# Sickman Overflow Bridge Preliminary Hydraulic and Scouring Assessment

Prepared for:
**Chehalis Confederated Indian Tribe**
**Oakville, Washington**

Prepared by:
**ENVIRON International Corporation**
**Seattle, Washington**

Date:
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Project Number:
**3029884A**

ENVIRON

# Signature and Engineering Certification

This Report was prepared under the supervision of the Professional Engineer named and signed below. We can specifically certify that the proposed relief bridge will not increase flooding depths associated with the 100-year and 50-year floods. Under the 100-year flooding, the flooding depths will actually decrease upstream of the Sickman Ford Bridge to the confluence with Black River (located at over 2 miles upstream). There will be neither increase nor decrease to the flooding downstream of the Sickman Ford Bridge, including towns of Porter (located at 9 to 10 miles downstream measured along Chehalis River) and Elma (located at 18 miles downstream measured along Chehalis River). This certification is based on the best information available to us on or before November 30, 2012. If any conditions affecting this analysis (such as man-made improvements or flow diversions, or changes to the river flows or geometry due to large flood flows, including excessive erosion and accretion) change, the results and conclusions of this Report may be invalid.

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Felix Kristanovich, PhD, PE
Water Resources Engineer

November 30, 2012

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# 1 Introduction

Confederated Tribes of the Chehalis Reservation (CTCR) has been evaluating measures to reduce the flooding in the vicinity of South Bank and Balch Roads. Brief hydrologic and hydraulic analyses of the area were conducted by GeoEngineers and included floodplain maps of the areas associated with the recent 2007 flood. In 2011, ENVIRON performed more specific evaluations of at least seven floodplain management alternatives at the South Bank and Balch Roads, including options for relieving flood pressure by placing culverts in the fill and constructing a bridge. This report specifically focuses on the 250-bridge replacement alternative, identified as the "preferred management alternative" by CTCR

This report addresses the deliverables for Task 3.0 - Hydraulics (Subtask 3.4 – Report) of the *Sickman Ford Overflow Bridge Preliminary Site Investigations and Conceptual Design* scope of services dated September 8, 2012. Submittals associated with Task 2-Survey, Task 4-Geotechnical Services, and Task 5- Conceptual design are provided as separate deliverables.

# 2 Purpose

The purpose of this assessment is to provide to CTCR hydraulic and scouring evaluations for the proposed 250-feet relief bridge to be constructed through the South Bank Road levee east of the existing Sickman Ford Bridge (see Figure 1). The 250-ft relief bridge was identified as the preferred management alternative by CTCR based on the ENVIRON's Chehalis River Flood Assessment Technical Memorandum (ENVIRON, 2011[1]). This assessment specifically addresses hydraulic evaluation of the selected alternative (for 50-year, 100-year, and 500-year floods) and corresponding scouring analyses (for the 500-year flows).

# 3 Methods

Our methodology included:

1. Development of a detailed elevation surface incorporating LIDAR data, and survey data collected in support of this project,
2. Hydraulic analysis (addressing flooding impacts) of the selected alternative (250-feet bridge crossing), and
3. Scouring analysis for piers and abutments of the relief bridge.

Details of the methods are provided in the following sections.

## 3.1 Detail Elevation Model

ENVIRON revised the 2011 flooding assessment to incorporate the detailed ground surveying completed in 2012 in the vicinity of the proposed bridge (see survey report for details). This ground surveying included the 2,300 feet of the South Bank roadway east of the Sickman Ford

[1] Chehalis River Flood Assessment, ENVIRON, Technical Memorandum to Mark White and Glen Connelly, December 8, 2011 (revised May 2012).

Bridge and 200 feet strip of land north and south of the bridge (including some relic floodplain channels). Following completion of the survey, ENVIRON used the surveying data to develop surface elevation of the project area (surface 1). This surface elevation was then integrated into the previously acquired LIDAR data in the CTCR floodplain area obtained from CTCR (surface 2). LIDAR data for the larger study area located upstream and downstream of the CRCR lands was acquired from the Puget Sound LIDAR Consortium (http://pugetsoundlidar.ess.washington.edu/lidardata/) (surface 3). The three surfaces were combined to create a composite surface layer in GIS. ENVIRON used the surface to correct the geometry of the previously developed hydraulic model[1] in the vicinity of the proposed relief bridge.

## 3.2 Hydraulic Analysis - Existing Conditions

ENVIRON used the previously developed HEC-RAS model[2], which was the LIDAR-improved version of the US Army Corps of Engineers unsteady HEC-RAS model for Chehalis River (COE, Version 4.0, 2008[2]). The HEC-RAS model geometry was corrected to include detailed elevations of the current South Bank Road and surrounding areas and the correct configuration of the existing Sickman-Ford Bridge (including the existing piers). Additional model cross-sections were established on both sides of the South Bank Road. Since LIDAR depicts the elevation of the water surface and not the bathymetry of the channel under water, the channel bathymetry information within the Corps' model was retained. The unknown bathymetry in the Chehalis River channel was linearly interpolated between the two adjacent model sections. All other features of the previous HEC-RAS model were retained. The vertical datum of the hydraulic model was converted to the 1988 NAVD datum, consistent with the existing LIDAR data.

To validate the hydraulic model accuracy, the revised HEC-RAS model (for the 100-year flood event) was compared to the known high flood-flow identified during December 2007 flood event located north of the South Bank Road. Hydrologic frequency analysis of the annual flood peaks at the downstream USGS gage (Chehalis River at Porter) confirmed that the 2007 flood event of 102,000 cfs at that location fall within the range of the 100-year flood estimate (95% confidence interval is [76,000 cfs, 109,000 cfs]). The location of the high water mark in the 2007 event was pointed out to us by the CCTR staff during the 08/28/2012 site visit. The site was surveyed at the Northing: 558,124.02 feet; Easting: 953,004.20 feet with elevation of 83.63 feet NAVD. The hydraulic model estimated water surface elevation that was less than 0.10 feet different at that location, so no adjustment to the hydraulic model was necessary.

The existing hydraulic model was then revised to include the following changes:

- Recently constructed Harris Creek box culverts under the South Bank Road, located east of the project site, just north of the Cemetery Road were included in the model. The 2010 as-built plans obtained from CTCR[3] were used to incorporate relief flow through these culverts.

[2] HEC-RAS River Analysis System, Version 4.0, User's Manual, US Army Corps of Engineers Hydrologic Engineering Center, Davis, California, 2008.

[3] Confederated Tribes of the Chehalis Reservation Harris Creek Culvert Replacement, Oakville, Washington (DCI Engineers, 7 sheets, March 2010)

However, this change did not affect water surface elevations or water flow depths in the Chehalis River floodplain.

- The Balch Road levee extension was assumed removed. This change was consistent with the previously tested ENVIRON's flow relief alternatives[1].

The hydraulic model was simulated for the following three flow conditions:

- 100-year flood event, consistent with the following HEC-RAS model: Plan: ENVIRON-Existing-*NAVD3;* Geometry: *Refined-SFBridge-Existing-NAVD3*; Unsteady Flow: *Chehalis 100 WOP Oct 2010-NAVD*.
- 50-year flood event, consistent with the following HEC-RAS model: Plan: *ENVIRON-Existing*–NAVD3 (50); Geometry: *Refined-SFBridge-Existing-NAVD3*; Unsteady Flow: *Chehalis 50 WOP Oct 2010-NAVD*.
- 500-year flood event, consistent with the following HEC-RAS model: Plan: *ENVIRON-Existing-NAVD* (500); Geometry: *Refined-SFBridge-Existing-NAVD3(500)*; Unsteady Flow: *Chehalis 500 WOP Oct 2010-NAVD*.

## 3.3 Hydraulic Analysis – Proposed Bridge Configuration

The relief bridge with the span of 250 feet was incorporated into this analysis. Note that this alternative was not included in the ENVIRON's 2012 Technical Memo to the CCTR, but was provided in a separate e-mail to CCTR (ENVIRON's e-mail to Mark White, May 15, 2012). The hydraulic analysis of this bridge assumed the following conditions:

- Bridge will be a 3-span bridge with two rows of intermediate piers with 2-ft diameters;
- The bridge will be a perched bridge designed and constructed with the lowest elevation of the bridge deck at or above the 100-year water surface elevation at this location (calculated by HEC-RAS model at 83.8 feet). The preliminary cost estimate for this perched bridge is approximately $2 million, which is the maximum allowed budget for this project (details are provided in the ENVIRON's Conceptual Design Memorandum, submitted as a deliverable for Task 5 on this project). Therefore, the CCTR alternative with this bridge raised by another 1 foot (and elevating the lowest bridge deck elevation to 84.70 feet – and providing the 1 foot drift clearance) was considered too expensive, as it would have exceeded the budget allowance.
- An 8-ft CMP culvert will be constructed east of the relief bridge at the location of the secondary channel crossing. This culvert will be partially buried into the ground to mimic a fish-type culvert. The culvert will convey water only at higher flows, so its invert was elevated above the invert of the channel under the relief bridge.
- The invert of the relief bridge and the 8-ft culvert will start flowing only at high flows (close to 5-year flows), specifically, when the Chehalis River discharge exceeds 20,000 cfs; which is approximately 23 percent of the 100-year flood flow, or 27 percent of the 50-year flood flow.
- The thickness of the roadway grade (distance between the low bridge chord and the top of the roadway) was assumed to be 2.5 to 3-feet, consistent with the thickness of the Sickman Ford Bridge above the Chehalis River main channel. The 3-foot roadway grade thickness

also allows construction of the 3-span bridge (instead of a 5-span bridge with a thinner roadway grade). Details of the roadway grade are provided in the Conceptual Design Memorandum.

- The channel under the relief bridge was assumed excavated down to the lowest elevation in the floodplain adjacent to the relief bridge (74 feet NAVD), removing some of the natural obstructions in the way.
- Mitigation improvements to prevent scouring at piers and abutments were not included in the hydraulic analysis.
- The Balch Road roadway extension was removed from the geometry of the HEC-RAS model for all future conditions.

The hydraulic model was simulated for the following three flow conditions:

- 100-year flood event, consistent with the following HEC-RAS model: Plan: ENVIRON-Bridge5b*;* Geometry: *Refined-SFBridge-Add250bridge-NAVD2*; Unsteady Flow: *Chehalis 100 WOP Oct 2010-NAVD*.
- 50-year flood event, consistent with the following HEC-RAS model: Plan: *ENVIRON-Bridge5b(50)*)); Geometry: *Refined-SFBridge-Add250bridge-NAVD2*; Unsteady Flow: *Chehalis 50 WOP Oct 2010-NAVD*.
- 500-year flood event, consistent with the following HEC-RAS model: Plan: *ENVIRON-Bridge-5b(500);* Geometry: *Refined-SFBridge-Add250bridge-NAVD2(500)*; Unsteady Flow: *Chehalis 500 WOP Oct 2010-NAVD*.

## 3.4 Scouring Analysis - Proposed Bridge Configuration

The results of the 500-year simulations were utilized in the bridge scouring analysis. The analysis followed the methods outlined in the Hydraulic Engineering Circular No. 18 (FHWA 2001[4]). It included contraction scour (scour of the bed)), local scour at bridge piers, and local scouring at bridge abutments. The analysis also utilized limited soil sampling information available from the geotechnical data report and assumed that sandy/silty soil is predominant as a surface soil in the floodplain (that soil was identified as a fine grained alluvium ESU II in the geotechnical report, about 12-14 feet thick). Although traces of gravel were found at the depth below, it was conservatively assumed that the same material would continue deeper.

For contraction scouring, the clear-water contraction scouring type was determined to be the applicable scouring type, as the approach flow velocity was always smaller than the critical velocity necessary to transport the median soil diameter (D50) (assumed at 2 mm based on the granulometric curve of the soil profile). The k1 coefficient was calculated as 0.64 (associated with some suspended bed material was used in this analysis).

[4] Hydraulic Engineering Circular (HEC) No 18:Evaluating Scour at Bridges. Federal Highway Administration, US Department of Transportation, Fourth Edition, May 2001.

Local scouring at piers was calculated by Colorado State University (CSU) equation (Richardson et al., 1990[5]), and verified by Froehlich equation (Froehlich, 1991[6]). Flow under the relief bridge was assumed perpendicular to the bridge piers; and the number of piers and dimension of the piers were consistent with the conceptual design of Task 5 of this project.

Local scouring at abutments was calculated using Froehlich equation (Froehlich, 1989[7]) following the procedures from the HEC No. 18 report. This equation is recommended whenever the wetted embankment length divided by the approach depth is less than or equal to 25 – the condition that was applicable under all design flood flow conditions. The calculation of scouring at the abutments conservatively assumed that flow from a much wider floodplain will be conveyed to the relief bridge.. Specifically, it was assumed that all of the flow between transect stations 2052 and 3700 would be conveyed to the relief bridge, and would manifest as either pressure flow through the 250-bridge and the 8-ft culvert openings, or as weir overflow over the roadway crest.

# 4 Results

## 4.1 Hydraulic Analysis - Existing Conditions

The maximum peak flows and stages at the bridge crossing are summarized for each size of flood event in Table 1. A snapshot of each cross-section (from HEC-RAS model) or transect running perpendicular to the flow in the Chehalis River channel and extending through the floodplain on the southern side (upstream of the bridge), parallel to the existing South Bank Road levee, is depicted in Figures 2 and 3. Each figure shows the distribution of flow velocities consistent with the 100-year and 50-year flood events, respectively. Yellow shaded areas in these figures represent locations just upstream of the South Bank Road with low flow velocities (so called “ineffective flow areas” in the HEC-RAS model). The existing bridge is located on the left of the figures where dark blue shading denotes the highest velocities in the main Chehalis River channel. Distance across the cross-section is shown as “Station (feet)” on the x-axis starting from the left side (west) of the floodplain and stretching across the main Chehalis River channel and the right (east) floodplain.

**Table 1 – Peak Discharges and Stages – Existing Conditions**

| Flooding conditions | Maximum Discharge – (cfs) | Peak Stage (feet) |
|---|---|---|
| 50-year | 73,214 | 83.02 |
| 100-year | 86,458 | 84.15 |
| 500-year | 119,661 | 86.49(1) |

Note: (1) = downstream side of the relief bridge

[5] Richardson, E.V., D.B. Simons, and P. Julien. Highways in the River Environment, FHWA-HI-90-016, Federal Highway Administration, US Department of Transportation, 1990.

[6] Froehlich, D.C. Analysis of on-site measurements of scour at piers, Proceedings of the ASCE National Hydraulic Engineering Conference, Colorado Springs, Colorado, 1991.

[7] Froehlich, D.C., Local Scour at Bridge Abutments, Proceedings of the 1989 National Conference on Hydraulic Engineering, ASCE< New Orleans, LA, 1989.

The peak stage during the 500-year flood event was on average 2 to 3 feet higher in the vicinity of the bridge than the peak stage during a 100-year flood. Total discharge during a 500-year flood event was estimated to be roughly 150 percent greater than the discharge during a 50-year event.

For the 50-year flood event, the maximum velocities were estimated at 15.9 ft/sec in the main channel and to 3.4 ft/sec in the right floodplain. For the 100-year flood event, the maximum velocity in the main channel of Chehalis River was estimated at 17.5 ft/sec; the average maximum velocity in the right floodplain through the existing bridge piers was estimated at 3.8 ft/sec. For the 500-year flood event, the estimated maximum velocities in the main channel increased to 20.1 ft/sec, while velocities in the floodplain increased to 4.4 ft/sec. A table detailing the velocities for all flood flows is provided at the end of this document in Appendix A.

## 4.2 Hydraulic Analysis – Proposed Bridge Configuration

At the peak of each flood, the maximum flows and peak stages at the bridge crossing associated with each flooding conditions are summarized in Table 2. A snapshot of each cross-section (from HEC-RAS model) or transect perpendicular to the flow in the Chehalis River channel and extending through the floodplain on the southern side parallel to the existing South Bank Road levee is shown in Figures 4, 5 and 6. Each figure shows distribution of flow velocities consistent with the 100-year, 50-year, and 500-year flood events in Figures 4, 5 and 6, respectively. Yellow shaded areas in these figures represent locations just upstream of the South Bank Road with low flow velocities (so called “ineffective flow areas” in the HEC-RAS model)The existing bridge is located on the left of the figures where dark blue shading denotes the highest velocities in the main Chehalis River channel. The distance across the cross-section is shown as “Station (feet)” on the x-axis starting from the left side of the floodplain and stretching across the main Chehalis River channel and the right floodplain. The proposed relief bridge opening is shown between stations 2,374 and 2,612. The culvert opening is shown between stations 2,842 and 2,849.

**Table 2 – Peak Discharge and Stages – Proposed Conditions**

| Flooding conditions | Maximum Discharge - (cfs) | Peak Stage (feet) |
|---|---|---|
| 50-year | 73,466 | 83.06 |
| 100-year | 86,596 | 83.85 |
| 500-year | 119,517 | 86.49* |

Note: * = downstream side of the relief bridge

During the 50-year flood, the average maximum velocity in the main channel of Chehalis River was estimated 14.2 ft/sec; the average maximum velocity in the right floodplain through the existing bridge piers was estimated at 3.0 ft/sec. The average maximum velocities under the relief bridge and through the new 8-ft culvert were estimated at 3.2 ft/sec, and 1.3 ft/sec, respectively.

During the 100-year flood, the average maximum velocity in the main channel of Chehalis River was estimated at 14.9 ft/sec; the average maximum velocity in the right floodplain through the existing bridge piers was estimated at 3.2 ft/sec. The average maximum velocity under the relief bridge was 3.4 ft/sec, and through the new 8-ft culvert was estimated at 1.3 ft/sec.

During the 500-year flood, the average maximum velocity in the main channel of Chehalis River was estimated 12.8 ft/sec; the average maximum velocity in the right floodplain through the existing bridge piers was estimated at 2.7 ft/sec. The average maximum velocities under the relief bridge and through the new 8-ft culvert were estimated at 1.8 ft/sec and 1.0 ft/sec, respectively.

The flow velocities associated with each flow conditions are summarized in Table 3 below.

**Table 3 – Comparison of Maximum Flow Velocities through the Existing Bridge and Proposed Relief Bridge (ft/sec)**

| Flow Conditions | Existing Sickman Ford Bridge | Relief Bridge | Relief Culvert |
|---|---|---|---|
| 50-year flood – Existing | 15.9 | N/A | N/A |
| 50-year flood – with Relief Bridge & Culvert | 14.2 | 3.2 | 1.3 |
| 100-year flood - Existing | 17.5 | N/A | N/A |
| 100-year flood – with Relief Bridge & Culvert | 14.9 | 3.4 | 1.3 |
| 500-year flood - Existing | 20.1 | N/A | N/A |
| 500-year flood – with Relief Bridge & Culvert | 12.8 | 1.8 | 1.0 |

It can be concluded that the opening of the relief bridge and its culvert would provide consistent reduction of flow velocities in the main Chehalis River flow channel.

The summary details for the bridge are illustrated in Table 4 below.

**Table 4 – Bridge Summary**

| Conditions | Existing Conditions | Proposed Conditions |
|---|---|---|
| Sickman Road Profile (grade) | 84' +-0.2' | 86.7 - 87.11 ft |
| 100 YR MRI | 84.15 ft | 83.85 ft |
| 100 YR velocity under relief bridge | NA | 3.4 ft/sec |
| Bottom of Bridge Superstructure | NA | 83.8 ft |
| Ordinary High Water Mark (OHWM) | NA | NA* |
| Drift Clearance | NA | 0 ft |

Note: * To be determined

Flow (hydraulic) depths associated with the 100-year flood event upstream and downstream of the proposed project are illustrated in Figure 7. The water surface elevations (base flood elevations) associated with the 100-year flood event are presented in Figure 8 (project area), and Figure 9 (within CTCR boundaries). Figures 10 and 11 illustrate reduction in flow depths between the proposed conditions and the existing conditions during the 100-year event: Figure 10 shows this reduction immediately upstream and downstream of the project area; Figure 11 illustrates this reduction along Chehalis River downstream to Porter. Figure 12 illustrates reduction of flow depths from the existing conditions during the 50-year flood event immediately upstream and downstream of the project area.

The longitudinal profile of the average main channel velocity and of the overall average velocities (main channel, left floodplain and right floodplain) through the Lower Chehalis River from the confluence with Black River upstream (Station 0 feet) to the Porter bridge downstream (distance of 22,000 feet) is illustrated in Figure 13 for the 100-year flood event and in Figure 14 for the 50-year flood event. The HEC-RAS transect at the South Bank Road (and the Sickman Ford Bridge) is approximately at a distance of 7,368 feet.

Similarly, the longitudinal profile of the hydraulic depths in the main Chehalis River channel at each transect through the Lower Chehalis River from the confluence with Black River upstream (Station 0 feet) to the Porter bridge downstream (distance of 22,000 feet) is illustrated in Figure 15 for the 100-year and 50-year flood events. The HEC-RAS transect at the South Bank Road (and the Sickman Ford Bridge) is approximately at a distance of 7,368 feet.

