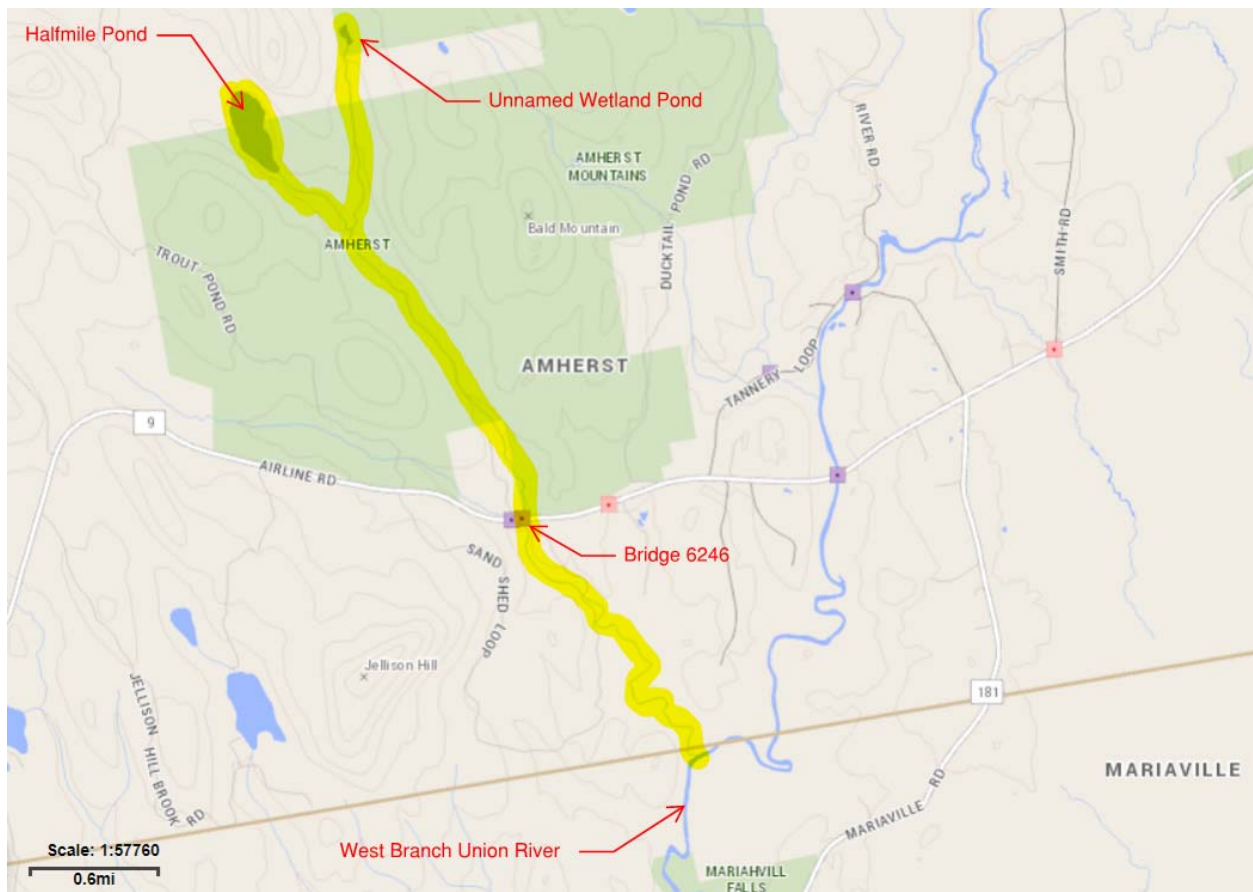


HYDROLOGY REPORT

The Half Mile Pond Brook Bridge (#6246) carries State Route 9 (Airline Road) over Half Mile Pond Brook in Amherst, Maine.

The drainage basin characteristics for this buried bridge culvert were provided by the Maine DOT Environmental Group, Hydrology Section. Peak flows were calculated with techniques described in the United States Geological Survey (USGS) Water-Resources Investigations Report 99-4008, “Estimating the Magnitude of Peak Flows for Streams in Maine for Selected Recurrence Intervals (Hodgkins, 1999) and “Peak flow regression equations for small, ungaged streams in Maine— Comparing map-based to field-based variables”, U.S. Geological Survey Scientific Investigations Report 2015–5049 (Lombard/Hodgkins, 2015).

