Final Design Hydrology, Hydraulics and Scour Report

Babsons Bridge over Meadow Brook, Route 198, Bridge # 5244

NORTHSTAR HYDRO

For: Kleinfelder and MaineDOT

November 9, 2022

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STATE OF MAINE
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Executive Summary: Bridge #5244 conveys flow from the Meadow Brook under Route 198 in Mount Desert, Maine. The outlet is a tidal stream connected to Somes Sound. The existing bridge is a an approximately 20' Single Span Cast in Place Concrete Slab Superstructure on concrete and stacked granite abutments, with a maximum span of 21'. The proposed structure is planned to be a 56' span with riprap on the abutments to support widening.

Summary Hydrology: This bridge conveys flow from the upstream drainage basin under Route 198 and is subject to daily and storm tide inundation. The bottom of the bridge channel is higher than low tide. The bottom chord is close to FEMA's 100-year storm surge elevation. Sea Level Rise of up to 4' could inundate the low chord during storm tides, and could overtop the existing bridge assuming current estimates of potential rise for 100-years. Table 1 summarizes project hydrology and tidal elevations.

Drainage Area, square miles	3.4
Design Discharge (Q50), cfs	285
Check Discharge (Q100), cfs	333
Scour Check Discharge (Q500), cfs	442
Ordinary High Water (Q1.1), cfs	49
Flood of Record, cfs	unknown
Mean Lower Low Water, ft NAVD	-5.97
Mean Low Water, ft, NAVD	-5.59
Mean High Water, ft NAVD	4.98
Mean High Water plus 4' SLR, ft, NAVD	9.0
Mean Higher High Water, ft, NAVD	5.4
HOWL (2/7/1978)	10.24
HAT – predicted (2019)	7.72
HAT https://www.maine.gov/dacf/mgs/hazards/highest_tide_line/index.shtml	7.2
10-year tidal surge, NAVD	8.5
10-year tidal surge with 4' of sea level rise. NAVD	12.5
50-year tidal surge	9.0
100-year tidal surge, NAVD	9.2
500-year tidal surge, NAVD	9.7
FEMA AE Zone Elevation	9

Summary Table 1. Hydrology Summary for Plans

Summary Hydraulics: Hydraulic model HECRAS was run in both steady and unsteady flow modes to simulate flow through this bridge which conveys daily and storm tides inland and upland flows seaward. Existing and proposed bridges were modeled, with geometric changes in the bridge deck, in the width of the bridge and in the embankments built to support the widened bridge.

Model combinations include:

Model Type	Tide Level	Upland Flow
Steady Flow	MHW	Q1.1-, Q10, Q25, Q50, Q100, Q500
Steady Flow	MHW + 4' SLR	same
Steady Flow	MLW	same
Unsteady Flow	DOT Calibration data	20 cfs (typical flow)
Unsteady Flow	MHW	1.1-year
Unsteady Flow	MHW plus 4'	1.1-year, 10-year
Unsteady Flow	50-year surge tide	1.1-year
Unsteady Flow	100-year surge tide	1.1-year

Modeling and onsite measurements by MaineDOT indicate that the bridge slightly restricts tidal and upland flows with the following notes:

- MaineDOT noted that a goal of the bridge reconstruction is to simulate existing conditions as closely as possible.
- Survey data within the bridge itself was difficult to obtain, but reasonable detail was gathered by MaineDOT for final design. Debris in the channel from what appears to be an old dam at the bridge likely impacts flow in the bridge.
- Under existing conditions, during a typical tide cycle, dataloggers recorded a difference of about 0.2' and about a 30 minute lag in peak elevations.
- Once the additional survey gathered for final design was added to the HECRAS model, the model reasonably simulated existing condition flow when compared to MaineDOT's measured water levels.
- The HECRAS model calibration to DOT recorded data did provide a good simulation of peak water levels and a reasonable simulation of difference in water level from downstream to upstream.
- The HECRAS model provides a good simulation when comparing existing and proposed bridge water levels.
- At maximum normal tide height, with high upland flows, the upstream level is very slightly higher than downstream for the existing bridge, but levels are projected to equilibrate for the proposed bridge.

- Modeling indicates that nearly full tidal surge levels are propagated upstream during storm tide events under existing conditions and the proposed bridge is likely to propagate the full 100-year surge.
- The existing bridge does not meet MaineDOT tidal bridge standards for clearance, using upland Q10 and MHW tide plus 4' with 0.3-0.6' of clearance.
- The proposed bridge will provide 1.4' to 1.9' of clearance across the bridge section using Q10 at MHW plus 4' SLR. MaineDOT recommends 2' of clearance but also includes engineering judgement based on the specifics of the project site.
- The proposed bridge will convey the upland 50-year flow against MHW plus 4' SLR with the same clearance as the 10-year upland flow.

Hydraulic data is summarized in Summary Table 2.

Elevations Data reported in feet NAVD88 Velocity Data in feet per second	Existing	Proposed
Low Chord	9.3-9.7'	10.4' to 10.9'
DOT tide data, 7/26/18 23:06	5.6 (datalogger) 5.8 modeled	5.8 modeled
Headwater El. @Q10, MHW/MLW + 4' SLR	9.0	9.0
Headwater El. @ Q50, ft NAVD, MHW/MHW + 4'SLR	9.1	9.0
Headwater El. @ Q100, ft NAVD, MHW/MHW + 4' SLR	9.1	9.1
Discharge Velocity @ Q50, fps (At MLW)	11.6	10.5
Discharge Velocity @ Q100, fps (100-year tidal surge)	5.6	6.8
Headwater, MHW with Q1.1, ft NAVD	5.0	5.0
Discharge Velocity @ typical daily tides July/August 2018	3.5/4.0	3.3/4.7
Clearance @ 50-year tidal surge (9.0)	0.4-0.7'	1.4' to 1.9'
Clearance @ 10-year upland flow, with MHW +4' SLR (9.0)	0.4-0.7'	1.4' to 1.9'
50-year storm tide, ft NAVD	9.0	9.0
100-year storm tide ft, NAVD	9.1	9.2
Bridge Opening Area, ft^2	182	442

Summary Table 2. Hydraulic Summary for Plans

Introduction:

This report details work related to hydrologic, hydraulic and scour analysis at Babsons Bridge, Route 198, over Meadow Brook in Somesville/Mount Desert, Bridge #5244. The project site is shown in Figure 1.

