

HYDROLOGY REPORT

Merrills Corner Bridge carries Old County Road over Shepards River in the town of Brownfield, Maine. A hydrology report for Shepards River watershed was developed. Peak flow estimates were provided by the Environmental Office and calculated using the 2021 United States Geological Survey Agency (USGS) regression equation (see Appendix C). The summary of the site hydrology is in the table below.

SUMMARY		
Drainage Area	18.11	mi ²
Q1.1	470	ft ³ /s
Q10	1870	ft ³ /s
Q25	2390	ft ³ /s
Q50	2810	ft ³ /s
Q100	3245	ft ³ /s
Q500	4190	ft ³ /s

Reported by: Brewer, Erin

Date: October 10, 2024

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

HYDRAULIC REPORT

The hydraulic analysis was completed using the U.S Army Corps of Engineers' HEC-RAS program, version 5.0.7. HEC-RAS supports one-dimensional, steady flow, water surface profile calculations. The existing bridge, and the new bridge options were analyzed. Cross-sections were taken from survey data and LiDAR data gathered for this project.

This bridge is inlet controlled so the main focus of improving the hydraulics was to increase the span length which would increase the hydraulic opening. This greatly improves the freeboard at Q10 flows. For higher flood flows such as Q25 and above, the only way to improve flooding is to raise the road significantly. Raising the road is not realistic at this location since:

- The low point of the road is located approximately 120 feet north of the bridge
- Corridor Priority is 5
- Low traffic volume
- Site constraints
- There is a short detour if needed

For a riverine bridge, the BDG recommends a freeboard depth of 2 feet for Q50 flows. The existing bridge has a freeboard of -2 feet at Q50. After determining the existing hydraulic situation, the design criteria became to pass Q10 flows. Properly designed scour countermeasures will be utilized to prevent scour to the abutments.

Below is a list of parameters used in each of the hydraulic models:

Existing Bridge

- Bridge Shape: Single-span steel girder bridge
- Span: 25' 7"
- Deck Width: 16' 4"
- Hydraulic Opening: 206.56 SF
- Skew: 7 degree at North Abutment, 3.31 degree at South Abutment

Proposed Bridge

- Bridge Shape: Single-span concrete solid slab
- Span: 51'
- Deck Width: 30'
- Skew: 14 degrees
- Hydraulic Opening: 268.58 SF
- 1.5:1 riprap slopes with wildlife shelves in front of both abutments

SUMMARY

		Existing Structure	Recommended Structure
		25' 7" Single Span Steel	51' Single Span Solid Slab
Total Area of Waterway Opening	ft ²	206.56	268.58
Headwater elevation @ Q _{1.1}	ft	466.31	466.28
Headwater elevation @ Q ₁₀	ft	473.42	470.21
Headwater elevation @ Q ₂₅	ft	473.82	473.17
Headwater elevation @ Q ₅₀	ft	474.00	473.50
Headwater elevation @ Q ₁₀₀	ft	474.73	473.77
Headwater elevation @ Q ₅₀₀	ft	475.30	474.03
Freeboard @ Q ₅₀	ft	-2.00	-2.90
Freeboard @ Q ₁₀₀	ft	-2.73	-3.17
Outlet Velocity @ Q _{1.1}	ft/s	6.43	8.29
Outlet Velocity @ Q ₁₀	ft/s	7.89	9.28
Outlet Velocity @ Q ₂₅	ft/s	8.46	8.15
Outlet Velocity @ Q ₅₀	ft/s	8.92	8.69
Outlet Velocity @ Q ₁₀₀	ft/s	9.09	9.01
Outlet Velocity @ Q ₅₀₀	ft/s	6.73	9.66

Reported by: Brewer, Erin
Date: April 2, 2024

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

Since this is in a regulated floodway, the water surface elevation at Q100 cannot increase and it decreased with the proposed bridge option.

HYDRAULIC REPORT

The following is a report of the hydraulic analysis of the existing bridge and proposed bridge on Old County Road over Shepards River in Brownfield, Maine.

INTRODUCTION

Merrills Corner Bridge carries Old County Road over Shepards River. The existing bridge is a 25 foot 7" single-span steel girder bridge. The low chord of the existing structure is at approximately 472 feet, which was determined using survey data points. The existing bridge has a hydraulic opening of approximately 207 square feet.

