Westwood

Final Drainage Report

Grazing Yak Solar

El Paso County, Colorado

April 2019

Prepared For:

Mortenson construction

Westwood

Final Drainage Report for

Grazing Yak Solar

Include signature Sheet, Page 2. See conceptual Core Consultants report, for an example.

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Date: 4/24/2019

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APPENDICES

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- Percent Impervious Calculations
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- CulvertMaster

The drainage plan needs to be at the end of the report.
Include an Existing conditions drainage plan.

I. GENERAL LOCATION AND DESCRIPTION

A. Site Location

This Final Drainage Report has been prepared on behalf of Grazing Yak Solar, LLC for the development of the proposed Grazing Yak Solar Project, referred to as “The Project”. The Project would consist of a 35 megawatt (MW) utility scale photovoltaic solar facility and underground collection line that would encompass approximately 317 acres in El Paso County (EPC), Colorado. The solar array site, referred to as “The Site”, is located to the east of the intersection of McQueen Road and Washington Road, approximately 4 miles southeast of the Town of Calhan on private, agricultural land. Rural residences and agricultural land surround the Site, as well as the Golden West Wind Energy Center located to the north, west, and south. The Site is located on 272-acres in Section 29, Township 12 South, Range 61 West of the 6th Principal Meridian, El Paso County, Colorado. A vicinity map for the site can be found in Appendix A.

B. Description of Property

The Site is flat to gently rolling, at elevations ranging from approximately 6,830 to 6,735 feet. The site has naturally occurring slopes ranging from 2 to 10 percent and is currently agricultural land. Surface runoff is to the north, south and east. Runoff from the northern portion of the site flows north overland through multiple conveyances. These flows continue north under Washington through a culvert and eventually into Horse Creek. Flows from the central portion of the site flow toward the drainage that bisects the site. Runoff travels east of the project through an unnamed drainage and eventually into Horse Creek. Flows from the southeast portion of the site flow southeast into an unnamed drainage and eventually into Horse Creek. The proposed improvements to the site consist of a 35 megawatt (MW) photovoltaic solar array, inverters, dirt and gravel access paths, and other necessary ancillary features. The soils vary throughout the site and include mainly Trackton sandy loam, (Hydrologic soil group A), Truckton-Bresser complex (Hydrologic soil group A), Bresser sandy loam (Hydrologic soil group B) and Ascalon sandy loam (Hydrologic soil group B). A soils map has been provided and can be found in Appendix A.

II. DRAINAGE BASINS AND SUB-BASINS

A. Major Drainage Basins

The existing drainage patterns for the major basin will follow the historic patterns. Grazing Yak will drain north, east and south through drainage ways and culverts and eventually discharging into Horse Creek. Horse Creek flows to the east and is part of the Arkansas River basin. The site falls within Zone X, as shown on the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (FIRM) panels 08041C0650 F and 0841C0625 F. A copy of the FIRM maps can be found in Appendix A.

Add: The Horse Creek drainage basin in El Paso County is unstudied, with no fees.

B. Minor Drainage Basins

Minor Drainage Basins for Grazing Yak Solar Project have been delineated per the layout of the solar arrays. The developed minor basins will include pole mounted solar arrays with native ground beneath and dirt and gravel access roads constructed of 12” re-compacted soil and Class 5 Gravel respectively. An Extended Detention Basin for the site will be designed to mitigate the increase in runoff. The EDB will be privately owned and maintained. Overall, the proposed drainage patterns for the sub-basins will follow the historic patterns prior to development. For sub-basins within the site, runoff will drain to the north, south and east.

Basin (A1) consists of dirt access paths, a portion of the solar array and offsite undeveloped land. Runoff generated in this basin will flow northeast toward the western property line of the project site. The runoff flows northeast, into the unnamed drainage bisecting the site. This runoff is conveyed through the site and eventually into Horse Creek. The improvements have negligible impact on runoff rates.

Basin (A2) consists of dirt access paths, a portion of the solar array and offsite

Undeveloped land. Runoff generated in this basin will flow northeast toward the southern property line of the project site. The runoff flows east and northeast, into the unnamed drainage bisecting the site. This runoff is conveyed through the site and eventually into Horse Creek. The improvements have negligible impact on runoff rates.

Basin (A3) consists of dirt access paths, a portion of the solar array and offsite undeveloped land. Runoff generated in this basin will flow north and east toward and existing stock pond located in the unnamed drainage within the project site. The runoff exits the stock pond into the unnamed drainage bisecting the site and travels northeast. This runoff leaves the site at the eastern boundary and eventually into Horse Creek. The improvements have negligible impact on runoff rates.

Basin (A4) consists of gravel access paths, dirt access paths, and a portion of the solar array. Runoff generated in this basin will flow north and south into the unnamed drainage and an extended detention basin (EDB) respectively within the project site. The EDB will be sized to provide a 10% reduction in predevelopment flows generated by the increase in imperviousness for the total site. Runoff is discharged from the EDB into the unnamed drainage and conveyed to the eastern property line. This runoff leaves the site at the eastern boundary and eventually into Horse Creek as described below in Section III. As shown in the rational spreadsheet, without the basin in place, this results in an increase of 1.4cfs. However the addition of the detention facility reduces this discharge by greater than 2.1cfs, which is the total increase from the site when including both basins A4 and D1. Utilizing HydroCAD modeling, the combination of culverts will restrict peak flows to 27cfs (see UD-Detention Worksheet), a decrease of 8cfs from the 35cfs existing condition, which is greater than the 2.1cfs reduction needed to maintain existing runoff rates (1.4cfs increase in basin A4 and 0.7cfs increase in basin D1).

Basin (B1) consists of dirt access paths and a portion of the solar array. Runoff generated in this basin will flow to the south east and eventually into Horse Creek. Flowrates or flow patterns within this basin will not be affected by this development. The improvements have negligible impact on runoff rates.

Basin (B2) consists of dirt access paths and a portion of the solar array. Runoff generated in this basin will flow to the south east and eventually into Horse Creek. Flowrates or flow patterns within this basin will not be affected by this development. The improvements have negligible impact on runoff rates.

Basin (C1) consists of dirt access paths and a portion of the solar array. Runoff generated in this basin flows will travel north through multiple conveyances towards the northern property line, under Washington road through a culvert and eventually into Horse Creek. Flowrates or flow patterns within this basin will not be affected by this development. The improvements have negligible impact on runoff rates.

Basin (D1) consists of gravel access paths, a portion of the solar array and undeveloped land. The increase in imperviousness is being mitigated in the EDB located in basing A4. Runoff generated in this basin flows will travel north along the proposed site access road towards Washington Rd. Flows are conveyed under Washington road through a culvert and eventually into Horse Creek. Though this area is included in the EDB sizing, the improvements increase runoff by 0.7cfs, which is mitigated in basin A4.

III. DRAINAGE DESIGN CRITERIA

A. Regulations

This Conceptual Drainage Report is in accordance with El Paso County Drainage Criteria Manual and the Urban Drainage and Flood Control District (UDFCD) Storm Drainage Criteria Manual. These manuals were used as a basis of design for the site. All applicable tables, figures, and charts from the referenced reports and criteria manuals used in the drainage design of the site can be found in Appendix B. The report will analyze the minor (5-year) and major (100-year) storm events.

B. Drainage Studies, Master Plans, and Site Constraints

A previous drainage study (Conceptual Drainage Report for Grazing Yak Solar Project) was completed for the project on October 23, 2018 and revised on January 16, 2019. There are no master plans or site constraints for this development.

C. Hydrology

All the basins within the site were less than 160 acres thus the Rational Method was used to determine the flow rates for various basins within the site. The sub-basins were delineated based on the existing topography for the project. Flow rates for each basin can be found in Appendix A. The impervious panels are going to be pole mounted with the ground underneath them to remain vegetated. The main access from Washington Road to just south of the unnamed drainage will be constructed with Class 5 Gravel. The remaining site access paths will be constructed as recompacted dirt to promote infiltration back into the ground. The intensity-frequency curves used in the Rational Method calculations were taken from the El Paso County Drainage Criteria Manual. All drainage facilities were analyzed and designed for both the minor (5-year) and major (100-year) storm events. Time of concentration calculations were used to determine the rainfall intensity. These calculations also can be found in Appendix A. There are three different locations of where offsite water will flow onto the project boundary. All three of these locations will continue to follow existing drainage patterns and will be allowed onsite.

D. Hydraulics

Hydraulic calculations for the EDB sizing were based on UDFCD design spreadsheets. Street and inlet capacity will not be necessary for this development. Two access road crossings were required for the project. The calculations for these can be seen in Appendix B.

Include a section "4 step process", list the steps, and use similar language as used

E. Water Quality Enhancement

The Project will require gravel access paths to a small portion of the site for access year-round. The remaining access paths will be constructed of recompacted dirt. The Project will employ runoff reduction practices such as allowing sheet flow across grass buffers and minimizing the increased imperviousness to 2% total for the site post construction. The site consists of Type A & B soils, allowing for optimal infiltration throughout the site. The proposed water quality facility for the site was designed as an EDB which incorporates a structure that release flows for the water quality capture volume (WQCV), Excess Urban Runoff Volume (EURV), and the 100-year storm event. The design of this structure can be found in the Appendix. The EDB is located in an area with a NRCS Type A soil designation. The EDB is located to receive the sheet flow runoff from the basin with the increased imperviousness. The total area of increased imperviousness (approximately 4 acres of 272 acres) will create a minimal impact to the natural drainage way that stabilization beyond protection at the EDB outlet will not be necessary. The natural drainage way will be protected from sediment discharge, introduction of contaminants and other site operations during construction activities in conformance with El Paso County GEC requirements and MS4 permit.

IV. STORMWATER MANAGEMENT FACILITY DESIGN

A. Stormwater Conveyance Facilities

The general concept for the drainage design is to maintain the historic drainage patterns and release rates. This approach reduces the impacts to existing wash and ultimately Horse Creek. No public infrastructure is proposed within this site. Culvert crossings will be added near the outfall of the site to allow for a dry road crossing. A basin will be constructed near this outfall location and will utilize a combination of culverts to provide flow bypass under the road and as a method of metering output from the proposed basin described in more detail below.

B. Stormwater Storage Facilities

Basin A4 EDB pond sizing calculations can be found in the Appendix. The EDB mitigates the increase of runoff generated by the gravel access roads and small electrical equipment pads throughout the site. Runoff generated by the access roads will flow into the EDB through a combination of sheet flow from the south and flows entering from the adjacent channelized bypass to the north. The EDB will have an approximate EURV volume of 1.54 acre-feet and release below historic runoff rates. The EDB will have a two stage discharge due to the relatively small volume being captured from a large site. The 1.54 acre-foot volume will be discharged through a 12" orifice plate with five 1.25" orifices. Flows above this will be discharged through a pair of 18" pipes. Since the UD-Detention spreadsheet does not allow for this configuration, a proxy using a weir and 21" pipe was used to approximate this discharge. Calculations done outside of the sheet have been included below showing a matching 27cfs discharge through a pair of 18" CMP pipes.

At the outlets of the pond riprap of will be placed with a D50 of a minimum of 6" and a minimum depth of 9" in order to reduce erosion from the outlet. The riprap has been sized based on an exit velocity of approximately 5.4 feet per second for the pair of 18" outlets. Flows will be slower at the 12" outlet, but riprap has been kept the same size for ease of construction. Any flows that exceed the capacity of the basin bypass the basin once full through a set of culverts placed approximately 2 feet higher than the basin outfall, allowing for a 2' pool elevation for the basin. This arrangement takes advantage of natural topography in the area where the wash becomes braided and currently exits the site at two locations; the lower braid being used as the water quality pool with the upper braid, sitting at an elevation 2' higher, being utilized as a bypass once the water quality pool is filled. The entire 100 year event can be accepted and released by the basin without overtopping the road and leaving approximately 15-inches of freeboard. In an extreme event larger than this, overtopping of the road could occur. This basin has not been designed for this "Act-of-God" type event and road damage is anticipated in such an event.

The detention pond accepts flows from the north that include a large percentage of the impervious area and are bounded by an existing berm.

C. Water Quality Enhancement Best Management Practices

Water quality measures have been included in the design of the proposed EDBs. The basin will be designed to incorporate a structure that release flows for the water quality capture volume (WQCV) and the 100-year storm event.

D. Floodplain Modification

There will be no modification to the floodplain

E. Additional Permitting Requirements

No additional permitting will be required for this site.

F. General

All applicable tables, figures, and charts from the referenced reports and criteria manuals used in the drainage design of the site can be found in the Appendix. The site is not going to be platted at this time therefore no drainage fees are due.

Provide a Full Spectrum Detention Facility that meets criteria, Look at UDFCD "Sand Filter combined with Full Spectrum detention" Figure 12-9. The outlet structure, detention calculations etc., can then be designed to meet UDFCD details. It appears existing soils here a as indicated by the Terracon study, can be used as the media for the sand filter.