The watershed area for this project is small at 3.28 square miles with 0.2 square miles of wetlands. The watershed is located primarily to the north and west of the bridge location (see Hydrology Report). Half Mile Pond Brook flows southerly at the project site under Airline Road, and receives streamflow from Halfmile Pond, as well as a second unnamed wetland pond to the northeast of Halfmile Pond. As shown in the figure below, Half Mile Pond Brook flows southeasterly into Mariaville where it joins the West Branch Union River, which flows into Graham Lake, then the Union River in Ellsworth, and out into Union River Bay.



Peak flows are shown in the table below. Since the bridge is in an inland region, it is not in a tidal zone.

<u>Return Period (yr.)</u>	<u>Flow (ft³/s)</u>
1.1	64
2	134
5	214
10	271
25	355
50	417
100	488
500	661

The hydrology report indicates a bankfull width (BFW) of 14.2 feet. However, BFW was measured by USFWS to be 16 ft per information provided by MaineDOT on July 19, 2018. To facilitate habitat connectivity, the proposed structure is to have a span of at least 1.2*BFW (19.2 ft).

HYDRAULIC REPORT

FLOOD INFORMATION

The FEMA Flood Insurance Study (FIS) that covers the Town of Amherst, Maine was published July 20, 2016, and is a comprehensive report covering many communities in Hancock County. The FIS and Maine Flood Hazard Map indicate that Bridge 6246 is in unshaded Zone X, which is an “area of minimal flood hazard”. Unshaded Zone X is defined in the FEMA FIS as “areas determined to be outside the 0.2% annual chance flood hazard”. Therefore, there are no base (1% annual chance) flood elevations (BFEs) or depths within this zone.

While there is no known flood elevation information at this bridge, the Maine Flood Hazard Map indicates that no flooding or overtopping of the roadway is expected to occur (see Figure 1). There is no information on whether any maintenance has been required in the past to clear obstructions or debris from the existing buried bridge. No public meetings have occurred so there is no information from abutters or town officials.

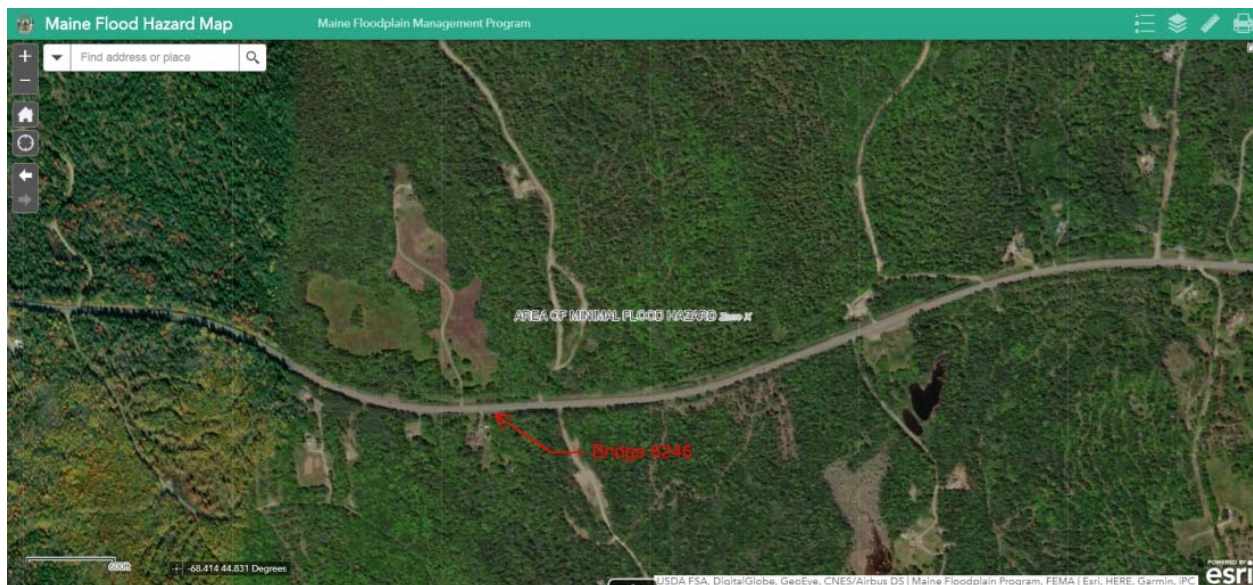


Figure 1 – Maine Flood Hazard Map showing Bridge 6246 in Zone X.