The proposed structure is a single span solid slab superstructure with integral abutments on h-piles founded on bedrock. The new bridge will have a longer span than the existing bridge and be longer than the BFW of 29 feet. This opening includes a 4 foot wildlife shelf at Abutment 1 and a 2 foot wildlife shelf at Abutment 2 just below the Q1.1 elevation. The low chord of the proposed structure is at approximately 470.60 feet. The proposed structure offers approximately 269 square feet of hydraulic opening. Since this is a regulated floodway, the proposed bridge water surface elevation at Q100 must be lower than the existing bridge is at that flow.

EXISTING DATA REVIEW

The existing site was reviewed for data that could be used in calibrating the model. Water elevation data was found in the Oxford County Flood Insurance Study (FIS).

The FIS has a longitudinal profile of the Shepards River, which includes the location of the bridge (labeled as Old County Road Bridge on the profile). There are also two cross-sections, one immediately upstream ("K") and one immediately downstream ("J") of the bridge, which are analyzed in the Floodway Data Table 11 in the FIS report. The locations of these cross sections are shown in the FIRM for Brownfield. Figure 1 shows this portion of the map from the Brownfield FIRM. Unfortunately the FIS report uses a largely different Q100 flow rate of 4170 cubic feet per second than the 3245 cubic feet per second calculated by StreamStats for this project. The FIS report dates from 2009 and used the 1999 Regression Equation to calculate flow. The 2021 Regression Equation was used to calculate the 3245 cubic feet per second. We have more confidence in the accuracy of the 2021 equation.