ENVIRON is reasonably confident that the results presented below are accurate for the 50-year and 100-year flow with respect to the prediction of flooding extents and average flood velocities.

## 4.3 Discussion of impacts and improvements

- During the 100-year flood event, predicted flooding depth reductions greater of 0.10 feet extended 1.9 miles to 2.4 miles upstream of the South Bank Road (Figures 10 and 11).There was no predicted change in the base flood elevations or flooding depths in Porter at the downstream model boundary.
- There were no significant changes in flooding predicted during the 50-year flood event (Figure 12). There was no change in water surface elevations or flooding depths in Porter at the downstream model boundary.
- The predicted increases in flow velocity were confined to the small reach upstream of South Bank Road and downstream of the Chehalis River- Black River confluence. However, in general, flow velocities in the main Chehalis River channel were all reduced (by around 10 percent) just upstream of the Sickman Ford bridge.
- As expected, the simulations predict a consistent decrease in flood depths for the 50-year and 100-year flows (Figure 15). For the 100-year flood flows, the predicted channel depths are decreased by the maximum of 2 percent just upstream of the bridge. For the 50-year flows, the predicted hydraulic depths are decreased by only 1 percent just upstream of the bridge.

## 4.4 Scouring Analysis – Proposed Bridge Configuration

Scouring analysis results are consistent with the above assumptions and methods used. We recommend re-confirming this analysis with more soil boring samples that include granulometric sieve analysis of soil samples at different depths.

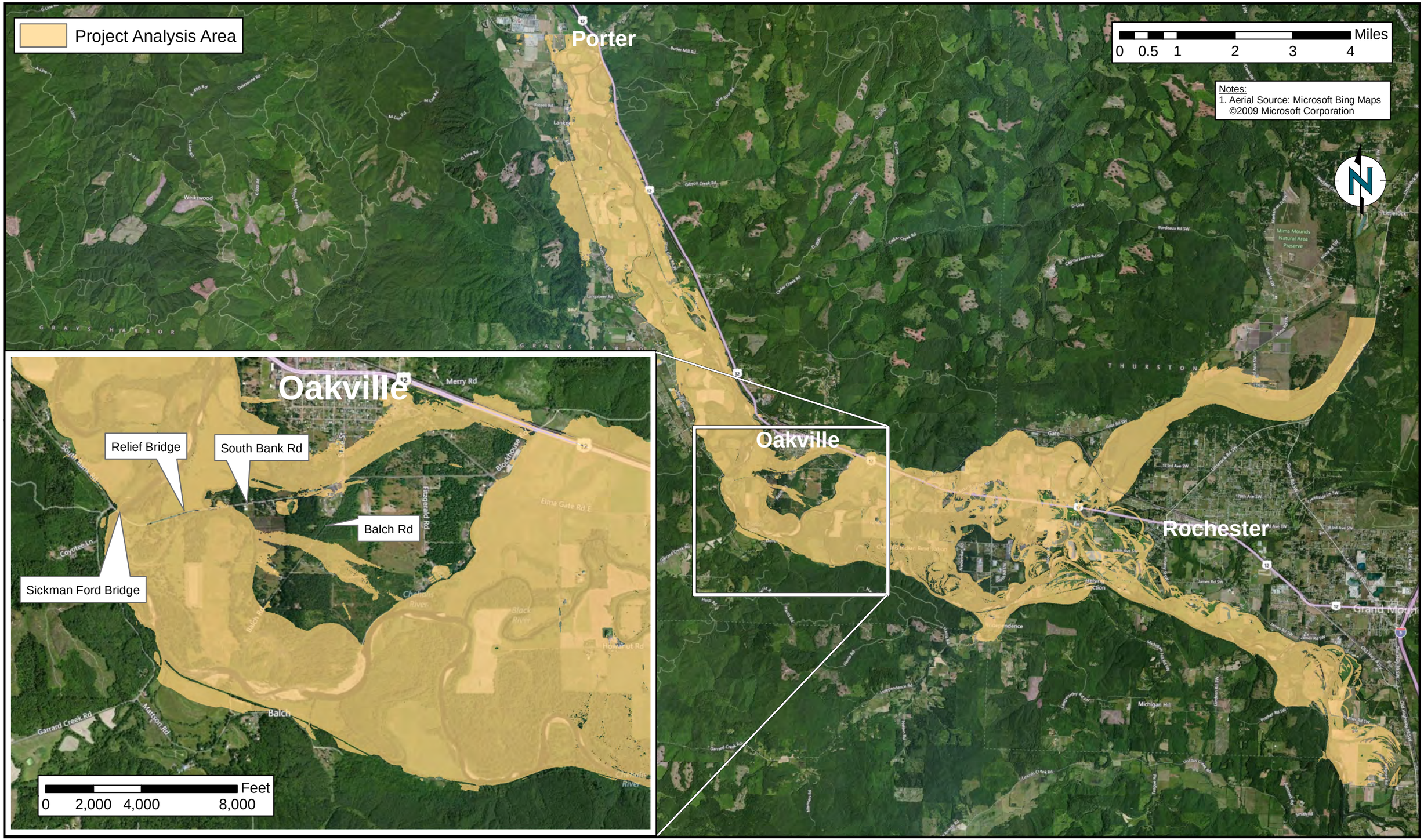
Results associated with the three scouring analyses are:

- *Contraction scouring* – sensitivity analysis of the contraction scour was conducted. Although D50 of 2 mm was calculated from the available three soil samples, reducing D50 below 0.5 mm, had significant effect on the contraction scouring. For D50 of 0.30 mm, the scouring depth was calculated at 1.5 feet; for D50 of 0.50 mm, the scouring depth was reduced to 0.27 feet. The scouring results associated with D50 of 0.50 mm are presented in Appendix B.
- *Pier Scouring* - The maximum scouring at relief bridge piers was calculated at 4.4 feet.
- *Abutment Scouring* - The maximum scouring at the relief bridge abutments was calculated at 18.5 feet. Sensitivity analysis on this scouring indicated that this maximum scour did not occur during the peak of the 500-year flood, but 6-7 hours earlier, at the time when the maximum flood flow (of about 10,000 cfs) was passing through the relief bridge. The scouring depth at the abutment does determine a depth of the wing-wall footing in the design, so it was entered into design calculations.

Consistent with the recommendations of the geotechnical report, the pile footings at the relief bridge would be extended down from 74 feet to 60 feet (total of 14 feet depth) to reach the ESU III type soil, recommended to support the foundation system. Thus, the 14 foot depth will govern the footing design, and not the maximum scouring depth from contraction and pier scouring processes. However, the foundation depth at the abutments would have to extend deeper than 18.5 feet to account for deep abutment scouring (that exceeds the 14 feet depth).

The model simulation scenario, consistent with the maximum scouring depth, is illustrated in Figure 16. Detailed output of scouring calculations (in a table format) for two representative scouring scenarios is included in Appendix B.

# Figures

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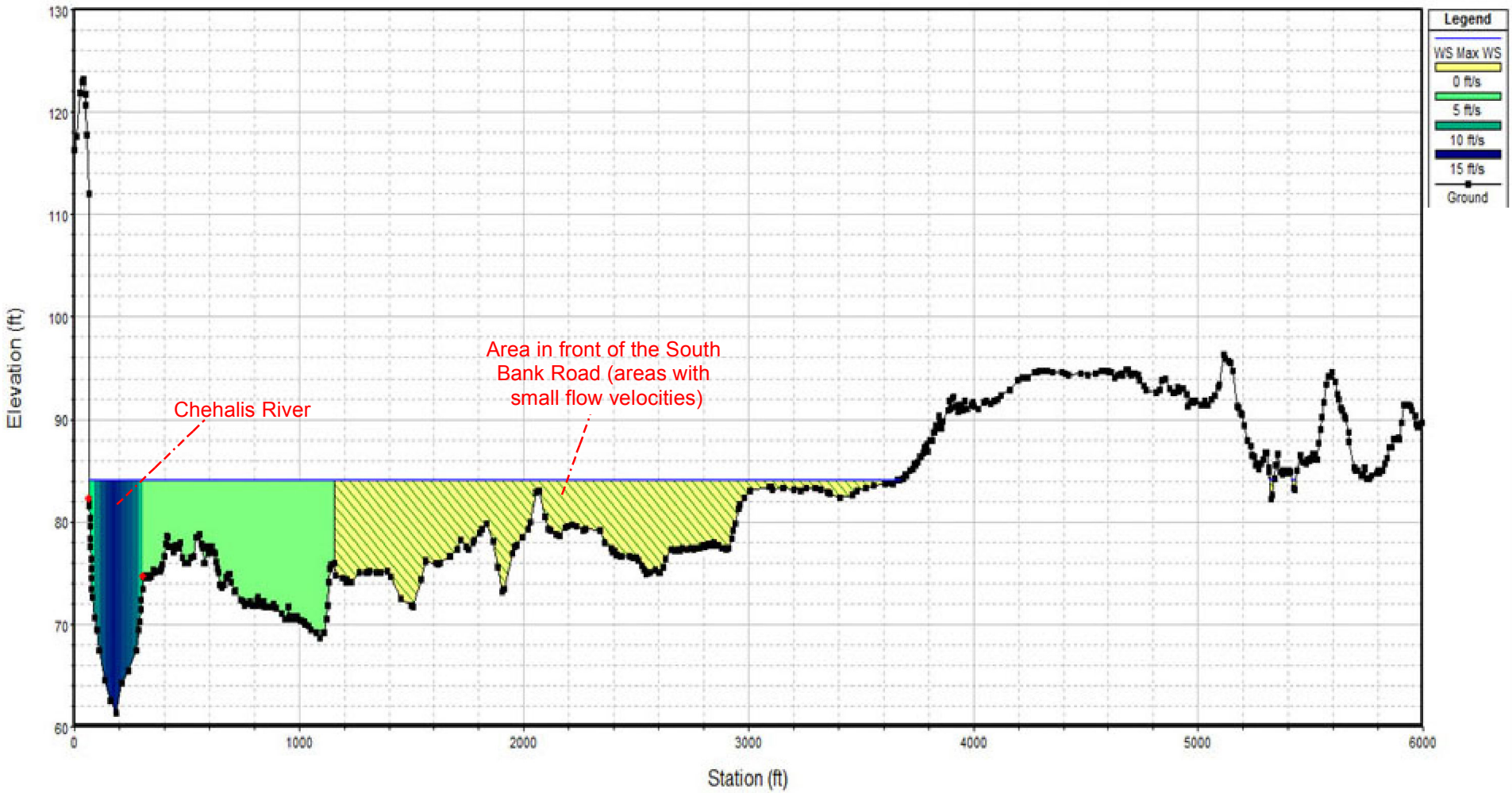
Overview of Project Analysis Area

Figure 1

PROJECT: 30-29884A

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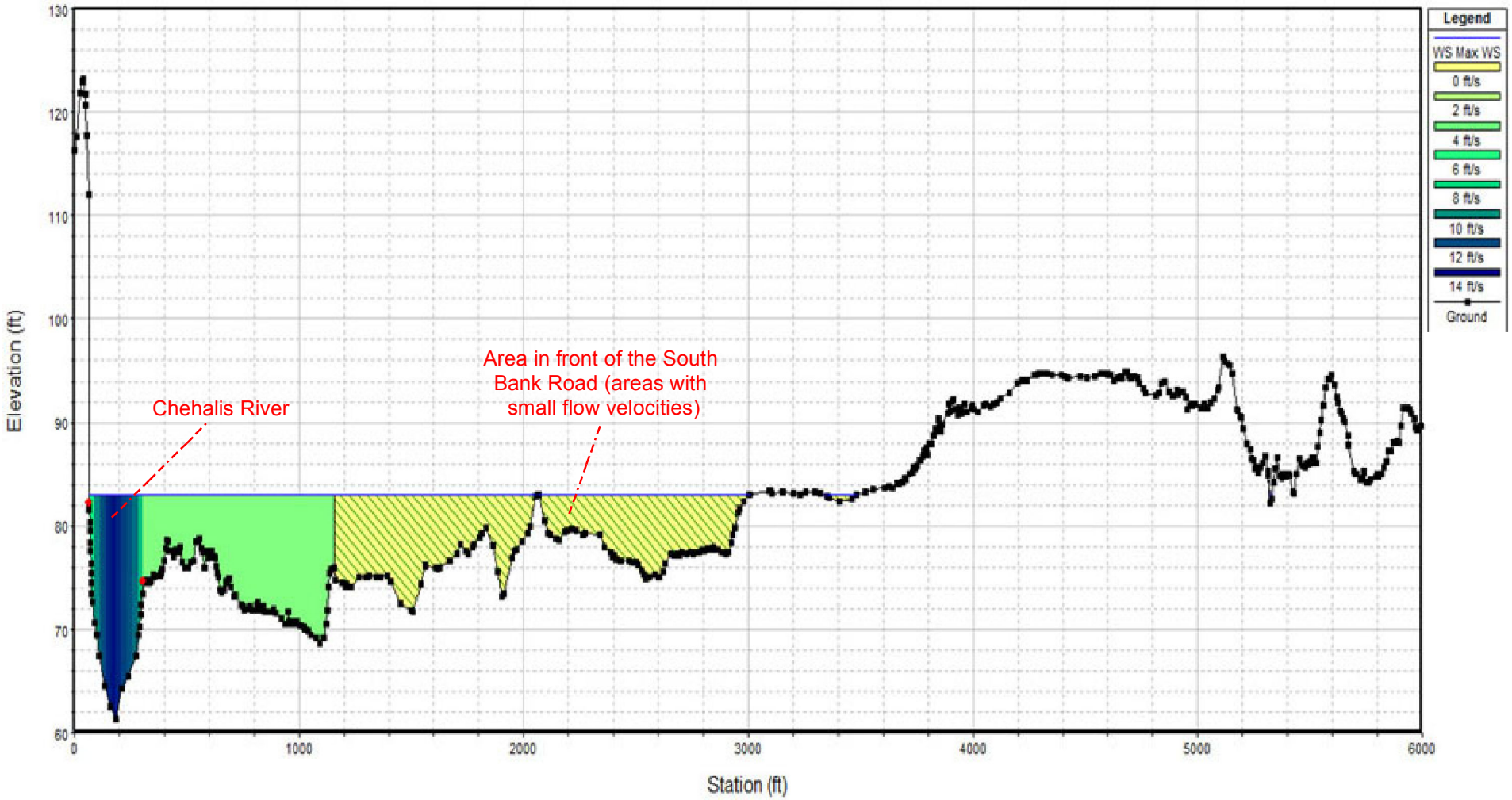
# Distribution of Velocities Upstream of the Bridge at 100-year, Existing Conditions

Figure 2

PROJECT: 30-29884A

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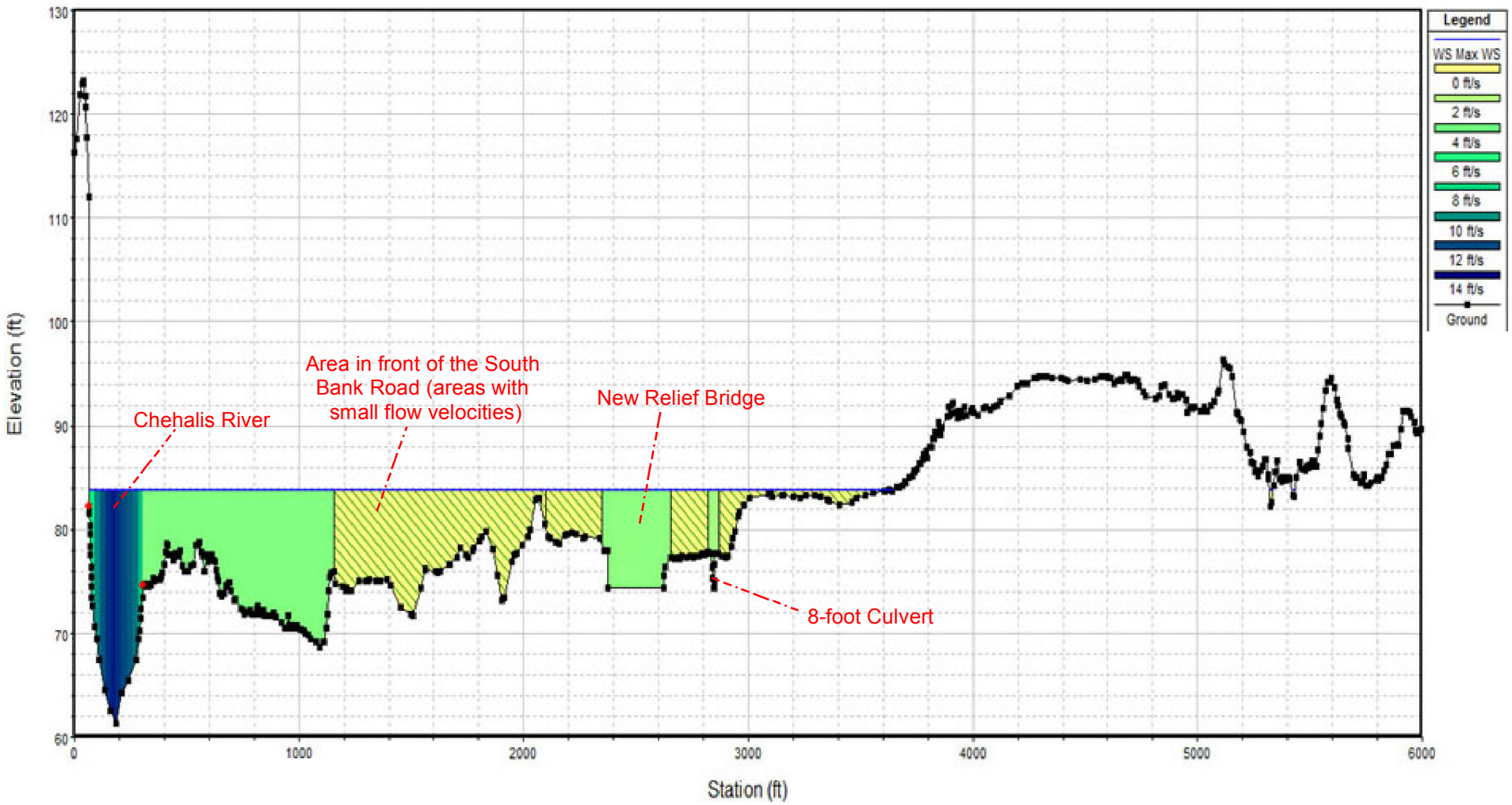
# Distribution of Velocities Upstream of the Bridge at 50-year, Existing Conditions

Figure 3

PROJECT: 30-29884A

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# Distribution of Velocities Upstream of the Bridge at 100-year, Future Conditions

Figure 4

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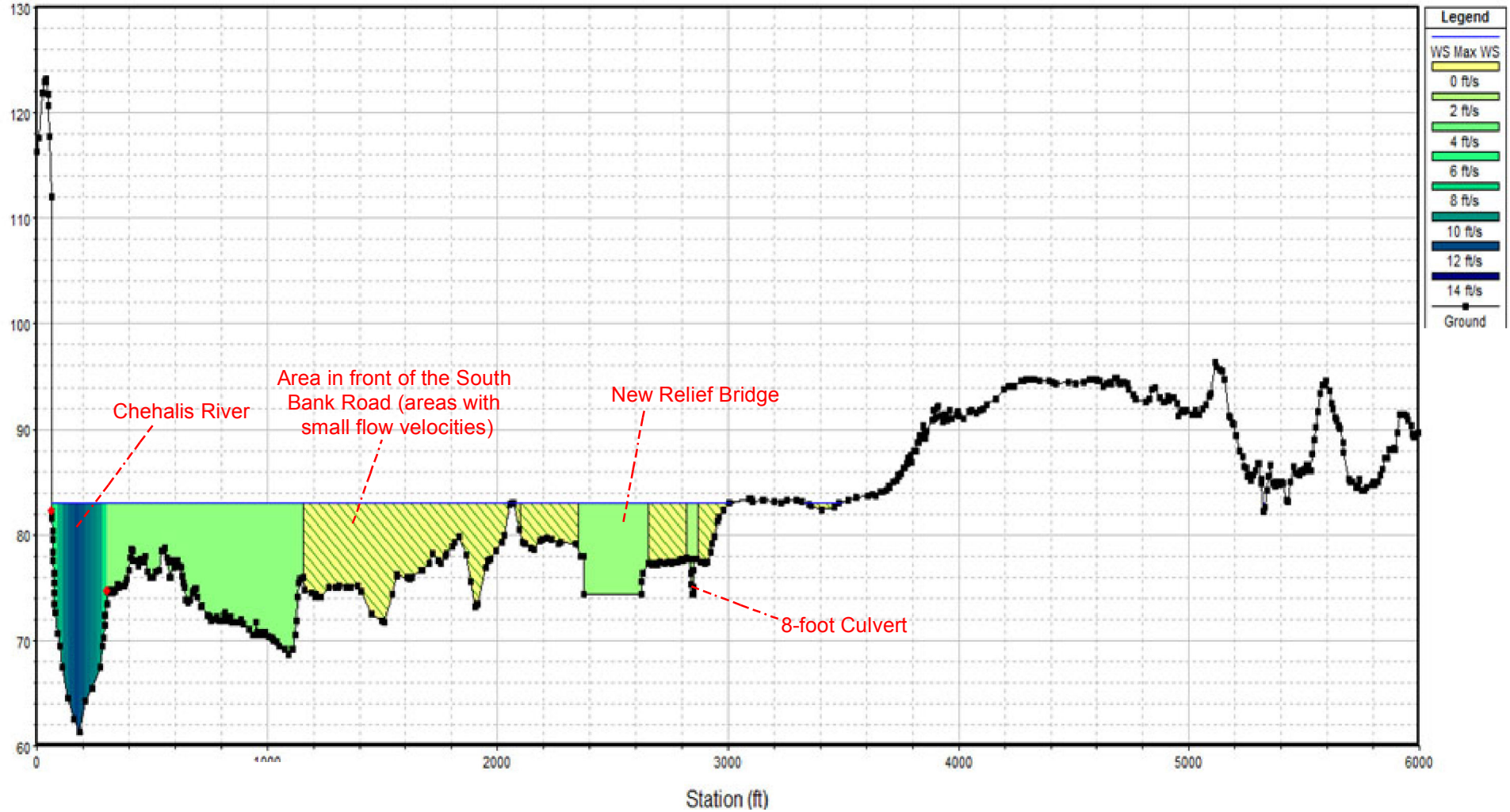


