Appendix F:
Bridge Design Hydraulic Study Report County Road 66B Bridge Replacement Project Glenn County, California

County Road 66B Bridge Replacement Project
Glenn County, California
Federal-Aid Project No. BRLO-5911(063)
Existing Bridge No. 11C0068

Bridge Design Hydraulic Study Report

Prepared for:

Prepared by:

February 2019

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County Road 66B Bridge Replacement Project
Glenn County, California
Federal-Aid Project No. BRLO-5911(063)
Existing Bridge No. 11C0068

Bridge Design Hydraulic Study Report

Submitted to:
County of Glenn ~~Planning and~~ Public Works

This report has been prepared by or under the supervision of the following Registered Engineer. The Registered Civil Engineer attests to the technical information contained herein and has judged the qualifications of any technical specialists providing engineering data upon which recommendations, conclusions, and decisions are based.

Han-Bin Liang, Ph.D., P.E.
Registered Civil Engineer

2/22/2019
Date

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February 2019

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Executive Summary

The Glenn County (County) ~~Planning and~~ Public Works Agency is proposing to replace the existing Colusa Drain bridge on County Road 66B (Bridge No. 11C0068). The County Road 66B Bridge Replacement at Colusa Drain (Project) is located at the southeastern part of Glenn County and approximately 2 miles (mi) west of California State Route 45. Colusa Drain is owned, operated, and maintained by the Provident Irrigation District (PID), Glenn-Codora-Princeton Irrigation District, and Glenn County Irrigation District.

The County Road 66B Bridge over Colusa Drain was built in 1940. It is approximately 54 feet (ft) long and 20 ft wide and has a 10-degree skew from the Colusa Drain. The structure consist of a three-span timber structure supported on concrete piles and concrete abutments. It currently has one lane for travelling in both directions. The Project proposes to replace the existing bridge with a new structure with two lanes with a width of 32 ft and length of 60 ft. The proposed bridge would meet the design guidelines specified by the American Association of State Highway and Transportation Officials.

The purpose of this report is to document the design flow characteristics of the Colusa Drain at the Project location for the existing and the proposed conditions. The report also documents the scour potential and recommends scour countermeasures for the proposed condition.

The Colusa Drain is owned, operated, and maintained by the Provident Irrigation District (PID), Glenn-Codora-Princeton Irrigation District, and Glenn County Irrigation District. The maximum irrigation design flow (MIDF) for Colusa Drain is 100 cubic feet per second (cfs), and was provided by PID. In addition to MIDF rate, an overtopping flow of 1,520 cfs was also evaluated based on the capacity of the channel. The overtopping flow of 1,520 cfs was used to perform the scour analysis.

The hydraulic analysis was performed using the U.S. Army Corps of Engineers' Hydrologic Engineering Center's River Analysis System and a survey provided by Quincy Engineering, Inc. in 2016. The existing and proposed water surface elevations (WSEs) at the County Road 66B bridge with the MIDF and overtopping flow are summarized in the following tables. Based on the hydraulic models, the proposed bridge would have an insignificant impact on the WSEs at the Project site.

Summary of MIDF Water Surface Elevations at the County Road 66B Bridge

River Station	Location/Distance from Existing Bridge Centerline	Water Surface Elevation (ft NAVD 88)	
		Existing	Proposed
1350.3	16 feet upstream of existing bridge	66.8	66.7
1338.3	4 feet upstream of existing bridge	66.8	--
1321 BR U	Upstream face of existing/proposed bridge	66.7	66.7
1321 BR D	Downstream face of existing/proposed bridge	66.7	66.6
1304.8	8 feet downstream of existing bridge	66.7	--
1293.3	19 feet downstream of existing bridge	66.7	66.6

Notes: Elevations are rounded to the nearest 0.1 ft.
NAVD 88 = North American Vertical Datum of 1988

Summary of Overtopping Water Surface Elevations at the County Road 66B Bridge

River Station	Location/Distance from Existing Bridge Centerline	Water Surface Elevation (ft NAVD 88)	
		Existing	Proposed
1350.3	16 feet upstream of existing bridge	75.6	75.5
1338.3	4 feet upstream of existing bridge	75.7	--
1321 BR U	Upstream face of existing/proposed bridge	75.7	75.5
1321 BR D	Downstream face of existing/proposed bridge	75.5	75.5
1304.8	8 feet downstream of existing bridge	75.5	--
1293.3	19 feet downstream of existing bridge	75.4	75.5

Notes: Elevations are rounded to the nearest 0.1 ft.
NAVD 88 = North American Vertical Datum of 1988

According to PID's standards, the proposed bridge soffit elevation must be equal to or higher than the existing bridge soffit elevation. The available freeboard heights are summarized in the following table.

Summary of the Existing and Proposed Bridge Freeboard at Upstream Face

Flow Scenario	Available Freeboard (ft)	
	Existing Bridge	Proposed Bridge
MIDF	9.7	9.8
Overtopping	0.7	1.0

Note: Elevations are rounded to the nearest 0.1 ft.

A scour analysis was performed for the proposed bridge using the overtopping flow. Long-term, contraction, and local scour were evaluated using the methods outlined in the FHWA's Hydraulic Engineering Circular No. 18, *Evaluating Scour at Bridges* (FHWA 2012). The following table summarizes the estimated scour depths and elevations for the proposed bridge. Because scour countermeasures will be provided at the abutments, the scour elevations reference the finished grade (FG) elevations at each respective abutment.

Summary of Scour Depths and Elevations

Location	Scour Depth (feet)				Elevation (ft NAVD 88)	
	Local	Contraction	Long-Term	Total	Reference FG Elevation	Scour Elevation
Abutment 1 (West)	2.5	3.1	0	5.6	74.6	69.0
Abutment 2 (East)	1.3	3.1	0	4.4	75.2	70.8

Rock slope protection (RSP) is proposed at the bridge abutments to reduce the erosion potential and thalweg migration. A minimum of Class IV RSP is recommended for this Project. Class IV RSP has a median particle weight of 300 pounds and a median particle diameter of 15 inches. The minimum layer thickness for Class IV RSP is 2.5 feet, which should be placed using Method B. Class 8 RSP geotextile filter fabric should be placed on the bank as the initial filter separator material between the layer of RSP and the channel bank.

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Acronyms

AASHTO	American Association of State Highway and Transportation Officials
BIR	Bridge Inspection Report
CABS	California Bank and Shores
Caltrans	California Department of Transportation
cfs	cubic feet per second
County	County of Glenn
D_{50}	median grain size diameter
ESRI	Environmental Systems Research Institute
FEMA	Federal Emergency Management Agency
FG	finished grade
FHWA	Federal Highway Administration
FIRM	Flood Insurance Rate Map
ft	feet
HBP	Highway Bridge Program
HEC-18	Hydraulic Engineering Circular No. 18
HEC-23	Hydraulic Engineering Circular No. 23
HEC-RAS	Hydraulic Engineering Centers River Analysis System
LRFD	Load and Resistance Factor Desgin
mi	miles
MIDF	maximum irrigation design flow
NAD 83	North American Datum of 1983
NAVD 88	North American Vertical Datum of 1988
PID	Provident Irrigation Distrcit
Project	County Road 66B over Colusa Drain Bridge Replacement Project
RS	river station
RSP	rock slope protection
WSE	water surface elevation

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1 GENERAL DESCRIPTION

The Glenn County (County) ~~Planning and~~ Public Works Agency is proposing to replace the existing Colusa Drain bridge on County Road 66B (Bridge No. 11C0068). The County Road 66B Bridge Replacement at Colusa Drain (Project) is located at the southeastern part of Glenn County and approximately 2 miles (mi) west of California State Route 45. See Figure 1 for the Project location map, Figure 2 for the Project vicinity map, and Figure 3 for the Project aerial map.

1.1 Project Purpose

The purpose of this Project is to remove the existing structure and replace it with a new bridge designed to meet the current structural and geometric standards, while minimizing adverse impacts to Colusa Drain and its surrounding area. The replacement bridge will meet current applicable County, American Association of State Highway and Transportation Officials (AASHTO), and California Department of Transportation (Caltrans) design criteria and standards.

1.2 Existing Bridge

The County Road 66B Bridge over Colusa Drain was built in 1940. It is approximately 54 feet (ft) long and 20 ft wide and has a 10-degree skew from the Colusa Drain. The structure consists of a three-span timber structure supported on concrete piles and concrete abutments. It currently has one lane for travelling in both directions.

1.3 Proposed Bridge

The Project proposes to replace the existing bridge with a new structure (see Figure 4 for the bridge general plan). Bridge replacement work includes lengthening of the bridge deck to improve channel hydraulics and reconstruction of the adjacent storm drain headwalls. The new bridge will have two lanes with each lane going in opposite directions. The proposed bridge has a minimum bridge width (inside rail to inside rail) of 32 ft and a bridge length of 60 feet. The design includes two 12-ft-wide travel lanes and a 4-ft-wide shoulder on both sides. The roadway will be crowned at the center with a 2% cross slope on both sides of the road. The precast prestressed concrete voided slab deck has a thickness of 2.25 feet.

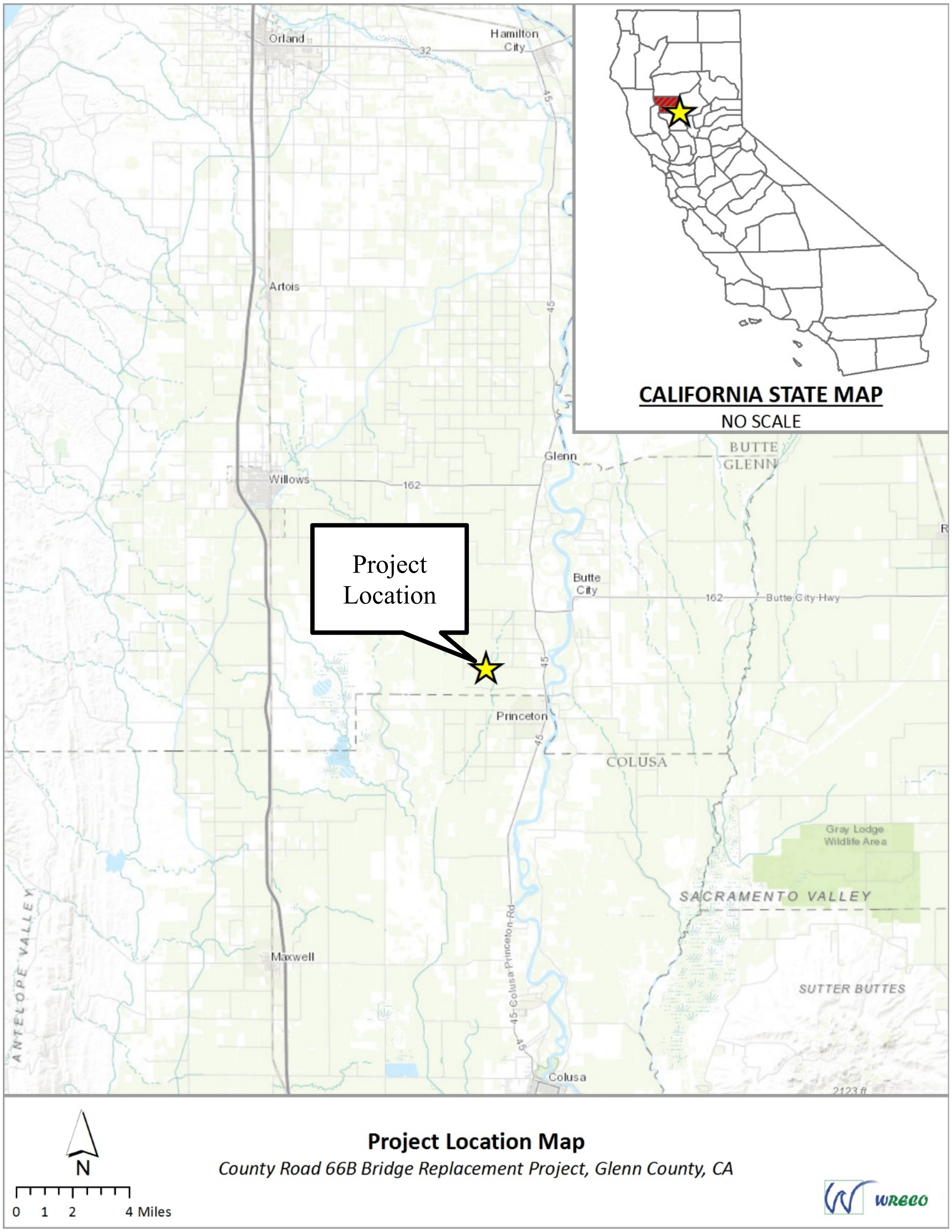

Figure 1. Project Location Map

Source: Environmental Systems Research Institute (ESRI)

Figure 2. Project Vicinity Map

Source: ESRI

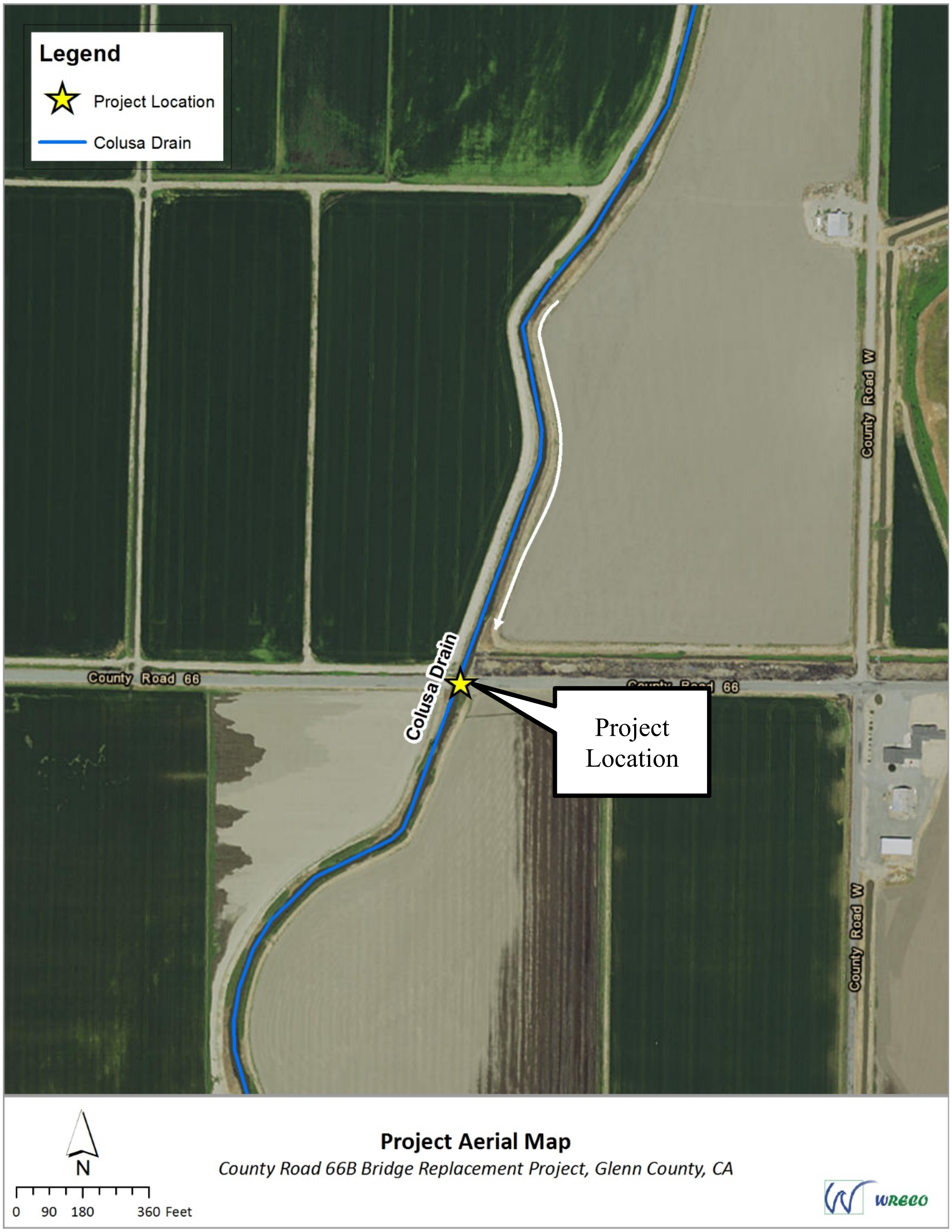

Figure 3. Project Aerial Map

Source: ESRI

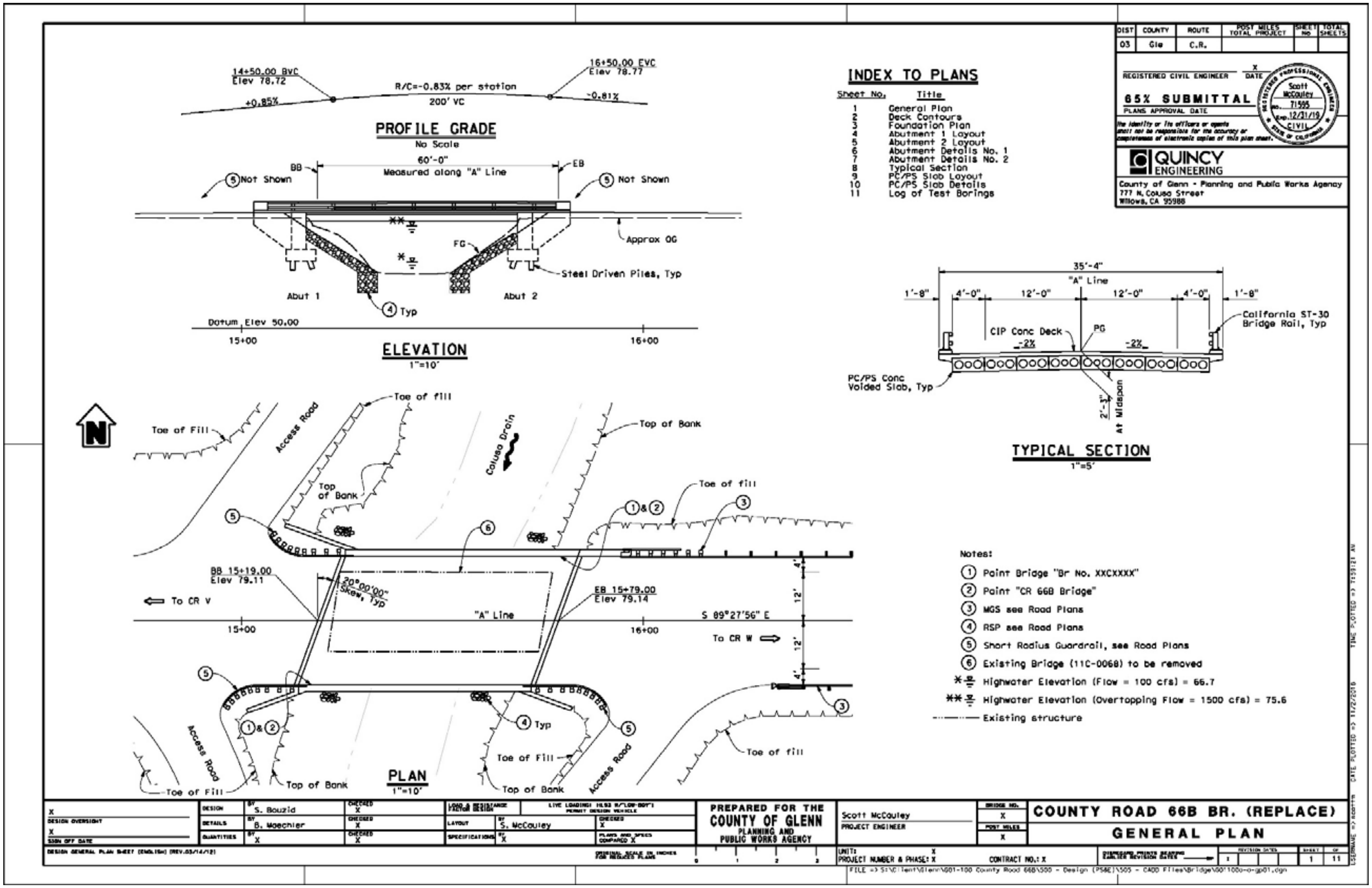

Figure 4. General Plan

Source: Quincy Engineering, Inc.

