

NOTE: THIS IS AN OLD VERSION OF THE REPORT.

**FINAL DRAINAGE REPORT  
FOR  
VOLLMER SUBSTATION  
EL PASO COUNTY, COLORADO**

**JUNE 2019**

Prepared For:

**MOUNTAIN VIEW ELECTRIC ASSOCIATION**

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TNE Job No. 1845.00

County Job No. #####



PPR2147

**FINAL DRAINAGE REPORT  
FOR  
VOLLMER SUBSTATION  
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## **CERTIFICATION STATEMENT:**

### **Engineers Statement**

This attached drainage plan and report were prepared under my direction and supervision and are correct to the best of my knowledge and belief. Said drainage report has been prepared according to the criteria established by the County for drainage reports and said report is in conformity with the master plan of the drainage basin. I accept responsibility for any liability caused by any negligent acts, errors or omissions on my part in preparing this report.

\_\_\_\_\_  
L DUCETT, P.E. 32339

\_\_\_\_\_  
Seal

### **Developers Statements**

I, Mountain View Electric Association, the developer have read and will comply with all of the requirements specified in this drainage report and plan.

### **Mountain View Electric Association**

Business Name

By: \_\_\_\_\_  
Title: \_\_\_\_\_  
Address: \_\_\_\_\_  
\_\_\_\_\_

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El Paso County Approval:

Filed in accordance with the requirements of the Drainage Criteria Manual, Volumes 1 & 2, El Paso County Engineering Criteria Manual and Land Development Code as amended.

\_\_\_\_\_  
Jennifer Irvine,  
County Engineer / ECM Administrator

\_\_\_\_\_  
Date

Conditions:

# **FINAL DRAINAGE REPORT FOR VOLLMER SUBSTATION EL PASO COUNTY, COLORADO**

## **PURPOSE**

The purpose of this Final Drainage Report is to identify and analyze the proposed drainage patterns, determine proposed runoff quantities, size drainage structures for conveyance of developed runoff, and present solutions to drainage impacts on-site and off-site resulting from this development. In an effort to protect receiving water and as part of the “four step process to minimize adverse impacts of urbanization” this site was analyzed in the following manner:

1. Reduce Runoff- The new improvements to the site, which consist of adding a gravel yard and access road will be routed to a proposed private sand filter. By capturing these flows in the sand filter the developed runoff will be detained and reduce the quantity of downstream runoff. Additionally, existing native grass areas are being retained that will act as natural grass buffers.
2. Stabilize Drainageways - By reducing the rate of runoff the site is helping to stabilize the downstream waterways. All of the drainageways proposed onsite are grass swales.
3. Provide Water Quality Capture Volume (WQCV)- The sand filter will detain the developed flows, allow a portion to infiltrate, and slowly release the remaining volume, thereby allowing solids and contaminants to settle out and stopping downstream transport.
4. Consider Need for Industrial and Commercial BMPs- As this development will not include outdoor storage or the potential for the introduction of contaminants to the County’s MS4, since it is not an industrial or commercial site, no source controls are proposed or necessary.

## **GENERAL DESCRIPTION**

This Final Drainage Report is an analysis of approximately 4.96 acres of undeveloped land in the northwest part of El Paso County, approximately 3,600 feet east of the north end of Mohawk Road. This site is being developed by our client as an electrical substation. The development will also include constructing a gravel access road. The site is located in the southeast quarter of Section 34, Township 12 South, Range 65 West of the 6<sup>th</sup> Principal Meridian currently within El Paso County, Colorado. The site is bounded on all sides by undeveloped open space (rural residential). The site is contained within the Sand Creek Basin.

Please move this section under its own header called the four step process.

Soils for this project are delineated by the map in the appendix as Columbine gravelly sandy loam (19), 0 to 3 percent slopes. Soils in the study area are shown as mapped by S.C.S. in the “Soils Survey of El Paso County Area” and contains soils of Hydrologic Group A.

## **FLOODPLAIN STATEMENT**

No portion of this site is within a designated F.E.M.A. floodplain, as determined by Flood Insurance Rate Map No. 08041C0535 G, dated December 7, 2018 (see appendix).

## **EXISTING DRAINAGE CONDITIONS**

The site is currently undeveloped and is open space. The site consists mostly of natural vegetative grass and weeds, with some small areas of bare earth. The site has been broken down into two existing basins, one on the northwest half of the site and the other on the southeast half of the site. An upgradient offsite basin consists of gently sloping plains appears to extend over one mile upgradient of the site. Another offsite basin partially drains into an existing swale that flows onto the site from the east.

Offsite basin OS-1's 138 acres consists primarily of undeveloped open space, with a small number of rural residences. Based on the USGS topo map, runoff sheet flows into several channels and flows south onto the site; however, the detailed topographic survey of the site does not show any channels entering the site on the north side. Based on the survey, runoff ( $Q_{10}=20$  cfs) sheet flows onto the site from the north, at Design Point Z. Runoff calculations for this basin were performed using the Soil Conservation Service Hydrograph Method due to the size of the basin.

Offsite basin OS-2's 79 acres consists primarily of undeveloped open space, with a small number of rural residences. Runoff ( $Q_5=7.1$  cfs and  $Q_{100}=43.7$  cfs) sheet and channel flows to the south and along the east side of the site. A small existing swale will direct some runoff from this basin onto the southeast corner of the site as Design Point Y. The maximum capacity of this existing swale is 36.6 cfs.

There are basins that not being captured by the proposed ponds. Explain in the narrative how WQ is being addressed for each basin. Possible exclusions include I.7.1.B.7 (land disturbance to undeveloped land that will remain undeveloped) and/or I.7.1.C.1 (which allows for 20% not to exceed 1 acre of the applicable development site area to not be captured). All other basins/areas that are not applicable to exclusions will need to be routed to the sand filter or to a secondary PBMP (like runoff reduction).

Basin EX-A's 2.77 acres consists of undeveloped open space. Runoff ( $Q_5=0.9$  cfs and  $Q_{100}=6.4$  cfs) sheet flows to the southwest corner of the site, and may channelize during heavier storm events, to Design Point A.

Basin EX-B's 2.16 acres consists of undeveloped open space. Runoff ( $Q_5=0.7$  cfs and  $Q_{100}=5.0$  cfs) sheet flows to the south edge of the site, before entering an existing shallow onsite swale and flowing a short distance west to Design Point B.

## **PROPOSED DRAINAGE CONDITIONS**

Runoff in the developed conditions will largely follow the historic drainage patterns with the exceptions of diverting upgradient runoff around the proposed yard and adding a sand filter to detain and treat the runoff from the proposed substation yard. For analysis the site has been broken down into six onsite basins (PR-1, PR-2, PR-3, PR-4, PR-5, PR-6) and three offsite basins (PR-7, PR-8, PR-9) for the proposed access road. Additionally, there are two offsite upgradient basins (OS-1 and OS-2). A small berm has been proposed along the north side of the site to prevent upgradient surface runoff from flowing onto the site and the substation yard. Below is a description of the runoff in the developed conditions and how it will be safely routed and treated. See appendix for calculations.

Offsite basin OS-1's 138 acres consists primarily of undeveloped open space, with a small number of rural residences. Bases on the USGS topo map, runoff sheet flows into several channels and flows south onto the site; however, the detailed topographic survey of the site does not show any channels entering the site on the north side. Based on the survey, runoff ( $Q_{10}=20$  cfs) will sheet flow to the north edge of the site where a proposed berm with stop southernly flow until the runoff reaches the west side of the site and resumes its southernly path, at Design Point Z. Runoff calculations for this basin were performed using the Soil Conservation Service Hydrograph Method due to the size of the basin.

Offsite basin OS-2's 79 acres consists primarily of undeveloped open space, with a small number of rural residences. Runoff ( $Q_5=7.1$  cfs and  $Q_{100}=43.7$  cfs) sheet and channel flows to the south and along the east side of the site. A small existing swale will direct some runoff from this basin

onto the southeast corner of the site as Design Point Y. The maximum capacity of this existing swale is 36.6 cfs. No modifications to the runoff patterns of this basin have been proposed.

Basin PR-1 (0.42 acres;  $Q_5=0.1$  cfs and  $Q_{100}=0.7$  cfs) includes the portion of the site north of the proposed substation yard and a section of swale channels runoff around the west side of the substation yard. Drainage in this basin sheet flows into a proposed grass swale before being discharged into Basin PR-5 at Design Point 1.

Basin PR-2 (1.70 acres;  $Q_5=1.6$  cfs and  $Q_{100}=4.4$  cfs) includes the proposed substation yard and the pond / sand filter area to the south of the yard. The yard and access road will be surfaced with gravel and the pond area will be surfaced with native grasses. Drainage in this basin sheet flows to the south center of the yard and into the pond area and from the access road into the pond area. Once in the pond area, runoff will flow west to the sand filter, and eventually discharge through a culvert at Design Point 3. The sand filter has been sized for water quality control volume only; however, the pond area has been graded to allow for some additional water storage in case of flood conditions.

Basin PR-3 (0.15 acres;  $Q_5=0.1$  cfs and  $Q_{100}=0.4$  cfs) includes a strip on the east side of the site adjacent to the substation yard. Drainage in this basin sheet flows into a proposed grass swale before being discharged into Basin PR-4 at Design Point 3.

Basin PR-4 (1.43 acres;  $Q_5=0.4$  cfs and  $Q_{100}=2.4$  cfs) includes the east edge of the site and a large area on the south half of the site. Drainage in this basin sheet flows into an existing natural grass swale (EXS1) before flowing west a short distance and being discharged through a culvert into Basin PR-5 at Design Point 4. The combined flows at Design Point 4 are  $Q_5=8.6$  cfs and  $Q_{100}=36.6$  cfs. Note: The maximum capacity of this existing swale is 36.6 cfs, which limits the flow at Design Point 4. Any runoff beyond the channel capacity will continue flowing to the south out of the basin. This basin includes existing and proposed native grasses that can serve as natural grass buffers. The majority of this basin has no proposed modifications from the existing conditions.

Basin PR-5 (1.07 acres;  $Q_5=0.4$  cfs and  $Q_{100}=3.0$  cfs) includes the west side of the site and most of the area to the west of the substation yard. Drainage in this basin sheet flows mostly south before collecting in a natural wide channel at Design Point 5. There is also a small existing swale (EXS1) that enters the south end of basin PR-5 from the east. Note: The maximum capacity of this existing swale EXS1 is 36.6 cfs, which limits the flow entering the basin at Design Point 4. The combined flows at Design Point 5 (from basins OS-2, PR-1, PR-2, PR-3, PR-4, and PR-5) are  $Q_5=9.7$  cfs and  $Q_{100}=47.5$  cfs. This basin includes existing and proposed native grasses that can serve as natural grass buffers. The majority of this basin has no proposed modifications from the existing conditions.

Basin PR-6 (0.06 acres;  $Q_5=0.03$  cfs and  $Q_{100}=0.2$  cfs) includes a strip along the southern edge of the site. Drainage in this basin sheet flows south off the site at Design Point 6. This basin includes existing and proposed native grasses that can serve as natural grass buffers. The entirety of this basin has no proposed modifications from the existing conditions.

Basin PR-7 (0.26 acres;  $Q_5=0.3$  cfs and  $Q_{100}=1.1$  cfs) includes a section of the proposed access road near the south west corner of the site that drains to the north. Drainage in this basin sheet flows to the north at Design Point 7, then collects at a point near the center of the basin, before flowing south under the access road through a culvert.

Basin PR-8 (0.58 acres;  $Q_5=0.4$  cfs and  $Q_{100}=2.1$  cfs) includes a section of the proposed access road near the south west corner of the site that drains to the south. Drainage in this basin sheet flows to the south at Design Point 8 onto undeveloped land.

Basin PR-9 (3.09 acres;  $Q_5=4.1$  cfs and  $Q_{100}=13.6$  cfs) includes a section of the proposed access road as it travels away from the site that drains to the south. Drainage in this basin sheet flows to the south at Design Point 9 onto undeveloped land.

Two new grass swales are proposed, both of which are along the edges of the proposed substation yard. The purpose of these swales is to direct runoff away from the proposed substation yard with the proposed flows for both swales being quite low (PRS1  $Q_{100}=0.7$  cfs and PRS2  $Q_{100}=0.4$  cfs).



Details and specs for these proposed swales are included on the Proposed Drainage Map and calculations in the appendix.

Three new culverts are proposed, one as a discharge for the sand filter and pond area, and two for transporting runoff under the proposed access road. Proposed culvert PRC1 discharges the sand filter into basin PR-2. PRC1 is a 18" diameter RCP culvert with a capacity of 14.9 cfs (Design Point 3  $Q_{100}=3.9$  cfs). Typically, this culvert will only be discharging the very low flow rate from the sand filter, but it can also accommodate flows exceeding the 100 year event. The PRC1 design includes outlet protection of 3'x5' type VL 6" riprap.

Proposed culvert PRC2 allows runoff in the existing swale (EXS1) on the south edge of the site to flow beneath the proposed access road and discharges basin PR-4 into basin PR-5. This culvert will also allow flow in EXS1 from the offsite basin OS-2 to cross the site. PRC2 is a 30" diameter RCP culvert with a capacity of 36.8 cfs (Design Point 4  $Q_{100}=36.6$  cfs). PRC2 was sized to exceed the maximum capacity of the existing swale EXS1 so that any future flow increases into this existing swale would not require an upsizing of this culvert. The PRC2 design includes outlet protection of 8'x22' type VL 9" riprap.

Proposed culvert PRC3 allows runoff to cross the proposed access road and flow to the south. PRC3 consists of 3-1.5'x2.0' reinforced concrete box culverts with a combined capacity of 58.6 cfs ( $Q_{100}=48.6$  cfs). PRC3 was sized to accommodate both the 100 year flows from the site and access road, and the maximum capacity of the existing swale EXS1. The PRC3 design includes outlet protection of 3'x6' type VL 6" riprap.

At Design Point 2 the flow ( $Q_5=1.6$  cfs and  $Q_{100}=4.4$  cfs) from the proposed substation yard (basin PR-3) is collected in a pond area and treated with a water quality sand filter. The area tributary to the sand filter is 1.70 acres, which is 63% of the 2.7 acres of the site that is being developed. Runoff in the substation yard will sheet flow south to the pond area. Portions of the surrounding access road also sheet flow into the pond area. In the pond area, runoff sheet flows to the west into the sand filter. The sand filter has a water quality storage volume of 0.06 acre-feet (required volume is 0.02 acre-feet) and the pond area has additional storage capacity for flood waters. The

pond area will be surfaced with native grasses, while the sand filter will be surface with filter sand. This sand filter was designed to be partially infiltrating. The sand filter sand surface area is 1,092 square feet and there is a 4-inch diameter underdrain running along the bottom of the sand filter that discharges into an outlet structure. The underdrain pipe will have a cap with a 0.39 inch diameter orifice in the outlet structure to provide the 40-hour water quality drain time. The 2'x2' reinforced outlet structure provides the overflow weir for the sand filter and connects to a 18" diameter RCP culvert that crosses the access road and discharges the runoff into basin PR-2. The outlet structure and culvert have been sized to accommodate 100-year events. If flood waters exceed the discharge capacity and fill the pond area volume, the pond area will overflow on the south and west sides and flow across the access road into basins PR-2 and PR-5. Due to being surrounded by access road, no formal riprap spillway is proposed. The sand filter consists of a 9-inch layer of bedding gravel (and the underdrain) on the bottom, then a 18-inch layer of filter sand, one foot of water quality volume, and one foot of freeboard.

## **HYDROLOGIC CALCULATIONS**

Hydrologic calculations were performed using the El Paso County Storm Drainage Design Criteria Manual - Volumes 1 & 2, latest editions. The Rational Method was used to estimate storm water runoff anticipated from design storms with 5-year and 100-year recurrence intervals. The Urban Drainage Criteria Manual was used to calculate the water quality volume.

## **HYDRAULIC CALCULATIONS**

Hydraulic calculations were estimated using the Manning's Formula and the methods described in the El Paso County Storm Drainage Design Criteria Manual – Volumes 1 & 2, latest editions. The pertinent data sheets are included in the appendix of this report.

One existing drainage channel is located onsite, and two proposed drainage channels have been added around the substation yard. Channel flow calculations have been included for both the existing and proposed drainage channels.

Culverts are proposed for the sand filter outfall and at two crossings of the proposed access road. Culvert design calculations have been included in the appendix.

## MAINTENANCE

The sand filter is private and therefore must be maintained by the owner (Mountain View Electric Association). The sand filter should be inspected at least twice per year and debris removed as necessary. Once per year, or as necessary to promote drainage, the filter surface should be scarified down to three to five inches. Remove the top three to five inches of filter sand as necessary to allow property drain times (typically every two to five years). After nine inches of filter sand have been removed, replace with nine inches of new filter sand (minimum sand depth is 12 inches).

The sand filters should be cleaned and checked after any significant precipitation event and at least once every three months. The proposed erosion control measures will be repaired and maintained by the property owner or owner's representative as required. Additional information on sand filter maintenance can be found in the El Paso County Drainage Manual – Volume 2.

Access to the sand filter is from the access road on three sides of the sand filter/pond area.

## CONSTRUCTION COST OPINION

### Public Reimbursable / Non-Reimbursable

Not applicable.

### Private Non Reimbursable

1. 18" RCP Culvert	70 LF	\$ 70	\$ 4,900
2. 30" RCP Culvert	55 LF	\$ 105	\$ 5,775
3. 1.5'x2.0' RC Box Culvert	150 LF	\$ 100	\$ 15,000
2. Sand Filter	1 LS	\$ 15,000	<u>\$ 15,000</u>
			<b>Total \$ 40,675</b>

## DRAINAGE FEES

The existing site is in the Sand Creek Basin. 2018 Drainage fees due prior to final plat recordation are as follows:

FEE TYPE	% IMP.	PARCEL AREA	MOD.	FEE PER IMP. AC.	SUBTOTAL
DRAINAGE FEES:	17% x	4.96 acres x	75% x	\$18,940 =	<u>\$11,978</u>
					<b>TOTAL \$11,978</b>

## SUMMARY

Development of this site will not adversely affect the surrounding developments. Proposed flows, as detailed in this report, will follow the drainage patterns outlined in this report showing how runoff will be safely routed downstream. The sand filter will provide water quality for this site. These water features will need to be periodically maintained by the owner in order to maintain their effectiveness in cleaning the discharge from the site.

PREPARED BY:  
**TERRA NOVA ENGINEERING, INC.**

L Ducett, P.E.  
 President  
 Jobs/1845.00/drainage/184500 FDR.doc

## **REFERENCE**

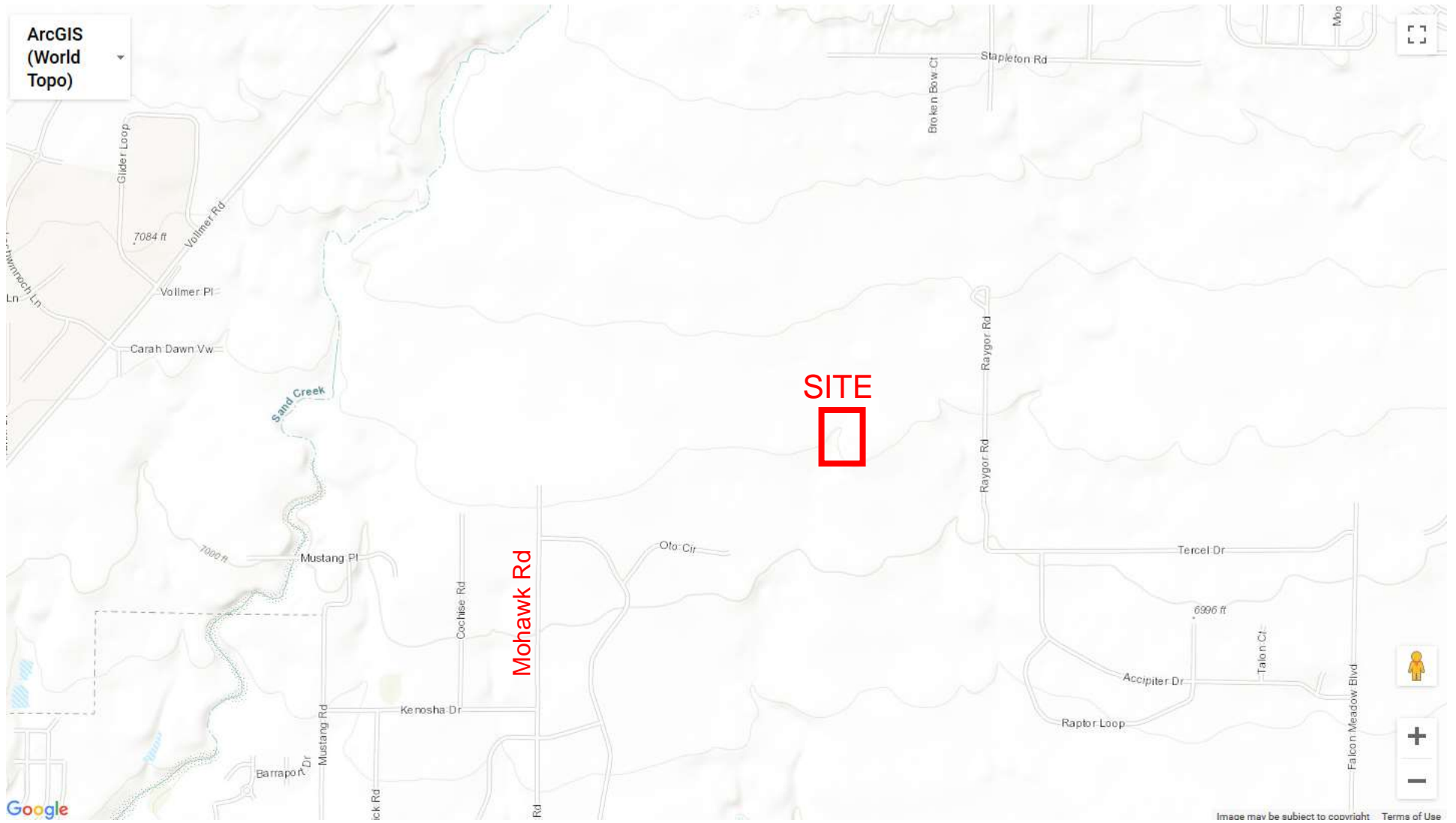
El Paso County Drainage Criteria Manual-Volumes 1 & 2, latest edition

El Paso County Board Resolution No 15-042 (Adoption of Chapter 6 and Section 3.2.1 Chapter 13 of the City of Colorado Springs Drainage Criteria Manual dated May 2014, Hydrology and Full Spectrum Detention)

SCS Soils Map for El Paso County

Federal Emergency Management Agency (FEMA) flood maps

## **VICINITY MAP**



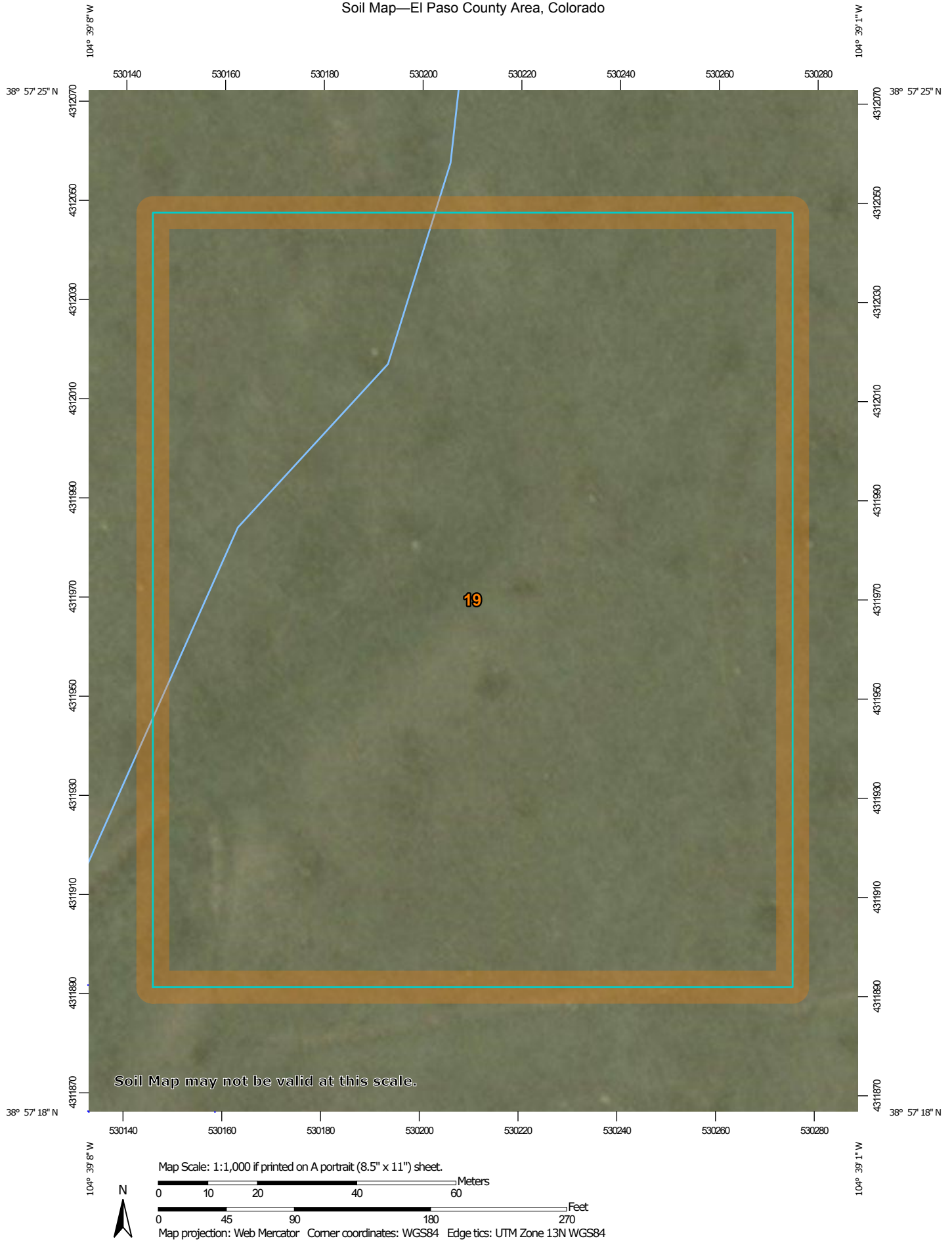
Vollmer Substation Vicinity Map






## **S.C.S. SOILS MAP**

# Soil Map—El Paso County Area, Colorado



## MAP LEGEND

### Area of Interest (AOI)

 Area of Interest (AOI)

### Soils

 Soil Map Unit Polygons

 Soil Map Unit Lines

 Soil Map Unit Points

### Special Point Features



Blowout



Borrow Pit



Clay Spot



Closed Depression



Gravel Pit



Gravelly Spot



Landfill



Lava Flow



Marsh or swamp



Mine or Quarry



Miscellaneous Water



Perennial Water



Rock Outcrop



Saline Spot



Sandy Spot



Severely Eroded Spot



Sinkhole



Slide or Slip



Sodic Spot



Spoil Area



Stony Spot



Very Stony Spot



Wet Spot



Other



Special Line Features

### 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 15, Oct 10, 2017

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

Date(s) aerial images were photographed: May 22, 2016—Mar 9, 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.

## Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
19	Columbine gravelly sandy loam, 0 to 3 percent slopes	5.0	100.0%
<b>Totals for Area of Interest</b>		<b>5.0</b>	<b>100.0%</b>

## El Paso County Area, Colorado

### 19—Columbine gravelly sandy loam, 0 to 3 percent slopes

#### Map Unit Setting

*National map unit symbol:* 367p

*Elevation:* 6,500 to 7,300 feet

*Mean annual precipitation:* 14 to 16 inches

*Mean annual air temperature:* 46 to 50 degrees F

*Frost-free period:* 125 to 145 days

*Farmland classification:* Not prime farmland

#### Map Unit Composition

*Columbine and similar soils:* 85 percent

*Estimates are based on observations, descriptions, and transects of the mapunit.*

#### Description of Columbine

##### Setting

*Landform:* Fan terraces, fans, flood plains

*Down-slope shape:* Linear

*Across-slope shape:* Linear

*Parent material:* Alluvium

##### Typical profile

*A - 0 to 14 inches:* gravelly sandy loam

*C - 14 to 60 inches:* very gravelly loamy sand

##### Properties and qualities

*Slope:* 0 to 3 percent

*Depth to restrictive feature:* More than 80 inches

*Natural drainage class:* Well drained

*Runoff class:* Very low

*Capacity of the most limiting layer to transmit water (Ksat):* High to very high (5.95 to 19.98 in/hr)

*Depth to water table:* More than 80 inches

*Frequency of flooding:* None

*Frequency of ponding:* None

*Available water storage in profile:* Very low (about 2.5 inches)

##### Interpretive groups

*Land capability classification (irrigated):* 4e

*Land capability classification (nonirrigated):* 6e

*Hydrologic Soil Group:* A

*Ecological site:* Gravelly Foothill (R049BY214CO)

*Hydric soil rating:* No

#### Minor Components

##### Fluvaquentic haplaquolls

*Percent of map unit:*

*Landform:* Swales

*Hydric soil rating: Yes*

**Other soils**

*Percent of map unit:*

*Hydric soil rating: No*

**Pleasant**

*Percent of map unit:*

*Landform: Depressions*

*Hydric soil rating: Yes*

## **Data Source Information**

Soil Survey Area: El Paso County Area, Colorado

Survey Area Data: Version 15, Oct 10, 2017

## **FEMA FIRM MAP**

## NOTES TO USERS

This map is for use in administering the National Flood Insurance Program. It does not necessarily identify all areas subject to flooding, particularly from local drainage sources of small size. The community map repository should be consulted for possible updated or additional flood hazard information.

To obtain more detailed information in areas where **Base Flood Elevations (BFEs)** and/or **Floodways** have been determined, users are encouraged to consult the **Flood Profiles and Floodway Data and/or Summary of Stillwater Elevations** tables contained within the Flood Insurance Study (FIS) report that accompanies this FIRM. Users should be aware that BFEs shown on the FIRM represent rounded whole-foot elevations. These BFEs are intended for flood insurance rating purposes only and should not be used as the sole source of flood elevation information. Accordingly, flood elevation data presented in the FIS report should be utilized in conjunction with the FIRM for purposes of construction and/or floodplain management.

**Coastal Base Flood Elevations** shown on this map apply only to landward of 0.0' North American Vertical Datum of 1988 (NAVD83). Users of this FIRM should be aware that coastal flood elevations are also provided in the Summary of Stillwater Elevations table in the Flood Insurance Study report for this jurisdiction. Elevations shown in the Summary of Stillwater Elevations table should be used for construction and/or floodplain management purposes when they are higher than the elevations shown on this FIRM.

Boundaries of the **floodways** were computed at cross sections and interpolated between cross sections. The floodways were based on hydraulic considerations with regard to requirements of the National Flood Insurance Program. Floodway widths and other pertinent floodway data are provided in the Flood Insurance Study report for this jurisdiction.

Certain areas not in Special Flood Hazard Areas may be protected by **flood control structures**. Refer to section 2.4 "Flood Protection Measures" of the Flood Insurance Study report for information on flood control structures for this jurisdiction.

The **projection** used in the preparation of this map was Universal Transverse Mercator (UTM) zone 13. The **horizontal datum** was NAD83, GRS80 spheroid. Differences in datum, spheroid, projection or UTM zones zones used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of this FIRM.

Flood elevations on this map are referenced to the **North American Vertical Datum of 1988 (NAVD83)**. These flood elevations must be compared to structure and ground elevations referenced to the same vertical datum. For information regarding conversion between the National Geospatial Vertical Datum of 1929 and the North American Vertical Datum of 1988, visit the National Geospatial Survey website at <http://www.ngs.noaa.gov> or contact the National Geospatial Survey at the following address:

NGS Information Services  
NOAA, NGS-12  
National Geospatial Survey  
SSMC-3, #9022  
1315 East-West Highway  
Silver Spring, MD 20910-3282

To obtain current elevation, description, and/or location information for **bench marks** shown on this map, please contact the Information Services Branch of the National Geospatial Survey at (301) 713-3422 or visit its website at <http://www.ngs.noaa.gov>.

**Base Map** information shown on this FIRM was provided in digital format by El Paso County, Colorado Springs Utilities, and Anderson Consulting Engineers, Inc. These data are current as of 2008.

This map reflects more detailed and up-to-date stream channel configurations and floodplain delineations than those shown on the previous FIRM for this jurisdiction. The floodplains and floodways that were transferred from the previous FIRM may have been adjusted to conform to these new stream channel configurations. As a result, the Flood Profiles and Floodway Data tables in the Flood Insurance Study Report (which contains authoritative hydraulic data) may reflect stream channel distances that differ from what is shown on this map. The profile baselines depicted on this map represent the hydraulic modeling baselines that match the flood profiles and Floodway Data Tables if applicable, in the FIS report. As a result, the profile baselines may deviate significantly from the new base map channel representation and may appear outside of the floodplain.

**Corporate limits** shown on this map are based on the best data available at the time of publication. Because changes due to annexations or de-annexations may have occurred after this map was published, map users should contact appropriate community officials to verify current corporate limit locations.

Please refer to the separately printed **Map Index** for an overview map of the county showing the layout of map panels, community map repository addresses, and Listing of Communities table containing National Flood Insurance Program dates for each community as well as a listing of the panels on which each community is located.

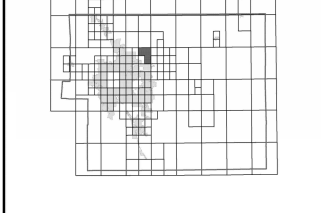
Contact **FEMA Map Service Center (MSC)** via the FEMA Map Information eXchange (FIMIX) 1-877-336-2627 for information on available products associated with this FIRM. Available products may include previously issued Letters of Map Change, a Flood Insurance Study Report, and/or digital versions of this map. The MSC may also be reached by Fax at 1-800-358-9620 and its website at <http://www.msc.fema.gov>.

If you have **questions about this map** or questions concerning the National Flood Insurance Program in general, please call 1-877-FEMA MAP (1-877-336-2627) or visit the FEMA website at <http://www.fema.gov/business/mfp>.

**El Paso County Vertical Datum Offset Table**

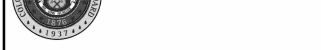
Flooding Source	Vertical Datum Offset (ft)
REFER TO SECTION 3.3 OF THE EL PASO COUNTY FLOOD INSURANCE STUDY FOR STREAM BY STREAM VERTICAL DATUM CONVERSION INFORMATION	

**Panel Location Map**



This Digital Flood Insurance Rate Map (DFIRM) was produced through a Cooperating Technical Partner (CTP) agreement between the State of Colorado Water Conservation Board (CWCB) and the Federal Emergency Management Agency (FEMA).

Additional Flood Hazard information and resources are available from local communities and the Colorado Water Conservation Board.



THIS PANEL SHOWN AT A  
SCALE OF 1"=500'  
ON MAP NUMBER 08041C0533

NOTE: MAP AREA SHOWN ON THIS PANEL IS LOCATED WITHIN TOWNSHIP 12 SOUTH, RANGE 65 WEST, AND TOWNSHIP 13 SOUTH, RANGE 65 WEST.

## LEGEND

**SPECIAL FLOOD HAZARD AREAS (SFHAS) SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD**

The 1% annual chance flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. This Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, M, X, and VE. The Base Flood Elevation is the water surface elevation of the 1% annual chance flood.

- ZONE A** No Base Flood Elevations determined.
- ZONE AE** Base Flood Elevations determined.
- ZONE AH** Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined.
- ZONE AO** Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of shallow flood ponding, vehicles also determined.
- ZONE AR** Special Flood Hazard Area Formerly protected from the 1% annual chance flood by a flood control system that was subsequently abandoned. Zone AR indicates that the former flood control system is being removed to provide protection from the 1% annual chance flood.
- ZONE A99** Area to be protected from 1% annual chance flood by a Federal flood protection system under construction; no Base Flood Elevations determined.
- ZONE V** Coastal flood zone with velocity hazard (wave action); no Base Flood Elevations determined.
- ZONE VE** Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.

**FLOODWAY AREAS IN ZONE AE**

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

**OTHER FLOOD AREAS**

**ZONE X** Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot in any given year. This Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood.

**OTHER AREAS**

**ZONE X** Areas determined to be outside the 0.2% annual chance floodplain.

**ZONE D** Areas in which flood hazards are undetermined, but possible.

**COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS**

**OTHERWISE PROTECTED AREAS (OPAs)**

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

Floodplain boundary

Floodway boundary

Zone D Boundary

CBRS and OPA boundary

Boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths or flood velocities.

Base Flood Elevation line and value; elevation in feet\*

Base Flood Elevation value where uniform within zone; elevation in feet\*

\* Referenced to the North American Vertical Datum of 1988 (NAVD 88)

Cross section line

Transsect line

Geographic coordinates referenced to the North American Vertical Datum of 1988 (NAVD 88)

1000-meter Universal Transverse Mercator grid ticks, zone 13

5000-foot grid ticks; Colorado State Plane coordinate system, central zone (PROJZONE 5003), Lambert Conformal Conic Projection

Bench mark (See explanation in Notes to Users section of this FIS report)

1:5

Refer to Map Repository for Map Index

EFFECTIVE DATE OF COUNTYWIDE FLOOD INSURANCE RATE MAP

MARCH 17, 1997

EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL

DECEMBER 7, 2014. In order to update map panels, to change Base Flood Elevations and Special Flood Hazard Areas, to update map format, to add roads and mail names, and to incorporate previously issued Letters of Map Change.

For community map revision history prior to countywide mapping, refer to the Community Map History Table located in 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 1-800-638-6622.

MAP SCALE 1" = 1000'

500 0 1000 2000 FEET

500 0 1000 2000 METERS

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0535G

**FIRM**

FLOOD INSURANCE RATE MAP

EL PASO COUNTY, COLORADO AND INCORPORATED AREAS

PANEL 535 OF 1300  
(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:	NUMBER	PANEL	SUFFIX
COLORADO SPECIAL DTY OF	0800	000	0
EL PASO COUNTY	0800	000	0

Notes to User: The Map Number shown below should be used when filing map claims. The Community Number shown above should be used on insurance applications for the subject community.

**MAP NUMBER**  
08041C0535G

**MAP REVISED**  
DECEMBER 7, 2018

Federal Emergency Management Agency



## **HYDROLOGIC CALCULATIONS**

**VOLLMER SUBSTATION**  
**(Area Runoff Coefficient Summary)**

**EXISTING CONDITIONS**

		<i>DEVELOPED</i>			<i>UNDEVELOPED</i>			<i>WEIGHTED</i>	
BASIN	TOTAL AREA	AREA	C <sub>5</sub>	C <sub>100</sub>	AREA	C <sub>5</sub>	C <sub>100</sub>	C <sub>5</sub>	C <sub>100</sub>
	(Acres)	(Acres)			(Acres)				
<i>OS-2</i>	79.00	0.00	0.30	0.50	79.00	0.09	0.36	0.09	0.36
<i>EX-A</i>	2.77	0.00	0.30	0.50	2.77	0.09	0.36	0.09	0.36
<i>EX-B</i>	2.16	0.00	0.30	0.50	2.16	0.09	0.36	0.09	0.36

Calculated by: DLF  
Date: 9/17/2018  
Checked by: LD

**VOLLMER SUBSTATION**  
**(Area Runoff Coefficient Summary)**

**DEVELOPED CONDITIONS**

		<i>DEVELOPED</i>			<i>UNDEVELOPED</i>			<i>WEIGHTED</i>	
BASIN	TOTAL AREA	AREA	C <sub>5</sub>	C <sub>100</sub>	AREA	C <sub>5</sub>	C <sub>100</sub>	C <sub>5</sub>	C <sub>100</sub>
	(Acres)	(Acres)			(Acres)				
<i>OS-2</i>	79.00	0.00	0.30	0.50	79.00	0.09	0.36	0.09	0.36
<i>PR-1</i>	0.42	0.00	0.30	0.50	0.42	0.09	0.36	0.09	0.36
<i>PR-2</i>	1.70	1.70	0.30	0.50	0.00	0.09	0.36	0.30	0.50
<i>PR-3</i>	0.15	0.02	0.30	0.50	0.13	0.09	0.36	0.12	0.38
<i>PR-4</i>	1.43	0.16	0.30	0.50	1.27	0.09	0.36	0.11	0.38
<i>PR-5</i>	1.07	0.00	0.30	0.50	1.07	0.09	0.36	0.09	0.36
<i>PR-6</i>	0.06	0.00	0.30	0.50	0.06	0.09	0.36	0.09	0.36
<i>PR-7</i>	0.26	0.15	0.30	0.50	0.11	0.09	0.36	0.21	0.44
<i>PR-8</i>	0.58	0.15	0.30	0.50	0.43	0.09	0.36	0.14	0.40
<i>PR-9</i>	3.09	2.46	0.30	0.50	0.63	0.09	0.36	0.26	0.47

Calculated by: DLF

Date: 9/17/2018

Checked by: LD

# VOLLMER SUBSTATION AREA DRAINAGE SUMMARY

## EXISTING CONDITIONS

		WEIGHTED		OVERLAND				STREET / CHANNEL FLOW				T <sub>i</sub>	INTENSITY		TOTAL FLOWS	
BASIN	AREA TOTAL (Acres)	C <sub>5</sub>	C <sub>100</sub>	C <sub>5</sub>	Length	Height	T <sub>C</sub>	Length	Slope	Velocity	T <sub>t</sub>	TOTAL	I <sub>5</sub>	I <sub>100</sub>	Q <sub>5</sub>	Q <sub>100</sub>
		* For Calcs See Runoff Summary										(min)				
OS-2	79.00	0.09	0.36	0.09	300	9.4	21.9	5500	3.1%	0.9	104.1	126.0	1.0	1.5	7.1	43.7
EX-A	2.77	0.09	0.36	0.09	300	9.0	22.2	0	3.0%	0.9	0.0	22.2	2.9	4.8	0.7	4.8
EX-B	2.16	0.09	0.36	0.09	300	9.0	22.2	0	3.0%	0.9	0.0	22.2	2.9	4.8	0.6	3.7

## DEVELOPED CONDITIONS

		WEIGHTED		OVERLAND				STREET / CHANNEL FLOW				T <sub>i</sub>	INTENSITY		TOTAL FLOWS	
BASIN	AREA TOTAL (Acres)	C <sub>5</sub>	C <sub>100</sub>	C <sub>5</sub>	Length (ft)	Height (ft)	T <sub>C</sub> (min)	Length (ft)	Slope (%)	Velocity (fps)	T <sub>i</sub> (min)	TOTAL (min)	I <sub>5</sub> (in/hr)	I <sub>100</sub> (in/hr)	Q <sub>5</sub> (c.f.s.)	Q <sub>100</sub> (c.f.s.)
		* For Calcs See Runoff Summary														
OS-2	79.00	0.09	0.36	0.09	300	9.4	21.9	5500	3.1%	0.9	104.1	126.0	1.0	1.5	7.1	43.7
PR-1	0.42	0.09	0.36	0.09	40	5.0	5.0	425	0.5%	0.4	20.0	25.1	2.7	4.5	0.1	0.7
PR-2	1.70	0.30	0.50	0.30	180	2.0	19.0	0	0.0%	1.1	0.0	19.0	3.1	5.2	1.6	4.4
PR-3	0.15	0.12	0.38	0.12	20	4.0	3.0	250	0.8%	0.4	9.3	12.3	3.8	6.5	0.1	0.4
PR-4	1.43	0.11	0.38	0.11	180	7.0	15.4	280	0.8%	0.4	10.4	25.8	2.7	4.4	0.4	2.4
PR-5	1.07	0.09	0.36	0.09	100	14.0	7.7	0	0.0%	0.4	0.0	7.7	4.4	7.8	0.4	3.0
PR-6	0.06	0.09	0.36	0.09	30	2.0	5.4	0	0.0%	1.1	0.0	5.4	4.9	8.9	0.03	0.2
PR-7	0.26	0.21	0.44	0.21	30	2.0	4.7	0	0.0%	1.1	0.0	4.7	5.1	9.2	0.3	1.1
PR-8	0.58	0.14	0.40	0.14	30	2.0	5.1	0	0.0%	1.1	0.0	5.1	5.0	9.0	0.4	2.1
PR-9	3.09	0.26	0.47	0.26	30	2.0	4.5	0	0.0%	1.1	0.0	4.5	5.1	9.3	4.1	13.6

Calculated by: DLF

Date: 9/17/2018

Checked by: LD

**VOLLMER SUBSTATION  
AREA DRAINAGE SUMMARY**

**EXISTING AND DEVELOPED CONDITIONS**

---

Site: Vollmer Substation  
Basin: OS-2  
Basin Area: 138 ac or 0.216 sq mi  
Method: Soil Conservation Service Hydrograph  
Hydrologic Soil Group: A, good condition  
CN= 39  
Tc= 21.9 min  
L= 13.1 min  
P10-2= 2.3"  
P100-2= 3.6"  
S= 15.6"  
Ia= 3.1"  
Q10= 0.05"  
Q100= 0.01"  
D= 2.9 min, using D=5 min (minimum value)  
Tp= 16 min or 0.26 hr  
Qp10= 20 cfs  
Qp100= 4.0 cfs

Calculated by: DLF  
Date: 9/17/2018  
Checked by: LD

# ***VOLLMER SUBSTATION***

## ***PROPOSED SURFACE ROUTING SUMMARY***

<i>Design Point(s)</i>	<i>Contributing Basins</i>	<i>Area Ac</i>	<i>Flow</i>		
			<i>Q<sub>5</sub></i>	<i>Q<sub>10</sub></i>	<i>Q<sub>100</sub></i>
<b>Z</b>	<b>OS-1</b>	138.00	<b>---</b>	<b>20</b>	<b>---</b>
<b>Y</b>	<b>OS-2</b>	79.00	<b>7.1</b>	<b>---</b>	<b>36.6*</b>
<b>1</b>	<b>PR-1</b>	0.42	<b>0.1</b>	<b>---</b>	<b>0.7</b>
<b>2</b>	<b>PR-2</b>	1.70	<b>1.6</b>	<b>---</b>	<b>4.4</b>
<b>3</b>	<b>PR-3</b>	0.15	<b>0.1</b>	<b>---</b>	<b>0.4</b>
<b>4</b>	<b>PR-3, PR-4, OS-2</b>	81.00	<b>8.6</b>	<b>---</b>	<b>36.6*</b>
<b>5</b>	<b>PR-1, PR-2, PR-3, PR-4, PR-5, OS-2</b>	84.00	<b>9.7</b>	<b>---</b>	<b>47.5*</b>
<b>6</b>	<b>PR-6</b>	0.06	<b>0.03</b>	<b>---</b>	<b>0.2</b>
<b>7</b>	<b>PR-7</b>	0.26	<b>0.3</b>	<b>---</b>	<b>1.1</b>
<b>8</b>	<b>PR-8</b>	0.58	<b>0.4</b>	<b>---</b>	<b>2.1</b>
<b>9</b>	<b>PR-9</b>	3.09	<b>4.1</b>	<b>---</b>	<b>13.6</b>

\* Note: the existing swale EXS1 has a max capacity of 36.6 cfs.

Calculated by: DLF

Date: 9/17/2018

Checked by: LD

**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.

## **HYDRAULIC CALCULATIONS**



# MANNING'S EQUATION for OPEN CHANNEL FLOW

Project: Vollmer Substation

Location: EXS1 - South edge of property line - Capacity

By: Dane Frank

Date: 8/27/2018

Chk By:

Date:

version 12-2004

Mannings Formula

$$Q = (1.486/n)AR_h^{2/3}S^{1/2}$$

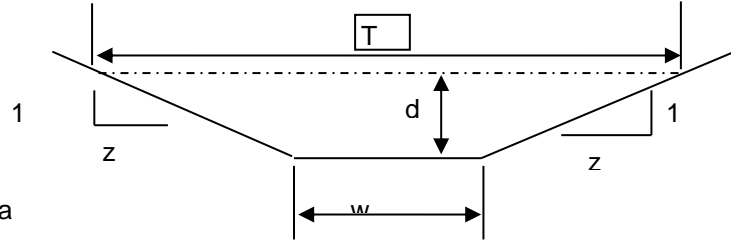
$$R = A/P$$

A = cross sectional area

P= wetted perimeter

S = slope of channel

n = Manning's roughness coefficient



$$V = (1.49/n)R_h^{2/3}S^{1/2}$$

$$Q = V \times A$$

INPUT

z (sideslope)= 22  
z (sideslope)= 48  
b (btm width, ft)= 0  
d (depth, ft)= 1.2  
S (slope, ft/ft) 0.008  
n low = 0.13  
n high = 0.13

Clear Data  
Entry Cells

				Low N		High N			
Depth, ft	Area, sf	Wetted Perimeter, ft	Hydraulic Radius, ft	Velocity, fps	Flow, cfs	Velocity, fps	Flow, cfs	T =	
1.2	50.40	84.04	0.60	0.7270711	36.6444	0.727071	36.6444	Dm =	84
				Sc low =	0.2919	Sc high =	0.2919		0.600
s <sub>c</sub> = critical slope    ft / ft									
T = top width of the stream				.7 Sc	1.3 Sc	.7 Sc	1.3 Sc		
d <sub>m</sub> = a/T = mean depth of flow				0.2043	0.3795	0.2043	0.3795		

s<sub>c</sub> = critical slope ft / ft

T = top width of the stream

d<sub>m</sub> = a/T = mean depth of flow

Created by: Mike O'Shea

# MANNING'S EQUATION for OPEN CHANNEL FLOW

Project: Vollmer Substation

Location: PRS1 - North edge of PR Yard - Q5 = 0.1 cfs

By: Dane Frank

Date: 8/27/2018

Chk By:

Date:

version 12-2004

Mannings Formula

$$Q = (1.486/n)AR_h^{2/3}S^{1/2}$$

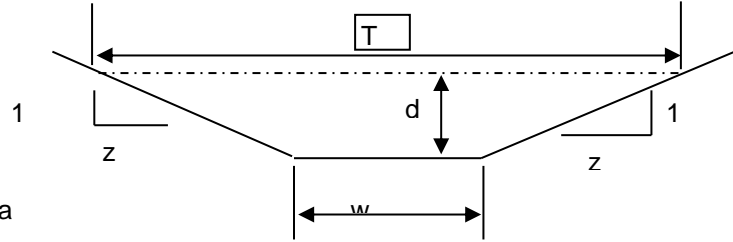
$$R = A/P$$

A = cross sectional area

P= wetted perimeter

S = slope of channel

n = Manning's roughness coefficient



$$V = (1.49/n)R_h^{2/3}S^{1/2}$$

$$Q = V \times A$$

INPUT

z (sideslope)= 4  
z (sideslope)= 4  
b (btm width, ft)= 0  
d (depth, ft)= 0.33  
S (slope, ft/ft) 0.005  
n low = 0.13  
n high = 0.13

Clear Data  
Entry Cells

Depth, ft	Area, sf	Wetted Perimeter, ft	Hydraulic Radius, ft	Low N		High N		
				Velocity, fps	Flow, cfs	Velocity, fps	Flow, cfs	
0.33	0.44	2.72	0.16	0.23827597	0.10379	0.238276	0.10379	T = 2.64
				Sc low = 0.4671		Sc high = 0.4671		Dm = 0.165
				.7 Sc	1.3 Sc	.7 Sc	1.3 Sc	
				0.3270	0.6072	0.3270	0.6072	

s<sub>c</sub> = critical slope ft / ft

T = top width of the stream

d<sub>m</sub> = a/T = mean depth of flow

Created by: Mike O'Shea

# MANNING'S EQUATION for OPEN CHANNEL FLOW

**Project:** Vollmer Substation      **Location:** PRS1 - North edge of PR Yard - Q100 = 0.7 cfs  
**By:** Dane Frank      **Date:** 8/27/2018  
**Chk By:**      **Date:**      version 12-2004

