

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

JANUARY 2022

Prepared For:

MOUNTAIN VIEW ELECTRIC ASSOCIATION

David Waldner
11140 E Woodmen Rd, Peyton, CO 80831
(719) 495-2283

Prepared By:

TERRA NOVA ENGINEERING, INC.

721 S. 23RD STREET
Colorado Springs, CO 80904
(719) 635-6422

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County Job No. AASI-19-006, PPR2147

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FOR
VOLLMER SUBSTATION
EL PASO COUNTY, COLORADO**

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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: Engineering Manager

Address: 11140 E. Woodman Road
Falcon, CO 80831

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

Conditions:

APPROVED
Engineering Department

02/10/2022 2:53:35 PM

dsdnijkamp

**EPC Planning & Community
Development Department**

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.

FOUR STEP PROCESS

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 proposed gravel yard and part of the gravel 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. The remainder of the access road will be covered by runoff reduction provided by the surrounding native prairie grasses. 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 located 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 6th 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.

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. 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) 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.

Offsite basin OS-3's 3.90 acres consists of undeveloped open space. Runoff ($Q_5=1.0$ cfs and $Q_{100}=6.3$ cfs) sheet flows to the east, west, or south (overall moves south).

Basin EX-A's 2.77 acres consists of undeveloped open space. Runoff ($Q_5=0.7$ cfs and $Q_{100}=4.8$ 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. 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) will sheet flow to the north edge of the site at Design Point Z. After flowing onto the site, a proposed berm/swale will redirect the flow west around the proposed substation, before it resumes flowing

south. The proposed berm/swale will carry the runoff to the existing swale on the south portion of the site, before the runoff leaves the site. 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-1 is almost entirely undeveloped or landscaping, with a sliver of the gravel yard being provided water quality treatment by runoff reduction in the grass swale.

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, the pond area will be surfaced with native grasses, and the sand filter will have a sand surface. 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-2 is provided water quality treatment by the sand filter.

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-3 is almost entirely

undeveloped or landscaping, with a small area of the gravel access road being provided water quality treatment by runoff reduction in the downstream prairie grasses area and grass swale.

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-4 is almost entirely undeveloped or landscaping, with a small area of the gravel access road being provided water quality treatment by runoff reduction in the downstream prairie grasses area and grass swale.

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-5 is almost entirely undeveloped or landscaping, with a small area of the gravel access road being provided water quality treatment by runoff reduction in the downstream prairie grasses area and grass swale.

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-5 is remaining undeveloped, so no water quality treatment is required.

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-7 is half of a section of the gravel access road and some undeveloped and landscaping area being provided water quality treatment by runoff reduction in the downstream prairie grasses area and grass swale.

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-8 is half of a section of the gravel access road and some undeveloped and landscaping area being provided water quality treatment by runoff reduction in the downstream prairie grasses area and grass swale.

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. Basin PR-9 is a section of the gravel access road and some undeveloped and landscaping area being provided water quality treatment by runoff reduction in the downstream prairie grasses area.

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.

There is also a proposed berm/swale along the north edge of the property that goes west and then south to the existing swale. The purpose of this berm/swale is to redirect the offsite flow around the proposed substation. This berm/swale can accommodate $Q=22.4$ cfs onsite and has a capacity

of $Q=66$ cfs +/- . A 25 feet wide drainage easement is proposed offsite to accommodate the backup of runoff during larger storm events.

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 (water quality treatment only). If flood waters exceed the discharge capacity and fill the pond area volume, the pond area will overflow on the west side 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. Embankment protection has been provided on both sides of the access road adjacent to the end of the spillway. 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
4. Sand Filter	1 LS	\$ 15,000	<u>\$ 15,000</u>
		Total	\$ 40,675

DRAINAGE FEES

Drainage fees do not apply to this site development plan.

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 treatment 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. Stormwater detention is not required for this project. Comparisons of historic to proposed flows onsite are difficult due to different flow patterns; however, the 100 year outflow of the proposed sand filter is less than the flow from the existing basin EX-A, which only accounts for ~3/4 of the developed area (4.2 cfs vs 4.8 cfs).

PREPARED BY:
TERRA NOVA ENGINEERING, INC.

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

REFERENCE

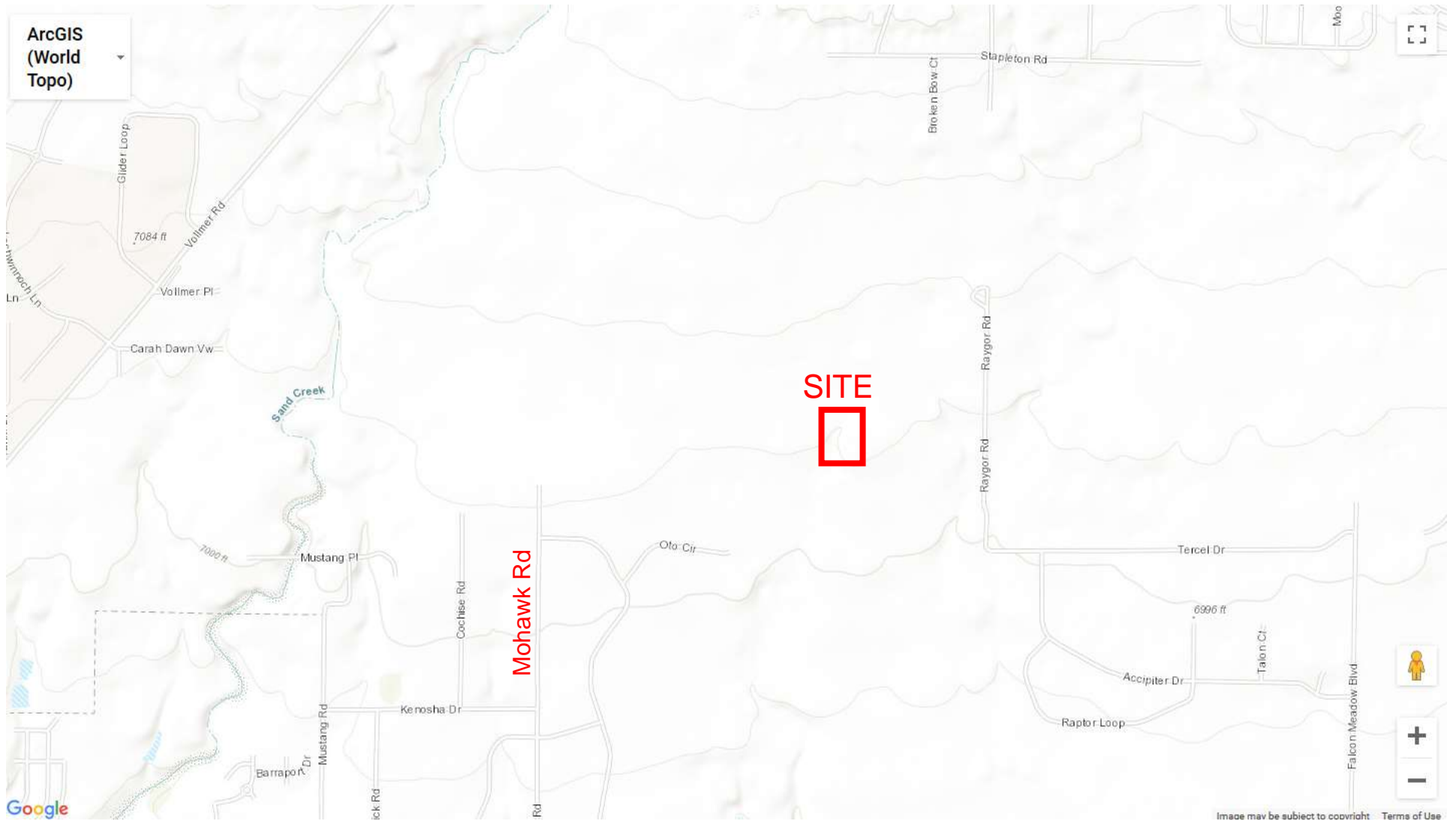
El Paso County Drainage Criteria Manual-Volumes 1 & 2, latest edition

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

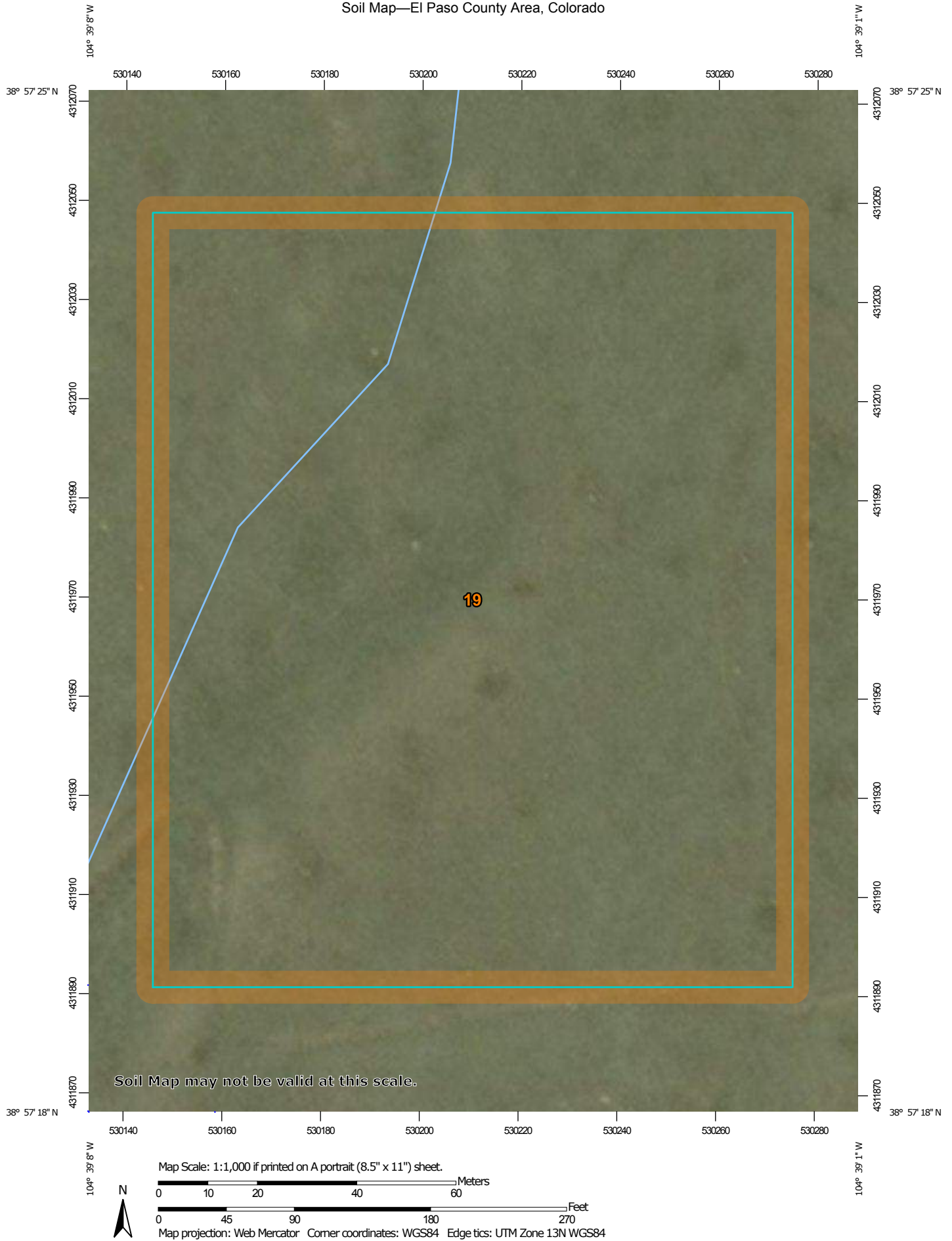
VICINITY MAP



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%
Totals for Area of Interest		5.0	100.0%

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

HYDROLOGIC CALCULATIONS

VOLLMER SUBSTATION
(Area Runoff Coefficient Summary)

EXISTING CONDITIONS

		<i>DEVELOPED</i>			<i>UNDEVELOPED</i>			<i>WEIGHTED</i>	
BASIN	TOTAL AREA	AREA	C₅	C₁₀₀	AREA	C₅	C₁₀₀	C₅	C₁₀₀
	<i>(Acres)</i>	<i>(Acres)</i>			<i>(Acres)</i>				
<i>OS-2</i>	79.00	0.00	0.30	0.50	79.00	0.09	0.36	0.09	0.36
<i>OS-3</i>	3.90	0.00	0.30	0.50	3.90	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 ₅	C ₁₀₀	AREA	C ₅	C ₁₀₀	C ₅	C ₁₀₀
	(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: 11/29/2021

Checked by: LD

VOLLMER SUBSTATION AREA DRAINAGE SUMMARY

EXISTING CONDITIONS

BASIN	AREA TOTAL (Acres)	WEIGHTED		OVERLAND				STREET / CHANNEL FLOW				T_t	INTENSITY		TOTAL FLOWS	
		C ₅	C ₁₀₀	C ₅	Length	Height	T _C	Length	Slope	Velocity	T _t	TOTAL	I ₅	I ₁₀₀	Q ₅	Q ₁₀₀
		* For Calcs See Runoff Summary			(ft)	(ft)	(min)	(ft)	(%)	(fps)	(min)	(min)	(in/hr)	(in/hr)	(c.f.s.)	(c.f.s.)
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
OS-3	3.90	0.09	0.36	0.09	300	6.0	25.4	0	2.0%	0.7	0.0	25.4	2.7	4.5	1.0	6.3
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

BASIN	AREA TOTAL (Acres)	WEIGHTED		OVERLAND				STREET / CHANNEL FLOW				T_t	INTENSITY		TOTAL FLOWS	
		C ₅	C ₁₀₀	C ₅	Length	Height	T _C	Length	Slope	Velocity	T _t	TOTAL	I ₅	I ₁₀₀	Q ₅	Q ₁₀₀
		* For Calcs See Runoff Summary			(ft)	(ft)	(min)	(ft)	(%)	(fps)	(min)	(min)	(in/hr)	(in/hr)	(c.f.s.)	(c.f.s.)
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: 11/29/2021

Checked by: LD

***VOLLMER SUBSTATION
AREA DRAINAGE SUMMARY***

EXISTING AND DEVELOPED CONDITIONS

Site: Vollmer Substation
Basin: OS-1
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: 11/29/2021
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>Q₅</i>	<i>Q₁₀</i>	<i>Q₁₀₀</i>
<i>Z</i>	OS-1	138.00	<i>---</i>	<i>20</i>	<i>---</i>
<i>Y</i>	OS-2	79.00	<i>7.1</i>	<i>---</i>	<i>36.6*</i>
<i>X</i>	OS-X	3.90	<i>1.0</i>	<i>---</i>	<i>6.3</i>
<i>1</i>	PR-1	0.42	<i>0.1</i>	<i>---</i>	<i>0.7</i>
<i>2</i>	PR-2	1.70	<i>1.6</i>	<i>---</i>	<i>4.4</i>
<i>3</i>	PR-3	0.15	<i>0.1</i>	<i>---</i>	<i>0.4</i>
<i>4</i>	PR-3, PR-4, OS-2	81.00	<i>8.6</i>	<i>---</i>	<i>36.6*</i>
<i>5</i>	PR-1, PR-2, PR-3, PR-4, PR-5, OS-2	84.00	<i>9.7</i>	<i>---</i>	<i>47.5*</i>
<i>6</i>	PR-6	0.06	<i>0.03</i>	<i>---</i>	<i>0.2</i>
<i>7</i>	PR-7	0.26	<i>0.3</i>	<i>---</i>	<i>1.1</i>
<i>8</i>	PR-8	0.58	<i>0.4</i>	<i>---</i>	<i>2.1</i>
<i>9</i>	PR-9	3.09	<i>4.1</i>	<i>---</i>	<i>13.6</i>

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

Calculated by: DLF

Date: 11/29/2021

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

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

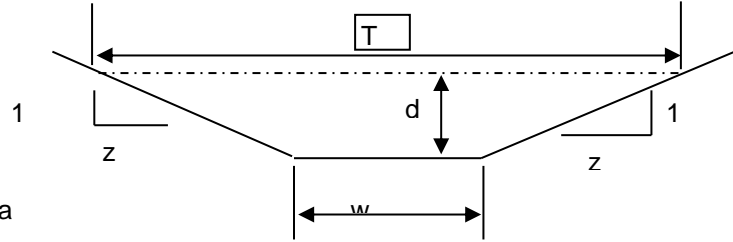
$$R = A/P$$

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 = 0.027
n high = 0.027

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		
1.2	50.40	84.04	0.60	3.50071268	176.436	3.500713	176.436	T =	84
				Sc low =		Sc high =		Dm =	0.600
				.7 Sc		.7 Sc			
				0.0088		0.0088			
				1.3 Sc		1.3 Sc			
				0.0164		0.0164			

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: 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

