HYDROLOGY REPORT

Staples Bridge #1238 over the Great Works River in North Berwick

Two sources of flow data are available for the subject bridge: the 1984 Flood Insurance Study (FIS) and the Maine Department of Transportation Office of the Environment – Hydrology Section. There are no USGS gaging stations located on the Great Works River.

The 1984 FIS notes "flood flows for the various frequencies of the Great Works River were computed from an analysis of stream hydraulics, soil cover, land use, and rainfall data using the Soil Conservation Service Technical Release No. 20 computer program". Table 1 on Page 6 of the FIS list various locations along the Great Works River and the calculated Drainage Area and Peak Discharge Flows at those locations. The closest location to the Staples Bridge is the crossing at Oak Woods Road, which is approximately 8,300 feet upstream of the subject bridge.

The hydrology developed by the Maine Department of Transportation Office of the Environment – Hydrology Section uses the USGS Regression Equations (Hodgkins, 1990 and Lombard/Hodgkins, 2015). The drainage area used in these computations was 22.8 square miles and the percentage of storage (combined water bodies and wetlands) from the National Wetland Inventory was 13.22%.

The table below compares the hydrology from the 1985 FIS and USGS Regression Equations.

Comparison of FIS and USGS Regression Equations				
	1984 FIS TR-20 Program	USGS Regression Equations	Numerical Difference	% Difference
Drainage Area(mi^2)	22.1	22.8	0.7	103%
Q10 (ft^3/s)	550	1014	464	184%
Q50 (ft^3/s)	1,160	1488	328	128%
Q100 (ft^3/s)	1,370	1710	340	125%
Q500 (ft^3/s)	2,160	2250	90	104%

Although the drainage areas are almost identical, discharge flows per USGS Equations used by the Maine Department of Transportation Office of the Environment – Hydrology Section range from 104% to 184% greater than the 1984 FIS flows. Since the hydrology developed by the MaineDOT reflects more current research and understanding of local hydrology in Maine, the hydrology developed by the Office of Environment – Hydrology Section is recommended over the 1984 FIS.

The following flows were used in the hydraulic analysis:

SUMMARY		
Drainage Area	22.80	mi^2
Q1.1	276	ft^3/s
Q10	1014	ft^3/s
Q25	1281	ft^3/s
Q50	1488	ft^3/s
Q100	1710	ft^3/s
Q500	2250	ft^3/s

Reported by: DFB
Date: November 16, 2017

Note: All elevations based on North American Vertical Datum (NAVD) of 1988.

HYDRAULIC REPORT

The hydraulic performance of the existing bridge and the replacement bridge was analyzed using HEC RAS version 5.0.3 software developed by the Hydrologic Engineering Center for the U.S. Army Corps of Engineers.

Stream cross sections created from recent survey were used to develop a model of the Great Works River in the vicinity of the project. A plan view of the cross-section locations is included in Appendix E – Hydraulics Data. The streambed consists of gravel, cobbles, and a scattering of small boulders. The banks of the brook are lined with medium brush and small trees. Manning's n values of 0.040 and 0.070 were used to model the streambed channel and overbank roughness. Bedrock is exposed under the existing bridge during low flows. A scour analysis was not performed.

Steady flow analyses were performed using a normal depth boundary condition with a downstream slope of 0.0028. The downstream slope was calculated starting at a point 25' beyond the scour hole (to normalize streambed conditions) and ending at a point 125' beyond the scour hole, which is approximately the end of available stream survey data. As a check, a second downstream slope was calculated to be 0.0077 using the stream bed elevations at the Card Mill Dam and at the State Route 4 Bridge from FIS Flood Profile (see Appendix – E). There was no change in the resulting headwater elevations when the HEC RAS model was rerun indicating that the relatively flat downstream slope typical of this reach of the Great Works River had little sensitivity on the HEC RAS model.

The HEC RAS model was calibrated with 1985 Flood Insurance Study (FIS) (see Appendix E for Flood Profile). The HEC RAS elevations are based on the North American Vertical Datum (NAVD) 1988 while the 1984 FIS elevations referenced the National Geodetic Vertical Datum of 1929 (NGVD). To provide an accurate comparison, FIS elevations were converted to NAVD 1988 by subtracting the appropriate shift (0.705') determined from the NGS Vertcon program. The table below summarizes the Q500, Q100, and Q50 headwater elevations from the HEC RAS and FIS models.

Comparison of FIS and HEC RAS Headwater Elevations				
Flow	FIS Elevations NGVD 1929	FIS Elevations converted to NAVD 1988 using 0.705' Datum Shift	HEC RAS Elevations Based on NAVD 1988	Difference
Q500	145.40'	144.70'	145.40'	0.71'
Q100	143.10'	142.40'	143.70'	1.31'
Q50	142.50'	141.80'	142.90'	1.11'

The table shows that the headwater elevations computed from the HEC RAS model were slightly higher than those obtained from the 1984 FIS. The slightly higher HEC RAS headwater elevations can be attributed in part to the following:

- The FIS water-surface elevations were computed using lower peak discharge flows as noted in the Hydrology Report.
- The FIS model considered the three dams along the Great Works River in North Berwick. The FIS noted that the dams "had not been designed for flood control in the community, but they do serve to reduce peak flows downstream". In contrast, the simplified HEC RAS model assumed unobstructed flow by only modeling the river in the immediate vicinity of the bridge and neglecting the dam located 200' upstream, which could impede flow and reduce water surface elevations at the bridge.

Acknowledging the above differences, the HEC RAS model appears to correlate well to available hydraulic information and provide an adequate, slightly conservative representation of the bridge hydraulics.

EXISTING BRIDGE

The existing bridge consists of vertical stacked stone abutments and closely spaced steel beams and a timber deck. The water way opening is approximately 23 feet wide and 8 feet high. The existing bridge constricts the stream which has a calculated and measured bankfull width of 40 feet. Freeboard is 0.14 feet at Q50 and the water surface is above the bottom flange of the upstream beam at Q100. The low chord elevation is approximately 143.0 feet. The Flood Profile in the Flood Insurance Study dated 1984 for the Town of North Berwick indicates a Q100 elevation of approximately 143.0 (Refer to Appendix E). The existing bridge has outlet velocities of 13.0 ft/s and 13.6 ft/s at Q50 and Q100 flows.

RECOMMENDED REPLACEMENT BRIDGE

The recommended replacement bridge will be located approximately 40 feet downstream of the existing bridge. The detail build substructure options include GRS-IBS or cast in place spread footings with cantilever wall abutments on bedrock. The detail build superstructure options include NEXT beams or prefabricated galvanized steel rolled beams with a cast in place concrete deck. The water way opening will be approximately 41 feet wide and 8 feet high. The 65% larger opening will increase freeboard to 2.3 feet and 1.9 feet at Q50 and Q100 flows and will reduce outlet velocities from 13.0 ft/s to 8.4 ft/s and from 13.6 ft/s to 9.0 ft/s at Q50 and Q100 flows. The headwater elevations will be decreased from 142.9 feet and 143.7 feet to 140.2 and 140.7 feet at Q50 and Q100 flows.

Riprap is recommended to be placed around the proposed abutments up to a minimum of the Q50 Elevation of 140.2 feet.

SUMMARY

		Existing Structure	Recommended Structure
		26' Single Span Steel	48' Single Span Steel
Total Area of Waterway Opening	ft^2	185	303
Headwater elevation @ $Q_{1.1}$	ft	137.7	137.3
Headwater elevation @ Q_{10}	ft	141.2	139.2
Headwater elevation @ Q_{25}	ft	142.2	139.8
Headwater elevation @ Q_{50}	ft	142.9	140.2
Headwater elevation @ Q_{100}	ft	143.7	140.7
Headwater elevation @ Q_{500}	ft	145.4	141.7
Freeboard @ Q_{50}	ft	0.14	2.25
Freeboard @ Q_{100}	ft	0	1.87
Outlet Velocity @ $Q_{1.1}$	ft/s	4.0	3.5
Outlet Velocity @ Q_{10}	ft/s	10.4	7.1
Outlet Velocity @ Q_{25}	ft/s	12.3	7.9
Outlet Velocity @ Q_{50}	ft/s	13.0	8.4
Outlet Velocity @ Q_{100}	ft/s	13.6	9.0
Outlet Velocity @ Q_{500}	ft/s	14.9	10.2

Reported by: Jack Burgess
Date: November 30, 2018

Note: All elevations based on North American Vertical Datum (NAVD) of 1988.

Appendix

Hydraulic Data

WIN:	22336.00	**Project Name:**	North Berwick 22336 Staples Br 1238
Town:	North Berwick	**Stream Name:**	Great Works River
Route No.	Card Mill Road	**Bridge Name:**	Staples Bridge
Asset ID:	1238	**Analysis by:**	DFB
Lat:	43.3167 **Long:** -70.74376	**Date:**	11/16/2017

Peak Flow Calculations by USGS Regression Equations (Hodgkins, 1999 & Lombard/Hodgkins, 2015)

Enter data in blue cells only!

	km²	mi²	ac	***Enter data in [mi²]***
A	59.05	22.80	14592.0	Watershed Area *DRNAREA*
W	7.81	3.0	1929.1	Wetlands area (by NWI)

P_c	356759	4805503	watershed centroid (E, N; UTM 19N; meters)
County	York		*choose county from drop-down menu*
pptA	46.7		mean annual precipitation (inches; by look-up)
SG	0.34		sand & gravel aquifer as decimal fraction of watershed A

A (km²)	59.05	**Conf Lvl**	0.67
W (%)	13.22		NWI Wetlands % *STORNWI*

Ret Pd	**Peak Flow Estimate**			
T (yr)	**Lower**	**Q_T (m^3/s)**	**Upper**	**Q_T (ft^3/s)**
1.1		7.82		276.0
2		15.20		536.6
5		23.02		812.9
10		28.72		1014.1
25		36.28		1281.1
50		42.15		1488.2
100		48.43		1709.9
500		63.71		2249.7

Worksheet prepared by:
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Environmental Office
Maine Dept. Transportation
Augusta, ME 04333-0016
207-557-1052
Charles.Hebson@maine.gov

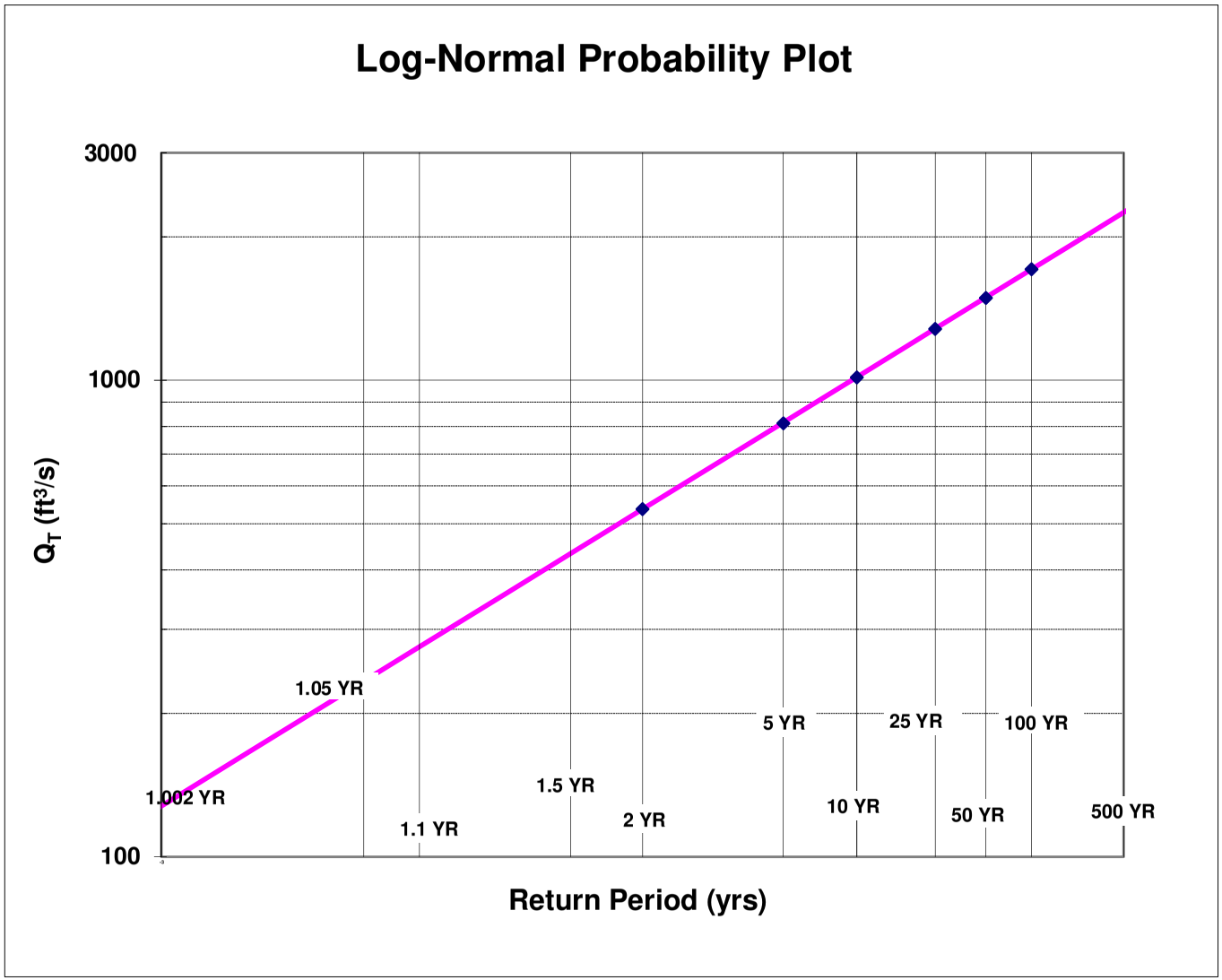
ver. 2017 Jun. 09

References:

Hodgkins, G.A., 1999.
Estimating the magnitude of peak flows for streams in Maine for selected recurrence intervals
WRIR 99-4008, USGS Augusta, ME

Lombard, P.J. & G.A. Hodgkins, 2015.
Peak flow regression equations for small, ungaged streams in Maine - Comparing map-based to field-based variables
SIR 2015-4059, USGS, Augusta, ME

$Q_T = b \times A^a \times 10^{-wW}$


Log-Normal Probability Plot
3000
1000
100
Q_T (ft³/s)
1.002 YR
1.05 YR
1.1 YR
1.5 YR
2 YR
5 YR
10 YR
25 YR
50 YR
100 YR
500 YR
Return Period (yrs)