HYDRAULIC MODELING

A hydraulic study of the reach was initiated, based on the existing topography, with 10 cross sections located upstream of the existing buried bridge pipe arch, and 7 located downstream. The cross sections were primarily developed using ground survey provided by Maine DOT for this project. Additionally, the ground survey data was supplemented with aerial LiDAR survey (10-ft contours) and field measurements/observations to better model the reach.

Based on the existing topography data, a hydraulic model for the existing conditions was generated and analyzed using HEC-RAS 5.0.3 (September 2016), a one-dimensional hydraulics software program developed by the United States Army Corps of Engineers. From this “Existing Conditions” model, two additional post-project models were developed. The first model, “Post-Project – Design”, is based on the actual proposed channel geometry to be built within the new box culvert (as shown in the project plans). A second model, “Post-Project – High VAP” (VAP = Vertical Adjustment Potential), was developed to assess possible future hydraulic conditions

due to the potential for long term aggradation of the channel. Aggradation of the channel can be due to any number of factors, and the development of the “High VAP” model was based on fluvial geomorphological design principles. For this model, the channel inside the box culvert was modeled as being filled in and aggraded by 2’ to account for possible debris jam and channel aggradation inside the structure.

All three of the hydraulic models were generated by modeling the existing and proposed structures as bridges to better model the channel and streambanks within the proposed box culvert.

The existing buried bridge is a 16’-7” span x 10’-1” rise structural plate pipe arch. The plans for the existing structure specify a hydraulic opening of 131 square feet for the pipe arch, however, the exact geometry was not shown. An assumed pipe arch shape was generated that resulted in a hydraulic opening of 126.85 sq ft (error of approximately 3%). This shape was used for the existing conditions model. The surveyed invert elevations, which indicate the pipe arch is set on a 0.49% slope, were used in the model instead of information from the existing plans, which indicate that it was set level.

The proposed structure is a 20’-0” span x 10’-0” rise precast concrete box culvert bridge to be constructed with a streambed and streambanks within it. Based on fluvial geomorphological design principles contained in MaineDOT’s habitat connectivity design (HCD) requirements, the box culvert will be set on a 1.50% slope with the culvert invert at the upstream end at El 197.00 ft, and the corresponding streambed elevation at El 199.00. This raises the existing streambed elevation by approximately 0.6 ft at the upstream end of the new box culvert, and regrades the lower end by filling in the scour hole at the outlet of the existing pipe arch. (See the separate Habitat Connectivity Design Report for more information.)

The following parameters were established for the existing and post-project hydraulic models:

- Steady flow analysis method
- Manning’s “n” of 0.04 for the channel, which is comprised of gravel, cobbles and boulders.
- Manning’s “n” of 0.06 for the overbank areas for light brush and trees.
- Expansion and contraction values of 0.3 and 0.1, respectively, except for the two reach cross sections immediately upstream of the existing pipe arch and one cross section immediately downstream of the existing pipe arch, which used 0.5 and 0.3, respectively.
- Ineffective flow areas were set with a contraction ratio of approximately 1:1 upstream of the structure, and an expansion ratio of approximately 3:1 to 4:1 on the downstream side.
- A mixed flow regime was initially selected for the steady flow analysis, but it provided unstable hydraulic computation results with different profiles changing flow regimes at different locations causing crossing profiles. Therefore, a subcritical flow regime was ultimately selected for this model, and it is conservative for determining water surface elevations.
- Boundary conditions upstream and downstream were set to “normal depth”, with slopes based on actual stream slopes at the model limits.
- Manning’s “n” of 0.025 for the existing pipe arch.