Mannings Formula

$$Q = (1.486/n)AR_h^{2/3}S^{1/2}$$

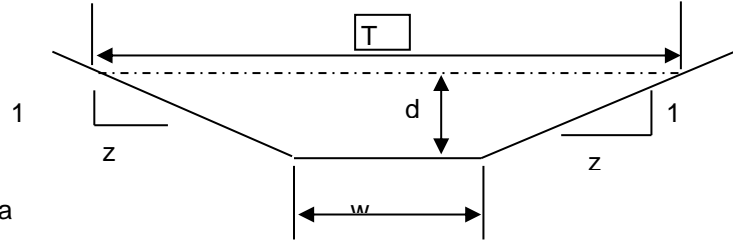
$$R = A/P$$

A = cross sectional area

P= wetted perimeter

S = slope of channel

n = Manning's roughness coefficient



$$V = (1.49/n)R_h^{2/3}S^{1/2}$$

$$Q = V \times A$$

INPUT

z (sideslope)= 4  
z (sideslope)= 4  
b (btm width, ft)= 0  
d (depth, ft)= 0.68  
S (slope, ft/ft) 0.005  
n low = 0.13  
n high = 0.13

Clear Data  
Entry Cells

Depth, ft	Area, sf	Wetted Perimeter, ft	Hydraulic Radius, ft	Low N		High N		
				Velocity, fps	Flow, cfs	Velocity, fps	Flow, cfs	
0.68	1.85	5.61	0.33	0.38585195	0.71367	0.385852	0.71367	T = 5.44
				Sc low = 0.3671		Sc high = 0.3671		Dm = 0.340
				.7 Sc	1.3 Sc	.7 Sc	1.3 Sc	
				0.2570	0.4772	0.2570	0.4772	

$s_c$  = critical slope ft / ft

T = top width of the stream

$d_m = a/T$  = mean depth of flow

Created by: Mike O'Shea

# MANNING'S EQUATION for OPEN CHANNEL FLOW

Project: **Vollmer Substation**

Location: **PRS2 - East edge of PR Yard - Q5 = 0.1 cfs**

By: **Dane Frank**

Date: **8/27/2018**

Chk By:

Date:

version 12-2004

Mannings Formula

$$Q = (1.486/n)AR_h^{2/3}S^{1/2}$$

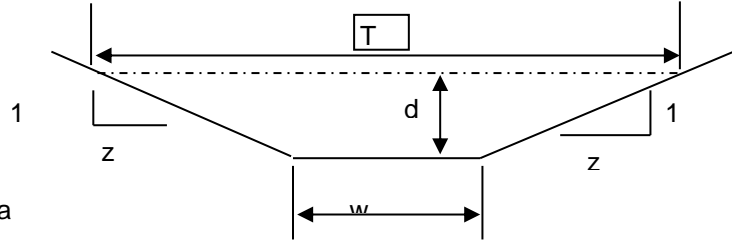
$$R = A/P$$

A = cross sectional area

P= wetted perimeter

S = slope of channel

n = Manning's roughness coefficient



$$V = (1.49/n)R_h^{2/3}S^{1/2}$$

$$Q = V \times A$$

INPUT

z (sideslope)= 4  
z (sideslope)= 4  
b (btm width, ft)= 0  
d (depth, ft)= 0.3  
S (slope, ft/ft) 0.008  
n low = 0.13  
n high = 0.13

Clear Data  
Entry Cells

				Low N		High N			
Depth, ft	Area, sf	Wetted Perimeter, ft	Hydraulic Radius, ft	Velocity, fps	Flow, cfs	Velocity, fps	Flow, cfs	T =	Dm =
0.3	0.36	2.47	0.15	0.2828419	0.10182	0.282842	0.10182	2.4	0.150
				Sc low =	0.4822	Sc high =	0.4822		
s <sub>c</sub> = critical slope    ft / ft									
T = top width of the stream				.7 Sc	1.3 Sc	.7 Sc	1.3 Sc		
d <sub>m</sub> = a/T = mean depth of flow				0.3375	0.6268	0.3375	0.6268		

s<sub>c</sub> = critical slope ft / ft

T = top width of the stream

d<sub>m</sub> = a/T = mean depth of flow

Created by: Mike O'Shea

# MANNING'S EQUATION for OPEN CHANNEL FLOW

Project: Vollmer Substation

By: Dane Frank

Chk By:

Location: PRS2 - East edge of PR Yard - Q100 = 0.4 cfs

Date: 8/27/2018

Date:

version 12-2004

Mannings Formula

$$Q = (1.486/n)AR_h^{2/3}S^{1/2}$$

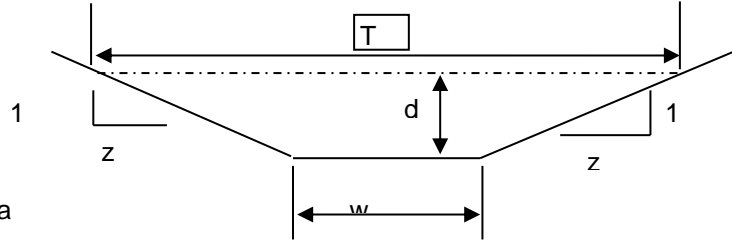
$$R = A/P$$

A = cross sectional area

P= wetted perimeter

S = slope of channel

n = Manning's roughness coefficient



$$V = (1.49/n)R_h^{2/3}S^{1/2}$$

$$Q = V \times A$$

INPUT

z (sideslope)= 4  
z (sideslope)= 4  
b (btm width, ft)= 0  
d (depth, ft)= 0.51  
S (slope, ft/ft) 0.008  
n low = 0.13  
n high = 0.13

Clear Data  
Entry Cells

Depth, ft	Area, sf	Wetted Perimeter, ft	Hydraulic Radius, ft	Low N		High N		
				Velocity, fps	Flow, cfs	Velocity, fps	Flow, cfs	
0.51	1.04	4.21	0.25	0.40288773	0.41916	0.402888	0.41916	T = 4.08
				Sc low = 0.4040		Sc high = 0.4040		Dm = 0.255
				.7 Sc	1.3 Sc	.7 Sc	1.3 Sc	
				0.2828	0.5252	0.2828	0.5252	

$s_c$  = critical slope ft / ft

T = top width of the stream

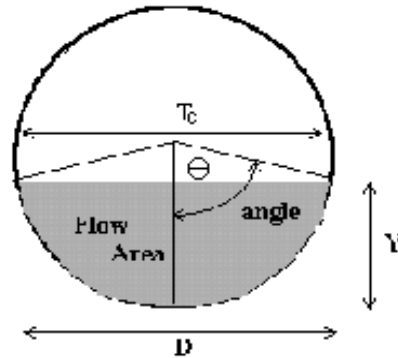
$d_m = a/T$  = mean depth of flow

Created by: Mike O'Shea

## CIRCULAR CONDUIT FLOW (Normal & Critical Depth Computation)

Project: **Vollmer Substation**

Pipe ID: **PRC1 - Sand Filter Discharge - 5 Yr**



### Design Information (Input)

Pipe Invert Slope	$S_o =$	0.0200	ft/ft
Pipe Manning's n-value	$n =$	0.0130	
Pipe Diameter	$D =$	18.00	inches
Design discharge	$Q =$	1.60	cfs

### Full-flow Capacity (Calculated)

Full-flow area	$A_f =$	1.77	sq ft
Full-flow wetted perimeter	$P_f =$	4.71	ft
Half Central Angle	$\theta =$	3.14	radians
Full-flow capacity	$Q_f =$	14.90	cfs

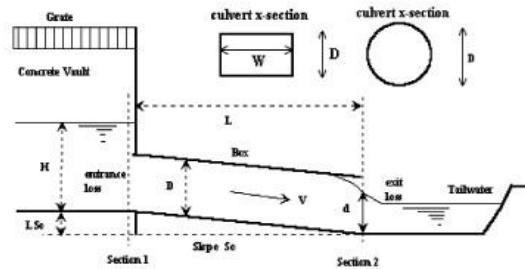
### Calculation of Normal Flow Condition

Half Central Angle ( $0 < \theta < 3.14$ )	$\theta =$	0.98	radians
Flow area	$A_n =$	0.29	sq ft
Top width	$T_n =$	1.25	ft
Wetted perimeter	$P_n =$	1.47	ft
Flow depth	$Y_n =$	0.33	ft
Flow velocity	$V_n =$	5.50	fps
Discharge	$Q_n =$	1.60	cfs
Percent Full Flow	$\text{Flow} =$	10.7%	of full flow
Normal Depth Froude Number	$Fr_n =$	2.01	supercritical

### Calculation of Critical Flow Condition

Half Central Angle ( $0 < \theta_c < 3.14$ )	$\theta_c =$	1.20	radians
Critical flow area	$A_c =$	0.48	sq ft
Critical top width	$T_c =$	1.40	ft
Critical flow depth	$Y_c =$	0.48	ft
Critical flow velocity	$V_c =$	3.33	fps
Critical Depth Froude Number	$Fr_c =$	1.00	

Project: **Voolmer Substation**  
 Basin ID: **PRC1 - Sand Filter Discharge - 5 Yr**  
 Status:



**Circular Culvert:** Barrel Diameter in Inches  
Inlet Edge Type (choose from pull-down list)

D = 18 inches

### Grooved End with Headwall

**Box Culvert:** Barrel Height (Rise) in Feet  
Barrel Width (Span) in Feet  
Inlet Edge Type (choose from pull-down list)

Height (Rise) =  ft.

Width (Span) =  ft.

Square Edge w/ 30-78 deg. Flared Wingwall

Number of Barrels  
Inlet Elevation at Culvert Invert  
Outlet Elevation at Culvert Invert **OR** Slope of Culvert (ft v./ft h.)  
Culvert Length in Feet  
Manning's Roughness  
Bend Loss Coefficient  
Exit Loss Coefficient

No = 1

Inlet Elev = 7021.5 ft. elev.

Outlet Elev = 7020.1 ft. elev.

L =  ft.

n =	0.013
-----	-------

$K_b =$	0
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$$K_x = 1$$

Entrance Loss Coefficient  
Friction Loss Coefficient  
Sum of All Loss Coefficients  
Orifice Inlet Condition Coefficient  
Minimum Energy Condition Coefficient

 $K_e = 0.20$ 

$K_f =$	1.27
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$K_s =$	2.47
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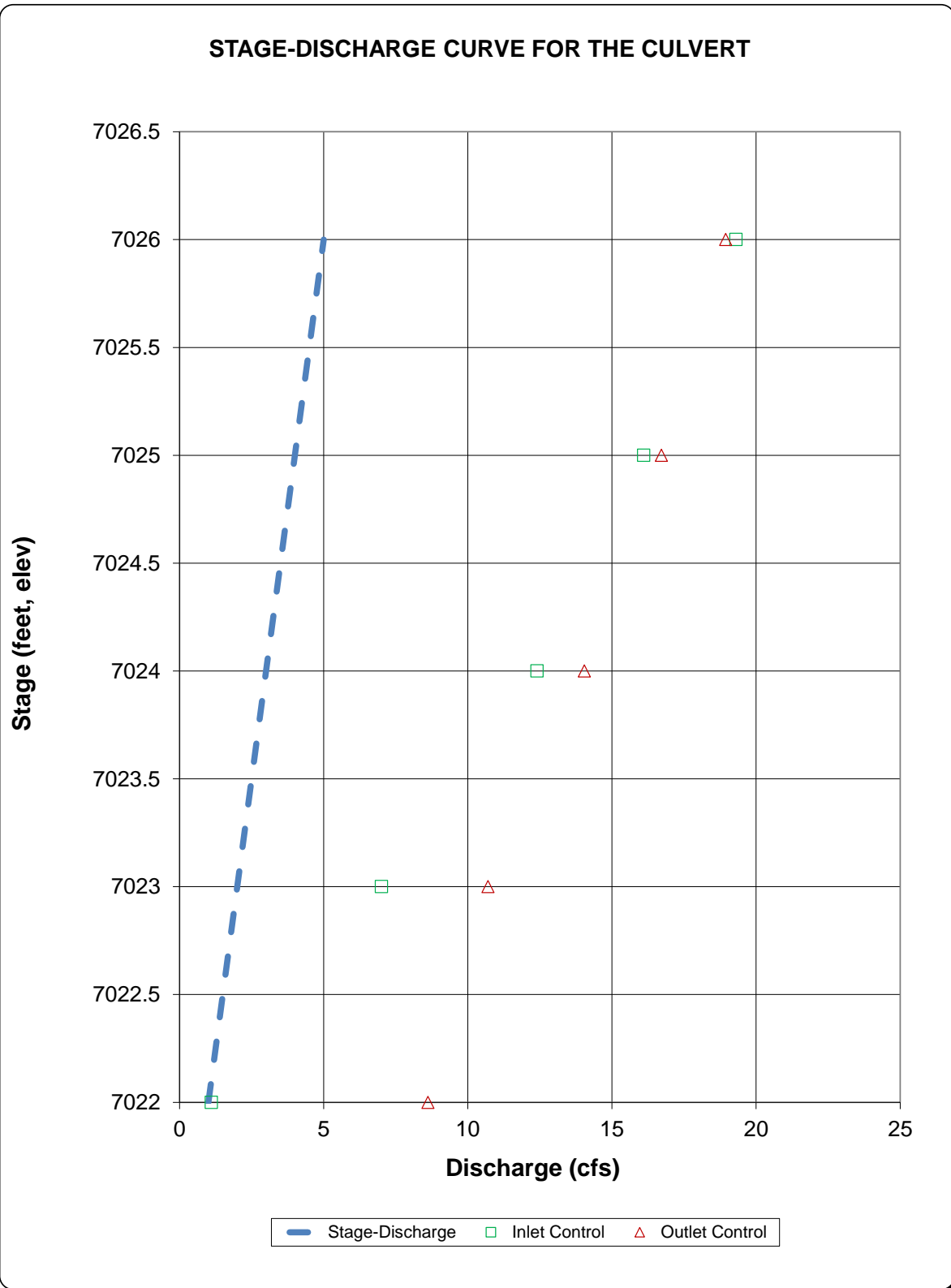
$C_d =$	0.99
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$$KE_{\text{low}} = -0.0860$$
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## CULVERT STAGE-DISCHARGE SIZING (INLET vs. OUTLET CONTROL WITH TAILWATER EFFECTS)

Project: Voolmer Substation  
Basin ID: PRC1 - Sand Filter Discharge - 5 Yr

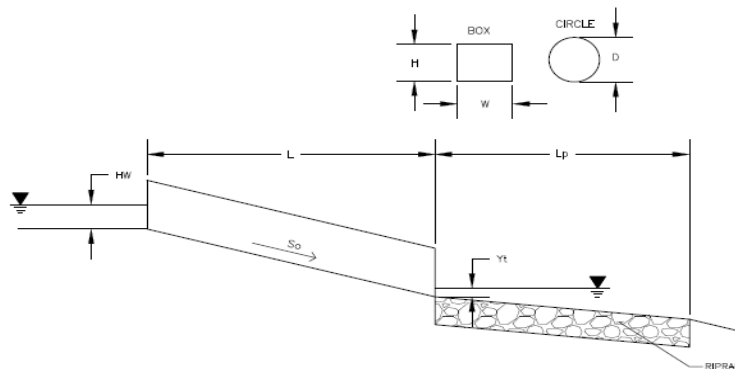




## Determination of Culvert Headwater and Outlet Protection

Project: **Vollmer Substation**

Basin ID: **PRC1 - Sand Filter Discharge - 5 Yr**



Soil Type:

Choose One:

☒ Sandy

☐ Non-Sandy

Supercritical Flow! Using  $D_a$  to calculate protection type.

### Design Information (Input):

Design Discharge

Q = 1.6 cfs

#### Circular Culvert:

Barrel Diameter in Inches

D = 18 inches

Inlet Edge Type (Choose from pull-down list)

Square End Projection

#### Box Culvert:

Barrel Height (Rise) in Feet

Height (Rise) =

Barrel Width (Span) in Feet

Width (Span) =

Inlet Edge Type (Choose from pull-down list)

Number of Barrels

No = 1

Inlet Elevation

Elev IN = 7021.5 ft

Outlet Elevation **OR** Slope

Elev OUT = 7020.1 ft

Culvert Length

L = 70 ft

Manning's Roughness

n = 0.013

Bend Loss Coefficient

$k_b$  = 0

Exit Loss Coefficient

$k_x$  = 1

Tailwater Surface Elevation

Elev  $Y_t$  =

Max Allowable Channel Velocity

V = 5 ft/s

### Required Protection (Output):

Tailwater Surface Height

$Y_t$  = 0.60 ft

Flow Area at Max Channel Velocity

$A_t$  = 0.32 ft<sup>2</sup>

Culvert Cross Sectional Area Available

A = 1.77 ft<sup>2</sup>

Entrance Loss Coefficient

$k_e$  = 0.50

Friction Loss Coefficient

$k_f$  = 1.27

Sum of All Losses Coefficients

$k_s$  = 2.77

Culvert Normal Depth

$Y_n$  = 0.33 ft

Culvert Critical Depth

$Y_c$  = 0.48 ft

Tailwater Depth for Design

d = 0.99 ft

Adjusted Diameter **OR** Adjusted Rise

$D_a$  = 0.92 ft

Expansion Factor

$1/(2*\tan(\Theta))$  = 6.70

Flow/Diameter<sup>2.5</sup> **OR** Flow/(Span \* Rise<sup>1.5</sup>)

$Q/D^{2.5}$  = 0.58 ft<sup>0.5</sup>/s

Froude Number

Fr = 2.01

Tailwater/Adjusted Diameter **OR** Tailwater/Adjusted Rise

$Y_t/D$  = 0.66

Supercritical!

Inlet Control Headwater

$HW_i$  = 0.66 ft

Outlet Control Headwater

$HW_o$  = -0.38

Design Headwater Elevation

HW = 7,022.16 ft

Headwater/Diameter **OR** Headwater/Rise Ratio

HW/D = 0.44

Minimum Theoretical Riprap Size

$d_{50}$  = 1 in

Nominal Riprap Size

$d_{50}$  = 6 in

UDFCD Riprap Type

Type = VL

Length of Protection

$L_p$  = 5 ft

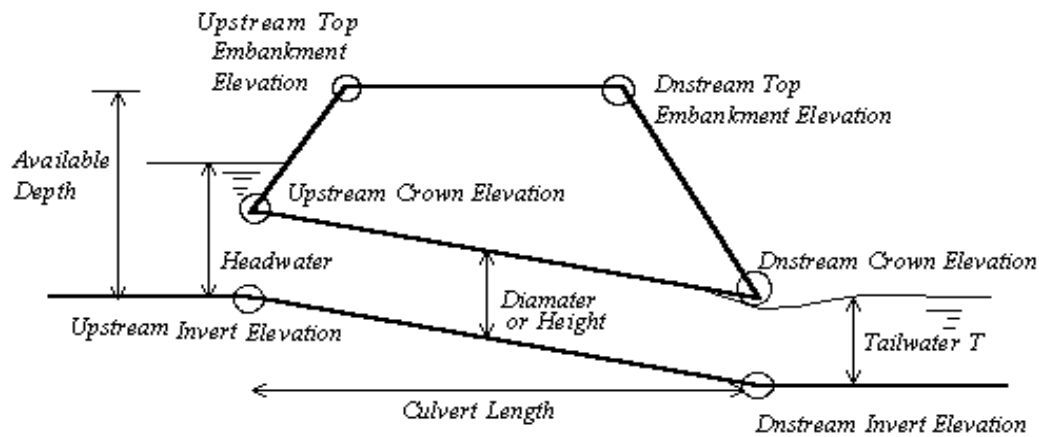
Width of Protection

T = 3 ft

## Vertical Profile for the Culvert

Project = Vollmer Substation

Box ID = PRC1 - Sand Filter Discharge - 5 Yr



### Culvert Information (Input)

Barrel Diameter or Height	D or H =	18.00	inches
Barrel Length	L =	70.00	ft
Barrel Invert Slope	So =	0.0200	ft/ft
Downstream Invert Elevation	EDI =	7020.10	ft
Downstream Top Embankment Elevation	EDT =	7026.00	ft
Upstream Top Embankment Elevation	EUT =	7026.00	ft
Design Headwater Depth (not elev.)	Hw =	0.66	ft
Tailwater Depth (not elev.)	Yt =	0.99	ft

### Culvert Hydraulics (Calculated)

Available Headwater Depth	HW-a =	4.50	ft
Design Hw/D ratio	Hw/D =	0.44	

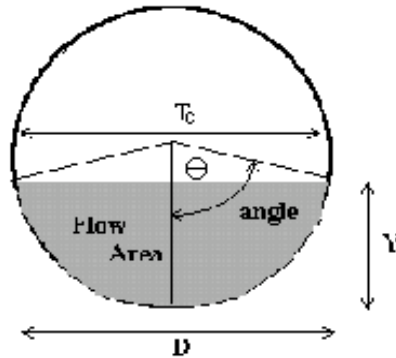
### Culvert Vertical Profile

Upstream Invert Elevation	EUI =	7021.50	ft
Upstream Crown Elevation	EUC =	7023.00	ft
Upstream Soil Cover Depth	Upsoil =	3.00	ft
Downstream Invert Elevation	EDI =	7020.10	ft
Downstream Crown Elevation	EDC =	7021.60	ft
Downstream Soil Cover Depth	Dnsoil =	4.40	ft

## CIRCULAR CONDUIT FLOW (Normal & Critical Depth Computation)

Project: **Vollmer Substation**

Pipe ID: **PRC1 - Sand Filter Discharge - 100 Yr**



### Design Information (Input)

Pipe Invert Slope	$S_o =$	0.0200	ft/ft
Pipe Manning's n-value	$n =$	0.0130	
Pipe Diameter	$D =$	18.00	inches
Design discharge	$Q =$	4.40	cfs

### Full-flow Capacity (Calculated)

Full-flow area	$A_f =$	1.77	sq ft
Full-flow wetted perimeter	$P_f =$	4.71	ft
Half Central Angle	$\theta =$	3.14	radians
Full-flow capacity	$Q_f =$	14.90	cfs

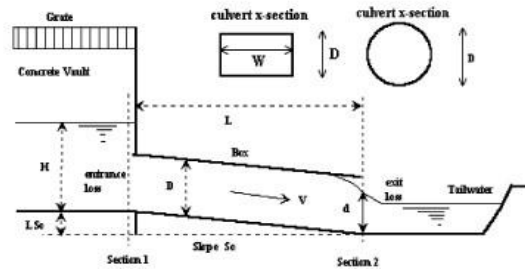
### Calculation of Normal Flow Condition

Half Central Angle ( $0 < \theta < 3.14$ )	$\theta =$	1.31	radians
Flow area	$A_n =$	0.60	sq ft
Top width	$T_n =$	1.45	ft
Wetted perimeter	$P_n =$	1.97	ft
Flow depth	$Y_n =$	0.56	ft
Flow velocity	$V_n =$	7.34	fps
Discharge	$Q_n =$	4.40	cfs
Percent Full Flow	$\text{Flow} =$	29.5%	of full flow
Normal Depth Froude Number	$Fr_n =$	2.01	supercritical

### Calculation of Critical Flow Condition

Half Central Angle ( $0 < \theta_c < 3.14$ )	$\theta_c =$	1.64	radians
Critical flow area	$A_c =$	0.97	sq ft
Critical top width	$T_c =$	1.50	ft
Critical flow depth	$Y_c =$	0.80	ft
Critical flow velocity	$V_c =$	4.56	fps
Critical Depth Froude Number	$Fr_c =$	1.00	

Project: **Voolmer Substation**  
 Basin ID: **PRC1 - Sand Filter Discharge - 100 Yr**  
 Status:



**Circular Culvert:** Barrel Diameter in Inches  
Inlet Edge Type (choose from pull-down list)

D = 18 inches

### Grooved End with Headwall

**Box Culvert:** Barrel Height (Rise) in Feet  
Barrel Width (Span) in Feet  
Inlet Edge Type (choose from pull-down list)

Height (Rise) =  ft.

Width (Span) =  ft.

Square Edge w/ 30-78 deg. Flared Wingwall

Number of Barrels  
Inlet Elevation at Culvert Invert  
Outlet Elevation at Culvert Invert **OR** Slope of Culvert (ft v./ft h.)  
Culvert Length in Feet  
Manning's Roughness  
Bend Loss Coefficient  
Exit Loss Coefficient

No = 1

Inlet Elev = 7021.5 ft. elev.

Outlet Elev = 7020.1 ft. elev.