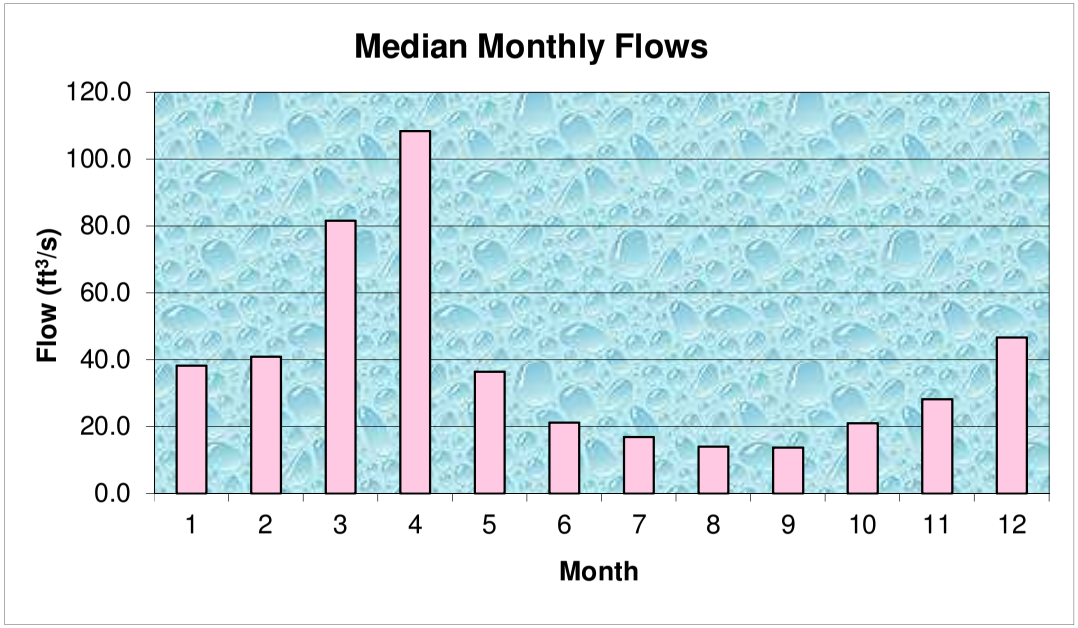
WIN:	22336.00	**Project Name:**	North Berwick 22336 Staples Br 1238
Town:	North Berwick	**Stream Name:**	Great Works River
Route No.	Card Mill Road	**Bridge Name:**	Staples Bridge
Asset ID:	1238	**Analysis by:**	DFB
Lat:	43.31673 **Long:** -70.74376	**Date:**	11/16/2017

DO NOT ENTER ANY DATA ON THIS PAGE; EVERYTHING IS CALCULATED

MAINE MONTHLY MEDIAN FLOWS and HYDRAULIC GEOMETRY BY USGS REGRESSION EQUATIONS (2004, 2013)

	Value	Variable	Explanation
	22.80	*A*	Area (mi^2)
356759.3	4805503	P_c	Watershed centroid (E,N; UTM; Zone 19; meters)
	31.38	*DIST*	Distance from Coastal reference line (mi)
	46.7	*pptA*	Mean Annual Precipitation (inches)
	0.34	*SG*	Sand & Gravel Aquifer (decimal fraction of watershed area)

Month	Q_{median} (ft3/s)	(m^3/s)
Jan	**38.25**	1.0838
Feb	**40.91**	1.1593
Mar	**81.58**	2.3117
Apr	**108.43**	3.0727
May	**36.41**	1.0318
Jun	**21.22**	0.6015
Jul	**16.95**	0.4805
Aug	**14.06**	0.3986
Sep	**13.71**	0.3886
Oct	**21.04**	0.5961
Nov	**28.21**	0.7995
Dec	**46.70**	1.3235



Q_{bf}	**138.4**	
ann avg	**47.3**	
ann med	**25.7**	
$Q_{1.002}$	**127.9**	
$Q_{1.01}$	**168.0**	
$Q_{1.05}$	**233.6**	
Q_{bf}	**279.2**	assume v = 4ft/s

W_{bf}	**40.6**	estimated bankfull width (ft)
d_{bf}	**1.7**	estimated bankfull depth (ft)
A_{bf}	**67.0**	estimated bankfull flow area (ft^2)

References

Dudley, R.W., 2013. FY2013 Progress Report - Phase 1 …, USFWS QRP Project

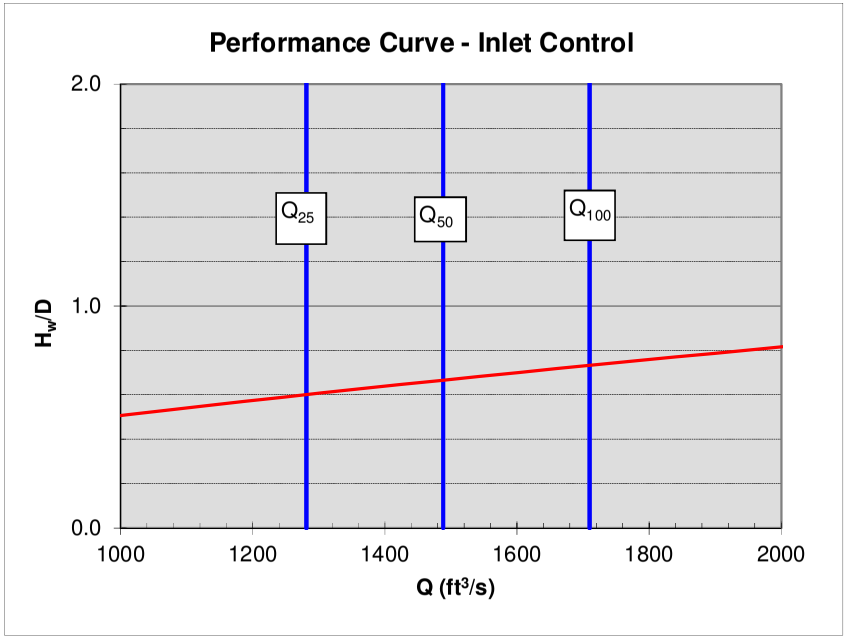
Dudley, R.W., 2004. Estimating Monthly Streamflows … , SIR 2004-5026

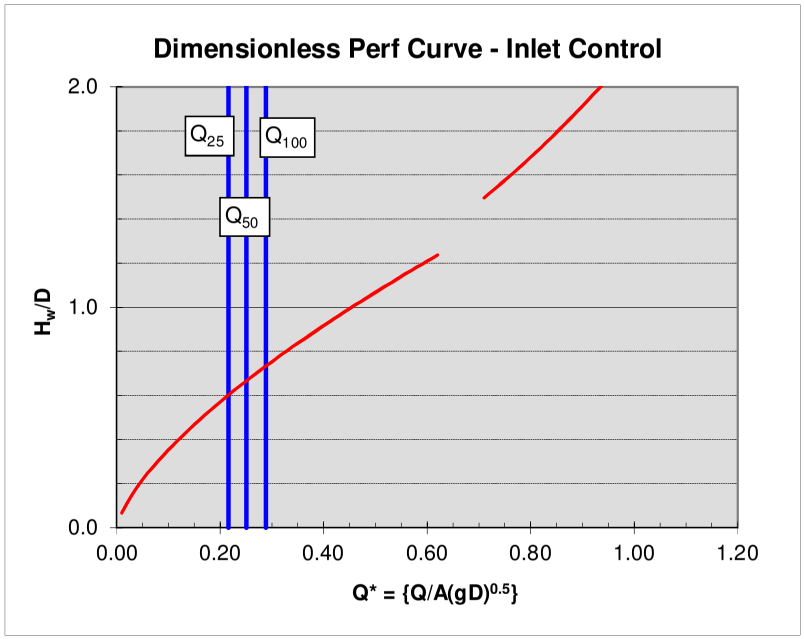
NOTE: ***This page is for preliminary sizing only.***
Final design should be done with HY8 or HDS-5

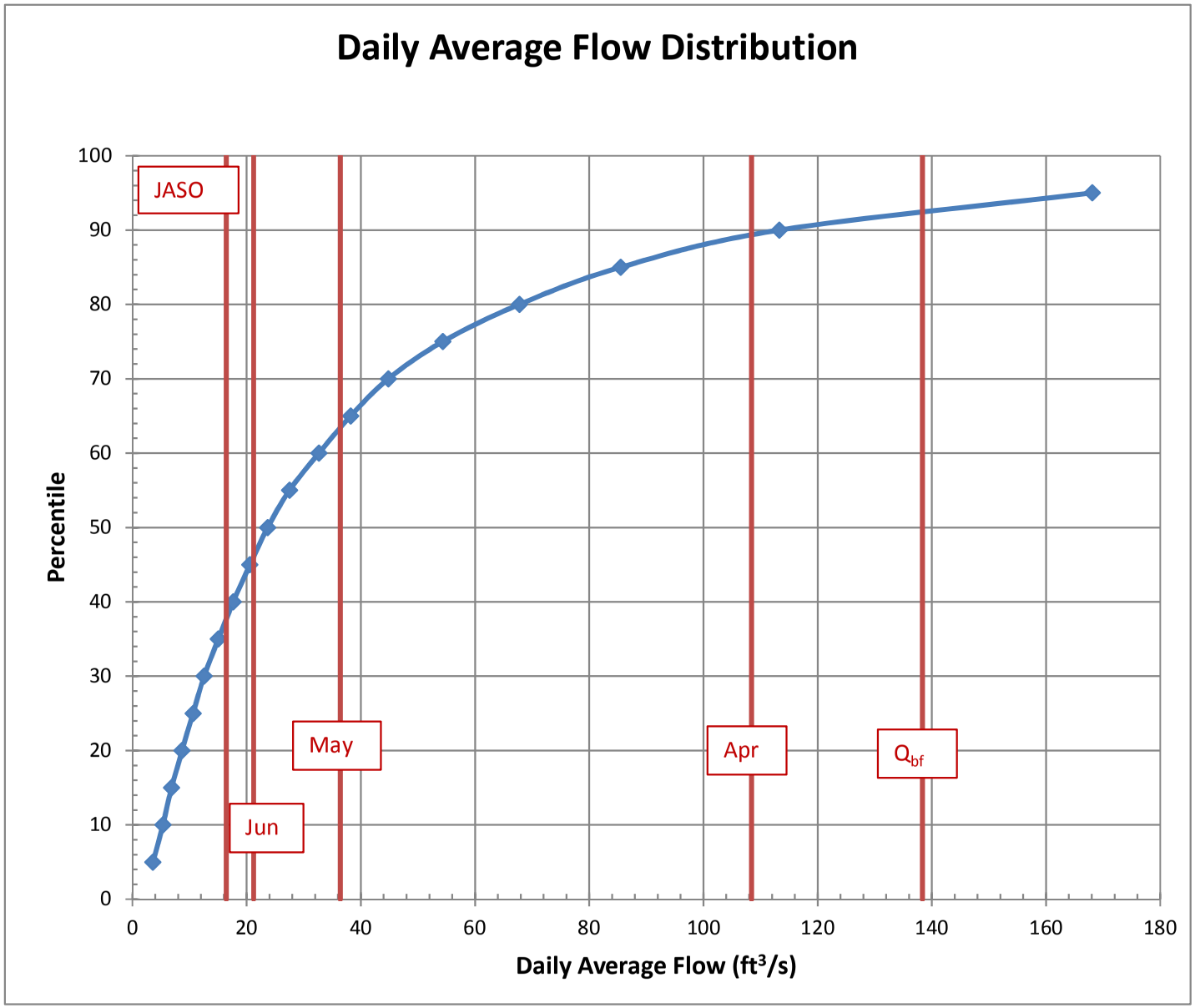
Preliminary Culvert Sizing - Round & Box Culverts

Shape:	Box						
Type:	Box 0 ww		Q_{25}	1281.1			
D or R (ft)	15		Q_{50}	1488.2	trial D / R =	15.3	
w (ft)	*18*	*box width*	Q_{100}	1709.9	trial w: BFW =	40.6	
Slope (ft/ft)	0.02						
A (ft^2)	270.00						
g (ft/s^2)	32.2						

Note:
culvert dimensions are for open flow area; adjust for lost capacity due to embedding / backfilling (min {2' / 25% rise} embedment)

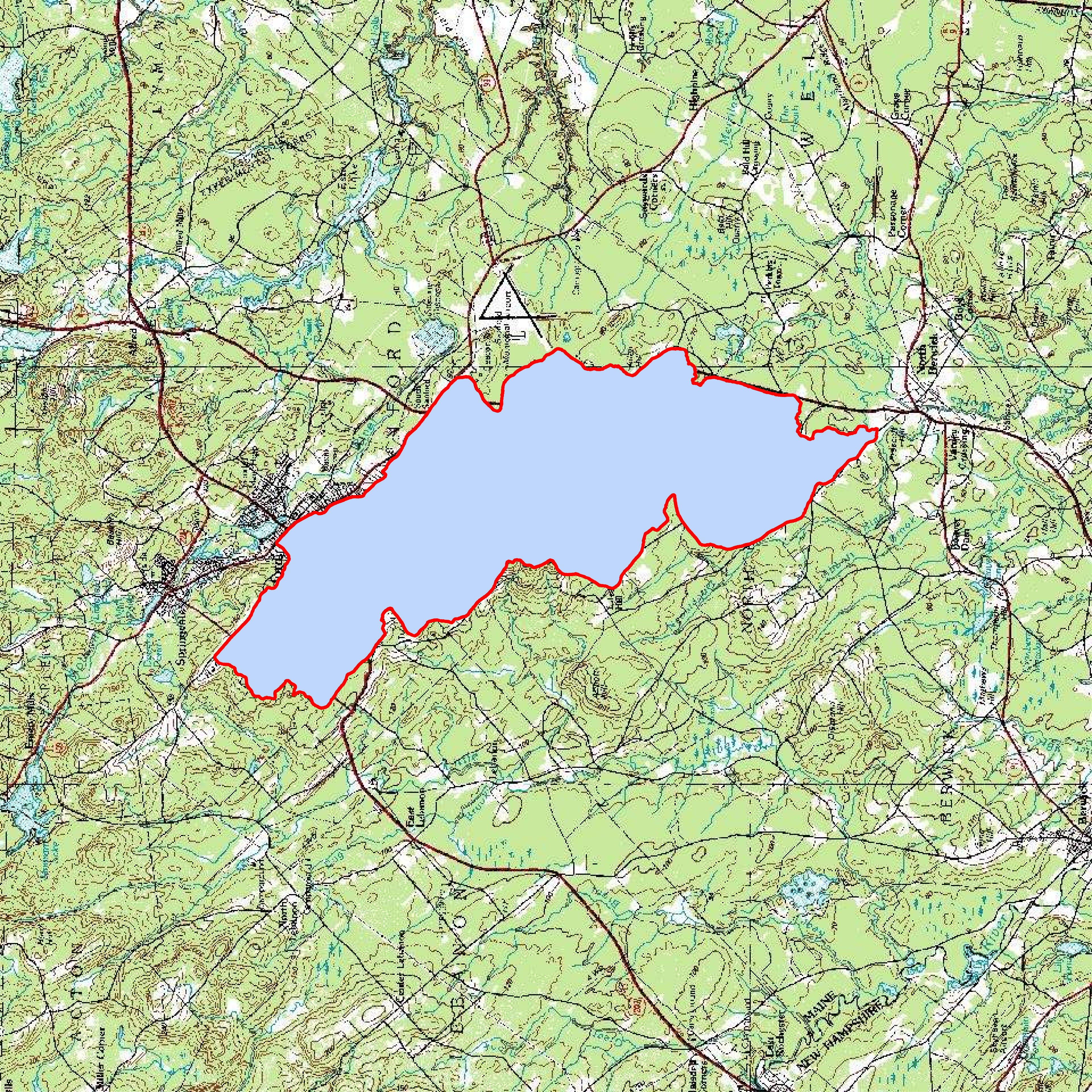






Daily Avg Flow Dist		
A_{ws} = (mi^2)		22.8
Q (ft^3/s)		
Pctl	**Median**	**84th pctl**
5	3.59	5.78
10	5.33	8.02
15	6.85	10.01
20	8.68	12.14
25	10.62	14.23
30	12.56	16.20
35	15.05	18.52
40	17.65	21.30
45	20.57	24.08
50	23.68	28.43
55	27.50	33.09
60	32.66	38.84
65	38.21	45.25
70	44.82	52.80
75	54.34	63.49
80	67.77	75.80
85	85.51	97.14
90	113.27	130.44
95	168.10	202.84

