San Joaquin County, California

Preliminary Hydraulic Report
Waverly Road Bridge Over Channel B,
San Joaquin County, California
Bridge #29C0368

Avila and Associates
Consulting Engineers, Inc.
May 2024

PRELIMINARY HYDRAULIC REPORT

WAVERLY ROAD BRIDGE OVER CHANNEL B, SAN JOAQUIN COUNTY, CALIFORNIA

Bridge #29C0368

MAY 20, 2024

PREPARED FOR:

MOFFATT & NICHOL FOR SAN JOAQUIN COUNTY, CALIFORNIA

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STATE OF CALIFORNIA

May 20, 2024

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TABLE OF CONTENTS

LIST OF FIGURES

EXECUTIVE SUMMARY

This Preliminary Hydraulic Report (PHR) presents the results of a preliminary hydrology and hydraulic analysis of the Waverly Road Bridge over Channel B (Bridge #29C0368) in San Joaquin County, California. Avila and Associates Consulting Engineers, Inc. (Avila) set up an existing conditions model based upon topography obtained from REY Engineers Inc. on November 8, 2023.

A HEC-RAS model was created for the existing conditions and HEC-RAS models were re-run for five different options. The HEC-RAS results are summarized in Table 1. The elevation datum used for this study is NAVD-88[1].

The County expressed several goals for an improved design within a December 2023 conference call:

1. Replace the existing bridge with a low-cost RCP or CMP culvert with a clear opening less than 20-ft
2. Determine the minimum size culvert that will not have impacts upstream or downstream of the bridge.
3. Avoid the designation of "bridge" per FHWA.
4. Propose a solution that can be easily constructed by County maintenance staff.

As noted above, the County has communicated they would prefer to replace the existing timber bridge with "either RCP or CMP pipe culvert" since the existing bridge "needs constant repairs and maintenance"[2]. Alternatives 2, 4, and 5 demonstrated a reduction in water surface elevation at the upstream face of the existing bridge relative to existing conditions. Since we must also consider water surface elevation impacts just upstream and downstream, Alternatives 2, 4, and 5 also demonstrated a reduction in water surface elevation 10 ft upstream of the face of the bridge relative to existing conditions. However, all alternatives except for Alternative 5 demonstrated an increase in water surface elevation at the downstream face of the existing bridge relative to existing conditions and 10 ft farther downstream than the downstream face of the bridge relative to existing conditions.

Note terrain modifications (grading assumptions) were included that will require additional work during design as grading was excluded from the scope of services.

Results of the alternatives analysis are shown graphically in Figure 1 and tabulated in Table 1. Alternative 5 is nearly identical to the existing structure thus it has virtually no change in hydraulic parameters nor increase in floodplain area while Alternative 3 provides the smallest box culvert with only a slight increase in water surface elevation. It is possible that different grading (or a slightly different size) could alleviate the small water surface elevation increase.

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[1] Vertical Datum shown on the project topographic survey prepared by received from REY Engineers, Inc. on November 8 via e-mail.
[2] Electronic mail from Brian Newberg, Engineer III with the San Joaquin County Public Works to Garrett Dekker, Project Manager with Moffatt & Nichol dated June 28, 2023.

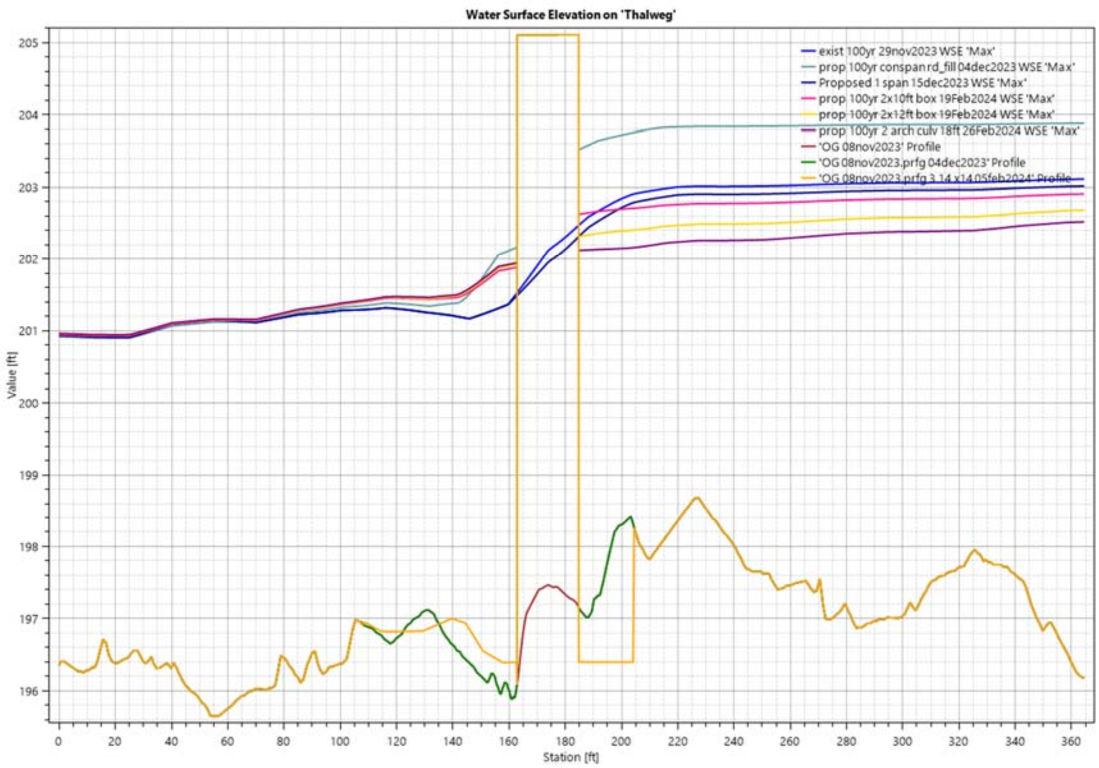


Figure 1: Water Surface Profile

Table 1: Summary of proposed HEC-RAS model results

Description	Alternative Number	Bridge Length (Culvert Clear Opening Width) (ft)	Approximate WSE for 100-Year Event (ft)			
			Upstream Face of Bridge (FOB)	10-ft Upstream	Downstream Face of Bridge (FOB)	10-ft Downstream
Existing Bridge		31	202.5	202.9	201.5	201.3
Proposed Single Arch Culvert	1	18	203.5	203.7	202.2	201.9
Proposed Double Arch Culvert	2	36	202.1	202.1	201.9	201.8
Proposed 2x10ft Box Culvert	3	20	202.6	202.7	201.9	201.7
Proposed 2x12ft Box Culvert	4	24	202.3	202.4	201.9	201.8
Proposed Single Span Bridge	5	31	202.4	202.7	201.5	201.3

HYDROLOGY

Channel B at Waverly Road drains an approximate 2.9 square miles as shown on the Figure 2 . The mean annual precipitation of the watershed is approximately 17.3 inches/year (streamstats).

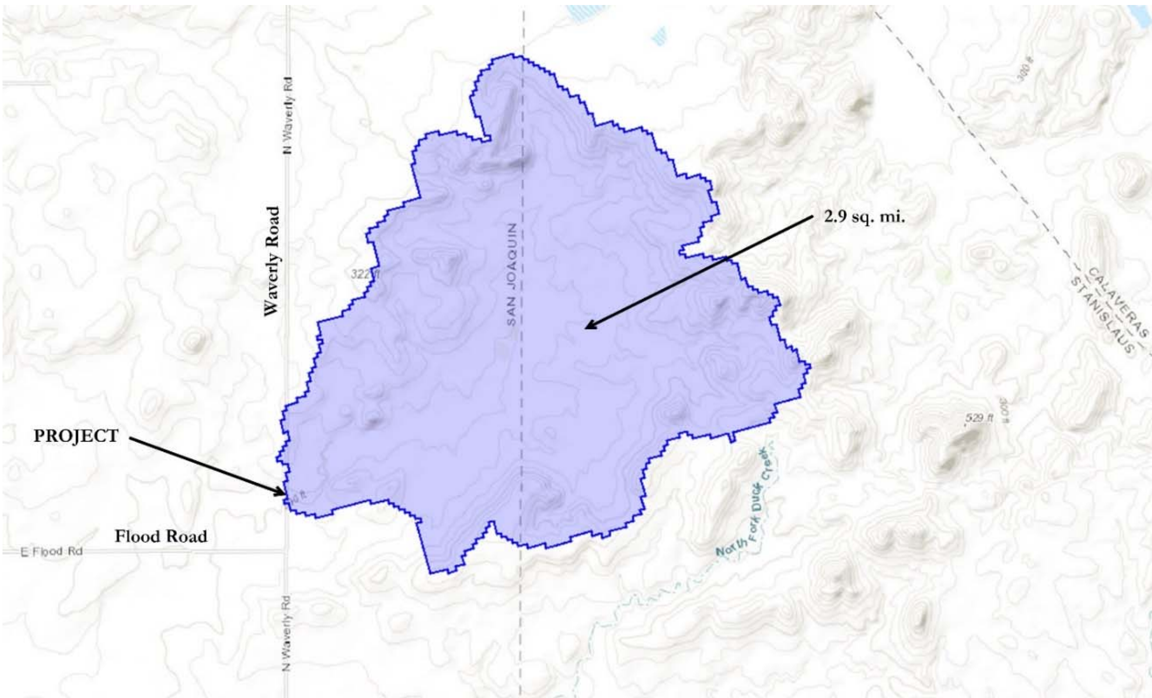


Figure 2: Hydrology Map

Two methods of analysis were performed to estimate the design discharges for the bridge hydraulic analyses:

- Regional Regression
- HEC-RAS 2D Point Precipitation Model (rain on grid)

Flow hydrographs were extracted from the results at the bridge location. The 50-year and 100-year hydrographs at the project used as the inflow for the bridge hydraulic analyses are shown in Figure 3.

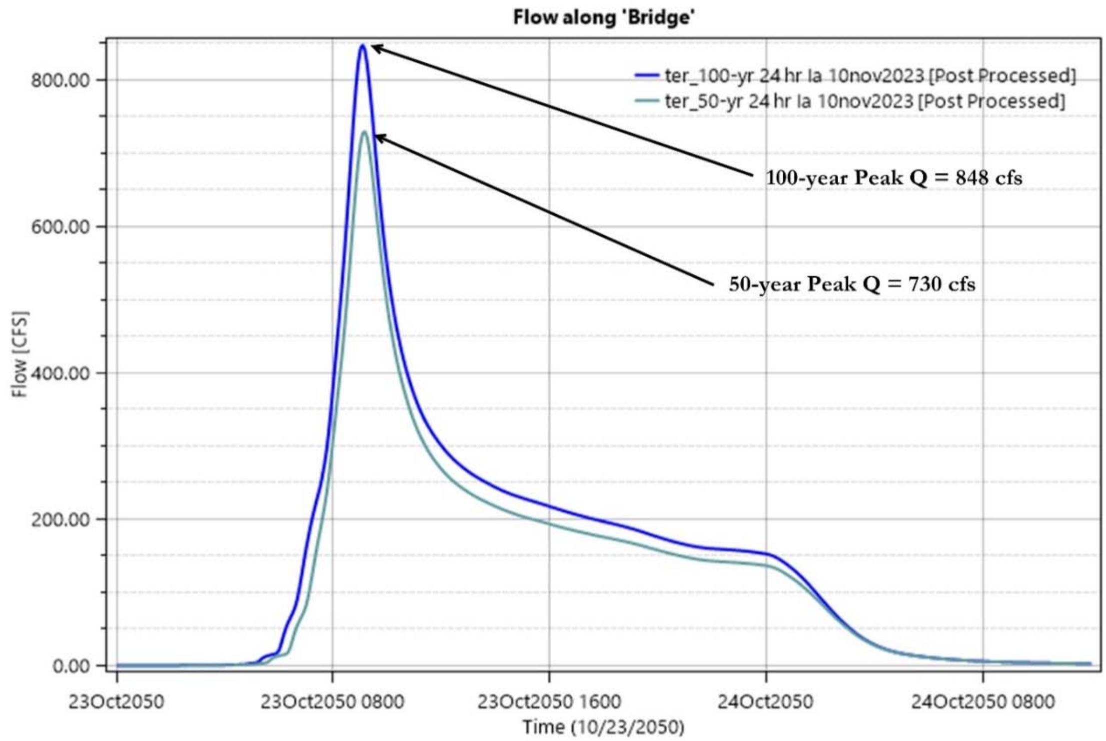


Figure 3: 50-year and 100-year Runoff Hydrographs at the Bridge Location

A summary of the results from the two hydrology methods is shown in Table 2.

Regional regression calculations typically underestimate discharges; therefore, results from the point precipitation method are more representative of the system since they use actual rainfall data compared to the regional regression results. These results were used for the hydraulic analyses of the bridge. Design discharges were obtained from a HEC-RAS rain-on-grid analysis of the project watershed.

Table 2. Regression and HEC-HMS analyses results

Method	Peak Discharge (cfs)	
	50-year	**100-year**
Regional Regression	382	440
HEC-RAS 2D Point Precipitation	730	848

A complete summary of the hydrology analysis is included in Appendix A.

HYDRAULICS

Hydraulic parameters (water surface elevations and velocity) were obtained using a 2D Unsteady Flow HEC-RAS (Hydraulic Engineering Center River Analysis System) version 6.3.1 model from the U.S. Army Corps of Engineers. Topography was obtained from REY (describe here). Cross-sections surveyed for the HEC-RAS model are shown in Figure 4.

Figure 4. Plan View of HEC-RAS mesh

The Manning "n" values used in the model were 0.030 for the channel bottom and .035 for the overbank areas. These are consistent with the USGS estimates (HH Barnes, 1967) and field reviews by Avila as shown in Figure 5.

Figure 5. The channel bottom is smooth with relatively low manning "n" value and the overbank areas are sparsely vegetated with relatively low manning "n" values.

The existing bridge is a two-span timber bridge that is 31 feet long as shown in Figure 6.

Figure 6: Looking east (upstream) at the existing bridge (1978 from BIRIS)

As shown in Figure 7, the existing 31-ft long bridge constricts the channel from 300-ft upstream to ~30-ft through the existing bridge.

