HoustonEngineering Inc.

HYDRAULIC ANALYSIS
IN SUPPORT OF THE KENNEDY BRIDGE PLANNING STUDY

U.S. HIGHWAY 2 OVER THE RED RIVER OF THE NORTH
GRAND FORKS, NORTH DAKOTA
EAST GRAND FORKS, MINNESOTA

4/25/2014 | Kennedy Bridge | U.S. Highway 2

This report documents the investigation and analysis completed as part of the Planning Study for the U.S. HWY 2 crossing over the Red River of the North located within the cities of Grand Forks, ND and East Grand Forks, MN.

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April 25, 2014

Grand Forks, Grand Forks County, North Dakota

East Grand Forks, Polk County, Minnesota

HoustonEngineering Inc.

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I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision, and that I am a duly Registered Professional Engineer under the laws of the State of North Dakota.

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ND Reg. No. PE-3777

Date 4/25/2014

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TABLE OF CONTENTS

PURPOSE 1

HYDROLOGY 1

HYDRAULICS 2

EXISTING STRUCTURE HYDRAULICS 2

REVISED EXISTING STRUCTURE HYDRAULICS 4

CONCLUSIONS 6

REFERENCES 9

PURPOSE

This report covers the investigation and analysis completed as part of the planning study for the U.S. HWY 2 crossing over the Red River of the North located within the cities of Grand Forks, ND and East Grand Forks, MN (GF/EGF). This report focuses on rehabilitation options, however, the concepts presented here will also apply to potential replacement options should they be pursued in the future. The crossing is also referred to as the Kennedy Bridge. On the North Dakota side, the project is located between Section 03, T151N, R50W, and Section 34, T152N, R50W, Grand Forks County, North Dakota. On the Minnesota side, the project is located between Section 02, T151N, R50W, and Section 35, T152N, R50W, Polk County, Minnesota.

HYDROLOGY

Hydrology for this site has been previously developed by the U.S. Army Corps of Engineers (USACE) in cooperation with the North Dakota State Water Commission (NDSWC), Minnesota Department of Natural Resources (MnDNR), U.S. Geological Survey (USGS), and the Federal Emergency Management Agency (FEMA) as part of the Grand Forks, ND Flood Insurance Study (FIS). The hydrology developed for the FIS includes the 30,100 square miles of drainage area (26,300 square miles contributing) as defined by the USGS at gage 05082500, Red River of the North at Grand Forks, ND. This USGS gage is approximately 0.5 miles upstream from the project location. The FIS takes into account the floodwall and levee system through the communities of Grand Forks, ND and East Grand Forks, MN that was constructed by the USACE after the flood of 1997 (Flood Control Project, Red River of the North, GF/EGF). Any channel modifications including floodwall and levees within the model are now considered as existing conditions for the purpose of this report. As part of the FIS, a floodway has also been defined through Grand Forks, ND and East Grand Forks, MN and as such, the 100-year event will require 0.00' of stage increase (no rise) from existing conditions to any proposed and/or rehabilitated conditions. The 10-, 50-, and 500-year events will also be evaluated to provide an understanding of the potential impacts over a range of events. The FIS discharges are as follows:

Return Period	Discharge (cfs)
10 – year	47,700
50 – year	87,600
100 – year	108,000
500 – year	161,000

HYDRAULICS

The hydraulic analysis for this project utilized the steady state Hydrologic Engineering Center – River Analysis System (HEC-RAS v 4.1) hydraulic modeling software. This is a widely accepted tool used to identify channel hydraulics and the effects a hydraulic structure may have on a river system. The HEC-RAS model developed for the effective FIS was used for the analysis.

Tailwater Calculation

The starting water surface elevations used in the HEC-RAS model were set to known water surface elevations and were based on an existing FIS developed by the USACE which ties in to the downstream end of the Grand Forks, ND FIS. The following tailwater elevation data was obtained from the results of the HEC-RAS analysis at a location just downstream from Kennedy Bridge. All elevations within this report reference NAVD 88.

