

HYDROLOGY/HYDRAULICS SUMMARY

The existing structure drains approximately 9 square miles of urban area with a 100 year storm event of 950 cubic feet per second. The existing structure layout (perpendicular to the roadway) is poorly aligned with the stream, creating a 90 degree bend at the inlet. The proposed structure is properly aligned with the stream at a 19 degree skew.

The proposed structure opening is marginally larger than the existing opening and no effective change in water elevations will occur. The outlet velocities have been significantly reduced, which will reduce downstream bank erosion. There will be approximately 3 feet of clearance (freeboard) between the 100 year water surface elevation and the inside top of box. The proposed structure will have a heavy riprap flowline that is designed for fish passage.

SUMMARY OF HYDOLOGY

Drainage Area = 9.25 square miles
 Low Flow (August) Q = 1.84 cfs
 Ordinary High Water (Q_{1.1}) = 133 cfs
 10 Year Flood (Q₁₀) = 541 cfs
 Design Discharge (Q₅₀) = 819 cfs
 Check Discharge (Q₁₀₀) = 950 cfs
 Q₅₀₀ = 1275 cfs

SUMMARY OF HYDRAULICS

Existing Culvert Summary Table			
Return Period	Discharge	Headwater	Outlet
	cfs	Elevation (ft)	Velocity (ft/s)
1.1	133.0	14.23	15.34
25	704.0	18.75	20.87
50	818.2	19.46	21.49
100	950.0	20.24	22.09
500	1275.0	22.11	23.42

Proposed Culvert Summary Table			
Return Period	Discharge	Headwater	Outlet
	cfs	Elevation (ft)	Velocity (ft/s)
1.1	133.0	15.36	9.42
25	704.0	19.25	17.13
50	818.2	19.89	17.68
100	950.0	20.6	18.46
500	1275.0	22.3	20.04

Hydrology/Hydraulics/Scour Data

Peak Flow Calculations by USGS Regression Equations (Hodgkins, 1999)

	km²	mi²	ac	<i>Enter data in [mi²]</i> Watershed Area Wetlands area (by NWI)
A	23.95	9.247	5917.9	
W	2.82	1.089	697.0	
P_c	519600	4965680		watershed centroid (E, N; UTM 19N; meters) <i>choose county from drop-down menu</i>
County	Penobscot S			
pptA	39.5			mean annual precipitation (inches; by look-up)
SG	0.00			sand & gravel aquifer as decimal fraction of watershed A
A (km²)	23.95			
W (%)	11.78			
		Conf Lvl	0.67	

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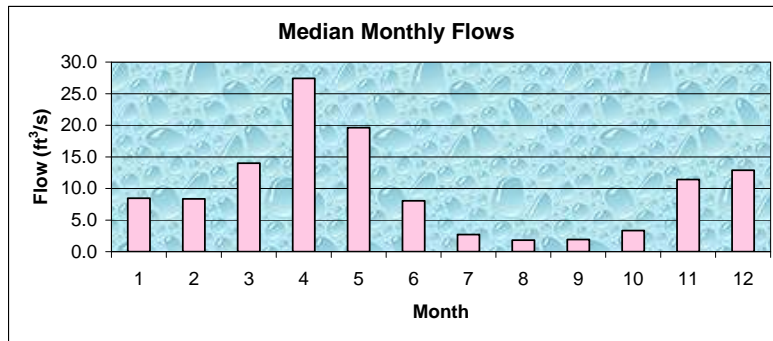
Ret Pd T (yr)	Peak Flow Estimate			Q _T (ft ³ /s)
	Lower	Q _T (m ³ /s)	Upper	
1.1		3.78		133.3
2	5.52	7.72	10.81	272.7
5	8.61	12.09	16.98	426.8
10	10.80	15.33	21.76	541.3
25	13.70	19.73	28.41	696.6
50	15.91	23.19	33.80	818.7
100	18.23	26.91	39.72	950.2
500	23.69	36.12	55.07	1275.4

MAINE MONTHLY MEDIAN FLOWS BY USGS REGRESSION EQUATIONS (2004)

Value	Variable	Explanation
9.247	A	Area (mi ²)
519600	P _c	Watershed centroid (E,N; UTM; Zone 19; meters)
66.71	DIST	Distance from Coastal reference line (mi)
39.5	pptA	Mean Annual Precipitation (inches)
0.00	SG	Sand & Gravel Aquifer (decimal fraction of watershed area)