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# Distribution of Velocities Upstream of the Bridge at 50-year, Future Conditions

Figure 5

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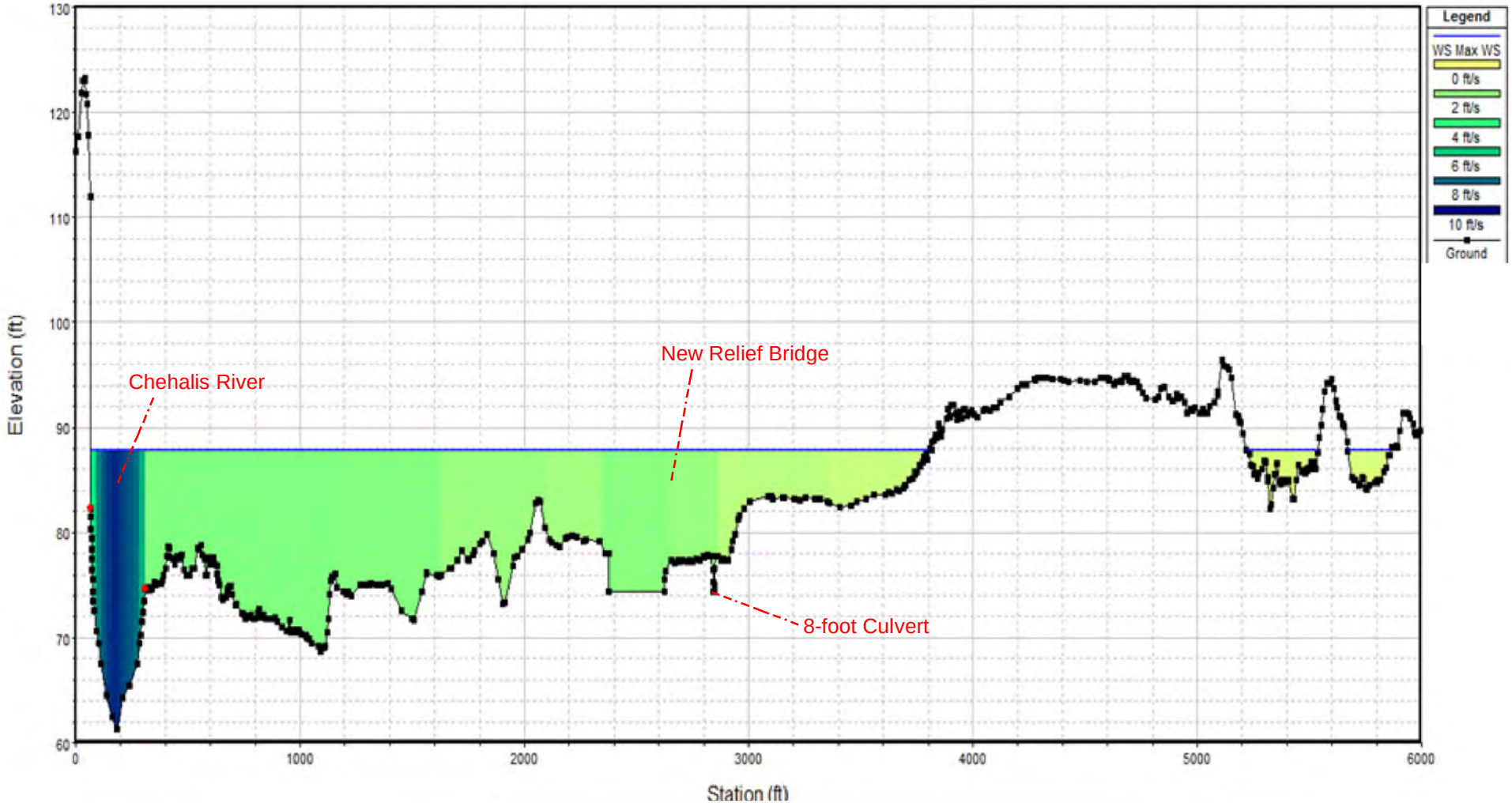


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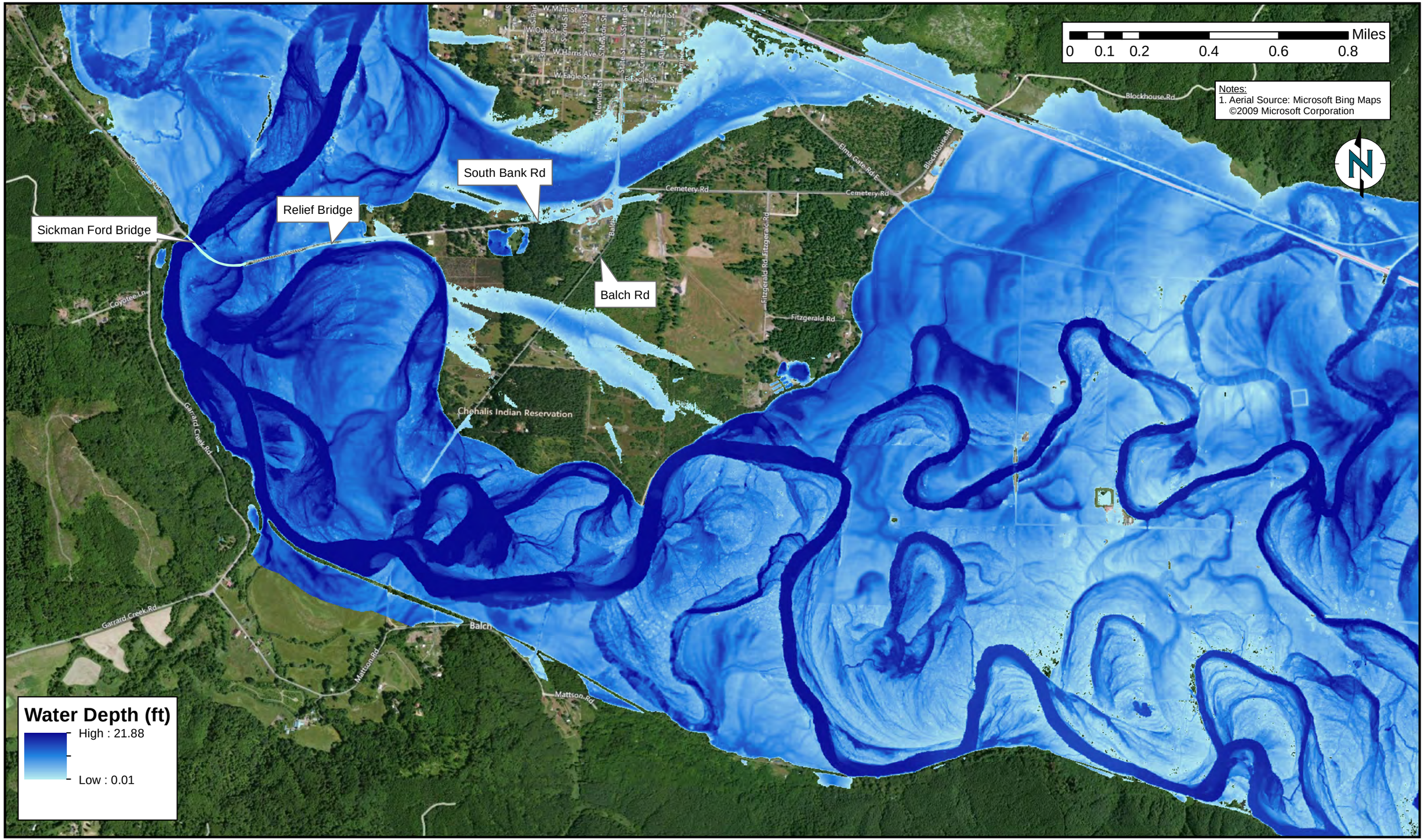
# Distribution of Velocities Upstream of the Bridge at 500-year, Future Conditions

Figure 6

PROJECT: 30-29884A




ENVIRON

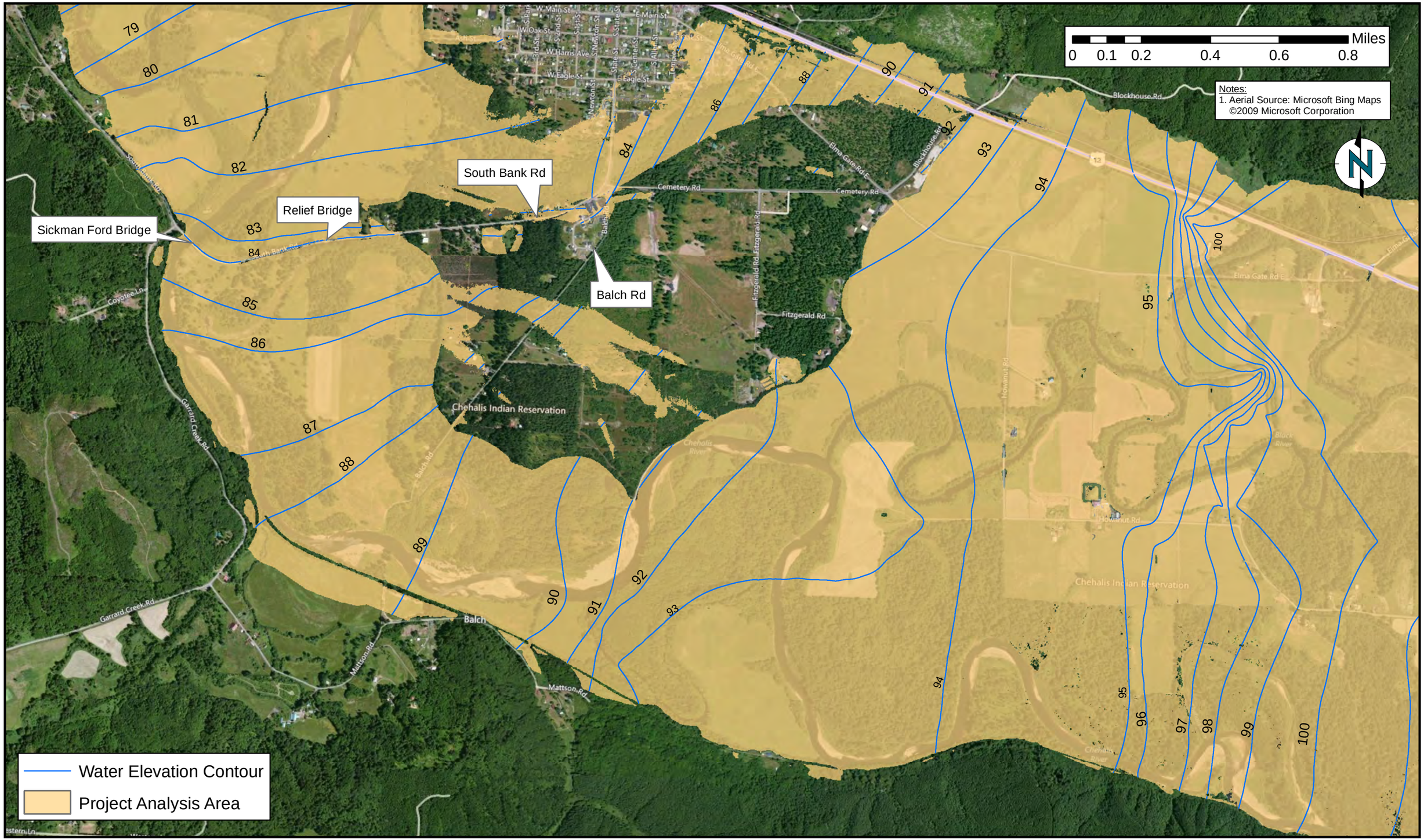
DRAFTED BY: JCampbell

Date: 11/28/2012

Water Depths during 100-year flood -
with Relief Bridge

Figure
7

PROJECT: 30-29884A




ENVIRON

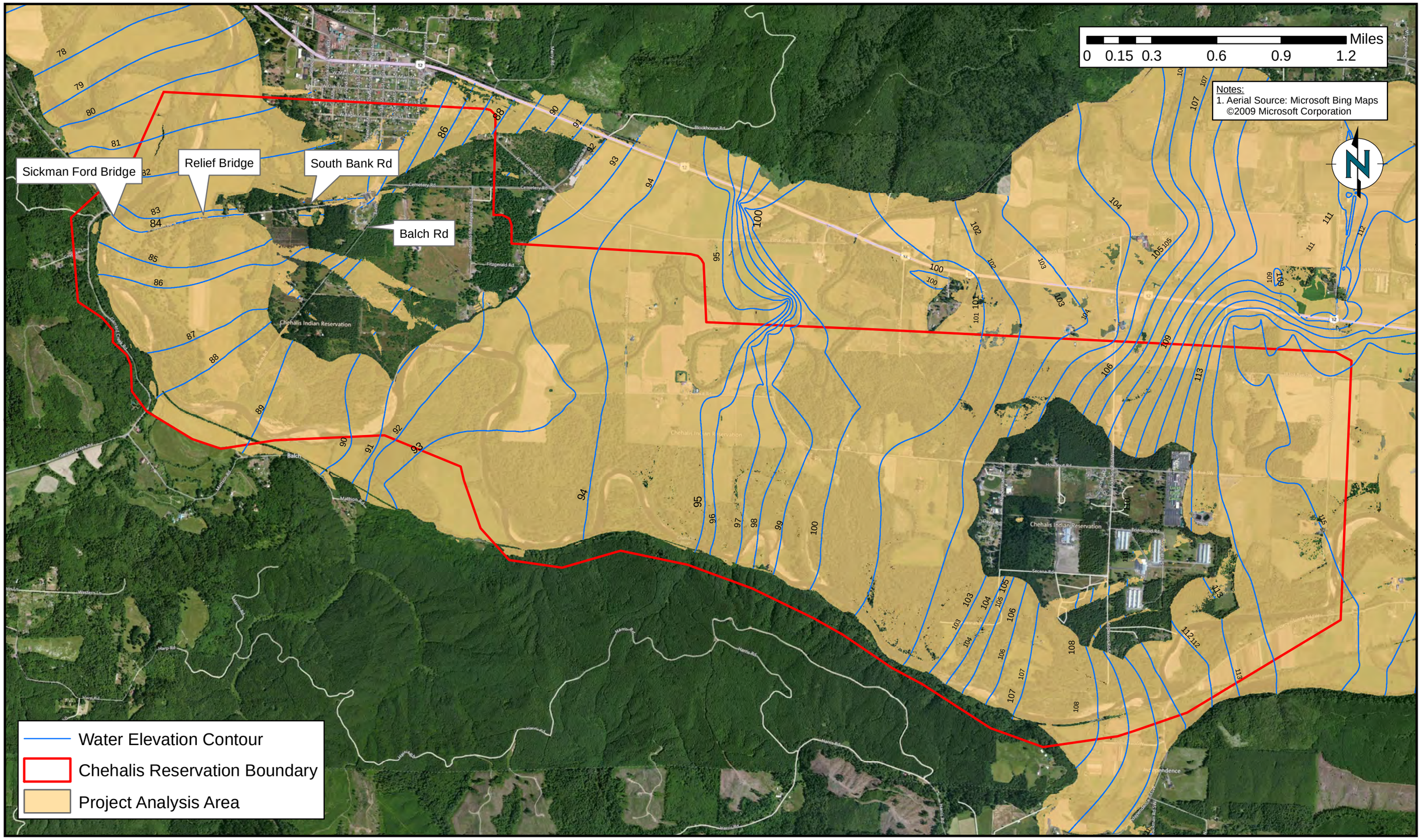
DRAFTED BY: JCampbell

Date: 11/28/2012

# Water Surface Elevation during 100-year Flood - with Relief Bridge (Project Area)

Figure 8

PROJECT: 30-29884A




ENVIRON

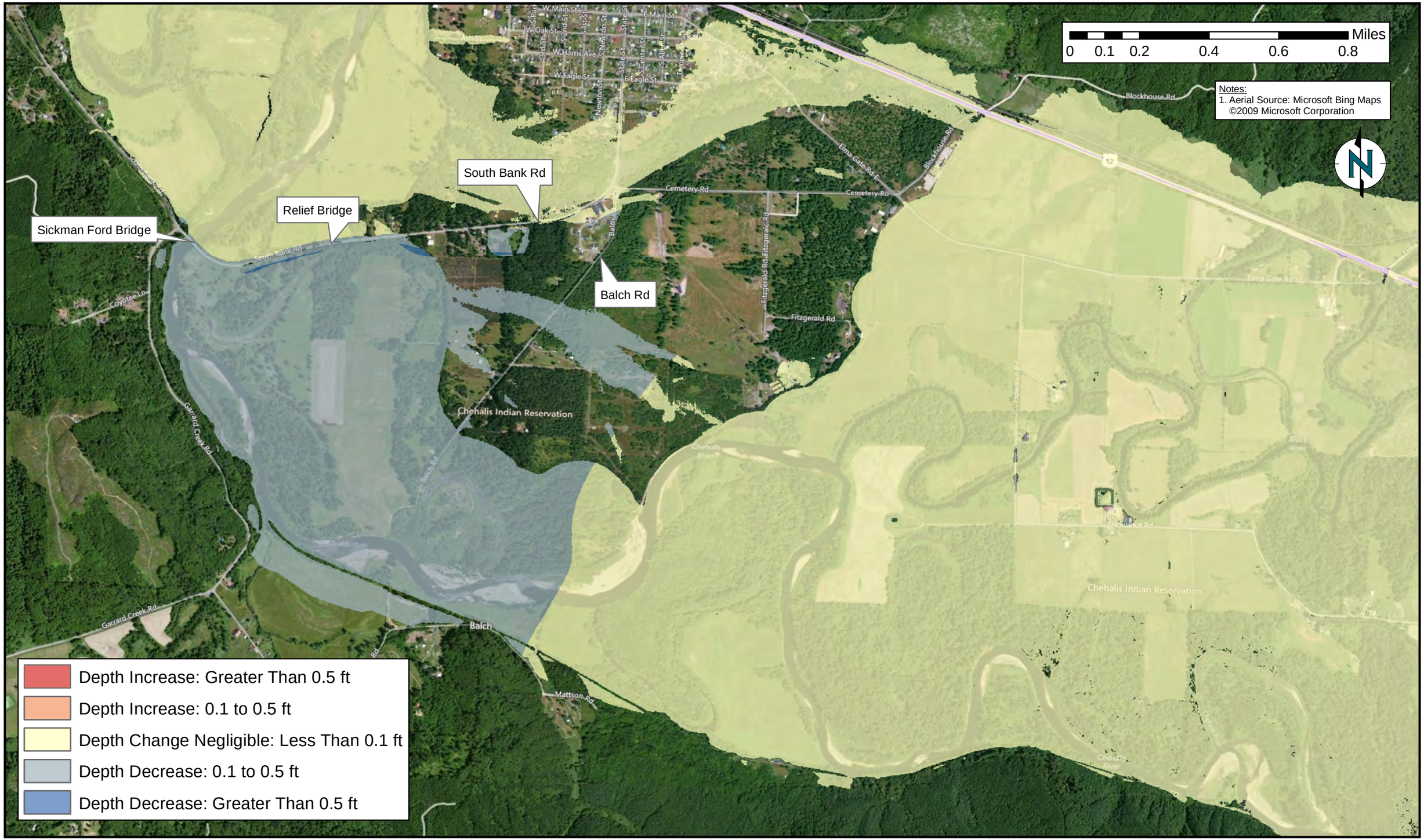
DRAFTED BY: JCampbell

Date: 11/28/2012

Water Surface Elevation during 100-year Flood - with Relief Bridge (CTCR Area)