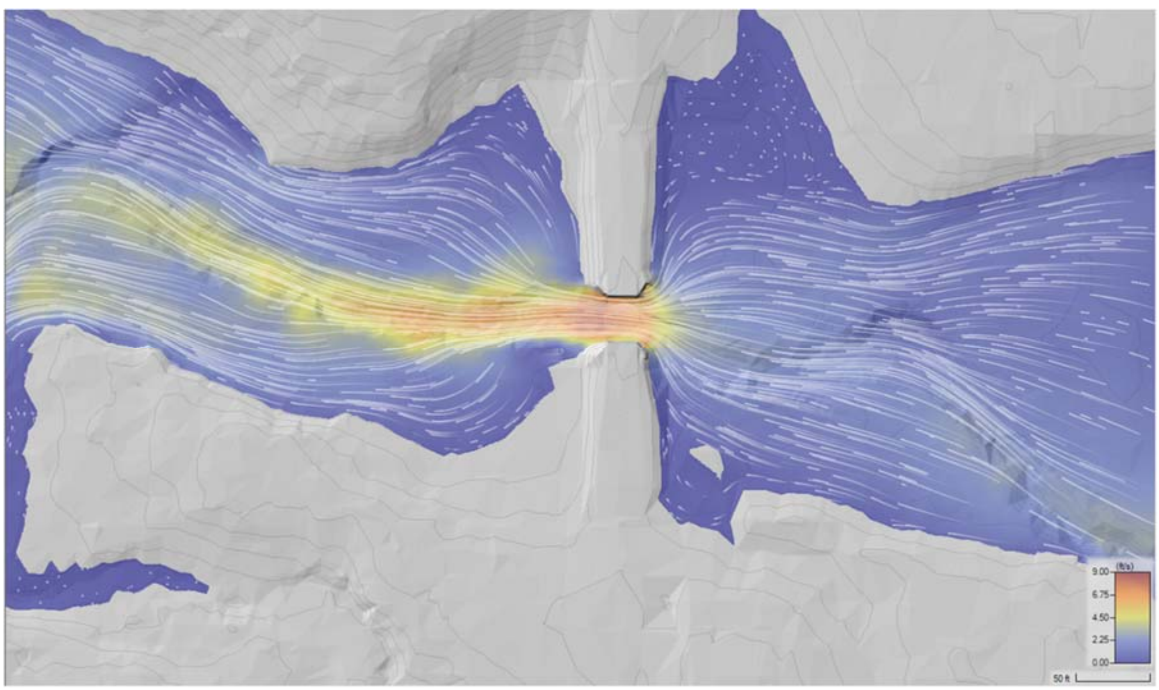


Figure 7: Existing Conditions Velocity and Water Extents

The constriction causes almost 2-ft of backwater as shown in profile in Figure 8 and plan view in Figure 9. The existing bridge is not under pressure flow as shown in Figure 10 and Figure 11.

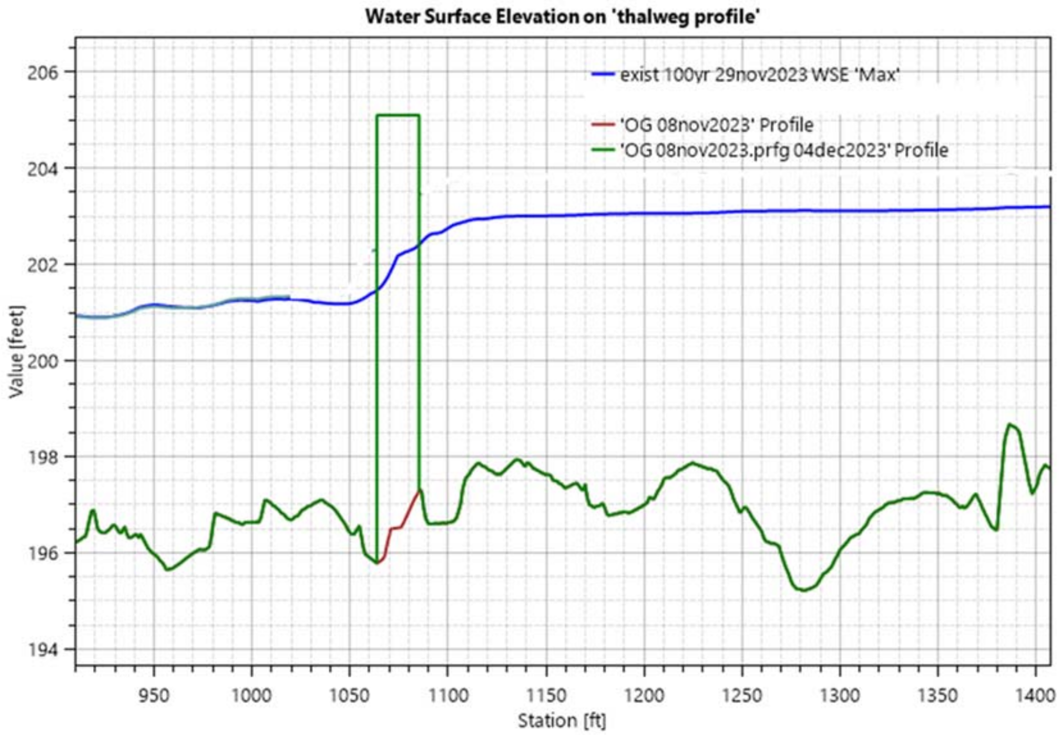


Figure 8: Water Surace Profile through the Existing Bridge

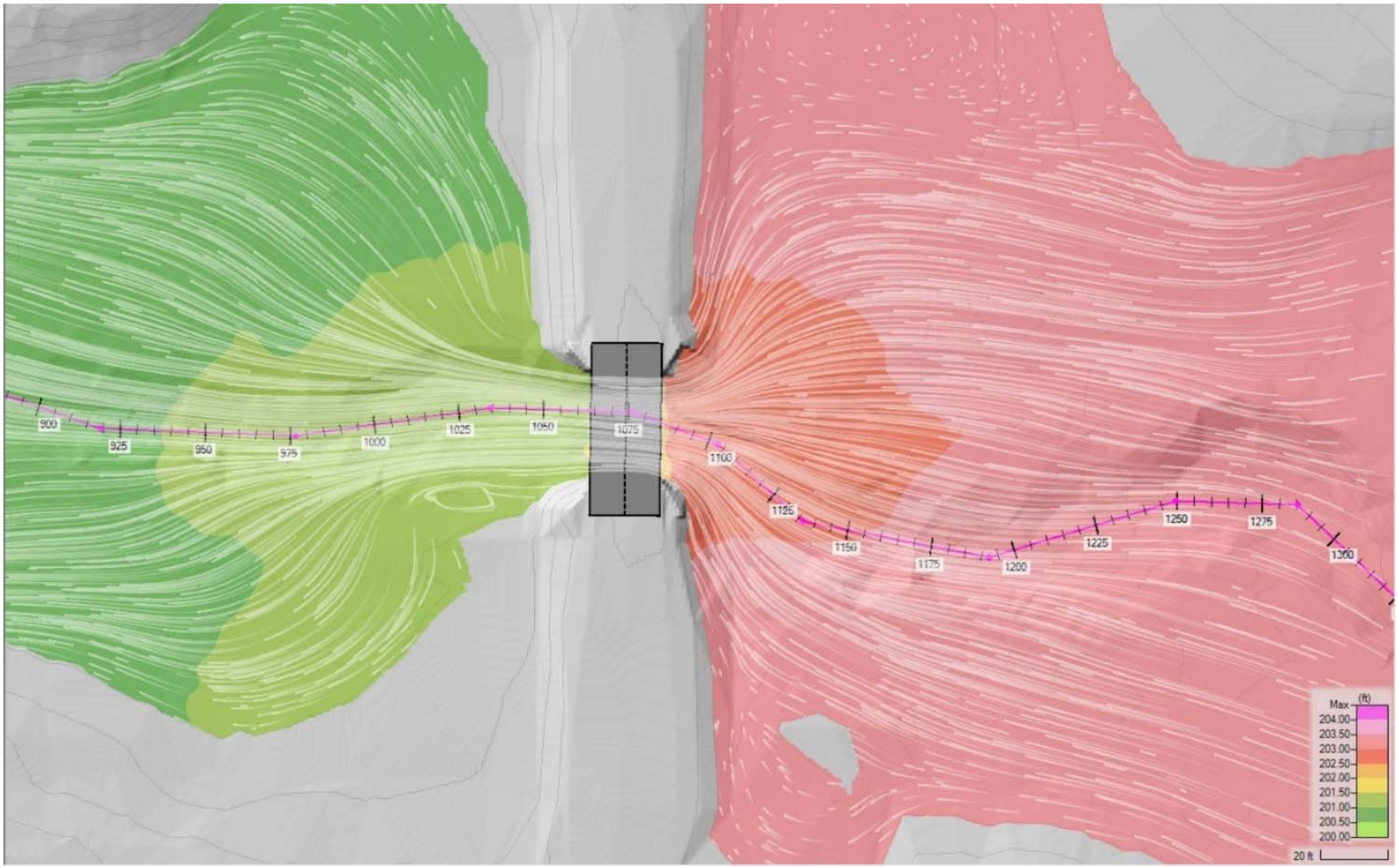


Figure 9: Existing Conditions Water Surface Elevation with Velocity Tracers

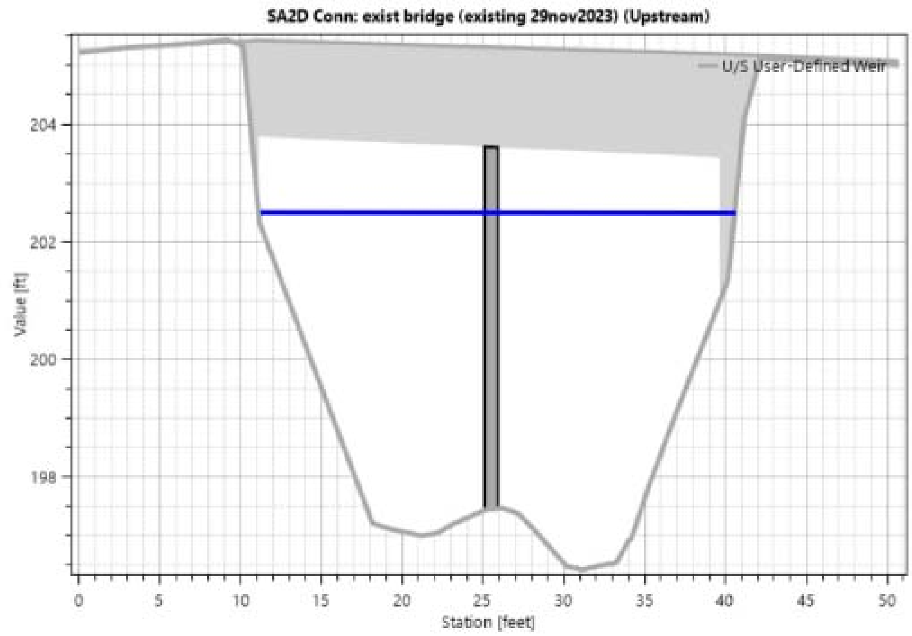


Figure 10: Existing Bridge Upstream

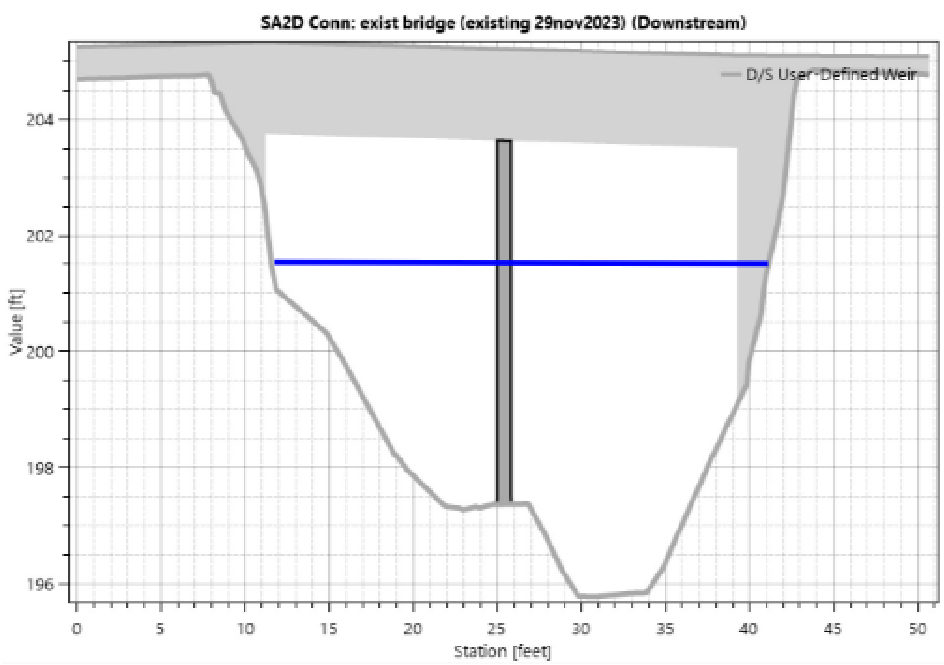


Figure 11: Existing Bridge Downstream

Alternative 1: 18 ft x 7 ft Single Arch Culvert

Alternative 1 is a relatively large 18 x 7 Single Arch Culvert as shown in Figure 12.

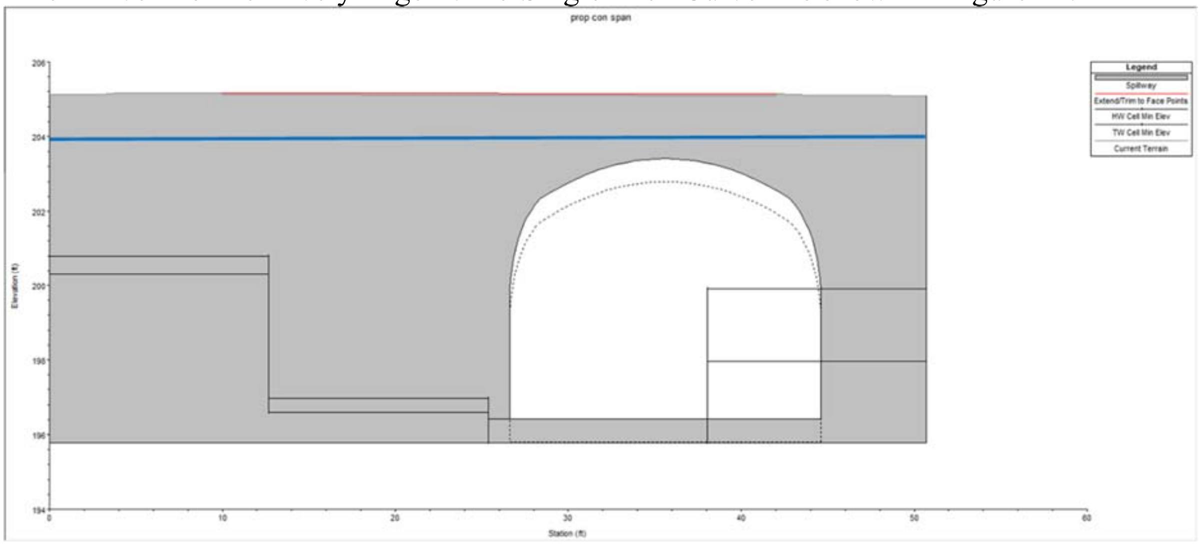


Figure 12: 18 x 7 Single Arch Culvert from HEC-RAS model

Alternative 1 causes an increase in water surface elevation upstream of approximately 0.8 ft from existing conditions as shown in Figure 13.