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1.4 Purpose

The purpose of this Bridge Design Hydraulic Study is to document the flow characteristics for existing and proposed conditions. This report also provides the calculated scour potential, recommendations on the need for scour countermeasures for the proposed bridge, and all of the detailed hydraulic model outputs.

1.5 Key Tasks

Key tasks performed in this study included: 1) coordinate with the Glenn County Irrigation District, Provident Irrigation District, and Princeton-Codora-Glenn Irrigation District to confirm the most recent design flows, 2) a hydraulic analysis to determine design water surface elevations (WSEs) and flow velocities for the existing and proposed bridges over Colusa Drain, 3) bridge scour analyses to estimate potential scour depths for the proposed condition, and 4) scour countermeasure analyses and recommendations for the proposed condition.

1.6 Design Standards

1.6.1 Freeboard Design Standards

The Colusa Drain is owned, operated, and maintained by three irrigation districts: the Provident Irrigation District (PID), Glenn-Codora-Princeton Irrigation District, and Glenn County Irrigation District. According to PID's standards, the proposed bridge soffit elevation must be equal to or higher than the existing bridge soffit elevation.

1.6.2 Scour Design Criteria

The evaluation of potential scour at the proposed bridge followed the criteria described in the FHWA's *Hydraulic Engineering Circular No. 18 (HEC-18)*, "Evaluating Scour at Bridges" (Fifth Edition). The evaluation of potential scour is typically based on hydraulic characteristics of the 100-year design discharge. For this Project, the scour analysis was based on the hydraulic characteristics of an estimated overtopping flow. The total scour was estimated based upon the cumulative effects of the long-term bed elevation change, general (contraction) scour, and local scour. The life expectancy of the bridge was considered in determining the long-term bed elevation change of the waterway; it was based on an assumed 75-year design life for a new replacement bridge.

1.6.3 Foundation Criteria

Per the *California Amendments to the* AASHTO LRFD *Bridge Design Specifications* (Caltrans 2014), foundations should be designed to withstand the conditions of scour. Caltrans' *Memo to Designers 16-1* (2017) provides additional guidance on foundation placement:

> The top of a spread footing must be placed at or below the anticipated total scour (Degradation + Contraction + Local) elevation (*LRFD 2.6.4.4.2 and LRFD-BDS-CA Figure C2.6.4.4.2-1*) unless founded on competent, scour-resistant bedrock.

The top of a pile cap footing must be placed at or below the estimated degradation plus contraction scour depth (*LRFD 2.6.4.4.2 and LRFD-BDS-CA Figure C2.6.4.4.2-2*). The bottom of a pile cap footing should be placed at or below the anticipated Total Scour elevation.

1.6.4 Rock Slope Protection Design Criteria

Two procedures for determining rock slope protection (RSP) design were considered for the proposed structure: the FHWA's *Hydraulic Engineering Circular No. 23* (HEC-23), "Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance" (Third Edition) (2009), and Caltrans HDM (2018). The final selection considers both of these procedures and is based on engineering judgment. The FHWA "Hydraulic Considerations for Shallow Abutment Footings" Technical Brief (2018) describes the extents and dimensions for the placement of the RSP, and supersedes the related information in HEC-23.

1.7 Vertical Datum

The Project references the North American Vertical Datum of 1988 (NAVD 88).

2 GEOGRAPHIC SETTING

2.1 Geographic Location

The Project is located 2 mi west of California State Route 45 at coordinates 39˚25'42.7" North and 122˚03'00" West between County Roads W and Vv.

2.2 Watershed Description

Colusa Drain is between the Sacramento River in the east and Willow Creek in the west, and receives water upstream from the Glenn Colusa Canal. It is a controlled flow irrigation canal that fluctuates more with farming demands than with weather demands. It joins Willow Creek downstream inside Colusa County. The general flow direction in the vicinity of the Project site is from north to south.

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3 HYDROLOGIC ANALYSIS

3.1 Design Flow for Hydraulic Analysis

The Project is located within the the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map (FIRM) number 06021C0850D panel 850 of 900 (see Appendix A). The Project site is within the Flood Hazard Zone A, which is subject to inundation of the 1% annual chance flood.

The maximum irrigation design flow (MIDF) rate, provided by the PID, for Colusa Drain is 100 cfs (Mike Niehus, Provident Irrigation District, Personal communication, October 27, 2016; see Appendix B). In addition to the MIDF rate, an overtopping flow of 1,520 cfs was also evaluated based on the capacity of the channel. The overtopping flow was estimated based on observations from PID, which indicated that flow overtops the banks upstream of the bridge.

3.2 Hydrologic Stability

The changes to the land use within the three irrigation districts at the Project location in Glenn County are not anticipated within the lifespan of the proposed bridge. The MIDF used for the design of the proposed bridge is consistent with the future design flow for the Colusa Drain at the Project location.

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4 HYDRAULIC ANALYSIS

The following sections discuss the development of the hydraulic models and summarize the results for the existing and proposed conditions. The water surface profile plots, hydraulic summary tables, and channel cross sections are included in Appendix C for the existing bridge and Appendix D for the proposed bridge.

4.1 Design Tools

The hydraulic analyses were performed for the existing and proposed conditions using the USACE Hydrologic Engineering Center's River Analysis System (HEC-RAS) modeling software, Version 5.0.1.

4.2 Cross Section Data

The cross-section channel geometry for the hydraulic model was developed using survey data provided by Quincy Engineering, Inc. The survey references the North American Datum of 1983 (NAD83) horizontal datum and the NAVD 88 vertical datum. The six cross-sections extend approximately 190 ft upstream and 310 ft downstream of the Project site along the Colusa Drain (see Figure 5, which shows the locations of the cross-sections). The cross-section naming convention is by river station (RS) with the cross-section number increasing in RS going upstream.

4.3 Model Boundary Condition

According to survey data, the downstream longitudinal slope is 0.00083 ft/ft, which was used as the downstream control for the hydraulic model.

4.4 Manning's Roughness Coefficients

Manning's roughness coefficients were used in the hydraulic model to estimate energy losses in the flow due to friction. A roughness coefficient of 0.035 was used to describe the channel, and a roughness coefficient of 0.045 was used to describe the overbank areas. The channel in the vicinity of County Road 66B is shown in Photo 1, which was taken on September 22, 2016 when the Project Team visited the Project site.

4.5 Expansion and Contraction Coefficients

Expansion and contraction coefficients were used in the hydraulic model to represent energy losses in the channel. An expansion coefficient of 0.3 and a contraction coefficient of 0.1 were used to represent the channel. These values represent a channel with gradual transitions between cross-sections. The expansion and contraction coefficients used in the vicinity of the bridge were 0.5 and 0.3, respectively. These values represent the flow interference caused by the bridge structure.

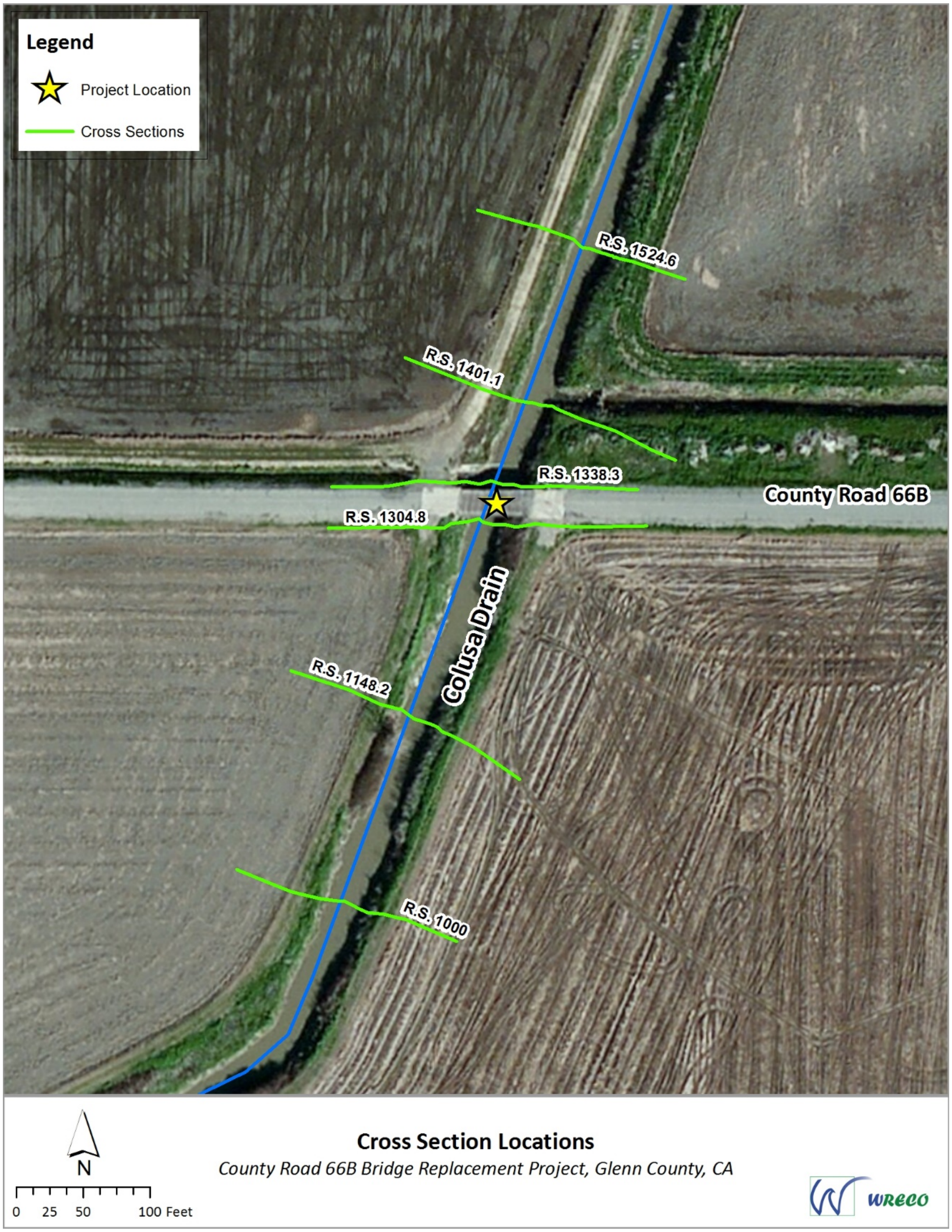

Figure 5: Cross Section Locations

Source: ESRI

Photo 1. Colusa Drain in the Vicinity of County Road 66B

4.6 Modeled Hydraulic Structures

The geometry of the existing bridge in the hydraulic model was based on information from the Caltrans BIR and survey data provided by Quincy Engineering, Inc. The existing bridge has an opening of 24 ft (abutment face to abutment face). The deck and soffit elevations are 77.8 and 76.4 ft, respectively.

The geometry of the proposed bridge in the hydraulic model was based on the general plan provided by Quincy Engineering in 2018. The replacement bridge will have an opening of 52.6 ft (abutment face to abutment face). The minimum bridge soffit elevation will be 76.5 feet.

4.7 Water Surface Elevations

The WSEs for the Colusa Drain at the Project location with the MIDF and overtopping flow for both the existing and proposed conditions are summarized in Table 1 and Table 2, respectively. The water surface profiles along the studied stream reach are presented in Figure 6 for the MIDF and Figure 7 for the overtopping flow. The cross-sections at the upstream sides of the bridges are shown in Figure 8 for the existing condition and Figure 9 for the proposed condition. The HEC-RAS calculations for the existing bridge can be found in Appendix C, and the calculations for the proposed bridge can be found in Appendix D.

Based on the HEC-RAS modeling, the proposed bridge would result in decreases in WSEs. The 100-year design flow at the Project site is governed by the spill flows from the Sacramento River and other streams that flow adjacent to Colusa Drain, and the actual WSEs are likely to be higher than the WSEs estimated in the hydraulic analysis. However, considering the flow is shallow in the flat valley floor area, the WSEs are unlikely to be significantly higher. In addition, the volume of flow carried by Colusa Drain is very small compared to the flow carried by the 100-year floodplain.

Table 1. Summary of MIDF Water Surface Elevations

River Station	Location/Distance from Existing Bridge Centerline	Water Surface Elevation (ft NAVD 88)	
		Existing	Proposed
1524.6	190 feet upstream of existing bridge	66.9	66.9
1401.1	67 feet upstream of existing bridge	66.8	66.7
1350.3	16 feet upstream of existing bridge	66.8	66.7
1338.3	4 feet upstream of existing bridge	66.8	--
1321 BR U	Upstream face of existing/proposed bridge	66.7	66.7
1321 BR D	Downstream face of existing/proposed bridge	66.7	66.6
1304.8	8 feet downstream of existing bridge	66.7	--
1293.3	19 feet downstream of existing bridge	66.7	66.6
1148.2	160 feet downstream of existing bridge	66.5	66.4
1000	310 feet downstream of existing bridge	66.3	66.2

Note: Elevations are rounded to the nearest 0.1 ft.

Table 2. Summary of Overtopping Flow Water Surface Elevations

River Station	Location/Distance from Existing Bridge Centerline	Water Surface Elevation (ft NAVD 88)	
		Existing	Proposed
1524.6	190 feet upstream of existing bridge	75.9	75.7
1401.1	67 feet upstream of existing bridge	75.8	75.6
1350.3	16 feet upstream of existing bridge	75.6	75.5
1338.3	4 feet upstream of existing bridge	75.7	--
1321 BR U	Upstream face of existing/proposed bridge	75.7	75.5
1321 BR D	Downstream face of existing/proposed bridge	75.5	75.5
1304.8	8 feet downstream of existing bridge	75.5	--
1293.3	19 feet downstream of existing bridge	75.4	75.5
1148.2	160 feet downstream of existing bridge	75.2	75.2
1000	310 feet downstream of existing bridge	75.1	75.1

Note: Elevations are rounded to the nearest 0.1 ft.

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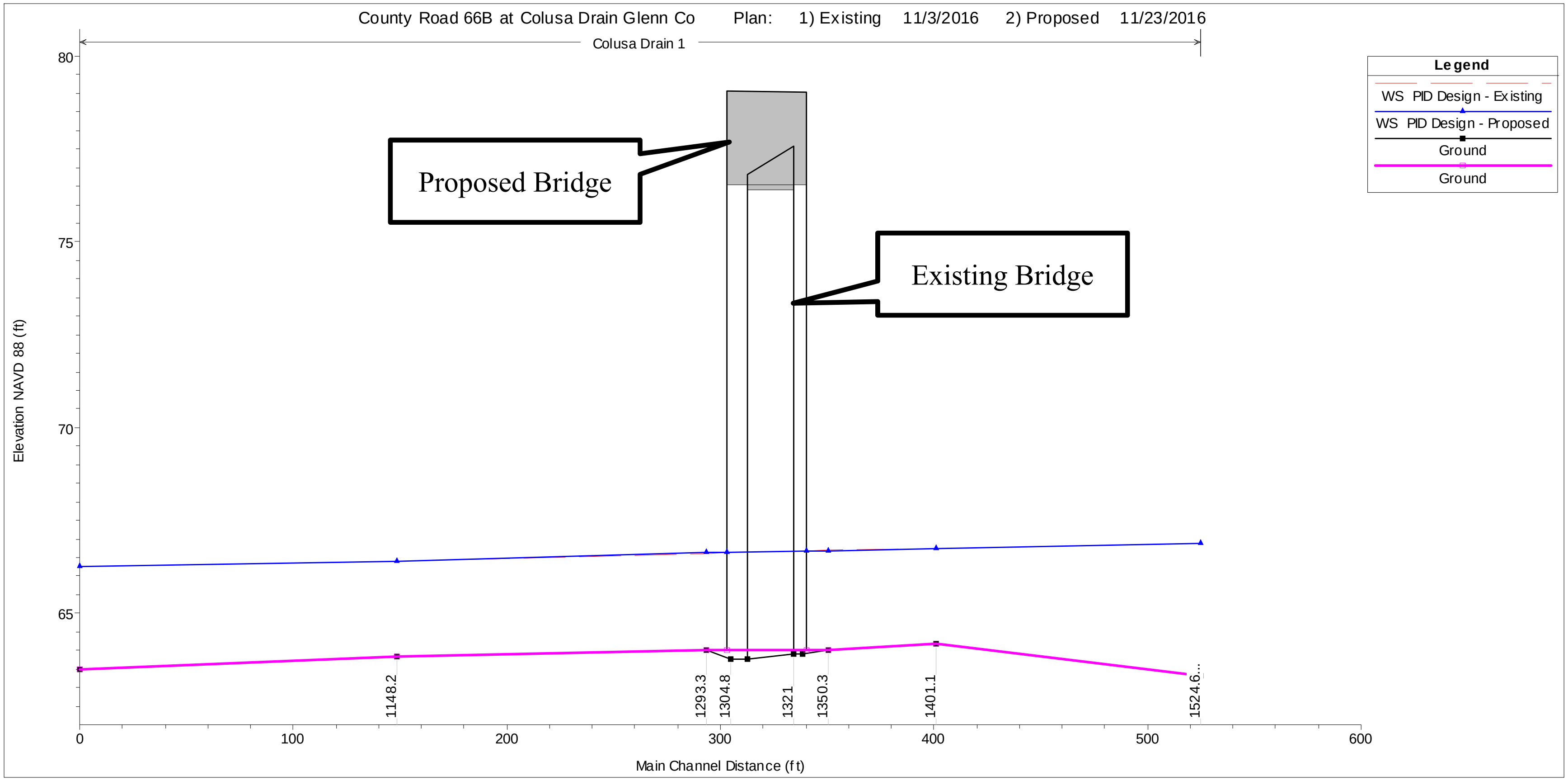

Figure 6. Water Surface Profile Comparison with MIDF

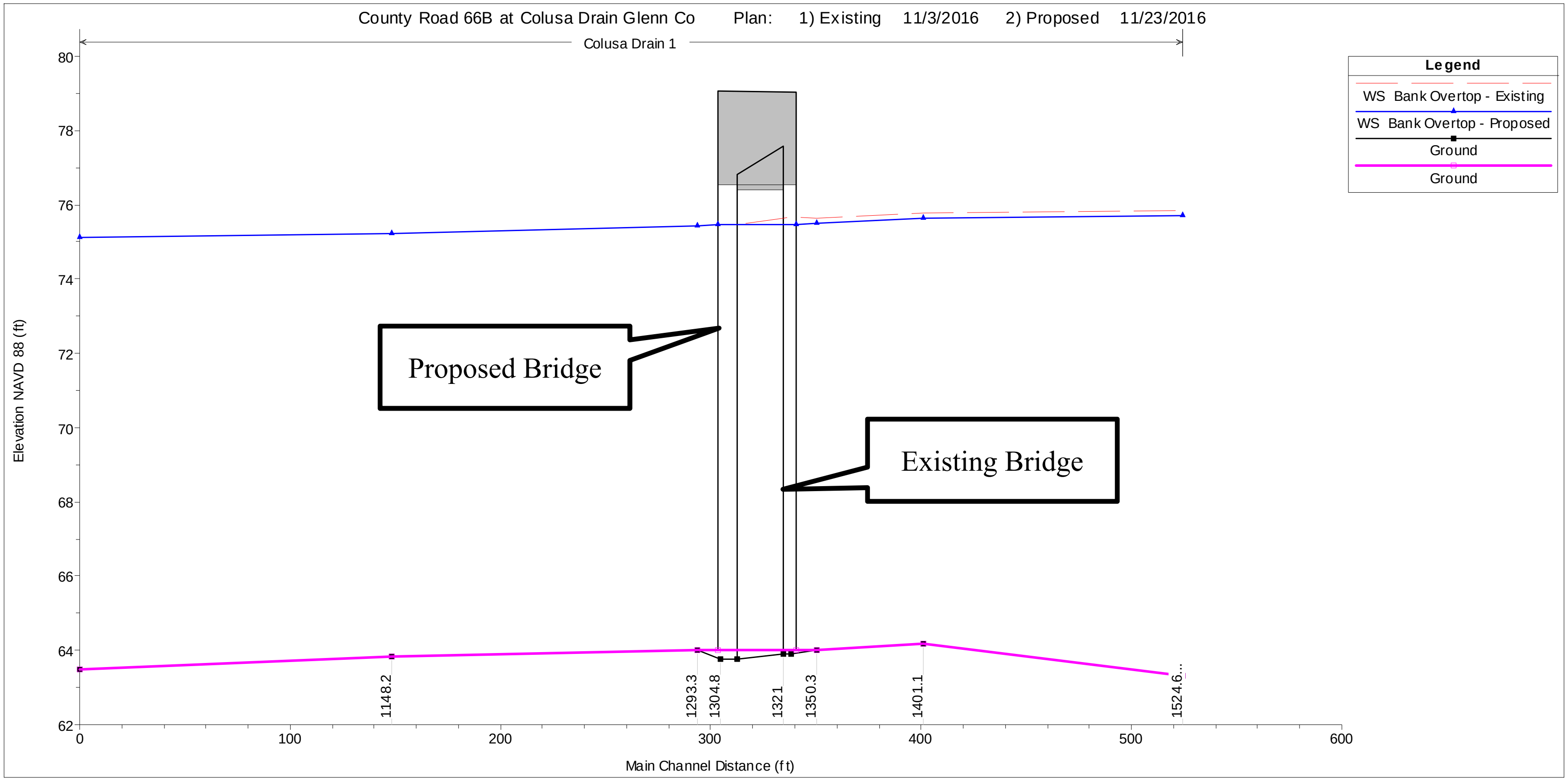

Figure 7. Water Surface Profile Comparison with Overtopping Flow

Figure 8. Water Surface Elevation at the Upstream Face of the Existing Bridge (Looking Downstream)