REFERENCES

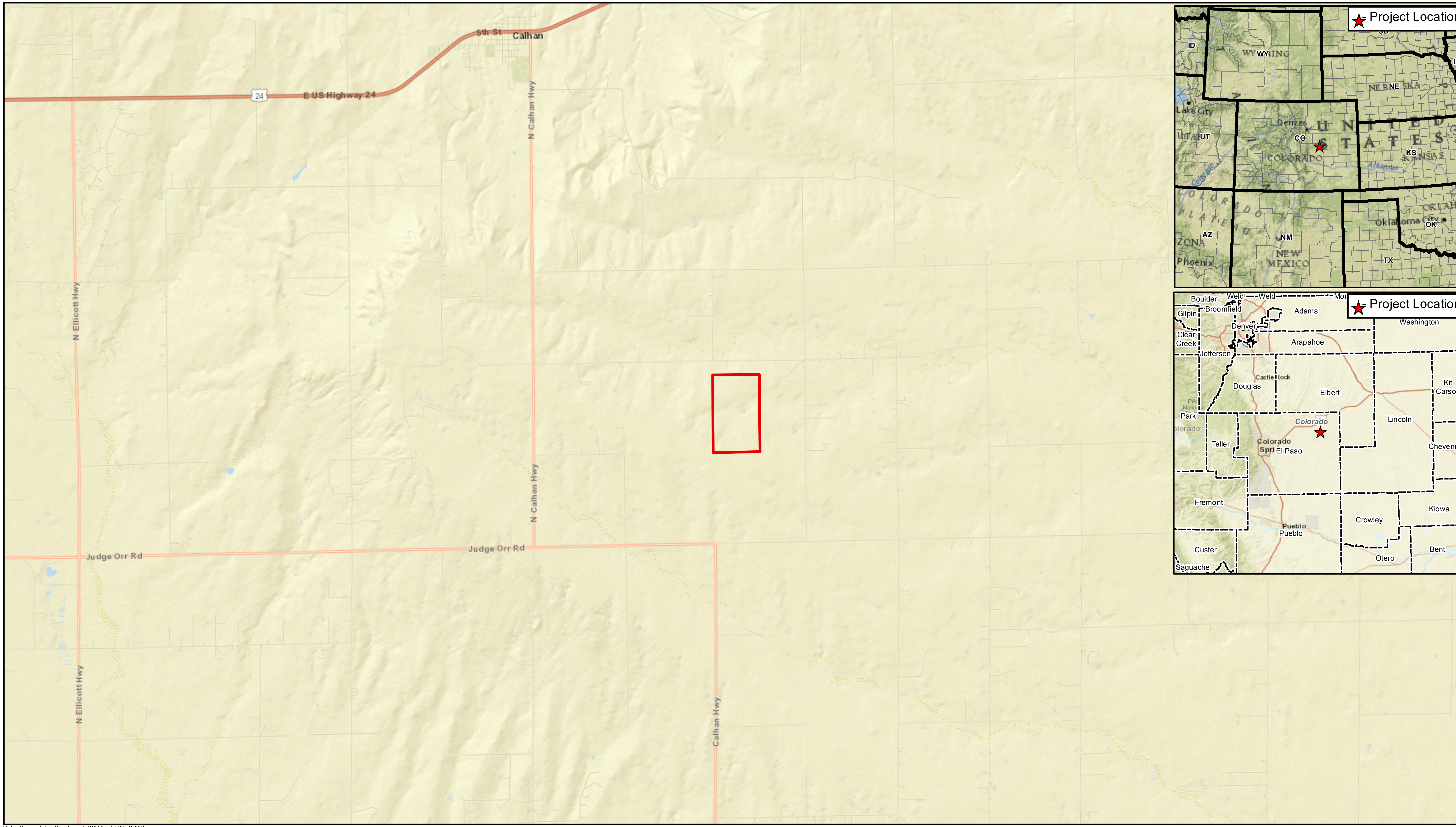
A. El Paso County Drainage Criteria Manual, Volumes 1 and 2.

B. Drainage Criteria Manual, Volumes 1, 2, & 3, Urban Drainage and Flood Control District, June 2001, Revised June 2004. 2017

El Paso County Engineering Criteria Manual.

Appendix A

Hydrologic Calculations



Data Source(s): Westwood (2019); ESRI WMS World Streets Basemap Imagery (Accessed 2019).

Legend

- Project Boundary
- County Boundary

Westwood

Toll Free (888) 937-5150 westwoodps.com

Westwood Professional Services, Inc.

N

0 1 Miles

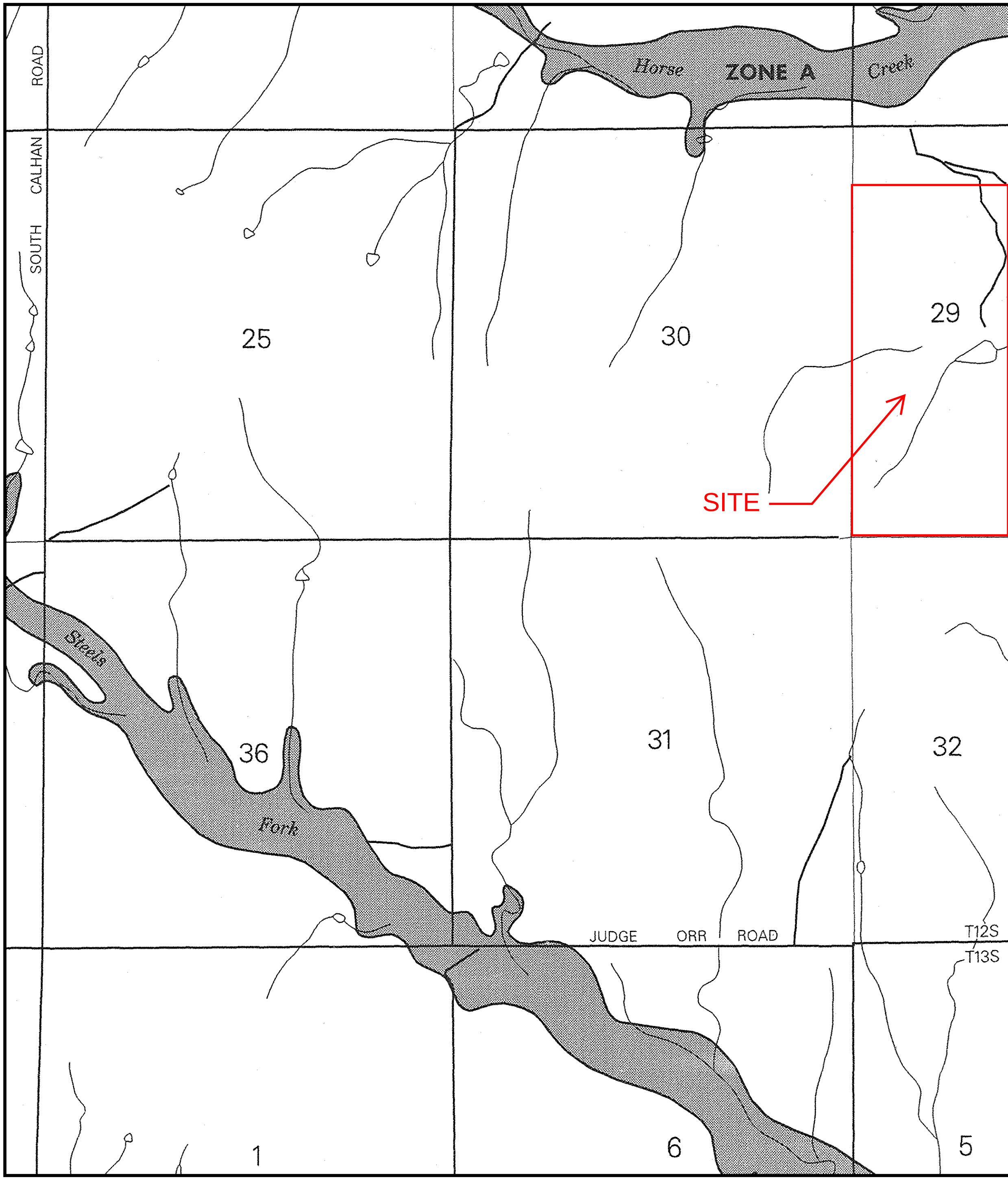
Grazing Yak Solar

El Paso County, Colorado

Exhibit 1: Location Map

March 21, 2019

Map Document: N:\0021201.00\GIS\Hydro Exhibits\2019-03-21_GrazingYak_Ex1_LocationMap.mxd mshildreth 3/21/2019 11:12:35 AM



APPROXIMATE SCALE IN FEET

2000 0 2000

NATIONAL FLOOD INSURANCE PROGRAM

FIRM

FLOOD INSURANCE RATE MAP

EL PASO COUNTY, COLORADO AND INCORPORATED AREAS

PANEL 625 OF 1300

(SEE MAP INDEX FOR PANELS NOT PRINTED)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
EL PASO COUNTY, UNINCORPORATED AREAS	080059	0625	F

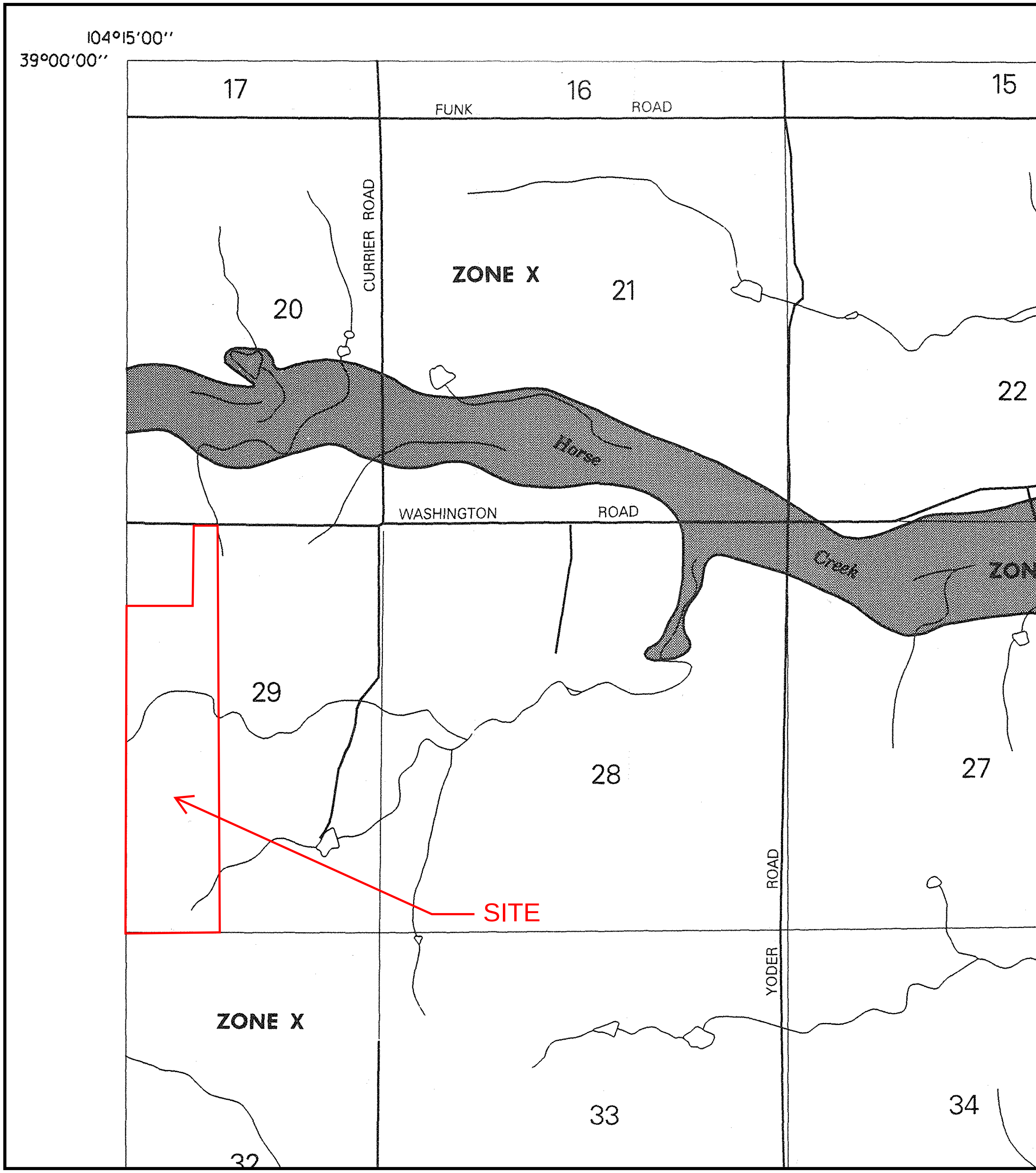
Up date panel to December, 7 2018 FIRM

MAP NUMBER 08041C0625 F

EFFECTIVE DATE: MARCH 17, 1997

Federal Emergency Management Agency

This is an official copy of a portion of the above referenced flood map. It was extracted using F-MIT On-Line. This map does not reflect changes or amendments which may have been made subsequent to the date on the title block. For the latest product information about National Flood Insurance Program flood maps check the FEMA Flood Map Store at www.msc.fema.gov



APPROXIMATE SCALE IN FEET

2000 0 2000

NATIONAL FLOOD INSURANCE PROGRAM

FIRM

FLOOD INSURANCE RATE MAP

EL PASO COUNTY, COLORADO AND INCORPORATED AREAS

PANEL 650 OF 1300

(SEE MAP INDEX FOR PANELS NOT PRINTED)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
EL PASO COUNTY, UNINCORPORATED AREAS	080059	0650	F