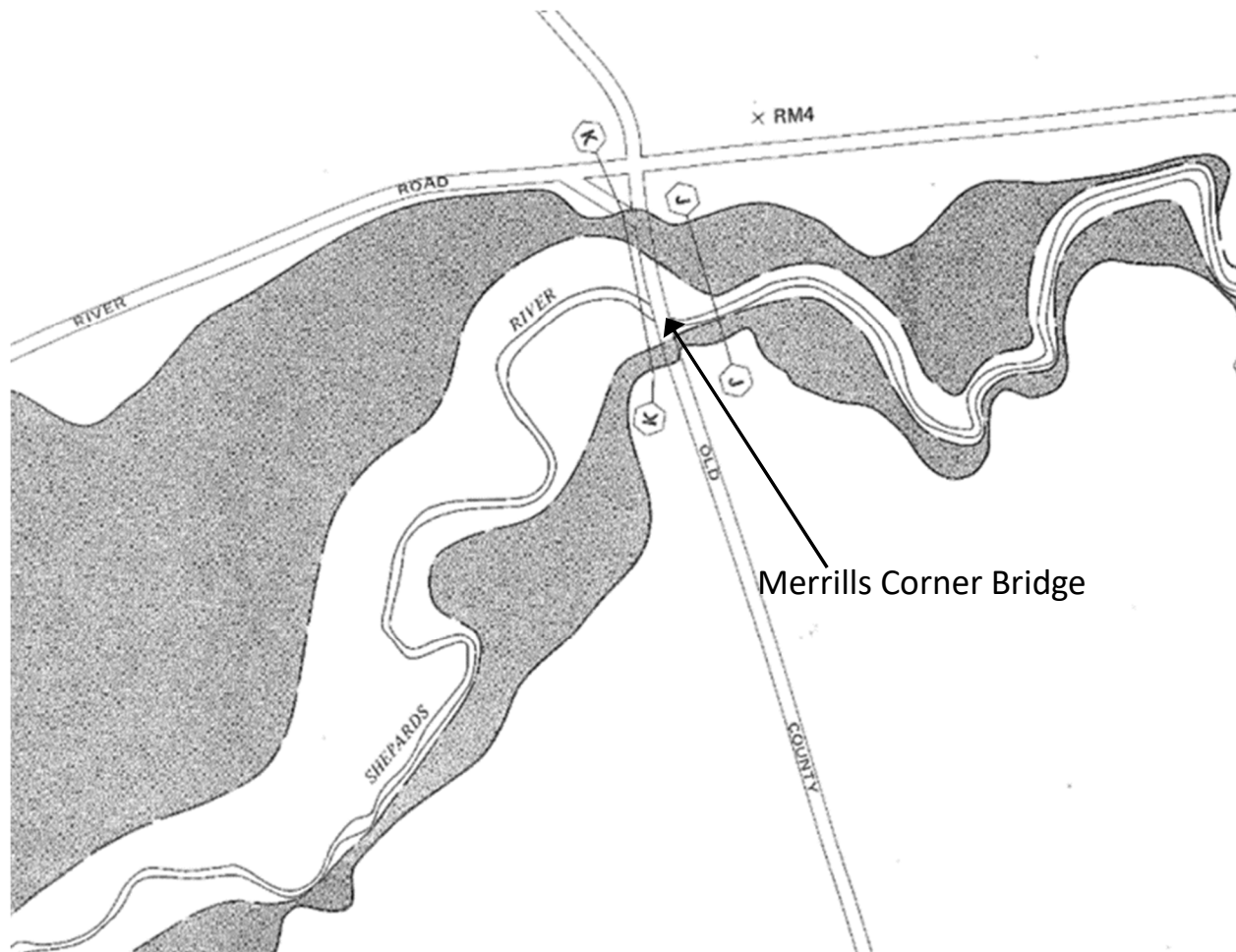


Figure 1. Location of Merrills Corner Bridge shown on the Brownfield FIRM

According to the FIS report, low lying areas of Brownfield are subject to periodic flooding caused by the overflow of the Saco River. Major floods occurring in Brownfield from the Saco River were in 1936, 1953, and 1987. Shepards River, which is a tributary of the Saco River, also causes flooding in Brownfield. The abutters stated that the adjacent hayfields were underwater 4 times in the Spring and Summer of 2023 with floodwater overtopping the roadway or coming close on these occasions.

HYDRAULIC ANALYSIS

Hydraulic calculations for the existing and proposed conditions along Shepards River were performed using the U.S. Army Corps of Engineers' HEC-RAS program, version 5.0.7. HEC-RAS supports one-dimensional, steady flow, water surface profile calculations. The existing bridge and the new bridge options were analyzed. Cross-sections were taken from survey data and LiDAR data gathered for this project.

The downstream boundary condition was set as the downstream slope. A downstream slope of 0.005 was estimated using the longitudinal profile of Shepards River in the FIS. Then a slope

sensitivity analysis was performed to make sure the slope wasn't affecting the hydraulic analysis. The downstream slope was varied to see how much and if the hydraulic output would change when the slope changed. Table 1 shows that for a downstream slope between 0.001 and 0.05 the headwater elevation remained the same. Therefore, this hydraulic model is satisfactory.

DS Slope	HW Elevation (ft) at Q100
0.001	474.73
0.004	475.73
0.005	475.73
0.006	475.73
0.01	475.73
0.05	475.73

Table 1. Downstream slope sensitivity analysis

