Example Box Culvert Hydraulic Report

HYDRAULIC ANALYSIS AND STRUCTURE SELECTION

BRIDGE NO. 32-006.121

PROJECT NO. SS-8-032(033)006

PCN 19853

SARGENT COUNTY

PREPARED BY

DESIGNER OR CONSULTANT NAME

NORTH DAKOTA DEPARTMENT OF TRANSPORTATION

BRIDGE DIVISION

MAY 2013

SS-8-032(033)006

4 Miles South of ND 11 East

CERTIFICATION

I hereby certify that this 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. This document was originally issued and sealed by Walter White, Registration number PE-#### on MM/DD/YY and the original document is stored at the North Dakota Department of Transportation.

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Walter White, P.E. /s/ Date

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I. PURPOSE

The purpose of this report is to determine the hydraulic requirements for a new structure which conveys the flows of the Wild Rice River through ND Highway 32 at RP 6.121 in Sargent County.

II. EXISTING STRUCTURE

A. Location

Figure 1 - Project Location Map

B. Project Construction History

Structure 32-006.121 was reconstructed in 1952 to carry ND Highway 32 traffic across the Wild Rice River. The structure is a 65 foot long by 32.8 foot wide steel stringer bridge. The abutments of the old bridge (a 30 foot long single-span I-beam bridge) were cut off to an elevation of 1244.5' (1929 National Geodetic Vertical Datum) when the bridge was reconstructed in 1952, and are located within the banks of the river underneath the bridge. The deck of the existing structure has been overlaid with HBP.

C. Existing Geometry

Structure 32-006.121

Length – 65 ft
Skew – 0 degrees
Clear Roadway Width – 27.9 ft

III. HYDROLOGY

Design flows were determined using methodology set forth in USGS Water-Resource Investigations Report 92-4020 *Techniques for Estimating Peak-Flow Frequency Relations for North Dakota Streams (USGS W-RI Report).*

Structure 32-006.121 is located on a gaged stream and is upstream of a gaging station near Rutland, ND. The contributing drainage area at the gaging station was reported to be 296 square miles. After estimating the area between downstream of the bridge to the gage station to be 35.44 square miles, the ungaged contributing drainage area at the bridge was calculated to be 260.56 square miles. Peak flows at the gage station were calculated using annual peak flows collected from gage station data and the software program PeakFQ. Because the ratio of contributing drainage areas for the ungaged site is between 75 and 150 percent of the contributing drainage area for the gaged site, the Weighted Peak-Flow method for estimating design flows for ungaged sites near a gaging station on the same stream can be used. The results of this method are shown below in Table 1:

$$Q_{T(u)} = Q_{TW(g)} \ (CA_u/CA_g)^x,$$

where

$Q_{T(u)}$ = peak flow, in cubic feet per second, for the ungaged site for a recurrence interval of T-years;

$Q_{TW(g)}$ = weighted peak flow, in cubic feet per second, for the gaging station for a recurrence interval of T-years;

CA_u = contributing drainage area, in square miles, for the ungaged site;

CA_g = contributing drainage area, in square miles, for the gaging station; and

x = mean exponent for the appropriate hydrologic region.

<u>Downstream Gage Extrapolation Calculations</u>

Q_2 = 192.4 cfs x (260.56 sq mi/296 sq mi)$^{0.57}$
Q_2 = 178.9 cfs

Q_{10} = 1,297 cfs x (260.56 sq mi/296 sq mi)$^{0.57}$
Q_{10} = 1,206.1 cfs

Q_{50} = 3,297 cfs x (260.56 sq mi/296 sq mi)$^{0.57}$
Q_{50} = 3,065.8 cfs

Q_{100} = 4,424 cfs x (260.56 sq mi/296 sq mi)$^{0.57}$
Q_{100} = 4,113.8 cfs

Q_{200} = 5,701 cfs x (260.56 sq mi/296 sq mi)$^{0.57}$
Q_{200} = 5,301.3 cfs

Q_{500} = 7,601 cfs x (260.56 sq mi/296 sq mi)$^{0.57}$
Q_{500} = 7,068.1 cfs

Table 1 – Calculated Peak Flows

Frequency (Years)	Discharge at Gaging Station (cfs)	Discharge at Br. 32-006.121 (cfs)
2	192.4	178.9
10	1,297.0	1,206.1
50*	3,297.0	3,065.8
100	4,424.0	4,113.8
200	5,701	5,301.3
500	7,601.0	7,068.1

*Design Frequency

The new structure alternatives have been modeled for a 50-year discharge. The US Army Corps of Engineers HEC-RAS computer program was used for the hydraulic analysis of the existing structure and for the proposed alternatives considered. The results of these alternatives are contained in the appendix.

IV. STRUCTURE SELECTION

In the Project Concept Report, it was proposed to replace the existing bridge with a reinforced concrete box culvert. The existing structure and three structure alternatives were analyzed for comparison. Alternative 1 is to install a quad 10’ x 10’ reinforced concrete box culvert. Alternative 2 would require installation of a triple 14’ x 10’ reinforced concrete box culvert. Alternative 3 is to install a quad 11’ x 10’ reinforced concrete box culvert. All alternatives were analyzed with a length of 98 feet and skewed approximately 10 degrees from perpendicular to the proposed roadway. For each of the alternatives, the box will be placed 1 foot lower than the existing channel bottom in order to provide for aquatic organism passage. The estimated cost for Alternative 1 is $714,000. The estimated cost for Alternative 2 is $801,400. The estimated cost for Alternative 3 is $779,650. Rock riprap will be necessary for installation of the new structures and is not included in this cost estimate. The estimated cost for each alternative is shown in Table 2 – Cost Estimate.

Selection of the alternatives was completed by modeling the flows through the existing structure against the structure alternatives in HEC-RAS. Each of the structure alternatives result in an increase in headwater compared to the existing structure. However, the increase is less than 2 feet at the 100-year storm event, and no structures are located upstream. The structure alternatives all maintained flow velocities at the structure below 10 feet per second on a 50-year storm event. The overtopping discharge for Alternative 1 is 6,539.3 cfs. Alternatives 2 and 3

produced slightly lower headwaters and outlet velocities than Alternative 1. However, it is recommended that Alternative 1, Quad 10’ x 10’ x 98’, be constructed since it has the lowest cost.

Table 2 – Cost Estimate

Alternative Number and Size	Estimated Cost
Alternative #1 – Quad 10’ x 10’ x 98’	$714,000
Alternative #2 – Triple 14’ x 10’ x 98’	$801,400
Alternative #3 – Quad 11’ x 10’ x 98’	$779,650

V. SCOUR

Scour calculations were not performed for the box culvert alternatives. It is recommended that riprap be placed in the channel at the ends of the RCB aprons for a distance of 10 feet upstream and 20 feet downstream to protect the channel and structure from possible scour.

VI. MISCELLANEOUS

The following items should be discussed at the TS&L inspection:

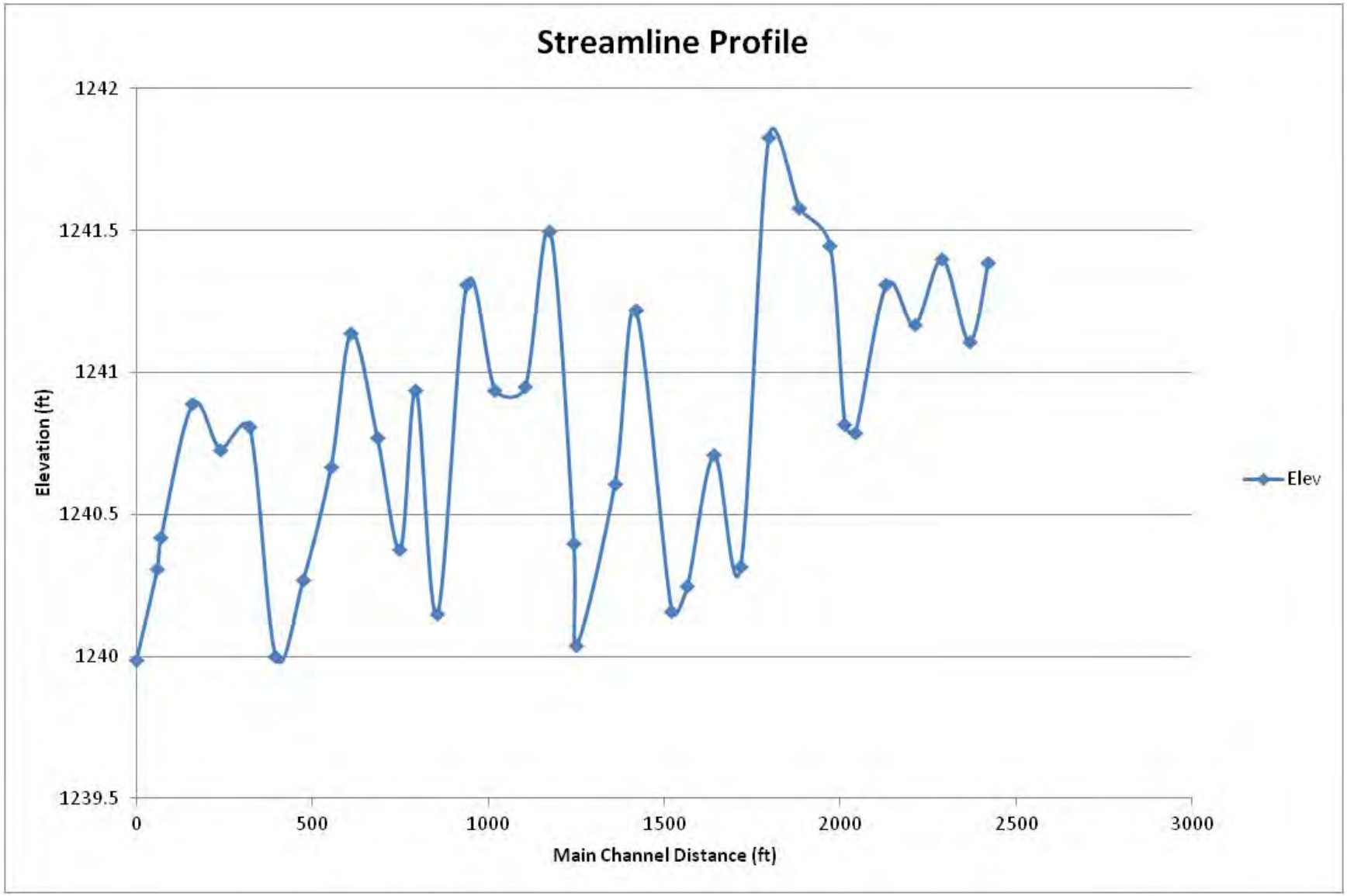
- Structure Selection
- Riprap Requirements
- Utilities
- Disposal of Existing Structure
- Temporary Bypass