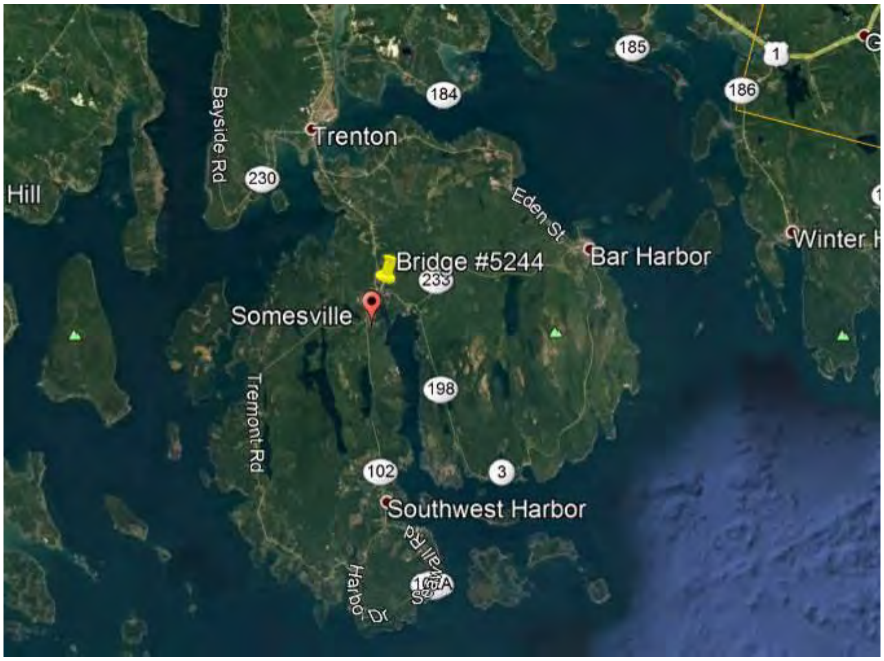

Figure 1: Site Location Route 198 over Meadow Brook #5244.

Babsons Bridge crosses over Meadow Brook, which collects limited amounts of upland runoff and cycles with the tides each day. The bridge site is protected from large ocean waves due to its location at the most inland point of Somes Sound. Figure 2 shows a closeup aerial view of the bridge location.

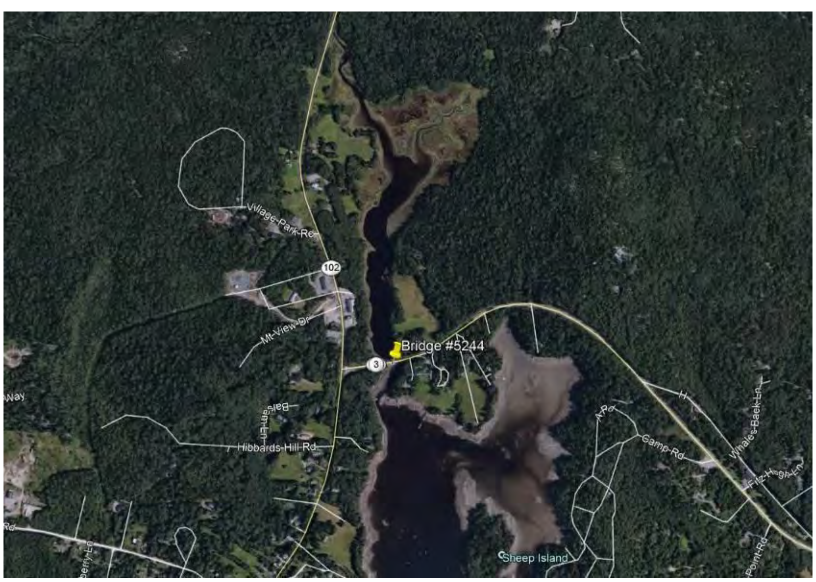

Figure 2: Aerial Photo, Meadow Brook, Somesville/Mt Desert.

According to inspection reports, the existing bridge consists of a 21' structure length, concrete cast-in-place slab on stone masonry abutments with stone retaining walls. The superstructure of the original bridge was replaced in 1949. The original date of construction of the abutments is unknown. The bridge was reconstructed again in 1977. The 2017 inspection report describes both abutments as having minor to moderate voids throughout and findings of undermining where voids occur, but that abutments appeared to be stable. The bridge has not been evaluated for scour. The 2017 inspection report notes occasional overtopping of approaches. Current notes in the Maine Bridge Database as of July 2019 show the bridge to be in a state of advanced deterioration. Bank slumping causing minor damage was also noted. The upstream face of the bridge is shown in Figure 3.

Figure 3. Upstream face of bridge near high tide. Utility line is lower than existing low chord.

Figure 4. Looking downstream from bridge at low tide.

Figure 5. Downstream face of bridge, outgoing tide near mid-tide.


Figure 6. Looking upstream from bridge.

In addition to upland flows, this bridge site is subject to flows in both directions due to tidal influx. A goal of the hydraulic analysis is to determine whether this bridge restricts the amount of tidal waters that can travel upstream and fill the basin above the bridge, or whether the bridge allows for the full tidal cycle to fill the pond upstream of the bridge.

Goals for hydrologic and hydraulic design included:

- Evaluate potential flood elevations for bridge profile design based on tidal and upland flood analyses.
- Evaluate up- and down-stream water levels under a variety of tide/streamflow conditions.
- Evaluate rate of flow through bridge under normal and flood tides and due to freshwater flows
- Evaluate whether the bridge restricts flows either from the tidal side to upstream or from the watershed flowing downstream.
- Evaluate scour potential based on predicted and measured velocity, observed bed material and bridge geometry

MaineDOT offers the following relevant guidelines in Chapter 2 of the Bridge Design Guide for bridge design clearance and freeboard:

Riverine:

- All bridges should be designed to safely convey Q50

Tidal Structures:

- Bridges – Design to protect the structure

- Minimum Design Freeboard “2 feet above Q10 (based on MHW) including wave heights”.

Sea Level Rise:

This report considers sea level rise of up to 4’ for the project. The May 2018 update to Maine DOT’s Bridge Design Guide includes the following:

“*2.3.7 Changes in Sea Level*
Historical data from NOAA shows that the sea level along the Maine coast over the past 80-100 years has risen between 0.5 and 0.75 feet per 100 years relative to local datums. More detailed information is available from the NOAA Tides and Currents website in the Sea Level Trends section. Based on this historical data and NOAA projections, the proposed design should assume 4 feet of sea level rise per 100 years.”

MaineDOT’s Bridge Design Guide recommends the following for tidal bridges:

“Bridges in tidal area - Bridges on tidal rivers/streams should be designed to protect the bridge structure itself. Most of the surrounding land and the approach roadways may be inundated by relatively frequent tidal storm surges. The minimum design freeboard in these areas is 2 feet above Q10 (based on MHW with sea level rise), including wave heights.” (pages 2-31)

MaineDOT recently provided updated guidance on Sea Level Rise with a graphic showing potential sea level rise scenarios, Figure 7. The “Intermediate or I” trend projects 4’ by 2100.