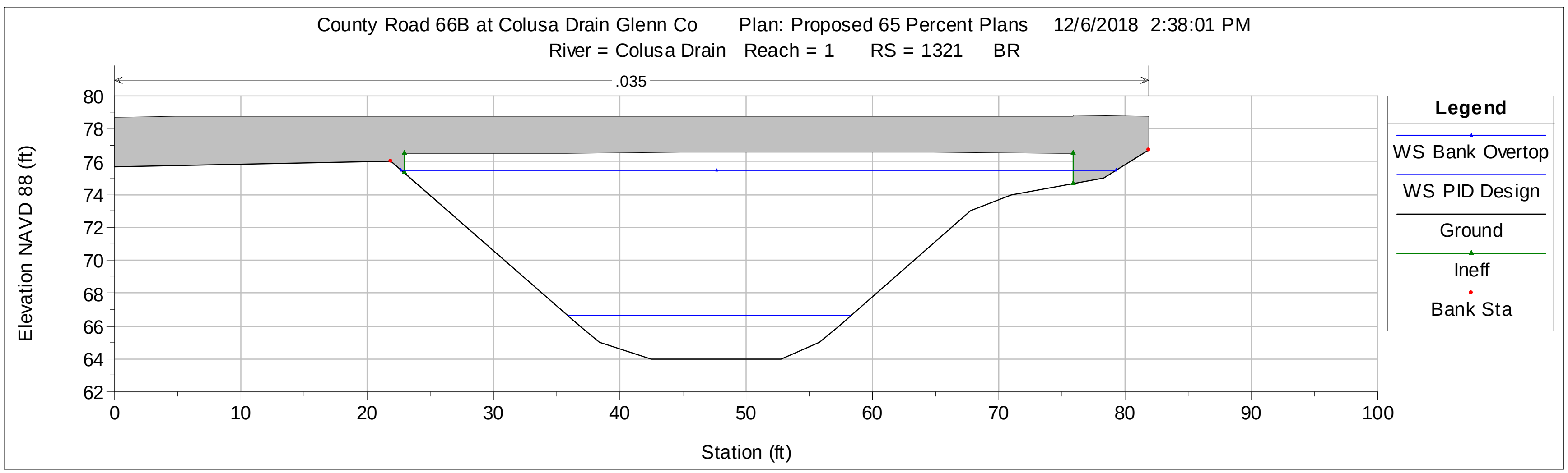

Figure 9. Water Surface Elevation at the Upstream Face of the Proposed Bridge (Looking Downstream)

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4.8 Freeboard

The freeboard requirements applicable to the Project are discussed in Section 1.6.1. Because flows inside the Colusa Drain are not governed by the duration and intensity of storm events, typical design standards from FHWA and Caltrans were not used to evaluate the freeboard criteria of the proposed bridge with the proposed conditions; only the criteria from the PID was used. The minimum soffit elevations and available freeboard for the bridges are presented in Table 3 for the MIDF, and Table 4 for the overtopping flow. The proposed bridge would have sufficient freeboard to meet the PID's design criterion.

Table 3. Available Freeboard at the Project Bridges for the MIDF

Project Condition	Soffit Elevation (ft NAVD 88)	Water Surface Elevation (ft NAVD 88)	Available Freeboard (ft)
Existing	76.4	66.8	9.7
Proposed	76.5	66.7	9.8

Note: Elevations are rounded to the nearest 0.1 ft.

Table 4. Available Freeboard at the Project Bridges for the Overtopping Flow

Project Condition	Soffit Elevation (ft NAVD 88)	Water Surface Elevation (ft NAVD 88)	Available Freeboard (ft)
Existing	76.4	75.7	0.7
Proposed	76.5	75.5	1.0

Note: Elevations are rounded to the nearest 0.1 ft.

4.9 Flow Velocities

The average channel velocities in the Project vicinity for the existing and proposed conditions are summarized in Table 5 for the MIDF, and Table 6 for the overtopping flow. The proposed bridge would result in slight increases in average channel velocities at the location upstream of the bridge. RSP is proposed at the abutments to decrease the potential for erosion due to the increase in channel velocity at the bridge.

Table 5. Comparison of the Average Channel Velocities with MIDF

River Station	Location/Distance from Existing Bridge Centerline	Average Channel Velocity (ft/s)	
		Existing Bridge	Proposed Bridge
1524.6	190 feet upstream of existing bridge	1.6	1.6
1401.1	67 feet upstream of existing bridge	2.2	2.2
1350.3	16 feet upstream of existing bridge	2.0	2.1
1338.3	4 feet upstream of existing bridge	1.9	--
1321 BR U	Upstream face of existing/proposed bridge	2.1	2.1
1321 BR D	Downstream face of existing/proposed bridge	2.1	2.1
1304.8	8 feet downstream of existing bridge	2.0	--
1293.3	19 feet downstream of existing bridge	2.1	2.1
1148.2	160 feet downstream of existing bridge	2.5	2.5
1000	310 feet downstream of existing bridge	1.9	1.9

Note: Average channel velocities are rounded to the nearest 0.1 ft.

Table 6. Comparison of the Average Channel Velocities with Overtopping Flow

River Station	Location/Distance from Existing Bridge Centerline	Average Channel Velocity (ft/s)	
		Existing Bridge	Proposed Bridge
1524.6	190 feet upstream of existing bridge	3.6	3.7
1401.1	67 feet upstream of existing bridge	3.2	3.4
1350.3	16 feet upstream of existing bridge	4.0	4.1
1338.3	4 feet upstream of existing bridge	3.3	--
1321 BR U	Upstream face of existing/proposed bridge	3.6	4.1
1321 BR D	Downstream face of existing/proposed bridge	4.5	4.1
1304.8	8 feet downstream of existing bridge	4.1	--
1293.3	19 feet downstream of existing bridge	4.3	4.1
1148.2	160 feet downstream of existing bridge	4.4	4.4
1000	310 feet downstream of existing bridge	3.8	3.8

Note: Average channel velocities are rounded to the nearest 0.1 ft.

5 SCOUR ANALYSIS

WRECO evaluated bridge scour per the criteria described in "Evaluating Scour at Bridges" (FHWA 2012). Usually, the minimum design criterion for bridge scour is the 100-year design storm. However, the Project site is located within Colusa Drain, and the channel flows are not governed by the duration and intensity of storm events. Therefore, the overtopping flow is used as the design criterion for bridge scour. WRECO evaluated the scour potential and scour countermeasure analysis using the results of HEC-RAS model for the proposed bridge. The following sub-sections summarize the results of the analysis.

5.1 Caltrans Bridge Inspection Reports

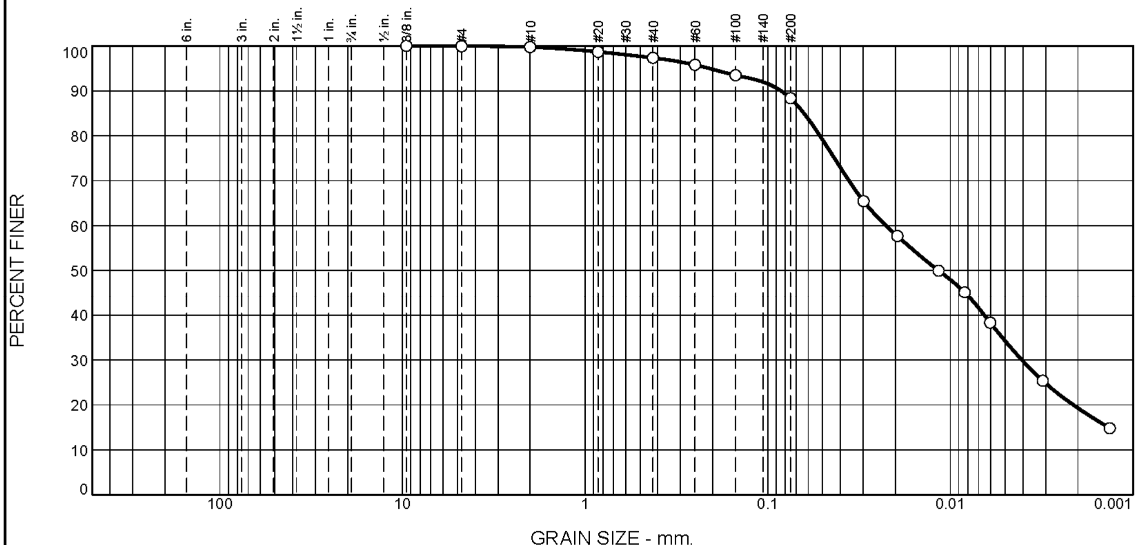
The Caltrans BIRs for the existing bridge were reviewed in support of the scour analysis. Based on the February 4, 2009 BIR, the bridge is determined not to be scour critical. Other details from the bridge inspection can be found in the BIR.

5.2 Existing Channel Bed

The contraction and local scour calculations were based on the flow characteristics from the hydraulic model for the overtopping flow and the grain size distribution from the sieve analysis. Based on the sieve analysis performed by Crawford and Associates Inc. (2016), the median grain size diameter (D_{50}) of 0.0116 mm was used for the scour analysis. The grain size distribution plot is shown in Figure 10.

Soils with fine grains that pass the #200 sieve are generally considered to be cohesive soils. While there is no clear division between cohesive and cohesionless soils, soils are divided into these two groups for the purpose of analyzing scour. In general, the threshold for cohesive bed materials is a D_{50} grain size that is 0.2 mm or less. Based on the median grain size, the potential scour for the Project was analyzed using the cohesive equations.

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.1	0.2	2.4	9.0	54.1	34.2

TEST RESULTS

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
.375	100.0		
#4	99.9		
#10	99.7		
#20	98.7		
#40	97.3		
#60	95.8		
#100	93.5		
#200	88.3		
0.0299 mm.	65.4		
0.0195 mm.	57.7		
0.0116 mm.	50.0		
0.0083 mm.	45.1		
0.0060 mm.	38.3		
0.0031 mm.	25.4		
0.0013 mm.	14.8		

* (no specification provided)

Material Description

Olive Elastic SILT

Atterberg Limits (ASTM D 4318)

PL= LL= PI=

Classification

USCS (D 2487)= AASHTO (M 145)=

Coefficients

D_{90}= 0.0844 D_{85}= 0.0632 D_{60}= 0.0225
D_{50}= 0.0116 D_{30}= 0.0041 D_{15}= 0.0014
D_{10}= C_u= C_c=

Remarks

Date Received: **Date Tested:** 10/3-5/16
Tested By: MR
Checked By: MR
Title: Lab Manager

Sample Number: Channel Bed **Date Sampled:**

GEOCON CONSULTANTS, INC.

Client: Crawford and Associates
Project: Crawford 16-322.1
Project No: S9763-05-80

Figure 10. Grain Size Distribution

Source: Crawford and Associates Inc.

5.3 Long-Term Bed Elevation Change

Aggradation at the bridge site is a result of the deposition of material eroded from the channel. Degradation at the bridge site is a result of scouring of the channel due to sediment deficit. Only degradation is accounted for in scour calculations. The long-term bed elevation changes (long-term bed degradation) are typically based on historical channel data at the bridge site.

The historical channel data at the bridge site was reviewed, and the stream measurements that were recorded in the Caltrans BIRs were compares to assess the long-term bed elevation changes. Historical stream measurements were taken at the bridge in previous BIRs from 1993 to 2013 (see Figure 11). Based on the stream measurements included in the BIRs, the thalweg elevation at the main channel exhibits an overall trend of degradation from 1993 to 2013. However, if the 2016 survey data provided by Quincy Engineer were incorporated, the thalweg channel elevation exhibits an overall trend of aggradation from 2009 to 2016. Based on the dynamic nature of the channel bed fluctuation, the long-term bed elevation change is considered to be insignificant.

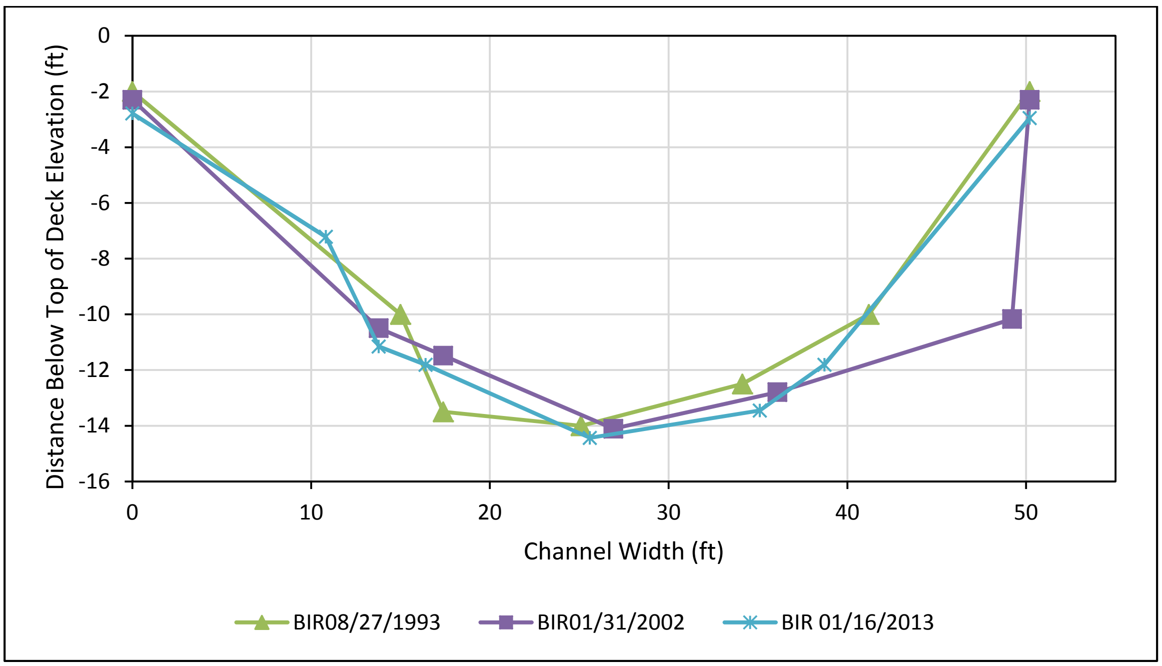


Figure 11. Cross Section Comparison

Source: Caltrans BIR

5.4 Contraction Scour

Contraction scour occurs when the flow area of a stream is reduced by: 1) the natural contraction of the stream channel; 2) a bridge structure; or 3) the overbank flow forced back to the channel by roadway embankments at the roadway approach to a bridge. From the continuity equation, a decrease in flow area results in an increase in average velocity and bed shear stress through the contraction. Hence, there is an increase in erosive forces in the contraction section, and more bed material is removed from the contracted reach than is transported into the reach. This increase in transport of bed material from the reach lowers the natural bed elevation. As the bed elevation is lowered, the flow area increases. Thus, the velocity and shear stress decrease until relative equilibrium is reached; i.e., the quantity of bed material that is transported into the reach is equal to that removed from the reach, or the bed shear stress is decreased to a value such that no sediment is transported out of the reach. Contraction scour, in a natural channel or at a bridge crossing, involves removal of material from the bed across most of or all of the channel width (FHWA 2012).

Ultimate (contraction) scour depth is estimated for channel bed materials that are considered cohesive. In general, the threshold for cohesive bed materials is a D_{50} grain size that is 0.2 mm or less.

The equation for estimating ultimate scour, as presented in HEC-18, is as follows:

$$y_{s-ult} = 0.94 y_1 * \left(\frac{1.83 V_2}{\sqrt{g y_1}} - \frac{K_u \sqrt{\frac{\tau_c}{\rho}}}{g n y_1^{\frac{1}{3}}} \right)$$

Where:

y_{s-ult} = scour depth for cohesive soils, ft

y_1 = average depth in the upstream main channel, ft

V_2 = average flow velocity in the contracted section, ft/s

g = gravitational acceleration, 32.2 ft/s^2

K_u = 1.486 for U.S. Customary units, and 1.0 for S.I. units

τ_c = critical shear stress, lbs/ft^2

ρ = density of sediment, slugs/ft^3

n = Manning's roughness coefficient, unitless

The contraction scour at the proposed bridge site was estimated to be 3.1 ft.

5.5 Abutment Scour

Abutment scour occurs when the bridge abutments block approaching flow. Abutment scour is commonly evaluated using either the Froehlich or HIRE live-bed scour equations. The HIRE equation is applicable when the ratio of the projected abutment length (the L parameter) to the flow depth (the y1 parameter) is greater than 25.

Abutment 1 uses the Froehlich equation, while Abutment 2 uses the HIRE equation.

The Froehlich equation is given below:

$$y_s = y_a \left[2.27 K_1 K_2 \left(\frac{L'}{y_a} \right)^{0.43} Fr^{0.61} + 1 \right]$$

Where:

y_s = scour depth, ft

K_1 = abutment shape coefficient (from Table 7.1 of HEC-18)

K_2 = coefficient for skew angle of abutment to flow

L' = length of active flow obstructed by the embankment, ft

Fr = Froude number, based on the velocity and depth adjacent to and upstream of the abutment

y_a = average depth of flow at the abutment = A_e/L , ft

- L = length of embankment projected normal to the flow, ft
- A_e = flow area of the approach cross section obstructed by the embankment, sq ft

The HIRE live-bed equation is given below:

$$y_s = 4y_1 F_r^{0.33} k_1 k_2 / 0.55$$

Where:

y_s = scour depth, ft

y_1 = flow depth at the abutment on the overbank or in the main channel, ft

Fr = Froude Number directly upstream of the pier

K_1 = abutment shape coefficient; 1 for vertical wall abutments

K_2 = coefficient for angle of embankment shape

The calculated local abutment scour depths are presented in Table 7.

Table 7. Local Abutment Scour Depths

Location	Local Abutment Scour Depth (feet)
Abutment 1 (West)	2.5
Abutment 2 (East)	1.3

5.6 Total Scour and Scour Countermeasures

Per the *California Amendments to the AASHTO LRFD Bridge Design Specifications* (Caltrans 2014), foundations should be designed to withstand the conditions of scour. The total estimated scour depths reflect the sum of the long-term bed elevation change, contraction scour, and local scour, assuming the bridge is supported on soil or degradable rock.

The total scour depth will depend on the local scour, contraction scour, and the long-term bed scour depth. Because the long-term scour depth is zero, only the local and contraction scours will be considered. The scour depths are summarized in Table 8. The scour depths were based on the cohesive soil equation. The detailed calculations are included in Appendix E. Because scour countermeasures will be provided at the abutments, the scour elevations reference the finished grade (FG) elevations at each respective abutment.

Table 8. Scour Depth and Elevation Summary Table

Location	Scour Depth (feet)				Elevation (ft NAVD 88)	
	Local	Contraction	Long-Term	Total	Reference FG Elevation	Scour Elevation
Abutment 1 (West)	2.5	3.1	0	5.6	74.6	69.0
Abutment 2 (East)	1.3	3.1	0	4.4	75.2	70.8

According to a Caltrans memorandum dated October 23, 2015, *Scour Data Table on Foundation Plan*, a scour data table on the Foundation Plan for all contract plans should also present a long-term scour elevation based upon the long-term bed degradation and contraction scour depths, and a short-term depth based upon the local scour depth. The scour data table (see Table 9) is the format that Caltrans requires on the foundation plans.