Up date panel to December, 7 2018 FIRM

MAP NUMBER
08041C0650 F

EFFECTIVE DATE:
MARCH 17, 1997

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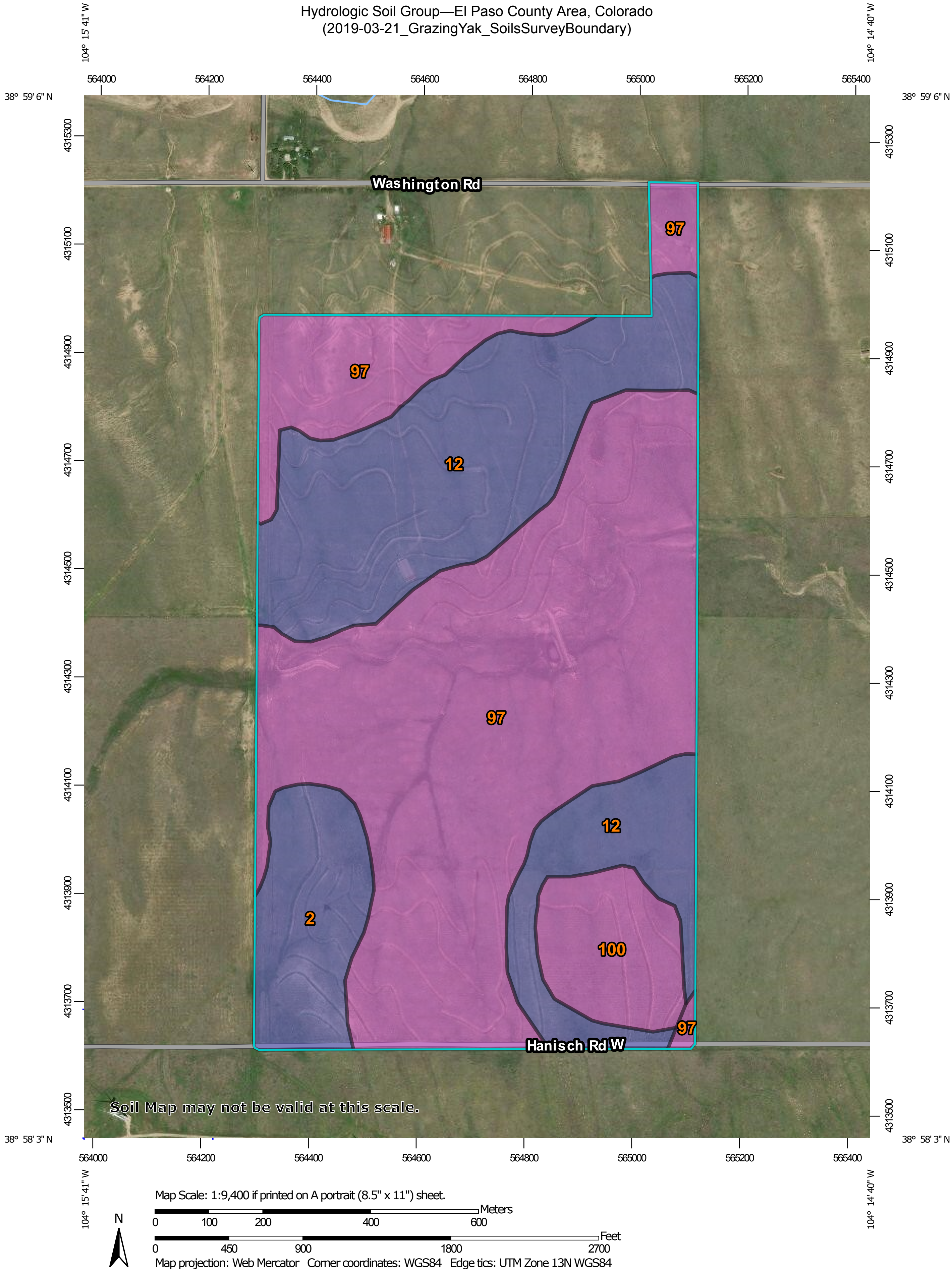
104° 15' 41" W
104° 14' 40" W
564000
564200
564400
564600
564800
565000
565200
565400
38° 59' 6" N
38° 58' 3" N
4315300
4315100
4314900
4314700
4314500
4314300
4314100
4313900
4313700
4313500
Washington Rd
Hanisch Rd W
97
12
97
2
12
100
97
Soil Map may not be valid at this scale.
Map Scale: 1:9,400 if printed on A portrait (8.5" x 11") sheet.
Meters
0 100 200 400 600
Feet
0 450 900 1800 2700
N
Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 13N 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 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

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: El Paso County Area, Colorado
Survey Area Data: Version 16, Sep 10, 2018

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

Date(s) aerial images were photographed: Jun 7, 2016—Aug 17, 2017

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
2	Ascalon sandy loam, 1 to 3 percent slopes	B	22.1	7.9%
12	Bresser sandy loam, cool, 3 to 5 percent slopes	B	82.9	29.6%
97	Truckton sandy loam, 3 to 9 percent slopes	A	158.5	56.5%
100	Truckton-Bresser complex, eroded	A	16.9	6.0%
Totals for Area of Interest			**280.4**	**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

Grazing Yak Solar

Westwood Project #:21201 18-082

Prepared By: MSH

COMPOSITE BASIN - WEIGHTED "C" CALCULATIONS - Existing Conditions

-REFERENCE UDFCD Vol.1 RUNOFF Table 6-3

	Residential							Lawns				
	Single Family			Multi-Unit				Clay Soil				
	0.25 acres	2.5 acres or larger	5 DU's/Ac 3,000 sf 2 story	(attached)	Roof	Streets: Paved	Gravel	2-7% Slope	>7% Slope	Historic		
% Imperv.	45.00%	12.00%	63.00%	75.00%	90.00%	100.00%	80.00%	2.00%	2.00%	2.00%		
BASIN	**Area**	**Area**	**Area**	**Area**	**Area**	**Area**	**Area**	**Area**	**Area**	**Area**	**Total Area**	**Percent Impervious**
A1										86.97	86.97	2.0%
A2										120.45	120.45	2.0%
A3										86.92	86.92	2.0%
A4										78.97	80.33	2.0%
Total A							**0.00**			**373.31**	**374.67**	**1.99%**
B1										3.82	3.82	2.0%
B2										5.60	5.60	2.0%
Total B										**9.42**	**9.42**	**2.0%**
C1										46.03	46.03	2.0%
Total C										**46.03**	**46.03**	**2.0%**
D1										5.12	5.68	1.8%
Total D							**0.00**			**5.12**	**5.68**	**1.80%**

Grazing Yak Solar

Westwood Project #:21201 18-082

Prepared By: MSH

COMPOSITE DEVELOPED BASIN -WEIGHTED "C" CALCULATIONS - Existing Conditions

-REFERENCE UDFCD Vol.1 RUNOFF Table 6-4

i = % imperviousness/100 expressed as a decimal
C_A = Runoff coefficient for NRCS HSG A soils
C_B = Runoff coefficient for NRCS HSG B soils
C_{CD} = Runoff coefficient for NRCS HSG C and D soils.
Natural Resource Conservation Service (NRCS)

Table 6-4. Runoff coefficient equations based on NRCS soil group and storm return period

NRCS Soil Group	Storm Return Period						
	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	500-Year
A	$C_A = 0.84i^{1.302}$	$C_A = 0.86i^{1.276}$	$C_A = 0.87i^{1.232}$	$C_A = 0.84i^{1.124}$	$C_A = 0.85i+0.025$	$C_A = 0.78i+0.110$	$C_A = 0.65i+0.254$
B	$C_B = 0.84i^{1.169}$	$C_B = 0.86i^{1.088}$	$C_B = 0.81i+0.057$	$C_B = 0.63i+0.249$	$C_B = 0.56i+0.328$	$C_B = 0.47i+0.426$	$C_B = 0.37i+0.536$
C/D	$C_{C/D} = 0.83i^{1.122}$	$C_{C/D} = 0.82i+0.035$	$C_{C/D} = 0.74i+0.132$	$C_{C/D} = 0.56i+0.319$	$C_{C/D} = 0.49i+0.393$	$C_{C/D} = 0.41i+0.484$	$C_{C/D} = 0.32i+0.588$

Basin ID	% Imperv.	*i*	Soil Type	Runoff Coefficients, C				Basin Area	Total Area	Weighted Runoff Coefficients, C			
				2-Year	5-Year	10-Year	100-Year			2-Year	5-Year	10-Year	100-Year
			A	0.01	0.01	0.01	0.13	50.70					
A1	2.0%	0.02	B	0.01	0.01	0.07	0.44	36.27	86.97	0.01	0.01	0.03	0.25
			C or D	0.01	0.05	0.15	0.49	0.00					
			A	0.01	0.01	0.01	0.13	72.11					
A2	2.0%	0.02	B	0.01	0.01	0.07	0.56	48.34	120.45	0.01	0.01	0.03	0.30
			C or D	0.01	0.05	0.15	0.49	0.00					
			A	0.01	0.01	0.01	0.13	53.99					
A3	2.0%	0.02	B	0.01	0.01	0.07	0.44	32.88	86.92	0.01	0.01	0.03	0.24
			C or D	0.01	0.05	0.15	0.49	0.05					
			A	0.01	0.01	0.01	0.13	52.23					
A4	2.0%	0.02	B	0.01	0.01	0.07	0.44	28.10	80.33	0.01	0.01	0.03	0.23
			C or D	0.01	0.05	0.15	0.49	0.00					
			A	0.01	0.01	0.01	0.13	2.04					
B1	2.0%	0.02	B	0.01	0.01	0.07	0.44	1.78	3.82	0.01	0.01	0.04	0.27
			C or D	0.01	0.05	0.15	0.49	0.00					
			A	0.01	0.01	0.01	0.13	4.66					
B2	2.0%	0.02	B	0.01	0.01	0.07	0.44	0.94	5.60	0.01	0.01	0.02	0.18
			C or D	0.01	0.05	0.15	0.49	0.00					
			A	0.01	0.01	0.01	0.13	25.62					
C1	2.0%	0.02	B	0.01	0.01	0.07	0.44	20.41	46.03	0.01	0.01	0.04	0.26
			C or D	0.01	0.05	0.15	0.49	0.00					
			A	0.00	0.01	0.01	0.12	1.24					
D1	1.8%	0.02	B	0.01	0.01	0.07	0.43	4.32	5.68	0.01	0.01	0.06	0.37
			C or D	0.01	0.05	0.15	0.49	0.12					

Grazing Yak Solar

Westwood Project #:21201 18-082
Prepared By: MSH

TIME OF CONCENTRATION CALCULATIONS - Existing Conditions

-REFERENCE UDFCD Vol.1 Section 2.4

SF-2

NRCS Conveyance factors, K -REFERENCE UDFCD Vol.1 RUNOFF Table 6-2

Heavy Meadow	2.50	Short Grass Pasture & Lawns	7.00	Grassed Waterway	15.00
Tillage/field	5.00	Nearly Bare Ground	10.00	Paved Area & Shallow Gutter	20.00

SUB-BASIN DATA			INITIAL / OVERLAND TIME			TRAVEL TIME T(t)						T(c) CHECK (URBANIZED BASINS)		FINAL T(c)
DRAIN BASIN	AREA ac.	C(5)	Length ft.	Slope %	T(i) min	Length ft.	Slope %	Coeff.	Velocity fps	T(t) min.	COMP. T(c)	% IMPER-VIOUS	USDCM Eq . 6-5	min.
A1	86.97	0.01	148	1.3	21.7	2623	2.4	5.00	0.8	54.7	76.4	2.0%		76.4
A2	120.45	0.01	300	1.7	28.8	3149	1.7	5.00	0.7	75.0	103.8	2.0%		103.8
A3	86.92	0.01	300	3.3	22.9	3203	2.4	5.00	0.8	66.7	89.6	2.0%		89.6
A4	80.33	0.01	300	3.7	22.2	3023	2.0	5.00	0.7	72.0	94.2	2.0%		94.2
B1	3.82	0.01	240	1.0	30.1	357	1.4	5.00	0.6	9.9	40.0	2.0%		40.0
B2	5.60	0.01	300	1.5	29.9	466	3.0	5.00	0.9	8.6	38.5	2.0%		38.5
C1	46.03	0.01	300	5.2	19.8	1517	1.6	5.00	0.6	42.1	61.9	2.0%		61.9
D1	5.68	0.01	529	0.9	47.7	1189	2.5	5.00	0.8	24.8	72.5	1.8%		72.5

Grazing Yak Solar

Westwood Project #:21201 18-082

Prepared By: MSH

Include this table (with both design storms) on the existing conditions Plan/Map.

RATIONAL METHOD PEAK RUNOFF - Existing Conditions

5-YR STORM

SF-3

Rainfall Depth-Duration-Frequency (1-hr) = **1.5**

-REFERENCE UDFCD Vol.1 EQ 5-1 & EQ 6-1

BASIN INFORMATON				DIRECT RUNOFF				TOTAL RUNOFF				
DESIGN POINT	DRAIN BASIN	AREA ac.	5yr RUNOFF COEFF	T(c) min	C x A	I in/hr	Q cfs	T(c) min	SUM C x A	I in/hr	Q cfs	REMARKS
1	A1	86.97	0.01	76.4	0.74	1.28	0.9					
2	A2	120.45	0.01	103.8	1.01	1.03	1.0					
3	A3	86.92	0.01	89.6	0.72	1.15	0.8					
4	A4	80.33	0.01	94.2	0.63	1.11	0.7					
5	B1	3.82	0.01	40.0	0.03	1.97	1.4					
6	B2	5.60	0.01	38.5	0.04	2.02	0.1					
7	C1	46.03	0.01	61.9	0.40	1.48	0.6					
8	D1	5.68	0.01	72.5	0.06	1.33	0.1					

Grazing Yak Solar

Westwood Project #:21201 18-082
Prepared By: MSH

See comment previous page.

RATIONAL METHOD PEAK RUNOFF - Existing Conditions
100-YR STORM

SF-3

Rainfall Depth-Duration-Frequency (1-hr) = **2.52**

-REFERENCE UDFCD Vol.1 EQ 5-1 & EQ 6-1

BASIN INFORMATON				DIRECT RUNOFF				TOTAL RUNOFF				
DESIGN POINT	DRAIN BASIN	AREA ac.	100yr RUNOFF COEFF	T(c) min	C x A	I in/hr	Q cfs	T(c) min	SUM C x A	I in/hr	Q cfs	REMARKS
1	A1	86.97	0.25	76.4	22.16	2.16	47.8					
2	A2	120.45	0.30	103.8	36.13	1.74	62.8					
3	A3	86.92	0.24	89.6	21.12	1.93	40.8					
4	A4	80.33	0.23	94.2	18.78	1.86	35.0					
5	B1	3.82	0.27	40.0	1.03	3.32	1.4					
6	B2	5.60	0.18	38.5	0.99	3.40	3.4					
7	C1	46.03	0.26	61.9	12.10	2.49	30.2					
8	D1	5.68	0.37	72.5	2.09	2.24	4.7					

Grazing Yak Solar

Westwood Project #:21201 18-082

Prepared By: MSH

COMPOSITE BASIN - WEIGHTED "C" CALCULATIONS

-REFERENCE UDFCD Vol.1 RUNOFF Table 6-3

	Residential							Lawns				
	Single Family			Multi-Unit				Clay Soil				
	0.25 acres	2.5 acres or larger	5 DU's/Ac 3,000 sf 2 story	(attached)	Roof	Streets: Paved	Gravel	2-7% Slope	>7% Slope	Historic		
% Imperv.	45.00%	12.00%	63.00%	75.00%	90.00%	100.00%	80.00%	2.00%	2.00%	2.00%		
											Total	Percent
BASIN	**Area**	**Area**	**Area**	**Area**	**Area**	**Area**	**Area**	**Area**	**Area**	**Area**	**Area**	**Impervious**
A1										86.97	86.97	2.0%
A2										120.45	120.45	2.0%
A3										86.92	86.92	2.0%
A4							1.36			78.97	80.33	3.3%
Total A							**1.36**			**373.31**	**374.67**	**2.28%**
B1										3.82	3.82	2.0%
B2										5.60	5.60	2.0%
Total B										**9.42**	**9.42**	**2.0%**
C1										46.03	46.03	2.0%
Total C										**46.03**	**46.03**	**2.0%**
D1							0.56			5.12	5.68	9.7%
Total D							**0.56**			**5.12**	**5.68**	**9.69%**