L = 70 ft.

n =	0.013
-----	-------

$$K_b = 0$$
$$K_x = 1$$

Entrance Loss Coefficient  
Friction Loss Coefficient  
Sum of All Loss Coefficients  
Orifice Inlet Condition Coefficient  
Minimum Energy Condition Coefficient

 $K_e = 0.20$  $K_f = 1.27$ 
$$K_s = 2.47$$

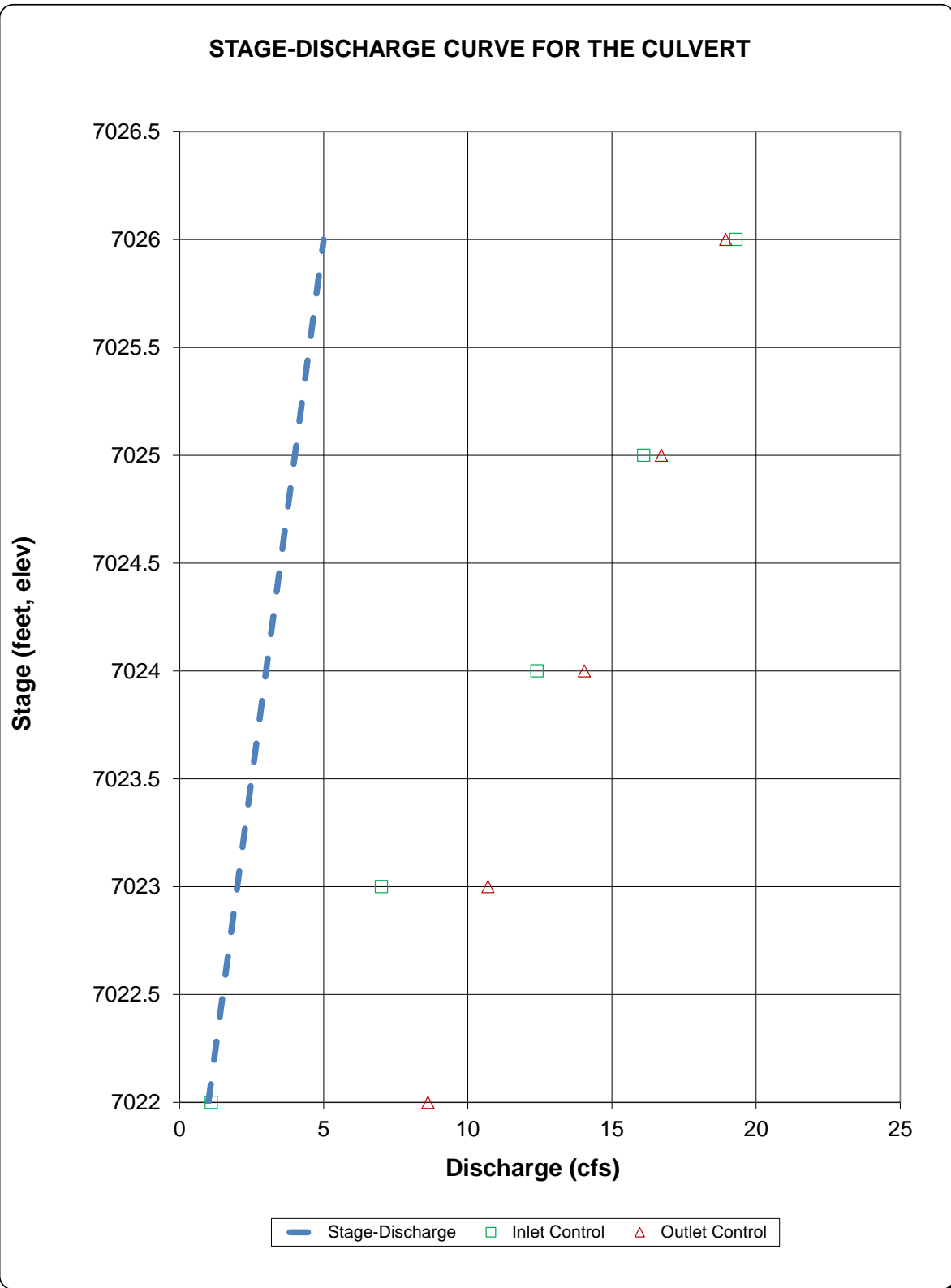
$C_d =$	0.99
---------	------

$$KE_{\text{low}} = -0.0860$$
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## CULVERT STAGE-DISCHARGE SIZING (INLET vs. OUTLET CONTROL WITH TAILWATER EFFECTS)

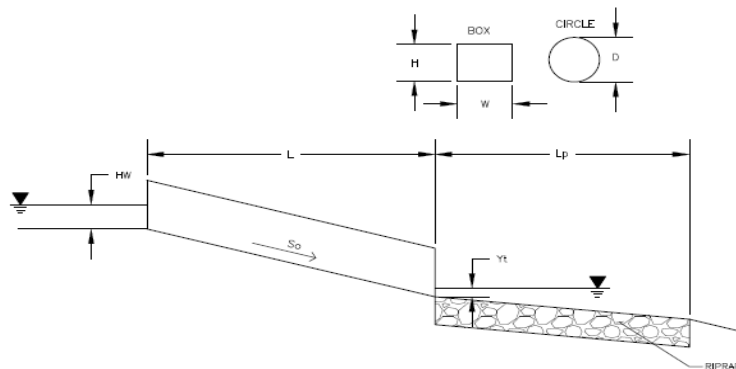
Project: Voolmer Substation  
Basin ID: PRC1 - Sand Filter Discharge - 100 Yr



## Determination of Culvert Headwater and Outlet Protection

Project: **Vollmer Substation**

Basin ID: **PRC1 - Sand Filter Discharge - 100 Yr**



Soil Type:

Choose One:

☒ Sandy

☐ Non-Sandy

Supercritical Flow! Using  $D_a$  to calculate protection type.

### Design Information (Input):

Design Discharge

Q = 4.4 cfs

#### Circular Culvert:

Barrel Diameter in Inches

D = 18 inches

Inlet Edge Type (Choose from pull-down list)

Square End Projection

#### Box Culvert:

Barrel Height (Rise) in Feet

Height (Rise) =

Barrel Width (Span) in Feet

Width (Span) =

Inlet Edge Type (Choose from pull-down list)

Number of Barrels

No = 1

Inlet Elevation

Elev IN = 7021.5 ft

Outlet Elevation **OR** Slope

Elev OUT = 7020.1 ft

Culvert Length

L = 70 ft

Manning's Roughness

n = 0.013

Bend Loss Coefficient

$k_b$  = 0

Exit Loss Coefficient

$k_x$  = 1

Tailwater Surface Elevation

Elev  $Y_t$  =

Max Allowable Channel Velocity

V = 5 ft/s

### Required Protection (Output):

Tailwater Surface Height

$Y_t$  = 0.60 ft

Flow Area at Max Channel Velocity

$A_t$  = 0.88 ft<sup>2</sup>

Culvert Cross Sectional Area Available

A = 1.77 ft<sup>2</sup>

Entrance Loss Coefficient

$k_e$  = 0.50

Friction Loss Coefficient

$k_f$  = 1.27

Sum of All Losses Coefficients

$k_s$  = 2.77

Culvert Normal Depth

$Y_n$  = 0.56 ft

Culvert Critical Depth

$Y_c$  = 0.80 ft

Tailwater Depth for Design

d = 1.15 ft

Adjusted Diameter **OR** Adjusted Rise

$D_a$  = 1.03 ft

Expansion Factor

$1/(2*\tan(\Theta))$  = 6.70

Flow/Diameter<sup>2.5</sup> **OR** Flow/(Span \* Rise<sup>1.5</sup>)

$Q/D^{2.5}$  = 1.60 ft<sup>0.5</sup>/s

Froude Number

Fr = 2.01

Tailwater/Adjusted Diameter **OR** Tailwater/Adjusted Rise

$Y_t/D$  = 0.58

Supercritical!

Inlet Control Headwater

$HW_i$  = 1.19 ft

Outlet Control Headwater

$HW_o$  = 0.02 ft

Design Headwater Elevation

HW = 7,022.69 ft

Headwater/Diameter **OR** Headwater/Rise Ratio

HW/D = 0.79

Minimum Theoretical Riprap Size

$d_{50}$  = 2 in

Nominal Riprap Size

$d_{50}$  = 6 in

UDFCD Riprap Type

Type = VL

Length of Protection

$L_p$  = 5 ft

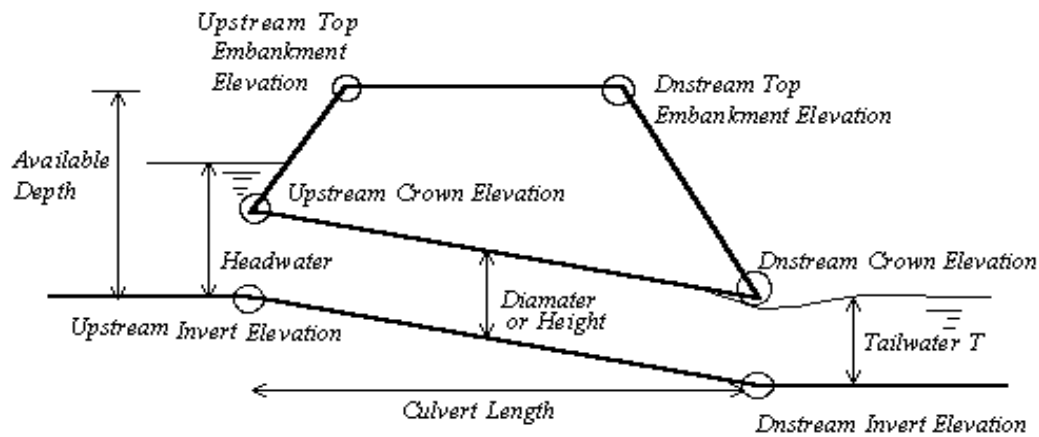
Width of Protection

T = 3 ft

## Vertical Profile for the Culvert

Project = Vollmer Substation

Box ID = PRC1 - Sand Filter Discharge - 100 Yr



### Culvert Information (Input)

Barrel Diameter or Height	D or H =	18.00	inches
Barrel Length	L =	70.00	ft
Barrel Invert Slope	So =	0.0200	ft/ft
Downstream Invert Elevation	EDI =	7020.10	ft
Downstream Top Embankment Elevation	EDT =	7026.00	ft
Upstream Top Embankment Elevation	EUT =	7026.00	ft
Design Headwater Depth (not elev.)	Hw =	1.19	ft
Tailwater Depth (not elev.)	Yt =	1.15	ft

### Culvert Hydraulics (Calculated)

Available Headwater Depth	HW-a =	4.50	ft
Design Hw/D ratio	Hw/D =	0.79	

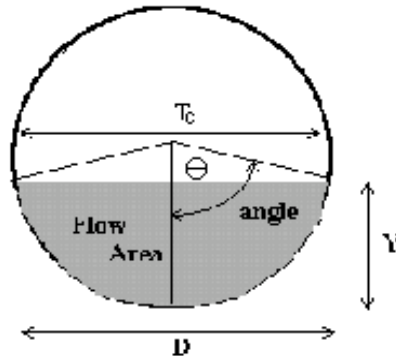
### Culvert Vertical Profile

Upstream Invert Elevation	EUI =	7021.50	ft
Upstream Crown Elevation	EUC =	7023.00	ft
Upstream Soil Cover Depth	Upsoil =	3.00	ft
Downstream Invert Elevation	EDI =	7020.10	ft
Downstream Crown Elevation	EDC =	7021.60	ft
Downstream Soil Cover Depth	Dnsoil =	4.40	ft

## CIRCULAR CONDUIT FLOW (Normal & Critical Depth Computation)

Project: **Vollmer Substation**

Pipe ID: **PRC2 - SW Property Corner Access Crossing - 5 Yr**



### Design Information (Input)

Pipe Invert Slope	$S_o =$	0.0080	ft/ft
Pipe Manning's n-value	$n =$	0.0130	
Pipe Diameter	$D =$	30.00	inches
Design discharge	$Q =$	8.60	cfs

### Full-flow Capacity (Calculated)

Full-flow area	$A_f =$	4.91	sq ft
Full-flow wetted perimeter	$P_f =$	7.85	ft
Half Central Angle	$\theta =$	3.14	radians
Full-flow capacity	$Q_f =$	36.79	cfs

### Calculation of Normal Flow Condition

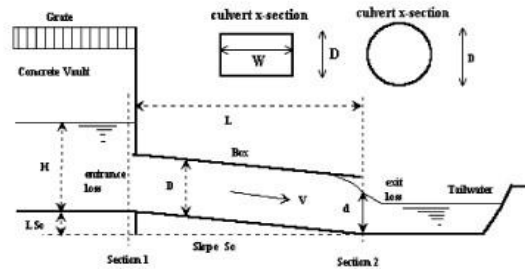
Half Central Angle ( $0 < \theta < 3.14$ )	$\theta =$	1.22	radians
Flow area	$A_n =$	1.41	sq ft
Top width	$T_n =$	2.35	ft
Wetted perimeter	$P_n =$	3.05	ft
Flow depth	$Y_n =$	0.82	ft
Flow velocity	$V_n =$	6.11	fps
Discharge	$Q_n =$	8.60	cfs
Percent Full Flow	$\text{Flow} =$	23.4%	of full flow
Normal Depth Froude Number	$Fr_n =$	1.39	supercritical

### Calculation of Critical Flow Condition

Half Central Angle ( $0 < \theta_c < 3.14$ )	$\theta_c =$	1.35	radians
Critical flow area	$A_c =$	1.78	sq ft
Critical top width	$T_c =$	2.44	ft
Critical flow depth	$Y_c =$	0.98	ft
Critical flow velocity	$V_c =$	4.84	fps
Critical Depth Froude Number	$Fr_c =$	1.00	



Project: **Voolmer Substation**  
 Basin ID: **PRC2 - SW Property Corner Access Crossing - 5 Yr**  
 Status:



**Circular Culvert:** Barrel Diameter in Inches  
Inlet Edge Type (choose from pull-down list)

D = 30 inches

### Grooved End with Headwall

**Box Culvert:** Barrel Height (Rise) in Feet  
Barrel Width (Span) in Feet  
Inlet Edge Type (choose from pull-down list)

Height (Rise) =  ft.

Width (Span) =  ft.

Square Edge w/ 30-78 deg. Flared Wingwall

No = 1

Inlet Elev = 7017.75 ft. elev.

Outlet Elev = 7017.31 ft. elev.

L =  ft.

n =	0.013
-----	-------

$$K_b = 0$$
$$K_x = 1$$

Entrance Loss Coefficient  
Friction Loss Coefficient  
Sum of All Loss Coefficients  
Orifice Inlet Condition Coefficient  
Minimum Energy Condition Coefficient

 $K_e = 0.20$ 

$K_f =$	0.50
---------	------

$K_s =$	1.70
---------	------

$C_d =$	0.99
---------	------

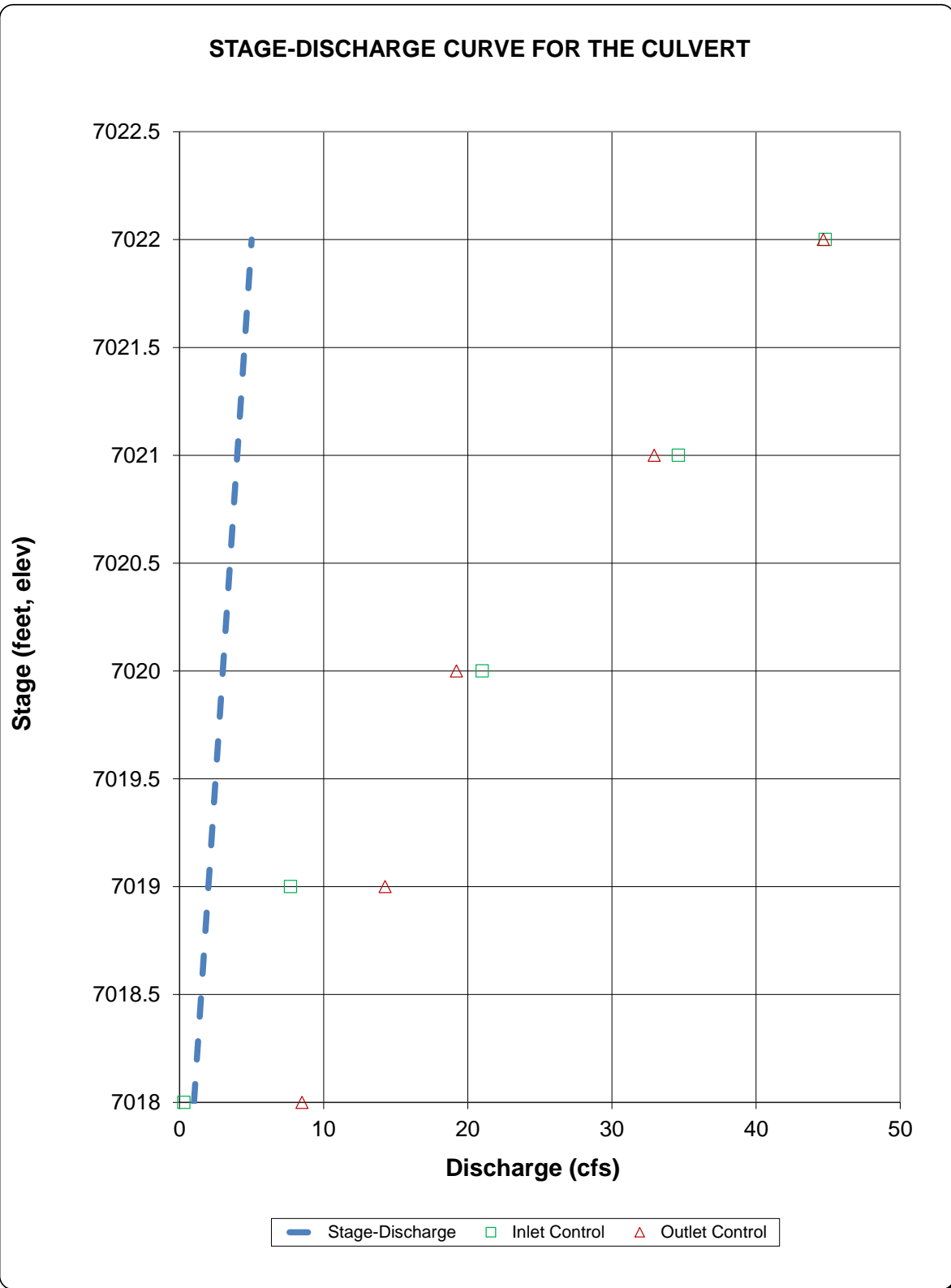
$$KE_{\text{low}} = -0.0373$$
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## CULVERT STAGE-DISCHARGE SIZING (INLET vs. OUTLET CONTROL WITH TAILWATER EFFECTS)

Project: Voolmer Substation

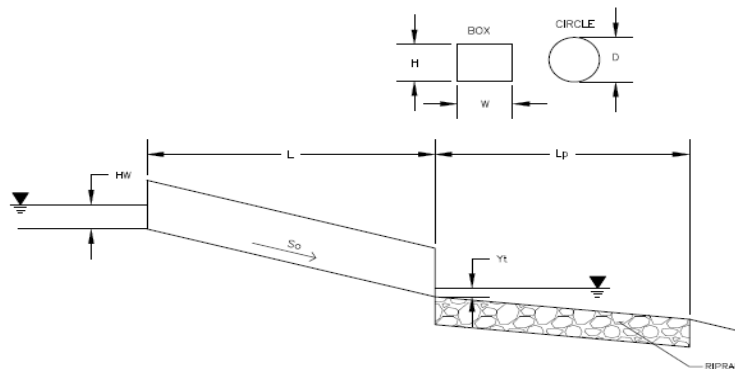
Basin ID: PRC2 - SW Property Corner Access Crossing - 5 Yr



## Determination of Culvert Headwater and Outlet Protection

Project: **Vollmer Substation**

Basin ID: **PRC2 - SW Property Corner Access Crossing - 5 Yr**



Soil Type:

Choose One:

☒ Sandy

☐ Non-Sandy

Supercritical Flow! Using  $D_a$  to calculate protection type.

### Design Information (Input):

Design Discharge

Q = 8.6 cfs

#### Circular Culvert:

Barrel Diameter in Inches

D = 30 inches

Inlet Edge Type (Choose from pull-down list)

Square End Projection

#### Box Culvert:

Barrel Height (Rise) in Feet

Height (Rise) =

Barrel Width (Span) in Feet

Width (Span) =

Inlet Edge Type (Choose from pull-down list)

Number of Barrels

No = 1

Inlet Elevation

Elev IN = 7017.75 ft

Outlet Elevation **OR** Slope

Elev OUT = 7017.31 ft

Culvert Length

L = 55 ft

Manning's Roughness

n = 0.013

Bend Loss Coefficient

$k_b$  = 0

Exit Loss Coefficient

$k_x$  = 1

Tailwater Surface Elevation

Elev  $Y_t$  =

Max Allowable Channel Velocity

V = 5 ft/s

### Required Protection (Output):

Tailwater Surface Height

$Y_t$  = 1.00 ft

Flow Area at Max Channel Velocity

$A_t$  = 1.72 ft<sup>2</sup>

Culvert Cross Sectional Area Available

A = 4.91 ft<sup>2</sup>

Entrance Loss Coefficient

$k_e$  = 0.50

Friction Loss Coefficient

$k_f$  = 0.50

Sum of All Losses Coefficients

$k_s$  = 2.00

Culvert Normal Depth

$Y_n$  = 0.82 ft

Culvert Critical Depth

$Y_c$  = 0.98 ft

Tailwater Depth for Design

d = 1.74 ft

Adjusted Diameter **OR** Adjusted Rise

$D_a$  = 1.66 ft

Expansion Factor

$1/(2*\tan(\Theta))$  = 6.70

Flow/Diameter<sup>2.5</sup> **OR** Flow/(Span \* Rise<sup>1.5</sup>)

$Q/D^{2.5}$  = 0.87 ft<sup>0.5</sup>/s

Froude Number

Fr = 1.39

Tailwater/Adjusted Diameter **OR** Tailwater/Adjusted Rise

$Y_t/D$  = 0.60

Supercritical!

Inlet Control Headwater

$HW_i$  = 1.39 ft

Outlet Control Headwater

$HW_o$  = 1.39 ft

Design Headwater Elevation

HW = 7,019.14 ft

Headwater/Diameter **OR** Headwater/Rise Ratio

HW/D = 0.56

Minimum Theoretical Riprap Size

$d_{50}$  = 2 in

Nominal Riprap Size

$d_{50}$  = 6 in

UDFCD Riprap Type

Type = VL

Length of Protection

$L_p$  = 8 ft

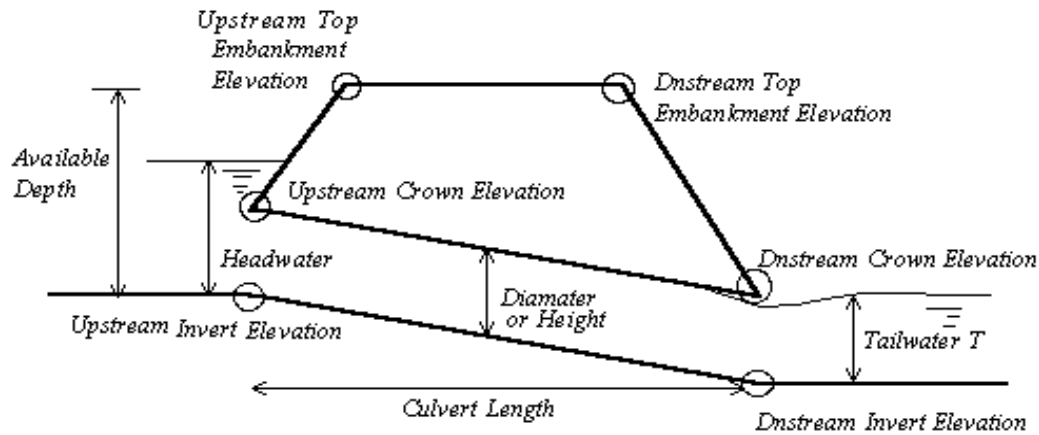
Width of Protection

T = 4 ft

## Vertical Profile for the Culvert

Project = Vollmer Substation

Box ID = PRC2 - SW Property Corner Access Crossing - 5 Yr



### Culvert Information (Input)

Barrel Diameter or Height	D or H =	30.00	inches
Barrel Length	L =	55.00	ft
Barrel Invert Slope	So =	0.0080	ft/ft
Downstream Invert Elevation	EDI =	7017.31	ft
Downstream Top Embankment Elevation	EDT =	7021.50	ft
Upstream Top Embankment Elevation	EUT =	7021.50	ft
Design Headwater Depth (not elev.)	Hw =	1.39	ft
Tailwater Depth (not elev.)	Yt =	1.74	ft

### Culvert Hydraulics (Calculated)

Available Headwater Depth	HW-a =	3.75	ft
Design Hw/D ratio	Hw/D =	0.56	

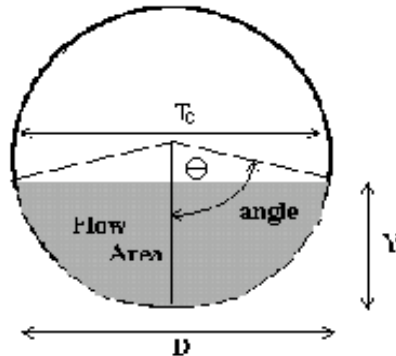
### Culvert Vertical Profile

Upstream Invert Elevation	EUI =	7017.75	ft
Upstream Crown Elevation	EUC =	7020.25	ft
Upstream Soil Cover Depth	Upsoil =	1.25	ft
Downstream Invert Elevation	EDI =	7017.31	ft
Downstream Crown Elevation	EDC =	7019.81	ft
Downstream Soil Cover Depth	Dnsoil =	1.69	ft

## CIRCULAR CONDUIT FLOW (Normal & Critical Depth Computation)

Project: **Vollmer Substation**

Pipe ID: **PRC2 - SW Property Corner Access Crossing - 100 Yr**



### Design Information (Input)

Pipe Invert Slope	$S_o =$	<b>0.0080</b>	ft/ft
Pipe Manning's n-value	$n =$	<b>0.0130</b>	
Pipe Diameter	$D =$	<b>30.00</b>	inches
Design discharge	$Q =$	<b>36.60</b>	cfs

### Full-flow Capacity (Calculated)

Full-flow area	$A_f =$	<b>4.91</b>	sq ft
Full-flow wetted perimeter	$P_f =$	<b>7.85</b>	ft
Half Central Angle	$\theta =$	<b>3.14</b>	radians
Full-flow capacity	$Q_f =$	<b>36.79</b>	cfs

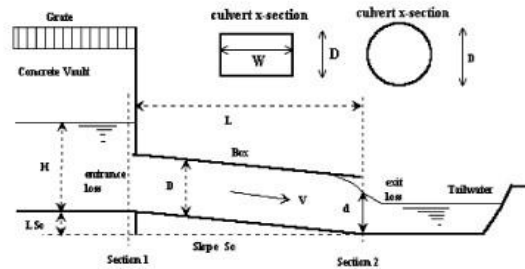
### Calculation of Normal Flow Condition

Half Central Angle ( $0 < \theta < 3.14$ )	$\theta =$	<b>2.25</b>	radians
Flow area	$A_n =$	<b>4.28</b>	sq ft
Top width	$T_n =$	<b>1.94</b>	ft
Wetted perimeter	$P_n =$	<b>5.63</b>	ft
Flow depth	$Y_n =$	<b>2.04</b>	ft
Flow velocity	$V_n =$	<b>8.54</b>	fps
Discharge	$Q_n =$	<b>36.60</b>	cfs
Percent Full Flow	$\text{Flow} =$	<b>99.5%</b>	of full flow
Normal Depth Froude Number	$Fr_n =$	<b>1.01</b>	supercritical

### Calculation of Critical Flow Condition

Half Central Angle ( $0 < \theta_c < 3.14$ )	$\theta_c =$	<b>2.27</b>	radians
Critical flow area	$A_c =$	<b>4.31</b>	sq ft
Critical top width	$T_c =$	<b>1.92</b>	ft
Critical flow depth	$Y_c =$	<b>2.05</b>	ft
Critical flow velocity	$V_c =$	<b>8.50</b>	fps
Critical Depth Froude Number	$Fr_c =$	<b>1.00</b>	

Project: **Voolmer Substation**  
 Basin ID: **PRC2 - SW Property Corner Access Crossing - 100 Yr**  
 Status:



**Circular Culvert:** Barrel Diameter in Inches  
Inlet Edge Type (choose from pull-down list)

D = 30 inches

### Grooved End with Headwall

**Box Culvert:** Barrel Height (Rise) in Feet  
Barrel Width (Span) in Feet  
Inlet Edge Type (choose from pull-down list)

Height (Rise) =  ft.