Table 9. Scour Data Table

Support No.	Long-Term (Degradation and Contraction) Scour Elevation (ft NAVD 88)	Short-Term (Local) Scour Depth (ft)
Abutment 1	71.5	2.5
Abutment 2	72.1	1.3

As stated in Section 1.6.3, the top of a spread footing must be placed at or below the total scour elevation. The top of a pile cap must be placed at or below the sum of the long-term scour elevation, and the bottom of a pile cap should be placed at or below the total scour elevation. The total scour elevations are presented in Table 8.

6 SCOUR COUNTERMEASURES

In consideration of the erosion and scour potential for the proposed bridge, placing RSP at the proposed bridge abutments along the embankment fill slopes will be recommended. RSP generally consists of rocks on channel and structure boundaries to limit the effects of erosion. It is the most common type of scour countermeasure due to its general availability, ease of installation, and relatively low cost. The RSP calculations are included in Appendix F.

6.1 RSP Median Particle Size Determination

The following sections present the calculations to evaluate the size of RSP that would be required along the channel bank slopes at the Project location to protect the channel banks from potential erosion. The primary design concern for RSP is to determine the median particle size such that the material will not be displaced during the peak design flows. Two design guidelines/methodologies were used to determine the minimum size of material required: FHWA HEC-23 and Caltrans' HDM.

6.1.1 FHWA HEC-23

The median stone diameter (D_{50}) of the RSP for the bridge abutments was calculated using the equations from HEC-23, Design Guideline 14. The following equations were used to determine the median stone diameter required for the proposed riprap erosion-control system to protect the channel slope under the bridge:

For Froude Numbers ≤ 0.80 (HEC-23, equation 14.1):

$$\frac{D_{50}}{y} = \frac{K}{S_s - 1}\left[\frac{V^2}{gy}\right]$$

For Froude Numbers > 0.80 (HEC-23, equation 14.2):

$$\frac{D_{50}}{y} = \frac{K}{S_s - 1}\left[\frac{V^2}{gy}\right]^{0.14}$$

Where:

D_{50} = median stone diameter (ft)
V = characteristic average velocity in the contracted section (ft/s)
S_s = specific gravity of rock riprap
g = gravitational acceleration (32.2 ft/s^2)
y = depth of flow in the contracted bridge opening (ft)
K = 0.89 for a spill-through abutment and 1.02 for a vertical wall abutment

The median stone diameter is a function of velocity and depth. The average channel flow velocities and flow depths from the hydraulic analysis were selected to calculate the median stone diameter of the RSP to protect the bridge abutments. The median stone diameter for the RSP was calculated immediately upstream, at the upstream face, at the downstream face, and immediately downstream of the proposed bridge. The largest of the four locations was selected as the minimum RSP class. The results from the RSP calculations and the scour countermeasure recommendations for the Project are presented in Section 6.2.

6.1.2 Caltrans Highway Design Manual

The following equations included in Caltrans' HDM Chapter 870, *Bank Protection – Erosion Control* were used to estimate the weight of the RSP required to protect the proposed bridge abutments:

$$D_{30} = y\left(S_f C_S C_V C_T\right)\left[\frac{V_{des}}{\sqrt{K_1\left(S_g - 1\right)gy}}\right]^{2.5}$$

$$D_{50} = 1.2 D_{30}$$

$$K_1 = \sqrt{1 - \left[\frac{\sin\left(\theta - 14^0\right)}{32^0}\right]^{1.6}}$$

Where:

D_{30} = particle size for which 30% is finer by weight (ft)
D_{50} = median particle size (ft)
y = local flow depth (ft)
S_f = safety factor (typically 1.1)
C_s = stability coefficient (0.3 for angular rock)
C_v = velocity distribution coefficient (1.0 for straight channel)
C_T = blanket thickness coefficient (1.0)
g = acceleration due to gravity (32.2 ft/sec^2)
V_{des} = characteristic velocity for design (ft/sec)
K_1 = side slope correction factor
θ = bank angle in degrees

The RSP diameter was calculated immediately upstream, at the upstream face, at the downstream face, and immediately downstream of the proposed bridge. The largest of the four locations was selected as the minimum RSP class. The results from the RSP calculations and the scour countermeasure recommendations for the Project are presented in Section 6.2.

6.2 RSP Results and Recommendations

The RSP class calculated using the equations provided in FHWA's HEC-23 and Caltrans' HDM is Class I. Detailed calculations are included in Appendix F. Class I RSP has an approximate median diameter of 0.5 ft, and an approximate median weight of 20 lbs., which is relatively light and has a high potential to be displaced over the lifespan of the proposed bridge.

Therefore, WRECO recommends Class IV RSP, which has an approximate median diameter of 15 inches and a median weight of 300 pounds. The larger RSP class would minimize the risk of RSP displacement. According to the HDM, the minimum thickness of the RSP layer needs to be 1.5 times the median particle diameter or the maximum diameter, whichever is greater. The minimum layer thickness for Class IV RSP is 2.5 ft. The placement method for Class IV RSP is Method B, which involves dumping the rock near its planned location, and working the rock to its final position with machinery. Class 8 RSP geotextile filter fabric should be placed on the bank as a separator material between the RSP and the channel bank.

The footprint of application of RSP is based on guidance from "Hydraulic Considerations for Shallow Abutment Footings" Technical Brief (FHWA 2018). The slope protection should be embedded a depth equal to the sum of the long-term degradation and contraction scour (3.1 ft). The slope protection should extend from the face of the abutment to the toe of slope, and wrap around the bridge abutments from the face of the abutment and behind it a distance of 25 ft. From the toe of slope, the RSP apron should extend horizontally towards the channel a distance equal to the depth of flow, or 7.1 ft. The extent, upstream and downstream of the bridge, is twice the flow depth, or 14.2 ft. The side slope of the RSP is 2:1 (horizontal to vertical), or flatter.

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7 REFERENCES

California Department of Transportation. (2016). *Bridge Inspection Report*. Bridge Number: 11C0068. Facility Carried: Road 66B. Location: 2 Mi W of SH 45. Date: 02/26/2016, 02/19/2015, 02/13/2014, 03/27/2013, 03/10/2011, 02/26/2009, 02/04/2009, 01/06/2004, 01/31/2002, 08/29/2000, 10/5/1995, 09/01/1993, 03/20/1992, 05/14/1991, 02/26/1985, 06/08/1983, and 04/04/1980.

California Department of Transportation (2014). *Preface to California Amendments.* California Amendments to the ASHTO LRFD Bridge Design Specifications (2012 Sixth Edition). <http://www.dot.ca.gov/hq/esc/techpubs/manual/bridgemanuals/ca-to-aashto-lrfd-bds/page/v6/preface.pdf>

California Department of Transportation. (2014). *California Amendments to AASHTO LRFD Bridge Design Specification*. Sixth Edition. <http://www.dot.ca.gov/hq/esc/techpubs/manual/bridgemanuals/ca-to-aashto-lrfd-bds/page/v6/section_2.pdf>

California Department of Transportation. (2011). *California Amendments to AASHTO LRFD Bridge Design Specification.* Fourth Edition. <http://www.dot.ca.gov/hq/esc/techpubs/manual/bridgemanuals/ca-to-aashto-lrfd-bds/page/sec_2_2011.pdf>

California Department of Transportation. (2000). *California Bank and Shore Rock Slope Protection Design.* Final Report No. FHWA-CA-TL-95-10. Caltrans Study No. F90TL03. Third Edition. October 2000.ESRI ArcGIS Online and data partners including USGS and 2007 National Geographic Society. *US topo maps*. <http://www.arcgis.com/home/item.html?id=99cd5fbd98934028802b4f797c4b1732> (Last accessed: August 27, 2012).

Crawford and Associates Inc. (2016). *Particle Size Distribution Report.* County Road 66B Bridge Replacement at Colusa Drain. Glenn County, California. Bridge No. 11C0068

ESRI ArcGIS Online and data partners including USGS and 2007 National Geographic Society. *US topo maps*. <http://www.arcgis.com/home/item.html?id=99cd5fbd98934028802b4f797c4b1732>

Federal Emergency Management Agency. (2015*). Federal Flood Risk Management Standards* <https://www.fema.gov/federal-flood-risk-management-standardffrms>

Federal Emergency Management Agency. (2010). *Flood Insurance Study* for Glenn County, California and Incorporated Areas. Flood Insurance Study Number 06021C0850D

Federal Emergency Management Agency. (2006). National Training and Education – Emergency Management Institute. "Chapter 13: Regulatory and Design Standards for Reducing Losses." *Floodplain Management – An Integrated Approach.*

Federal Highway Administration. (December 2018). "Hydraulic Considerations for Shallow Abutment Footings" Technical Brief. FHWA-HIF-19-007.

Federal Highway Administration. (2012). "Evaluating Scour at Bridges." *Hydraulic Engineering Circular No. 18.* Fifth Edition.

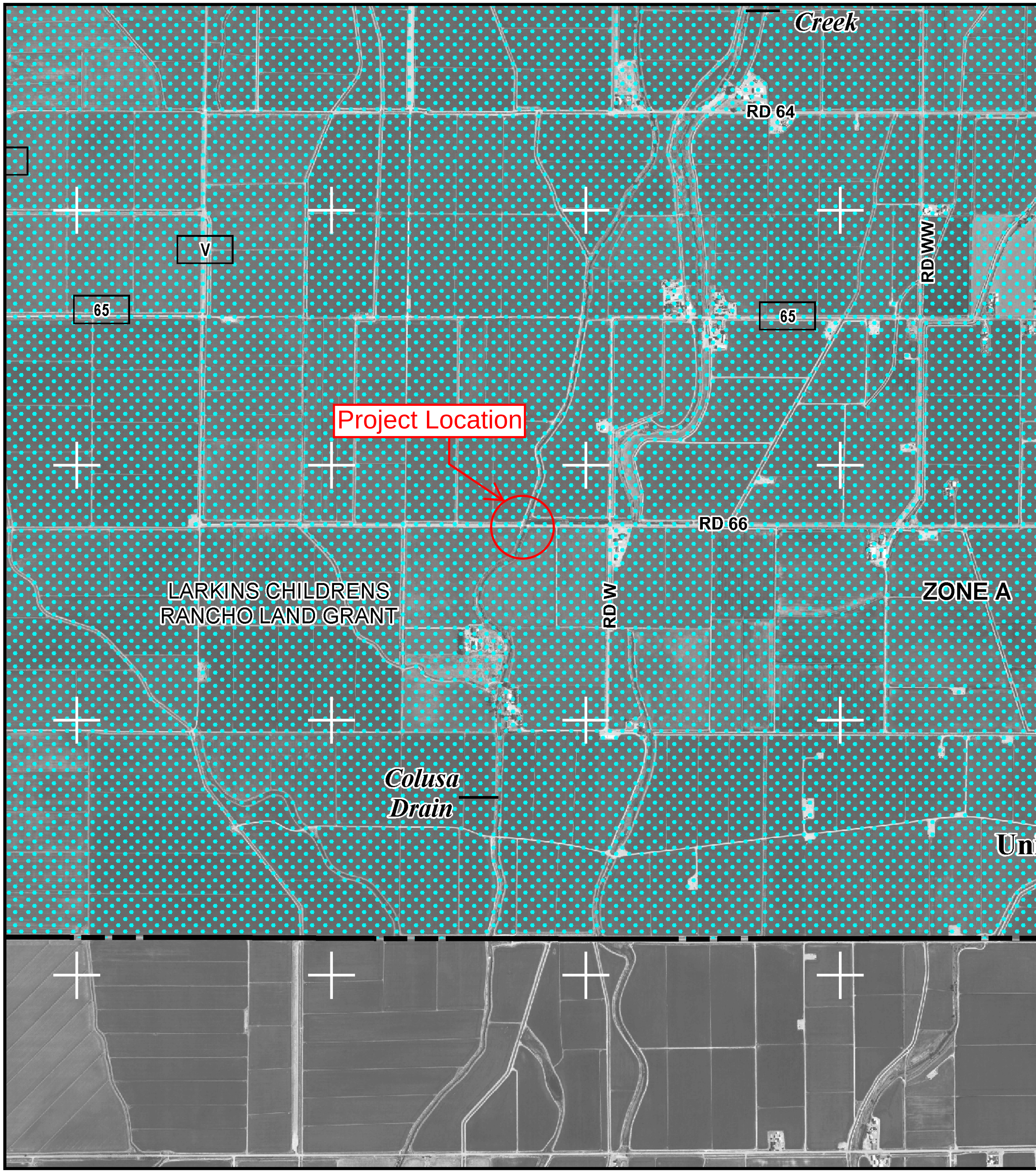
Federal Highway Administration. (2009). "Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance." *Hydraulic Engineering Circular No. 23.* Third Edition.

Federal Highway Administration. (1979). Floodplain Management and Protection. *Department of Transportation Order 5650.2.* <http://isddc.dot.gov/OLPFiles/DOT/007652.pdf>

United States Army Corps of Engineers - Hydrologic Engineering Center. (2016). River Analysis System. HEC-RAS. (Version 5.0.1) [Computer software]. April 2016. Available from: http://www.hec.usace.army.mil/software/hec-ras/hecras-download.html.

United States Geological Survey. (2001). *California: Seamless USGS Topographic Maps (CDROM, Version 2.6.8, 2001, Part Number: 113-100-004*). National Geographic Holdings, Inc.

Appendix A FEMA Flood Insurance Rate Map



MAP SCALE 1" = 2000'

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0850D

FIRM

FLOOD INSURANCE RATE MAP

GLENN COUNTY, CALIFORNIA

AND INCORPORATED AREAS

PANEL 850 OF 900

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
GLENN COUNTY	060057	0850	D

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

U.S. DEPARTMENT OF HOMELAND SECURITY

MAP NUMBER
06021C0850D

EFFECTIVE DATE
AUGUST 5, 2010

Federal Emergency Management Agency

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

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Appendix B Provident Irrigation District Coordination

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County Road 66B Bridge 11C-0068 Replacement
Record of Telephone Conversation

Date: October 27, 2016, 3:30pm **Job#:** G01-100

Where Held:

☒ By Telephone ☒ QEI Office ☐ Other Party's Office ☐ Other:

Initiated By:

☒ Quincy Engineering ☐ Other Party ☐ Other:

Participants:

Name	Company	Telephone #
Jim Foster	Quincy Engineering	916-368-9181
Scott McCauley	Quincy Engineering	916-368-9181
Mike Niehus	Provident Irrigation District	530-518-2320

SUBJECT: Coordination with Provident Irrigation District

Discussion Summary:

Jim and Scott initiated conversation with Mike to discuss his knowledge of the Colusa Drain, specifically as it relates to the bridge project. Mike shared the following information:

- To his knowledge, the bridge has never overtopped. The highest he has seen the flow is about half way up (the embankment) at the bridge location. The flow overtops the banks upstream of the bridge and floods the nearby fields. He has been with the District for 6 years.
- Jim then asked Mike to confirm that we wouldn't be affecting the flow of the canal if we match the soffit of the existing bridge with the new structure. Mike confirmed.
- Mike mentioned this bridge is on the border of the Provident Irrigation District and the Princeton Irrigation District, who pulls water downstream of the bridge. Mike said that new bridge will not affect them either.
- Mike is okay with placing rock slope protection (RSP) on the channel banks
- Mike mentioned that the lowest flow is in March-April, then it picks up
- Jim asked Mike if the irrigation district had any stream gauges and flow data available. Mike said they do not. He did mention that the flow 15 miles upstream is 100cfs and they pull 50cfs from the canal upstream of the bridge, and 100cfs is a reasonable estimate at our bridge site.

Next Steps / Action Items

No.	Who	What	Status
1	Quincy	Forward info to WRECO	
2	Quincy	Set profile to match existing soffit & RSP ok	

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Appendix C Hydraulic Analysis, Existing Condition

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Appendix C.1 HEC-RAS Existing Bridge with Design Flow of 100 cfs

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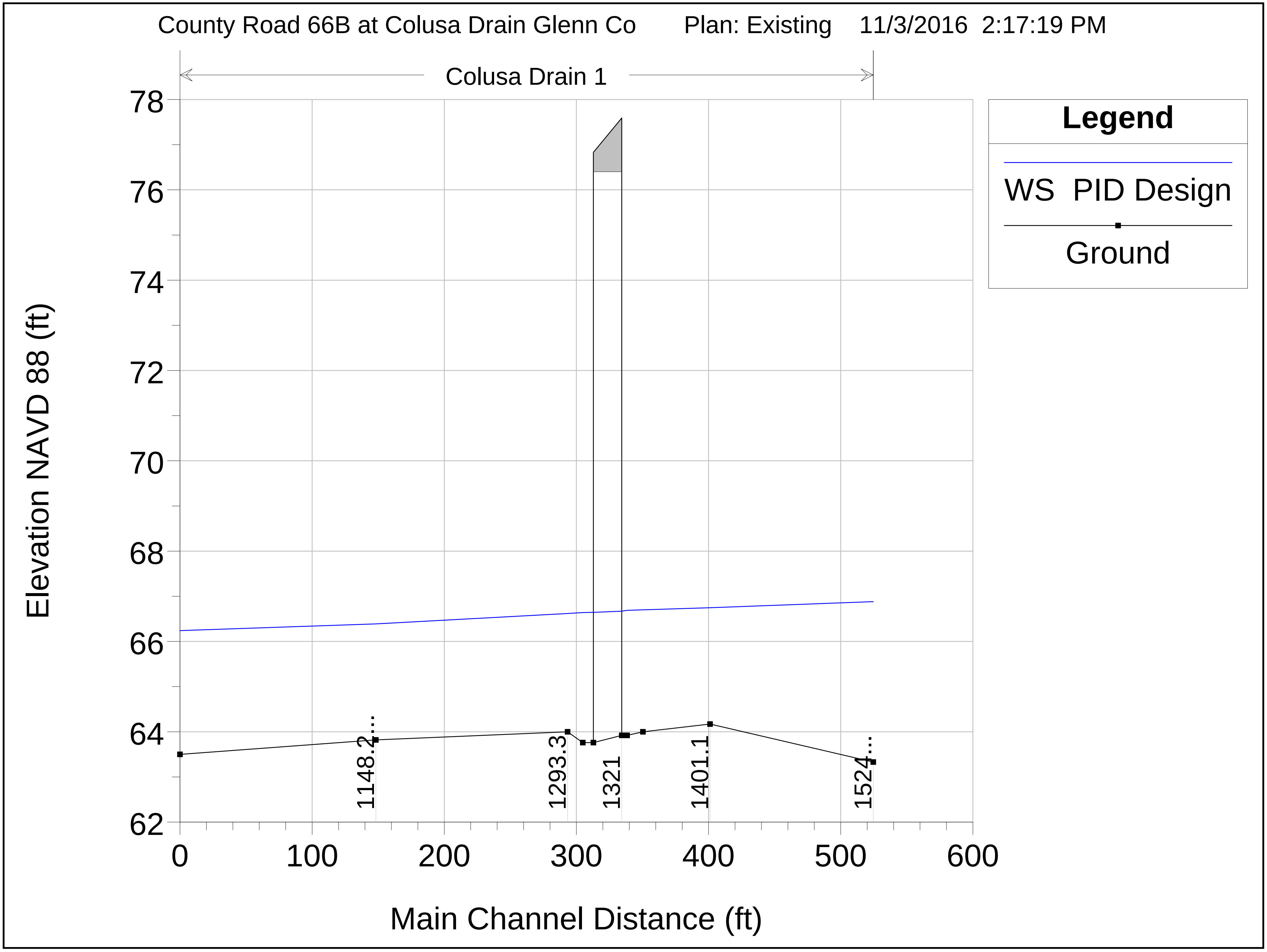
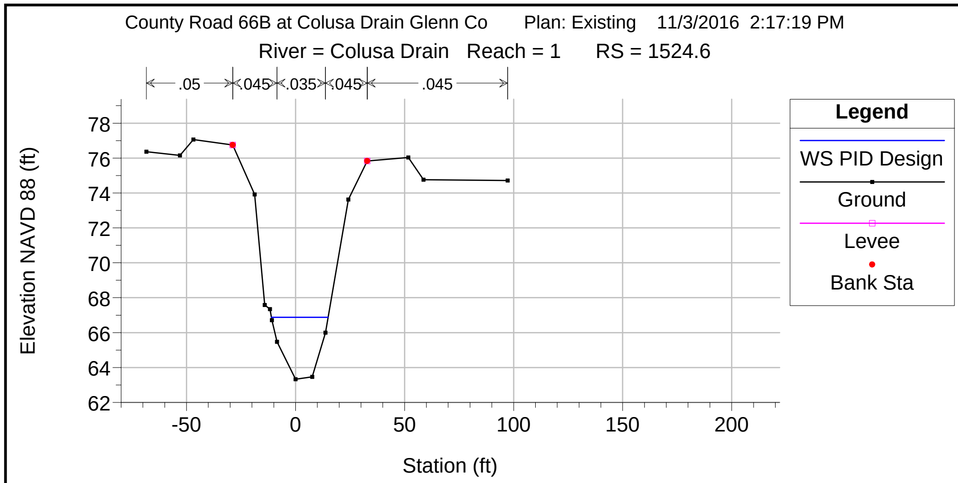
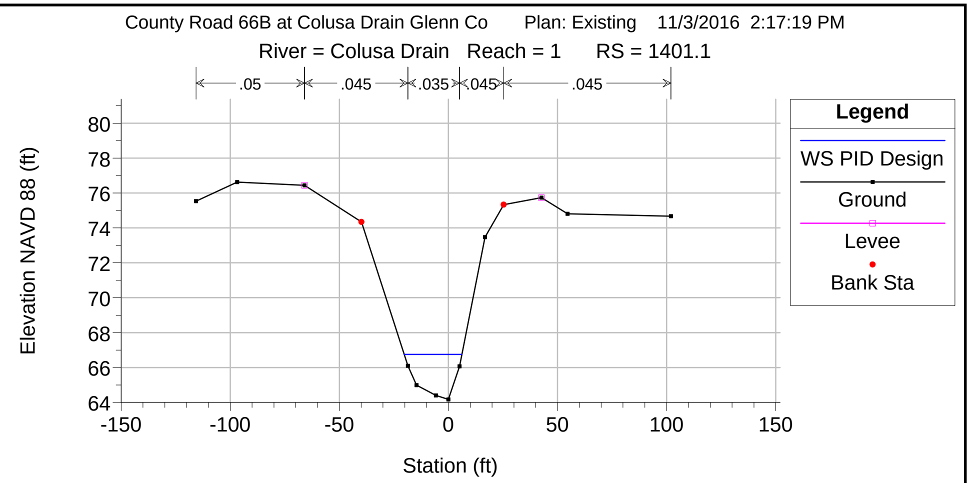


