HYDROLOGY REPORT

The Spring Brook Bridge (#2794) on South Belfast Road (Route 1) in Camden spans over Spring Brook. The flows in Spring Brook can be flashy and unpredictable, because it is in a mountainous drainage basin. Spring Brook flows southeast into the Atlantic Ocean about 1,400 feet from the project. Spring Brook originates from three elevated areas. The first point is at the Camden-Lincolnville town line at an elevation of 720 feet. The second point is southwest of the first point at an elevation of 780 feet. These two meet just south of a gravel pit. The third point is southeast of the first point at an elevation of 510 feet. This point meets the brook just south of the Spring Brook trail about 3,000 feet from the project.

Local inhabitants have observed the water level in the culvert at half-full capacity. Some have even said that they have seen it completely full. To simulate this level in HEC-RAS, a flow of 600 cubic feet per second was added to the steady flow analysis as the observed flood level flow. This gave a headwater elevation of 54.23 feet in the existing culvert, which is at about half the culvert height and the height of the banks. A water level at the bank height would be a good estimate for the flood level, since that is also the level of bank erosion. The HEC-RAS results for this flow were also used to calculate the scour depth for the recommended bridge.

On Wednesday, September 30th, 2015 there was very heavy rainfall and flooding in many parts of the state. The amount of rainfall in Camden from 1:00 AM Tuesday, September 29th through 10:00 PM Wednesday, September 30th was 7.24 inches (NOAA 2015). A nearby resident took a picture of the upstream side of Spring Brook the morning after the flooding, which can also be found in Appendix B. The gabions had tilted due to the flooding. According to the neighbor, the cobble bar had increased in size and the stream had shifted more to river right.

There is a FEMA flood insurance study and rate map that was completed for the town of Camden in 1988, but Spring Brook was not studied. Spring Brook is categorized under Zone A, which means that it is determined in the flood insurance study by approximate methods, so no base flood elevations or depths are given. Hydrology was evaluated for Spring Brook by the Maine Department of Transportation Environmental Office- Hydrology Section. Peak flows were calculated with techniques described in the United States Geological Survey Water-Resources Investigations Report 99-4008 (Hodgkins, 1999). The table below summarizes the flow events and the drainage area.

SUMMARY

Drainage Area	2.00	mi^2
Q1.1	49.8	ft^3/s
Q10	216.8	ft^3/s
Q50	336.5	ft^3/s
Q100	393.8	ft^3/s
Q500	538.9	ft^3/s
Observed Flood Level	600.0	ft^3/s

Reported by: Kendra Nash
Date: February 21, 2018

Note: Relevant data and reports are provided in the appendix of this Preliminary Design Report.

HYDRAULIC REPORT

Spring Brook runs through the existing culvert below Route 1 on South Belfast Road. At the time of the survey for original construction in 1933, the water depth was 0.9 feet at the deepest point along the brook per the original plans. For the bridge that was built in 1918, the high-water elevation during surveying was 53.1 feet (NGVD). This elevation would have been about 7 feet deep in the existing culvert.

During a team site visit on June 30th, 2015 the stream was moving at a high velocity. The upstream had water flowing from a pool area and separating around a sandbar, which met back up in a V just before flowing into the culvert. There was also a small stream of water from the northern direction that flowed into the culvert. The upstream channel is rocky with some fallen trees and brush. The upstream floodplains consist of vegetation and trees. As the water flowed into the culvert, it would flow at a steep slope at a small water depth with high velocity (supercritical flow). The water exiting the culvert is opaque, because it is flowing at such a high velocity. The downstream outlet is hanging, creating a waterfall, which flows into a scour hole directly downstream of the outlet. The downstream is rocky after the scour hole and has some fallen trees. The downstream flood plains consist of vegetation and trees.

Hydraulics for the existing and proposed bridges was analyzed with the HEC-RAS 4.1.0 program, using flows calculated from the USGS Regression Equations (2015) and the observed flood level flow. Levees were added to the cross sections where the overflow channel was located, so that water would only flow in that channel when it reached above an elevation of approximately 49 feet. This is the elevation upstream that the water would need to reach to flow over the banks of the main channel. Below is a list of parameters used for the stream and for the existing culvert.

<u>Stream</u>

- Cross Section: Irregular; survey data was used to input stations and elevations of 10 cross-sections that represent the upstream and downstream.
- Ineffective Flow: Ineffective flow areas were selected, assuming an expansion rate of 1.5:1 downstream and a contraction rate of 1:1 upstream.
- Culvert slope: 5.25%
- Stream slope: 4.6% upstream
3.5% downstream of scour hole
- Manning's n: 0.05 stream
0.08 flood plain

Existing Culvert

- Concrete Box: 10’-6” span and a 10’ rise
- Straight Culvert with a 45° flare wingwall
- Manning’s n: 0.012
- Inlet Elevation: 49.57 feet
- Outlet Elevation: 43.24 feet

A 35-foot span and a 14-foot rise Arch was used for proposed structure hydraulic analysis. Below is a list of parameters used for the stream and for the proposed arch system.