Grazing Yak Solar

Westwood Project #:21201 18-082
Prepared By: MSH

COMPOSITE DEVELOPED BASIN -WEIGHTED "C" CALCULATIONS
-REFERENCE UDFCD Vol.1 RUNOFF Table 6-4

i = % imperviousness/100 expressed as a decimal
C_A = Runoff coefficient for NRCS HSG A soils
C_B = Runoff coefficient for NRCS HSG B soils
C_{CD} = Runoff coefficient for NRCS HSG C and D soils.
Natural Resource Conservation Service (NRCS)

Table 6-4. Runoff coefficient equations based on NRCS soil group and storm return period

NRCS Soil Group	Storm Return Period						
	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	500-Year
A	$C_A = 0.84i^{1.302}$	$C_A = 0.86i^{1.276}$	$C_A = 0.87i^{1.232}$	$C_A = 0.84i^{1.124}$	$C_A = 0.85i+0.025$	$C_A = 0.78i+0.110$	$C_A = 0.65i+0.254$
B	$C_B = 0.84i^{1.169}$	$C_B = 0.86i^{1.088}$	$C_B = 0.81i+0.057$	$C_B = 0.63i+0.249$	$C_B = 0.56i+0.328$	$C_B = 0.47i+0.426$	$C_B = 0.37i+0.536$
C/D	$C_{C/D} = 0.83i^{1.122}$	$C_{C/D} = 0.82i+0.035$	$C_{C/D} = 0.74i+0.132$	$C_{C/D} = 0.56i+0.319$	$C_{C/D} = 0.49i+0.393$	$C_{C/D} = 0.41i+0.484$	$C_{C/D} = 0.32i+0.588$

Basin ID	% Imperv.	*i*	Soil Type	Runoff Coefficients, C				Basin	Total	Weighted Runoff Coefficients, C			
				2-Year	5-Year	10-Year	100-Year	Area	Area	2-Year	5-Year	10-Year	100-Year
			A	0.01	0.01	0.01	0.13	50.70					
A1	2.0%	0.02	B	0.01	0.01	0.07	0.44	36.27	86.97	0.01	0.01	0.03	0.25
			C or D	0.01	0.05	0.15	0.49	0.00					
			A	0.01	0.01	0.01	0.13	72.11					
A2	2.0%	0.02	B	0.01	0.01	0.07	0.56	48.34	120.45	0.01	0.01	0.03	0.30
			C or D	0.01	0.05	0.15	0.49	0.00					
			A	0.01	0.01	0.01	0.13	53.99					
A3	2.0%	0.02	B	0.01	0.01	0.07	0.44	32.88	86.92	0.01	0.01	0.03	0.24
			C or D	0.01	0.05	0.15	0.49	0.05					
			A	0.01	0.01	0.01	0.14	52.23					
A4	3.3%	0.03	B	0.02	0.02	0.08	0.44	28.10	80.33	0.01	0.01	0.04	0.24
			C or D	0.02	0.06	0.16	0.50	0.00					
			A	0.01	0.01	0.01	0.13	2.04					
B1	2.0%	0.02	B	0.01	0.01	0.07	0.44	1.78	3.82	0.01	0.01	0.04	0.27
			C or D	0.01	0.05	0.15	0.49	0.00					
			A	0.01	0.01	0.01	0.13	4.66					
B2	2.0%	0.02	B	0.01	0.01	0.07	0.44	0.94	5.60	0.01	0.01	0.02	0.18
			C or D	0.01	0.05	0.15	0.49	0.00					
			A	0.01	0.01	0.01	0.13	25.62					
C1	2.0%	0.02	B	0.01	0.01	0.07	0.44	20.41	46.03	0.01	0.01	0.04	0.26
			C or D	0.01	0.05	0.15	0.49	0.00					
			A	0.04	0.04	0.05	0.19	1.24					
D1	9.7%	0.10	B	0.05	0.07	0.14	0.47	4.32	5.68	0.05	0.06	0.12	0.41
			C or D	0.06	0.11	0.20	0.52	0.12					

Grazing Yak Solar

Westwood Project #:21201 18-082

Prepared By: MSH

TIME OF CONCENTRATION CALCULATIONS

-REFERENCE UDFCD Vol.1 Section 2.4

SF-2

NRCS Conveyance factors, K -REFERENCE UDFCD Vol.1 RUNOFF Table 6-2

Heavy Meadow	2.50	Short Grass Pasture & Lawns	7.00	Grassed Waterway	15.00
Tillage/field	5.00	Nearly Bare Ground	10.00	Paved Area & Shallow Gutter	20.00

SUB-BASIN DATA			INITIAL / OVERLAND TIME			TRAVEL TIME T(t)						T(c) CHECK (URBANIZED BASINS)		FINAL T(c)
DRAIN BASIN	AREA ac.	C(5)	Length ft.	Slope %	T(i) min	Length ft.	Slope %	Coeff.	Velocity fps	T(t) min.	COMP. T(c)	% IMPER-VIOUS	USDCM Eq . 6-5	min.
A1	86.97	0.01	148	1.3	21.7	2623	2.4	5.00	0.8	54.7	76.4	2.0%		76.4
A2	120.45	0.01	300	1.7	28.8	3149	1.7	5.00	0.7	75.0	103.8	2.0%		103.8
A3	86.92	0.01	300	3.3	22.9	3203	2.4	5.00	0.8	66.7	89.6	2.0%		89.6
A4	80.33	0.01	300	3.7	22.1	3023	2.0	5.00	0.7	72.0	94.1	3.3%		94.1
B1	3.82	0.01	240	1.0	30.1	357	1.4	5.00	0.6	9.9	40.0	2.0%		40.0
B2	5.60	0.01	300	1.5	29.9	466	3.0	5.00	0.9	8.6	38.5	2.0%		38.5
C1	46.03	0.01	300	5.2	19.8	1517	1.6	5.00	0.6	42.1	61.9	2.0%		61.9
D1	5.68	0.06	529	0.9	45.4	1189	2.5	5.00	0.8	24.8	70.2	9.7%		70.2

Include this table (with both design storms) on the Proposed drainage Plan/Map.

Grazing Yak Solar

Westwood Project #:21201 18-082

Prepared By: MSH

RATIONAL METHOD PEAK RUNOFF

5-YR STORM

SF-3

Rainfall Depth-Duration-Frequency (1-hr) = **1.5**

-REFERENCE UDFCD Vol.1 EQ 5-1 & EQ 6-1

BASIN INFORMATON				DIRECT RUNOFF				TOTAL RUNOFF				
DESIGN POINT	DRAIN BASIN	AREA ac.	5yr RUNOFF COEFF	T(c) min	C x A	I in/hr	Q cfs	T(c) min	SUM C x A	I in/hr	Q cfs	REMARKS
1	A1	86.97	0.01	76.4	0.74	1.28	0.9					
2	A2	120.45	0.01	103.8	1.01	1.03	1.0					
3	A3	86.92	0.01	89.6	0.72	1.15	0.8					
4	A4	80.33	0.01	94.1	1.18	1.11	1.3					
5	B1	3.82	0.01	40.0	0.03	1.97	1.4					
6	B2	5.60	0.01	38.5	0.04	2.02	0.1					
7	C1	46.03	0.01	61.9	0.40	1.48	0.6					
8	D1	5.68	0.06	70.2	0.36	1.36	0.5					

Grazing Yak Solar

Westwood Project #:21201 18-082

Prepared By: MSH

RATIONAL METHOD PEAK RUNOFF

100-YR STORM

SF-3

Rainfall Depth-Duration-Frequency (1-hr) = **2.52**

-REFERENCE UDFCD Vol.1 EQ 5-1 & EQ 6-1

BASIN INFORMATON				DIRECT RUNOFF				TOTAL RUNOFF				
DESIGN POINT	DRAIN BASIN	AREA ac.	100yr RUNOFF COEFF	T(c) min	C x A	I in/hr	Q cfs	T(c) min	SUM C x A	I in/hr	Q cfs	REMARKS
1	A1	86.97	0.25	76.4	22.16	2.16	47.8					
2	A2	120.45	0.30	103.8	36.13	1.74	62.8					
3	A3	86.92	0.24	89.6	21.12	1.93	40.8					
4	A4	80.33	0.24	94.1	19.51	1.86	36.4					
5	B1	3.82	0.27	40.0	1.03	3.32	1.4					
6	B2	5.60	0.18	38.5	0.99	3.40	3.4					
7	C1	46.03	0.26	61.9	12.10	2.49	30.2					
8	D1	5.68	0.41	70.2	2.33	2.29	5.3					

For Colorado Springs and much of the Fountain Creek watershed, the 1-hour depths are fairly uniform and are summarized in Table 6-2. Depending on the location of the project, rainfall depths may be calculated using the described method and the NOAA Atlas maps shown in Figures 6-6 through 6-17.

Table 6-2. Rainfall Depths for Colorado Springs

Return Period	1-Hour Depth	6-Hour Depth	24-Hour Depth
2	1.19	1.70	2.10
5	1.50	2.10	2.70
10	1.75	2.40	3.20
25	2.00	2.90	3.60
50	2.25	3.20	4.20
100	2.52	3.50	4.60

Where Z= 6,840 ft/100

These depths can be applied to the design storms or converted to intensities (inches/hour) for the Rational Method as described below. However, as the basin area increases, it is unlikely that the reported point rainfalls will occur uniformly over the entire basin. To account for this characteristic of rain storms an adjustment factor, the Depth Area Reduction Factor (DARF) is applied. This adjustment to rainfall depth and its effect on design storms is also described below. The UDFCD UD-Rain spreadsheet, available on UDFCD's website, also provides tools to calculate point rainfall depths and Intensity-Duration-Frequency curves[2] and should produce similar depth calculation results.

2.2 Design Storms

Design storms are used as input into rainfall/runoff models and provide a representation of the typical temporal distribution of rainfall events when the creation or routing of runoff hydrographs is required. It has long been observed that rainstorms in the Front Range of Colorado tend to occur as either short-duration, high-intensity, localized, convective thunderstorms (cloud bursts) or longer-duration, lower-intensity, broader, frontal (general) storms. The significance of these two types of events is primarily determined by the size of the drainage basin being studied. Thunderstorms can create high rates of runoff within a relatively small area, quickly, but their influence may not be significant very far downstream. Frontal storms may not create high rates of runoff within smaller drainage basins due to their lower intensity, but tend to produce larger flood flows that can be hazardous over a broader area and extend further downstream.

- **Thunderstorms**: Based on the extensive evaluation of rain storms completed in the Carlton study (Carlton 2011), it was determined that typical thunderstorms have a duration of about 2 hours. The study evaluated over 300,000 storm cells using gage-adjusted NEXRAD data, collected over a 14-year period (1994 to 2008). Storms lasting longer than 3 hours were rarely found. Therefore, the results of the Carlton study have been used to define the shorter duration design storms.

  To determine the temporal distribution of thunderstorms, 22 gage-adjusted NEXRAD storm cells were studied in detail. Through a process described in a technical memorandum prepared by the City of Colorado Springs (City of Colorado Springs 2012), the results of this analysis were interpreted and normalized to the 1-hour rainfall depth to create the distribution shown in Table 6-3 with a 5 minute time interval for drainage basins up to 1 square mile in size. This distribution represents the rainfall

Table 6-6. Runoff Coefficients for Rational Method

(Source: UDFCD 2001)

Land Use or Surface Characteristics	Percent Impervious	Runoff Coefficients											
		2-year		5-year		10-year		25-year		50-year		100-year	
		HSG A&B	HSG C&D	HSG A&B	HSG C&D	HSG A&B	HSG C&D	HSG A&B	HSG C&D	HSG A&B	HSG C&D	HSG A&B	HSG C&D
Business													
Commercial Areas	95	0.79	0.80	0.81	0.82	0.83	0.84	0.85	0.87	0.87	0.88	0.88	0.89
Neighborhood Areas	70	0.45	0.49	0.49	0.53	0.53	0.57	0.58	0.62	0.60	0.65	0.62	0.68
Residential													
1/8 Acre or less	65	0.41	0.45	0.45	0.49	0.49	0.54	0.54	0.59	0.57	0.62	0.59	0.65
1/4 Acre	40	0.23	0.28	0.30	0.35	0.36	0.42	0.42	0.50	0.46	0.54	0.50	0.58
1/3 Acre	30	0.18	0.22	0.25	0.30	0.32	0.38	0.39	0.47	0.43	0.52	0.47	0.57
1/2 Acre	25	0.15	0.20	0.22	0.28	0.30	0.36	0.37	0.46	0.41	0.51	0.46	0.56
1 Acre	20	0.12	0.17	0.20	0.26	0.27	0.34	0.35	0.44	0.40	0.50	0.44	0.55
Industrial													
Light Areas	80	0.57	0.60	0.59	0.63	0.63	0.66	0.66	0.70	0.68	0.72	0.70	0.74
Heavy Areas	90	0.71	0.73	0.73	0.75	0.75	0.77	0.78	0.80	0.80	0.82	0.81	0.83
Parks and Cemeteries	7	0.05	0.09	0.12	0.19	0.20	0.29	0.30	0.40	0.34	0.46	0.39	0.52
Playgrounds	13	0.07	0.13	0.16	0.23	0.24	0.31	0.32	0.42	0.37	0.48	0.41	0.54
Railroad Yard Areas	40	0.23	0.28	0.30	0.35	0.36	0.42	0.42	0.50	0.46	0.54	0.50	0.58
Undeveloped Areas													
Historic Flow Analysis-- Greenbelts, Agriculture	2	0.03	0.05	0.09	0.16	0.17	0.26	0.26	0.38	0.31	0.45	0.36	0.51
Pasture/Meadow	0	0.02	0.04	0.08	0.15	0.15	0.25	0.25	0.37	0.30	0.44	0.35	0.50
Forest	0	0.02	0.04	0.08	0.15	0.15	0.25	0.25	0.37	0.30	0.44	0.35	0.50
Exposed Rock	100	0.89	0.89	0.90	0.90	0.92	0.92	0.94	0.94	0.95	0.95	0.96	0.96
Offsite Flow Analysis (when landuse is undefined)	45	0.26	0.31	0.32	0.37	0.38	0.44	0.44	0.51	0.48	0.55	0.51	0.59
Streets													
Paved	100	0.89	0.89	0.90	0.90	0.92	0.92	0.94	0.94	0.95	0.95	0.96	0.96
Gravel	80	0.57	0.60	0.59	0.63	0.63	0.66	0.66	0.70	0.68	0.72	0.70	0.74
Drive and Walks	100	0.89	0.89	0.90	0.90	0.92	0.92	0.94	0.94	0.95	0.95	0.96	0.96
Roofs	90	0.71	0.73	0.73	0.75	0.75	0.77	0.78	0.80	0.80	0.82	0.81	0.83
Lawns	0	0.02	0.04	0.08	0.15	0.15	0.25	0.25	0.37	0.30	0.44	0.35	0.50

3.2 Time of Concentration

One of the basic assumptions underlying the Rational Method is that runoff is a function of the average rainfall rate during the time required for water to flow from the hydraulically most remote part of the drainage area under consideration to the design point. However, in practice, the time of concentration can be an empirical value that results in reasonable and acceptable peak flow calculations.