The HEC-RAS existing bridge model was originally run assuming subcritical flow. A Warning stated that when the assumed water surface was set equal to critical depth, the calculated water surface came back below critical depth. This indicates that there is not a valid subcritical answer. The final iteration of the existing bridge model was then run assuming a mixed flow. Just downstream of the bridge, the model showed supercritical flow since the bridge constricts the river.

The models included approximately 402 feet of Shepards River, with approximately 190 feet upstream and 168 feet downstream of the bridge.

Manning's n was determined using guidance from the *Hydraulic Design of Safe Bridges*; Table 3.1 included the Values for the Computation of the Manning Roughness Coefficient Using Equation 3.43 (after Chow 1959). Manning's n was determined to be 0.052 in the channel and 0.075 in the overbank using Equation 3.43. Ineffective flow areas were set upstream and downstream of the bridge based on contraction and expansion from the bridge in the model. The contraction rate (CR) was assumed to be 1.5 and the expansion rate (ER) was assumed to be 1.5 based off Table 5.1 in the *Hydraulic Design of Safe Bridges*.

All proposed bridge superstructure options will have a deeper superstructure depth and a lower low chord elevation than the existing bridge. A few superstructure options were looked at: they included a NEXT beam, steel girder, or a solid slab. A solid slab option is the shallowest proposed bridge superstructure option. The span length of 51 feet was determined since it allows for freeboard at Q10, while the water would touch the solid slab for a shorter span. The depth of the superstructure was measured from the top of the crown at centerline to the bottom of the exterior beam (the low chord). The lower low chord does provide less freeboard even as the headwater elevation decreases.