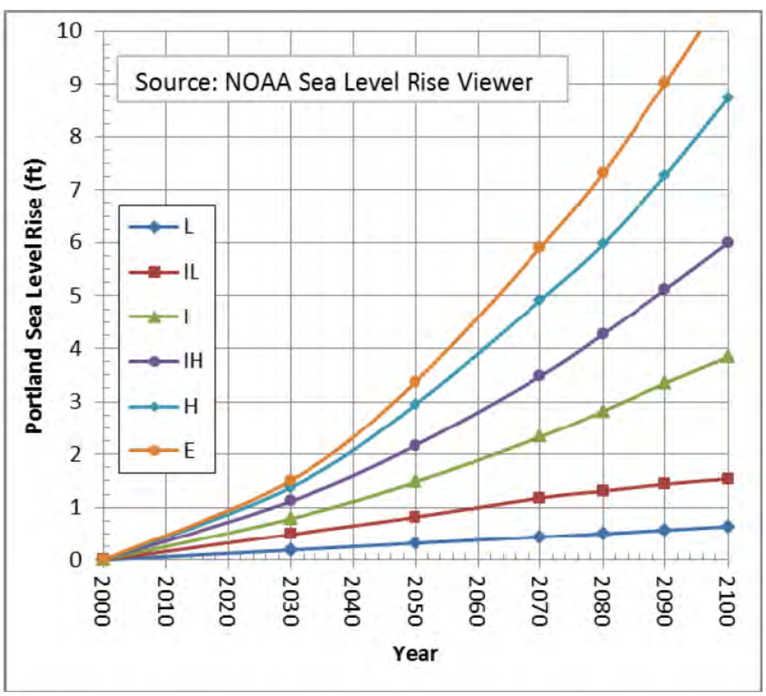

Figure 7: Sea Level Rise Projections for Portland (From NOAA Sea Level Rise Viewer)

Additional DOT guidance includes: The finished grade of the bridge will be set by considering this requirement, along with navigation clearance, the approach roadways, topography, and good engineering judgment.

2.0 Review of Existing Data and Site Visit:

Existing information was gathered and reviewed. Data included:

- FEMA Flood Insurance Studies of Mount Desert, including LOMR/LOMA map revisions. Figure 8 shows the Effective FIS map for the bridge area, with a zone designation of VE 10 feet on the downstream side of the bridge and AE 10 feet upstream of the bridge. The map is based on updated FEMA analysis published in July of 2016.
- NOAA tide data and coastal charts, Figure 9.
- MaineDOT file information:
  1. Babsons Bridge, Plans. May 1949. 21 foot width plank roadway with 5 foot sidewalk.
  2. MaineDOT Correspondence 1948 – 1977: Note that this correspondence describes a fire detention dam in the bridge and an oyster farming dam upstream of the bridge.
  3. Inspection report notes: 2011, 2014, 2014, 2015, and 2017.
- Air photos
- Topographic Maps
- Historical Flood Information
- NOAA Tide gage data: NOAA publishes predicted tide data for several stations near the site, including at the opening to Somes Sound and the recording station # 8413320 at Bar Harbor (Figure 10).

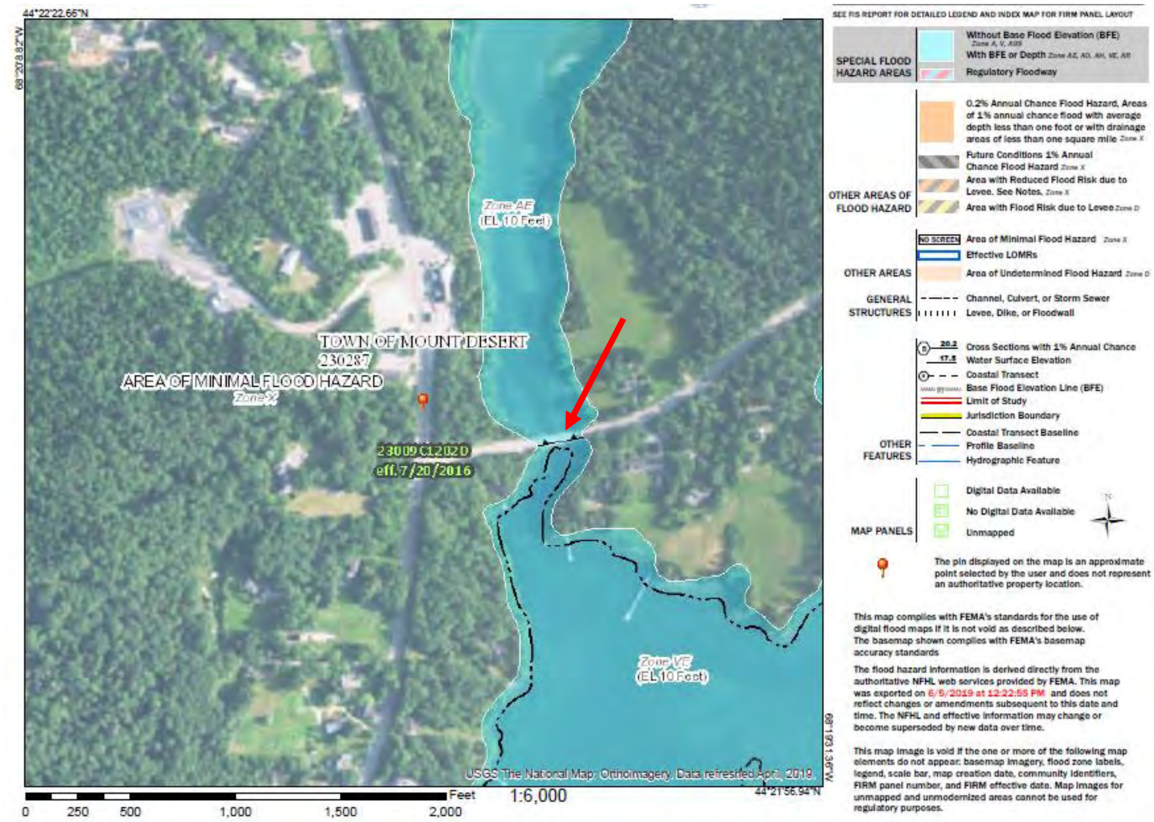

Figure 8. FEMA map panel for Mount Desert at the project site (red arrow).

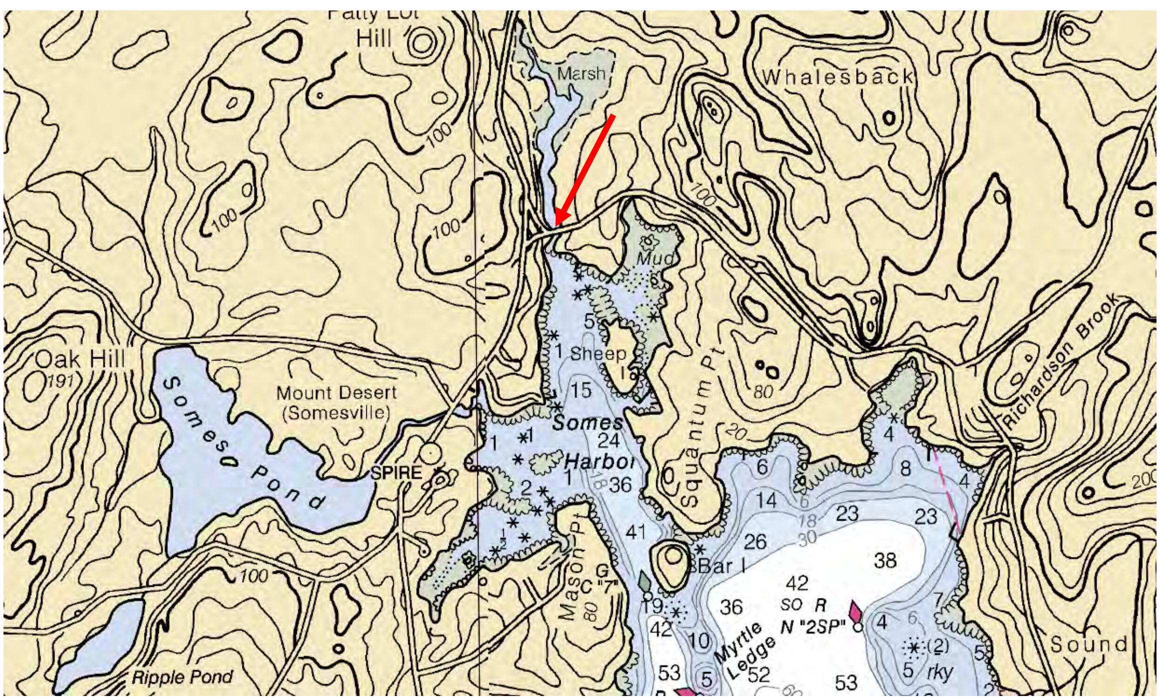

Figure 9. NOAA Chart 13318 near project site. Note that water depths do not extend up to site (red arrow). All depths are shown as MLLW datum, used for navigation (0' MLLW = -5.95 'NAVD).