APPENDIX A

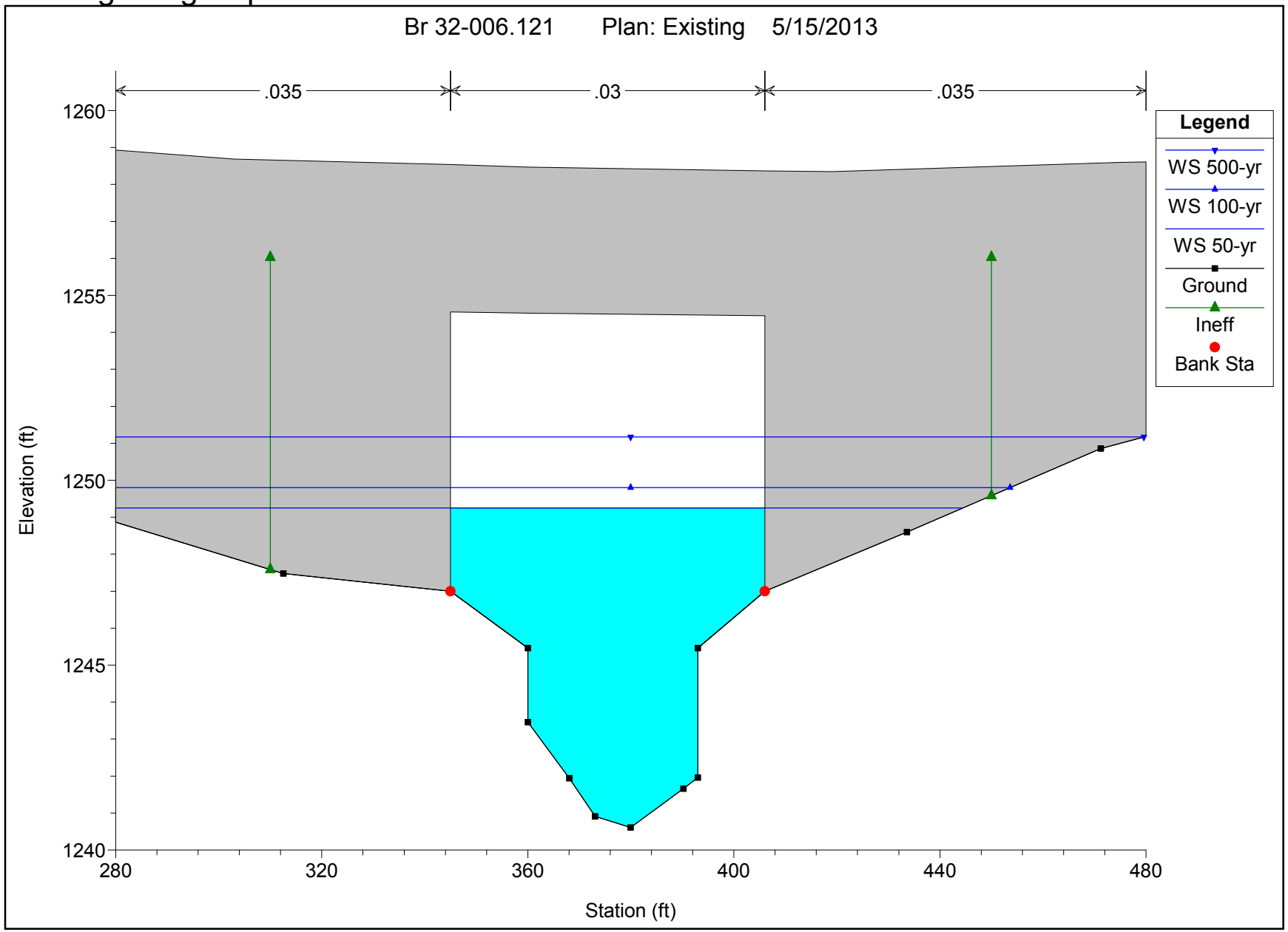
Hydraulic Calculations HEC-RAS

Wild Rice River

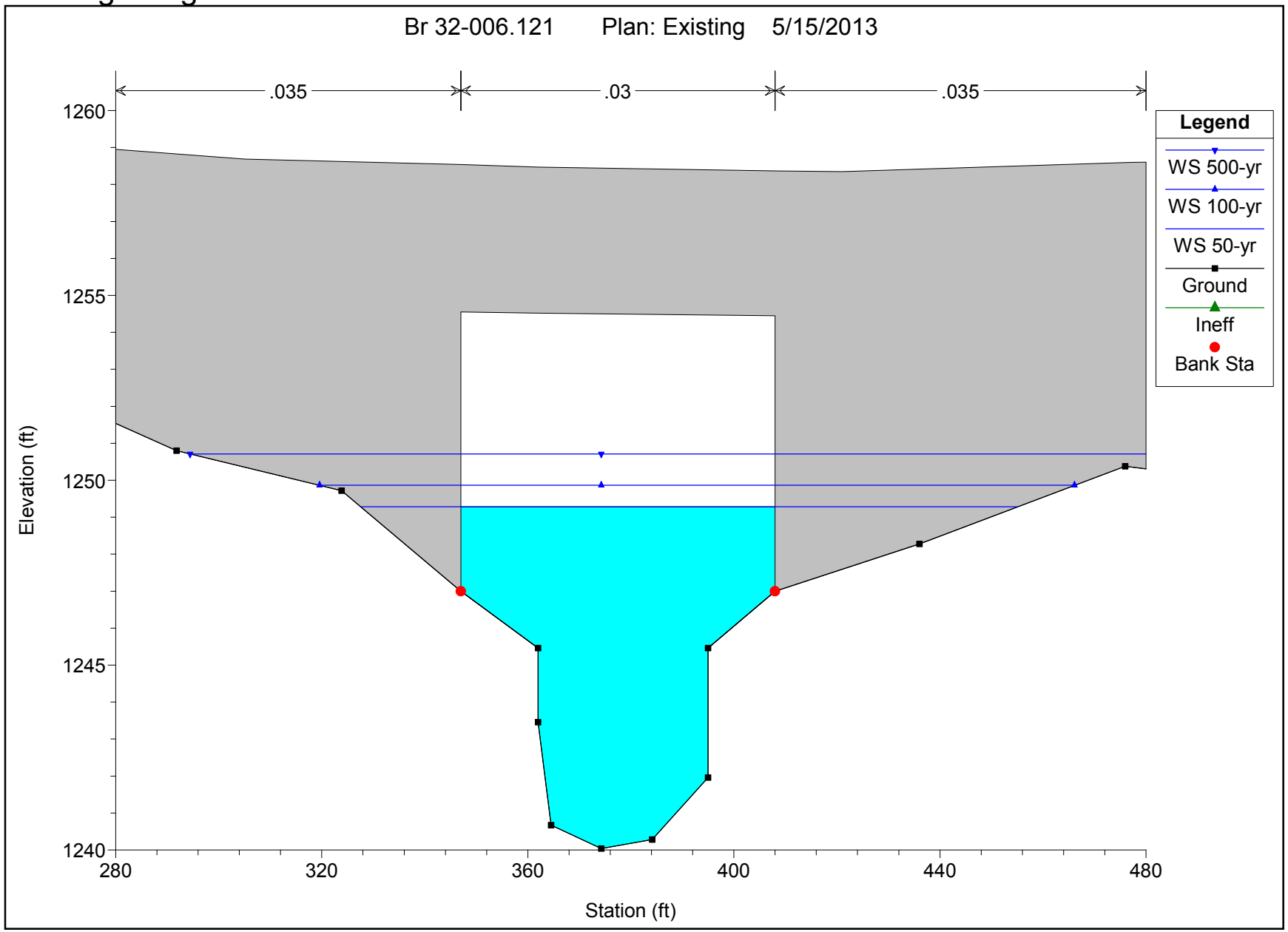
Existing Structure


Streamline Profile
1242
1241.5
1241
1240.5
1240
1239.5
Elevation (ft)
0
500
1000
1500
2000
2500
3000
Main Channel Distance (ft)
Elev

Existing Bridge Upstream



Existing Bridge Downstream



Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Main Channel	2472	50-yr	3065.8	1241.44	1250.88		1250.89	0.000026	1	4328.86	754.93	0.06
Main Channel	2472	100-yr	4113.8	1241.44	1252.12		1252.13	0.000025	1.08	5270.78	773.17	0.06
Main Channel	2472	500-yr	7068.1	1241.44	1255.46		1255.47	0.00002	1.2	7937.46	822.61	0.06
Main Channel	1970	50-yr	3065.8	1240.82	1250.84		1250.87	0.000097	2.09	2212.5	395.35	0.12
Main Channel	1970	100-yr	4113.8	1240.82	1252.06		1252.1	0.000097	2.28	2714.86	422.73	0.12
Main Channel	1970	500-yr	7068.1	1240.82	1255.4		1255.45	0.00008	2.5	4242.59	489.55	0.12
Main Channel	1310	50-yr	3065.8	1240.61	1250.25	1247.95	1250.67	0.001032	6.52	680.06	214.26	0.38
Main Channel	1310	100-yr	4113.8	1240.61	1251.45	1248.62	1251.91	0.000963	6.85	848.12	271.39	0.38
Main Channel	1310	500-yr	7068.1	1240.61	1254.78	1250.35	1255.29	0.000724	7.16	1313.55	509.76	0.34
Main Channel	1255.5		Bridge									
Main Channel	1201	50-yr	3065.8	1240.04	1249.62		1250.12	0.000936	6.31	644.15	219.64	0.38
Main Channel	1201	100-yr	4113.8	1240.04	1250.4		1251.12	0.001234	7.68	765.41	341.84	0.44
Main Channel	1201	500-yr	7068.1	1240.04	1252.17		1253.14	0.001465	9.39	1124.29	375.66	0.5
Main Channel	834	50-yr	3065.8	1240.61	1249.41		1249.77	0.000803	5.35	785.91	220.39	0.34
Main Channel	834	100-yr	4113.8	1240.61	1250.24		1250.67	0.000884	6.01	993.24	267.56	0.37
Main Channel	834	500-yr	7068.1	1240.61	1252.09		1252.61	0.000931	7.05	1541.16	327.98	0.39
Main Channel	278	50-yr	3065.8	1241.14	1248.84		1249.28	0.001122	6.03	675.81	163.29	0.4
Main Channel	278	100-yr	4113.8	1241.14	1249.51		1250.1	0.001369	7.08	790.37	178.72	0.45
Main Channel	278	500-yr	7068.1	1241.14	1250.94		1251.9	0.001913	9.37	1068.98	211.6	0.55
Main Channel	0	50-yr	3065.8	1240.31	1248.9	1246.96	1249.02	0.0005	4.07	1299.76	388.58	0.26
Main Channel	0	100-yr	4113.8	1240.31	1249.65	1247.39	1249.79	0.0005	4.34	1600	407.01	0.27
Main Channel	0	500-yr	7068.1	1240.31	1251.3	1248.19	1251.48	0.000501	4.9	2293.41	425.19	0.27