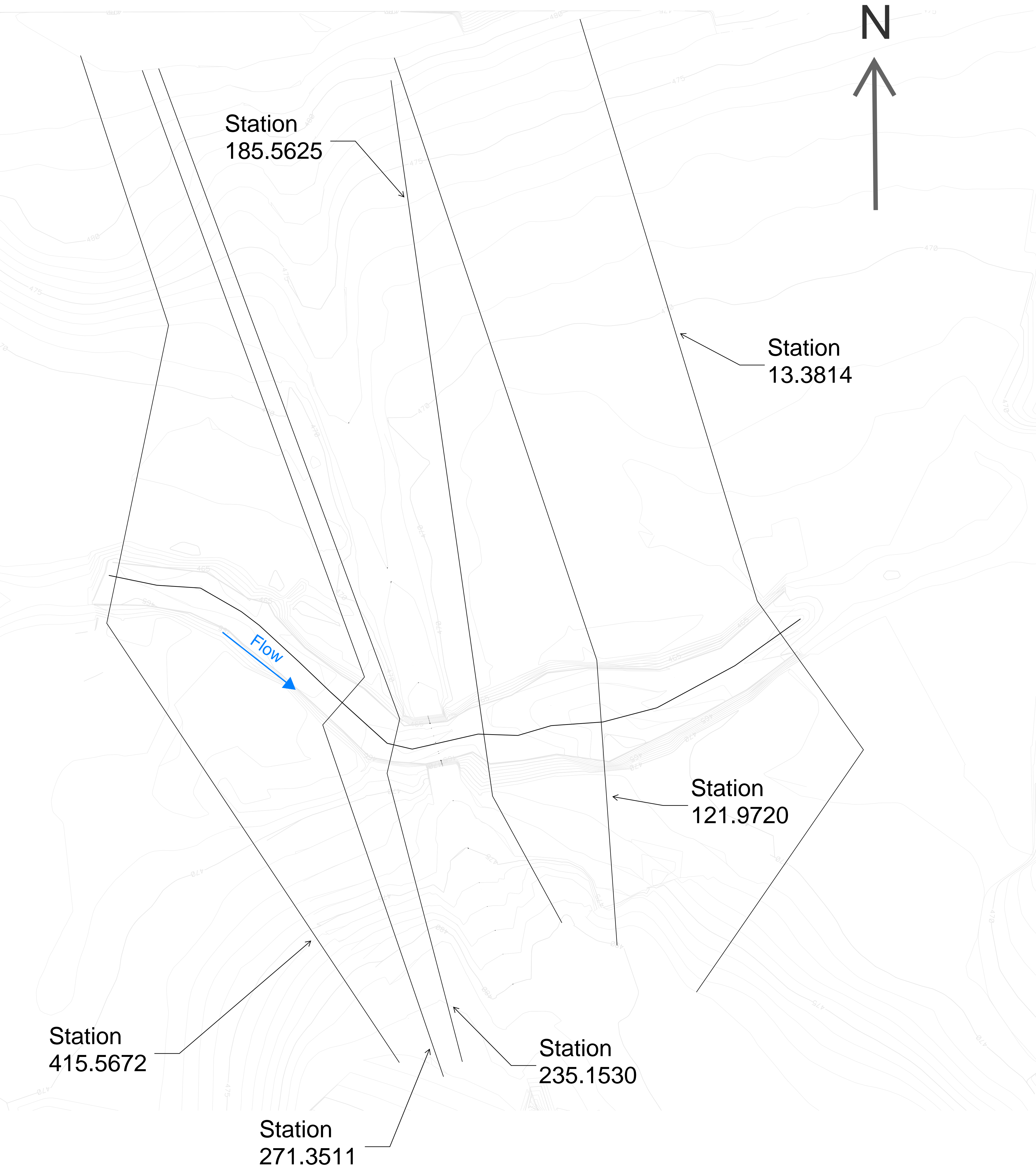
The analysis found that the proposed bridge and existing bridge were both overtopped by a Q25 storm event. This is supported by the abutments. Both the existing and proposed bridges do not satisfy BDG recommendations for freeboard when the water is experiencing a Q50 flow. At Q50 flow, the existing bridge has a freeboard of -2.00 feet and a headwater elevation of 474.00 feet while the proposed bridge has a freeboard of -2.90 feet and a headwater elevation of 473.50 feet.