For urban areas, the time of concentration (t_c) consists of an initial time or overland flow time (t_i) plus the travel time (t_t) in the storm sewer, paved gutter, roadside drainage ditch, or drainage channel. For non-urban areas, the time of concentration consists of an overland flow time (t_i) plus the time of travel in a concentrated form, such as a swale or drainageway. The travel portion (t_t) of the time of concentration can be estimated from the hydraulic properties of the storm sewer, gutter, swale, ditch, or drainageway. Initial time, on the other hand, will vary with surface slope, depression storage, surface cover, antecedent rainfall, and infiltration capacity of the soil, as well as distance of surface flow. The time of concentration is represented by Equation 6-7 for both urban and non-urban areas.

DETENTION BASIN DESIGN WORKBOOK

UD-Detention, Version 3.07 (February 2017)

Urban Drainage and Flood Control District
Denver, Colorado
www.udfcd.org

Purpose: **This workbook aids in the estimation of stormwater detention basin sizing and outlet routing based on the modified puls routing method for urban watersheds. Several different BMP types and various outlet configurations can be sized.**

Function:

1. **Approximates the stage-area-volume relationship for a detention basin based on watershed parameters and basin geometry parameters. Also evaluates existing user-defined basin stage-area relationships.**

2. **Sizes filtration media orifice, outlet orifices, elliptical slots, weirs, trash racks, and develops stage-discharge relationships. Uses the Modified Puls method to route a series of hydrographs (i.e., 2-, 5-, 10-, 25-, 50-, 100- and 500-year) and calibrates the peak discharge out of the basin to match the pre-development peak discharges for the watershed.**

Content: **This workbook consists of the following sheets:**

Basin	Tabulates stage-area-volume relationship estimates based on watershed parameters
Outlet Structure	Tabulates a stage-discharge relationship for the user-defined outlet structure (inlet control).
Reference	Provides reference equations and figures.
User Tips and Tools	Provides instructions and video links to assist in using this workbook. Includes a stage-area calculator.
BMP Zone Images	Provides images of typical BMP zone confirgurations corresponding with Zone pulldown selections.

Acknowledgements:
Spreadsheet Development Team:
Ken MacKenzie, P.E., Holly Piza, P.E.
Urban Drainage and Flood Control District

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Professor, Department of Civil Engineering, University of Colorado at Denver

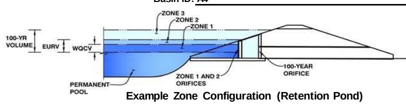
Comments? Direct all comments regarding this spreadsheet workbook to: **UDFCD email**
Revisions? Check for revised versions of this or any other workbook at: Downloads

DETENTION BASIN STAGE-STORAGE TABLE BUILDER

UD-Detention, Version 3.07 (February 2017)

Project: Grazing Yak Solar

Basin ID: A4



Example Zone Configuration (Retention Pond)

Required Volume Calculation

			Optional User Override 1-hr Precipitation	
Selected BMP Type =	EDB			
Watershed Area =	86.01	acres		
Watershed Length =	3,300	ft		
Watershed Slope =	0.024	ft/ft		
Watershed Imperviousness =	3.74%	percent		
Percentage Hydrologic Soil Group A =	60.0%	percent		
Percentage Hydrologic Soil Group B =	39.0%	percent		
Percentage Hydrologic Soil Groups C/D =	1.0%	percent		
Desired WQCV Drain Time =	40.0	hours		
Location for 1-hr Rainfall Depths =	User Input			
Water Quality Capture Volume (WQCV) =	0.198	acre-feet		
Excess Urban Runoff Volume (EURV) =	0.219	acre-feet		
2-yr Runoff Volume (P1 = 1.19 in.) =	0.138	acre-feet	1.19	inches
5-yr Runoff Volume (P1 = 1.5 in.) =	0.218	acre-feet	1.50	inches
10-yr Runoff Volume (P1 = 1.75 in.) =	0.625	acre-feet	1.75	inches
25-yr Runoff Volume (P1 = 2 in.) =	2.040	acre-feet	2.00	inches
50-yr Runoff Volume (P1 = 2.25 in.) =	3.242	acre-feet	2.25	inches
100-yr Runoff Volume (P1 = 2.52 in.) =	5.391	acre-feet	2.52	inches
500-yr Runoff Volume (P1 = 0 in.) =	0.000	acre-feet		inches
Approximate 2-yr Detention Volume =	0.126	acre-feet		
Approximate 5-yr Detention Volume =	0.202	acre-feet		
Approximate 10-yr Detention Volume =	0.517	acre-feet		
Approximate 25-yr Detention Volume =	0.784	acre-feet		
Approximate 50-yr Detention Volume =	0.925	acre-feet		
Approximate 100-yr Detention Volume =	1.541	acre-feet		

Stage-Storage Calculation

Zone 1 Volume (WQCV) =	0.198	acre-feet
Zone 2 Volume (100-year - Zone 1) =	1.343	acre-feet
Zone 3 Volume (User Defined - Zones 1 & 2) =	8.020	acre-feet
Total Detention Basin Volume =	9.561	acre-feet
Initial Surcharge Volume (ISV) =	user	ft^3
Initial Surcharge Depth (ISD) =	user	ft
Total Available Detention Depth (H_{total}) =	user	ft
Depth of Trickle Channel (H_{TC}) =	user	ft
Slope of Trickle Channel (S_{TC}) =	user	ft/ft
Slopes of Main Basin Sides (S_{main}) =	user	H:V
Basin Length-to-Width Ratio ($R_{L/W}$) =	user	
Initial Surcharge Area (A_{ISV}) =	user	ft^2
Surcharge Volume Length (L_{ISV}) =	user	ft
Surcharge Volume Width (W_{ISV}) =	user	ft
Depth of Basin Floor (H_{FLOOR}) =	user	ft
Length of Basin Floor (L_{FLOOR}) =	user	ft
Width of Basin Floor (W_{FLOOR}) =	user	ft
Area of Basin Floor (A_{FLOOR}) =	user	ft^2
Volume of Basin Floor (V_{FLOOR}) =	user	ft^3
Depth of Main Basin (H_{MAIN}) =	user	ft
Length of Main Basin (L_{MAIN}) =	user	ft
Width of Main Basin (W_{MAIN}) =	user	ft
Area of Main Basin (A_{MAIN}) =	user	ft^2
Volume of Main Basin (V_{MAIN}) =	user	ft^3
Calculated Total Basin Volume (V_{total}) =	user	acre-feet

Depth Increment = 1 ft

Stage - Storage Description	Stage (ft)	Optional Override Stage (ft)	Length (ft)	Width (ft)	Area (ft^2)	Optional Override Area (ft^2)	Area (acre)	Volume (ft^3)	Volume (ac-ft)
Top of Micropool	--	0.00	--	--	--	1	0.000		
Bottom of EURV	--	0.33	--	--	--	8,353	0.192	1,295	0.030
	--	1.33	--	--	--	36,793	0.845	23,584	0.541
Top of EURV	--	2.33	--	--	--	39,378	0.904	62,036	1.424
	--	3.33	--	--	--	55,423	1.272	109,436	2.512
	--	4.33	--	--	--	62,524	1.435	168,410	3.866
Top of Basin	--	5.33	--	--	--	74,355	1.707	236,849	5.437
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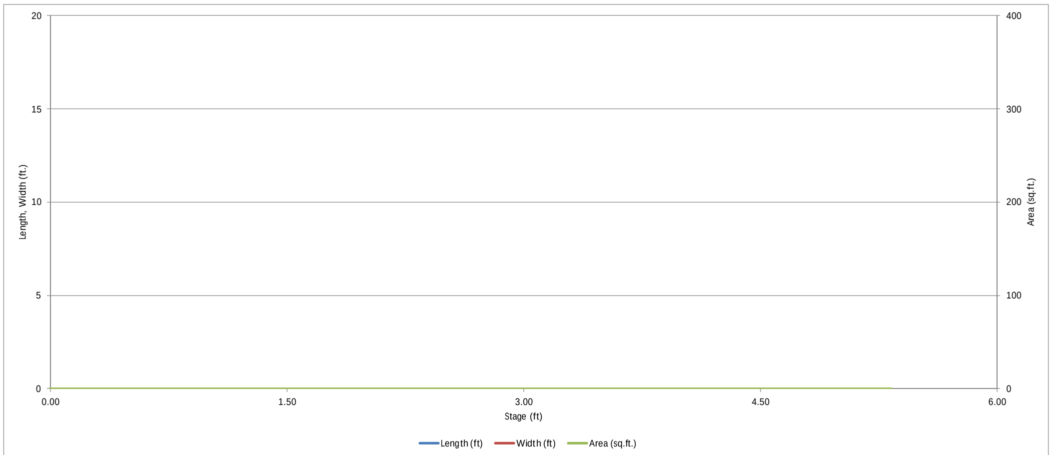
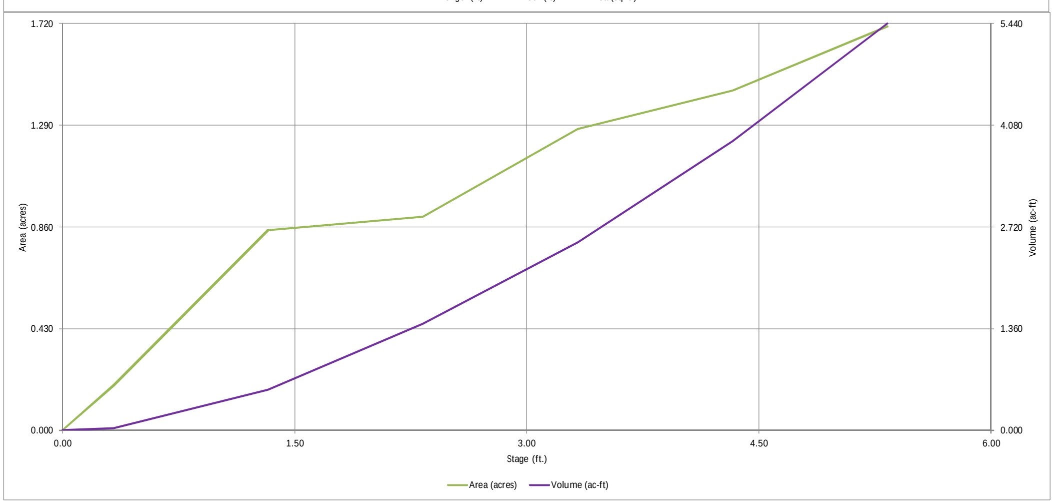
DETENTION BASIN STAGE-STORAGE TABLE BUILDER

UD-Detention, Version 3.07 (February 2017)



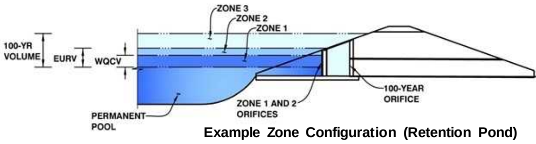


Detention Basin Outlet Structure Design

UD-Detention, Version 3.07 (February 2017)

Project: Grazing Yak Solar

Basin ID: A4



Example Zone Configuration (Retention Pond)

	Stage (ft)	Zone Volume (ac-ft)	Outlet Type
Zone 1 (WQCV)	0.81	0.198	Orifice Plate
Zone 2 (100-year)	2.46	1.343	Weir&Pipe (Circular)
Zone 3 (User)		8.020	
		9.561	Total

User Input: Orifice at Underdrain Outlet (typically used to drain WQCV in a Filtration BMP)

Underdrain Orifice Invert Depth =	N/A	ft (distance below the filtration media surface)
Underdrain Orifice Diameter =	N/A	inches

Calculated Parameters for Underdrain

Underdrain Orifice Area =	N/A	ft^2
Underdrain Orifice Centroid =	N/A	feet

User Input: Orifice Plate with one or more orifices or Elliptical Slot Weir (typically used to drain WQCV and/or EURV in a sedimentation BMP)

Invert of Lowest Orifice =	0.00	ft (relative to basin bottom at Stage = 0 ft)
Depth at top of Zone using Orifice Plate =	0.81	ft (relative to basin bottom at Stage = 0 ft)
Orifice Plate: Orifice Vertical Spacing =	2.00	inches
Orifice Plate: Orifice Area per Row =	1.23	sq. inches (diameter = 1-1/4 inches)

Calculated Parameters for Plate

WQ Orifice Area per Row =	8.542E-03	ft^2
Elliptical Half-Width =	N/A	feet
Elliptical Slot Centroid =	N/A	feet
Elliptical Slot Area =	N/A	ft^2

User Input: Stage and Total Area of Each Orifice Row (numbered from lowest to highest)

	Row 1 (required)	Row 2 (optional)	Row 3 (optional)	Row 4 (optional)	Row 5 (optional)	Row 6 (optional)	Row 7 (optional)	Row 8 (optional)
Stage of Orifice Centroid (ft)	0.00	0.20	0.40	0.60	0.80			
Orifice Area (sq. inches)	1.23	1.23	1.23	1.23	1.23			

	Row 9 (optional)	Row 10 (optional)	Row 11 (optional)	Row 12 (optional)	Row 13 (optional)	Row 14 (optional)	Row 15 (optional)	Row 16 (optional)
Stage of Orifice Centroid (ft)								
Orifice Area (sq. inches)								

User Input: Vertical Orifice (Circular or Rectangular)

	Not Selected	Not Selected	
Invert of Vertical Orifice =			ft (relative to basin bottom at Stage = 0 ft)
Depth at top of Zone using Vertical Orifice =			ft (relative to basin bottom at Stage = 0 ft)
Vertical Orifice Diameter =			inches

Calculated Parameters for Vertical Orifice

	Not Selected	Not Selected	
Vertical Orifice Area =			ft^2
Vertical Orifice Centroid =			feet