Return Period	Discharge (cfs)	TW Elevation
10 – year	47,700	823.0
50 – year	87,600	829.7
100 – year	108,000	832.2
500 – year	161,000	837.1

EXISTING STRUCTURE HYDRAULICS

Existing Structure at Site:

66'W x 1,258'L 13-span bridge – Kennedy bridge – U.S. HWY 2
Waterway Area: Approximately 32,200 sq. ft.
AADT: 18,440 (2013)
Flow Line: 769.1 ft.
Road Overtopping Elevation: 831.6 ft. – located approximately midway between the eastern most abutment of Kennedy Bridge and the western most abutment of the 4th St overpass.

Existing Upstream Structure:

58' W x 600'L 2-span bridge 0.5 miles upstream – Sorlie bridge – Demers Avenue
Waterway Area: Approximately 14,400 sq. ft.

Existing Downstream Structure:

15'W x 400'L 6-span bridge 1.2 miles downstream – Pedestrian foot bridge
Waterway Area = Approximately 11,400 sq. ft. below bridge. The bridge is designed to be overtopped during large flood events.

The Effective FIS existing structure at this site has the following hydraulic characteristics:

10 – Year Flood Event	
Flow:	47,700 cfs
Headwater Elevation:	823.0 ft.
Stage Increase:	<0.1 ft.
Mean Velocity through Bridge:	2.6 fps
Mean Velocity in Downstream Channel:	3.3 fps

50 – Year Flood Event	
Flow:	87,600 cfs
Headwater Elevation:	829.8 ft.
Stage Increase:	0.1 ft.
Mean Velocity through Bridge:	3.3 fps
Mean Velocity in Downstream Channel:	4.5 fps

100 – Year Flood Event	
Flow:	108,000 cfs
Headwater Elevation:	832.4 ft.
Stage Increase:	0.2 ft.
Mean Velocity through Bridge:	3.6 fps
Mean Velocity in Downstream Channel:	4.9 fps

500 – Year Flood Event	
Flow:	161,000 cfs
Headwater Elevation:	837.6 ft.
Stage Increase:	0.5 ft.
Mean Velocity through Bridge:	4.6 fps
Mean Velocity in Downstream Channel:	6.1 fps

During our overall QA/QC process for the FIS HEC-RAS model, the level of detail within the model cross sections as well as the top of road profile for U.S. Highway 2 came into question. It was found that the previously developed FIS model used duplicate cross sections in the vicinity of Kennedy Bridge. For comparison, new cross sections were created using available LiDAR (International Water Institute, 2008) data, and minor variations were found within the conveyance area of the duplicated cross sections verses the FIS cross sections. It was also found from the LiDAR data that the minimum overtopping elevation of the low area to the east of Kennedy Bridge near the 4th St overpass was higher than shown in the FIS HEC-RAS model (832.4 vs. 831.6). Because of this, changes have been implemented within the model to create a revised existing conditions model, and the results are presented below. The updates made to the cross sections provide a more detailed, and accurate representation of the flow distribution near Kennedy Bridge, yet resulted in less than a 0.1 foot difference in water surface elevation as compared to the FIS.

REVISED EXISTING STRUCTURE HYDRAULICS

The Revised Existing Conditions structure at this site has the following hydraulic characteristics:

10 – Year Flood Event	
Flow:	47,700 cfs
Headwater Elevation:	823.0 ft.
Stage Increase:	<0.1 ft.
Mean Velocity through Culverts:	2.6 fps
Mean Velocity in Downstream Channel:	3.2 fps

50 – Year Flood Event	
Flow:	87,600 cfs
Headwater Elevation:	829.8 ft.
Stage Increase:	0.1 ft.
Mean Velocity through Culverts:	3.2 fps
Mean Velocity in Downstream Channel:	4.3 fps