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

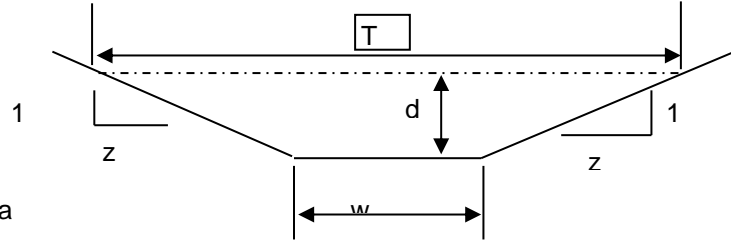
$$R = A/P$$

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)= 0.19
S (slope, ft/ft) 0.005
n low = 0.027
n high = 0.027

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	
0.19	0.14	1.57	0.09	0.79398377	0.11465	0.793984	0.11465	T = 1.52
				Sc low = 0.0242		Sc high = 0.0242		Dm = 0.095
				.7 Sc	1.3 Sc	.7 Sc	1.3 Sc	
				0.0170	0.0315	0.0170	0.0315	

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:** 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

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

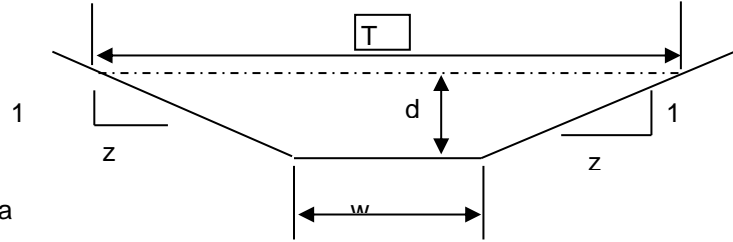
$$R = A/P$$

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)= 0.38
S (slope, ft/ft) 0.005
n low = 0.027
n high = 0.027

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	
0.38	0.58	3.13	0.18	1.26039979	0.72801	1.2604	0.72801	T = 3.04
				Sc low = 0.0192		Sc high = 0.0192		Dm = 0.190
				.7 Sc	1.3 Sc	.7 Sc	1.3 Sc	
				0.0135	0.0250	0.0135	0.0250	

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

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

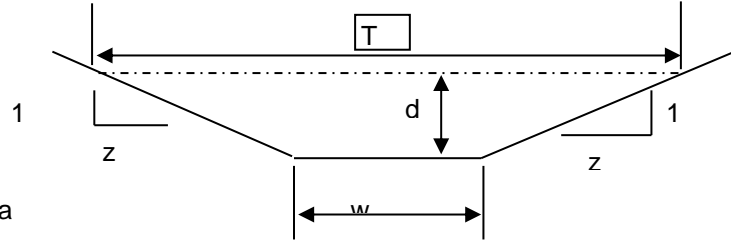
$$R = A/P$$

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)= 0.17
S (slope, ft/ft) 0.008
n low = 0.027
n high = 0.027

Clear Data
Entry Cells

Depth, ft	Area, sf	Wetted Perimeter, ft	Hydraulic Radius, ft	Low N		High N		T =	Dm =
				Velocity, fps	Flow, cfs	Velocity, fps	Flow, cfs		
0.17	0.12	1.40	0.08	0.93253874	0.1078	0.932539	0.1078	1.36	0.085
Sc low =				0.0251	Sc high =		0.0251		
s _c = critical slope				ft / ft					
T = top width of the stream				.7 Sc		1.3 Sc			
d _m = a/T = mean depth of flow				0.0176		0.0327			

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**

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

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

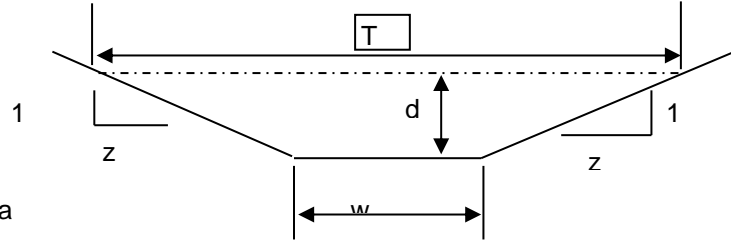
$$R = A/P$$

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)= 0.28
S (slope, ft/ft) 0.008
n low = 0.027
n high = 0.027

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	
0.28	0.31	2.31	0.14	1.30060928	0.40787	1.300609	0.40787	T = 2.24
				Sc low = 0.0213		Sc high = 0.0213		Dm = 0.140
				.7 Sc	1.3 Sc	.7 Sc	1.3 Sc	
				0.0149	0.0277	0.0149	0.0277	

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

By: Dane Frank

Chk By:

Location: North Berm - Q10 = 20 cfs

Date: 11/30/2021

Date:

version 12-2004

Mannings Formula

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

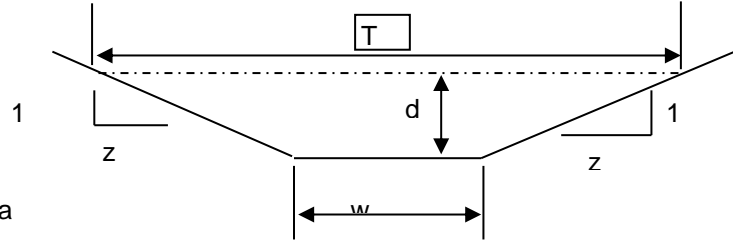
$$R = A/P$$

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)= 2
z (sideslope)= 0
b (btm width, ft)= 5
d (depth, ft)= 1.2
S (slope, ft/ft) 0.007
n low = 0.027
n high = 0.027

Clear Data
Entry Cells

				Low N		High N			
Depth, ft	Area, sf	Wetted Perimeter, ft	Hydraulic Radius, ft	Velocity,		Velocity,		T =	Dm =
				fps	Flow, cfs	fps	Flow, cfs		
1.2	7.44	8.88	0.84	4.09136134	30.4397	4.091361	30.4397	7.4	1.005
				Sc low =		0.0135		Sc high =	
				0.0135		0.0135			
s _c = critical slope				ft / ft					
T = top width of the stream				.7 Sc		1.3 Sc		.7 Sc	
d _m = a/T = mean depth of flow				0.0095		0.0176		0.0095	
						0.0176			

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: North Berm - Capacity

By: Dane Frank

Date: 11/30/2021

Chk By:

Date:

version 12-2004

Mannings Formula

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

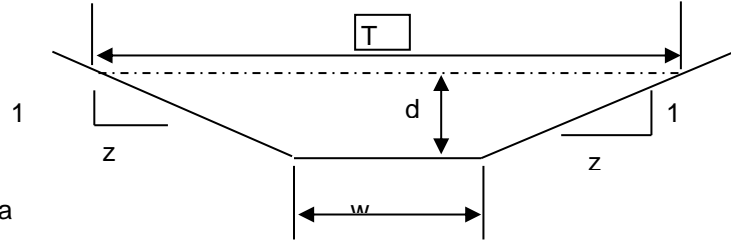
$$R = A/P$$

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)= 2
z (sideslope)= 30
b (btm width, ft)= 5
d (depth, ft)= 1.2
S (slope, ft/ft) 0.007
n low = 0.027
n high = 0.027

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
1.2	29.04	43.70	0.66	3.50633355	101.824	3.506334	101.824
				T =		43.4	
				Dm =		0.669	
				Sc low =		0.0122	
				Sc high =		0.0122	
				.7 Sc		1.3 Sc	
				0.0086		0.0159	

s_c = critical slope ft / ft

T = top width of the stream

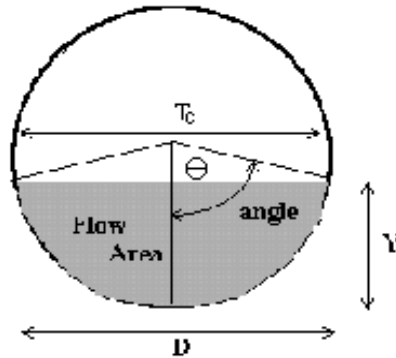
d_m = a/T = mean depth of flow

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

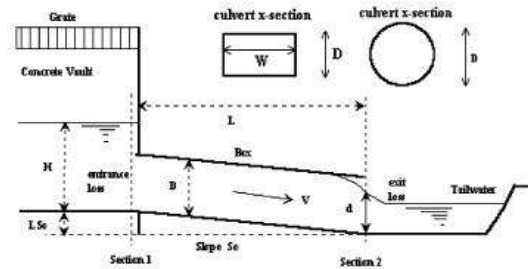
Calculation of Normal Flow Condition

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

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

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

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

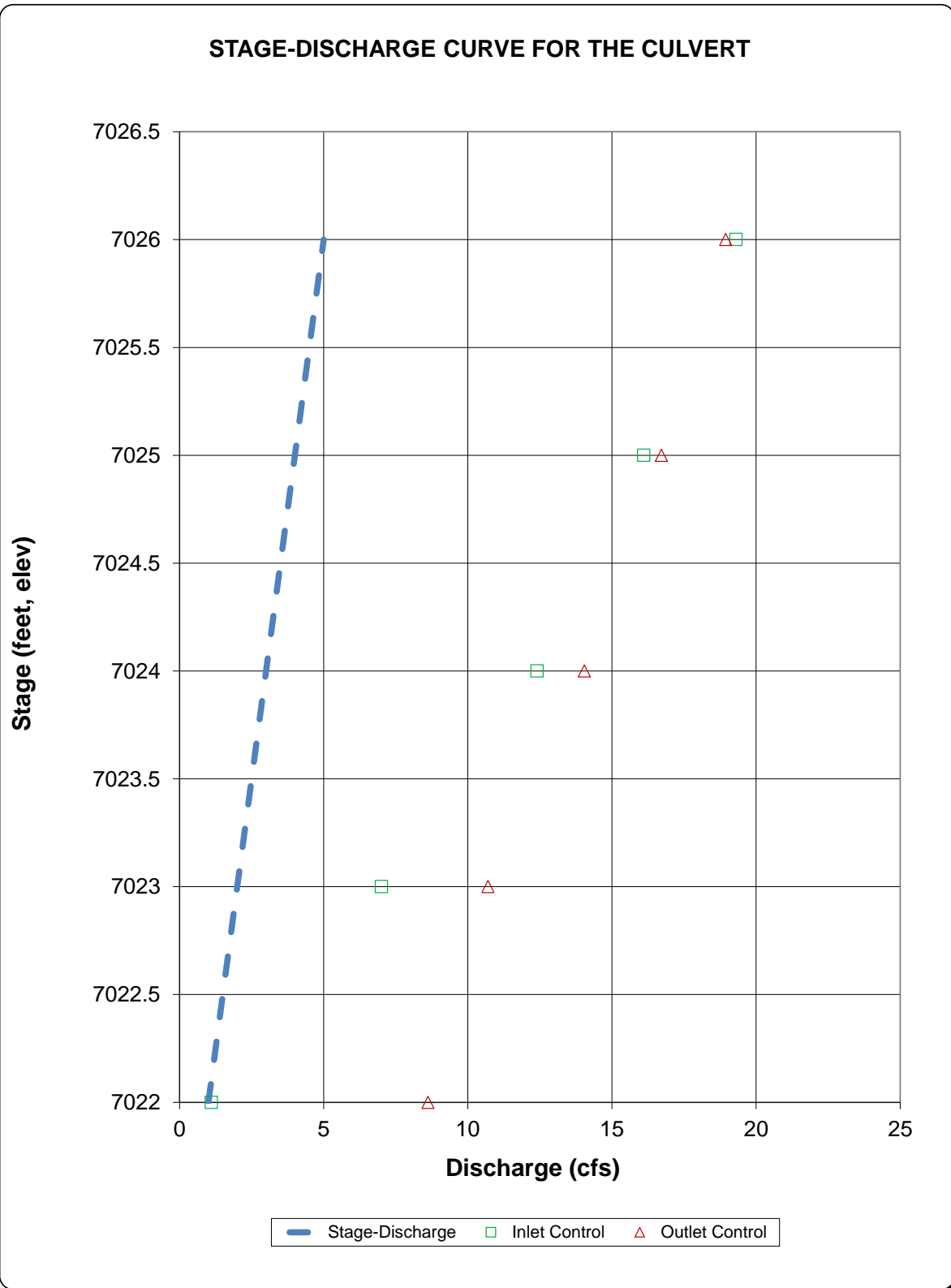
$C_d =$	0.99
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$$KE_{\text{low}} = -0.0860$$
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CULVERT STAGE-DISCHARGE SIZING (INLET vs. OUTLET CONTROL WITH TAILWATER EFFECTS)

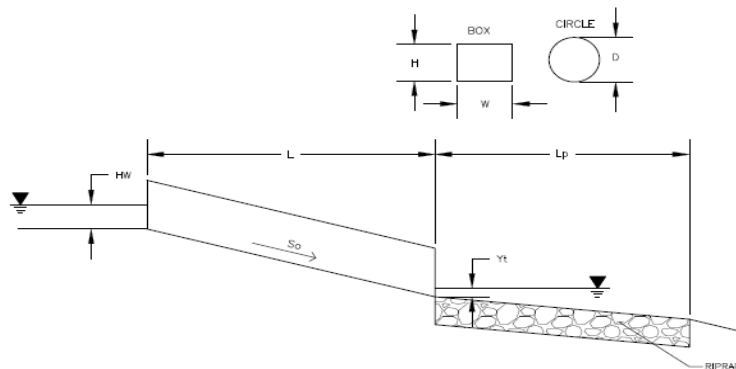
Project: Voolmer Substation
Basin ID: PRC1 - Sand Filter Discharge - 5 Yr



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 Da 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 ft²

Culvert Cross Sectional Area Available

A = 1.77 ft²

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(Θ)) = 6.70

Flow/Diameter^{2.5} **OR** Flow/(Span * Rise^{1.5})

Q/D^{2.5} = 0.58 ft^{0.5}/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 ft

Design Headwater Elevation

HW = 7,022.16 ft

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

HW/D = 0.44

Minimum Theoretical Riprap Size

d₅₀ = 1 in

Nominal Riprap Size

d₅₀ = 6 in

UDFCD Riprap Type

Type = VL

Length of Protection

L_p = 5 ft

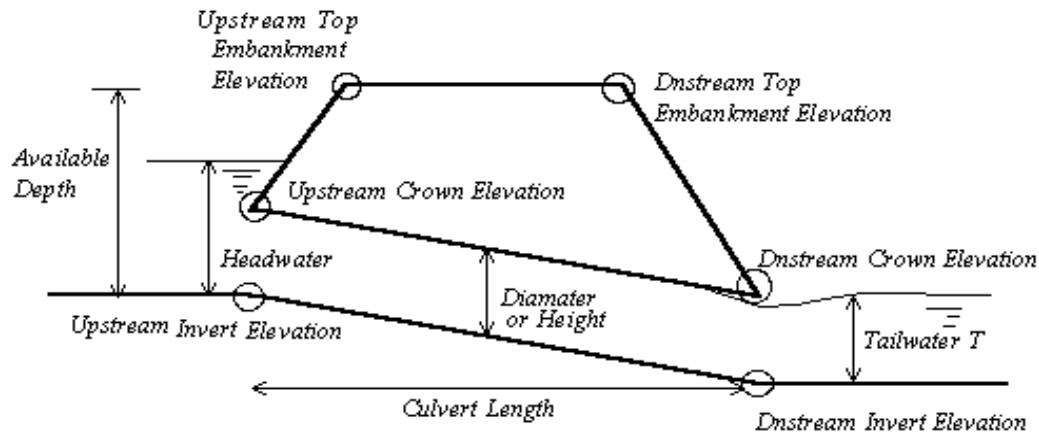
Width of Protection

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	

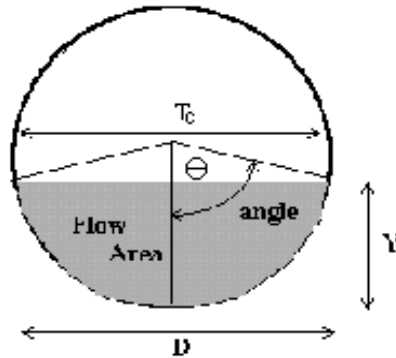
Culvert Vertical Profile

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

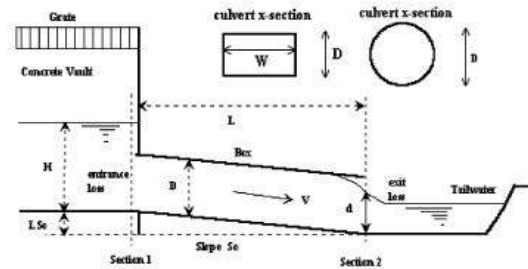
Calculation of Normal Flow Condition

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

No = 1

Inlet Elev = 7021.5 ft. elev.