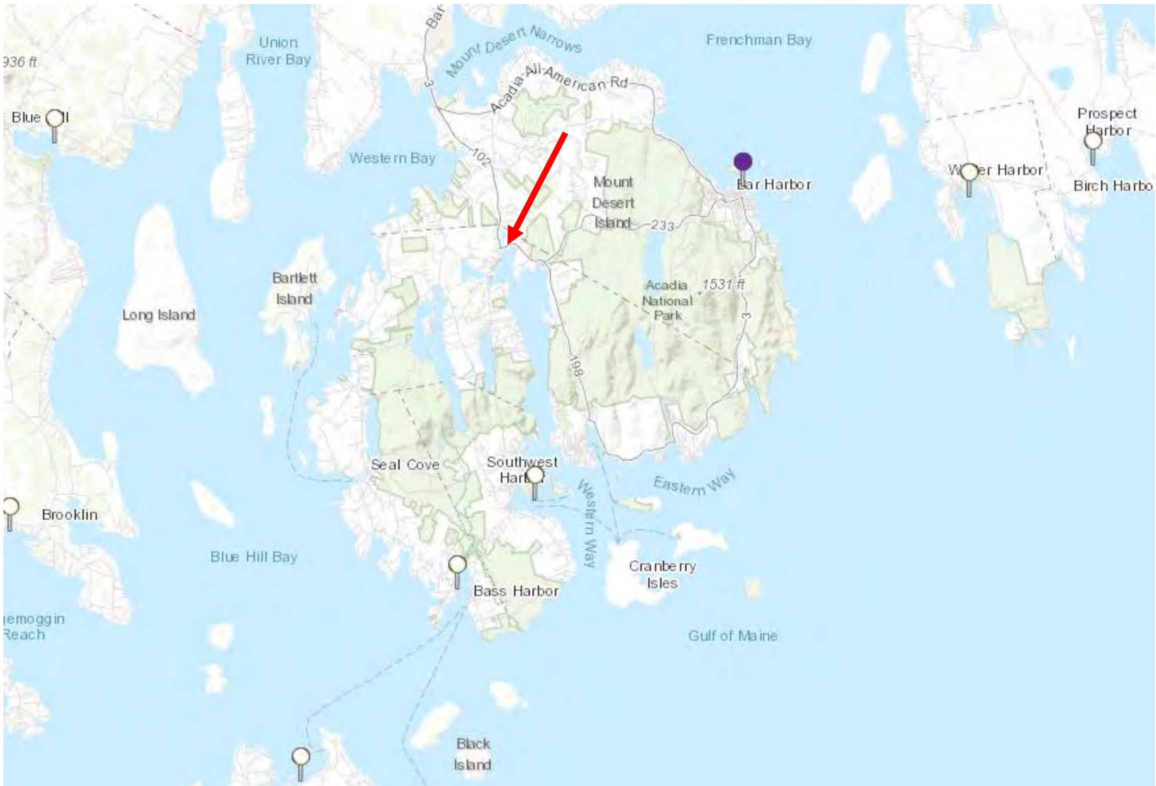

Figure 10: NOAA Tide Prediction Stations (white pins) and Recording Station at Bar Harbor (blue pin), bridge site shown by red arrow.

A table in the appendix summarizes available tidal datum information. Project tidal hydrology is summarized in section 3.0 of this report.

2.1 MaineDOT Tidal Measurements:

MaineDOT conducted tide measurements using pressure transducers and data loggers from July 11 through August 23, 2018. The internal memorandum from Charles Hebson on November 16, 2018 titled *23515 Mt Desert – Babson Bridge #5244 – Tidal Hydrology* summarizes the analysis of their measurements and is included as an appendix to this report. The analysis shows a tidal restriction at the bridge which is caused by grade control within the bridge and may be exacerbated by the bridge opening. Figure 11 shows a 12-hour tide cycle. The plot shows that upstream elevations remain several feet above downstream elevations at low tide due to a grade control within the bridge. The tide cycle also shows a time lag between upstream and downstream elevations above the grade control. This is likely the result of the bridge restricting upland flow. This record shows a difference of a few tenths of a foot from upstream to downstream, and a time lag of about an hour.

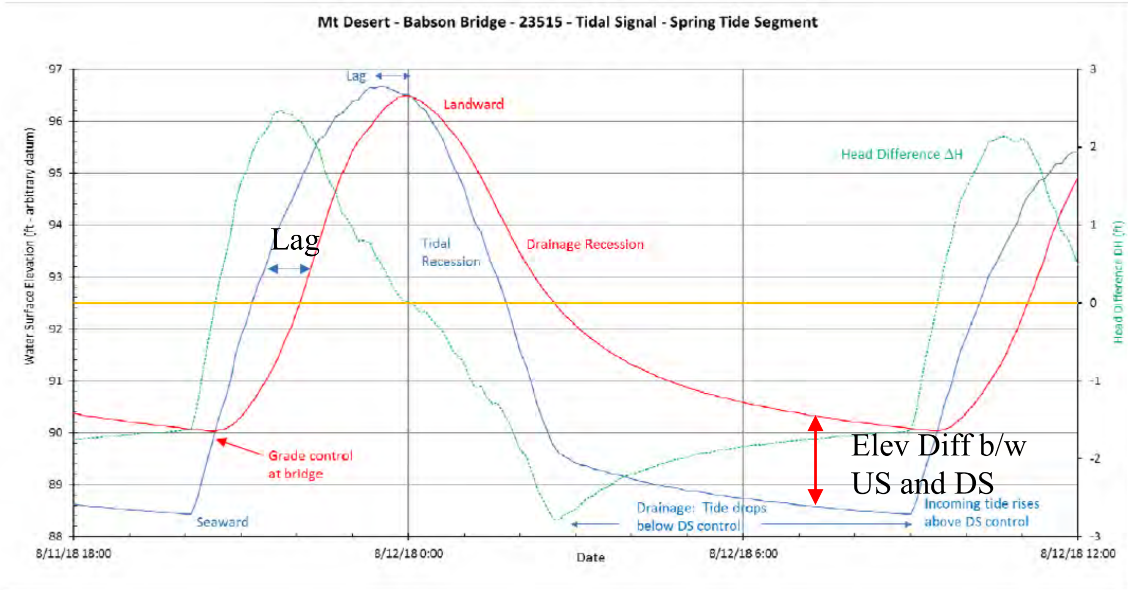

Figure 11: Rising and falling tide hydrograph at bridge. Note graph shows that the low tide upstream (red curve) of the bridge is several feet higher than downstream (blue curve) of the bridge (red arrow) and there is a lag between the DS and US hydrographs.