		Existing Structure	Recommended Structure
		25' 7" Single Span Steel Beam	51' Single Span Solid Slab
Total Area of Waterway Opening	ft ²	206.56	268.58
Headwater elevation @ Q _{1.1}	ft	466.31	466.28
Headwater elevation @ Q ₁₀	ft	473.42	470.21
Headwater elevation @ Q ₂₅	ft	473.82	473.17
Headwater elevation @ Q ₅₀	ft	474.00	473.50
Headwater elevation @ Q ₁₀₀	ft	474.73	473.77
Headwater elevation @ Q ₅₀₀	ft	475.30	474.03
Freeboard @ Q ₅₀	ft	-2.00	-2.90
Freeboard @ Q ₁₀₀	ft	-2.73	-3.17
Outlet Velocity @ Q _{1.1}	ft/s	6.43	8.29
Outlet Velocity @ Q ₁₀	ft/s	7.89	9.28
Outlet Velocity @ Q ₂₅	ft/s	8.46	8.15
Outlet Velocity @ Q ₅₀	ft/s	8.92	8.69
Outlet Velocity @ Q ₁₀₀	ft/s	9.09	9.01
Outlet Velocity @ Q ₅₀₀	ft/s	6.73	9.66

Table 2. Hydraulic analysis summary

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

Hydraulic Model Cross Section Locations



HEC-RAS Plan: All River: Shepards River Reach: Reach

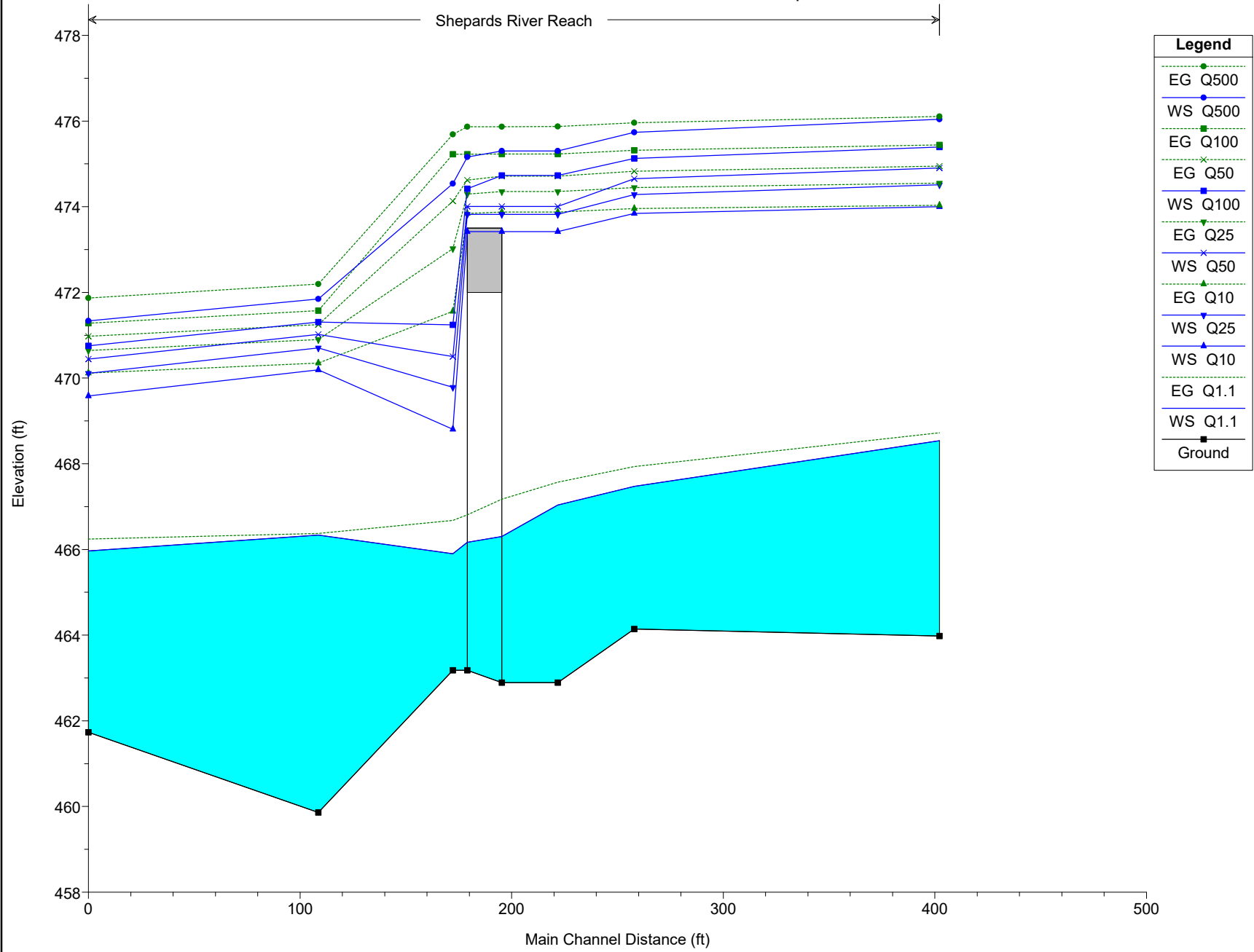
Reach	River Sta	Profile	E.G. US. (ft)	Min El Prs (ft)	BR Open Area (sq ft)	Prs O WS (ft)	Q Total (cfs)	Min El Weir Flow (ft)	Q Weir (cfs)	Delta EG (ft)	BR Sluice Coef
Reach	212	Q1.1	467.57	472.00	206.56		470.00	473.51		0.89	
Reach	212	Q10	473.88	472.00	206.56	473.84	1870.00	473.51	133.45	2.32	0.43
Reach	212	Q25	474.35	472.00	206.56	476.36	2390.00	473.51	493.23	1.33	0.45
Reach	212	Q50	474.71	472.00	206.56	479.42	2810.00	473.51	835.44	0.58	0.46
Reach	212	Q100	475.23	472.00	206.56	483.30	3245.00	473.51	1109.12	0.01	0.48
Reach	212	Q500	475.87	472.00	206.56		4190.00	473.51	2661.88	0.08	