When possible, a hydraulic model of the existing conditions is calibrated with known water surface elevations for a given flow rate. However, this information is not known for this reach, so the model was checked for reasonableness using the following considerations:

1. Water surface elevations from the existing conditions hydraulic model were compared against measured water surface elevations obtained during site visits on October 2 and December 1, 2018. The measured water surface elevations were approximately 1' lower than the model results for the 1.1-year flow. This data appears reasonable, especially since the subcritical flow regime will determine conservative (higher) water surface elevations.
2. Rust staining on the existing pipe arch indicates the approximate ordinary high water elevations, and these were compared with elevations of the 1.1-year and 2-year flows from the model. The ordinary high water elevations appear to be approximately 0.5' lower than the 1.1-year flow elevations from the model.
3. The relative drop in water surface elevations between the upstream end of the existing pipe arch and its downstream end is consistent between the measured field data and the model results. See the Hydraulic Study Narrative in Appendix E.
4. The model indicates that the existing pipe arch allows all flows up to the 100-year flow to pass without causing a substantial increase in water surface elevations upstream of the structure vs downstream (i.e. hydraulically sufficient). This is consistent with field observations.
5. The model indicates that overtopping of the road doesn't occur for any of the flows. This is corroborated by the Maine Flood Hazard Map in Figure 1 and field observations.

HYDRAULIC RESULTS

“Existing Conditions” Model

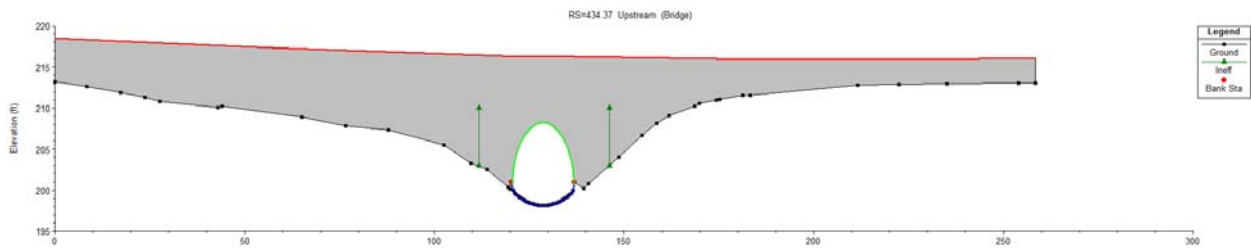


Figure 2 – Existing Conditions bridge section.

The model for the existing pipe arch indicates that it is expected to pass all design flows with freeboard heights of at least 5 feet for the 50-year and 100-year flows. See the Summary of Hydraulic Results Table for details. For the analyzed flow profiles, only the 500-year flow appears to cause a significant rise in the water surface elevations just upstream of the existing pipe arch. See Figure 3.