2.2 NHI Site Visit, Measure water levels and estimate flow velocities:

NHI measured water levels and estimated flow velocities over a portion of a falling tide cycle to determine how the bridge interacts with the complex flows generated by combined tides and upland flows. Tidal elevation and flow data were gathered at the site over an ebbing tide starting at peak tide level. Up- and down-stream elevations at the bridge were measured at selected intervals. Measurements were taken on March 20, 2019 from 10:41 am to 1:09 pm. Measurements were taken from top of rail of bridge at each abutment as well as at center-bridge, at both up- and down-stream faces. High tide for that day was predicted to occur at Station # 8413564 (Southwest Harbor) at 10:49 am. At the project site, the tide continued to flow upstream until 10:55 am. Predicted high tide was 6.50’ NAVD and predicted low tide was predicted -7.47’ at 4:42 pm.

Figure 12. Example tide measurement location from top of rail at DS Right Abutment (red X).

The bridge was surveyed in 2019. Field measurements of the rail, fascia, and beam depths were made, and combined with survey data to determine the existing top of rail and associated bottom chord elevations. Table 2 lists computed bridge elevations.

Location Along Bridge	Side of Bridge	Top of Rail Elevation (ft)	Bottom Chord Elevation (ft)
East End	North (US-L)	15.21	9.69
	South (DS-L)	14.98	9.28
West End	North (US-R)	15.16	9.67
	South (DS-L)	15.10	9.57

Table 1. Bridge rail elevations, US – upstream, DS – downstream L – left, and R - right.

Field measured water levels, velocities and calculations are included in the appendix. Tide elevation values calculated from measured data combined with bridge survey data ranged from 6.5 to 2.1 feet NAVD on the downstream side of the bridge. Field data are graphed in Section 5.0 of this report on hydraulic analysis and modeling.

2.3 Velocity Estimates:

To assist in calibration of the hydraulic model, tidal flow velocities were estimated by tossing and timing a thrown object as it passed through the bridge. Each measurement was repeated at least three times and averaged. While this method provides rough estimates of velocity, previous comparison to flow meter data has been found to be quite close at other project sites.

Time	Estimated Velocity, fps	Velocity Head, ft, $V^2/2g$
11:35 AM	2.70	0.11
11:54 AM	4.80	0.36
12:08 PM	5.59	0.49
12:27 PM	6.95	0.75
12:49 PM	7.70	0.92
1:09 PM	8.58	1.14
4:30 PM	5.21*	0.42*

Table 2. Summary of calculated velocity measurements (3/20/19). * Denotes high levels of turbulence in outflow making velocity measurements difficult to obtain. Flow was likely supercritical.

2.4 Predicted Tides on Day of Measurements:

To assist in calibrating the hydraulic model, measured tide data was compared to predicted tide data. Available tide data was analyzed to determine the best data to use for prediction of tide elevations at the project site. Two NOAA tide stations were evaluated, with the final choice being station # 8413564, the Southwest Harbor Station at the inlet of Somes Sound, which is a prediction station rather than recording station. Data for the day of tide measurements is shown below. Bar Harbor is the closest recording tide gage. Southwest Harbor allows tide elevation computations based on the predicted or recorded tides at Bar Harbor. At the project site, the Southwest Harbor predicted tides were adjusted slightly based on recorded tides at Bar Harbor, which were slightly different than predicted.

1. Tides at Station # 8413564, Southwest Harbor, Predicted based on Bar Harbor

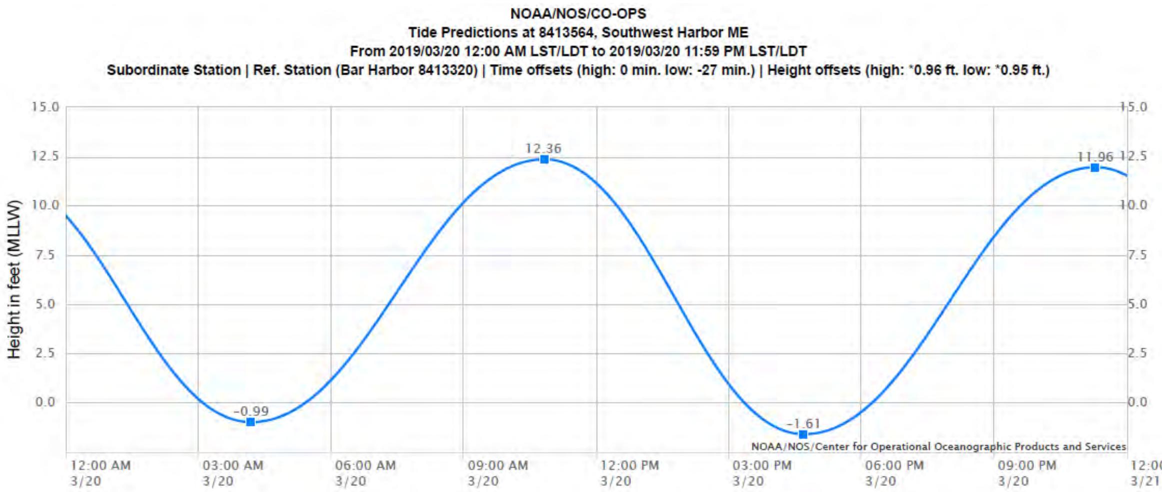

Figure 13. Predicted tides at Station 8413564, Southwest Harbor, 3/20/19. Based on Bar Harbor * 0.96 H, 0.95 L

Time	Predicted, at Bar Harbor, ft MLLW/ NAVD Station 8413320	Recorded at Bar Harbor, ft MLLW/ NAVD Station 8413320	Predicted SW Harbor MLLW/ NAVD Station 8413564	SW Harbor based on Bar Harbor Recorded NAVD	Measured at Project Site, Downstream NAVD	Measured at Site, Upstream, NAVD
4.:11 AM			-0.99/-6.853			
4:38 AM	-1.05/-6.99	-1.43/-7.38				
10:49 AM	12.88/6.93	12.64/6.70	12.36/6.497	6.2	6.5	6.3
11:06 AM					6.55	6.56
4:42 PM			-1.61/-7.473			
5:09 PM	-1.73/-7.67	-1.6/-7.55				
11:18 PM	12.48/6.53	12.49/6.54	11.96/6.097			

Table 3. Measured Tides at Project Site vs Predicted Tides 3/20/19
Bar Harbor Tides Recorded adjusted to Station # 8413564