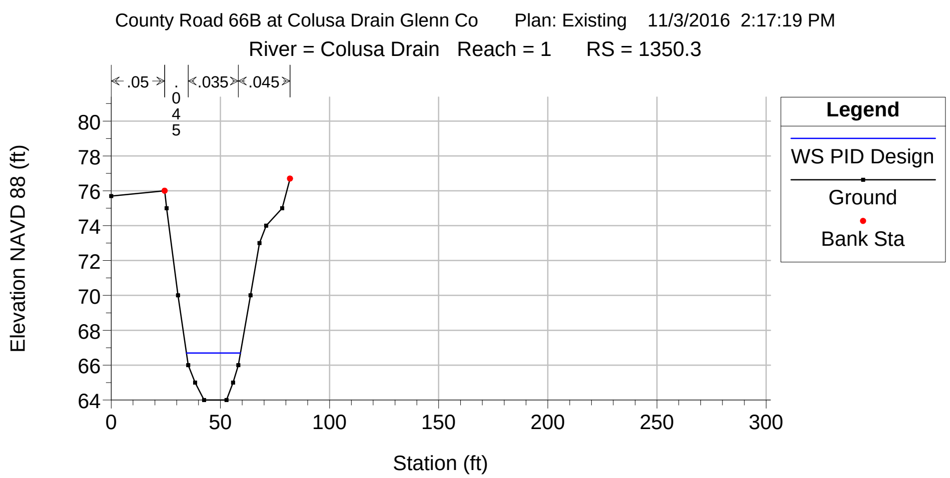
County Road 66B at Colusa Drain Glenn Co Plan: Existing 11/3/2016 2:17:19 PM
Colusa Drain 1
Legend
WS PID Design
Ground
Elevation NAVD 88 (ft)
Main Channel Distance (ft)
78
76
74
72
70
68
66
64
62
0
100
200
300
400
500
600
1148.2...
1293.3
1321
1401.1
1524...

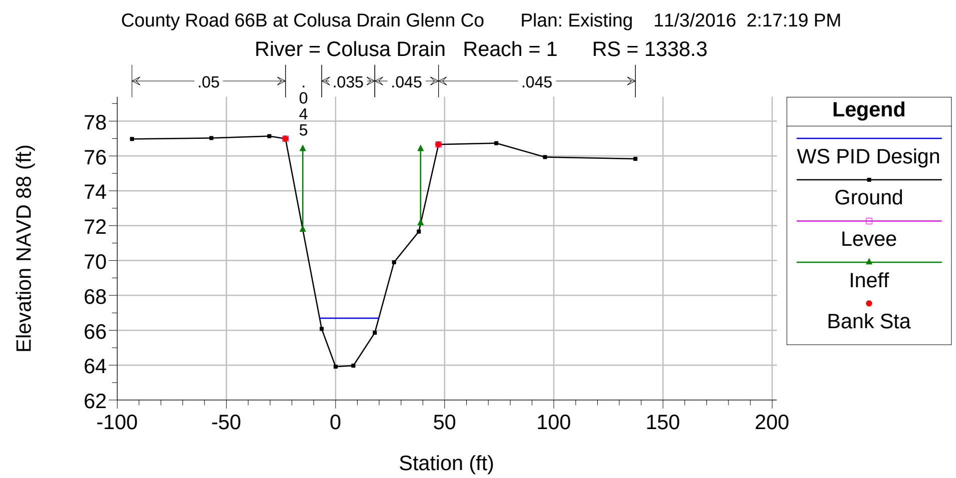
HEC-RAS Plan: Existing River: Colusa Drain Reach: 1 Profile: PID Design

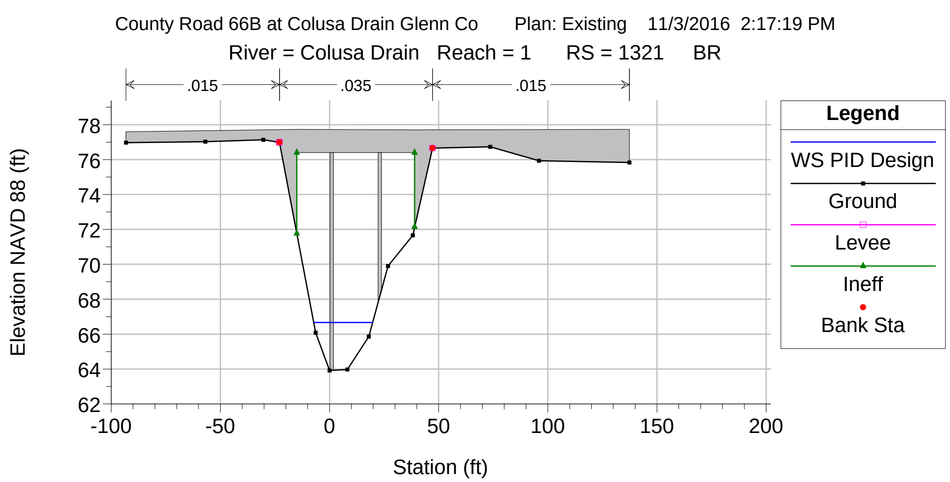
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Hydr Depth	Hydr Depth C	Length Chnl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(ft)	(ft)	(ft)
1	1524.6	PID Design	100.00	63.33	66.88	64.82	66.92	0.000507	1.59	63.00	25.99	0.18	2.42	2.42	123.49
1	1401.1	PID Design	100.00	64.17	66.75	65.58	66.82	0.001364	2.16	46.29	26.38	0.29	1.75	1.75	50.81
1	1350.3	PID Design	100.00	64.00	66.70		66.76	0.000929	1.97	50.65	24.70	0.24	2.05	2.05	12.00
1	1338.3	PID Design	100.00	63.92	66.69	65.28	66.75	0.000986	1.94	51.56	27.06	0.25	1.91	1.91	4.00
1	1321 BR U	PID Design	100.00	63.92	66.67	65.38	66.74	0.001506	2.13	46.90	25.48	0.28	1.84	1.84	21.50
1	1321 BR D	PID Design	100.00	63.76	66.65	65.13	66.71	0.001011	2.05	48.68	21.80	0.24	2.23	2.23	7.99
1	1304.8	PID Design	100.00	63.76	66.64	65.14	66.70	0.000906	1.97	50.86	23.97	0.24	2.12	2.12	11.50
1	1293.3	PID Design	100.00	64.00	66.62		66.69	0.001083	2.09	47.89	23.38	0.26	2.05	2.05	145.10
1	1148.2	PID Design	100.00	63.82	66.39	65.36	66.48	0.001813	2.49	40.19	23.45	0.34	1.71	1.71	148.21
1	1000	PID Design	100.00	63.50	66.24	64.67	66.30	0.000830	1.91	52.42	25.65	0.24	2.04	2.04	

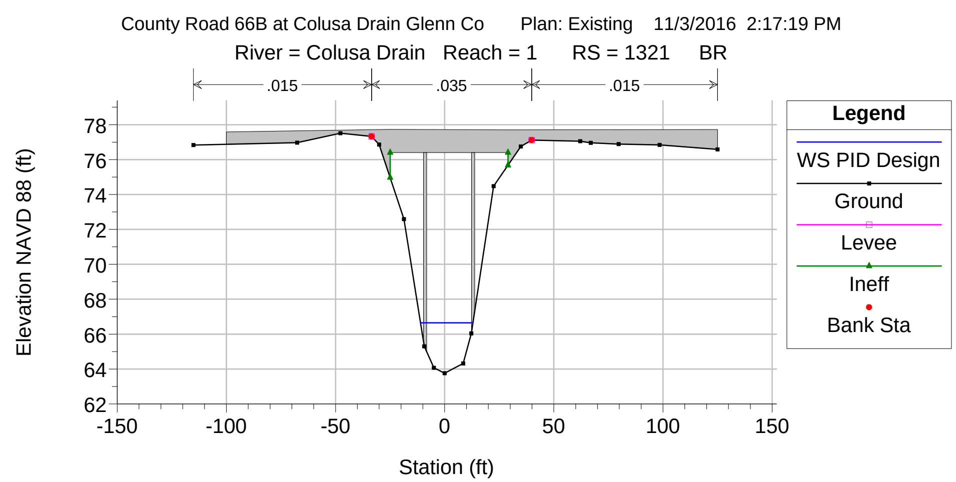








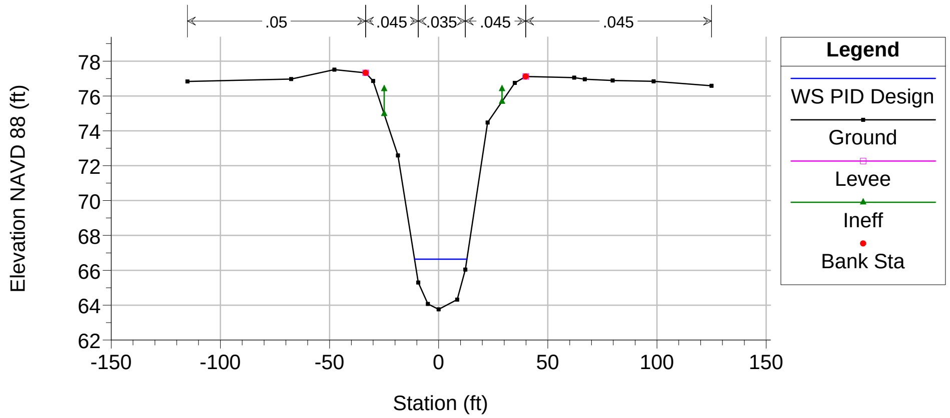




1 in Horiz. = 88 ft 1 in Vert. = 11 ft

County Road 66B at Colusa Drain Glenn Co Plan: Existing 11/3/2016 2:17:19 PM

River = Colusa Drain Reach = 1 RS = 1304.8



County Road 66B at Colusa Drain Glenn Co Plan: Existing 11/3/2016 2:17:19 PM

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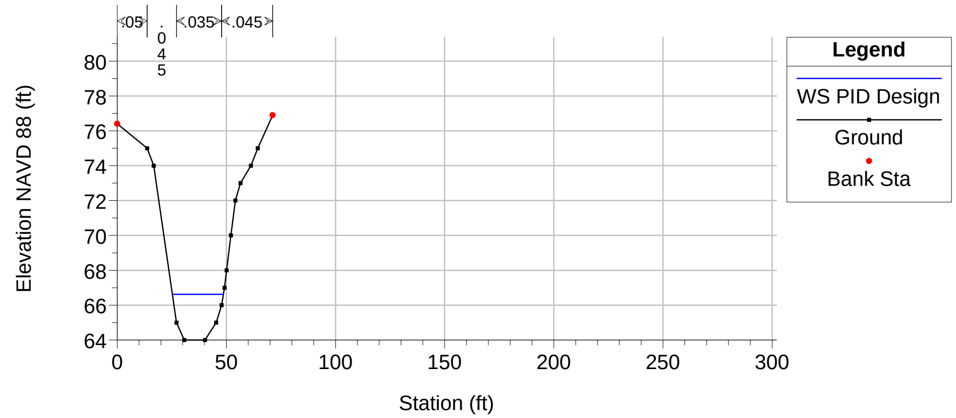
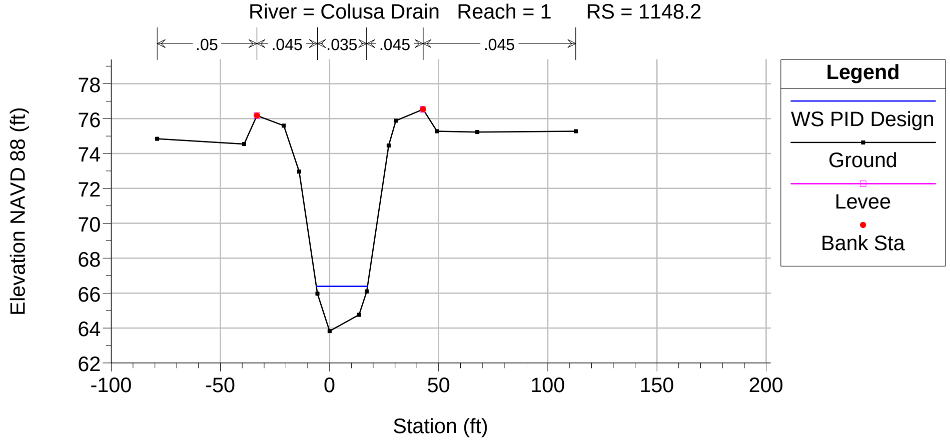


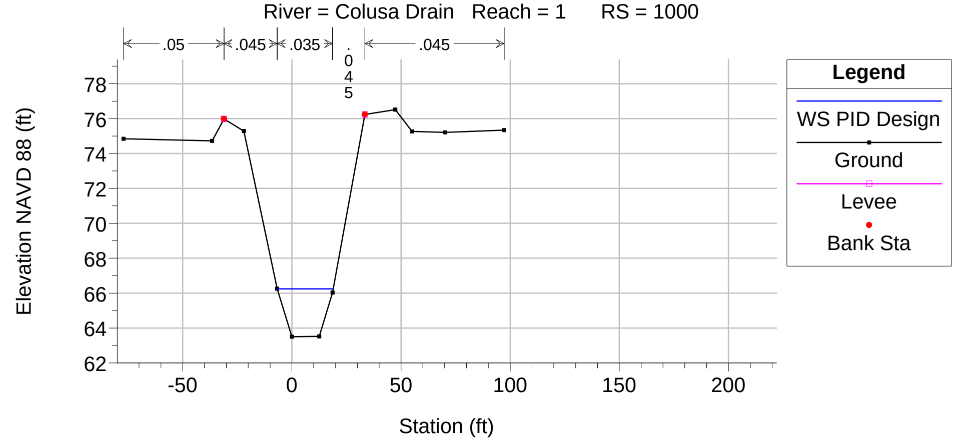
County Road 66B at Colusa Drain Glenn Co Plan: Existing 11/3/2016 2:17:19 PM

River = Colusa Drain Reach = 1 RS = 1148.2



County Road 66B at Colusa Drain Glenn Co Plan: Existing 11/3/2016 2:17:19 PM

River = Colusa Drain Reach = 1 RS = 1000



1 in Horiz. = 88 ft 1 in Vert. = 11 ft

Appendix C.2 HEC-RAS Existing Bridge with West Bank Overtopping Flow of 1,520 cfs