Q_{bf}	138.4
$Q_{1.002}$	127.9
$Q_{1.1}$	276.0
Q_2	536.6


MAINE
NEW HAMPSHIRE

North berwick 22336 Staples Bridge 1238

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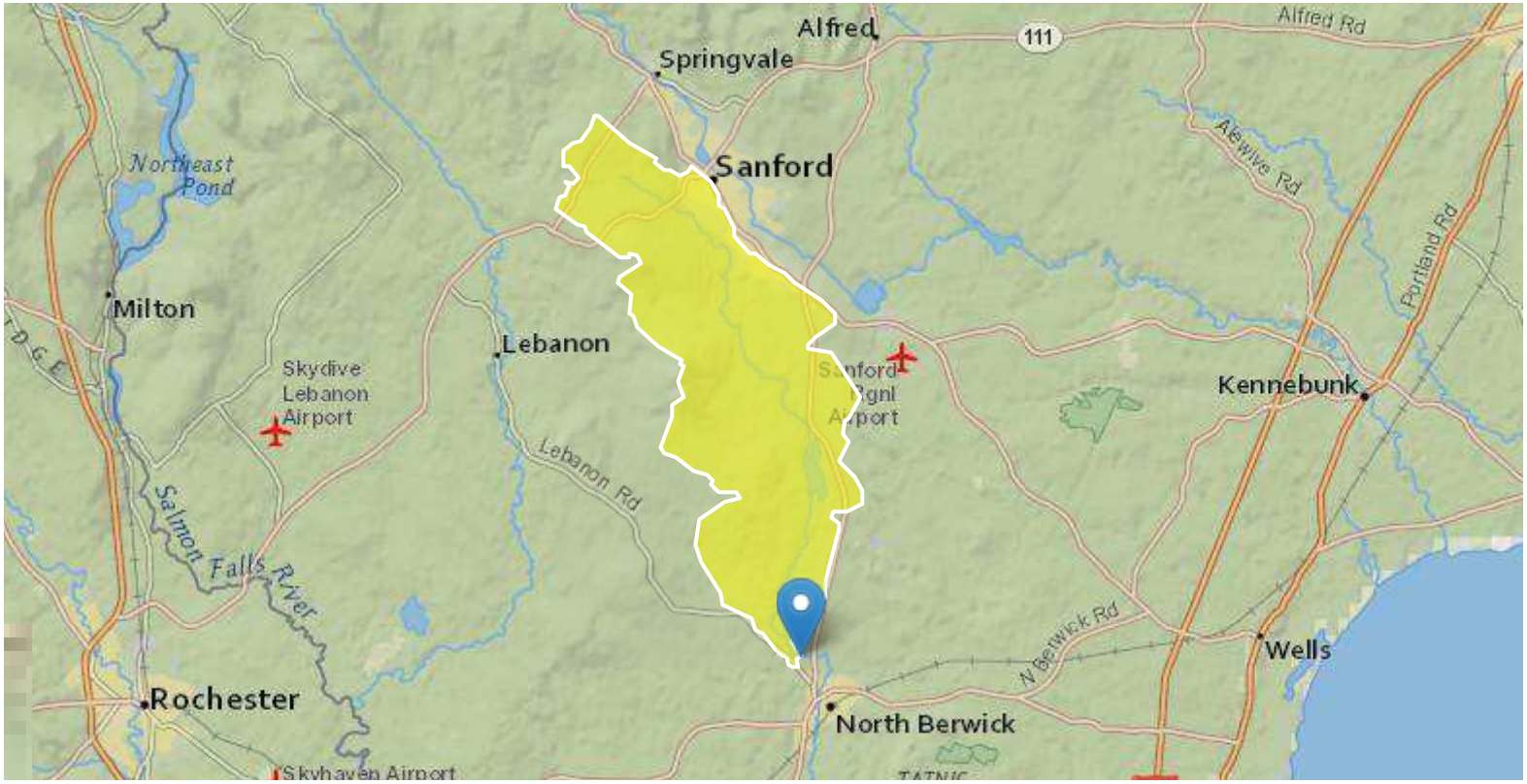


Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	22.8	square miles
STORNWI	Percentage of strorage (combined water bodies and wetlands) from the Nationa Wetlands Inventory	13.22	percent

Parameter Code	Parameter Description	Value	Unit
SANDGRAVAP	Percentage of land surface underlain by sand and gravel aquifers	34.43	percent
COASTDIST	Shortest distance from the coastline to the basin centroid	31	miles
BSLDEM10M	Mean basin slope computed from 10 m DEM	5.77	percent
LC06WATER	Percent of open water, class 11, from NLCD 2006	1.76	percent
SANDGRAVAF	Fraction of land surface underlain by sand and gravel aquifers	0.344	dimensionless
ELEV	Mean Basin Elevation	334.8	feet
CENTROIDX	Basin centroid horizontal (x) location in state plane coordinates	356759.27	
CENTROIDY	Basin centroid vertical (y) location in state plane units	4805502.77	
ELEVMAX	Maximum basin elevation	873	feet
LC11DEV	Percentage of developed (urban) land from NLCD 2011 classes 21-24	13.6	percent
LC11IMP	Average percentage of impervious area determined from NLCD 2011 impervious dataset	3.15	percent
PRECIP	Mean Annual Precipitation	46.9	inches
STATSGOA	Percentage of area of Hydrologic Soil Type A from STATSGO	46.4	percent

Bankfull Statistics Parameters [Central and Coastal Bankfull 2004 5042]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	22.8	square miles	2.92	298

Bankfull Statistics Flow Report [Central and Coastal Bankfull 2004 5042]

Statistic	Value	Unit
Bankfull Streamflow	138	ft^3/s
Bankfull Width	39	ft
Bankfull Depth	1.72	ft
Bankfull Area	67	ft^2

Bankfull Statistics Citations

Dudley, R.W.,2004, Hydraulic-Geometry Relations for Rivers in Coastal and Central Maine: U.S. Geological Survey Scientific Investigations Report 2004-5042, 30 p (http://pubs.usgs.gov/sir/2004/5042/pdf/sir2004-5042.pdf)

Peak-Flow Statistics Parameters [Statewide Peak Flow Full GT 12sqmi WRI 99 4008]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	22.8	square miles	0.93	1653
STORNWI	Percentage of Storage from NWI	13.22	percent	0.7	26.7

Peak-Flow Statistics Flow Report [Statewide Peak Flow Full GT 12sqmi WRI 99 4008]

PII: Prediction Interval-Lower, PIu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PII	PIu	SE	SEp	Equiv. Yrs.
2 Year Peak Flood	537	ft^3/s	299	962	35.1	35.1	1.8
5 Year Peak Flood	813	ft^3/s	449	1470	36.1	36.1	2.5
10 Year Peak Flood	1010	ft^3/s	551	1870	36.8	36.8	3.2
25 Year Peak Flood	1280	ft^3/s	679	2420	38.6	38.6	4.1
50 Year Peak Flood	1490	ft^3/s	772	2870	39.9	39.9	4.8
100 Year Peak Flood	1710	ft^3/s	868	3370	41.2	41.2	5.4
500 Year Peak Flood	2250	ft^3/s	1080	4690	44.9	44.9	6.4

Peak-Flow Statistics Citations

Hodgkins, G. A.,1999, Estimating the Magnitude of Peak Flows for Streams in Maine for Selected Recurrence Intervals: U.S. Geological Survey Water-Resources Investigations Report 99-4008, 45 p. (http://me.water.usgs.gov/99-4008.pdf)

Low-Flow Statistics Parameters [Statewide LowFlow SIR 2004 5026]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	22.8	square miles	9.79	1418
SANDGRAVAF	Fraction of Sand and Gravel Aquifers	0.344	dimensionless	0	0.455

Low-Flow Statistics Flow Report [Statewide LowFlow SIR 2004 5026]

PII: Prediction Interval-Lower, Plu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	SE	SEp	Equiv. Yrs.
7 Day 10 Year Low Flow	6.74	ft^3/s	44.3	44.3	2.9

Low-Flow Statistics Citations

Dudley, R.W.,2004, Estimating Monthly, Annual, and Low 7-Day, 10-Year Streamflows for Ungaged Rivers in Maine: U.S. Geological Survey Scientific Investigations Report 2004-5026, 22 p. (http://water.usgs.gov/pubs/sir/2004/5026/pdf/sir2004-5026.pdf)

Flow-Duration Statistics Parameters [Statewide Annual SIR 2015 5151]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	22.8	square miles	14.9	1419
SANDGRAVAF	Fraction of Sand and Gravel Aquifers	0.344	dimensionless	0	0.212
ELEV	Mean Basin Elevation	334.8	feet	239	2120

Flow-Duration Statistics Disclaimers [Statewide Annual SIR 2015 5151]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Flow-Duration Statistics Flow Report [Statewide Annual SIR 2015 5151]

Statistic	Value	Unit
1 Percent Duration	9.59	ft^3/s
5 Percent Duration	9.22	ft^3/s
10 Percent Duration	10.2	ft^3/s
25 Percent Duration	16.5	ft^3/s
50 Percent Duration	35.7	ft^3/s
75 Percent Duration	68.2	ft^3/s
90 Percent Duration	120	ft^3/s
95 Percent Duration	171	ft^3/s
99 Percent Duration	382	ft^3/s

Flow-Duration Statistics Citations

Dudley, R.W.,2015, Regression equations for monthly and annual mean and selected percentile streamflows for ungaged rivers in Maine: U.S. Geological Survey Scientific Investigations Report 2015–5151, 35 p. (http://dx.doi.org/10.3133/sir20155151)

Annual Flow Statistics Parameters [Statewide Annual SIR 2015 5151]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	22.8	square miles	14.9	1419
SANDGRAVAF	Fraction of Sand and Gravel Aquifers	0.344	dimensionless	0	0.212
ELEV	Mean Basin Elevation	334.8	feet	239	2120

Annual Flow Statistics Disclaimers [Statewide Annual SIR 2015 5151]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Annual Flow Statistics Flow Report [Statewide Annual SIR 2015 5151]

Statistic	Value	Unit
Mean Annual Flow	56.9	ft^3/s

Annual Flow Statistics Citations

Dudley, R.W.,2015, Regression equations for monthly and annual mean and selected percentile streamflows for ungaged rivers in Maine: U.S. Geological Survey Scientific Investigations Report 2015–5151, 35 p. (http://dx.doi.org/10.3133/sir20155151)

FLOOD INSURANCE STUDY

TOWN OF NORTH BERWICK, MAINE
YORK COUNTY

AUGUST 1, 1984

Federal Emergency Management Agency

COMMUNITY NUMBER - 230197

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER SURFACE ELEVATION			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
					(FEET NGVD)			
Great Works River								
A	2,305	224	2,105	2.5	105.3	105.3	106.3	1.0
B	2,345	247	1,303	2.8	105.4	105.4	106.4	1.0
C	7,305	245	2,600	1.3	108.8	108.8	109.8	1.0
D	8,725	385	3,834	0.9	109.6	109.6	110.6	1.0
E	9,825	45	418	5.7	111.1	111.1	112.1	1.0
F	10,025	39	359	6.6	111.8	111.8	112.8	1.0
G	10,125	58	417	5.7	112.0	112.0	113.0	1.0
H	10,425	107	933	2.5	119.3	119.3	120.3	1.0
I	10,555	203	1,399	1.7	125.7	125.7	126.7	1.0
J	17,535	63	383	3.7	130.5	130.5	131.5	1.0
K	19,680	87	527	2.7	144.4	144.4	145.4	1.0
L	19,805	177	1,587	0.9	152.8	152.8	153.8	1.0
M	27,960	89	345	4.0	171.0	171.0	172.0	1.0
N	28,110	74	774	1.8	178.6	178.6	179.6	1.0
O	34,465	76	490	2.6	187.4	187.4	188.4	1.0
P	39,625	77	391	3.2	200.5	200.5	201.5	1.0
Q	47,565	281[2]	2,313	1.0	210.3	210.3	211.3	1.0
R	56,250	85[2]	472	4.1	219.1	219.1	220.1	1.0
S	56,335	31[2]	207	9.4	219.2	219.2	220.2	1.0
T	56,500	56[2]	516	3.8	220.9	220.9	221.9	1.0

[1]Feet from corporate limits

[2]This width extends beyond corporate limits

TABLE 3

FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF NORTH BERWICK, ME

(YORK CO.)

FLOODWAY DATA

GREAT WORKS RIVER

REACH 2
ZONE A5

CONFLUENCE OF WEST BROOK

STATE ROUTE 4

CARDWILL ROAD

CARDWILL DAM

ELEVATION IN FEET

170
160
150
140
130
120
110

Q500 - 145.4'
Q100 - 143.1'
Q50 - 142.5'

137.0'

Slope = (137'-121.2')/(19700'-17,600') = 0.0077 ft/ft

121.2'

LEGEND

- 500 YEAR FLOOD
- 100 YEAR FLOOD
- 50 YEAR FLOOD
- 10 YEAR FLOOD
- STREAM BED
- CROSS SECTION LOCATION

12 13 14 15 16 17 18 19 20 21 22 23 24 25

STREAM DISTANCE IN THOUSANDS OF FEET FROM CORPORATE LIMITS

17,650'

19,700'

J K L

K&E 19 1284 9-83 A1766

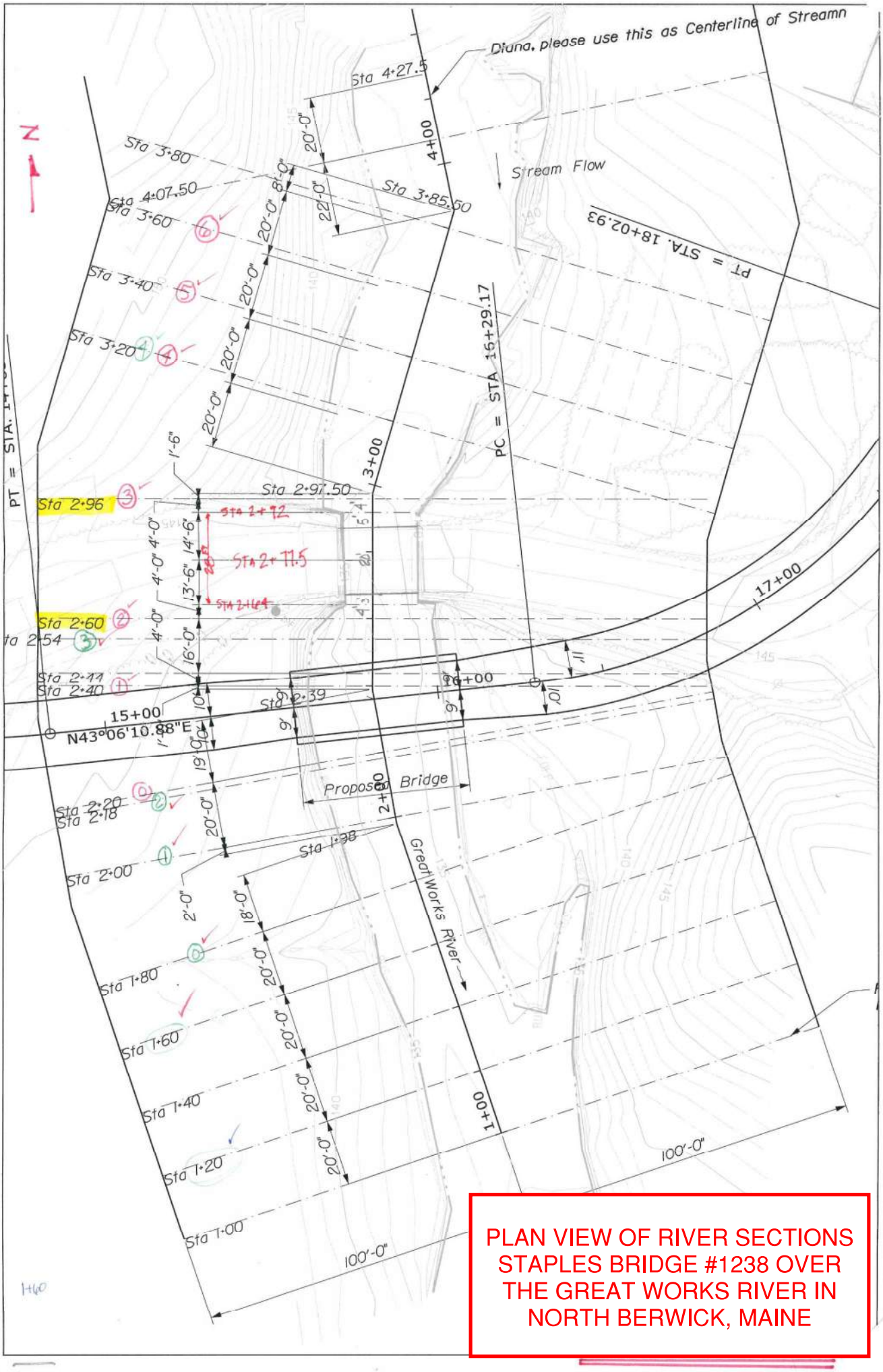
FLOOD PROFILES

GREAT WORKS RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

TOWN OF NORTH BERWICK, ME
(YORK CO.)

