STORMWATER REPORT

Anamite Solar, LLC

Nesler Road

Elgin (Kane County), IL 60124

Prepared by:
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Prepared on:
June 13, 2025

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EXHIBITS

1. PROJECT DESCRIPTION

Anamite Solar, LLC (Project) is proposing to construct a 2.7-MW Solar Farm located in Kane County, Illinois. The proposed Project will include solar panels, gravel access drives, and associated electrical equipment. The Project will be surrounded by a perimeter fence.

This report evaluates the pre and post development runoff characteristics of the development and addresses the stormwater requirements of Kane County and the State of Illinois. The analysis compares peak runoff rates in pre and post development conditions during large storm events. The analysis was completed with the assistance of HydroCAD Version 10.20-5c.

1.1. Pre-Development Conditions

The existing site area is approximately 63 acres of agricultural land, and the proposed development is on approximately 28.9 acres of agricultural land. The Project is located in Kane County, Illinois. The property is west of Nesler Rd, with proposed site access approximately 1900 feet north of the intersection of Nesler Rd and Bowes Rd. The site generally drains offsite to the southwest towards an existing wetland, with a small portion draining to the northeast toward another existing wetland. In the existing conditions, there is a swale running north to south through the middle of the site, and high points in the northwest and southeast corners of the site. The existing drainage areas can be broken down as follows:

- EX-01 flows north following a swale towards an existing wetland
- EX-02 flows south following a swale towards existing agricultural fields and an existing wetland
- EX-03 flows west following a swale towards existing agricultural fields
- EX-04 flows southwest towards existing agricultural fields
- EX-05 flows east towards existing agricultural fields
- EX-06 flows southeast towards Nesler Rd

Refer to **Exhibit 5** for the Pre-Development Drainage Area Map.

According to data obtained from FEMA GIS data website, the Project lies in panel 17089C0144H, with an effective date of 08/03/2009. A portion of the project parcel lies in Zone A, a special flood hazard area, but the majority of the project area is designated as Zone X, area of minimal flood hazard. Refer to **Exhibit 2** for FEMA Firm Map.

The National Wetlands Inventory map, dated 04/17/2025, indicates that there are two freshwater emergent wetlands within the project area. Refer to **Exhibit 1** for the NWI Map.

The NRCS Report dated 04/17/2025, concludes that onsite soils consist mostly of silt loams and silty clay loams of hydrologic soil groups B/D, A/D, B, and C. Soil types B and C were used for analysis. Refer to **Exhibit 4** for the NRCS Report.

1.2. Post-Development Conditions

The proposed Project is a solar power generating facility. The Solar Farm will consist of rows of Photovoltaic Solar Modules, gravel access driveways, associated electrical equipment, and underground utilities. The gravel access road will consist of clean gravel with no fines, and there will be a 20' vegetative filter strip upstream of the road. These specifications will allow the gravel road to count as pervious according to a call with Anne Wilford, the Stormwater Manager for Kane County, on 05/06/2025. Solar modules will be mounted on piles and elevated above the ground as to preserve the existing underlying soil and allow for revegetation and infiltration. The Project will be surrounded by a perimeter fence. Ground area within the fence perimeter that is not occupied by gravel roads or foundations will be seeded. To conform with a study published in the Journal of Hydrologic Engineering, the proposed solar farm grass mix will be adequately established and well maintained. This is to ensure the proposed solar farm does not have an adverse hydrologic impact from excess runoff or contribute eroded soil particles to receiving streams and waterways. Refer to **Exhibit 9** for the study published in the Journal of Hydrologic Engineering. The existing drainage patterns will be maintained in the proposed condition. Refer to **Exhibit 6** for the Post-Development Drainage Area Map.

2. STORMWATER SUMMARY

2.1. Stormwater Management

A study published in the Journal of Hydrologic Engineering researched the hydrologic impacts of utility scale solar generating facilities. The study utilized a model to simulate runoff from pre-and post-solar panel conditions. The study concluded that the solar panels themselves have little to no impact on runoff volumes or rates. Rainfall losses, most notably infiltration, are not impacted by the solar panels. Rainfall that falls directly on a solar panel runs to the pervious areas around and under the surrounding panels. Refer to **Exhibit 9** for the study published in the Journal of Hydrologic Engineering.

2.2. Kane County Stormwater Requirements

Per the Kane County Stormwater Ordinance and coordination with the County, developments with 5,000 to 24,999 sf of new impervious area must have a Category I BMP. The Category I BMP must provide volume reduction and water quality treatment for the first inch of rainfall over the proposed impervious areas. The Minnesota Pollution Control Agency (MPCA) solar panel calculator was used to calculate the water quality volume to be treated per panel. Then, the required water quality volume storage was calculated for both DA-01 (flowing north) and DA-02 (flowing south) based on the runoff per panel calculated per MPCA, as well as all other proposed impervious areas on the site for the first inch of rainfall. The site has approximately 4,540 sf of proposed impervious area. For DA-01, it was determined that about 3,700 cf of storage is required. For DA-02, it was determined that about 5,120 cf of storage is required. A BMP depth of three feet was assumed to calculate the surface area of both BMPs, which were placed along the flowlines outside of the fenced area. See **Exhibit 6** for the locations and approximate size of the two BMPs. See **Exhibits 10 and 11** for the Excel calculations used to determine the solar panel runoff and storage volume required for the site per MPCA.

2.3. Peak Flow Calculation Summary

The site peak discharges were estimated using methods outlined in the NRCS TR-55 and the following parameters: subbasin area (acres), flowlines (ft.), time of concentrations (Tc, hours), slope (ft./ft.), and Curve Number. Curve Numbers were determined based upon soil classification and land use for each subbasin. The Illinois State Water Survey Bulletin 75 was used to model the rainfall on site. The 1-foot contour interval topographic survey was examined to identify points where onsite flow discharges from the development area. The release rates for the 2-year and 100-year storm were calculated using HydroCAD Version 10.20-5c. Detailed calculations have been provided in **Exhibits 7** and **8** and a summary of the pre vs. post development runoff rates are provided below.

Table 1: Summary Pre vs. Post Development 2-Year Storm Runoff Rates		
Point of Analysis	*Pre (cfs)*	*Post (cfs)*
POA-01	11.30	1.43
POA-02	18.45	2.81
POA-03	4.33	1.76
POA-04	4.85	2.30
POA-05	6.74	2.87
POA-06	6.53	3.51

Table 2: Summary Pre vs. Post Development 100-Year Storm Runoff Rates		
Point of Analysis	*Pre (cfs)*	*Post (cfs)*
POA-01	49.05	22.32
POA-02	80.12	39.06
POA-03	17.95	12.34
POA-04	15.60	10.54
POA-05	22.44	14.39
POA-06	21.37	16.16

3. CONCLUSION

As noted above, a study published in the Journal of Hydrologic Engineering researched the hydrologic impacts of ground mounted solar generating facilities. The study utilized a model to simulate runoff from pre-development and post-development solar panel conditions. The study concluded that the solar panels themselves have little to no impact on runoff volumes or rates. Rainfall losses, most notably infiltration, are not impacted by the solar panels. Rainfall that falls directly on a solar panel runs to the pervious areas around and under the surrounding panels. Onsite access roads will be clean gravel with no fines.

Based on the proposed improvements on the project site, the findings of the above referenced study, and the calculations included within this report, increases in runoff rate are not anticipated for the Project. Runoff rates decrease for all drainage areas in the post-development conditions. The HydroCAD model shows a decrease in the average Curve Number for the whole site as well as a decrease in the total runoff volume. Refer to **Exhibit 7** and **Exhibit 8** for additional detail. Overall, the proposed conditions will reduce both peak runoff rate and volume on the property.

Exhibit 1 – National Wetlands Inventory Map

U.S. Fish and Wildlife Service

National Wetlands Inventory

Anamite Wetlands

April 17, 2025

Wetlands

- Estuarine and Marine Deepwater
- Estuarine and Marine Wetland
- Freshwater Emergent Wetland
- Freshwater Forested/Shrub Wetland
- Freshwater Pond
- Lake
- Other
- Riverine

This map is for general reference only. The US Fish and Wildlife Service is not responsible for the accuracy or currentness of the base data shown on this map. All wetlands related data should be used in accordance with the layer metadata found on the Wetlands Mapper web site.

National Wetlands Inventory (NWI)
This page was produced by the NWI mapper

Exhibit 2 – FEMA Firm Map

88°24'22.95"W 42°1'59.14"N

88°22'29.59"W 41°59'53.46"N

FLOOD HAZARD INFORMATION

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR DRAFT FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS	Without Base Flood Elevation (BFE) *Zone A, V, A99*
	With BFE or Depth *Zone AE, AO, AH, VE, AR*
	Regulatory Floodway
OTHER AREAS OF FLOOD HAZARD	0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
	Future Conditions 1% Annual Chance Flood Hazard *Zone X*
	Area with Reduced Flood Risk due to Levee See Notes *Zone X*
	Area with Flood Risk due to Levee *Zone D*
OTHER AREAS	NO SCREEN Area of Minimal Flood Hazard *Zone X*
	Effective LOMRs
	Area of Undetermined Flood Hazard *Zone D*
GENERAL STRUCTURES	Channel, Culvert, or Storm Sewer
	Levee, Dike, or Floodwall
OTHER FEATURES	(B) 20.2 Cross Sections with 1% Annual Chance
	17.5 Water Surface Elevation
	(8) Coastal Transect
	Coastal Transect Baseline
	Profile Baseline
	Hydrographic Feature
	513 Base Flood Elevation Line (BFE)
	Limit of Study
	Jurisdiction Boundary

NOTES TO USERS

For information and questions about this Flood Insurance Rate Map (FIRM), available products associated with this FIRM, including historic versions, the current map date for each FIRM panel, how to order products, or the National Flood Insurance Program (NFIP) in general, please call the FEMA Map Information eXchange at 1-877-FEMA-MAP (1-877-336-2627) or visit the FEMA Flood Map Service Center website at https://msc.fema.gov. Available products may include previously issued Letters of Map Change, a Flood Insurance Study Report, and/or digital versions of this map. Many of these products can be ordered or obtained directly from the website.

Communities annexing land on adjacent FIRM panels must obtain a current copy of the adjacent panel as well as the current FIRM Index. These may be ordered directly from the Flood Map Service Center at the number listed above.

For community and countywide map dates, refer to the Flood Insurance Study Report for this jurisdiction.

To determine if flood insurance is available in this community, contact your Insurance agent or call the National Flood Insurance Program at 1-800-638-6620.

Basemap information shown on this FIRM was provided in digital format by USDA, Farm Service Agency (FSA). This information was derived from NAIP, dated April 11, 2018.

This map was exported from FEMA's National Flood Hazard Layer (NFHL) on **4/17/2025 6:25 PM** and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time. For additional information, please see the Flood Hazard Mapping Updates Overview Fact Sheet at https://www.fema.gov/media-library/assets/documents/118418

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards. This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date.

SCALE

Map Projection:
GCS, Geodetic Reference System 1980;
Vertical Datum: NAVD88
For information about the specific vertical datum for elevation features, datum conversions, or vertical monuments used to create this map, please see the Flood Insurance Study (FIS) Report for your community at https://msc.fema.gov

N

1 inch = 500 feet 1:6,000

0 250 500 1,000 1,500 2,000 Feet

0 50 100 200 300 400 Meters

FEMA

National Flood Insurance Program

NATIONAL FLOOD INSURANCE PROGRAM

FLOOD INSURANCE RATE MAP

PANEL **144** OF **410**

Panel Contains:

COMMUNITY	NUMBER	PANEL
CITY OF ELGIN	170087	0144
KANE COUNTY	170896	0144

MAP NUMBER
17089C0144H
EFFECTIVE DATE
August 03, 2009

Exhibit 3 - USGS Map

USGS science for a changing world

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

The National Map US Topo

PINGREE GROVE QUADRANGLE
ILLINOIS - KANE COUNTY
7.5-MINUTE SERIES

Produced by the United States Geological Survey
North American Datum of 1983 (NAD83)
World Geodetic System of 1984 (WGS84). Projection and 1 000-meter grid:Universal Transverse Mercator, Zone 16T

This map is not a legal document. Boundaries may be generalized for this map scale. Private lands within government reservations may not be shown. Obtain permission before entering private lands.

Imagery....NAIP, August 2019 - September 2019
Roads.... U.S. Census Bureau, 2017
Names....GNIS, 1980 - 2023
Hydrography....National Hydrography Dataset, 2002 - 2022
Contours....National Elevation Dataset, 2015
Boundaries....Multiple sources; see metadata file 2021 - 2022
Public Land Survey System....BLM, 2020
Wetlands....FWS National Wetlands Inventory Not Available

3½° 62 MILS
0°58´ 17 MILS

UTM GRID AND 2023 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

U.S. National Grid
100,000 - m Square ID
CM
Grid Zone Designation 16T

SCALE 1:24 000

CONTOUR INTERVAL 10 FEET
NORTH AMERICAN VERTICAL DATUM OF 1988

This map was produced to conform with the National Geospatial Program US Topo Product Standard.

QUADRANGLE LOCATION

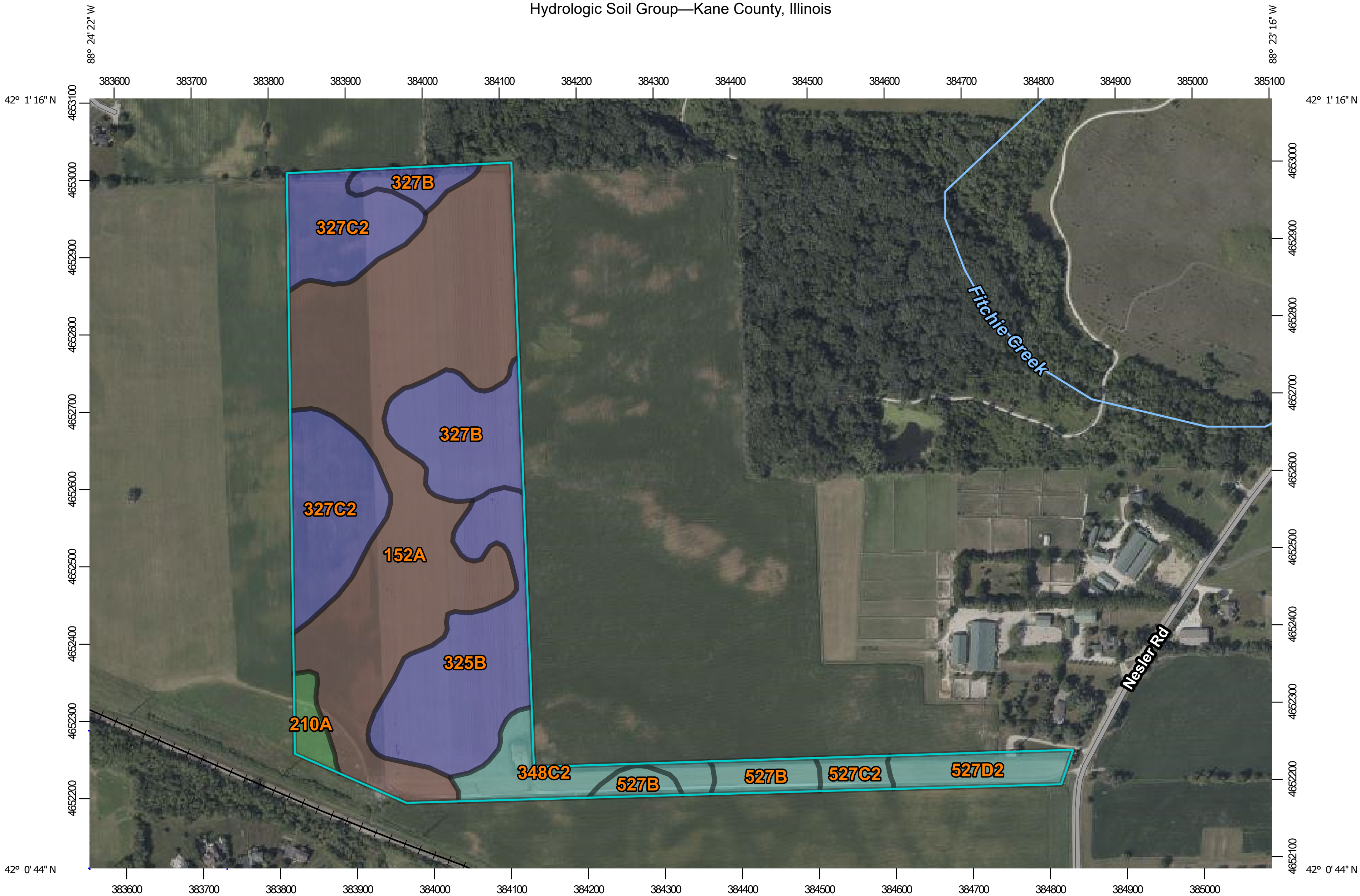
ADJOINING QUADRANGLES
1 Marengo South
2 Huntley
3 Crystal Lake
4 Hampshire
5 Elgin
6 Maple Park
7 Elburn
8 Geneva

ROAD CLASSIFICATION
Expressway — Local Connector
Secondary Hwy — Local Road
Ramp — 4WD
Interstate Route — US Route — State Route

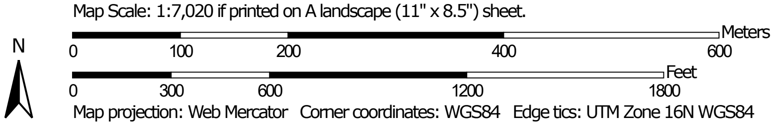
PINGREE GROVE, IL
2024

NSN. 7643016365664
NGA REF NO. USGSX24K35355

Exhibit 4 – NRCS Report



Map Scale: 1:7,020 if printed on A landscape (11" x 8.5") sheet.



Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 16N WGS84

MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

Soil Rating Polygons

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Lines

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Points

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:12,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Kane County, Illinois
Survey Area Data: Version 18, Aug 21, 2024

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Mar 1, 2023—Sep 1, 2023

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Hydrologic Soil Group

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
152A	Drummer silty clay loam, 0 to 2 percent slopes	B/D	29.3	43.3%
210A	Lena muck, 0 to 2 percent slopes	A/D	1.1	1.6%
325B	Dresden silt loam, 2 to 4 percent slopes	B	9.9	14.6%
327B	Fox silt loam, 2 to 4 percent slopes	B	7.1	10.5%
327C2	Fox silt loam, 4 to 6 percent slopes, eroded	B	11.0	16.3%
348C2	Wingate silt loam, 5 to 10 percent slopes, eroded	C	3.4	5.1%
527B	Kidami silt loam, 2 to 4 percent slopes	C	2.3	3.4%
527C2	Kidami loam, 4 to 6 percent slopes, eroded	C	1.0	1.5%
527D2	Kidami loam, 6 to 12 percent slopes, eroded	C	2.5	3.7%
Totals for Area of Interest			**67.6**	**100.0%**

Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

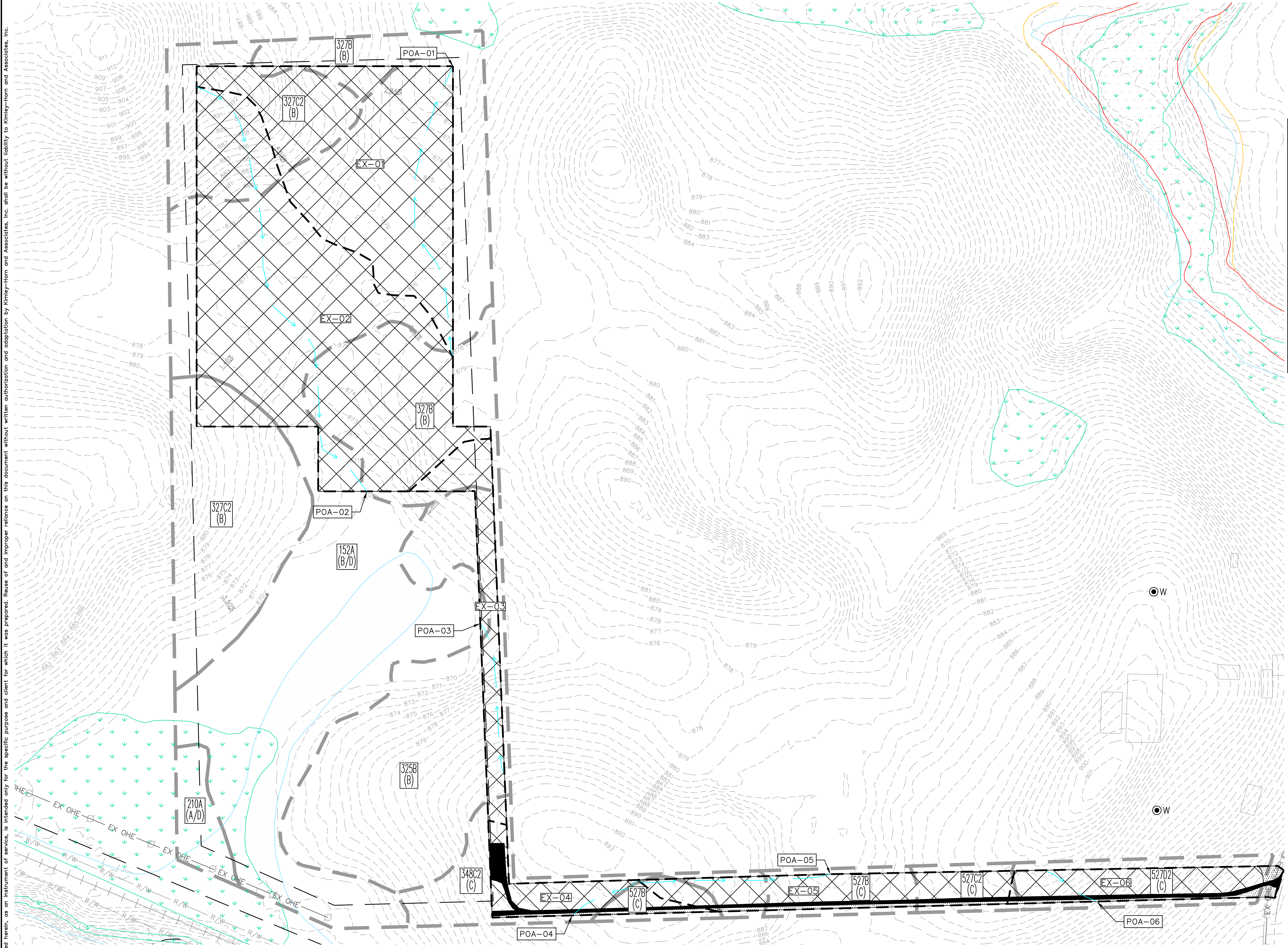
Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

Exhibit 5 – Pre-Development Drainage Area Map



LEGEND

— — —	DRAINAGE BOUNDARY / LIMITS OF ANALYSIS
→	TIME OF CONCENTRATION FLOW PATH
700	EX. CONTOURS
X.XX%	EX. SLOPE LABEL
▬ ▬ ▬	LIMITS OF SOIL TYPE
	EX. WETLAND (PER NWI)
	FEMA 100 YEAR STORM FLOOD ZONE
	ROW CROP
	GRASSLAND
	IMPERVIOUS

PRE-DEVELOPMENT DRAINAGE AREAS

DRAINAGE AREAS	ROW CROPS GOOD TYPE B (78)	ROW CROPS GOOD TYPE C (85)	PASTURE FAIR TYPE C (79)	IMPERVIOUS TYPE C (98)	TOTAL DA AREA	DA COMPOSITE CURVE NUMBER
EX-01 (AC)	8.04	0.00	0.00	0.00	8.04	78
EX-02 (AC)	13.24	0.00	0.00	0.00	13.24	78
EX-03 (AC)	1.87	0.00	0.00	0.00	1.87	78
EX-04 (AC)	0.00	1.05	0.13	0.30	1.48	87
EX-05 (AC)	0.00	2.03	0.20	0.23	2.46	86
EX-06 (AC)	0.00	1.35	0.23	0.23	1.81	86
TOTAL (AC)	23.15	4.43	0.56	0.76	28.90	80

SOILS DATA TABLE

MAP UNIT SYMBOL	MAP UNIT NAME	HYDROLOGIC SOIL GROUP
152A	DRUMMER SILTY CLAY LOAM, 0 TO 2 PERCENT SLOPES	B/D
210A	LENA MUCK, 0 TO 2 PERCENT SLOPES	A/D
325B	DRESDEN SILT LOAM, 2 TO 4 PERCENT SLOPES	B
327B	FOX SILT LOAM, 2 TO 4 PERCENT SLOPES	B
327C2	FOX SILT LOAM, 4 TO 6 PERCENT SLOPES, ERODED	B
348C2	WINGATE SILT LOAM, 5 TO 10 PERCENT SLOPES, ERODED	C
527B	KIDAMI SILT LOAM, 2 TO 4 PERCENT SLOPES	C
527C2	KIDAMI LOAM, 4 TO 6 PERCENT SLOPES, ERODED	C
527D2	KIDAMI LOAM, 6 TO 12 PERCENT SLOPES, ERODED	C

Table 2-2a Runoff curve numbers for urban areas 1/

Cover type and hydrologic condition	Average percent impervious area 2/	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.) 3/:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only) 4/		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation) 5/		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

Table 2-2b Runoff curve numbers for cultivated agricultural lands 1/

Cover type	Treatment 2/	Hydrologic condition 3/	A	B	C	D
Fallow	Bare soil	—	77	86	91	94
	Crop residue cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	C&T+ CR	Poor	65	73	79	81
		Good	61	70	77	80
Small grain	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR + CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C + CR	Poor	62	73	81	84
		Good	60	72	80	83
	C&T	Poor	61	72	79	82
		Good	59	70	78	81
	C&T+ CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation meadow	SR	Poor	66	77	85	89
		Good	58	72	81	85
	C	Poor	64	75	83	85
		Good	55	69	78	83
	C&T	Poor	63	73	80	83
		Good	51	67	76	80

Table 2-2c Runoff curve numbers for other agricultural lands 1/

Cover type	Hydrologic condition	A	B	C	D
Pasture, grassland, or range—continuous forage for grazing. 2/	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element. 3/	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30 4/	48	65	73
Woods—grass combination (orchard or tree farm). 5/	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods. 6/	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30 4/	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

No. | REVISIONS | DATE

CULTIVATE POWER

Kimley»Horn
570 LAKE COOK RD SUITE 200
DEERFIELD, IL 60015
WWW.KIMLEY-HORN.COM

PRELIMINARY NOT FOR CONSTRUCTION

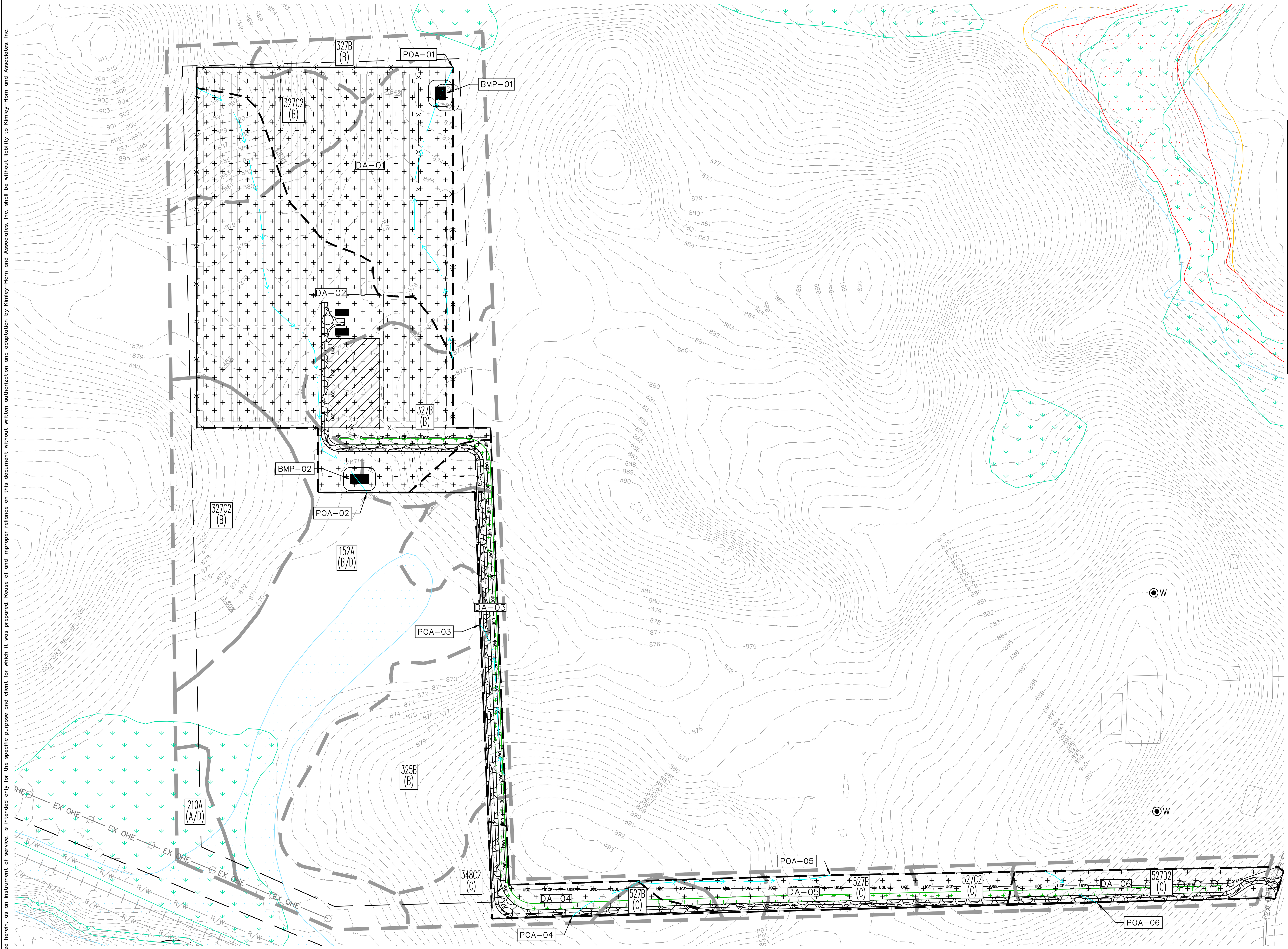
KHA PROJECT 268262054
ORIGINAL DATE 04/22/2025
SCALE AS SHOWN
DESIGNED BY SFH
DRAWN BY SFH
CHECKED BY CPC

PRE-DEVELOPMENT DRAINAGE AREA MAP

ANAMITE SOLAR, LLC
KANE COUNTY, IL

SHEET NUMBER
EX-5

Exhibit 6 – Post-Development Drainage Area Map



NORTH

GRAPHIC SCALE IN FEET
0 75 150 300

LEGEND

(dashed black line)	DRAINAGE BOUNDARY / LIMITS OF ANALYSIS
(cyan arrow line)	TIME OF CONCENTRATION FLOW PATH
—700—	EX. CONTOURS
X.XX%	EX. SLOPE LABEL
(heavy grey dashes)	LIMITS OF SOIL TYPE
(hatched green)	EX. WETLAND (PER NWI)
(light cyan)	FEMA 100 YEAR STORM FLOOD ZONE
+ + + + +	MEADOW
(solid black)	IMPERVIOUS
(gravel pattern)	CLEAN GRAVEL, NO FINES

Table 2-2a Runoff curve numbers for urban areas 1/

Cover type and hydrologic condition	Average percent impervious area 2/	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.) 3/:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only) 4/		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation) 5/		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

Table 2-2b Runoff curve numbers for cultivated agricultural lands 1/

Cover type	Treatment 2/	Hydrologic condition 3/	A	B	C	D
Fallow	Bare soil	—	77	86	91	94
	Crop residue cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	C&T+ CR	Poor	65	73	79	81
		Good	61	70	77	80
Small grain	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR + CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C + CR	Poor	62	73	81	84
		Good	60	72	80	83
	C&T	Poor	61	72	79	82
		Good	59	70	78	81
	C&T+ CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation meadow	SR	Poor	66	77	85	89
		Good	58	72	81	85
	C	Poor	64	75	83	85
		Good	55	69	78	83
	C&T	Poor	63	73	80	83
		Good	51	67	76	80

Table 2-2c Runoff curve numbers for other agricultural lands 1/

Cover type	Hydrologic condition	A	B	C	D
Pasture, grassland, or range—continuous forage for grazing. 2/	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element. 3/	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30 4/	48	65	73
Woods—grass combination (orchard or tree farm). 5/	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods. 6/	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30 4/	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

POST-DEVELOPMENT DRAINAGE AREAS

DRAINAGE AREAS	MEADOW TYPE B (58)	MEADOW TYPE C (71)	GRAVEL TYPE B (85)	GRAVEL TYPE C (89)	IMPERVIOUS TYPE B (98)	TOTAL DA AREA	DA COMPOSITE CURVE NUMBER
DA-01 (AC)	8.01	0.00	0.00	0.00	0.03	8.04	58
DA-02 (AC)	12.75	0.00	0.41	0.00	0.08	13.24	59
DA-03 (AC)	1.33	0.00	0.54	0.00	0.00	1.87	66
DA-04 (AC)	0.00	1.04	0.00	0.44	0.00	1.48	76
DA-05 (AC)	0.00	2.03	0.00	0.43	0.00	2.46	74
DA-06 (AC)	0.00	1.41	0.00	0.40	0.00	1.81	75
TOTAL (AC)	22.09	4.48	0.95	1.27	0.11	28.90	62

SOILS DATA TABLE

MAP UNIT SYMBOL	MAP UNIT NAME	HYDROLOGIC SOIL GROUP
152A	DRUMMER SILTY CLAY LOAM, 0 TO 2 PERCENT SLOPES	B/D
210A	LENA MUCK, 0 TO 2 PERCENT SLOPES	A/D
325B	DRESDEN SILT LOAM, 2 TO 4 PERCENT SLOPES	B
327B	FOX SILT LOAM, 2 TO 4 PERCENT SLOPES	B
327C2	FOX SILT LOAM, 4 TO 6 PERCENT SLOPES, ERODED	B
348C2	WINGATE SILT LOAM, 5 TO 10 PERCENT SLOPES, ERODED	C
527B	KIDAMI SILT LOAM, 2 TO 4 PERCENT SLOPES	C
527C2	KIDAMI LOAM, 4 TO 6 PERCENT SLOPES, ERODED	C
527D2	KIDAMI LOAM, 6 TO 12 PERCENT SLOPES, ERODED	C

No.	REVISIONS	DATE

CULTIVATE POWER

Kimley»Horn

570 LAKE COOK RD SUITE 200
DEERFIELD, IL 60015
WWW.KIMLEY-HORN.COM

PRELIMINARY NOT FOR CONSTRUCTION

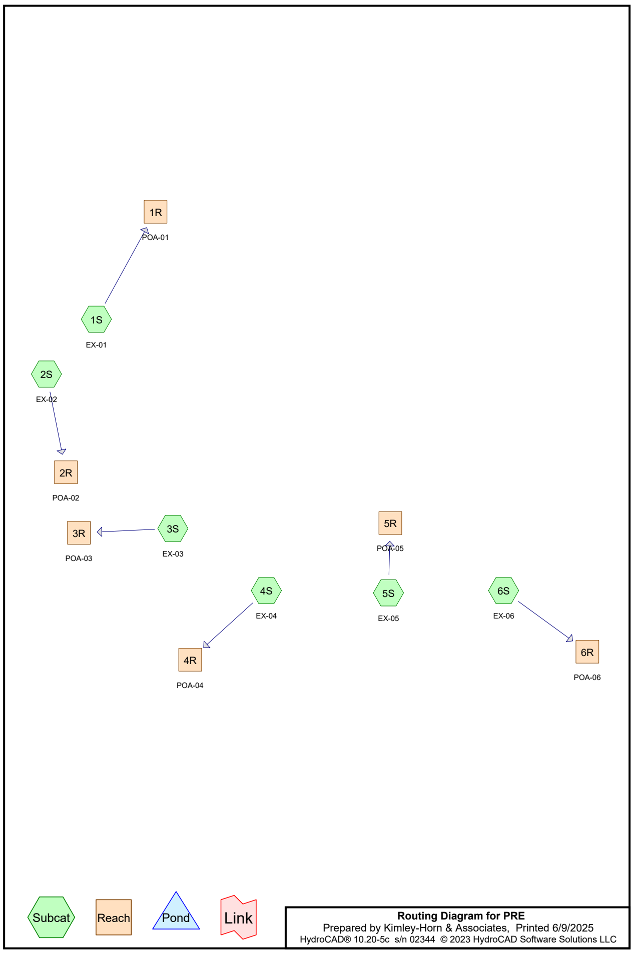
KHA PROJECT 268262054
ORIGINAL DATE 04/22/2025
SCALE AS SHOWN
DESIGNED BY SFH
DRAWN BY SFH
CHECKED BY CPC

