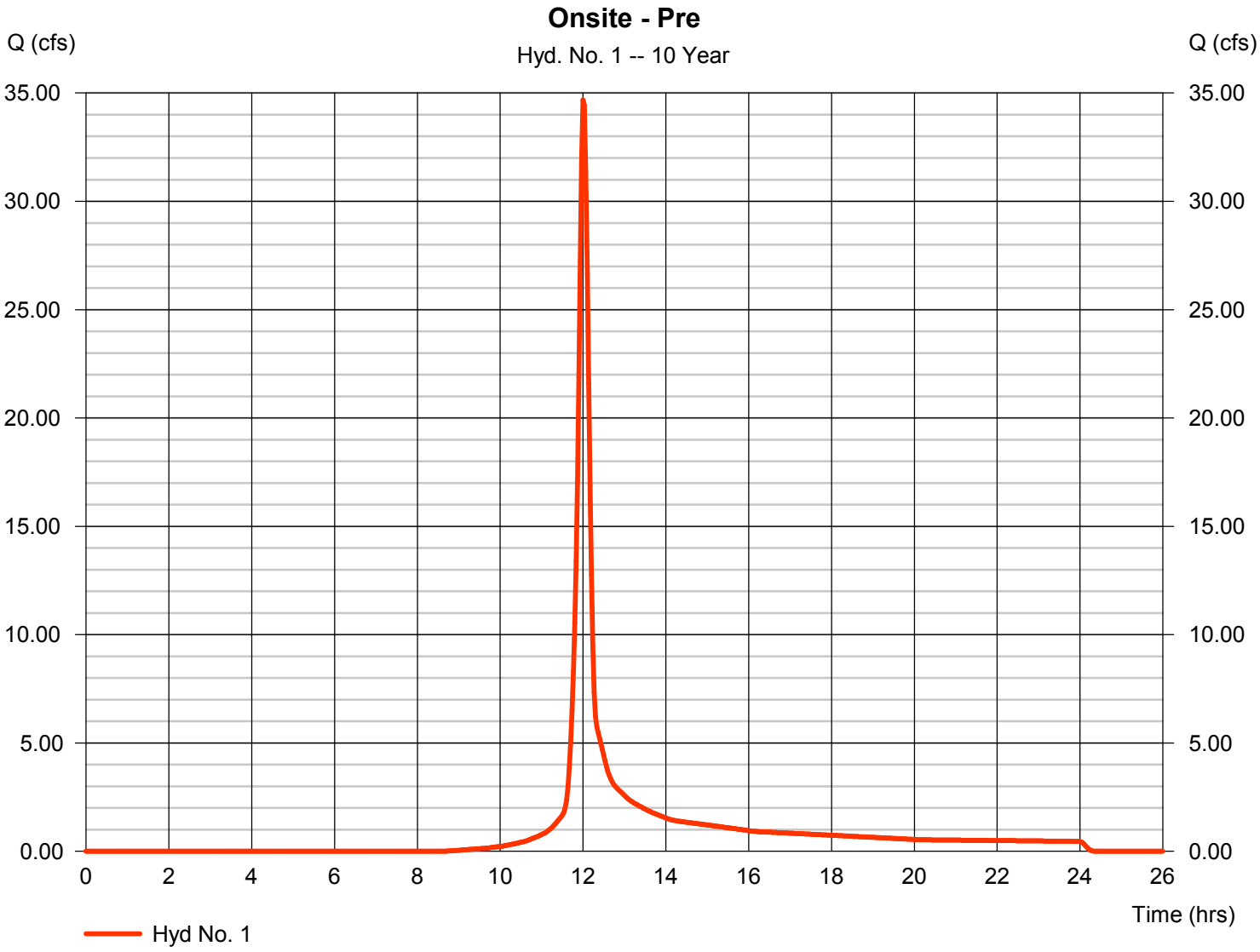
Hydrograph Report

Hyd. No. 1

Onsite - Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 34.68 cfs
Storm frequency	= 10 yrs	Time to peak	= 12.00 hrs
Time interval	= 2 min	Hyd. volume	= 90,035 cuft
Drainage area	= 9.230 ac	Curve number	= 74*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.60 min
Total precip.	= 5.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(5.540 x 98) + (3.690 x 74)] / 9.230

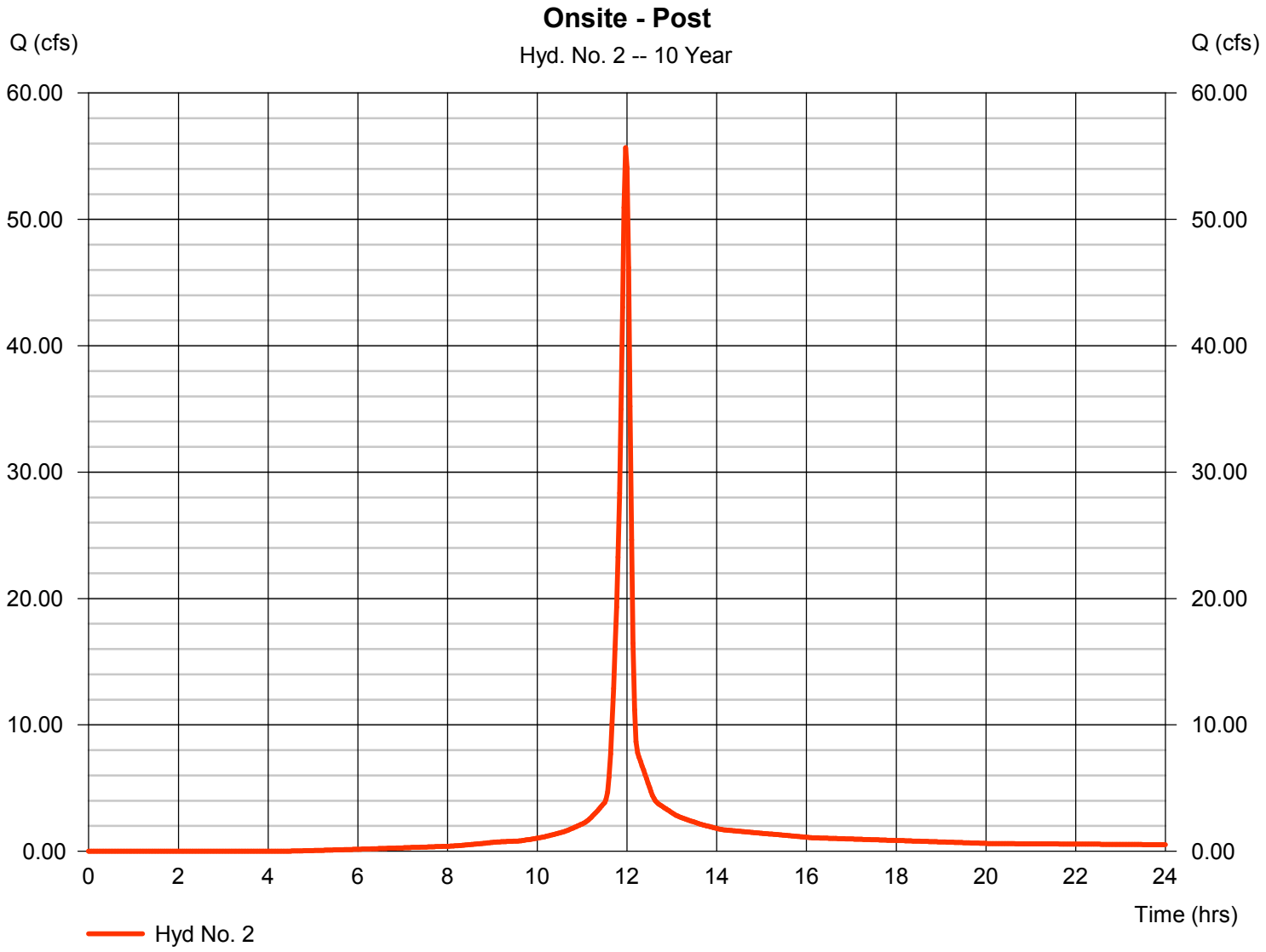


Hydrograph Report

Hyd. No. 2

Onsite - Post

Hydrograph type	= SCS Runoff	Peak discharge	= 55.67 cfs
Storm frequency	= 10 yrs	Time to peak	= 11.97 hrs
Time interval	= 2 min	Hyd. volume	= 132,498 cuft
Drainage area	= 9.230 ac	Curve number	= 88
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.00 min
Total precip.	= 5.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