Plan: Existing Wild Rice River Main Channel RS: 1255.5 Profile: 50-yr				
E.G. US. (ft)	1250.67	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	1250.25	E.G. Elev (ft)	1250.52	1250.35
Q Total (cfs)	3065.8	W.S. Elev (ft)	1249.25	1249.28
Q Bridge (cfs)	3065.8	Crit W.S. (ft)	1247.97	1247.52
Q Weir (cfs)		Max Chl Dpth (ft)	8.64	9.24
Weir Sta Lft (ft)		Vel Total (ft/s)	9.04	8.3
Weir Sta Rgt (ft)		Flow Area (sq ft)	338.98	369.3
Weir Submerg		Froude # Chl	0.54	0.48
Weir Max Depth (ft)		Specif Force (cu ft)	1982.39	2152.14
Min El Weir Flow (ft)	1258.36	Hydr Depth (ft)	5.56	6.05
Min El Prs (ft)	1254.55	W.P. Total (ft)	66.99	68.07
Delta EG (ft)	0.55	Conv. Total (cfs)	49486.3	56476.9
Delta WS (ft)	0.63	Top Width (ft)	61	61
BR Open Area (sq ft)	659.09	Frctn Loss (ft)	0.11	0.06
BR Open Vel (ft/s)	9.04	C & E Loss (ft)	0.06	0.17
Coef of Q		Shear Total (lb/sq ft)	1.21	1
Br Sel Method	Energy only	Power Total (lb/ft s)	0	0

Plan: Existing Wild Rice River Main Channel RS: 1255.5 Profile: 100-yr				
E.G. US. (ft)	1251.91	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	1251.45	E.G. Elev (ft)	1251.7	1251.47
Q Total (cfs)	4113.8	W.S. Elev (ft)	1249.81	1249.86
Q Bridge (cfs)	4113.8	Crit W.S. (ft)	1248.92	1248.44
Q Weir (cfs)		Max Chl Dpth (ft)	9.19	9.82
Weir Sta Lft (ft)		Vel Total (ft/s)	11.03	10.16
Weir Sta Rgt (ft)		Flow Area (sq ft)	372.84	404.9
Weir Submerg		Froude # Chl	0.64	0.57
Weir Max Depth (ft)		Specif Force (cu ft)	2728.47	2885.64
Min El Weir Flow (ft)	1258.36	Hydr Depth (ft)	6.11	6.64
Min El Prs (ft)	1254.55	W.P. Total (ft)	66.99	68.07
Delta EG (ft)	0.79	Conv. Total (cfs)	57995.5	65837.3
Delta WS (ft)	1.05	Top Width (ft)	61	61
BR Open Area (sq ft)	659.09	Frctn Loss (ft)	0.14	0.08
BR Open Vel (ft/s)	11.03	C & E Loss (ft)	0.09	0.26
Coef of Q		Shear Total (lb/sq ft)	1.75	1.45
Br Sel Method	Energy only	Power Total (lb/ft s)	0	0

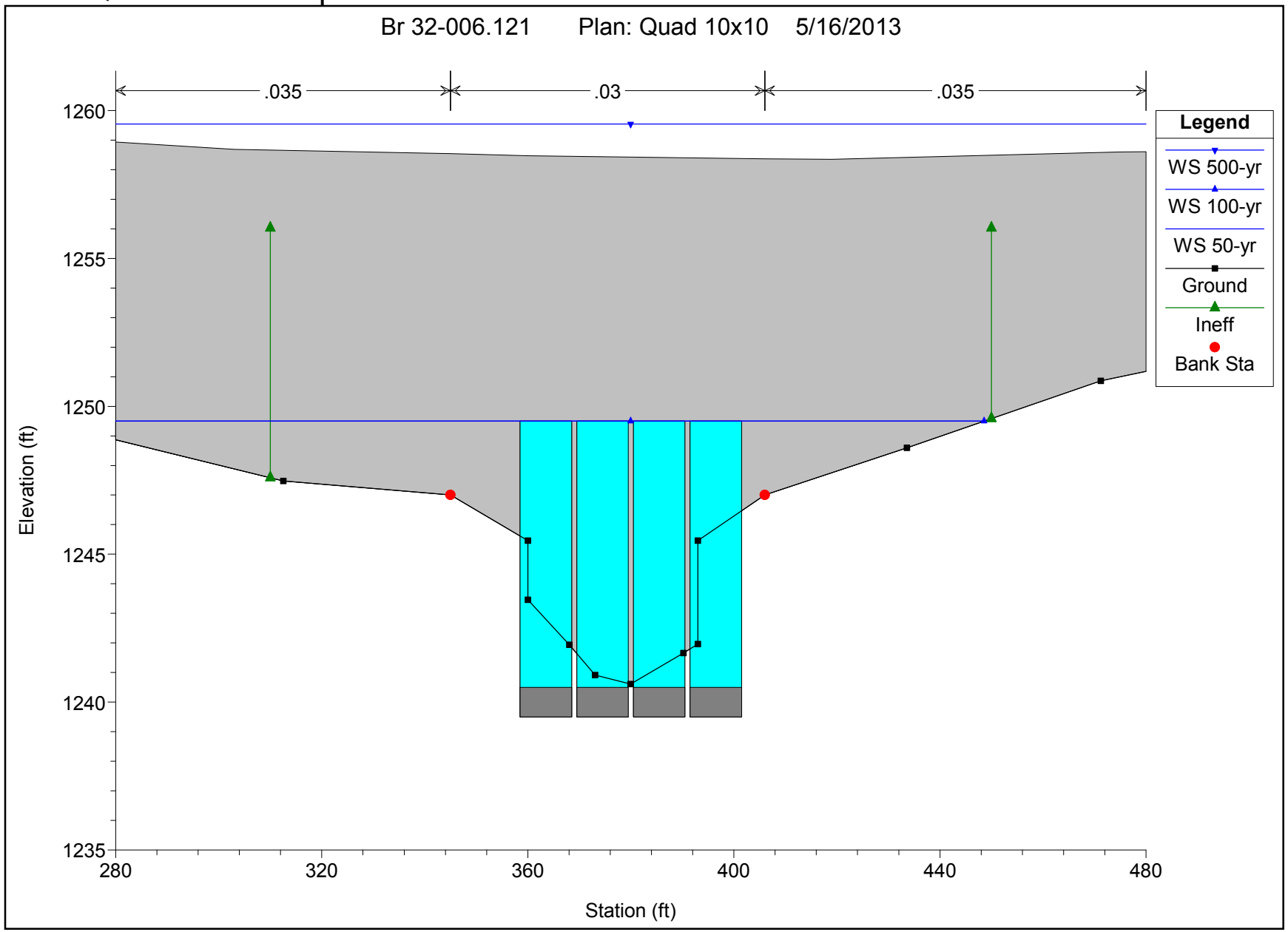
Plan: Existing Wild Rice River Main Channel RS: 1255.5 Profile: 500-yr				
E.G. US. (ft)	1255.29	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	1254.78	E.G. Elev (ft)	1254.9	1254.43
Q Total (cfs)	7068.1	W.S. Elev (ft)	1251.17	1250.71
Q Bridge (cfs)	7068.1	Crit W.S. (ft)	1251.17	1250.71
Q Weir (cfs)		Max Chl Dpth (ft)	10.56	10.67
Weir Sta Lft (ft)		Vel Total (ft/s)	15.5	15.48
Weir Sta Rgt (ft)		Flow Area (sq ft)	456.04	456.59
Weir Submerg		Froude # Chl	0.84	0.84
Weir Max Depth (ft)		Specif Force (cu ft)	5286.19	5350.63
Min El Weir Flow (ft)	1258.36	Hydr Depth (ft)	7.48	7.49
Min El Prs (ft)	1254.55	W.P. Total (ft)	66.99	68.07
Delta EG (ft)	2.15	Conv. Total (cfs)	81131.6	80434.1
Delta WS (ft)	2.61	Top Width (ft)	61	61
BR Open Area (sq ft)	659.09	Frctn Loss (ft)	0.25	0.11
BR Open Vel (ft/s)	15.5	C & E Loss (ft)	0	0.83
Coef of Q		Shear Total (lb/sq ft)	3.23	3.23
Br Sel Method	Energy only	Power Total (lb/ft s)	0	0