POST-DEVELOPMENT DRAINAGE AREA MAP

ANAMITE SOLAR, LLC
KANE COUNTY, IL

SHEET NUMBER
EX-6

Exhibit 7 – Pre-Development HydroCAD Model



Rainfall Events Listing

Event#	Event Name	Storm Type	Curve	Mode	Duration (hours)	B/B	Depth (inches)	AMC
1	2-YR 24-HR	Type II 24-hr		Default	24.00	1	3.34	2
2	100-YR 24-HR	Type II 24-hr		Default	24.00	1	8.57	2

Area Listing (all nodes)

Area (acres)	CN	Description (subcatchment-numbers)
0.760	98	IMPERVIOUS TYPE C (4S, 5S, 6S)
0.560	79	PASTURE FAIR TYPE C (4S, 5S, 6S)
23.150	78	ROW CROP GOOD TYPE B (1S, 2S, 3S)
4.430	85	ROW CROP GOOD TYPE C (4S, 5S, 6S)
28.900	**80**	**TOTAL AREA**

Time span=0.00-48.00 hrs, dt=0.05 hrs, 961 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment1S: EX-01 Runoff Area=8.040 ac 0.00% Impervious Runoff Depth=1.38"
Flow Length=934' Tc=22.3 min CN=78 Runoff=11.30 cfs 0.923 af

Subcatchment2S: EX-02 Runoff Area=13.240 ac 0.00% Impervious Runoff Depth=1.38"
Flow Length=1,423' Tc=22.6 min CN=78 Runoff=18.45 cfs 1.519 af

Subcatchment3S: EX-03 Runoff Area=1.870 ac 0.00% Impervious Runoff Depth=1.38"
Flow Length=469' Tc=7.2 min CN=78 Runoff=4.33 cfs 0.215 af

Subcatchment4S: EX-04 Runoff Area=1.480 ac 20.27% Impervious Runoff Depth=2.04"
Flow Length=230' Tc=8.1 min CN=87 Runoff=4.85 cfs 0.252 af

Subcatchment5S: EX-05 Runoff Area=2.460 ac 9.35% Impervious Runoff Depth=1.96"
Flow Length=588' Tc=12.3 min CN=86 Runoff=6.74 cfs 0.401 af

Subcatchment6S: EX-06 Runoff Area=1.810 ac 12.71% Impervious Runoff Depth=1.96"
Flow Length=185' Tc=4.1 min CN=86 Runoff=6.53 cfs 0.295 af

Reach 1R: POA-01 Inflow=11.30 cfs 0.923 af
Outflow=11.30 cfs 0.923 af

Reach 2R: POA-02 Inflow=18.45 cfs 1.519 af
Outflow=18.45 cfs 1.519 af

Reach 3R: POA-03 Inflow=4.33 cfs 0.215 af
Outflow=4.33 cfs 0.215 af

Reach 4R: POA-04 Inflow=4.85 cfs 0.252 af
Outflow=4.85 cfs 0.252 af

Reach 5R: POA-05 Inflow=6.74 cfs 0.401 af
Outflow=6.74 cfs 0.401 af

Reach 6R: POA-06 Inflow=6.53 cfs 0.295 af
Outflow=6.53 cfs 0.295 af

Total Runoff Area = 28.900 ac Runoff Volume = 3.604 af Average Runoff Depth = 1.50"
97.37% Pervious = 28.140 ac 2.63% Impervious = 0.760 ac

Summary for Subcatchment 1S: EX-01

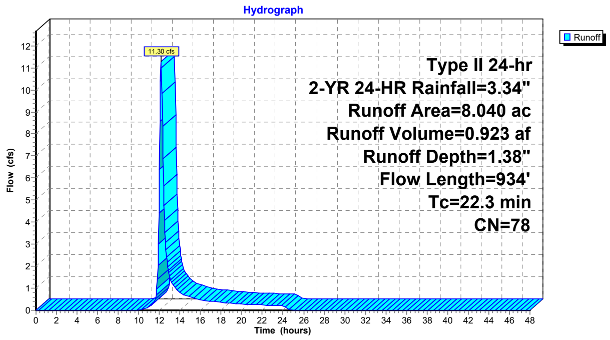
Runoff = 11.30 cfs @ 12.16 hrs, Volume= 0.923 af, Depth= 1.38"
Routed to Reach 1R : POA-01

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 2-YR 24-HR Rainfall=3.34"

	Area (ac)	CN	Description
*	8.040	78	ROW CROP GOOD TYPE B
	8.040		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.9	100	0.0107	0.28		**Sheet Flow, ROW CROP** Cultivated: Residue<=20% n= 0.060 P2= 3.34"
16.4	834	0.0089	0.85		**Shallow Concentrated Flow, ROW CROP** Cultivated Straight Rows Kv= 9.0 fps
22.3	934	Total			

Subcatchment 1S: EX-01



Summary for Subcatchment 2S: EX-02

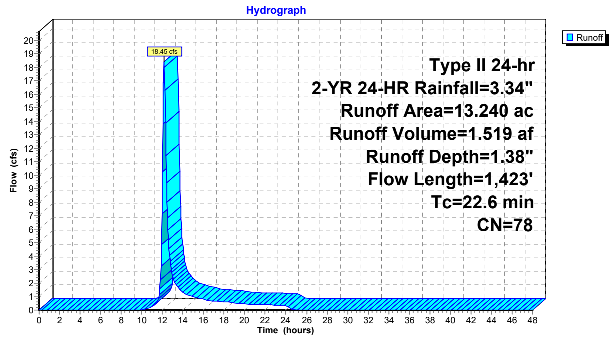
Runoff = 18.45 cfs @ 12.17 hrs, Volume= 1.519 af, Depth= 1.38"
Routed to Reach 2R : POA-02

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 2-YR 24-HR Rainfall=3.34"

	Area (ac)	CN	Description
*	13.240	78	ROW CROP GOOD TYPE B
	13.240		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.7	100	0.0342	0.45		**Sheet Flow, ROW CROP** Cultivated: Residue<=20% n= 0.060 P2= 3.34"
18.9	1,323	0.0168	1.17		**Shallow Concentrated Flow, ROW CROP** Cultivated Straight Rows Kv= 9.0 fps
22.6	1,423	Total			

Subcatchment 2S: EX-02



Summary for Subcatchment 3S: EX-03

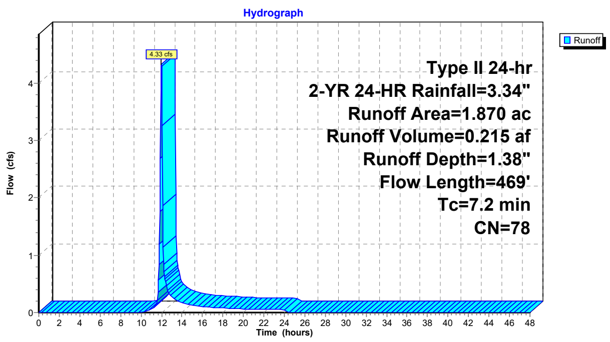
Runoff = 4.33 cfs @ 11.99 hrs, Volume= 0.215 af, Depth= 1.38"
Routed to Reach 3R : POA-03

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 2-YR 24-HR Rainfall=3.34"

	Area (ac)	CN	Description
*	1.870	78	ROW CROP GOOD TYPE B
	1.870		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.6	100	0.0361	0.46		**Sheet Flow, ROW CROP** Cultivated: Residue<=20% n= 0.060 P2= 3.34"
3.6	369	0.0367	1.72		**Shallow Concentrated Flow, ROW CROP** Cultivated Straight Rows Kv= 9.0 fps
7.2	469	Total			

Subcatchment 3S: EX-03



Summary for Subcatchment 4S: EX-04

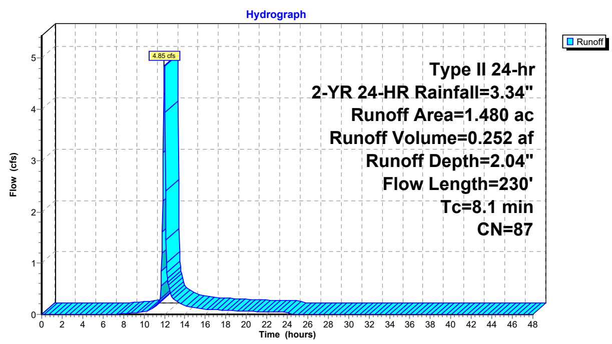
Runoff = 4.85 cfs @ 11.99 hrs, Volume= 0.252 af, Depth= 2.04"
Routed to Reach 4R : POA-04

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 2-YR 24-HR Rainfall=3.34"

	Area (ac)	CN	Description
*	1.050	85	ROW CROP GOOD TYPE C
*	0.130	79	PASTURE FAIR TYPE C
*	0.300	98	IMPERVIOUS TYPE C
	1.480	87	Weighted Average
	1.180		79.73% Pervious Area
	0.300		20.27% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.5	100	0.0084	0.26		**Sheet Flow, ROW CROP** Cultivated: Residue<=20% n= 0.060 P2= 3.34"
1.3	101	0.0199	1.27		**Shallow Concentrated Flow, ROW CROP** Cultivated Straight Rows Kv= 9.0 fps
0.1	17	0.0165	2.61		**Shallow Concentrated Flow, IMPERVIOUS** Paved Kv= 20.3 fps
0.2	12	0.0175	0.93		**Shallow Concentrated Flow, PASTURE** Short Grass Pasture Kv= 7.0 fps
8.1	230	Total			

Subcatchment 4S: EX-04



Summary for Subcatchment 5S: EX-05

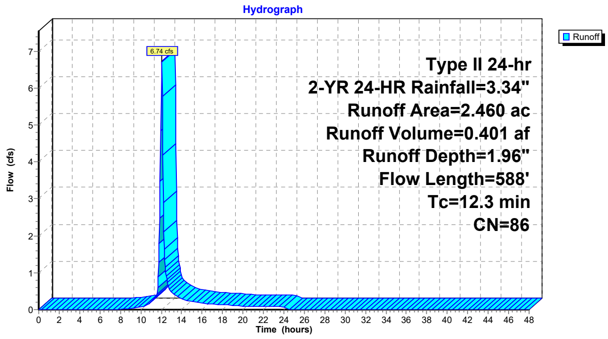
Runoff = 6.74 cfs @ 12.04 hrs, Volume= 0.401 af, Depth= 1.96"
Routed to Reach 5R : POA-05

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 2-YR 24-HR Rainfall=3.34"

	Area (ac)	CN	Description
*	2.030	85	ROW CROP GOOD TYPE C
*	0.200	79	PASTURE FAIR TYPE C
*	0.230	98	IMPERVIOUS TYPE C
	2.460	86	Weighted Average
	2.230		90.65% Pervious Area
	0.230		9.35% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.3	100	0.0091	0.26		**Sheet Flow, ROW CROP** Cultivated: Residue<=20% n= 0.060 P2= 3.34"
6.0	488	0.0224	1.35		**Shallow Concentrated Flow, ROW CROP** Cultivated Straight Rows Kv= 9.0 fps
12.3	588	Total			

Subcatchment 5S: EX-05



Summary for Subcatchment 6S: EX-06

[49] Hint: Tc<2dt may require smaller dt

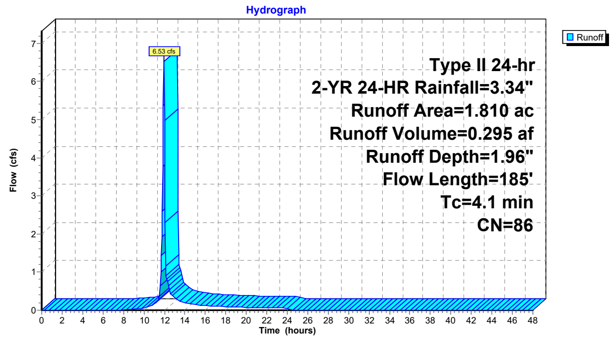
Runoff = 6.53 cfs @ 11.95 hrs, Volume= 0.295 af, Depth= 1.96"
Routed to Reach 6R : POA-06

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 2-YR 24-HR Rainfall=3.34"

	Area (ac)	CN	Description
*	1.350	85	ROW CROP GOOD TYPE C
*	0.230	79	PASTURE FAIR TYPE C
*	0.230	98	IMPERVIOUS TYPE C
	1.810	86	Weighted Average
	1.580		87.29% Pervious Area
	0.230		12.71% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.5	100	0.0388	0.47		**Sheet Flow, ROW CROP** Cultivated: Residue<=20% n= 0.060 P2= 3.34"
0.3	41	0.0573	2.15		**Shallow Concentrated Flow, ROW CROP** Cultivated Straight Rows Kv= 9.0 fps
0.1	29	0.0534	4.69		**Shallow Concentrated Flow, IMPERVIOUS** Paved Kv= 20.3 fps
0.2	15	0.0547	1.64		**Shallow Concentrated Flow, PASTURE** Short Grass Pasture Kv= 7.0 fps
4.1	185	Total			

Subcatchment 6S: EX-06



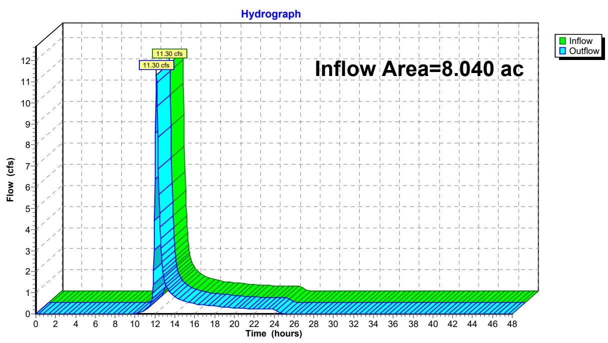
Summary for Reach 1R: POA-01

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 8.040 ac, 0.00% Impervious, Inflow Depth = 1.38" for 2-YR 24-HR event
Inflow = 11.30 cfs @ 12.16 hrs, Volume= 0.923 af
Outflow = 11.30 cfs @ 12.16 hrs, Volume= 0.923 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

Reach 1R: POA-01



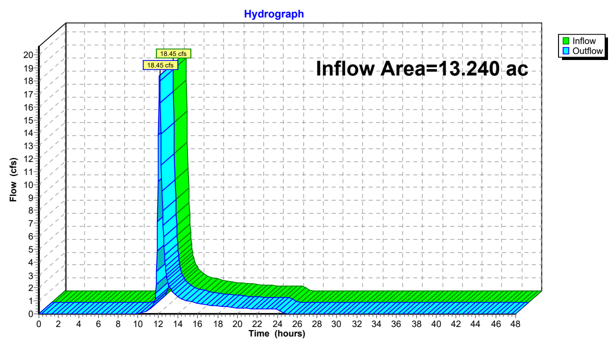
Summary for Reach 2R: POA-02

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 13.240 ac, 0.00% Impervious, Inflow Depth = 1.38" for 2-YR 24-HR event
Inflow = 18.45 cfs @ 12.17 hrs, Volume= 1.519 af
Outflow = 18.45 cfs @ 12.17 hrs, Volume= 1.519 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

Reach 2R: POA-02



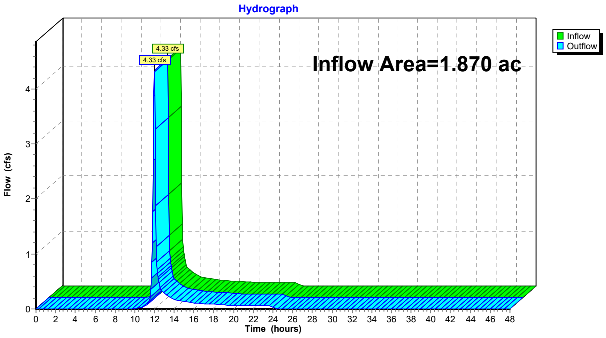
Summary for Reach 3R: POA-03

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 1.870 ac, 0.00% Impervious, Inflow Depth = 1.38" for 2-YR 24-HR event
Inflow = 4.33 cfs @ 11.99 hrs, Volume= 0.215 af
Outflow = 4.33 cfs @ 11.99 hrs, Volume= 0.215 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

Reach 3R: POA-03



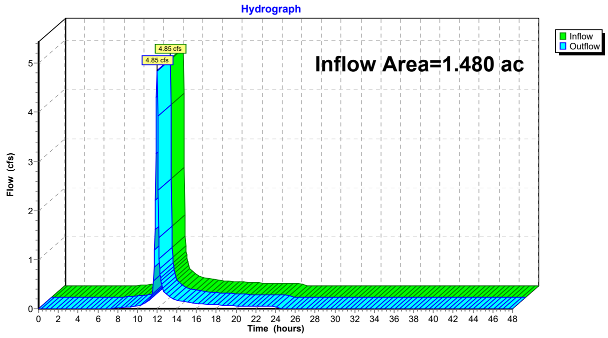
Summary for Reach 4R: POA-04

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 1.480 ac, 20.27% Impervious, Inflow Depth = 2.04" for 2-YR 24-HR event
Inflow = 4.85 cfs @ 11.99 hrs, Volume= 0.252 af
Outflow = 4.85 cfs @ 11.99 hrs, Volume= 0.252 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

Reach 4R: POA-04



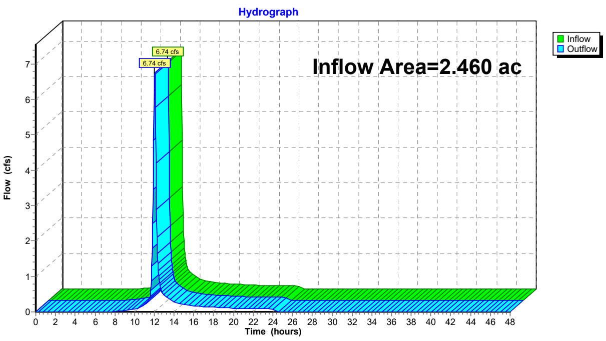
Summary for Reach 5R: POA-05

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 2.460 ac, 9.35% Impervious, Inflow Depth = 1.96" for 2-YR 24-HR event
Inflow = 6.74 cfs @ 12.04 hrs, Volume= 0.401 af
Outflow = 6.74 cfs @ 12.04 hrs, Volume= 0.401 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