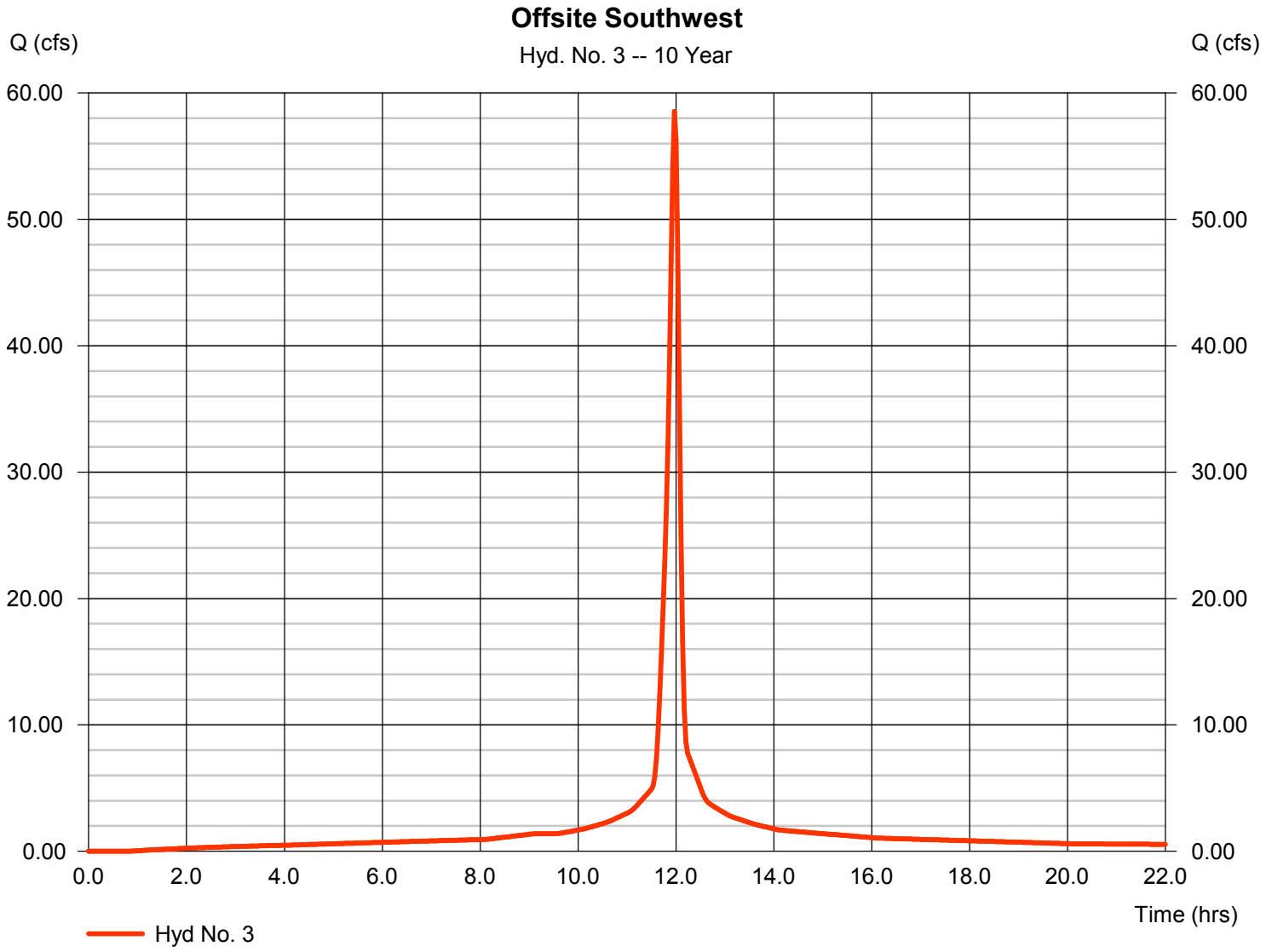


Hydrograph Report

Hyd. No. 3

Offsite Southwest

Hydrograph type	= SCS Runoff	Peak discharge	= 58.54 cfs
Storm frequency	= 10 yrs	Time to peak	= 11.97 hrs
Time interval	= 2 min	Hyd. volume	= 156,210 cuft
Drainage area	= 8.500 ac	Curve number	= 98
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 7.10 min
Total precip.	= 5.30 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484



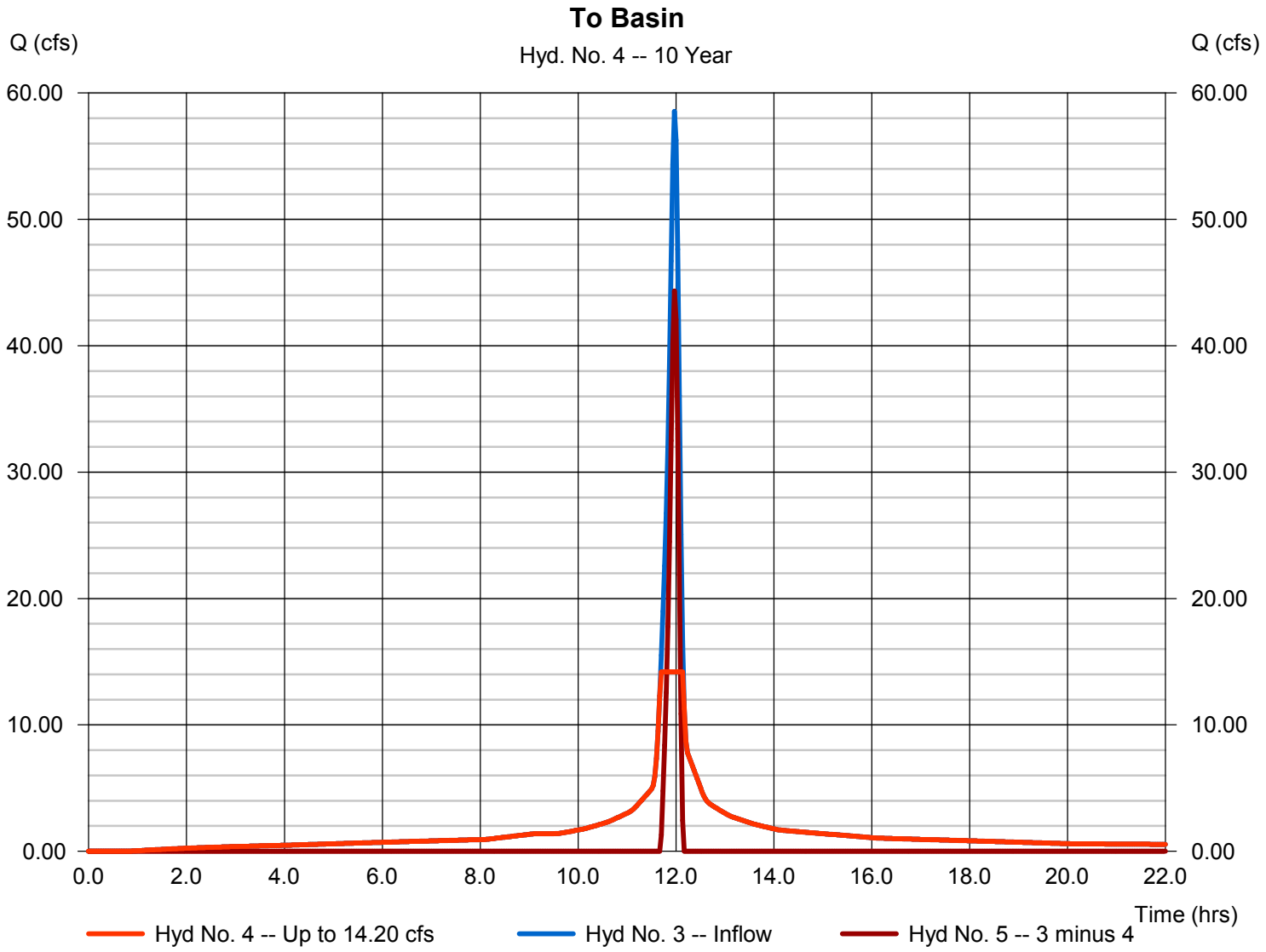
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2011 by Autodesk, Inc. v8 Friday, Oct 24, 2014

Hyd. No. 4

To Basin

Hydrograph type	= Diversion1	Peak discharge	= 14.20 cfs
Storm frequency	= 10 yrs	Time to peak	= 11.83 hrs
Time interval	= 2 min	Hyd. volume	= 120,579 cuft
Inflow hydrograph	= 3 - Offsite Southwest	2nd diverted hyd.	= 5
Diversion method	= Constant Q	Constant Q	= 14.20 cfs