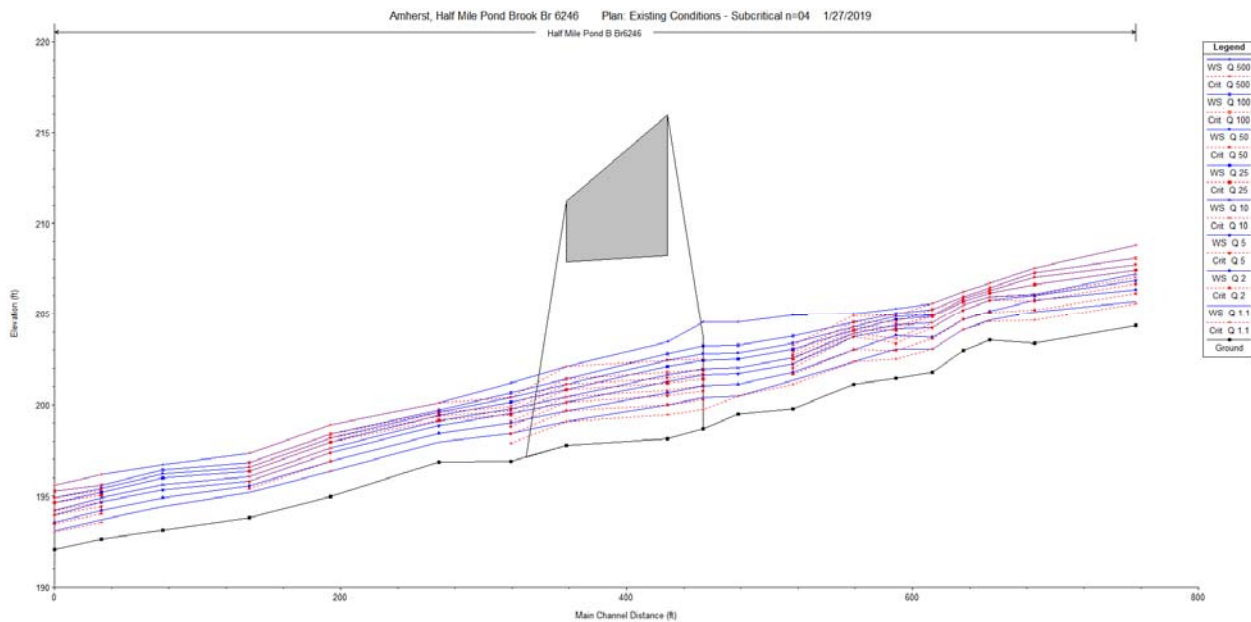


Figure 3 – Flow profiles for Existing Conditions model.

“Post-Project – Design” Model

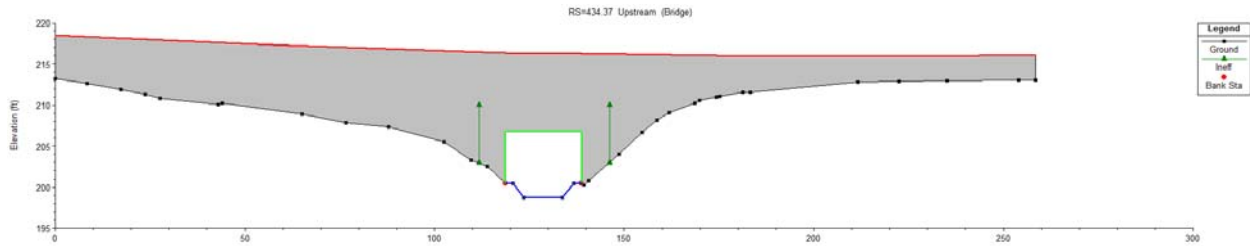


Figure 4 – “Post- Project – Design” bridge section.

The proposed “design” condition has a hydraulic opening of over 149 square feet, which is almost 14% larger than the existing hydraulic opening of 131 square feet.

Like the existing pipe arch, the proposed box culvert is expected to pass all flows up to and including the 500-year return period flow. See Figure 5. While the proposed box culvert has less freeboard than the existing pipe arch, it does provide more than 2’ of freeboard over the 50-year flow, and more than 1’ of freeboard over the 100-year flow. See the Summary of Hydraulic Results table for detailed information. Furthermore, for the respective 100-year water surface elevations, the proposed box culvert has an available hydraulic opening above its 100-year water surface that is slightly larger than that of the existing pipe arch.

