Example Bridge Hydraulic Report

HYDRAULIC ANALYSIS AND STRUCTURE SELECTION

BRIDGE NO. 0011-083.957

PROJECT NO. SS-BRS-2-011(035)083

PCN 20280

DICKEY COUNTY

PREPARED BY

DESIGNER OR CONSULTANT NAME

NORTH DAKOTA DEPARTMENT OF TRANSPORTATION

BRIDGE DIVISION

DECEMBER 2014

SS-BRS-2-011(035)083

6 Miles East of Ellendale

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 John Doe, Registration number PE-#### on MM/DD/YYYY and the original document is stored at the North Dakota Department of Transportation.

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John Doe, 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 Maple River through ND Highway 11 at RP 83.957 in Dickey County.

II. EXISTING STRUCTURE

A. Location

Figure 1 - Project Location Map

B. Project Construction History

Bridge 11-083.957 was constructed in 1955 to carry ND Highway 11 traffic across the Maple River. The structure is a 90 foot long by 27.9 foot three-span concrete slab bridge. A double box beam rail retrofit was added in 2004.

C. Existing Geometry

Bridge 11-083.957

Length – 90 ft
Skew – 0 degrees
Clear Roadway Width – 27.9 ft

III. HYDROLOGY

The drainage area for this structure was determined to be 440.66 square miles with a stream gradient of 3.17 feet per mile and is located in Hydrologic Region

C. A map of the drainage area is provided in the appendix. This structure is not located in a FEMA floodplain. The USGS Regression Equations were used to determine flood frequency discharge values. The results from the USGS Regression Equations are shown below in Table 1.

Table 1 – USGS Regression Equations

USGS REGRESSION RESULTS

Contributing Drainage Area	Channel Slope	Hydrologic Region
440.66 Sq. Mi	3.17 Ft/Mi	Region C

RESULTS

Recurrence Interval (years)	Peak Flow Q
2	296 CFS
10	1756 CFS
15	2325 CFS
25	3127 CFS
50	4375 CFS
100	5822 CFS
500	9913 CFS

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 Documented CatEx, it was proposed to replace the existing bridge. The existing structure and four structure alternatives were analyzed for comparison. The selection process was governed by *Article 89-14 of the North Dakota Administrative Code* (ND Stream Crossing Standards), and Chapter V of the NDDOT Design Manual.

According to the NDDOT minimum bridge width guidelines, a new bridge on a District Corridor with an ADT between 400 and 750 should have a minimum clear roadway width of 36 feet. Therefore, all bridge alternatives were evaluated with a width of 36 feet.

As per the Stream Crossing Standards and the NDDOT Design Manual, the new structure alternatives were designed to pass the 50-year flow. The NDDOT Design Manual recommends that the maximum velocity for the design discharge shall be 5.0 ft/sec, generally.

Selection of the alternatives was completed by modeling the flows through the existing structure against the structure alternatives in HEC-RAS. Alternative 1 is to install a 3-span, 120’ bridge with 2.5:1 end slopes and 27” girders. Alternative 2 is to install a 3-span, 140’ bridge with 3:1 end slopes and 21” girders. Alternative 3 is to install a 2-span, 120’ bridge with 2.5:1 end slopes and 27” girders. Alternative 4 is to install a 2-span, 138’ bridge with 3:1 end slopes and 27” girders. Each of the alternatives were evaluated with an approximate channel width of 23 to 26 feet. The estimated cost for each alternative is shown in Table 2 – Cost Estimate.

Table 2 – Cost Estimate

Alternative Number and Size	Estimated Cost
Alternative #1 – 120’ bridge, 3-span, 27” girders, 2.5:1 side slopes	$1,010,000
Alternative #2 – 140’ bridge, 3-span, 21” girders, 3:1 side slopes	$1,132,000
Alternative #3 – 120’ bridge, 2-span, 27” girders, 2.5:1 side slopes	$970,000
Alternative #4 – 138’ bridge, 2-span, 27” girders, 3:1 side slopes	$1,116,000

The structure alternatives all maintained flow velocities at the structure below 5 feet per second during a 50-year flood event. Each of the structure alternatives also provided at least 1 foot of freeboard between the bottom of bridge girders and the 50-year water elevation. The overtopping discharges for the alternatives were not calculated, but it exceeds the 500-year discharge of 9,913 cfs. Materials and Research Division recommends 2.5:1 abutment slopes for this bridge. Therefore, it is recommended that Alternative 1, a 3-span, 120’ bridge with 27” girders, be constructed.

Figure 2 – Alternative 1 Bridge Layout

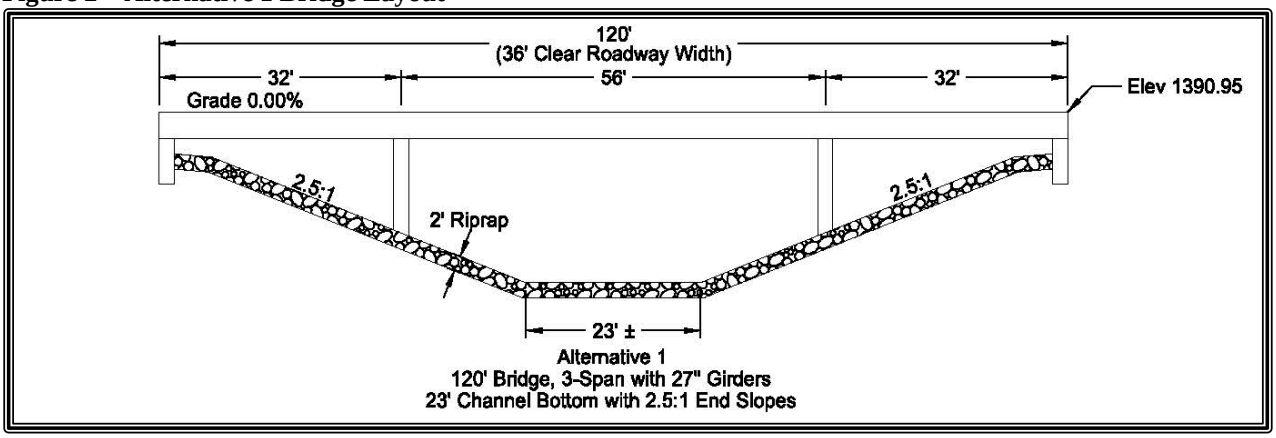


Figure 3 – Alternative 2 Bridge Layout

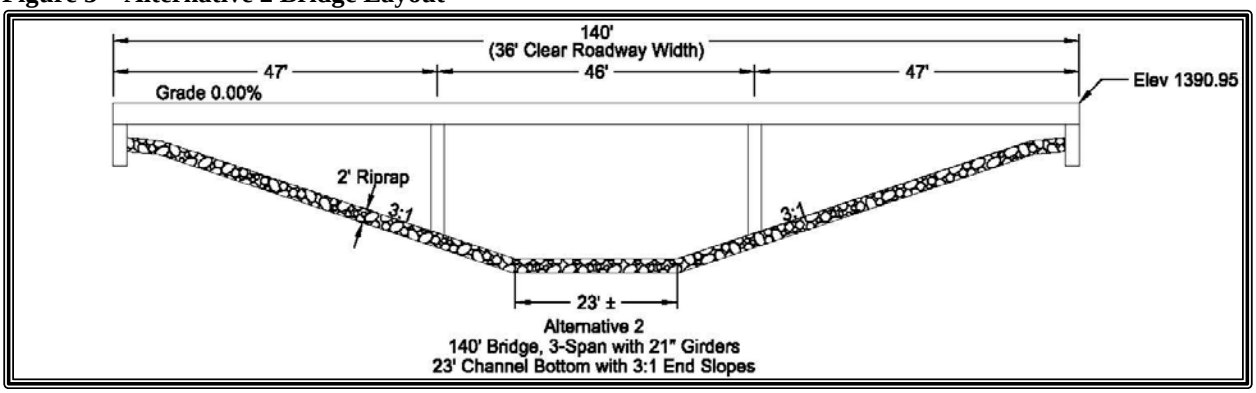


Figure 4 – Alternative 3 Bridge Layout

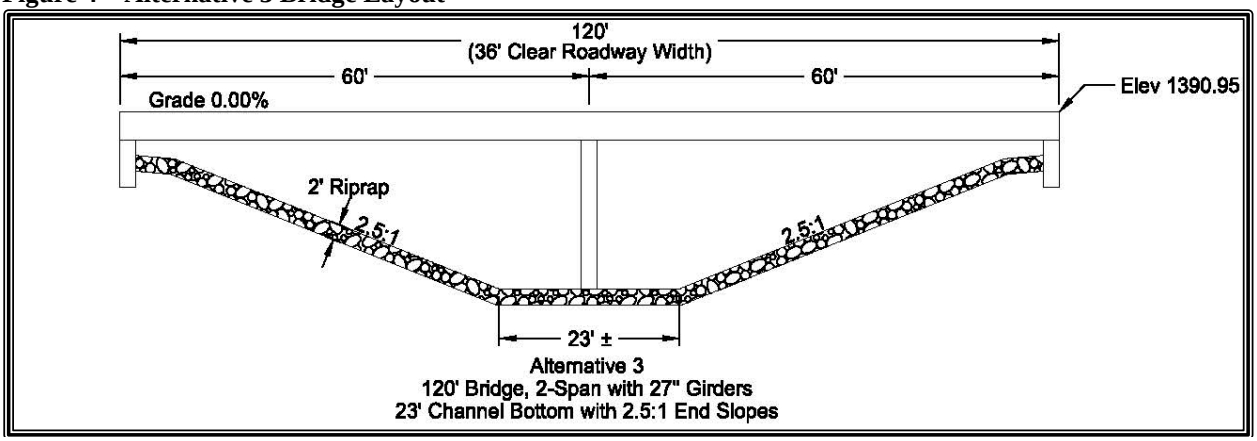
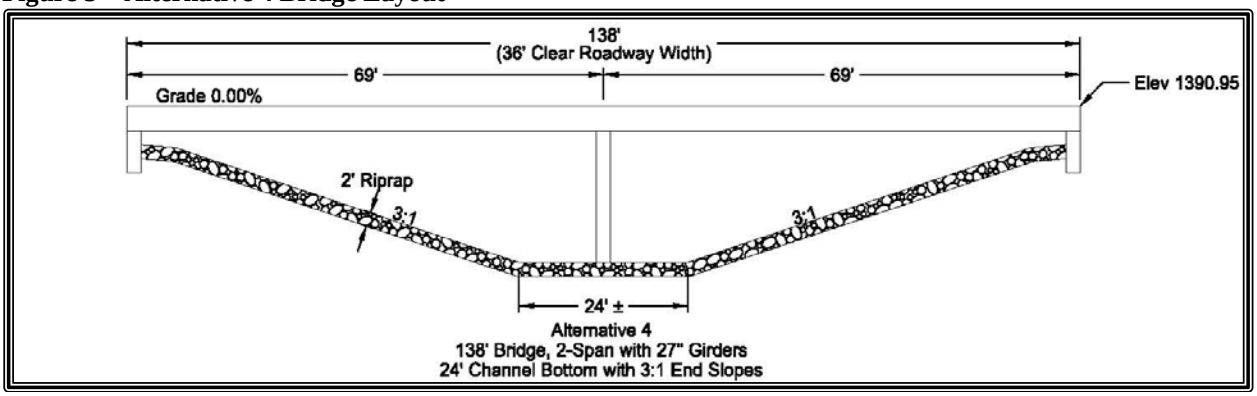


Figure 5 – Alternative 4 Bridge Layout



V. SCOUR ANALYSIS

Scour calculations at the bridge were performed using HEC-RAS software. HEC-RAS provides estimates for contraction, abutment, and pier scour based upon methods outlined in Hydraulic Engineering Circular No. 18 (HEC 18).

Table 3 – Estimated Scour, Alternative 1

Recurrence Interval	Discharge (cfs)	Contraction Scour (ft)	Pier Scour (ft)	Abutment Scour (ft)
100-yr	5,822	2.57	3.89	2.85
500-yr	9,913	6.05	4.65	7.46

A summary of the calculated scour is provided in the appendix. It is recommended that a 24" layer of riprap on filter fabric be placed at the bridge to protect the channel and structure from possible scour. This riprap should cover the entire waterway through the bridge and extend 55' upstream and downstream, measured from the roadway centerline.