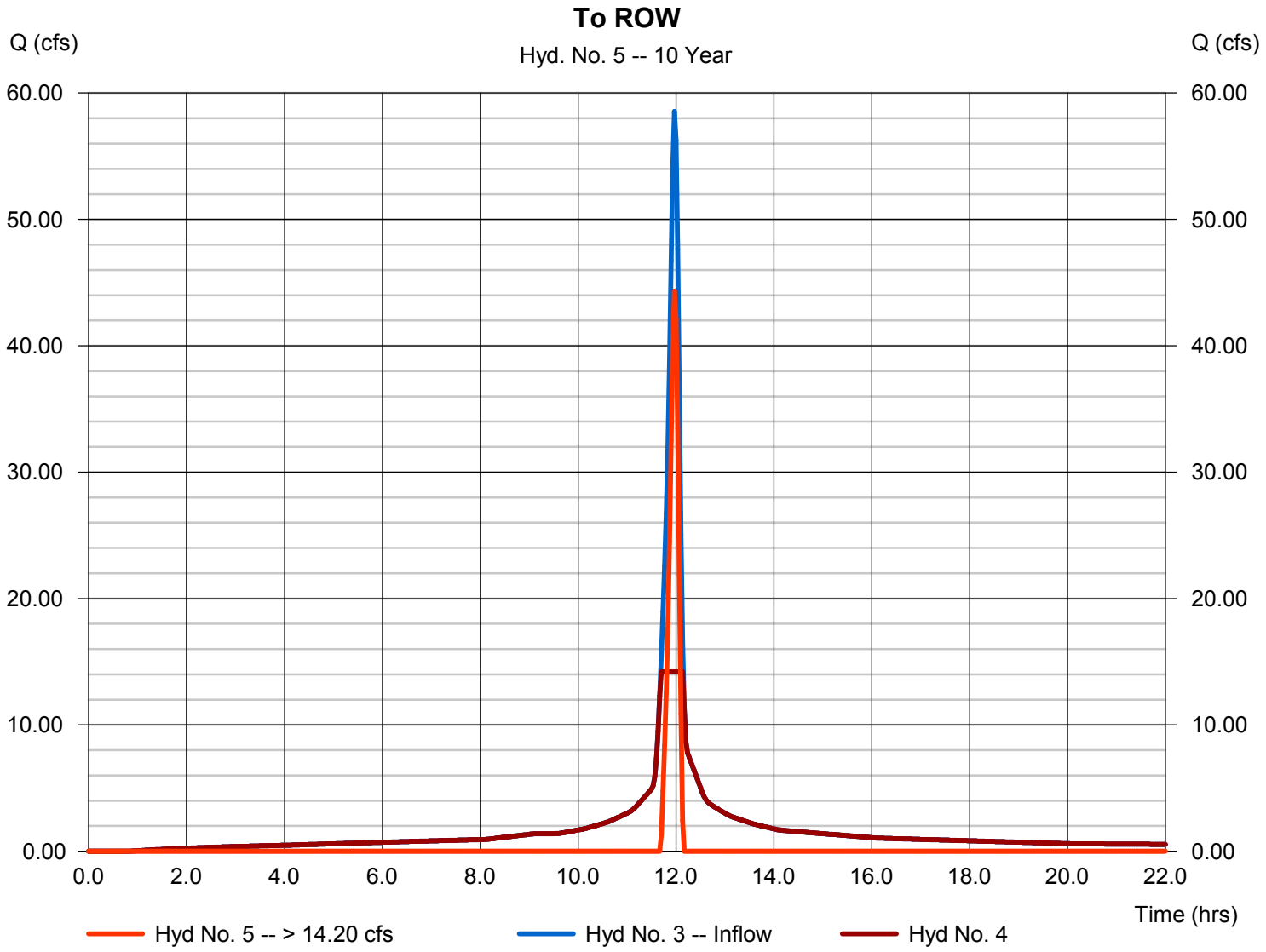


Hydrograph Report

Hyd. No. 5

To ROW

Hydrograph type	= Diversion2	Peak discharge	= 44.34 cfs
Storm frequency	= 10 yrs	Time to peak	= 11.97 hrs
Time interval	= 2 min	Hyd. volume	= 35,631 cuft
Inflow hydrograph	= 3 - Offsite Southwest	2nd diverted hyd.	= 4
Diversion method	= Constant Q	Constant Q	= 14.20 cfs



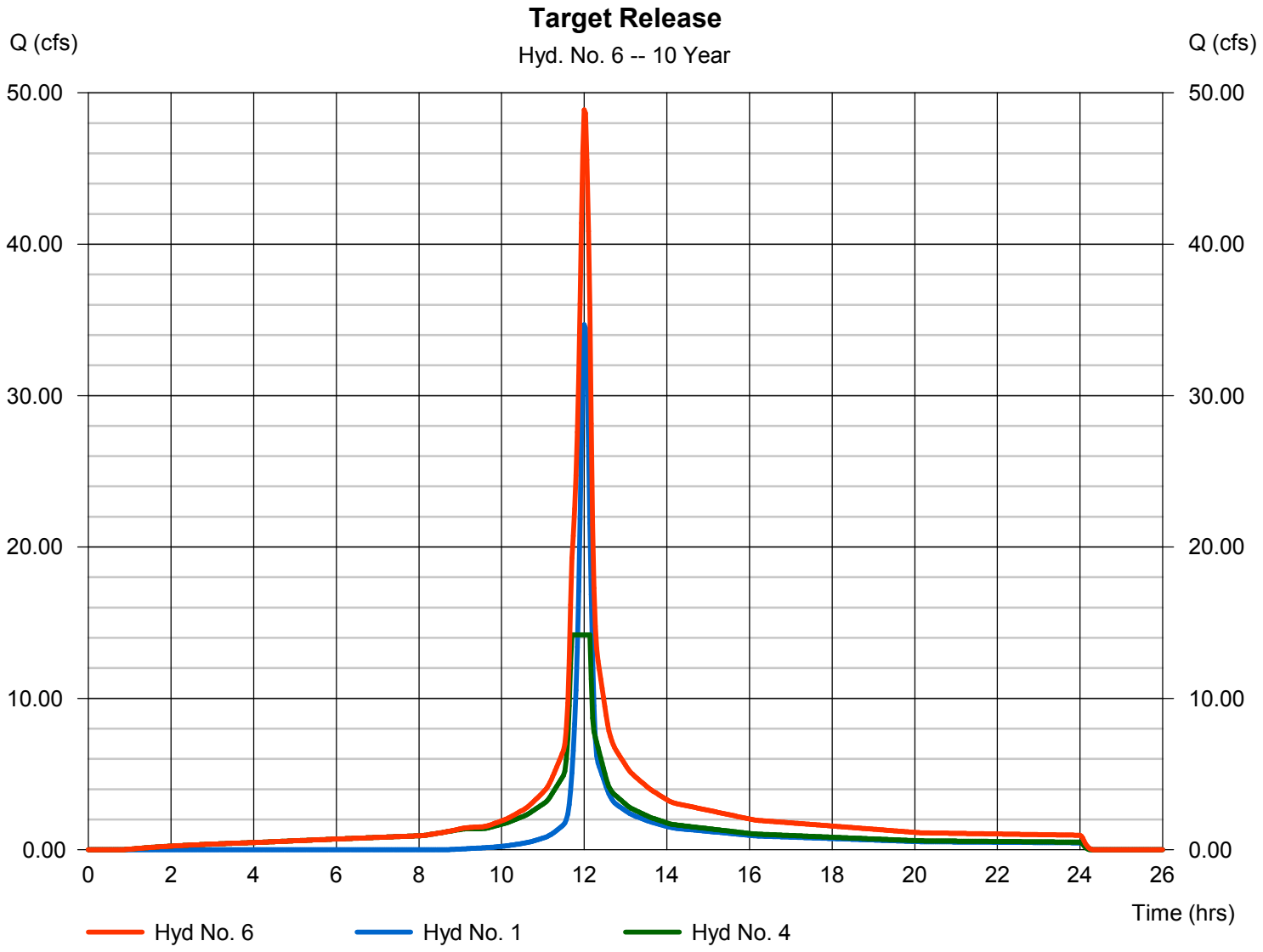
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2011 by Autodesk, Inc. v8 Friday, Oct 24, 2014

Hyd. No. 6

Target Release

Hydrograph type	= Combine	Peak discharge	= 48.88 cfs
Storm frequency	= 10 yrs	Time to peak	= 12.00 hrs
Time interval	= 2 min	Hyd. volume	= 210,615 cuft
Inflow hyds.	= 1, 4	Contrib. drain. area	= 9.230 ac



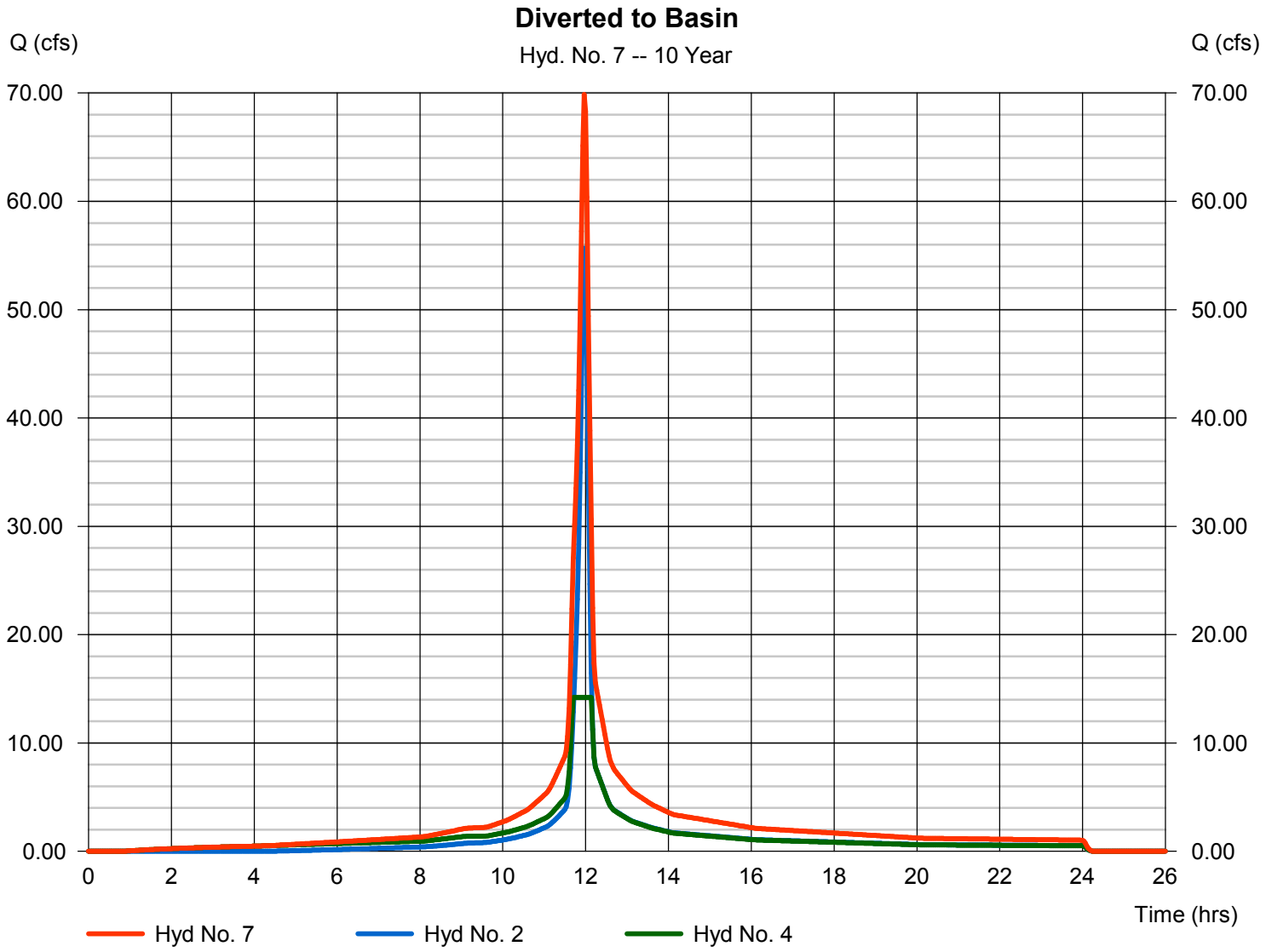
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2011 by Autodesk, Inc. v8 Friday, Oct 24, 2014