100 – Year Flood Event	
Flow:	108,000 cfs
Headwater Elevation:	832.4 ft.
Stage Increase:	0.2 ft.
Mean Velocity through Culverts:	3.5 fps
Mean Velocity in Downstream Channel:	4.8 fps

500 – Year Flood Event	
Flow:	161,000 cfs
Headwater Elevation:	837.6 ft.
Stage Increase:	0.5 ft.
Mean Velocity through Culverts:	4.6 fps
Mean Velocity in Downstream Channel:	5.9 fps

The table below shows the comparison of existing conditions water surface elevations for Kennedy Bridge, and the corresponding elevations at the USGS Gage which is located approximately 0.5 miles upstream from Kennedy Bridge, based on the revised existing conditions model. Also shown on this table is the stage relationship at the USGS gaging station, for familiarity.

Return Period	Water Surface Elevation (NAVD 88)			Equivalent Stage @ the USGS Gage
	Downstream	Upstream	USGS Gage (approx 0.5 miles upstream)	
10 – year	823.0	823.0	823.3	43.2
50 – year	829.7	829.8	830.1	50.0
100 – year	832.2	832.4	832.7	52.6
500 – year	837.1	837.6	837.9	57.8

This report provides hydraulic analysis of the existing conditions as part of the Kennedy Bridge Planning Study, and as such, will not be providing a formal recommendation regarding a proposed bridge or structure replacement. This report should be used as an aid in evaluating options for rehabilitation and/or replacement of the existing structure. Potential replacement and rehabilitation alternatives have been considered but have not been formally analyzed as part of this study.

CONCLUSIONS

Rehabilitation of the Existing Bridge:

The following conclusions are for the rehabilitation of the existing bridge where the Kennedy Bridge remains in place as the U.S. HWY 2 crossing over the Red River of the North. The table below shows various critical elevations comparison along Kennedy Bridge and U.S. HWY 2. There is a low point in the road profile of U.S. HWY 2 east of the Kennedy Bridge Crossing, and west of the 4th St NW underpass. The low point elevation between Kennedy Bridge and 4th Street NW is shown for both the effective FIS and the revised existing conditions, respectively.

Location	Kennedy Bridge (U.S. Highway 2)	Equivalent Elevation @ the USGS Gage	Equivalent Stage @ the USGS Gage
Low Truss	832.4	832.7	52.6
Eastern Abutment	831.4	831.7	51.6
Low point between Kennedy and 4th St (Effective FIS)	831.6	831.9	51.8
Low point between Kennedy and 4th St (Revised Existing)	832.4	832.7	52.6
High Point at 4th St	837.9	838.3	58.2

To help explain this, **Figure 1** and **Figure 2** show basic plots from the HEC-RAS model showing the existing bridge, and the critical elevations within Kennedy Bridge and U.S. HWY 2 based on the effective FIS and the Revised Existing Conditions, respectively.

Profile Grade Equalization of East-Bound and West-Bound Lanes:

The east-bound (EB) and west-bound (WB) lanes of U.S. HWY 2 currently have a different profile in the vicinity of Kennedy Bridge. The issue is that the EB lanes in the low area (East of Kennedy Bridge and west of 4th St NW Bridge) dip to a lower point than the WB lanes so the overtopping elevation that controls the hydraulic profile is at the WB lanes. As the water rises, it floods the EB lanes first, however, MnDOT sandbags this area upstream of the low point (approximately 2 ft. high) to gain additional open time before the WB lanes overtop. Therefore, a project to raise the EB lanes up to the WB elevation, which is being considered as part of the rehab project will not impact the hydraulic profile during large flood events, it just keeps the water off the road until it would overtop the WB lanes anyway.