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Month	Q _{median}	
	(ft ³ /s)	(m ³ /s)
Jan	8.45	0.2395
Feb	8.35	0.2366
Mar	13.99	0.3965
Apr	27.40	0.7763
May	19.63	0.5562
Jun	8.04	0.2278
Jul	2.70	0.0767
Aug	1.84	0.0520
Sep	1.92	0.0545
Oct	3.35	0.0948
Nov	11.40	0.3231
Dec	12.86	0.3645



HY-8 Existing Culvert Analysis Report

Table 1 - Summary of Culvert Flows at Crossing: Bangor Red Bridge

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
14.23	133.00	133.00	0.00	1
15.36	247.20	247.20	0.00	1
16.32	361.40	361.40	0.00	1
17.19	475.60	475.60	0.00	1
17.99	589.80	589.80	0.00	1
18.75	704.00	704.00	0.00	1
19.46	818.20	818.20	0.00	1
20.14	932.40	932.40	0.00	1
20.24	950.00	950.00	0.00	1
21.46	1160.80	1160.80	0.00	1
22.11	1275.00	1275.00	0.00	1
29.00	2666.18	2666.18	0.00	Overtopping

Rating Curve Plot for Crossing: Bangor Red Bridge

Total Rating Curve Crossing: Bangor Red Bridge

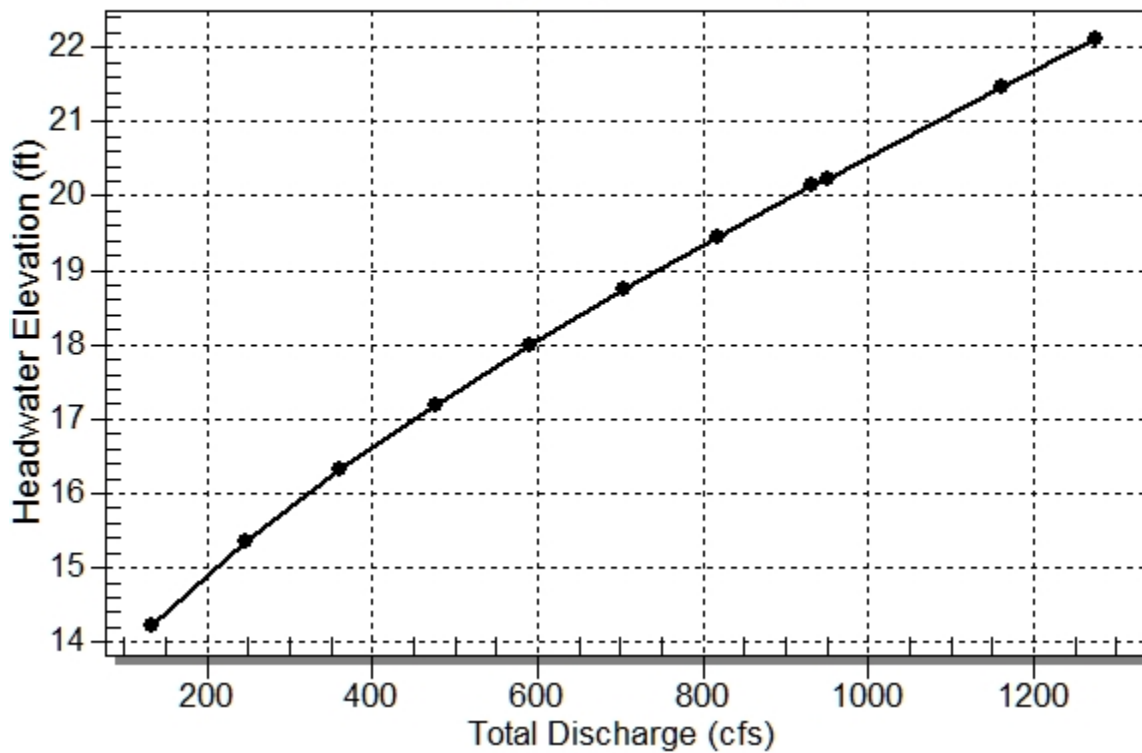
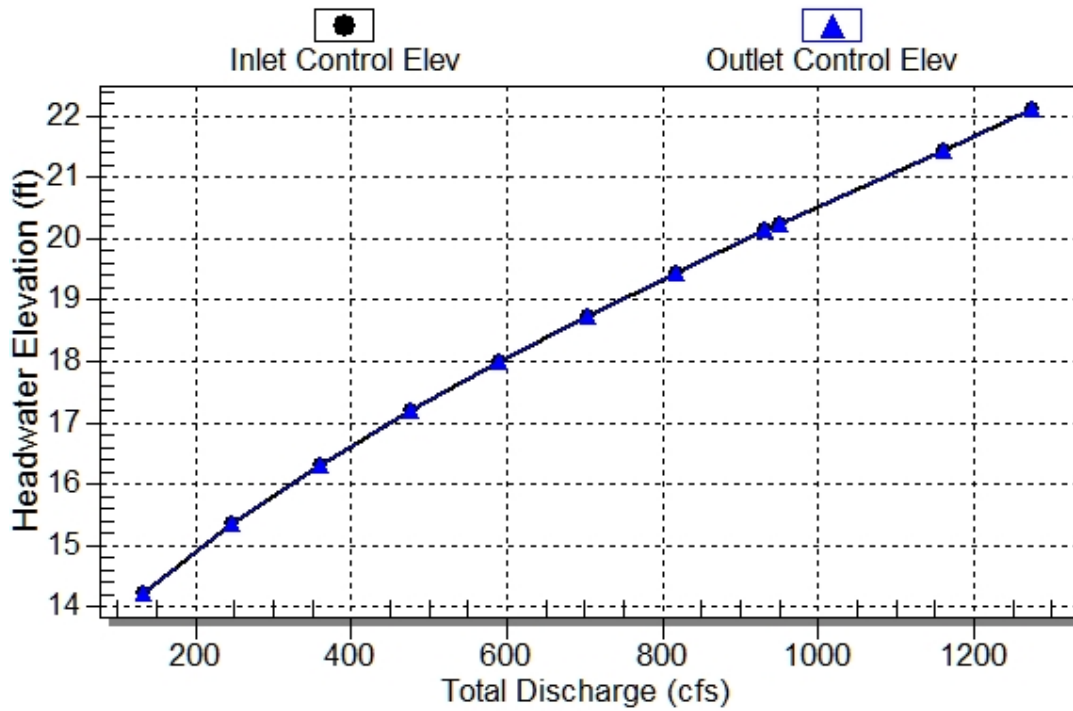