VI. MISCELLANEOUS

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

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

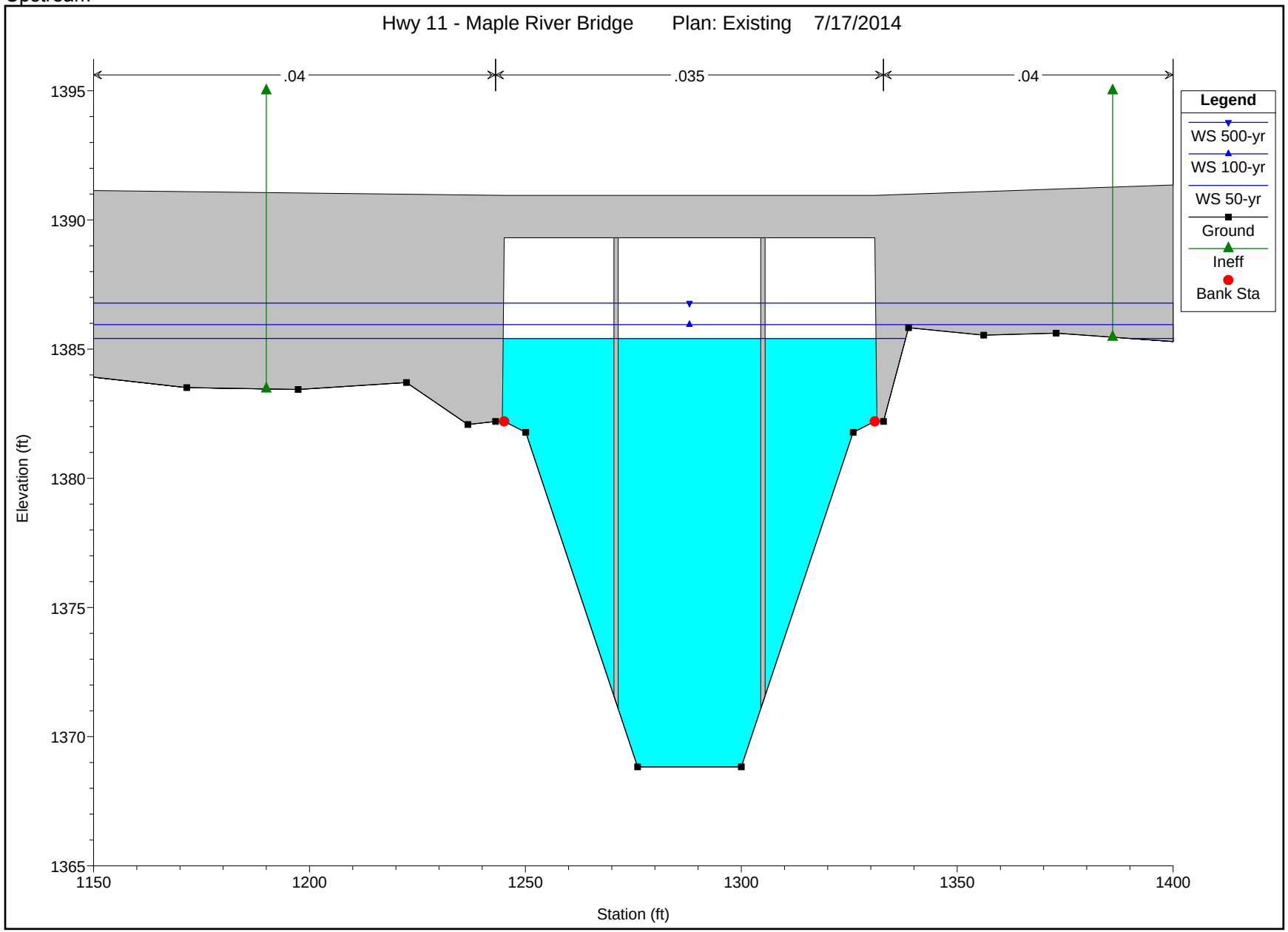
APPENDIX A

Hydraulic Calculations HEC-RAS

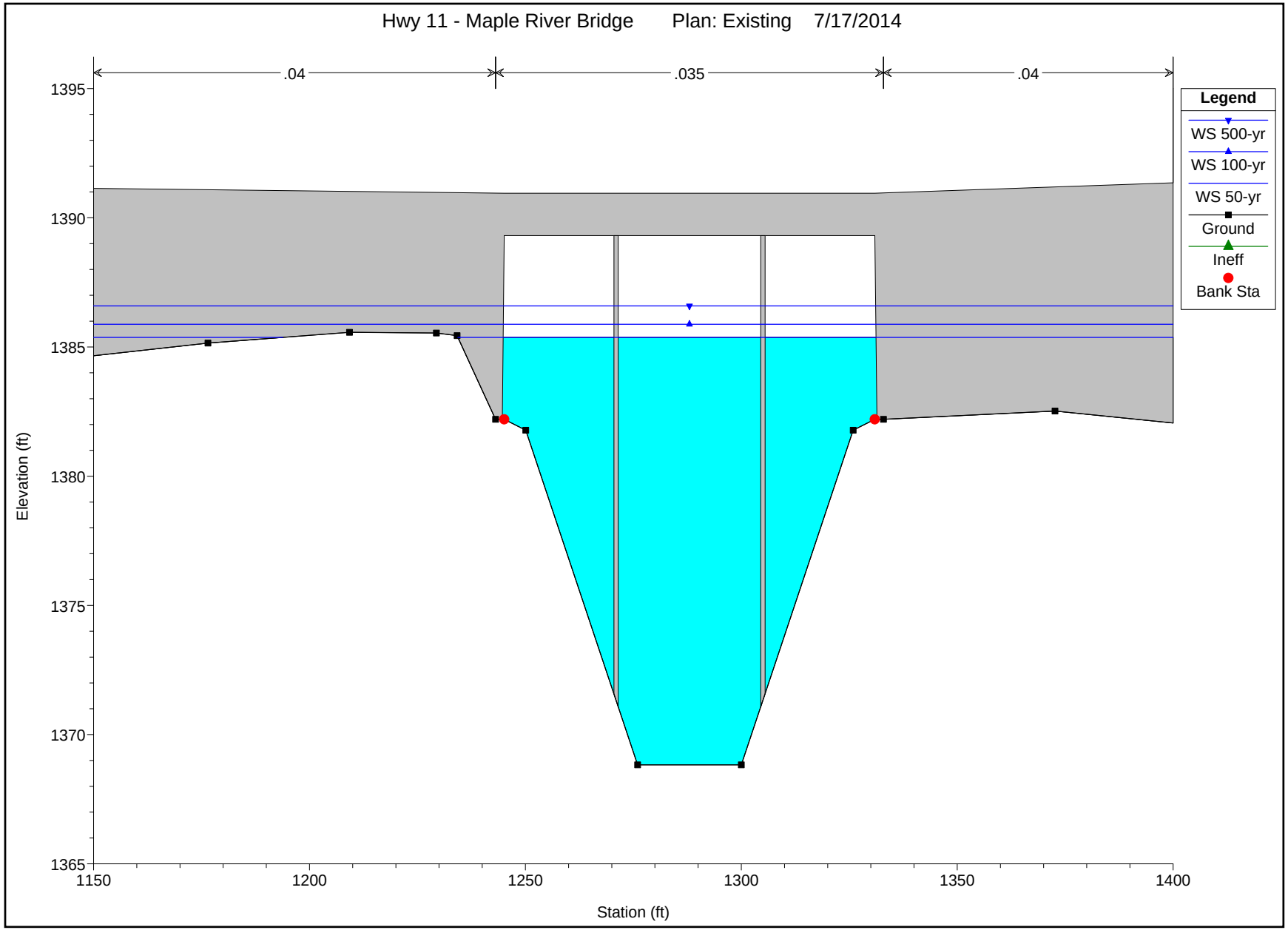
Maple River

Existing Structure

Existing Bridge
Upstream



Existing Bridge
Downstream



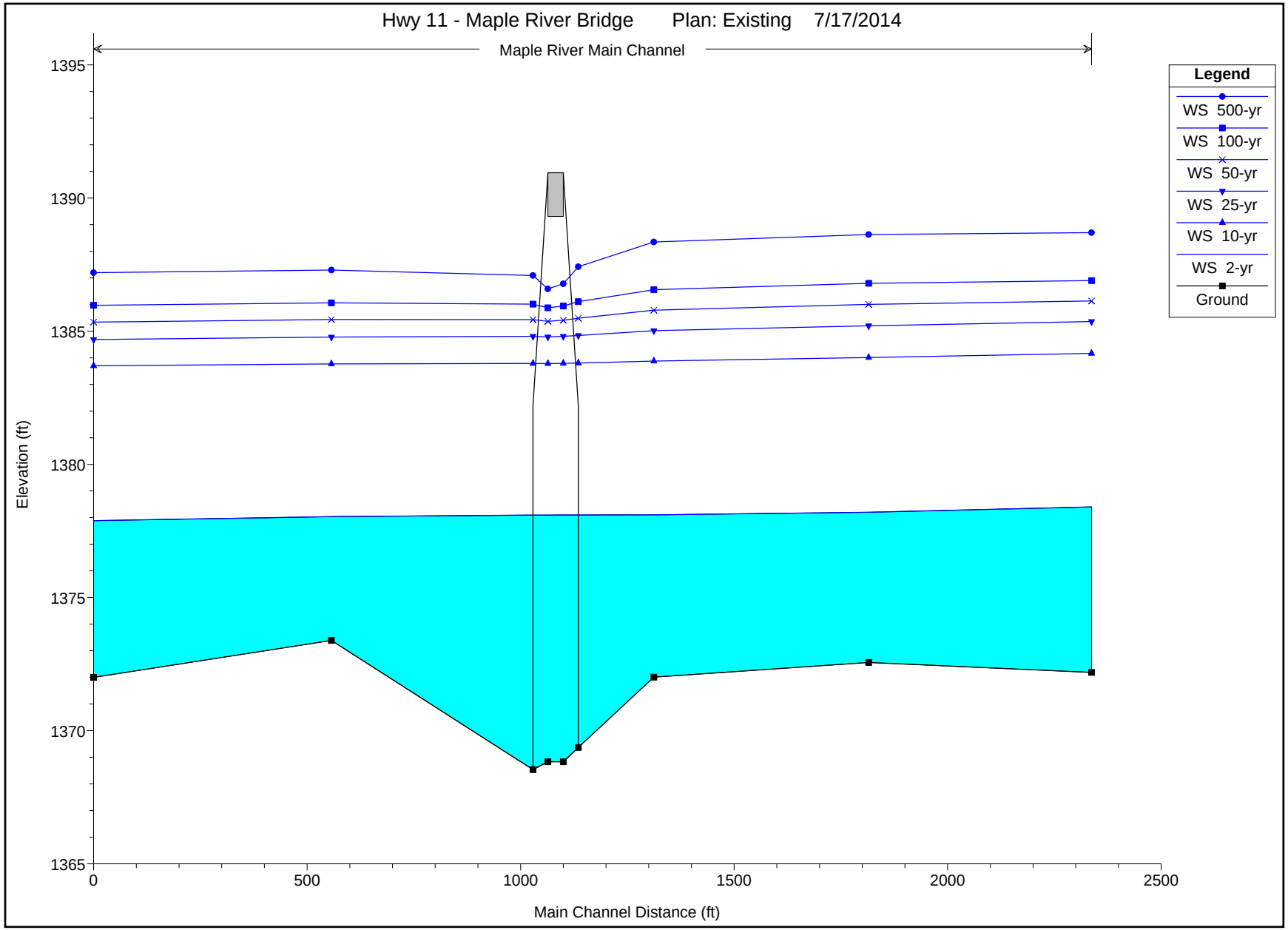
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Main Channel	2337	50-yr	4375	1372.19	1386.14	1380.61	1386.21	0.000293	2.48	2823.92	1326.79	0.17
Main Channel	2337	100-yr	5822	1372.19	1386.9	1381.88	1386.97	0.000249	2.47	3867.61	1395.13	0.16
Main Channel	2337	500-yr	9913	1372.19	1388.7	1384.74	1388.76	0.000185	2.47	6539.34	1570.83	0.15
Main Channel	1815	50-yr	4375	1372.56	1386.01	1381.87	1386.06	0.00033	2.11	2888.57	1292.8	0.17
Main Channel	1815	100-yr	5822	1372.56	1386.8	1382.77	1386.85	0.000259	2.08	3942.74	1370.1	0.16
Main Channel	1815	500-yr	9913	1372.56	1388.63	1384.67	1388.68	0.000178	2.1	6607.39	1548.7	0.14
Main Channel	1312	50-yr	4375	1372.01	1385.79	1379.7	1385.9	0.000384	2.71	1753.38	1539.01	0.2
Main Channel	1312	100-yr	5822	1372.01	1386.56	1381.59	1386.7	0.000421	3.07	2151.45	1671.52	0.21
Main Channel	1312	500-yr	9913	1372.01	1388.35	1383.46	1388.54	0.000457	3.75	3135.03	1888.27	0.23
Main Channel	1135	50-yr	4375	1369.37	1385.49	1378.21	1385.79	0.000675	4.45	1024.42	1561.81	0.27
Main Channel	1135	100-yr	5822	1369.37	1386.11	1379.44	1386.56	0.000949	5.45	1139.64	1672.47	0.32
Main Channel	1135	500-yr	9913	1369.37	1387.42	1382.48	1388.32	0.001623	7.81	1396.96	1813.83	0.43
Main Channel	1082		Bridge									
Main Channel	1029	50-yr	4375	1368.54	1385.44	1377.67	1385.66	0.000455	4.01	1306.76	1251.57	0.22
Main Channel	1029	100-yr	5822	1368.54	1386.02	1378.88	1386.34	0.000622	4.87	1478.65	1560.71	0.26
Main Channel	1029	500-yr	9913	1368.54	1387.09	1381.75	1387.73	0.001133	7.01	1803.1	1956.03	0.36
Main Channel	557	50-yr	4375	1373.39	1385.44	1379.54	1385.46	0.000144	1.28	4097.41	1383.16	0.11
Main Channel	557	100-yr	5822	1373.39	1386.07	1380.19	1386.09	0.000144	1.41	4984.64	1439.18	0.12
Main Channel	557	500-yr	9913	1373.39	1387.3	1381.81	1387.34	0.000166	1.77	6832.19	1563.47	0.13
Main Channel	0	50-yr	4375	1372	1385.34	1380.26	1385.37	0.0002	1.69	3724.69	1442.31	0.14
Main Channel	0	100-yr	5822	1372	1385.97	1382.41	1386.01	0.0002	1.83	4757.4	1702.73	0.14
Main Channel	0	500-yr	9913	1372	1387.2	1383.5	1387.24	0.0002	2.1	6911.51	1806.58	0.14

Plan: Existing Maple River Main Channel RS: 1082 Profile: 50-yr				
E.G. US. (ft)	1385.79	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	1385.49	E.G. Elev (ft)	1385.76	1385.72
Q Total (cfs)	4375	W.S. Elev (ft)	1385.41	1385.37
Q Bridge (cfs)	4375	Crit W.S. (ft)	1377.03	1377.03
Q Weir (cfs)		Max Chl Dpth (ft)	16.58	16.54
Weir Sta Lft (ft)		Vel Total (ft/s)	4.7	4.72
Weir Sta Rgt (ft)		Flow Area (sq ft)	930.16	926.76
Weir Submerg		Froude # Chl	0.2	0.2
Weir Max Depth (ft)		Specif Force (cu ft)	6813.82	6778.66
Min El Weir Flow (ft)	1390.96	Hydr Depth (ft)	11.03	10.99
Min El Prs (ft)	1389.31	W.P. Total (ft)	153.44	153.2
Delta EG (ft)	0.13	Conv. Total (cfs)	135153.6	134431.4
Delta WS (ft)	0.05	Top Width (ft)	84.33	84.34
BR Open Area (sq ft)	1257.83	Frctn Loss (ft)	0.04	0.02
BR Open Vel (ft/s)	4.72	C & E Loss (ft)	0	0.04
Coef of Q		Shear Total (lb/sq ft)	0.4	0.4
Br Sel Method	Energy only	Power Total (lb/ft s)	0	0

Plan: Existing Maple River Main Channel RS: 1082 Profile: 100-yr				
E.G. US. (ft)	1386.56	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	1386.11	E.G. Elev (ft)	1386.5	1386.44
Q Total (cfs)	5822	W.S. Elev (ft)	1385.95	1385.88
Q Bridge (cfs)	5822	Crit W.S. (ft)	1378.41	1378.41
Q Weir (cfs)		Max Chl Dpth (ft)	17.12	17.05
Weir Sta Lft (ft)		Vel Total (ft/s)	5.97	6
Weir Sta Rgt (ft)		Flow Area (sq ft)	975.15	969.62
Weir Submerg		Froude # Chl	0.25	0.26
Weir Max Depth (ft)		Specif Force (cu ft)	7763.65	7705.94
Min El Weir Flow (ft)	1390.96	Hydr Depth (ft)	11.57	11.51
Min El Prs (ft)	1389.31	W.P. Total (ft)	156.65	156.25
Delta EG (ft)	0.22	Conv. Total (cfs)	144781	143587.5
Delta WS (ft)	0.09	Top Width (ft)	84.26	84.27
BR Open Area (sq ft)	1257.83	Frctn Loss (ft)	0.06	0.03
BR Open Vel (ft/s)	6	C & E Loss (ft)	0	0.07
Coef of Q		Shear Total (lb/sq ft)	0.63	0.64
Br Sel Method	Energy only	Power Total (lb/ft s)	0	0

Plan: Existing Maple River Main Channel RS: 1082 Profile: 500-yr				
E.G. US. (ft)	1388.32	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	1387.42	E.G. Elev (ft)	1388.18	1388.04
Q Total (cfs)	9913	W.S. Elev (ft)	1386.78	1386.59
Q Bridge (cfs)	9913	Crit W.S. (ft)	1381.53	1381.53
Q Weir (cfs)		Max Chl Dpth (ft)	17.95	17.76
Weir Sta Lft (ft)		Vel Total (ft/s)	9.48	9.63
Weir Sta Rgt (ft)		Flow Area (sq ft)	1045.36	1029.46
Weir Submerg		Froude # Chl	0.4	0.4
Weir Max Depth (ft)		Specif Force (cu ft)	10449.94	10299.03
Min El Weir Flow (ft)	1390.96	Hydr Depth (ft)	12.42	12.23
Min El Prs (ft)	1389.31	W.P. Total (ft)	161.65	160.52
Delta EG (ft)	0.59	Conv. Total (cfs)	160137	156624.1
Delta WS (ft)	0.33	Top Width (ft)	84.15	84.18
BR Open Area (sq ft)	1257.83	Frctn Loss (ft)	0.14	0.07
BR Open Vel (ft/s)	9.63	C & E Loss (ft)	0	0.24
Coef of Q		Shear Total (lb/sq ft)	1.55	1.6
Br Sel Method	Energy only	Power Total (lb/ft s)	0	0