02P


Diana, please use this as Centerline of Streamn
N
Sta 4+27.5
Sta 3+80
Sta 4+07.50
Sta 3+60
Sta 3+40
Sta 3+20
Sta 3+85.50
Stream Flow
PT = STA. 18+02.93
PC = STA 16+29.17
PT = STA. 14+
4+00
3+00
2+00
1+00
17+00
16+00
15+00
Sta 2+96
Sta 2+97.50
Sta 2+72
Sta 2+77.5
Sta 2+82.4
Sta 2+60
Sta 2+54
Sta 2+44
Sta 2+40
Sta 2+39
N43°06'10.88"E
Proposed Bridge
Sta 2+20
Sta 2+18
Sta 2+00
Sta 1+98
Great Works River
Sta 1+80
Sta 1+60
Sta 1+40
Sta 1+20
Sta 1+00
20'-0"
22'-0"
8'-0"
1'-6"
4'-0"
14'-6"
13'-6"
16'-0"
19'-0"
2'-0"
18'-0"
100'-0"
PLAN VIEW OF RIVER SECTIONS
STAPLES BRIDGE #1238 OVER
THE GREAT WORKS RIVER IN
NORTH BERWICK, MAINE

HEC-RAS Plan: Existing River: Great Works Rive Reach: Staples Bridge

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)	
Staples Bridge	360	Q1.1	276.00	136.26	138.02		138.26	0.006844	3.91	71.55	54.44	0.57
Staples Bridge	360	Q2	536.60	136.26	139.37		139.58	0.002777	3.82	152.72	67.65	0.40
Staples Bridge	360	Q5	812.90	136.26	140.68		140.88	0.001625	3.78	250.49	80.84	0.33
Staples Bridge	360	Q10	1014.10	136.26	141.54		141.75	0.001266	3.79	324.20	89.13	0.30
Staples Bridge	360	Q25	1281.10	136.26	142.62		142.82	0.000990	3.82	425.14	99.37	0.27
Staples Bridge	360	Q50	1488.20	136.26	143.40		143.60	0.000863	3.86	509.59	118.56	0.26
Staples Bridge	360	Q100	1709.90	136.26	144.21		144.41	0.000746	3.87	614.30	139.97	0.25
Staples Bridge	360	Q500	2249.70	136.26	146.06		146.24	0.000529	3.77	887.60	149.73	0.22
Staples Bridge	340	Q1.1	276.00	136.34	137.95		138.12	0.004698	3.29	83.90	56.45	0.48
Staples Bridge	340	Q2	536.60	136.34	139.36		139.52	0.001925	3.23	168.87	64.50	0.34
Staples Bridge	340	Q5	812.90	136.34	140.68		140.84	0.001208	3.30	258.94	72.24	0.29
Staples Bridge	340	Q10	1014.10	136.34	141.54		141.72	0.000981	3.38	323.96	78.98	0.27
Staples Bridge	340	Q25	1281.10	136.34	142.61		142.79	0.000800	3.47	415.17	91.77	0.25
Staples Bridge	340	Q50	1488.20	136.34	143.39		143.58	0.000709	3.54	498.79	122.86	0.24
Staples Bridge	340	Q100	1709.90	136.34	144.20		144.39	0.000610	3.53	606.09	135.13	0.22
Staples Bridge	340	Q500	2249.70	136.34	146.06		146.23	0.000450	3.51	865.50	146.09	0.20
Staples Bridge	320	Q1.1	276.00	135.82	137.85		138.03	0.004223	3.40	81.29	47.72	0.46
Staples Bridge	320	Q2	536.60	135.82	139.29		139.48	0.002128	3.52	153.50	53.80	0.36
Staples Bridge	320	Q5	812.90	135.82	140.61		140.81	0.001439	3.68	230.89	63.47	0.31
Staples Bridge	320	Q10	1014.10	135.82	141.47		141.69	0.001197	3.79	288.68	69.83	0.29
Staples Bridge	320	Q25	1281.10	135.82	142.54		142.77	0.001006	3.93	368.16	87.97	0.28
Staples Bridge	320	Q50	1488.20	135.82	143.32		143.56	0.000890	4.00	456.20	135.65	0.26
Staples Bridge	320	Q100	1709.90	135.82	144.15		144.37	0.000749	3.95	569.07	137.65	0.25
Staples Bridge	320	Q500	2249.70	135.82	146.02		146.22	0.000540	3.86	837.23	150.92	0.22
Staples Bridge	296	Q1.1	276.00	134.93	137.73	136.74	137.93	0.003590	3.62	76.30	36.93	0.43
Staples Bridge	296	Q2	536.60	134.93	139.10	137.47	139.39	0.002766	4.30	124.85	42.53	0.40
Staples Bridge	296	Q5	812.90	134.93	140.37	138.11	140.73	0.002373	4.78	170.01	47.69	0.39
Staples Bridge	296	Q10	1014.10	134.93	141.20	138.50	141.60	0.002199	5.08	199.74	51.05	0.38
Staples Bridge	296	Q25	1281.10	134.93	142.21	139.00	142.67	0.002004	5.42	236.30	58.71	0.37
Staples Bridge	296	Q50	1488.20	134.93	142.95	139.39	143.45	0.001897	5.66	262.83	88.41	0.37
Staples Bridge	296	Q100	1709.90	134.93	143.71	139.74	144.25	0.001803	5.89	290.06	153.93	0.37
Staples Bridge	296	Q500	2249.70	134.93	145.43	140.59	146.06	0.001636	6.39	352.10	171.12	0.36
Staples Bridge	278		Bridge									
Staples Bridge	260	Q1.1	276.00	133.05	137.26	135.79	137.44	0.002113	3.39	82.07	34.04	0.35
Staples Bridge	260	Q2	536.60	133.05	137.92	136.63	138.36	0.003970	5.33	101.87	37.02	0.50
Staples Bridge	260	Q5	812.90	133.05	138.47	137.35	139.22	0.005593	6.97	118.34	40.26	0.61
Staples Bridge	260	Q10	1014.10	133.05	138.82	137.82	139.81	0.006559	7.99	129.05	42.38	0.67
Staples Bridge	260	Q25	1281.10	133.05	139.23	138.38	140.55	0.007790	9.23	141.23	44.78	0.74
Staples Bridge	260	Q50	1488.20	133.05	139.51	138.79	141.09	0.008725	10.14	149.49	46.41	0.79
Staples Bridge	260	Q100	1709.90	133.05	139.77	139.22	141.66	0.009736	11.07	157.34	47.96	0.84
Staples Bridge	260	Q500	2249.70	133.05	140.26	140.16	143.00	0.012544	13.33	172.13	50.87	0.97
Staples Bridge	240	Q1.1	276.00	134.49	137.20		137.38	0.003658	3.45	80.52	42.44	0.44
Staples Bridge	240	Q2	536.60	134.49	137.86		138.24	0.005158	4.96	110.98	51.76	0.54
Staples Bridge	240	Q5	812.90	134.49	138.45		139.01	0.005809	6.04	144.96	63.04	0.60
Staples Bridge	240	Q10	1014.10	134.49	138.87		139.52	0.005842	6.58	172.85	70.97	0.61
Staples Bridge	240	Q25	1281.10	134.49	139.38		140.13	0.005755	7.14	211.57	80.70	0.62
Staples Bridge	240	Q50	1488.20	134.49	139.75		140.57	0.005621	7.47	243.06	87.82	0.62
Staples Bridge	240	Q100	1709.90	134.49	140.13		141.00	0.005447	7.77	278.05	95.11	0.62
Staples Bridge	240	Q500	2249.70	134.49	141.00		141.95	0.005005	8.31	367.64	111.62	0.61
Staples Bridge	218	Q1.1	276.00	134.66	137.10		137.29	0.004093	3.57	80.13	57.10	0.46
Staples Bridge	218	Q2	536.60	134.66	137.75		138.12	0.005348	5.00	120.50	65.26	0.56
Staples Bridge	218	Q5	812.90	134.66	138.36		138.87	0.005562	5.90	162.50	71.36	0.59
Staples Bridge	218	Q10	1014.10	134.66	138.80		139.37	0.005375	6.33	194.75	76.47	0.59
Staples Bridge	218	Q25	1281.10	134.66	139.33		139.98	0.005200	6.83	237.65	86.20	0.60
Staples Bridge	218	Q50	1488.20	134.66	139.71		140.42	0.005025	7.13	272.32	93.32	0.59
Staples Bridge	218	Q100	1709.90	134.66	140.11		140.85	0.004830	7.39	310.55	100.60	0.59
Staples Bridge	218	Q500	2249.70	134.66	140.99		141.81	0.004395	7.88	407.10	116.97	0.58
Staples Bridge	200	Q1.1	276.00	134.61	136.96		137.20	0.005599	3.99	78.00	67.58	0.53
Staples Bridge	200	Q2	536.60	134.61	137.60		138.01	0.006694	5.37	123.42	73.70	0.61
Staples Bridge	200	Q5	812.90	134.61	138.26		138.76	0.006097	6.04	173.81	78.47	0.61
Staples Bridge	200	Q10	1014.10	134.61	138.72		139.26	0.005665	6.40	210.76	84.02	0.60
Staples Bridge	200	Q25	1281.10	134.61	139.27		139.87	0.005246	6.79	259.41	91.70	0.59
Staples Bridge	200	Q50	1488.20	134.61	139.67		140.31	0.004977	7.04	297.19	97.25	0.59
Staples Bridge	200	Q100	1709.90	134.61	140.08		140.74	0.004729	7.27	337.72	102.87	0.58
Staples Bridge	200	Q500	2249.70	134.61	140.99		141.70	0.004189	7.68	436.85	112.43	0.56
Staples Bridge	180	Q1.1	276.00	134.56	136.42	136.41	136.98	0.020398	6.13	51.06	55.46	0.97
Staples Bridge	180	Q2	536.60	134.56	137.35		137.84	0.009515	6.02	116.74	74.95	0.72
Staples Bridge	180	Q5	812.90	134.56	138.12		138.62	0.006855	6.26	176.49	79.53	0.64
Staples Bridge	180	Q10	1014.10	134.56	138.61		139.14	0.006014	6.50	215.82	82.42	0.62
Staples Bridge	180	Q25	1281.10	134.56	139.18		139.75	0.005384	6.82	264.21	85.83	0.60
Staples Bridge	180	Q50	1488.20	134.56	139.59		140.19	0.005070	7.06	299.69	88.25	0.59
Staples Bridge	180	Q100	1709.90	134.56	140.00		140.64	0.004861	7.33	336.67	96.26	0.59
Staples Bridge	180	Q500	2249.70	134.56	140.90		141.61	0.004394	7.82	434.40	118.87	0.58
Staples Bridge	120	Q1.1	276.00	133.68	136.35	135.43	136.48	0.002801	2.96	95.20	52.79	0.38
Staples Bridge	120	Q2	536.60	133.68	137.25	135.99	137.48	0.002803	3.84	145.81	59.90	0.41
Staples Bridge	120	Q5	812.90	133.68	138.01	136.49	138.32	0.002800	4.51	193.81	66.85	0.42
Staples Bridge	120	Q10	1014.10	133.68	138.49	136.81	138.85	0.002801	4.91	226.77	71.22	0.43

HEC-RAS Plan: Existing River: Great Works Rive Reach: Staples Bridge (Continued)

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)	
Staples Bridge	120	Q25	1281.10	133.68	139.05	137.23	139.48	0.002803	5.37	268.75	76.44	0.44
Staples Bridge	120	Q50	1488.20	133.68	139.46	137.51	139.94	0.002801	5.68	300.40	80.15	0.45
Staples Bridge	120	Q100	1709.90	133.68	139.86	137.80	140.38	0.002804	5.98	333.26	83.82	0.46
Staples Bridge	120	Q500	2249.70	133.68	140.75	138.46	141.38	0.002801	6.63	412.10	93.67	0.47