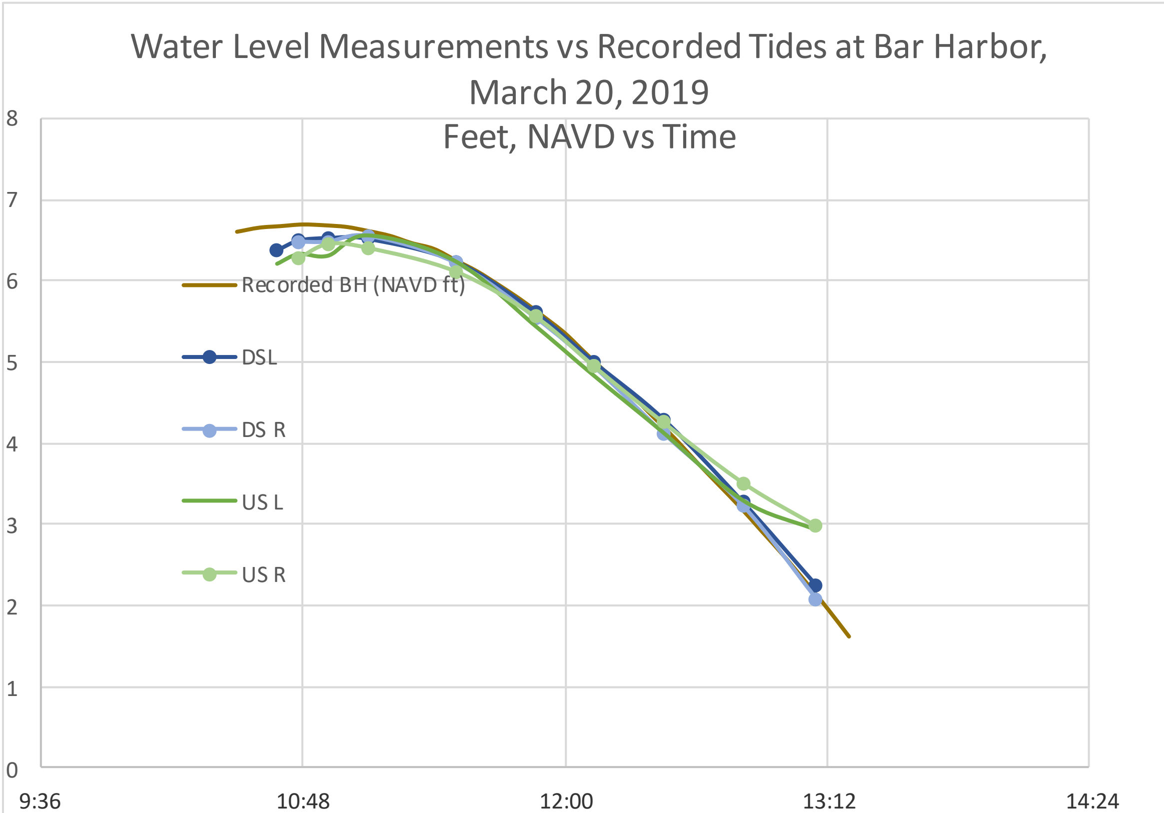

Figure 14. NHI measured water levels at Babson's Bridge vs Recorded at Bar Harbor. Note that peak at site is about 0.1' lower than Bar Harbor and lagged by about 15 minutes.

2.5 Site Visit Photographs

Photographs were taken on March 20, 2019.

Figure 15. Upstream face mid-falling tide. Note utility line near upstream face of bridge.

Figure 16: Looking at west abutment at mid-falling tide, note grade control in channel.

Figure 17. Downstream face of bridge, low tide.

Figure 18. Downstream of bridge, near low tide.

Figure 19. Looking upstream near low tide.

Figure 20. Looking through bridge US to DS near low tide.

3.0 Hydrologic Analysis:

Tidal and upland hydrology were computed at the project site. Upland hydrology for Meadow Brook was computed by MaineDOT using USGS methodology. Drainage basin and drainage basin characteristics are shown in figure 16.

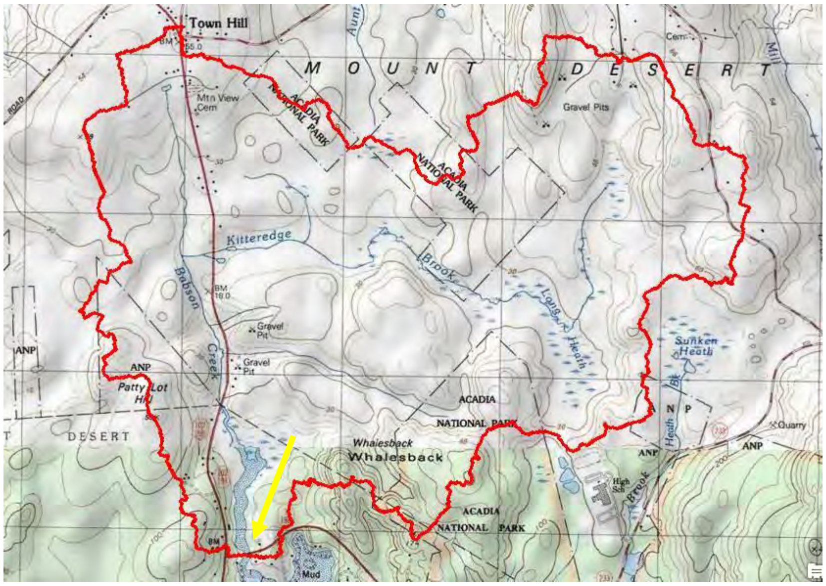

Figure 21. Drainage basin to Babson Bridge (yellow arrow), 3.4 sq. mi. drainage area (red).

Recurrance Interval	Flow (ft3/s)
1.1	49
2	98.3
5	152.6
10	189.1
25	247.9
50	284.6
100	333.2
500	441.8

Table 4. Summary of Peak upland flows, Meadow Brook.

Tidal elevations are based on NOAA tide station 8413320, Bar Harbor and FEMA storm surge elevations as published in their July, 2016 county-wide study of Hancock County.

Tide Level	**Bar Harbor Gage, Recording Station, ID 8413320**	
Datum	MLLW	NAVD
HOWL, 2/7/78	16.21	10.24
HAT (2019 predicted)	13.69	7.72
HAT https://www.maine.gov/dacf/mgs/hazards/highest_tide_line/index.shtml	1.23	7.2
MHHW	11.37	5.4
MHW	10.95	4.98
NAVD88	5.97	0
MSL	5.67	-0.3
MTL	5.66	-0.31
MLW	0.38	-5.59
MLLW	0	-5.97
LAT	-2.91	-8.88
LOWL	-2.28	-8.25
Storm Surge based on FEMA 2016 FIS Storm Surge, Transect 095		
10-year		8.5
50-year		9
100-year		9.2
500-year		9.7

Table 5. Summary of Tidal Elevations

The following flow/tide combinations were selected as boundary conditions for analysis in the hydraulic model.