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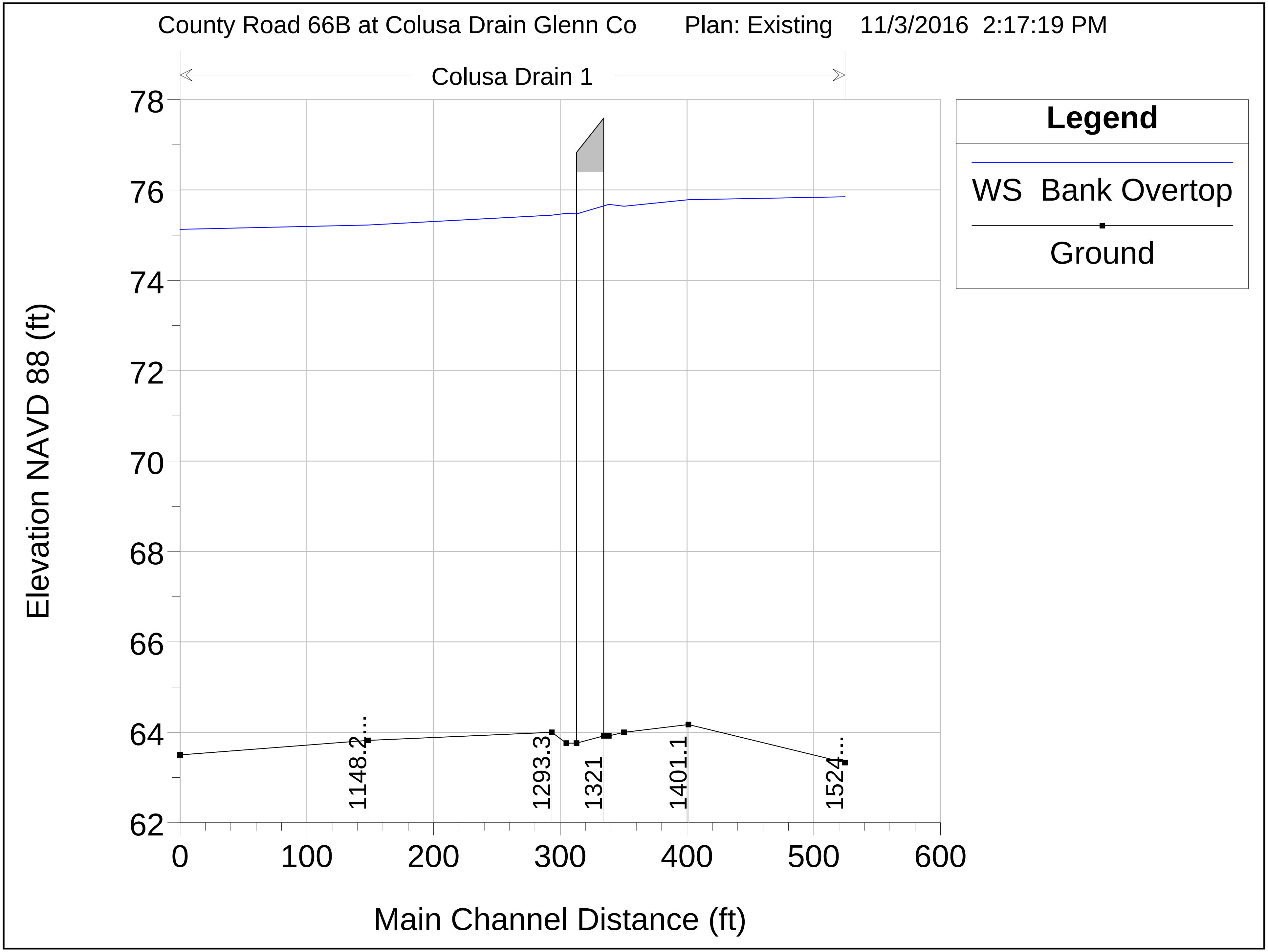
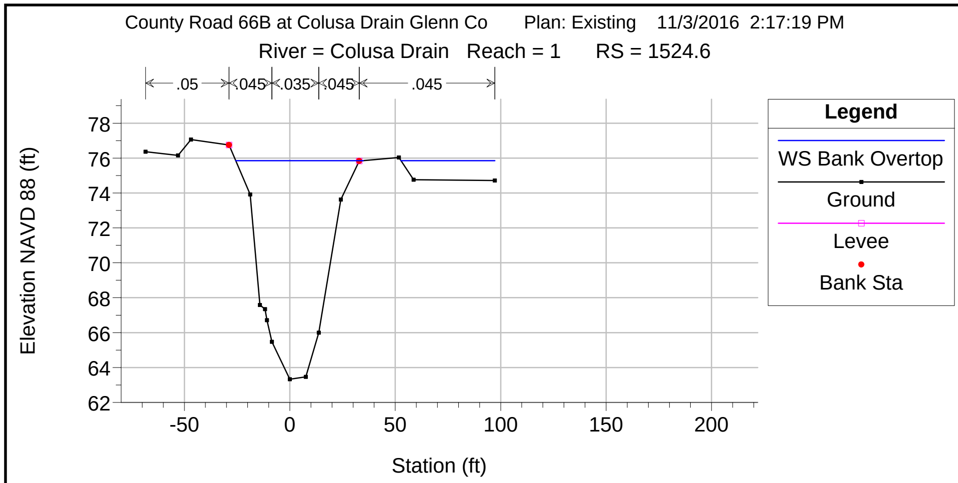
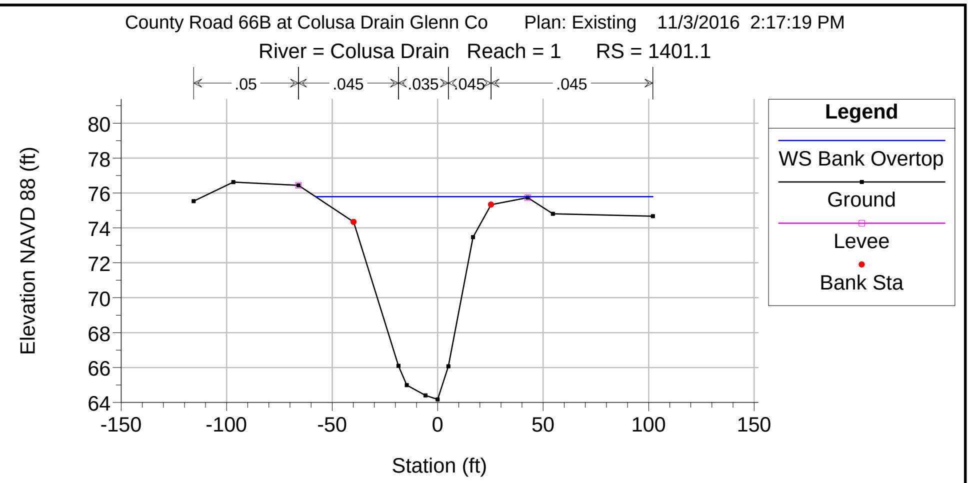
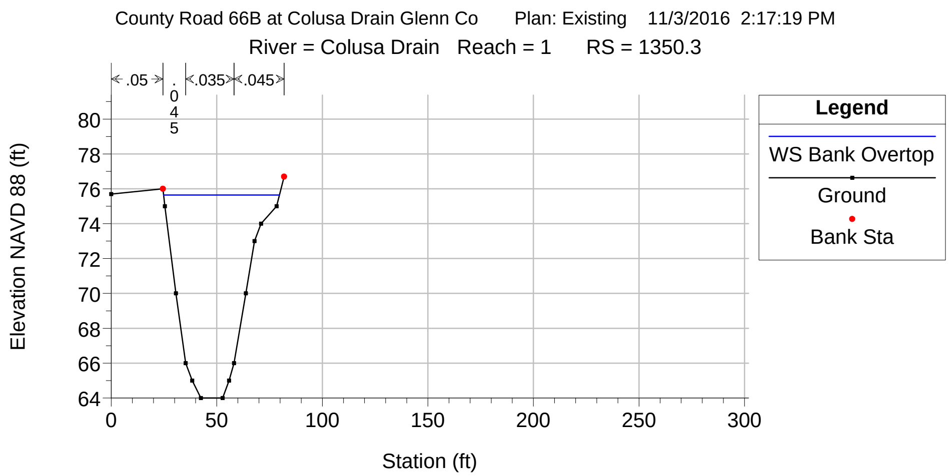

County Road 66B at Colusa Drain Glenn Co Plan: Existing 11/3/2016 2:17:19 PM
Colusa Drain 1
Legend
WS Bank Overtop
Ground
Elevation NAVD 88 (ft)
Main Channel Distance (ft)
78
76
74
72
70
68
66
64
62
0
100
200
300
400
500
600
1148.2...
1293.3
1321
1401.1
1524...

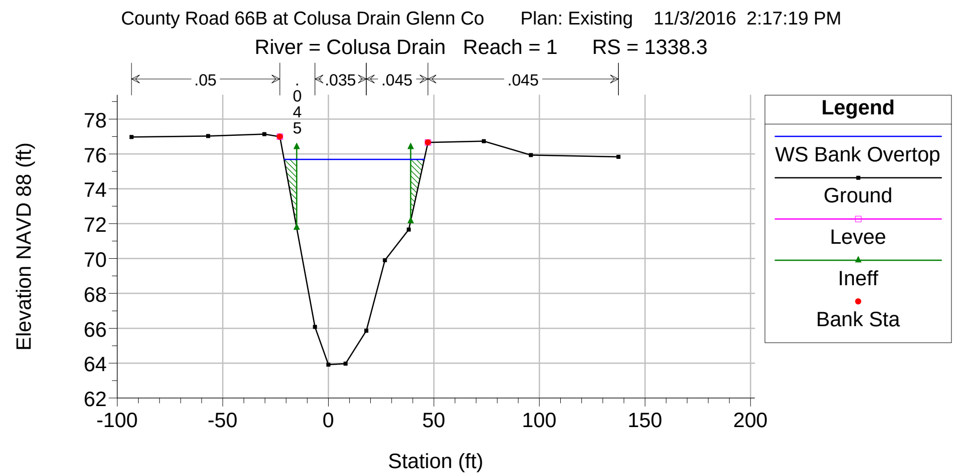
HEC-RAS Plan: Existing River: Colusa Drain Reach: 1 Profile: Bank Overtop

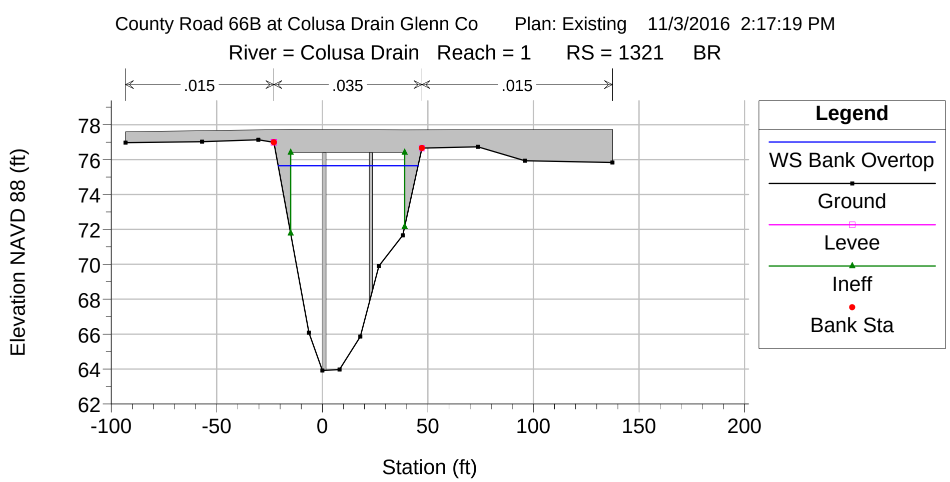
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Hydr Depth	Hydr Depth C	Length Chnl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(ft)	(ft)	(ft)
1	1524.6	Bank Overtop	1520.00	63.33	75.85	69.21	76.04	0.000862	3.56	460.50	104.98	0.24	4.39	7.08	123.49
1	1401.1	Bank Overtop	1520.00	64.17	75.79	69.65	75.94	0.000648	3.20	532.62	159.78	0.21	3.33	7.05	50.81
1	1350.3	Bank Overtop	1520.00	64.00	75.64		75.89	0.001078	3.97	382.41	54.84	0.27	6.97	6.97	12.00
1	1338.3	Bank Overtop	1520.00	63.92	75.68	69.40	75.86	0.000531	3.34	455.46	66.35	0.20	8.44	8.44	4.00
1	1321 BR U	Bank Overtop	1520.00	63.92	75.65	69.60	75.85	0.000933	3.58	424.70	50.99	0.22	8.33	8.33	21.50
1	1321 BR D	Bank Overtop	1520.00	63.76	75.47	69.80	75.78	0.002016	4.49	338.67	49.84	0.30	6.79	6.79	7.99
1	1304.8	Bank Overtop	1520.00	63.76	75.48	69.54	75.75	0.001172	4.13	367.77	54.26	0.28	6.95	6.95	11.50
1	1293.3	Bank Overtop	1520.00	64.00	75.44		75.73	0.001485	4.28	355.31	56.63	0.30	6.27	6.27	145.10
1	1148.2	Bank Overtop	1520.00	63.82	75.22	69.70	75.53	0.001294	4.41	345.02	48.81	0.29	7.07	7.07	148.21
1	1000	Bank Overtop	1520.00	63.50	75.13	69.00	75.35	0.000831	3.76	404.67	53.60	0.24	7.55	7.55	

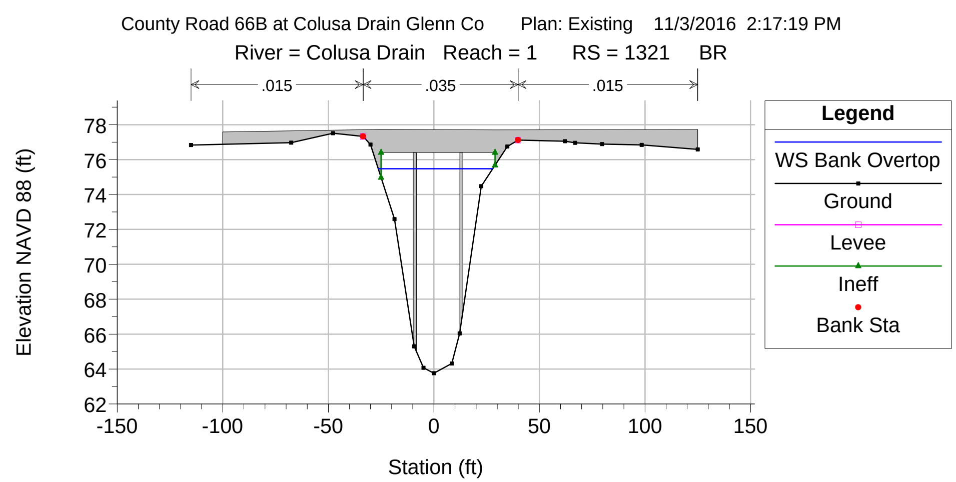




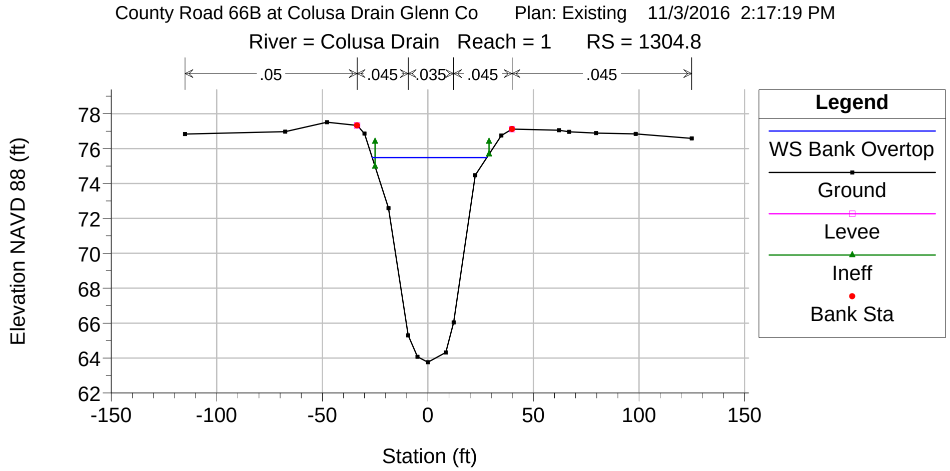


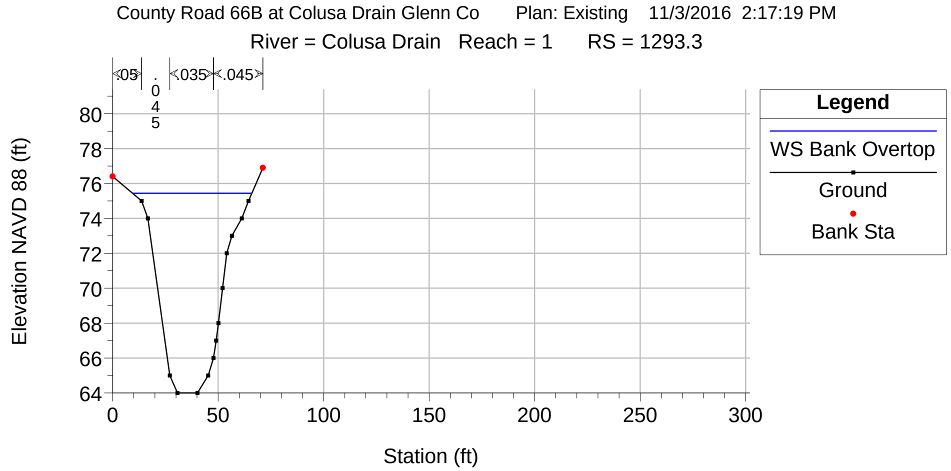


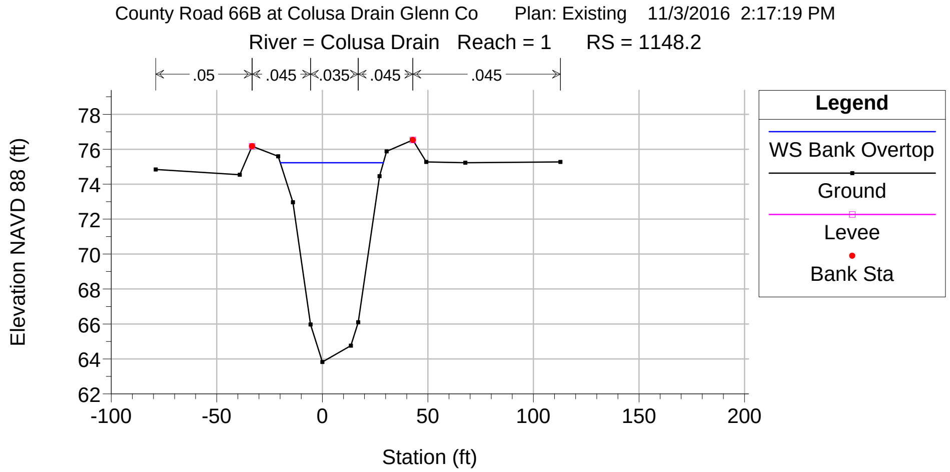


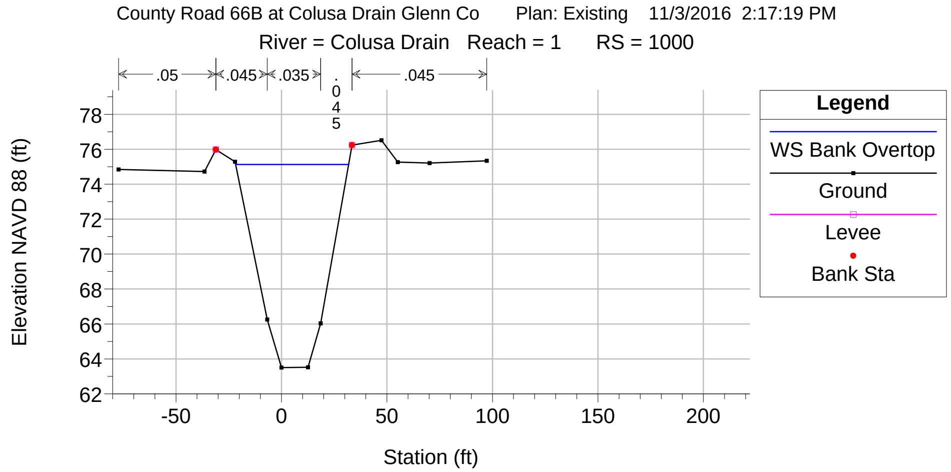


1 in Horiz. = 91 ft 1 in Vert. = 11 ft









1 in Horiz. = 91 ft 1 in Vert. = 11 ft

Appendix D Hydraulic Analysis, Proposed Condition

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Appendix D.1 HEC-RAS Proposed Bridge with Design Flow of 100 cfs