Outlet Elev = 7020.1 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

 $K_e = 0.20$

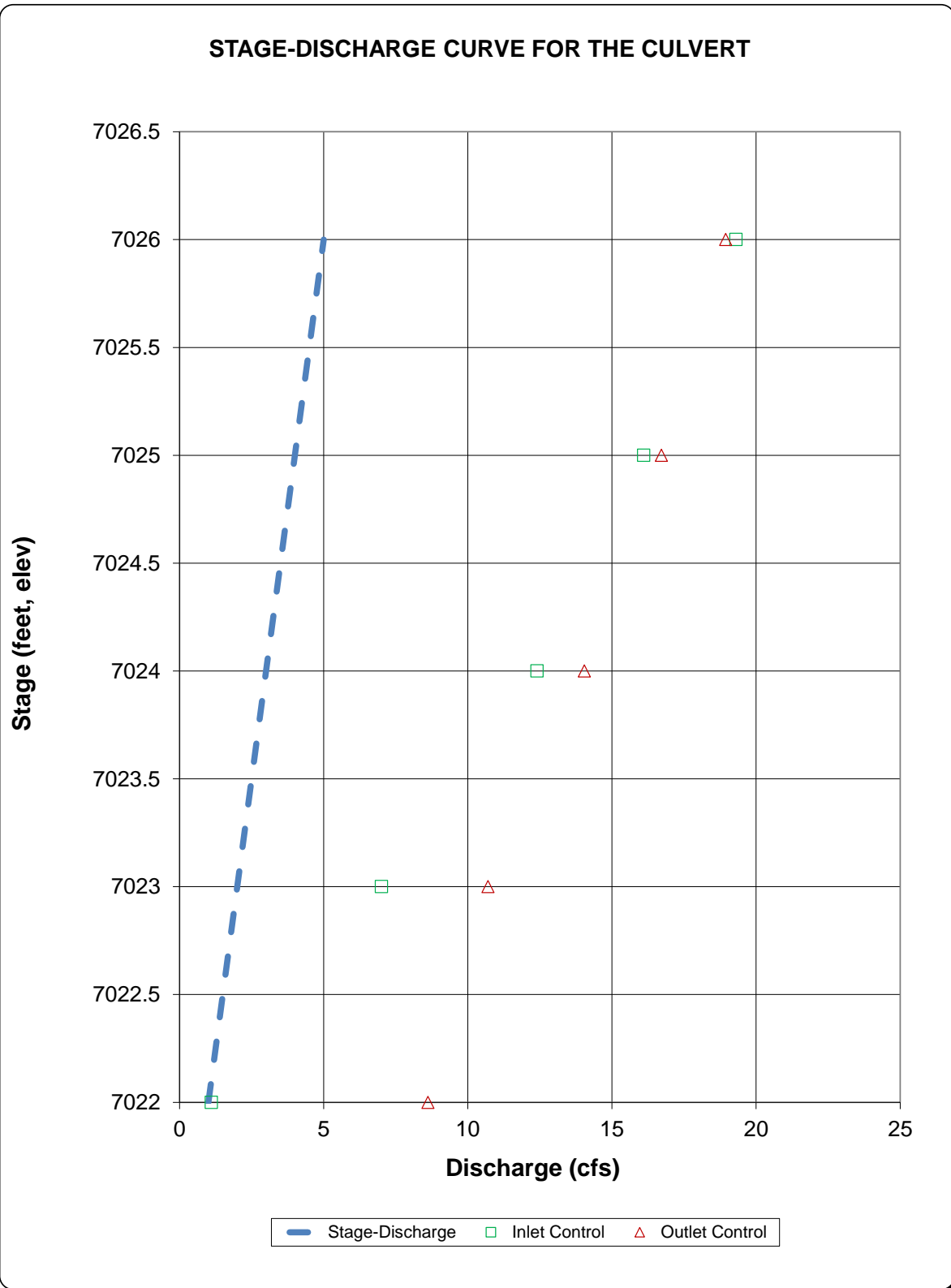
$K_f =$	1.27
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$$K_s = 2.47$$
$$C_d = 0.99$$
$$KE_{\text{low}} = -0.0860$$
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CULVERT STAGE-DISCHARGE SIZING (INLET vs. OUTLET CONTROL WITH TAILWATER EFFECTS)

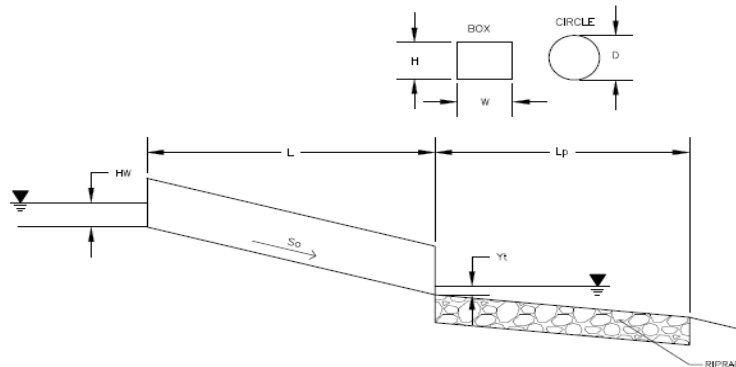
Project: Voolmer Substation
Basin ID: PRC1 - Sand Filter Discharge - 100 Yr



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 Da 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 ft²

Culvert Cross Sectional Area Available

A = 1.77 ft²

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(Θ)) = 6.70

Flow/Diameter^{2.5} **OR** Flow/(Span * Rise^{1.5})

Q/D^{2.5} = 1.60 ft^{0.5}/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

d₅₀ = 2 in

Nominal Riprap Size

d₅₀ = 6 in

UDFCD Riprap Type

Type = VL

Length of Protection

L_p = 5 ft

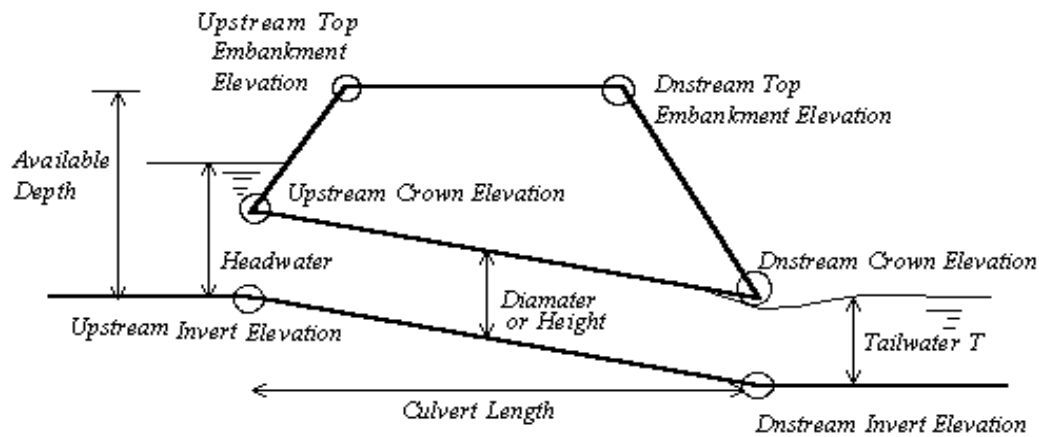
Width of Protection

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	

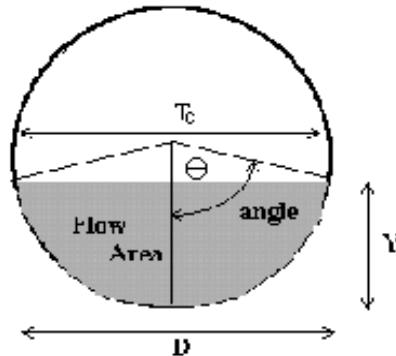
Culvert Vertical Profile

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

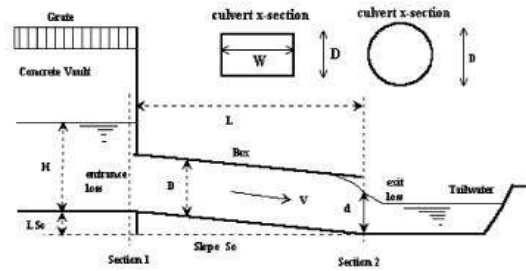
Calculation of Normal Flow Condition

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

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

$C_d =$	0.99
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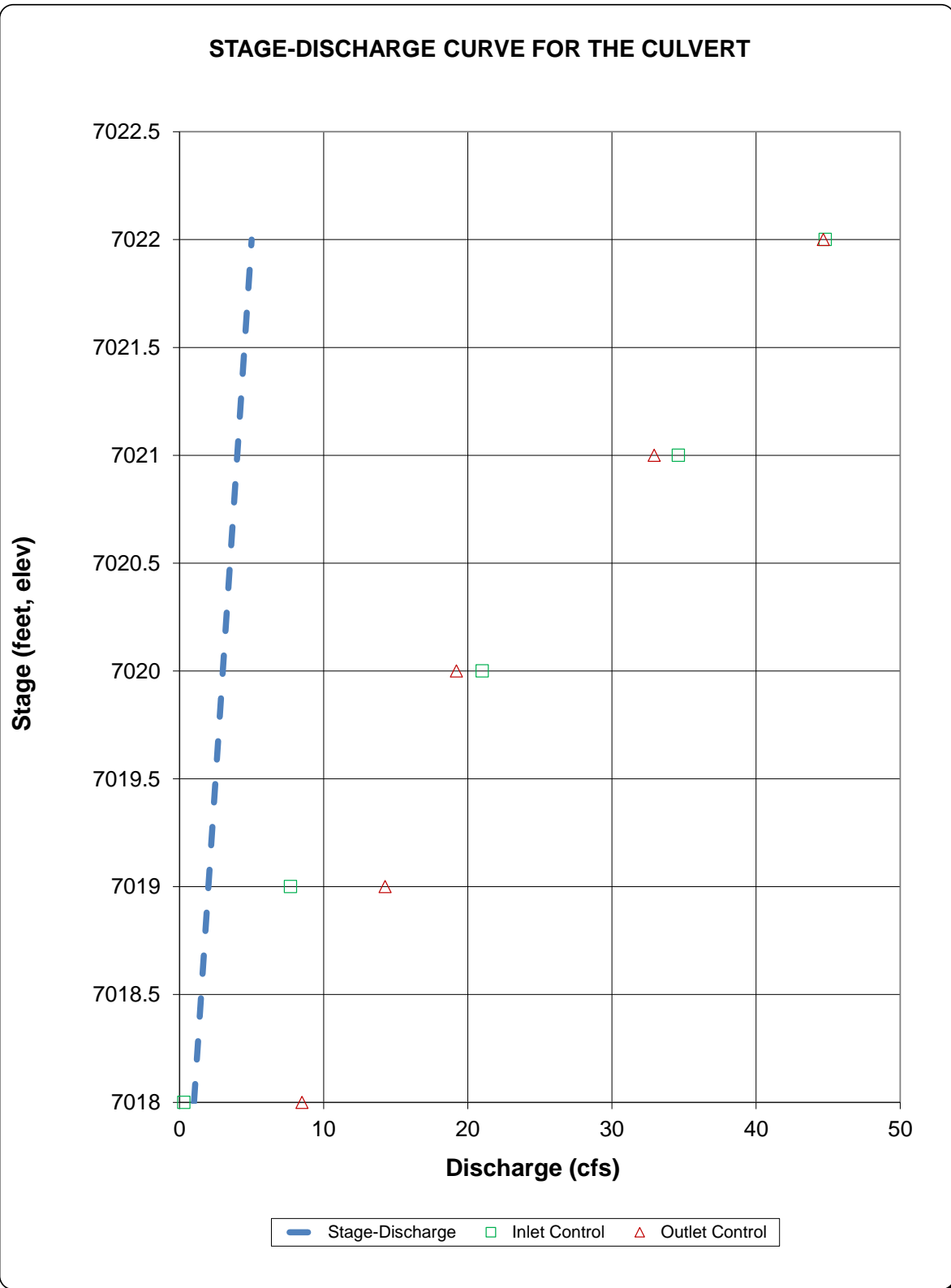
$$KE_{\text{low}} = -0.0373$$
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CULVERT STAGE-DISCHARGE SIZING (INLET vs. OUTLET CONTROL WITH TAILWATER EFFECTS)

Project: Voolmer Substation

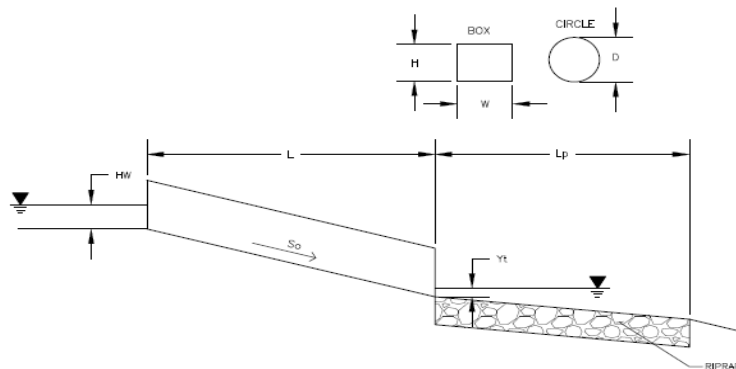
Basin ID: PRC2 - SW Property Corner Access Crossing - 5 Yr



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 Da 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 ft²

Culvert Cross Sectional Area Available

A = 4.91 ft²

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(Θ)) = 6.70

Flow/Diameter^{2.5} **OR** Flow/(Span * Rise^{1.5})

Q/D^{2.5} = 0.87 ft^{0.5}/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

d₅₀ = 2 in

Nominal Riprap Size

d₅₀ = 6 in

UDFCD Riprap Type

Type = VL

Length of Protection

L_p = 8 ft

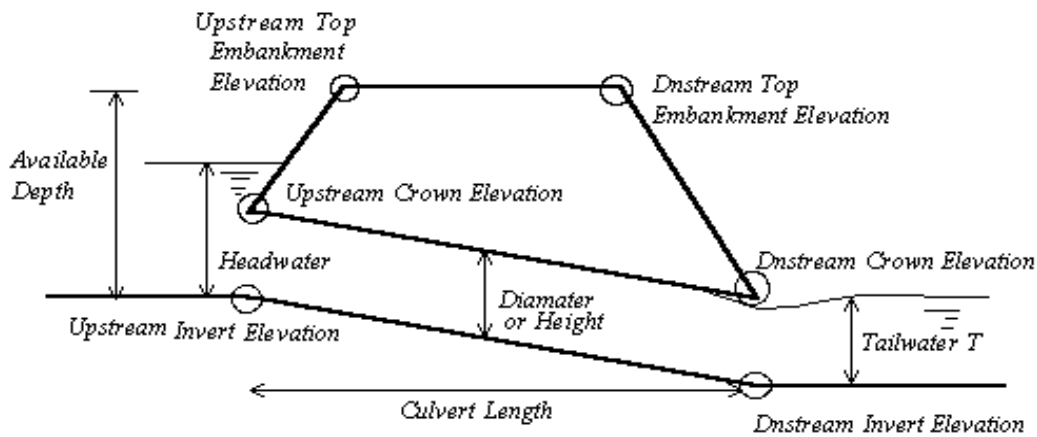
Width of Protection

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	

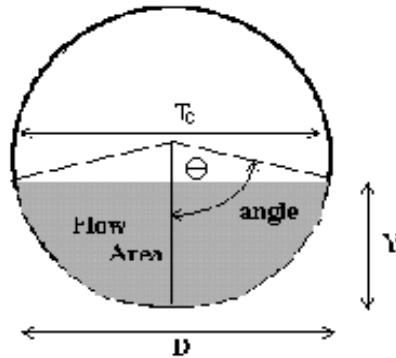
Culvert Vertical Profile

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	$S_o =$	0.0080	ft/ft
Pipe Manning's n-value	$n =$	0.0130	
Pipe Diameter	$D =$	30.00	inches
Design discharge	$Q =$	36.60	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