APPENDIX B

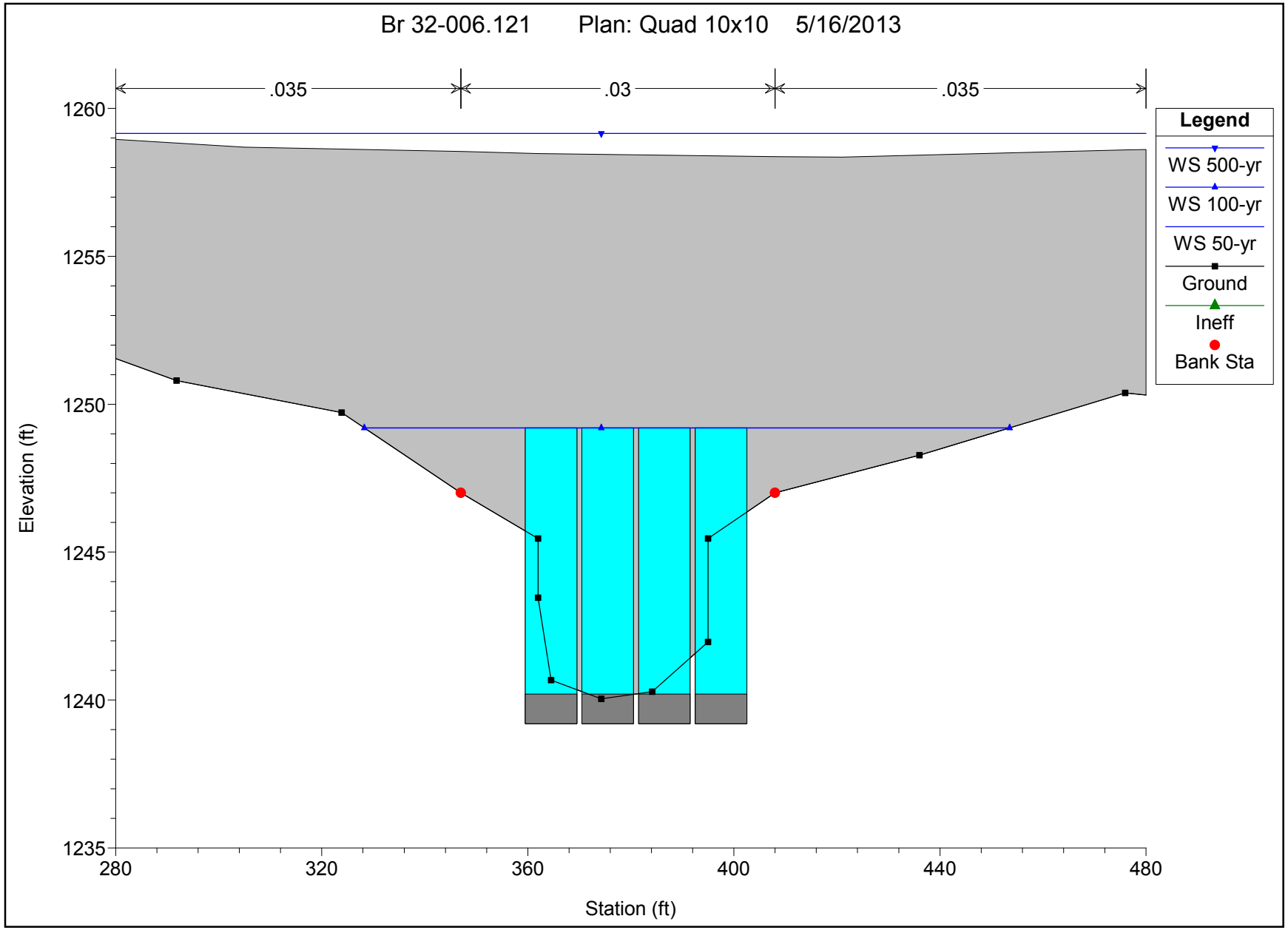
Hydraulic Calculations HEC-RAS

Alternative 1
Quad 10’ x 10’ RCB

Alt 1: Quad 10' x 10' Upstream



Alt 1: Quad 10' x 10' Downstream



Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Main Channel	2472	50-yr	3065.8	1241.44	1251.44		1251.45	0.000019	0.9	4751.85	763.18	0.05
Main Channel	2472	100-yr	4113.8	1241.44	1253.51		1253.51	0.000014	0.88	6359.88	793.74	0.05
Main Channel	2472	500-yr	7068.1	1241.44	1259.81		1259.81	0.000007	0.83	11772.5	958.06	0.04
Main Channel	1970	50-yr	3065.8	1240.82	1251.4		1251.43	0.000073	1.89	2440.3	408	0.11
Main Channel	1970	100-yr	4113.8	1240.82	1253.47		1253.5	0.000054	1.86	3332.87	452.95	0.1
Main Channel	1970	500-yr	7068.1	1240.82	1259.79		1259.81	0.000023	1.6	6551.77	554	0.07
Main Channel	1310	50-yr	3065.8	1240.61	1250.99	1247.95	1251.29	0.000682	5.59	782.36	245.94	0.32
Main Channel	1310	100-yr	4113.8	1240.61	1253.13	1248.62	1253.4	0.000452	5.19	1083.19	383.5	0.27
Main Channel	1310	500-yr	7068.1	1240.61	1259.55	1250.35	1259.76	0.000192	4.51	1980.92	594.57	0.19
Main Channel	1255.5		Culvert									
Main Channel	1201	50-yr	3065.8	1240.04	1249.62		1250.12	0.000936	6.31	644.15	219.64	0.38
Main Channel	1201	100-yr	4113.8	1240.04	1250.4		1251.12	0.001234	7.68	765.41	341.84	0.44
Main Channel	1201	500-yr	7068.1	1240.04	1252.17		1253.14	0.001465	9.39	1124.29	375.66	0.5
Main Channel	834	50-yr	3065.8	1240.61	1249.41		1249.77	0.000803	5.35	785.91	220.39	0.34
Main Channel	834	100-yr	4113.8	1240.61	1250.24		1250.67	0.000884	6.01	993.24	267.56	0.37
Main Channel	834	500-yr	7068.1	1240.61	1252.09		1252.61	0.000931	7.05	1541.16	327.98	0.39
Main Channel	278	50-yr	3065.8	1241.14	1248.84		1249.28	0.001122	6.03	675.81	163.29	0.4
Main Channel	278	100-yr	4113.8	1241.14	1249.51		1250.1	0.001369	7.08	790.37	178.72	0.45
Main Channel	278	500-yr	7068.1	1241.14	1250.94		1251.9	0.001913	9.37	1068.98	211.6	0.55
Main Channel	0	50-yr	3065.8	1240.31	1248.9	1246.96	1249.02	0.0005	4.07	1299.76	388.58	0.26
Main Channel	0	100-yr	4113.8	1240.31	1249.65	1247.39	1249.79	0.0005	4.34	1600	407.01	0.27
Main Channel	0	500-yr	7068.1	1240.31	1251.3	1248.19	1251.48	0.000501	4.9	2293.41	425.19	0.27

Plan: Quad 10x10 Wild Rice River Main Channel RS: 1255.5 Culv Group: Quad 10x10 Profile: 50-yr			
Q Culv Group (cfs)	3065.8	Culv Full Len (ft)	98
# Barrels	4	Culv Vel US (ft/s)	8.52
Q Barrel (cfs)	766.45	Culv Vel DS (ft/s)	8.52
E.G. US. (ft)	1251.29	Culv Inv El Up (ft)	1239.5
W.S. US. (ft)	1250.99	Culv Inv El Dn (ft)	1239.2
E.G. DS (ft)	1250.12	Culv Frctn Ls (ft)	0.32
W.S. DS (ft)	1249.62	Culv Exit Loss (ft)	0.63
Delta EG (ft)	1.17	Culv Entr Loss (ft)	0.23
Delta WS (ft)	1.36	Q Weir (cfs)	
E.G. IC (ft)	1249.71	Weir Sta Lft (ft)	
E.G. OC (ft)	1251.29	Weir Sta Rgt (ft)	
Culvert Control	Outlet	Weir Submerg	
Culv WS Inlet (ft)	1249.5	Weir Max Depth (ft)	
Culv WS Outlet (ft)	1249.2	Weir Avg Depth (ft)	
Culv Nml Depth (ft)		Weir Flow Area (sq ft)	
Culv Crt Depth (ft)	6.67	Min El Weir Flow (ft)	1258.36

Plan: Quad 10x10 Wild Rice River Main Channel RS: 1255.5 Culv Group: Quad 10x10 Profile: 100-yr			
Q Culv Group (cfs)	4113.8	Culv Full Len (ft)	98
# Barrels	4	Culv Vel US (ft/s)	11.43
Q Barrel (cfs)	1028.45	Culv Vel DS (ft/s)	11.43
E.G. US. (ft)	1253.4	Culv Inv El Up (ft)	1239.5
W.S. US. (ft)	1253.13	Culv Inv El Dn (ft)	1239.2
E.G. DS (ft)	1251.12	Culv Frctn Ls (ft)	0.57
W.S. DS (ft)	1250.4	Culv Exit Loss (ft)	1.3
Delta EG (ft)	2.28	Culv Entr Loss (ft)	0.41
Delta WS (ft)	2.73	Q Weir (cfs)	
E.G. IC (ft)	1251.72	Weir Sta Lft (ft)	
E.G. OC (ft)	1253.4	Weir Sta Rgt (ft)	
Culvert Control	Outlet	Weir Submerg	
Culv WS Inlet (ft)	1249.5	Weir Max Depth (ft)	
Culv WS Outlet (ft)	1249.2	Weir Avg Depth (ft)	
Culv Nml Depth (ft)		Weir Flow Area (sq ft)	
Culv Crt Depth (ft)	7.9	Min El Weir Flow (ft)	1258.36

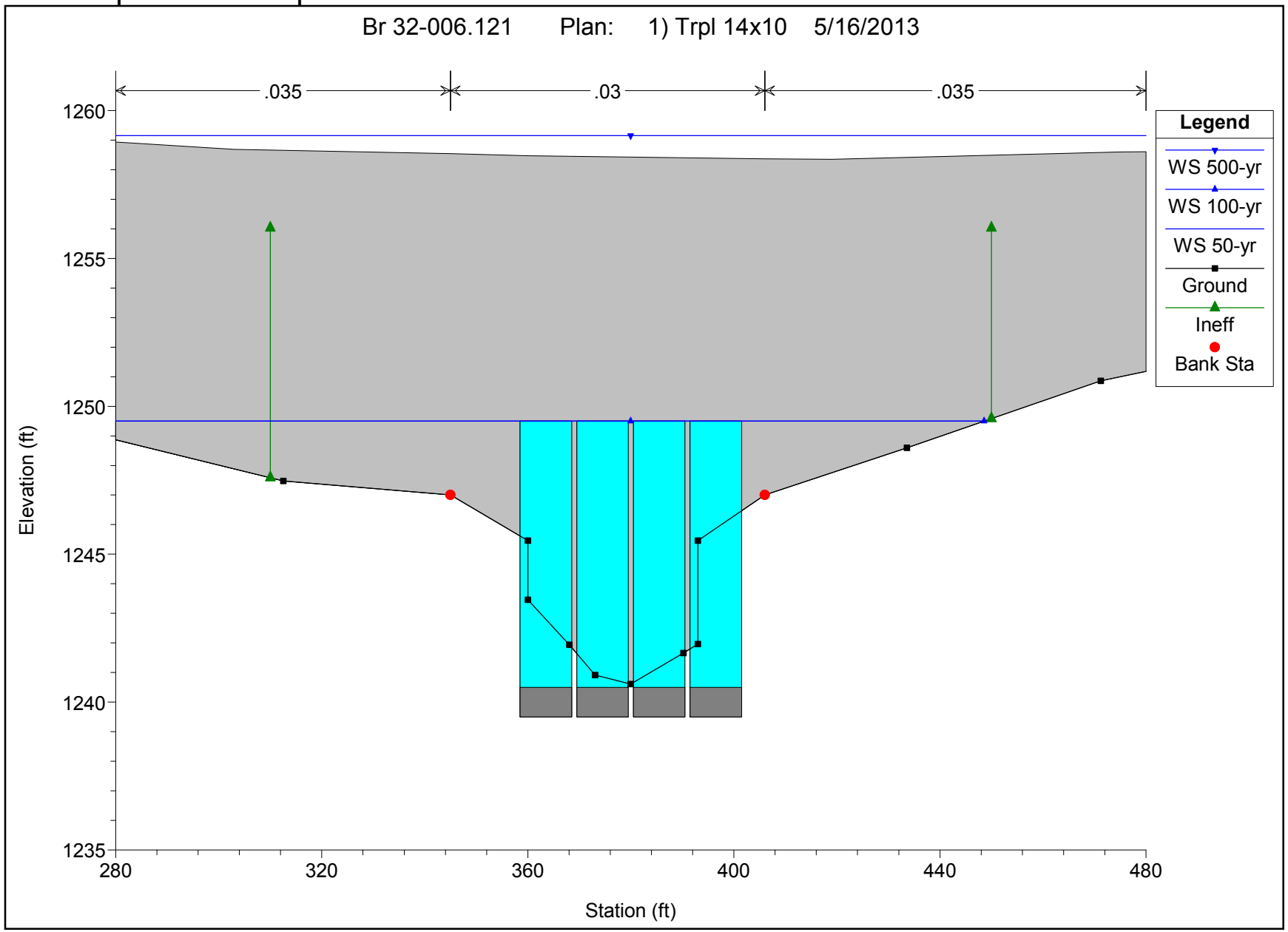
Plan: Quad 10x10 Wild Rice River Main Channel RS: 1255.5 Culv Group: Quad 10x10 Profile: 500-yr			
Q Culv Group (cfs)	6539.25	Culv Full Len (ft)	98
# Barrels	4	Culv Vel US (ft/s)	18.16
Q Barrel (cfs)	1634.81	Culv Vel DS (ft/s)	18.16
E.G. US. (ft)	1259.76	Culv Inv El Up (ft)	1239.5
W.S. US. (ft)	1259.55	Culv Inv El Dn (ft)	1239.2
E.G. DS (ft)	1253.14	Culv Frctn Ls (ft)	1.44
W.S. DS (ft)	1252.17	Culv Exit Loss (ft)	4.16
Delta EG (ft)	6.62	Culv Entr Loss (ft)	1.02
Delta WS (ft)	7.37	Q Weir (cfs)	528.85
E.G. IC (ft)	1259.07	Weir Sta Lft (ft)	310
E.G. OC (ft)	1259.76	Weir Sta Rgt (ft)	450
Culvert Control	Outlet	Weir Submerg	0
Culv WS Inlet (ft)	1249.5	Weir Max Depth (ft)	1.4
Culv WS Outlet (ft)	1249.2	Weir Avg Depth (ft)	1.28
Culv Nml Depth (ft)	10	Weir Flow Area (sq ft)	179.4
Culv Crt Depth (ft)	10	Min El Weir Flow (ft)	1258.36