Table 2 - Culvert Summary Table: Culvert 1

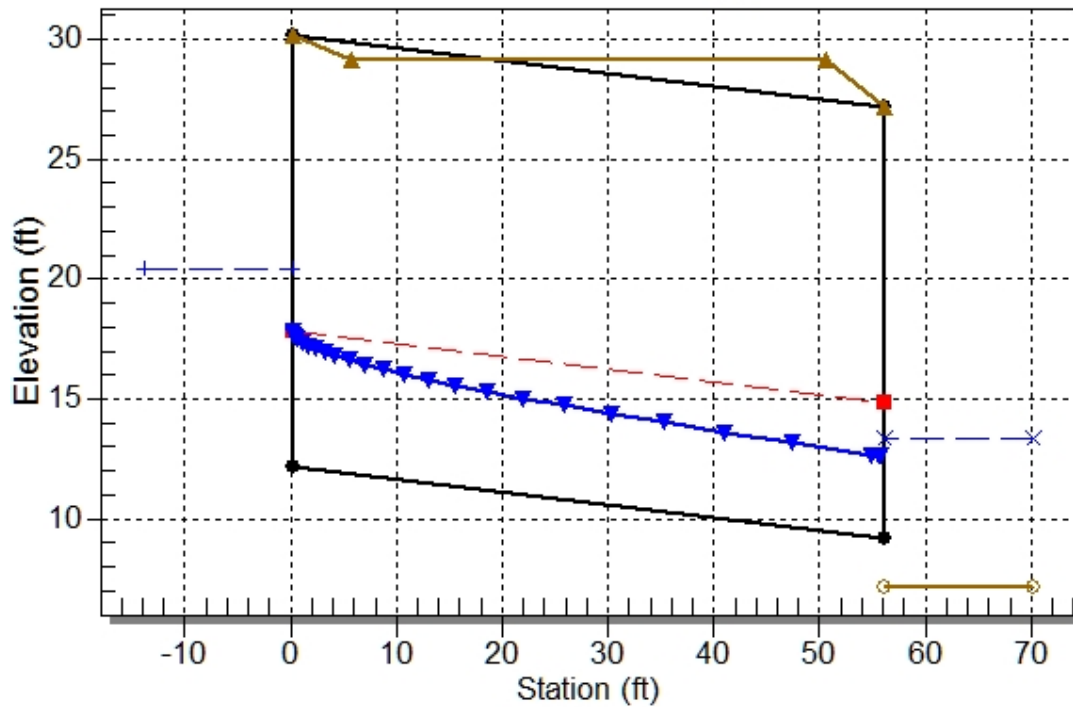
Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
133.00	133.00	14.23	2.228	2.228	1-S2n	0.296	1.524	0.694	2.384	15.335	2.905
247.20	247.20	15.36	3.356	3.356	1-S2n	0.551	2.304	1.148	3.205	17.233	3.544
361.40	361.40	16.32	4.323	4.323	1-S2n	0.805	2.967	1.566	3.858	18.459	3.983
475.60	475.60	17.19	5.195	5.195	1-S2n	1.060	3.563	1.961	4.405	19.398	4.342
589.80	589.80	17.99	5.994	5.994	1-S2n	1.314	4.113	2.338	4.891	20.180	4.644
704.00	704.00	18.75	6.745	6.745	1-S2n	1.569	4.628	2.698	5.335	20.873	4.904
818.20	818.20	19.46	7.457	7.457	1-S2n	1.813	5.116	3.046	5.746	21.488	5.132
932.40	932.40	20.14	8.137	8.137	1-S2n	1.956	5.582	3.389	6.130	22.012	5.337
950.00	950.00	20.24	8.239	8.239	1-S2n	1.978	5.652	3.440	6.187	22.094	5.366
1160.80	1160.80	21.46	9.456	9.456	1-S2n	2.243	6.460	4.040	6.835	22.988	5.692
1275.00	1275.00	22.11	10.110	10.110	1-S2n	2.386	6.877	4.356	7.161	23.418	5.849