HEC-RAS Plan: Existing River: Great Works Rive Reach: Staples Bridge

Reach	River Sta	Profile	E.G. Elev	W.S. Elev	Crit W.S.	Frctn Loss	C & E Loss	Top Width	Q Left	Q Channel	Q Right	Vel Chnl
			(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft/s)
Staples Bridge	320	Q1.1	138.03	137.85		0.09	0.01	47.72		276.00		3.40
Staples Bridge	320	Q2	139.48	139.29		0.06	0.03	53.80	0.07	536.04	0.49	3.52
Staples Bridge	320	Q5	140.81	140.61		0.04	0.04	63.47	4.57	804.16	4.17	3.68
Staples Bridge	320	Q10	141.69	141.47		0.04	0.05	69.83	12.88	992.15	9.06	3.79
Staples Bridge	320	Q25	142.77	142.54		0.03	0.07	87.97	23.78	1239.15	18.18	3.93
Staples Bridge	320	Q50	143.56	143.32		0.03	0.08	135.65	44.45	1416.76	27.00	4.00
Staples Bridge	320	Q100	144.37	144.15		0.03	0.10	137.65	110.14	1562.44	37.32	3.95
Staples Bridge	320	Q500	146.22	146.02		0.02	0.13	150.92	298.83	1890.41	60.46	3.86
Staples Bridge	296	Q1.1	137.93	137.73	136.74	0.02	0.11	36.93		276.00		3.62
Staples Bridge	296	Q2	139.39	139.10	137.47	0.02	0.28	42.53		536.60		4.30
Staples Bridge	296	Q5	140.73	140.37	138.11	0.02	0.40	47.69		812.90		4.78
Staples Bridge	296	Q10	141.60	141.20	138.50	0.02	0.47	51.05		1014.10		5.08
Staples Bridge	296	Q25	142.67	142.21	139.00	0.02	0.55	58.71		1281.10		5.42
Staples Bridge	296	Q50	143.45	142.95	139.39	0.02	0.61	88.41		1488.20		5.66
Staples Bridge	296	Q100	144.25	143.71	139.74	0.02	0.67	153.93		1709.90		5.89
Staples Bridge	296	Q500	146.06	145.43	140.59	0.02	0.81	171.12		2249.70		6.39
Staples Bridge	278 BR U	Q1.1	137.80	137.24	136.89	0.16	0.16	23.25		276.00		6.01
Staples Bridge	278 BR U	Q2	139.09	137.87	137.81	0.32	0.28	23.20		536.60		8.86
Staples Bridge	278 BR U	Q5	140.31	138.63	138.63	0.44	0.23	23.15		812.90		10.39
Staples Bridge	278 BR U	Q10	141.11	139.15	139.15	0.51	0.14	23.12		1014.10		11.22
Staples Bridge	278 BR U	Q25	142.10	139.81	139.81	0.59	0.02	23.07		1281.10		12.14
Staples Bridge	278 BR U	Q50	142.82	140.30	140.30	0.60	0.03	23.04		1488.20		12.75
Staples Bridge	278 BR U	Q100	143.56	140.79	140.79	0.61	0.03	23.01		1709.90		13.36
Staples Bridge	278 BR U	Q500	145.23	141.88	141.88	0.62	0.03	22.93		2249.70		14.68
Staples Bridge	278 BR D	Q1.1	137.48	137.23	135.80	0.01	0.03	22.07		276.00		3.99
Staples Bridge	278 BR D	Q2	138.49	137.83	136.74	0.02	0.11	22.03		536.60		6.52
Staples Bridge	278 BR D	Q5	139.48	138.27	137.58	0.03	0.23	22.00		812.90		8.83
Staples Bridge	278 BR D	Q10	140.20	138.52	138.13	0.04	0.35	21.98		1014.10		10.40
Staples Bridge	278 BR D	Q25	141.17	138.81	138.81	0.05	0.52	21.96		1281.10		12.34
Staples Bridge	278 BR D	Q50	141.92	139.31	139.31	0.05	0.51	21.93		1488.20		12.96
Staples Bridge	278 BR D	Q100	142.68	139.80	139.80	0.06	0.49	21.90		1709.90		13.61
Staples Bridge	278 BR D	Q500	144.41	140.96	140.96	0.07	0.36	21.82		2249.70		14.90
Staples Bridge	260	Q1.1	137.44	137.26	135.79	0.05	0.00	34.04		275.69	0.31	3.39
Staples Bridge	260	Q2	138.36	137.92	136.63	0.09	0.03	37.02		534.76	1.84	5.33
Staples Bridge	260	Q5	139.22	138.47	137.35	0.11	0.10	40.26		808.63	4.27	6.97
Staples Bridge	260	Q10	139.81	138.82	137.82	0.12	0.17	42.38		1007.69	6.41	7.99
Staples Bridge	260	Q25	140.55	139.23	138.38	0.13	0.28	44.78		1271.61	9.49	9.23
Staples Bridge	260	Q50	141.09	139.51	138.79	0.14	0.38	46.41		1476.18	12.02	10.14
Staples Bridge	260	Q100	141.66	139.77	139.22	0.14	0.51	47.96		1695.09	14.81	11.07
Staples Bridge	260	Q500	143.00	140.26	140.16	0.15	0.89	50.87		2227.95	21.75	13.33
Staples Bridge	240	Q1.1	137.38	137.20		0.09	0.00	42.44		275.71	0.29	3.45
Staples Bridge	240	Q2	138.24	137.86		0.12	0.00	51.76	1.07	534.20	1.33	4.96
Staples Bridge	240	Q5	139.01	138.45		0.12	0.02	63.04	10.05	799.70	3.15	6.04
Staples Bridge	240	Q10	139.52	138.87		0.12	0.02	70.97	24.37	984.77	4.96	6.58
Staples Bridge	240	Q25	140.13	139.38		0.12	0.03	80.70	53.41	1219.87	7.82	7.14
Staples Bridge	240	Q50	140.57	139.75		0.11	0.03	87.82	83.58	1394.24	10.38	7.47
Staples Bridge	240	Q100	141.00	140.13		0.11	0.04	95.11	122.81	1573.68	13.41	7.77
Staples Bridge	240	Q500	141.95	141.00		0.10	0.04	111.62	244.78	1983.12	21.80	8.31

Plan: Existing Great Works Rive Staples Bridge RS: 278 Profile: Q1.1

E.G. US. (ft)	137.93	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	137.73	E.G. Elev (ft)	137.80	137.48
Q Total (cfs)	276.00	W.S. Elev (ft)	137.24	137.23
Q Bridge (cfs)	276.00	Crit W.S. (ft)	136.89	135.80
Q Weir (cfs)		Max Chl Dpth (ft)	2.31	4.18
Weir Sta Lft (ft)		Vel Total (ft/s)	6.01	3.99
Weir Sta Rgt (ft)		Flow Area (sq ft)	45.94	69.22
Weir Submerg		Froude # Chl	0.70	0.34
Weir Max Depth (ft)		Specif Force (cu ft)	97.44	147.12
Min El Weir Flow (ft)	145.32	Hydr Depth (ft)	1.98	3.14
Min El Prs (ft)	143.42	W.P. Total (ft)	26.52	26.68
Delta EG (ft)	0.49	Conv. Total (cfs)	2461.6	4854.0
Delta WS (ft)	0.47	Top Width (ft)	23.25	22.07
BR Open Area (sq ft)	184.38	Frctn Loss (ft)	0.16	0.01
BR Open Vel (ft/s)	6.01	C & E Loss (ft)	0.16	0.03
BR Sluice Coef		Shear Total (lb/sq ft)	1.36	0.52
BR Sel Method	Energy only	Power Total (lb/ft s)	8.17	2.09

Plan: Existing Great Works Rive Staples Bridge RS: 278 Profile: Q10

E.G. US. (ft)	141.60	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	141.20	E.G. Elev (ft)	141.11	140.20
Q Total (cfs)	1014.10	W.S. Elev (ft)	139.15	138.52
Q Bridge (cfs)	1014.10	Crit W.S. (ft)	139.15	138.13
Q Weir (cfs)		Max Chl Dpth (ft)	4.22	5.47
Weir Sta Lft (ft)		Vel Total (ft/s)	11.22	10.40
Weir Sta Rgt (ft)		Flow Area (sq ft)	90.38	97.47
Weir Submerg		Froude # Chl	0.96	0.78
Weir Max Depth (ft)		Specif Force (cu ft)	530.27	547.76
Min El Weir Flow (ft)	145.32	Hydr Depth (ft)	3.91	4.43
Min El Prs (ft)	143.42	W.P. Total (ft)	30.35	29.25
Delta EG (ft)	1.79	Conv. Total (cfs)	6948.7	8078.2
Delta WS (ft)	2.37	Top Width (ft)	23.12	21.98
BR Open Area (sq ft)	184.38	Frctn Loss (ft)	0.51	0.04
BR Open Vel (ft/s)	11.22	C & E Loss (ft)	0.14	0.35
BR Sluice Coef		Shear Total (lb/sq ft)	3.96	3.28
BR Sel Method	Energy only	Power Total (lb/ft s)	44.43	34.11

Plan: Existing Great Works Rive Staples Bridge RS: 278 Profile: Q25

E.G. US. (ft)	142.67	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	142.21	E.G. Elev (ft)	142.10	141.17
Q Total (cfs)	1281.10	W.S. Elev (ft)	139.81	138.81
Q Bridge (cfs)	1281.10	Crit W.S. (ft)	139.81	138.81
Q Weir (cfs)		Max Chl Dpth (ft)	4.88	5.76
Weir Sta Lft (ft)		Vel Total (ft/s)	12.14	12.34
Weir Sta Rgt (ft)		Flow Area (sq ft)	105.53	103.85
Weir Submerg		Froude # Chl	0.97	0.91
Weir Max Depth (ft)		Specif Force (cu ft)	724.25	740.25
Min El Weir Flow (ft)	145.32	Hydr Depth (ft)	4.57	4.73
Min El Prs (ft)	143.42	W.P. Total (ft)	31.67	29.83
Delta EG (ft)	2.12	Conv. Total (cfs)	8746.0	8861.7

Plan: Existing Great Works Rive Staples Bridge RS: 278 Profile: Q25 (Continued)

Delta WS (ft)	2.98	Top Width (ft)	23.07	21.96
BR Open Area (sq ft)	184.38	Frctn Loss (ft)	0.59	0.05
BR Open Vel (ft/s)	12.34	C & E Loss (ft)	0.02	0.52
BR Sluice Coef		Shear Total (lb/sq ft)	4.46	4.54
BR Sel Method	Energy only	Power Total (lb/ft s)	54.19	56.03

Plan: Existing Great Works Rive Staples Bridge RS: 278 Profile: Q50

E.G. US. (ft)	143.45	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	142.95	E.G. Elev (ft)	142.82	141.92
Q Total (cfs)	1488.20	W.S. Elev (ft)	140.30	139.31
Q Bridge (cfs)	1488.20	Crit W.S. (ft)	140.30	139.31
Q Weir (cfs)		Max Chl Dpth (ft)	5.37	6.26
Weir Sta Lft (ft)		Vel Total (ft/s)	12.75	12.96
Weir Sta Rgt (ft)		Flow Area (sq ft)	116.76	114.85
Weir Submerg		Froude # Chl	0.97	0.91
Weir Max Depth (ft)		Specif Force (cu ft)	884.57	903.22
Min El Weir Flow (ft)	145.32	Hydr Depth (ft)	5.07	5.24
Min El Prs (ft)	143.42	W.P. Total (ft)	32.64	30.84
Delta EG (ft)	2.36	Conv. Total (cfs)	10145.3	10250.9
Delta WS (ft)	3.44	Top Width (ft)	23.04	21.93
BR Open Area (sq ft)	184.38	Frctn Loss (ft)	0.60	0.05
BR Open Vel (ft/s)	12.96	C & E Loss (ft)	0.03	0.51
BR Sluice Coef		Shear Total (lb/sq ft)	4.81	4.90
BR Sel Method	Energy only	Power Total (lb/ft s)	61.25	63.51

Plan: Existing Great Works Rive Staples Bridge RS: 278 Profile: Q100

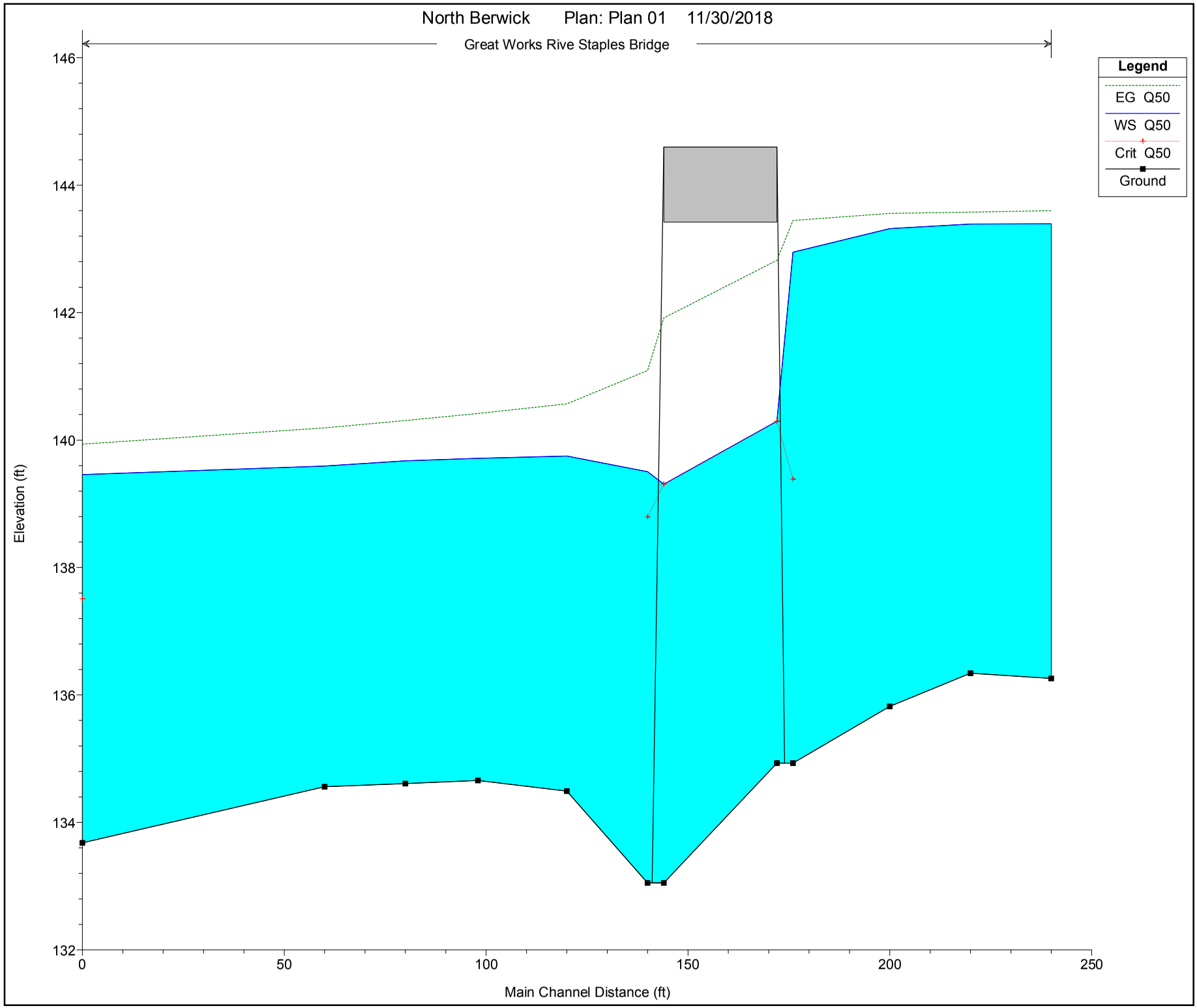
E.G. US. (ft)	144.25	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	143.71	E.G. Elev (ft)	143.56	142.68
Q Total (cfs)	1709.90	W.S. Elev (ft)	140.79	139.80
Q Bridge (cfs)	1709.90	Crit W.S. (ft)	140.79	139.80
Q Weir (cfs)		Max Chl Dpth (ft)	5.86	6.75
Weir Sta Lft (ft)		Vel Total (ft/s)	13.36	13.61
Weir Sta Rgt (ft)		Flow Area (sq ft)	128.00	125.68
Weir Submerg		Froude # Chl	0.97	0.92
Weir Max Depth (ft)		Specif Force (cu ft)	1064.71	1086.35
Min El Weir Flow (ft)	145.32	Hydr Depth (ft)	5.56	5.74
Min El Prs (ft)	143.42	W.P. Total (ft)	33.62	31.82
Delta EG (ft)	2.59	Conv. Total (cfs)	11594.3	11664.4
Delta WS (ft)	3.94	Top Width (ft)	23.01	21.90
BR Open Area (sq ft)	184.38	Frctn Loss (ft)	0.61	0.06
BR Open Vel (ft/s)	13.61	C & E Loss (ft)	0.03	0.49
BR Sluice Coef		Shear Total (lb/sq ft)	5.17	5.30
BR Sel Method	Energy only	Power Total (lb/ft s)	69.06	72.08