Existing 90' Bridge
Profile

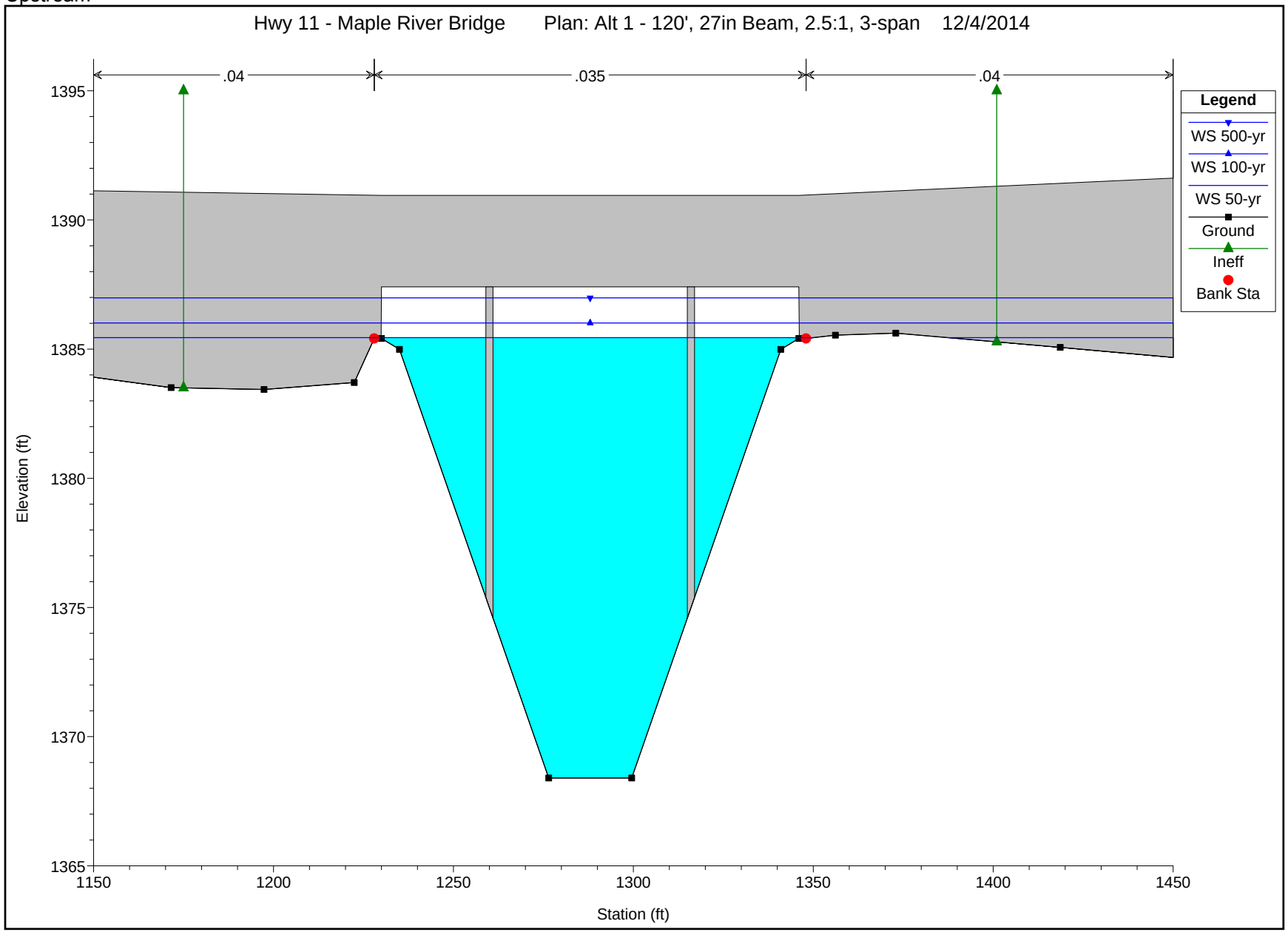


APPENDIX B

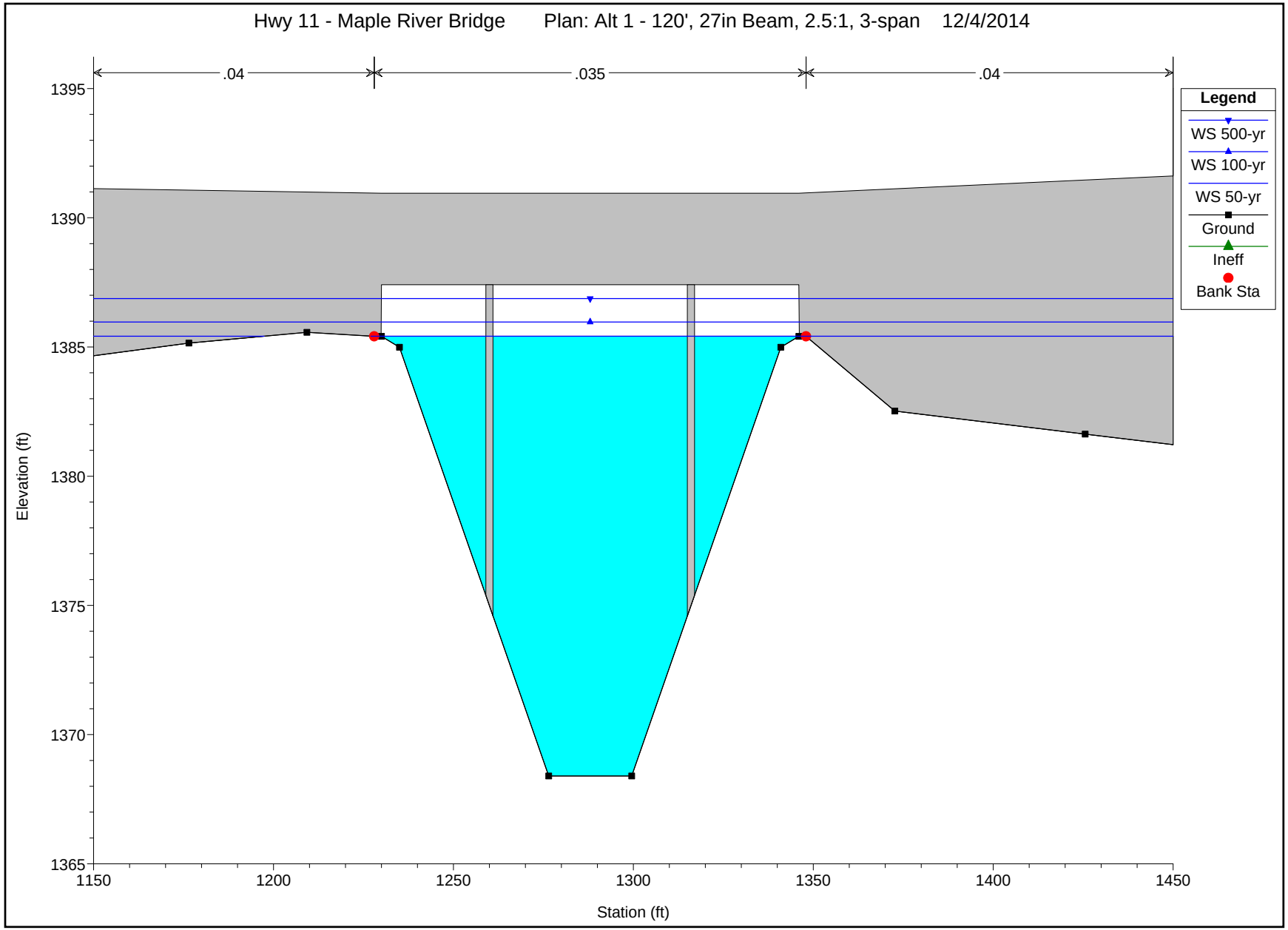
Hydraulic Calculations HEC-RAS

Alternative 1
120’ Bridge (3-span) with 27” Girders
23’ Channel Bottom with 2.5:1 End Slopes

Alt 1 - 120' Bridge, 27" Girders, 2.5:1, 3-span
Upstream



Alt 1 - 120' Bridge, 27" Girders, 2.5:1, 3-span
Downstream



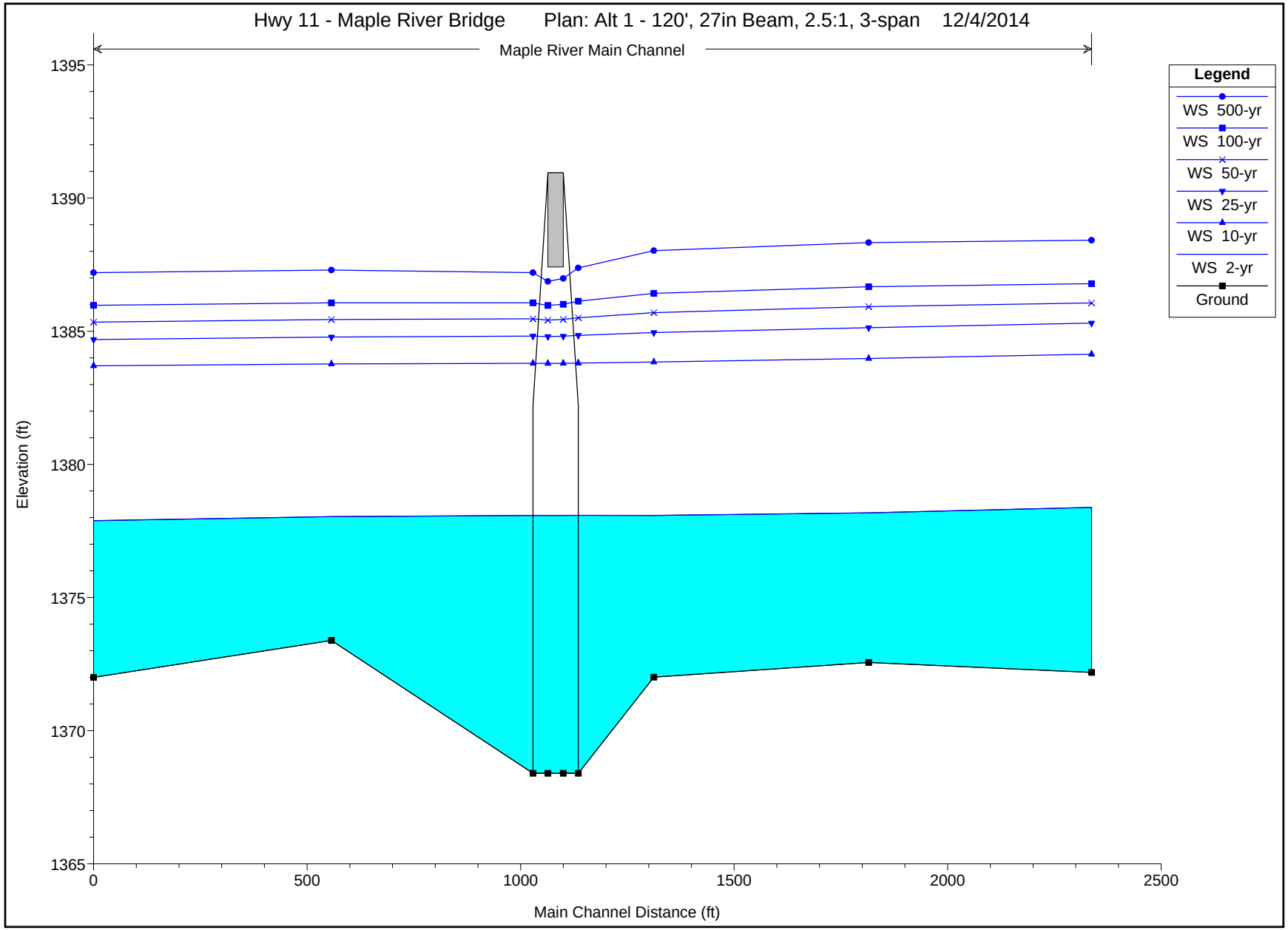
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Main Channel	2337	50-yr	4375	1372.19	1386.06	1380.61	1386.14	0.000317	2.56	2724.83	1317.26	0.18
Main Channel	2337	100-yr	5822	1372.19	1386.78	1381.88	1386.85	0.000278	2.58	3702.84	1385.1	0.17
Main Channel	2337	500-yr	9913	1372.19	1388.42	1384.74	1388.48	0.000224	2.66	6095.58	1541.8	0.16
Main Channel	1815	50-yr	4375	1372.56	1385.92	1381.87	1385.98	0.000365	2.19	2775.32	1283.42	0.18
Main Channel	1815	100-yr	5822	1372.56	1386.67	1382.77	1386.72	0.000293	2.18	3763.29	1357.26	0.17
Main Channel	1815	500-yr	9913	1372.56	1388.33	1384.67	1388.38	0.00022	2.27	6148.69	1519.2	0.15
Main Channel	1312	50-yr	4375	1372.01	1385.7	1379.7	1385.81	0.000396	2.72	1754.26	1522.66	0.2
Main Channel	1312	100-yr	5822	1372.01	1386.42	1381.59	1386.56	0.000441	3.1	2145.01	1647.43	0.21
Main Channel	1312	500-yr	9913	1372.01	1388.03	1383.49	1388.23	0.000511	3.86	3072.44	1850.91	0.24
Main Channel	1135	50-yr	4375	1368.4	1385.51	1376.23	1385.72	0.000426	3.77	1230.5	1583.77	0.22
Main Channel	1135	100-yr	5822	1368.4	1386.13	1377.51	1386.45	0.000592	4.64	1368.83	1673.56	0.26
Main Channel	1135	500-yr	9913	1368.4	1387.38	1380.36	1388.04	0.001075	6.76	1651.41	1810.14	0.35
Main Channel	1082		Bridge									
Main Channel	1029	50-yr	4375	1368.4	1385.47	1376.23	1385.63	0.000354	3.43	1504.5	1274.17	0.2
Main Channel	1029	100-yr	5822	1368.4	1386.06	1377.51	1386.3	0.000477	4.15	1702.26	1585.93	0.23
Main Channel	1029	500-yr	9913	1368.4	1387.2	1380.36	1387.66	0.000845	5.93	2078.55	1978.39	0.31
Main Channel	557	50-yr	4375	1373.39	1385.44	1379.54	1385.46	0.000144	1.28	4097.41	1383.16	0.11
Main Channel	557	100-yr	5822	1373.39	1386.07	1380.19	1386.09	0.000144	1.41	4984.64	1439.18	0.12
Main Channel	557	500-yr	9913	1373.39	1387.3	1381.81	1387.34	0.000166	1.77	6832.19	1563.47	0.13
Main Channel	0	50-yr	4375	1372	1385.34	1380.26	1385.37	0.0002	1.69	3724.69	1442.31	0.14
Main Channel	0	100-yr	5822	1372	1385.97	1382.41	1386.01	0.0002	1.83	4757.4	1702.73	0.14
Main Channel	0	500-yr	9913	1372	1387.2	1383.5	1387.24	0.0002	2.1	6911.51	1806.58	0.14

Plan: 1) 120', 3-span Maple River Main Channel RS: 1082 Profile: 50-yr				
E.G. US. (ft)	1385.72	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	1385.51	E.G. Elev (ft)	1385.7	1385.67
Q Total (cfs)	4375	W.S. Elev (ft)	1385.45	1385.42
Q Bridge (cfs)	4375	Crit W.S. (ft)	1376.18	1376.18
Q Weir (cfs)		Max Chl Dpth (ft)	17.04	17.02
Weir Sta Lft (ft)		Vel Total (ft/s)	4.05	4.06
Weir Sta Rgt (ft)		Flow Area (sq ft)	1079.39	1076.36
Weir Submerg		Froude # Chl	0.17	0.23
Weir Max Depth (ft)		Specif Force (cu ft)	7808.05	7780.53
Min El Weir Flow (ft)	1390.96	Hydr Depth (ft)	9.62	9.59
Min El Prs (ft)	1387.41	W.P. Total (ft)	160.25	160.07
Delta EG (ft)	0.09	Conv. Total (cfs)	163440.3	162797.4
Delta WS (ft)	0.04	Top Width (ft)	112.23	112.24
BR Open Area (sq ft)	1299.72	Frctn Loss (ft)	0.03	0.02
BR Open Vel (ft/s)	4.06	C & E Loss (ft)	0	0.03
Coef of Q		Shear Total (lb/sq ft)	0.3	0.3
Br Sel Method	Energy only	Power Total (lb/ft s)	0	0

Plan: 1) 120', 3-span Maple River Main Channel RS: 1082 Profile: 100-yr				
E.G. US. (ft)	1386.45	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	1386.13	E.G. Elev (ft)	1386.41	1386.38
Q Total (cfs)	5822	W.S. Elev (ft)	1386.01	1385.97
Q Bridge (cfs)	5822	Crit W.S. (ft)	1377.53	1377.53
Q Weir (cfs)		Max Chl Dpth (ft)	17.61	17.57
Weir Sta Lft (ft)		Vel Total (ft/s)	5.09	5.12
Weir Sta Rgt (ft)		Flow Area (sq ft)	1142.87	1138.12
Weir Submerg		Froude # Chl	0.21	0.22
Weir Max Depth (ft)		Specif Force (cu ft)	8807.09	8762.62
Min El Weir Flow (ft)	1390.96	Hydr Depth (ft)	10.19	10.15
Min El Prs (ft)	1387.41	W.P. Total (ft)	163.64	163.39
Delta EG (ft)	0.15	Conv. Total (cfs)	177277.8	176233.5
Delta WS (ft)	0.06	Top Width (ft)	112.17	112.17
BR Open Area (sq ft)	1299.72	Frctn Loss (ft)	0.04	0.02
BR Open Vel (ft/s)	5.12	C & E Loss (ft)	0	0.05
Coef of Q		Shear Total (lb/sq ft)	0.47	0.47
Br Sel Method	Energy only	Power Total (lb/ft s)	0	0

Plan: 1) 120', 3-span Maple River Main Channel RS: 1082 Profile: 500-yr				
E.G. US. (ft)	1388.04	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	1387.38	E.G. Elev (ft)	1387.96	1387.87
Q Total (cfs)	9913	W.S. Elev (ft)	1386.98	1386.87
Q Bridge (cfs)	9913	Crit W.S. (ft)	1380.54	1380.54
Q Weir (cfs)		Max Chl Dpth (ft)	18.58	18.47
Weir Sta Lft (ft)		Vel Total (ft/s)	7.92	8
Weir Sta Rgt (ft)		Flow Area (sq ft)	1251.72	1239.44
Weir Submerg		Froude # Chl	0.32	0.33
Weir Max Depth (ft)		Specif Force (cu ft)	11486.61	11374.23
Min El Weir Flow (ft)	1390.96	Hydr Depth (ft)	11.17	11.06
Min El Prs (ft)	1387.41	W.P. Total (ft)	169.48	168.82
Delta EG (ft)	0.38	Conv. Total (cfs)	201543.6	198773
Delta WS (ft)	0.18	Top Width (ft)	112.05	112.06
BR Open Area (sq ft)	1299.72	Frctn Loss (ft)	0.09	0.05
BR Open Vel (ft/s)	8	C & E Loss (ft)	0	0.16
Coef of Q		Shear Total (lb/sq ft)	1.12	1.14
Br Sel Method	Energy only	Power Total (lb/ft s)	0	0