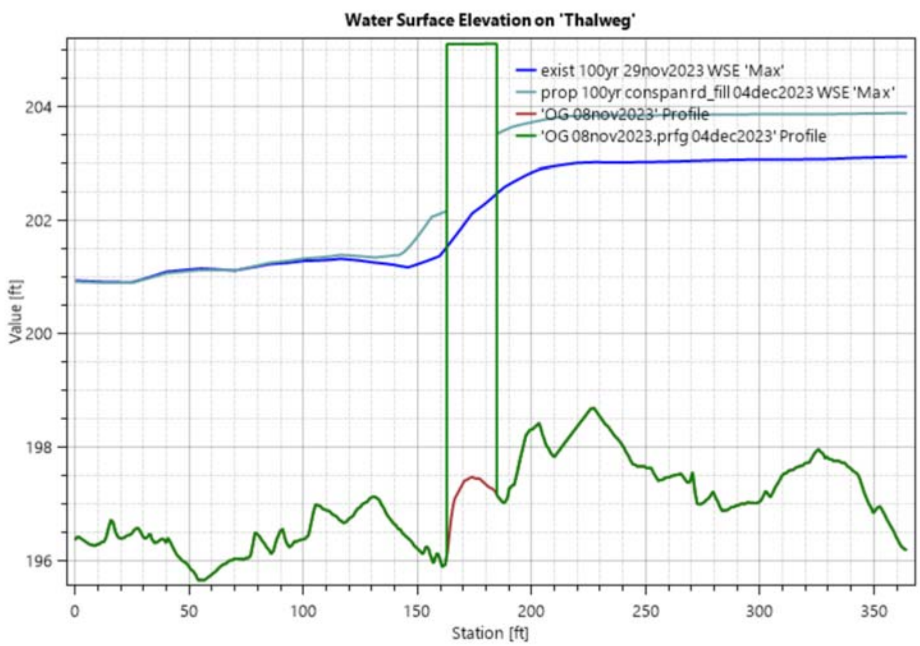


Figure 13: Water Surface profile for Existing (lower) and proposed (higher) through the Existing and Arch Culvert (proposed) structures

The cross sections show that the water surface elevation increases between existing (blue) and proposed (turquoise) by over 1-ft at the upstream (Figure 14) side and by about 0.7-ft at the downstream (Figure 15) side of the bridge.

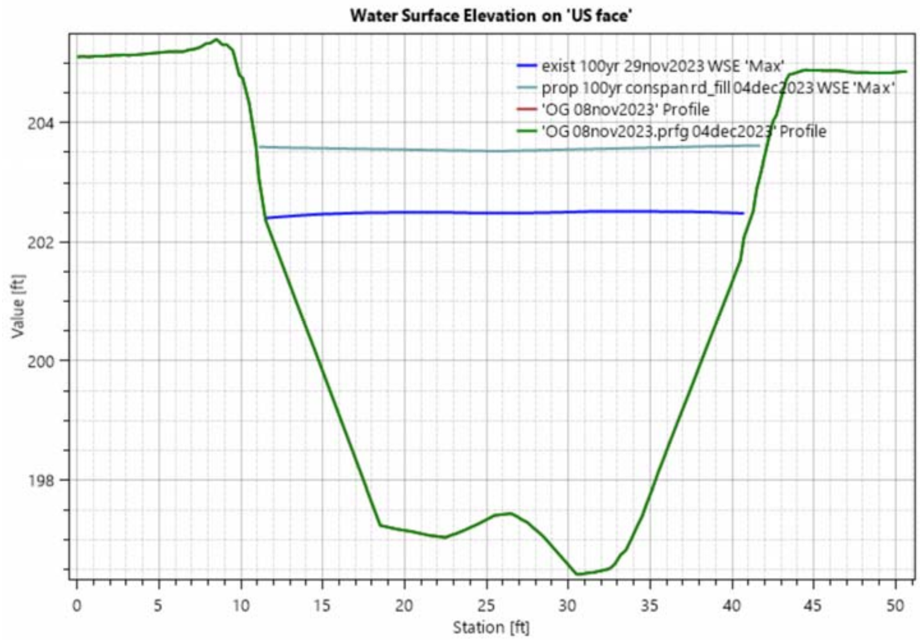


Figure 14: Existing and Proposed Water Surface Elevations Upstream of the Structure

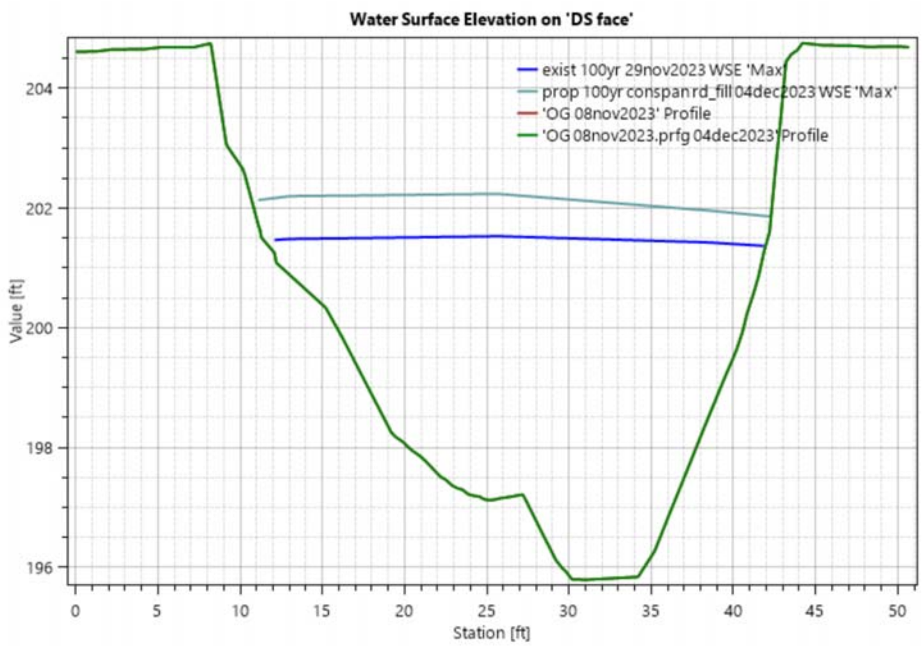


Figure 15: Existing and Proposed Water Surface Elevations Downstream of the Structure

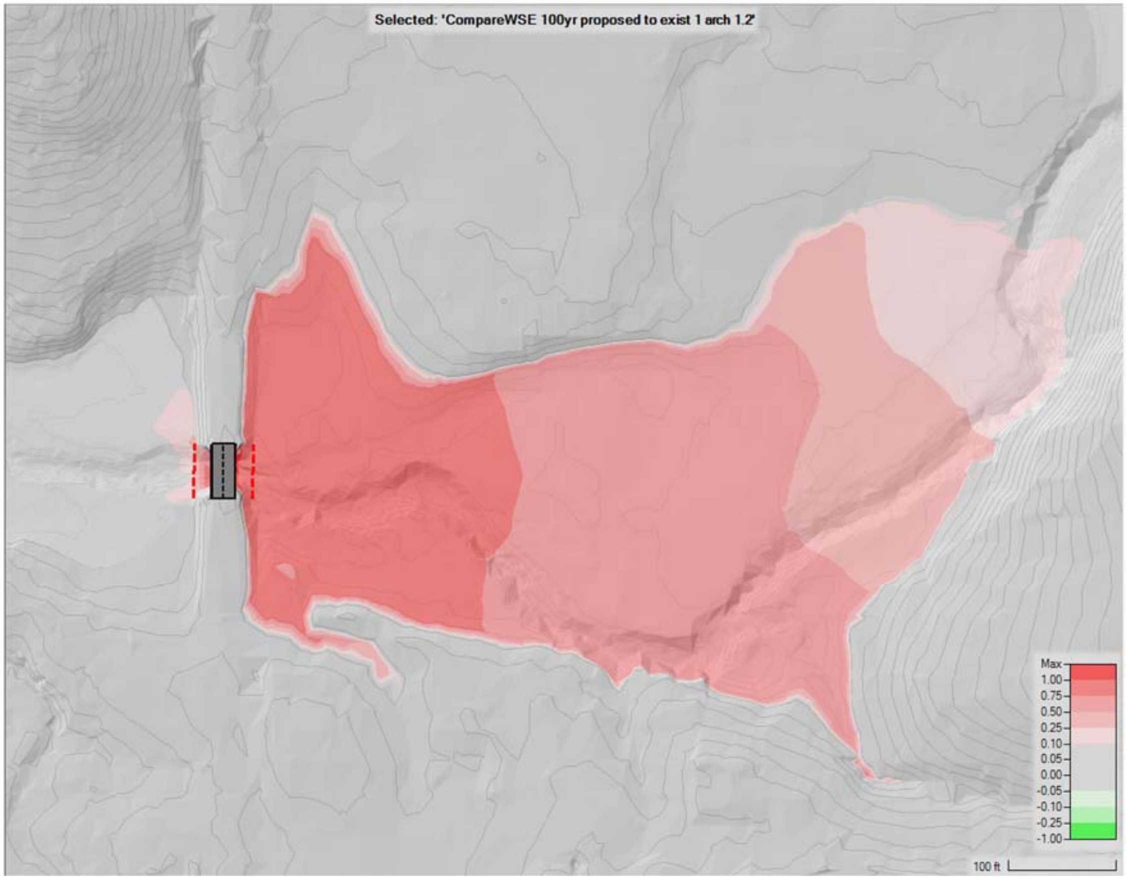


Figure 16: Water Surface elevation Comparison between existing and proposed conditions

This water surface elevation increase extends almost 1,000 feet upstream as shown in Figure 16.

Alternative 2: 18 ft x 7 ft Double Arch Culvert

Alternative 2 doubled the size of Alternative 1 to model two 18ft x 7ft Arch Culverts as shown in Figure 17.

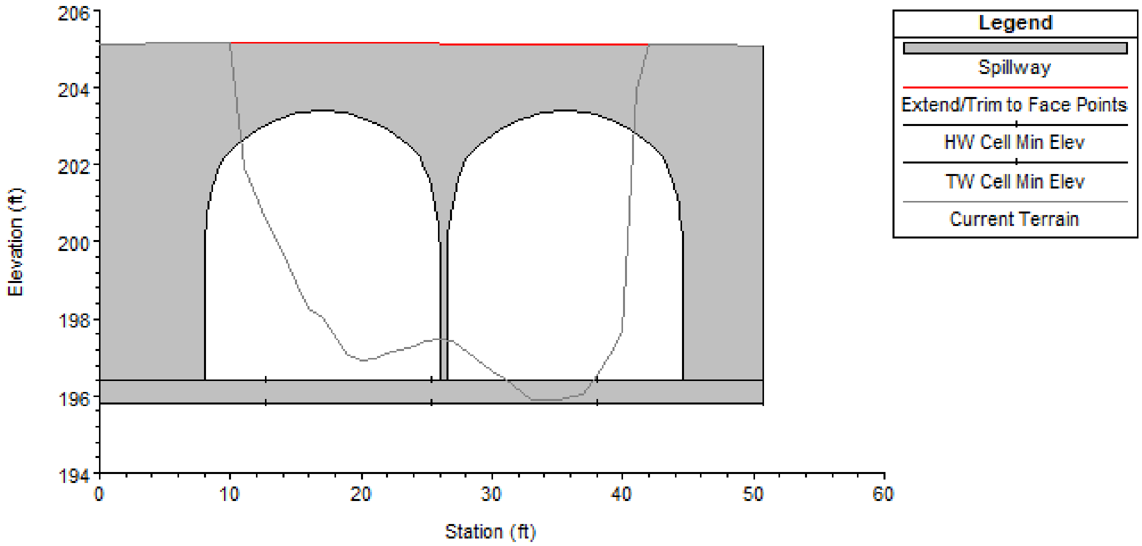


Figure 17: Two 18 x 7 Arch Culverts from HEC-RAS model

Alternative 2 causes a decrease in water surface elevation upstream of approximately 0.73 ft from existing conditions as shown in Figure 18.

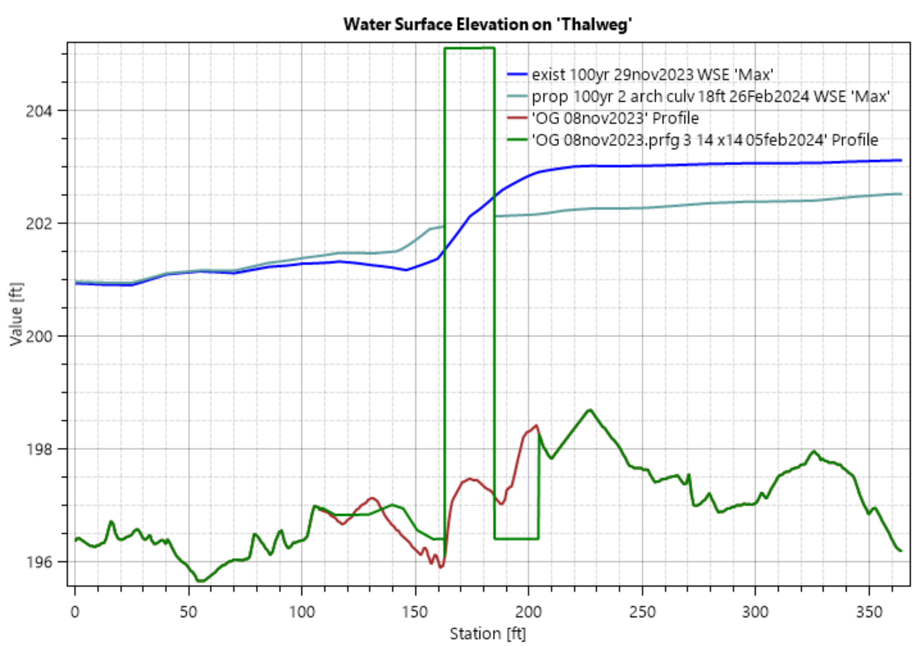


Figure 18: Water Surface profile for Existing (lower) and proposed (higher) through the Existing and Arch Culvert (proposed) structures

Cross sections show that the water surface elevation decreases between existing (blue) and proposed (turquoise) by about 0.37 ft at the upstream (Figure 19) face and increases the water surface elevation by about 0.43 ft at the downstream (Figure 20) face of the bridge.