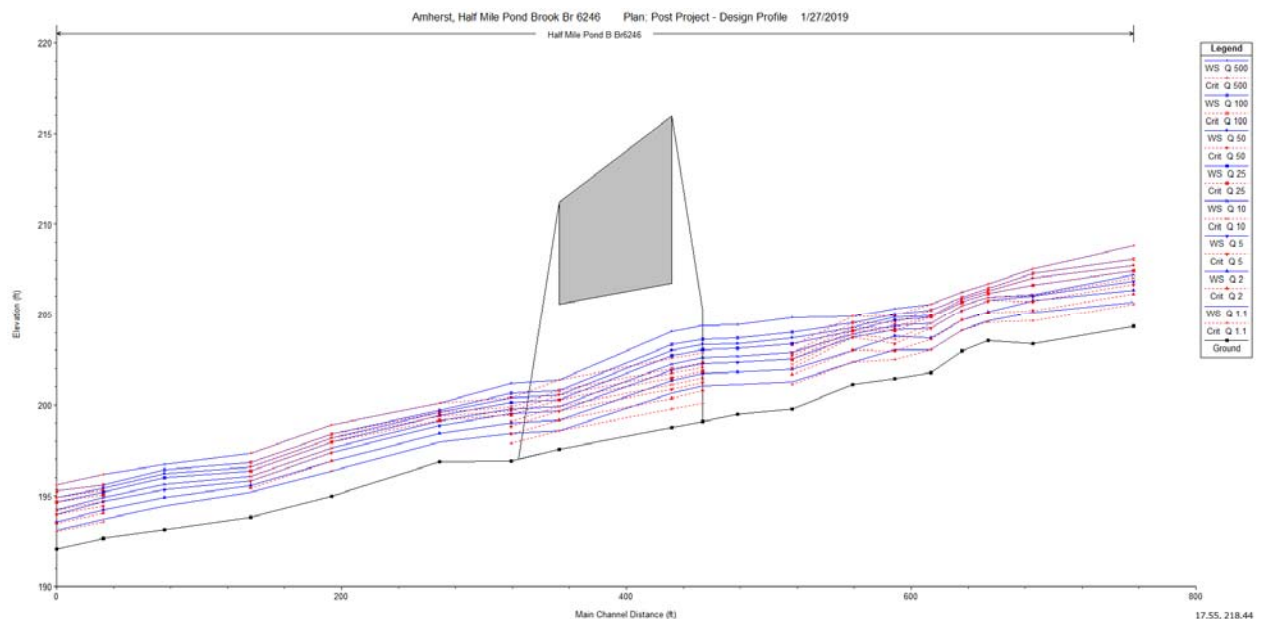


Figure 5 – Flow profiles for “Post-Project – Design” model.

Comparing water surface profiles from the existing conditions model with the flow profiles from the “Post-Project – Design” model results in the following observations:

1. There is not a significant difference in the relative water surface profiles, except for the 500-year flow, which has a smaller rise in the water surface elevations upstream of the structure in the post-project condition.
2. Water surface elevations for the “Post-Project – Design” model are higher than those for the existing conditions model. This is largely because of two reasons:

- a. The streambed elevation is being raised by approximately 0.6' at the upstream end of the new box culvert.
- b. The proposed channel within the new box culvert has a narrower streambed than the “streambed” width at the bottom of the existing pipe arch.

Figure 6 illustrates the relative differences between the water surface profiles from the existing conditions model and the “Post-Project – Design” model for the 1.1-year and 100-year flows. Relative differences in the water surface profiles are similar for the other analyzed flows. Notably, there is no change in the water surface elevations or channel velocities at any of the downstream reach stations (RS) up to and including RS 360.00, which is approximately 25' downstream from the existing pipe arch. Therefore, the hydraulic study indicates that there should be no changes to reach hydraulics (water surface elevations and channel velocities) downstream from the proposed box culvert due to this project.