Steady Flow:

- 1.1-year, 10-year, 25-year, 50-year, 100-year and 500- year Q with MHW
- 1.1-year, 10-year, 25-year, 50-year, 100-year and 500- year Q with MLW
- 1.1-year, 10-year, 25-year, 50-year, 100-year and 500- year Q with MHW+4’ Sea Level Rise (SLR)

Unsteady Flow:

- Data logger data coupled with estimated upland flow
- Typical daily flow coupled with MHW/MLW
- 10-year upland flow with MHW/MLW
- 10-year upland flow with MHW/MLW plus 4’ SLR
- 1-year upland flow coupled with 50-year surge
- 1-year upland flow with 100-year surge

Synthetic storm surge hydrographs for the project site were compiled as follows:

1. A tide curve simulating predicted MHW to MLW tides was generated via spreadsheet.
2. A second tide hydrograph set was created by adding 4’ to the MHW-MLW hydrograph to simulate potential sea level rise.
3. MaineDOT provided a suggested method for calculation of storm surge based on a regional ADCIRC model that covered multiple states. These surge levels were then added to the MHW/MLW representative tide cycle to produce simulated 50- and 100-year storm tides.
4. Tide/surge hydrographs were routed through the model as the downstream boundary condition.
5. These surge levels may be compared to the estimated HOWL of 10.24’ of February 7, 1978. This is based on the Bar Harbor gage.
6. Velocity estimates were prepared to evaluate potential scour. For tidal systems, fastest velocities occur when tides are changing most rapidly, such as during a surge event and when water levels are low, usually mid-tide. Peak velocities were selected from modeled hydrographs at the proposed bridge at times of highest flow rates.

4.0 Site Survey and Topography

Project survey was completed by MaineDOT on June 26, 2019 for the bridge, roadway, and bathymetry in the area of the bridge. This survey was merged with a 1-m DEM derived from the 2010 USGS ARRA Lidar for the Northeast: Maine Project for all areas outside of the project survey. For the tidal basin portion of Meadow Brook upstream of the surveyed area, bathymetry was estimated through aerial photography to create an elevation-area relationship used to calculate tidal storage volumes. Bathymetry for the furthest downstream cross sections was developed based on estimates from NOAA Navigational Chart 13318. The elevations were merged to create a terrain surface for the hydraulic model.

For final design, MaineDOT provided additional survey data points under the bridge such that the hydraulic control at the upstream edge of the bridge could be defined in the model.

Survey points are shown in figure 22 below. Points were used to create a best estimate of the control section elevation by selecting critical points within the data and considering MaineDOT's measured water levels from 2018. The selected bridge section is shown in the report section detailing hydraulics and modeling and the report appendix.

Figure 22. Survey points in bridge section.

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5.0 Hydraulic Analysis:

A HECRAS hydraulic model, version 6.0, was prepared for the project site to simulate tidal and upland flow through the existing bridge and the proposed bridge.

The model was calibrated based on MaineDOT datalogger data as described in section 2.1 above. NHI also collected and observed water level changes and rates of flow over part of a dropping tide cycle to assist in calibrating the hydraulic model.

The HECRAS model was compiled in both steady and unsteady flow modes, and uses predicted tides at Bar Harbor for the downstream boundary condition and peak flows as calculated in section 3.0 above for upland flows. Calibration runs compared downstream model cross section 888 and upstream section 1013 to datalogger data. These sections are also used to report water levels for theoretical storm events.

Bridge geometries include:

- Existing: span of 25', Low Chord 9.3 to 9.8' downstream and 9.7 upstream. Span at channel base is approximately 15' with base elevations upstream of about 0.5' and downstream face of -1.0'.
- Proposed: span of 56', low chord of 10.4' to 10.9', and a road profile at 14.1 to 14.7' at the abutments. Base of channel to be same as existing bridge, with riprap abutment protection sloping from the new abutments to the channel base to maintain same base width.

Goals of the hydraulic analysis include:

- Assessment of flood elevations for existing and proposed bridges
- Flow velocity studies for scour analyses under existing and proposed conditions.
- Understanding of interaction of tides, upland flows and bridge structure.

Figure 23 shows the geometric model layout with cross sections shown in green, storage area shown in blue, and channel banks in red.

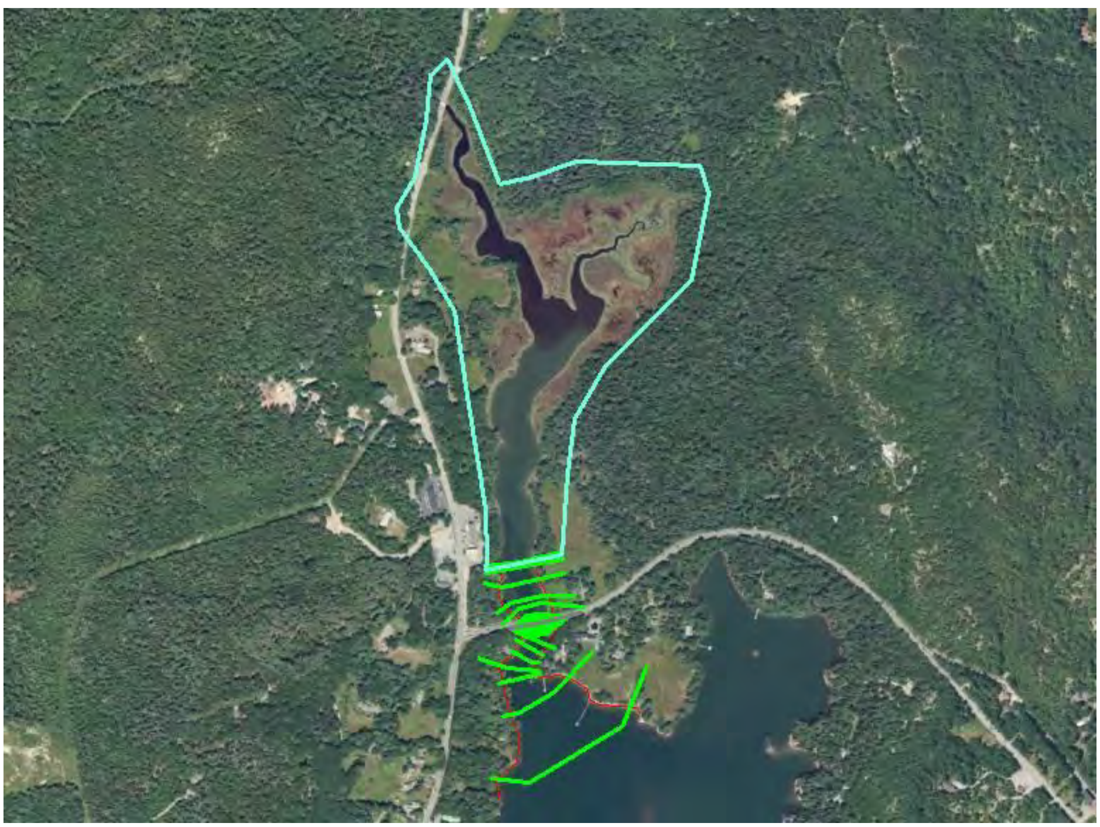


Figure 23. Full hydraulic model layout with upstream tidal basin (approximate boundary shown).