Reach 5R: POA-05



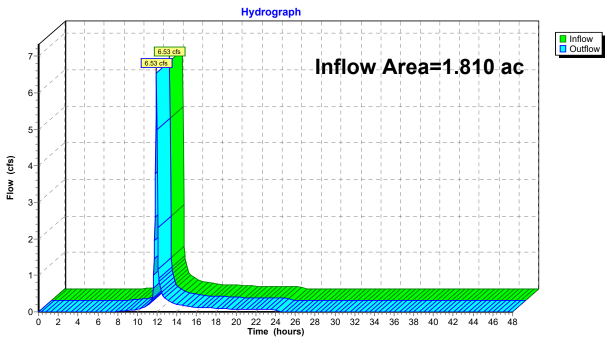
Summary for Reach 6R: POA-06

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 1.810 ac, 12.71% Impervious, Inflow Depth = 1.96" for 2-YR 24-HR event
Inflow = 6.53 cfs @ 11.95 hrs, Volume= 0.295 af
Outflow = 6.53 cfs @ 11.95 hrs, Volume= 0.295 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

Reach 6R: POA-06



Time span=0.00-48.00 hrs, dt=0.05 hrs, 961 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment1S: EX-01 Runoff Area=8.040 ac 0.00% Impervious Runoff Depth=5.92"
Flow Length=934' Tc=22.3 min CN=78 Runoff=49.05 cfs 3.967 af

Subcatchment2S: EX-02 Runoff Area=13.240 ac 0.00% Impervious Runoff Depth=5.92"
Flow Length=1,423' Tc=22.6 min CN=78 Runoff=80.12 cfs 6.532 af

Subcatchment3S: EX-03 Runoff Area=1.870 ac 0.00% Impervious Runoff Depth=5.92"
Flow Length=469' Tc=7.2 min CN=78 Runoff=17.95 cfs 0.923 af

Subcatchment4S: EX-04 Runoff Area=1.480 ac 20.27% Impervious Runoff Depth=7.01"
Flow Length=230' Tc=8.1 min CN=87 Runoff=15.60 cfs 0.864 af

Subcatchment5S: EX-05 Runoff Area=2.460 ac 9.35% Impervious Runoff Depth=6.88"
Flow Length=588' Tc=12.3 min CN=86 Runoff=22.44 cfs 1.411 af

Subcatchment6S: EX-06 Runoff Area=1.810 ac 12.71% Impervious Runoff Depth=6.88"
Flow Length=185' Tc=4.1 min CN=86 Runoff=21.37 cfs 1.038 af

Reach 1R: POA-01 Inflow=49.05 cfs 3.967 af
Outflow=49.05 cfs 3.967 af

Reach 2R: POA-02 Inflow=80.12 cfs 6.532 af
Outflow=80.12 cfs 6.532 af

Reach 3R: POA-03 Inflow=17.95 cfs 0.923 af
Outflow=17.95 cfs 0.923 af

Reach 4R: POA-04 Inflow=15.60 cfs 0.864 af
Outflow=15.60 cfs 0.864 af

Reach 5R: POA-05 Inflow=22.44 cfs 1.411 af
Outflow=22.44 cfs 1.411 af

Reach 6R: POA-06 Inflow=21.37 cfs 1.038 af
Outflow=21.37 cfs 1.038 af

Total Runoff Area = 28.900 ac Runoff Volume = 14.735 af Average Runoff Depth = 6.12"
97.37% Pervious = 28.140 ac 2.63% Impervious = 0.760 ac

Summary for Subcatchment 1S: EX-01

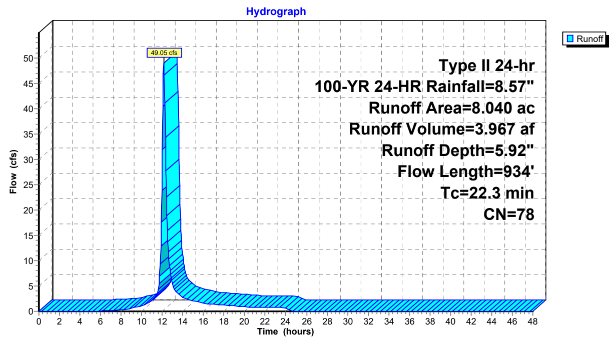
Runoff = 49.05 cfs @ 12.15 hrs, Volume= 3.967 af, Depth= 5.92"
Routed to Reach 1R : POA-01

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 100-YR 24-HR Rainfall=8.57"

	Area (ac)	CN	Description
*	8.040	78	ROW CROP GOOD TYPE B
	8.040		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.9	100	0.0107	0.28		**Sheet Flow, ROW CROP** Cultivated: Residue<=20% n= 0.060 P2= 3.34"
16.4	834	0.0089	0.85		**Shallow Concentrated Flow, ROW CROP** Cultivated Straight Rows Kv= 9.0 fps
22.3	934	Total			

Subcatchment 1S: EX-01



Summary for Subcatchment 2S: EX-02

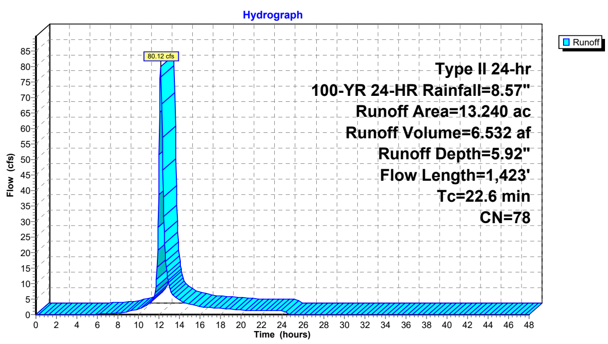
Runoff = 80.12 cfs @ 12.15 hrs, Volume= 6.532 af, Depth= 5.92"
Routed to Reach 2R : POA-02

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 100-YR 24-HR Rainfall=8.57"

	Area (ac)	CN	Description
*	13.240	78	ROW CROP GOOD TYPE B
	13.240		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.7	100	0.0342	0.45		**Sheet Flow, ROW CROP** Cultivated: Residue<=20% n= 0.060 P2= 3.34"
18.9	1,323	0.0168	1.17		**Shallow Concentrated Flow, ROW CROP** Cultivated Straight Rows Kv= 9.0 fps
22.6	1,423	Total			

Subcatchment 2S: EX-02



Summary for Subcatchment 3S: EX-03

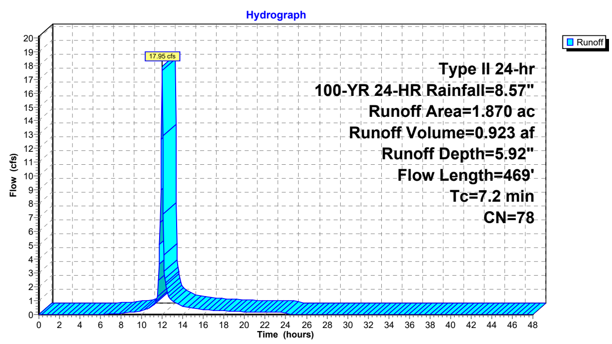
Runoff = 17.95 cfs @ 11.98 hrs, Volume= 0.923 af, Depth= 5.92"
Routed to Reach 3R : POA-03

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 100-YR 24-HR Rainfall=8.57"

	Area (ac)	CN	Description
*	1.870	78	ROW CROP GOOD TYPE B
	1.870		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.6	100	0.0361	0.46		**Sheet Flow, ROW CROP** Cultivated: Residue<=20% n= 0.060 P2= 3.34"
3.6	369	0.0367	1.72		**Shallow Concentrated Flow, ROW CROP** Cultivated Straight Rows Kv= 9.0 fps
7.2	469	Total			

Subcatchment 3S: EX-03



Summary for Subcatchment 4S: EX-04

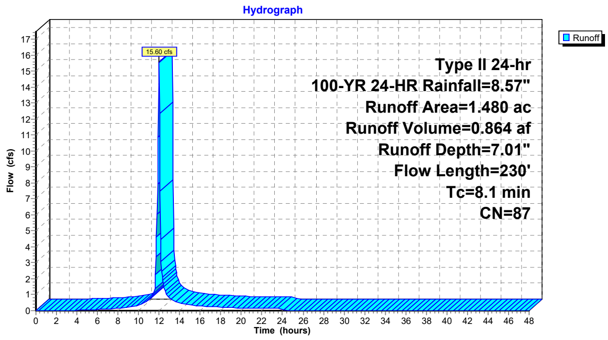
Runoff = 15.60 cfs @ 11.99 hrs, Volume= 0.864 af, Depth= 7.01"
Routed to Reach 4R : POA-04

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 100-YR 24-HR Rainfall=8.57"

	Area (ac)	CN	Description
*	1.050	85	ROW CROP GOOD TYPE C
*	0.130	79	PASTURE FAIR TYPE C
*	0.300	98	IMPERVIOUS TYPE C
	1.480	87	Weighted Average
	1.180		79.73% Pervious Area
	0.300		20.27% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.5	100	0.0084	0.26		**Sheet Flow, ROW CROP** Cultivated: Residue<=20% n= 0.060 P2= 3.34"
1.3	101	0.0199	1.27		**Shallow Concentrated Flow, ROW CROP** Cultivated Straight Rows Kv= 9.0 fps
0.1	17	0.0165	2.61		**Shallow Concentrated Flow, IMPERVIOUS** Paved Kv= 20.3 fps
0.2	12	0.0175	0.93		**Shallow Concentrated Flow, PASTURE** Short Grass Pasture Kv= 7.0 fps
8.1	230	Total			

Subcatchment 4S: EX-04



Summary for Subcatchment 5S: EX-05

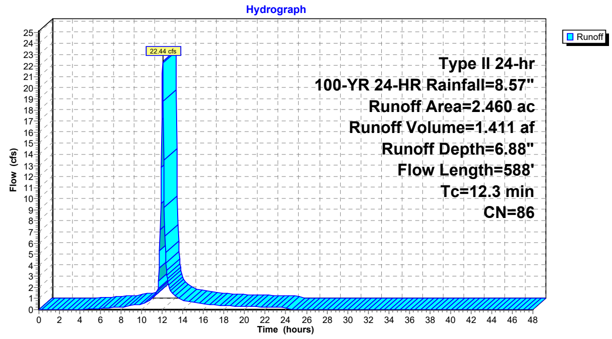
Runoff = 22.44 cfs @ 12.04 hrs, Volume= 1.411 af, Depth= 6.88"
Routed to Reach 5R : POA-05

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 100-YR 24-HR Rainfall=8.57"

	Area (ac)	CN	Description
*	2.030	85	ROW CROP GOOD TYPE C
*	0.200	79	PASTURE FAIR TYPE C
*	0.230	98	IMPERVIOUS TYPE C
	2.460	86	Weighted Average
	2.230		90.65% Pervious Area
	0.230		9.35% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.3	100	0.0091	0.26		**Sheet Flow, ROW CROP** Cultivated: Residue<=20% n= 0.060 P2= 3.34"
6.0	488	0.0224	1.35		**Shallow Concentrated Flow, ROW CROP** Cultivated Straight Rows Kv= 9.0 fps
12.3	588	Total			

Subcatchment 5S: EX-05



Summary for Subcatchment 6S: EX-06

[49] Hint: Tc<2dt may require smaller dt

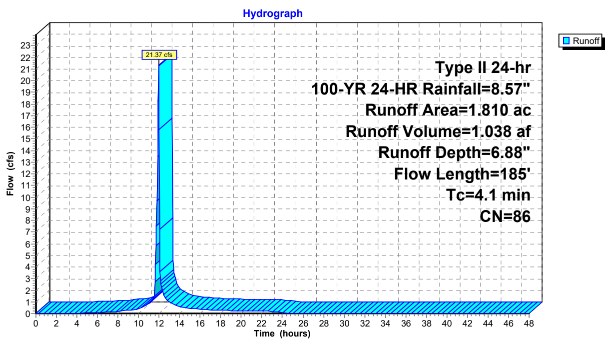
Runoff = 21.37 cfs @ 11.94 hrs, Volume= 1.038 af, Depth= 6.88"
Routed to Reach 6R : POA-06

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 100-YR 24-HR Rainfall=8.57"

	Area (ac)	CN	Description
*	1.350	85	ROW CROP GOOD TYPE C
*	0.230	79	PASTURE FAIR TYPE C
*	0.230	98	IMPERVIOUS TYPE C
	1.810	86	Weighted Average
	1.580		87.29% Pervious Area
	0.230		12.71% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
3.5	100	0.0388	0.47		**Sheet Flow, ROW CROP** Cultivated: Residue<=20% n= 0.060 P2= 3.34"
0.3	41	0.0573	2.15		**Shallow Concentrated Flow, ROW CROP** Cultivated Straight Rows Kv= 9.0 fps
0.1	29	0.0534	4.69		**Shallow Concentrated Flow, IMPERVIOUS** Paved Kv= 20.3 fps
0.2	15	0.0547	1.64		**Shallow Concentrated Flow, PASTURE** Short Grass Pasture Kv= 7.0 fps
4.1	185	Total			

Subcatchment 6S: EX-06



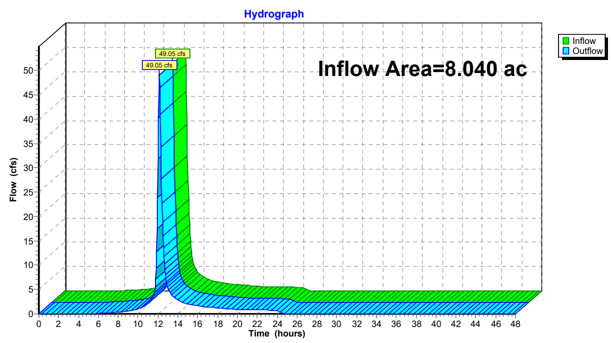
Summary for Reach 1R: POA-01

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 8.040 ac, 0.00% Impervious, Inflow Depth = 5.92" for 100-YR 24-HR event
Inflow = 49.05 cfs @ 12.15 hrs, Volume= 3.967 af
Outflow = 49.05 cfs @ 12.15 hrs, Volume= 3.967 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

Reach 1R: POA-01



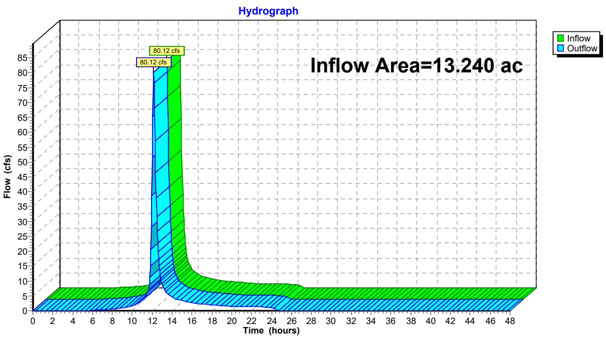
Summary for Reach 2R: POA-02

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 13.240 ac, 0.00% Impervious, Inflow Depth = 5.92" for 100-YR 24-HR event
Inflow = 80.12 cfs @ 12.15 hrs, Volume= 6.532 af
Outflow = 80.12 cfs @ 12.15 hrs, Volume= 6.532 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

Reach 2R: POA-02



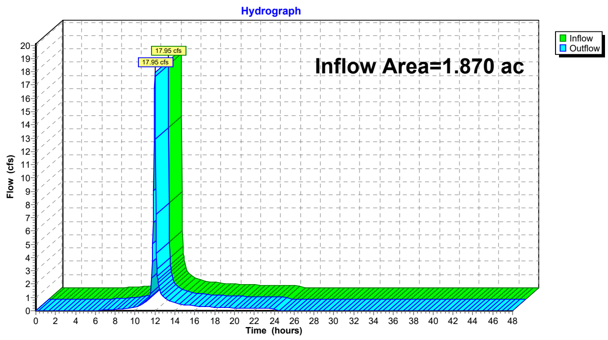
Summary for Reach 3R: POA-03

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 1.870 ac, 0.00% Impervious, Inflow Depth = 5.92" for 100-YR 24-HR event
Inflow = 17.95 cfs @ 11.98 hrs, Volume= 0.923 af
Outflow = 17.95 cfs @ 11.98 hrs, Volume= 0.923 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

Reach 3R: POA-03



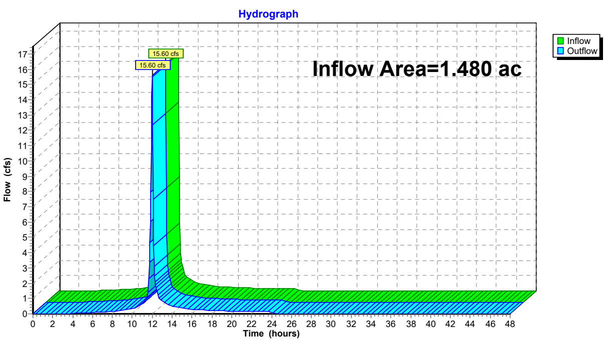
Summary for Reach 4R: POA-04

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 1.480 ac, 20.27% Impervious, Inflow Depth = 7.01" for 100-YR 24-HR event
Inflow = 15.60 cfs @ 11.99 hrs, Volume= 0.864 af
Outflow = 15.60 cfs @ 11.99 hrs, Volume= 0.864 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

Reach 4R: POA-04



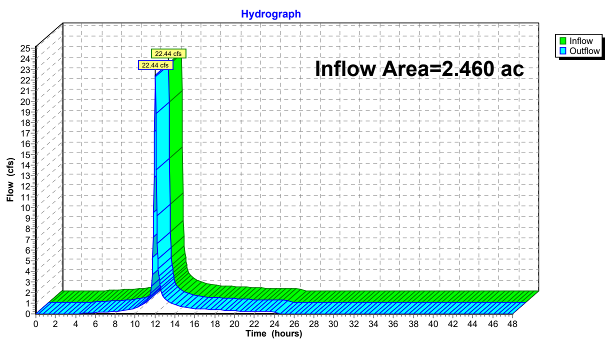
Summary for Reach 5R: POA-05

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 2.460 ac, 9.35% Impervious, Inflow Depth = 6.88" for 100-YR 24-HR event
Inflow = 22.44 cfs @ 12.04 hrs, Volume= 1.411 af
Outflow = 22.44 cfs @ 12.04 hrs, Volume= 1.411 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

Reach 5R: POA-05



Summary for Reach 6R: POA-06

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 1.810 ac, 12.71% Impervious, Inflow Depth = 6.88" for 100-YR 24-HR event
Inflow = 21.37 cfs @ 11.94 hrs, Volume= 1.038 af
Outflow = 21.37 cfs @ 11.94 hrs, Volume= 1.038 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