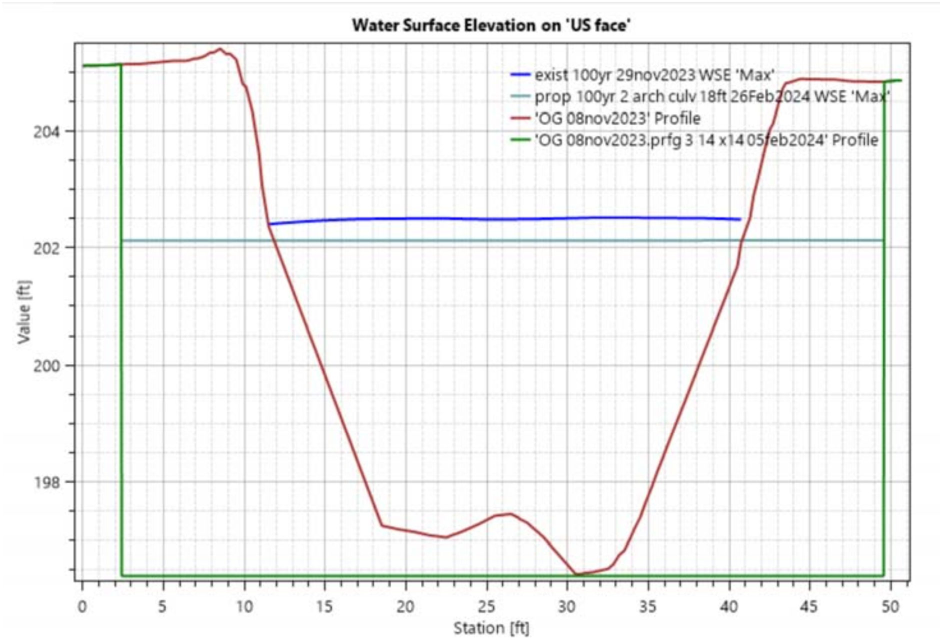


Figure 19: Existing and Proposed Water Surface Elevations Upstream of the Structure

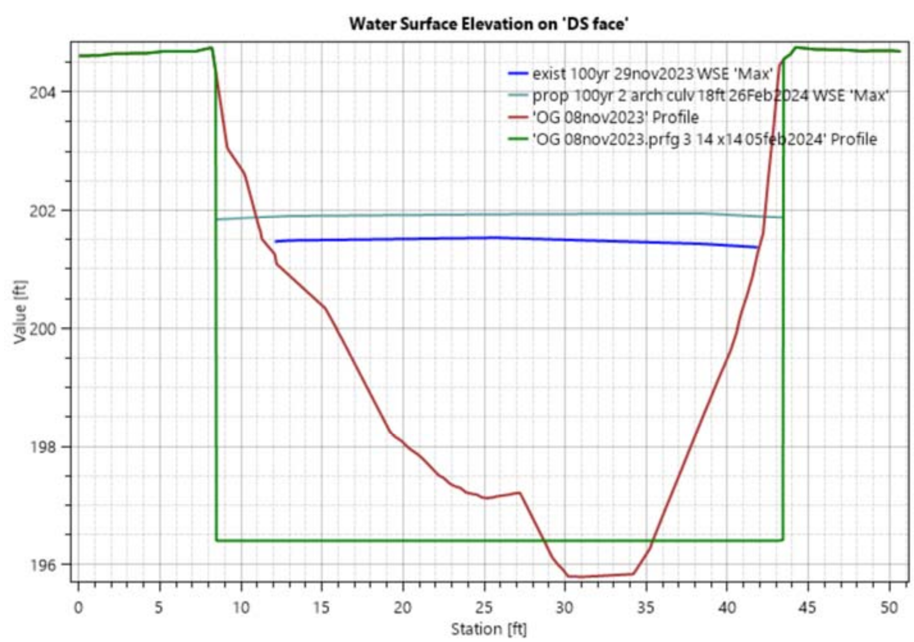


Figure 20: Existing and Proposed Water Surface Elevations Downstream of the Structure

This water surface elevation decrease as large as 0.7 ft extends about 800 ft upstream as shown in Figure 21. Just downstream of the proposed structure, the water surface elevation of the proposed condition increases by as much as 0.6 ft compared to existing conditions. This water surface elevation increase extends approximately 55 ft downstream of the culverts.

Figure 21: Water Surface elevation Comparison between existing and proposed conditions

Alternative 3: 10 ft x 7 ft Double Box Culvert

Alternative 3 is a series of double 10ft x 7ft box culverts as shown in Figure 22.

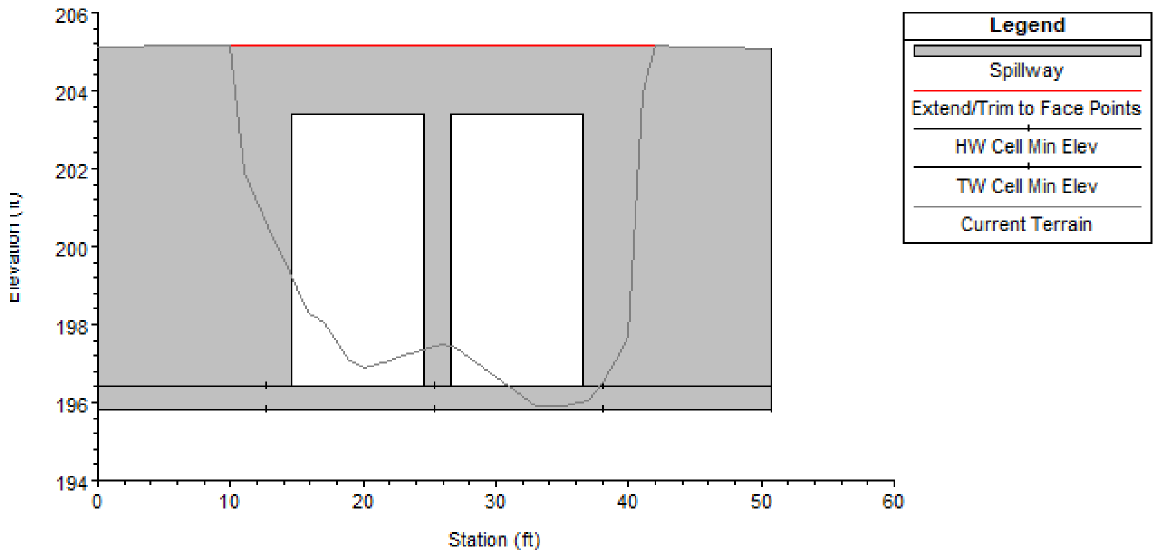


Figure 22: Two 10 x 7 Box Culverts from HEC-RAS model with entrance and exit loss coefficients of 0.2 and 0, respectively

The upstream water surface profile decreases by approximately 0.25 ft from existing conditions as shown in Figure 23.

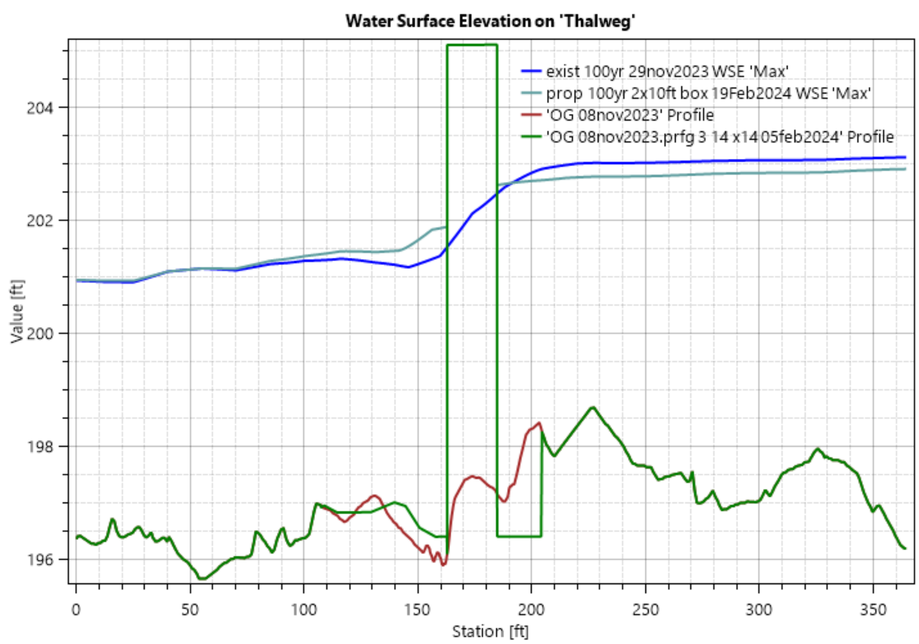


Figure 23: Water Surface profile for Existing and proposed through the Existing and box culvert (proposed) structures

Cross sections just upstream of the culvert system inlet show that the water surface elevation increases between existing (blue) and proposed (turquoise) by about 0.13 ft at the upstream (Figure 24) side and by about 0.37 ft at the downstream (Figure 25) side of the bridge.

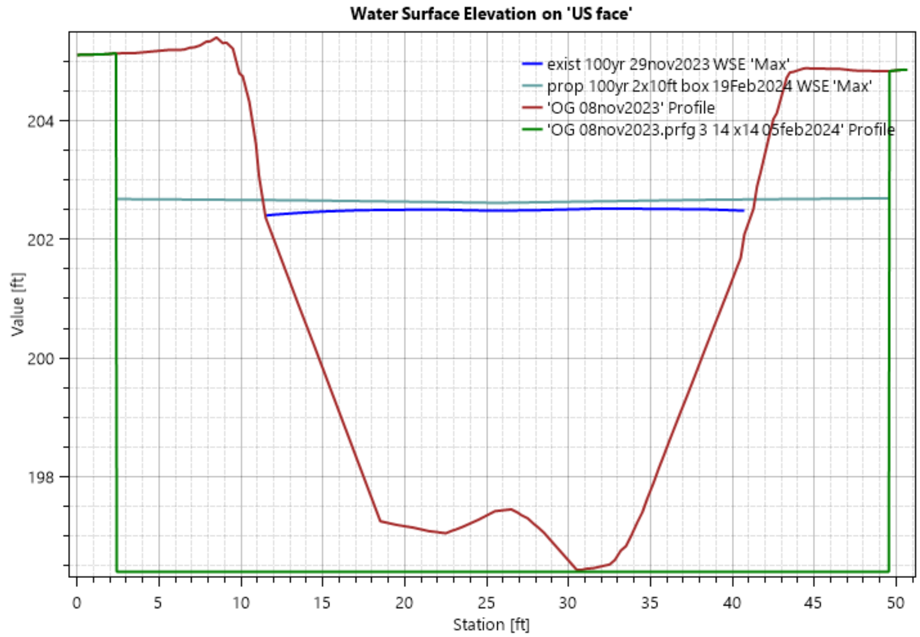


Figure 24: Existing and Proposed Water Surface Elevations Upstream of the Structure

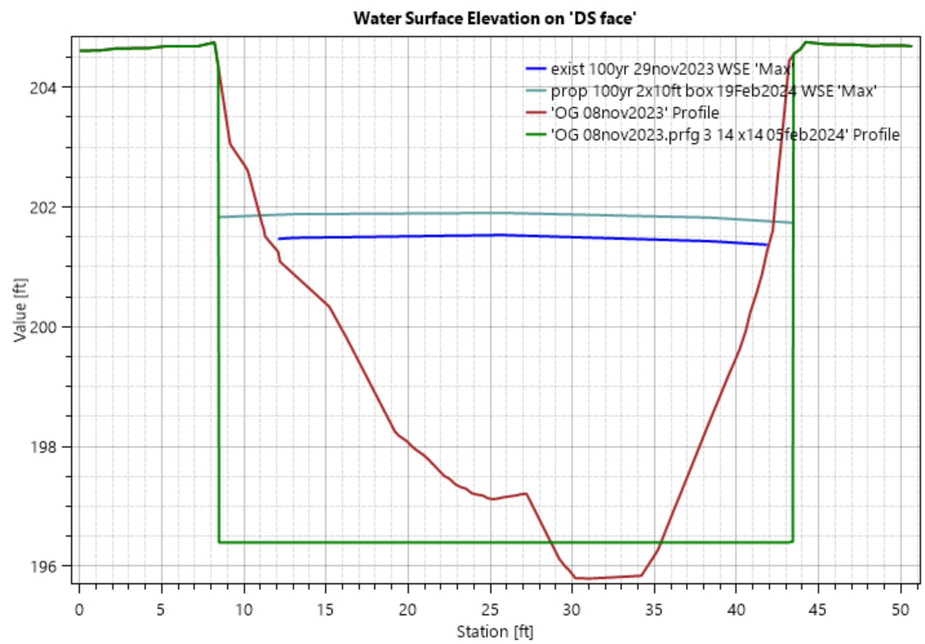


Figure 25: Existing and Proposed Water Surface Elevations Downstream of the Structure

The maximum upstream water surface elevation of proposed condition is reduced by as much as 0.25 ft relative to the existing water surface. This relative reduction in maximum water surface elevation extends approximately 720 ft upstream.

However, downstream of the proposed structure, the water surface elevation of the proposed conditions increases by as much as 0.5 ft. the increase in water surface elevation extends approximately 60 ft downstream of the culvert.