Figure 9

PROJECT: 30-29884A



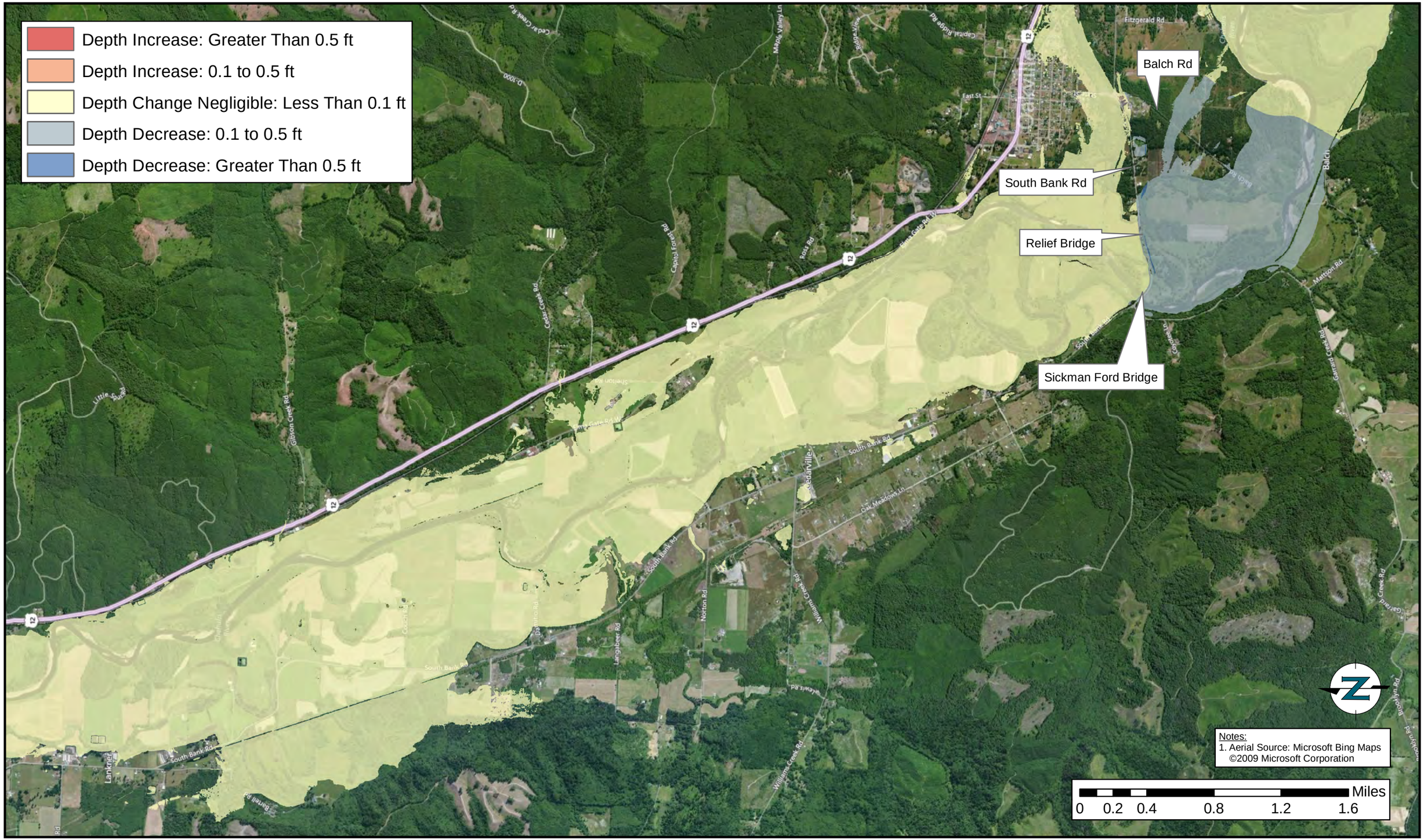

ENVIRON

DRAFTED BY: JCampbell | Date: 11/28/2012

100-year Flood Depth Differences between
Relief Bridge Alternative and Existing Conditions

Figure
10

PROJECT: 30-29884A




ENVIRON

DRAFTED BY: JCampbell

Date: 11/28/2012

# 100-year Flood Depth Differences between Relief Bridge Alternative and Existing Conditions

Figure 11

PROJECT: 30-29884A

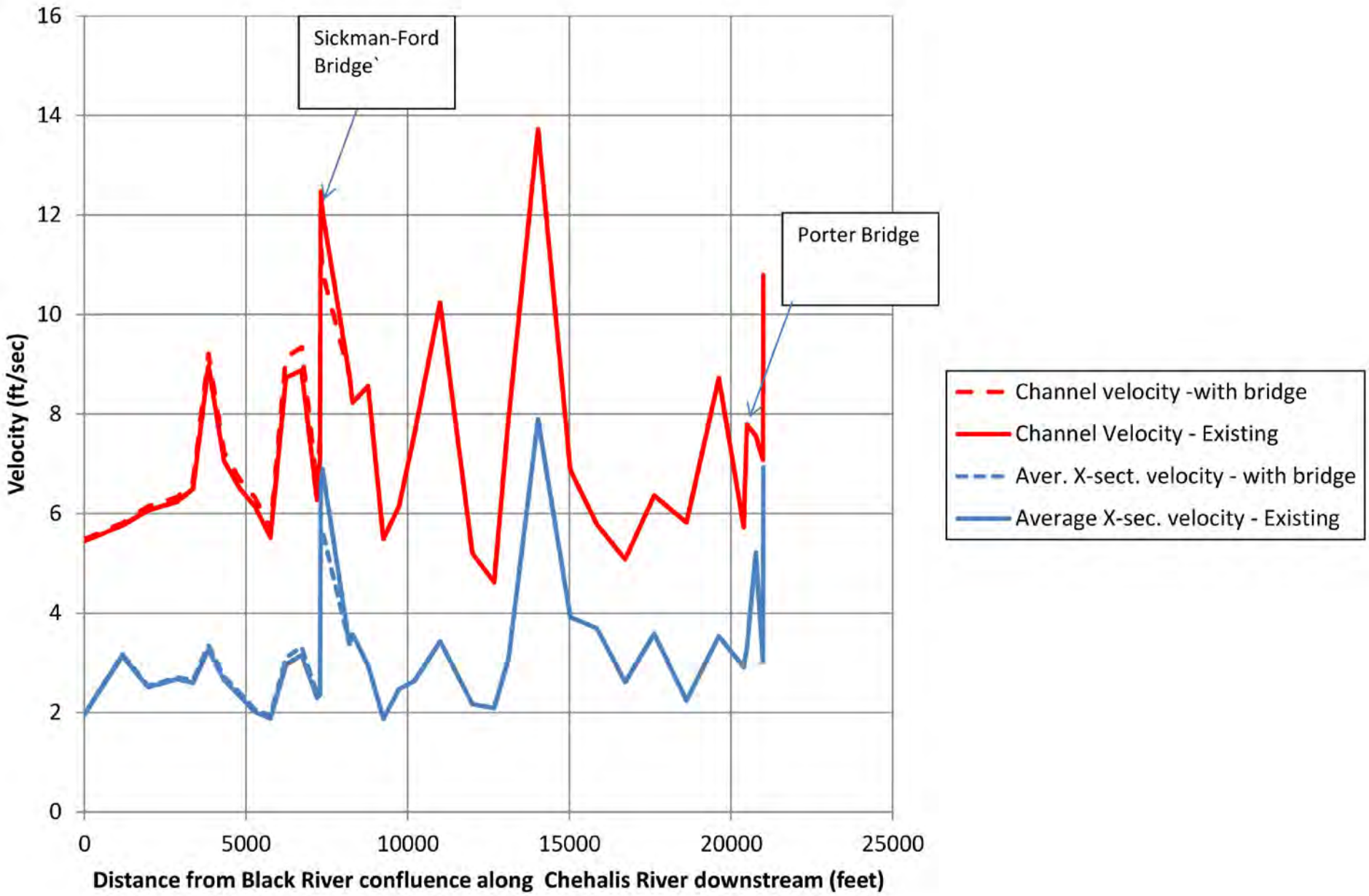
ENVIRON

DRAFTED BY: JCampbell | Date: 11/28/2012

50-year Flood Depth Differences between
Relief Bridge Alternative and Existing Conditions

Figure
12

PROJECT: 30-29884A




ENVIRON

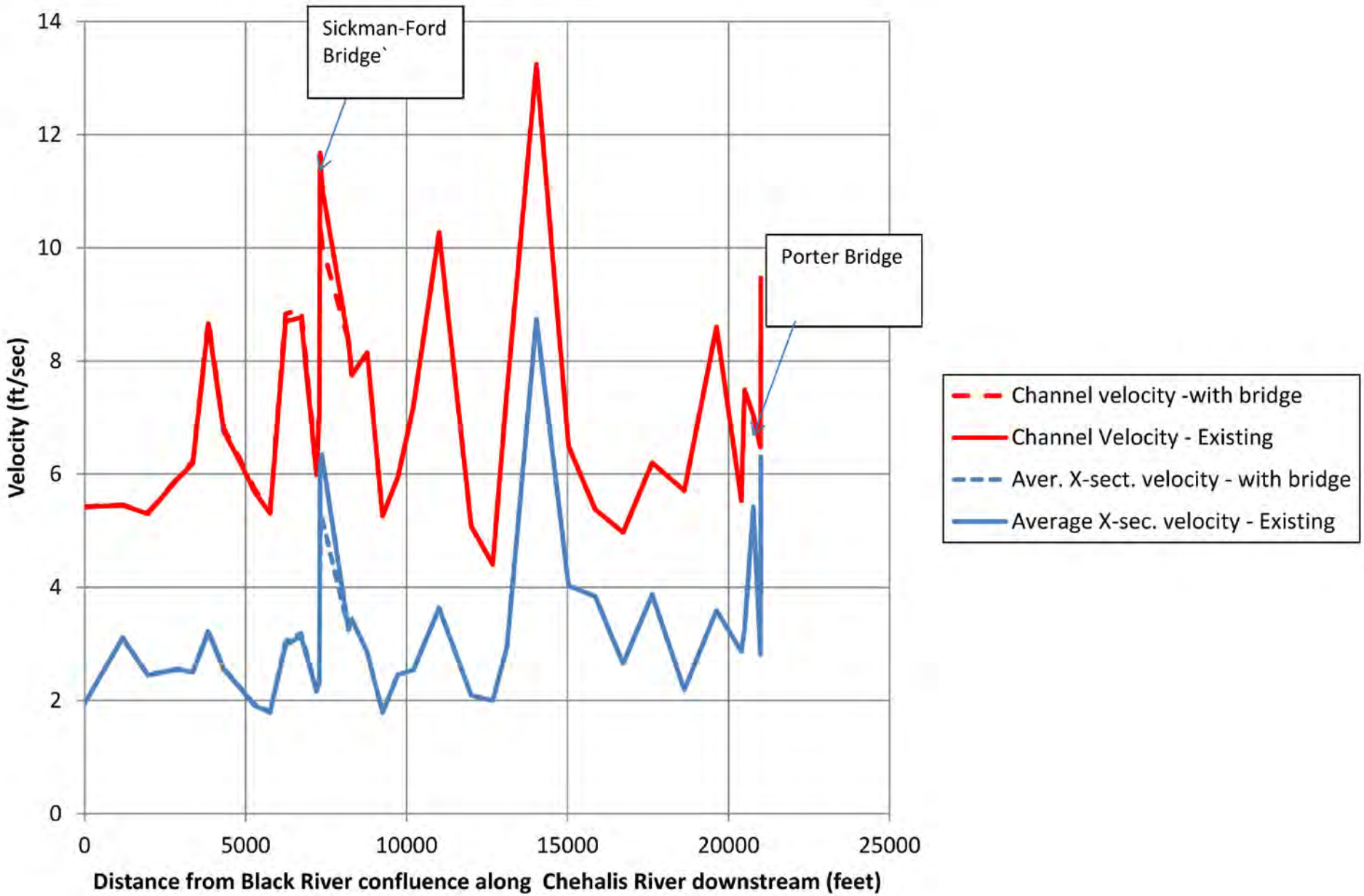
Comparison of velocities at the 100-year flood flow - Lower Chehalis River downstream of Black River

Figure 13

DRAFTED BY: JCampbell

Date: 11/28/2012

PROJECT: 30-29884A




ENVIRON

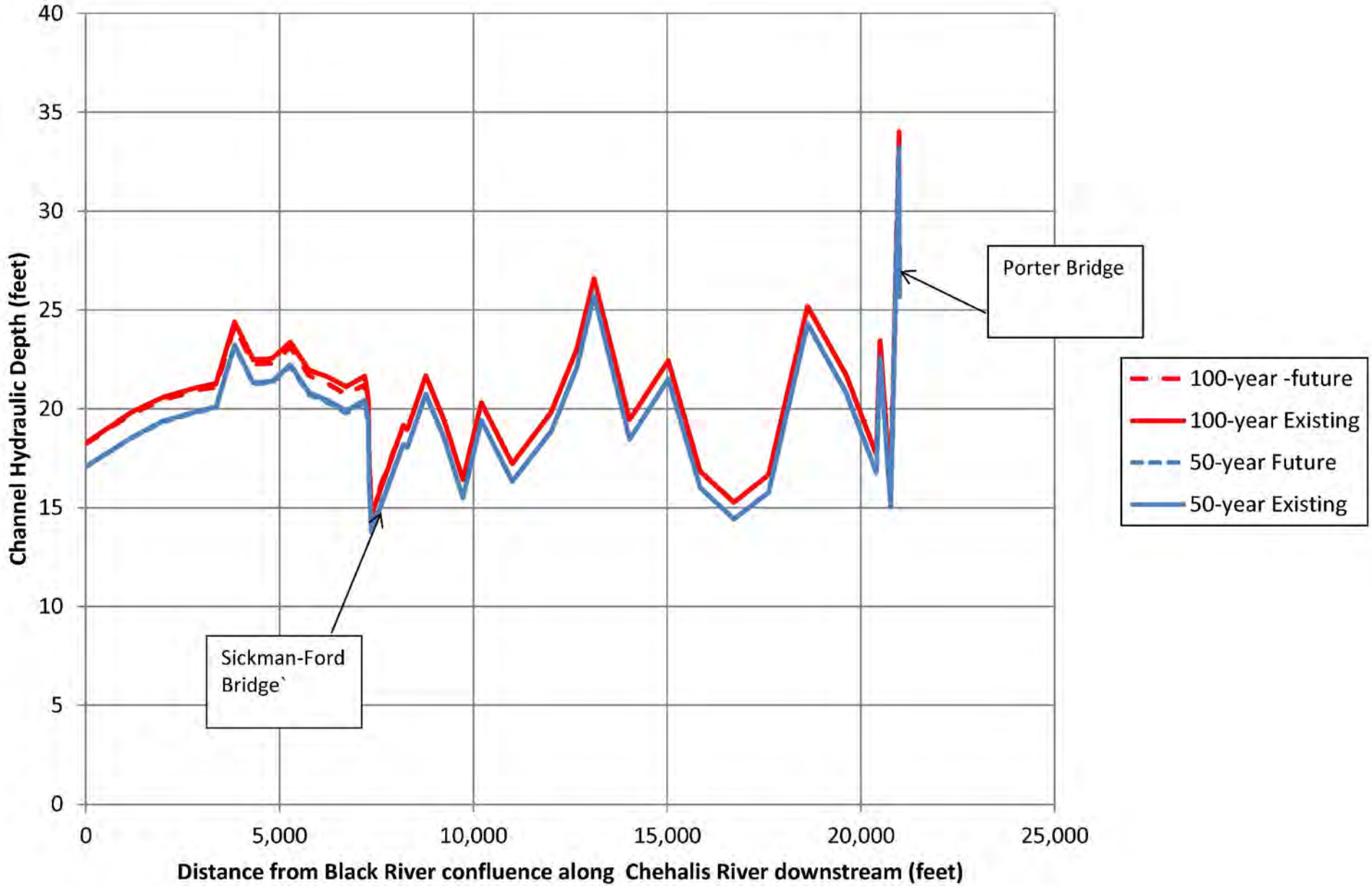
Comparison of velocities at the 50-year flood flow - Lower Chehalis River downstream of Black River

Figure 14

DRAFTED BY: JCampbell

Date: 11/28/2012

PROJECT: 30-29884A




ENVIRON

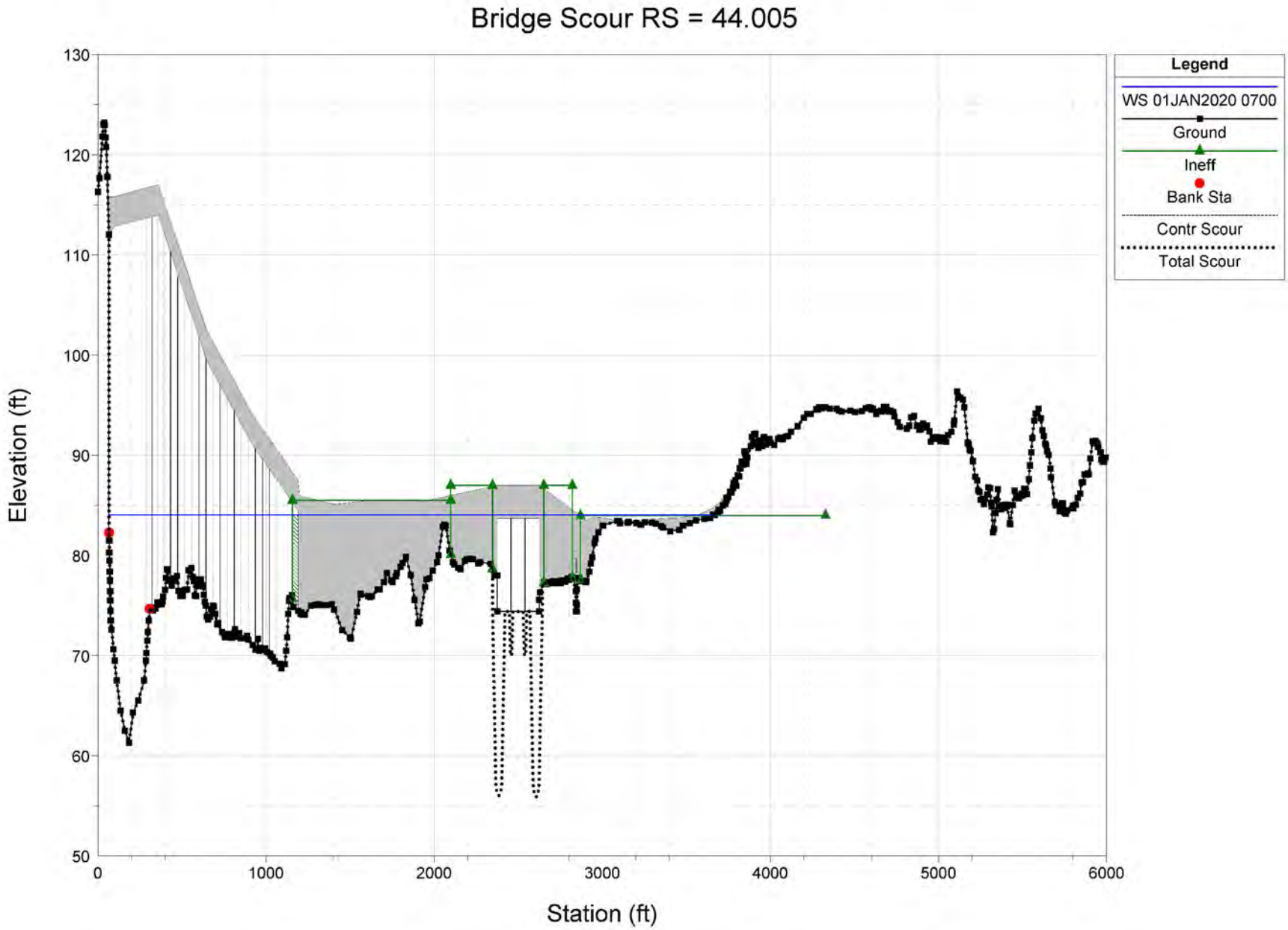
Comparison of hydraulic depths at the 100- and 50-year flood flows - Lower Chehalis River downstream of Black River

Figure 15

DRAFTED BY: JCampbell

Date: 11/28/2012

PROJECT: 30-29884A




ENVIRON

DRAFTED BY: JCampbell

Date: 11/28/2012

Scouring upstream of the Relief Bridge
(HEC-RAS model output)