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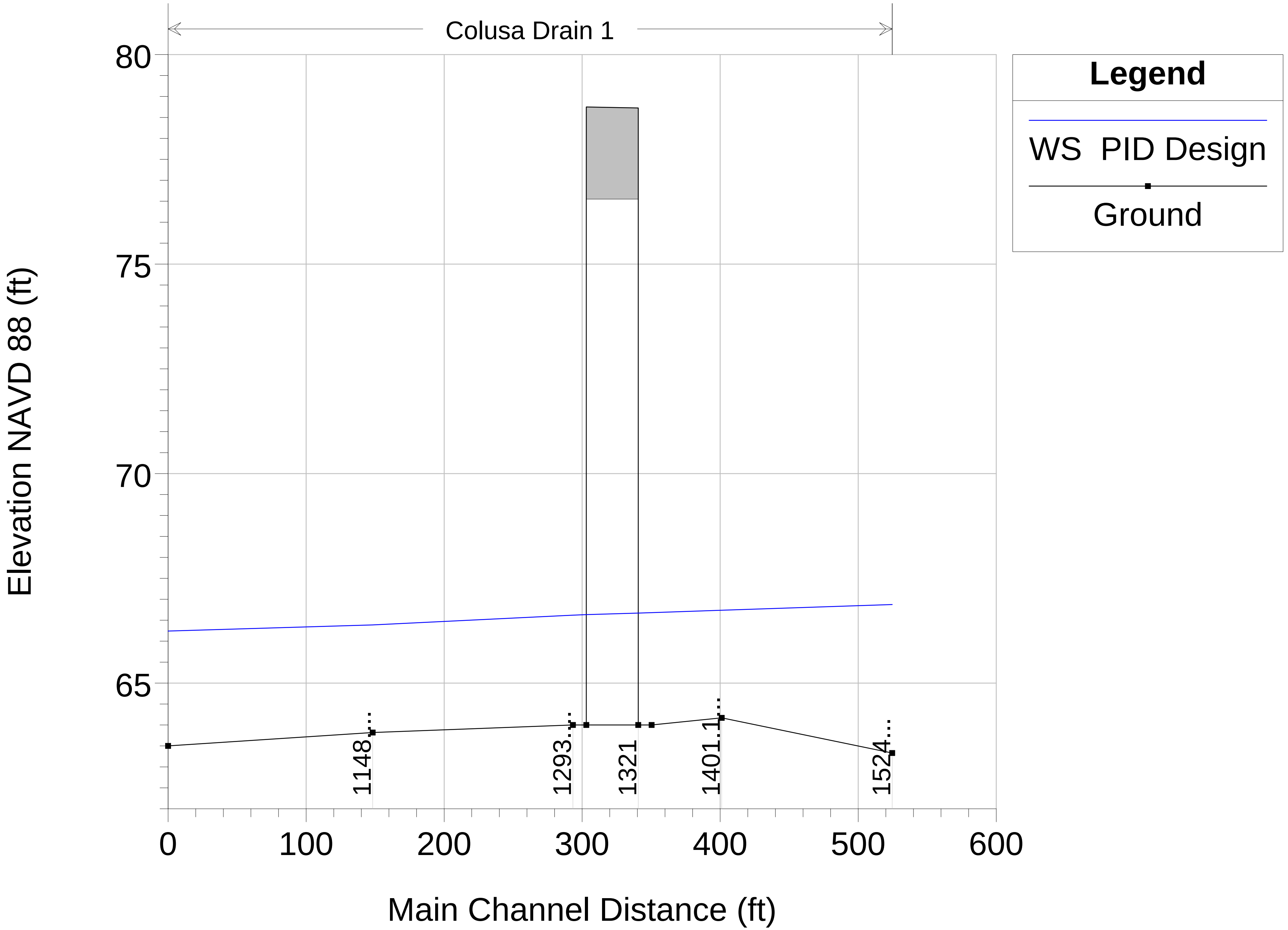
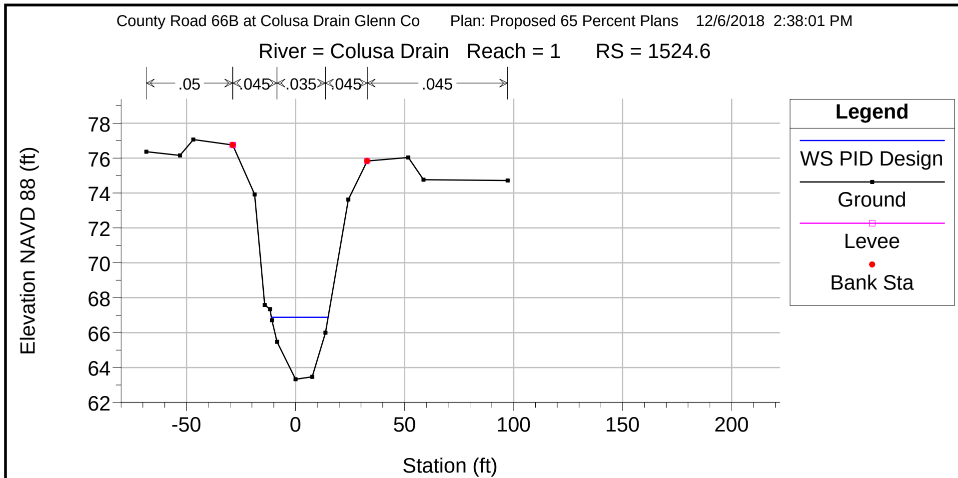
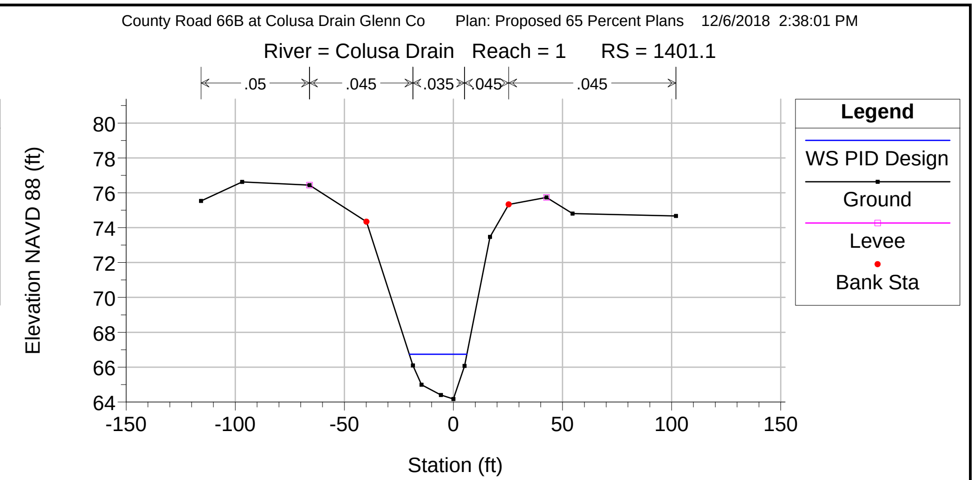
County Road 66B at Colusa Drain Glenn Co   Plan: Proposed 65 Percent Plans   12/6/2018 2:38:01 PM

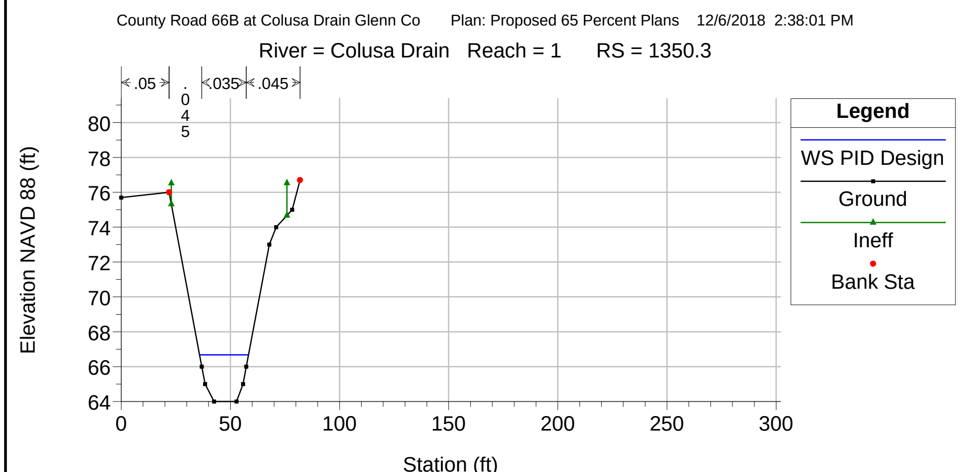


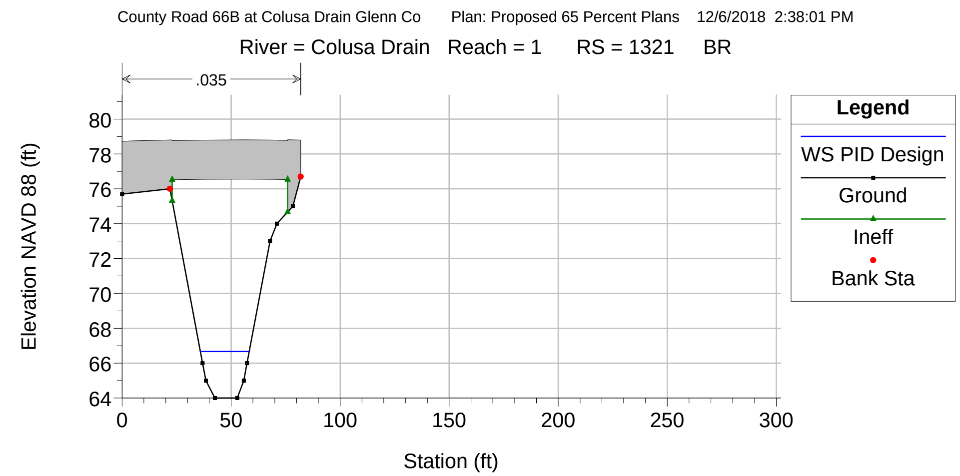
HEC-RAS Plan: Proposed 65 Percent Plans River: Colusa Drain Reach: 1 Profile: PID Design

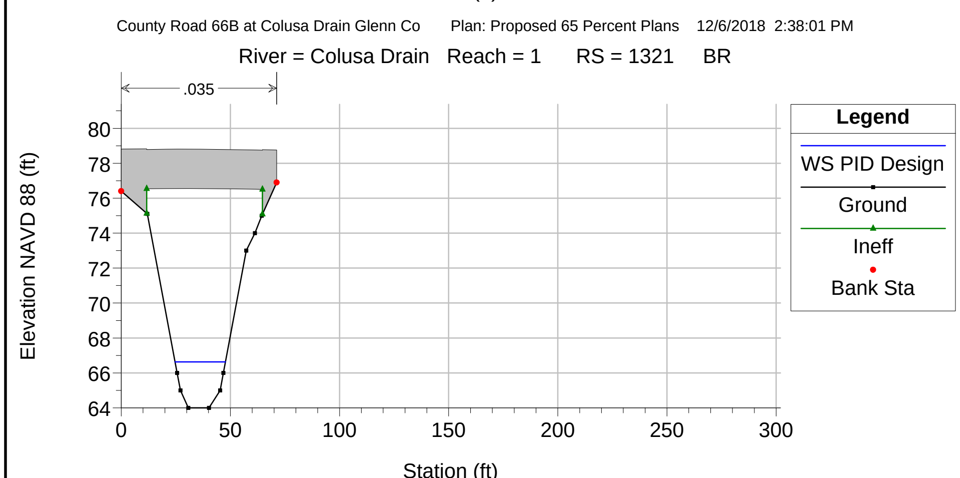
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Hydr Depth	Hydr Depth C	Length Chnl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(ft)	(ft)	(ft)
1	1524.6	PID Design	100.00	63.33	66.87	64.82	66.91	0.000512	1.59	62.80	25.97	0.18	2.42	2.42	123.49
1	1401.1	PID Design	100.00	64.17	66.74	65.58	66.81	0.001384	2.17	46.05	26.34	0.29	1.75	1.75	50.81
1	1350.3	PID Design	100.00	64.00	66.68	65.22	66.75	0.001050	2.11	47.33	22.44	0.26	2.11	2.11	9.70
1	1321 BR U	PID Design	100.00	64.00	66.67	65.22	66.74	0.001002	2.12	47.09	22.41	0.26	2.10	2.10	37.60
1	1321 BR D	PID Design	100.00	64.00	66.63	65.23	66.70	0.001002	2.10	47.57	23.10	0.26	2.06	2.06	9.69
1	1293.3	PID Design	100.00	64.00	66.62	65.23	66.69	0.001123	2.11	47.31	23.07	0.26	2.05	2.05	145.10
1	1148.2	PID Design	100.00	63.82	66.39	65.36	66.48	0.001813	2.49	40.19	23.45	0.34	1.71	1.71	148.21
1	1000	PID Design	100.00	63.50	66.24	64.67	66.30	0.000830	1.91	52.42	25.65	0.24	2.04	2.04	

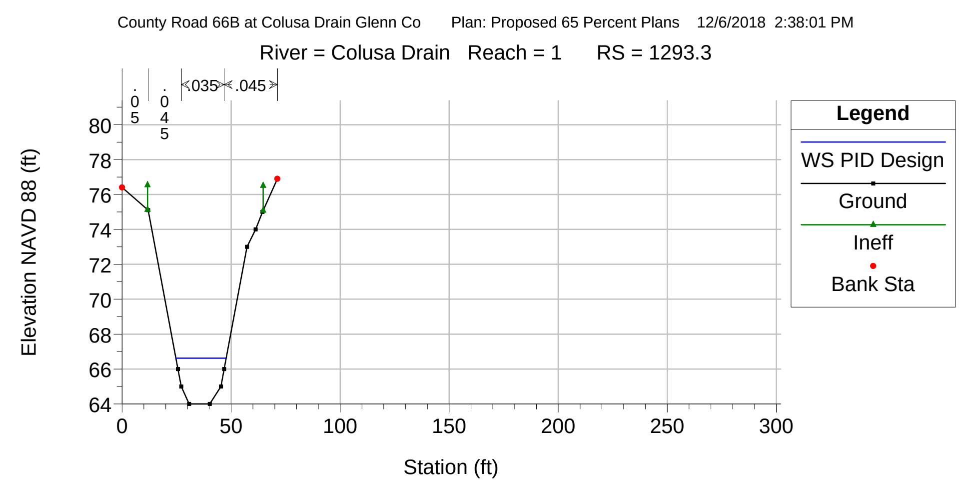




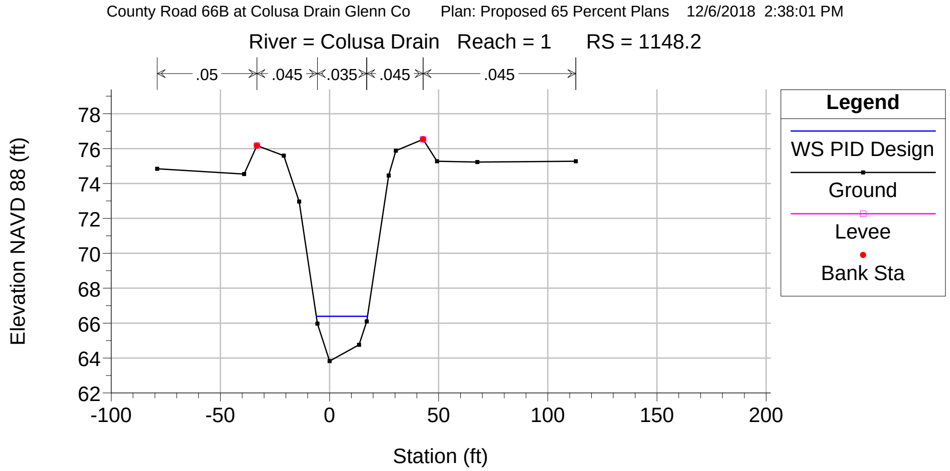


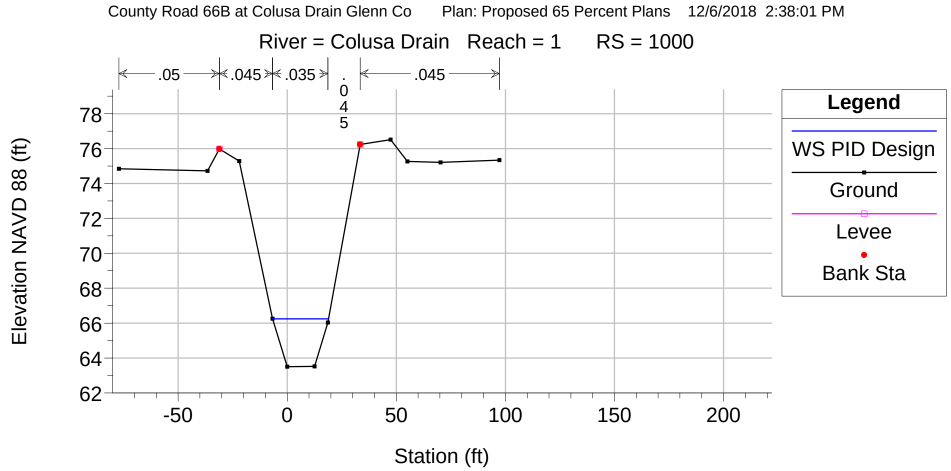






1 in Horiz. = 88 ft 1 in Vert. = 11 ft





1 in Horiz. = 88 ft 1 in Vert. = 11 ft

Appendix D.2 HEC-RAS Proposed Bridge with West Bank Overtopping Flow of 1,520 cfs

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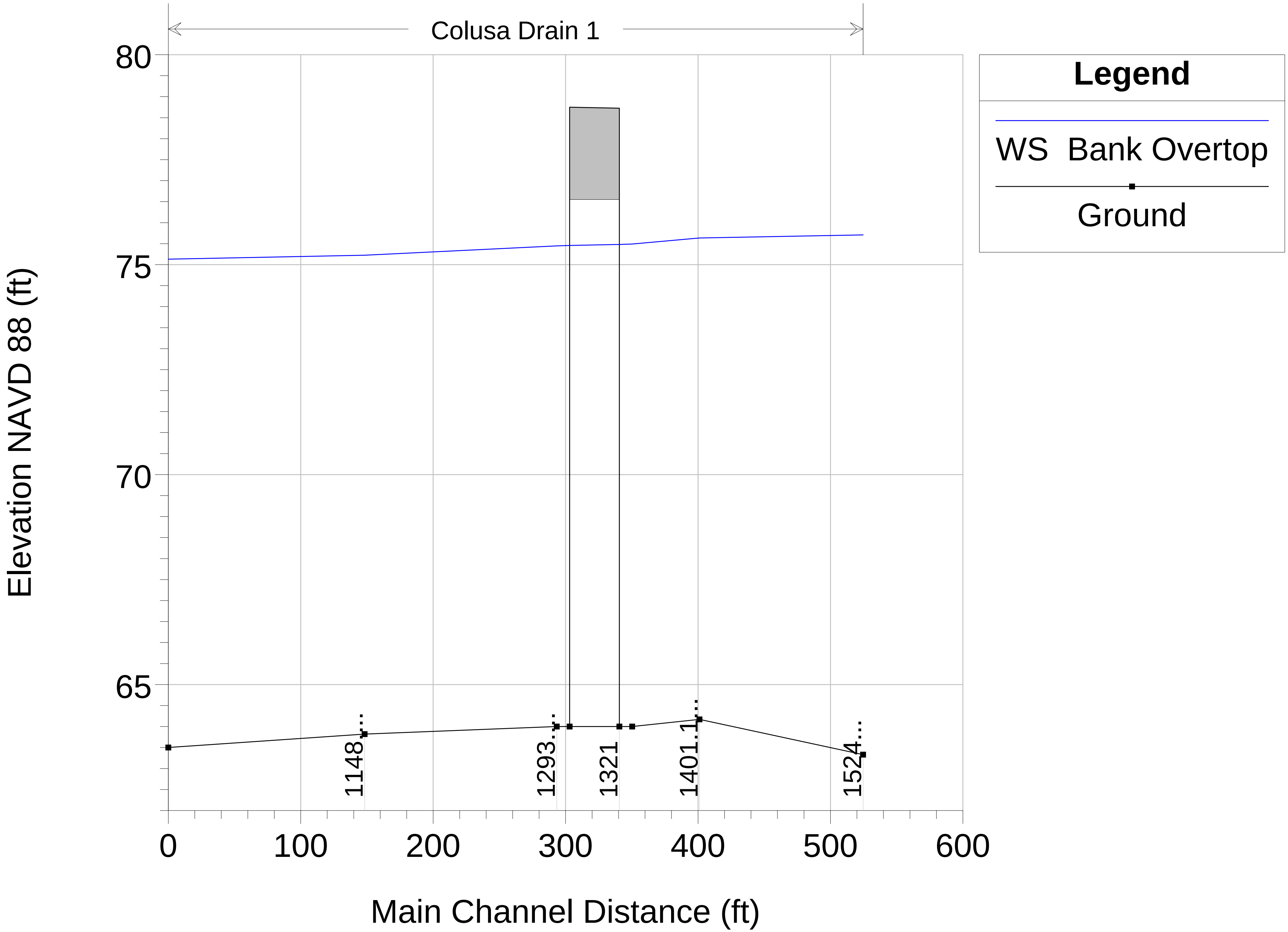
County Road 66B at Colusa Drain Glenn Co   Plan: Proposed 65 Percent Plans   12/6/2018 2:38:01 PM

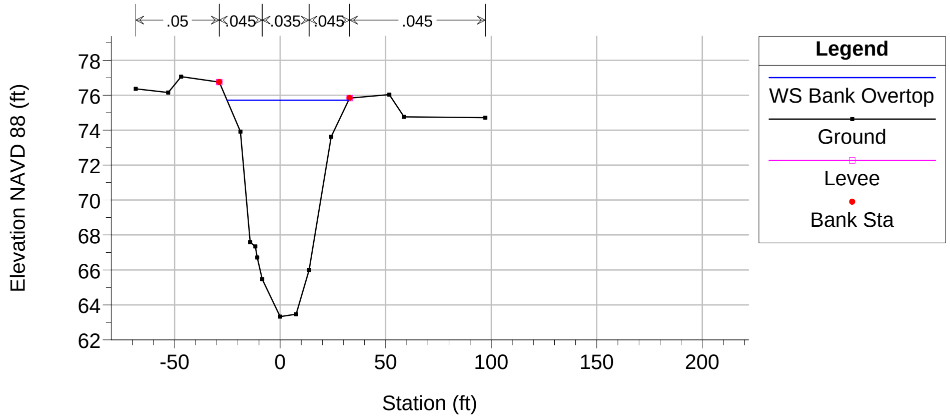


HEC-RAS Plan: Proposed 65 Percent Plans River: Colusa Drain Reach: 1 Profile: Bank Overtop