 Inlet Elevation (invert): 12.00 ft, Outlet Elevation (invert): 9.00 ft
 Culvert Length: 56.08 ft, Culvert Slope: 0.0536

Culvert Performance Curve Plot: Culvert 1
Performance Curve
 Culvert: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1
 Crossing - Bangor Red Bridge, Design Discharge - 950.0 cfs
 Culvert - Culvert 1, Culvert Discharge - 950.0 cfs



Site Data - Culvert 1
 Site Data Option: Culvert Invert Data
 Inlet Station: 0.00 ft
 Inlet Elevation: 12.00 ft
 Outlet Station: 56.00 ft
 Outlet Elevation: 9.00 ft
 Number of Barrels: 1
 Culvert Data Summary - Culvert 1
 Barrel Shape: Concrete Box
 Barrel Span: 12.50 ft
 Barrel Rise: 18.00 ft
 Barrel Material: Concrete
 Embedment: 0.00 in
 Barrel Manning's n: 0.0120
 Inlet Type: Conventional
 Inlet Edge Condition: Square Edge (30-75° flare) Wingwall
 Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: Bangor Red Bridge)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
133.00	9.38	2.38	2.90	0.74	0.40
247.20	10.21	3.21	3.54	1.00	0.42
361.40	10.86	3.86	3.98	1.20	0.43
475.60	11.41	4.41	4.34	1.37	0.43
589.80	11.89	4.89	4.64	1.53	0.44
704.00	12.33	5.33	4.90	1.66	0.44
818.20	12.75	5.75	5.13	1.79	0.45
932.40	13.13	6.13	5.34	1.91	0.45
950.00	13.19	6.19	5.37	1.93	0.45
1160.80	13.83	6.83	5.69	2.13	0.46
1275.00	14.16	7.16	5.85	2.23	0.46

Tailwater Channel Data - Bangor Red Bridge

Tailwater Channel Option: Irregular Channel

Channel Slope: 0.0050

User Defined Channel Cross-Section:

Coord No.	Station (ft)	Elevation (ft)	Manning's n
1	0.00	16.00	0.0500
2	46.00	16.00	0.0500
3	48.00	15.00	0.0500
4	50.00	14.00	0.0500
5	52.00	13.00	0.0500
6	54.00	12.00	0.0500
7	56.00	11.00	0.0500
8	58.00	10.00	0.0500
9	60.00	9.00	0.0500
10	64.00	8.00	0.0500
11	71.00	7.00	0.0500
12	78.00	7.00	0.0500
13	83.00	8.00	0.0500
14	86.00	9.00	0.0500
15	88.00	10.00	0.0500
16	90.00	11.00	0.0500
17	94.00	15.00	0.0500
18	98.00	18.00	0.0500
19	138.00	19.00	0.0500
20	152.00	20.00	0.0000