HEC-RAS Plan: All River: Shepards River Reach: Reach

Reach	River Sta	Profile	E.G. Elev (ft)	W.S. Elev (ft)	Crit W.S. (ft)	Frctn Loss (ft)	C & E Loss (ft)	Top Width (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Vel Chnl (ft/s)
Reach	271.3511	Q1.1	467.93	467.47		0.36	0.01	33.43		469.88	0.12	5.44
Reach	271.3511	Q10	473.95	473.84		0.04	0.03	351.35	372.41	1029.88	467.71	3.41
Reach	271.3511	Q25	474.45	474.28		0.06	0.04	358.16	554.12	1324.27	511.61	4.17
Reach	271.3511	Q50	474.83	474.65		0.06	0.05	363.90	730.07	1458.74	621.19	4.42
Reach	271.3511	Q100	475.32	475.13		0.05	0.03	371.38	912.99	1620.84	711.18	4.68
Reach	271.3511	Q500	475.96	475.74		0.06	0.03	381.46	1342.37	1904.40	943.23	5.19
Reach	235.1530	Q1.1	467.57	467.04	465.94	0.36	0.03	29.22		470.00		5.85
Reach	235.1530	Q10	473.88	473.42	469.41			330.36	332.53	1477.88	59.59	6.08
Reach	235.1530	Q25	474.35	473.82	470.42			340.12	562.77	1731.08	96.16	6.79
Reach	235.1530	Q50	474.71	474.00	471.16			344.21	694.69	2042.36	72.95	7.84
Reach	235.1530	Q100	475.23	474.73	473.59			356.36	1085.01	1993.26	166.73	7.07
Reach	235.1530	Q500	475.87	475.30	473.98			365.43	1562.78	2333.55	293.67	7.81
Reach	212 BR U	Q1.1	467.17	466.31	465.96	0.30	0.07	23.82		470.00		7.48
Reach	212 BR U	Q10	473.88	473.42	469.42				117.99	1741.54	10.48	8.63
Reach	212 BR U	Q25	474.35	473.82	470.41			340.12	418.10	1960.15	11.75	9.28
Reach	212 BR U	Q50	474.71	474.00	471.16			344.21	726.02	2124.75	12.58	9.81
Reach	212 BR U	Q100	475.23	474.73	474.85			356.36	914.42	2370.01	20.12	9.96
Reach	212 BR U	Q500	475.87	475.30	475.23			365.43	2088.83	2030.00	58.59	7.97
Reach	212 BR D	Q1.1	466.81	466.16	465.50	0.11	0.01	25.54		470.00		6.43
Reach	212 BR D	Q10	473.84	473.42	468.81				117.99	1751.88	0.13	7.89
Reach	212 BR D	Q25	474.30	473.82	469.79			354.66	418.10	1971.45	0.45	8.46
Reach	212 BR D	Q50	474.62	474.00	470.53			358.87	726.02	2136.56	0.77	8.92
Reach	212 BR D	Q100	475.22	474.42	471.25			368.64	914.42	2382.74	7.39	9.09
Reach	212 BR D	Q500	475.87	475.16	475.16			384.57	2088.83	2039.11	49.49	6.73
Reach	185.5625	Q1.1	466.68	465.90		0.08	0.22	39.60		470.00		7.09
Reach	185.5625	Q10	471.56	468.81	468.81	0.16	0.78	48.69		1870.00		13.31
Reach	185.5625	Q25	473.02	469.78	469.78	0.18	0.91	205.34		2390.00		14.44
Reach	185.5625	Q50	474.13	470.50	470.50	0.20	1.02	223.35		2810.00		15.29
Reach	185.5625	Q100	475.22	471.24	471.24	0.22	1.11	243.56		3245.00		16.01
Reach	185.5625	Q500	475.69	474.54	474.54	0.21	0.24	371.51	1088.60	3084.88	16.51	9.83
Reach	121.9720	Q1.1	466.38	466.33		0.11	0.02	55.75		470.00		1.62
Reach	121.9720	Q10	470.35	470.19	464.33	0.19	0.04	243.25	173.21	1696.79		3.31
Reach	121.9720	Q25	470.90	470.71	464.93	0.22	0.03	252.46	326.66	2063.34		3.79
Reach	121.9720	Q50	471.25	471.02	465.38	0.25	0.03	260.34	457.03	2352.96	0.01	4.18
Reach	121.9720	Q100	471.58	471.31	465.82	0.27	0.03	274.78	597.46	2647.13	0.41	4.56
Reach	121.9720	Q500	472.19	471.84	466.73	0.31	0.02	308.21	930.48	3254.12	5.40	5.31

Extended Cross Sections - Brownfield Plan: All Flows - Shepards River 3/19/2024

Shepards River Reach



Proposed Bridge HEC-RAS Output at the Bridge

HEC-RAS Plan: River: Shepards River Reach: Reach

Reach	River Sta	Profile	E.G. US. (ft)	Min El Prs (ft)	BR Open Area (sq ft)	Prs O WS (ft)	Q Total (cfs)	Min El Weir Flow (ft)	Q Weir (cfs)	Delta EG (ft)	BR Sluice Coef
Reach	212	Q1.1	467.32	471.68	268.58		470.00	473.09		0.79	
Reach	212	Q10	471.46	471.68	268.58		1870.00	473.09		0.81	
Reach	212	Q25	473.59	471.68	268.58	473.66	2390.00	473.09	177.35	2.26	0.46
Reach	212	Q50	473.99	471.68	268.58	475.25	2810.00	473.09	441.42	2.18	0.47
Reach	212	Q100	474.33	471.68	268.58	477.56	3245.00	473.09	770.92	1.66	0.48
Reach	212	Q500	474.95	471.68	268.58	483.65	4190.00	473.09	1559.98	0.71	0.48