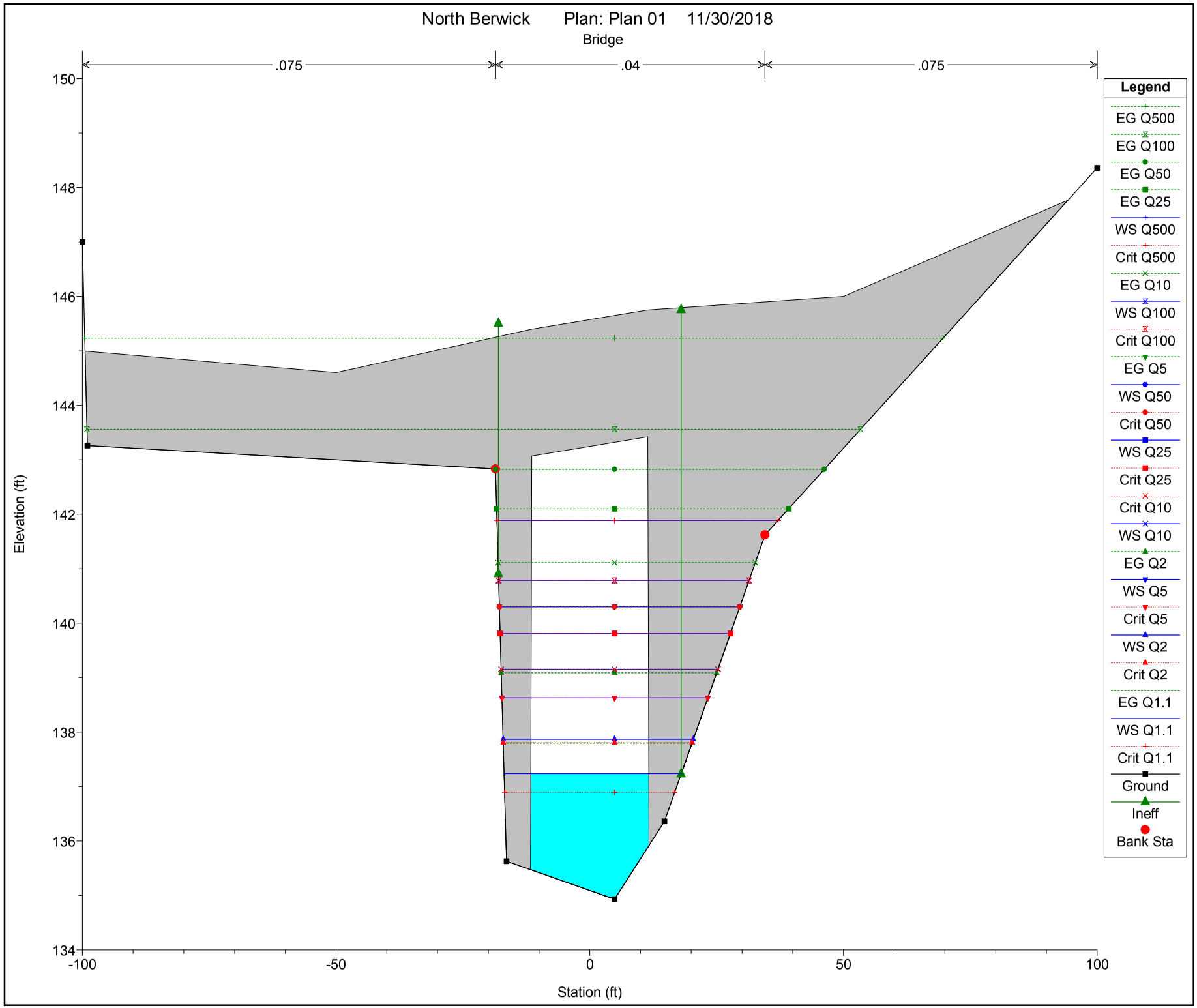
Plan: Existing Great Works Rive Staples Bridge RS: 278 Profile: Q500

E.G. US. (ft)	146.06	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	145.43	E.G. Elev (ft)	145.23	144.41
Q Total (cfs)	2249.70	W.S. Elev (ft)	141.88	140.96
Q Bridge (cfs)	2249.70	Crit W.S. (ft)	141.88	140.96
Q Weir (cfs)		Max Chl Dpth (ft)	6.95	7.91

Plan: Existing Great Works Rive Staples Bridge RS: 278 Profile: Q500 (Continued)

Weir Sta Lft (ft)		Vel Total (ft/s)	14.68	14.90
Weir Sta Rgt (ft)		Flow Area (sq ft)	153.23	151.01
Weir Submerg		Froude # Chl	0.98	0.93
Weir Max Depth (ft)		Specif Force (cu ft)	1535.83	1565.33
Min El Weir Flow (ft)	145.32	Hydr Depth (ft)	6.68	6.92
Min El Prs (ft)	143.42	W.P. Total (ft)	35.82	34.14
Delta EG (ft)	3.07	Conv. Total (cfs)	15001.5	15114.6
Delta WS (ft)	5.17	Top Width (ft)	22.93	21.82
BR Open Area (sq ft)	184.38	Frctn Loss (ft)	0.62	0.07
BR Open Vel (ft/s)	14.90	C & E Loss (ft)	0.03	0.36
BR Sluice Coef		Shear Total (lb/sq ft)	6.01	6.12
BR Sel Method	Energy only	Power Total (lb/ft s)	88.19	91.13


North Berwick Plan: Plan 01 11/30/2018
Great Works Rive Staples Bridge
Legend
EG Q50
WS Q50
Crit Q50
Ground
Elevation (ft)
146
144
142
140
138
136
134
132
0
50
100
150
200
250
Main Channel Distance (ft)


North Berwick Plan: Plan 01 11/30/2018
Bridge
.075
.04
.075
150
148
146
144
142
140
138
136
134
Elevation (ft)
-100
-50
0
50
100
Station (ft)
Legend
EG Q500
EG Q100
EG Q50
EG Q25
WS Q500
Crit Q500
EG Q10
WS Q100
Crit Q100
EG Q5
WS Q50
Crit Q50
WS Q25
Crit Q25
Crit Q10
WS Q10
EG Q2
WS Q5
Crit Q5
WS Q2
Crit Q2
EG Q1.1
WS Q1.1
Crit Q1.1
Ground
Ineff
Bank Sta

HEC-RAS Plan: Propsed Bridge River: Great Works Rive Reach: Staples Bridge

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)	
Staples Bridge	360	Q1.1	276.00	136.26	137.85		138.15	0.010252	4.42	62.69	51.43	0.69
Staples Bridge	360	Q2	536.60	136.26	138.60		139.04	0.008348	5.35	104.70	58.67	0.66
Staples Bridge	360	Q5	812.90	136.26	139.31		139.84	0.006845	5.91	148.90	66.92	0.63
Staples Bridge	360	Q10	1014.10	136.26	139.80		140.37	0.005949	6.16	183.38	72.46	0.60
Staples Bridge	360	Q25	1281.10	136.26	140.43		141.03	0.005052	6.39	230.63	78.45	0.57
Staples Bridge	360	Q50	1488.20	136.26	140.89		141.51	0.004523	6.52	268.30	82.92	0.55
Staples Bridge	360	Q100	1709.90	136.26	141.37		142.01	0.004083	6.65	309.18	87.50	0.53
Staples Bridge	360	Q500	2249.70	136.26	142.50		143.15	0.003273	6.85	413.93	98.29	0.50
Staples Bridge	340	Q1.1	276.00	136.34	137.72		137.95	0.008115	3.91	70.62	55.37	0.61
Staples Bridge	340	Q2	536.60	136.34	138.54		138.87	0.005979	4.56	118.12	59.71	0.56
Staples Bridge	340	Q5	812.90	136.34	139.29		139.68	0.004801	5.02	164.42	64.09	0.53
Staples Bridge	340	Q10	1014.10	136.34	139.80		140.23	0.004231	5.27	197.64	67.07	0.51
Staples Bridge	340	Q25	1281.10	136.34	140.43		140.90	0.003702	5.55	241.21	70.78	0.50
Staples Bridge	340	Q50	1488.20	136.34	140.90		141.40	0.003391	5.73	274.95	73.53	0.48
Staples Bridge	340	Q100	1709.90	136.34	141.37		141.90	0.003137	5.90	310.76	76.97	0.47
Staples Bridge	340	Q500	2249.70	136.34	142.49		143.07	0.002645	6.22	404.24	90.27	0.45
Staples Bridge	320	Q1.1	276.00	135.82	137.49		137.78	0.008732	4.28	64.52	46.37	0.64
Staples Bridge	320	Q2	536.60	135.82	138.30		138.72	0.007654	5.21	102.96	49.40	0.64
Staples Bridge	320	Q5	812.90	135.82	139.03		139.55	0.006581	5.83	139.80	51.90	0.62
Staples Bridge	320	Q10	1014.10	135.82	139.52		140.11	0.005922	6.17	166.31	55.52	0.60
Staples Bridge	320	Q25	1281.10	135.82	140.14		140.80	0.005275	6.53	201.91	60.03	0.58
Staples Bridge	320	Q50	1488.20	135.82	140.59		141.30	0.004865	6.76	230.21	63.40	0.57
Staples Bridge	320	Q100	1709.90	135.82	141.07		141.81	0.004507	6.97	260.89	66.85	0.56
Staples Bridge	320	Q500	2249.70	135.82	142.18		142.99	0.003777	7.33	339.91	75.02	0.53
Staples Bridge	280	Q1.1	276.00	134.80	137.35		137.53	0.003639	3.43	80.92	42.76	0.44
Staples Bridge	280	Q2	536.60	134.80	138.12		138.47	0.004465	4.75	115.92	48.60	0.51
Staples Bridge	280	Q5	812.90	134.80	138.84		139.32	0.004555	5.62	153.10	54.32	0.54
Staples Bridge	280	Q10	1014.10	134.80	139.34		139.90	0.004428	6.07	181.12	58.26	0.54
Staples Bridge	280	Q25	1281.10	134.80	139.96		140.60	0.004212	6.53	218.98	63.20	0.54
Staples Bridge	280	Q50	1488.20	134.80	140.43		141.12	0.004023	6.82	249.26	66.89	0.54
Staples Bridge	280	Q100	1709.90	134.80	140.90		141.64	0.003836	7.07	282.09	70.67	0.53
Staples Bridge	280	Q500	2249.70	134.80	142.02		142.84	0.003424	7.56	367.41	84.38	0.52
Staples Bridge	252	Q1.1	276.00	134.49	137.26	136.35	137.43	0.003297	3.34	83.18	42.57	0.42
Staples Bridge	252	Q2	536.60	134.49	138.00	136.99	138.34	0.004332	4.71	116.19	47.65	0.50
Staples Bridge	252	Q5	812.90	134.49	138.71	137.54	139.20	0.004524	5.62	149.49	53.29	0.53
Staples Bridge	252	Q10	1014.10	134.49	139.19	137.93	139.77	0.004506	6.12	172.31	57.12	0.55
Staples Bridge	252	Q25	1281.10	134.49	139.78	138.36	140.47	0.004460	6.69	200.59	61.80	0.56
Staples Bridge	252	Q50	1488.20	134.49	140.22	138.69	140.98	0.004407	7.07	221.50	65.23	0.56
Staples Bridge	252	Q100	1709.90	134.49	140.65	139.02	141.49	0.004367	7.45	242.68	68.67	0.57
Staples Bridge	252	Q500	2249.70	134.49	141.66	139.73	142.68	0.004216	8.20	292.41	79.09	0.57
Staples Bridge	236		Bridge									
Staples Bridge	220	Q1.1	276.00	134.66	137.12		137.31	0.003961	3.54	79.38	58.07	0.46
Staples Bridge	220	Q2	536.60	134.66	137.72		138.14	0.005797	5.17	106.85	65.05	0.58
Staples Bridge	220	Q5	812.90	134.66	138.34		138.94	0.006320	6.25	134.87	71.11	0.63
Staples Bridge	220	Q10	1014.10	134.66	138.75		139.47	0.006402	6.85	154.09	75.63	0.64
Staples Bridge	220	Q25	1281.10	134.66	139.26		140.12	0.006499	7.54	177.19	84.89	0.66
Staples Bridge	220	Q50	1488.20	134.66	139.61		140.59	0.006570	8.03	193.65	91.50	0.68
Staples Bridge	220	Q100	1709.90	134.66	139.97		141.07	0.006644	8.51	210.16	98.12	0.69
Staples Bridge	220	Q500	2249.70	134.66	140.76		142.15	0.006838	9.57	246.39	112.65	0.72
Staples Bridge	200	Q1.1	276.00	134.61	136.96		137.20	0.005599	3.99	78.00	67.58	0.53
Staples Bridge	200	Q2	536.60	134.61	137.60		138.01	0.006694	5.37	123.42	73.70	0.61
Staples Bridge	200	Q5	812.90	134.61	138.26		138.76	0.006097	6.04	173.81	78.47	0.61
Staples Bridge	200	Q10	1014.10	134.61	138.72		139.26	0.005665	6.40	210.76	84.02	0.60
Staples Bridge	200	Q25	1281.10	134.61	139.27		139.87	0.005246	6.79	259.41	91.70	0.59
Staples Bridge	200	Q50	1488.20	134.61	139.67		140.31	0.004977	7.04	297.19	97.25	0.59
Staples Bridge	200	Q100	1709.90	134.61	140.08		140.74	0.004729	7.27	337.72	102.87	0.58
Staples Bridge	200	Q500	2249.70	134.61	140.99		141.70	0.004189	7.68	436.85	112.43	0.56
Staples Bridge	180	Q1.1	276.00	134.56	136.42	136.41	136.98	0.020398	6.13	51.06	55.46	0.97
Staples Bridge	180	Q2	536.60	134.56	137.35		137.84	0.009515	6.02	116.74	74.95	0.72
Staples Bridge	180	Q5	812.90	134.56	138.12		138.62	0.006855	6.26	176.49	79.53	0.64
Staples Bridge	180	Q10	1014.10	134.56	138.61		139.14	0.006014	6.50	215.82	82.42	0.62
Staples Bridge	180	Q25	1281.10	134.56	139.18		139.75	0.005384	6.82	264.21	85.83	0.60
Staples Bridge	180	Q50	1488.20	134.56	139.59		140.19	0.005070	7.06	299.69	88.25	0.59
Staples Bridge	180	Q100	1709.90	134.56	140.00		140.64	0.004861	7.33	336.67	96.26	0.59
Staples Bridge	180	Q500	2249.70	134.56	140.90		141.61	0.004394	7.82	434.40	118.87	0.58
Staples Bridge	120	Q1.1	276.00	133.68	136.35	135.43	136.48	0.002801	2.96	95.20	52.79	0.38
Staples Bridge	120	Q2	536.60	133.68	137.25	135.99	137.48	0.002803	3.84	145.81	59.90	0.41
Staples Bridge	120	Q5	812.90	133.68	138.01	136.49	138.32	0.002800	4.51	193.81	66.85	0.42
Staples Bridge	120	Q10	1014.10	133.68	138.49	136.81	138.85	0.002801	4.91	226.77	71.22	0.43
Staples Bridge	120	Q25	1281.10	133.68	139.05	137.23	139.48	0.002803	5.37	268.75	76.44	0.44
Staples Bridge	120	Q50	1488.20	133.68	139.46	137.51	139.94	0.002801	5.68	300.40	80.15	0.45
Staples Bridge	120	Q100	1709.90	133.68	139.86	137.80	140.38	0.002804	5.98	333.26	83.82	0.46
Staples Bridge	120	Q500	2249.70	133.68	140.75	138.46	141.38	0.002801	6.63	412.10	93.67	0.47