Alt 1: 120' Bridge, 3-span, 21" Beams, 2.5:1 slopes
Profile

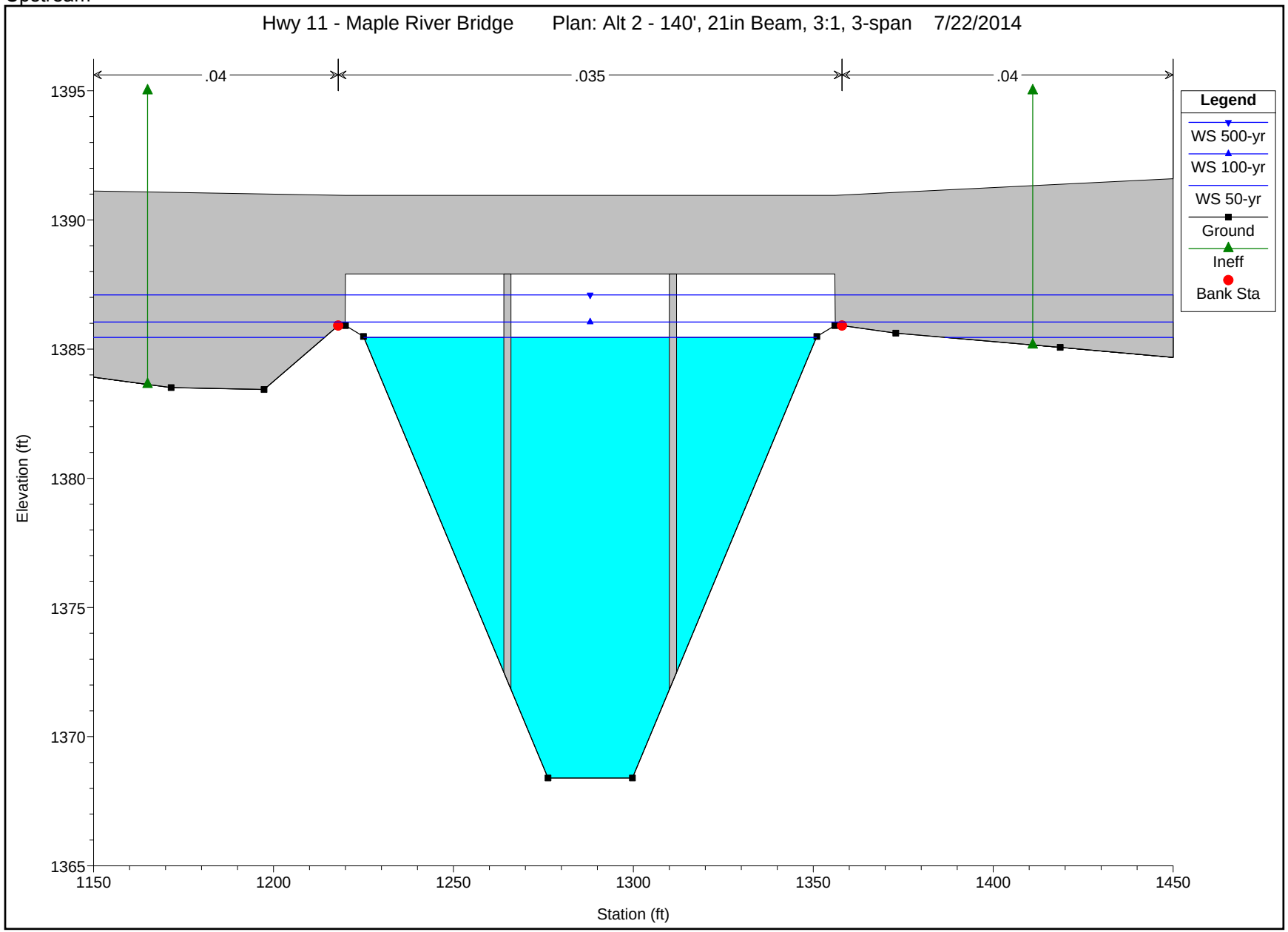


APPENDIX C

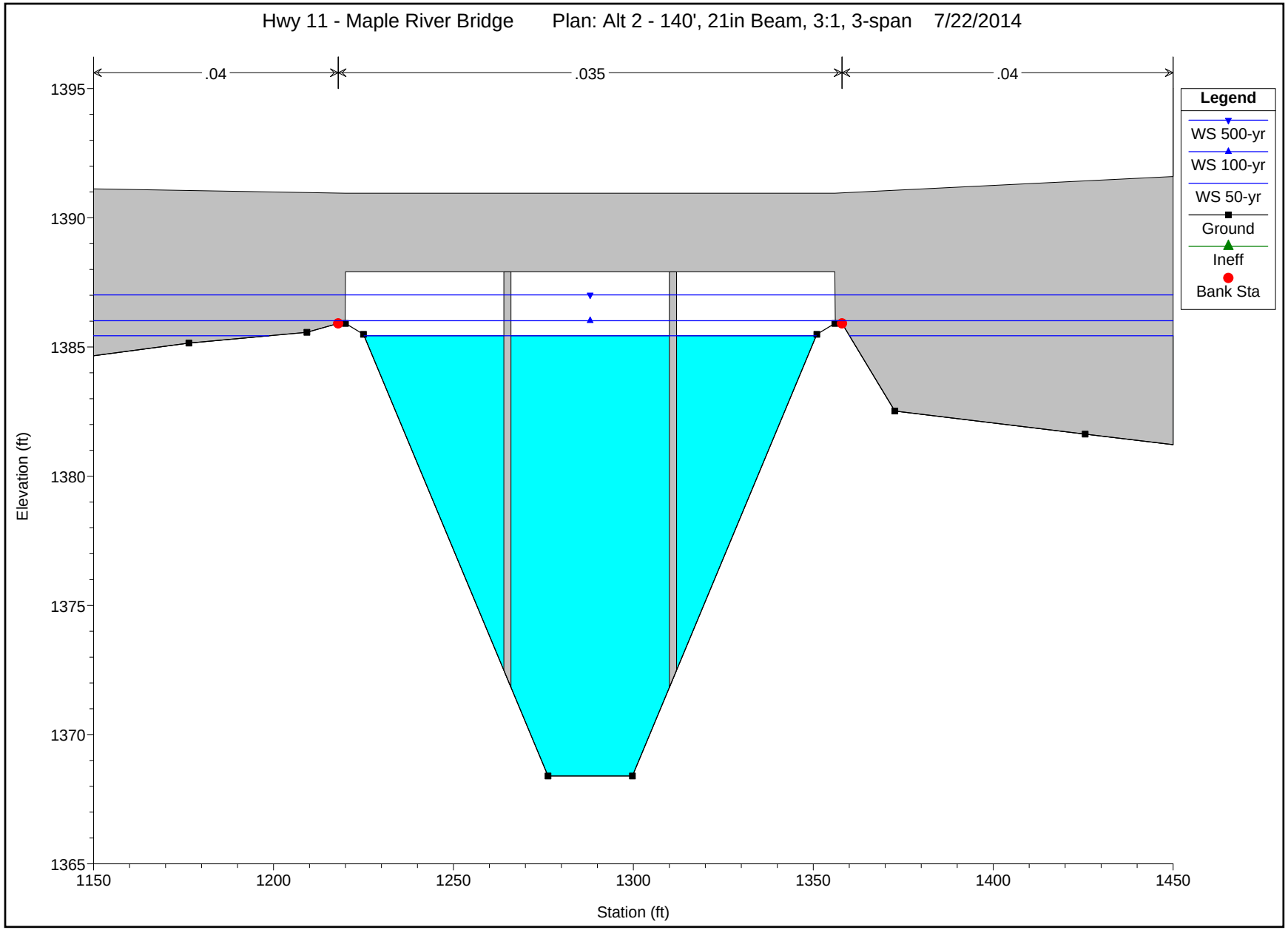
Hydraulic Calculations HEC-RAS

Alternative 2
140’ Bridge (3-span) with 21” Girders
23’ Channel Bottom with 3:1 End Slopes

Alt 2 - 140' Bridge
Upstream



Alt 2 - 140' Bridge
Downstream



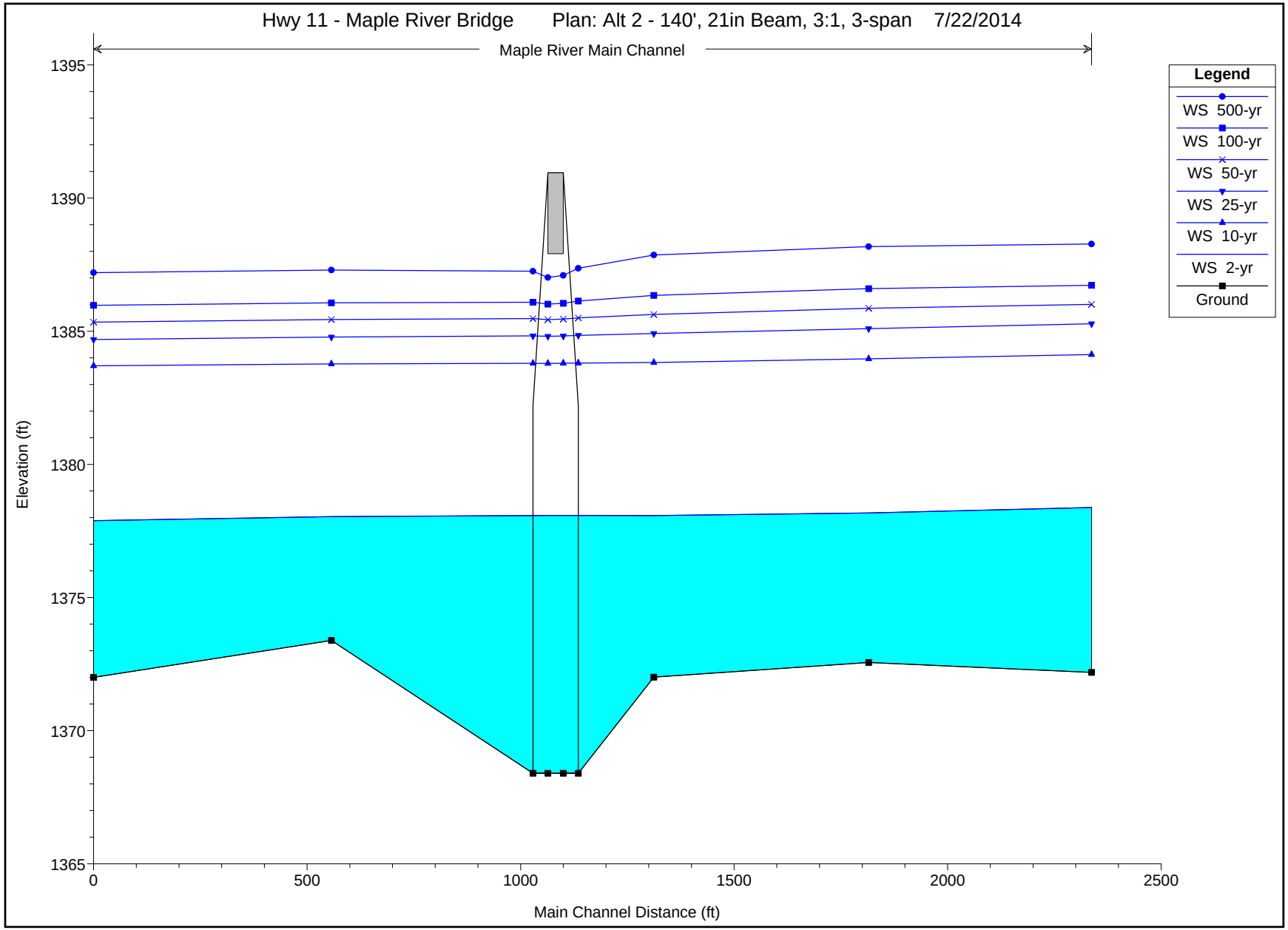
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Main Channel	2337	50-yr	4375	1372.19	1386.01	1380.61	1386.09	0.000334	2.62	2656.02	1310.6	0.18
Main Channel	2337	100-yr	5822	1372.19	1386.72	1381.88	1386.8	0.000294	2.63	3618.12	1379.92	0.18
Main Channel	2337	500-yr	9913	1372.19	1388.28	1384.74	1388.34	0.000247	2.76	5877.7	1530.29	0.17
Main Channel	1815	50-yr	4375	1372.56	1385.86	1381.87	1385.92	0.000392	2.25	2695.79	1271.76	0.19
Main Channel	1815	100-yr	5822	1372.56	1386.6	1382.77	1386.66	0.000313	2.23	3669.91	1350.52	0.17
Main Channel	1815	500-yr	9913	1372.56	1388.18	1384.67	1388.23	0.000245	2.35	5919.67	1504.41	0.16
Main Channel	1312	50-yr	4375	1372.01	1385.63	1379.7	1385.74	0.000405	2.73	1750.62	1487.62	0.2
Main Channel	1312	100-yr	5822	1372.01	1386.35	1381.59	1386.49	0.00045	3.11	2149.59	1634.98	0.21
Main Channel	1312	500-yr	9913	1372.01	1387.86	1383.49	1388.07	0.000538	3.91	3053.43	1832.27	0.24
Main Channel	1135	50-yr	4375	1368.4	1385.5	1375.89	1385.67	0.000303	3.36	1365.66	1568.8	0.19
Main Channel	1135	100-yr	5822	1368.4	1386.13	1377.09	1386.39	0.000482	4.14	1512.4	1673.84	0.23
Main Channel	1135	500-yr	9913	1368.4	1387.37	1379.76	1387.9	0.000879	6.05	1815.66	1809.06	0.32
Main Channel	1082		Bridge									
Main Channel	1029	50-yr	4375	1368.4	1385.47	1375.89	1385.6	0.000247	3.03	1697.24	1264.18	0.17
Main Channel	1029	100-yr	5822	1368.4	1386.09	1377.09	1386.27	0.000377	3.65	1907.12	1598.13	0.21
Main Channel	1029	500-yr	9913	1368.4	1387.25	1379.76	1387.61	0.000662	5.22	2317.08	1990.12	0.28
Main Channel	557	50-yr	4375	1373.39	1385.44	1379.54	1385.46	0.000144	1.28	4097.41	1383.16	0.11
Main Channel	557	100-yr	5822	1373.39	1386.07	1380.19	1386.09	0.000144	1.41	4984.64	1439.18	0.12
Main Channel	557	500-yr	9913	1373.39	1387.3	1381.81	1387.34	0.000166	1.77	6832.19	1563.47	0.13
Main Channel	0	50-yr	4375	1372	1385.34	1380.26	1385.37	0.0002	1.69	3724.69	1442.31	0.14
Main Channel	0	100-yr	5822	1372	1385.97	1382.41	1386.01	0.0002	1.83	4757.4	1702.73	0.14
Main Channel	0	500-yr	9913	1372	1387.2	1383.5	1387.24	0.0002	2.1	6911.51	1806.58	0.14

Plan: 2) 140', 21" Bm Maple River Main Channel RS: 1082 Profile: 50-yr				
E.G. US. (ft)	1385.67	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	1385.5	E.G. Elev (ft)	1385.66	1385.64
Q Total (cfs)	4375	W.S. Elev (ft)	1385.46	1385.44
Q Bridge (cfs)	4375	Crit W.S. (ft)	1376.05	1376.05
Q Weir (cfs)		Max Chl Dpth (ft)	17.06	17.03
Weir Sta Lft (ft)		Vel Total (ft/s)	3.59	3.59
Weir Sta Rgt (ft)		Flow Area (sq ft)	1219.69	1217.17
Weir Submerg		Froude # Chl	0.2	0.2
Weir Max Depth (ft)		Specif Force (cu ft)	8508.02	8483.75
Min El Weir Flow (ft)	1390.96	Hydr Depth (ft)	10.01	10
Min El Prs (ft)	1387.91	W.P. Total (ft)	180.31	180.1
Delta EG (ft)	0.07	Conv. Total (cfs)	185207.1	184714.5
Delta WS (ft)	0.03	Top Width (ft)	121.79	121.67
BR Open Area (sq ft)	1541.46	Frctn Loss (ft)	0.02	0.01
BR Open Vel (ft/s)	3.59	C & E Loss (ft)	0	0.02
Coef of Q		Shear Total (lb/sq ft)	0.24	0.24
Br Sel Method	Energy only	Power Total (lb/ft s)	0	0