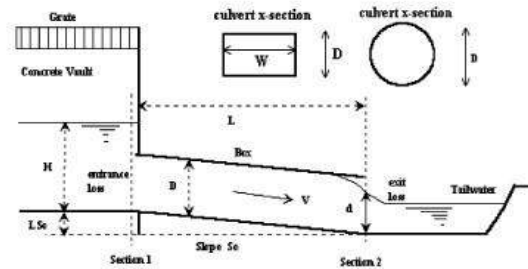
Calculation of Normal Flow Condition

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

Calculation of Critical Flow Condition

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

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
---------	---

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
---------	------

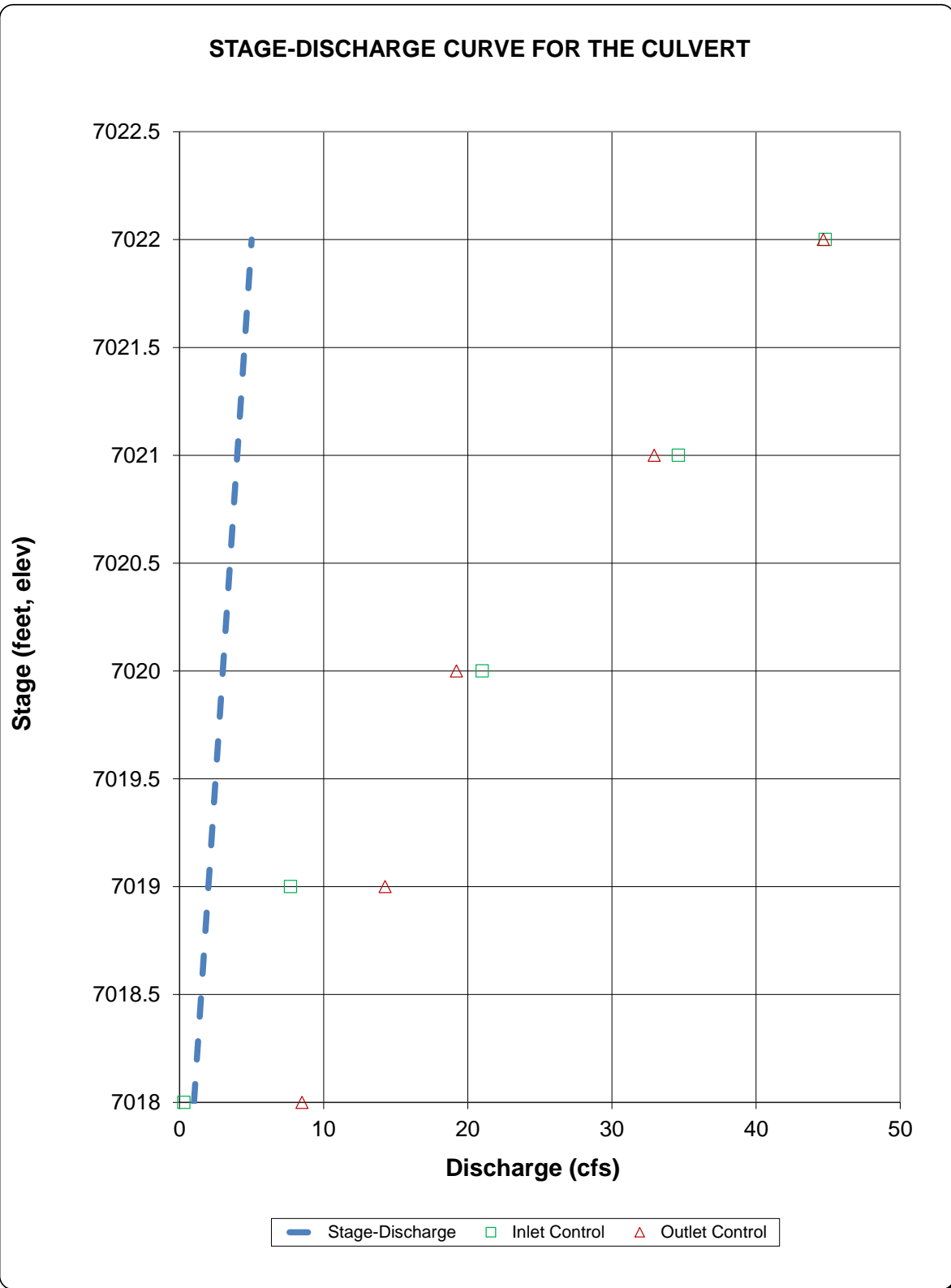
$$C_d = 0.99$$
$$KE_{\text{low}} = -0.0373$$
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CULVERT STAGE-DISCHARGE SIZING (INLET vs. OUTLET CONTROL WITH TAILWATER EFFECTS)

Project: Voolmer Substation

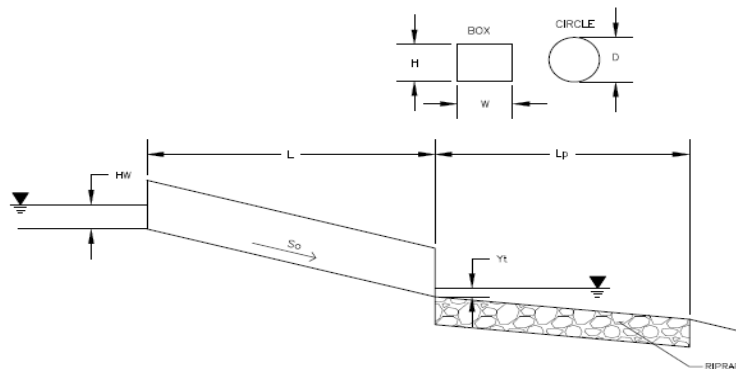
Basin ID: PRC2 - SW Property Corner Access Crossing - 100 Yr



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 D_a 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_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 = 7.32 ft²

Culvert Cross Sectional Area Available

A = 4.91 ft²

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 = 2.04 ft

Culvert Critical Depth

Y_c = 2.05 ft

Tailwater Depth for Design

d = 2.28 ft

Adjusted Diameter **OR** Adjusted Rise

D_a = 2.27 ft

Expansion Factor

$1/(2*\tan(\Theta))$ = 4.37

Flow/Diameter^{2.5} **OR** Flow/(Span * Rise^{1.5})

$Q/D^{2.5}$ = 3.70 ft^{0.5}/s

Froude Number

Fr = 1.01

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

Y_t/D = 0.44

Inlet Control Headwater

HW_i = 3.92 ft

Outlet Control Headwater

HW_o = 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_{50} = 8 in

Nominal Riprap Size

d_{50} = 9 in

UDFCD Riprap Type

Type = L

Length of Protection

L_p = 22 ft

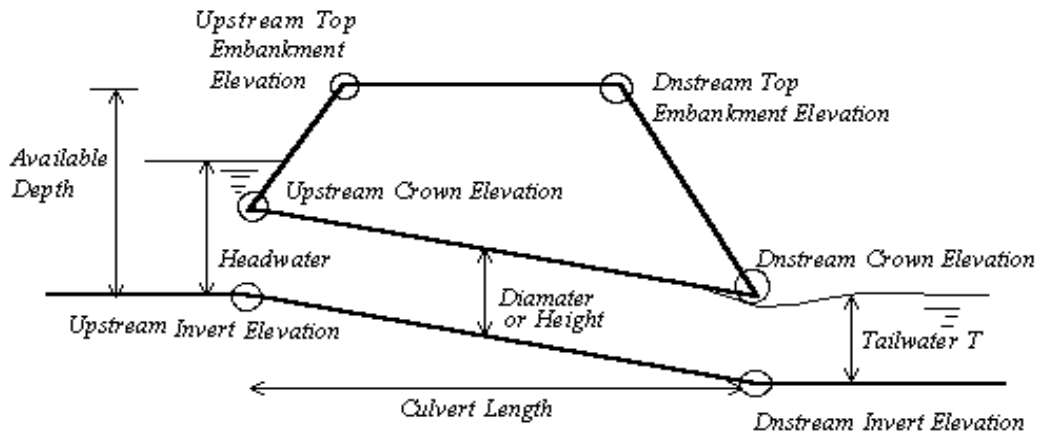
Width of Protection

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	

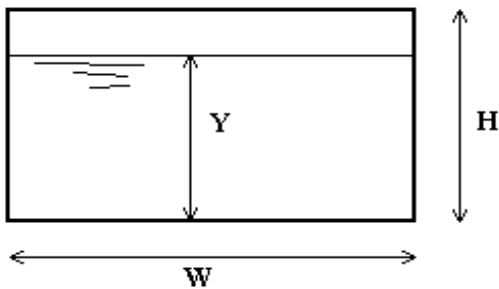
Culvert Vertical Profile

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

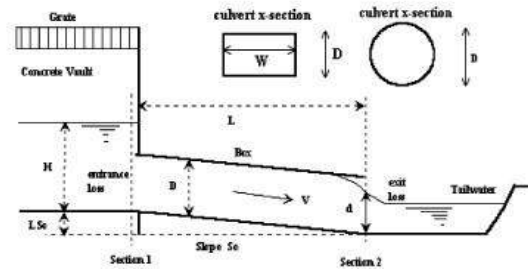
Calculations of Normal Flow Condition

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 _n =	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 _c =	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

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
---------	------

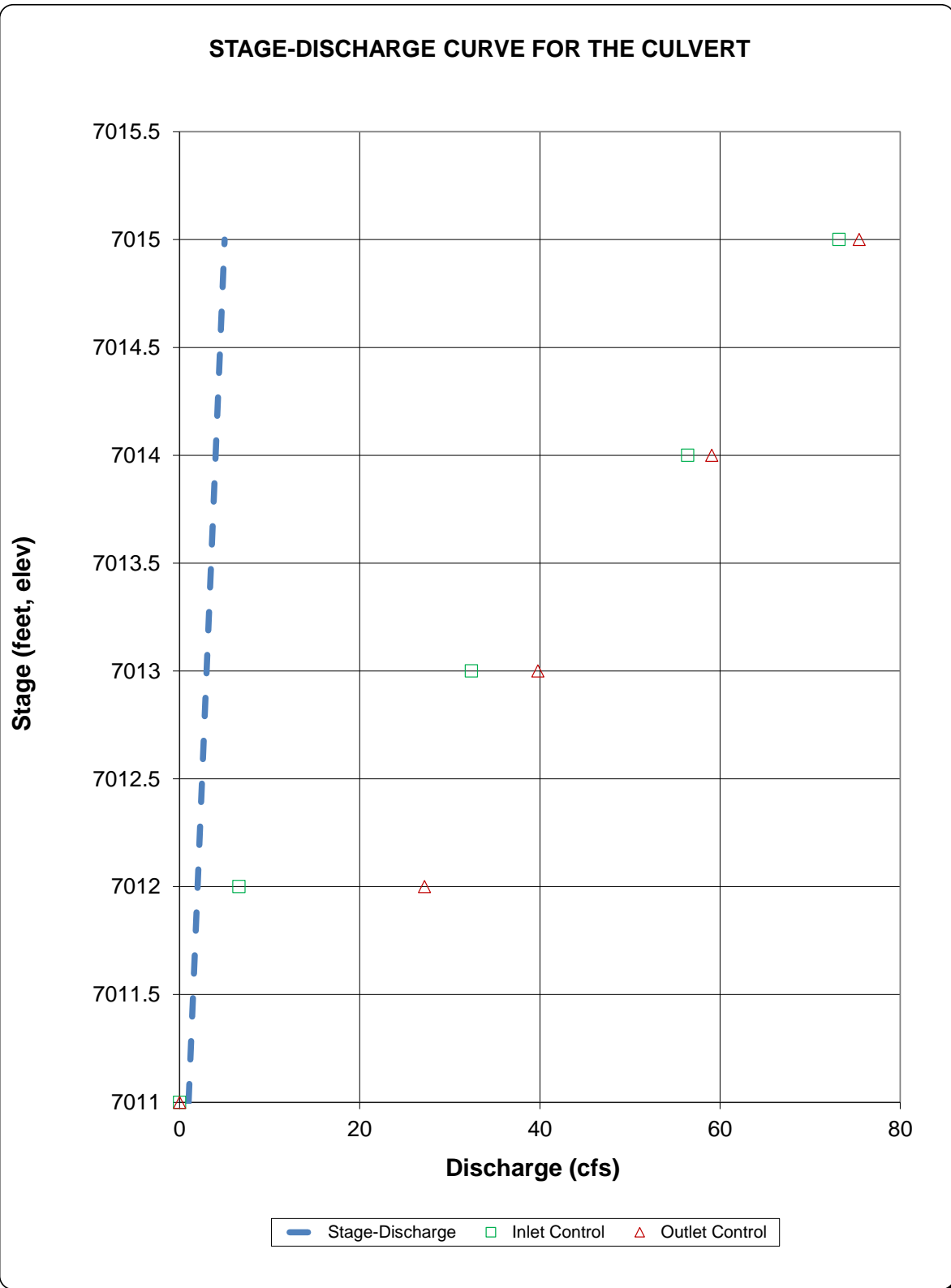
$C_d =$	0.87
---------	------

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

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

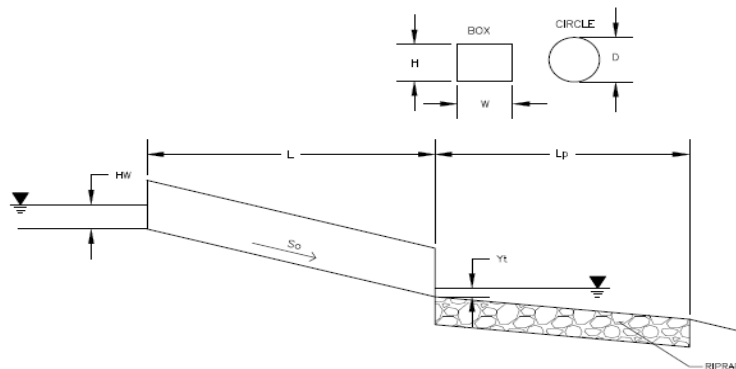
Project: Voolmer Substation
Basin ID: PRC3 - Crossing Access South of Property - 5 Yr



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 H_a 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 ft²

Culvert Cross Sectional Area Available

A = 3.00 ft²

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^{2.5} **OR** Flow/(Span * Rise^{1.5})

$Q/WH^{1.5}$ = 0.30 ft^{0.5}/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

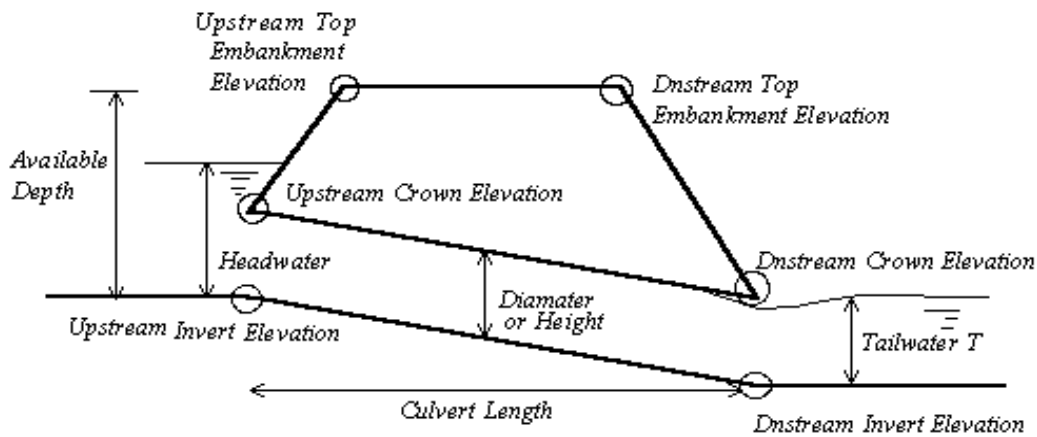
Width of Protection

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	

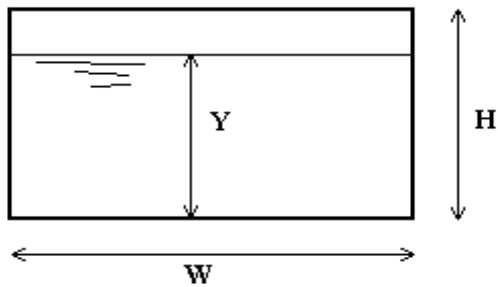
Culvert Vertical Profile

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

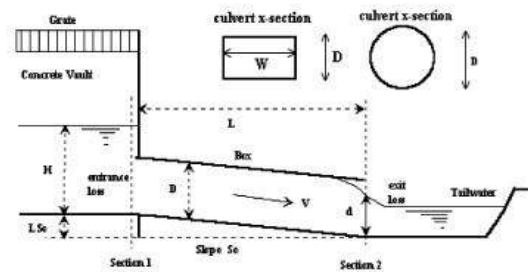
Calculations of Normal Flow Condition

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
---------	------

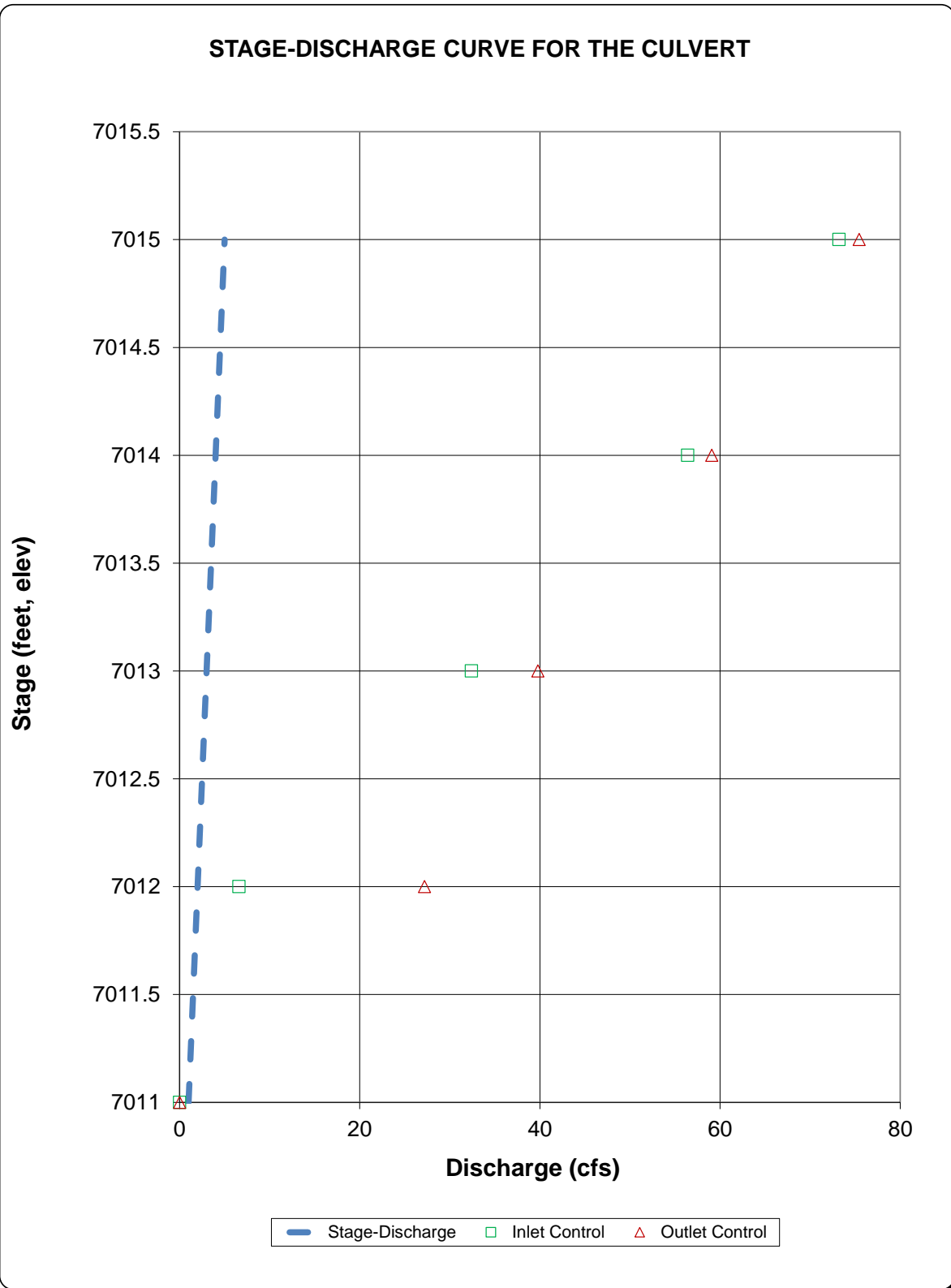
$$K_s = 2.31$$
$$C_d = \frac{2.97}{0.87}$$
$$KE_{\text{low}} = 0.0062$$
[illegible]