HEC-RAS Plan: Propsed Bridge River: Great Works Rive Reach: Staples Bridge

Reach	River Sta	Profile	E.G. Elev	W.S. Elev	Crit W.S.	Frctn Loss	C & E Loss	Top Width	Q Left	Q Channel	Q Right	Vel Chnl
			(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft/s)
Staples Bridge	280	Q1.1	137.53	137.35		0.10	0.01	42.76		275.57	0.43	3.43
Staples Bridge	280	Q2	138.47	138.12		0.12	0.00	48.60	1.23	533.55	1.81	4.75
Staples Bridge	280	Q5	139.32	138.84		0.13	0.00	54.32	7.85	800.79	4.26	5.62
Staples Bridge	280	Q10	139.90	139.34		0.13	0.00	58.26	16.99	990.47	6.64	6.07
Staples Bridge	280	Q25	140.60	139.96		0.12	0.01	63.20	34.75	1235.88	10.47	6.53
Staples Bridge	280	Q50	141.12	140.43		0.12	0.02	66.89	52.94	1421.32	13.94	6.82
Staples Bridge	280	Q100	141.64	140.90		0.11	0.03	70.67	76.29	1615.52	18.09	7.07
Staples Bridge	280	Q500	142.84	142.02		0.11	0.06	84.38	142.23	2077.42	30.04	7.56
Staples Bridge	252	Q1.1	137.43	137.26	136.35	0.02	0.00	42.57		275.67	0.33	3.34
Staples Bridge	252	Q2	138.34	138.00	136.99	0.02	0.01	47.65	0.81	534.28	1.50	4.71
Staples Bridge	252	Q5	139.20	138.71	137.54	0.03	0.03	53.29	4.64	804.54	3.72	5.62
Staples Bridge	252	Q10	139.77	139.19	137.93	0.03	0.04	57.12	8.47	999.73	5.91	6.12
Staples Bridge	252	Q25	140.47	139.78	138.36	0.03	0.05	61.80	14.27	1257.35	9.48	6.69
Staples Bridge	252	Q50	140.98	140.22	138.69	0.03	0.07	65.23	19.18	1456.27	12.75	7.07
Staples Bridge	252	Q100	141.49	140.65	139.02	0.03	0.08	68.67	24.68	1668.55	16.67	7.45
Staples Bridge	252	Q500	142.68	141.66	139.73	0.03	0.12	79.09	39.02	2182.53	28.16	8.20
Staples Bridge	236 BR U	Q1.1	137.41	137.23	136.36	0.08	0.00	40.65		275.69	0.31	3.46
Staples Bridge	236 BR U	Q2	138.30	137.92	137.00	0.12	0.01	41.00		535.17	1.43	4.99
Staples Bridge	236 BR U	Q5	139.14	138.57	137.57	0.14	0.02	41.00		809.99	2.91	6.09
Staples Bridge	236 BR U	Q10	139.70	139.00	137.94	0.15	0.02	41.00		1010.11	3.99	6.72
Staples Bridge	236 BR U	Q25	140.39	139.52	138.40	0.15	0.03	41.00		1275.73	5.37	7.47
Staples Bridge	236 BR U	Q50	140.88	139.89	138.73	0.16	0.03	41.00		1481.79	6.41	7.98
Staples Bridge	236 BR U	Q100	141.39	140.27	139.07	0.17	0.04	41.00		1702.41	7.49	8.49
Staples Bridge	236 BR U	Q500	142.53	141.11	139.84	0.18	0.05	41.00		2239.70	10.00	9.58
Staples Bridge	236 BR D	Q1.1	137.33	137.14	136.30	0.02	0.00	41.00		275.26	0.74	3.54
Staples Bridge	236 BR D	Q2	138.17	137.75	136.97	0.03	0.01	41.00		535.11	1.49	5.22
Staples Bridge	236 BR D	Q5	138.99	138.35	137.53	0.03	0.02	41.00		810.68	2.22	6.39
Staples Bridge	236 BR D	Q10	139.53	138.76	137.89	0.03	0.03	41.00		1011.40	2.70	7.06
Staples Bridge	236 BR D	Q25	140.20	139.25	138.35	0.04	0.04	41.00		1277.79	3.31	7.85
Staples Bridge	236 BR D	Q50	140.69	139.59	138.68	0.04	0.06	41.00		1484.44	3.76	8.40
Staples Bridge	236 BR D	Q100	141.18	139.94	139.02	0.04	0.07	41.00		1705.68	4.22	8.95
Staples Bridge	236 BR D	Q500	142.29	140.69	139.78	0.04	0.11	41.00		2244.41	5.29	10.16
Staples Bridge	220	Q1.1	137.31	137.12		0.09	0.01	58.07	0.23	274.44	1.33	3.54
Staples Bridge	220	Q2	138.14	137.72		0.12	0.00	65.05	1.75	530.91	3.94	5.17
Staples Bridge	220	Q5	138.94	138.34		0.12	0.05	71.11	4.31	800.20	8.39	6.25
Staples Bridge	220	Q10	139.47	138.75		0.12	0.09	75.63	6.50	994.80	12.80	6.85
Staples Bridge	220	Q25	140.12	139.26		0.12	0.13	84.89	9.62	1252.39	19.10	7.54
Staples Bridge	220	Q50	140.59	139.61		0.11	0.17	91.50	12.14	1451.84	24.22	8.03
Staples Bridge	220	Q100	141.07	139.97		0.11	0.22	98.12	14.93	1665.09	29.88	8.51
Staples Bridge	220	Q500	142.15	140.76		0.11	0.34	112.65	21.95	2183.59	44.16	9.57
Staples Bridge	200	Q1.1	137.20	136.96		0.20	0.03	67.58	10.74	264.62	0.64	3.99
Staples Bridge	200	Q2	138.01	137.60		0.16	0.01	73.70	47.43	486.61	2.56	5.37
Staples Bridge	200	Q5	138.76	138.26		0.14	0.00	78.47	107.12	699.77	6.01	6.04
Staples Bridge	200	Q10	139.26	138.72		0.12	0.01	84.02	152.93	851.81	9.36	6.40
Staples Bridge	200	Q25	139.87	139.27		0.11	0.01	91.70	218.94	1047.51	14.65	6.79
Staples Bridge	200	Q50	140.31	139.67		0.11	0.01	97.25	275.08	1193.80	19.32	7.04
Staples Bridge	200	Q100	140.74	140.08		0.10	0.01	102.87	339.40	1345.70	24.80	7.27
Staples Bridge	200	Q500	141.70	140.99		0.09	0.00	112.43	521.91	1688.03	39.76	7.68

Plan: Propsed Bridge Great Works Rive Staples Bridge RS: 236 Profile: Q1.1

E.G. US. (ft)	137.43	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	137.26	E.G. Elev (ft)	137.41	137.33
Q Total (cfs)	276.00	W.S. Elev (ft)	137.23	137.14
Q Bridge (cfs)	276.00	Crit W.S. (ft)	136.36	136.30
Q Weir (cfs)		Max Chl Dpth (ft)	2.74	2.48
Weir Sta Lft (ft)		Vel Total (ft/s)	3.44	3.50
Weir Sta Rgt (ft)		Flow Area (sq ft)	80.30	78.80
Weir Submerg		Froude # Chl	0.43	0.40
Weir Max Depth (ft)		Specif Force (cu ft)	113.88	111.21
Min El Weir Flow (ft)	145.27	Hydr Depth (ft)	1.98	1.92
Min El Prs (ft)	142.80	W.P. Total (ft)	41.21	42.82
Delta EG (ft)	0.12	Conv. Total (cfs)	4719.7	4452.7
Delta WS (ft)	0.14	Top Width (ft)	40.65	41.00
BR Open Area (sq ft)	302.63	Frctn Loss (ft)	0.08	0.02
BR Open Vel (ft/s)	3.50	C & E Loss (ft)	0.00	0.00
BR Sluice Coef		Shear Total (lb/sq ft)	0.42	0.44
BR Sel Method	Energy only	Power Total (lb/ft s)	1.43	1.55

Plan: Propsed Bridge Great Works Rive Staples Bridge RS: 236 Profile: Q10

E.G. US. (ft)	139.77	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	139.19	E.G. Elev (ft)	139.70	139.53
Q Total (cfs)	1014.10	W.S. Elev (ft)	139.00	138.76
Q Bridge (cfs)	1014.10	Crit W.S. (ft)	137.94	137.89
Q Weir (cfs)		Max Chl Dpth (ft)	4.51	4.10
Weir Sta Lft (ft)		Vel Total (ft/s)	6.62	6.97
Weir Sta Rgt (ft)		Flow Area (sq ft)	153.10	145.45
Weir Submerg		Froude # Chl	0.56	0.61
Weir Max Depth (ft)		Specif Force (cu ft)	502.86	485.28
Min El Weir Flow (ft)	145.27	Hydr Depth (ft)	3.73	3.55
Min El Prs (ft)	142.80	W.P. Total (ft)	46.42	46.07
Delta EG (ft)	0.30	Conv. Total (cfs)	12891.7	11988.6
Delta WS (ft)	0.44	Top Width (ft)	41.00	41.00
BR Open Area (sq ft)	302.63	Frctn Loss (ft)	0.15	0.03
BR Open Vel (ft/s)	6.97	C & E Loss (ft)	0.02	0.03
BR Sluice Coef		Shear Total (lb/sq ft)	1.27	1.41
BR Sel Method	Energy only	Power Total (lb/ft s)	8.44	9.83

Plan: Propsed Bridge Great Works Rive Staples Bridge RS: 236 Profile: Q25

E.G. US. (ft)	140.47	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	139.78	E.G. Elev (ft)	140.39	140.20
Q Total (cfs)	1281.10	W.S. Elev (ft)	139.52	139.25
Q Bridge (cfs)	1281.10	Crit W.S. (ft)	138.40	138.35
Q Weir (cfs)		Max Chl Dpth (ft)	5.03	4.59
Weir Sta Lft (ft)		Vel Total (ft/s)	7.35	7.75
Weir Sta Rgt (ft)		Flow Area (sq ft)	174.38	165.36
Weir Submerg		Froude # Chl	0.59	0.65
Weir Max Depth (ft)		Specif Force (cu ft)	672.97	650.56
Min El Weir Flow (ft)	145.27	Hydr Depth (ft)	4.25	4.03
Min El Prs (ft)	142.80	W.P. Total (ft)	47.45	47.04
Delta EG (ft)	0.35	Conv. Total (cfs)	15844.4	14722.2

Plan: Propsed Bridge Great Works Rive Staples Bridge RS: 236 Profile: Q25 (Continued)

Delta WS (ft)	0.53	Top Width (ft)	41.00	41.00
BR Open Area (sq ft)	302.63	Frctn Loss (ft)	0.15	0.04
BR Open Vel (ft/s)	7.75	C & E Loss (ft)	0.03	0.04
BR Sluice Coef		Shear Total (lb/sq ft)	1.50	1.66
BR Sel Method	Energy only	Power Total (lb/ft s)	11.02	12.87

Plan: Propsed Bridge Great Works Rive Staples Bridge RS: 236 Profile: Q50

E.G. US. (ft)	140.98	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	140.22	E.G. Elev (ft)	140.88	140.69
Q Total (cfs)	1488.20	W.S. Elev (ft)	139.89	139.59
Q Bridge (cfs)	1488.20	Crit W.S. (ft)	138.73	138.68
Q Weir (cfs)		Max Chl Dpth (ft)	5.40	4.93
Weir Sta Lft (ft)		Vel Total (ft/s)	7.85	8.29
Weir Sta Rgt (ft)		Flow Area (sq ft)	189.64	179.55
Weir Submerg		Froude # Chl	0.60	0.67
Weir Max Depth (ft)		Specif Force (cu ft)	812.40	786.11
Min El Weir Flow (ft)	145.27	Hydr Depth (ft)	4.63	4.38
Min El Prs (ft)	142.80	W.P. Total (ft)	48.20	47.74
Delta EG (ft)	0.38	Conv. Total (cfs)	18090.3	16789.3
Delta WS (ft)	0.60	Top Width (ft)	41.00	41.00
BR Open Area (sq ft)	302.63	Frctn Loss (ft)	0.16	0.04
BR Open Vel (ft/s)	8.29	C & E Loss (ft)	0.03	0.06
BR Sluice Coef		Shear Total (lb/sq ft)	1.66	1.84
BR Sel Method	Energy only	Power Total (lb/ft s)	13.05	15.29

Plan: Propsed Bridge Great Works Rive Staples Bridge RS: 236 Profile: Q100

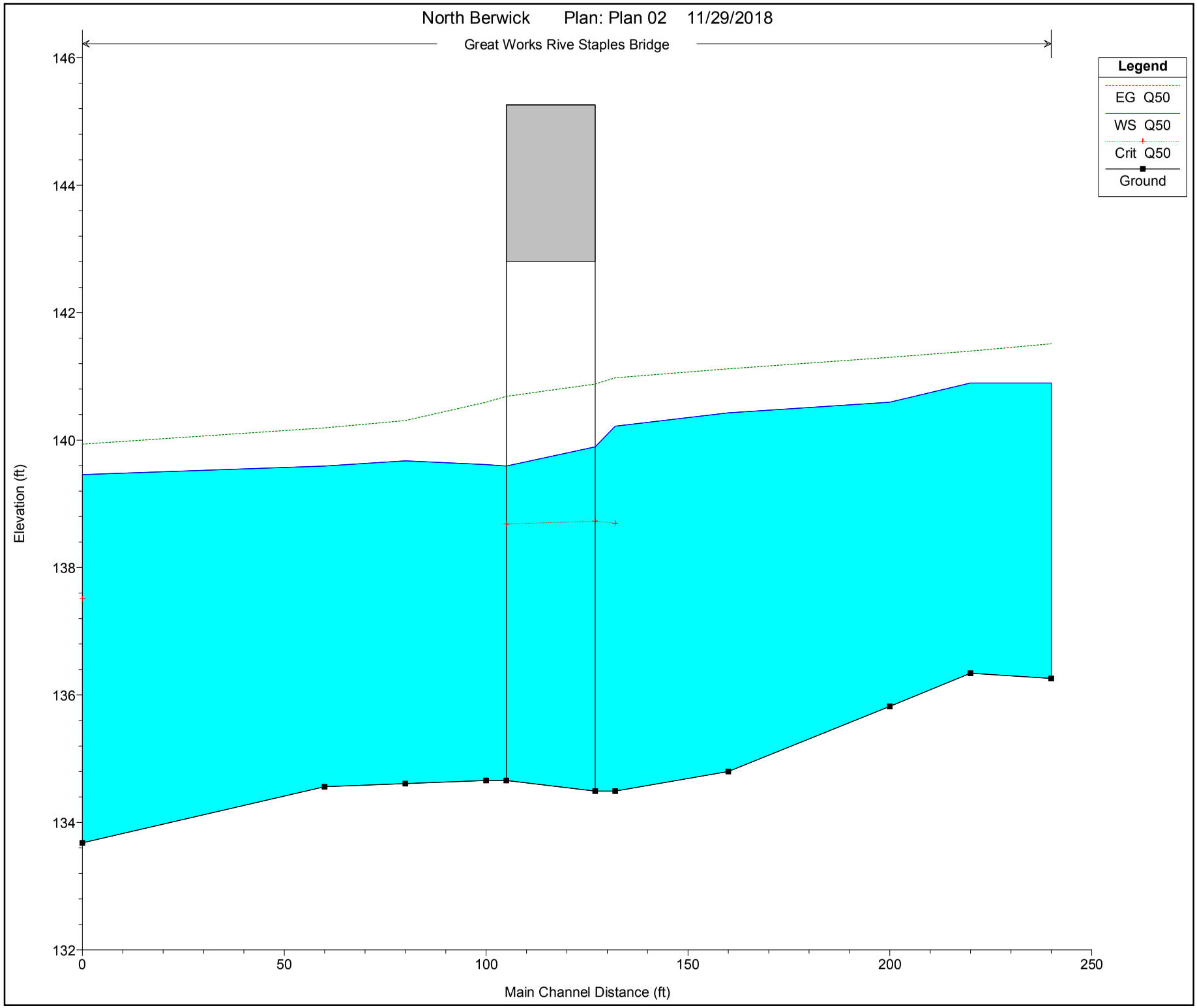
E.G. US. (ft)	141.49	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	140.65	E.G. Elev (ft)	141.39	141.18
Q Total (cfs)	1709.90	W.S. Elev (ft)	140.27	139.94
Q Bridge (cfs)	1709.90	Crit W.S. (ft)	139.07	139.02
Q Weir (cfs)		Max Chl Dpth (ft)	5.78	5.28
Weir Sta Lft (ft)		Vel Total (ft/s)	8.34	8.83
Weir Sta Rgt (ft)		Flow Area (sq ft)	205.02	193.72
Weir Submerg		Froude # Chl	0.62	0.69
Weir Max Depth (ft)		Specif Force (cu ft)	968.13	937.45
Min El Weir Flow (ft)	145.27	Hydr Depth (ft)	5.00	4.72
Min El Prs (ft)	142.80	W.P. Total (ft)	48.95	48.43
Delta EG (ft)	0.42	Conv. Total (cfs)	20455.8	18947.0
Delta WS (ft)	0.68	Top Width (ft)	41.00	41.00
BR Open Area (sq ft)	302.63	Frctn Loss (ft)	0.17	0.04
BR Open Vel (ft/s)	8.83	C & E Loss (ft)	0.04	0.07
BR Sluice Coef		Shear Total (lb/sq ft)	1.83	2.03
BR Sel Method	Energy only	Power Total (lb/ft s)	15.24	17.95