Figure
16

PROJECT: 30-29884A

# Appendix A

## HEC-RAS Output (Hydraulics)

# Simulation Scenario: 100-year Flood, Existing Conditions

HEC-RAS Plan: Exst-NAVD3 River: LOWER CHEHALIS Reach: REACH 23 Profile: Max WS

| Reach | River Sta | Profile | Length Chnl | 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 C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (ft) | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (sq ft) | (ft) | | (ft) |
| REACH 23 | 46.94 | Max WS | 964.99 | 85631.48 | 66.62 | 92.73 | | 92.96 | 0.000505 | 5.44 | 43780.27 | 5464.34 | 0.22 | 18.27 |
| REACH 23 | 46.05 CHEH 45.25 | Max WS | 1177.12 | 85605.05 | 55.89 | 90.48 | | 90.89 | 0.000500 | 5.76 | 27284.68 | 3096.73 | 0.23 | 19.83 |
| REACH 23 | 45.25 | Max WS | 784.75 | 86482.77 | 54.90 | 89.37 | | 89.72 | 0.000531 | 6.06 | 34502.86 | 3999.01 | 0.24 | 20.56 |
| REACH 23 | 45.09 | Max WS | 918.33 | 86480.20 | 54.57 | 88.96 | | 89.31 | 0.000551 | 6.24 | 32427.61 | 3144.26 | 0.24 | 21.08 |
| REACH 23 | 45.04 LateralWeir#113 | | Lat Struct | | | | | | | | | | | |
| REACH 23 | 44.83 CHEH 44.02 | Max WS | 479.89 | 86472.63 | 54.57 | 87.79 | | 88.14 | 0.000593 | 6.50 | 33196.43 | 3350.55 | 0.25 | 21.27 |
| REACH 23 | 44.74 | Max WS | 479.89 | 86467.90 | 54.80 | 87.26 | | 88.02 | 0.000932 | 8.97 | 26500.20 | 3131.68 | 0.32 | 24.39 |
| REACH 23 | 44.65 | Max WS | 479.89 | 86468.31 | 55.02 | 87.04 | | 87.46 | 0.000644 | 7.05 | 32623.59 | 3302.96 | 0.26 | 22.47 |
| REACH 23 | 44.56 | Max WS | 479.89 | 86467.85 | 55.25 | 86.82 | | 87.12 | 0.000555 | 6.51 | 37058.63 | 3891.41 | 0.24 | 22.54 |
| REACH 23 | 44.47 | Max WS | 479.89 | 86466.00 | 55.47 | 86.62 | | 86.85 | 0.000465 | 6.14 | 43105.39 | 4284.72 | 0.22 | 23.36 |
| REACH 23 | 44.38 | Max WS | 479.89 | 86466.59 | 55.70 | 86.43 | | 86.62 | 0.000407 | 5.52 | 45884.28 | 4300.00 | 0.21 | 21.95 |
| REACH 23 | 44.29 | Max WS | 479.89 | 86463.20 | 55.92 | 85.91 | | 86.57 | 0.001053 | 8.73 | 29253.27 | 3960.56 | 0.33 | 21.61 |
| REACH 23 | 44.2 | Max WS | 479.89 | 86463.46 | 56.15 | 85.40 | | 86.07 | 0.001112 | 8.88 | 27481.90 | 3375.60 | 0.34 | 21.11 |
| REACH 23 | 44.11 | Max WS | 479.89 | 86462.31 | 56.37 | 85.20 | | 85.45 | 0.000533 | 6.27 | 37817.91 | 3230.63 | 0.24 | 21.64 |
| REACH 23 | 44.02 | Max WS | 88.00 | 86462.01 | 56.60 | 84.87 | | 85.21 | 0.000752 | 7.11 | 36716.23 | 4193.36 | 0.28 | 20.48 |
| REACH 23 | 44.01 | Max WS | 26.00 | 86460.96 | 61.30 | 84.15 | 80.13 | 85.71 | 0.002827 | 12.47 | 13162.34 | 3656.42 | 0.53 | 17.44 |
| REACH 23 | 44.005 | | Bridge | | | | | | | | | | | |
| REACH 23 | 44.0 | Max WS | 55.00 | 86450.12 | 61.30 | 83.18 | | 84.71 | 0.003327 | 12.06 | 12548.56 | 3255.72 | 0.56 | 14.63 |
| REACH 23 | 43.99 CHEH 43.99 | Max WS | 828.00 | 86453.34 | 58.30 | 83.55 | | 84.22 | 0.001221 | 8.78 | 25555.26 | 3145.28 | 0.35 | 19.17 |
| REACH 23 | 43.95 LateralWeir#114 | | Lat Struct | | | | | | | | | | | |
| REACH 23 | 43.91 CHEH 43.05 | Max WS | 100.00 | 86902.63 | 56.06 | 82.55 | | 83.26 | 0.001082 | 8.23 | 24348.42 | 3257.84 | 0.33 | 18.96 |
| REACH 23 | 43.7681 | Max WS | 477.73 | 86902.05 | 55.92 | 82.50 | | 83.15 | 0.000983 | 8.56 | 29553.30 | 3948.35 | 0.32 | 21.66 |
| REACH 23 | 43.6263 | Max WS | 477.73 | 86900.62 | 55.79 | 82.32 | | 82.54 | 0.000466 | 5.49 | 46388.22 | 5595.25 | 0.22 | 19.40 |
| REACH 23 | 43.4845 | Max WS | 477.73 | 86896.14 | 55.65 | 81.95 | | 82.32 | 0.000730 | 6.14 | 35227.61 | 5804.49 | 0.27 | 16.42 |
| REACH 23 | 43.3427 | Max WS | 477.73 | 86891.66 | 55.51 | 81.56 | | 82.00 | 0.000839 | 7.58 | 33029.12 | 4651.79 | 0.30 | 20.30 |
| REACH 23 | 42.35 CHEH 42.35 | Max WS | 797.76 | 86850.98 | 54.55 | 78.69 | | 79.70 | 0.001914 | 10.24 | 25309.76 | 5544.85 | 0.43 | 17.23 |
| REACH 23 | 41.74 CHEH 41.74 | Max WS | 1000.00 | 86803.74 | 52.17 | 76.58 | | 76.75 | 0.000408 | 5.20 | 39926.21 | 4782.48 | 0.21 | 19.82 |
| REACH 23 | 41.1 | Max WS | 666.68 | 86783.14 | 44.60 | 75.48 | | 75.67 | 0.000271 | 4.62 | 41534.67 | 4876.10 | 0.17 | 23.02 |
| REACH 23 | 40.35 CHEH 40.35 | Max WS | 442.86 | 86779.11 | 42.70 | 74.18 | | 74.68 | 0.000694 | 7.89 | 28298.56 | 3743.02 | 0.27 | 26.58 |
| REACH 23 | 39.84 CHEH 39.84 | Max WS | 916.67 | 86776.38 | 45.30 | 69.48 | | 71.94 | 0.003036 | 13.72 | 11004.70 | 2550.54 | 0.55 | 19.45 |
| REACH 23 | 39.42 | | Lat Struct | | | | | | | | | | | |
| REACH 23 | 39 CHEH 39.00 | Max WS | 1000.00 | 87806.72 | 35.10 | 65.70 | | 66.33 | 0.000610 | 6.87 | 22382.35 | 4126.73 | 0.26 | 22.42 |
| REACH 23 | 38.48 | Max WS | 825.00 | 88404.52 | 39.60 | 64.32 | | 64.76 | 0.000630 | 5.78 | 23952.09 | 6393.78 | 0.25 | 16.83 |
| REACH 23 | 37.72 | Max WS | 866.67 | 88356.84 | 39.60 | 63.17 | | 63.46 | 0.000554 | 5.08 | 33914.88 | 6420.00 | 0.23 | 15.27 |
| REACH 23 | 37 | Max WS | 900.00 | 88271.34 | 33.50 | 61.12 | | 61.64 | 0.000784 | 6.36 | 24677.15 | 5821.40 | 0.27 | 16.67 |
| REACH 23 | 36.435 | | Lat Struct | | | | | | | | | | | |
| REACH 23 | 35.87 | Max WS | 1000.00 | 88248.88 | 31.80 | 59.98 | | 60.25 | 0.000411 | 5.82 | 39356.64 | 5541.81 | 0.20 | 25.18 |
| REACH 23 | 35 | Max WS | 1000.00 | 88239.62 | 29.30 | 58.22 | | 58.93 | 0.001040 | 8.72 | 24964.42 | 4361.79 | 0.33 | 21.69 |
| REACH 23 | 34 CHEH 34.00 | Max WS | 775.01 | 88234.91 | 27.00 | 56.81 | | 57.10 | 0.000597 | 5.73 | 30295.46 | 4319.59 | 0.24 | 17.70 |
| REACH 23 | 33.41 CHEH 33.41 | Max WS | 100.00 | 88233.84 | 21.30 | 55.59 | | 56.11 | 0.000765 | 7.79 | 26767.41 | 4223.15 | 0.28 | 23.43 |
| REACH 23 | 33.39 CHEH 33.39 | Max WS | 270.00 | 88233.56 | 22.40 | 55.29 | | 56.04 | 0.001179 | 7.56 | 16888.61 | 3664.78 | 0.33 | 15.88 |
| REACH 23 | 33.365 LateralWeir#115 | | Lat Struct | | | | | | | | | | | |
| REACH 23 | 33.34 CHEH 33.34 | Max WS | 220.00 | 89228.48 | 10.70 | 55.29 | | 55.78 | 0.000438 | 7.08 | 29638.37 | 3141.89 | 0.21 | 34.00 |
| REACH 23 | 33.3 CHEH 33.30 | Max WS | 0.10 | 89228.48 | 10.20 | 55.01 | 35.04 | 55.75 | 0.000455 | 7.29 | 20630.72 | 2644.95 | 0.23 | 32.56 |
| REACH 23 | 33.295 | | Bridge | | | | | | | | | | | |
| REACH 23 | 33.29 CHEH 33.29 | Max WS | 10.00 | 89228.48 | 16.60 | 53.23 | | 54.89 | 0.001343 | 10.79 | 12874.04 | 2358.31 | 0.37 | 25.98 |
| REACH 23 | 33.28 CHEH 33.28 | Max WS | | 89228.47 | 16.60 | 53.68 | 40.63 | 54.63 | 0.000911 | 8.93 | 20809.94 | 2603.40 | 0.31 | 26.32 |

## Simulation Scenario: 100-year Flood, Relief Bridge Alternative

HEC-RAS Plan: Bridge-5b River: LOWER CHEHALIS Reach: REACH 23 Profile: Max WS

| Reach | River Sta | Profile | Length Chnl | 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 C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (ft) | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (sq ft) | (ft) | | (ft) |
| REACH 23 | 46.94 | Max WS | 964.99 | 85736.22 | 66.62 | 92.69 | | 92.92 | 0.000514 | 5.48 | 43551.64 | 5464.22 | 0.23 | 18.23 |
| REACH 23 | 46.05 CHEH 45.25 | Max WS | 1177.12 | 85724.68 | 55.89 | 90.39 | | 90.80 | 0.000512 | 5.81 | 27002.50 | 3074.82 | 0.23 | 19.74 |
| REACH 23 | 45.25 | Max WS | 784.75 | 86612.54 | 54.90 | 89.25 | | 89.62 | 0.000549 | 6.14 | 34040.40 | 3988.98 | 0.24 | 20.44 |
| REACH 23 | 45.09 | Max WS | 918.33 | 86610.31 | 54.57 | 88.83 | | 89.19 | 0.000571 | 6.33 | 32019.32 | 3137.52 | 0.24 | 20.95 |
| REACH 23 | 45.04 LateralWeir#113 | | Lat Struct | | | | | | | | | | | |
| REACH 23 | 44.83 CHEH 44.02 | Max WS | 479.89 | 86607.62 | 54.57 | 87.60 | | 87.97 | 0.000623 | 6.63 | 32584.45 | 3331.35 | 0.25 | 21.08 |
| REACH 23 | 44.74 | Max WS | 479.89 | 86606.19 | 54.80 | 87.04 | | 87.85 | 0.000992 | 9.20 | 25816.00 | 3130.38 | 0.33 | 24.17 |
| REACH 23 | 44.65 | Max WS | 479.89 | 86605.09 | 55.02 | 86.81 | | 87.25 | 0.000686 | 7.23 | 31856.58 | 3302.52 | 0.27 | 22.24 |
| REACH 23 | 44.56 | Max WS | 479.89 | 86604.96 | 55.25 | 86.57 | | 86.89 | 0.000595 | 6.69 | 36103.43 | 3786.16 | 0.25 | 22.29 |
| REACH 23 | 44.47 | Max WS | 479.89 | 86603.69 | 55.47 | 86.36 | | 86.61 | 0.000501 | 6.32 | 41992.87 | 4282.18 | 0.23 | 23.10 |
| REACH 23 | 44.38 | Max WS | 479.89 | 86603.81 | 55.70 | 86.16 | | 86.36 | 0.000440 | 5.69 | 44705.05 | 4300.00 | 0.22 | 21.67 |
| REACH 23 | 44.29 | Max WS | 479.89 | 86602.88 | 55.92 | 85.57 | | 86.31 | 0.001178 | 9.14 | 27922.15 | 3960.00 | 0.35 | 21.27 |
| REACH 23 | 44.2 | Max WS | 479.89 | 86602.20 | 56.15 | 85.00 | | 85.76 | 0.001263 | 9.34 | 26118.18 | 3374.97 | 0.36 | 20.71 |
| REACH 23 | 44.11 | Max WS | 479.89 | 86601.09 | 56.37 | 84.77 | | 85.05 | 0.000596 | 6.54 | 36440.04 | 3229.96 | 0.25 | 21.21 |
| REACH 23 | 44.02 | Max WS | 88.00 | 86599.73 | 56.60 | 84.39 | | 84.78 | 0.000878 | 7.58 | 34691.87 | 4187.72 | 0.30 | 20.05 |
| REACH 23 | 44.01 | Max WS | 26.00 | 86596.25 | 61.30 | 83.85 | 79.93 | 85.05 | 0.002440 | 11.46 | 15909.81 | 3612.58 | 0.49 | 17.14 |
| REACH 23 | 44.005 | | Bridge | | | | | | | | | | | |
| REACH 23 | 44.0 | Max WS | 55.00 | 86585.58 | 61.30 | 83.39 | | 84.52 | 0.002637 | 10.84 | 15360.99 | 3314.16 | 0.50 | 14.84 |
| REACH 23 | 43.99 CHEH 43.99 | Max WS | 828.00 | 86587.54 | 58.30 | 83.56 | | 84.22 | 0.001221 | 8.78 | 25584.04 | 3146.86 | 0.35 | 19.18 |
| REACH 23 | 43.95 LateralWeir#114 | | Lat Struct | | | | | | | | | | | |
| REACH 23 | 43.91 CHEH 43.05 | Max WS | 100.00 | 87035.63 | 56.06 | 82.56 | | 83.27 | 0.001083 | 8.24 | 24376.21 | 3259.70 | 0.33 | 18.96 |
| REACH 23 | 43.7681 | Max WS | 477.73 | 87037.13 | 55.92 | 82.51 | | 83.16 | 0.000984 | 8.56 | 29587.50 | 3948.40 | 0.32 | 21.66 |
| REACH 23 | 43.6263 | Max WS | 477.73 | 87033.25 | 55.79 | 82.32 | | 82.54 | 0.000466 | 5.49 | 46436.33 | 5595.31 | 0.22 | 19.41 |
| REACH 23 | 43.4845 | Max WS | 477.73 | 87030.09 | 55.65 | 81.96 | | 82.33 | 0.000730 | 6.14 | 35277.43 | 5804.94 | 0.27 | 16.43 |
| REACH 23 | 43.3427 | Max WS | 477.73 | 87023.51 | 55.51 | 81.57 | | 82.01 | 0.000839 | 7.58 | 33068.21 | 4654.94 | 0.30 | 20.31 |
| REACH 23 | 42.35 CHEH 42.35 | Max WS | 797.76 | 86973.70 | 54.55 | 78.70 | | 79.71 | 0.001912 | 10.24 | 25355.24 | 5544.96 | 0.43 | 17.24 |
| REACH 23 | 41.74 CHEH 41.74 | Max WS | 1000.00 | 86918.95 | 52.17 | 76.59 | | 76.76 | 0.000408 | 5.20 | 39968.11 | 4783.65 | 0.21 | 19.83 |
| REACH 23 | 41.1 | Max WS | 666.68 | 86898.52 | 44.60 | 75.49 | | 75.68 | 0.000271 | 4.63 | 41578.46 | 4876.55 | 0.17 | 23.03 |
| REACH 23 | 40.35 CHEH 40.35 | Max WS | 442.86 | 86890.45 | 42.70 | 74.19 | | 74.68 | 0.000694 | 7.89 | 28331.65 | 3743.23 | 0.27 | 26.59 |
| REACH 23 | 39.84 CHEH 39.84 | Max WS | 916.67 | 86885.02 | 45.30 | 69.49 | | 71.95 | 0.003035 | 13.72 | 11027.37 | 2550.58 | 0.55 | 19.46 |
| REACH 23 | 39.42 | | Lat Struct | | | | | | | | | | | |
| REACH 23 | 39 CHEH 39.00 | Max WS | 1000.00 | 87944.08 | 35.10 | 65.71 | | 66.34 | 0.000611 | 6.87 | 22416.61 | 4127.52 | 0.26 | 22.42 |
| REACH 23 | 38.48 | Max WS | 825.00 | 88536.03 | 39.60 | 64.33 | | 64.77 | 0.000630 | 5.78 | 23997.70 | 6393.88 | 0.25 | 16.84 |
| REACH 23 | 37.72 | Max WS | 866.67 | 88475.74 | 39.60 | 63.18 | | 63.47 | 0.000554 | 5.08 | 33960.14 | 6421.88 | 0.23 | 15.28 |
| REACH 23 | 37 | Max WS | 900.00 | 88379.52 | 33.50 | 61.12 | | 61.65 | 0.000784 | 6.36 | 24719.87 | 5821.44 | 0.27 | 16.67 |
| REACH 23 | 36.435 | | Lat Struct | | | | | | | | | | | |
| REACH 23 | 35.87 | Max WS | 1000.00 | 88357.23 | 31.80 | 59.99 | | 60.25 | 0.000411 | 5.82 | 39397.43 | 5541.91 | 0.20 | 25.18 |
| REACH 23 | 35 | Max WS | 1000.00 | 88346.59 | 29.30 | 58.22 | | 58.94 | 0.001039 | 8.72 | 24998.58 | 4361.98 | 0.33 | 21.70 |
| REACH 23 | 34 CHEH 34.00 | Max WS | 775.01 | 88343.26 | 27.00 | 56.82 | | 57.10 | 0.000597 | 5.73 | 30331.96 | 4320.33 | 0.24 | 17.71 |
| REACH 23 | 33.41 CHEH 33.41 | Max WS | 100.00 | 88341.98 | 21.30 | 55.60 | | 56.12 | 0.000765 | 7.79 | 26804.54 | 4226.18 | 0.28 | 23.44 |
| REACH 23 | 33.39 CHEH 33.39 | Max WS | 270.00 | 88341.95 | 22.40 | 55.30 | | 56.05 | 0.001178 | 7.56 | 16920.13 | 3667.58 | 0.33 | 15.89 |
| REACH 23 | 33.365 LateralWeir#115 | | Lat Struct | | | | | | | | | | | |
| REACH 23 | 33.34 CHEH 33.34 | Max WS | 220.00 | 89344.10 | 10.70 | 55.30 | | 55.79 | 0.000439 | 7.08 | 29664.70 | 3142.75 | 0.21 | 34.01 |
| REACH 23 | 33.3 CHEH 33.30 | Max WS | 0.10 | 89344.02 | 10.20 | 55.01 | 35.04 | 55.76 | 0.000456 | 7.30 | 20651.64 | 2649.50 | 0.23 | 32.57 |
| REACH 23 | 33.295 | | Bridge | | | | | | | | | | | |
| REACH 23 | 33.29 CHEH 33.29 | Max WS | 10.00 | 89344.02 | 16.60 | 53.24 | | 54.89 | 0.001345 | 10.80 | 12883.45 | 2359.78 | 0.37 | 25.99 |
| REACH 23 | 33.28 CHEH 33.28 | Max WS | | 89344.05 | 16.60 | 53.68 | 40.65 | 54.64 | 0.000913 | 8.93 | 20822.76 | 2603.71 | 0.31 | 26.33 |