Road Raise between Kennedy and 4th Street NW bridges:

This analysis includes consideration of a project to raise the low portion of U.S. HWY 2 between Kennedy Bridge and 4th Street NW to an approximate elevation of 834.1 ft. in an effort to allow access along this stretch of the road as long as the bridge remains open during flood events. Raising this portion of the road will eliminate approximately 600 sq. ft. of conveyance during large events, which has potential to make upstream flooding conditions worse, and thus may need to be mitigated in accordance with FEMA's no rise standards. Mitigation could take the form of additional culverts, and/or widening of bridge abutments, either at Kennedy Bridge or the 4th St NW overpass. For reference; a single 10 ft. by 10 ft. Reinforced Concrete Box Culvert with standard slab, wall, and haunch thicknesses provides 98 sq. ft. of waterway opening. However, installing box culverts, or widening the existing bridge may affect the conveyance of lesser events by increasing the conveyance capacity at a lower elevation. This has potential to make downstream flooding conditions worse, although any impacts would likely be minor.

A preliminary analysis was performed to represent a potential road raise to the low area east of Kennedy Bridge. The 100-year water surface elevation upstream from Kennedy Bridge is very near the revised existing conditions top of road elevation based on LiDAR (832.4). Therefore, almost no increase in water surface elevation was realized on the 100-year flood event or smaller events, with a road raise. The 500-year water surface elevation is significantly higher than the potential road raise elevation, and there was minimal impact on this event. It would appear that the critical flood event would fall in between the 100-, and 500-year events in which a significant portion of the overtopping was blocked. This was not studied in further detail at this time.

Survey information for top of road, as well as cross sections, will be required for more detailed analysis moving forward.

Further detailed analysis will be necessary to determine and quantify any upstream, as well as downstream impacts, as further design elements are developed.

Potential impacts to construction from flooding:

During construction, various techniques may be employed to accomplish certain aspects of a Kennedy Bridge replacement, or rehabilitation. Temporary earthworks and/or cofferdams are commonplace, especially when working with piers along a bridge. Unforeseen flooding could potentially disrupt the construction, or rehabilitation process. Without the aid of a construction plan, it is difficult to predict the possible impacts to construction from flooding. A hydraulic analysis and review of construction impacts in future phases of project development is recommended, in order to fully understand the potential implications.

FEMA has defined a regulatory floodway through this reach of the Red River of the North, and further questions will need answering as part of the permitting process on the topic of temporary earthworks or cofferdams being allowed in the floodplain.

Replacement of Existing Bridge:

As stated previously, this report does not provide a formal recommendation for a proposed bridge replacement of Kennedy Bridge. If a bridge replacement option is pursued, further design details will be necessary (such as pier size/shape/location, structure depth, beam thickness, abutment slope, bottom width, bench location and elevations, etc.) to allow a meaningful analysis of options. Any replacement options will be required to conform to the regulatory floodway requirements as developed and defined by FEMA as part of the Grand Forks, ND and East Grand Forks, MN Flood Insurance Studies.

The selection process for the type of structure to replace the existing bridge is susceptible to many factors. From a design standpoint, it is desirable to place piers aligned parallel with the flow of the river. Based on the location and alignment of Kennedy Bridge, and the specific meandering of the Red River of the north in the immediate vicinity of Kennedy Bridge; keeping piers aligned parallel to the flow of the river may cause the bridge to be set on a skew with the piers. This may potentially limit the selection of a bridge replacement structure to those structures that can be placed on piers at a skew to the bridge alignment. Alternatively, the piers can be set in line with the bridge, but skew to the flow of the river. This type of design is possible, but not desirable. According to the National Highway Institute, in conjunction with the Federal Highway Administration, and U.S. Department of Transportation; “The most common cause of bridge failures is from floods scouring bed material from around bridge foundations (piers and abutments).” Having piers set skew to the flow reduces the hydraulic capacity of the bridge and increases the potential for scour and can subsequently compromise bridge integrity. Although it is possible to account for these complications in the design process, we do not recommend setting piers on a skew to the natural flow of the Red River. As part of the Kennedy Bridge Planning Study, HZ United has completed a scour memorandum which can be referenced for further details on the effects of scour.