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

Project: Voolmer Substation

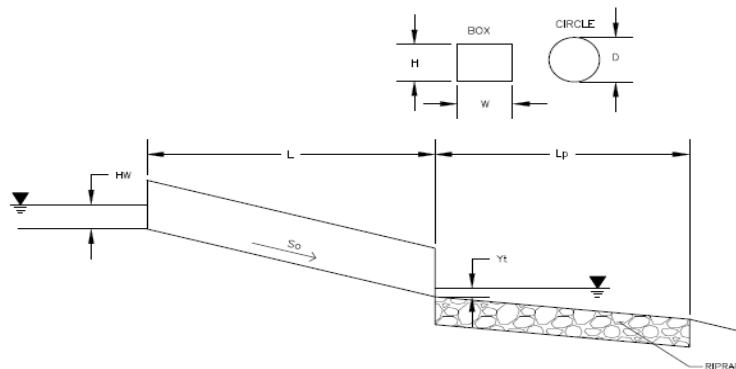
Basin ID: PRC3 - Crossing Access South of Property - 100 Yr



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^2

Culvert Cross Sectional Area Available

A = 3.00 ft^2

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^{2.5} **OR** Flow/(Span * Rise^{1.5})

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

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

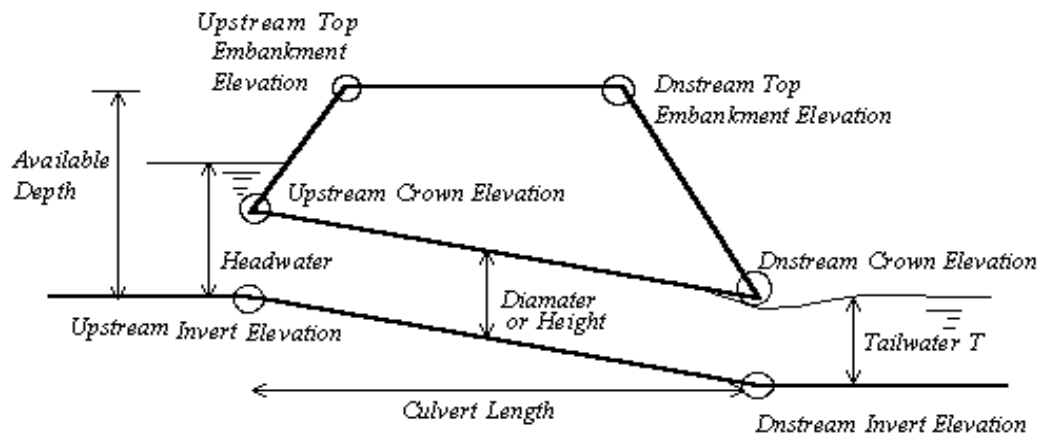
Width of Protection

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

Design Procedure Form: Runoff Reduction

UD-BMP (Version 3.07, March 2018)

Sheet 1 of 1

Designer: Dane Frank
Company: Terra Nova Engineering
Date: November 30, 2021
Project: Vollmer Substation
Location:

SITE INFORMATION (User Input in Blue Cells)

WQCV Rainfall Depth 0.60 inches
Depth of Average Runoff Producing Storm, d_6 = 0.43 inches (for Watersheds Outside of the Denver Region, Figure 3-1 in USDCM Vol. 3)

Area Type	UIA:RPA	UIA:RPA	UIA:RPA	UIA:RPA								
Area ID	NE Yard	S Yard	Acc Rd N	Acc Rd S								
Downstream Design Point ID	0	0	0	0								
Downstream BMP Type	None	None	None	None								
DCIA (ft ²)	--	--	--	--								
UIA (ft ²)	350	5,550	45,400	45,400								
RPA (ft ²)	1,680	73,075	30,000	30,000								
SPA (ft ²)	--	--	--	--								
HSG A (%)	100%	100%	100%	100%								
HSG B (%)	0%	0%	0%	0%								
HSG C/D (%)	0%	0%	0%	0%								
Average Slope of RPA (ft/ft)	0.005	0.050	0.020	0.020								
UIA:RPA Interface Width (ft)	140.00	425.00	3450.00	3450.00								

CALCULATED RUNOFF RESULTS

Area ID	NE Yard	S Yard	Acc Rd N	Acc Rd S								
UIA:RPA Area (ft ²)	2,030	78,625	75,400	75,400								
L / W Ratio	0.10	0.44	0.06	0.06								
UIA / Area	0.1724	0.0706	0.6021	0.6021								
Runoff (in)	0.00	0.00	0.00	0.00								
Runoff (ft ³)	0	0	0	0								
Runoff Reduction (ft ³)	15	231	1892	1892								

CALCULATED WQCV RESULTS

Area ID	NE Yard	S Yard	Acc Rd N	Acc Rd S								
WQCV (ft ³)	15	231	1892	1892								
WQCV Reduction (ft ³)	15	231	1892	1892								
WQCV Reduction (%)	100%	100%	100%	100%								
Untreated WQCV (ft ³)	0	0	0	0								

CALCULATED DESIGN POINT RESULTS (sums results from all columns with the same Downstream Design Point ID)

Downstream Design Point ID	0	0	0	0								
DCIA (ft ²)	0	0	0	0								
UIA (ft ²)	96,700	96,700	96,700	96,700								
RPA (ft ²)	134,755	134,755	134,755	134,755								
SPA (ft ²)	0	0	0	0								
Total Area (ft ²)	231,455	231,455	231,455	231,455								
Total Impervious Area (ft ²)	96,700	96,700	96,700	96,700								
WQCV (ft ³)	4,029	4,029	4,029	4,029								
WQCV Reduction (ft ³)	4,029	4,029	4,029	4,029								
WQCV Reduction (%)	100%	100%	100%	100%								
Untreated WQCV (ft ³)	0	0	0	0								

CALCULATED SITE RESULTS (sums results from all columns in worksheet)

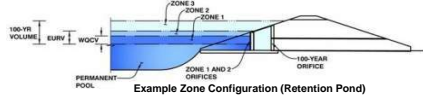
Total Area (ft ²)	925,820
Total Impervious Area (ft ²)	386,800
WQCV (ft ³)	4,029
WQCV Reduction (ft ³)	4,029
WQCV Reduction (%)	100%
Untreated WQCV (ft ³)	0

DETENTION BASIN STAGE-STORAGE TABLE BUILDER

UD-Detention, Version 3.07 (February 2017)

Project: Volmer Substation

Basin ID: PR-3 (Design Point 3)



Example Zone Configuration (Retention Pond)

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 =	100.0% 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 _{total}) =	1.00 ft
Depth of Trickle Channel (H _{TC}) =	N/A ft
Slope of Trickle Channel (S _{TC}) =	N/A ft/ft
Slopes of Main Basin Sides (S _{main}) =	4:01 H:V
Basin Length-to-Width Ratio (R _{L/W}) =	4
Initial Surcharge Area (A _{ISV}) =	0 ft²
Surcharge Volume Length (L _{SV}) =	0.0 ft
Surcharge Volume Width (W _{SV}) =	0.0 ft
Depth of Basin Floor (H _{basin}) =	0.00 ft
Length of Basin Floor (L _{basin}) =	59.2 ft
Width of Basin Floor (W _{basin}) =	14.8 ft
Area of Basin Floor (A _{basin}) =	875 ft²
Volume of Basin Floor (V _{basin}) =	0 ft³
Depth of Main Basin (H _{main}) =	1.00 ft
Length of Main Basin (L _{main}) =	59.5 ft
Width of Main Basin (W _{main}) =	15.1 ft
Area of Main Basin (A _{main}) =	900 ft²
Volume of Main Basin (V _{main}) =	888 ft³
Calculated Total Basin Volume (V _{total}) =	0.020 acre-feet

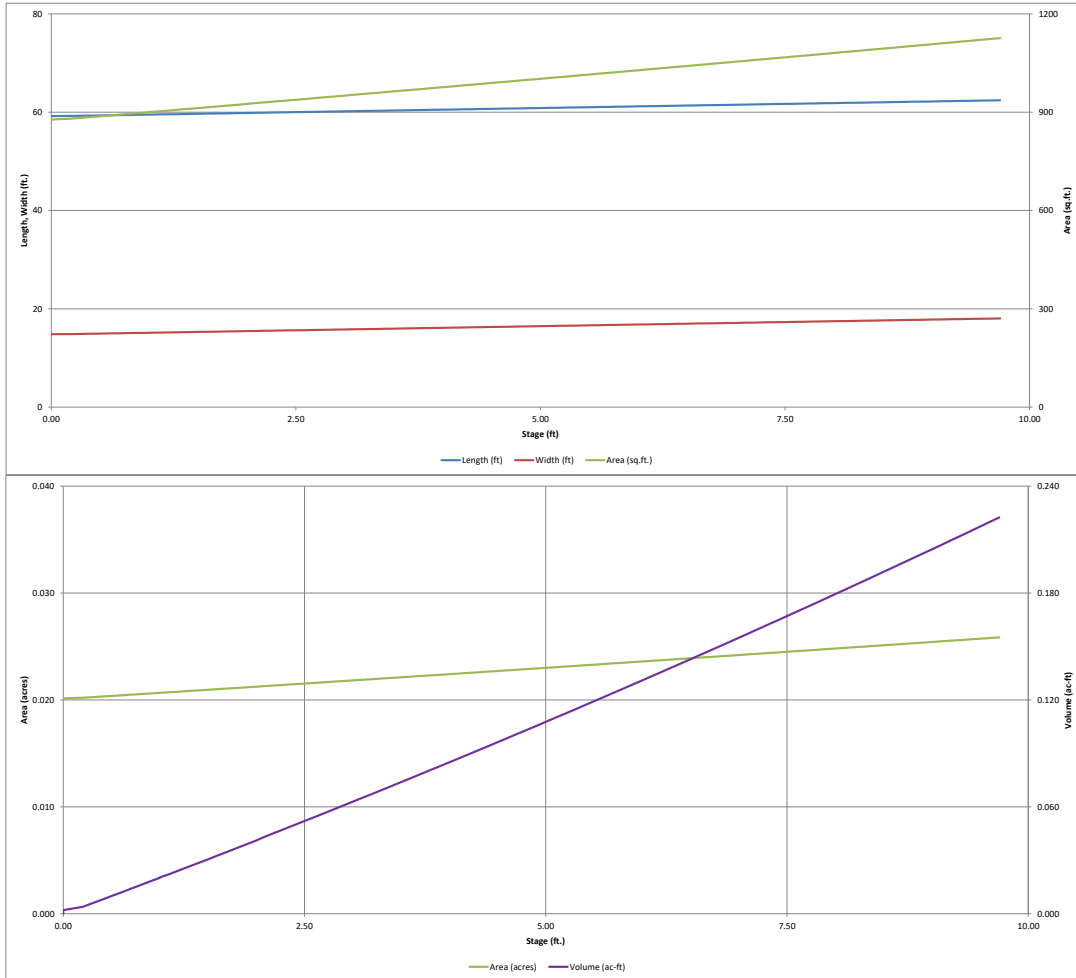
Total detention volume
is less than 100-year
volume.

Smain not typical.

Depth Increment =	0.1							
Stage - Storage Description	Stage (ft)	Optional Override Stage (ft)	Length (ft)	Width (ft)	Area (ft ²)	Optional Override Area (ft ²)	Area (ac-ft)	Volume (ft ³)
Media Surface	0.00		59.2	14.8	875		0.020	
	0.10		59.2	14.8	878		0.020	88
	0.20		59.2	14.9	880		0.020	167
	0.30		59.3	14.9	883		0.020	255
	0.40		59.3	14.9	885		0.020	343
	0.50		59.3	15.0	888		0.020	432
	0.60		59.4	15.0	890		0.020	521
	0.70		59.4	15.0	893		0.020	610
	0.80		59.4	15.1	895		0.021	699
	0.90		59.5	15.1	898		0.021	789
	1.00		59.5	15.1	900		0.021	879
Zone 1 (WQCV)	1.00		59.5	15.1	900		0.021	888
	1.10		59.5	15.2	903		0.021	969
	1.20		59.6	15.2	905		0.021	1,059
	1.30		59.6	15.2	908		0.021	1,150
	1.40		59.6	15.3	910		0.021	1,241
	1.50		59.7	15.3	913		0.021	1,332
	1.60		59.7	15.3	915		0.021	1,423
	1.70		59.7	15.4	918		0.021	1,515
	1.80		59.8	15.4	920		0.021	1,607
	1.90		59.8	15.4	923		0.021	1,699
	2.00		59.8	15.5	925		0.021	1,791
	2.10		59.9	15.5	928		0.021	1,893
	2.20		59.9	15.5	930		0.021	1,986
	2.30		59.9	15.6	933		0.021	2,079
	2.40		60.0	15.6	935		0.021	2,173
	2.50		60.0	15.6	938		0.022	2,267
	2.60		60.0	15.7	941		0.022	2,360
	2.70		60.1	15.7	943		0.022	2,455
	2.80		60.1	15.7	946		0.022	2,549
	2.90		60.1	15.8	948		0.022	2,644
	3.00		60.2	15.8	951		0.022	2,739
	3.10		60.2	15.8	953		0.022	2,834
	3.20		60.2	15.9	956		0.022	2,929
	3.30		60.3	15.9	958		0.022	3,025
	3.40		60.3	15.9	961		0.022	3,121
	3.50		60.3	16.0	963		0.022	3,217
	3.60		60.4	16.0	966		0.022	3,314
	3.70		60.4	16.0	969		0.022	3,410
	3.80		60.4	16.1	971		0.022	3,507
	3.90		60.5	16.1	974		0.022	3,605
	4.00		60.5	16.1	976		0.022	3,702
	4.10		60.5	16.2	979		0.022	3,800
	4.20		60.6	16.2	981		0.023	3,898
	4.30		60.6	16.2	984		0.023	3,996
	4.40		60.6	16.3	987		0.023	4,095
	4.50		60.7	16.3	989		0.023	4,194
	4.60		60.7	16.3	992		0.023	4,293
	4.70		60.7	16.4	994		0.023	4,392
	4.80		60.8	16.4	997		0.023	4,491
	4.90		60.8	16.4	999		0.023	4,591
	5.00		60.8	16.5	1,002		0.023	4,691
	5.10		60.9	16.5	1,005		0.023	4,792
	5.20		60.9	16.5	1,007		0.023	4,892
	5.30		60.9	16.6	1,010		0.023	4,993
	5.40		61.0	16.6	1,012		0.023	5,094
	5.50		61.0	16.6	1,015		0.023	5,196
	5.60		61.0	16.7	1,018		0.023	5,297
	5.70		61.1	16.7	1,020		0.023	5,399
	5.80		61.1	16.7	1,023		0.023	5,501
	5.90		61.2	16.8	1,025		0.024	5,604
6.00		61.2	16.8	1,028		0.024	5,706	
6.10		61.2	16.8	1,031		0.024	5,808	
6.20		61.3	16.9	1,033		0.024	5,912	
6.30		61.3	16.9	1,036		0.024	6,016	
6.40		61.3	16.9	1,038		0.024	6,120	
6.50		61.4	17.0	1,041		0.024	6,224	
6.60		61.4	17.0	1,044		0.024	6,328	
6.70		61.4	17.0	1,046		0.024	6,432	
6.80		61.5	17.1	1,049		0.024	6,537	
6.90		61.5	17.1	1,052		0.024	6,642	
7.00		61.5	17.1	1,054		0.024	6,747	
7.10		61.6	17.2	1,057		0.024	6,853	
7.20		61.6	17.2	1,060		0.024	6,959	
7.30		61.6	17.2	1,062		0.024	7,065	
7.40		61.7	17.3	1,065		0.024	7,171	
7.50		61.7	17.3	1,067		0.025	7,278	
7.60		61.7	17.3	1,070		0.025	7,385	
7.70		61.8	17.4	1,073		0.025	7,492	
7.80		61.8	17.4	1,075		0.025	7,599	
7.90		61.8	17.4	1,078		0.025	7,707	
8.00		61.9	17.5	1,081		0.025	7,815	
8.10		61.9	17.5	1,083		0.025	7,923	
8.20		61.9	17.5	1,086		0.025	8,032	
8.30		62.0	17.6	1,089		0.025	8,140	
8.40		62.0	17.6	1,091		0.025	8,249	
8.50		62.0	17.6	1,094		0.025	8,359	
8.60		62.1	17.7	1,097		0.025	8,468	
8.70		62.1	17.7	1,099		0.025	8,578	
8.80		62.1	17.7	1,102		0.025	8,688	
8.90		62.2	17.8	1,105		0.025	8,798	
9.00		62.2	17.8	1,107		0.025	8,909	
9.10		62.2	17.8	1,110		0.025	9,020	
9.20		62.3	17.9	1,113		0.026	9,131	
9.30		62.3	17.9	1,115		0.026	9,242	
9.40		62.3	17.9	1,118		0.026	9,354	
9.50		62.4	18.0	1,121		0.026	9,466	
9.60		62.4	18.0	1,123		0.026	9,578	
9.70		62.4	18.0	1,126		0.026	9,691	