# Simulation Scenario: 50-year Flood, Existing Conditions

HEC-RAS Plan: Exst-NAVD(50) River: LOWER CHEHALIS Reach: REACH 23 Profile: Max WS

| Reach | River Sta | Profile | Length Chnl | 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 C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (ft) | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (sq ft) | (ft) | | (ft) |
| REACH 23 | 46.94 | Max WS | 964.99 | 72581.34 | 66.62 | 91.55 | | 91.79 | 0.000548 | 5.42 | 37302.28 | 5460.90 | 0.23 | 17.08 |
| REACH 23 | 46.05 CHEH 45.25 | Max WS | 1177.12 | 72545.42 | 55.89 | 89.19 | | 89.57 | 0.000490 | 5.45 | 23404.43 | 2929.63 | 0.22 | 18.54 |
| REACH 23 | 45.25 | Max WS | 784.75 | 73306.98 | 54.90 | 88.16 | | 88.43 | 0.000440 | 5.30 | 29937.49 | 3383.98 | 0.21 | 19.36 |
| REACH 23 | 45.09 | Max WS | 918.33 | 73320.77 | 54.57 | 87.77 | | 88.10 | 0.000533 | 5.91 | 28738.04 | 3046.04 | 0.23 | 19.89 |
| REACH 23 | 45.04 LateralWeir#113 | | Lat Struct | | | | | | | | | | | |
| REACH 23 | 44.83 CHEH 44.02 | Max WS | 479.89 | 73359.20 | 54.57 | 86.62 | | 86.96 | 0.000579 | 6.19 | 29379.62 | 3204.69 | 0.24 | 20.10 |
| REACH 23 | 44.74 | Max WS | 479.89 | 73365.31 | 54.80 | 86.09 | | 86.86 | 0.000928 | 8.66 | 22846.68 | 3124.96 | 0.32 | 23.22 |
| REACH 23 | 44.65 | Max WS | 479.89 | 73372.48 | 55.02 | 85.88 | | 86.29 | 0.000635 | 6.76 | 28798.84 | 3300.93 | 0.26 | 21.31 |
| REACH 23 | 44.56 | Max WS | 479.89 | 73382.02 | 55.25 | 85.66 | | 85.96 | 0.000547 | 6.24 | 32814.39 | 3523.04 | 0.24 | 21.38 |
| REACH 23 | 44.47 | Max WS | 479.89 | 73391.08 | 55.47 | 85.47 | | 85.69 | 0.000427 | 5.69 | 38422.66 | 3900.84 | 0.21 | 22.22 |
| REACH 23 | 44.38 | Max WS | 479.89 | 73399.70 | 55.70 | 85.29 | | 85.48 | 0.000404 | 5.31 | 40987.11 | 4300.00 | 0.20 | 20.81 |
| REACH 23 | 44.29 | Max WS | 479.89 | 73407.59 | 55.92 | 84.73 | | 85.45 | 0.001126 | 8.70 | 24592.39 | 3958.48 | 0.34 | 20.43 |
| REACH 23 | 44.2 | Max WS | 479.89 | 73417.17 | 56.15 | 84.20 | | 84.91 | 0.001174 | 8.77 | 23434.92 | 3373.66 | 0.35 | 19.91 |
| REACH 23 | 44.11 | Max WS | 479.89 | 73426.35 | 56.37 | 84.01 | | 84.25 | 0.000525 | 5.99 | 33966.19 | 3228.74 | 0.23 | 20.44 |
| REACH 23 | 44.02 | Max WS | 88.00 | 73435.27 | 56.60 | 83.65 | | 84.01 | 0.000805 | 7.10 | 31612.46 | 4177.76 | 0.28 | 19.40 |
| REACH 23 | 44.01 | Max WS | 26.00 | 73434.32 | 61.30 | 83.02 | 78.09 | 84.41 | 0.002708 | 11.67 | 11923.38 | 3091.08 | 0.51 | 16.31 |
| REACH 23 | 44.005 | | Bridge | | | | | | | | | | | |
| REACH 23 | 44.0 | Max WS | 55.00 | 73425.66 | 61.30 | 82.32 | | 83.63 | 0.003048 | 11.09 | 11576.48 | 3184.83 | 0.53 | 13.77 |
| REACH 23 | 43.99 CHEH 43.99 | Max WS | 828.00 | 73429.85 | 58.30 | 82.60 | | 83.23 | 0.001182 | 8.35 | 22601.34 | 3036.00 | 0.34 | 18.21 |
| REACH 23 | 43.95 LateralWeir#114 | | Lat Struct | | | | | | | | | | | |
| REACH 23 | 43.91 CHEH 43.05 | Max WS | 100.00 | 73807.88 | 56.06 | 81.64 | | 82.30 | 0.001024 | 7.75 | 21465.77 | 3146.45 | 0.32 | 18.05 |
| REACH 23 | 43.7681 | Max WS | 477.73 | 73810.03 | 55.92 | 81.59 | | 82.21 | 0.000943 | 8.15 | 25937.41 | 3942.19 | 0.32 | 20.74 |
| REACH 23 | 43.6263 | Max WS | 477.73 | 73819.14 | 55.79 | 81.40 | | 81.62 | 0.000456 | 5.26 | 41291.82 | 5588.90 | 0.22 | 18.49 |
| REACH 23 | 43.4845 | Max WS | 477.73 | 73825.80 | 55.65 | 81.03 | | 81.41 | 0.000740 | 5.95 | 29958.67 | 5660.33 | 0.27 | 15.50 |
| REACH 23 | 43.3427 | Max WS | 477.73 | 73831.34 | 55.51 | 80.66 | | 81.08 | 0.000801 | 7.18 | 29103.51 | 3944.16 | 0.29 | 19.41 |
| REACH 23 | 42.35 CHEH 42.35 | Max WS | 797.76 | 73856.91 | 54.55 | 77.80 | | 78.92 | 0.002064 | 10.27 | 20365.47 | 5533.43 | 0.45 | 16.33 |
| REACH 23 | 41.74 CHEH 41.74 | Max WS | 1000.00 | 73851.50 | 52.17 | 75.61 | | 75.78 | 0.000417 | 5.08 | 35340.29 | 4711.50 | 0.21 | 18.85 |
| REACH 23 | 41.1 | Max WS | 666.68 | 73896.52 | 44.60 | 74.54 | | 74.72 | 0.000261 | 4.41 | 36981.29 | 4828.48 | 0.17 | 22.08 |
| REACH 23 | 40.35 CHEH 40.35 | Max WS | 442.86 | 73965.38 | 42.70 | 73.33 | | 73.81 | 0.000649 | 7.47 | 25179.15 | 3640.05 | 0.26 | 25.74 |
| REACH 23 | 39.84 CHEH 39.84 | Max WS | 916.67 | 74026.74 | 45.30 | 68.48 | | 70.94 | 0.003034 | 13.24 | 8472.57 | 2546.27 | 0.54 | 18.46 |
| REACH 23 | 39.42 | | Lat Struct | | | | | | | | | | | |
| REACH 23 | 39 CHEH 39.00 | Max WS | 1000.00 | 74974.88 | 35.10 | 64.78 | | 65.38 | 0.000576 | 6.49 | 18618.64 | 4073.34 | 0.25 | 21.50 |
| REACH 23 | 38.48 | Max WS | 825.00 | 75464.13 | 39.60 | 63.50 | | 63.89 | 0.000585 | 5.38 | 19668.87 | 2609.98 | 0.24 | 16.01 |
| REACH 23 | 37.72 | Max WS | 866.67 | 75478.80 | 39.60 | 62.33 | | 62.62 | 0.000574 | 4.97 | 28525.88 | 6316.44 | 0.23 | 14.42 |
| REACH 23 | 37 | Max WS | 900.00 | 75489.07 | 33.50 | 60.23 | | 60.77 | 0.000804 | 6.20 | 19530.40 | 5777.90 | 0.28 | 15.78 |
| REACH 23 | 36.435 | | Lat Struct | | | | | | | | | | | |
| REACH 23 | 35.87 | Max WS | 1000.00 | 75531.02 | 31.80 | 59.09 | | 59.37 | 0.000414 | 5.71 | 34459.04 | 5526.22 | 0.20 | 24.29 |
| REACH 23 | 35 | Max WS | 1000.00 | 75572.45 | 29.30 | 57.31 | | 58.06 | 0.001070 | 8.60 | 21075.85 | 4109.85 | 0.33 | 20.78 |
| REACH 23 | 34 CHEH 34.00 | Max WS | 775.01 | 75601.77 | 27.00 | 55.89 | | 56.17 | 0.000596 | 5.53 | 26372.96 | 4232.28 | 0.24 | 16.78 |
| REACH 23 | 33.41 CHEH 33.41 | Max WS | 100.00 | 75647.40 | 21.30 | 54.72 | | 55.24 | 0.000745 | 7.49 | 23190.19 | 4030.16 | 0.28 | 22.56 |
| REACH 23 | 33.39 CHEH 33.39 | Max WS | 270.00 | 75649.15 | 22.40 | 54.46 | | 55.13 | 0.001097 | 7.04 | 13966.59 | 3470.99 | 0.32 | 15.05 |
| REACH 23 | 33.365 LateralWeir#115 | | Lat Struct | | | | | | | | | | | |
| REACH 23 | 33.34 CHEH 33.34 | Max WS | 220.00 | 76525.17 | 10.70 | 54.48 | | 54.91 | 0.000380 | 6.48 | 27123.02 | 3036.72 | 0.20 | 33.19 |
| REACH 23 | 33.3 CHEH 33.30 | Max WS | 0.10 | 76529.17 | 10.20 | 54.25 | 33.67 | 54.86 | 0.000378 | 6.54 | 18693.40 | 2455.07 | 0.20 | 31.80 |
| REACH 23 | 33.295 | | Bridge | | | | | | | | | | | |
| REACH 23 | 33.29 CHEH 33.29 | Max WS | 10.00 | 76529.07 | 16.60 | 52.91 | | 54.19 | 0.001051 | 9.47 | 12130.74 | 2210.37 | 0.33 | 25.66 |
| REACH 23 | 33.28 CHEH 33.28 | Max WS | | 76529.09 | 16.60 | 53.25 | 38.78 | 54.02 | 0.000740 | 7.96 | 19683.73 | 2575.88 | 0.28 | 25.89 |

## Simulation Scenario: 50-year Flood, Relief Bridge Alternative

HEC-RAS Plan: Bridge-5b(50) River: LOWER CHEHALIS Reach: REACH 23 Profile: Max WS

| Reach | River Sta | Profile | Length Chnl | 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 C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (ft) | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (sq ft) | (ft) | | (ft) |
| REACH 23 | 46.94 | Max WS | 964.99 | 72598.98 | 66.62 | 91.54 | | 91.78 | 0.000551 | 5.43 | 37241.95 | 5460.87 | 0.23 | 17.07 |
| REACH 23 | 46.05 CHEH 45.25 | Max WS | 1177.12 | 72566.45 | 55.89 | 89.16 | | 89.54 | 0.000493 | 5.46 | 23329.48 | 2926.65 | 0.22 | 18.52 |
| REACH 23 | 45.25 | Max WS | 784.75 | 73331.95 | 54.90 | 88.13 | | 88.40 | 0.000444 | 5.32 | 29821.51 | 3378.64 | 0.21 | 19.32 |
| REACH 23 | 45.09 | Max WS | 918.33 | 73344.84 | 54.57 | 87.73 | | 88.06 | 0.000539 | 5.93 | 28620.89 | 3044.46 | 0.23 | 19.85 |
| REACH 23 | 45.04 LateralWeir#113 | | Lat Struct | | | | | | | | | | | |
| REACH 23 | 44.83 CHEH 44.02 | Max WS | 479.89 | 73384.10 | 54.57 | 86.57 | | 86.91 | 0.000588 | 6.23 | 29207.35 | 3195.47 | 0.25 | 20.05 |
| REACH 23 | 44.74 | Max WS | 479.89 | 73391.66 | 54.80 | 86.02 | | 86.81 | 0.000946 | 8.73 | 22644.72 | 3124.63 | 0.32 | 23.16 |
| REACH 23 | 44.65 | Max WS | 479.89 | 73399.12 | 55.02 | 85.81 | | 86.23 | 0.000648 | 6.81 | 28572.23 | 3300.82 | 0.26 | 21.25 |
| REACH 23 | 44.56 | Max WS | 479.89 | 73408.77 | 55.25 | 85.59 | | 85.89 | 0.000558 | 6.29 | 32556.11 | 3519.41 | 0.24 | 21.31 |
| REACH 23 | 44.47 | Max WS | 479.89 | 73418.27 | 55.47 | 85.40 | | 85.61 | 0.000437 | 5.74 | 38120.13 | 3896.30 | 0.22 | 22.14 |
| REACH 23 | 44.38 | Max WS | 479.89 | 73427.71 | 55.70 | 85.21 | | 85.40 | 0.000414 | 5.36 | 40633.63 | 4300.00 | 0.21 | 20.73 |
| REACH 23 | 44.29 | Max WS | 479.89 | 73435.38 | 55.92 | 84.63 | | 85.38 | 0.001169 | 8.83 | 24184.44 | 3958.29 | 0.35 | 20.33 |
| REACH 23 | 44.2 | Max WS | 479.89 | 73441.69 | 56.15 | 84.08 | | 84.82 | 0.001225 | 8.92 | 23011.07 | 3373.44 | 0.35 | 19.79 |
| REACH 23 | 44.11 | Max WS | 479.89 | 73452.12 | 56.37 | 83.88 | | 84.12 | 0.000544 | 6.08 | 33538.68 | 3228.52 | 0.24 | 20.31 |
| REACH 23 | 44.02 | Max WS | 88.00 | 73460.17 | 56.60 | 83.50 | | 83.88 | 0.000849 | 7.26 | 30977.12 | 4175.71 | 0.29 | 19.26 |
| REACH 23 | 44.01 | Max WS | 26.00 | 73461.22 | 61.30 | 83.06 | 78.55 | 84.07 | 0.002164 | 10.45 | 14750.30 | 3119.16 | 0.46 | 16.35 |
| REACH 23 | 44.005 | | Bridge | | | | | | | | | | | |
| REACH 23 | 44.0 | Max WS | 55.00 | 73454.41 | 61.30 | 82.48 | | 83.48 | 0.002467 | 10.05 | 14044.08 | 3202.54 | 0.47 | 13.93 |
| REACH 23 | 43.99 CHEH 43.99 | Max WS | 828.00 | 73456.27 | 58.30 | 82.60 | | 83.23 | 0.001182 | 8.35 | 22607.57 | 3036.26 | 0.34 | 18.21 |
| REACH 23 | 43.95 LateralWeir#114 | | Lat Struct | | | | | | | | | | | |
| REACH 23 | 43.91 CHEH 43.05 | Max WS | 100.00 | 73834.93 | 56.06 | 81.64 | | 82.30 | 0.001024 | 7.75 | 21471.89 | 3146.45 | 0.32 | 18.05 |
| REACH 23 | 43.7681 | Max WS | 477.73 | 73836.48 | 55.92 | 81.59 | | 82.21 | 0.000943 | 8.15 | 25945.12 | 3942.22 | 0.32 | 20.74 |
| REACH 23 | 43.6263 | Max WS | 477.73 | 73844.26 | 55.79 | 81.41 | | 81.62 | 0.000456 | 5.26 | 41302.77 | 5588.91 | 0.22 | 18.49 |
| REACH 23 | 43.4845 | Max WS | 477.73 | 73850.25 | 55.65 | 81.03 | | 81.41 | 0.000740 | 5.95 | 29969.77 | 5660.68 | 0.27 | 15.50 |
| REACH 23 | 43.3427 | Max WS | 477.73 | 73856.36 | 55.51 | 80.66 | | 81.08 | 0.000801 | 7.18 | 29111.04 | 3944.79 | 0.29 | 19.41 |
| REACH 23 | 42.35 CHEH 42.35 | Max WS | 797.76 | 73880.67 | 54.55 | 77.80 | | 78.93 | 0.002064 | 10.27 | 20376.23 | 5533.46 | 0.45 | 16.34 |
| REACH 23 | 41.74 CHEH 41.74 | Max WS | 1000.00 | 73875.50 | 52.17 | 75.61 | | 75.78 | 0.000417 | 5.08 | 35351.36 | 4711.54 | 0.21 | 18.85 |
| REACH 23 | 41.1 | Max WS | 666.68 | 73922.39 | 44.60 | 74.55 | | 74.72 | 0.000261 | 4.41 | 36992.93 | 4828.60 | 0.17 | 22.08 |
| REACH 23 | 40.35 CHEH 40.35 | Max WS | 442.86 | 73990.47 | 42.70 | 73.34 | | 73.81 | 0.000649 | 7.47 | 25187.99 | 3640.25 | 0.26 | 25.74 |
| REACH 23 | 39.84 CHEH 39.84 | Max WS | 916.67 | 74052.64 | 45.30 | 68.49 | | 70.94 | 0.003034 | 13.24 | 8478.18 | 2546.28 | 0.54 | 18.46 |
| REACH 23 | 39.42 | | Lat Struct | | | | | | | | | | | |
| REACH 23 | 39 CHEH 39.00 | Max WS | 1000.00 | 75003.03 | 35.10 | 64.79 | | 65.38 | 0.000576 | 6.49 | 18626.91 | 4073.44 | 0.25 | 21.50 |
| REACH 23 | 38.48 | Max WS | 825.00 | 75484.46 | 39.60 | 63.50 | | 63.90 | 0.000585 | 5.38 | 19672.92 | 2610.02 | 0.24 | 16.01 |
| REACH 23 | 37.72 | Max WS | 866.67 | 75504.98 | 39.60 | 62.33 | | 62.62 | 0.000574 | 4.97 | 28537.19 | 6316.69 | 0.23 | 14.42 |
| REACH 23 | 37 | Max WS | 900.00 | 75513.41 | 33.50 | 60.23 | | 60.77 | 0.000804 | 6.20 | 19540.66 | 5778.09 | 0.28 | 15.78 |
| REACH 23 | 36.435 | | Lat Struct | | | | | | | | | | | |
| REACH 23 | 35.87 | Max WS | 1000.00 | 75555.67 | 31.80 | 59.10 | | 59.37 | 0.000414 | 5.71 | 34468.82 | 5526.22 | 0.20 | 24.29 |
| REACH 23 | 35 | Max WS | 1000.00 | 75596.84 | 29.30 | 57.31 | | 58.06 | 0.001070 | 8.60 | 21083.89 | 4109.88 | 0.33 | 20.78 |
| REACH 23 | 34 CHEH 34.00 | Max WS | 775.01 | 75626.29 | 27.00 | 55.89 | | 56.17 | 0.000596 | 5.53 | 26380.70 | 4232.40 | 0.24 | 16.78 |
| REACH 23 | 33.41 CHEH 33.41 | Max WS | 100.00 | 75672.15 | 21.30 | 54.73 | | 55.24 | 0.000745 | 7.49 | 23196.75 | 4030.48 | 0.28 | 22.56 |
| REACH 23 | 33.39 CHEH 33.39 | Max WS | 270.00 | 75674.03 | 22.40 | 54.46 | | 55.13 | 0.001097 | 7.04 | 13971.85 | 3471.57 | 0.32 | 15.05 |
| REACH 23 | 33.365 LateralWeir#115 | | Lat Struct | | | | | | | | | | | |
| REACH 23 | 33.34 CHEH 33.34 | Max WS | 220.00 | 76549.92 | 10.70 | 54.48 | | 54.91 | 0.000380 | 6.48 | 27127.61 | 3036.95 | 0.20 | 33.19 |
| REACH 23 | 33.3 CHEH 33.30 | Max WS | 0.10 | 76553.95 | 10.20 | 54.25 | 33.68 | 54.86 | 0.000378 | 6.55 | 18696.87 | 2455.40 | 0.20 | 31.80 |
| REACH 23 | 33.295 | | Bridge | | | | | | | | | | | |
| REACH 23 | 33.29 CHEH 33.29 | Max WS | 10.00 | 76553.87 | 16.60 | 52.91 | | 54.20 | 0.001052 | 9.47 | 12131.93 | 2210.57 | 0.33 | 25.66 |
| REACH 23 | 33.28 CHEH 33.28 | Max WS | | 76553.96 | 16.60 | 53.25 | 38.79 | 54.02 | 0.000741 | 7.96 | 19685.67 | 2575.93 | 0.28 | 25.89 |