Reach 6R: POA-06

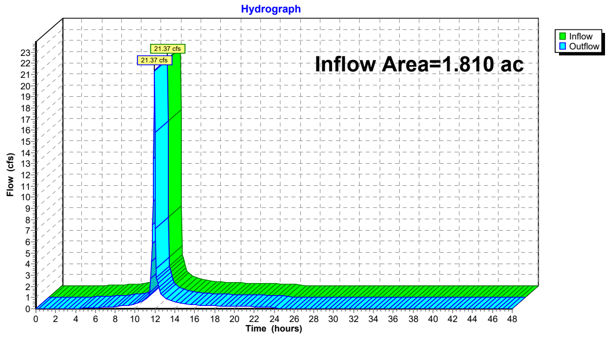
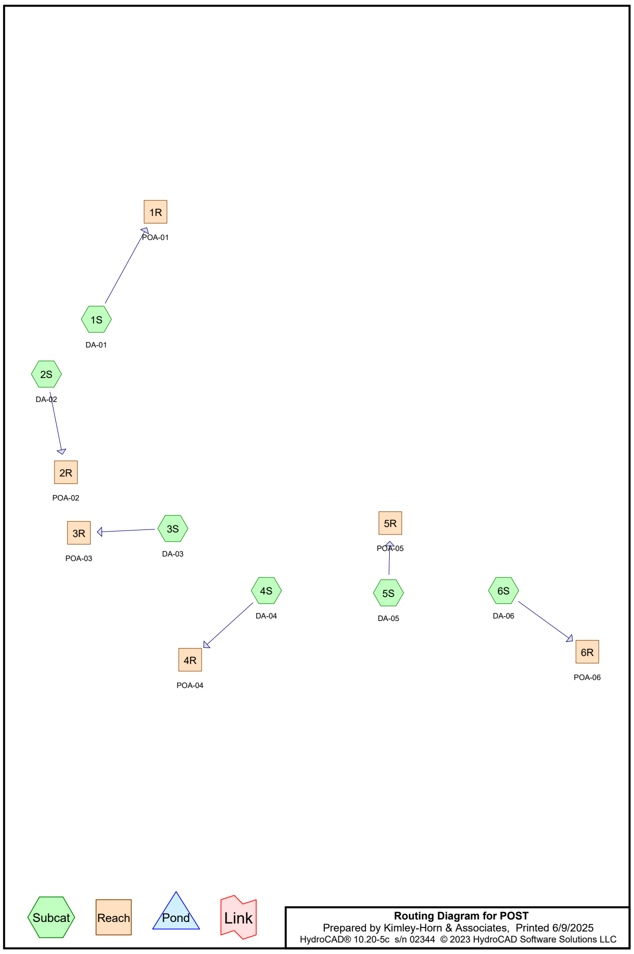


Exhibit 8 – Post-Development HydroCAD Model



Rainfall Events Listing

Event#	Event Name	Storm Type	Curve	Mode	Duration (hours)	B/B	Depth (inches)	AMC
1	2-YR 24-HR	Type II 24-hr		Default	24.00	1	3.34	2
2	100-YR 24-HR	Type II 24-hr		Default	24.00	1	8.57	2

Area Listing (all nodes)

Area (acres)	CN	Description (subcatchment-numbers)
0.950	85	GRAVEL TYPE B (2S, 3S)
1.270	89	GRAVEL TYPE C (4S, 5S, 6S)
0.030	89	IMPERVIOUS TYPE B (1S)
0.080	98	IMPERVIOUS TYPE B (2S)
22.090	58	MEADOW TYPE B (1S, 2S, 3S)
4.480	71	MEADOW TYPE C (4S, 5S, 6S)
28.900	**62**	**TOTAL AREA**

Time span=0.00-48.00 hrs, dt=0.05 hrs, 961 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment1S: DA-01 Runoff Area=8.040 ac 0.00% Impervious Runoff Depth=0.39"
Flow Length=934' Tc=33.2 min CN=58 Runoff=1.43 cfs 0.263 af

Subcatchment2S: DA-02 Runoff Area=13.240 ac 0.60% Impervious Runoff Depth=0.43"
Flow Length=1,423' Tc=32.0 min CN=59 Runoff=2.81 cfs 0.472 af

Subcatchment3S: DA-03 Runoff Area=1.870 ac 0.00% Impervious Runoff Depth=0.71"
Flow Length=469' Tc=10.8 min CN=66 Runoff=1.76 cfs 0.111 af

Subcatchment4S: DA-04 Runoff Area=1.480 ac 0.00% Impervious Runoff Depth=1.25"
Flow Length=229' Tc=15.4 min CN=76 Runoff=2.30 cfs 0.154 af

Subcatchment5S: DA-05 Runoff Area=2.460 ac 0.00% Impervious Runoff Depth=1.13"
Flow Length=588' Tc=20.9 min CN=74 Runoff=2.87 cfs 0.232 af

Subcatchment6S: DA-06 Runoff Area=1.810 ac 0.00% Impervious Runoff Depth=1.19"
Flow Length=185' Tc=7.9 min CN=75 Runoff=3.51 cfs 0.179 af

Reach 1R: POA-01 Inflow=1.43 cfs 0.263 af
Outflow=1.43 cfs 0.263 af

Reach 2R: POA-02 Inflow=2.81 cfs 0.472 af
Outflow=2.81 cfs 0.472 af

Reach 3R: POA-03 Inflow=1.76 cfs 0.111 af
Outflow=1.76 cfs 0.111 af

Reach 4R: POA-04 Inflow=2.30 cfs 0.154 af
Outflow=2.30 cfs 0.154 af

Reach 5R: POA-05 Inflow=2.87 cfs 0.232 af
Outflow=2.87 cfs 0.232 af

Reach 6R: POA-06 Inflow=3.51 cfs 0.179 af
Outflow=3.51 cfs 0.179 af

Total Runoff Area = 28.900 ac Runoff Volume = 1.411 af Average Runoff Depth = 0.59"
99.72% Pervious = 28.820 ac 0.28% Impervious = 0.080 ac

Summary for Subcatchment 1S: DA-01

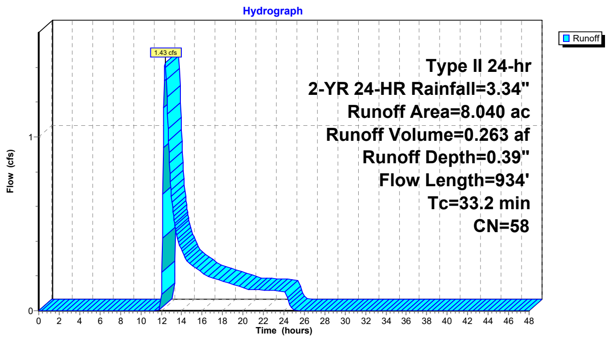
Runoff = 1.43 cfs @ 12.39 hrs, Volume= 0.263 af, Depth= 0.39"
Routed to Reach 1R : POA-01

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 2-YR 24-HR Rainfall=3.34"

	Area (ac)	CN	Description
*	8.010	58	MEADOW TYPE B
*	0.030	89	IMPERVIOUS TYPE B
	8.040	58	Weighted Average
	8.040		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
12.3	100	0.0107	0.14		**Sheet Flow, MEADOW** Grass: Short n= 0.150 P2= 3.34"
18.6	726	0.0086	0.65		**Shallow Concentrated Flow, MEADOW** Short Grass Pasture Kv= 7.0 fps
0.3	44	0.0166	2.62		**Shallow Concentrated Flow, IMPERVIOUS** Paved Kv= 20.3 fps
2.0	64	0.0061	0.55		**Shallow Concentrated Flow, MEADOW** Short Grass Pasture Kv= 7.0 fps
33.2	934	Total			

Subcatchment 1S: DA-01



Summary for Subcatchment 2S: DA-02

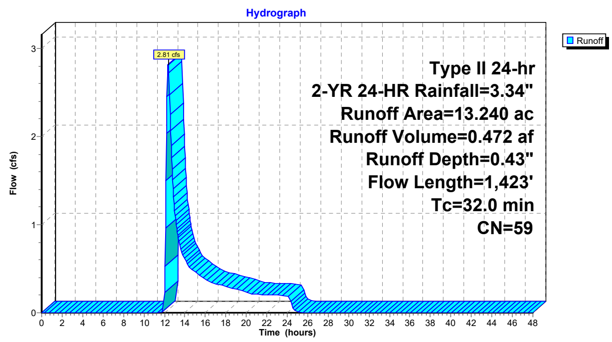
Runoff = 2.81 cfs @ 12.37 hrs, Volume= 0.472 af, Depth= 0.43"
Routed to Reach 2R : POA-02

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 2-YR 24-HR Rainfall=3.34"

	Area (ac)	CN	Description
*	12.750	58	MEADOW TYPE B
*	0.410	85	GRAVEL TYPE B
*	0.080	98	IMPERVIOUS TYPE B
	13.240	59	Weighted Average
	13.160		99.40% Pervious Area
	0.080		0.60% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
7.7	100	0.0342	0.22		**Sheet Flow, MEADOW** Grass: Short n= 0.150 P2= 3.34"
22.6	1,253	0.0174	0.92		**Shallow Concentrated Flow, MEADOW** Short Grass Pasture Kv= 7.0 fps
0.9	38	0.0011	0.67		**Shallow Concentrated Flow, IMPERVIOUS** Paved Kv= 20.3 fps
0.8	32	0.0097	0.69		**Shallow Concentrated Flow, MEADOW** Short Grass Pasture Kv= 7.0 fps
32.0	1,423	Total			

Subcatchment 2S: DA-02



Summary for Subcatchment 3S: DA-03

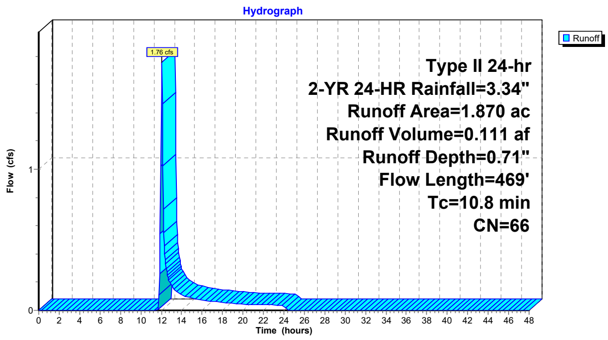
Runoff = 1.76 cfs @ 12.04 hrs, Volume= 0.111 af, Depth= 0.71"
Routed to Reach 3R : POA-03

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 2-YR 24-HR Rainfall=3.34"

	Area (ac)	CN	Description
*	1.330	58	MEADOW TYPE B
*	0.540	85	GRAVEL TYPE B
	1.870	66	Weighted Average
	1.870		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
7.6	100	0.0361	0.22		**Sheet Flow, MEADOW** Grass: Short n= 0.150 P2= 3.34"
2.6	296	0.0760	1.93		**Shallow Concentrated Flow, MEADOW** Short Grass Pasture Kv= 7.0 fps
0.6	73	0.0147	1.95		**Shallow Concentrated Flow, GRAVEL** Unpaved Kv= 16.1 fps
10.8	469	Total			

Subcatchment 3S: DA-03



Summary for Subcatchment 4S: DA-04

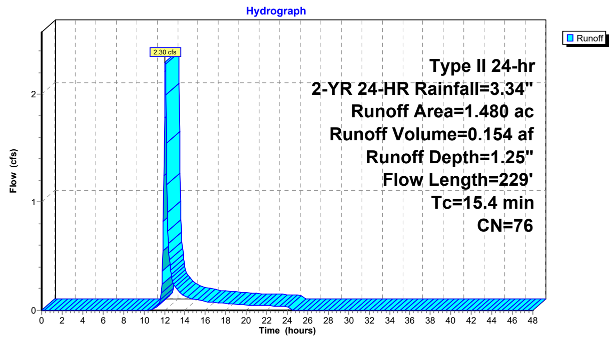
Runoff = 2.30 cfs @ 12.08 hrs, Volume= 0.154 af, Depth= 1.25"
Routed to Reach 4R : POA-04

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 2-YR 24-HR Rainfall=3.34"

	Area (ac)	CN	Description
*	1.040	71	MEADOW TYPE C
*	0.440	89	GRAVEL TYPE C
	1.480	76	Weighted Average
	1.480		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.6	100	0.0084	0.12		**Sheet Flow, MEADOW** Grass: Short n= 0.150 P2= 3.34"
1.5	92	0.0202	0.99		**Shallow Concentrated Flow, MEADOW** Short Grass Pasture Kv= 7.0 fps
0.3	37	0.0173	2.12		**Shallow Concentrated Flow, GRAVEL** Unpaved Kv= 16.1 fps
15.4	229	Total			

Subcatchment 4S: DA-04



Summary for Subcatchment 5S: DA-05

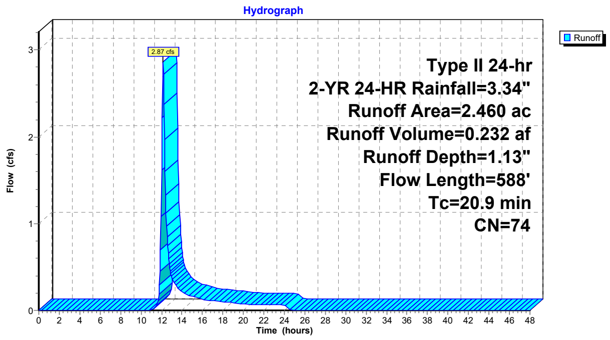
Runoff = 2.87 cfs @ 12.15 hrs, Volume= 0.232 af, Depth= 1.13"
Routed to Reach 5R : POA-05

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 2-YR 24-HR Rainfall=3.34"

	Area (ac)	CN	Description
*	2.030	71	MEADOW TYPE C
*	0.430	89	GRAVEL TYPE C
	2.460	74	Weighted Average
	2.460		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.1	100	0.0091	0.13		**Sheet Flow, MEADOW** Grass: Short n= 0.150 P2= 3.34"
7.8	488	0.0224	1.05		**Shallow Concentrated Flow, MEADOW** Short Grass Pasture Kv= 7.0 fps
20.9	588	Total			

Subcatchment 5S: DA-05



Summary for Subcatchment 6S: DA-06

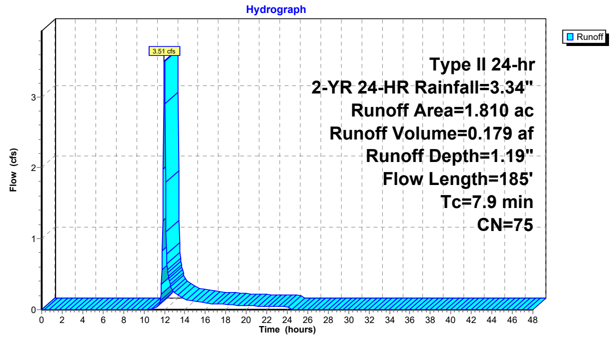
Runoff = 3.51 cfs @ 12.00 hrs, Volume= 0.179 af, Depth= 1.19"
Routed to Reach 6R : POA-06

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 2-YR 24-HR Rainfall=3.34"

	Area (ac)	CN	Description
*	1.410	71	MEADOW TYPE C
*	0.400	89	GRAVEL TYPE C
	1.810	75	Weighted Average
	1.810		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
7.4	100	0.0388	0.23		**Sheet Flow, MEADOW** Grass: Short n= 0.150 P2= 3.34"
0.3	33	0.0570	1.67		**Shallow Concentrated Flow, MEADOW** Short Grass Pasture Kv= 7.0 fps
0.2	52	0.0546	3.76		**Shallow Concentrated Flow, GRAVEL** Unpaved Kv= 16.1 fps
7.9	185	Total			

Subcatchment 6S: DA-06



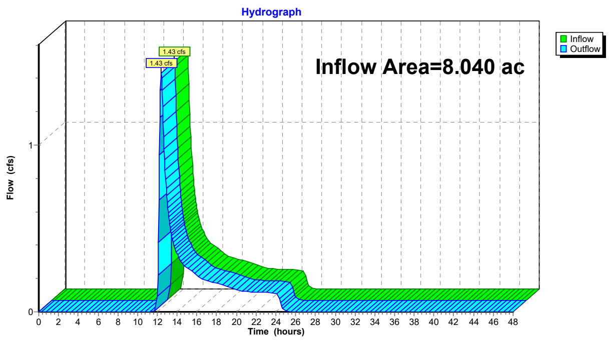
Summary for Reach 1R: POA-01

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 8.040 ac, 0.00% Impervious, Inflow Depth = 0.39" for 2-YR 24-HR event
Inflow = 1.43 cfs @ 12.39 hrs, Volume= 0.263 af
Outflow = 1.43 cfs @ 12.39 hrs, Volume= 0.263 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

Reach 1R: POA-01



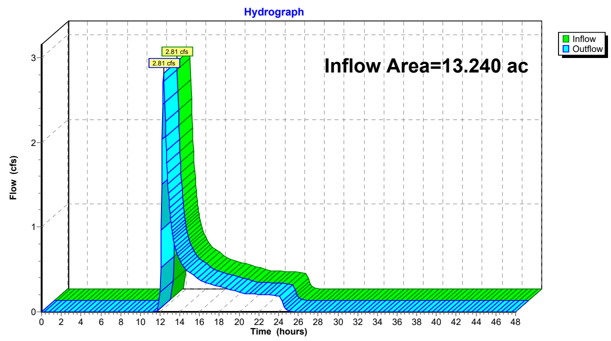
Summary for Reach 2R: POA-02

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 13.240 ac, 0.60% Impervious, Inflow Depth = 0.43" for 2-YR 24-HR event
Inflow = 2.81 cfs @ 12.37 hrs, Volume= 0.472 af
Outflow = 2.81 cfs @ 12.37 hrs, Volume= 0.472 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

Reach 2R: POA-02



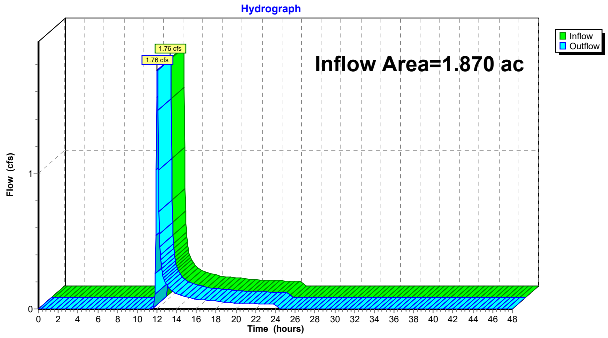
Summary for Reach 3R: POA-03

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 1.870 ac, 0.00% Impervious, Inflow Depth = 0.71" for 2-YR 24-HR event
Inflow = 1.76 cfs @ 12.04 hrs, Volume= 0.111 af
Outflow = 1.76 cfs @ 12.04 hrs, Volume= 0.111 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