Hyd. No. 7

Diverted to Basin

Hydrograph type	= Combine	Peak discharge	= 69.87 cfs
Storm frequency	= 10 yrs	Time to peak	= 11.97 hrs
Time interval	= 2 min	Hyd. volume	= 253,077 cuft
Inflow hyds.	= 2, 4	Contrib. drain. area	= 9.230 ac



Hydrograph Report

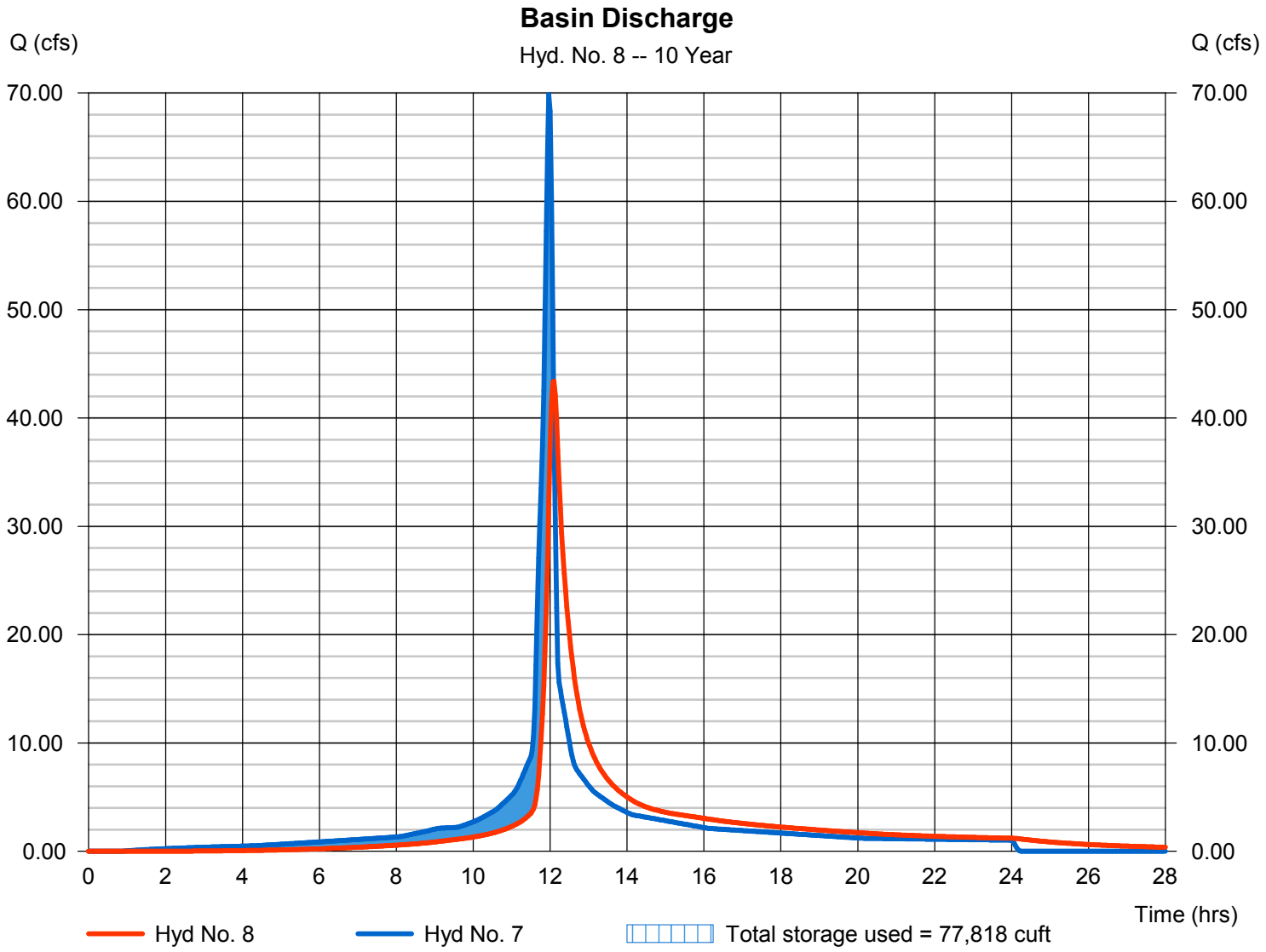
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2011 by Autodesk, Inc. v8 — Friday, Oct 24, 2014

Hyd. No. 8

Basin Discharge

Hydrograph type	= Reservoir	Peak discharge	= 43.39 cfs
Storm frequency	= 10 yrs	Time to peak	= 12.10 hrs
Time interval	= 2 min	Hyd. volume	= 252,933 cuft
Inflow hyd. No.	= 7 - Diverted to Basin	Max. Elevation	= 1018.86 ft
Reservoir name	= Detention Basin	Max. Storage	= 77,818 cuft

Storage Indication method used.



Hydrograph Summary Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2011 by Autodesk, Inc. v8

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	61.86	2	720	160,952	------	------	------	Onsite - Pre
2	SCS Runoff	85.98	2	718	210,249	------	------	------	Onsite - Post
3	SCS Runoff	85.26	2	718	230,190	------	------	------	Offsite Southwest
4	Diversion1	11.20	2	704	160,348	3	------	------	To Basin
5	Diversion2	74.06	2	718	69,843	3	------	------	To ROW
6	Combine	73.06	2	720	321,300	1, 4,	------	------	Target Release
7	Combine	97.18	2	718	370,596	2, 4,	------	------	Diverted to Basin
8	Reservoir	67.79	2	724	370,446	7	1019.37	91,697	Basin Discharge

Hydrograph Report

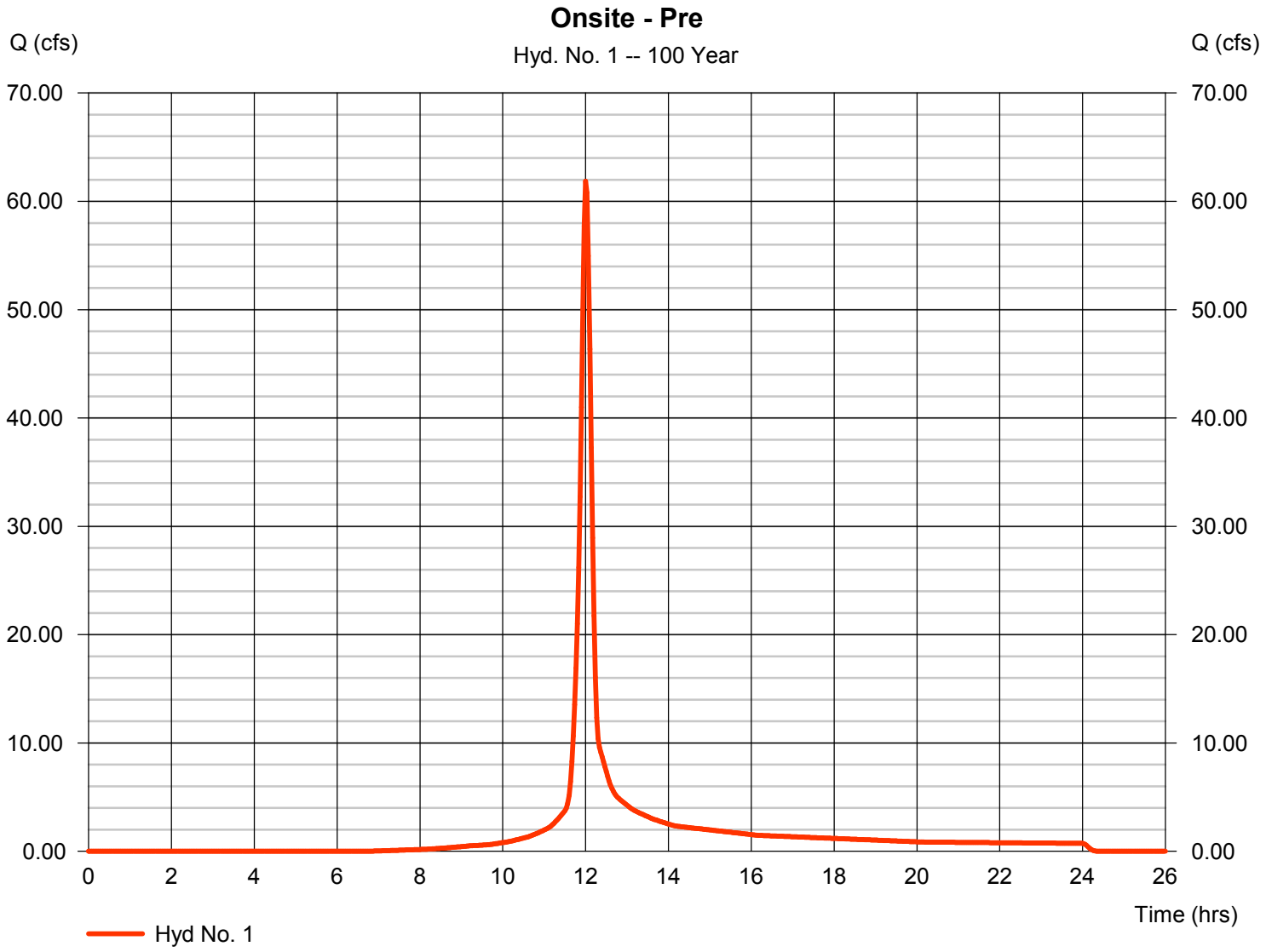
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2011 by Autodesk, Inc. v8 Friday, Oct 24, 2014