# Simulation Scenario: 500-year Flood, Existing Conditions

HEC-RAS Plan: ExstNAVD(500) River: LOWER CHEHALIS Reach: REACH 23 Profile: Max WS

| Reach | River Sta | Profile | Length Chnl | 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 C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (ft) | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (sq ft) | (ft) | | (ft) |
| REACH 23 | 46.94 | Max WS | 4824.95 | 117989.50 | 66.62 | 95.45 | | 95.66 | 0.000430 | 5.50 | 58676.80 | 5505.06 | 0.21 | 20.99 |
| REACH 23 | 46.05 CHEH 45.25 | Max WS | 2354.24 | 117961.30 | 55.89 | 93.17 | | 93.63 | 0.000523 | 6.41 | 37276.51 | 4599.96 | 0.24 | 22.52 |
| REACH 23 | 45.25 | Max WS | 784.75 | 119455.40 | 54.90 | 92.03 | | 92.40 | 0.000531 | 6.58 | 45327.96 | 4094.88 | 0.24 | 23.22 |
| REACH 23 | 45.09 | Max WS | 2754.99 | 119479.40 | 54.57 | 91.59 | | 91.99 | 0.000586 | 6.96 | 41757.34 | 4262.09 | 0.25 | 23.71 |
| REACH 23 | 45.04 LateralWeir#113 | | Lat Struct | | | | | | | | | | | |
| REACH 23 | 44.83 CHEH 44.02 | Max WS | 479.89 | 119547.80 | 54.57 | 90.22 | | 90.62 | 0.000635 | 7.24 | 41889.44 | 3762.68 | 0.26 | 23.70 |
| REACH 23 | 44.74 | Max WS | 479.89 | 119561.20 | 54.80 | 89.68 | | 90.48 | 0.000976 | 9.77 | 34110.35 | 3148.23 | 0.33 | 26.81 |
| REACH 23 | 44.65 | Max WS | 479.89 | 119576.40 | 55.02 | 89.44 | | 89.90 | 0.000690 | 7.81 | 40553.10 | 3307.44 | 0.28 | 24.87 |
| REACH 23 | 44.56 | Max WS | 479.89 | 119591.90 | 55.25 | 89.18 | | 89.55 | 0.000637 | 7.46 | 46531.19 | 4021.34 | 0.26 | 24.90 |
| REACH 23 | 44.47 | Max WS | 479.89 | 119606.20 | 55.47 | 88.97 | | 89.23 | 0.000493 | 6.74 | 53222.18 | 4305.93 | 0.23 | 25.72 |
| REACH 23 | 44.38 | Max WS | 479.89 | 119623.20 | 55.70 | 88.78 | | 88.99 | 0.000436 | 6.11 | 55955.43 | 4300.00 | 0.22 | 24.29 |
| REACH 23 | 44.29 | Max WS | 479.89 | 119635.40 | 55.92 | 88.27 | | 88.89 | 0.001006 | 9.14 | 38613.64 | 3965.06 | 0.33 | 23.97 |
| REACH 23 | 44.2 | Max WS | 479.89 | 119643.60 | 56.15 | 87.76 | | 88.43 | 0.001104 | 9.49 | 35435.24 | 3379.43 | 0.35 | 23.47 |
| REACH 23 | 44.11 | Max WS | 479.89 | 119657.70 | 56.37 | 87.53 | | 87.83 | 0.000596 | 7.10 | 45343.71 | 3234.13 | 0.26 | 23.96 |
| REACH 23 | 44.02 | Max WS | 88.00 | 119664.00 | 56.60 | 87.21 | | 87.54 | 0.000748 | 7.54 | 46584.06 | 4285.50 | 0.28 | 22.52 |
| REACH 23 | 44.01 | Max WS | 26.00 | 119623.90 | 61.30 | 86.23 | 82.03 | 88.33 | 0.003395 | 14.73 | 15429.49 | 4086.63 | 0.59 | 19.52 |
| REACH 23 | 44.005 | | Bridge | | | | | | | | | | | |
| REACH 23 | 44.0 | Max WS | 55.00 | 119614.20 | 61.30 | 85.92 | | 87.75 | 0.003271 | 13.41 | 15655.07 | 3871.28 | 0.57 | 17.37 |
| REACH 23 | 43.99 CHEH 43.99 | Max WS | 828.00 | 119655.90 | 58.30 | 86.49 | | 87.15 | 0.001128 | 9.28 | 35514.20 | 3562.63 | 0.35 | 22.10 |
| REACH 23 | 43.95 LateralWeir#114 | | Lat Struct | | | | | | | | | | | |
| REACH 23 | 43.91 CHEH 43.05 | Max WS | 100.00 | 120480.70 | 56.06 | 85.61 | | 86.27 | 0.000938 | 8.47 | 34856.98 | 3538.75 | 0.32 | 22.02 |
| REACH 23 | 43.7681 | Max WS | 477.73 | 120486.80 | 55.92 | 85.61 | | 86.13 | 0.000798 | 8.43 | 41855.21 | 4011.72 | 0.30 | 24.76 |
| REACH 23 | 43.6263 | Max WS | 477.73 | 120500.80 | 55.79 | 85.46 | | 85.65 | 0.000367 | 5.39 | 64058.95 | 5626.16 | 0.20 | 22.55 |
| REACH 23 | 43.4845 | Max WS | 477.73 | 120516.50 | 55.65 | 85.21 | | 85.48 | 0.000500 | 5.73 | 54192.75 | 5821.35 | 0.23 | 19.68 |
| REACH 23 | 43.3427 | Max WS | 3344.11 | 120527.70 | 55.51 | 84.90 | | 85.26 | 0.000666 | 7.47 | 50695.88 | 5694.11 | 0.27 | 23.65 |
| REACH 23 | 42.35 CHEH 42.35 | Max WS | 3191.04 | 120558.20 | 54.55 | 81.82 | | 82.36 | 0.001105 | 8.70 | 43411.71 | 5851.12 | 0.34 | 20.36 |
| REACH 23 | 41.74 CHEH 41.74 | Max WS | 4000.00 | 120601.10 | 52.17 | 79.85 | | 79.99 | 0.000309 | 5.01 | 56793.49 | 5449.33 | 0.18 | 23.09 |
| REACH 23 | 41.1 | Max WS | 4000.08 | 120702.60 | 44.60 | 78.96 | | 79.11 | 0.000213 | 4.50 | 58966.86 | 5144.70 | 0.15 | 26.49 |
| REACH 23 | 40.35 CHEH 40.35 | Max WS | 3100.02 | 120829.60 | 42.70 | 77.51 | | 77.86 | 0.000522 | 7.41 | 40903.96 | 3843.67 | 0.24 | 29.91 |
| REACH 23 | 39.84 CHEH 39.84 | Max WS | 5500.02 | 120934.70 | 45.30 | 73.41 | | 74.80 | 0.001753 | 11.78 | 21221.26 | 2717.76 | 0.43 | 23.38 |
| REACH 23 | 39.42 | | Lat Struct | | | | | | | | | | | |
| REACH 23 | 39 CHEH 39.00 | Max WS | 3000.00 | 122781.30 | 35.10 | 68.75 | | 69.29 | 0.000529 | 6.96 | 35272.01 | 4390.50 | 0.24 | 25.47 |
| REACH 23 | 38.48 | Max WS | 3300.00 | 123637.00 | 39.60 | 67.41 | | 67.74 | 0.000450 | 5.47 | 43819.50 | 6468.73 | 0.22 | 19.92 |
| REACH 23 | 37.72 | Max WS | 5200.02 | 123677.90 | 39.60 | 66.26 | | 66.45 | 0.000355 | 4.60 | 53929.90 | 6488.59 | 0.19 | 18.36 |
| REACH 23 | 37 | Max WS | 4500.00 | 123729.30 | 33.50 | 64.01 | | 64.38 | 0.000552 | 5.93 | 41556.51 | 5835.52 | 0.24 | 19.56 |
| REACH 23 | 36.435 | | Lat Struct | | | | | | | | | | | |
| REACH 23 | 35.87 | Max WS | 4000.00 | 123816.40 | 31.80 | 62.50 | | 62.73 | 0.000365 | 5.85 | 53387.13 | 5570.66 | 0.20 | 27.70 |
| REACH 23 | 35 | Max WS | 6000.00 | 123892.60 | 29.30 | 60.71 | | 61.26 | 0.000854 | 8.50 | 37182.21 | 5362.69 | 0.30 | 24.18 |
| REACH 23 | 34 CHEH 34.00 | Max WS | 3100.04 | 123950.50 | 27.00 | 58.87 | | 59.19 | 0.000628 | 6.32 | 39434.64 | 4624.81 | 0.25 | 19.76 |
| REACH 23 | 33.41 CHEH 33.41 | Max WS | 100.00 | 124035.00 | 21.30 | 56.16 | | 57.02 | 0.001275 | 10.22 | 29241.67 | 4431.35 | 0.37 | 24.00 |
| REACH 23 | 33.39 CHEH 33.39 | Max WS | 270.00 | 124037.10 | 22.40 | 55.58 | | 56.97 | 0.002143 | 10.32 | 17941.27 | 3719.51 | 0.45 | 16.16 |
| REACH 23 | 33.365 LateralWeir#115 | | Lat Struct | | | | | | | | | | | |
| REACH 23 | 33.34 CHEH 33.34 | Max WS | 220.00 | 125696.30 | 10.70 | 55.56 | | 56.49 | 0.000825 | 9.76 | 30483.58 | 3193.58 | 0.29 | 34.27 |
| REACH 23 | 33.3 CHEH 33.30 | Max WS | 40.00 | 125703.20 | 10.20 | 54.97 | | 56.45 | 0.000908 | 10.29 | 20534.98 | 2624.02 | 0.32 | 32.52 |
| REACH 23 | 33.29 CHEH 33.29 | Max WS | 10.00 | 125704.60 | 16.60 | 54.09 | | 56.99 | 0.002296 | 14.42 | 15111.08 | 2900.61 | 0.49 | 26.84 |
| REACH 23 | 33.28 CHEH 33.28 | Max WS | | 125704.60 | 16.60 | 54.93 | 48.20 | 56.41 | 0.001396 | 11.39 | 24216.61 | 2927.79 | 0.38 | 27.57 |

## Simulation Scenario: 500-year Flood, Relief Bridge Alternative

HEC-RAS Plan: Bridge-5b(500) River: LOWER CHEHALIS Reach: REACH 23 Profile: Max WS

| Reach | River Sta | Profile | Length Chnl | 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 C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (ft) | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (sq ft) | (ft) | | (ft) |
| REACH 23 | 46.94 | Max WS | 4824.95 | 117912.00 | 66.62 | 95.56 | | 95.76 | 0.000417 | 5.44 | 59287.05 | 5506.20 | 0.21 | 21.10 |
| REACH 23 | 46.05 CHEH 45.25 | Max WS | 2354.24 | 117888.30 | 55.89 | 93.36 | | 93.81 | 0.000501 | 6.31 | 38188.53 | 4700.10 | 0.23 | 22.72 |
| REACH 23 | 45.25 | Max WS | 784.75 | 119382.30 | 54.90 | 92.28 | | 92.64 | 0.000500 | 6.43 | 46380.68 | 4097.08 | 0.23 | 23.48 |
| REACH 23 | 45.09 | Max WS | 2754.99 | 119409.60 | 54.57 | 91.87 | | 92.25 | 0.000551 | 6.81 | 42991.75 | 4480.13 | 0.24 | 23.99 |
| REACH 23 | 45.04 LateralWeir#113 | | Lat Struct | | | | | | | | | | | |
| REACH 23 | 44.83 CHEH 44.02 | Max WS | 479.89 | 119410.70 | 54.57 | 90.61 | | 90.98 | 0.000582 | 7.00 | 43344.50 | 3807.28 | 0.25 | 24.09 |
| REACH 23 | 44.74 | Max WS | 479.89 | 119426.90 | 54.80 | 90.12 | | 90.84 | 0.000881 | 9.39 | 35489.78 | 3151.49 | 0.32 | 27.25 |
| REACH 23 | 44.65 | Max WS | 479.89 | 119444.10 | 55.02 | 89.90 | | 90.32 | 0.000622 | 7.51 | 42079.95 | 3308.30 | 0.26 | 25.33 |
| REACH 23 | 44.56 | Max WS | 479.89 | 119463.20 | 55.25 | 89.67 | | 90.00 | 0.000565 | 7.12 | 48509.86 | 4021.34 | 0.25 | 25.39 |
| REACH 23 | 44.47 | Max WS | 479.89 | 119481.10 | 55.47 | 89.49 | | 89.72 | 0.000440 | 6.45 | 55444.13 | 4311.48 | 0.22 | 26.23 |
| REACH 23 | 44.38 | Max WS | 479.89 | 119499.40 | 55.70 | 89.31 | | 89.50 | 0.000386 | 5.83 | 58268.80 | 4300.00 | 0.21 | 24.83 |
| REACH 23 | 44.29 | Max WS | 479.89 | 119517.90 | 55.92 | 88.88 | | 89.41 | 0.000854 | 8.57 | 41043.37 | 3966.20 | 0.30 | 24.59 |
| REACH 23 | 44.2 | Max WS | 479.89 | 119536.00 | 56.15 | 88.45 | | 89.02 | 0.000926 | 8.86 | 37780.21 | 3380.49 | 0.32 | 24.16 |
| REACH 23 | 44.11 | Max WS | 479.89 | 119554.50 | 56.37 | 88.26 | | 88.52 | 0.000511 | 6.71 | 47691.80 | 3235.19 | 0.24 | 24.69 |
| REACH 23 | 44.02 | Max WS | 88.00 | 119573.20 | 56.60 | 87.99 | | 88.27 | 0.000615 | 6.97 | 49991.56 | 4375.94 | 0.25 | 23.19 |
| REACH 23 | 44.01 | Max WS | 26.00 | 119576.70 | 61.30 | 87.87 | 81.60 | 88.27 | 0.000934 | 8.15 | 42269.37 | 4252.45 | 0.31 | 21.16 |
| REACH 23 | 44.005 | | Bridge | | | | | | | | | | | |
| REACH 23 | 44.0 | Max WS | 55.00 | 119529.70 | 61.30 | 86.62 | | 87.12 | 0.001235 | 8.46 | 35619.36 | 3978.07 | 0.35 | 18.07 |
| REACH 23 | 43.99 CHEH 43.99 | Max WS | 828.00 | 119531.80 | 58.30 | 86.49 | | 87.15 | 0.001126 | 9.27 | 35511.79 | 3562.55 | 0.35 | 22.10 |
| REACH 23 | 43.95 LateralWeir#114 | | Lat Struct | | | | | | | | | | | |
| REACH 23 | 43.91 CHEH 43.05 | Max WS | 100.00 | 120464.70 | 56.06 | 85.61 | | 86.27 | 0.000938 | 8.47 | 34854.01 | 3538.71 | 0.32 | 22.01 |
| REACH 23 | 43.7681 | Max WS | 477.73 | 120469.20 | 55.92 | 85.61 | | 86.13 | 0.000798 | 8.43 | 41850.78 | 4011.62 | 0.30 | 24.76 |
| REACH 23 | 43.6263 | Max WS | 477.73 | 120486.30 | 55.79 | 85.46 | | 85.64 | 0.000367 | 5.39 | 64053.20 | 5626.16 | 0.20 | 22.54 |
| REACH 23 | 43.4845 | Max WS | 477.73 | 120499.40 | 55.65 | 85.20 | | 85.48 | 0.000500 | 5.73 | 54186.84 | 5821.35 | 0.23 | 19.68 |
| REACH 23 | 43.3427 | Max WS | 3344.11 | 120511.60 | 55.51 | 84.90 | | 85.26 | 0.000666 | 7.47 | 50690.01 | 5694.04 | 0.27 | 23.64 |
| REACH 23 | 42.35 CHEH 42.35 | Max WS | 3191.04 | 120535.20 | 54.55 | 81.82 | | 82.36 | 0.001105 | 8.70 | 43403.98 | 5851.09 | 0.34 | 20.36 |
| REACH 23 | 41.74 CHEH 41.74 | Max WS | 4000.00 | 120580.40 | 52.17 | 79.85 | | 79.99 | 0.000309 | 5.01 | 56785.22 | 5448.99 | 0.18 | 23.09 |
| REACH 23 | 41.1 | Max WS | 4000.08 | 120681.30 | 44.60 | 78.95 | | 79.11 | 0.000213 | 4.50 | 58958.91 | 5144.58 | 0.15 | 26.49 |
| REACH 23 | 40.35 CHEH 40.35 | Max WS | 3100.02 | 120805.00 | 42.70 | 77.50 | | 77.86 | 0.000522 | 7.41 | 40898.19 | 3843.62 | 0.24 | 29.91 |
| REACH 23 | 39.84 CHEH 39.84 | Max WS | 5500.02 | 120908.10 | 45.30 | 73.40 | | 74.80 | 0.001753 | 11.79 | 21214.46 | 2717.60 | 0.43 | 23.38 |
| REACH 23 | 39.42 | | Lat Struct | | | | | | | | | | | |
| REACH 23 | 39 CHEH 39.00 | Max WS | 3000.00 | 122729.20 | 35.10 | 68.75 | | 69.29 | 0.000529 | 6.96 | 35257.07 | 4388.52 | 0.24 | 25.46 |
| REACH 23 | 38.48 | Max WS | 3300.00 | 123572.50 | 39.60 | 67.41 | | 67.74 | 0.000450 | 5.47 | 43797.14 | 6468.73 | 0.22 | 19.92 |
| REACH 23 | 37.72 | Max WS | 5200.02 | 123613.70 | 39.60 | 66.26 | | 66.45 | 0.000355 | 4.60 | 53906.73 | 6488.57 | 0.19 | 18.35 |
| REACH 23 | 37 | Max WS | 4500.00 | 123656.40 | 33.50 | 64.01 | | 64.38 | 0.000552 | 5.93 | 41534.61 | 5835.50 | 0.24 | 19.56 |
| REACH 23 | 36.435 | | Lat Struct | | | | | | | | | | | |
| REACH 23 | 35.87 | Max WS | 4000.00 | 123743.20 | 31.80 | 62.50 | | 62.73 | 0.000365 | 5.85 | 53366.25 | 5570.61 | 0.20 | 27.70 |
| REACH 23 | 35 | Max WS | 6000.00 | 123818.30 | 29.30 | 60.70 | | 61.25 | 0.000854 | 8.50 | 37161.74 | 5362.14 | 0.30 | 24.18 |
| REACH 23 | 34 CHEH 34.00 | Max WS | 3100.04 | 123875.50 | 27.00 | 58.87 | | 59.19 | 0.000628 | 6.32 | 39416.52 | 4623.97 | 0.25 | 19.76 |
| REACH 23 | 33.41 CHEH 33.41 | Max WS | 100.00 | 123959.50 | 21.30 | 56.16 | | 57.02 | 0.001275 | 10.22 | 29226.34 | 4430.06 | 0.37 | 24.00 |
| REACH 23 | 33.39 CHEH 33.39 | Max WS | 270.00 | 123961.90 | 22.40 | 55.57 | | 56.96 | 0.002142 | 10.31 | 17929.21 | 3719.08 | 0.45 | 16.16 |
| REACH 23 | 33.365 LateralWeir#115 | | Lat Struct | | | | | | | | | | | |
| REACH 23 | 33.34 CHEH 33.34 | Max WS | 220.00 | 125615.70 | 10.70 | 55.55 | | 56.48 | 0.000825 | 9.76 | 30473.97 | 3192.84 | 0.29 | 34.27 |
| REACH 23 | 33.3 CHEH 33.30 | Max WS | 40.00 | 125622.60 | 10.20 | 54.97 | | 56.44 | 0.000907 | 10.29 | 20528.66 | 2622.64 | 0.32 | 32.52 |
| REACH 23 | 33.29 CHEH 33.29 | Max WS | 10.00 | 125624.00 | 16.60 | 54.09 | | 56.99 | 0.002293 | 14.41 | 15106.94 | 2899.91 | 0.49 | 26.84 |
| REACH 23 | 33.28 CHEH 33.28 | Max WS | | 125624.00 | 16.60 | 54.93 | 46.54 | 56.41 | 0.001395 | 11.39 | 24209.52 | 2927.71 | 0.38 | 27.57 |

# Appendix B

## HEC-RAS Output (Scouring)

# Simulation Scenario: Highest Water Surface (Peak of the Flood – 500 –year simulation with Relief Bridge)

Contraction Scour

| | | Left | Channel | Right |
|---|---|---|---|---|
| Input Data | | | | |
| | Average Depth (ft): | 11 | 11 | 11 |
| | Approach Velocity (ft/s): | 1.70 | 1.70 | 1.70 |
| | Br Average Depth (ft): | 7 | 9 | 9 |
| | BR Opening Flow (cfs): | 0.00 | 4107.00 | 0.00 |
| | BR Top WD (ft): | 30.00 | 250.00 | 30.00 |
| | Grain Size D50 (mm): | 1.00 | 1.00 | 1.00 |
| | Approach Flow (cfs): | 11010.00 | 5526.00 | 11520.00 |
| | Approach Top WD (ft): | 300.00 | 250.00 | 1500.00 |
| | K1 Coefficient: | 0.690 | 0.640 | 0.640 |
| Results | | | | |
| | Scour Depth Ys (ft): | | 0.00 | |
| | Critical Velocity (ft/s): | | 2.48 | |
| | Equation: | | Clear | |

Pier Scour

Pier: #1 (CL = 289)

Input Data

| | |
|---|---|
| Pier Shape: | Circulare cylinder |
| Pier Width (ft): | 2.00 |
| Grain Size D50 (mm): | 1.00000 |
| Depth Upstream (ft): | 17.68 |
| Velocity Upstream (ft/s): | 6.58 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 100.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #2 (CL = 323)