User Input: Overflow Weir (Dropbox) and Grate (Flat or Sloped)

	Zone 2 Weir	Not Selected	
Overflow Weir Front Edge Height, Ho =	2.33		ft (relative to basin bottom at Stage = 0 ft)
Overflow Weir Front Edge Length =	100.00		feet
Overflow Weir Slope =	0.00		H:V (enter zero for flat grate)
Horiz. Length of Weir Sides =	100.00		feet
Overflow Grate Open Area % =	80%		%, grate open area/total area
Debris Clogging % =	50%		%

Calculated Parameters for Overflow Weir

	Zone 2 Weir	Not Selected	
Height of Grate Upper Edge, H_t =	2.33		feet
Over Flow Weir Slope Length =	100.00		feet
Grate Open Area / 100-yr Orifice Area =	3326.01		should be $\geq$ 4
Overflow Grate Open Area w/o Debris =	8000.00		ft^2
Overflow Grate Open Area w/ Debris =	4000.00		ft^2

User Input: Outlet Pipe w/ Flow Restriction Plate (Circular Orifice, Restrictor Plate, or Rectangular Orifice)

	Zone 2 Circular	Not Selected	
Depth to Invert of Outlet Pipe =	2.33		ft (distance below basin bottom at Stage = 0 ft)
Circular Orifice Diameter =	21.00		inches

Calculated Parameters for Outlet Pipe w/ Flow Restriction Plate

	Zone 2 Circular	Not Selected	
Outlet Orifice Area =	2.41		ft^2
Outlet Orifice Centroid =	0.88		feet
Half-Central Angle of Restrictor Plate on Pipe =	N/A	N/A	radians

User Input: Emergency Spillway (Rectangular or Trapezoidal)

Spillway Invert Stage=		ft (relative to basin bottom at Stage = 0 ft)
Spillway Crest Length =		feet
Spillway End Slopes =		H:V
Freeboard above Max Water Surface =		feet

Calculated Parameters for Spillway

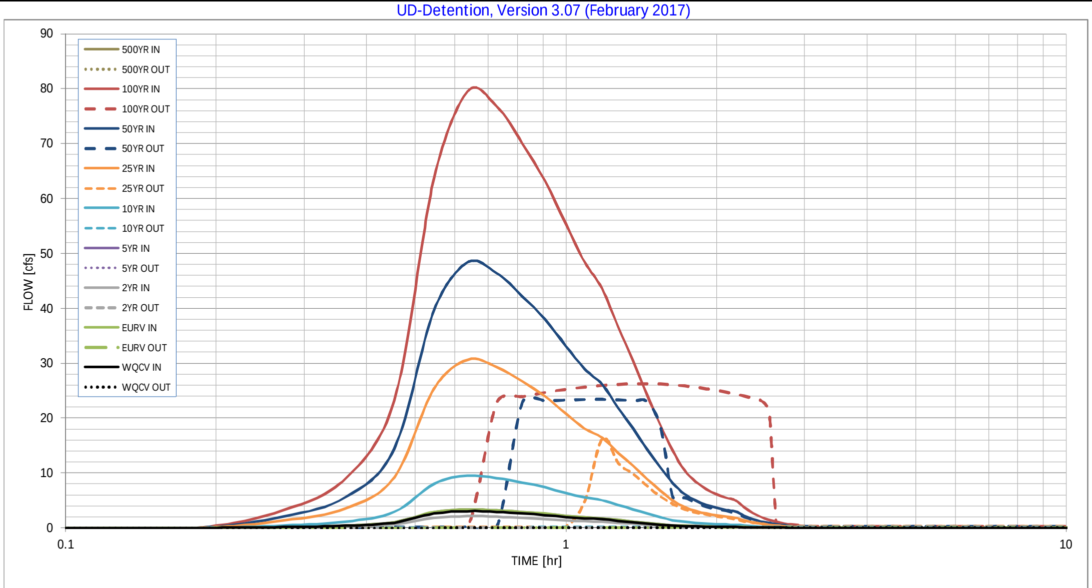
Spillway Design Flow Depth=		feet
Stage at Top of Freeboard =		feet
Basin Area at Top of Freeboard =		acres

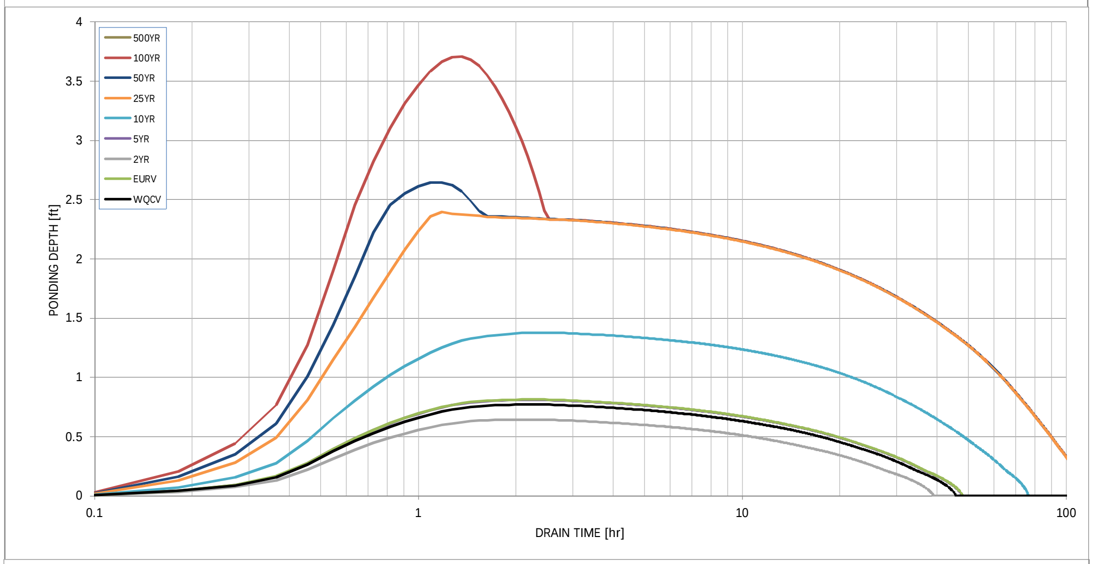
Routed Hydrograph Results

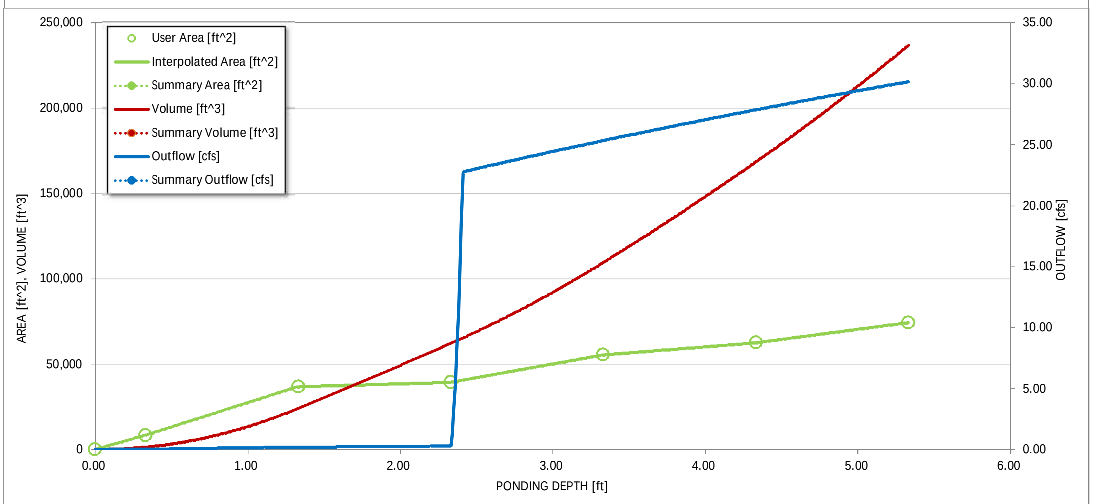
Design Storm Return Period =	WQCV	EURV	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year	500 Year
One-Hour Rainfall Depth (in) =	0.53	1.07	1.19	1.50	1.75	2.00	2.25	2.52	0.00
Calculated Runoff Volume (acre-ft) =	0.198	0.219	0.138	0.218	0.625	2.040	3.242	5.391	0.000
OPTIONAL Override Runoff Volume (acre-ft) =									
Inflow Hydrograph Volume (acre-ft) =	0.197	0.219	0.137	0.217	0.624	2.038	3.239	5.378	#N/A
Predevelopment Unit Peak Flow, q (cfs/acre) =	0.00	0.00	0.00	0.01	0.08	0.25	0.44	0.70	0.00
Predevelopment Peak Q (cfs) =	0.0	0.0	0.4	0.9	6.7	21.8	37.5	60.3	0.0
Peak Inflow Q (cfs) =	3.0	3.4	2.1	3.3	9.5	30.6	48.4	79.5	#N/A
Peak Outflow Q (cfs) =	0.1	0.1	0.1	0.1	0.2	16.3	23.5	26.3	#N/A
Ratio Peak Outflow to Predevelopment Q =	N/A	N/A	N/A	0.1	0.0	0.7	0.6	0.4	#N/A
Structure Controlling Flow =	Plate	Plate	Plate	Plate	Plate	Overflow Grate 1	Outlet Plate 1	Outlet Plate 1	#N/A
Max Velocity through Grate 1 (fps) =	N/A	N/A	N/A	N/A	N/A	0.0	0.0	0.0	#N/A
Max Velocity through Grate 2 (fps) =	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	#N/A
Time to Drain 97% of Inflow Volume (hours) =	40	41	34	41	63	92	86	77	#N/A
Time to Drain 99% of Inflow Volume (hours) =	43	45	37	45	70	104	100	94	#N/A
Maximum Ponding Depth (ft) =	0.77	0.81	0.65	0.81	1.38	2.39	2.65	3.71	#N/A
Area at Maximum Ponding Depth (acres) =	0.48	0.51	0.39	0.51	0.85	0.93	1.02	1.33	#N/A
Maximum Volume Stored (acre-ft) =	0.179	0.199	0.122	0.199	0.584	1.479	1.722	2.994	#N/A

Detention Basin Outlet Structure Design

UD-Detention, Version 3.07 (February 2017)







S-A-V-D Chart Axis Override	X-axis	Left Y-Axis	Right Y-Axis
minimum bound			
maximum bound			

Detention Basin Outlet Structure Design

Outflow Hydrograph Workbook Filename:

Storm Inflow Hydrographs UD-Detention, Version 3.07 (February 2017)

The user can override the calculated inflow hydrographs from this workbook with inflow hydrographs developed in a separate program.

	SOURCE	WORKBOOK	WORKBOOK	WORKBOOK	WORKBOOK	WORKBOOK	WORKBOOK	WORKBOOK	WORKBOOK	#N/A
Time Interval	TIME	WQCV [cfs]	EURV [cfs]	2 Year [cfs]	5 Year [cfs]	10 Year [cfs]	25 Year [cfs]	50 Year [cfs]	100 Year [cfs]	500 Year [cfs]
5.45 min	0:00:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A
	0:05:27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A
Hydrograph	0:10:54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A
Constant	0:16:21	0.14	0.15	0.10	0.15	0.42	1.32	2.04	3.22	#N/A
0.917	0:21:48	0.37	0.41	0.26	0.40	1.14	3.59	5.63	9.05	#N/A
	0:27:15	0.95	1.05	0.67	1.04	2.92	9.23	14.44	23.23	#N/A
	0:32:42	2.60	2.88	1.83	2.86	8.02	25.34	39.62	63.64	#N/A
	0:38:09	3.04	3.38	2.14	3.35	9.52	30.62	48.36	79.50	#N/A
	0:43:36	2.89	3.21	2.03	3.18	9.08	29.33	46.41	76.83	#N/A
	0:49:03	2.63	2.92	1.84	2.89	8.27	26.69	42.23	70.12	#N/A
	0:54:30	2.33	2.59	1.63	2.57	7.38	23.97	38.01	63.20	#N/A
	0:59:57	2.00	2.22	1.39	2.20	6.37	20.84	33.18	55.39	#N/A
	1:05:24	1.75	1.94	1.22	1.92	5.55	18.12	28.93	48.41	#N/A
	1:10:51	1.58	1.76	1.10	1.74	5.03	16.42	26.16	43.61	#N/A
	1:16:18	1.29	1.43	0.90	1.42	4.15	13.69	21.88	36.66	#N/A
	1:21:45	1.04	1.16	0.72	1.15	3.39	11.30	18.10	30.42	#N/A
	1:27:12	0.78	0.88	0.54	0.87	2.61	8.86	14.29	24.20	#N/A
	1:32:39	0.57	0.64	0.39	0.63	1.94	6.75	10.99	18.76	#N/A
	1:38:06	0.42	0.47	0.29	0.46	1.41	4.97	8.17	14.08	#N/A
	1:43:33	0.33	0.37	0.23	0.36	1.09	3.77	6.15	10.51	#N/A
	1:49:00	0.27	0.30	0.19	0.30	0.90	3.07	4.97	8.42	#N/A
	1:54:27	0.23	0.26	0.16	0.26	0.76	2.59	4.18	7.08	#N/A
	1:59:54	0.20	0.23	0.14	0.23	0.67	2.26	3.65	6.15	#N/A
	2:05:21	0.18	0.21	0.13	0.20	0.60	2.03	3.26	5.49	#N/A
	2:10:48	0.17	0.19	0.12	0.19	0.56	1.86	2.99	5.02	#N/A
	2:16:15	0.13	0.14	0.09	0.14	0.41	1.37	2.22	3.77	#N/A
	2:21:42	0.09	0.10	0.06	0.10	0.30	1.00	1.61	2.73	#N/A
	2:27:09	0.07	0.07	0.05	0.07	0.22	0.74	1.19	2.02	#N/A
	2:32:36	0.05	0.05	0.03	0.05	0.16	0.55	0.88	1.50	#N/A
	2:38:03	0.03	0.04	0.02	0.04	0.12	0.40	0.64	1.10	#N/A
	2:43:30	0.02	0.03	0.02	0.03	0.08	0.28	0.46	0.79	#N/A
	2:48:57	0.02	0.02	0.01	0.02	0.06	0.21	0.34	0.58	#N/A
	2:54:24	0.01	0.01	0.01	0.01	0.04	0.14	0.23	0.40	#N/A
	2:59:51	0.01	0.01	0.00	0.01	0.02	0.09	0.15	0.26	#N/A
	3:05:18	0.00	0.00	0.00	0.00	0.01	0.05	0.08	0.15	#N/A
	3:10:45	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.07	#N/A
	3:16:12	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	#N/A
	3:21:39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A
	3:27:06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A
	3:32:33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A
	3:38:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A
	3:43:27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A
	3:48:54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A
	3:54:21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A
	3:59:48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A
	4:05:15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A
	4:10:42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A
	4:16:09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A
	4:21:36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A
	4:27:03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A
	4:32:30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A
	4:37:57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A
	4:43:24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A
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	4:54:18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A
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	5:21:33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A
	5:27:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A
	5:32:27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A
	5:37:54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A
	5:43:21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A
	5:48:48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A
	5:54:15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A
	5:59:42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A
	6:05:09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A
	6:10:36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A
	6:16:03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A
	6:21:30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A
	6:26:57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A
	6:32:24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	#N/A