Plan: 2) 140', 21" Bm Maple River Main Channel RS: 1082 Profile: 100-yr				
E.G. US. (ft)	1386.39	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	1386.13	E.G. Elev (ft)	1386.36	1386.33
Q Total (cfs)	5822	W.S. Elev (ft)	1386.05	1386.02
Q Bridge (cfs)	5822	Crit W.S. (ft)	1377.28	1377.28
Q Weir (cfs)		Max Chl Dpth (ft)	17.65	17.62
Weir Sta Lft (ft)		Vel Total (ft/s)	4.49	4.51
Weir Sta Rgt (ft)		Flow Area (sq ft)	1295.65	1291.13
Weir Submerg		Froude # Chl	0.19	0.19
Weir Max Depth (ft)		Specif Force (cu ft)	9579.5	9538.14
Min El Weir Flow (ft)	1390.96	Hydr Depth (ft)	9.8	9.77
Min El Prs (ft)	1387.91	W.P. Total (ft)	193.44	193.24
Delta EG (ft)	0.12	Conv. Total (cfs)	195451.5	194454.3
Delta WS (ft)	0.04	Top Width (ft)	132.21	132.21
BR Open Area (sq ft)	1541.46	Frctn Loss (ft)	0.03	0.02
BR Open Vel (ft/s)	4.51	C & E Loss (ft)	0	0.04
Coef of Q		Shear Total (lb/sq ft)	0.37	0.37
Br Sel Method	Energy only	Power Total (lb/ft s)	0	0

Plan: 2) 140', 21" Bm Maple River Main Channel RS: 1082 Profile: 500-yr				
E.G. US. (ft)	1387.9	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	1387.37	E.G. Elev (ft)	1387.84	1387.77
Q Total (cfs)	9913	W.S. Elev (ft)	1387.1	1387.02
Q Bridge (cfs)	9913	Crit W.S. (ft)	1380.06	1380.06
Q Weir (cfs)		Max Chl Dpth (ft)	18.7	18.62
Weir Sta Lft (ft)		Vel Total (ft/s)	6.91	6.96
Weir Sta Rgt (ft)		Flow Area (sq ft)	1434.17	1423.3
Weir Submerg		Froude # Chl	0.28	0.28
Weir Max Depth (ft)		Specif Force (cu ft)	12325.69	12224.39
Min El Weir Flow (ft)	1390.96	Hydr Depth (ft)	10.86	10.77
Min El Prs (ft)	1387.91	W.P. Total (ft)	199.73	199.24
Delta EG (ft)	0.29	Conv. Total (cfs)	226617.9	224130.7
Delta WS (ft)	0.11	Top Width (ft)	132.09	132.1
BR Open Area (sq ft)	1541.46	Frctn Loss (ft)	0.07	0.04
BR Open Vel (ft/s)	6.96	C & E Loss (ft)	0	0.12
Coef of Q		Shear Total (lb/sq ft)	0.86	0.87
Br Sel Method	Energy only	Power Total (lb/ft s)	0	0

Alt 2: 140' Bridge, 3-span, 21" Beams, 3:1 slopes
Profile

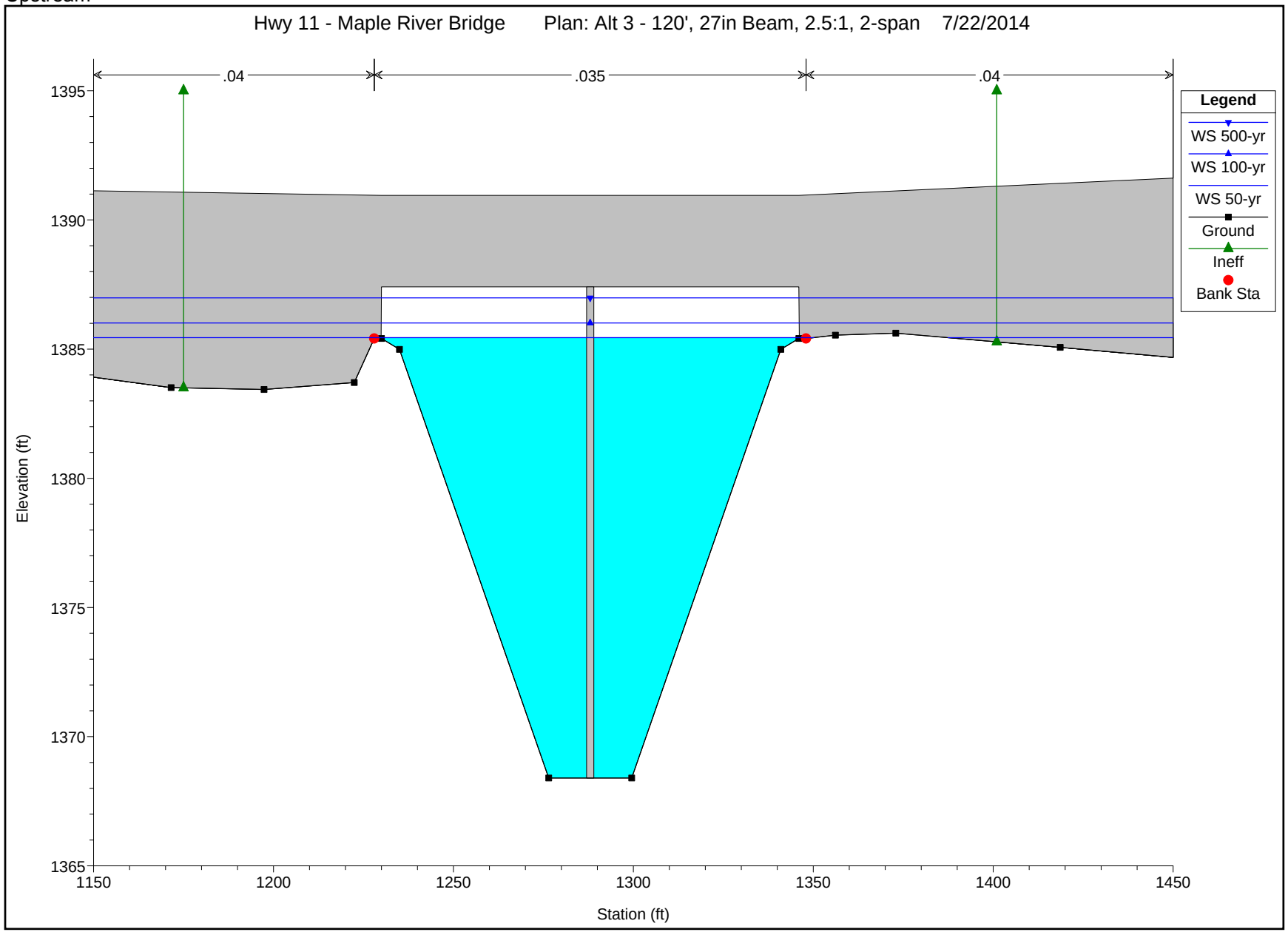


APPENDIX D

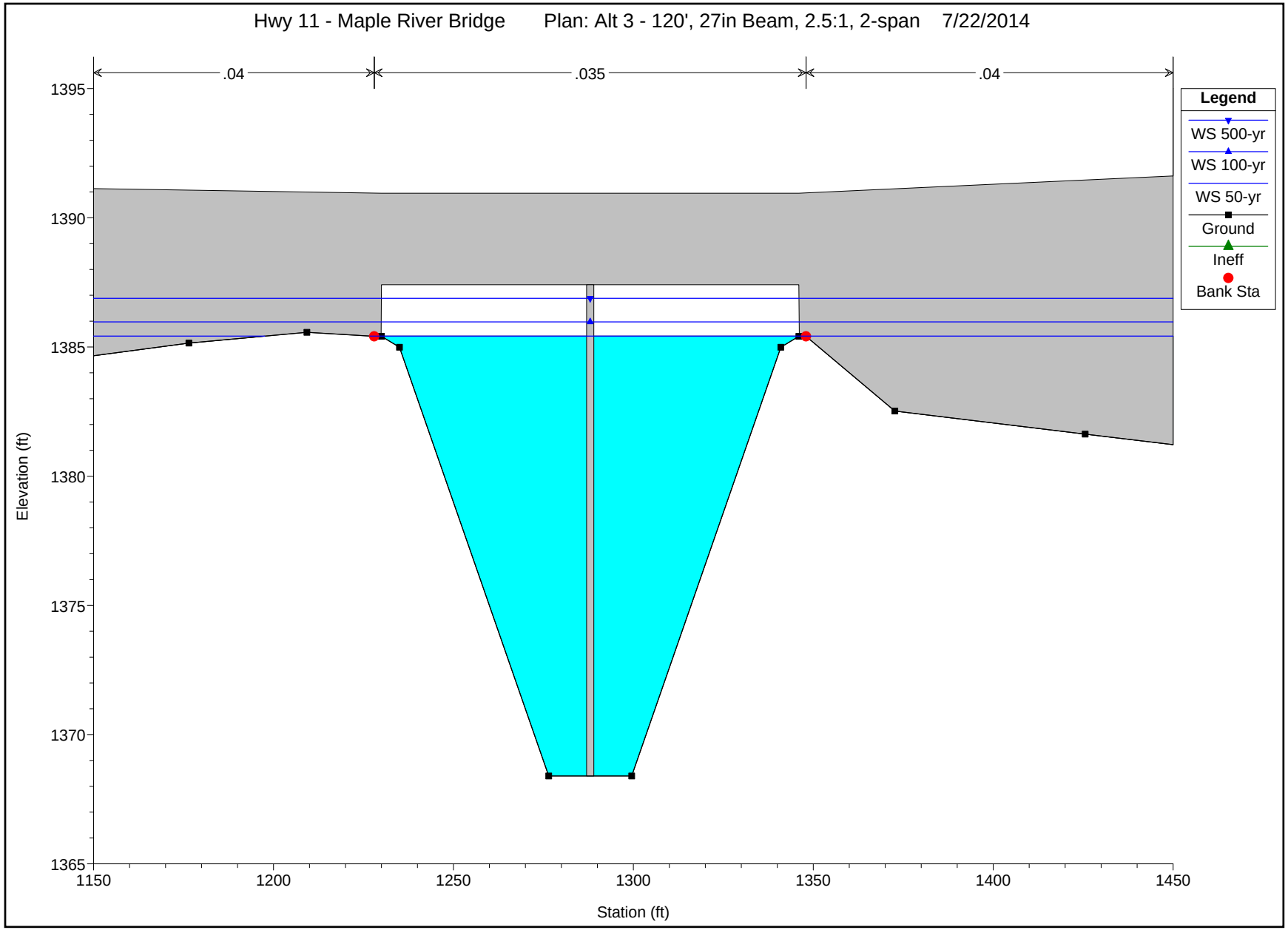
Hydraulic Calculations HEC-RAS

Alternative 3
120’ Bridge (2-span) with 27” Girders
23’ Channel Bottom with 2.5:1 End Slopes

Alt 3 - 120' Bridge
Upstream



Alt 3 - 120' Bridge
Downstream



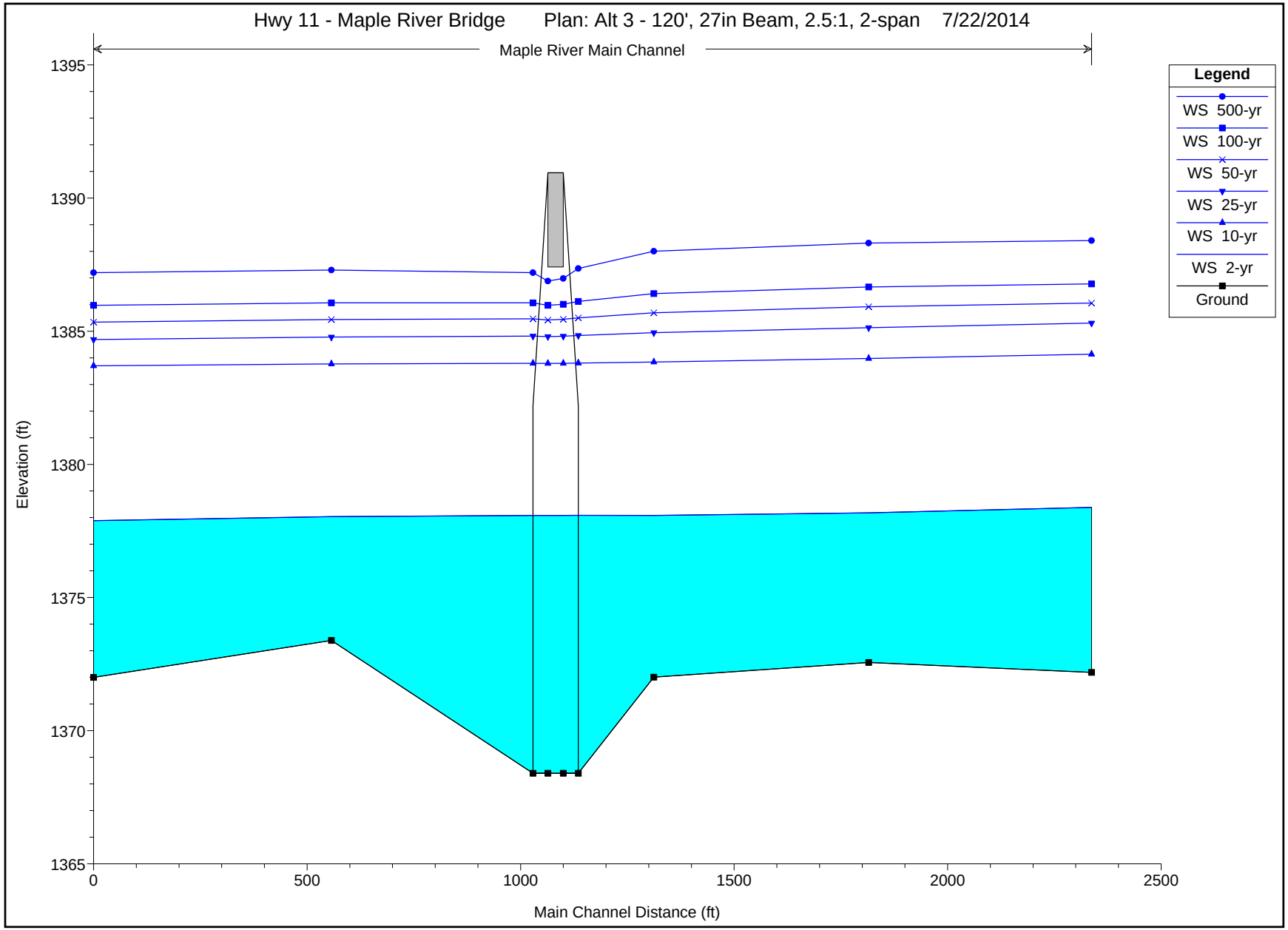
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Main Channel	2337	50-yr	4375	1372.19	1386.06	1380.61	1386.14	0.000318	2.56	2720.65	1316.86	0.18
Main Channel	2337	100-yr	5822	1372.19	1386.78	1381.88	1386.85	0.000279	2.58	3695.24	1384.64	0.17
Main Channel	2337	500-yr	9913	1372.19	1388.4	1384.74	1388.47	0.000226	2.67	6070.94	1540.5	0.16
Main Channel	1815	50-yr	4375	1372.56	1385.92	1381.87	1385.98	0.000366	2.19	2770.78	1282.75	0.18
Main Channel	1815	100-yr	5822	1372.56	1386.66	1382.77	1386.72	0.000295	2.18	3754.84	1356.65	0.17
Main Channel	1815	500-yr	9913	1372.56	1388.31	1384.67	1388.36	0.000223	2.28	6122.74	1517.53	0.15
Main Channel	1312	50-yr	4375	1372.01	1385.69	1379.7	1385.8	0.000397	2.72	1752.05	1521.59	0.2
Main Channel	1312	100-yr	5822	1372.01	1386.41	1381.59	1386.55	0.000443	3.11	2140.9	1646.17	0.21
Main Channel	1312	500-yr	9913	1372.01	1388.01	1383.49	1388.21	0.000516	3.87	3060.9	1848.63	0.24
Main Channel	1135	50-yr	4375	1368.4	1385.5	1376.23	1385.72	0.000427	3.78	1229.63	1582.58	0.22
Main Channel	1135	100-yr	5822	1368.4	1386.12	1377.51	1386.44	0.000594	4.64	1367.06	1673.11	0.26
Main Channel	1135	500-yr	9913	1368.4	1387.35	1380.36	1388.02	0.001084	6.78	1646.03	1808.14	0.36
Main Channel	1082		Bridge									
Main Channel	1029	50-yr	4375	1368.4	1385.47	1376.23	1385.63	0.000354	3.43	1504.5	1274.17	0.2
Main Channel	1029	100-yr	5822	1368.4	1386.06	1377.51	1386.3	0.000477	4.15	1702.26	1585.93	0.23
Main Channel	1029	500-yr	9913	1368.4	1387.2	1380.36	1387.66	0.000845	5.93	2078.55	1978.39	0.31
Main Channel	557	50-yr	4375	1373.39	1385.44	1379.54	1385.46	0.000144	1.28	4097.41	1383.16	0.11
Main Channel	557	100-yr	5822	1373.39	1386.07	1380.19	1386.09	0.000144	1.41	4984.64	1439.18	0.12
Main Channel	557	500-yr	9913	1373.39	1387.3	1381.81	1387.34	0.000166	1.77	6832.19	1563.47	0.13
Main Channel	0	50-yr	4375	1372	1385.34	1380.26	1385.37	0.0002	1.69	3724.69	1442.31	0.14
Main Channel	0	100-yr	5822	1372	1385.97	1382.41	1386.01	0.0002	1.83	4757.4	1702.73	0.14
Main Channel	0	500-yr	9913	1372	1387.2	1383.5	1387.24	0.0002	2.1	6911.51	1806.58	0.14