Input Data

| | |
|---|---|
| Pier Shape: | Circulare cylinder |
| Pier Width (ft): | 2.50 |
| Grain Size D50 (mm): | 1.00000 |
| Depth Upstream (ft): | 13.39 |
| Velocity Upstream (ft/s): | 2.47 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 100.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |

| | |
|---|---|
| Froude #: | |
| Equation: | CSU equation |

Pier: #3 (CL = 357)

Input Data

| | |
|---|---|
| Pier Shape: | Circulare cylinder |
| Pier Width (ft): | 2.50 |
| Grain Size D50 (mm): | 1.00000 |
| Depth Upstream (ft): | 12.78 |
| Velocity Upstream (ft/s): | 2.47 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 100.00000 |
| K4 Armouring Coef: | 1.00 |

Set K1 value to 1.0 because angle > 5 degrees

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #4 (CL = 391)

Input Data

| | |
|---|---|
| Pier Shape: | Circulare cylinder |
| Pier Width (ft): | 3.00 |
| Grain Size D50 (mm): | 1.00000 |
| Depth Upstream (ft): | 11.83 |
| Velocity Upstream (ft/s): | 2.47 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 100.00000 |
| K4 Armouring Coef: | 1.00 |

Set K1 value to 1.0 because angle > 5 degrees

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #5 (CL = 433)

Input Data

| | |
|---|---|
| Pier Shape: | Circulare cylinder |
| Pier Width (ft): | 3.00 |
| Grain Size D50 (mm): | 1.00000 |
| Depth Upstream (ft): | 10.52 |
| Velocity Upstream (ft/s): | 2.47 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 100.00000 |
| K4 Armouring Coef: | 1.00 |

| | |
|---|---|
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #6 (CL = 475)

Input Data

| | |
|---|---|
| Pier Shape: | Circulare cylinder |
| Pier Width (ft): | 2.50 |
| Grain Size D50 (mm): | 1.00000 |
| Depth Upstream (ft): | 10.40 |
| Velocity Upstream (ft/s): | 2.47 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 100.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #7 (CL = 517)

Input Data

| | |
|---|---|
| Pier Shape: | Circulare cylinder |
| Pier Width (ft): | 2.50 |
| Grain Size D50 (mm): | 1.00000 |
| Depth Upstream (ft): | 11.33 |
| Velocity Upstream (ft/s): | 2.47 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 100.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #8 (CL = 559)

Input Data

| | |
|---|---|
| Pier Shape: | Circulare cylinder |
| Pier Width (ft): | 3.00 |
| Grain Size D50 (mm): | 1.00000 |
| Depth Upstream (ft): | 9.40 |
| Velocity Upstream (ft/s): | 2.47 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |

| | |
|---|---|
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 100.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #9 (CL = 601)

Input Data

| | |
|---|---|
| Pier Shape: | Circulare cylinder |
| Pier Width (ft): | 2.50 |
| Grain Size D50 (mm): | 1.00000 |
| Depth Upstream (ft): | 10.36 |
| Velocity Upstream (ft/s): | 2.47 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 100.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #10 (CL = 643)

Input Data

| | |
|---|---|
| Pier Shape: | Circulare cylinder |
| Pier Width (ft): | 2.50 |
| Grain Size D50 (mm): | 1.00000 |
| Depth Upstream (ft): | 13.06 |
| Velocity Upstream (ft/s): | 2.47 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 100.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #11 (CL = 685)

Input Data

| | |
|---|---|
| Pier Shape: | Circulare cylinder |
| Pier Width (ft): | 3.00 |
| Grain Size D50 (mm): | 1.00000 |
| Depth Upstream (ft): | 12.95 |
| Velocity Upstream (ft/s): | 2.47 |
| K1 Nose Shape: | 1.00 |

| | |
|---|---|
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 100.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #12 (CL = 727)

Input Data

| | |
|---|---|
| Pier Shape: | Circulare cylinder |
| Pier Width (ft): | 2.50 |
| Grain Size D50 (mm): | 1.00000 |
| Depth Upstream (ft): | 15.05 |
| Velocity Upstream (ft/s): | 2.47 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 100.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #13 (CL = 769)

Input Data

| | |
|---|---|
| Pier Shape: | Circulare cylinder |
| Pier Width (ft): | 2.50 |
| Grain Size D50 (mm): | 1.00000 |
| Depth Upstream (ft): | 15.94 |
| Velocity Upstream (ft/s): | 2.47 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 100.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #14 (CL = 811)

Input Data

| | |
|---|---|
| Pier Shape: | Circulare cylinder |
| Pier Width (ft): | 3.00 |
| Grain Size D50 (mm): | 1.00000 |

| | |
|---|---|
| Depth Upstream (ft): | 15.64 |
| Velocity Upstream (ft/s): | 2.47 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 100.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #15 (CL = 853)

Input Data

| | |
|---|---|
| Pier Shape: | Circulare cylinder |
| Pier Width (ft): | 2.50 |
| Grain Size D50 (mm): | 1.00000 |
| Depth Upstream (ft): | 16.13 |
| Velocity Upstream (ft/s): | 2.47 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 100.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #16 (CL = 895)

Input Data

| | |
|---|---|
| Pier Shape: | Circulare cylinder |
| Pier Width (ft): | 2.50 |
| Grain Size D50 (mm): | 1.00000 |
| Depth Upstream (ft): | 16.22 |
| Velocity Upstream (ft/s): | 2.47 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 100.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #17 (CL = 937)

Input Data

| | |
|---|---|
| Pier Shape: | Circulare cylinder |
| Pier Width (ft): | 3.00 |
| Grain Size D50 (mm): | 1.00000 |
| Depth Upstream (ft): | 17.28 |
| Velocity Upstream (ft/s): | 2.47 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 100.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #18 (CL = 979)

Input Data

| | |
|---|---|
| Pier Shape: | Circulare cylinder |
| Pier Width (ft): | 2.50 |
| Grain Size D50 (mm): | 1.00000 |
| Depth Upstream (ft): | 17.31 |
| Velocity Upstream (ft/s): | 2.47 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 100.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #19 (CL = 1021)

Input Data

| | |
|---|---|
| Pier Shape: | Circulare cylinder |
| Pier Width (ft): | 2.50 |
| Grain Size D50 (mm): | 1.00000 |
| Depth Upstream (ft): | 17.66 |
| Velocity Upstream (ft/s): | 2.47 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 100.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |

| | |
|---|---|
| Equation: | CSU equation |

Pier: #20 (CL = 1063)

Input Data

| | |
|---|---|
| Pier Shape: | Circulare cylinder |
| Pier Width (ft): | 2.50 |
| Grain Size D50 (mm): | 1.00000 |
| Depth Upstream (ft): | 18.53 |
| Velocity Upstream (ft/s): | 2.47 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 100.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #21 (CL = 2458)

Input Data

| | |
|---|---|
| Pier Shape: | Circulare cylinder |
| Pier Width (ft): | 3.00 |
| Grain Size D50 (mm): | 1.00000 |
| Depth Upstream (ft): | 13.47 |
| Velocity Upstream (ft/s): | 2.30 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | 0.00 |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | 1.00 |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 100.00000 |
| K4 Armouring Coef: | 1.00 |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | 4.33 |
| Froude #: | 0.11 |
| Equation: | CSU equation |

Pier: #22 (CL = 2541)

Input Data

| | |
|---|---|
| Pier Shape: | Circulare cylinder |
| Pier Width (ft): | 3.00 |
| Grain Size D50 (mm): | 1.00000 |
| Depth Upstream (ft): | 13.47 |
| Velocity Upstream (ft/s): | 2.30 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | 0.00 |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | 1.00 |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 100.00000 |
| K4 Armouring Coef: | 1.00 |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | 4.33 |

| | | |
|---|---|---|
| Froude #: | 0.11 | |
| Equation: | CSU equation | |

Abutment Scour

| | Left | Right |
|---|---|---|
| **Input Data** | | |
| Station at Toe (ft): | 2384.00 | 2615.00 |
| Toe Sta at appr (ft): | 2374.00 | 2700.00 |
| Abutment Length (ft): | 10.00 | 10.00 |
| Depth at Toe (ft): | 10.00 | 10.00 |
| K1 Shape Coef: | 0.55 - Spill-through abutment | |
| Degree of Skew (degrees): | 90.00 | 45.00 |
| K2 Skew Coef: | 1.00 | 0.91 |
| Projected Length L' (ft): | 7.0 | 7.07 |
| Avg Depth Obstructed Ya (ft): | 7.0 | 9.73 |
| Flow Obstructed Qe (cfs): | 12000 | 12000 |
| Area Obstructed Ae (sq ft): | 3000. | 3000. |
| **Results** | | |
| Scour Depth Ys (ft): | 10.90 | 13.62 |
| Qe/Ae = Ve: | 4.00 | 4.00 |
| Froude #: | 0.27 | 0.23 |
| Equation: | Froehlich | Froehlich |

# Simulation Scenario: Largest Flow through Relief Bridge (500 –year simulation with Relief Bridge)

Contraction Scour

| | Left | Channel | Right |
|---|---|---|---|
| Input Data | | | |
| Average Depth (ft): | 7.90 | 8.00 | 8.00 |
| Approach Velocity (ft/s): | 1.70 | 1.70 | 1.70 |
| Br Average Depth (ft): | 5.70 | 9.30 | 9.30 |
| BR Opening Flow (cfs): | 0.00 | 4950.00 | 48.00 |
| BR Top WD (ft): | 30.00 | 246.00 | 30.00 |
| Grain Size D50 (mm): | 0.50 | 0.50 | 0.50 |
| Approach Flow (cfs): | 7031.00 | 3535.00 | 7493.00 |
| Approach Top WD (ft): | 300.00 | 250.00 | 1500.00 |
| K1 Coefficient: | 0.640 | 0.640 | 0.640 |
| Results | | | |
| Scour Depth Ys (ft): | | 0.27 | 0.00 |
| Critical Velocity (ft/s): | | 1.87 | 1.87 |
| Equation: | | Clear | Clear |

Pier Scour

Pier: #1 (CL = 289)

Input Data

| | |
|---|---|
| Pier Shape: | Round nose |
| Pier Width (ft): | 2.00 |
| Grain Size D50 (mm): | 0.50000 |
| Depth Upstream (ft): | 13.98 |
| Velocity Upstream (ft/s): | 9.24 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 35.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #2 (CL = 323)

Input Data

| | |
|---|---|
| Pier Shape: | Round nose |
| Pier Width (ft): | 2.50 |
| Grain Size D50 (mm): | 0.50000 |
| Depth Upstream (ft): | 9.68 |
| Velocity Upstream (ft/s): | 2.97 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 35.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |

| | |
|---|---|
| Froude #: | |
| Equation: | CSU equation |

Pier: #3 (CL = 357)

Input Data

| | |
|---|---|
| Pier Shape: | Round nose |
| Pier Width (ft): | 2.50 |
| Grain Size D50 (mm): | 0.50000 |
| Depth Upstream (ft): | 9.08 |
| Velocity Upstream (ft/s): | 2.97 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 35.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #4 (CL = 391)

Input Data

| | |
|---|---|
| Pier Shape: | Round nose |
| Pier Width (ft): | 3.00 |
| Grain Size D50 (mm): | 0.50000 |
| Depth Upstream (ft): | 8.13 |
| Velocity Upstream (ft/s): | 2.97 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 35.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #5 (CL = 433)

Input Data

| | |
|---|---|
| Pier Shape: | Round nose |
| Pier Width (ft): | 3.00 |
| Grain Size D50 (mm): | 0.50000 |
| Depth Upstream (ft): | 6.82 |
| Velocity Upstream (ft/s): | 2.97 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 35.00000 |
| K4 Armouring Coef: | 1.00 |

| | |
|---|---|
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #6 (CL = 475)

Input Data

| | |
|---|---|
| Pier Shape: | Round nose |
| Pier Width (ft): | 2.50 |
| Grain Size D50 (mm): | 0.50000 |
| Depth Upstream (ft): | 6.70 |
| Velocity Upstream (ft/s): | 2.97 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 35.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #7 (CL = 517)

Input Data

| | |
|---|---|
| Pier Shape: | Round nose |
| Pier Width (ft): | 2.50 |
| Grain Size D50 (mm): | 0.50000 |
| Depth Upstream (ft): | 7.62 |
| Velocity Upstream (ft/s): | 2.97 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 35.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #8 (CL = 559)

Input Data

| | |
|---|---|
| Pier Shape: | Round nose |
| Pier Width (ft): | 3.00 |
| Grain Size D50 (mm): | 0.50000 |
| Depth Upstream (ft): | 5.70 |
| Velocity Upstream (ft/s): | 2.97 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |

| | |
|---|---|
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 35.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #9 (CL = 601)

Input Data

| | |
|---|---|
| Pier Shape: | Round nose |
| Pier Width (ft): | 2.50 |
| Grain Size D50 (mm): | 0.50000 |
| Depth Upstream (ft): | 6.66 |
| Velocity Upstream (ft/s): | 2.97 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 35.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #10 (CL = 643)

Input Data

| | |
|---|---|
| Pier Shape: | Round nose |
| Pier Width (ft): | 2.50 |
| Grain Size D50 (mm): | 0.50000 |
| Depth Upstream (ft): | 9.35 |
| Velocity Upstream (ft/s): | 2.97 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 35.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #11 (CL = 685)

Input Data

| | |
|---|---|
| Pier Shape: | Round nose |
| Pier Width (ft): | 3.00 |
| Grain Size D50 (mm): | 0.50000 |
| Depth Upstream (ft): | 9.25 |
| Velocity Upstream (ft/s): | 2.97 |
| K1 Nose Shape: | 1.00 |

| | |
|---|---|
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 35.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #12 (CL = 727)

Input Data

| | |
|---|---|
| Pier Shape: | Round nose |
| Pier Width (ft): | 2.50 |
| Grain Size D50 (mm): | 0.50000 |
| Depth Upstream (ft): | 11.34 |
| Velocity Upstream (ft/s): | 2.97 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 35.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #13 (CL = 769)

Input Data

| | |
|---|---|
| Pier Shape: | Round nose |
| Pier Width (ft): | 2.50 |
| Grain Size D50 (mm): | 0.50000 |
| Depth Upstream (ft): | 12.24 |
| Velocity Upstream (ft/s): | 2.97 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 35.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #14 (CL = 811)

Input Data

| | |
|---|---|
| Pier Shape: | Round nose |
| Pier Width (ft): | 3.00 |
| Grain Size D50 (mm): | 0.50000 |

| | |
|---|---|
| Depth Upstream (ft): | 11.94 |
| Velocity Upstream (ft/s): | 2.97 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 35.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #15 (CL = 853)

Input Data

| | |
|---|---|
| Pier Shape: | Round nose |
| Pier Width (ft): | 2.50 |
| Grain Size D50 (mm): | 0.50000 |
| Depth Upstream (ft): | 12.43 |
| Velocity Upstream (ft/s): | 2.97 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 35.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #16 (CL = 895)

Input Data

| | |
|---|---|
| Pier Shape: | Round nose |
| Pier Width (ft): | 2.50 |
| Grain Size D50 (mm): | 0.50000 |
| Depth Upstream (ft): | 12.52 |
| Velocity Upstream (ft/s): | 2.97 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 35.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #17 (CL = 937)

Input Data

| | |
|---|---|
| Pier Shape: | Round nose |
| Pier Width (ft): | 3.00 |
| Grain Size D50 (mm): | 0.50000 |
| Depth Upstream (ft): | 13.58 |
| Velocity Upstream (ft/s): | 2.97 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 35.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #18 (CL = 979)

Input Data

| | |
|---|---|
| Pier Shape: | Round nose |
| Pier Width (ft): | 2.50 |
| Grain Size D50 (mm): | 0.50000 |
| Depth Upstream (ft): | 13.60 |
| Velocity Upstream (ft/s): | 2.97 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 35.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #19 (CL = 1021)

Input Data

| | |
|---|---|
| Pier Shape: | Round nose |
| Pier Width (ft): | 2.50 |
| Grain Size D50 (mm): | 0.50000 |
| Depth Upstream (ft): | 13.96 |
| Velocity Upstream (ft/s): | 2.97 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 35.00000 |
| K4 Armouring Coef: | 1.00 |
| Set K1 value to 1.0 because angle > 5 degrees | |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |

| | |
|---|---|
| Equation: | CSU equation |

Pier: #20 (CL = 1063)

Input Data

| | |
|---|---|
| Pier Shape: | Round nose |
| Pier Width (ft): | 2.50 |
| Grain Size D50 (mm): | 0.50000 |
| Depth Upstream (ft): | 14.83 |
| Velocity Upstream (ft/s): | 2.97 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 35.00000 |
| K4 Armouring Coef: | 1.00 |

Set K1 value to 1.0 because angle > 5 degrees

Results

| | |
|---|---|
| Scour Depth Ys (ft): | |
| Froude #: | |
| Equation: | CSU equation |

Pier: #21 (CL = 2458)

Input Data

| | |
|---|---|
| Pier Shape: | Circulare cylinder |
| Pier Width (ft): | 3.00 |
| Grain Size D50 (mm): | 0.50000 |
| Depth Upstream (ft): | 9.77 |
| Velocity Upstream (ft/s): | 2.70 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | 0.00 |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | 1.00 |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 40.00000 |
| K4 Armouring Coef: | 1.00 |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | 4.44 |
| Froude #: | 0.15 |
| Equation: | CSU equation |

Pier: #22 (CL = 2541)

Input Data

| | |
|---|---|
| Pier Shape: | Round nose |
| Pier Width (ft): | 3.00 |
| Grain Size D50 (mm): | 0.50000 |
| Depth Upstream (ft): | 9.77 |
| Velocity Upstream (ft/s): | 2.70 |
| K1 Nose Shape: | 1.00 |
| Pier Angle: | 0.00 |
| Pier Length (ft): | 28.00 |
| K2 Angle Coef: | 1.00 |
| K3 Bed Cond Coef: | 1.10 |
| Grain Size D90 (mm): | 35.00000 |
| K4 Armouring Coef: | 1.00 |

Results

| | |
|---|---|
| Scour Depth Ys (ft): | 4.44 |

| | | |
|---|---|---|
| Froude #: | 0.15 | |
| Equation: | CSU equation | |

Abutment Scour

| | Left | Right |
|---|---|---|
| **Input Data** | | |
| Station at Toe (ft): | 2384.00 | 2606.00 |
| Toe Sta at appr (ft): | 2384.00 | 2606.00 |
| Abutment Length (ft): | 300.00 | 300.00 |
| Depth at Toe (ft): | 9.70 | 9.70 |
| K1 Shape Coef: | 0.55 - Spill-through abutment | |
| Degree of Skew (degrees): | 90.00 | 90.00 |
| K2 Skew Coef: | 1.00 | 1.00 |
| Projected Length L' (ft): | 300. | 300. |
| Avg Depth Obstructed Ya (ft): | 5.00 | 7.00 |
| Flow Obstructed Qe (cfs): | 2600.00 | 11550.00 |
| Area Obstructed Ae (sq ft): | 2247.00 | 9900.00 |
| **Results** | | |
| Scour Depth Ys (ft): | 18.36 | 18.49 |
| Froude #: | 0.10 | 0.11 |
| Equation: | HIRE | HIRE |

Combined Scour Depths

| | |
|---|---|
| Pier : #1 (CL = 289) (Contr + Pier) (ft): | |
| Pier : #2 (CL = 323) (Contr + Pier) (ft): | |
| Pier : #3 (CL = 357) (Contr + Pier) (ft): | |
| Pier : #4 (CL = 391) (Contr + Pier) (ft): | |
| Pier : #5 (CL = 433) (Contr + Pier) (ft): | |
| Pier : #6 (CL = 475) (Contr + Pier) (ft): | |
| Pier : #7 (CL = 517) (Contr + Pier) (ft): | |
| Pier : #8 (CL = 559) (Contr + Pier) (ft): | |
| Pier : #9 (CL = 601) (Contr + Pier) (ft): | |
| Pier : #10 (CL = 643) (Contr + Pier) (ft): | |
| Pier : #11 (CL = 685) (Contr + Pier) (ft): | |
| Pier : #12 (CL = 727) (Contr + Pier) (ft): | |
| Pier : #13 (CL = 769) (Contr + Pier) (ft): | |
| Pier : #14 (CL = 811) (Contr + Pier) (ft): | |
| Pier : #15 (CL = 853) (Contr + Pier) (ft): | |
| Pier : #16 (CL = 895) (Contr + Pier) (ft): | |
| Pier : #17 (CL = 937) (Contr + Pier) (ft): | |
| Pier : #18 (CL = 979) (Contr + Pier) (ft): | |
| Pier : #19 (CL = 1021) (Contr + Pier) (ft): | |
| Pier : #20 (CL = 1063) (Contr + Pier) (ft): | |
| Pier : #21 (CL = 2458) (Contr + Pier) (ft): | 4.44 |
| Pier : #22 (CL = 2541) (Contr + Pier) (ft): | 4.44 |

| | |
|---|---|
| Left abutment scour + contraction scour (ft): | 18.36 |
| Right abutment scour + contraction scour (ft): | 18.49 |