Width (Span) =  ft.

Square Edge w/ 30-78 deg. Flared Wingwall

No = 1

Inlet Elev = 7017.75 ft. elev.

Outlet Elev = 7017.31 ft. elev.

L =  ft.

n =	0.013
-----	-------

$$K_b = 0$$

$K_x =$	1
---------	---

 $K_e = 0.20$ 

$K_f =$	0.50
---------	------

$K_s =$	1.70
---------	------

$$C_d = 0.99$$
$$K_{\text{low}} = -0.0373$$

LOW

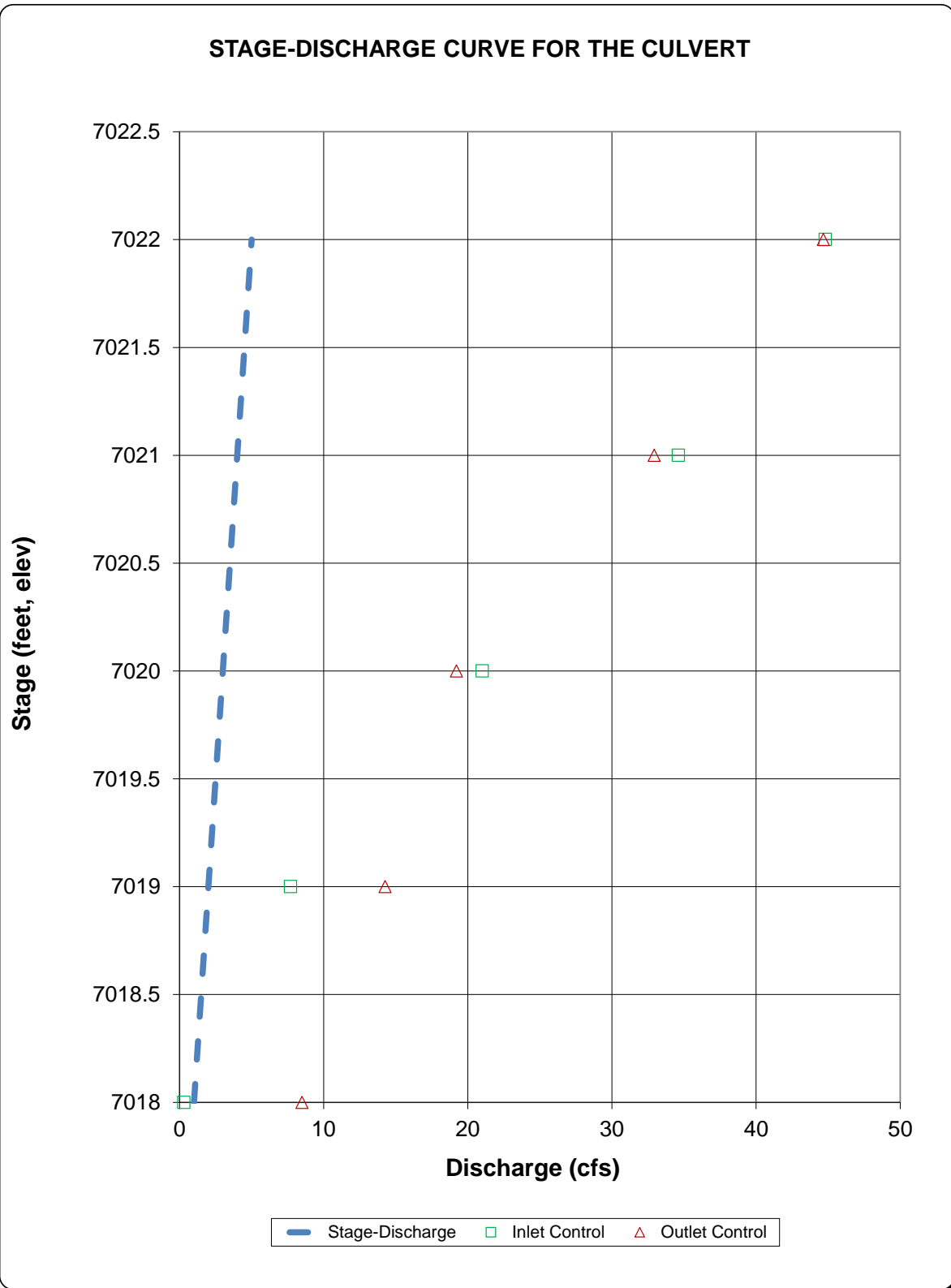
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# CULVERT STAGE-DISCHARGE SIZING (INLET vs. OUTLET CONTROL WITH TAILWATER EFFECTS)

Project: Voolmer Substation

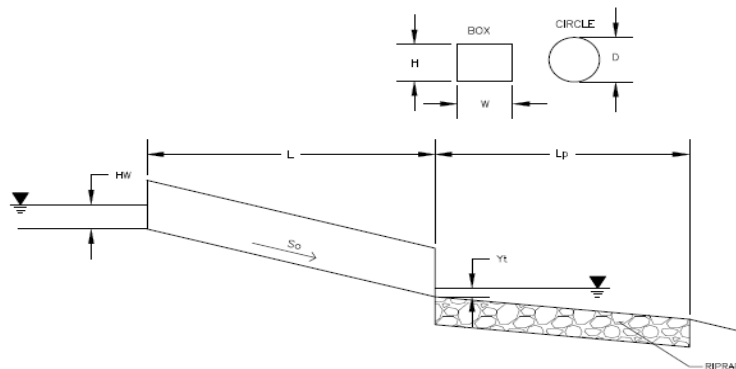
Basin ID: PRC2 - SW Property Corner Access Crossing - 100 Yr



## Determination of Culvert Headwater and Outlet Protection

Project: **Vollmer Substation**

Basin ID: **PRC2 - SW Property Corner Access Crossing - 100 Yr**



Soil Type:

Choose One:

☒ Sandy

☐ Non-Sandy

Supercritical Flow! Using Da to calculate protection type.

### Design Information (Input):

Design Discharge

Q = 36.6 cfs

#### Circular Culvert:

Barrel Diameter in Inches

D = 30 inches

Inlet Edge Type (Choose from pull-down list)

Square End Projection

#### Box Culvert:

Barrel Height (Rise) in Feet

Height (Rise) =

Barrel Width (Span) in Feet

Width (Span) =

Inlet Edge Type (Choose from pull-down list)

Number of Barrels

No = 1

Inlet Elevation

Elev IN = 7017.75 ft

Outlet Elevation **OR** Slope

Elev OUT = 7017.31 ft

Culvert Length

L = 55 ft

Manning's Roughness

n = 0.013

Bend Loss Coefficient

k<sub>b</sub> = 0

Exit Loss Coefficient

k<sub>x</sub> = 1

Tailwater Surface Elevation

Elev Y<sub>t</sub> =

Max Allowable Channel Velocity

V = 5 ft/s

### Required Protection (Output):

Tailwater Surface Height

Y<sub>t</sub> = 1.00 ft

Flow Area at Max Channel Velocity

A<sub>t</sub> = 7.32 ft<sup>2</sup>

Culvert Cross Sectional Area Available

A = 4.91 ft<sup>2</sup>

Entrance Loss Coefficient

k<sub>e</sub> = 0.50

Friction Loss Coefficient

k<sub>f</sub> = 0.50

Sum of All Losses Coefficients

k<sub>s</sub> = 2.00

Culvert Normal Depth

Y<sub>n</sub> = 2.04 ft

Culvert Critical Depth

Y<sub>c</sub> = 2.05 ft

Tailwater Depth for Design

d = 2.28 ft

Adjusted Diameter **OR** Adjusted Rise

D<sub>a</sub> = 2.27 ft

Expansion Factor

1/(2\*tan(Θ)) = 4.37

Flow/Diameter<sup>2.5</sup> **OR** Flow/(Span \* Rise<sup>1.5</sup>)

Q/D<sup>2.5</sup> = 3.70 ft<sup>0.5</sup>/s

Froude Number

Fr = 1.01

Tailwater/Adjusted Diameter **OR** Tailwater/Adjusted Rise

Y<sub>t</sub>/D = 0.44

Supercritical!

Inlet Control Headwater

HW<sub>i</sub> = 3.92 ft

Outlet Control Headwater

HW<sub>o</sub> = 3.57 ft

Design Headwater Elevation

HW = 7,021.67 ft

Headwater/Diameter **OR** Headwater/Rise Ratio

HW/D = 1.57 **HW/D > 1.5!**

Minimum Theoretical Riprap Size

d<sub>50</sub> = 8 in

Nominal Riprap Size

d<sub>50</sub> = 9 in

UDFCD Riprap Type

Type = L

Length of Protection

L<sub>p</sub> = 22 ft

Width of Protection

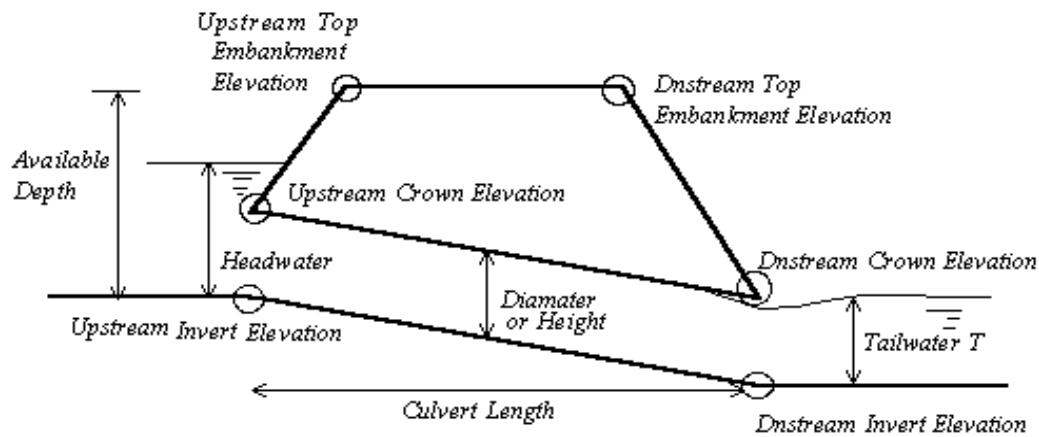
T = 8 ft



## Vertical Profile for the Culvert

Project = Vollmer Substation

Box ID = PRC2 - SW Property Corner Access Crossing - 100 Yr



### Culvert Information (Input)

Barrel Diameter or Height	D or H =	30.00	inches
Barrel Length	L =	55.00	ft
Barrel Invert Slope	So =	0.0080	ft/ft
Downstream Invert Elevation	EDI =	7017.31	ft
Downstream Top Embankment Elevation	EDT =	7021.50	ft
Upstream Top Embankment Elevation	EUT =	7021.50	ft
Design Headwater Depth (not elev.)	Hw =	3.92	ft
Tailwater Depth (not elev.)	Yt =	2.28	ft

### Culvert Hydraulics (Calculated)

Available Headwater Depth	HW-a =	3.75	ft
Design Hw/D ratio	Hw/D =	1.57	

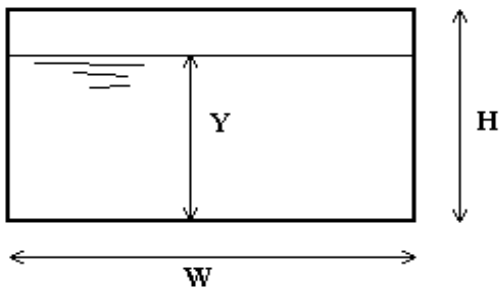
### Culvert Vertical Profile

Upstream Invert Elevation	EUI =	7017.75	ft
Upstream Crown Elevation	EUC =	7020.25	ft
Upstream Soil Cover Depth	Upsoil =	1.25	ft
Downstream Invert Elevation	EDI =	7017.31	ft
Downstream Crown Elevation	EDC =	7019.81	ft
Downstream Soil Cover Depth	Dnsoil =	1.69	ft

## BOX CONDUIT FLOW (Normal & Critical Depth Computation)

Project: Vollmer Substation

Box ID: PRC3 - Crossing Access South of Property - 5 Yr



### Design Information (Input)

Box conduit invert slope	So =	0.0100	ft/ft
Box Manning's n-value	n =	0.0130	
Box Width	W =	2.00	ft
Box Height	H =	1.50	ft
Design discharge	Q =	3.33	cfs

### Full-flow capacity (Calculated)

Full-flow area	Af =	3.00	sq ft
Full-flow wetted perimeter	Pf =	7.00	ft
Full-flow capacity	Qf =	19.55	cfs

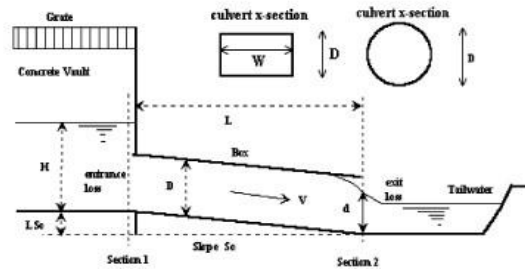
### Calculations of Normal Flow Condition

Normal flow depth (<H)	Yn =	0.35	ft
Flow area	An =	0.71	sq ft
Wetted perimeter	Pn =	2.71	ft
Flow velocity	Vn =	4.69	fps
Discharge	Qn =	3.33	cfs
Percent Full	Flow =	17.0%	of full flow
Normal Depth Froude Number	Fr <sub>n</sub> =	1.39	supercritical

### Calculation of Critical Flow Condition

Critical flow depth	Yc =	0.44	ft
Critical flow area	Ac =	0.88	sq ft
Critical flow velocity	Vc =	3.77	fps
Critical Depth Froude Number	Fr <sub>c</sub> =	1.00	

Project: **Voolmer Substation**  
 Basin ID: **PRC3 - Crossing Access South of Property - 5 Yr**  
 Status:



**Circular Culvert:** Barrel Diameter in Inches  
Inlet Edge Type (choose from pull-down list)

D =  inches

### Grooved End with Headwall

**Box Culvert:** Barrel Height (Rise) in Feet  
Barrel Width (Span) in Feet  
Inlet Edge Type (choose from pull-down list)

Height (Rise) = 1.50 ft.

Width (Span) = 2.00 ft.

Square Edge w/ 30-78 deg. Flared Wingwall

Number of Barrels  
Inlet Elevation at Culvert Invert  
Outlet Elevation at Culvert Invert **OR** Slope of Culvert (ft v./ft h.)  
Culvert Length in Feet  
Manning's Roughness  
Bend Loss Coefficient  
Exit Loss Coefficient

No = 3

Inlet Elev = 7011.5 ft. elev.

Outlet Elev = 7011 ft. elev.

L = 50 ft.

n =	0.013
-----	-------

$$K_b = 0$$
$$K_x = 1$$

Entrance Loss Coefficient  
Friction Loss Coefficient  
Sum of All Loss Coefficients  
Orifice Inlet Condition Coefficient  
Minimum Energy Condition Coefficient

 $K_e = 0.40$ 

$K_f =$	0.91
---------	------

$$K_s = 2.31$$

$C_d =$	0.87
---------	------

$KE_{low} =$	0.0062
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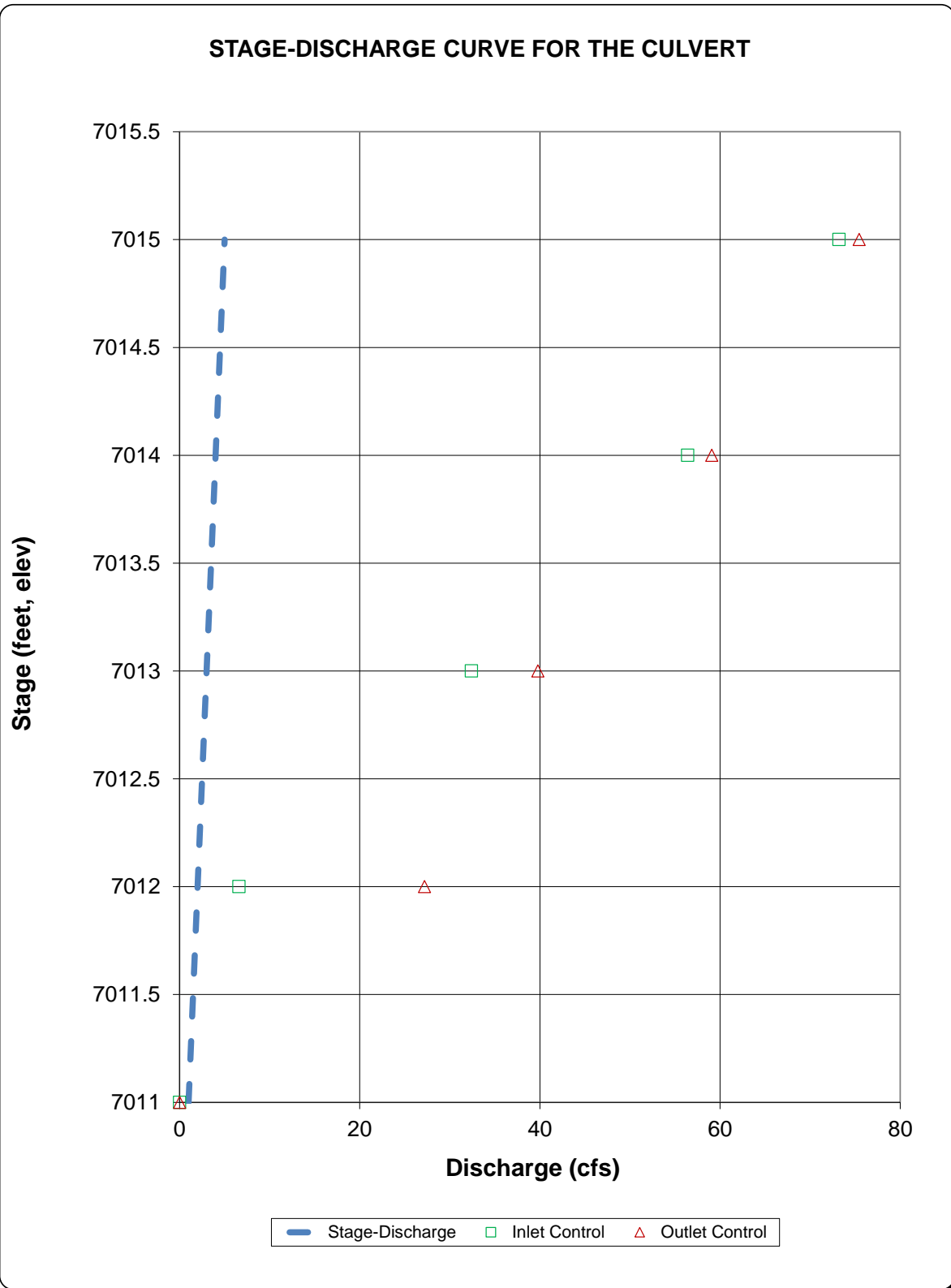
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## CULVERT STAGE-DISCHARGE SIZING (INLET vs. OUTLET CONTROL WITH TAILWATER EFFECTS)

Project: Voolmer Substation

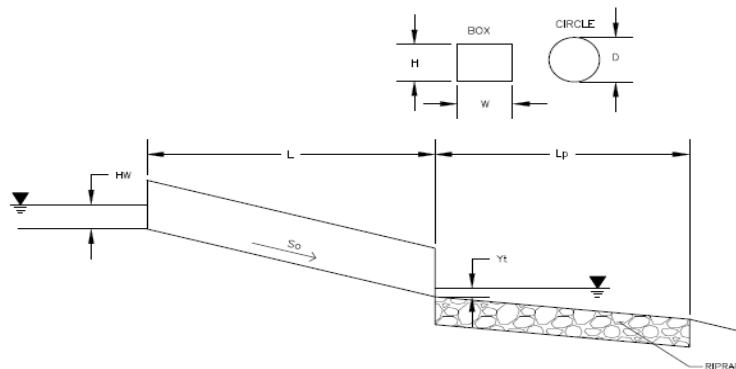
Basin ID: PRC3 - Crossing Access South of Property - 5 Yr



## Determination of Culvert Headwater and Outlet Protection

Project: **Vollmer Substation**

Basin ID: **PRC3 - Crossing Access South of Property - 5 Yr**



Soil Type:

Choose One:

☒ Sandy

☐ Non-Sandy

Supercritical Flow! Using Ha to calculate protection type.

### Design Information (Input):

Design Discharge

Q = 3.33 cfs

#### Circular Culvert:

Barrel Diameter in Inches

D = inches

Inlet Edge Type (Choose from pull-down list)

Square End Projection

#### Box Culvert:

Barrel Height (Rise) in Feet

Height (Rise) = 1.5 ft

Barrel Width (Span) in Feet

Width (Span) = 2 ft

Inlet Edge Type (Choose from pull-down list)

Square Edge w/ 30-78 deg. Flared Wingwall

Number of Barrels

No = 3

Inlet Elevation

Elev IN = 7011.5 ft

Outlet Elevation **OR** Slope

Elev OUT = 7011 ft

Culvert Length

L = 50 ft

Manning's Roughness

n = 0.013

Bend Loss Coefficient

$k_b$  = 0

Exit Loss Coefficient

$k_x$  = 1

Tailwater Surface Elevation

Elev  $Y_t$  = ft

Max Allowable Channel Velocity

V = 5 ft/s

### Required Protection (Output):

Tailwater Surface Height

$Y_t$  = 0.60 ft

Flow Area at Max Channel Velocity

$A_t$  = 0.22 ft<sup>2</sup>

Culvert Cross Sectional Area Available

A = 3.00 ft<sup>2</sup>

Entrance Loss Coefficient

$k_e$  = 0.40

Friction Loss Coefficient

$k_f$  = 0.91

Sum of All Losses Coefficients

$k_s$  = 2.31

Culvert Normal Depth

$Y_n$  = 0.17 ft

Culvert Critical Depth

$Y_c$  = 0.21 ft

Tailwater Depth for Design

d = 0.86 ft

Adjusted Diameter **OR** Adjusted Rise

$H_a$  = 0.84 ft

Expansion Factor

$1/(2*\tan(\Theta))$  = 6.65

Flow/Diameter<sup>2.5</sup> **OR** Flow/(Span \* Rise<sup>1.5</sup>)

$Q/WH^{1.5}$  = 0.30 ft<sup>0.5</sup>/s

Froude Number

Fr = 1.36

Tailwater/Adjusted Diameter **OR** Tailwater/Adjusted Rise

$Y_t/H$  = 0.72

Supercritical!

Inlet Control Headwater

$HW_i$  = 0.32 ft

Outlet Control Headwater

$HW_o$  = 0.36 ft

Design Headwater Elevation

HW = 7,011.86 ft

Headwater/Diameter **OR** Headwater/Rise Ratio

HW/H = 0.24

Minimum Theoretical Riprap Size

$d_{50}$  = 0 in

Nominal Riprap Size

$d_{50}$  = 6 in

UDFCD Riprap Type

Type = VL

Length of Protection

$L_p$  = 5 ft

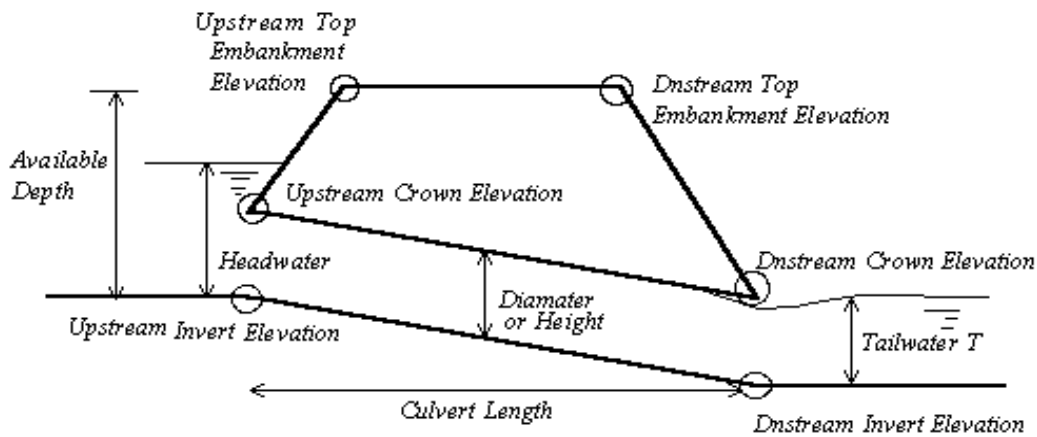
Width of Protection

T = 3 ft

## Vertical Profile for the Culvert

Project = Vollmer Substation

Box ID = PRC3 - Crossing Access South of Property - 5 Yr



### Culvert Information (Input)

Barrel Diameter or Height	D or H =	18.00	inches
Barrel Length	L =	50.00	ft
Barrel Invert Slope	So =	0.0100	ft/ft
Downstream Invert Elevation	EDI =	7011.00	ft
Downstream Top Embankment Elevation	EDT =	7014.00	ft
Upstream Top Embankment Elevation	EUT =	7014.00	ft
Design Headwater Depth (not elev.)	Hw =	0.36	ft
Tailwater Depth (not elev.)	Yt =	0.86	ft

### Culvert Hydraulics (Calculated)

Available Headwater Depth	HW-a =	2.50	ft
Design Hw/D ratio	Hw/D =	0.24	

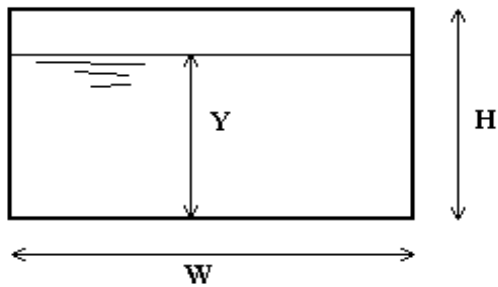
### Culvert Vertical Profile

Upstream Invert Elevation	EUI =	7011.50	ft
Upstream Crown Elevation	EUC =	7013.00	ft
Upstream Soil Cover Depth	Upsoil =	1.00	ft
Downstream Invert Elevation	EDI =	7011.00	ft
Downstream Crown Elevation	EDC =	7012.50	ft
Downstream Soil Cover Depth	Dnsoil =	1.50	ft

## BOX CONDUIT FLOW (Normal & Critical Depth Computation)

Project: **Vollmer Substation**

Box ID: **PRC3 - Crossing Access South of Property - 100 Yr**



### Design Information (Input)

Box conduit invert slope	$S_o =$	<input type="text" value="0.0100"/>	ft/ft
Box Manning's n-value	$n =$	<input type="text" value="0.0130"/>	
Box Width	$W =$	<input type="text" value="2.00"/>	ft
Box Height	$H =$	<input type="text" value="1.50"/>	ft
Design discharge	$Q =$	<input type="text" value="16.20"/>	cfs

### Full-flow capacity (Calculated)

Full-flow area	$A_f =$	<input type="text" value="3.00"/>	sq ft
Full-flow wetted perimeter	$P_f =$	<input type="text" value="7.00"/>	ft
Full-flow capacity	$Q_f =$	<input type="text" value="19.55"/>	cfs

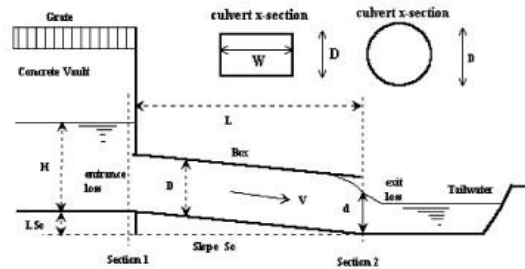
### Calculations of Normal Flow Condition

Normal flow depth ( $<H$ )	$Y_n =$	<input type="text" value="1.09"/>	ft
Flow area	$A_n =$	<input type="text" value="2.18"/>	sq ft
Wetted perimeter	$P_n =$	<input type="text" value="4.18"/>	ft
Flow velocity	$V_n =$	<input type="text" value="7.43"/>	fps
Discharge	$Q_n =$	<input type="text" value="16.20"/>	cfs
Percent Full	Flow =	<input type="text" value="82.9%"/>	of full flow
Normal Depth Froude Number	$Fr_n =$	<input type="text" value="1.25"/>	supercritical

### Calculation of Critical Flow Condition

Critical flow depth	$Y_c =$	<input type="text" value="1.27"/>	ft
Critical flow area	$A_c =$	<input type="text" value="2.54"/>	sq ft
Critical flow velocity	$V_c =$	<input type="text" value="6.39"/>	fps
Critical Depth Froude Number	$Fr_c =$	<input type="text" value="1.00"/>	

Project: **Voolmer Substation**  
 Basin ID: **PRC3 - Crossing Access South of Property - 100 Yr**  
 Status:



**Circular Culvert:** Barrel Diameter in Inches  
Inlet Edge Type (choose from pull-down list)

D =  inches

### Grooved End with Headwall

**Box Culvert:** Barrel Height (Rise) in Feet  
Barrel Width (Span) in Feet  
Inlet Edge Type (choose from pull-down list)

Height (Rise) = 1.50 ft.