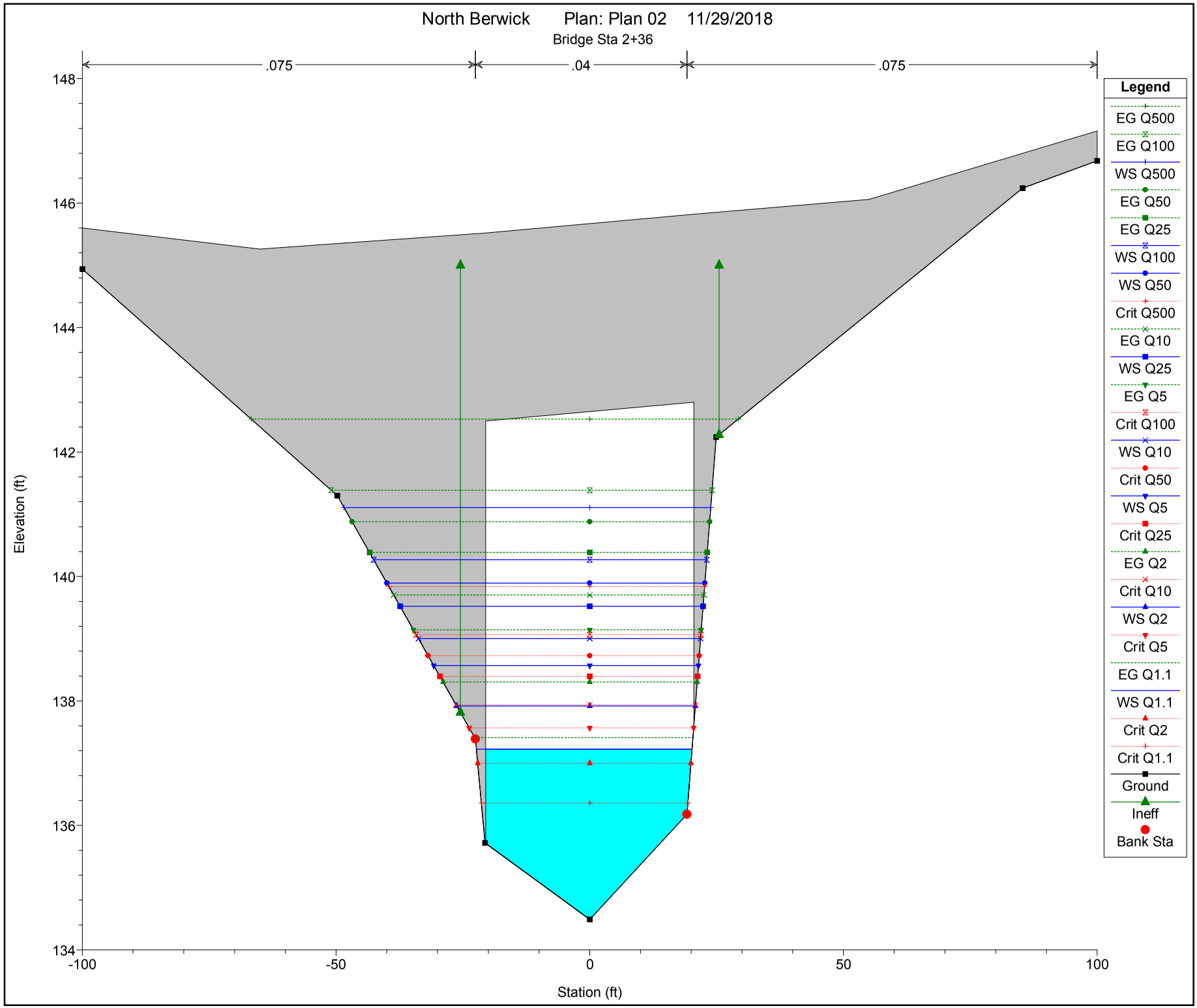
Plan: Propsed Bridge Great Works Rive Staples Bridge RS: 236 Profile: Q500

E.G. US. (ft)	142.68	Element	Inside BR US	Inside BR DS
W.S. US. (ft)	141.66	E.G. Elev (ft)	142.53	142.29
Q Total (cfs)	2249.70	W.S. Elev (ft)	141.11	140.69
Q Bridge (cfs)	2249.70	Crit W.S. (ft)	139.84	139.78
Q Weir (cfs)		Max Chl Dpth (ft)	6.62	6.03

Plan: Propsed Bridge Great Works Rive Staples Bridge RS: 236 Profile: Q500 (Continued)

Weir Sta Lft (ft)		Vel Total (ft/s)	9.40	10.02
Weir Sta Rgt (ft)		Flow Area (sq ft)	239.39	224.62
Weir Submerg		Froude # Chl	0.66	0.73
Weir Max Depth (ft)		Specif Force (cu ft)	1372.34	1329.45
Min El Weir Flow (ft)	145.27	Hydr Depth (ft)	5.84	5.48
Min El Prs (ft)	142.80	W.P. Total (ft)	50.63	49.94
Delta EG (ft)	0.53	Conv. Total (cfs)	26088.9	23955.8
Delta WS (ft)	0.90	Top Width (ft)	41.00	41.00
BR Open Area (sq ft)	302.63	Frctn Loss (ft)	0.18	0.04
BR Open Vel (ft/s)	10.02	C & E Loss (ft)	0.05	0.11
BR Sluice Coef		Shear Total (lb/sq ft)	2.20	2.48
BR Sel Method	Energy only	Power Total (lb/ft s)	20.63	24.80


North Berwick Plan: Plan 02 11/29/2018
Great Works Rive Staples Bridge
Legend
EG Q50
WS Q50
Crit Q50
Ground
Elevation (ft)
146
144
142
140
138
136
134
132
0
50
100
150
200
250
Main Channel Distance (ft)


North Berwick Plan: Plan 02 11/29/2018
Bridge Sta 2+36
.075
.04
.075
148
146
144
142
140
138
136
134
Elevation (ft)
-100
-50
0
50
100
Station (ft)
Legend
EG Q500
EG Q100
WS Q500
EG Q50
EG Q25
WS Q100
WS Q50
Crit Q500
EG Q10
WS Q25
EG Q5
Crit Q100
WS Q10
Crit Q50
WS Q5
Crit Q25
EG Q2
Crit Q10
WS Q2
Crit Q5
EG Q1.1
WS Q1.1
Crit Q2
Crit Q1.1
Ground
Ineff
Bank Sta

Appendix F

Substructure Memorandum

BECKER
STRUCTURAL ENGINEERS

Memorandum

TO:	Joel Kittredge and Laura Krusinski
FROM:	Jack Burgess and Liz Brownell
DATE/TIME:	October 3, 2018
SUBJECT:	WIN 22336.00 – Staples Bridge (#1238) over the Great Works River

Purpose

The purpose of this memo is to discuss the existing conditions and potential rehabilitation or replacement options for the stone abutments and wingwalls at the Staples Bridge (#1238) carrying Card Mill Road over the Great Works River in the town of North Berwick. The bridge was constructed circa 1928, making the substructure 90 years old. The superstructure was replaced circa 1987 with closely spaced steel beams and a timber deck. At an unknown date, a major concrete repair was performed on the downstream side of the east abutment. Plans for the existing bridge and the rehabilitations are not available. The most recent inspection report rates the substructure in poor condition (4).

Field Observations and Existing Conditions

BSE performed a site visit on May 31, 2018 to assess the condition of the existing stone abutments and wingwalls. The walls are constructed of dry stacked stones of irregular shapes and varying sizes. The walls have many large voids and the stones have shifted over time. A major concrete repair was performed at the southwest wingwall. During the site visit, a five-foot probe was inserted in a void with no refusal. Chipmunks were noted crawling through voids in the abutments and wingwalls. The northeast wingwall is settling and rotating; and has loose and missing stones. The side slopes are stabilized by tree growth, some of which will have to be removed during construction. Concrete approach slabs were constructed behind both abutments circa 1987, likely to address settlement issues due to loss of material through voids in the wingwall and abutments. Upon completion of the probes, S.W. Cole had difficulty filling the probe holes because of loss of material. BSE contacted the Region 1 Bridge Maintenance Supervisor for more information regarding the concrete substructure repairs that were performed at the south corner of the east abutment, but no further information was provided since there is no record of the repairs, which took place prior to the existing Bridge Maintenance Supervisor taking on his current position. There is evidence of the north east wingwall beginning to fail, as the top course of stones is shifting outward. It is assumed that a similar issue occurred at the southeast wingwall, prompting this major concrete repair. Photos from the site visit are included in Attachment A.

On April 27, 2018 SW Cole Engineering (SW Cole) took field measurements of the stones along the front face of both abutments. Where possible, height, width, and depth of the stones were measured and documented. These measurements demonstrate the irregularity of the stone sizes that make up the abutments and wingwalls. The measurements are included in Attachment B. On May 31, 2018 SW Cole conducted a series of probes to better understand the geometry and construction of the existing

abutments. The results of these probes were used to determine the interpretive abutment geometry that was used to analyze the existing bridge substructure. The location and depth of the probes are summarized in a Draft Geotechnical Report, prepared by SW Cole and dated August 15, 2018.

Substructure Analysis

BSE evaluated the existing wingwalls and abutments for sliding and overturning about a point at the toe of the footing (Case I) and about a point at the toe of second course of stone (Case II). See attached sketch and calculations in Attachment C. Bearing resistance was also evaluated, but calculations are not attached, since this limit state did not govern for any of the load cases evaluated. The size and shape of the abutment used in the analysis is based on the interpretive abutment section provided on page 6 of SW Cole's Draft Geotechnical Report. The back face of the abutment was interpolated by a series of probes taken behind both abutments. A similar section was assumed for evaluation of the existing wingwalls.

Case I includes lateral earth pressure from the top of existing grade to the bottom of footing. This load case includes the weight of the soil (EV) over the heel and the weight of the footing as resisting forces. Case II includes lateral earth pressure from top of existing grade to top of footing. Case II does not include the weight of the soil (EV) over the heel or the weight of the footing as resisting forces. The vertical component of the lateral earth pressure is not including as a resisting force in either Case I or Case II, in accordance with the recommendation of the Draft Geotechnical Report.

As recommended by SW Cole, the following soil parameters were used in calculation of active earth pressure coefficient using Coulomb Theory:

Angle of internal friction = 32°
Angle of backfill = 0°
Angle of wall face batter = 90°
Friction angle between fill material and wall backface = 21.33°

The existing abutments were evaluated at their existing heights, with dead loads and live loads from the existing superstructure for the same load cases (I and II) as described above. In addition, the abutments were evaluated for a 2' profile raise with dead loads and live loads from a steel superstructure replacement; and no profile raise with dead loads and live loads from a precast concrete superstructure replacement.

The results of these preliminary analyses indicate that, in their existing conditions, the abutments and the wingwalls do not meet eccentricity requirements for the Case II evaluations under any of the load conditions described above (existing superstructure or superstructure replacement). The results and recommendations provided are based on observations and available subsurface information. More definitive abutment and wingwall geometry could be obtained through geophysical survey techniques including ground penetrating radar (GPR) and multichannel analysis of surface waves (MASW), but the cost of additional testing may not provide valuable information or change the conclusions. Detailed calculations for the analysis of the existing abutments and wingwalls are included in Attachment C.

Rehabilitation Alternatives

In addition to the above analysis, the following rehabilitation alternatives were evaluated:

1. Restack shifted, loose stones of the existing abutments and wingwalls and construct an at-grade load distribution slab,
2. Remove upper portion of the existing abutment stones and construct larger cast-in-place concrete footing and a short stem wall. (See sketch and calculations in Attachment C)

Alternative 1, restacking shifted, loose stones is not recommended because this would require close to full reconstruction of the walls. The size of stone varies greatly, there are large voids throughout the wall, and construction beyond the visible front faces of the walls is unknown. Furthermore, this rehabilitation alternative is similar to the 1987 repair, which is already in need of retrofit. Grouting the voids between the stones is not recommended. This would restrict drainage and increase hydrostatic pressure behind the walls.

Alternative 2, removing the upper portion of the existing abutments, was evaluated analytically. While it works analytically, there are constructability concerns with this alternative. Due to the constructability concerns discussed below, this alternative is not recommended.

Constructability

Construction of the existing walls is unknown. The size and shape of the abutments have been interpolated by a series of probes. Evaluation of the existing abutments and potential rehabilitation alternatives, is based on best available information. The stones of the wingwalls are much less uniform than those of the abutments. The wingwalls will require close to full reconstruction. If the existing conditions vary greatly from what is assumed in the analysis, field changes will be required. There is an increased project cost and potential increase in construction duration related to the risks associated with these unknown conditions. Also, this level of stone work is a specialized, time-consuming skill set that many bridge Contractors are not experienced in.

In the bridge's existing state, the superstructure and approach slabs contribute to the stability of the abutments. Based on an evaluation of the existing conditions with the superstructure and approach slabs removed, the existing abutments are not stable. This creates constructability concerns, as the walls may not be adequate to support backfill during construction after the superstructure and approach slabs are removed.

In addition, tree growth is helping to stabilize the side slopes and wingwalls. See Photo 3 in Attachment A. When these trees and root systems are removed for construction access, there is potential for the walls and side slopes to have stability issues. The southwest wingwall will need to be rebuilt in its entirety.

Bedrock is shallow in the vicinity of the bridge, which presents challenges for driving sheeting for temporary earth support and cofferdam construction. This makes reconstruction of the existing wingwalls in place challenging without large areas of slope excavation.

Lastly, the bridge is located on a road that provides the access to a group of residential homes and businesses. Since this road is the only means of access and egress for these homes and business, the road cannot be closed to traffic for an extended period of time. For this reason, rehabilitation alternatives will require construction of a temporary bridge detour.

Full Replacement

Full replacement of the substructure can be constructed off-alignment or on the existing alignment behind the existing abutments. Below is a list of advantages of the full replacement alternative:

1. Eliminates the need for a temporary crossing, if constructed off-alignment.
2. Reduces risks associated with unknown geometry and construction of the existing abutments.
3. Improves stream crossing.
    - The existing bridge spans roughly 26 feet, which is much shorter than the calculated and measured bank full width of the stream, equal to approximately 40 feet.
4. Improves roadway alignment, if constructed off-alignment.
5. Results in a superstructure and substructure with comparable remaining service lives.
    - A superstructure replacement with substructure rehabilitation will result in a superstructure with a longer expected service life than the substructure. This is not ideal, since the superstructure may have to be replaced before it has reached its full service life due to the need to replace the substructure at an earlier date.

Summary

The existing stone walls are in poor condition, exhibiting signs of movement, large voids, and irregularly shaped and sized stones. In their existing state, the abutments and wingwalls cannot support HL-93 loading, therefore extensive rehabilitation or replacement of the walls is required. In addition to the poor condition of the stone walls, the existing geometry of the walls is only partially known, which presents increased risk associated with the design and construction of rehabilitation alternatives. Two rehabilitation alternatives were investigated but are not recommended from a constructability standpoint since they would require close to full reconstruction of the walls.

Recommendations

For the reasons discussed above, a full replacement of the existing substructure is recommended over the rehabilitation alternatives. Replacement of the substructure allows off-alignment construction alternatives to be evaluated. It is recommended that the next steps be that full replacement off-alignment and full replacement behind the existing abutments be evaluated and documented in the Preliminary Design Report.

If you have any questions on the existing conditions, the work performed to date, or the recommendations included herein, please don't hesitate to contact us. We're available to discuss this information in person or over the phone. We look forward to continuing our work with you on this project.

List of Attachments:

Attachment A – Photographs
Attachment B – Field Measurements
Attachment C – Calculations