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Hydr Depth	Hydr Depth C	Length Chnl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(ft)	(ft)	(ft)
1	1524.6	Bank Overtop	1520.00	63.33	75.71	69.21	75.93	0.000957	3.74	406.00	57.55	0.25	7.05	7.05	123.49
1	1401.1	Bank Overtop	1520.00	64.17	75.64	69.65	75.81	0.000738	3.36	462.28	94.53	0.23	4.89	6.90	50.81
1	1350.3	Bank Overtop	1520.00	64.00	75.49	69.79	75.75	0.001153	4.12	368.86	56.68	0.28	6.96	6.96	9.70
1	1321 BR U	Bank Overtop	1520.00	64.00	75.48	69.79	75.75	0.000823	4.13	368.32	53.00	0.28	6.95	6.95	37.60
1	1321 BR D	Bank Overtop	1520.00	64.00	75.46	69.69	75.71	0.000778	4.06	374.46	53.00	0.27	7.07	7.07	9.69
1	1293.3	Bank Overtop	1520.00	64.00	75.45	69.70	75.70	0.001111	4.06	373.93	57.24	0.27	7.06	7.06	145.10
1	1148.2	Bank Overtop	1520.00	63.82	75.22	69.70	75.53	0.001294	4.41	345.02	48.81	0.29	7.07	7.07	148.21
1	1000	Bank Overtop	1520.00	63.50	75.13	69.00	75.35	0.000831	3.76	404.67	53.60	0.24	7.55	7.55	

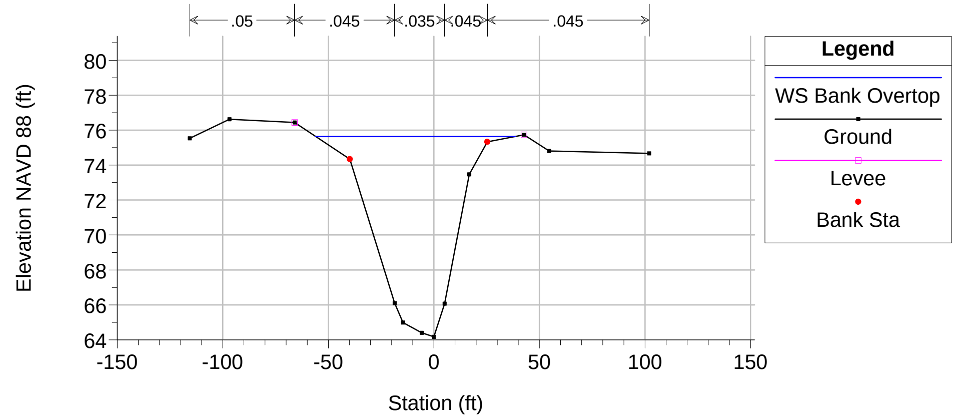
County Road 66B at Colusa Drain Glenn Co   Plan: Proposed 65 Percent Plans   12/6/2018 2:38:01 PM

River = Colusa Drain   Reach = 1   RS = 1524.6



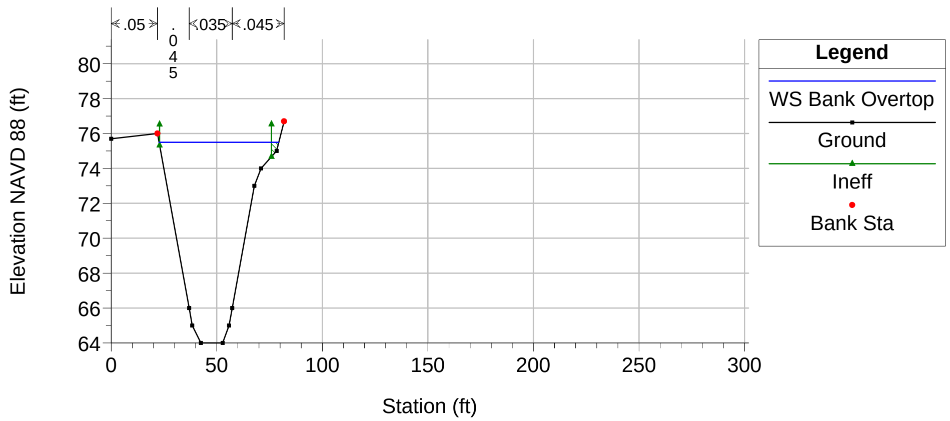
County Road 66B at Colusa Drain Glenn Co   Plan: Proposed 65 Percent Plans   12/6/2018 2:38:01 PM

River = Colusa Drain   Reach = 1   RS = 1401.1



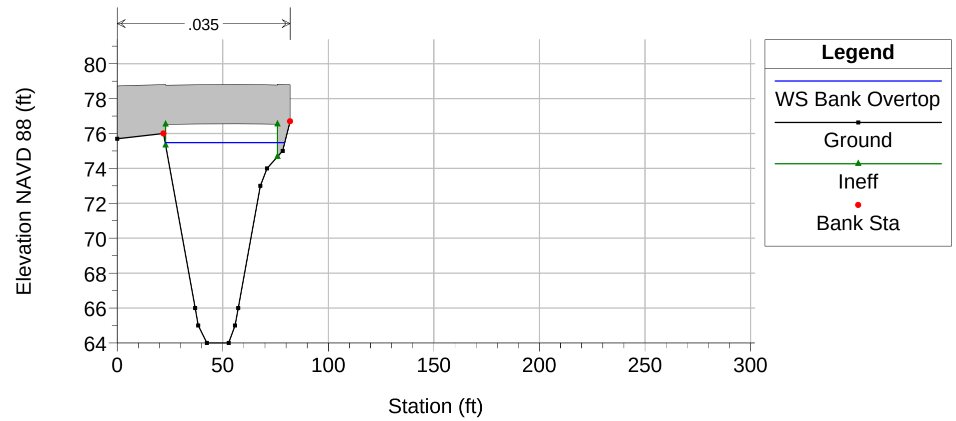
County Road 66B at Colusa Drain Glenn Co   Plan: Proposed 65 Percent Plans   12/6/2018 2:38:01 PM

River = Colusa Drain   Reach = 1   RS = 1350.3



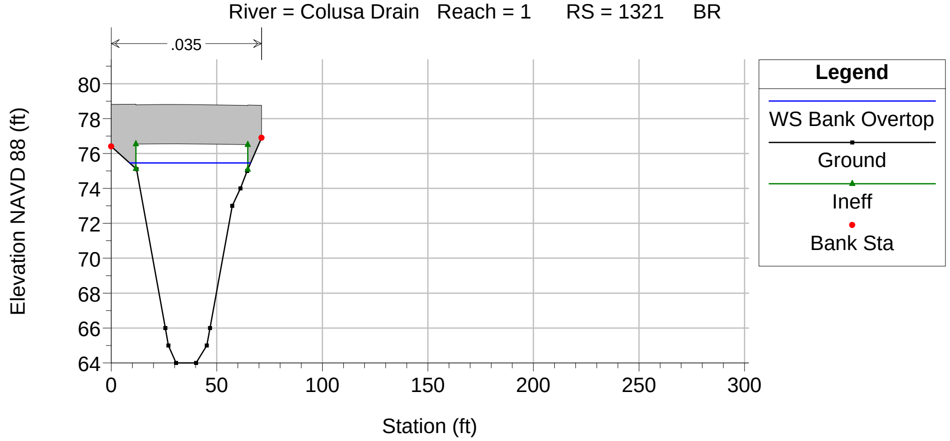
County Road 66B at Colusa Drain Glenn Co   Plan: Proposed 65 Percent Plans   12/6/2018 2:38:01 PM

River = Colusa Drain   Reach = 1   RS = 1321   BR



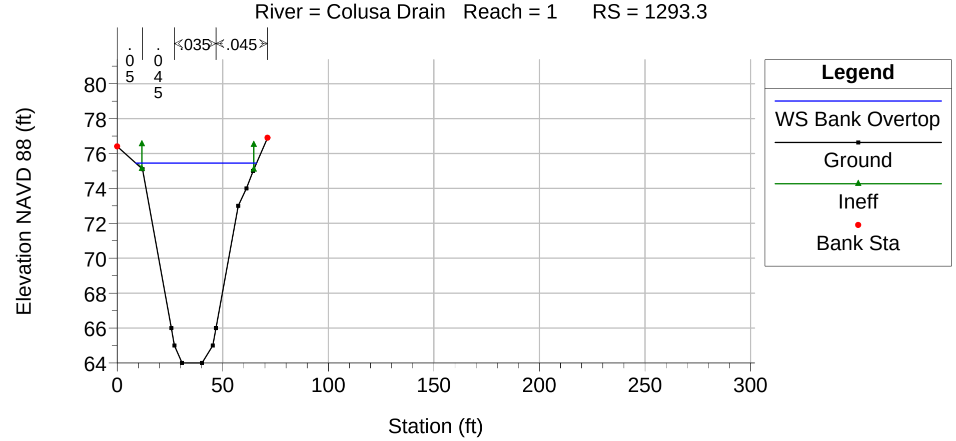
County Road 66B at Colusa Drain Glenn Co   Plan: Proposed 65 Percent Plans   12/6/2018 2:38:01 PM

River = Colusa Drain   Reach = 1   RS = 1321   BR

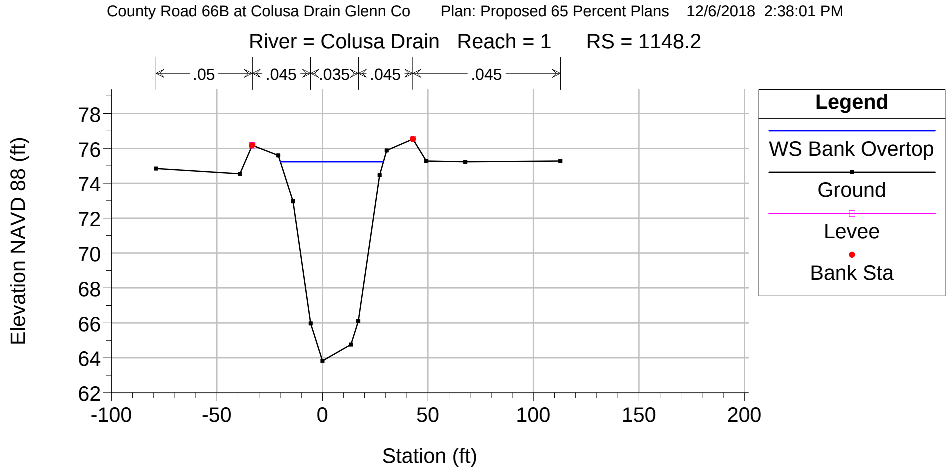


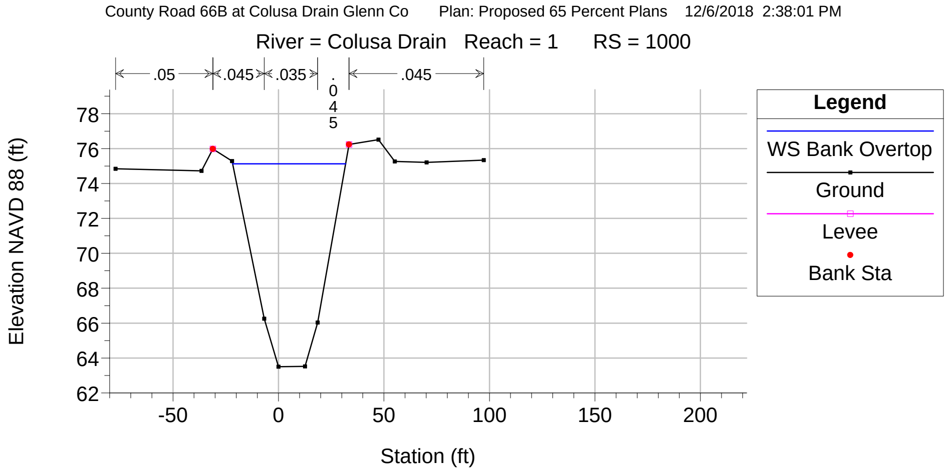
County Road 66B at Colusa Drain Glenn Co   Plan: Proposed 65 Percent Plans   12/6/2018 2:38:01 PM

River = Colusa Drain   Reach = 1   RS = 1293.3



1 in Horiz. = 91 ft   1 in Vert. = 11 ft





1 in Horiz. = 91 ft 1 in Vert. = 11 ft

Appendix E Scour Analysis

1243 Alpine Road, Suite 108
Walnut Creek, CA 94596
Phone: 925.941.0017
FAX: 925.941.0018
www.wreco.com

CR 66B Bridge Replacement Project
Glenn County, California
Ultimate (Contraction) Scour

Overtopping Flow
Calculation guideline from HEC-18 5th Edition
Input from HEC-RAS for Proposed Alternative 1

Equation 6.6:

$$y_{s-ult} = 0.94 y_1 \left(\frac{1.83 V_2}{\sqrt{g y_1}} - \frac{K_u \sqrt{\frac{\tau_c}{\rho}}}{g n {y_1}^{1/3}} \right)$$

Input

Variable	English Units		Metric Units		Description
y1	6.9	ft	2.1	m	Upstream depth
V2	4.1	ft/s	1.3	m/s	Average velocity in contracted section
n	0.035		0.035		Manning's roughness coefficient
Ku	1.486		1		1.486 for U.S. Customary, and 1.0 for S.I.
r		slugs/ft^3			Density 1,000 kg/m^3 = 1.94 slugs/ft^3
g	32.2	ft/s^2	9.81	m/s^2	acceleration due to gravity
D50			0.0116	mm	grain size for which 50% of bed material is finer

Density, rho

Material	Density			
	Metric Units		English Units	
min	1,400	kg/m^3	2.72	slugs/ft^3
max	1,550	kg/m^3	3.01	slugs/ft^3
Water, sea	1,026	kg/m^3	1.99	slugs/ft^3
Water, pure	1,000	kg/m^3	1.94	slugs/ft^3

Critical Shear Stress Tc	Tc (N/m^2)
Tc=0.05(D50)^-0.4	0.3
Tc=0.006(D50)^-2	44.6

Scour Depths, ys

With Density for min and Critical Shear Stress Equation Tc=0.05(D50)^-0.4			With Density for max and Critical Shear Stress Equation Tc=0.05(D50)^-0.4		
ys =	0.94	m	ys =	0.94	m
ys =	3.1	ft	ys =	3.1	ft
With Density for min and Critical Shear Stress Equation Tc=0.006(D50)^-2			**With Density for max and Critical Shear Stress Equation Tc=0.006(D50)^-2**		
ys =	0.20	m	ys =	0.24	m
ys =	0.7	ft	ys =	0.8	ft

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CR 66B Bridge Replacement Project
Glenn County, California
Local Scour at Abutments - Froehlich or HIRE

Overtopping Flow
Calculation guideline from HEC-18 5th Edition
Input from HEC-RAS for Proposed Alternative 1

Units = (SI or English)	English	
g = acceleration due to gravity =	32.2	ft/s^2

Left Overbank = Abutment 2 (East)

y1 = depth of flow at abutment on the overbank or in the main channel =	0.3	ft
L = length of embankment projected normal to flow =	26.1	ft
Ratio of projected embankment length to flow depth = L/y1 =	8.703E+01	
Abutment scour equation to be used =	HIRE	

HIRE Live Bed Abutment Scour Equation

V = velocity of flow at upstream face of abutment =	0.7	ft/s
Fr = Froude Number = V/((g*y1)^.5) =	0.2	
Θ = abutment skew =	90	degrees
K1 = coefficient for abutment shape =	1	
K2 = coefficient for angle of embankment shape = (Θ/90)^0.13 =	1	
Ys = abutment scour = y1*(4*(Fr^0.33)*(K1/0.55)*K2) =	**1.3**	**ft**

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CR 66B Bridge Replacement Project
Glenn County, California
Local Scour at Abutments - Froehlich or HIRE

Overtopping Flow
Calculation guideline from HEC-18 5th Edition
Input from HEC-RAS for Proposed Alternative 1

Units = (SI or English)	English	
g = acceleration due to gravity =	32.2	ft/s^2

Right Overbank = Abutment 1 (West)

y1 = depth of flow at abutment on the overbank or in the main channel =	0.9	ft
L = length of embankment projected normal to flow =	7.6	ft
Ratio of projected embankment length to flow depth =	8.422E+00	
Abutment scour equation to be used =	Froehlich	

Froehlich's Live Bed Abutment Scour Equation

L' = length of active flow obstructed by the embankment =	4.6	ft
Ae = flow area of the approach cross section obstructed by the embankment =	8.5	ft^2
ya = average depth of flow on the flood plain = Ae/L	1.13	ft
Qe = flow obstructed by the abutment and approach embankment =	7	ft^3/s
Ve = flow velocity = Qe/Ae =	0.8	ft/s
Fr = Froude Number of approach flow upstream of the abutment =	0.13	
Θ = abutment skew =	90	degrees
K1 = coefficient for abutment shape =	1	
K2 = coefficient for angle of embankment shape = (Θ/90)^0.13 =	1	
Ys = abutment scour = ya*(2.27*k1*k2*((L'/ya)^0.43)*(Fr^0.61)+1) =	**2.5**	**ft**

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Appendix F Scour Countermeasures

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CR 66B Bridge Replacement Project
Glenn County, California
Streambank Rock Slope Protection
Calculation guideline from Caltrans Highway Design Manual

Input from HEC-RAS for Proposed Bridge Replacement
Overtopping Flow

Input

Location along stream:	Upstream	Upstream Face	Downstream Face	Downstream	
V_{avg}	4.1	4.1	4.1	4.1	ft/s
g	32.2	32.2	32.2	32.2	ft/s^2
Depth based on	Average	Average	Average	Average	
y	7.0	7.0	7.1	7.1	ft
S_f	1.1	1.1	1.1	1.1	
C_s	0.3	0.3	0.3	0.3	
Cross section location:	Straight channel	Straight channel	Straight channel	Straight channel	
C_v	1.00	1.00	1.00	1.00	

For outside of bends, need R_c and W:

Note: these parameters also affect the V_{des}; for natural channels, V_{des}=V_{avg} for R_c/W>26

Note: these parameters also affect the V_{des}; for trapezoidal channels, V_{des}=V_{avg} for R_c/W>8

R_c	26	26	26	26	ft
W	1.0	1.0	1.0	1.0	ft
C_t	1.0	1.0	1.0	1.0	
S_g	2.65	2.65	2.65	2.65	
Type of channel:	Natural	Natural	Natural	Natural	
V_{des}	4.1	4.1	4.1	4.1	ft/s
K_1	0.72	0.72	0.72	0.72	
θ	33.7	33.7	33.7	33.7	degrees
SS	1.5	1.5	1.5	1.5	
D_{30}	0.1	0.1	0.1	0.1	ft
D_{50}	0.1	0.1	0.1	0.1	ft
D_{50}	1.1	1.1	1.0	1.0	inches
	I	I	I	I	RSP Class
	20 lb	**20 lb**	**20 lb**	**20 lb**	Median particle weight
	6	**6**	**6**	**6**	Median particle diameter (inches)

CR 66B Bridge Replacement Project

Glenn County, California

Rock Slope Protection Calculations for Abutments

Calculation guideline from HEC-23 3rd Edition

Input from HEC-RAS for Proposed Bridge Replacement

Overtopping Flow

Location	Upstream	Upstream Face	Downstream Face	Downstream	
V	4.1	4.1	4.1	4.1	ft/s
g	32.2	32.2	32.2	32.2	ft/s^2
y	7.0	7.0	7.1	7.1	ft
Fr	0.28	0.28	0.27	0.27	
Equation	**Isbash**	**Isbash**	**Isbash**	**Isbash**	

For Froude Numbers $(V/(gy)^{1/2})$<=0.80, Isbash relationship (Equation 14.1)

$$D_{50} = \frac{yK}{(S_s - 1)}\left[\frac{V^2}{gy}\right]$$

y	7.0	7.0	7.1	7.1	depth of flow in the contracted bridge opening, ft
K	1.02	1.02	1.02	1.02	1.02 for vertical wall abutment, 0.89 or for spill-through abutment
S_s	2.65	2.65	2.65	2.65	specific gravity of rock
V	4.1	4.1	4.1	4.1	average velocity in contracted section, ft/s
g	32.2	32.2	32.2	32.2	gravitational acceleration, ft/s^2
D_{50}	0.3	0.3	0.3	0.3	median stone diameter, ft
D_{50}	3.9	3.9	3.8	3.8	median stone diameter, inches

I	I	I	I	RSP Class
20 lb	20 lb	20 lb	20 lb	Median particle weight
6	6	6	6	Median particle diameter (inches)