Detention Basin Outlet Structure Design

UD-Detention, Version 3.07 (February 2017)

Summary Stage-Area-Volume-Discharge Relationships

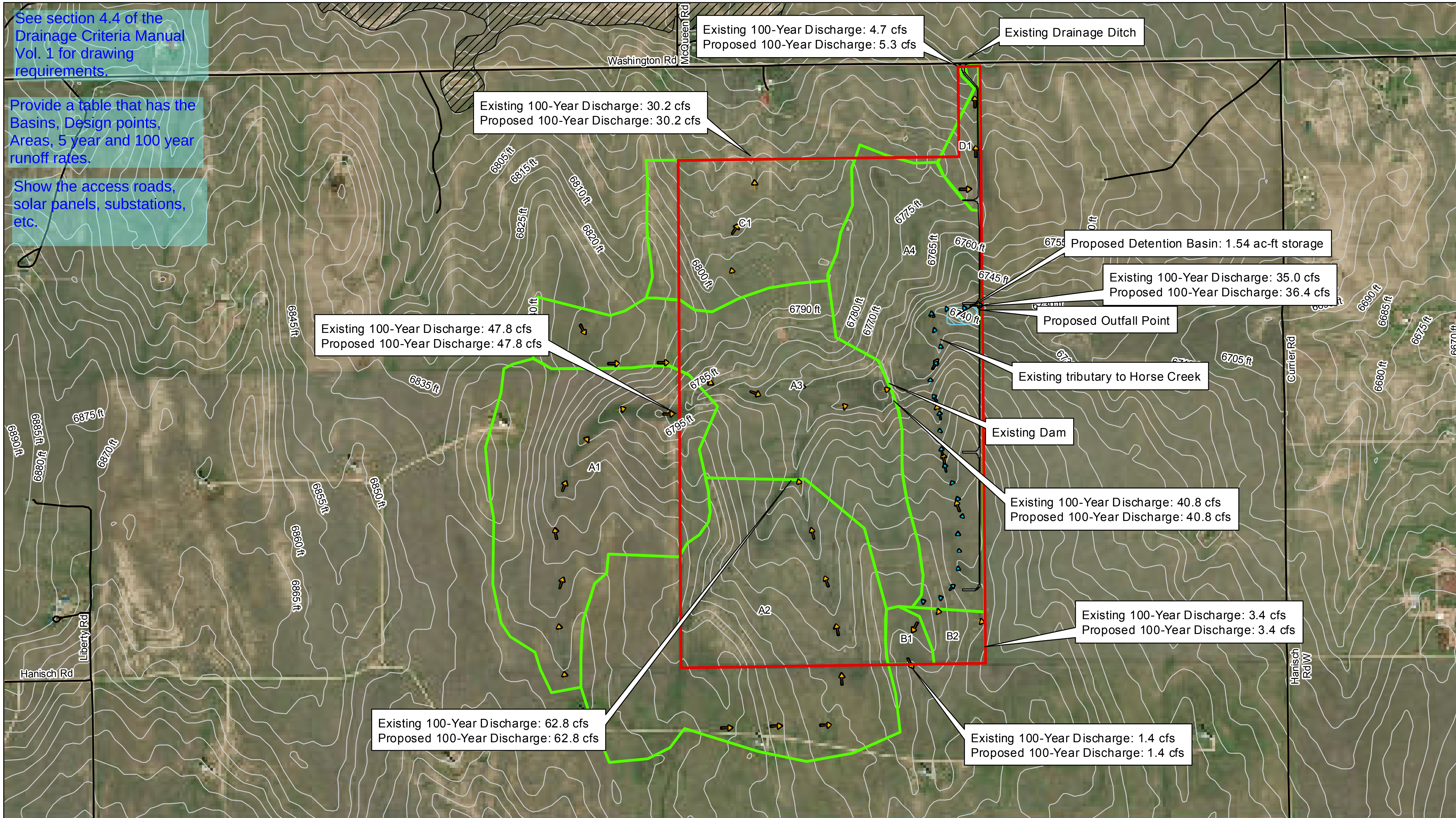
The user can create a summary S-A-V-D by entering the desired stage increments and the remainder of the table will populate automatically.

The user should graphically compare the summary S-A-V-D table to the full S-A-V-D table in the chart to confirm it captures all key transition points.

Stage - Storage Description	Stage [ft]	Area [ft^2]	Area [acres]	Volume [ft^3]	Volume [ac-ft]	Total Outflow [cfs]

For best results, include the stages of all grade slope changes (e.g. ISV and Floor) from the S-A-V table on Sheet 'Basin'.

Also include the inverts of all outlets (e.g. vertical orifice, overflow grate, and spillway, where applicable).



Data Source(s): Westwood (2019); ESRI WMS World Streets Basemap Imagery (Accessed 2019).

Legend

Project Boundary	Gravel Roads	5' Contours
County Boundary	Drainage Areas	Existing Road
Flow Path	Detention Basin	Time of Concentration Path
FEMA Zone A	FEMA Zone AE	

N

0 800 Feet

Westwood

Toll Free (888) 937-5150 westwoodps.com
Westwood Professional Services, Inc.

Grazing Yak Solar

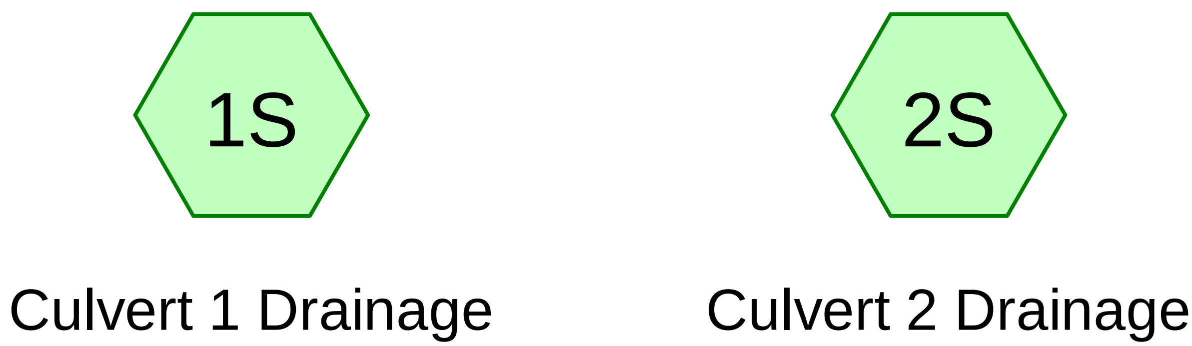
El Paso County, Colorado

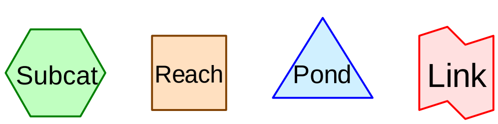
Drainage Plan

April 23, 2019

Appendix B

Hydraulic Calculations





Routing Diagram for 2019-03-21_GrazingYak_Culverts
Prepared by Westwood Professional Services, Inc., Printed 3/21/2019
HydroCAD® 10.00-19 s/n 10449 © 2016 HydroCAD Software Solutions LLC

Area Listing (selected nodes)

Area (acres)	CN	Description (subcatchment-numbers)
502.500	62	(1S, 2S)
502.500	**62**	**TOTAL AREA**

Soil Listing (selected nodes)

Area (acres)	Soil Group	Subcatchment Numbers
0.000	HSG A	
0.000	HSG B	
0.000	HSG C	
0.000	HSG D	
502.500	Other	1S, 2S
502.500		**TOTAL AREA**

Ground Covers (selected nodes)

HSG-A (acres)	HSG-B (acres)	HSG-C (acres)	HSG-D (acres)	Other (acres)	Total (acres)	Ground Cover	Subcatchment Numbers
0.000	0.000	0.000	0.000	502.500	502.500		1S, 2S
0.000	**0.000**	**0.000**	**0.000**	**502.500**	**502.500**	**TOTAL AREA**	

Time span=5.00-20.00 hrs, dt=0.05 hrs, 301 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 1S: Culvert 1 Drainage Runoff Area=374.000 ac 0.00% Impervious Runoff Depth>0.24"
Flow Length=5,400' Slope=0.0206 '/' Tc=140.4 min CN=62 Runoff=27.01 cfs 7.473 af

Subcatchment 2S: Culvert 2 Drainage Runoff Area=128.500 ac 0.00% Impervious Runoff Depth>0.25"
Flow Length=3,000' Slope=0.0230 '/' Tc=83.0 min CN=62 Runoff=13.71 cfs 2.677 af

Total Runoff Area = 502.500 ac Runoff Volume = 10.150 af Average Runoff Depth = 0.24"
100.00% Pervious = 502.500 ac 0.00% Impervious = 0.000 ac

Summary for Subcatchment 1S: Culvert 1 Drainage

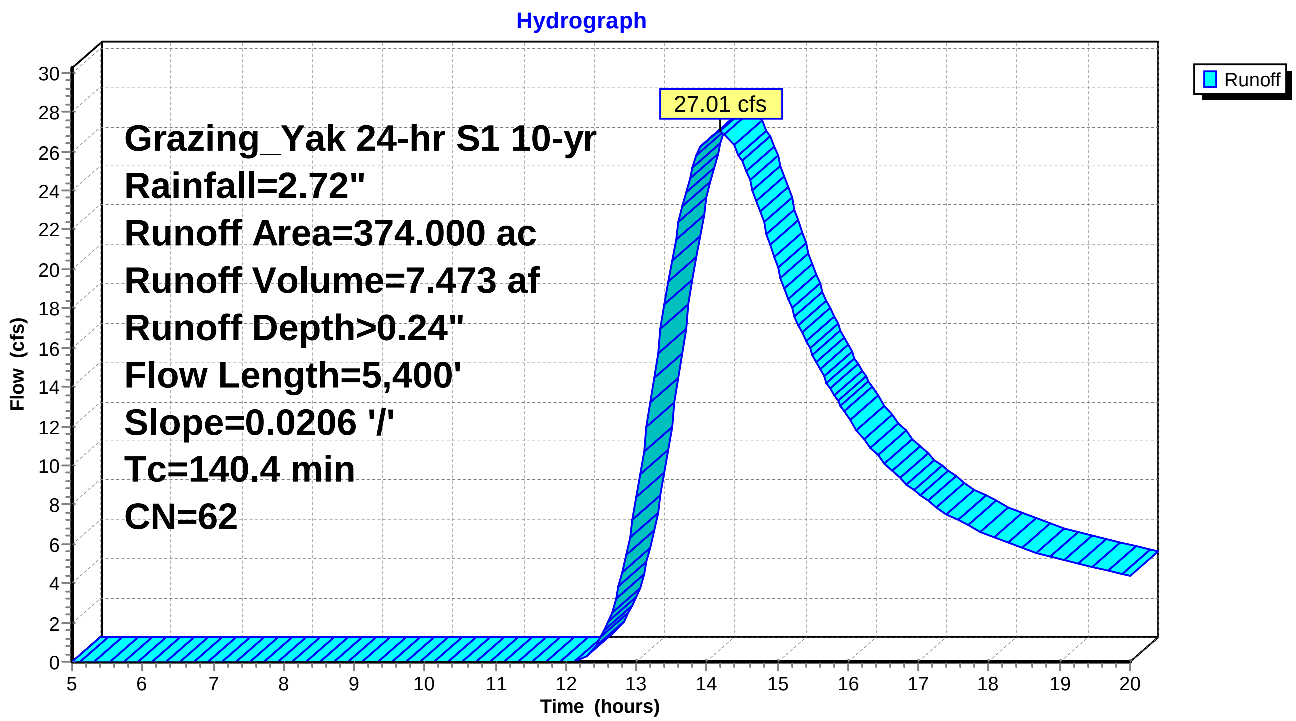
Runoff = 27.01 cfs @ 14.18 hrs, Volume= 7.473 af, Depth> 0.24"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Grazing_Yak 24-hr S1 10-yr Rainfall=2.72"

	Area (ac)	CN	Description
*	374.000	62	
	374.000		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
140.4	5,400	0.0206	0.64		**Lag/CN Method,**