Roadway Data for Crossing: Bangor Red Bridge

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 300.00 ft

Crest Elevation: 29.00 ft

Roadway Surface: Paved

Roadway Top Width: 45.00 ft

HY-8 Proposed Culvert Analysis Report

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
15.36	133.00	133.00	0.00	1
16.31	247.20	247.20	0.00	1
17.12	361.40	361.40	0.00	1
17.85	475.60	475.60	0.00	1
18.57	589.80	589.80	0.00	1
19.25	704.00	704.00	0.00	1
19.89	818.20	818.20	0.00	1
20.51	932.40	932.40	0.00	1
20.60	950.00	950.00	0.00	1
21.70	1160.80	1160.80	0.00	1
22.30	1275.00	1275.00	0.00	1
29.00	2302.03	2302.03	0.00	Overtopping

Table 1 - Summary of Culvert Flows at Crossing: Bangor Red Bridge

Rating Curve Plot for Crossing: Bangor Red Bridge

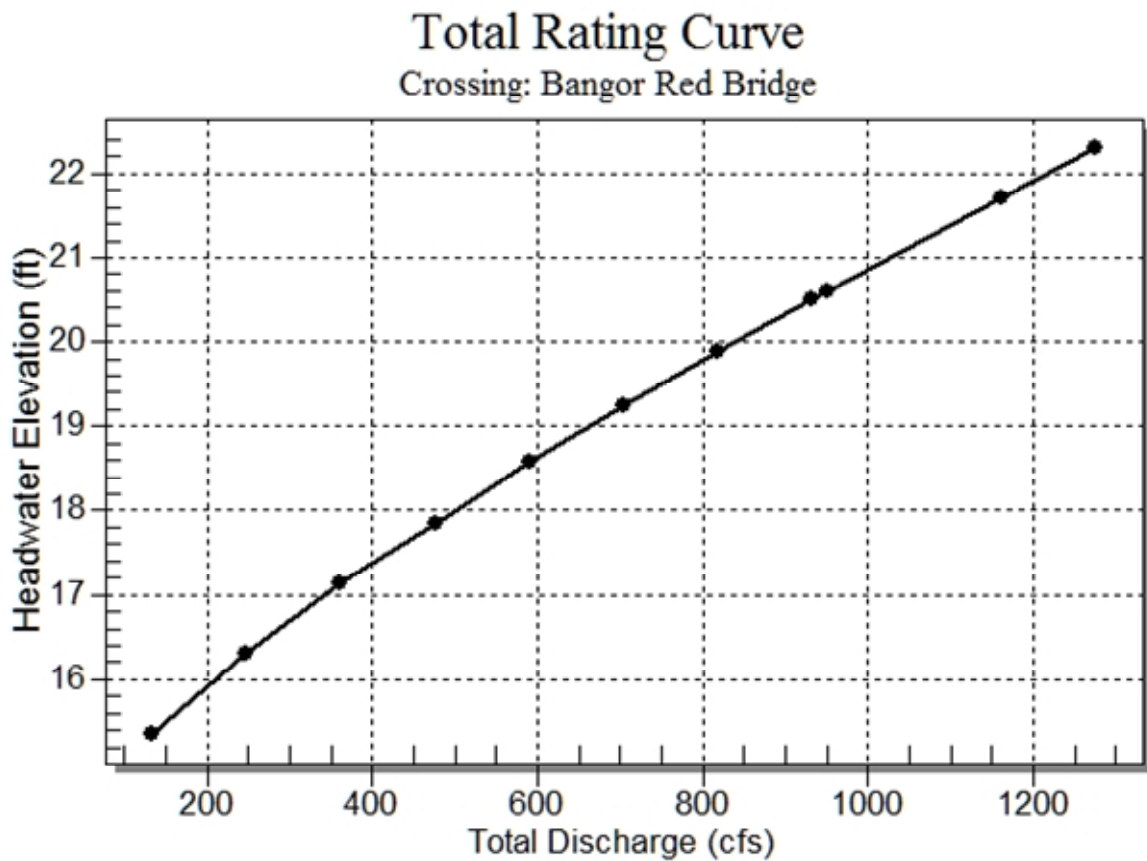


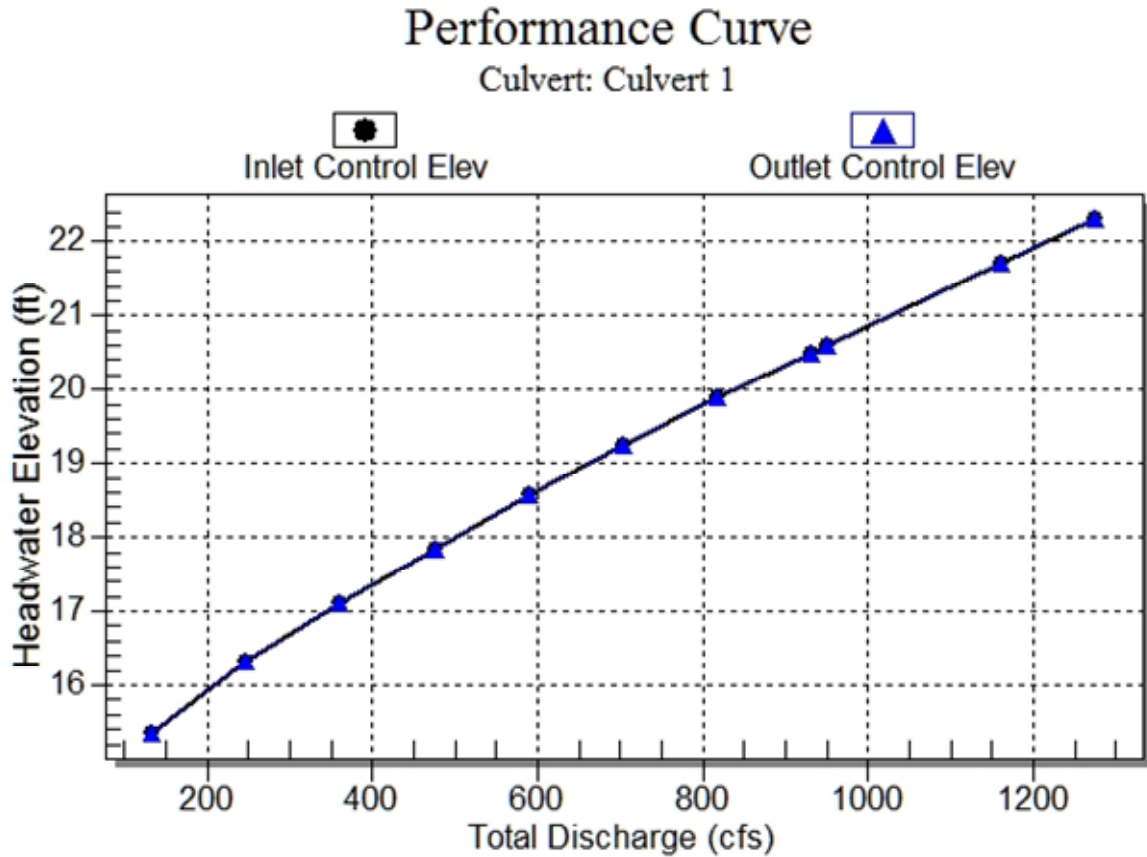
Table 2 - Culvert Summary Table: Culvert 1

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