Reach 3R: POA-03



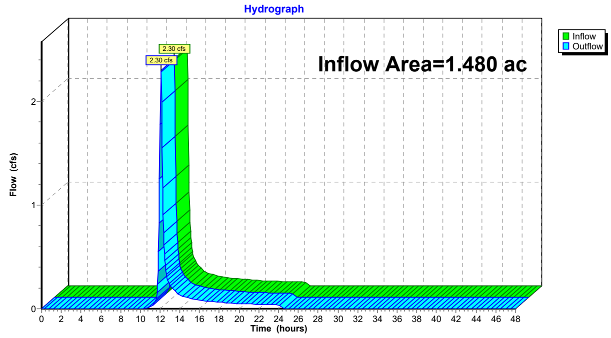
Summary for Reach 4R: POA-04

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 1.480 ac, 0.00% Impervious, Inflow Depth = 1.25" for 2-YR 24-HR event
Inflow = 2.30 cfs @ 12.08 hrs, Volume= 0.154 af
Outflow = 2.30 cfs @ 12.08 hrs, Volume= 0.154 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

Reach 4R: POA-04



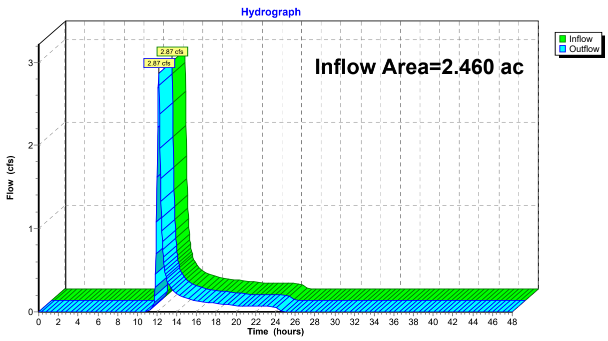
Summary for Reach 5R: POA-05

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 2.460 ac, 0.00% Impervious, Inflow Depth = 1.13" for 2-YR 24-HR event
Inflow = 2.87 cfs @ 12.15 hrs, Volume= 0.232 af
Outflow = 2.87 cfs @ 12.15 hrs, Volume= 0.232 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

Reach 5R: POA-05



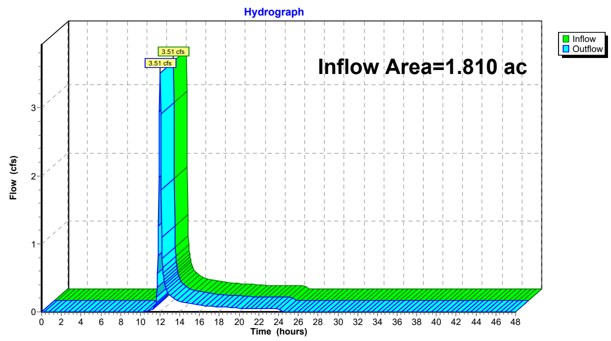
Summary for Reach 6R: POA-06

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 1.810 ac, 0.00% Impervious, Inflow Depth = 1.19" for 2-YR 24-HR event
Inflow = 3.51 cfs @ 12.00 hrs, Volume= 0.179 af
Outflow = 3.51 cfs @ 12.00 hrs, Volume= 0.179 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

Reach 6R: POA-06



Time span=0.00-48.00 hrs, dt=0.05 hrs, 961 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment1S: DA-01	Runoff Area=8.040 ac 0.00% Impervious Runoff Depth=3.53" Flow Length=934' Tc=33.2 min CN=58 Runoff=22.32 cfs 2.366 af
Subcatchment2S: DA-02	Runoff Area=13.240 ac 0.60% Impervious Runoff Depth=3.65" Flow Length=1,423' Tc=32.0 min CN=59 Runoff=39.06 cfs 4.026 af
Subcatchment3S: DA-03	Runoff Area=1.870 ac 0.00% Impervious Runoff Depth=4.48" Flow Length=469' Tc=10.8 min CN=66 Runoff=12.34 cfs 0.698 af
Subcatchment4S: DA-04	Runoff Area=1.480 ac 0.00% Impervious Runoff Depth=5.68" Flow Length=229' Tc=15.4 min CN=76 Runoff=10.54 cfs 0.700 af
Subcatchment5S: DA-05	Runoff Area=2.460 ac 0.00% Impervious Runoff Depth=5.44" Flow Length=588' Tc=20.9 min CN=74 Runoff=14.39 cfs 1.115 af
Subcatchment6S: DA-06	Runoff Area=1.810 ac 0.00% Impervious Runoff Depth=5.56" Flow Length=185' Tc=7.9 min CN=75 Runoff=16.16 cfs 0.838 af
Reach 1R: POA-01	Inflow=22.32 cfs 2.366 af Outflow=22.32 cfs 2.366 af
Reach 2R: POA-02	Inflow=39.06 cfs 4.026 af Outflow=39.06 cfs 4.026 af
Reach 3R: POA-03	Inflow=12.34 cfs 0.698 af Outflow=12.34 cfs 0.698 af
Reach 4R: POA-04	Inflow=10.54 cfs 0.700 af Outflow=10.54 cfs 0.700 af
Reach 5R: POA-05	Inflow=14.39 cfs 1.115 af Outflow=14.39 cfs 1.115 af
Reach 6R: POA-06	Inflow=16.16 cfs 0.838 af Outflow=16.16 cfs 0.838 af

Total Runoff Area = 28.900 ac Runoff Volume = 9.744 af Average Runoff Depth = 4.05"
99.72% Pervious = 28.820 ac 0.28% Impervious = 0.080 ac

Summary for Subcatchment 1S: DA-01

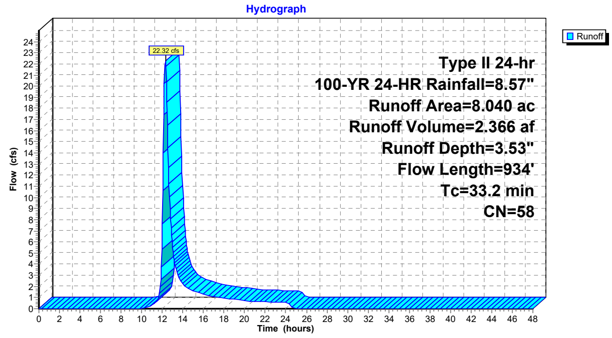
Runoff = 22.32 cfs @ 12.30 hrs, Volume= 2.366 af, Depth= 3.53"
Routed to Reach 1R : POA-01

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 100-YR 24-HR Rainfall=8.57"

	Area (ac)	CN	Description
*	8.010	58	MEADOW TYPE B
*	0.030	89	IMPERVIOUS TYPE B
	8.040	58	Weighted Average
	8.040		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
12.3	100	0.0107	0.14		**Sheet Flow, MEADOW** Grass: Short n= 0.150 P2= 3.34"
18.6	726	0.0086	0.65		**Shallow Concentrated Flow, MEADOW** Short Grass Pasture Kv= 7.0 fps
0.3	44	0.0166	2.62		**Shallow Concentrated Flow, IMPERVIOUS** Paved Kv= 20.3 fps
2.0	64	0.0061	0.55		**Shallow Concentrated Flow, MEADOW** Short Grass Pasture Kv= 7.0 fps
33.2	934	Total			

Subcatchment 1S: DA-01



Summary for Subcatchment 2S: DA-02

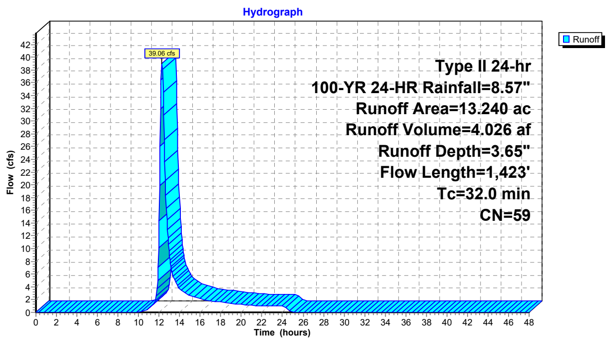
Runoff = 39.06 cfs @ 12.28 hrs, Volume= 4.026 af, Depth= 3.65"
Routed to Reach 2R : POA-02

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 100-YR 24-HR Rainfall=8.57"

	Area (ac)	CN	Description
*	12.750	58	MEADOW TYPE B
*	0.410	85	GRAVEL TYPE B
*	0.080	98	IMPERVIOUS TYPE B
	13.240	59	Weighted Average
	13.160		99.40% Pervious Area
	0.080		0.60% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
7.7	100	0.0342	0.22		**Sheet Flow, MEADOW** Grass: Short n= 0.150 P2= 3.34"
22.6	1,253	0.0174	0.92		**Shallow Concentrated Flow, MEADOW** Short Grass Pasture Kv= 7.0 fps
0.9	38	0.0011	0.67		**Shallow Concentrated Flow, IMPERVIOUS** Paved Kv= 20.3 fps
0.8	32	0.0097	0.69		**Shallow Concentrated Flow, MEADOW** Short Grass Pasture Kv= 7.0 fps
32.0	1,423	Total			

Subcatchment 2S: DA-02



Summary for Subcatchment 3S: DA-03

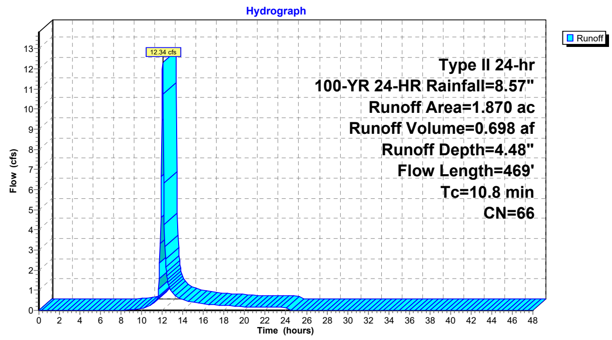
Runoff = 12.34 cfs @ 12.03 hrs, Volume= 0.698 af, Depth= 4.48"
Routed to Reach 3R : POA-03

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 100-YR 24-HR Rainfall=8.57"

	Area (ac)	CN	Description
*	1.330	58	MEADOW TYPE B
*	0.540	85	GRAVEL TYPE B
	1.870	66	Weighted Average
	1.870		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
7.6	100	0.0361	0.22		**Sheet Flow, MEADOW** Grass: Short n= 0.150 P2= 3.34"
2.6	296	0.0760	1.93		**Shallow Concentrated Flow, MEADOW** Short Grass Pasture Kv= 7.0 fps
0.6	73	0.0147	1.95		**Shallow Concentrated Flow, GRAVEL** Unpaved Kv= 16.1 fps
10.8	469	Total			

Subcatchment 3S: DA-03



Summary for Subcatchment 4S: DA-04

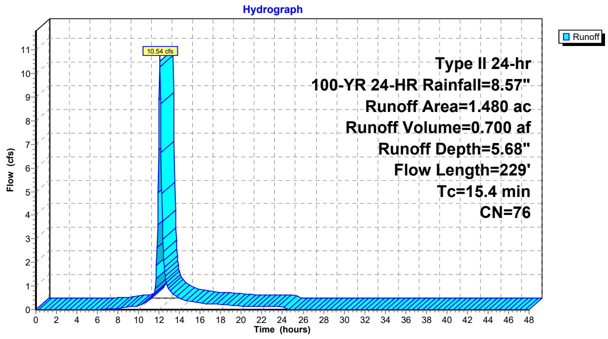
Runoff = 10.54 cfs @ 12.07 hrs, Volume= 0.700 af, Depth= 5.68"
Routed to Reach 4R : POA-04

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 100-YR 24-HR Rainfall=8.57"

	Area (ac)	CN	Description
*	1.040	71	MEADOW TYPE C
*	0.440	89	GRAVEL TYPE C
	1.480	76	Weighted Average
	1.480		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.6	100	0.0084	0.12		**Sheet Flow, MEADOW** Grass: Short n= 0.150 P2= 3.34"
1.5	92	0.0202	0.99		**Shallow Concentrated Flow, MEADOW** Short Grass Pasture Kv= 7.0 fps
0.3	37	0.0173	2.12		**Shallow Concentrated Flow, GRAVEL** Unpaved Kv= 16.1 fps
15.4	229	Total			

Subcatchment 4S: DA-04



Summary for Subcatchment 5S: DA-05

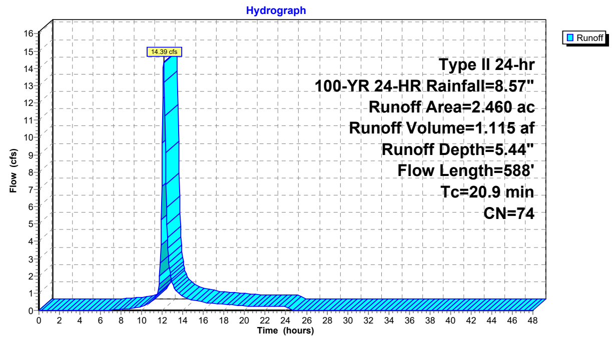
Runoff = 14.39 cfs @ 12.14 hrs, Volume= 1.115 af, Depth= 5.44"
Routed to Reach 5R : POA-05

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 100-YR 24-HR Rainfall=8.57"

	Area (ac)	CN	Description
*	2.030	71	MEADOW TYPE C
*	0.430	89	GRAVEL TYPE C
	2.460	74	Weighted Average
	2.460		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
13.1	100	0.0091	0.13		**Sheet Flow, MEADOW** Grass: Short n= 0.150 P2= 3.34"
7.8	488	0.0224	1.05		**Shallow Concentrated Flow, MEADOW** Short Grass Pasture Kv= 7.0 fps
20.9	588	Total			

Subcatchment 5S: DA-05



Summary for Subcatchment 6S: DA-06

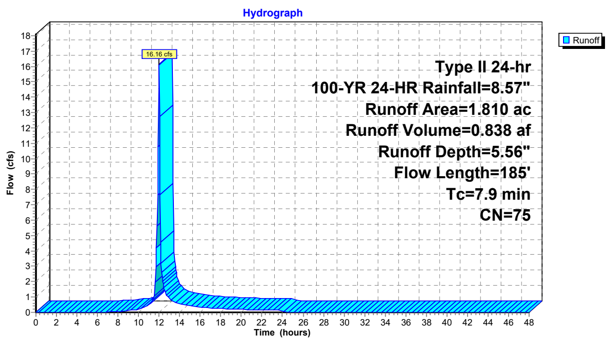
Runoff = 16.16 cfs @ 11.99 hrs, Volume= 0.838 af, Depth= 5.56"
Routed to Reach 6R : POA-06

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs
Type II 24-hr 100-YR 24-HR Rainfall=8.57"

	Area (ac)	CN	Description
*	1.410	71	MEADOW TYPE C
*	0.400	89	GRAVEL TYPE C
	1.810	75	Weighted Average
	1.810		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
7.4	100	0.0388	0.23		**Sheet Flow, MEADOW** Grass: Short n= 0.150 P2= 3.34"
0.3	33	0.0570	1.67		**Shallow Concentrated Flow, MEADOW** Short Grass Pasture Kv= 7.0 fps
0.2	52	0.0546	3.76		**Shallow Concentrated Flow, GRAVEL** Unpaved Kv= 16.1 fps
7.9	185	Total			

Subcatchment 6S: DA-06



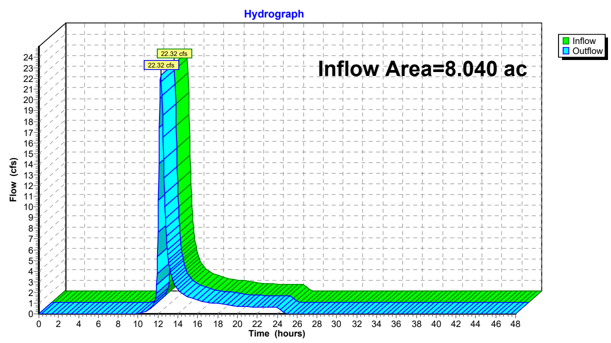
Summary for Reach 1R: POA-01

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 8.040 ac, 0.00% Impervious, Inflow Depth = 3.53" for 100-YR 24-HR event
Inflow = 22.32 cfs @ 12.30 hrs, Volume= 2.366 af
Outflow = 22.32 cfs @ 12.30 hrs, Volume= 2.366 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

Reach 1R: POA-01



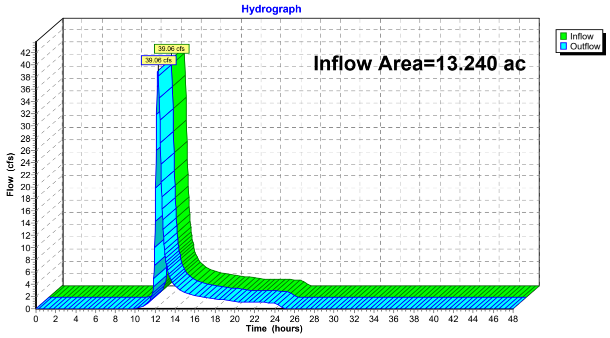
Summary for Reach 2R: POA-02

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 13.240 ac, 0.60% Impervious, Inflow Depth = 3.65" for 100-YR 24-HR event
Inflow = 39.06 cfs @ 12.28 hrs, Volume= 4.026 af
Outflow = 39.06 cfs @ 12.28 hrs, Volume= 4.026 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

Reach 2R: POA-02



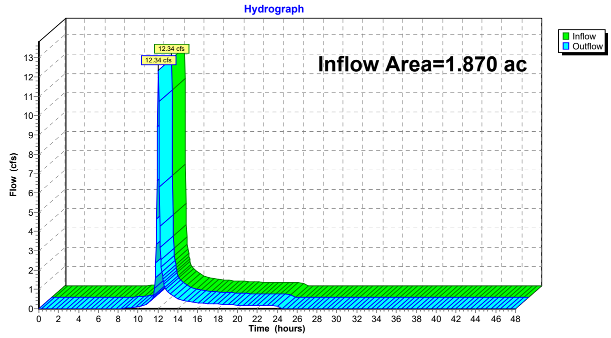
Summary for Reach 3R: POA-03

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 1.870 ac, 0.00% Impervious, Inflow Depth = 4.48" for 100-YR 24-HR event
Inflow = 12.34 cfs @ 12.03 hrs, Volume= 0.698 af
Outflow = 12.34 cfs @ 12.03 hrs, Volume= 0.698 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