Figure 26: Water Surface elevation Comparison between existing and proposed conditions

Alternative 4: 12 ft x 7 ft Double Box Culvert

Alternative 4 is a series of double 12ft x 7ft box culverts as shown in Figure 27.

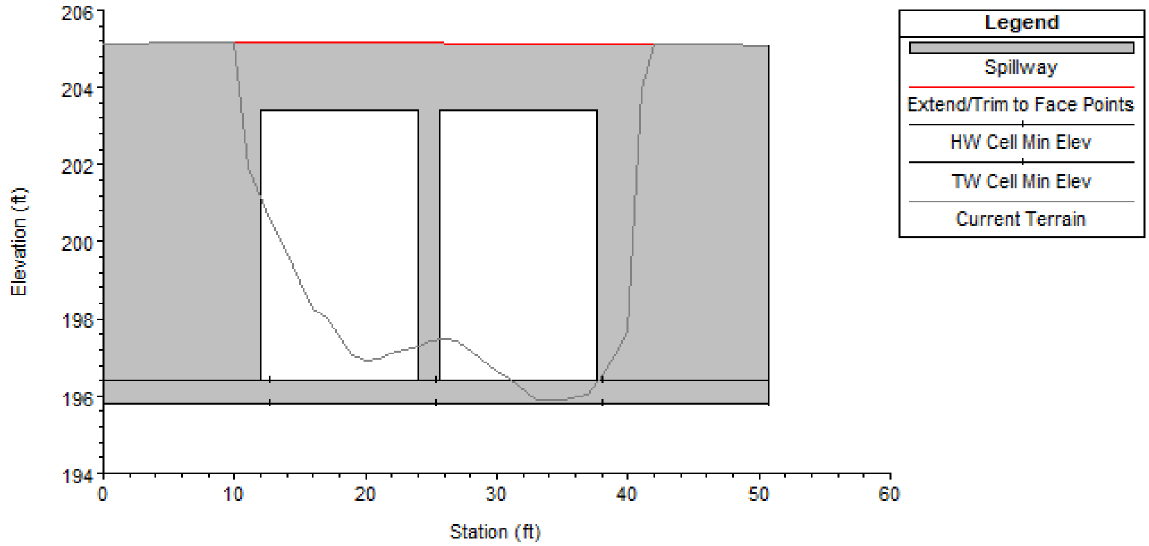


Figure 27: Two 12x7 Box Culverts from HEC-RAS model

The upstream water surface profile decreases approximately 0.5 ft from existing conditions as shown in Figure 28.

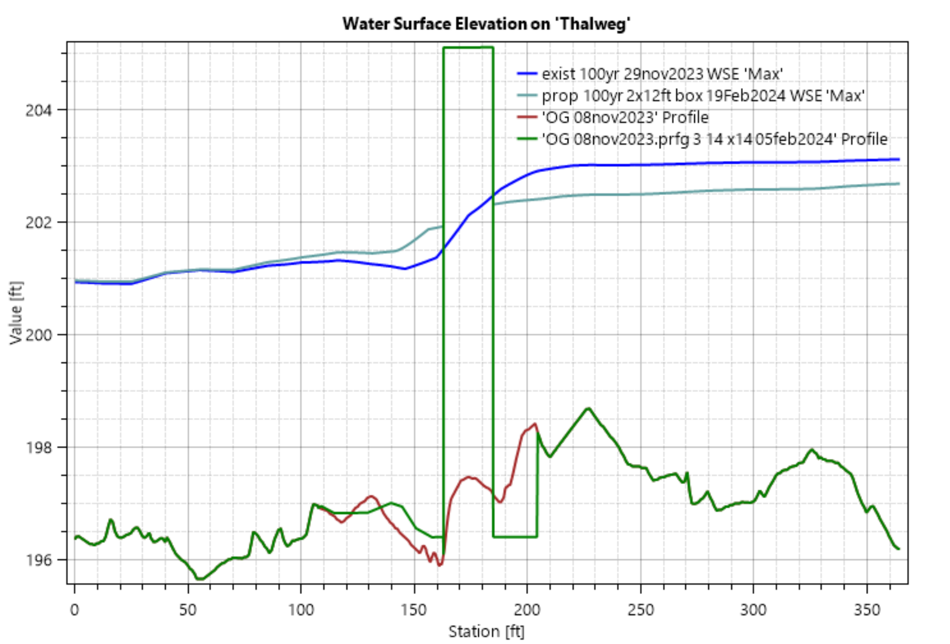


Figure 28: Water Surface Profile through existing and box culvert (proposed) structures

Cross sections demonstrate that the water surface elevation decreases between existing (blue) and proposed (turquoise) by approximately 0.18 ft at the upstream face and increases the water surface elevation by 0.41 ft on the downstream face.

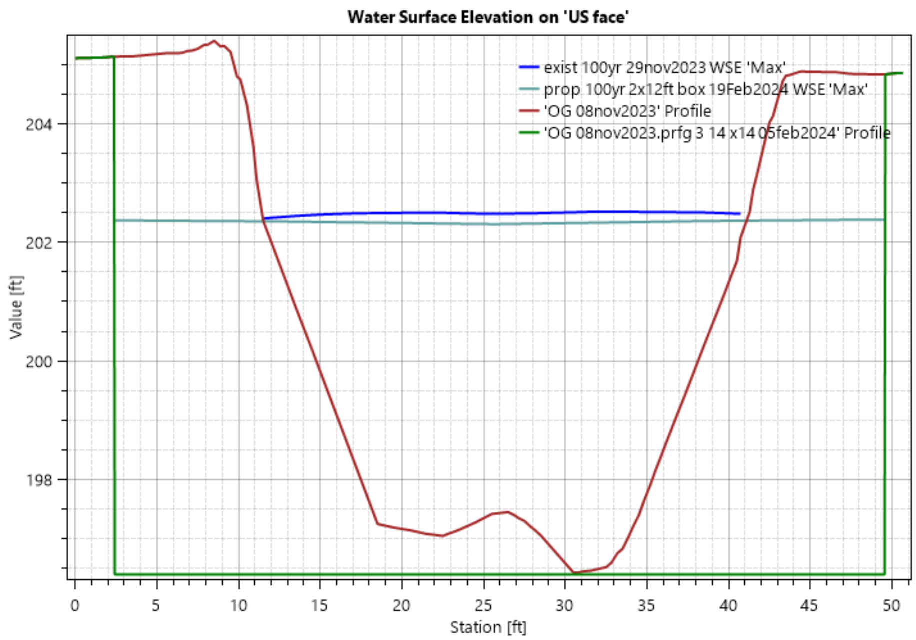


Figure 29: Existing and Proposed Water Surface Elevations Upstream of the Structure

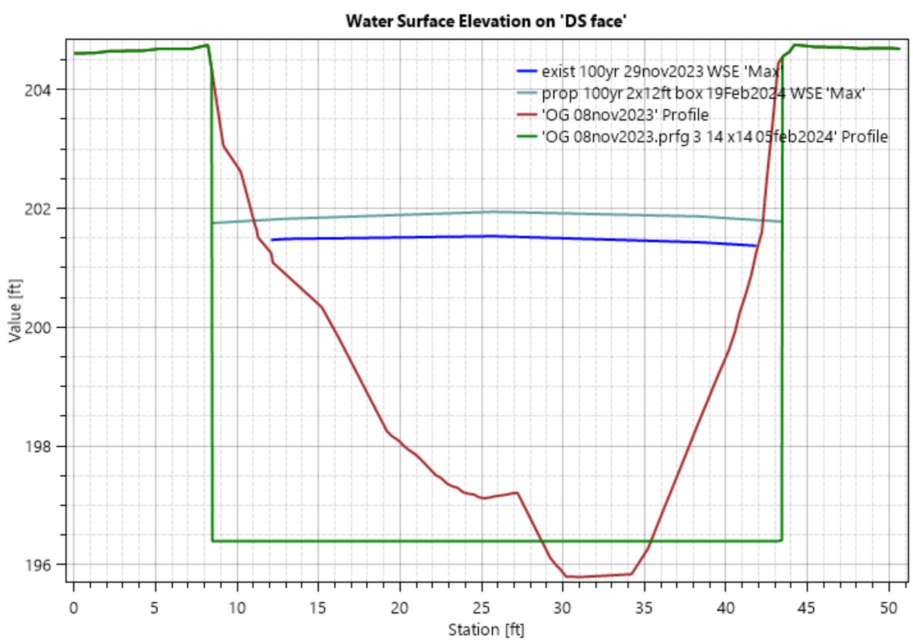


Figure 30: Existing and Proposed Water Surface Elevations Downstream of the Structure

This water surface elevation decrease extends almost 790 feet upstream, where the maximum decrease in WSE is about 0.5 ft as shown in Figure 31. The increase in water surface elevation of as much as 0.5 ft extends approximately 55 ft downstream.

Figure 31: Water Surface Elevation Comparison between Existing and Proposed Conditions

Alternative 5: Single Span Bridge

Alternative 5 is a Single Span Bridge as shown in Figure 32.

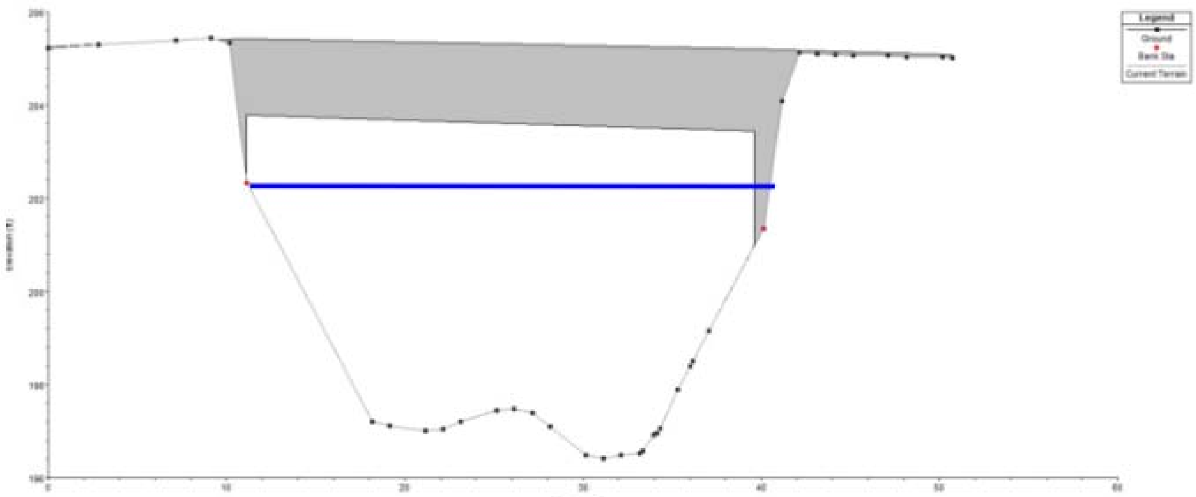


Figure 32: Single Span Bridge

The upstream water surface profile drops in elevation by about 0.1-ft from existing conditions resulting from removing the pier from the existing bridge design as shown in Figure 33.

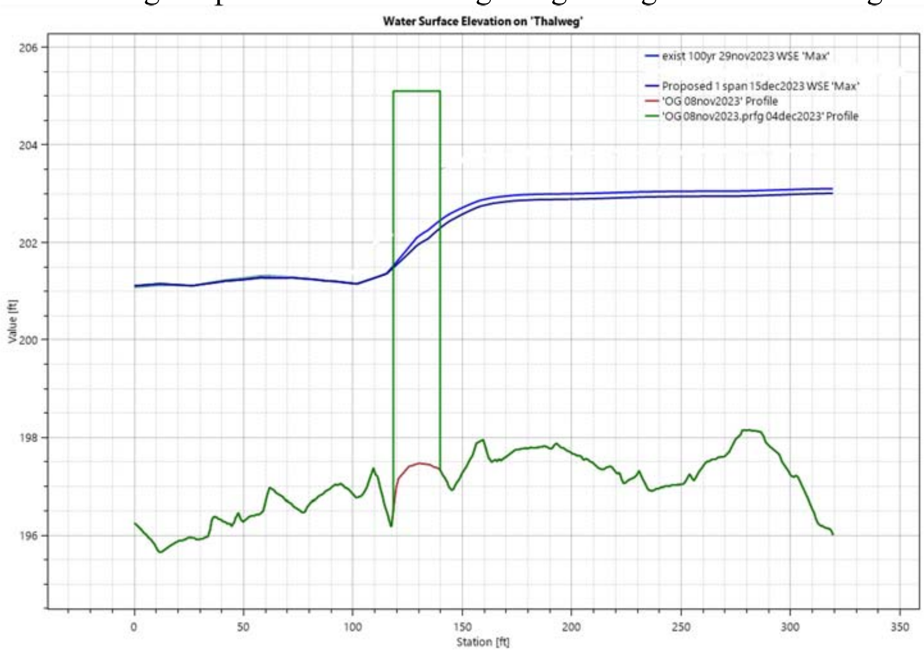


Figure 33: Water Surface profile for Existing (higher) and proposed (lower) through the Existing and Single Span Bridge (proposed) structures

Cross sections show that the water surface elevation decreases between existing (blue) and proposed (darker blue) by about 0.2-ft at the upstream (Figure 34) side and by less than 0.1-ft at the downstream (Figure 35) side of the bridge.