Hyd. No. 1

Onsite - Pre

Hydrograph type	= SCS Runoff	Peak discharge	= 61.86 cfs
Storm frequency	= 100 yrs	Time to peak	= 12.00 hrs
Time interval	= 2 min	Hyd. volume	= 160,952 cuft
Drainage area	= 9.230 ac	Curve number	= 74*
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 11.60 min
Total precip.	= 7.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

* Composite (Area/CN) = [(5.540 x 98) + (3.690 x 74)] / 9.230

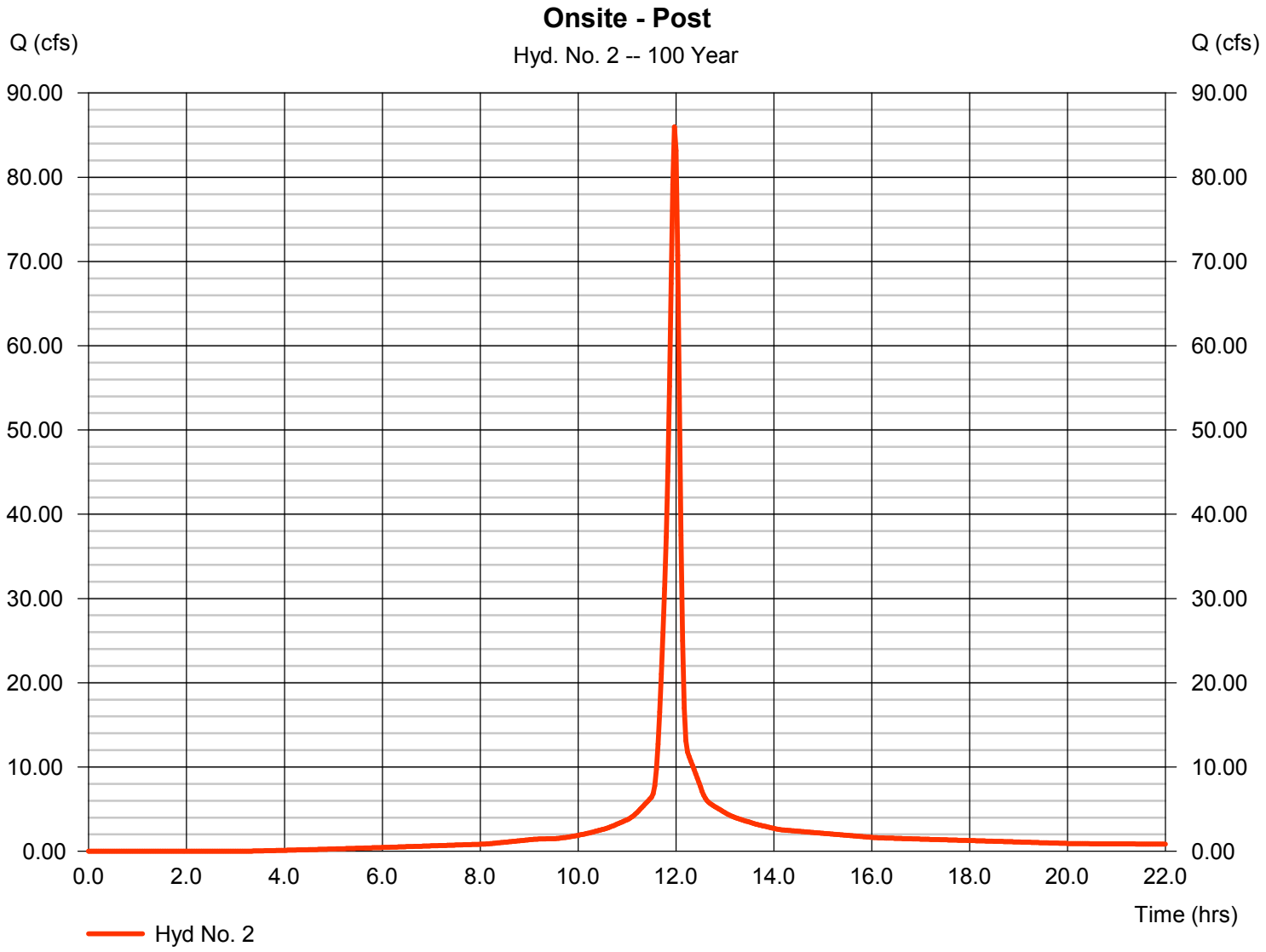


Hydrograph Report

Hyd. No. 2

Onsite - Post

Hydrograph type	= SCS Runoff	Peak discharge	= 85.98 cfs
Storm frequency	= 100 yrs	Time to peak	= 11.97 hrs
Time interval	= 2 min	Hyd. volume	= 210,249 cuft
Drainage area	= 9.230 ac	Curve number	= 88
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 8.00 min
Total precip.	= 7.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

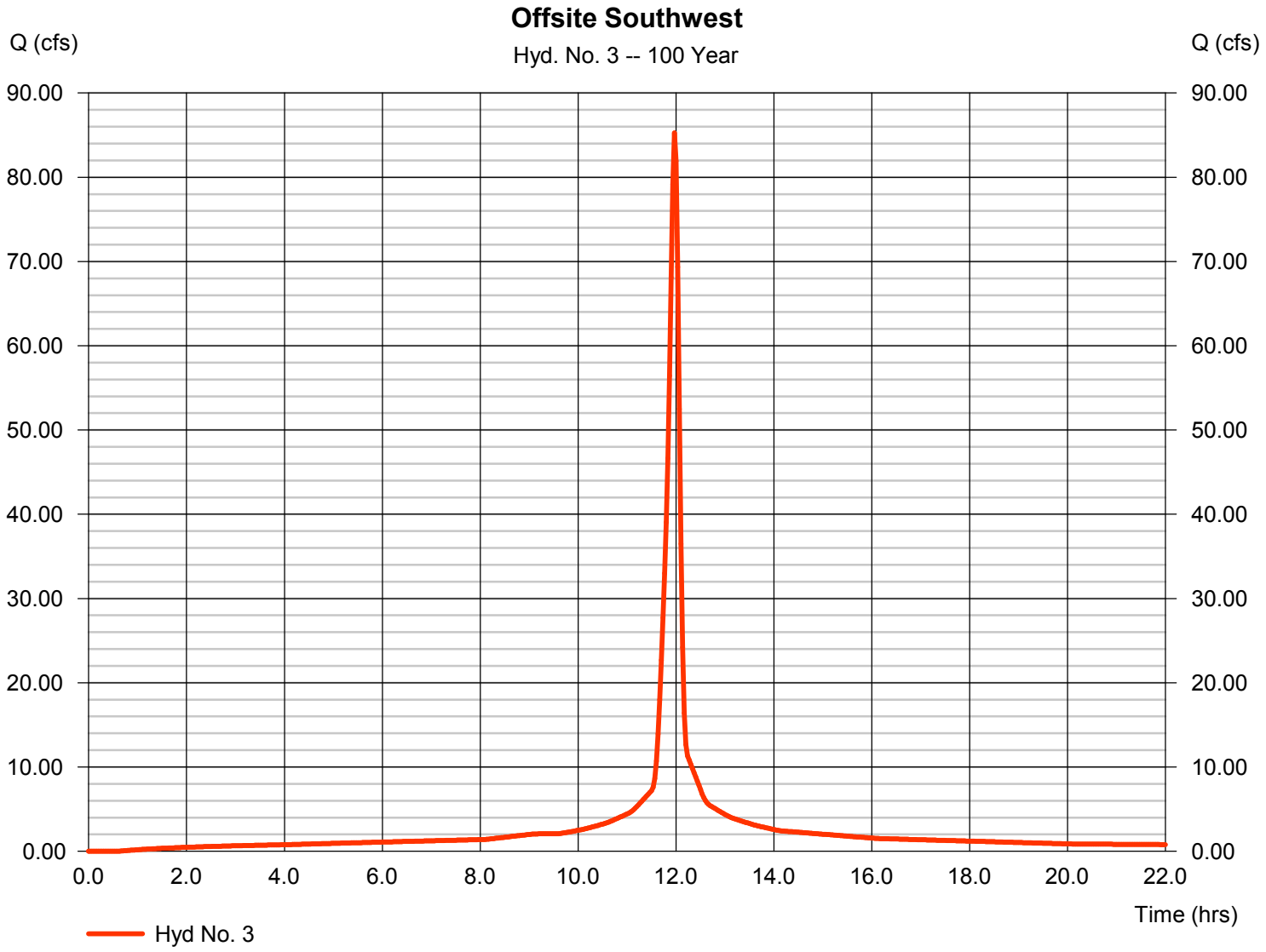


Hydrograph Report

Hyd. No. 3

Offsite Southwest

Hydrograph type	= SCS Runoff	Peak discharge	= 85.26 cfs
Storm frequency	= 100 yrs	Time to peak	= 11.97 hrs
Time interval	= 2 min	Hyd. volume	= 230,190 cuft
Drainage area	= 8.500 ac	Curve number	= 98
Basin Slope	= 0.0 %	Hydraulic length	= 0 ft
Tc method	= TR55	Time of conc. (Tc)	= 7.10 min
Total precip.	= 7.70 in	Distribution	= Type II
Storm duration	= 24 hrs	Shape factor	= 484