Stream

- Cross Section: Irregular; survey data was used to input stations and elevations of 10 cross-sections that represent the upstream and downstream. A cross section was manually added upstream and downstream of the culvert as well.
- Ineffective Flow: Ineffective flow areas were selected, assuming an expansion rate of 1.5:1 downstream and a contraction rate of 1:1 upstream.
- Stream slope: 4.5%
- Manning’s n: 0.05 stream
0.08 flood plain

Proposed Bridge: Concrete Arch

- Concrete Arche: 35’-0” span by 14’-0” rise
- Culvert slope: 4.5%
- A culvert was not modeled for the proposed bridge, because the banks and footings could not be modeled inside the culvert. Instead, 10 cross-sections were added to the stream to model where the culvert would be placed. The inlet and outlet cross sections are included in the hydraulic results in Appendix E.
- Manning’s n: 0.012 sides and footings
0.05 bottom and banks
0.08 flood plain
- Inlet Elevation: 49.69 feet
- Outlet Elevation: 44.02 feet

The results of the analysis for the existing and the recommended bridge are summarized at the end of this section. The complete HEC-RAS analysis reports for these bridges are provided in appendix E. The estimated headwater elevations in the summary table for both the existing and proposed bridges are the average of the estimated water surface elevations from HEC-RAS from the culvert inlet to up to 100 feet upstream. The downstream outlet velocities for both the existing and proposed bridges are the maximum of the culvert outlet average velocity and the average velocity of the cross section downstream of the outlet. The headwater elevation to culvert depth (HW/D) ratio of the existing culvert is 0.47 at the Q50 event which is much lower than the recommended maximum of 0.90. Therefore, the existing culvert is adequate to meet hydraulic standards. The HW/D for the proposed culvert is even lower at 0.24, since the proposed arch has a 35-foot opening, while the existing box culvert has a 10.5-foot opening.

Water flows through the exiting culvert at a high velocity. The Q1.1 event outlet velocity is an estimated 14.1 fps (feet per second). This high velocity has created a scour hole just after the outlet. The proposed bridge decreased the estimated velocity to 7.1 fps. This is due to the proposed grade change from 5.25% to 4.5%, as well as the increased opening of the proposed structure.

The channel and culvert will be designed to better serve the hydraulics at this site. There is large debris that runs through the culvert, which needs to be able to pass through it. The culvert is both too small and poorly aligned with the stream channel. This has caused the banks to erode and aggradation in the channel, because the water is unable to flow through the culvert properly. The sand bar in the middle of the channel is a function of the lateral migration of the stream bed material from the channel bank, which blocks part of the flow and will force the channel migration to continue. The centerline of the culvert will be moved approximately 5 feet south west to align with the channel. The larger structure opening should reduce the bank erosion and stream aggradation. The 35-foot opening will likely be set on 4-foot footings, which will take up 2 feet of the opening on each side. Banks will be added inside the structure to connect the upstream banks. This will give a 27-foot opening on the bottom. A sloped low flow channel will also be added to accommodate fish passage during low flow situations. The preliminary plans in Appendix A show a cross-section of the proposed arch. To further correct the stream lateral migration, the culvert grade reduction mentioned previously should eliminate the grade change from the upstream to the culvert, which should further reduce the bank erosion.

SUMMARY

		Existing Structure 10'-6" Concrete Box Culvert	Proposed Bridges 35'-0" Span x 14" Rise Concrete Arch
Total Area of Waterway Opening	ft^2	105	380.0
Headwater elevation @ $Q_{1.1}$	ft	52.2	51.7
Headwater elevation @ Q_{10}	ft	53.6	52.6
Headwater elevation @ Q_{25}	ft	54.0	52.9
Headwater elevation @ Q_{50}	ft	54.3	53.1
Headwater elevation @ Q_{100}	ft	54.8	53.3
Headwater elevation @ Q_{500}	ft	56.0	53.8
Headwater elevation @ observed elevation	ft	56.5	54.0
Hw/D @ Q50		0.47	0.24
Outlet Velocity @ $Q_{1.1}$	ft/s	14.1	7.1
Outlet Velocity @ Q_{10}	ft/s	20.8	9.5
Outlet Velocity @ Q_{25}	ft/s	21.9	9.9
Outlet Velocity @ Q_{50}	ft/s	22.6	10.6
Outlet Velocity @ Q_{100}	ft/s	23.3	11.1
Outlet Velocity @ Q_{500}	ft/s	24.5	12.3
Outlet Velocity @ observed elevation	ft/s	25.0	12.9

Values are reported for the original buried arch design. Proposed values for the bridge structure being advertised will not match those shown here, but should be lower elevations and velocities overall since the opening size is larger.

J. Hasbrouck
10 August 2023

Scour Depth

Scour depth was calculated at this site for a 35’ span concrete arch. The existing structure is currently rated as a 5 for scour, which is stable within the footing. However, scour is evident at this location due to the scour hole that is directly downstream of the culvert outlet as well as the integral migration of the channel upstream. This scour hole goes as deep as eight feet below the elevation of the bottom of the existing culvert. There is also undermining at the culvert outlet.

Scour depth calculations were performed using HEC-18 (2012) and are included in Appendix E. The observed elevation discharge flow, which is 600 ft^3/s, was used to evaluate scour. It was found that this location experiences live-bed contraction scour, which means that the bed materials are lifted and move with the water. The equation for open-bottom culverts was used to calculate scour. This equation is for clear-water conditions, but was used because there are no equations available for live-bed contraction conditions for open-bottom culverts. The scour depth was calculated to be 8.04 feet. Since footings are recommended to be buried 2 feet below the calculated scour depth, the footings should be buried at least 10.1 feet below the surface. For better protection against scour, the concrete should be buried down to the bedrock which is predicted to be as deep as 16 feet and as shallow as 4 feet below the proposed top of the footing.

Reported by: Kendra Nash
Date: February 21, 2018

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