133.00	133.00	15.36	1.859	1.859	1-S2n	0.869	1.293	0.883	2.384	9.418	2.905
247.20	247.20	16.31	2.812	2.812	1-S2n	1.262	1.954	1.294	3.205	11.940	3.544
361.40	361.40	17.12	3.623	3.623	1-S2n	1.639	2.517	1.647	3.858	13.714	3.983
475.60	475.60	17.85	4.351	4.351	1-S2n	1.968	3.023	1.973	4.405	15.068	4.342
589.80	589.80	18.57	5.074	5.074	1-S2n	2.262	3.489	2.308	4.891	15.974	4.644
704.00	704.00	19.25	5.753	5.753	1-S2n	2.555	3.926	2.568	5.335	17.132	4.904
818.20	818.20	19.89	6.393	6.393	1-S2n	2.829	4.340	2.893	5.746	17.677	5.132
932.40	932.40	20.51	7.007	7.007	1-S2n	3.084	4.735	3.174	6.130	18.361	5.337
950.00	950.00	20.60	7.100	7.100	1-S2n	3.123	4.794	3.216	6.187	18.461	5.366
1160.80	1160.80	21.70	8.200	8.200	1-S2n	3.594	5.479	3.714	6.835	19.532	5.692
1275.00	1275.00	22.30	8.800	8.800	1-S2n	3.827	5.833	3.977	7.161	20.036	5.849

Inlet Elevation (invert): 13.50 ft. Outlet Elevation (invert): 8.00 ft.