APPENDIX C

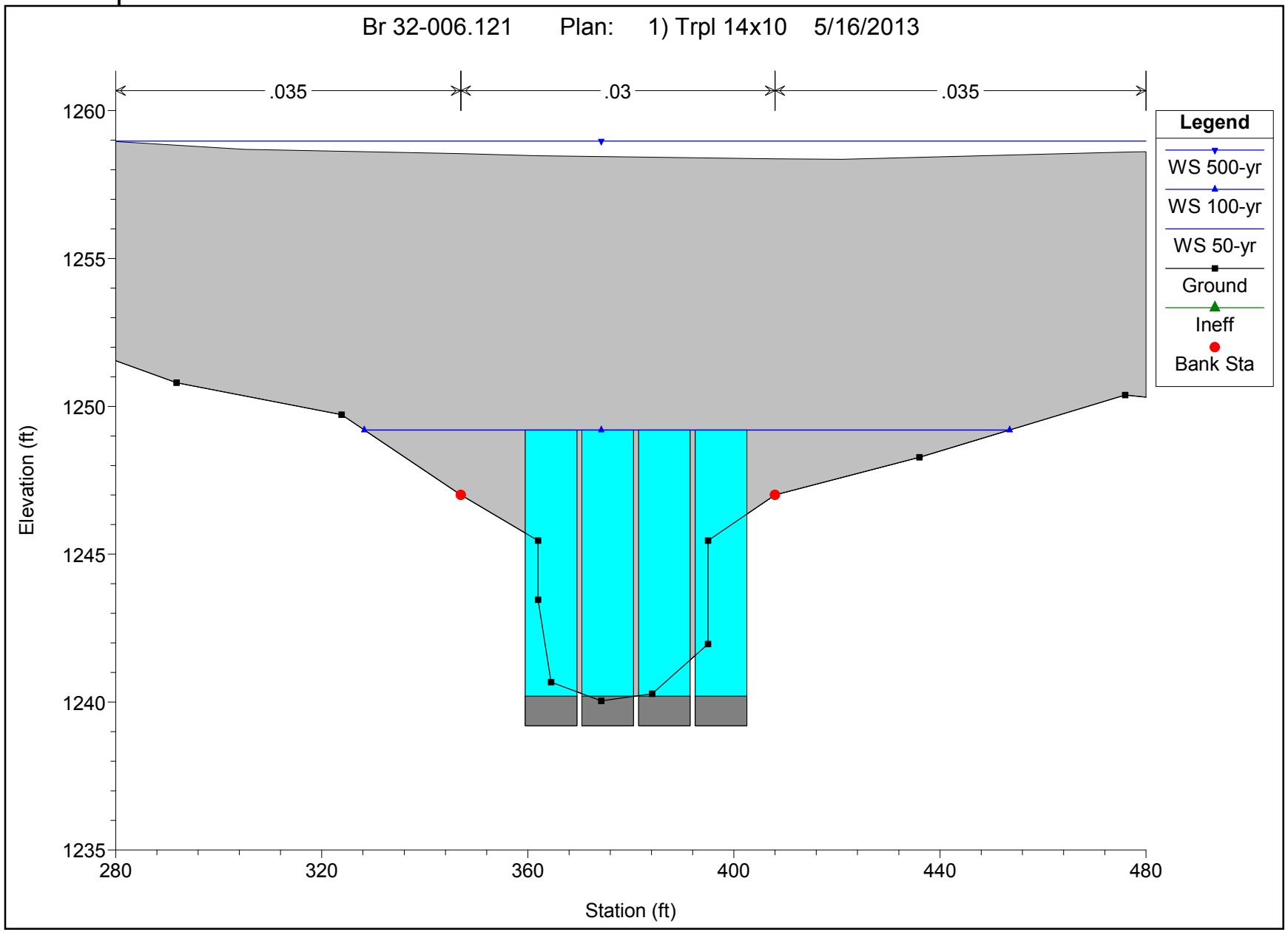
Hydraulic Calculations HEC-RAS

Alternative 2
Triple 14’ x 10’ RCB

Alt 2: Trpl 14' x 10' Upstream



Alt 2: Trpl 14' x 10' Downstream



Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Main Channel	2472	50-yr	3065.8	1241.44	1251.27		1251.28	0.000021	0.93	4623.12	760.68	0.06
Main Channel	2472	100-yr	4113.8	1241.44	1253.19		1253.19	0.000016	0.92	6108.33	789.03	0.05
Main Channel	2472	500-yr	7068.1	1241.44	1259.43		1259.44	0.000007	0.85	11412.2	944.33	0.04
Main Channel	1970	50-yr	3065.8	1240.82	1251.23		1251.26	0.00008	1.95	2370.61	404.17	0.11
Main Channel	1970	100-yr	4113.8	1240.82	1253.15		1253.18	0.000062	1.94	3188.27	446.86	0.1
Main Channel	1970	500-yr	7068.1	1240.82	1259.41		1259.43	0.000025	1.66	6341.88	549.97	0.07
Main Channel	1310	50-yr	3065.8	1240.61	1250.77	1247.95	1251.1	0.000766	5.83	752.69	235.53	0.33
Main Channel	1310	100-yr	4113.8	1240.61	1252.77	1248.62	1253.06	0.000525	5.48	1032.37	352.66	0.28
Main Channel	1310	500-yr	7068.1	1240.61	1259.15	1250.35	1259.37	0.00021	4.65	1925.43	594.57	0.19
Main Channel	1255.5		Culvert									
Main Channel	1201	50-yr	3065.8	1240.04	1249.62		1250.12	0.000936	6.31	644.15	219.64	0.38
Main Channel	1201	100-yr	4113.8	1240.04	1250.4		1251.12	0.001234	7.68	765.41	341.84	0.44
Main Channel	1201	500-yr	7068.1	1240.04	1252.17		1253.14	0.001465	9.39	1124.29	375.66	0.5
Main Channel	834	50-yr	3065.8	1240.61	1249.41		1249.77	0.000803	5.35	785.91	220.39	0.34
Main Channel	834	100-yr	4113.8	1240.61	1250.24		1250.67	0.000884	6.01	993.24	267.56	0.37
Main Channel	834	500-yr	7068.1	1240.61	1252.09		1252.61	0.000931	7.05	1541.16	327.98	0.39
Main Channel	278	50-yr	3065.8	1241.14	1248.84		1249.28	0.001122	6.03	675.81	163.29	0.4
Main Channel	278	100-yr	4113.8	1241.14	1249.51		1250.1	0.001369	7.08	790.37	178.72	0.45
Main Channel	278	500-yr	7068.1	1241.14	1250.94		1251.9	0.001913	9.37	1068.98	211.6	0.55
Main Channel	0	50-yr	3065.8	1240.31	1248.9	1246.96	1249.02	0.0005	4.07	1299.76	388.58	0.26
Main Channel	0	100-yr	4113.8	1240.31	1249.65	1247.39	1249.79	0.0005	4.34	1600	407.01	0.27
Main Channel	0	500-yr	7068.1	1240.31	1251.3	1248.19	1251.48	0.000501	4.9	2293.41	425.19	0.27

Plan: Trpl 14x10 Wild Rice River Main Channel RS: 1255.5 Culv Group: Trpl 14x10 Profile: 50-yr			
Q Culv Group (cfs)	3065.8	Culv Full Len (ft)	98
# Barrels	3	Culv Vel US (ft/s)	8.11
Q Barrel (cfs)	1021.93	Culv Vel DS (ft/s)	8.11
E.G. US. (ft)	1251.1	Culv Inv El Up (ft)	1239.5
W.S. US. (ft)	1250.77	Culv Inv El Dn (ft)	1239.2
E.G. DS (ft)	1250.12	Culv Frctn Ls (ft)	0.26
W.S. DS (ft)	1249.62	Culv Exit Loss (ft)	0.52
Delta EG (ft)	0.98	Culv Entr Loss (ft)	0.2
Delta WS (ft)	1.15	Q Weir (cfs)	
E.G. IC (ft)	1249.41	Weir Sta Lft (ft)	
E.G. OC (ft)	1251.1	Weir Sta Rgt (ft)	
Culvert Control	Outlet	Weir Submerg	
Culv WS Inlet (ft)	1249.5	Weir Max Depth (ft)	
Culv WS Outlet (ft)	1249.2	Weir Avg Depth (ft)	
Culv Nml Depth (ft)		Weir Flow Area (sq ft)	
Culv Crt Depth (ft)	6.49	Min El Weir Flow (ft)	1258.36

Plan: Trpl 14x10 Wild Rice River Main Channel RS: 1255.5 Culv Group: Trpl 14x10 Profile: 100-yr			
Q Culv Group (cfs)	4113.8	Culv Full Len (ft)	98
# Barrels	3	Culv Vel US (ft/s)	10.88
Q Barrel (cfs)	1371.27	Culv Vel DS (ft/s)	10.88
E.G. US. (ft)	1253.07	Culv Inv El Up (ft)	1239.5
W.S. US. (ft)	1252.77	Culv Inv El Dn (ft)	1239.2
E.G. DS (ft)	1251.12	Culv Frctn Ls (ft)	0.46
W.S. DS (ft)	1250.4	Culv Exit Loss (ft)	1.12
Delta EG (ft)	1.95	Culv Entr Loss (ft)	0.37
Delta WS (ft)	2.37	Q Weir (cfs)	
E.G. IC (ft)	1251.35	Weir Sta Lft (ft)	
E.G. OC (ft)	1253.07	Weir Sta Rgt (ft)	
Culvert Control	Outlet	Weir Submerg	
Culv WS Inlet (ft)	1249.5	Weir Max Depth (ft)	
Culv WS Outlet (ft)	1249.2	Weir Avg Depth (ft)	
Culv Nml Depth (ft)		Weir Flow Area (sq ft)	
Culv Crt Depth (ft)	7.68	Min El Weir Flow (ft)	1258.36