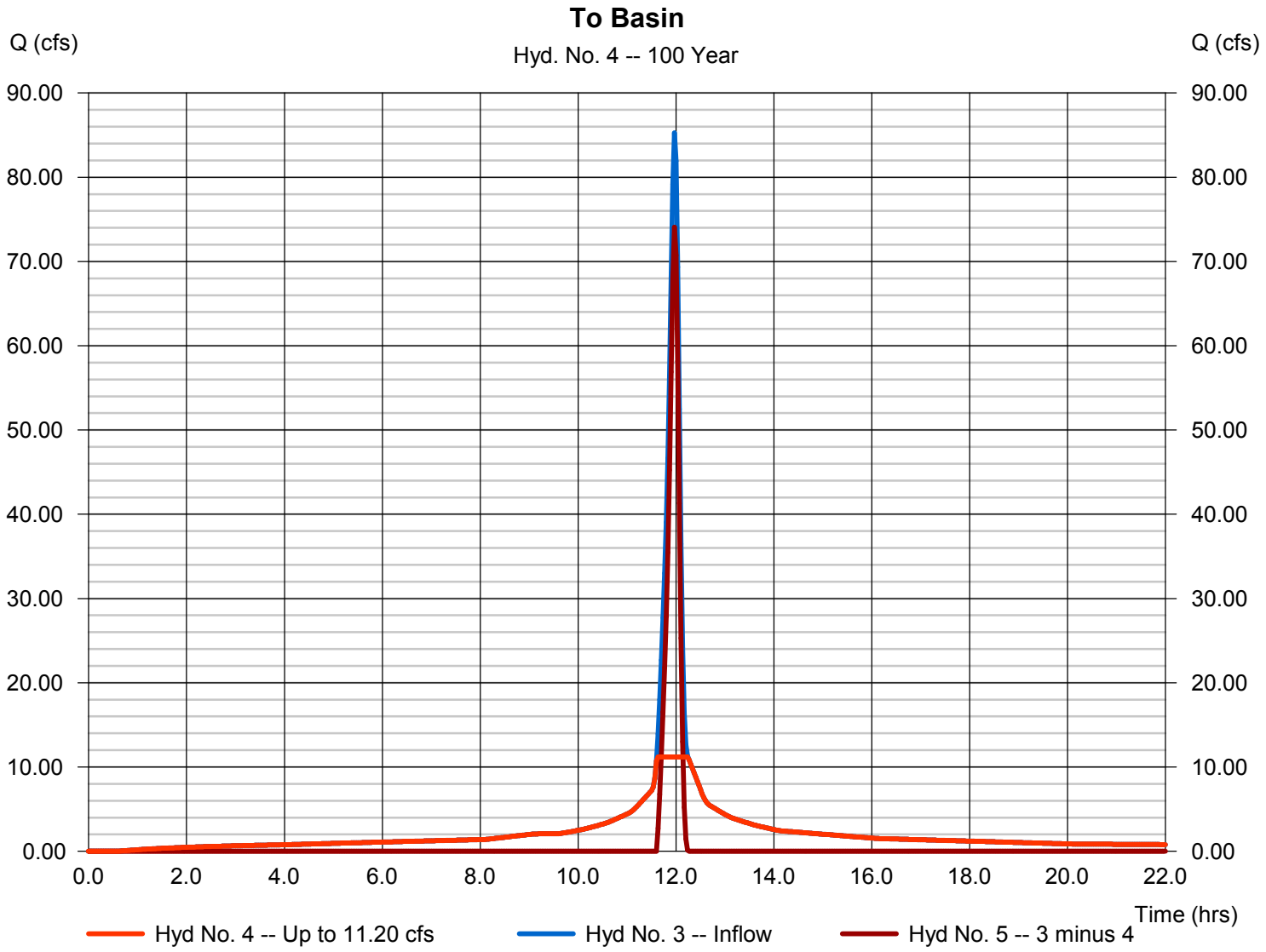


Hydrograph Report

Hyd. No. 4

To Basin

Hydrograph type	= Diversion1	Peak discharge	= 11.20 cfs
Storm frequency	= 100 yrs	Time to peak	= 11.73 hrs
Time interval	= 2 min	Hyd. volume	= 160,348 cuft
Inflow hydrograph	= 3 - Offsite Southwest	2nd diverted hyd.	= 5
Diversion method	= Constant Q	Constant Q	= 11.20 cfs



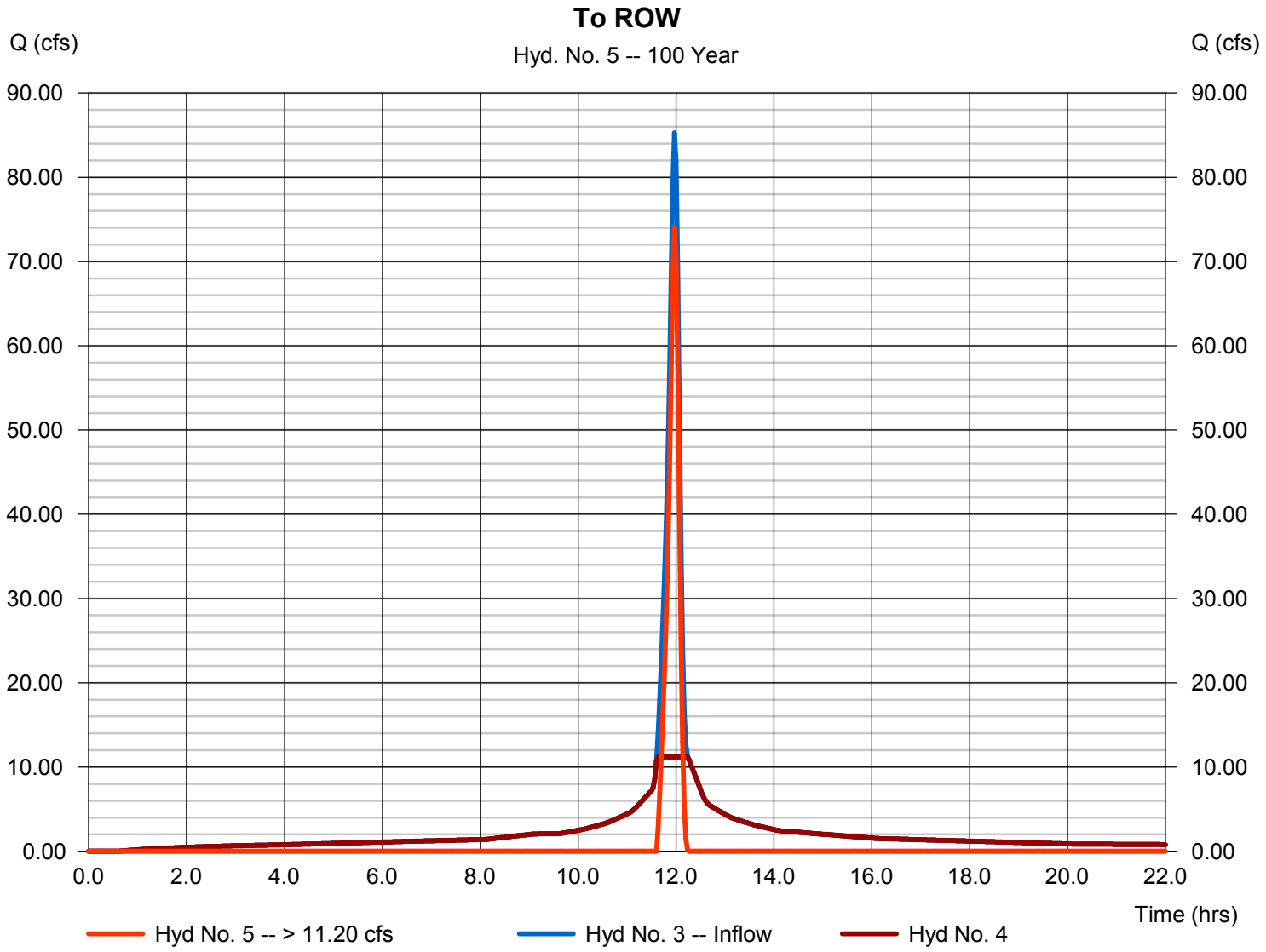
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2011 by Autodesk, Inc. v8 Friday, Oct 24, 2014

Hyd. No. 5

To ROW

Hydrograph type	= Diversion2	Peak discharge	= 74.06 cfs
Storm frequency	= 100 yrs	Time to peak	= 11.97 hrs
Time interval	= 2 min	Hyd. volume	= 69,843 cuft
Inflow hydrograph	= 3 - Offsite Southwest	2nd diverted hyd.	= 4
Diversion method	= Constant Q	Constant Q	= 11.20 cfs