Reach 3R: POA-03



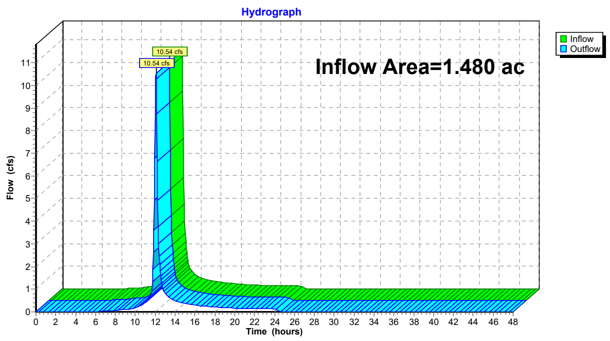
Summary for Reach 4R: POA-04

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 1.480 ac, 0.00% Impervious, Inflow Depth = 5.68" for 100-YR 24-HR event
Inflow = 10.54 cfs @ 12.07 hrs, Volume= 0.700 af
Outflow = 10.54 cfs @ 12.07 hrs, Volume= 0.700 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

Reach 4R: POA-04



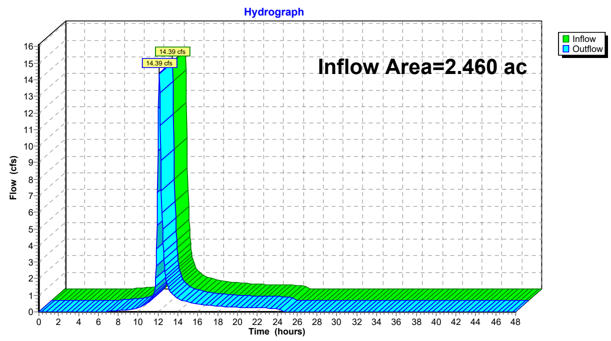
Summary for Reach 5R: POA-05

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 2.460 ac, 0.00% Impervious, Inflow Depth = 5.44" for 100-YR 24-HR event
Inflow = 14.39 cfs @ 12.14 hrs, Volume= 1.115 af
Outflow = 14.39 cfs @ 12.14 hrs, Volume= 1.115 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

Reach 5R: POA-05



Summary for Reach 6R: POA-06

[40] Hint: Not Described (Outflow=Inflow)

Inflow Area = 1.810 ac, 0.00% Impervious, Inflow Depth = 5.56" for 100-YR 24-HR event
Inflow = 16.16 cfs @ 11.99 hrs, Volume= 0.838 af
Outflow = 16.16 cfs @ 11.99 hrs, Volume= 0.838 af, Atten= 0%, Lag= 0.0 min

Routing by Stor-Ind+Trans method, Time Span= 0.00-48.00 hrs, dt= 0.05 hrs

Reach 6R: POA-06

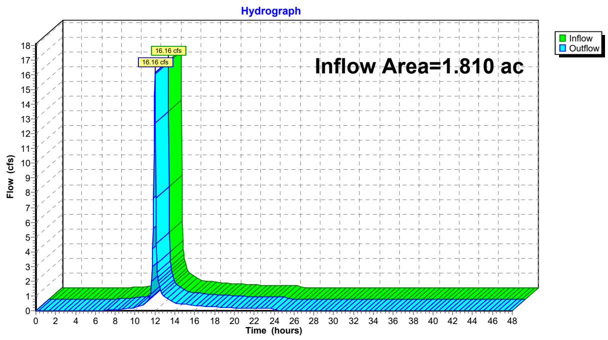


Exhibit 9 – Hydrologic Response of Solar Farms (By Others)

Hydrologic Response of Solar Farms

Lauren M. Cook, S.M.ASCE[1]; and Richard H. McCuen, M.ASCE[2]

Abstract: Because of the benefits of solar energy, the number of solar farms is increasing; however, their hydrologic impacts have not been studied. The goal of this study was to determine the hydrologic effects of solar farms and examine whether or not storm-water management is needed to control runoff volumes and rates. A model of a solar farm was used to simulate runoff for two conditions: the pre- and postpaneled conditions. Using sensitivity analyses, modeling showed that the solar panels themselves did not have a significant effect on the runoff volumes, peaks, or times to peak. However, if the ground cover under the panels is gravel or bare ground, owing to design decisions or lack of maintenance, the peak discharge may increase significantly with storm-water management needed. In addition, the kinetic energy of the flow that drains from the panels was found to be greater than that of the rainfall, which could cause erosion at the base of the panels. Thus, it is recommended that the grass beneath the panels be well maintained or that a buffer strip be placed after the most downgradient row of panels. This study, along with design recommendations, can be used as a guide for the future design of solar farms. **DOI:** 10.1061/(ASCE)HE.1943-5584.0000530.

CE Database subject headings: Hydrology; Land use; Solar power; Floods; Surface water; Runoff; Stormwater management.

Author keywords: Hydrology; Land use change; Solar energy; Flooding; Surface water runoff; Storm-water management.

Introduction

Storm-water management practices are generally implemented to reverse the effects of land-cover changes that cause increases in volumes and rates of runoff. This is a concern posed for new types of land-cover change such as the solar farm. Solar energy is a renewable energy source that is expected to increase in importance in the near future. Because solar farms require considerable land, it is necessary to understand the design of solar farms and their potential effect on erosion rates and storm runoff, especially the impact on offsite properties and receiving streams. These farms can vary in size from 8 ha (20 acres) in residential areas to 250 ha (600 acres) in areas where land is abundant.

The solar panels are impervious to rain water; however, they are mounted on metal rods and placed over pervious land. In some cases, the area below the panel is paved or covered with gravel. Service roads are generally located between rows of panels. Although some panels are stationary, others are designed to move so that the angle of the panel varies with the angle of the sun. The angle can range, depending on the latitude, from 22° during the summer months to 74° during the winter months. In addition, the angle and direction can also change throughout the day. The issue posed is whether or not these rows of impervious panels will change the runoff characteristics of the site, specifically increase runoff volumes or peak discharge rates. If the increases are hydrologically significant, storm-water management facilities may be needed. Additionally, it is possible that the velocity of water draining from the edge of the panels is sufficient to cause erosion of the soil below the panels, especially where the maintenance roadways are bare ground.

The outcome of this study provides guidance for assessing the hydrologic effects of solar farms, which is important to those who plan, design, and install arrays of solar panels. Those who design solar farms may need to provide for storm-water management. This study investigated the hydrologic effects of solar farms, assessed whether or not storm-water management might be needed, and if the velocity of the runoff from the panels could be sufficient to cause erosion of the soil below the panels.

Model Development

Solar farms are generally designed to maximize the amount of energy produced per unit of land area, while still allowing space for maintenance. The hydrologic response of solar farms is not usually considered in design. Typically, the panels will be arrayed in long rows with separations between the rows to allow for maintenance vehicles. To model a typical layout, a unit width of one panel was assumed, with the length of the downgradient strip depending on the size of the farm. For example, a solar farm with 30 rows of 200 panels each could be modeled as a strip of 30 panels with space between the panels for maintenance vehicles. Rainwater that drains from the upper panel onto the ground will flow over the land under the 29 panels on the downgradient strip. Depending on the land cover, infiltration losses would be expected as the runoff flows to the bottom of the slope.

To determine the effects that the solar panels have on runoff characteristics, a model of a solar farm was developed. Runoff in the form of sheet flow without the addition of the solar panels served as the prepaneled condition. The paneled condition assumed a downgradient series of cells with one solar panel per ground cell. Each cell was separated into three sections: wet, dry, and spacer.

The dry section is that portion directly underneath the solar panel, unexposed directly to the rainfall. As the angle of the panel from the horizontal increases, more of the rain will fall directly onto

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the ground; this section of the cell is referred to as the wet section. The spacer section is the area between the rows of panels used by maintenance vehicles. Fig. 1 is an image of two solar panels and the spacer section allotted for maintenance vehicles. Fig. 2 is a schematic of the wet, dry, and spacer sections with their respective dimensions. In Fig. 1, tracks from the vehicles are visible on what is modeled within as the spacer section. When the solar panel is horizontal, then the length longitudinal to the direction that runoff will occur is the length of the dry and wet sections combined. Runoff from a dry section drains onto the downgradient spacer section. Runoff from the spacer section flows to the wet section of the next downgradient cell. Water that drains from a solar panel falls directly onto the spacer section of that cell.

The length of the spacer section is constant. During a storm event, the loss rate was assumed constant for the 24-h storm because a wet antecedent condition was assumed. The lengths of the wet and dry sections changed depending on the angle of the solar panel. The total length of the wet and dry sections was set equal to the length of one horizontal solar panel, which was assumed to be 3.5 m. When a solar panel is horizontal, the dry section length would equal 3.5 m and the wet section length would be zero. In the paneled condition, the dry section does not receive direct rainfall because the rain first falls onto the solar panel then drains onto the spacer section. However, the dry section does infiltrate some of the runoff that comes from the upgradient wet section. The wet section was modeled similar to the spacer section with rain falling directly onto the section and assuming a constant loss rate.

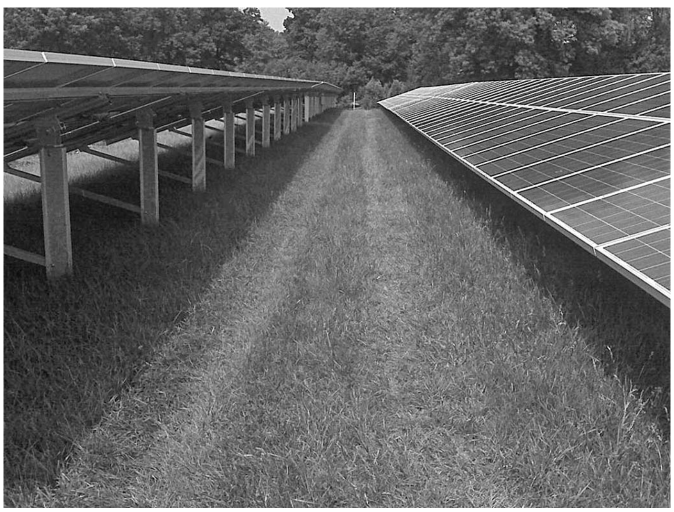

Fig. 1. Maintenance or "spacer" section between two rows of solar panels (photo by John E. Showler, reprinted with permission)

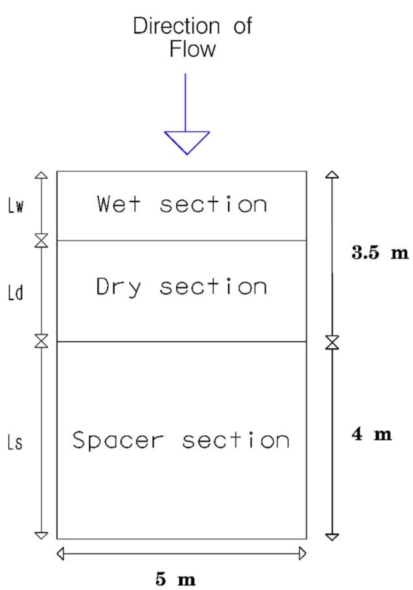

Fig. 2. Wet, dry, and spacer sections of a single cell with lengths *Lw*, *Ls*, and *Ld* with the solar panel covering the dry section

For the presolar panel condition, the spacer and wet sections are modeled the same as in the paneled condition; however, the cell does not include a dry section. In the prepaneled condition, rain falls directly onto the entire cell. When modeling the prepaneled condition, all cells receive rainfall at the same rate and are subject to losses. All other conditions were assumed to remain the same such that the prepaneled and paneled conditions can be compared.

Rainfall was modeled after an natural resources conservation service (NRCS) Type II Storm (McCuen 2005) because it is an accurate representation of actual storms of varying characteristics that are imbedded in intensity-duration-frequency (IDF) curves. For each duration of interest, a dimensionless hyetograph was developed using a time increment of 12 s over the duration of the storm (see Fig. 3). The depth of rainfall that corresponds to each storm magnitude was then multiplied by the dimensionless hyetograph. For a 2-h storm duration, depths of 40.6, 76.2, and 101.6 mm were used for the 2-, 25-, and 100-year events. The 2- and 6-h duration hyetographs were developed using the center portion of the 24-h storm, with the rainfall depths established with the Baltimore IDF curve. The corresponding depths for a 6-h duration were 53.3, 106.7, and 132.1 mm, respectively. These magnitudes were chosen to give a range of storm conditions.

During each time increment, the depth of rain is multiplied by the cell area to determine the volume of rain added to each section of each cell. This volume becomes the storage in each cell. Depending on the soil group, a constant volume of losses was subtracted from the storage. The runoff velocity from a solar panel was calculated using Manning's equation, with the hydraulic radius for sheet flow assumed to equal the depth of the storage on the panel (Bedient and Huber 2002). Similar assumptions were made to compute the velocities in each section of the surface sections.

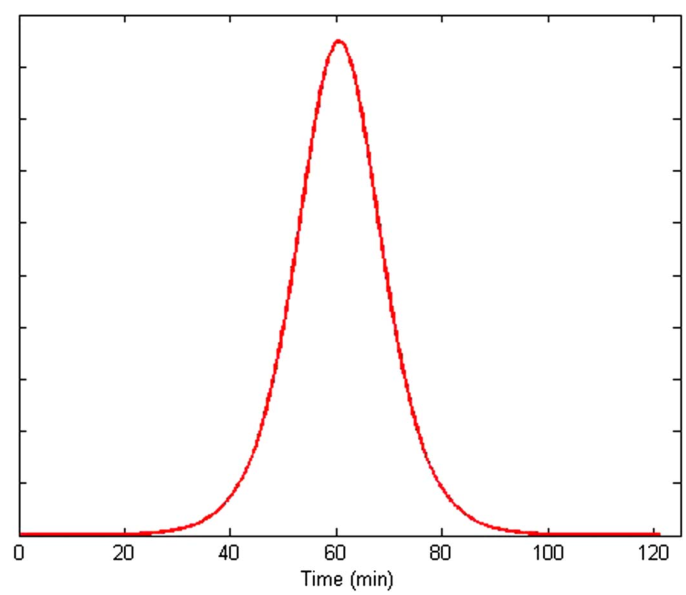

Fig. 3. Dimensionless hyetograph of 2-h Type II storm

Runoff from one section to the next and then to the next downgradient cell was routed using the continuity of mass. The routing coefficient depended on the depth of flow in storage and the velocity of runoff. Flow was routed from the wet section to the dry section to the spacer section, with flow from the spacer section draining to the wet section of the next cell. Flow from the most downgradient cell was assumed to be the outflow. Discharge rates and volumes from the most downgradient cell were used for comparisons between the prepaneled and paneled conditions.

Alternative Model Scenarios

To assess the effects of the different variables, a section of 30 cells, each with a solar panel, was assumed for the base model. Each cell was separated individually into wet, dry, and spacer sections. The area had a total ground length of 225 m with a ground slope of 1% and width of 5 m, which was the width of an average solar panel. The roughness coefficient (Engman 1986) for the silicon solar panel was assumed to be that of glass, 0.01. Roughness coefficients of 0.15 for grass and 0.02 for bare ground were also assumed. Loss rates of 0.5715 cm/h (0.225 in./h) and 0.254 cm/h (0.1 in./h) for B and C soils, respectively, were assumed.

The prepaneled condition using the 2-h, 25-year rainfall was assumed for the base condition, with each cell assumed to have a good grass cover condition. All other analyses were made assuming a paneled condition. For most scenarios, the runoff volumes and peak discharge rates from the paneled model were not significantly greater than those for the prepaneled condition. Over a total length of 225 m with 30 solar panels, the runoff increased by 0.26 m^3, which was a difference of only 0.35%. The slight increase in runoff volume reflects the slightly higher velocities for the paneled condition. The peak discharge increased by 0.0013 m^3, a change of only 0.31%. The time to peak was delayed by one time increment, i.e., 12 s. Inclusion of the panels did not have a significant hydrologic impact.

Storm Magnitude

The effect of storm magnitude was investigated by changing the magnitude from a 25-year storm to a 2-year storm. For the 2-year storm, the rainfall and runoff volumes decreased by approximately 50%. However, the runoff from the paneled watershed condition increased compared to the prepaneled condition by approximately the same volume as for the 25-year analysis, 0.26 m^3. This increase represents only a 0.78% increase in volume. The peak discharge and the time to peak did not change significantly. These results reflect runoff from a good grass cover condition and indicated that the general conclusion of very minimal impacts was the same for different storm magnitudes.

Ground Slope

The effect of the downgradient ground slope of the solar farm was also examined. The angle of the solar panels would influence the velocity of flows from the panels. As the ground slope was increased, the velocity of flow over the ground surface would be closer to that on the panels. This could cause an overall increase in discharge rates. The ground slope was changed from 1 to 5%, with all other conditions remaining the same as the base conditions.

With the steeper incline, the volume of losses decreased from that for the 1% slope, which is to be expected because the faster velocity of the runoff would provide less opportunity for infiltration. However, between the prepaneled and paneled conditions, the increase in runoff volume was less than 1%. The peak discharge and the time to peak did not change. Therefore, the greater ground slope did not significantly influence the response of the solar farm.

Soil Type

The effect of soil type on the runoff was also examined. The soil group was changed from B soil to C soil by varying the loss rate. As expected, owing to the higher loss rate for the C soil, the depths of runoff increased by approximately 7.5% with the C soil when compared with the volume for B soils. However, the runoff volume for the C soil condition only increased by 0.17% from the prepaneled condition to the paneled condition. In comparison with the B soil, a difference of 0.35% in volume resulted between the two conditions. Therefore, the soil group influenced the actual volumes and rates, but not the relative effect of the paneled condition when compared to the prepaneled condition.