Width (Span) = 2.00 ft.

Square Edge w/ 30-78 deg. Flared Wingwall

No = 3

Inlet Elev = 7011.5 ft. elev.

Outlet Elev = 7011 ft. elev.

L = 50 ft.

n =	0.013
-----	-------

$$K_b = 0$$
$$K_x = 1$$

Entrance Loss Coefficient  
Friction Loss Coefficient  
Sum of All Loss Coefficients  
Orifice Inlet Condition Coefficient  
Minimum Energy Condition Coefficient

$$K_e = 0.40$$

$K_f =$	0.91
---------	------

$K_s =$	2.31
---------	------

$C_d =$	0.87
---------	------

$$KE_{\text{low}} = 0.0062$$
[illegible]

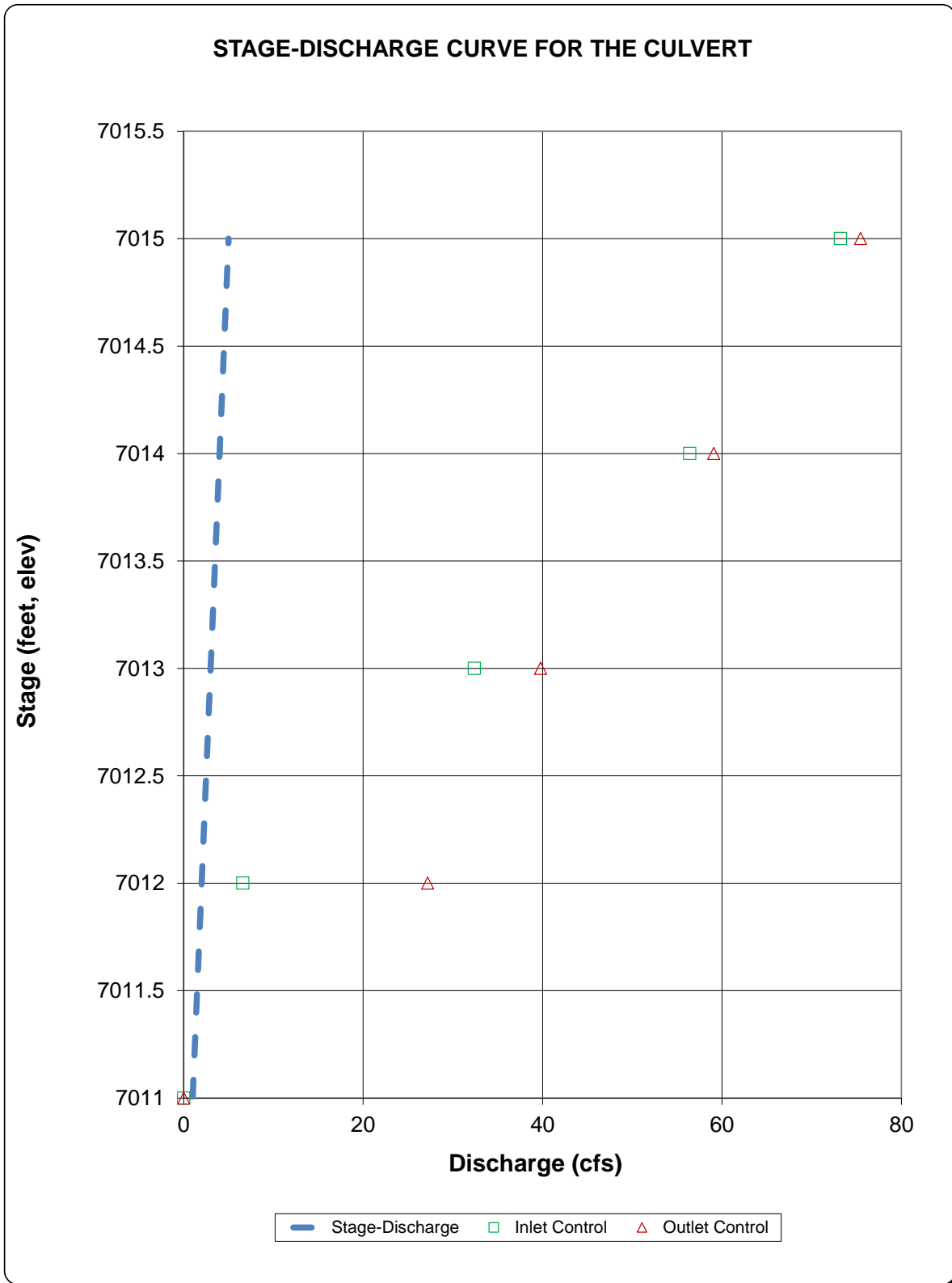
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## CULVERT STAGE-DISCHARGE SIZING (INLET vs. OUTLET CONTROL WITH TAILWATER EFFECTS)

Project: Voolmer Substation

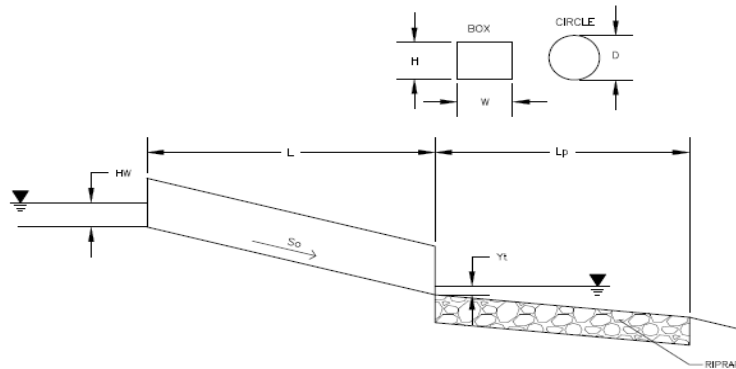
Basin ID: PRC3 - Crossing Access South of Property - 100 Yr



## Determination of Culvert Headwater and Outlet Protection

Project: **Vollmer Substation**

Basin ID: **PRC3 - Crossing Access South of Property - 100 Yr**



Soil Type:

Choose One:

☒ Sandy

☐ Non-Sandy

Supercritical Flow! Using  $H_a$  to calculate protection type.

### Design Information (Input):

Design Discharge

Q = 48.5 cfs

#### Circular Culvert:

Barrel Diameter in Inches

D = inches

Inlet Edge Type (Choose from pull-down list)

Square End Projection

#### Box Culvert:

Barrel Height (Rise) in Feet

Height (Rise) = 1.5 ft

Barrel Width (Span) in Feet

Width (Span) = 2 ft

Inlet Edge Type (Choose from pull-down list)

Square Edge w/ 30-78 deg. Flared Wingwall

Number of Barrels

No = 3

Inlet Elevation

Elev IN = 7011.5 ft

Outlet Elevation **OR** Slope

Elev OUT = 7011 ft

Culvert Length

L = 50 ft

Manning's Roughness

n = 0.013

Bend Loss Coefficient

$k_b$  = 0

Exit Loss Coefficient

$k_x$  = 1

Tailwater Surface Elevation

Elev  $Y_t$  = ft

Max Allowable Channel Velocity

V = 5 ft/s

### Required Protection (Output):

Tailwater Surface Height

$Y_t$  = 0.60 ft

Flow Area at Max Channel Velocity

$A_t$  = 3.23 ft<sup>2</sup>

Culvert Cross Sectional Area Available

A = 3.00 ft<sup>2</sup>

Entrance Loss Coefficient

$k_e$  = 0.40

Friction Loss Coefficient

$k_f$  = 0.91

Sum of All Losses Coefficients

$k_s$  = 2.31

Culvert Normal Depth

$Y_n$  = 1.09 ft

Culvert Critical Depth

$Y_c$  = 1.27 ft

Tailwater Depth for Design

d = 1.38 ft

Adjusted Diameter **OR** Adjusted Rise

$H_a$  = 1.29 ft

Expansion Factor

$1/(2*\tan(\Theta))$  = 3.01

Flow/Diameter<sup>2.5</sup> **OR** Flow/(Span \* Rise<sup>1.5</sup>)

$Q/WH^{1.5}$  = 4.40 ft<sup>0.5</sup>/s

Froude Number

Fr = 1.25

Tailwater/Adjusted Diameter **OR** Tailwater/Adjusted Rise

$Y_t/H$  = 0.46

Supercritical!

Inlet Control Headwater

$HW_i$  = 2.13 ft

Outlet Control Headwater

$HW_o$  = 1.92 ft

Design Headwater Elevation

HW = 7,013.63 ft

Headwater/Diameter **OR** Headwater/Rise Ratio

HW/H = 1.42

Minimum Theoretical Riprap Size

$d_{50}$  = 3 in

Nominal Riprap Size

$d_{50}$  = 6 in

UDFCD Riprap Type

Type = VL

Length of Protection

$L_p$  = 11 ft

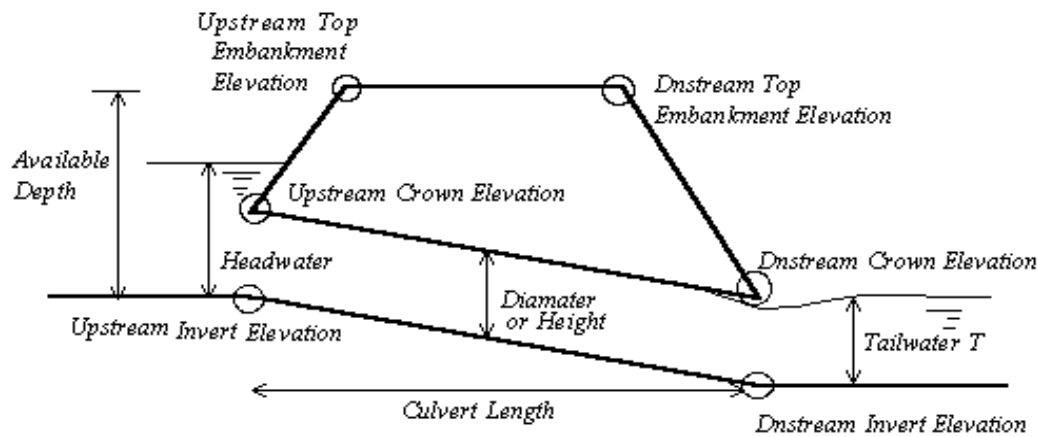
Width of Protection

T = 6 ft

## Vertical Profile for the Culvert

Project = Vollmer Substation

Box ID = PRC3 - Crossing Access South of Property - 100 Yr



### Culvert Information (Input)

Barrel Diameter or Height	D or H =	18.00	inches
Barrel Length	L =	50.00	ft
Barrel Invert Slope	So =	0.0100	ft/ft
Downstream Invert Elevation	EDI =	7011.00	ft
Downstream Top Embankment Elevation	EDT =	7014.00	ft
Upstream Top Embankment Elevation	EUT =	7014.00	ft
Design Headwater Depth (not elev.)	Hw =	2.13	ft
Tailwater Depth (not elev.)	Yt =	1.38	ft

### Culvert Hydraulics (Calculated)

Available Headwater Depth	HW-a =	2.50	ft
Design Hw/D ratio	Hw/D =	1.42	

### Culvert Vertical Profile

Upstream Invert Elevation	EUI =	7011.50	ft
Upstream Crown Elevation	EUC =	7013.00	ft
Upstream Soil Cover Depth	Upsoil =	1.00	ft
Downstream Invert Elevation	EDI =	7011.00	ft
Downstream Crown Elevation	EDC =	7012.50	ft
Downstream Soil Cover Depth	Dnsoil =	1.50	ft

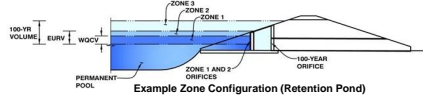
## **WATER QUALITY CALCULATIONS**

# DETENTION BASIN STAGE-STORAGE TABLE BUILDER

UD-Detention, Version 3.07 (February 2017)

Project: Volmer Substation

Basin ID: PR-3 (Design Point 3)



## Required Volume Calculation

Selected BMP Type =	SF
Watershed Area =	1.70 acres
Watershed Length =	180 ft
Watershed Slope =	0.010 ft/ft
Watershed Imperviousness =	40.00% percent
Percentage Hydrologic Soil Group A =	100.00% percent
Percentage Hydrologic Soil Group B =	0.0% percent
Percentage Hydrologic Soil Groups C/D =	0.0% percent
Desired WQCV Drain Time =	40.0 hours
Location for 1-hr Rainfall Depths =	Denver - Capitol Building
Water Quality Capture Volume (WQCV) =	0.020 acre-feet
Excess Urban Runoff Volume (EURV) =	0.074 acre-feet
2-yr Runoff Volume (P1 = 1.19 in.) =	0.050 acre-feet
5-yr Runoff Volume (P1 = 1.5 in.) =	0.066 acre-feet
10-yr Runoff Volume (P1 = 1.75 in.) =	0.082 acre-feet
25-yr Runoff Volume (P1 = 2 in.) =	0.105 acre-feet
50-yr Runoff Volume (P1 = 2.25 in.) =	0.136 acre-feet
100-yr Runoff Volume (P1 = 2.52 in.) =	0.175 acre-feet
500-yr Runoff Volume (P1 = 3.14 in.) =	0.265 acre-feet
Approximate 2-yr Detention Volume =	0.047 acre-feet
Approximate 5-yr Detention Volume =	0.062 acre-feet
Approximate 10-yr Detention Volume =	0.077 acre-feet
Approximate 25-yr Detention Volume =	0.095 acre-feet
Approximate 50-yr Detention Volume =	0.107 acre-feet
Approximate 100-yr Detention Volume =	0.125 acre-feet

Note: L / W Ratio < 1

L / W Ratio = 0.4

Drain Time Too Long

Optional User Override

1-hr Precipitation

1.19 inches

1.50 inches

1.75 inches

2.00 inches

2.25 inches

2.52 inches

## Stage-Storage Calculation

Zone 1 Volume (WQCV) =	0.020	acre-feet
Select Zone 2 Storage Volume (Optional) =		acre-feet
Select Zone 3 Storage Volume (Optional) =		acre-feet
Total Detention Basin Volume =	0.020	acre-feet
Initial Surcharge Volume (ISV) =	N/A	ft³
Initial Surcharge Depth (ISD) =	N/A	ft
Total Available Detention Depth (H <sub>total</sub> ) =	1.00	ft
Depth of Trickle Channel (H <sub>TC</sub> ) =	N/A	ft
Slope of Trickle Channel (S <sub>TC</sub> ) =	N/A	ft/ft
Slopes of Main Basin Sides (S <sub>main</sub> ) =	4:01	H:V
Basin Length-to-Width Ratio (R <sub>L/W</sub> ) =	4	
Initial Surcharge Area (A <sub>ISV</sub> ) =	0	ft²
Surcharge Volume Length (L <sub>SV</sub> ) =	0.0	ft
Surcharge Volume Width (W <sub>SV</sub> ) =	0.0	ft
Depth of Basin Floor (H <sub>basin</sub> ) =	0.00	ft
Length of Basin Floor (L <sub>basin</sub> ) =	59.2	ft
Width of Basin Floor (W <sub>basin</sub> ) =	14.8	ft
Area of Basin Floor (A <sub>basin</sub> ) =	875	ft²
Volume of Basin Floor (V <sub>basin</sub> ) =	0	ft³
Depth of Main Basin (H <sub>main</sub> ) =	1.00	ft
Length of Main Basin (L <sub>main</sub> ) =	59.5	ft
Width of Main Basin (W <sub>main</sub> ) =	15.1	ft
Area of Main Basin (A <sub>main</sub> ) =	900	ft²
Volume of Main Basin (V <sub>main</sub> ) =	888	ft³
Calculated Total Basin Volume (V <sub>total</sub> ) =	0.020	acre-feet

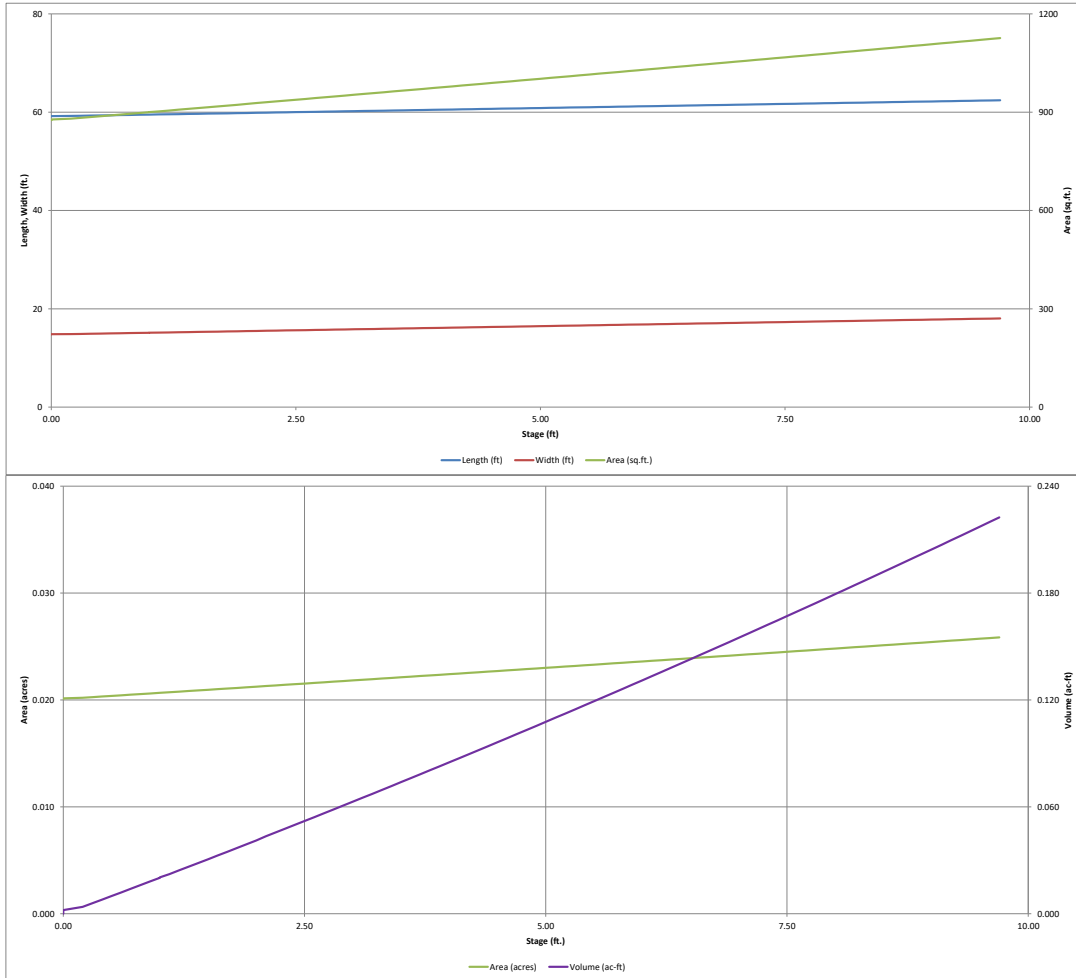
Total detention volume is less than 100-year volume.

Smain not typical.

Depth Increment =	0.1	ft							
Stage - Storage Description	Stage (ft)	Optional Override Stage (ft)	Length (ft)	Width (ft)	Area (ft²)	Optional Override Area (ft²)	Area (acres)	Volume (ft³)	Volume (ac-ft)
Media Surface	0.00		59.2	14.8	875		0.020		
	0.10		59.2	14.8	878		0.020	88	0.002
	0.20		59.2	14.9	880		0.020	167	0.004
	0.30		59.3	14.9	883		0.020	255	0.006
	0.40		59.3	14.9	885		0.020	343	0.008
	0.50		59.3	15.0	888		0.020	432	0.010
	0.60		59.4	15.0	890		0.020	521	0.012
	0.70		59.4	15.0	893		0.020	610	0.014
	0.80		59.4	15.1	895		0.021	699	0.016
	0.90		59.5	15.1	898		0.021	789	0.018
Zone 1 (WQCV)	1.00		59.5	15.1	900		0.021	879	0.020
	1.10		59.5	15.2	903		0.021	888	0.020
	1.20		59.6	15.2	905		0.021	969	0.022
	1.30		59.6	15.2	908		0.021	1,059	0.024
	1.40		59.6	15.3	910		0.021	1,150	0.026
	1.50		59.7	15.3	913		0.021	1,241	0.028
	1.60		59.7	15.3	915		0.021	1,332	0.031
	1.70		59.7	15.4	918		0.021	1,423	0.033
	1.80		59.8	15.4	920		0.021	1,515	0.035
	1.90		59.8	15.4	923		0.021	1,607	0.037
	2.00		59.8	15.5	925		0.021	1,699	0.039
	2.10		59.9	15.5	928		0.021	1,791	0.041
	2.20		59.9	15.5	930		0.021	1,883	0.043
	2.30		59.9	15.6	933		0.021	1,986	0.046
	2.40		60.0	15.6	935		0.021	2,079	0.048
	2.50		60.0	15.6	938		0.022	2,173	0.050
	2.60		60.0	15.7	941		0.022	2,267	0.052
	2.70		60.1	15.7	943		0.022	2,360	0.054
	2.80		60.1	15.7	946		0.022	2,455	0.056
	2.90		60.1	15.8	948		0.022	2,549	0.059
	3.00		60.2	15.8	951		0.022	2,644	0.061
	3.10		60.2	15.8	953		0.022	2,739	0.063
	3.20		60.2	15.9	956		0.022	2,834	0.065
	3.30		60.3	15.9	958		0.022	2,929	0.067
	3.40		60.3	15.9	961		0.022	3,025	0.069
	3.50		60.3	16.0	963		0.022	3,121	0.072
	3.60		60.4	16.0	966		0.022	3,217	0.074
	3.70		60.4	16.0	969		0.022	3,314	0.076
	3.80		60.4	16.1	971		0.022	3,410	0.078
	3.90		60.5	16.1	974		0.022	3,507	0.081
	4.00		60.5	16.1	976		0.022	3,605	0.083
	4.10		60.5	16.2	979		0.022	3,702	0.085
	4.20		60.6	16.2	981		0.022	3,800	0.087
	4.30		60.6	16.2	984		0.023	3,898	0.089
	4.40		60.6	16.2	987		0.023	3,996	0.092
	4.50		60.6	16.3	989		0.023	4,095	0.094
	4.60		60.7	16.3	989		0.023	4,194	0.096
	4.70		60.7	16.3	992		0.023	4,293	0.099
	4.80		60.7	16.4	994		0.023	4,392	0.101
	4.90		60.8	16.4	997		0.023	4,491	0.103
	5.00		60.8	16.4	999		0.023	4,591	0.105
	5.10		60.8	16.5	1,002		0.023	4,691	0.108
	5.20		60.9	16.5	1,005		0.023	4,792	0.110
	5.30		60.9	16.5	1,007		0.023	4,892	0.112
	5.40		61.0	16.6	1,010		0.023	4,993	0.115
	5.50		61.0	16.6	1,012		0.023	5,094	0.117
	5.60		61.0	16.6	1,015		0.023	5,196	0.119
	5.70		61.1	16.7	1,018		0.023	5,297	0.122
	5.80		61.1	16.7	1,020		0.023	5,399	0.124
	5.90		61.1	16.7	1,023		0.023	5,501	0.126
6.00		61.2	16.8	1,025		0.024	5,604	0.129	
6.10		61.2	16.8	1,028		0.024	5,706	0.131	
6.20		61.2	16.8	1,031		0.024	5,808	0.133	
6.30		61.3	16.9	1,033		0.024	5,912	0.136	
6.40		61.3	16.9	1,036		0.024	6,016	0.138	
6.50		61.3	16.9	1,038		0.024	6,120	0.140	
6.60		61.4	17.0	1,041		0.024	6,224	0.143	
6.70		61.4	17.0	1,044		0.024	6,328	0.145	
6.80		61.4	17.0	1,046		0.024	6,432	0.148	
6.90		61.5	17.1	1,049		0.024	6,537	0.150	
7.00		61.5	17.1	1,052		0.024	6,642	0.152	
7.10		61.5	17.1	1,054		0.024	6,747	0.155	
7.20		61.6	17.2	1,057		0.024	6,853	0.157	
7.30		61.6	17.2	1,060		0.024	6,959	0.160	
7.40		61.7	17.3	1,062		0.024	7,065	0.162	
7.50		61.7	17.3	1,065		0.024	7,171	0.165	
7.60		61.7	17.3	1,067		0.025	7,278	0.167	
7.70		61.7	17.3	1,070		0.025	7,385	0.170	
7.80		61.8	17.4	1,073		0.025	7,492	0.172	
7.90		61.8	17.4	1,075		0.025	7,599	0.174	
8.00		61.8	17.4	1,078		0.025	7,707	0.177	
8.10		61.9	17.5	1,081		0.025	7,815	0.179	
8.20		61.9	17.5	1,083		0.025	7,923	0.182	
8.30		61.9	17.5	1,086		0.025	8,032	0.184	
8.40		62.0	17.6	1,089		0.025	8,140	0.187	
8.50		62.0	17.6	1,091		0.025	8,249	0.189	
8.60		62.0	17.6	1,094		0.025	8,359	0.192	
8.70		62.1	17.7	1,097		0.025	8,468	0.194	
8.80		62.1	17.7	1,099		0.025	8,578	0.197	
8.90		62.1	17.7	1,102		0.025	8,688	0.199	
9.00		62.2	17.8	1,105		0.025	8,798	0.202	
9.10		62.2	17.8	1,107		0.025	8,909	0.205	
9.20		62.2	17.8	1,110		0.025	9,020	0.207	
9.30		62.3	17.9	1,113		0.026	9,131	0.210	
9.40		62.3	17.9	1,115		0.026	9,242	0.212	
9.50		62.3	17.9	1,118		0.026	9,354	0.215	
9.60		62.4	18.0	1,121		0.026	9,466	0.217	
9.70		62.4	18.0	1,123		0.026	9,578	0.220	
9.80		62.4	18.0	1,126		0.026	9,691	0.222	