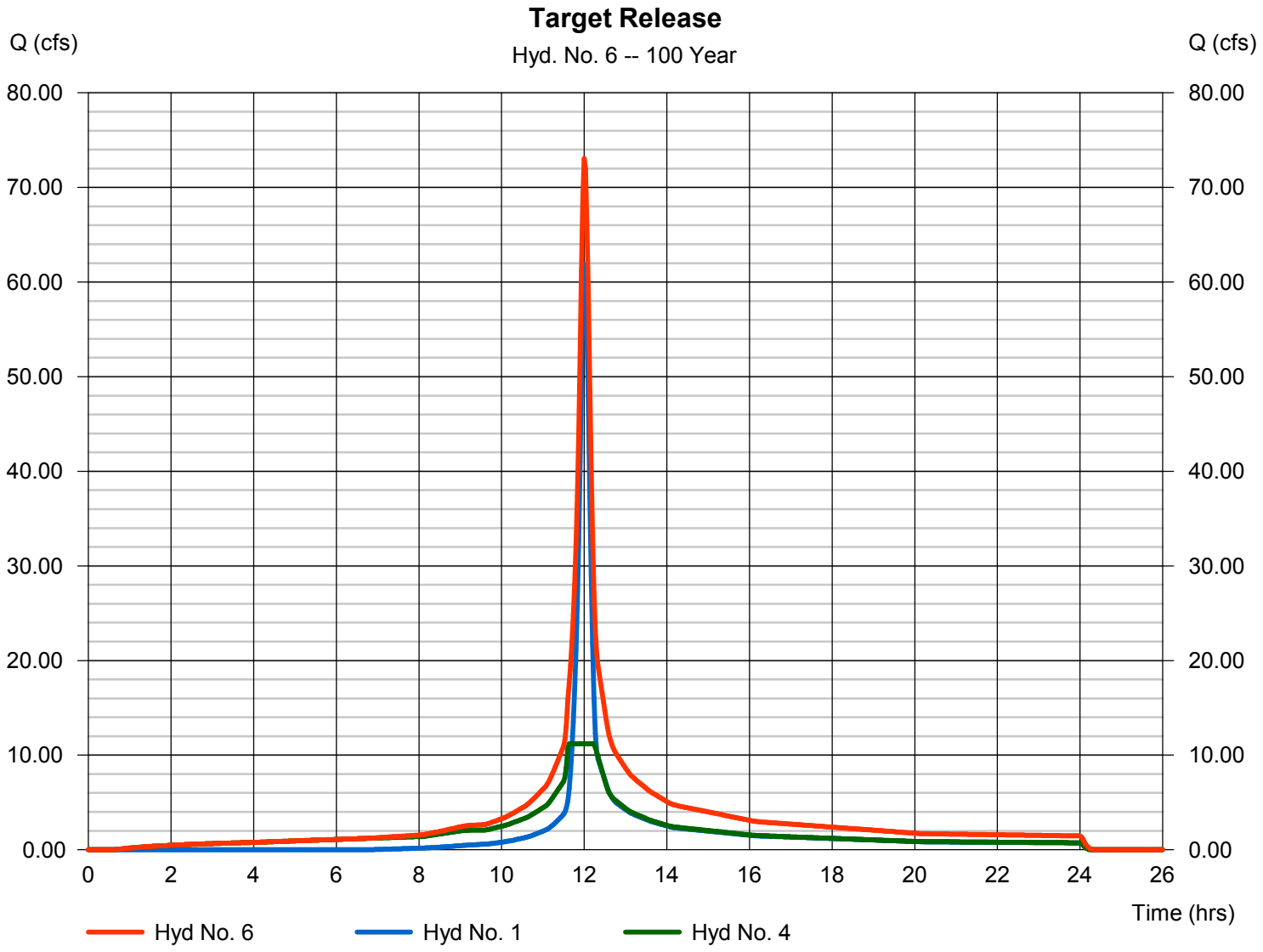
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2011 by Autodesk, Inc. v8 Friday, Oct 24, 2014

Hyd. No. 6

Target Release

Hydrograph type	= Combine	Peak discharge	= 73.06 cfs
Storm frequency	= 100 yrs	Time to peak	= 12.00 hrs
Time interval	= 2 min	Hyd. volume	= 321,300 cuft
Inflow hyds.	= 1, 4	Contrib. drain. area	= 9.230 ac



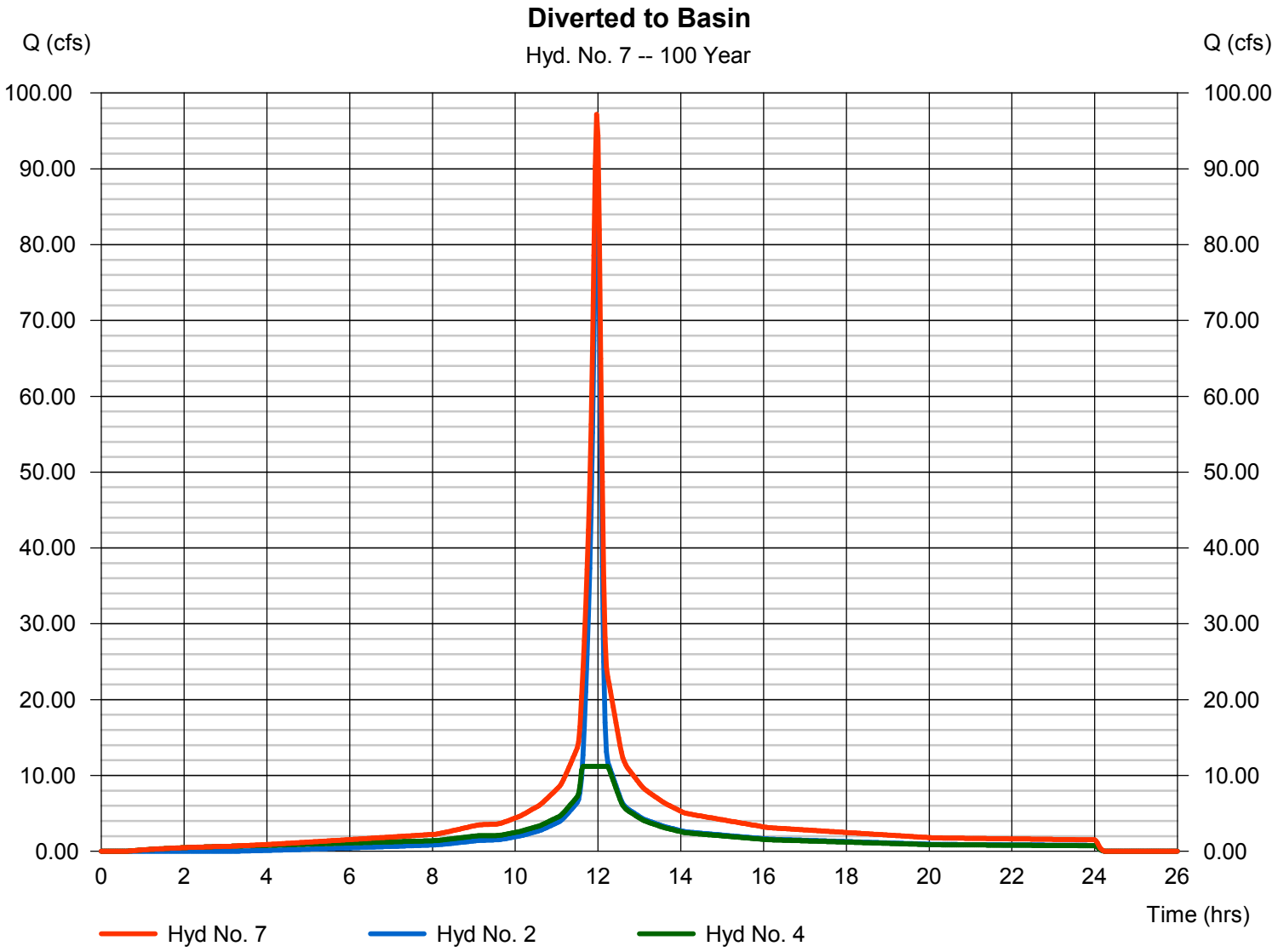
Hydrograph Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2011 by Autodesk, Inc. v8 Friday, Oct 24, 2014

Hyd. No. 7

Diverted to Basin

Hydrograph type	= Combine	Peak discharge	= 97.18 cfs
Storm frequency	= 100 yrs	Time to peak	= 11.97 hrs
Time interval	= 2 min	Hyd. volume	= 370,596 cuft
Inflow hyds.	= 2, 4	Contrib. drain. area	= 9.230 ac