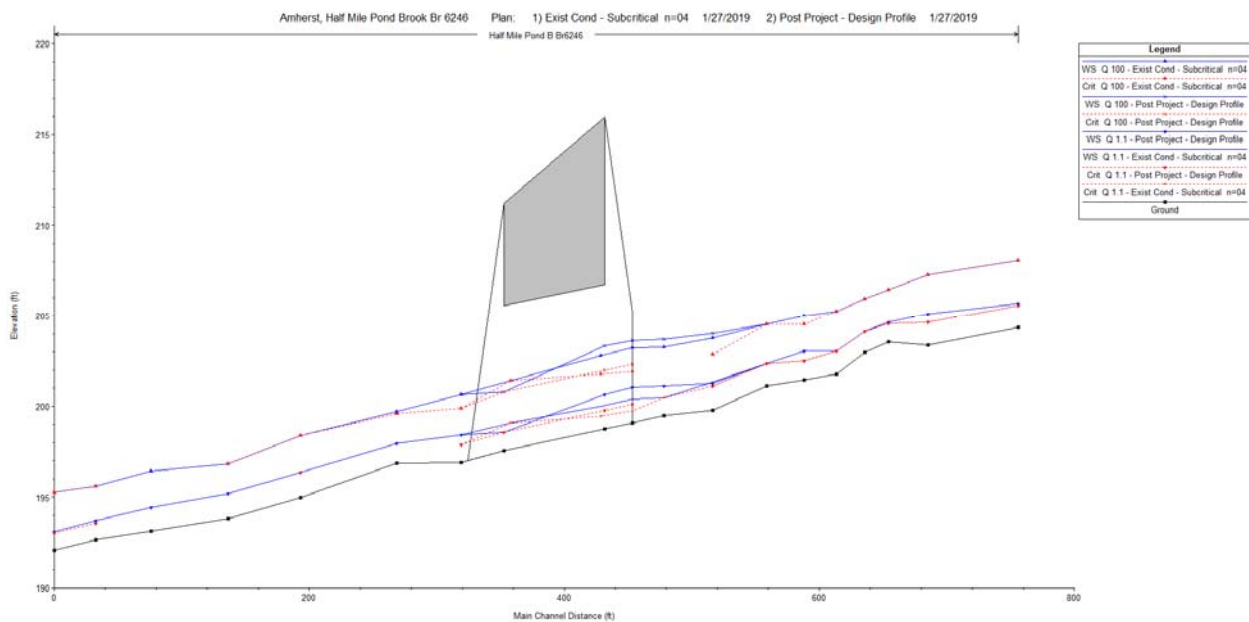


Figure 6 – Relative flow profiles for 1.1-year and 100-year Existing Conditions and Post-Project – Design models.

The “Post-Project – Design” model does indicate that increased water surface elevations and changes in channel velocities will likely be experienced at the proposed box culvert and upstream of it as far as RS 599.70, which is approximately 115' upstream of the existing pipe arch. This is applicable for all flows except for the 500-year flow. For the 500-year flow, water surface elevations and channel velocities are barely affected at RS 629.09, and are unaffected at RS 654.61. Therefore, any rise in water surface elevations is expected to dissipate at a location approximately 170 feet upstream of the proposed box culvert. These changes in the upstream water surface elevations are not concerning because this region of the stream is well bounded in a narrow valley with no human dwellings near the expected streamflow limits.

“Post-Project – High VAP” Model

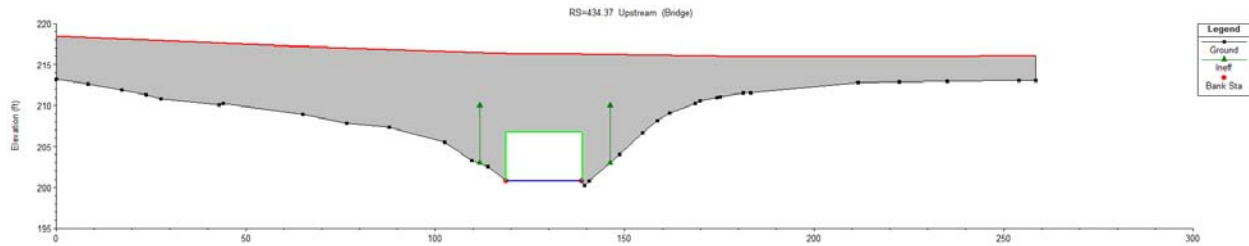


Figure 7 – “Post-Project – High VAP” bridge section.

The purpose of this model is to verify that the proposed box culvert has long-term resilience to stream processes and behavior. Results from this model indicate that MaineDOT’s preferred freeboard criteria of at least 2 feet over the 50-year flow and at least 1 foot over the 100-year flow will likely be met even if the stream aggrades by 2’ from the constructed “Post-Project – Design” condition. Figure 8 shows the relative increase in the 100-year flow profiles between the two post-project models.