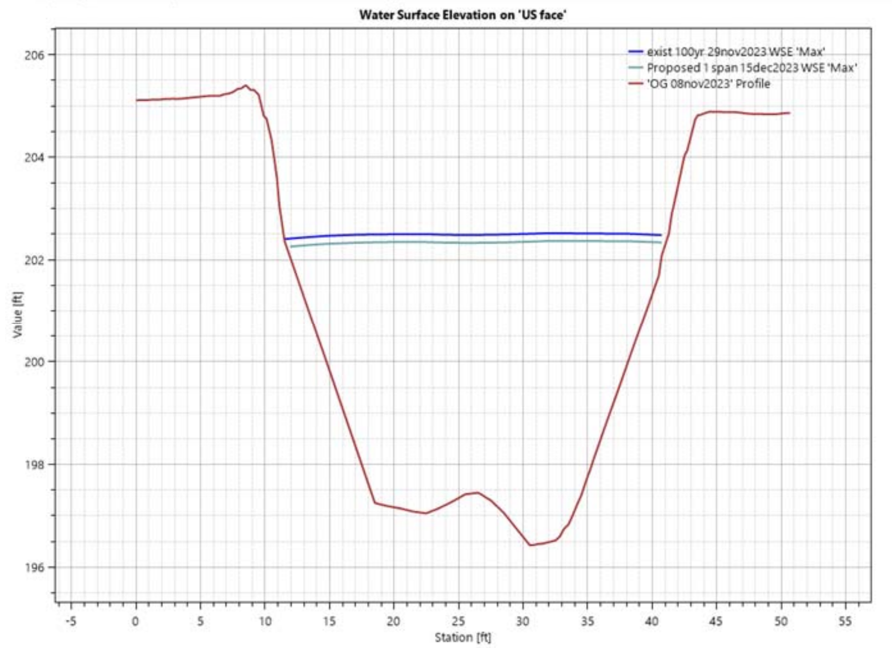


Figure 34: Existing and Proposed Water Surface Elevations Upstream of the Structure

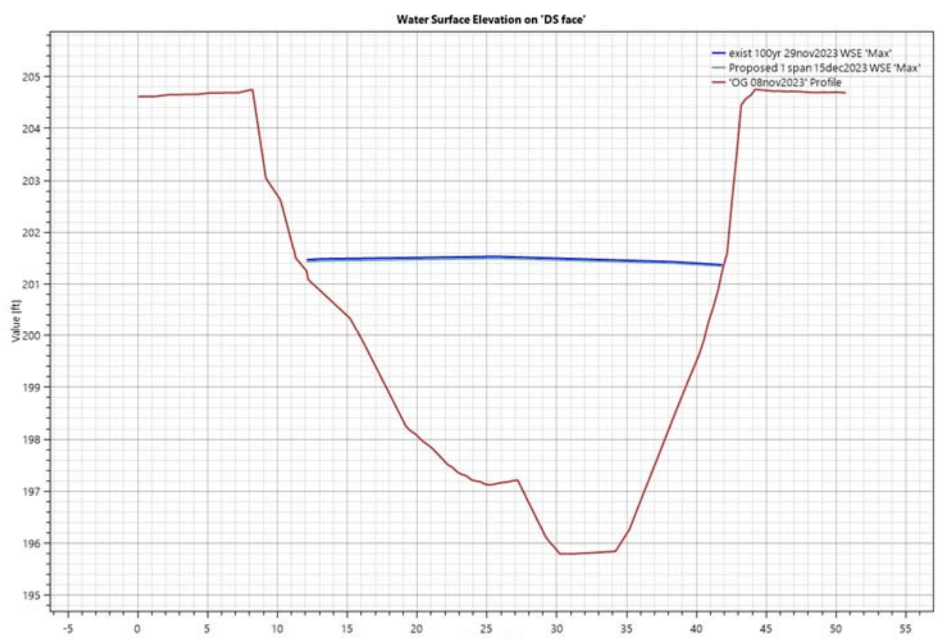


Figure 35: Existing and Proposed Water Surface Elevations Downstream of the Structure

This water surface elevation decrease extends almost 500 feet upstream as shown in Figure 36.

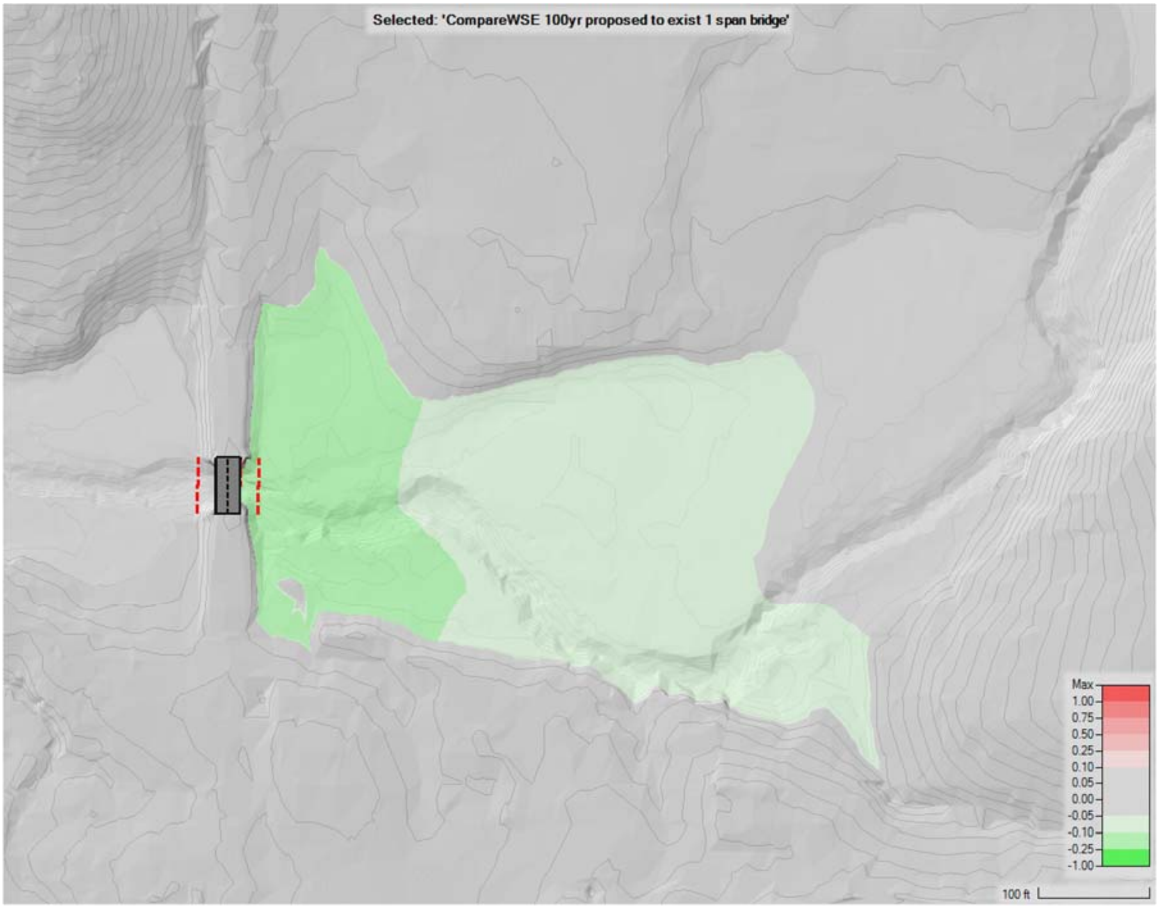


Figure 36: Water Surface elevation Comparison between existing and proposed conditions

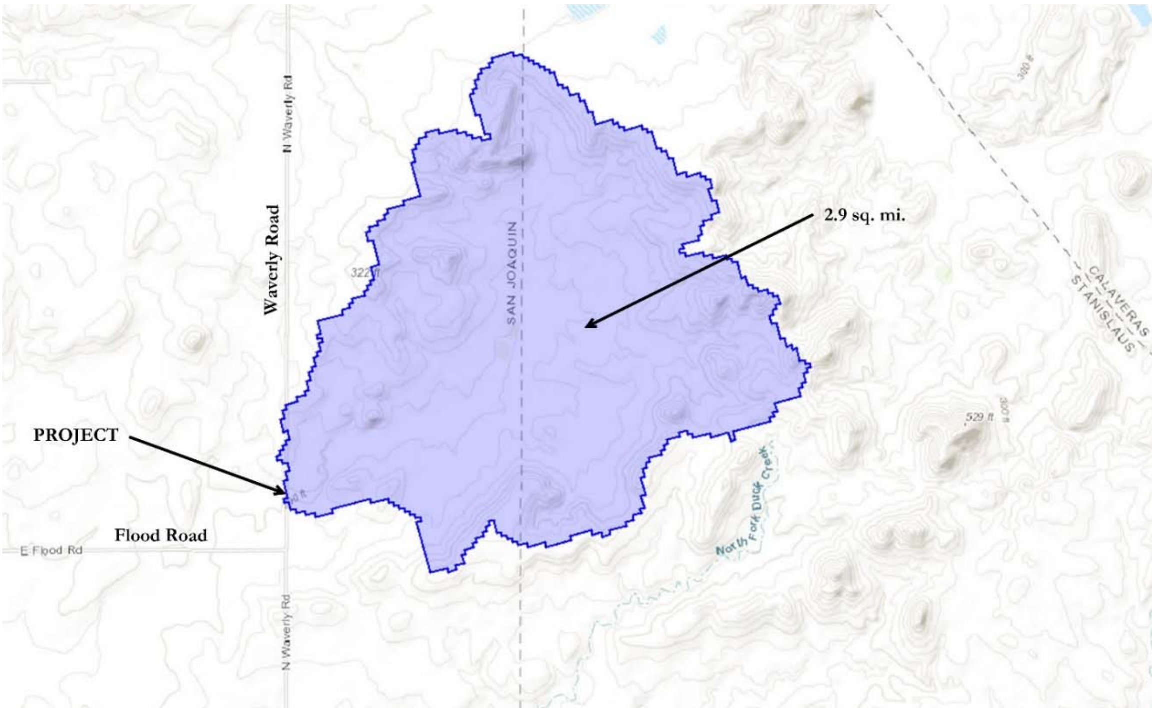
RECOMMENDATIONS

The current analysis demonstrates that culvert Alternative 1 is under-sized showing a significant increase in water surface elevation upstream of the bridge. Alternatives 2 through 4, however, show decreases in water surface elevation upstream and only small increases in water surface elevations downstream. All of the downstream impacts are less than 60-ft downstream of the downstream face of the bridge and do not affect any insurable structures. If a small and limited increase in water surface elevation is acceptable to San Joaquin County, Alternatives 2-4 are viable alternatives.

Because the proposed bridge (Alternative 5) mimics the drawdown curve from existing conditions, this “in-kind” bridge replacement, shows minimal water surface elevation changes at either the upstream or downstream faces of the proposed structure. Additionally, Alternative 5 is the only option demonstrating no rise in water surface elevation outside the San Joaquin County’s right of way (Figure 36). If no water surface elevation rise is allowed by San Joaquin County, Alternative 5 is the recommended alternative.

Appendix A – Regional Regression and HEC-RAS Point Precipitation Hydrology Analysis

Channel B at Waverly Road drains an approximate 2.9 square miles as shown on the Hydrology Map. The mean annual precipitation of the watershed is approximately 17.3 inches/year (streamstats).



Hydrology Map

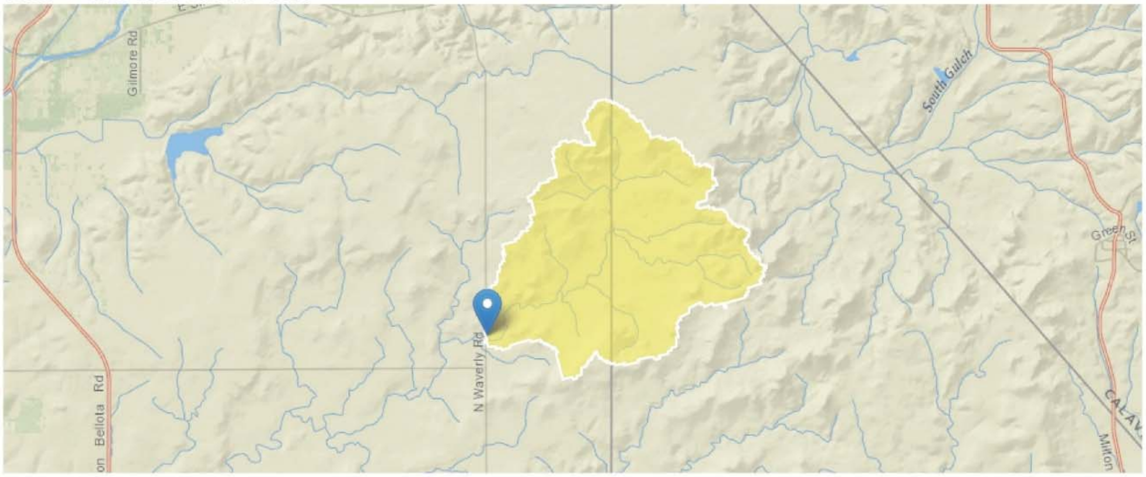
Two methods of analysis were performed to estimate the design discharges for the bridge hydraulic analyses:

- Regional Regression
- HEC-RAS 2D Point Precipitation Model (rain on grid)

METHOD 1: REGIONAL REGRESSION
U.S. Geological Survey website application Streamstats (water.usgs.gov/osw/streamstats/) was used to obtain the basin characteristics and flow statistics for both the project and tributary watersheds. Flow characteristics are based on Methods for Determining Magnitude and Frequency of Floods in California, Based on Data through Water Year 2006 (USGS SIR 2012-5113).
The streamstats report for the project is shown below.