Hydrograph Report

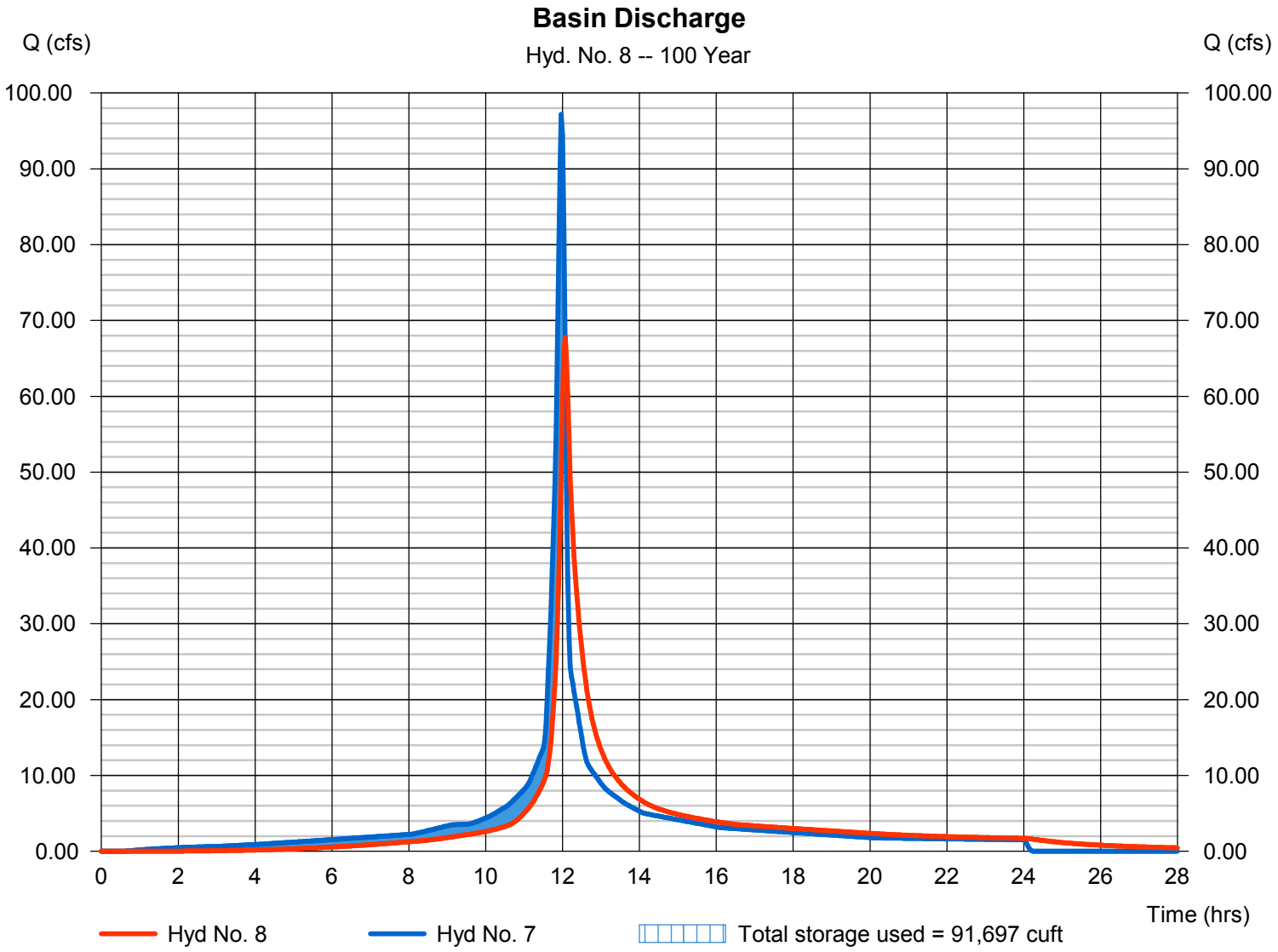
Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2011 by Autodesk, Inc. v8 — Friday, Oct 24, 2014

Hyd. No. 8

Basin Discharge

Hydrograph type	= Reservoir	Peak discharge	= 67.79 cfs
Storm frequency	= 100 yrs	Time to peak	= 12.07 hrs
Time interval	= 2 min	Hyd. volume	= 370,446 cuft
Inflow hyd. No.	= 7 - Diverted to Basin	Max. Elevation	= 1019.37 ft
Reservoir name	= Detention Basin	Max. Storage	= 91,697 cuft

Storage Indication method used.



Pond Report

Hydraflow Hydrographs Extension for AutoCAD® Civil 3D® 2011 by Autodesk, Inc. v8 Friday, Oct 24, 2014

Pond No. 1 - Detention Basin

Pond Data

Contours -User-defined contour areas. Conic method used for volume calculation. Begining Elevation = 1016.00 ft

Stage / Storage Table

Stage (ft)	Elevation (ft)	Contour area (sqft)	Incr. Storage (cuft)	Total storage (cuft)
0.00	1016.00	27,264	0	0
0.50	1016.50	27,264	13,631	13,631
1.00	1017.00	27,264	13,631	27,261
1.50	1017.50	27,264	13,631	40,892
2.00	1018.00	27,264	13,631	54,523
2.50	1018.50	27,264	13,631	68,153
3.00	1019.00	27,264	13,631	81,784
3.50	1019.50	27,264	13,631	95,414
4.00	1020.00	27,264	13,631	109,045
4.50	1020.50	29,423	14,167	123,212
5.00	1021.00	31,581	15,246	138,458
5.50	1021.50	32,975	16,136	154,594
6.00	1022.00	34,369	16,833	171,428

Culvert / Orifice Structures

	[A]	[B]	[C]	[PrfRsr]
Rise (in)	= 48.00	Inactive	0.00	0.00
Span (in)	= 48.00	0.00	0.00	0.00
No. Barrels	= 1	1	0	0
Invert El. (ft)	= 1012.25	0.00	0.00	0.00
Length (ft)	= 181.00	0.00	0.00	0.00
Slope (%)	= 0.55	0.00	0.00	n/a
N-Value	= .013	.013	.013	n/a
Orifice Coeff.	= 0.60	0.66	0.60	0.60
Multi-Stage	= n/a	Yes	No	No

Weir Structures

	[A]	[B]	[C]	[D]
Crest Len (ft)	= 3.84	0.00	6.00	0.50
Crest El. (ft)	= 1017.25	1016.00	1019.00	1016.00
Weir Coeff.	= 3.33	0.68	3.33	3.33
Weir Type	= Rect	30 degV	Rect	Rect
Multi-Stage	= Yes	Yes	Yes	Yes

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	1016.00	0.00	---	---	---	0.00	---	0.00	0.00	---	---	0.000
0.50	13,631	1016.50	65.68 oc	---	---	---	0.00	0.12	0.00	0.59	---	---	0.709
1.00	27,261	1017.00	65.68 oc	---	---	---	0.00	0.68	0.00	1.66	---	---	2.346
1.50	40,892	1017.50	65.68 oc	---	---	---	1.60	1.88	0.00	3.06	---	---	6.534
2.00	54,523	1018.00	65.68 oc	---	---	---	8.31	3.85	0.00	4.71	---	---	16.87
2.50	68,153	1018.50	65.68 oc	---	---	---	17.87	6.73	0.00	6.58	---	---	31.18
3.00	81,784	1019.00	65.68 oc	---	---	---	29.60	10.62	0.00	8.65	---	---	48.87
3.50	95,414	1019.50	75.97 oc	---	---	---	43.16	15.16 s	7.06	10.59 s	---	---	75.97
4.00	109,045	1020.00	105.89 oc	---	---	---	55.72 s	18.74 s	19.98	11.46 s	---	---	105.89
4.50	123,212	1020.50	128.52 oc	---	---	---	59.89 s	20.93 s	36.33 s	11.37 s	---	---	128.52
5.00	138,458	1021.00	143.06 oc	---	---	---	62.07 s	22.94 s	46.84 s	11.22 s	---	---	143.06
5.50	154,594	1021.50	153.97 oc	---	---	---	63.61 s	24.93 s	54.33 s	11.08 s	---	---	153.97
6.00	171,428	1022.00	162.81 ic	---	---	---	64.74 s	26.90 s	60.20 s	10.96 s	---	---	162.80

OUTLET STRUCTURE DISCHARGE COMPUTATIONS
FOR EXTENDED DETENTION BASINS

FLOWLINE ELEVATION
AT BOTTOM OF BASIN: 1016.00

V ANGLE: 30
TOP V ELEV: 1017.25

MAXIMUM PONDING
ELEV. FOR
EXTENDED DETENTION: 1020.00

****

WATER ELEVATION	AVERAGE AREA (SF)	AVERAGE VOL (CF)	BOTTOM WEIR LENGTH	NOTCH WEIR LENGTH	WEIR DISCHARGE	ORIFICE DISCHARGE	CONTROLLING DISCHARGE	DRAIN TIME (HOURS)	TOTAL DISCHARGE
1020.00	27264.00	6816	0.50	0.67	101.59	23.500	23.50	0.081	160.434
1019.75	27264.00	6816	0.50	0.67	86.45	21.331	21.33	0.089	136.934
1019.50	27264.00	6816	0.50	0.67	72.76	19.234	19.23	0.098	115.603
1019.25	27264.00	6816	0.50	0.67	60.45	17.211	17.21	0.110	96.369
1019.00	27264.00	6816	0.50	0.67	49.49	15.264	15.26	0.124	79.158
1018.75	27264.00	6816	0.50	0.67	39.81	13.396	13.40	0.141	63.895
1018.50	27264.00	6816	0.50	0.67	31.37	11.611	11.61	0.163	50.499
1018.25	27264.00	6816	0.50	0.67	24.11	9.914	9.91	0.191	38.887
1018.00	27264.00	6816	0.50	0.67	17.96	8.308	8.31	0.228	28.973
1017.75	27264.00	6816	0.50	0.67	12.86	6.800	6.80	0.278	20.665
1017.50	27264.00	6816	0.50	0.67	8.75	5.396	5.40	0.351	13.865
1017.25	27264.00	6816	0.50	0.67	5.55	4.105	4.11	0.461	8.468
1017.00	27264.00	6816	0.50	0.54	2.84	2.702	2.70	0.701	4.363
1016.75	27264.00	6816	0.50	0.40	1.22	1.602	1.22	1.552	1.661
1016.50	27264.00	6816	0.50	0.27	0.38	0.789	0.38	4.936	0.441
1016.25	27264.00	6816	0.50	0.13	0.06	0.249	0.06	33.018	0.057
1016.00	27264.00	0	0.50	0.00	0.00	0.000	0.00	0.000	0.000
		109056							

TOTAL DRAIN TIME 42.5 hours

WATER QUALITY DRAIN TIME 40.7 hours