# DETENTION BASIN STAGE-STORAGE TABLE BUILDER

UD-Detention, Version 3.07 (February 2017)

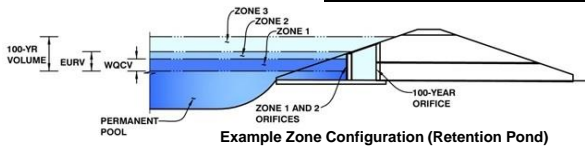


## Detention Basin Outlet Structure Design

UD-Detention, Version 3.07 (February 2017)

Project: Vollmer Substation

Basin ID: PR-3 (Design Point 3)



	Stage (ft)	Zone Volume (ac-ft)	Outlet Type
Zone 1 (WQCV)	1.00	0.020	Filtration Media
Zone 2			
Zone 3			
		0.020	Total

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

Underdrain Orifice Invert Depth = 2.17 ft (distance below the filtration media surface)  
Underdrain Orifice Diameter = 0.37 inches

Calculated Parameters for Underdrain

Underdrain Orifice Area = 0.0 ft<sup>2</sup>  
Underdrain Orifice Centroid = 0.02 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 = ft (relative to basin bottom at Stage = 0 ft)  
Depth at top of Zone using Orifice Plate = ft (relative to basin bottom at Stage = 0 ft)  
Orifice Plate: Orifice Vertical Spacing = inches  
Orifice Plate: Orifice Area per Row = inches

Calculated Parameters for Plate

WQ Orifice Area per Row = N/A ft<sup>2</sup>  
Elliptical Half-Width = N/A feet  
Elliptical Slot Centroid = N/A feet  
Elliptical Slot Area = N/A ft<sup>2</sup>

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

	Row 1 (optional)	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)								
Orifice Area (sq. inches)								

	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 (rela  
Depth at top of Zone using Vertical Orifice = ft (rela  
Vertical Orifice Diameter = inches

- The current version of the report may have cleared this up.
- 1. The overflow outlet structure can pass the 500 year flow with volume to spare.
- 2. The sand filter is surrounded on all sides by gravel access roads. Putting a spillway across a gravel road is problematic.
- 3. There is a ponding area around the sand filter that is much larger than the sand filter where even more water can pond up before it would get up to the access roads.

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

Not Selected Not Selected  
Overflow Weir Front Edge Height, Ho = 7025.00 ft (rela  
Overflow Weir Front Edge Length = 2.00 feet  
Overflow Weir Slope = 0.00 H:V (e  
Horiz. Length of Weir Sides = 2.00 feet  
Overflow Grate Open Area % = 70% % grat  
Debris Clogging % = 50% %

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

Not Selected Not Selected  
Depth to Invert of Outlet Pipe = ft (distance below basin bottom at Stage = 0 ft)  
Circular Orifice Diameter = inches  
Half-Central Angle of Restrictor Plate on Pipe =

Calculated Parameters for Outlet Pipe w/ Flow

Not Selected Not Selected  
Outlet Orifice Area = ft<sup>2</sup>  
Outlet Orifice Centroid = ft  
Half-Central Angle of Restrictor Plate on Pipe = N/A

Per DCM Vol. 1 11.3.2, all detention facilities should have an emergency spillway.

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

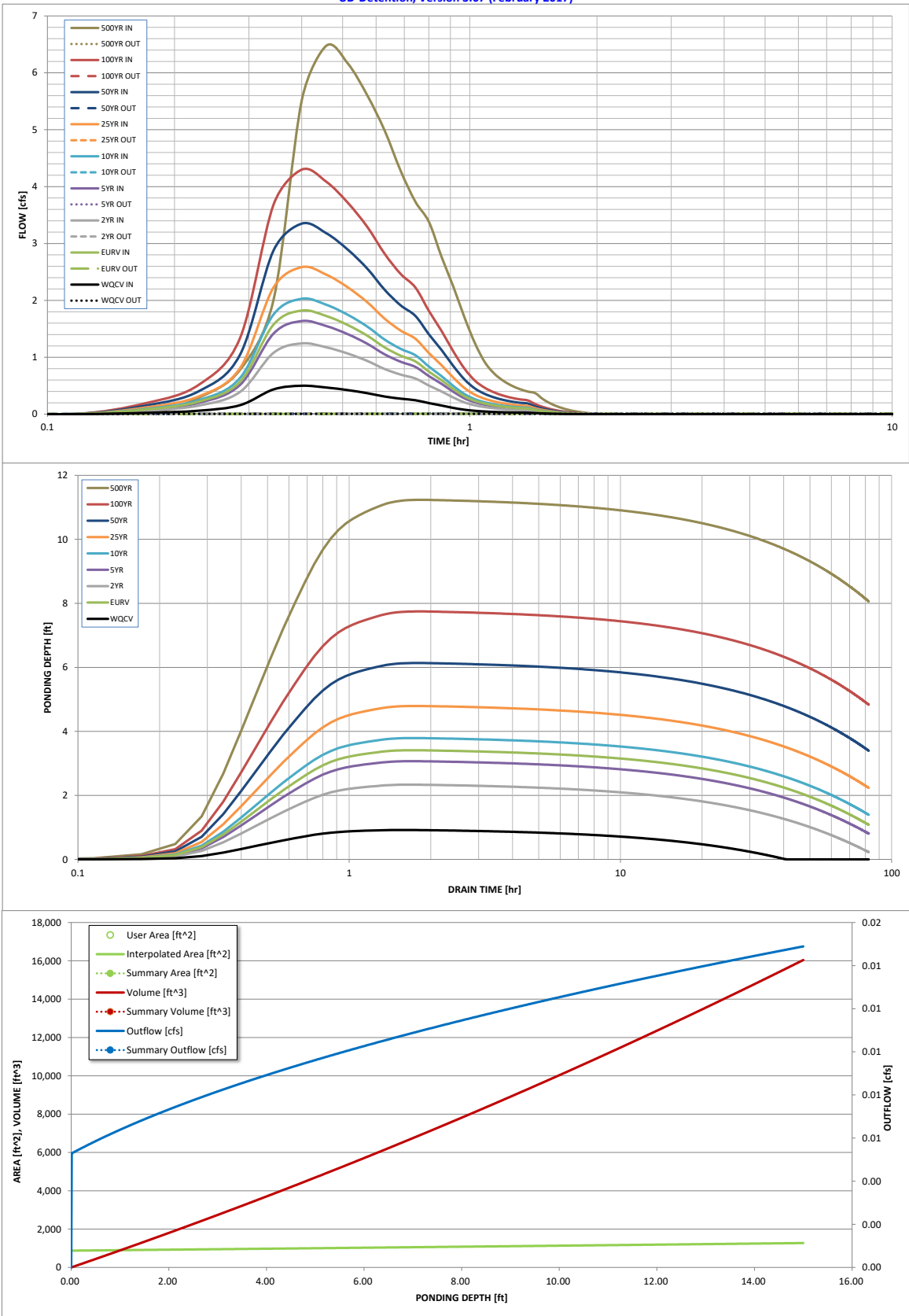
	WQCV	EURV	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year	500 Year
Design Storm Return Period =									
One-Hour Rainfall Depth (in) =	0.53	1.07	1.19	1.50	1.75	2.00	2.25	2.52	3.14
Calculated Runoff Volume (acre-ft) =	0.020	0.074	0.050	0.066	0.082	0.105	0.136	0.175	0.265
OPTIONAL Override Runoff Volume (acre-ft) =									
Inflow Hydrograph Volume (acre-ft) =	0.020	0.073	0.049	0.065	0.081	0.104	0.136	0.175	0.265
Predevelopment Unit Peak Flow, q (cfs/acre) =	0.00	0.00	0.00	0.01	0.01	0.03	0.23	0.56	1.25
Predevelopment Peak Q (cfs) =	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.9	2.1
Peak Inflow Q (cfs) =	0.5	1.8	1.2	1.6	2.0	2.6	3.3	4.3	6.5
Peak Outflow Q (cfs) =	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ratio Peak Outflow to Predevelopment Q =	N/A	N/A	N/A	0.8	0.4	0.2	0.0	0.0	0.0
Structure Controlling Flow =	Filtration Media	Filtration Media	Filtration Media	Filtration Media	Filtration Media	Filtration Media	Filtration Media	Filtration Media	Filtration Media
Max Velocity through Grate 1 (fps) =	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	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	>120	>120	>120	>120	>120	>120	>120	>120
Time to Drain 99% of Inflow Volume (hours) =	40	>120	>120	>120	>120	>120	>120	>120	>120
Maximum Ponding Depth (ft) =	0.92	3.41	2.33	3.07	3.79	4.79	6.14	7.75	11.24
Area at Maximum Ponding Depth (acres) =	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03
Maximum Volume Stored (acre-ft) =	0.019	0.072	0.048	0.064	0.080	0.103	0.134	0.173	0.263

something is off about the two "Time to Drain" rows. The SDI form shows these as <48hrs but they are >120hrs here. Check inputs and revise as needed.

Already fixed in the current report version

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			





## **DRAINAGE MAPS**

**VOLLMER SUBSTATION**  
EL PASO COUNTY, CO  
**EXISTING DRAINAGE MAP**  
SEPTEMBER 2018

## DESIGN POINT SUMMARY










DP	CONTRIBUTING BASINS	AREA AC.	Q5 CFS	Q10 CFS	Q100 CFS
Z	OS-1	138	---	20	---
Y	OS-2	79	7.1	---	43.7
A	EX-A	2.77	0.7	---	4.8
B	EX-B, OS-2	81	7.7	---	36.6*

\* NOTE: THE EXISTING SWALE EXS1 HAS A MAX CAPACITY OF 36.6 CFS.

### PROPOSED CONDITIONS

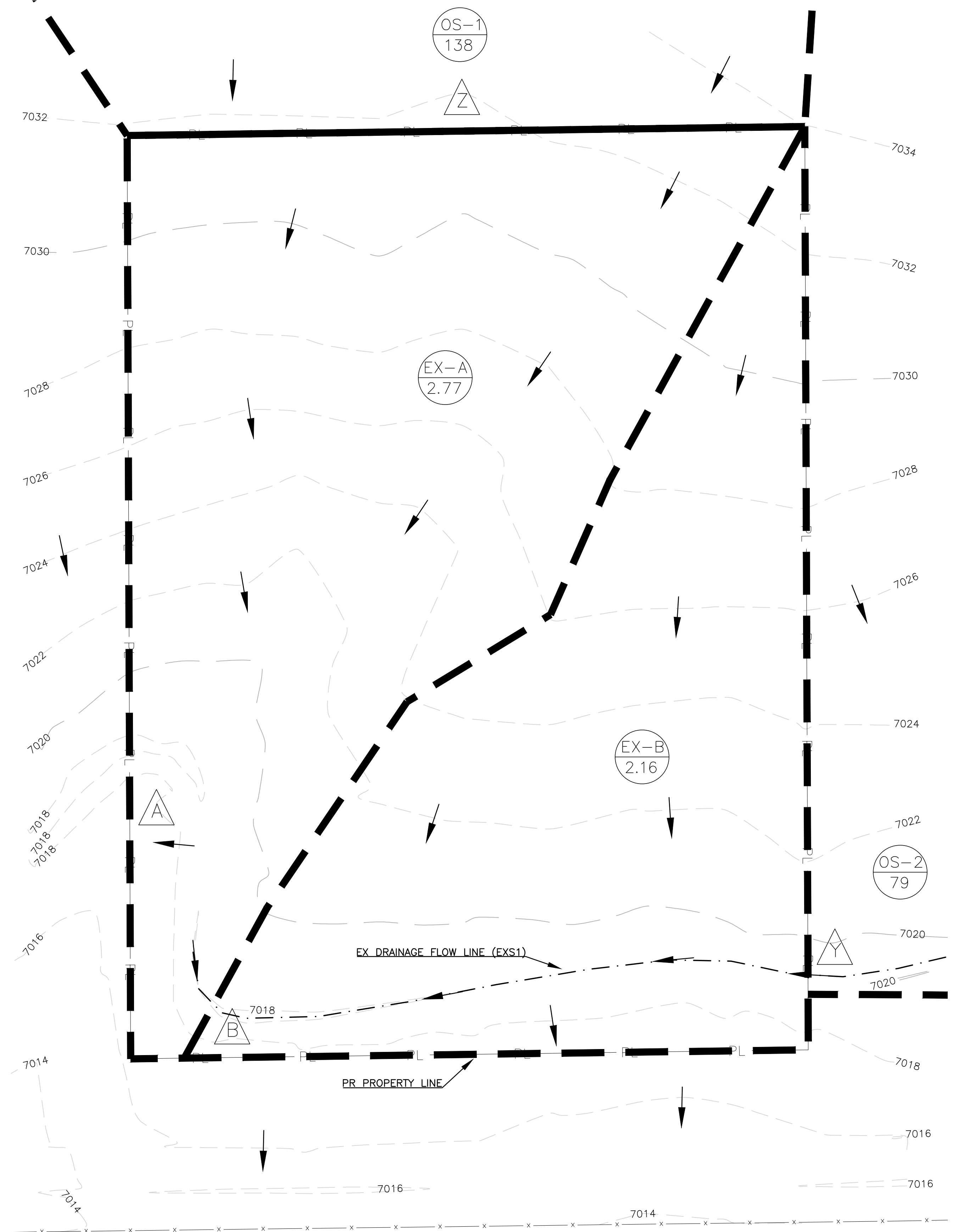
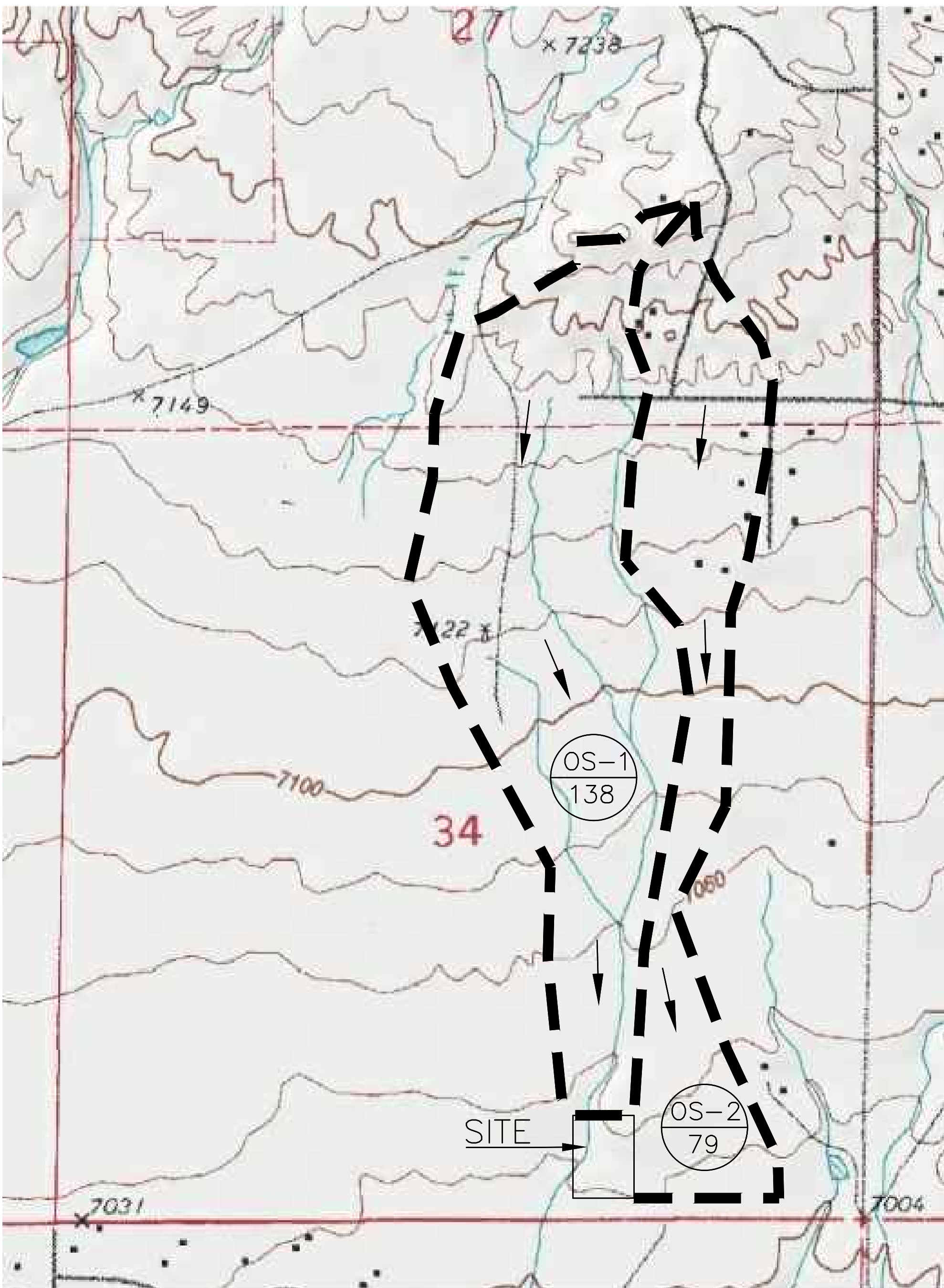
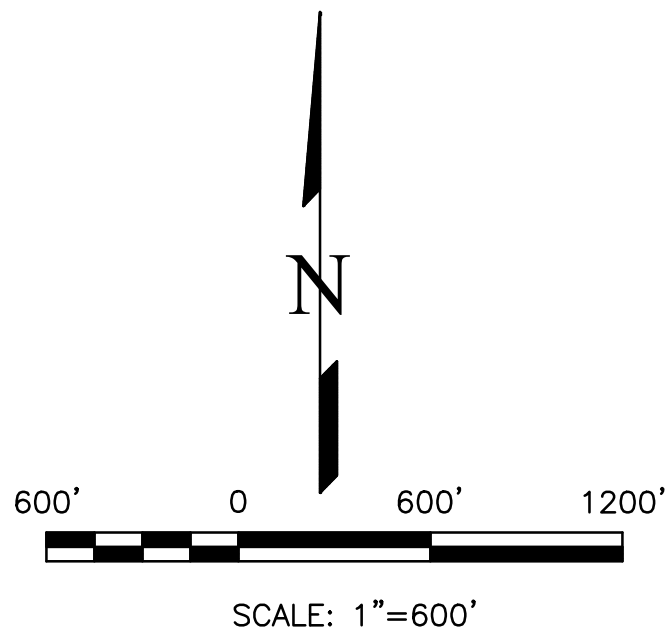
BASIN	ACRES	Q5 CFS	Q10 CFS	Q100 CFS
OS-1	138	---	20	---
OS-2	79	7.1	---	43.7
EX-A	2.77	0.9	---	6.4
EX-B	2.16	0.7	---	5.0

**LEGEND**

- |   |                      |
|---|----------------------|
|  | BASIN DESIGNATION    |
|  | AREA IN BASIN (AC)   |
|  | DESIGN POINT         |
|  | BASIN BOUNDARY       |
|  | EXISTING 2' CONTOUR  |
|  | EXISTING 10' CONTOUR |
|  | FLOW DIRECTION       |
|  | SURFACE FLOW CHANNEL |
|  | FENCE LINE           |
| PR  | PROPOSED             |
| EX  | EXISTING             |

## NOTES

1. EXISTING GROUND SURFACE CONDITIONS ARE PRIMARILY PRAIRIE GRASSES IN NATURAL CONDITION.

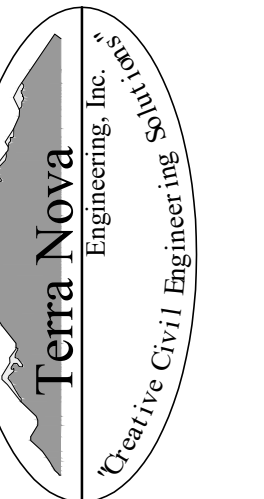


Please include the existing conditions for the areas where the road will be built.

[illegible]

UNIL SUCH TIME AS THESE  
DRAWINGS ARE APPROVED  
BY THE APPROPRIATE  
REVIEWING AGENCIES,  
TERRA NOVA ENGINEERING,  
INC. APPROVES THEIR USE  
ONLY FOR THE  
PURPOSES DESIGNATED BY  
WRITTEN AUTHORIZATION.

ATTN: DAVE WALDMAN  
11140 E. WOODMEAD  
PEYTON, CO 80601  
(719) 495-2211



721 S. 23RD STREET  
COLORADO SPRINGS, CO 80904

---

OFFICE: 719-635-6422  
FAX: 719-635-6426  
[www.tnesinc.com](http://www.tnesinc.com)

---

SIGNED BY LD
DRAWN BY DLF
CHECKED BY LD
SCALE 1"=40'
SCALE NA
3 NO. 1845.00
DATE ISSUED 09/17/18
SHEET NO. 1 OF 3



REFERENCED THE MDDP AND NOTED THEIR FLOW INFO FROM BASIN EX-13. THE MDDP USES DIFFERENT BASINS AND METHODS THAN THIS REPORT, SO I DIDN'T TRY TO INCORPORATE THEIR CALCS. I RAISED THE DIVERSION BERM BY

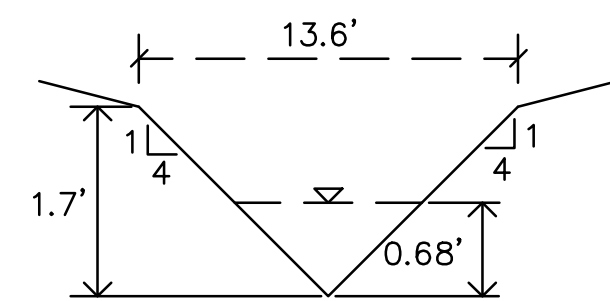
Per SR MDDP, Basin EX-13 / RT-17A  
<https://epcdevplanreview.com/Public/ProjectDetails/103541>  
 the flow is as copied below

DP	CONTRIBUTING BASINS	AREA AC.	Q5 CFS	Q10 CFS	Q100 CFS
Z	OS-1	138	---	20	---
Y	OS-2	79	7.1	---	36.6*
1	PR-1	0.42	0.1	---	0.7
2	PR-2	1.70	1.6	---	4.4
3	PR-3	0.15	0.1	---	0.4
4	PR-3, PR-4, OS-2	81	8.6	---	36.6*
5	PR-1,PR-2,PR-3,PR-4,PR-5,OS-2	84	9.7	---	47.5*
6	PR-6	0.06	0.03	---	0.2
7	PR-7	0.26	0.3	---	1.1
8	PR-8	0.58	0.4	---	2.1
9	PR-9	3.09	4.1	---	13.6

\* NOTE: THE EXISTING SWALE EXS1 HAS A MAX CAPACITY OF 36.6 CFS.