DETENTION BASIN STAGE-STORAGE TABLE BUILDER

UD-Detention, Version 3.07 (February 2017)

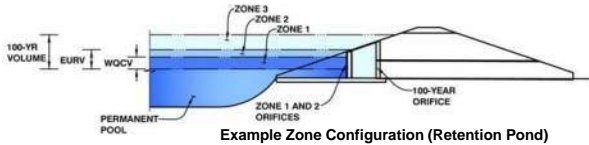


Detention Basin Outlet Structure Design

UD-Detention, Version 3.07 (February 2017)

Project: Vollmer Substation

Basin ID: PR-3 (Design Point 3)



Example Zone Configuration (Retention Pond)

	Stage (ft)	Zone Volume (ac-ft)	Outlet Type
Zone 1 (WQCV)	1.00	0.020	Filtration Media
Zone 2			Weir&Pipe (Circular)
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 ²
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 =	N/A	ft (relative to basin bottom at Stage = 0 ft)
Depth at top of Zone using Orifice Plate =	N/A	ft (relative to basin bottom at Stage = 0 ft)
Orifice Plate: Orifice Vertical Spacing =	N/A	inches
Orifice Plate: Orifice Area per Row =	N/A	inches

Calculated Parameters for Plate

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

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

	Row 1 (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)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Orifice Area (sq. inches)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

	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)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Orifice Area (sq. inches)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

User Input: Vertical Orifice (Circular or Rectangular)

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

Calculated Parameters for Vertical Orifice

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

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

	Zone 2 Weir	Not Selected	
Overflow Weir Front Edge Height, Ho =	1.00		ft (relative to basin bottom at Stage = 0 ft)
Overflow Weir Front Edge Length =	2.00		feet
Overflow Weir Slope =	0.00		H:V (enter zero for flat grate)
Horiz. Length of Weir Sides =	2.00		feet
Overflow Grate Open Area % =	70%		% grate open area/total area
Debris Clogging % =	50%		%

Calculated Parameters for Overflow Weir

	Zone 2 Weir	Not Selected	
Height of Grate Upper Edge, H _u =	1.00		feet
Over Flow Weir Slope Length =	2.00		feet
Grate Open Area / 100-yr Orifice Area =	1.58		should be ≥ 4
Overflow Grate Open Area w/o Debris =	2.80		ft ²
Overflow Grate Open Area w/ Debris =	1.40		ft ²

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

	Zone 2 Circular	Not Selected	
Depth to Invert of Outlet Pipe =	2.50		ft (distance below basin bottom at Stage = 0 ft)
Circular Orifice Diameter =	18.00		inches

Calculated Parameters for Outlet Pipe w/ Flow Restriction Plate

	Zone 2 Circular	Not Selected	
Outlet Orifice Area =	1.77		ft ²
Outlet Orifice Centroid =	0.75		feet
Half-Central Angle of Restrictor Plate on Pipe =	N/A	N/A	radians

User Input: Emergency Spillway (Rectangular or Trapezoidal)

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

Calculated Parameters for Spillway

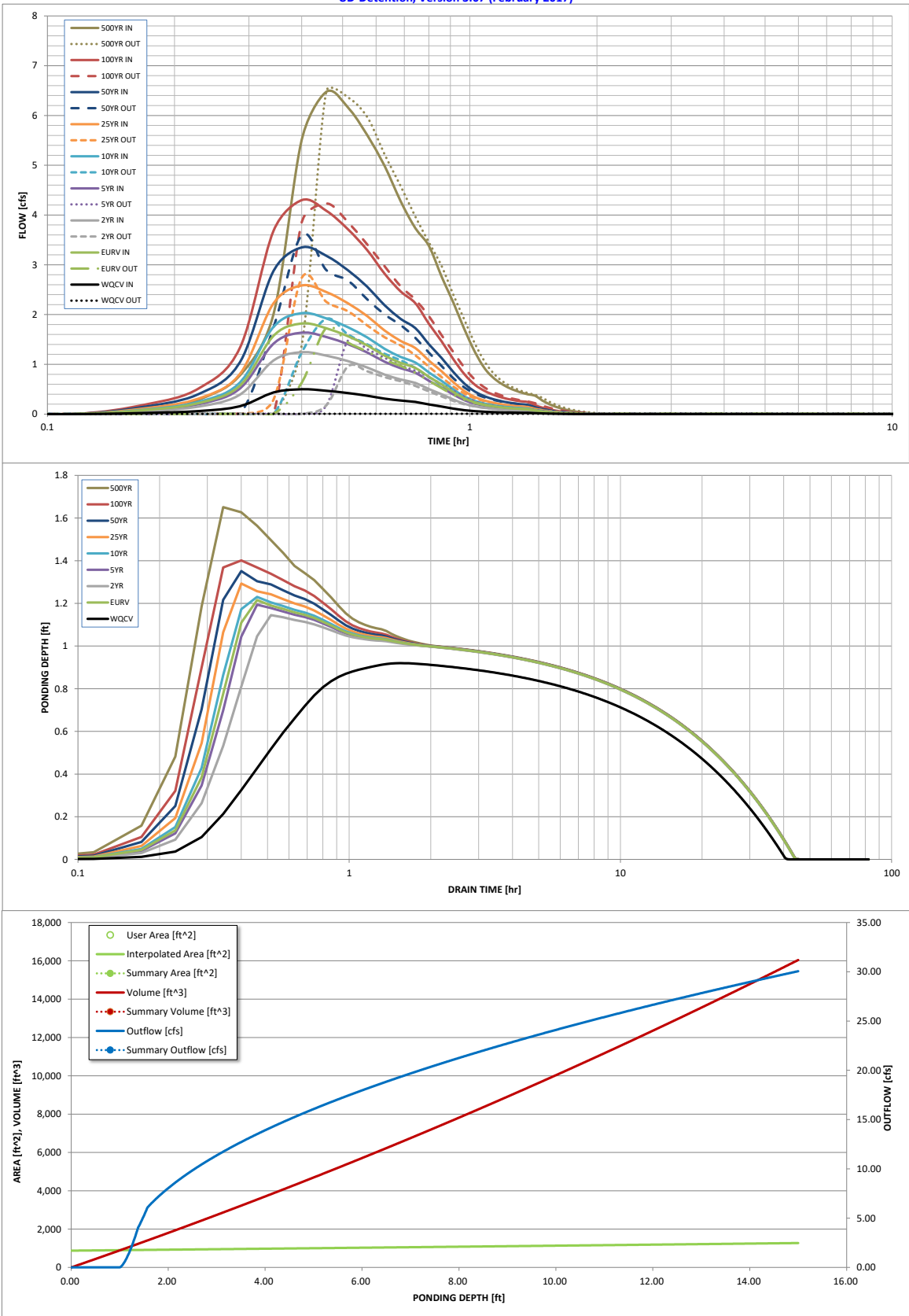
Spillway Design Flow Depth=		feet
Stage at Top of Freeboard =		feet
Basin Area at Top of Freeboard =		acres

Routed Hydrograph Results

	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	1.7	1.0	1.5	1.9	2.7	3.6	4.2	6.5
Ratio Peak Outflow to Predevelopment Q =	N/A	N/A	N/A	144.1	80.3	53.1	9.1	4.5	3.1
Structure Controlling Flow =	Filtration Media	Overflow Grate 1	Overflow Grate 1	Overflow Grate 1	Overflow Grate 1	Overflow Grate 1	Overflow Grate 1	Overflow Grate 1	Overflow Grate 1
Max Velocity through Grate 1 (fps) =	N/A	0.59	0.29	0.5	0.6	0.9	1.2	1.5	2.3
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	39	41	40	39	37	35	33	27
Time to Drain 99% of Inflow Volume (hours) =	40	43	43	43	42	42	41	40	38
Maximum Ponding Depth (ft) =	0.92	1.22	1.14	1.19	1.23	1.29	1.35	1.40	1.65
Area at Maximum Ponding Depth (acres) =	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Maximum Volume Stored (acre-ft) =	0.019	0.025	0.023	0.024	0.025	0.026	0.028	0.029	0.034

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

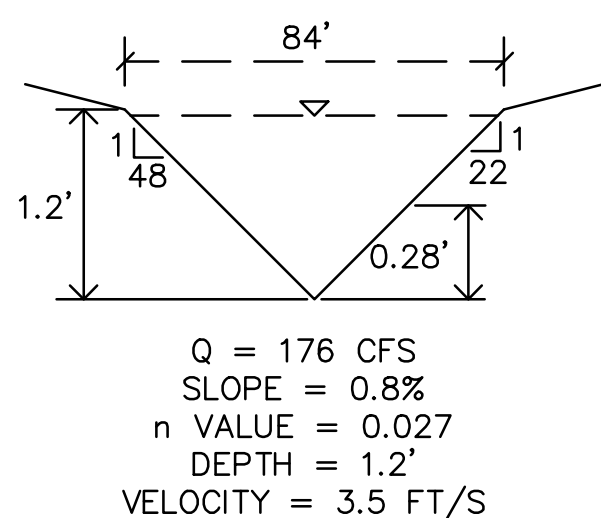
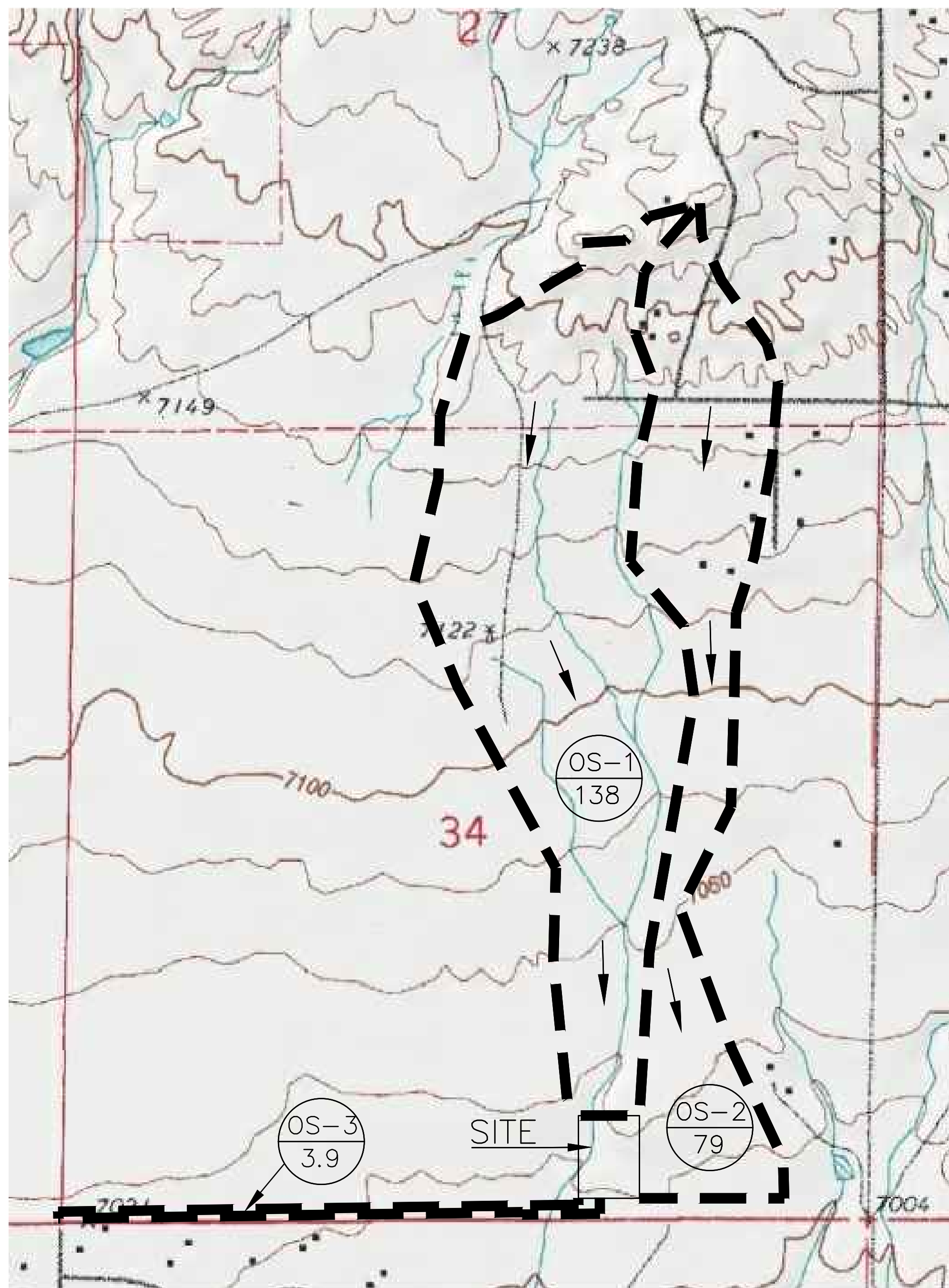
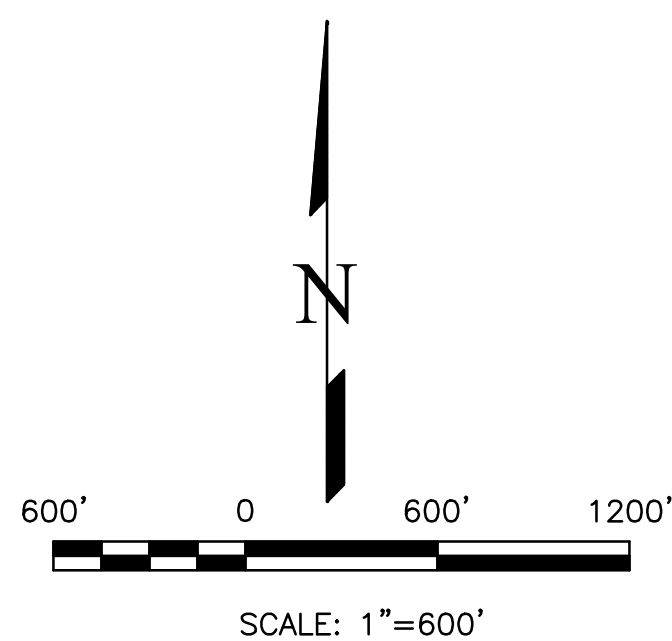
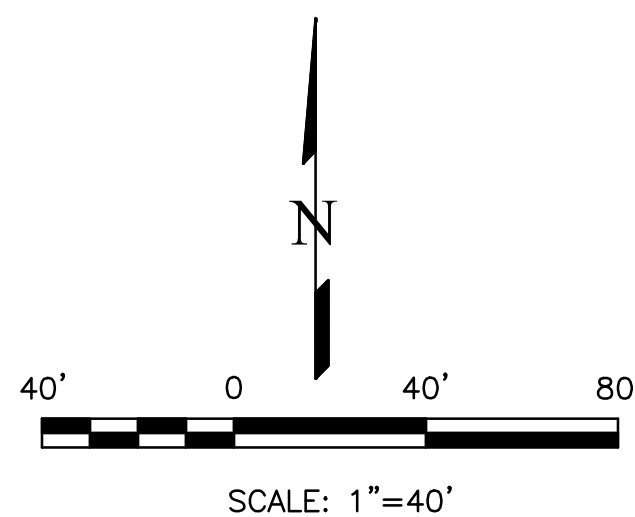
JANUARY 2022