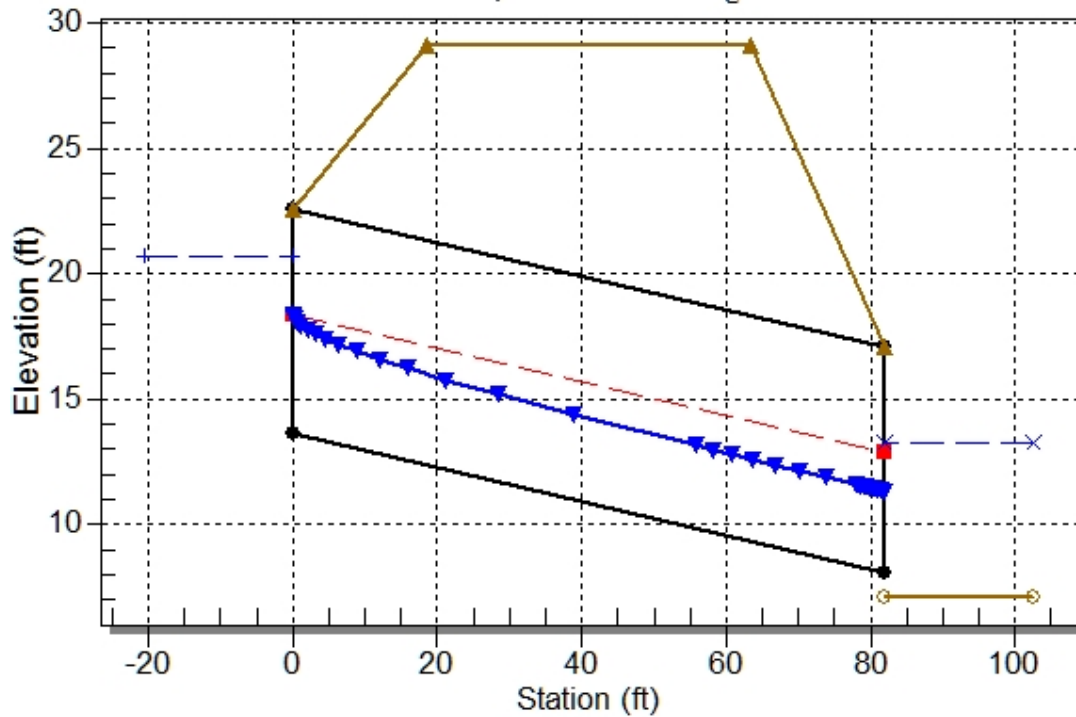
Culvert Length: 82.18 ft, Culvert Slope: 0.0671

Culvert Performance Curve Plot: Culvert 1



Water Surface Profile Plot for Culvert: Culvert 1

Crossing - Bangor Red Bridge, Design Discharge - 950.0 cfs
Culvert - Culvert 1, Culvert Discharge - 950.0 cfs



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 13.50 ft

Outlet Station: 82.00 ft

Outlet Elevation: 8.00 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: Concrete Box

Barrel Span: 16.00 ft

Barrel Rise: 9.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0350

Inlet Type: Conventional

Inlet Edge Condition: Square Edge (30-75° flare) Wingwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: Bangor Red Bridge)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
133.00	9.38	2.38	2.90	0.74	0.40
247.20	10.21	3.21	3.54	1.00	0.42
361.40	10.86	3.86	3.98	1.20	0.43
475.60	11.41	4.41	4.34	1.37	0.43
589.80	11.89	4.89	4.64	1.53	0.44
704.00	12.33	5.33	4.90	1.66	0.44
818.20	12.75	5.75	5.13	1.79	0.45
932.40	13.13	6.13	5.34	1.91	0.45
950.00	13.19	6.19	5.37	1.93	0.45
1160.80	13.83	6.83	5.69	2.13	0.46
1275.00	14.16	7.16	5.85	2.23	0.46