Plan: 3) 120', 27" Bm Maple River Main Channel RS: 1082 Profile: 50-yr				
E.G. US. (ft)	1385.72	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	1385.5	E.G. Elev (ft)	1385.7	1385.67
Q Total (cfs)	4375	W.S. Elev (ft)	1385.45	1385.42
Q Bridge (cfs)	4375	Crit W.S. (ft)	1376.46	1376.46
Q Weir (cfs)		Max Chl Dpth (ft)	17.05	17.02
Weir Sta Lft (ft)		Vel Total (ft/s)	4.02	4.03
Weir Sta Rgt (ft)		Flow Area (sq ft)	1087.19	1084.3
Weir Submerg		Froude # Chl	0.17	0.17
Weir Max Depth (ft)		Specif Force (cu ft)	7732.95	7706.97
Min El Weir Flow (ft)	1390.96	Hydr Depth (ft)	9.52	9.49
Min El Prs (ft)	1387.41	W.P. Total (ft)	154.83	154.72
Delta EG (ft)	0.09	Conv. Total (cfs)	169253.7	168580.4
Delta WS (ft)	0.04	Top Width (ft)	114.23	114.24
BR Open Area (sq ft)	1311.39	Frctn Loss (ft)	0.02	0.02
BR Open Vel (ft/s)	4.03	C & E Loss (ft)	0	0.03
Coef of Q		Shear Total (lb/sq ft)	0.29	0.29
Br Sel Method	Energy only	Power Total (lb/ft s)	0	0

Plan: 3) 120', 27" Bm Maple River Main Channel RS: 1082 Profile: 100-yr				
E.G. US. (ft)	1386.44	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	1386.12	E.G. Elev (ft)	1386.41	1386.37
Q Total (cfs)	5822	W.S. Elev (ft)	1386.01	1385.97
Q Bridge (cfs)	5822	Crit W.S. (ft)	1377.74	1377.74
Q Weir (cfs)		Max Chl Dpth (ft)	17.61	17.57
Weir Sta Lft (ft)		Vel Total (ft/s)	5.05	5.07
Weir Sta Rgt (ft)		Flow Area (sq ft)	1151.81	1147.35
Weir Submerg		Froude # Chl	0.21	0.21
Weir Max Depth (ft)		Specif Force (cu ft)	8733.66	8692.3
Min El Weir Flow (ft)	1390.96	Hydr Depth (ft)	10.09	10.05
Min El Prs (ft)	1387.41	W.P. Total (ft)	157.09	156.93
Delta EG (ft)	0.14	Conv. Total (cfs)	184557.8	183489.4
Delta WS (ft)	0.06	Top Width (ft)	114.17	114.17
BR Open Area (sq ft)	1311.39	Frctn Loss (ft)	0.04	0.02
BR Open Vel (ft/s)	5.07	C & E Loss (ft)	0	0.05
Coef of Q		Shear Total (lb/sq ft)	0.46	0.46
Br Sel Method	Energy only	Power Total (lb/ft s)	0	0

Plan: 3) 120', 27" Bm Maple River Main Channel RS: 1082 Profile: 500-yr				
E.G. US. (ft)	1388.02	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	1387.35	E.G. Elev (ft)	1387.94	1387.86
Q Total (cfs)	9913	W.S. Elev (ft)	1386.98	1386.88
Q Bridge (cfs)	9913	Crit W.S. (ft)	1380.64	1380.64
Q Weir (cfs)		Max Chl Dpth (ft)	18.58	18.48
Weir Sta Lft (ft)		Vel Total (ft/s)	7.85	7.92
Weir Sta Rgt (ft)		Flow Area (sq ft)	1262.66	1251.34
Weir Submerg		Froude # Chl	0.32	0.32
Weir Max Depth (ft)		Specif Force (cu ft)	11409.45	11306.56
Min El Weir Flow (ft)	1390.96	Hydr Depth (ft)	11.07	10.97
Min El Prs (ft)	1387.41	W.P. Total (ft)	160.98	160.58
Delta EG (ft)	0.36	Conv. Total (cfs)	211621.3	208811.9
Delta WS (ft)	0.16	Top Width (ft)	114.05	114.06
BR Open Area (sq ft)	1311.39	Frctn Loss (ft)	0.08	0.05
BR Open Vel (ft/s)	7.92	C & E Loss (ft)	0	0.15
Coef of Q		Shear Total (lb/sq ft)	1.07	1.1
Br Sel Method	Energy only	Power Total (lb/ft s)	0	0

Alt 3: 120' Bridge, 2-span, 27" Beams, 2.5:1 slopes
Profile

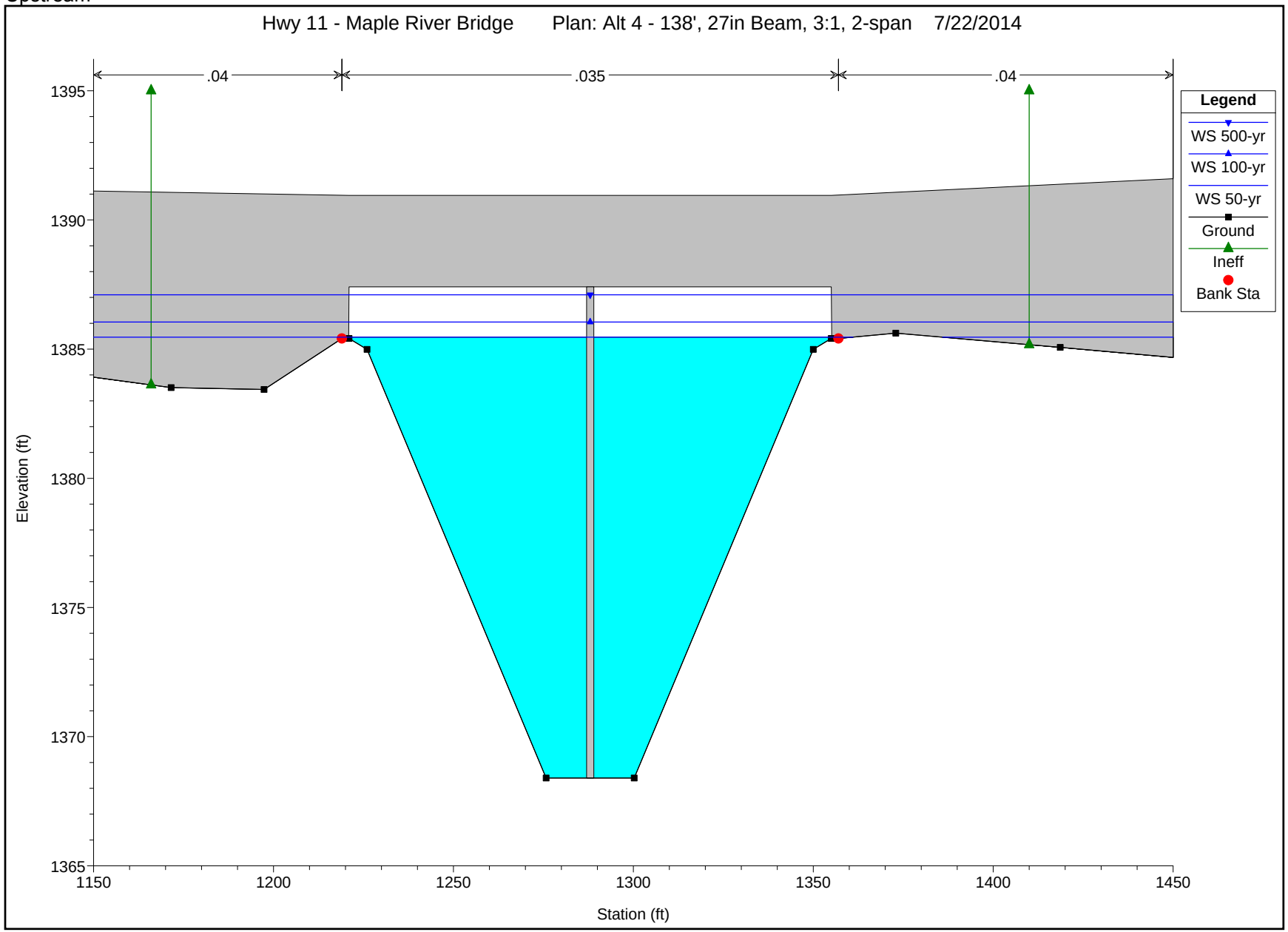


APPENDIX E

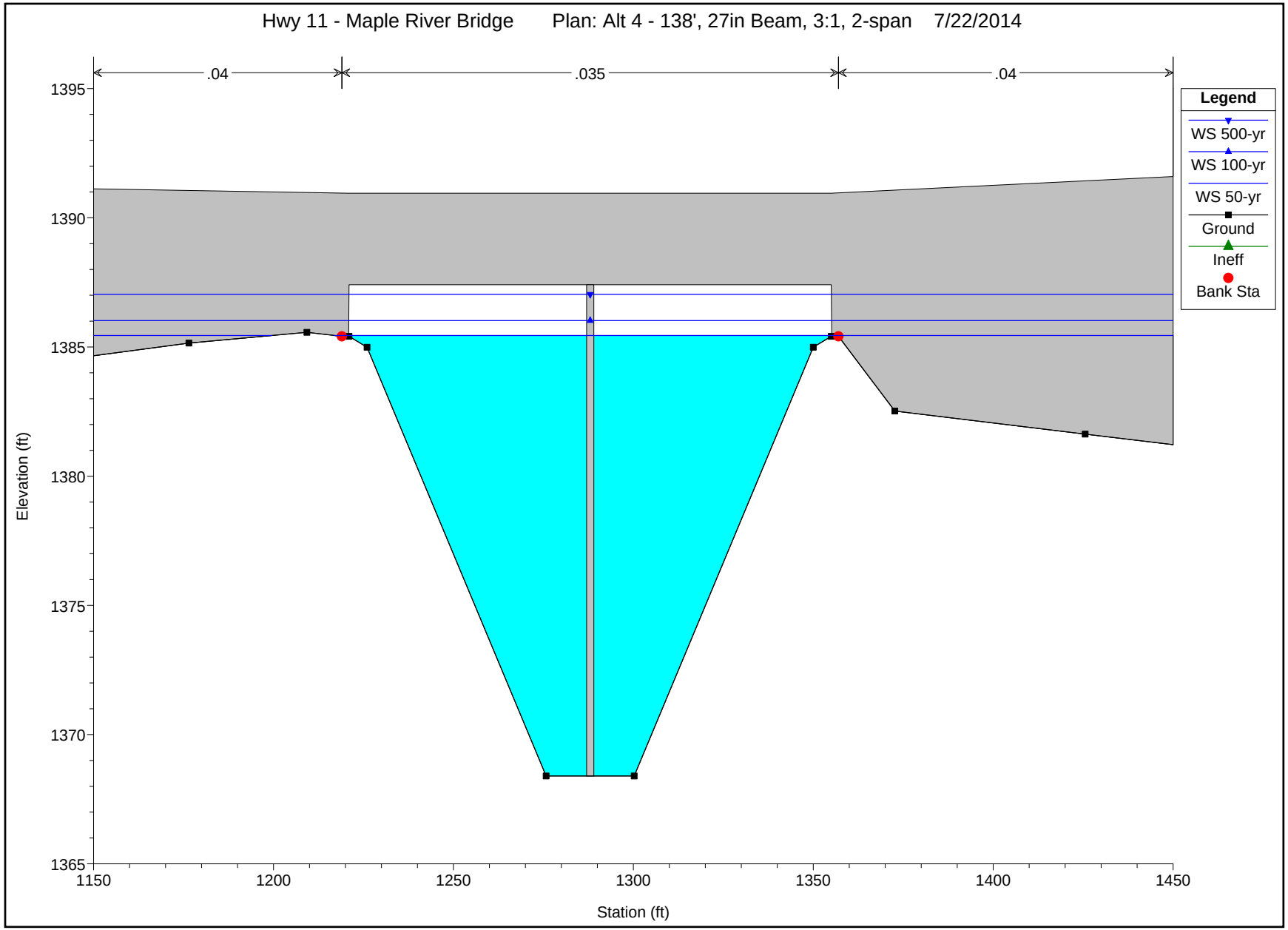
Hydraulic Calculations HEC-RAS

Alternative 4
138’ Bridge (2-span) with 27” Girders
24’ Channel Bottom with 3:1 End Slopes