Subcatchment 1S: Culvert 1 Drainage



Summary for Subcatchment 2S: Culvert 2 Drainage

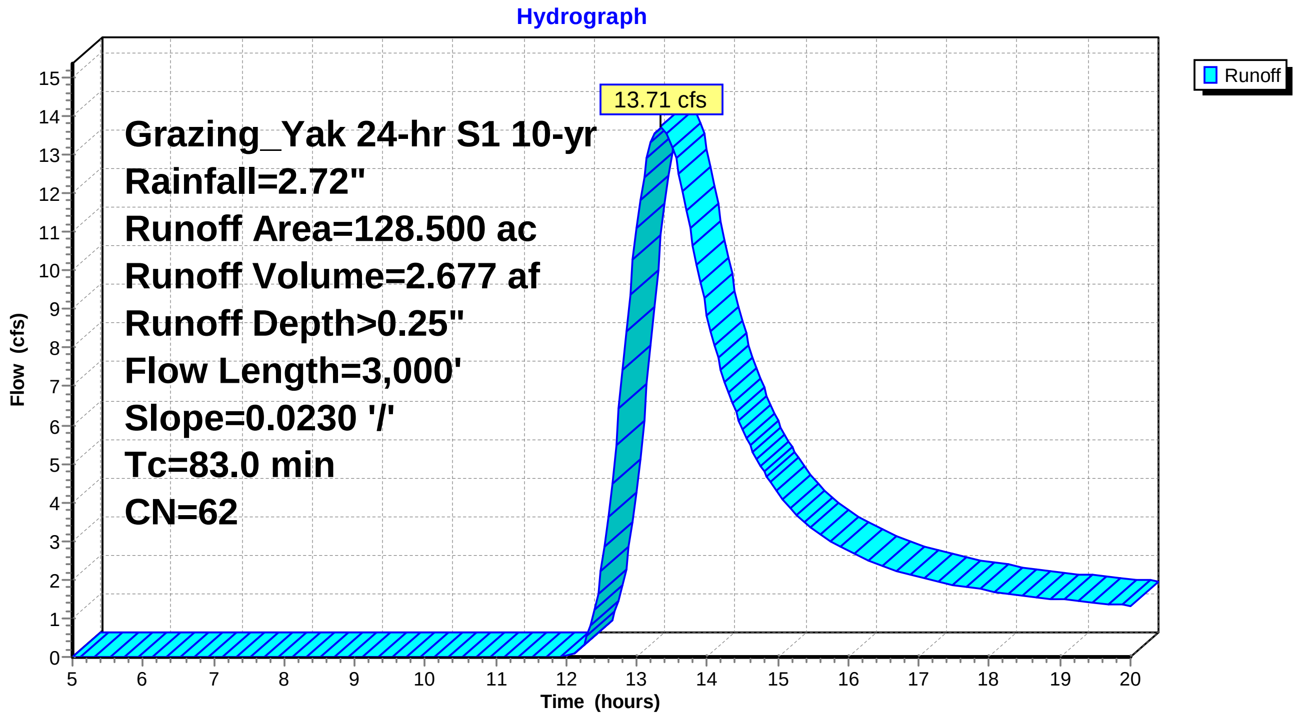
Runoff = 13.71 cfs @ 13.34 hrs, Volume= 2.677 af, Depth> 0.25"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-20.00 hrs, dt= 0.05 hrs
Grazing_Yak 24-hr S1 10-yr Rainfall=2.72"

	Area (ac)	CN	Description
*	128.500	62	
	128.500		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
83.0	3,000	0.0230	0.60		**Lag/CN Method,**

Subcatchment 2S: Culvert 2 Drainage



Culvert Design Report
Culvert 1

Peak Discharge Method: User-Specified

Design Discharge	27.01 cfs	Check Discharge	0.00 cfs

Grades Model: Inverts

Invert Upstream	6,734.00 ft	Invert Downstream	6,733.75 ft
Length	50.00 ft	Slope	0.005000 ft/ft
Drop	0.25 ft		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater

Tailwater Elevation	N/A ft

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-30 inch Circular	27.01 cfs	6,737.47 ft	7.26 ft/s
	Trial-2	2-24 inch Circular	27.01 cfs	6,736.50 ft	6.12 ft/s
	Trial-3	4-18 inch Circular	27.01 cfs	6,736.10 ft	5.36 ft/s

Culvert Design Report
Culvert 1

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A ft	Storm Event	Design
Computed Headwater Elevation	6,737.47 ft	Discharge	27.01 cfs
Headwater Depth/Height	1.39	Tailwater Elevation	N/A ft
Inlet Control HW Elev.	6,737.14 ft	Control Type	Outlet Control
Outlet Control HW Elev.	6,737.47 ft		

Grades			
Upstream Invert	6,734.00 ft	Downstream Invert	6,733.75 ft
Length	50.00 ft	Constructed Slope	0.005000 ft/ft

Hydraulic Profile			
Profile	CompositeM2PressureProfile	Depth, Downstream	1.77 ft
Slope Type	Mild	Normal Depth	N/A ft
Flow Regime	Subcritical	Critical Depth	1.77 ft
Velocity Downstream	7.26 ft/s	Critical Slope	0.020412 ft/ft

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	2.50 ft
Section Size	30 inch	Rise	2.50 ft
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	6,737.47 ft	Upstream Velocity Head	0.47 ft
Ke	0.90	Entrance Loss	0.42 ft

Inlet Control Properties			
Inlet Control HW Elev.	6,737.14 ft	Flow Control	Unsubmerged
Inlet Type	Projecting	Area Full	4.9 ft²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Culvert 1

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	N/A ft	Storm Event	Design
Computed Headwater Elevation	6,736.50 ft	Discharge	27.01 cfs
Headwater Depth/Height	1.25	Tailwater Elevation	N/A ft
Inlet Control HW Elev.	6,736.26 ft	Control Type	Outlet Control
Outlet Control HW Elev.	6,736.50 ft		

Grades

Upstream Invert	6,734.00 ft	Downstream Invert	6,733.75 ft
Length	50.00 ft	Constructed Slope	0.005000 ft/ft

Hydraulic Profile

Profile	M2	Depth, Downstream	1.32 ft
Slope Type	Mild	Normal Depth	N/A ft
Flow Regime	Subcritical	Critical Depth	1.32 ft
Velocity Downstream	6.12 ft/s	Critical Slope	0.020208 ft/ft

Section

Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	2.00 ft
Section Size	24 inch	Rise	2.00 ft
Number Sections	2		

Outlet Control Properties

Outlet Control HW Elev.	6,736.50 ft	Upstream Velocity Head	0.29 ft
Ke	0.90	Entrance Loss	0.26 ft

Inlet Control Properties

Inlet Control HW Elev.	6,736.26 ft	Flow Control	Unsubmerged
Inlet Type	Projecting	Area Full	6.3 ft²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Culvert 1

Design:Trial-3

Solve For: Headwater Elevation

Culvert Summary

Allowable HW Elevation	N/A ft	Storm Event	Design
Computed Headwater Elevation	6,736.10 ft	Discharge	27.01 cfs
Headwater Depth/Height	1.40	Tailwater Elevation	N/A ft
Inlet Control HW Elev.	6,735.73 ft	Control Type	Outlet Control
Outlet Control HW Elev.	6,736.10 ft		

Grades

Upstream Invert	6,734.00 ft	Downstream Invert	6,733.75 ft
Length	50.00 ft	Constructed Slope	0.005000 ft/ft

Hydraulic Profile

Profile	CompositeM2PressureProfile	Depth, Downstream	1.01 ft
Slope Type	Mild	Normal Depth	N/A ft
Flow Regime	Subcritical	Critical Depth	1.01 ft
Velocity Downstream	5.36 ft/s	Critical Slope	0.022567 ft/ft

Section

Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	1.50 ft
Section Size	18 inch	Rise	1.50 ft
Number Sections	4		

Outlet Control Properties

Outlet Control HW Elev.	6,736.10 ft	Upstream Velocity Head	0.23 ft
Ke	0.90	Entrance Loss	0.20 ft

Inlet Control Properties

Inlet Control HW Elev.	6,735.73 ft	Flow Control	Unsubmerged
Inlet Type	Projecting	Area Full	7.1 ft²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Culvert 2

Peak Discharge Method: User-Specified			
Design Discharge	13.71 cfs	Check Discharge	0.00 cfs

Grades Model: Inverts			
Invert Upstream	6,769.00 ft	Invert Downstream	6,768.75 ft
Length	50.00 ft	Slope	0.005000 ft/ft
Drop	0.25 ft		

Headwater Model: Unspecified

Tailwater Conditions: Constant Tailwater	
Tailwater Elevation	N/A ft

	Name	Description	Discharge	HW Elev.	Velocity
x	Trial-1	1-24 inch Circular	13.71 cfs	6,771.54 ft	6.16 ft/s
	Trial-2	2-18 inch Circular	13.71 cfs	6,771.14 ft	5.40 ft/s

Culvert Design Report
Culvert 2

Design:Trial-1

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A ft	Storm Event	Design
Computed Headwater Elevation	6,771.54 ft	Discharge	13.71 cfs
Headwater Depth/Height	1.27	Tailwater Elevation	N/A ft
Inlet Control HW Elev.	6,771.29 ft	Control Type	Outlet Control
Outlet Control HW Elev.	6,771.54 ft		

Grades			
Upstream Invert	6,769.00 ft	Downstream Invert	6,768.75 ft
Length	50.00 ft	Constructed Slope	0.005000 ft/ft

Hydraulic Profile			
Profile	M2	Depth, Downstream	1.33 ft
Slope Type	Mild	Normal Depth	N/A ft
Flow Regime	Subcritical	Critical Depth	1.33 ft
Velocity Downstream	6.16 ft/s	Critical Slope	0.020361 ft/ft

Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	2.00 ft
Section Size	24 inch	Rise	2.00 ft
Number Sections	1		

Outlet Control Properties			
Outlet Control HW Elev.	6,771.54 ft	Upstream Velocity Head	0.30 ft
Ke	0.90	Entrance Loss	0.27 ft

Inlet Control Properties			
Inlet Control HW Elev.	6,771.29 ft	Flow Control	Unsubmerged
Inlet Type	Projecting	Area Full	3.1 ft²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Culvert Design Report
Culvert 2

Design:Trial-2

Solve For: Headwater Elevation

Culvert Summary			
Allowable HW Elevation	N/A ft	Storm Event	Design
Computed Headwater Elevation	6,771.14 ft	Discharge	13.71 cfs
Headwater Depth/Height	1.43	Tailwater Elevation	N/A ft
Inlet Control HW Elev.	6,770.75 ft	Control Type	Outlet Control
Outlet Control HW Elev.	6,771.14 ft		

Grades			
Upstream Invert	6,769.00 ft	Downstream Invert	6,768.75 ft
Length	50.00 ft	Constructed Slope	0.005000 ft/ft

Hydraulic Profile			
Profile	CompositeM2PressureProfile	Depth, Downstream	1.01 ft
Slope Type	Mild	Normal Depth	N/A ft
Flow Regime	Subcritical	Critical Depth	1.01 ft
Velocity Downstream	5.40 ft/s	Critical Slope	0.022772 ft/ft

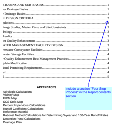
Section			
Section Shape	Circular	Mannings Coefficient	0.024
Section Material	CMP	Span	1.50 ft
Section Size	18 inch	Rise	1.50 ft
Number Sections	2		

Outlet Control Properties			
Outlet Control HW Elev.	6,771.14 ft	Upstream Velocity Head	0.23 ft
Ke	0.90	Entrance Loss	0.21 ft

Inlet Control Properties			
Inlet Control HW Elev.	6,770.75 ft	Flow Control	Unsubmerged
Inlet Type	Projecting	Area Full	3.5 ft²
K	0.03400	HDS 5 Chart	2
M	1.50000	HDS 5 Scale	3
C	0.05530	Equation Form	1
Y	0.54000		

Markup Summary

Steve Kuehster (19)



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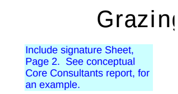
Include a section "Four Step Process" in the Report contents section.



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Date: 5/15/2019 7:58:24 AM
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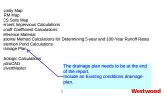
Include signature Sheet, Page 2. See conceptual Core Consultants report, for an example.



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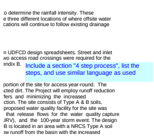
The drainage plan needs to be at the end of the report.
Include an Existing conditions drainage plan.



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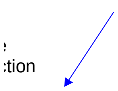
Include a section "4 step process", list the steps, and use similar language as used

---



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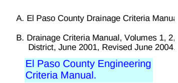

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El Paso County Engineering Criteria Manual.

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Date: 5/23/2019 2:38:04 PM
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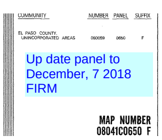
Up date panel to December, 7 2018 FIRM



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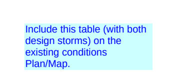

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Include this table (with both design storms) on the existing conditions Plan/Map.

See comment previous page.

'all Depth-Duration-Frequency (1-hr) = 2.52

Subject: text box
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Author: Steve Kuehster
Date: 5/23/2019 2:50:12 PM
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See comment previous page.

Include this table (with both design storms) on the Proposed drainage Plan/Map.

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Page Label: 25
Author: Steve Kuehster
Date: 5/23/2019 3:00:13 PM
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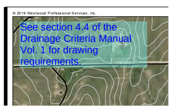
Include this table (with both design storms) on the Proposed drainage Plan/Map.

Subject: text box
Page Label: 36
Author: Steve Kuehster
Date: 5/23/2019 3:16:37 PM
Color:

Show the access roads, solar panels, substations, etc.



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Author: Steve Kuehster
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See section 4.4 of the Drainage Criteria Manual Vol. 1 for drawing requirements.

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Author: Steve Kuehster
Date: 5/23/2019 3:19:50 PM
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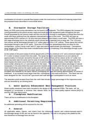
Provide a table that has the Basins, Design points, Areas, 5 year and 100 year runoff rates.



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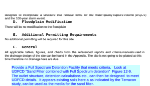

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Author: Steve Kuehster
Date: 5/24/2019 11:51:12 AM
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Provide a Full Spectrum Detention Facility that meets criteria, Look at UDFCD "Sand Filter combined with Full Spectrum detention" Figure 12-9.
The outlet structure, detention calculations etc., can then be designed to meet UDFCD details. It appears existing soils here a as indicated by the Terracon study, can be used as the media for the sand filter.

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nes 1, 2, & 3
ne 2004.

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Page Label: 8
Author: Steve Kuehster
Date: 5/24/2019 11:52:13 AM
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2004.

& 3, Urban Drain
2017

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Page Label: 8
Author: Steve Kuehster
Date: 5/24/2019 11:52:35 AM
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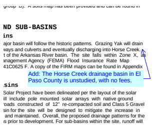
2017


ND SUB-BASINS
ins
ajor basin will follow the historic patterns. Grazing Yak will drain
ways and culverts and eventually discharging into Horse Creek.
t of the Arkansas River basin. The site falls within Zone X, as
anagement Agency (FEMA) Flood Insurance Rate Map
41C0625 F. A copy of the FIRM maps can be found in Appendix
sins
Solar Project have been delineated per the layout of the solar
ill include pole mounted solar arrays with native ground
roads constructed of 12" re-compacted soil and Class 5 Gravel
sin for the site will be designed to mitigate the increase in
and maintained. Overall, the proposed drainage patterns for the
s prior to development. For sub-basins within the site, runoff will

Subject: arrow & box
Page Label: 4
Author: Steve Kuehster
Date: 5/24/2019 12:02:28 PM
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Add: The Horse Creek drainage basin in El Paso County is unstudied, with no fees.