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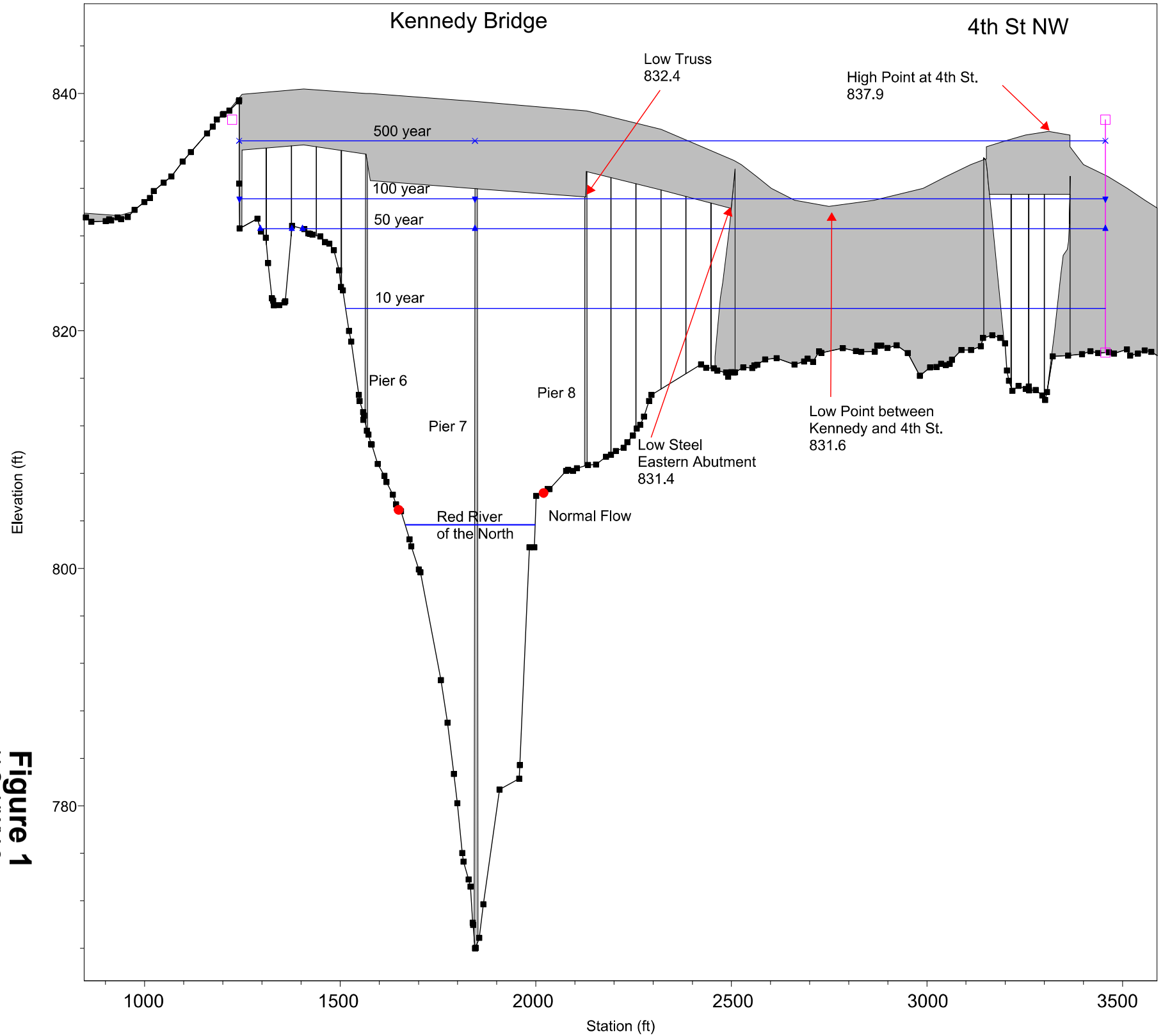