StreamStats Report

Region ID: CA
Workspace ID: CA20231023203544080000
Clicked Point (Latitude, Longitude): 38.02097, -120.94475
Time: 2023-10-23 13:36:07 -0700



Collapse All

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
BASINPERIM	Perimeter of the drainage basin as defined in SIR 2004-5262	10.5	miles
BSLDEM30M	Mean basin slope computed from 30 m DEM	5.81	percent
CENTROXA83	X coordinate of the centroid, in NAD_1983_Albers, meters	-2142385.6	meters
CENTROYA83	Basin centroid horizontal (y) location in NAD 1983 Albers	1948871	meters
DRNAREA	Area that drains to a point on a stream	2.9	square miles
EL6000	Percent of area above 6000 ft	0	percent
ELEV	Mean Basin Elevation	275	feet
ELEVMAX	Maximum basin elevation	431	feet
FOREST	Percentage of area covered by forest	0	percent
JANMAXTMP	Mean Maximum January Temperature	53.79	degrees F
JANMINTMP	Mean Minimum January Temperature	36.25	degrees F
LAKEAREA	Percentage of Lakes and Ponds	0.48	percent
LC11DEV	Percentage of developed (urban) land from NLCD 2011 classes 21-24	1.7	percent
LC11IMP	Average percentage of impervious area determined from NLCD 2011 impervious dataset	0.4	percent
LFPLENGTH	Length of longest flow path	3	miles
MINBELEV	Minimum basin elevation	202	feet
OUTLETELEV	Elevation of the stream outlet in feet above NAVD88	203	feet

Parameter Code	Parameter Description	Value	Unit
PRECIP	Mean Annual Precipitation	17.3	inches
RELIEF	Maximum - minimum elevation	229	feet
RELRELF	Basin relief divided by basin perimeter	21.8	feet per mi

Peak-Flow Statistics

Peak-Flow Statistics Parameters [2012 5113 Region 3 Sierra Nevada]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	2.9	square miles	0.07	2000
ELEV	Mean Basin Elevation	275	feet	90	11000
PRECIP	Mean Annual Precipitation	17.3	inches	15	100

Peak-Flow Statistics Flow Report [2012 5113 Region 3 Sierra Nevada]

PIl: Prediction Interval-Lower, PIu: Prediction Interval-Upper, ASEp: Average Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PIl	PIu	ASEp
50-percent AEP flood	61.3	ft^3/s	19.7	191	74.4
20-percent AEP flood	161	ft^3/s	66.9	388	54.4
10-percent AEP flood	235	ft^3/s	102	544	51.5
4-percent AEP flood	320	ft^3/s	137	747	52.3
2-percent AEP flood	382	ft^3/s	158	926	54.6
1-percent AEP flood	440	ft^3/s	173	1120	58
0.5-percent AEP flood	492	ft^3/s	184	1310	61.5
0.2-percent AEP flood	558	ft^3/s	193	1610	67.3

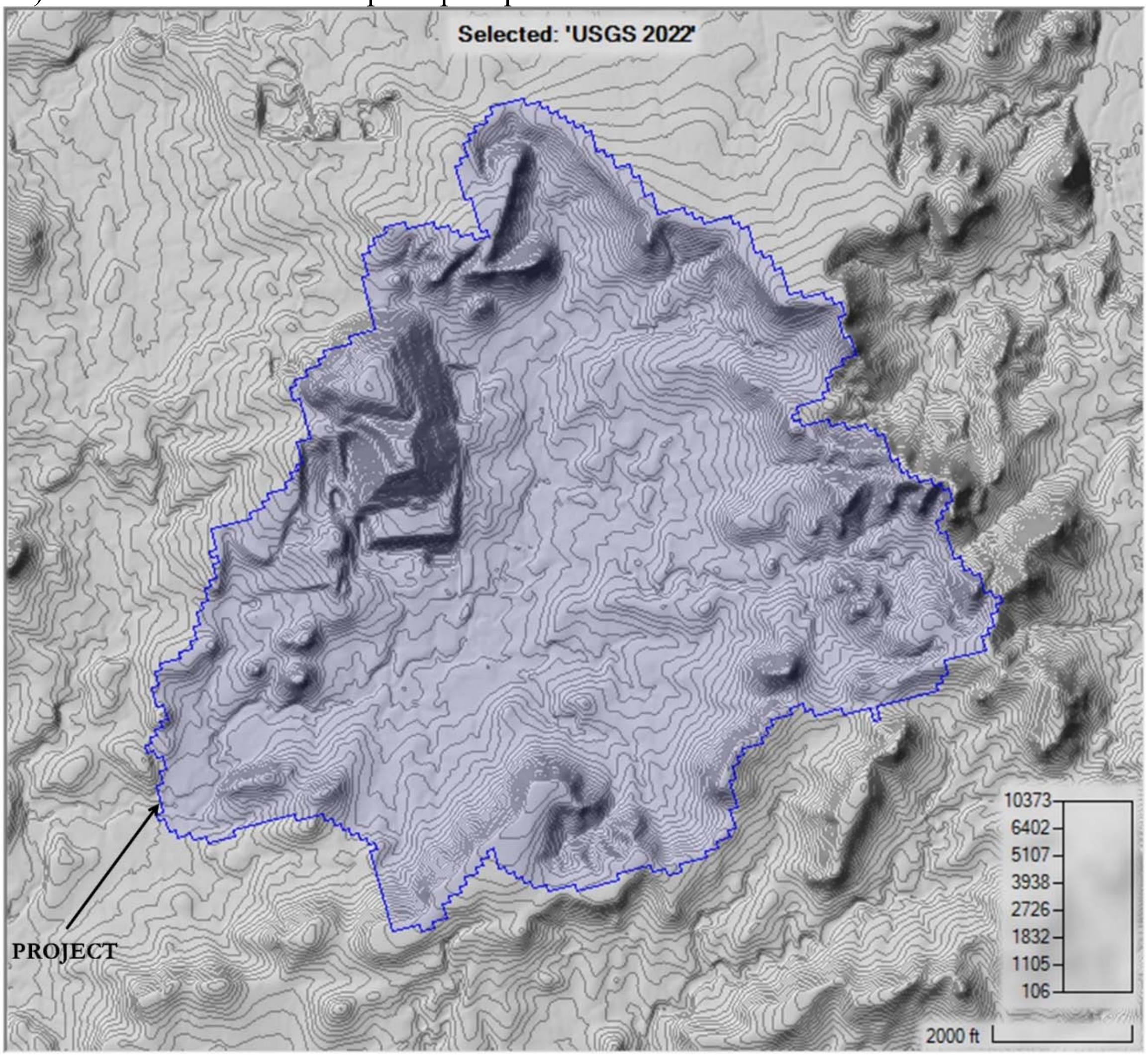
Peak-Flow Statistics Citations

Gotvald, A.J., Barth, N.A., Veilleux, A.G., and Parrett, Charles,2012, Methods for determining magnitude and frequency of floods in California, based on data through water year 2006: U.S. Geological Survey Scientific Investigations Report 2012–5113, 38 p., 1 pl. (http://pubs.usgs.gov/sir/2012/5113/)

Application Version: 4.18.0
StreamStats Services Version: 1.2.22
NSS Services Version: 2.2.1

METHOD 2: HEC-RAS 2D POINT PRECIPITATION MODEL

Design runoff hydrographs were developed by creating a 2D HEC-RAS model of the entire project watershed. A terrain was created from a USGS 1/3 arc-second Digital Elevation Model (DEM). The terrain used for the point precipitation model is shown below.



Terrain used for HEC-RAS Point Precipitation Model

A 2D flow area was created that was offset from the watershed boundary to make sure all runoff was captured within the watershed. A 50-ft grid was used for the 2D flow area. Boundary condition lines were created that completely surround the 2D flow area to release runoff from outside the project watershed which would otherwise accumulate along the edges of the 2D flow area. Precipitation was used as the boundary condition that was applied to the entire 2D flow area. For this analysis, a 24-hour event was simulated.

Precipitation data was obtained from the NOAA's National Weather Service Hydrometeorological Design Studies Center Precipitation Frequency Data Server by manually entering the latitude and longitude of the centroid of the watershed area.

http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=ca (NOAA Atlas 14)

The 50-yr and 100-yr, 24-hour precipitation totals are 3.67 inches and 4.08 inches respectively as shown below. Type 1a rainfall distributions were used for this analysis. The 50-yr and 100-yr rainfall distributions are also shown below.

NOAA Atlas 14, Volume 6, Version 2
Location name: Farmington, California, USA*
Latitude: 38.031°, Longitude: -120.9256°
Elevation: 231 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Sarah Dietz, Sarah Heim, Lillian Hiner, Kazungu Maitaria, Deborah Martin, Sandra Pavlovic, Ishani Roy, Carl Trypaluk, Dale Unruh, Fenglin Yan, Michael Yekta, Tan Zhao, Geoffrey Bonnin, Daniel Brewer, Li-Chuan Chen, Tye Parzybok, John Yarchoan

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	**2**	**5**	**10**	**25**	**50**	**100**	**200**	**500**	**1000**
5-min	**0.108** (0.093-0.125)	**0.139** (0.121-0.163)	**0.182** (0.157-0.213)	**0.217** (0.186-0.257)	**0.267** (0.219-0.328)	**0.306** (0.244-0.386)	**0.346** (0.269-0.450)	**0.389** (0.293-0.523)	**0.449** (0.321-0.635)	**0.498** (0.342-0.732)
10-min	**0.154** (0.134-0.180)	**0.200** (0.173-0.233)	**0.261** (0.225-0.305)	**0.311** (0.266-0.368)	**0.382** (0.313-0.471)	**0.438** (0.350-0.553)	**0.497** (0.386-0.646)	**0.558** (0.419-0.750)	**0.644** (0.461-0.910)	**0.713** (0.490-1.05)
15-min	**0.186** (0.162-0.217)	**0.242** (0.209-0.282)	**0.315** (0.272-0.369)	**0.377** (0.322-0.445)	**0.462** (0.379-0.569)	**0.530** (0.424-0.669)	**0.600** (0.466-0.781)	**0.675** (0.507-0.907)	**0.779** (0.557-1.10)	**0.862** (0.592-1.27)
30-min	**0.260** (0.225-0.303)	**0.337** (0.291-0.393)	**0.440** (0.379-0.515)	**0.525** (0.448-0.621)	**0.644** (0.529-0.794)	**0.739** (0.591-0.933)	**0.837** (0.650-1.09)	**0.941** (0.707-1.26)	**1.09** (0.777-1.53)	**1.20** (0.826-1.77)
60-min	**0.349** (0.303-0.407)	**0.453** (0.392-0.528)	**0.591** (0.509-0.692)	**0.706** (0.602-0.835)	**0.866** (0.710-1.07)	**0.993** (0.794-1.25)	**1.12** (0.874-1.46)	**1.26** (0.950-1.70)	**1.46** (1.04-2.06)	**1.62** (1.11-2.38)
2-hr	**0.495** (0.429-0.577)	**0.618** (0.534-0.721)	**0.786** (0.678-0.921)	**0.929** (0.793-1.10)	**1.13** (0.928-1.39)	**1.30** (1.04-1.64)	**1.47** (1.14-1.91)	**1.65** (1.24-2.22)	**1.92** (1.37-2.71)	**2.13** (1.46-3.13)
3-hr	**0.599** (0.519-0.698)	**0.739** (0.639-0.862)	**0.931** (0.803-1.09)	**1.10** (0.935-1.30)	**1.33** (1.09-1.64)	**1.52** (1.22-1.92)	**1.72** (1.34-2.24)	**1.94** (1.45-2.60)	**2.24** (1.60-3.17)	**2.50** (1.71-3.67)
6-hr	**0.823** (0.713-0.959)	**1.01** (0.870-1.17)	**1.26** (1.08-1.47)	**1.47** (1.25-1.74)	**1.77** (1.45-2.18)	**2.01** (1.61-2.54)	**2.27** (1.76-2.95)	**2.54** (1.91-3.41)	**2.92** (2.09-4.13)	**3.24** (2.22-4.76)
12-hr	**1.09** (0.944-1.27)	**1.35** (1.17-1.57)	**1.69** (1.46-1.98)	**1.98** (1.69-2.34)	**2.38** (1.95-2.93)	**2.69** (2.15-3.40)	**3.01** (2.34-3.91)	**3.34** (2.51-4.50)	**3.81** (2.72-5.38)	**4.17** (2.86-6.13)
24-hr	**1.46** (1.31-1.66)	**1.84** (1.65-2.09)	**2.33** (2.08-2.66)	**2.73** (2.42-3.14)	**3.26** (2.79-3.89)	**3.67** (3.07-4.48)	**4.08** (3.32-5.11)	**4.50** (3.56-5.81)	**5.06** (3.83-6.84)	**5.50** (4.01-7.70)
2-day	**1.82** (1.64-2.07)	**2.30** (2.06-2.61)	**2.90** (2.59-3.31)	**3.38** (2.99-3.89)	**4.00** (3.42-4.78)	**4.47** (3.74-5.46)	**4.94** (4.02-6.19)	**5.40** (4.27-6.98)	**6.01** (4.55-8.12)	**6.47** (4.72-9.06)
3-day	**2.09** (1.88-2.38)	**2.64** (2.36-3.00)	**3.32** (2.97-3.79)	**3.86** (3.42-4.44)	**4.56** (3.89-5.44)	**5.07** (4.24-6.19)	**5.57** (4.54-6.99)	**6.08** (4.80-7.84)	**6.73** (5.08-9.08)	**7.21** (5.25-10.1)
4-day	**2.30** (2.07-2.62)	**2.90** (2.60-3.30)	**3.65** (3.26-4.17)	**4.23** (3.75-4.88)	**4.99** (4.26-5.95)	**5.54** (4.63-6.76)	**6.07** (4.95-7.61)	**6.60** (5.22-8.53)	**7.29** (5.51-9.84)	**7.79** (5.68-10.9)
7-day	**2.79** (2.50-3.17)	**3.52** (3.15-4.00)	**4.42** (3.95-5.04)	**5.11** (4.53-5.89)	**6.00** (5.13-7.16)	**6.65** (5.56-8.11)	**7.27** (5.92-9.11)	**7.87** (6.22-10.2)	**8.65** (6.54-11.7)	**9.21** (6.71-12.9)
10-day	**3.12** (2.80-3.55)	**3.94** (3.53-4.49)	**4.95** (4.42-5.65)	**5.72** (5.07-6.59)	**6.71** (5.74-8.01)	**7.42** (6.20-9.05)	**8.10** (6.59-10.1)	**8.76** (6.92-11.3)	**9.60** (7.25-13.0)	**10.2** (7.43-14.3)
20-day	**4.13** (3.71-4.70)	**5.25** (4.71-5.98)	**6.60** (5.90-7.54)	**7.63** (6.76-8.78)	**8.91** (7.62-10.6)	**9.82** (8.21-12.0)	**10.7** (8.70-13.4)	**11.5** (9.10-14.9)	**12.5** (9.48-16.9)	**13.3** (9.67-18.6)
30-day	**4.99** (4.48-5.67)	**6.34** (5.69-7.22)	**7.98** (7.13-9.11)	**9.20** (8.16-10.6)	**10.7** (9.17-12.8)	**11.8** (9.86-14.4)	**12.8** (10.4-16.0)	**13.8** (10.9-17.8)	**14.9** (11.3-20.2)	**15.7** (11.5-22.0)
45-day	**6.18** (5.54-7.02)	**7.85** (7.04-8.94)	**9.85** (8.80-11.2)	**11.3** (10.0-13.0)	**13.2** (11.3-15.7)	**14.4** (12.1-17.6)	**15.6** (12.7-19.6)	**16.7** (13.2-21.6)	**18.1** (13.7-24.4)	**19.0** (13.9-26.6)
60-day	**7.42** (6.66-8.43)	**9.40** (8.43-10.7)	**11.7** (10.5-13.4)	**13.5** (11.9-15.5)	**15.6** (13.3-18.6)	**17.0** (14.2-20.8)	**18.4** (15.0-23.1)	**19.7** (15.5-25.4)	**21.2** (16.0-28.6)	**22.2** (16.2-31.1)