Alt 4 - 138' Bridge
Upstream



Alt 4 - 138' Bridge
Downstream



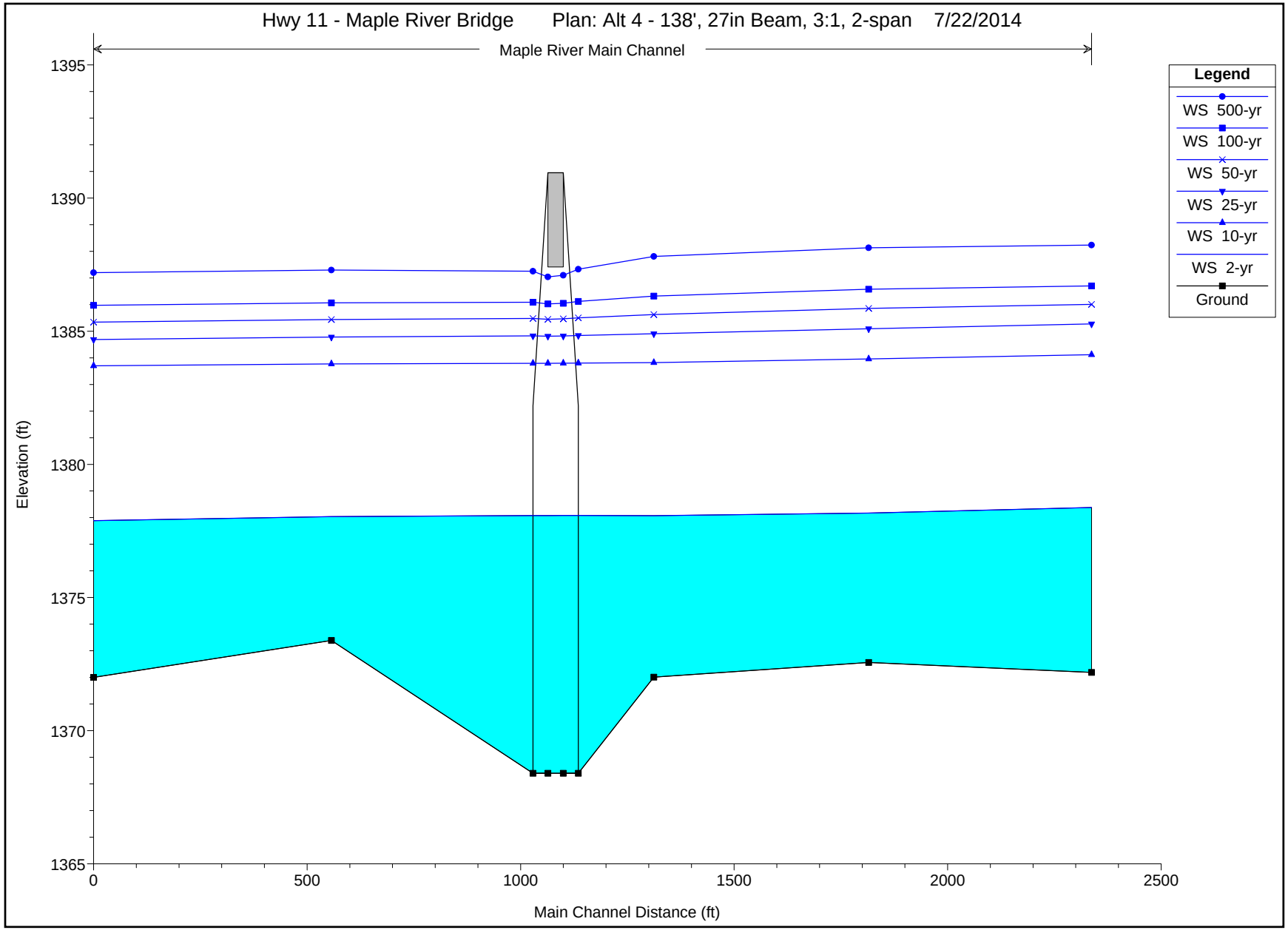
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Main Channel	2337	50-yr	4375	1372.19	1386.01	1380.61	1386.09	0.000335	2.62	2652.34	1310.24	0.18
Main Channel	2337	100-yr	5822	1372.19	1386.7	1381.88	1386.78	0.000299	2.65	3590.01	1378.2	0.18
Main Channel	2337	500-yr	9913	1372.19	1388.24	1384.74	1388.31	0.000254	2.79	5815.38	1526.99	0.17
Main Channel	1815	50-yr	4375	1372.56	1385.86	1381.87	1385.92	0.000393	2.25	2691.59	1271.14	0.19
Main Channel	1815	100-yr	5822	1372.56	1386.58	1382.77	1386.63	0.000321	2.25	3638.78	1348.27	0.17
Main Channel	1815	500-yr	9913	1372.56	1388.13	1384.67	1388.19	0.000252	2.38	5853.65	1500.12	0.16
Main Channel	1312	50-yr	4375	1372.01	1385.63	1379.7	1385.74	0.000407	2.74	1745.07	1484.8	0.2
Main Channel	1312	100-yr	5822	1372.01	1386.32	1381.59	1386.46	0.00046	3.13	2128.89	1630.13	0.22
Main Channel	1312	500-yr	9913	1372.01	1387.81	1383.47	1388.02	0.000555	3.95	3014.12	1826.18	0.25
Main Channel	1135	50-yr	4375	1368.4	1385.5	1375.8	1385.67	0.000322	3.31	1389	1591.83	0.19
Main Channel	1135	100-yr	5822	1368.4	1386.12	1376.99	1386.37	0.000449	4.08	1538.62	1672.99	0.23
Main Channel	1135	500-yr	9913	1368.4	1387.33	1379.67	1387.86	0.000834	6	1834.44	1806.11	0.32
Main Channel	1082		Bridge									
Main Channel	1029	50-yr	4375	1368.4	1385.48	1375.8	1385.6	0.000262	2.98	1717.45	1285.41	0.17
Main Channel	1029	100-yr	5822	1368.4	1386.09	1376.99	1386.27	0.000353	3.61	1930.36	1597.89	0.2
Main Channel	1029	500-yr	9913	1368.4	1387.25	1379.67	1387.61	0.000628	5.18	2338.17	1990.12	0.27
Main Channel	557	50-yr	4375	1373.39	1385.44	1379.54	1385.46	0.000144	1.28	4097.41	1383.16	0.11
Main Channel	557	100-yr	5822	1373.39	1386.07	1380.19	1386.09	0.000144	1.41	4984.64	1439.18	0.12
Main Channel	557	500-yr	9913	1373.39	1387.3	1381.81	1387.34	0.000166	1.77	6832.19	1563.47	0.13
Main Channel	0	50-yr	4375	1372	1385.34	1380.26	1385.37	0.0002	1.69	3724.69	1442.31	0.14
Main Channel	0	100-yr	5822	1372	1385.97	1382.41	1386.01	0.0002	1.83	4757.4	1702.73	0.14
Main Channel	0	500-yr	9913	1372	1387.2	1383.5	1387.24	0.0002	2.1	6911.51	1806.58	0.14

Plan: 4) 138', 27" Bm Maple River Main Channel RS: 1082 Profile: 50-yr				
E.G. US. (ft)	1385.67	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	1385.5	E.G. Elev (ft)	1385.65	1385.63
Q Total (cfs)	4375	W.S. Elev (ft)	1385.46	1385.45
Q Bridge (cfs)	4375	Crit W.S. (ft)	1375.99	1375.99
Q Weir (cfs)		Max Chl Dpth (ft)	17.06	17.05
Weir Sta Lft (ft)		Vel Total (ft/s)	3.48	3.48
Weir Sta Rgt (ft)		Flow Area (sq ft)	1258.79	1256.47
Weir Submerg		Froude # Chl	0.15	0.15
Weir Max Depth (ft)		Specif Force (cu ft)	8711.49	8690.26
Min El Weir Flow (ft)	1390.96	Hydr Depth (ft)	9.52	9.5
Min El Prs (ft)	1387.41	W.P. Total (ft)	171.87	171.81
Delta EG (ft)	0.06	Conv. Total (cfs)	201546.3	200980.1
Delta WS (ft)	0.02	Top Width (ft)	132.22	132.22
BR Open Area (sq ft)	1515.94	Frctn Loss (ft)	0.02	0.01
BR Open Vel (ft/s)	3.48	C & E Loss (ft)	0	0.02
Coef of Q		Shear Total (lb/sq ft)	0.22	0.22
Br Sel Method	Energy only	Power Total (lb/ft s)	0	0

Plan: 4) 138', 27" Bm Maple River Main Channel RS: 1082 Profile: 100-yr				
E.G. US. (ft)	1386.37	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	1386.12	E.G. Elev (ft)	1386.34	1386.32
Q Total (cfs)	5822	W.S. Elev (ft)	1386.05	1386.02
Q Bridge (cfs)	5822	Crit W.S. (ft)	1377.21	1377.21
Q Weir (cfs)		Max Chl Dpth (ft)	17.65	17.62
Weir Sta Lft (ft)		Vel Total (ft/s)	4.36	4.37
Weir Sta Rgt (ft)		Flow Area (sq ft)	1336.24	1332.77
Weir Submerg		Froude # Chl	0.18	0.18
Weir Max Depth (ft)		Specif Force (cu ft)	9787.31	9754.34
Min El Weir Flow (ft)	1390.96	Hydr Depth (ft)	10.11	10.09
Min El Prs (ft)	1387.41	W.P. Total (ft)	174.22	174.12
Delta EG (ft)	0.1	Conv. Total (cfs)	220632.4	219765.3
Delta WS (ft)	0.03	Top Width (ft)	132.15	132.15
BR Open Area (sq ft)	1515.94	Frctn Loss (ft)	0.03	0.02
BR Open Vel (ft/s)	4.37	C & E Loss (ft)	0	0.04
Coef of Q		Shear Total (lb/sq ft)	0.33	0.34
Br Sel Method	Energy only	Power Total (lb/ft s)	0	0

Plan: 4) 138', 27" Bm Maple River Main Channel RS: 1082 Profile: 500-yr				
E.G. US. (ft)	1387.86	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	1387.33	E.G. Elev (ft)	1387.8	1387.75
Q Total (cfs)	9913	W.S. Elev (ft)	1387.1	1387.04
Q Bridge (cfs)	9913	Crit W.S. (ft)	1379.89	1379.89
Q Weir (cfs)		Max Chl Dpth (ft)	18.7	18.64
Weir Sta Lft (ft)		Vel Total (ft/s)	6.72	6.76
Weir Sta Rgt (ft)		Flow Area (sq ft)	1475.22	1466.89
Weir Submerg		Froude # Chl	0.27	0.28
Weir Max Depth (ft)		Specif Force (cu ft)	12547.25	12466.16
Min El Weir Flow (ft)	1390.96	Hydr Depth (ft)	11.17	11.11
Min El Prs (ft)	1387.41	W.P. Total (ft)	178.43	178.18
Delta EG (ft)	0.25	Conv. Total (cfs)	256078.7	253911.5
Delta WS (ft)	0.08	Top Width (ft)	132.03	132.04
BR Open Area (sq ft)	1515.94	Frctn Loss (ft)	0.05	0.03
BR Open Vel (ft/s)	6.76	C & E Loss (ft)	0	0.11
Coef of Q		Shear Total (lb/sq ft)	0.77	0.78
Br Sel Method	Energy only	Power Total (lb/ft s)	0	0

Alt 4: 138' Bridge, 2-span, 27" Beams, 3:1 slopes
Profile



APPENDIX F

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	ALT. NUMBER 4
TYPE OR DESCRIPTION	Concrete Slab	27" Box Beam	21" Box Beam	27" Box Beam	27" Box Beam
NUMBER OF BARRELS	3-span (2:1)	3-span (2.5:1)	3-span (3:1)	2-span (2.5:1)	2-span (3:1)
OVERALL LENGTH	90	120	140	120	138
TOTAL WATERWAY AREA (FT^2)	1,257.83	1,299.72	1,541.46	1,311.39	1,515.94
CLEARANCE ELEVATION	1389.31	1387.41	1387.91	1387.41	1387.41
ROADWAY OVERTOPPING ELEVATION	1390.95	1390.95	1390.95	1390.95	1390.95

Hydraulic Comparison

50-Year Frequency	Q = 4,375 CFS				
ITEM	**EXISTING**	**ALT. NUMBER 1**	**ALT. NUMBER 2**	**ALT. NUMBER 3**	**ALT. NUMBER 4**
DISCHARGE THROUGH STRUCTURE (CFS)	4,375	4,375	4,375	4,375	4,375
DISCHARGE OVER ROADWAY (CFS)	0	0	0	0	0
UPSTREAM STAGE	1385.49	1385.51	1385.5	1385.5	1385.5
DOWNSTREAM STAGE	1385.37	1385.42	1385.44	1385.42	1385.45
AVG. VEL. THROUGH STRUCTURE (FT/SEC)	4.71	4.06	3.59	4.03	3.48

Hydraulic Comparison

100-Year Frequency	Q = 5,822 CFS				
ITEM	**EXISTING**	**ALT. NUMBER 1**	**ALT. NUMBER 2**	**ALT. NUMBER 3**	**ALT. NUMBER 4**
DISCHARGE THROUGH STRUCTURE (CFS)	5,822	5,822	5,822	5,822	5,822
DISCHARGE OVER ROADWAY (CFS)	0	0	0	0	0
UPSTREAM STAGE	1386.11	1386.13	1386.13	1386.12	1386.12
DOWNSTREAM STAGE	1385.88	1385.97	1386.02	1385.97	1386.02
AVG. VEL. THROUGH STRUCTURE (FT/SEC)	5.99	5.11	4.5	5.06	4.37

Hydraulic Comparison

500-Year Frequency	Q = 9,913 CFS				
ITEM	**EXISTING**	**ALT. NUMBER 1**	**ALT. NUMBER 2**	**ALT. NUMBER 3**	**ALT. NUMBER 4**
DISCHARGE THROUGH STRUCTURE (CFS)	9,913	9,913	9,913	9,913	9,913
DISCHARGE OVER ROADWAY (CFS)	0	0	0	0	0
UPSTREAM STAGE	1387.42	1387.38	1387.37	1387.35	1387.33
DOWNSTREAM STAGE	1386.59	1386.87	1387.02	1386.88	1387.04
AVG. VEL. THROUGH STRUCTURE (FT/SEC)	9.56	7.96	6.94	7.89	6.74

COMMENTS:

APPENDIX G

Hydraulic Design Data for Bridges

HYDRAULIC DESIGN DATA FOR BRIDGES
North Dakota Department of Transportation, Bridge
SFN 9634 (Rev. 1-2000)

Project Number: BRS-SS-2-011(035)083	Bridge Number: 0011-083.957
Drainage Area	440.66 square miles
Design Frequency	50-Year
Design Discharge	4,375 cfs
Design Stage (upstream)	1385.51 ft
Stream Gradient (ft/ft)	0.0002 ft/ft
Waterway Provided Below Design Stage	1087.19 sq ft
Waterway Provided Below Clearance Elevation	1299.72 sq ft
Average Velocity of Flow in Natural Channel	2.41 ft/sec
Depth of Flow	17.11 ft
Velocity of Flow Under Bridge	4.06 ft/sec
Freeboard Provided	1.9 ft
100-year Frequency Discharge	5,822 cfs
100-year Frequency Stage	1386.13 ft
Overtopping Stage	1390.95 ft
Overtopping Discharge	Unknown
Minimum Water Elevation	1368.40 ft

COMMENTS:

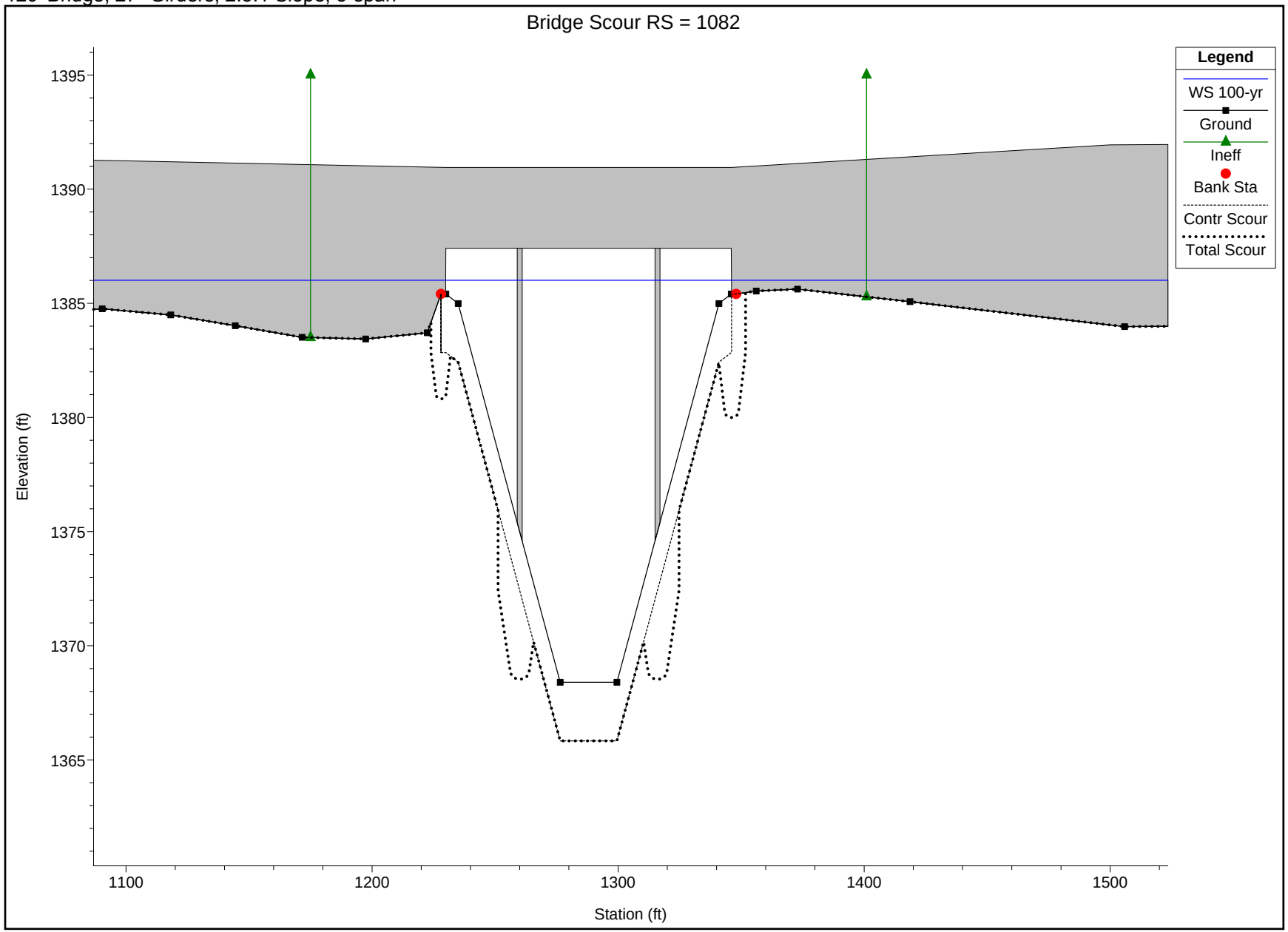
Alternative 1: 3-Span, 36' Clear Roadway Width, 23' Channel Bottom with 2.5:1 Slopes, 120' Length

Bottom Elevation = 1368.40 ft

APPENDIX H

Estimated Scour

Alt 1 - 100-yr
120' Bridge, 27" Girders, 2.5:1 Slope, 3-span



Alt 1 - 100-yr
120' Bridge, 27" Girders, 2.5:1 Slope, 3-span
Contraction Scour

		Left	Channel	Right
Input Data				
	Average Depth (ft):	3.32	6.59	0.92
	Approach Velocity (ft/s):	1.74	3.10	0.75
	Br Average Depth (ft):		10.19	
	BR Opening Flow (cfs):		5822.00	
	BR Top WD (ft):		112.17	
	Grain Size D50 (mm):	.2	0.20	.2
	Approach Flow (cfs):	421.47	5239.99	160.54
	Approach Top WD (ft):	73.09	256.37	231.06
	K1 Coefficient:	0.590	0.690	0.590
Results				
	Scour Depth Ys (ft):		2.57	
	Critical Velocity (ft/s):		1.33	
	Equation:		Live	