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

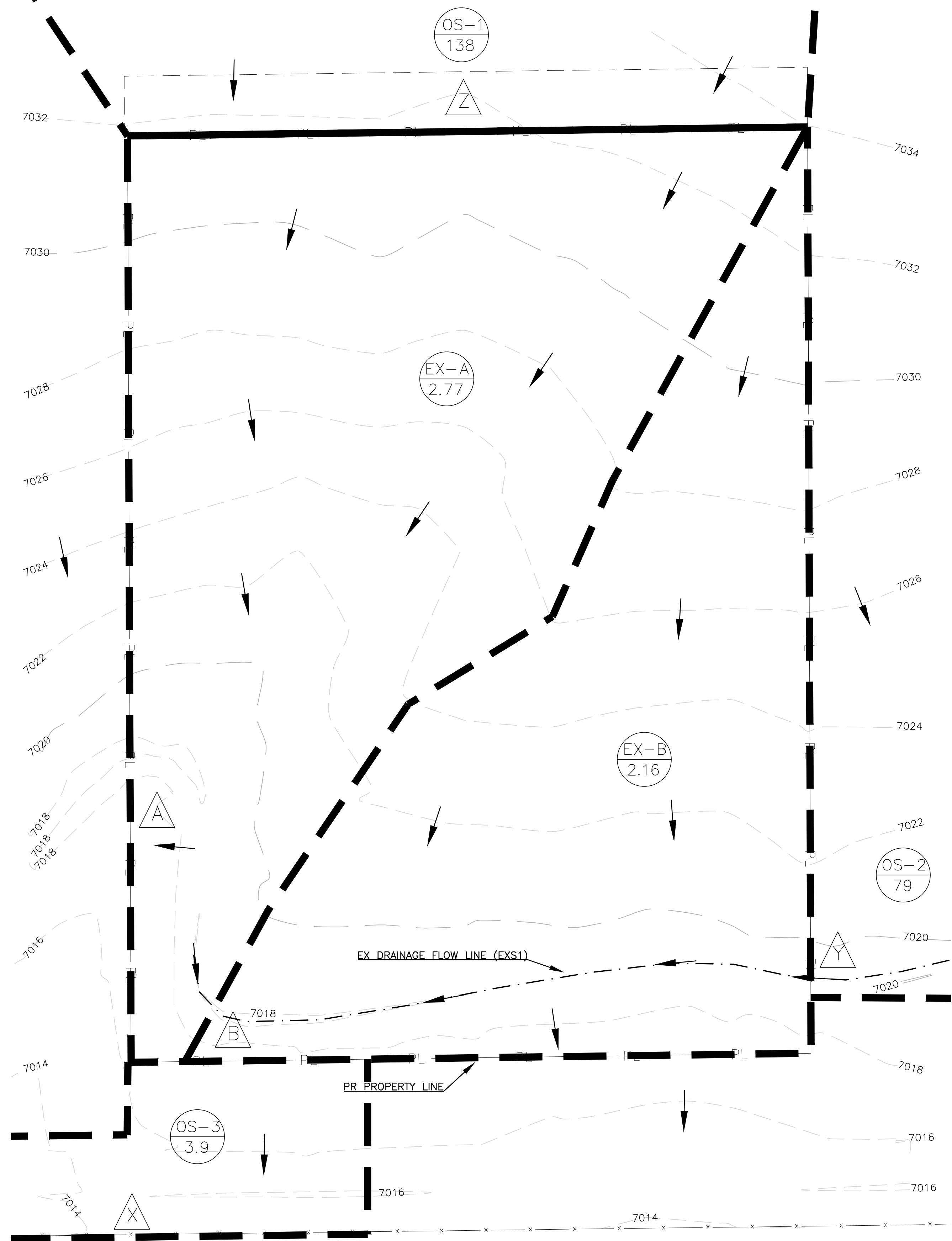
BASIN	ACRES	Q5 CFS	Q10 CFS	Q100 CFS
OS-1	138	---	20	---
OS-2	79	7.1	---	43.7
OS-3	3.9	1.0	---	6.3
EX-A	2.77	0.9	---	6.4
EX-B	2.16	0.7	---	5.0

EX	EXISTING
----	----------

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



NOTE: THIS IS AN EXISTING NATURAL SWALE AND IRREGULAR. THIS SECTION IS A ROUGH GENERALIZATION.

[illegible]

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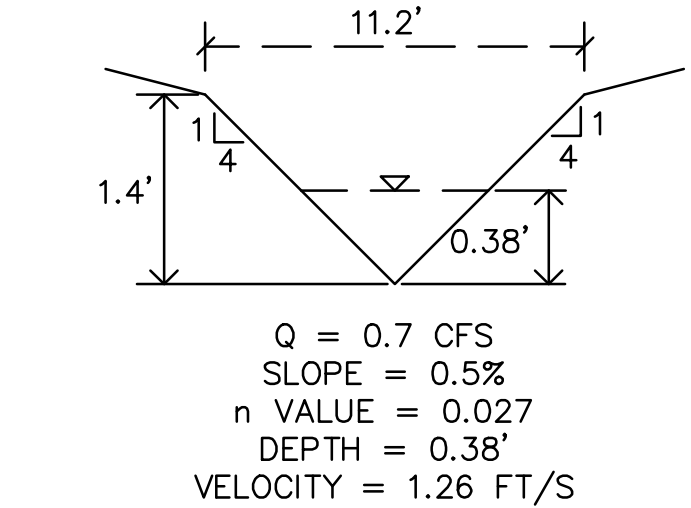
VOLLMER SUBSTATION
EL PASO COUNTY, CO
DEVELOPED DRAINAGE MAP
JANUARY 2022

DESIGN POINT SUMMARY

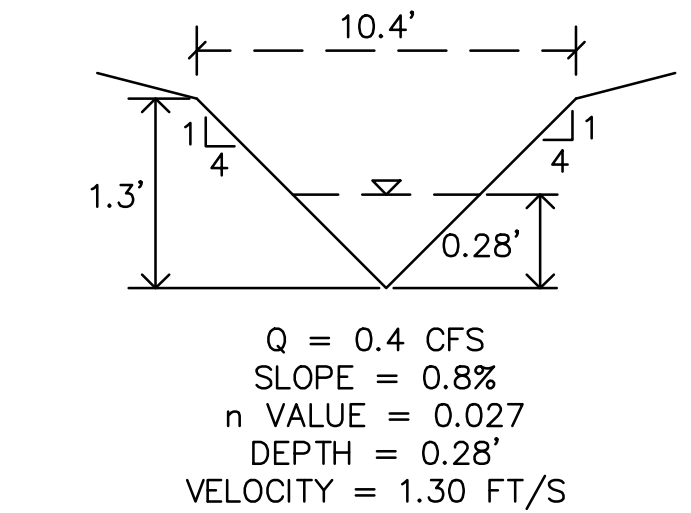
DP	CONTRIBUTING BASINS	AREA AC.	Q5 CFS	Q10 CFS	Q100 CFS
Z	OS-1	138	---	20	---
Y	OS-2	79	7.1	---	36.6*
1	PR-1	0.42	0.1	---	0.7
2	PR-2	1.70	1.6	---	4.4
3	PR-3	0.15	0.1	---	0.4
4	PR-3, PR-4, OS-2	81	8.6	---	36.6*
5	PR-1,PR-2,PR-3,PR-4,PR-5,OS-2	84	9.7	---	47.5*
6	PR-6	0.06	0.03	---	0.2
7	PR-7	0.26	0.3	---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

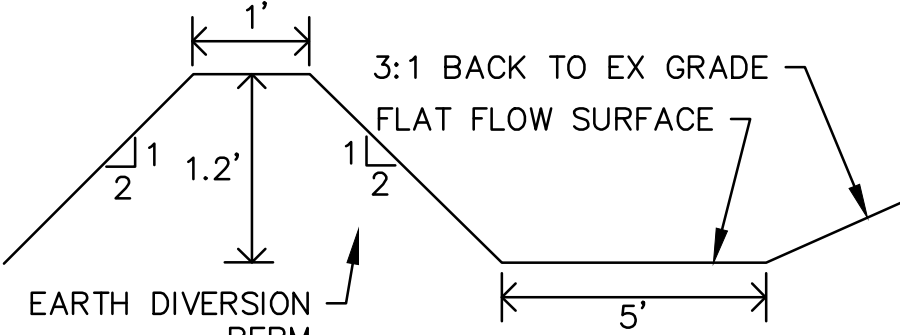
NOTE: PER THE MDDP FOR STERLING RANCH, OCTOBER 2018, BY M&S CIVIL CONSULTANTS, INC; OFFSITE RUNOFF FLOWING THROUGH THE SITE IS Q5=15.2 CFS, Q10=27.1 CFS, Q100=78.4 CFS (FROM THEIR BASIN EX-13 AND FLOWING IN CHANNEL RT-17A). THE SURVEY DATA, BASINS, AND HYDROLOGY CALCULATION METHOD USED IN THE MDDP ARE DIFFERENT THAN WHAT IS USED IN THIS REPORT. BASED ON THE TOPO DATA, THE CHANNELIZATION OF THIS FLOW APPEARS LIMITED AT THE NORTH EDGE OF THE SITE. THE NORTH BERM/SWALE THAT DIVERTS OFFSITE RUNOFF AROUND THE SITE HAS BEEN SIZED TO ACCOMMODATE MORE THAN THE 100 YEAR FLOW IN THE MDDP.



SWALE CROSS SECTION - PRS1 (TYP)



SWALE CROSS SECTION - PRS2 (TYP)



NORTH DIVERSION BERM/SWALE
CROSS SECTION (TYP)

PROPOSED CONDITIONS

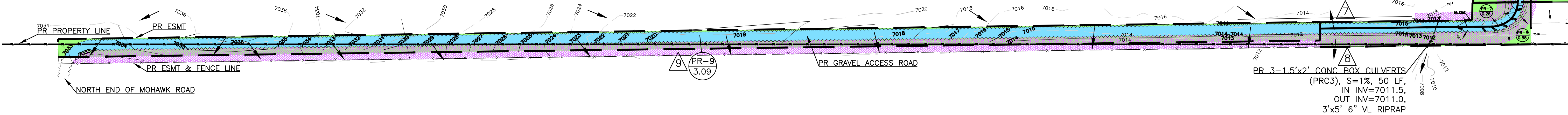
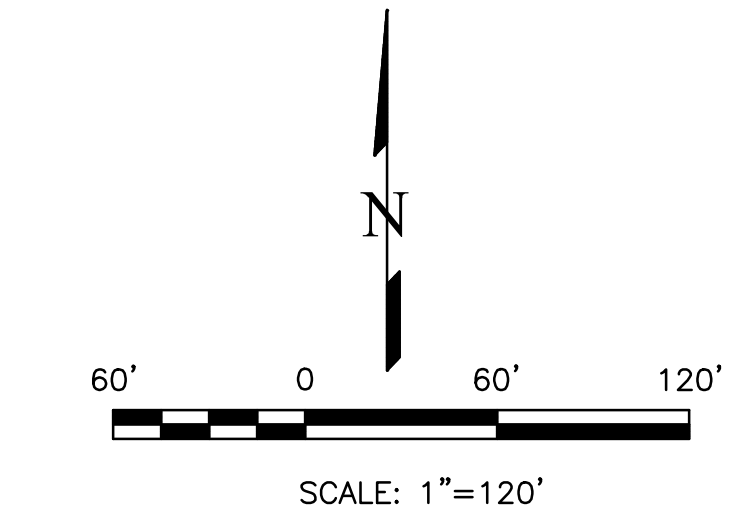
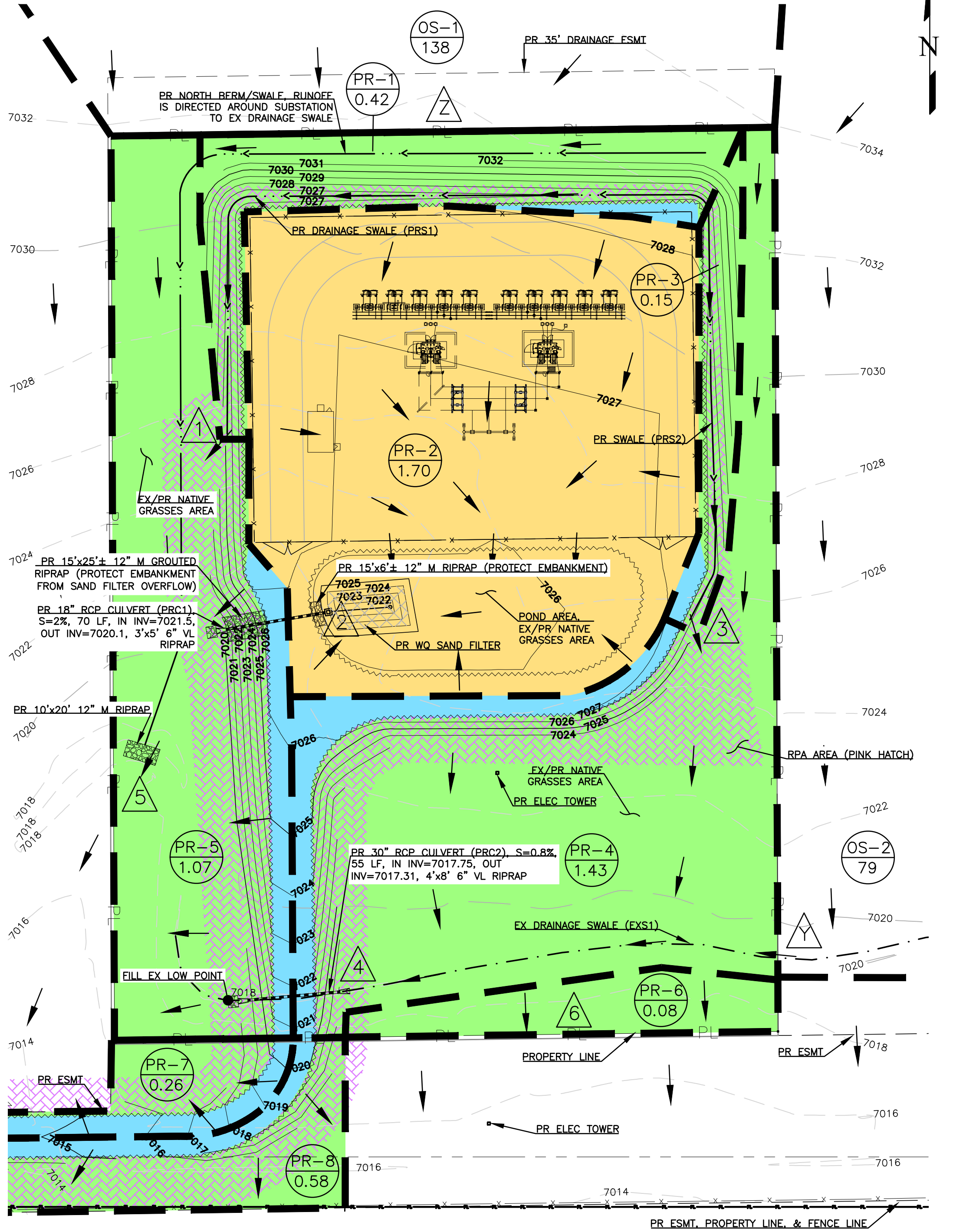
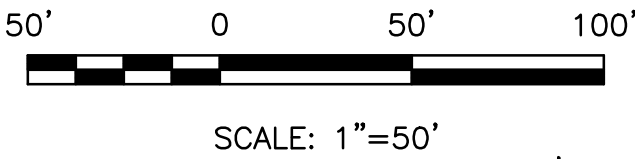
BASIN	ACRES	Q5 CFS	Q10 CFS	Q100 CFS
OS-1	138	---	20	---
OS-2	79	7.1	---	43.7
PR-1	0.42	0.1	---	0.7
PR-2	1.70	1.6	---	4.4
PR-3	0.15	0.1	---	0.4
PR-4	1.43	0.4	---	2.4
PR-5	1.07	0.4	---	3.0
PR-6	0.06	0.03	---	0.2
PR-7	0.26	0.3	---	1.1
PR-8	0.58	0.4	---	2.1
PR-9	3.09	4.1	---	13.6

LEGEND

- BASIN DESIGNATION
- AREA IN BASIN (AC)
- DESIGN POINT
- BASIN BOUNDARY
- EXISTING 2' CONTOUR
- EXISTING 10' CONTOUR
- FLOW DIRECTION
- SURFACE FLOW CHANNEL
- FENCE LINE
- PROPOSED 1' CONTOUR
- PROPOSED 5' CONTOUR
- PROPOSED EDGE OF GRAVEL
- PROPOSED/EXISTING
- DEVELOPED AREA THAT DRAINS TO WQ TREATMENT SAND FILTER
- DEVELOPED AREA (GRAVEL ROAD OR GRAVEL YARD) THAT DRAINS TO UNDEVELOPED OR LANDSCAPING AREAS, WQ TREATMENT BY RUNOFF REDUCTION (GRASS SWALE, GRASS BUFFER, NATIVE PRAIRIE GRASSES)
- AREA TO REMAIN UNDEVELOPED (PRAIRIE GRASSES)

NOTES

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



DATE

DESCRIPTION

REVISIONS

NO.