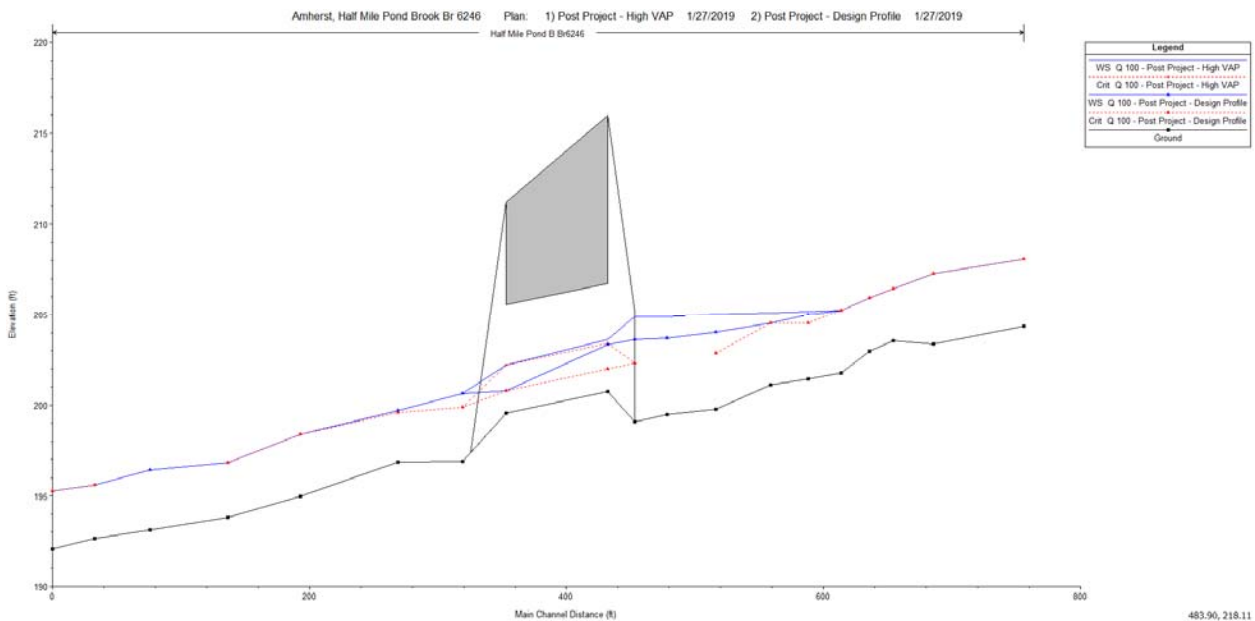


Figure 8 – Relative flow profiles for 100-year “Post-Project – Design” and “Post-Project – High VAP” models.

Summary of Results

While the post-project freeboard clearances are less than that for the existing conditions, the proposed hydraulic opening is increased by almost 14% over existing for the Post-Project – Design condition. Results from both post-project models indicate that the proposed box culvert is expected to meet or exceed the hydraulic design requirements for this project, including the desired freeboard clearances of at least 2 feet over the 50-year flow and at least 1 foot over the 100-year flow. In addition to being shown in the Summary of Results Table below, results for the “Post-Project – Design” model are presented in the bridge contract plans.

This hydraulic study indicates that there should be no changes to reach hydraulics (water surface elevations and channel velocities) downstream from the proposed box culvert due to

this project. It also indicates that changes in water surface elevations upstream of the proposed box culvert are not expected to be detrimental because this portion of the stream is well bounded in a narrow valley with no human dwellings in the area.

For a complete table of hydraulic results, see Appendix E.

Summary of Hydraulic Analysis Results

Return Period (Years)	Existing Conditions	Post-Project – Design	Post-Project – High VAP
Water Surface Elevations – Upstream * (ft.)			
1.1	200.38	201.06	201.91
2	201.04	201.74	202.57
25	202.42	203.03	204.11
50	202.78	203.32	204.48
100	203.21	203.62	204.88
Water Surface Elevations – Downstream * (ft.)			
1.1	198.42	198.42	198.42
2	199.01	199.01	199.01
25	200.14	200.14	200.14
50	200.37	200.37	200.37
100	200.65	200.65	200.65
Discharge Velocity – Upstream * (ft./s)			
1.1	2.74	2.31	1.38
2	3.76	3.15	2.17
25	5.52	4.84	3.44
50	5.78	5.14	3.67
100	5.89	5.46	3.90
500	5.60	5.99	4.36
Discharge Velocity – Downstream * (ft./s)			
1.1	2.76	2.76	2.76
2	3.75	3.75	3.75
25	5.58	5.58	5.58
50	6.00	6.00	6.00
100	6.39	6.39	6.39
500	7.36	7.36	7.36
Freeboard at Upstream End of Structure (ft.)			
50	5.44	3.44	2.28
100	5.01	3.14	1.88
Hydraulic Opening (square feet)			
N/A	131 (per plans) 126.85 (modeled)	149.06	120.56

* Upstream Water Surface Elevations and Discharges at RS 494.2011
Downstream Water Surface Elevations and Discharges at RS 360.00

SCOUR ANALYSIS

The proposed bridge is a four-sided box culvert, with a constructed stream channel (streambed and streambanks) contained within the box. It is therefore not susceptible to scour. The downstream channel velocities are not affected by the proposed project. Most of the upstream reach stations indicate no change or a slight reduction in channel velocities, although a few channel velocities for the 500-year flow do increase by up to 10%. Plain riprap aprons will be placed under the streambed materials at the box culvert inlet and outlet. Additionally, a 2-foot deep concrete toewall will be installed at both ends of the box culvert, providing additional protection against undermining.