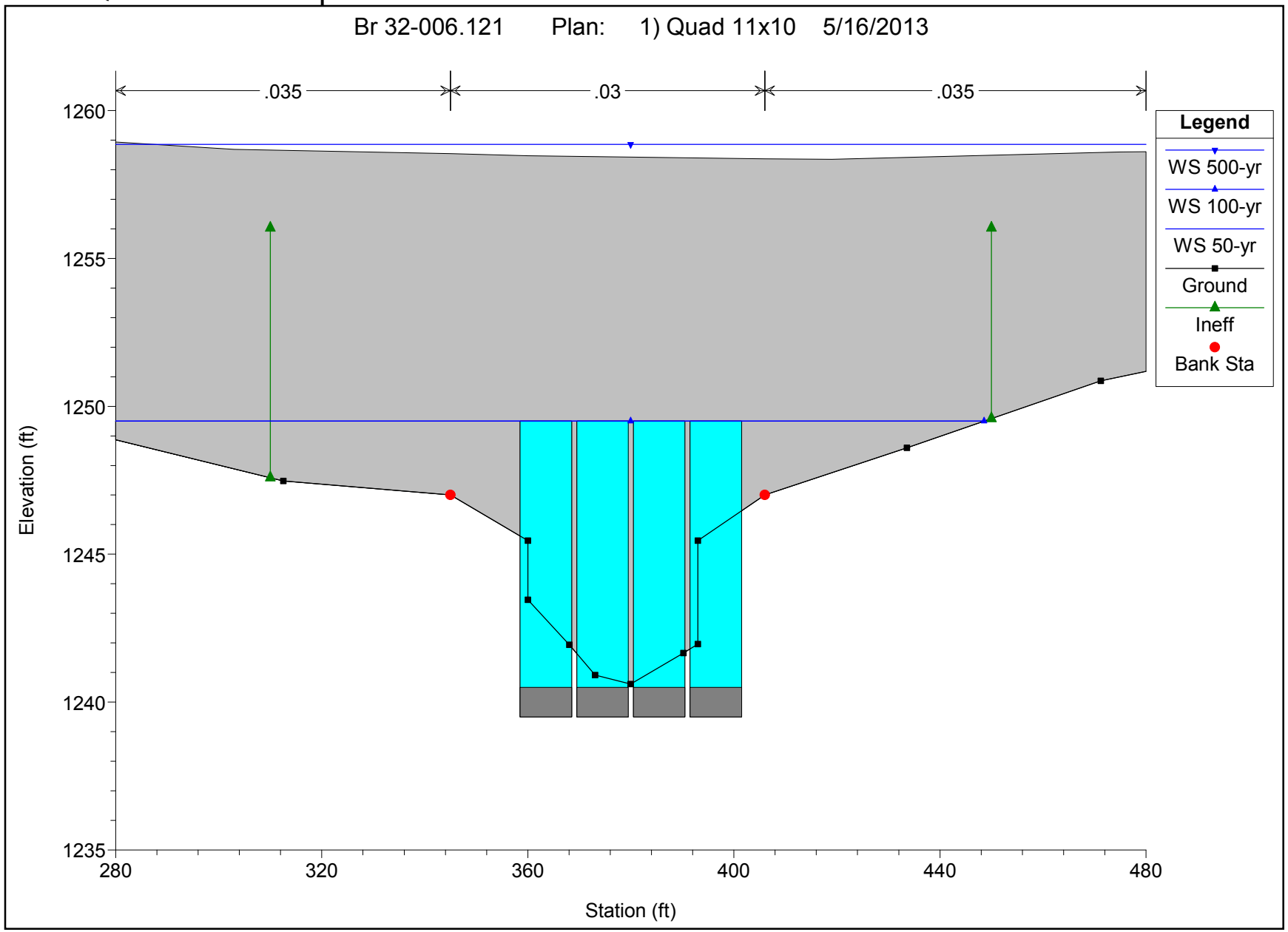
Plan: Trpl 14x10 Wild Rice River Main Channel RS: 1255.5 Culv Group: Trpl 14x10 Profile: 500-yr			
Q Culv Group (cfs)	6755.06	Culv Full Len (ft)	98
# Barrels	3	Culv Vel US (ft/s)	17.87
Q Barrel (cfs)	2251.69	Culv Vel DS (ft/s)	17.87
E.G. US. (ft)	1259.38	Culv Inv El Up (ft)	1239.5
W.S. US. (ft)	1259.15	Culv Inv El Dn (ft)	1239.2
E.G. DS (ft)	1253.14	Culv Frctn Ls (ft)	1.25
W.S. DS (ft)	1252.17	Culv Exit Loss (ft)	3.99
Delta EG (ft)	6.24	Culv Entr Loss (ft)	0.99
Delta WS (ft)	6.98	Q Weir (cfs)	313.04
E.G. IC (ft)	1258.49	Weir Sta Lft (ft)	310
E.G. OC (ft)	1259.38	Weir Sta Rgt (ft)	450
Culvert Control	Outlet	Weir Submerg	0
Culv WS Inlet (ft)	1249.5	Weir Max Depth (ft)	1.02
Culv WS Outlet (ft)	1249.2	Weir Avg Depth (ft)	0.9
Culv Nml Depth (ft)	10	Weir Flow Area (sq ft)	126.33
Culv Crt Depth (ft)	10	Min El Weir Flow (ft)	1258.36