Tailwater Channel Data - Bangor Red Bridge

Tailwater Channel Option: Irregular Channel

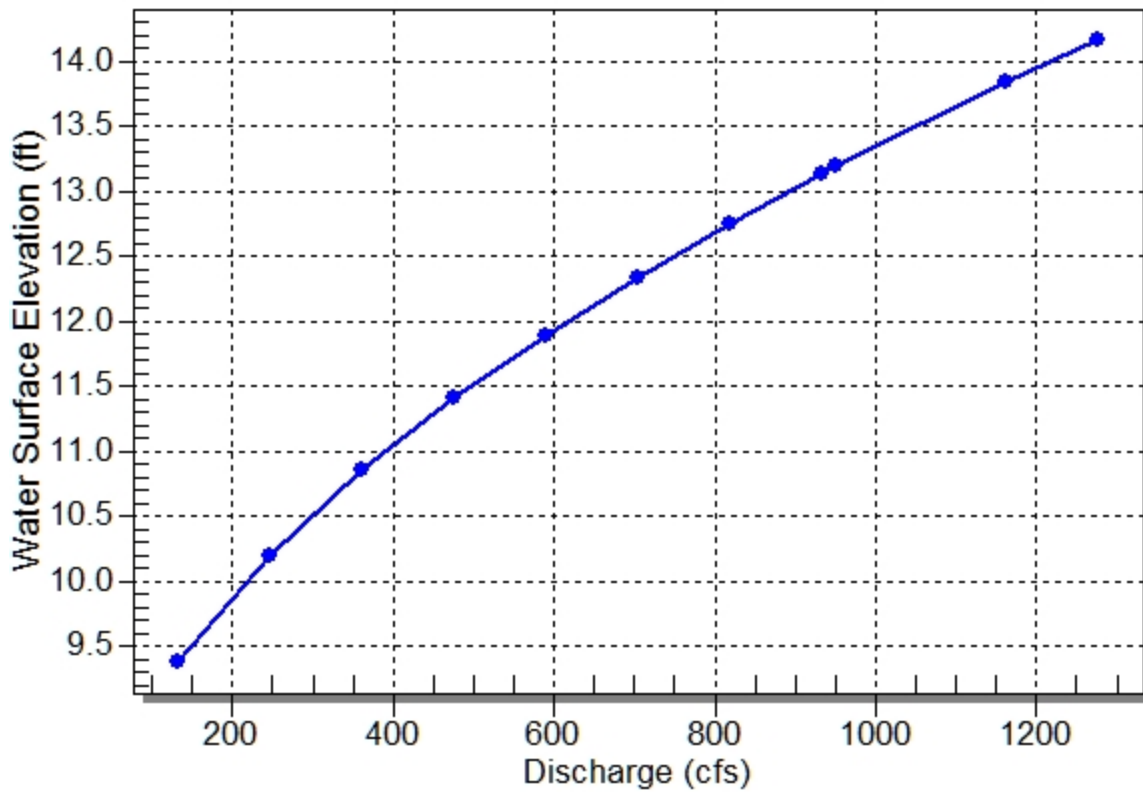
Channel Slope: 0.0050

User Defined Channel Cross-Section:

Coord No.	Station (ft)	Elevation (ft)	Manning's n
1	0.00	16.00	0.0500
2	46.00	16.00	0.0500
3	48.00	15.00	0.0500
4	50.00	14.00	0.0500
5	52.00	13.00	0.0500
6	54.00	12.00	0.0500
7	56.00	11.00	0.0500
8	58.00	10.00	0.0500
9	60.00	9.00	0.0500
10	64.00	8.00	0.0500
11	71.00	7.00	0.0500
12	78.00	7.00	0.0500
13	83.00	8.00	0.0500
14	86.00	9.00	0.0500
15	88.00	10.00	0.0500
16	90.00	11.00	0.0500
17	94.00	15.00	0.0500
18	98.00	18.00	0.0500
19	138.00	19.00	0.0500
20	152.00	20.00	0.0000

Tailwater Rating Curve Plot for Crossing: Bangor Red Bridge

Downstream Channel Rating Curve



Roadway Data for Crossing: Bangor Red Bridge

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 300.00 ft

Crest Elevation: 29.00 ft

Roadway Surface: Paved

Roadway Top Width: 45.00 ft