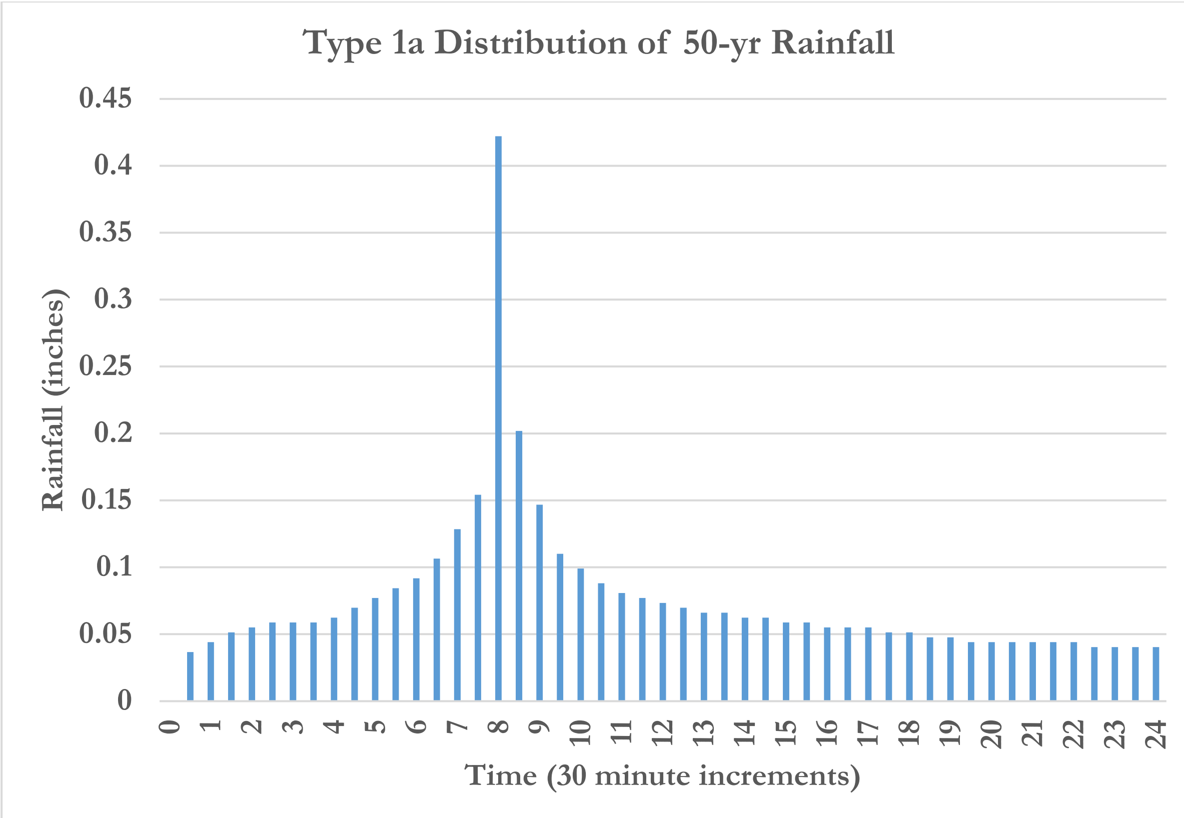
[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

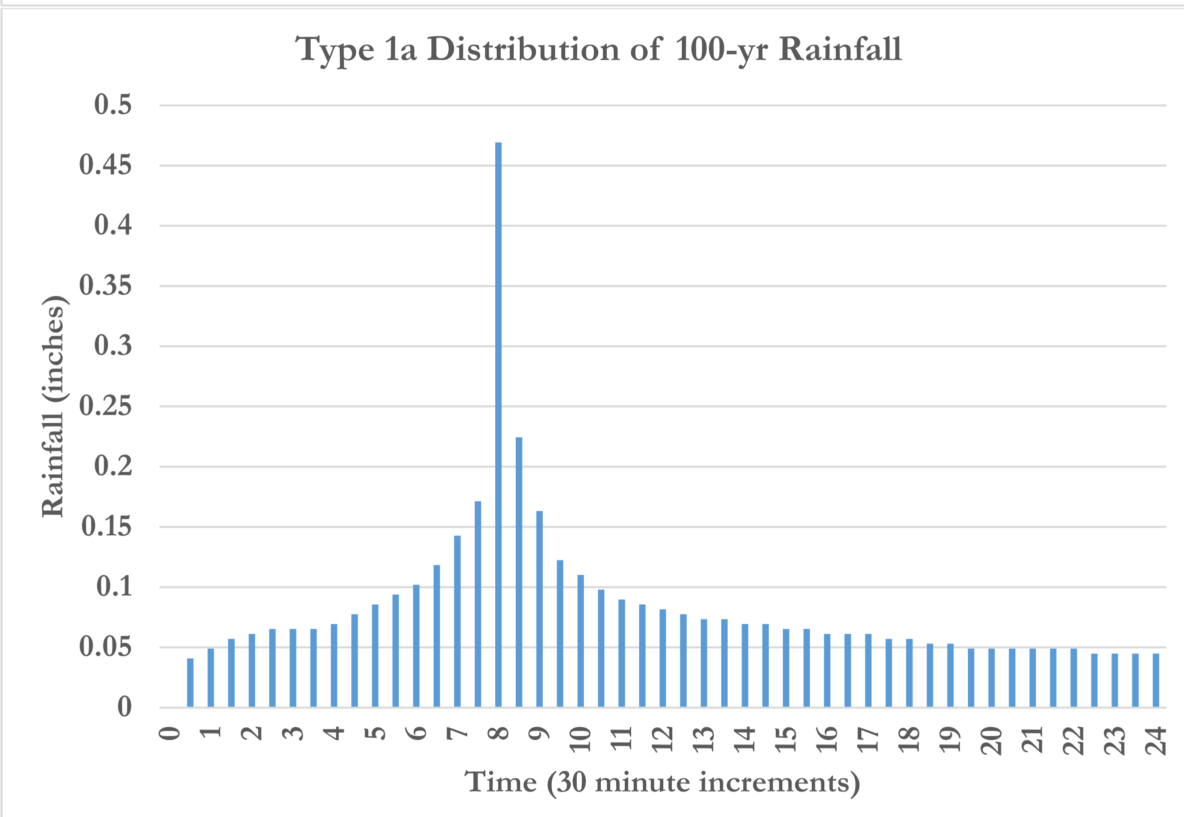
Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

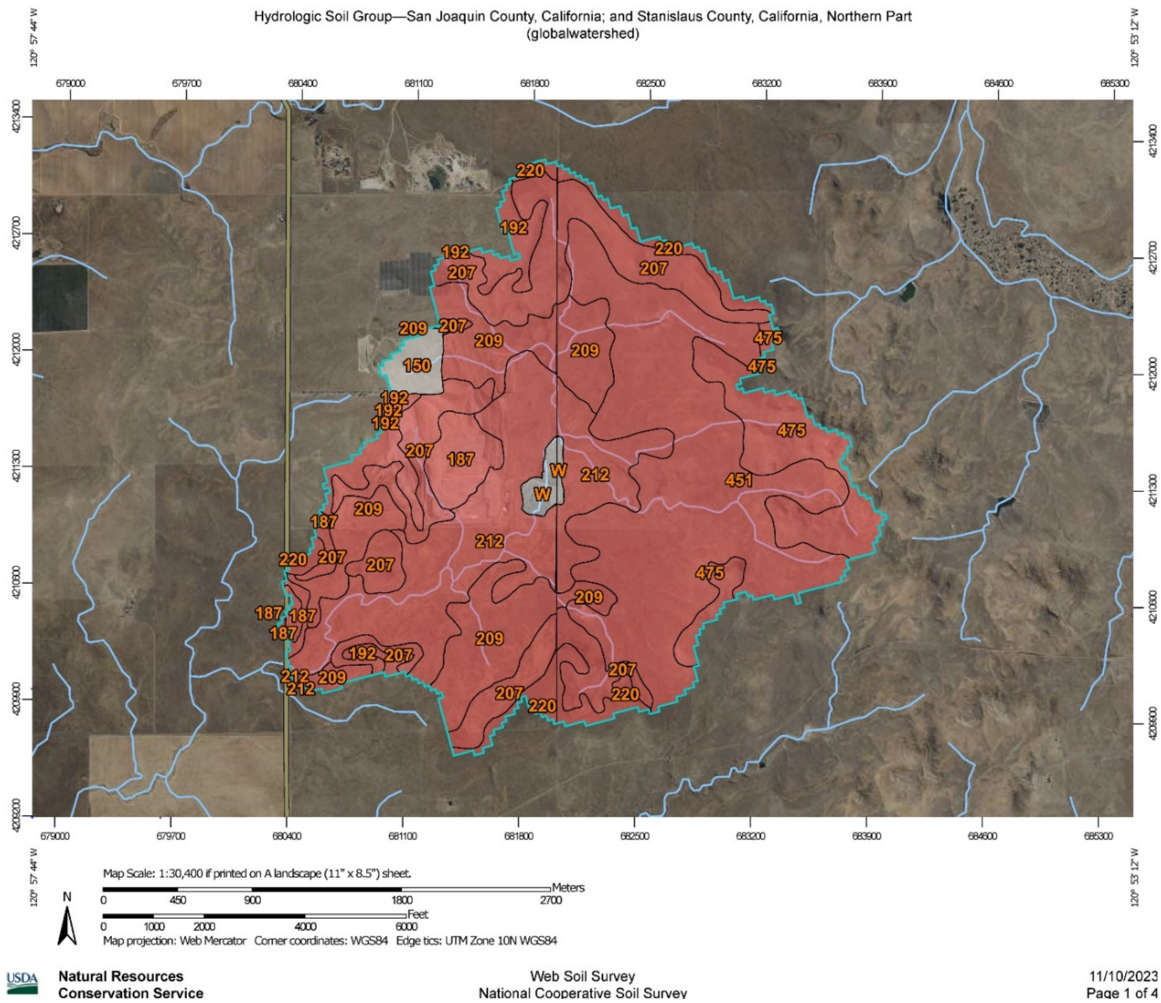
Back to Top

PF graphical


Type 1a Distribution of 50-yr Rainfall
Rainfall (inches)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Time (30 minute increments)


Type 1a Distribution of 100-yr Rainfall
Rainfall (inches)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Time (30 minute increments)

The soils within the project watershed are composed primarily of one hydrologic soil group, Class D, as shown below. A SCS infiltration mapping layer was created for the 2D flow area using a composite curve number (CN) of 92 and abstraction ratio of 0.2.



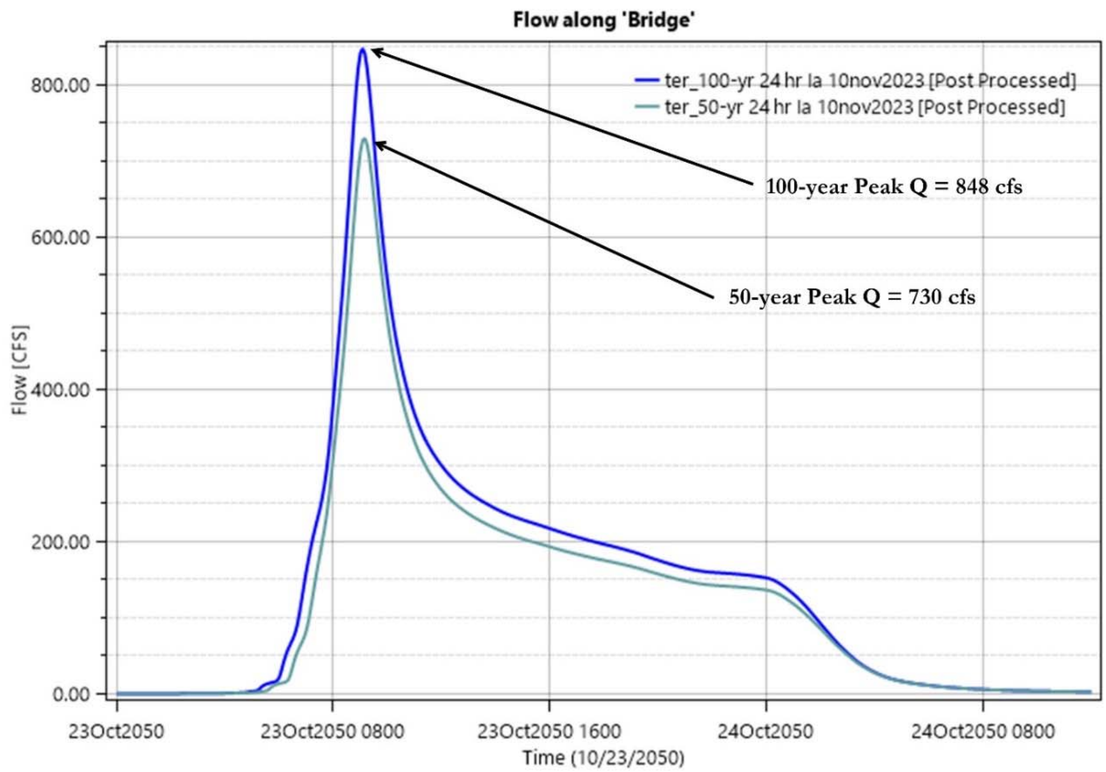
Salmon = Class D, Grey = undefined

Project Watershed Soils Map (USDA NRCS Web Soil Survey)

Parameters and data sets used for the HEC-RAS 2D point precipitation model are:

- One-third arc-second National Elevation Dataset (NED) terrain data obtained from United States Geological Survey (USGS) as projected to California State Plane Zone 3 (Feet) geographic coordinate system of NAD 83 horizontal datum and NAVD 88 vertical datum.
- Simulation time of 36 hours.
- Computational time interval of 1 second.
- SWE-ELM (full momentum) equation set.
- 2D flow area grid size of 50-feet.

Flow hydrographs were extracted from the results at the bridge location. The 50-year and 100-year hydrographs at the project used as the inflow for the bridge hydraulic analyses are shown below.



50-year and 100-year Runoff Hydrographs at the Bridge Location

A summary of the results from the two hydrology methods is shown in the table below.

Method	**Peak Discharge** (cfs)	
	50-year	**100-year**
Regional Regression	382	440
HEC-RAS 2D Point Precipitation	730	848

The results from the point precipitation method are conservative compared to the regional regression results and were used for the hydraulic analyses of the bridge.