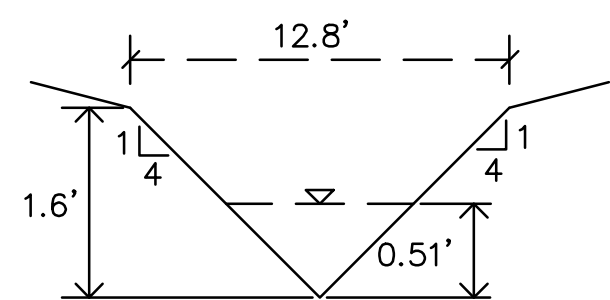
BASIN	ACRES	Q5 CFS	Q10 CFS	Q100 CFS
OS-1	138	---	20	---
OS-2	79	7.1	---	43.7
PR-1	0.42	0.1	---	0.7
PR-2	1.70	1.6	---	4.4
PR-3	0.15	0.1	---	0.4
PR-4	1.43	0.4	---	2.4
PR-5	1.07	0.4	---	3.0
PR-6	0.06	0.03	---	0.2
PR-7	0.26	0.3	---	1.1
PR-8	0.58	0.4	---	2.1
PR-9	3.09	4.1	---	13.6

BASIN SUMMARY- ARC II									
BASIN	CN	AREA (ACRES)	AREA (SQ MI)	Q <sub>3</sub> (CFS)	Q <sub>5</sub> (CFS)	Q <sub>10</sub> (CFS)	Q <sub>25</sub> (CFS)	Q <sub>50</sub> (CFS)	Q <sub>100</sub> (CFS)
EX-13	55	89.3	0.139	7.7	15.2	27.1	44.2	60.5	78.4



Q = 0.7 CFS  
SLOPE = 0.5%  
n VALUE = 0.13  
DEPTH = 0.68'  
VELOCITY = 0.39 FT/S

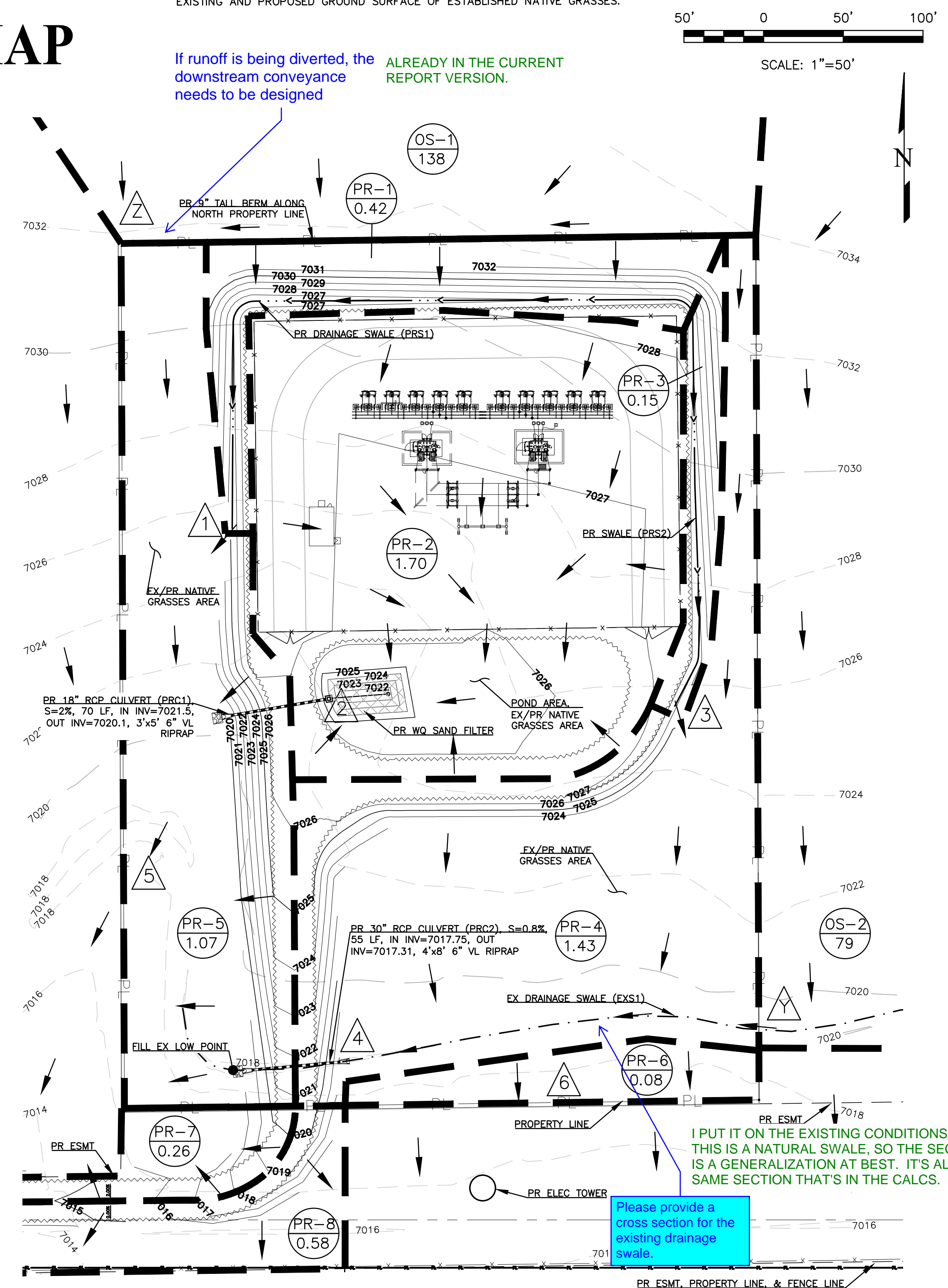
SWALE CROSS SECTION - PRS1 (TYP)



Q = 0.4 CFS  
SLOPE = 0.8%  
n VALUE = 0.13  
DEPTH = 0.51'  
VELOCITY = 0.40 FT/S

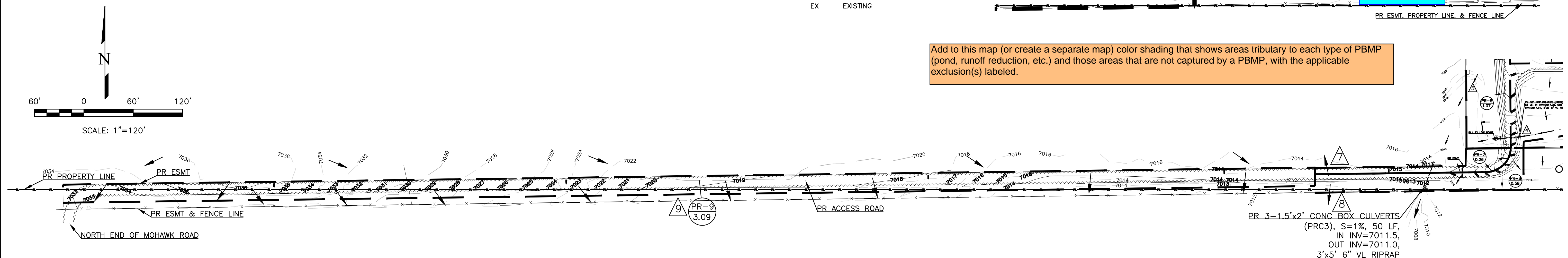
SWALE CROSS SECTION - PRS2 (TYP)

1. THE MAJORITY OF PROPOSED BASINS PR-2, PR-5, AND PR-6 HAVE AN EXISTING AND PROPOSED GROUND SURFACE OF ESTABLISHED NATIVE GRASSES.



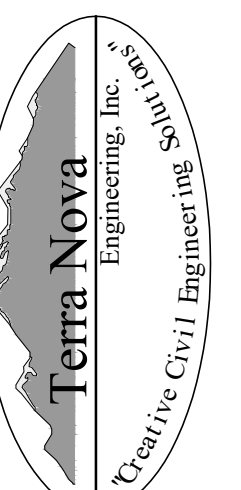
I PUT IT ON THE EXISTING CONDITIONS MAP.  
THIS IS A NATURAL SWALE, SO THE SECTION  
IS A GENERALIZATION AT BEST. IT'S ALSO THE  
SAME SECTION THAT'S IN THE CALCS.

Add to this map (or create a separate map) color shading that shows areas tributary to each type of PBMP (pond, runoff reduction, etc.) and those areas that are not captured by a PBMP, with the applicable exclusion(s) labeled.



NO.	DESCRIPTION	DATE.
	UNTIL SUCH TIME AS THESE	
	REVIEW AGENCIES	
	BY THIS APPROPRIATE	
	REVIEWING AGENCIES,	
	TERRA NOVA ENGINEERING,	
	FOR THEIR USE	
	ONLY FOR THE	
	PURPOSES DESIGNATED BY	
	WRITTEN AUTHORIZATION.	

PREPARED FOR:  
MVEA  
ATTN: DAVE WALDNER  
11140 E. WOODMEN RD  
PEYTON, CO 80831  
(719) 495-2283



21 S. 23RD STREET  
COLORADO SPRINGS, CO 80904  
OFFICE: 719-635-6422  
FAX: 719-635-6426  
[www.tnesinc.com](http://www.tnesinc.com)

VOLLMER SUBSTATION

DEVELOPED DRAINAGE MAP

SIGNED BY LD
DRAWN BY DLF
CHECKED BY LD
SCALE AS SHOWN
SCALE NA
SB NO. 1845.00
DATE ISSUED 09/17/18
SHEET NO. 2 OF 3



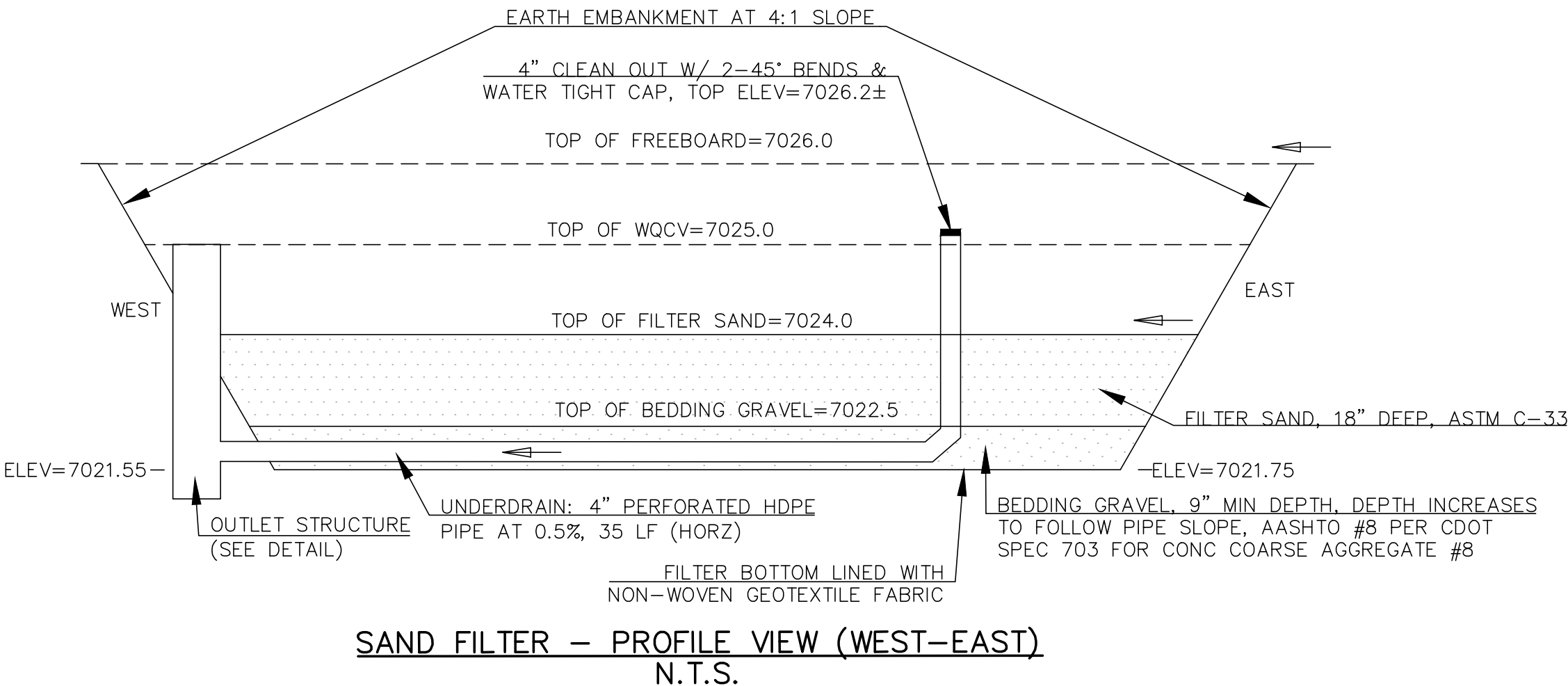
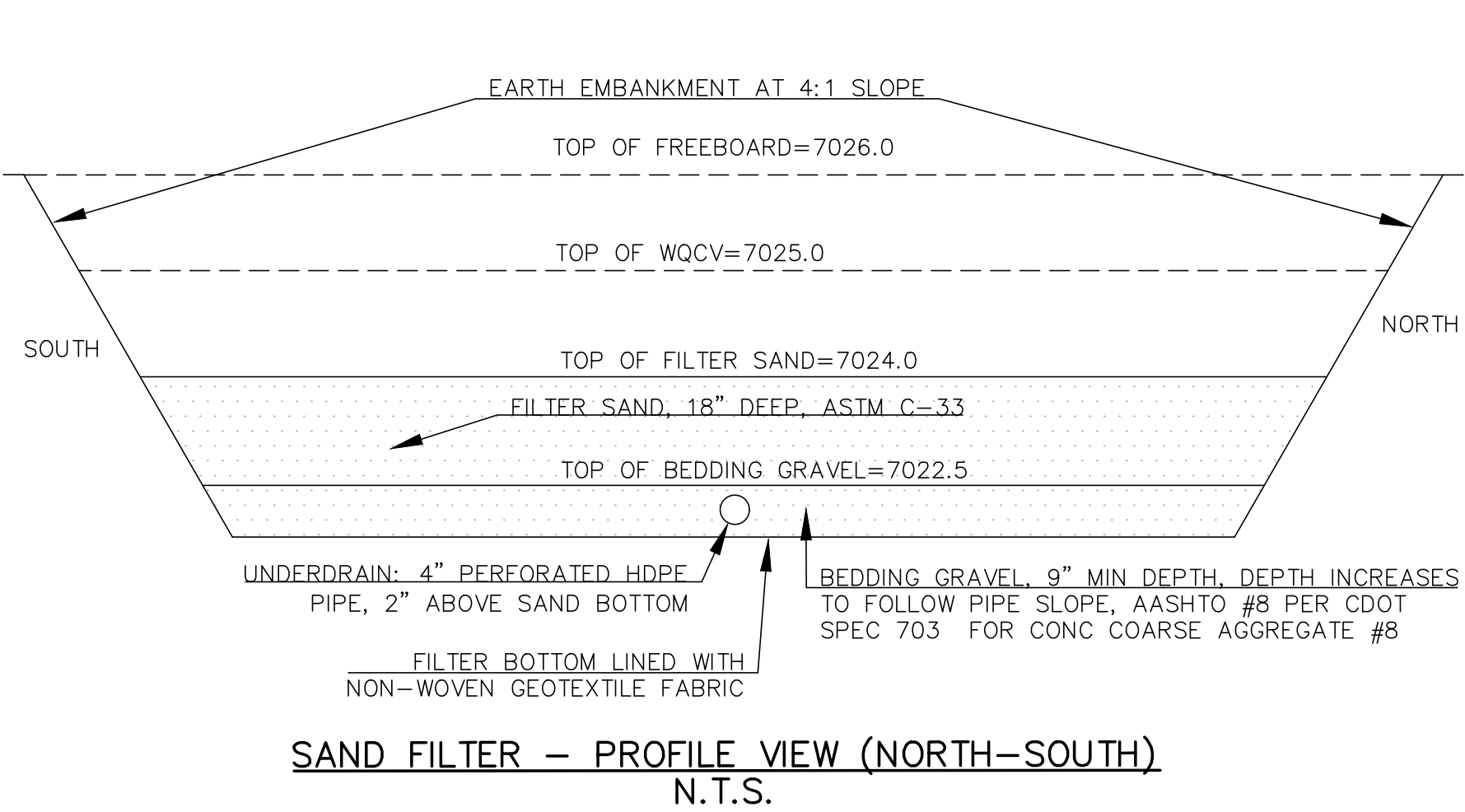
N:\jobs\1845.00\Drawings\184500 FDM.dwg, WQ DETAILS, 9/17/2018 3:09:37 PM

VOLLMER SUBSTATION  
EL PASO COUNTY, CO  
WATER QUALITY DETAILS  
SEPTEMBER 2018

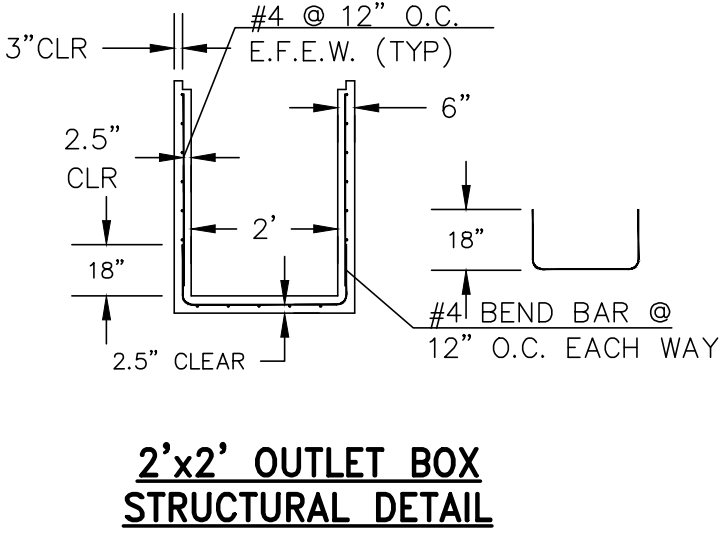
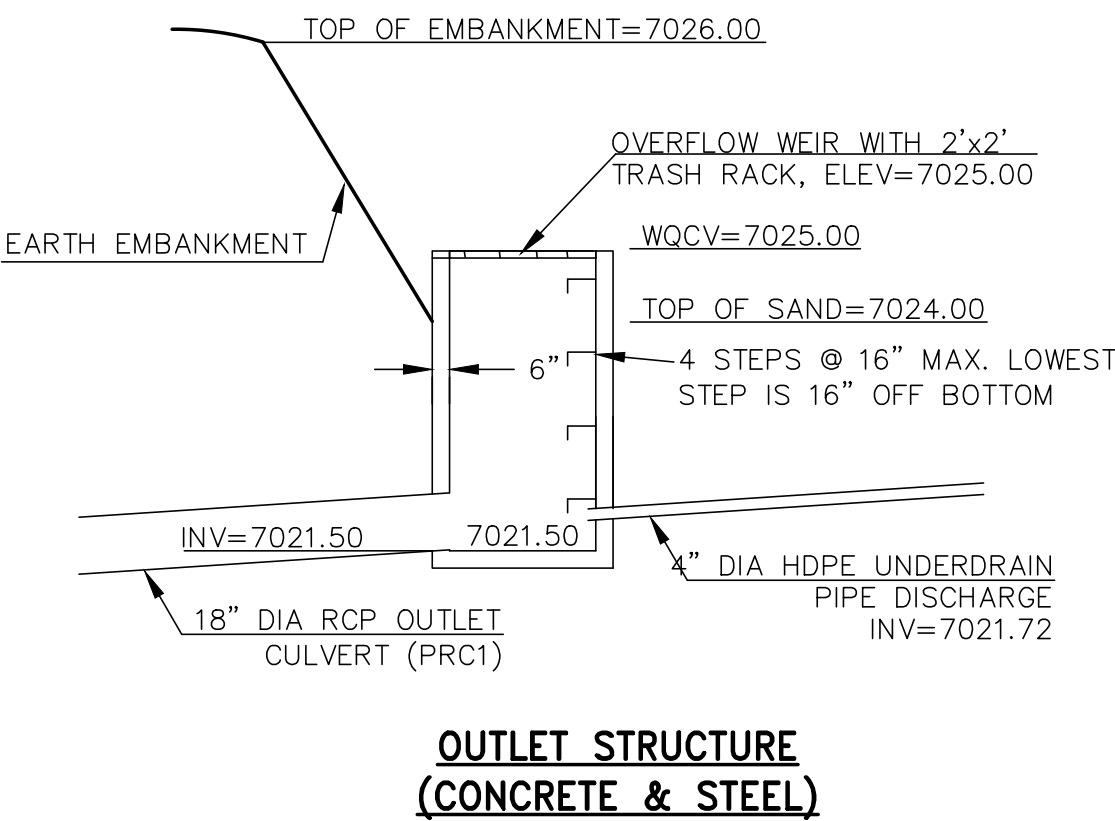
NOTES

1. COMBINED WQCV PROVIDED BY SAND FILTER = 2662 CU FT = 0.06 AC-FT.  
2. PROTECT SAND FILTERS FROM SEDIMENT LOADING DURING CONSTRUCTION ACTIVITIES. SITE MUST BE STABILIZED BEFORE ALLOWING FLOW INTO THE SAND FILTERS.

PRELIMINARY  
NOT FOR CONSTRUCTION



PRELIMINARY  
NOT FOR CONSTRUCTION

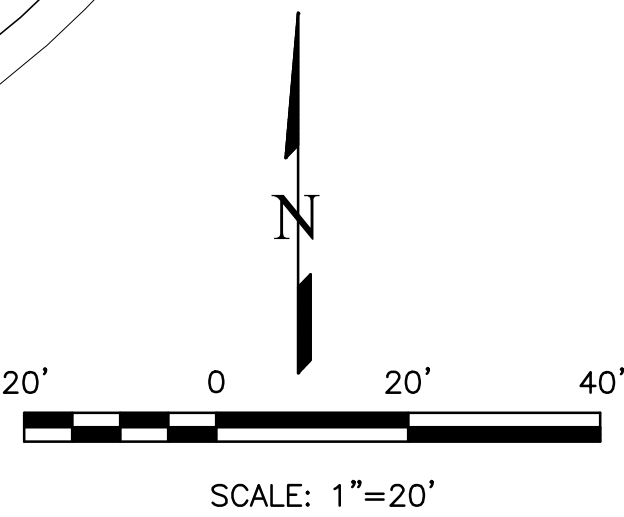
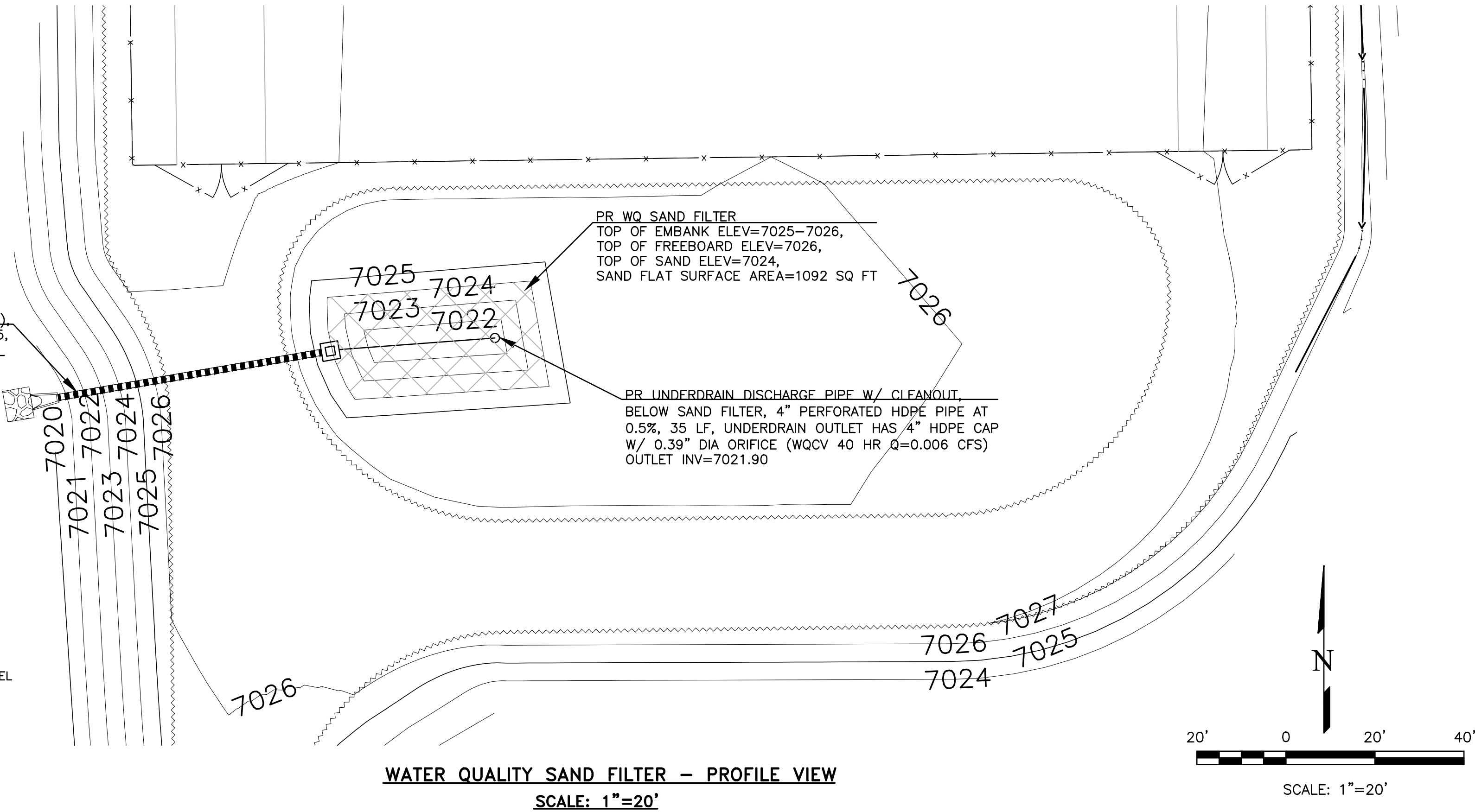


Please show a cross section of the sand filter basin spillway.

PR 18" RCP CULVERT (PRC1)  
S=2%, 70 LF, IN INV=7021.5,  
OUT INV=7020.1, 3'x5' 6" VL  
RIPRAP

LEGEND

- X FENCE LINE  
7261 PROPOSED 1' CONTOUR  
7265 PROPOSED 5' CONTOUR  
~ ~ ~ PROPOSED EDGE OF GRAVEL  
PR PROPOSED  
EX EXISTING



REVISIONS	NO.	DESCRIPTION	DATE
UNTIL SUCH TIME AS THESE DRAWINGS ARE APPROVED FOR CONSTRUCTION BY THE EL PASO COUNTY ENGINEER, TERRA NOVA ENGINEERING, INC. APPROVES THEIR USE ONLY FOR THE PROJECT DESIGNATED BY THE EL PASO COUNTY ENGINEER. WRITTEN AUTHORIZATION.			

PREPARED FOR:  
MVEA  
ATTN: DAVE WALDNER  
11140 E. WOODMEN RD  
PEYTON, CO 80831  
(719) 495-2283

Terra Nova Engineering, Inc.  
Creative Civil Engineering  
721 S. 29th STREET  
COLORADO SPRINGS, CO 80904  
OFFICE: 719-635-6422  
FAX: 719-635-6426  
www.tnainc.com

VOLLMER SUBSTATION	WATER QUALITY DETAILS
--------------------	-----------------------

DESIGNED BY LD	DRAWN BY DLF
CHECKED BY LD	H-SCALE AS SHOWN
V-SCALE NA	JOB NO. 1845.00
DATE ISSUED 09/17/18	SHEET NO. 3 OF 3