Pier Scour

All piers have the same scour depth

Input Data		
	Pier Shape:	Sharp nose
	Pier Width (ft):	2.00
	Grain Size D50 (mm):	0.20000
	Depth Upstream (ft):	10.03
	Velocity Upstream (ft/s):	4.64
	K1 Nose Shape:	0.90
	Pier Angle:	0.00
	Pier Length (ft):	36.00
	K2 Angle Coef:	1.00
	K3 Bed Cond Coef:	1.10
	Grain Size D90 (mm):	7.50000
	K4 Armouring Coef:	1.00
Results		
	Scour Depth Ys (ft):	3.89
	Froude #:	0.26
	Equation:	CSU equation

Abutment Scour

		Left	Right
Input Data			
	Station at Toe (ft):	1228.00	1346.13
	Toe Sta at appr (ft):	1076.09	1330.59
	Abutment Length (ft):	73.09	232.93
	Depth at Toe (ft):	0.72	0.72
	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):	73.09	232.93
	Avg Depth Obstructed Ya (ft):	3.32	0.97
	Flow Obstructed Qe (cfs):	421.47	198.78
	Area Obstructed Ae (sq ft):	242.66	225.18
Results			
	Scour Depth Ys (ft):	2.03	2.85
	Froude #:	0.34	0.96

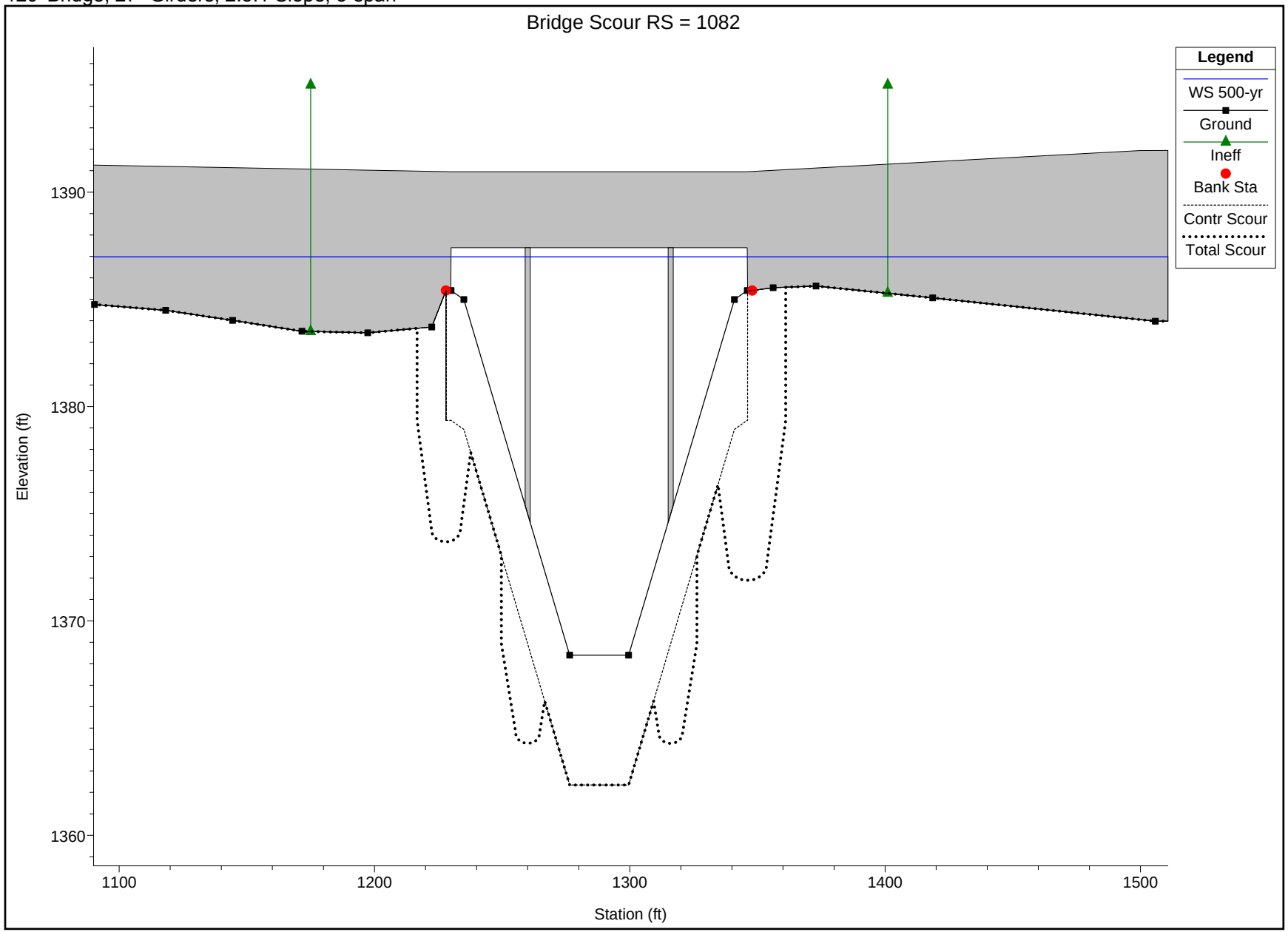
Alt 1 - 100-yr
120' Bridge, 27" Girders, 2.5:1 Slope, 3-span

Equation:	HIRE	HIRE

Combined Scour Depths

Pier Scour + Contraction Scour (ft):		
	Channel:	6.46
Left abutment scour + contraction scour (ft):	4.59	
Right abutment scour + contraction scour (ft):	5.41	

Alt 1 - 500-yr
120' Bridge, 27" Girders, 2.5:1 Slope, 3-span



Alt 1 - 500-yr
120' Bridge, 27" Girders, 2.5:1 Slope, 3-span
Contraction Scour

		Left	Channel	Right
Input Data				
	Average Depth (ft):	4.92	8.19	2.44
	Approach Velocity (ft/s):	2.43	3.86	1.52
	Br Average Depth (ft):		11.17	
	BR Opening Flow (cfs):		9913.00	
	BR Top WD (ft):		112.05	
	Grain Size D50 (mm):		0.20	
	Approach Flow (cfs):	874.90	8107.13	930.97
	Approach Top WD (ft):	73.09	256.37	250.54
	K1 Coefficient:	0.590	0.690	0.590
Results				
	Scour Depth Ys (ft):		6.05	
	Critical Velocity (ft/s):		1.38	
	Equation:		Live	

Pier Scour

All piers have the same scour depth

Input Data		
	Pier Shape:	Sharp nose
	Pier Width (ft):	2.00
	Grain Size D50 (mm):	0.20000
	Depth Upstream (ft):	11.28
	Velocity Upstream (ft/s):	6.76
	K1 Nose Shape:	0.90
	Pier Angle:	0.00
	Pier Length (ft):	36.00
	K2 Angle Coef:	1.00
	K3 Bed Cond Coef:	1.10
	Grain Size D90 (mm):	7.50000
	K4 Armouring Coef:	1.00
Results		
	Scour Depth Ys (ft):	4.65
	Froude #:	0.35
	Equation:	CSU equation

Abutment Scour

		Left	Right
Input Data			
	Station at Toe (ft):	1228.00	1346.13
	Toe Sta at appr (ft):	1076.09	1330.59
	Abutment Length (ft):	73.09	252.41
	Depth at Toe (ft):	1.97	1.97
	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):	73.09	252.41
	Avg Depth Obstructed Ya (ft):	4.92	2.48
	Flow Obstructed Qe (cfs):	874.90	990.13
	Area Obstructed Ae (sq ft):	359.95	626.92
Results			
	Scour Depth Ys (ft):	5.67	7.46
	Froude #:	0.37	0.85

Alt 1 - 500-yr
120' Bridge, 27" Girders, 2.5:1 Slope, 3-span

Equation:	HIRE	HIRE

Combined Scour Depths

Pier Scour + Contraction Scour (ft):		
	Channel:	10.70
Left abutment scour + contraction scour (ft):	11.72	
Right abutment scour + contraction scour (ft):	13.52	

APPENDIX I

Structure Inventory & Appraisal Sheet

North Dakota Department of Transportation

Bridge Inventory - Structure Inventory And Appraisal Sheet

Structure Number: 0011-083.957

200 System Designation: 1 - State
201 Status: Structurally Deficient
202 Sufficiency Rating: 85.70

Identification

02 Highway District: Valley City District
03 County: Dickey
04 City: VAN METER TOWNSHIP
05 Inventory Route: Route On Structure
3 State Hwy: 1 Mainline 00011 0 N/A (NBI)
06 Feats Intersect: MAPLE RIVER
09 Location: 6 EAST OF ELLENDALE
11 Milepoint: 83.939
13 LRS Inv Route. Subroute: 0000000000 00
16 Latitude: 46d 00' 32.00"
17 Longitude: 98d 24' 38.00"
GPS Coordinates XY: 545637.5 5095207.1
98 Border Bridge: Unknown (P) -2.00 %
99 Border Bridge Struct No.: _

Structure Type and Material

43 Main Struct Type: Concrete cont
Slab
44 Approach Struct Type: Unknown (NBI)
Unknown (P)
45 No. Spans in Main Unit: 3
46 No. Approach Spans: 0
107 Deck Struct Type: 1 Concrete-Cast-in-Place
108 Wearing Surface: 1 Monolithic Concrete
Membrane: 0 None
Dk Protect: None
208 Dk Overburden: None

Age and Service

27 Yr Built: 1955 106 Yr Reconstructed: 1970
42 Type of Service: 1 Highway - On
5 Waterway - Under
28 Lanes on Structure: 2
29 ADT: 570 30 Year of ADT: 2014
109 Average Daily Truck Traffic: 14.00
19 Bypass, Detour Length: 4 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: 33 Feet
49 Structure Length: 89.90 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: 33.1 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: 4 Hist sign not determin
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
104 Highway System of Inventory Rte: 0 Not on NHS
105 Federal Lands Highways: Not applicable
110 Designated National Network: 1 Part of natl network
112 NBIS Bridge Length
226 Functional Under

Condition

58 Deck: 4 Poor
59 Superstructure: 7 Good
60 Substructure: 7 Good
61 Chan. & Chan. Protection: 7 Minor Damage
62 Culvert and Retaining Walls: N N/A (NBI)

Load Rating and Posting

31 Design Load
MS 13.5 (HS 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 30 54 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: 6 Equal Min Criteria
68 Deck Geometry: 5 Above Tolerable
69 Underclear. Vert & Horiz: N Not applicable (NBI)
71 Waterway Adequacy: 8 Equal Desirable
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 19, 2013
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 07/01/2004
207 Transporter Erector Routes and Sites: -1
212 Structure Load Rated: 01/01/1901
213 Federal Aid Project Number: S-2-011(00)078
214 Delayed Inspection: Not Applicable
216 Inspector: Carlson, Rowell, Schlagel

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: Unknown (NBI)
116 Minimum Navigation Vertical Clearance: -1 Feet

February 05, 2014

North Dakota Department of Transportation

Bridge Inventory - Structure Inventory And Appraisal Sheet

SEC 409

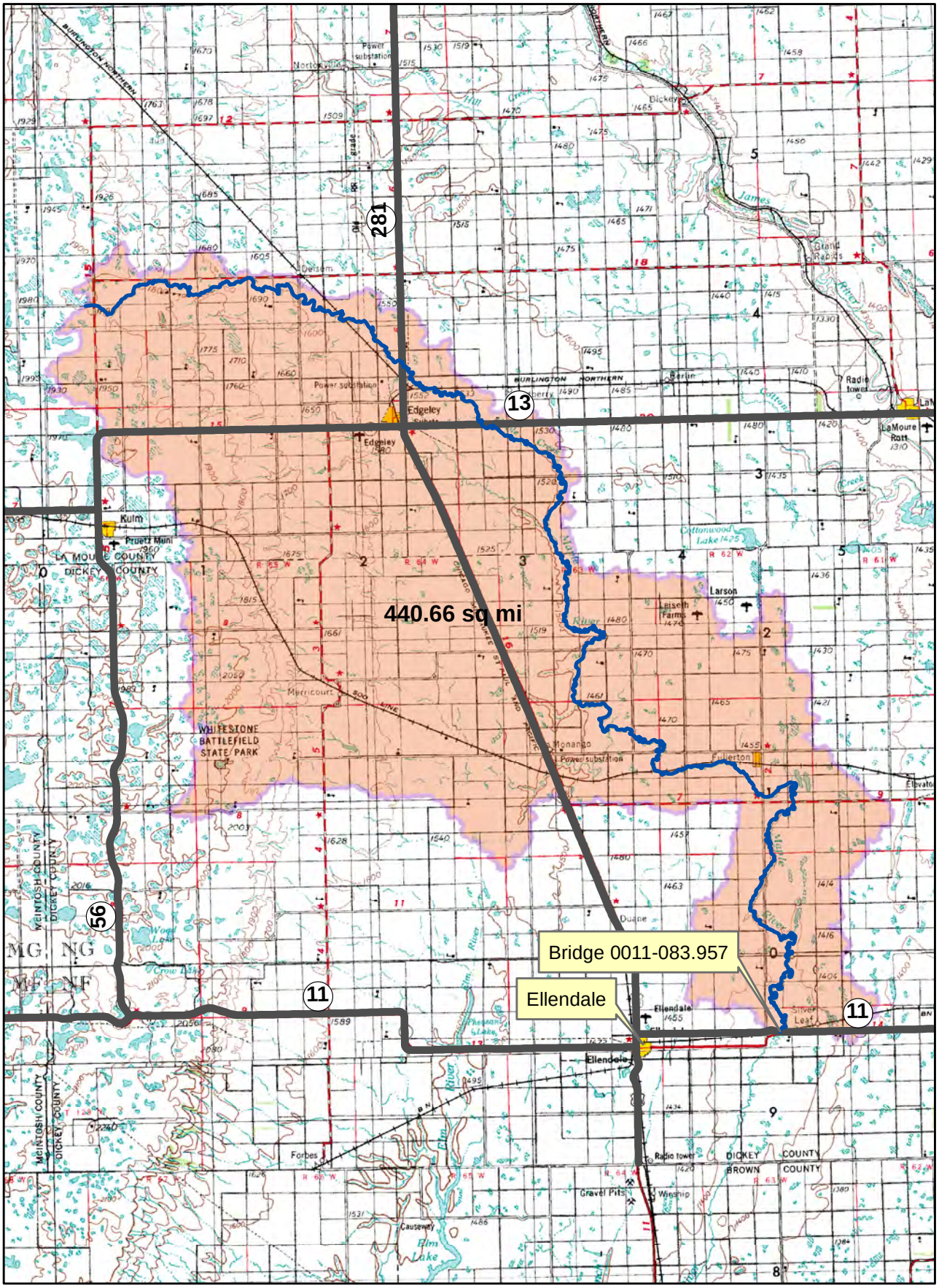
Structure Number: 0011-083.957

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
38 / 1	Bare Concrete Slab	(SF)	2,519	0%	0	0%	0	100%	2,519	0%	0	0 %	0
210 / 3	R/Conc Pier Wall	(LF)	56	100%	56	0%	0	0%	0	0%	0	0 %	0
215 / 1	R/Conc Abutment	(LF)	66	61%	40	39%	26	0%	0	0%	0	0 %	0
331 / 1	Conc Bridge Railing	(LF)	180	0%	0	100%	180	0%	0	0%	0	0 %	0
398 / 3	Slope Protection	(EA)	2	100%	2	0%	0	0%	0	0%	0	0 %	0
401 / 1	Wings	(EA)	4	100%	4	0%	0	0%	0	0%	0	0 %	0

Remarks: Majority of spalling is occurring on west half of bridge in WB lane.
Moderate popouts & surface cracks on deck. Moderate spalling west half wb aprox. 60 sq ft spalled. 3 minor cracks east abut. 6 minor cracks west abut. Roadway settlement west end of bridges

APPENDIX J

Watershed Area Map


440.66 sq mi
Bridge 0011-083.957
Ellendale
281
13
11
56
Edgeley
Kulm
Ellendale
Dickey
Larson
Fullerton
Monango
Duane
Forbes
Grand Rapids
LA MOURE COUNTY
DICKEY COUNTY
WHITESTONE BATTLEFIELD STATE PARK
McINTOSH COUNTY
DICKEY COUNTY
BROWN COUNTY
BURLINGTON NORTHERN