Proposed Bridge HEC-RAS Output

HEC-RAS Plan: River: Shepards River Reach: Reach

Reach	River Sta	Profile	E.G. Elev (ft)	W.S. Elev (ft)	Crit W.S. (ft)	Frctn Loss (ft)	C & E Loss (ft)	Top Width (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Vel Chnl (ft/s)
Reach	271.3511	Q1.1	467.70	467.08		0.26	0.12	30.43		470.00		6.35
Reach	271.3511	Q10	471.57	470.98	469.94	0.16	0.00	259.53	157.59	1425.67	286.74	6.97
Reach	271.3511	Q25	473.67	473.53		0.05	0.03	346.54	714.86	1161.52	513.62	3.98
Reach	271.3511	Q50	474.07	473.92		0.05	0.03	352.55	903.88	1289.69	616.43	4.23
Reach	271.3511	Q100	474.43	474.24		0.06	0.04	357.47	1063.65	1502.80	678.55	4.76
Reach	271.3511	Q500	475.10	474.88		0.07	0.07	367.33	1511.32	1764.42	914.26	5.22
Reach	235.1530	Q1.1	467.32	467.11	465.69	0.07	0.07	49.56	5.72	454.43	9.86	3.75
Reach	235.1530	Q10	471.46	470.85	468.06	0.05	0.05	234.76	53.68	1740.10	76.22	6.43
Reach	235.1530	Q25	473.59	473.17	468.71			324.19	246.75	2042.93	100.32	5.62
Reach	235.1530	Q50	473.99	473.50	469.23			332.66	387.34	2308.03	114.63	6.13
Reach	235.1530	Q100	474.33	473.77	469.72			338.95	536.67	2579.12	129.21	6.65
Reach	235.1530	Q500	474.95	474.03	470.71			344.86	769.76	3389.15	31.09	8.51
Reach	212 BR U	Q1.1	467.18	466.28	466.28			33.86		470.00		7.64
Reach	212 BR U	Q10	471.36	470.21	468.98	0.39	0.02	47.00	15.12	1844.95	9.93	8.64
Reach	212 BR U	Q25	473.59	473.17	469.73			236.09	195.65	2169.22	30.55	8.67
Reach	212 BR U	Q50	473.99	473.50	470.26			254.30	433.80	2345.53	32.70	9.28
Reach	212 BR U	Q100	474.33	473.77	470.58			269.18	703.10	2490.68	47.26	9.63
Reach	212 BR U	Q500	474.95	474.03	471.04			283.45	1341.02	2759.26	88.21	10.33
Reach	212 BR D	Q1.1	466.94	465.87	465.87			26.44		470.00		8.29
Reach	212 BR D	Q10	470.94	469.60	468.84	0.11	0.17	46.50	0.17	1869.84		9.28
Reach	212 BR D	Q25	473.53	473.17	469.61			250.49	175.57	2219.85		8.15
Reach	212 BR D	Q50	473.88	473.50	470.11			271.79	412.31	2399.73		8.69
Reach	212 BR D	Q100	474.22	473.77	470.60			289.25	680.65	2547.29	13.10	9.01
Reach	212 BR D	Q500	474.95	474.03	470.92			305.98	1317.15	2819.44	51.90	9.66
Reach	185.5625	Q1.1	466.53	466.20		0.07	0.09	40.56		470.00		4.64
Reach	185.5625	Q10	470.65	469.89		0.12	0.18	207.34	0.25	1869.75		7.01
Reach	185.5625	Q25	471.33	470.21		0.15	0.28	216.38	0.54	2389.46		8.48
Reach	185.5625	Q50	471.81	470.31		0.18	0.38	219.13	0.72	2809.28		9.81
Reach	185.5625	Q100	472.30	470.31	469.49	0.21	0.52	219.00	0.83	3244.17		11.34
Reach	185.5625	Q500	473.63	470.46	470.46	0.27	0.84	222.51	1.27	4188.73		14.28
Reach	121.9720	Q1.1	466.38	466.33		0.11	0.02	55.75		470.00		1.62
Reach	121.9720	Q10	470.35	470.19		0.19	0.04	243.25	173.22	1696.78		3.31
Reach	121.9720	Q25	470.90	470.71		0.22	0.03	252.46	326.66	2063.34		3.79
Reach	121.9720	Q50	471.25	471.02		0.25	0.03	260.35	457.05	2352.95	0.01	4.18
Reach	121.9720	Q100	471.58	471.31		0.27	0.03	274.78	597.48	2647.12	0.41	4.56
Reach	121.9720	Q500	472.19	471.84	466.75	0.31	0.02	308.20	930.44	3254.16	5.40	5.31

Proposed Bridge Longitudinal Profile