UNTIL SUCH TIME AS THESE DRAWINGS ARE APPROVED BY THE REVIEWING AGENCIES, THE TERRA NOVA ENGINEERING, INC. APPROVES THEIR USE ONLY FOR THE PROJECT AND FOR THE PURPOSES SPECIFIED BY WRITTEN AUTHORIZATION.

PREPARED FOR:

MVEA

ATTN: DAVE WALDNER

11140 E. WOODMEN RD

PEYTON, CO 80831

(719) 495-2283

721 S. 2900 STREET

COLORADO SPRINGS, CO 80904

OFFICE: 719-635-6422

FAX: 719-635-6426

www.tnnae.com

VOLLMER SUBSTATION

DEVELOPED DRAINAGE MAP

DESIGNED BY LD

DRAWN BY DLF

CHECKED BY LD

H-SCALE AS SHOWN

V-SCALE NA

JOB NO. 1845.00

DATE ISSUED 01/10/22

SHEET NO. 2 OF 3

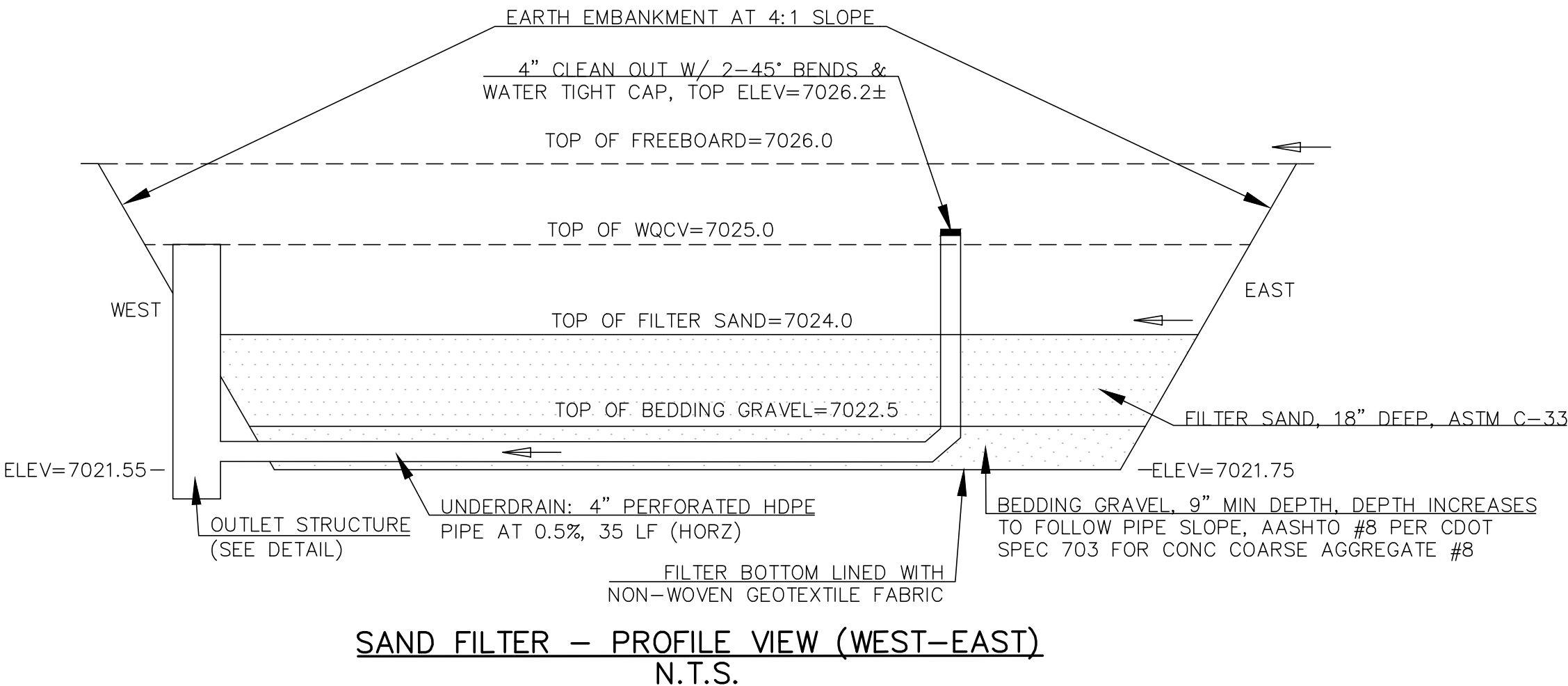
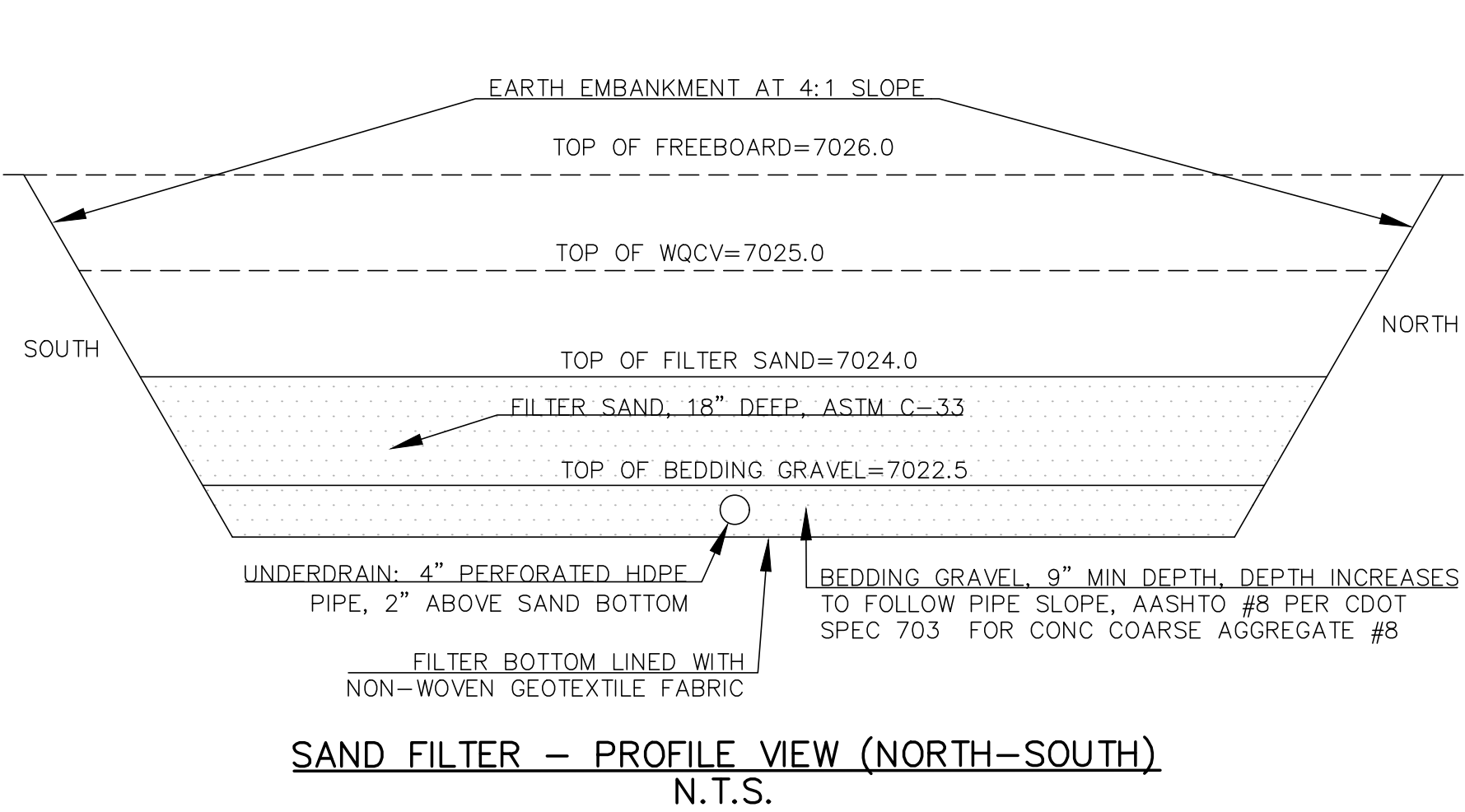
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VOLLMER SUBSTATION
EL PASO COUNTY, CO
WATER QUALITY DETAILS
JANUARY 2022

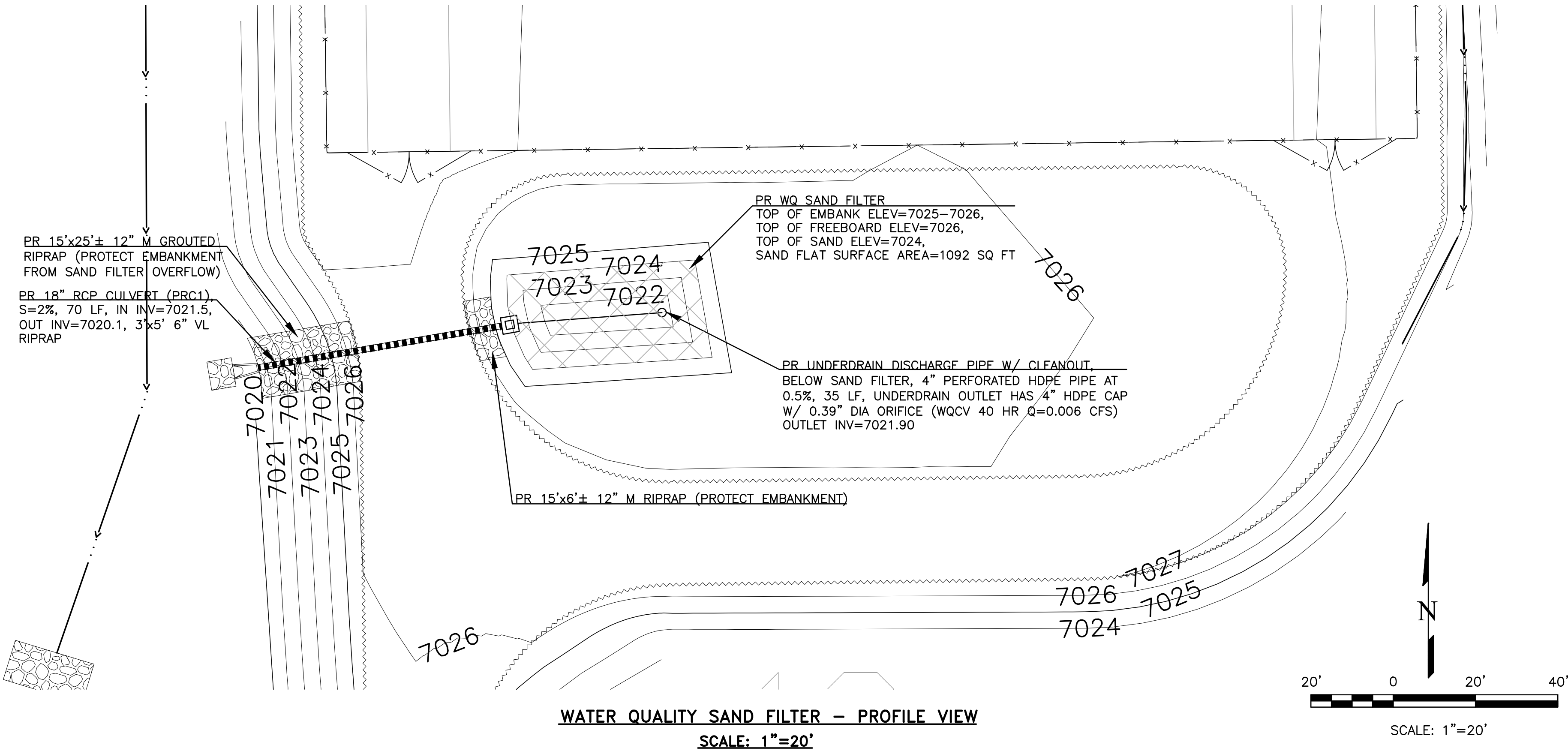
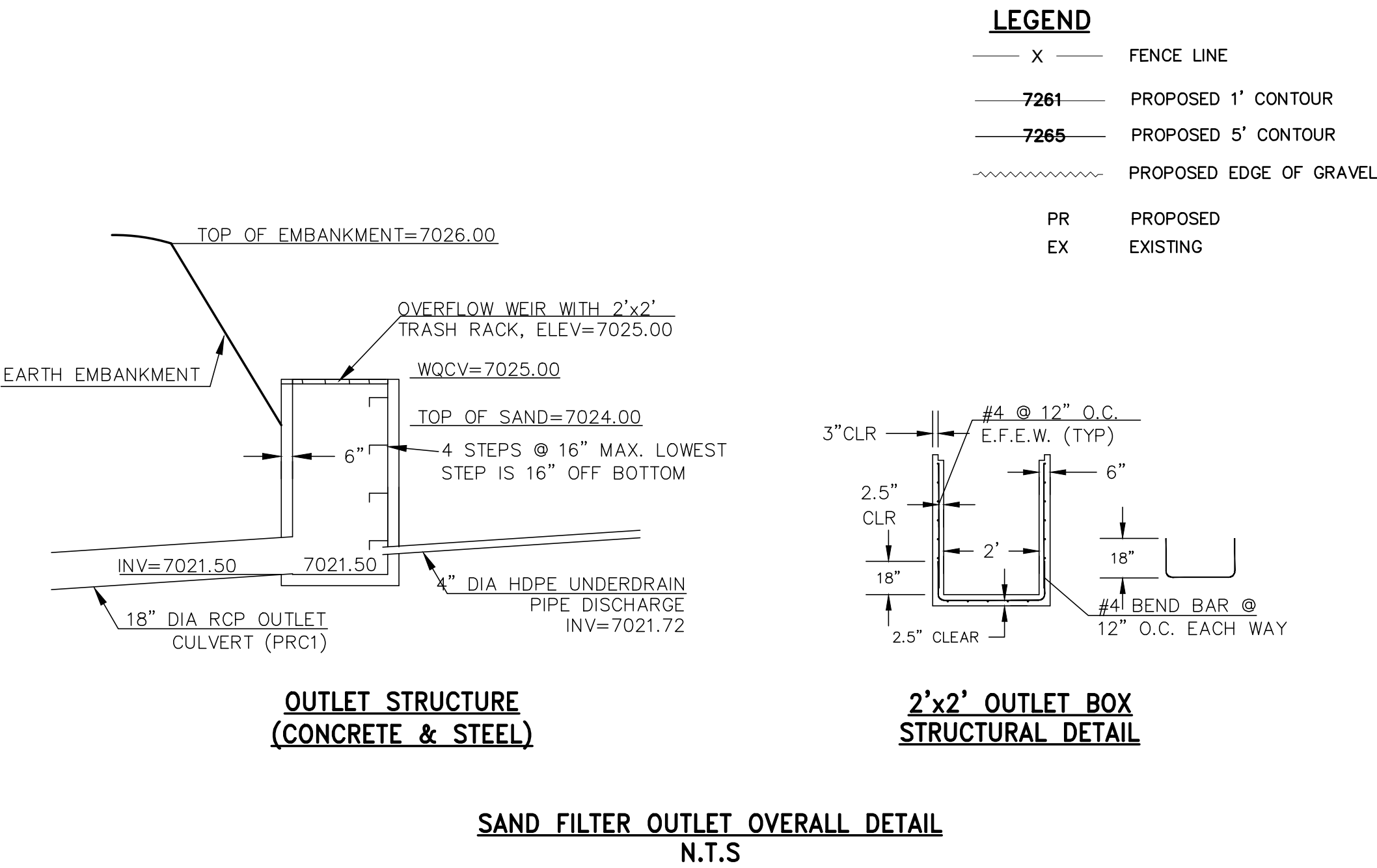
NOTES

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



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REVISIONS	
NO.	DESCRIPTION

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11140 E. WOODMEN RD
PEYTON, CO 80831
(719) 495-2283

Terra Nova
Engineering, Inc.
Creative Civil Engineering

721 S. 2900 STREET
COLORADO SPRINGS, CO 80904
OFFICE: 719-635-6422
FAX: 719-635-6426
www.tnainc.com

VOLLMER SUBSTATION
WATER QUALITY DETAILS

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V-SCALE NA
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SHEET NO. 3 OF 3