APPENDIX D

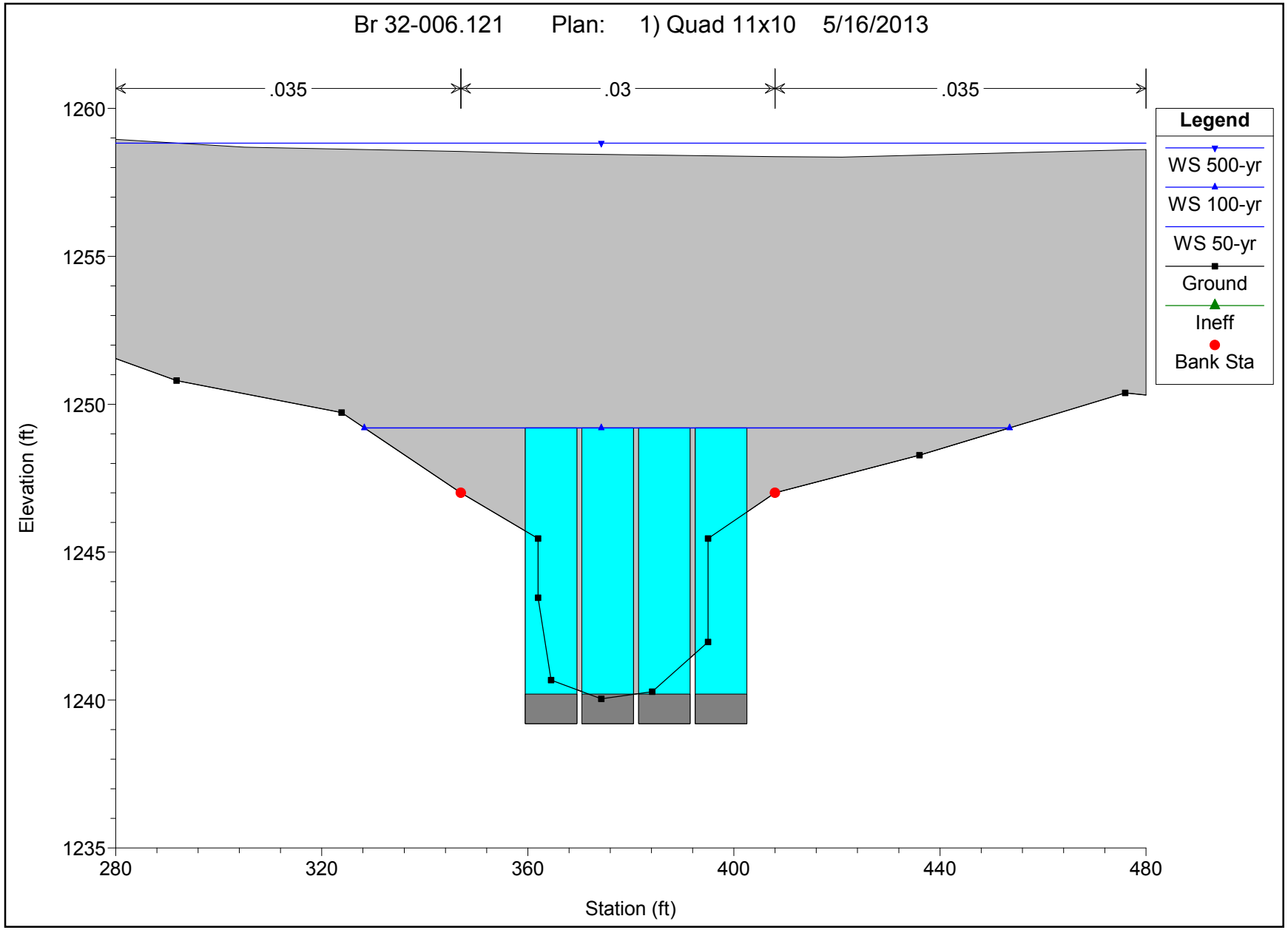
Hydraulic Calculations HEC-RAS

Alternative 3
Quad 11’ x 10’ RCB

Alt 3: Quad 11' x 10' Upstream



Alt 3: Quad 11' x 10' Downstream



Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Main Channel	2472	50-yr	3065.8	1241.44	1251.17		1251.17	0.000022	0.95	4544.18	759.14	0.06
Main Channel	2472	100-yr	4113.8	1241.44	1253		1253.01	0.000017	0.95	5962.18	786.29	0.05
Main Channel	2472	500-yr	7068.1	1241.44	1259.15		1259.16	0.000008	0.87	11149.3	934.07	0.04
Main Channel	1970	50-yr	3065.8	1240.82	1251.13		1251.16	0.000084	1.99	2328.01	401.81	0.11
Main Channel	1970	100-yr	4113.8	1240.82	1252.96		1253	0.000067	1.99	3104.63	442.81	0.1
Main Channel	1970	500-yr	7068.1	1240.82	1259.13		1259.15	0.000027	1.7	6187.69	546.98	0.07
Main Channel	1310	50-yr	3065.8	1240.61	1250.64	1247.95	1250.99	0.000825	6	733.96	230.05	0.34
Main Channel	1310	100-yr	4113.8	1240.61	1252.55	1248.62	1252.87	0.000576	5.67	1002.12	334.31	0.3
Main Channel	1310	500-yr	7068.1	1240.61	1258.86	1250.35	1259.09	0.000226	4.77	1884.25	594.57	0.2
Main Channel	1255.5		Culvert									
Main Channel	1201	50-yr	3065.8	1240.04	1249.62		1250.12	0.000936	6.31	644.15	219.64	0.38
Main Channel	1201	100-yr	4113.8	1240.04	1250.4		1251.12	0.001234	7.68	765.41	341.84	0.44
Main Channel	1201	500-yr	7068.1	1240.04	1252.17		1253.14	0.001465	9.39	1124.29	375.66	0.5
Main Channel	834	50-yr	3065.8	1240.61	1249.41		1249.77	0.000803	5.35	785.91	220.39	0.34
Main Channel	834	100-yr	4113.8	1240.61	1250.24		1250.67	0.000884	6.01	993.24	267.56	0.37
Main Channel	834	500-yr	7068.1	1240.61	1252.09		1252.61	0.000931	7.05	1541.16	327.98	0.39
Main Channel	278	50-yr	3065.8	1241.14	1248.84		1249.28	0.001122	6.03	675.81	163.29	0.4
Main Channel	278	100-yr	4113.8	1241.14	1249.51		1250.1	0.001369	7.08	790.37	178.72	0.45
Main Channel	278	500-yr	7068.1	1241.14	1250.94		1251.9	0.001913	9.37	1068.98	211.6	0.55
Main Channel	0	50-yr	3065.8	1240.31	1248.9	1246.96	1249.02	0.0005	4.07	1299.76	388.58	0.26
Main Channel	0	100-yr	4113.8	1240.31	1249.65	1247.39	1249.79	0.0005	4.34	1600	407.01	0.27
Main Channel	0	500-yr	7068.1	1240.31	1251.3	1248.19	1251.48	0.000501	4.9	2293.41	425.19	0.27

Plan: Quad 11x10 Wild Rice River Main Channel RS: 1255.5 Culv Group: Quad 11x10 Profile: 50-yr			
Q Culv Group (cfs)	3065.8	Culv Full Len (ft)	98
# Barrels	4	Culv Vel US (ft/s)	7.74
Q Barrel (cfs)	766.45	Culv Vel DS (ft/s)	7.74
E.G. US. (ft)	1250.99	Culv Inv El Up (ft)	1239.5
W.S. US. (ft)	1250.64	Culv Inv El Dn (ft)	1239.2
E.G. DS (ft)	1250.12	Culv Frctn Ls (ft)	0.25
W.S. DS (ft)	1249.62	Culv Exit Loss (ft)	0.43
Delta EG (ft)	0.87	Culv Entr Loss (ft)	0.19
Delta WS (ft)	1.02	Q Weir (cfs)	
E.G. IC (ft)	1249.14	Weir Sta Lft (ft)	
E.G. OC (ft)	1250.99	Weir Sta Rgt (ft)	
Culvert Control	Outlet	Weir Submerg	
Culv WS Inlet (ft)	1249.5	Weir Max Depth (ft)	
Culv WS Outlet (ft)	1249.2	Weir Avg Depth (ft)	
Culv Nml Depth (ft)		Weir Flow Area (sq ft)	
Culv Crt Depth (ft)	6.32	Min El Weir Flow (ft)	1258.36

Plan: Quad 11x10 Wild Rice River Main Channel RS: 1255.5 Culv Group: Quad 11x10 Profile: 100-yr			
Q Culv Group (cfs)	4113.8	Culv Full Len (ft)	98
# Barrels	4	Culv Vel US (ft/s)	10.39
Q Barrel (cfs)	1028.45	Culv Vel DS (ft/s)	10.39
E.G. US. (ft)	1252.87	Culv Inv El Up (ft)	1239.5
W.S. US. (ft)	1252.55	Culv Inv El Dn (ft)	1239.2
E.G. DS (ft)	1251.12	Culv Frctn Ls (ft)	0.46
W.S. DS (ft)	1250.4	Culv Exit Loss (ft)	0.95
Delta EG (ft)	1.74	Culv Entr Loss (ft)	0.34
Delta WS (ft)	2.15	Q Weir (cfs)	
E.G. IC (ft)	1251.01	Weir Sta Lft (ft)	
E.G. OC (ft)	1252.87	Weir Sta Rgt (ft)	
Culvert Control	Outlet	Weir Submerg	
Culv WS Inlet (ft)	1249.5	Weir Max Depth (ft)	
Culv WS Outlet (ft)	1249.2	Weir Avg Depth (ft)	
Culv Nml Depth (ft)		Weir Flow Area (sq ft)	
Culv Crt Depth (ft)	7.48	Min El Weir Flow (ft)	1258.36

Plan: Quad 11x10 Wild Rice River Main Channel RS: 1255.5 Culv Group: Quad 11x10 Profile: 500-yr			
Q Culv Group (cfs)	6890.87	Culv Full Len (ft)	98
# Barrels	4	Culv Vel US (ft/s)	17.4
Q Barrel (cfs)	1722.72	Culv Vel DS (ft/s)	17.4
E.G. US. (ft)	1259.09	Culv Inv El Up (ft)	1239.5
W.S. US. (ft)	1258.86	Culv Inv El Dn (ft)	1239.2
E.G. DS (ft)	1253.14	Culv Frctn Ls (ft)	1.28
W.S. DS (ft)	1252.17	Culv Exit Loss (ft)	3.74
Delta EG (ft)	5.95	Culv Entr Loss (ft)	0.94
Delta WS (ft)	6.68	Q Weir (cfs)	177.23
E.G. IC (ft)	1257.54	Weir Sta Lft (ft)	310
E.G. OC (ft)	1259.09	Weir Sta Rgt (ft)	450
Culvert Control	Outlet	Weir Submerg	0
Culv WS Inlet (ft)	1249.5	Weir Max Depth (ft)	0.73
Culv WS Outlet (ft)	1249.2	Weir Avg Depth (ft)	0.62
Culv Nml Depth (ft)	10	Weir Flow Area (sq ft)	86.24
Culv Crt Depth (ft)	10	Min El Weir Flow (ft)	1258.36

APPENDIX E

Structure Comparison Sheet

STRUCTURE COMPARISON SUMMARY

North Dakota Department of Transportation, Bridge
SFN 18323 (Rev. 1-2000)

STRUCTURE DATA

ITEM	EXISTING	ALT. NUMBER 1	ALT. NUMBER 2	ALT. NUMBER 3
TYPE OR DESCRIPTION	Steel Stringer Bridge	Quad 10'x10' RCB	Trpl 14'x10' RCB	Quad 11'x10' RCB
NUMBER OF SPANS, BARRELS	Single-Span	4	3	4
OVERALL LENGTH (FT)	65	98	98	98
TOTAL WATERWAY AREA (FT^2)	659.1	400	420	440
CLEARANCE ELEVATION	1254.45	1249.5	1249.5	1249.5
ROADWAY OVERTOPPING ELEVATION	1258.35	1258.35	1258.35	1258.35

Hydraulic Comparison

50-Year Frequency	Q = 3065.8 CFS			
ITEM	**EXISTING**	**ALT. NUMBER 1**	**ALT. NUMBER 2**	**ALT. NUMBER 3**
DISCHARGE THROUGH STRUCTURE (CFS)	3065.8	3065.8	3065.8	3065.8
DISCHARGE OVER ROADWAY (CFS)	0	0	0	0
UPSTREAM STAGE	1250.25	1250.99	1250.77	1250.64
DOWNSTREAM STAGE	1249.62	1249.62	1249.62	1249.62
AVG. VEL. THROUGH STRUCTURE (FT/SEC)	8.3	8.52	8.11	7.74

Hydraulic Comparison

100-Year Frequency	Q = 4113.8 CFS			
ITEM	**EXISTING**	**ALT. NUMBER 1**	**ALT. NUMBER 2**	**ALT. NUMBER 3**
DISCHARGE THROUGH STRUCTURE (CFS)	4113.8	4113.8	4113.8	4113.8
DISCHARGE OVER ROADWAY (CFS)	0	0	0	0
UPSTREAM STAGE	1251.45	1253.13	1252.77	1252.55
DOWNSTREAM STAGE	1250.4	1250.4	1250.4	1250.4
AVG. VEL. THROUGH STRUCTURE (FT/SEC)	10.16	11.43	10.88	10.39

Hydraulic Comparison

500-Year Frequency	Q = 7068.1 CFS			
ITEM	**EXISTING**	**ALT. NUMBER 1**	**ALT. NUMBER 2**	**ALT. NUMBER 3**
DISCHARGE THROUGH STRUCTURE (CFS)	7068.1	6539.3	6755.1	6890.9
DISCHARGE OVER ROADWAY (CFS)	0	528.8	313	177.2
UPSTREAM STAGE	1254.78	1259.55	1259.15	1258.86
DOWNSTREAM STAGE	1252.17	1252.17	1252.17	1252.17
AVG. VEL. THROUGH STRUCTURE (FT/SEC)	15.48	18.16	17.87	17.4

COMMENTS:

APPENDIX F

Hydraulic Design Data for Culverts

HYDRAULIC DESIGN DATA FOR CULVERTS

North Dakota Department of Transportation, Bridge

SFN 9636 (Rev. 1-2000)

Project Number: SS-8-032(033)006	**Bridge Number:** 32-006.121
Drainage Area	260.56 Sq. Miles
Stream Gradient (ft/ft)	.0006
Design Frequency	50 Year
Design Discharge	3,065.8 cfs
Design Headwater Stage	1,250.99 ft
Design Tailwater Stage	1,249.62 ft
Velocity Through Culvert	8.52 ft/sec
100-year Frequency Discharge	4,113.8 cfs
100-year Frequency Headwater	1,253.13 ft
Overtopping Stage	1,258.35 ft
Overtopping Discharge	6,539.3 cfs
Structure Selection	Quad 10' x 10' x 98' RCB

COMMENTS:

Estimated Invert Elevations: Inlet = 1,239.50 ft Outlet = 1,239.20 ft RCB Skew Angle: 10° Right, Ahead
(Inverts to be set one foot below the existing channel bottom to provide for aquatic organism passage.
The inverts above reflect the one foot sinking of the RCB).