Figure 1
U.S. HWY 2
Effective FIS

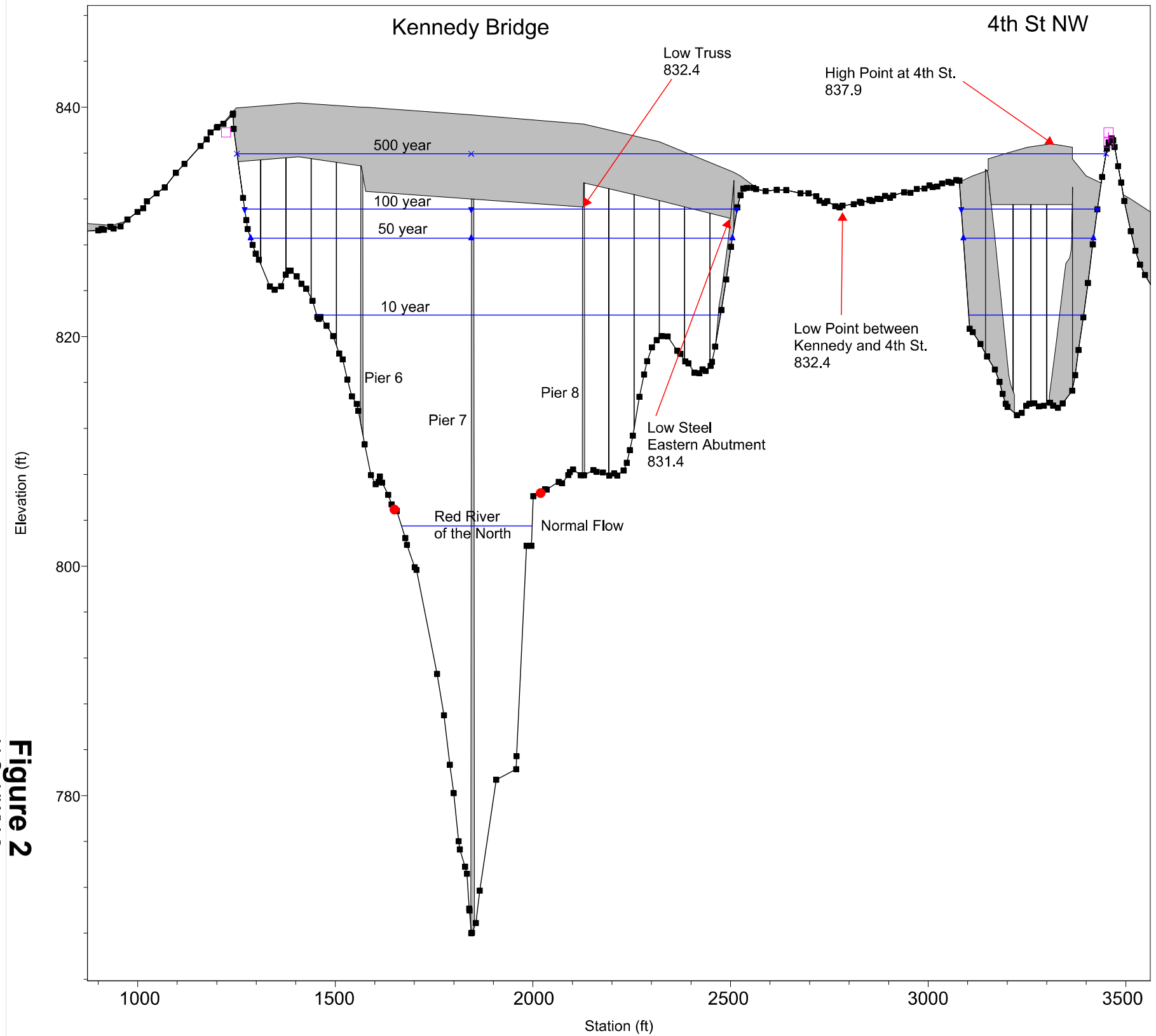

Figure 2

U.S. HWY 2

Revised Existing Conditions

with IWI LiDAR