Panel Angle

Because runoff velocities increase with slope, the effect of the angle of the solar panel on the hydrologic response was examined. Analyses were made for angles of 30° and 70° to test an average range from winter to summer. The hydrologic response for these angles was compared to that of the base condition angle of 45°. The other site conditions remained the same. The analyses showed that the angle of the panel had only a slight effect on runoff volumes and discharge rates. The lower angle of 30° was associated with an increased runoff volume, whereas the runoff volume decreased for the steeper angle of 70° when compared with the base condition of 45°. However, the differences (~0.5%) were very slight. Nevertheless, these results indicate that, when the solar panel was closer to horizontal, i.e., at a lower angle, a larger difference in runoff volume occurred between the prepaneled and paneled conditions. These differences in the response result are from differences in loss rates.

The peak discharge was also lower at the lower angle. At an angle of 30°, the peak discharge was slightly lower than at the higher angle of 70°. For the 2-h storm duration, the time to peak of the 30° angle was 2 min delayed from the time to peak of when the panel was positioned at a 70° angle, which reflects the longer travel times across the solar panels.

Storm Duration

To assess the effect of storm duration, analyses were made for 6-h storms, testing magnitudes for 2-, 25-, and 100-year return periods, with the results compared with those for the 2-h rainfall events. The longer storm duration was tested to determine whether a longer duration storm would produce a different ratio of increase in runoff between the prepaneled and paneled conditions. When compared to runoff volumes from the 2-h storm, those for the 6-h storm were 34% greater in both the paneled and prepaneled cases. However, when comparing the prepaneled to the paneled condition, the increase in the runoff volume with the 6-h storm was less than 1% regardless of the return period. The peak discharge and the time-to-peak did not differ significantly between the two conditions. The trends in the hydrologic response of the solar farm did not vary with storm duration.

Ground Cover

The ground cover under the panels was assumed to be a native grass that received little maintenance. For some solar farms, the area beneath the panel is covered in gravel or partially paved because the panels prevent the grass from receiving sunlight. Depending on the

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volume of traffic, the spacer cell could be grass, patches of grass, or bare ground. Thus, it was necessary to determine whether or not these alternative ground-cover conditions would affect the runoff characteristics. This was accomplished by changing the Manning's *n* for the ground beneath the panels. The value of *n* under the panels, i.e., the dry section, was set to 0.015 for gravel, with the value for the spacer or maintenance section set to 0.02, i.e., bare ground. These can be compared to the base condition of a native grass ($n = 0.15$). A good cover should promote losses and delay the runoff.

For the smoother surfaces, the velocity of the runoff increased and the losses decreased, which resulted in increasing runoff volumes. This occurred both when the ground cover under the panels was changed to gravel and when the cover in the spacer section was changed to bare ground. Owing to the higher velocities of the flow, runoff rates from the cells increased significantly such that it was necessary to reduce the computational time increment. Fig. 4(a) shows the hydrograph from a 30-panel area with a time increment of 12 s. With a time increment of 12 s, the water in each cell is discharged at the end of every time increment, which results in no attenuation of the flow; thus, the undulations shown in Fig. 4(a) result. The time increment was reduced to 3 s for the 2-h storm, which resulted in watershed smoothing and a rational hydrograph shape [Fig. 4(b)]. The results showed that the storm runoff increased by 7% from the grass-covered scenario to the scenario with gravel under the panel. The peak discharge increased by 73% for the gravel ground cover when compared with the grass cover without the panels. The time to peak was 10 min less with the gravel than with the grass, which reflects the effect of differences in surface roughness and the resulting velocities.

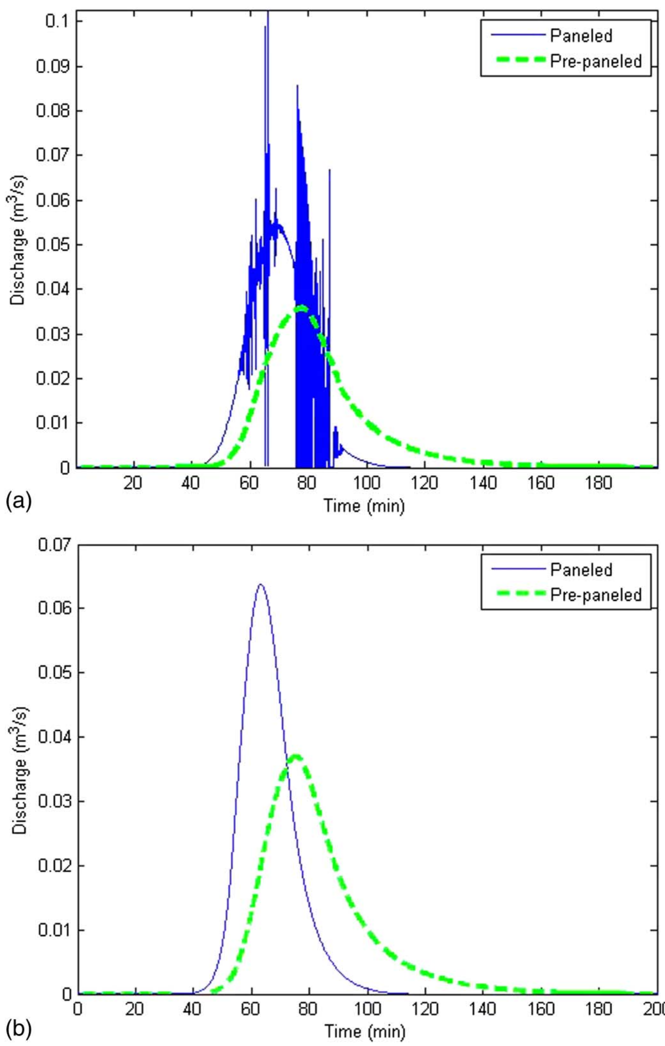

Fig. 4. Hydrograph with time increment of (a) 12 s; (b) 3 s with Manning's *n* for bare ground

If maintenance vehicles used the spacer section regularly and the grass cover was not adequately maintained, the soil in the spacer section would be compacted and potentially the runoff volumes and rates would increase. Grass that is not maintained has the potential to become patchy and turn to bare ground. The grass under the panel may not get enough sunlight and die. Fig. 1 shows the result of the maintenance trucks frequently driving in the spacer section, which diminished the grass cover.

The effect of the lack of solar farm maintenance on runoff characteristics was modeled by changing the Manning's *n* to a value of 0.02 for bare ground. In this scenario, the roughness coefficient for the ground under the panels, i.e., the dry section, as well as in the spacer cell was changed from grass covered to bare ground ($n = 0.02$).The effects were nearly identical to that of the gravel. The runoff volume increased by 7% from the grass-covered to the bare-ground condition. The peak discharge increased by 72% when compared with the grass-covered condition. The runoff for the bare-ground condition also resulted in an earlier time to peak by approximately 10 min. Two other conditions were also modeled, showing similar results. In the first scenario, gravel was placed directly under the panel, and healthy grass was placed in the spacer section, which mimics a possible design decision. Under these conditions, the peak discharge increased by 42%, and the volume of runoff increased by 4%, which suggests that storm-water management would be necessary if gravel is placed anywhere.

Fig. 5 shows two solar panels from a solar farm in New Jersey. The bare ground between the panels can cause increased runoff rates and reductions in time of concentration, both of which could necessitate storm-water management. The final condition modeled involved the assumption of healthy grass beneath the panels and bare ground in the spacer section, which would simulate the condition of unmaintained grass resulting from vehicles that drive over the spacer section. Because the spacer section is 53% of the cell, the change in land cover to bare ground would reduce losses and decrease runoff travel times, which would cause runoff to amass as it

Fig. 5. Site showing the initiation of bare ground below the panels, which increases the potential for erosion (photo by John Showler, reprinted with permission)

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moves downgradient. With the spacer section as bare ground, the peak discharge increased by 100%, which reflected the increases in volume and decrease in timing. These results illustrate the need for maintenance of the grass below and between the panels.

Design Suggestions

With well-maintained grass underneath the panels, the solar panels themselves do not have much effect on total volumes of the runoff or peak discharge rates. Although the panels are impervious, the rainwater that drains from the panels appears as runoff over the downgradient cells. Some of the runoff infiltrates. If the grass cover of a solar farm is not maintained, it can deteriorate either because of a lack of sunlight or maintenance vehicle traffic. In this case, the runoff characteristics can change significantly with both runoff rates and volumes increasing by significant amounts. In addition, if gravel or pavement is placed underneath the panels, this can also contribute to a significant increase in the hydrologic response.

If bare ground is foreseen to be a problem or gravel is to be placed under the panels to prevent erosion, it is necessary to counteract the excess runoff using some form of storm-water management. A simple practice that can be implemented is a buffer strip (Dabney et al. 2006) at the downgradient end of the solar farm. The buffer strip length must be sufficient to return the runoff characteristics with the panels to those of runoff experienced before the gravel and panels were installed. Alternatively, a detention basin can be installed.

A buffer strip was modeled along with the panels. For approximately every 200 m of panels, or 29 cells, the buffer must be 5 cells long (or 35 m) to reduce the runoff volume to that which occurred before the panels were added. Even if a gravel base is not placed under the panels, the inclusion of a buffer strip may be a good practice when grass maintenance is not a top funding priority. Fig. 6 shows the peak discharge from the graveled surface versus the length of the buffer needed to keep the discharge to prepaneled peak rate.

Water draining from a solar panel can increase the potential for erosion of the spacer section. If the spacer section is bare ground, the high kinetic energy of water draining from the panel can cause soil detachment and transport (Garde and Raju 1977; Beuselinck et al. 2002). The amount and risk of erosion was modeled using the velocity of water coming off a solar panel compared with the velocity and intensity of the rainwater. The velocity of panel

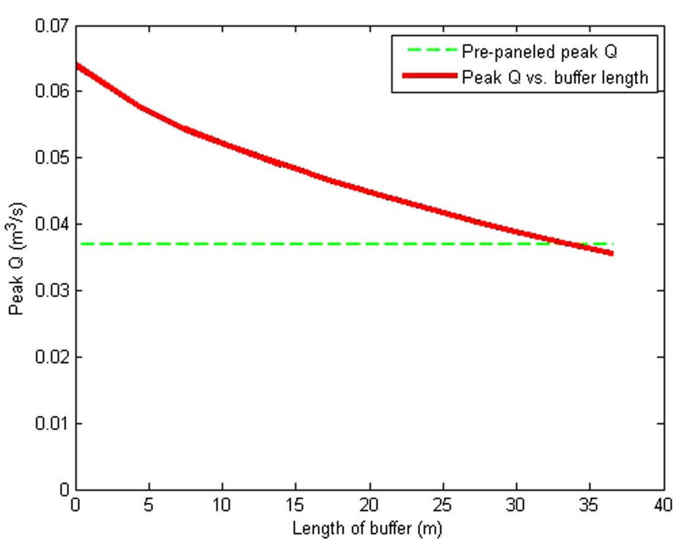

Fig. 6. Peak discharge over gravel compared with buffer length

runoff was calculated using Manning's equation, and the velocity of falling rainwater was calculated using the following:

$$V_t = 120\, d_r^{0.35} \quad (1)$$

where d_r = diameter of a raindrop, assumed to be 1 mm. The relationship between kinetic energy and rainfall intensity is

$$K_e = 916 + 330 \log_{10} i \quad (2)$$

where i = rainfall intensity (in./h) and K_e = kinetic energy (ft-tons per ac-in. of rain) of rain falling onto the wet section and the panel, as well as the water flowing off of the end of the panel (Wischmeier and Smith 1978). The kinetic energy (Salles et al. 2002) of the rainfall was greater than that coming off the panel, but the area under the panel (i.e., the product of the length, width, and cosine of the panel angle) is greater than the area under the edge of the panel where the water drains from the panel onto the ground. Thus, dividing the kinetic energy by the respective areas gives a more accurate representation of the kinetic energy experienced by the soil. The energy of the water draining from the panel onto the ground can be nearly 10 times greater than the rain itself falling onto the ground area. If the solar panel runoff falls onto an unsealed soil, considerable detachment can result (Motha et al. 2004). Thus, because of the increased kinetic energy, it is possible that the soil is much more prone to erosion with the panels than without. Where panels are installed, methods of erosion control should be included in the design.

Conclusions

Solar farms are the energy generators of the future; thus, it is important to determine the environmental and hydrologic effects of these farms, both existing and proposed. A model was created to simulate storm-water runoff over a land surface without panels and then with solar panels added. Various sensitivity analyses were conducted including changing the storm duration and volume, soil type, ground slope, panel angle, and ground cover to determine the effect that each of these factors would have on the volumes and peak discharge rates of the runoff.

The addition of solar panels over a grassy field does not have much of an effect on the volume of runoff, the peak discharge, nor the time to peak. With each analysis, the runoff volume increased slightly but not enough to require storm-water management facilities. However, when the land-cover type was changed under the panels, the hydrologic response changed significantly. When gravel or pavement was placed under the panels, with the spacer section left as patchy grass or bare ground, the volume of the runoff increased significantly and the peak discharge increased by approximately 100%. This was also the result when the entire cell was assumed to be bare ground.

The potential for erosion of the soil at the base of the solar panels was also studied. It was determined that the kinetic energy of the water draining from the solar panel could be as much as 10 times greater than that of rainfall. Thus, because the energy of the water draining from the panels is much higher, it is very possible that soil below the base of the solar panel could erode owing to the concentrated flow of water off the panel, especially if there is bare ground in the spacer section of the cell. If necessary, erosion control methods should be used.

Bare ground beneath the panels and in the spacer section is a realistic possibility (see Figs. 1 and 5). Thus, a good, well-maintained grass cover beneath the panels and in the spacer section is highly recommended. If gravel, pavement, or bare ground is

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deemed unavoidable below the panels or in the spacer section, it may necessary to add a buffer section to control the excess runoff volume and ensure adequate losses. If these simple measures are taken, solar farms will not have an adverse hydrologic impact from excess runoff or contribute eroded soil particles to receiving streams and waterways.

Acknowledgments

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Exhibit 10 – MPCA Solar Panel Calculations

This spreadsheet makes calculations for an individual solar panel.

Enter values in blue cells

Soil	D		select from dropdown; determine soil on site
I/P ratio	0.299		calculated
Term	**Value**	**Units**	
Pervious area	97.09	square feet	user entered; determine on site
Impervious area (area of solar panel)	29.07	square feet	user entered; determine on site
Runoff depth from pervious areas	7.20	inches	default = 4.4 for A soil, 5.7 for B, 6.1 for C, 7.2 for D
Redirected runoff depth from solar panel (called average annual runoff depth)	8.20	inches	determine from plot called ***Average annual runoff depth***
Runoff depth from solar panel	22.50	inches	default = 22.5 inches
Performance goal	1.00	inches	
SUMMARY			
Pre-disconnection			
Runoff from impervious	55	ft3	calculated
Runoff from pervious	58	ft3	calculated
Total runoff	113	ft3	calculated
Post-disconnection			
Total runoff	86	ft3	calculated
Total runoff reduced	27	ft3	calculated
Runoff from pervious	58	ft3	calculated
Runoff from impervious	28	ft3	calculated
Adjusted impervious	14.910	square feet	calculated
Performance Goal Summary			
Performance goal	**2.42**	ft3	calculated
BMP volume credit ($BMP_{volume\ credit}$)	**1.18**	ft3	calculated
% of performance goal achieved	**48.7**	%	calculated
Remaining water quality volume to be treated (per panel)	**1.24**	ft3	calculated

Pervious area = (Y + Z) * W; where W is the width of the solar panel and Z is the average horizontal distance of the panel

Impervious area = Z * W; where W is the width of the solar panel and Z is the average horizontal distance of the panel

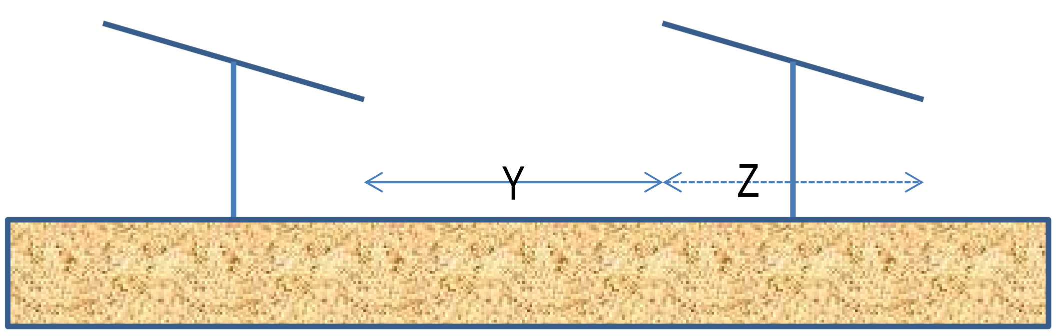

Exhibit 11 – MPCA Impervious Storage Calculations

Anamite MPCA Storage Requirements (DA-01)

Impervious Areas as defined by Minnesota Pollution Control Agency:

	Water Quality - Total		Water Quality - DA-01	
Total drainage area	**8.04**	**ac**	**8.0385**	**ac**
Inverter Area	**0.00**	sf	-	sf
Stormwater Pond	1,432.94	Type D Soil	1,432.94	Type D Soil
Subtotal	*1,432.94*	*sf*	*1,432.94*	*sf*
# of Panels	2,889.00	#	2889	
WQV/panel (based on Solar Panel Calc. Sprdsht.)	1.24	*cf*	1.24	*cf*
Required Volume:				
1.0" over new impervious areas	119.41	cf	119.41	cf
Panel impervious areas	3,582.36	cf	3,582.36	cf
Water Quality Volume Required (CF)	**3,701.77**	**cf**	**3,701.77**	**cf**
Water Quality Volume Required (AC-FT)	**0.085**	**ac-ft**	**0.085**	**ac-ft**

Anamite MPCA Storage Requirements (DA-02)

Impervious Areas as defined by Minnesota Pollution Control Agency:

	Water Quality - Total		Water Quality - DA-02	
Total drainage area	**13.24**	**ac**	**13.2443**	**ac**
Inverter Area	**1588.15**	sf	1,588.15	sf
Stormwater Pond	1,980.18	Type D Soil	1,980.18	Type D Soil
Subtotal	*3,568.33*	*sf*	*3,568.33*	*sf*
# of Panels	3,886.00	#	3886	
WQV/panel (based on Solar Panel Calc. Sprdsht.)	1.24	*cf*	1.24	*cf*
Required Volume:				
1.0" over new impervious areas	297.36	cf	297.36	cf
Panel impervious areas	4,818.64	cf	4,818.64	cf
Water Quality Volume Required (CF)	**5,116.00**	**cf**	**5,116.00**	**cf**
Water Quality Volume Required (AC-FT)	**0.117**	**ac-ft**	**0.117**	**ac-ft**