APPENDIX G

Structure Inventory & Appraisal Sheet

North Dakota Department of Transportation

Bridge Inventory - Structure Inventory And Appraisal Sheet

Structure Number: 0032-006.121

200 System Designation	1 - State
201 Status	Structurally Deficient
202 Sufficiency Rating	74.30

Identification

02 Highway District	Fargo District
03 County	Sargent
04 City	TAYLOR TOWNSHIP
05 Inventory Route	Route On Structure
3 State Hwy	1 Mainline 00032 0 N/A (NBI)
06 Feats Intersect	WILD RICE RIVER
09 Location	4 SOUTH OF ND 11 EAST
11 Milepoint	6.120
13 LRS Inv Route. Subroute	0000000000 00
16 Latitude	46d 01' 18.00"
17 Longitude	97d 37' 60.00"
GPS Coordinates XY	605788.3 5097368.0
98 Border Bridge	Unknown (P) -2.00 %
99 Border Bridge Struct No.	_

Structure Type and Material

43 Main Struct Type	Steel
Stringer	
44 Approach Struct Type	Unknown (NBI)
	Unknown (P)
45 No. Spans in Main Unit	1
46 No. Approach Spans	0
107 Deck Struct Type	1 Concrete-Cast-in-Place
108 Wearing Surface	6 Bituminous
Membrane	0 None
Dk Protect	None
208 Dk Overburden	02 in. Asphalt

Age and Service

27 Yr Built	1952 106 Yr Reconstructed -1
42 Type of Service	1 Highway - On
	5 Waterway - Under
28 Lanes on Structure	2
29 ADT	580 30 Year of ADT 2012
109 Average Daily Truck Traffic	19.00
19 Bypass, Detour Length	14 Miles

Geometric Data

10 Min Vert Clearance	328 Ft. 1 In.
32 Approach Roadway Width	26 Feet
33 Bridge Median	0 No median
34 Skew	0.00
35 Structure Flared	0 No flare
47 Total Horizontal Clearance	27.9 Feet
48 Length of Max Span	60 Feet
49 Structure Length	64.96 Feet
50 Curb/Sidewalk Widths	0.0 Ft Rt-Side
	0.0 Ft Lt-Side
51 Bridge Rdwy Width - Curb to Curb	27.9 Feet
52 Deck Width	32.8 Feet
53 Min Vert Clear. Over Bridge	328 Ft. 1 In.
54 Min Vert Underclearance	0 Ft. 0 In.
	N Feature not hwy or RR
55 Min Lateral UnderClear. - Rt	327.8 Feet
	N Feature not hwy or RR
56 Min Lateral UnderClear. - Lt	0.0 Feet
210 Culvert / 211 Description	

Classification

12 Base Highway Network	On Base Network
20 Toll	3 On free road
21 Maint Responsibility	01 State Highway Agency
22 Owner	01 State Highway Agency
26 Functional	Rural, Minor Arterial
37 Historical Significance	3 Possibly eligible for
100 Defense Highway Designation	0 Not a STRAHNET hwy
101 Parallel Structure Designation	No || bridge exists
102 Direction of Traffic	2 2-way traffic
103 Temporary Structure Designation	Unknown (NBI)
104 Highway System of Inventory Rte	0 Not on NHS
105 Federal Lands Highways	Not applicable
110 Designated National Network	0 Not part of natl netwo
112 NBIS Bridge Length	
226 Functional Under	

Condition

58 Deck	4 Poor
59 Superstructure	6 Satisfactory
60 Substructure	5 Fair
61 Chan. & Chan. Protection	6 Bank Slumping
62 Culvert and Retaining Walls	N N/A (NBI)

Load Rating and Posting

31 Design Load	M 13.5 (H 15) (live load for which structure was designated)
41 Structure Open, Closed or Posted	A Open, no restriction
63 Operating Rating Method	1 LF Load Factor
64 Oper. Rating	HS 29 53 Tons
65 Inventory Rating Method	1 LF Load Factor
66 Inv. Rating	HS 13 25 Tons
70 Bridge Posting	5 At/Above Legal Loads
209 Posted in "Tons"	00 Tons

Appraisal

67 Structural Condition	5 Above Min Tolerable
68 Deck Geometry	5 Above Tolerable
69 Underclear. Vert & Horiz	N Not applicable (NBI)
71 Waterway Adequacy	7 Above Minimum
72 App. Rdwy. Alignment	8 Equal Desirable Crit
36 Traffic Safety Features	1 1 1 1
113 Scour Critical	8 Stable Above Footing

Inspections

90 Date of Last Inspection	November 02, 2011
91 Designated Inspection Frequency	24 Months
92 Critical Feature Inspected / 93 Critical Feature Last Inpsection Dt	
Fracture Critical	N
Underwater	N
Other Special	N
218 Channel Profile	Y 48 07/01/2007
207 Transporter Erector Routes and Sites	-1
212 Structure Load Rated	01/03/2013
213 Federal Aid Project Number	F-8-032(00)000
214 Delayed Inspection	Not Applicable
216 Inspector	LILLEHOFF / WATLAND

Navigation Data

38 Navigation Control	Permit Not Required
39 Navigation Vertical Clearance	0 Feet
40 Navigation Horizontal Clearance	0 Feet
111 Pier or Abutment Protection	Not Applicable (P)
116 Minimum Navigation Vertical Clearance	-1 Feet

North Dakota Department of Transportation

Bridge Inventory - Structure Inventory And Appraisal Sheet

Structure Number: 0032-006.121

Elm/Env	Description	Units	Total Qty	% in 1	1-Qty St	% in 2	2-Qty St	% in 3	3-Qty St	% in 4	4-Qty St	% in 5	5-Qty St
13 / 1	Unp Conc Deck/AC Ovl	(SF)	1,819	0%	0	100%	1,819	0%	0	0%	0	0 %	0
107 / 1	Paint Stl Opn Girder	(LF)	259	0%	0	100%	259	0%	0	0%	0	0 %	0
215 / 2	R/Conc Abutment	(LF)	66	65%	43	35%	23	0%	0	0%	0	0 %	0
311 / 1	Moveable Bearing	(EA)	4	0%	0	100%	4	0%	0	0%	0	0 %	0
313 / 1	Fixed Bearing	(EA)	4	0%	0	100%	4	0%	0	0%	0	0 %	0
331 / 1	Conc Bridge Railing	(LF)	131	0%	0	89%	116	11%	15	0%	0	0 %	0
333 / 1	Other Bridge Railing	(LF)	131	100%	131	0%	0	0%	0	0%	0	0 %	0
359 / 1	Soffit Smart Flag	(EA)	1	0%	0	100%	1	0%	0	0%	0	0 %	0
401 / 2	Wings	(EA)	4	100%	4	0%	0	0%	0	0%	0	0 %	0

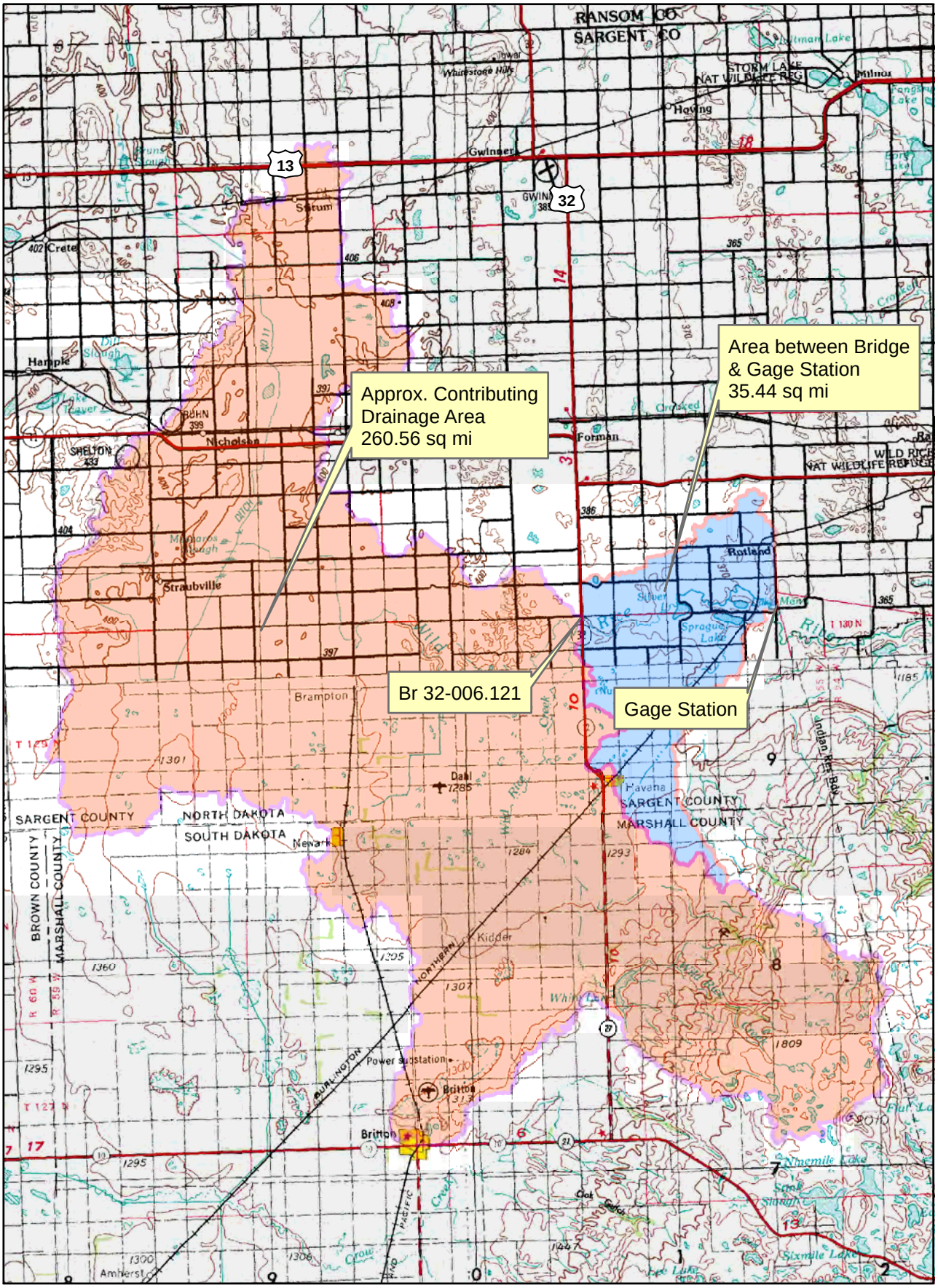
Remarks:

NBI Remarks: Se wing has a hairline diagonal crack. Nw & ne corners of abutments are cracked from backwall down 11" into breastwall. Effloresencevisible under deck. Paint peeled to shop coat.

Alert Code 1: North abutment rockers are tipped & beams are tight against backwall. minor cracking & deterioration throughout substructure.

APPENDIX H

Watershed Area Map


Approx. Contributing Drainage Area 260.56 sq mi
Area between Bridge & Gage Station 35.44 sq mi
Br 32-006.121
Gage Station
RANSOM CO
SARGENT CO
STORM LAKE NAT WILDLIFE REG
Milnor
Havana
Gwinner
Sotum
Crete
Hampie
Nicholson
Forman
Rutland
Straubville
Brampton
Dail
Havana
SARGENT COUNTY
MARSHALL COUNTY
NORTH DAKOTA
SOUTH DAKOTA
Newark
BROWN COUNTY
Kidder
Power substation
Britton
Amherst
13
32