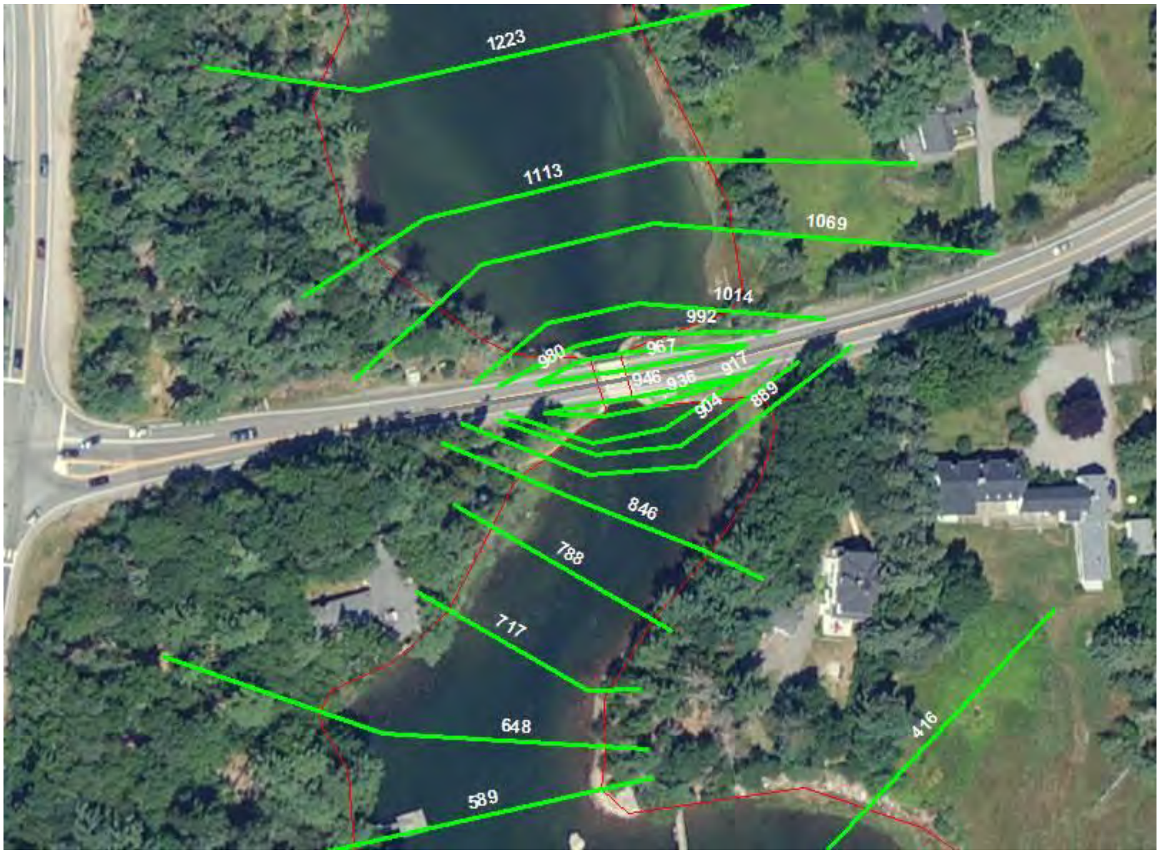


Figure 24: Hydraulic model layout in bridge area


Figure 25. Model contours (1 ft interval) .

Initial model runs were performed using data collected by MaineDOT at the project site using installed data loggers, as described above. Downstream data logger elevations were used for the boundary condition in the hydraulic model, and an assumed low upland flow of 6 cfs was used for the upstream boundary condition. Median flows for these months are predicted to be about 0.2 to 0.5 cfs. However, the unsteady flow model was unstable with flows lower than about 6 cfs. The model was run for the full data set that runs from July 11 to August 23, 2018.

Figure 26 shows calibration data plotted against modeled data for existing conditions at model locations that were representative of the data logger locations. The figure shows datalogger data at up- and down-stream locations, model data, and elevation differences from up-to down-stream for both conditions.

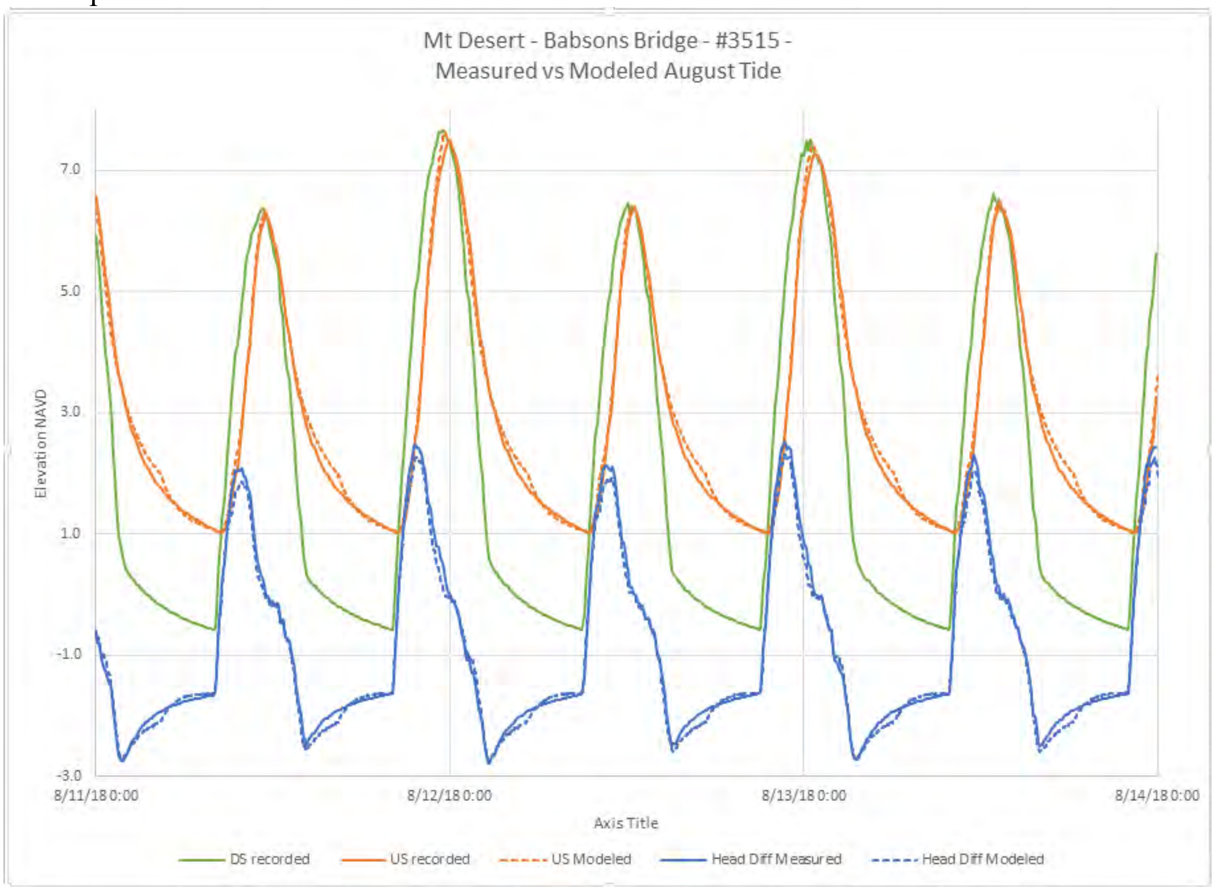


Figure 26: MaineDOT measured water levels plotted against HECRAS model data, water levels and water level change from up- to down-stream.

Figures 27, and 28 show model results for the full model profile, and section through the existing bridge with typical conditions of upland flow and MHW-MLW tide range.

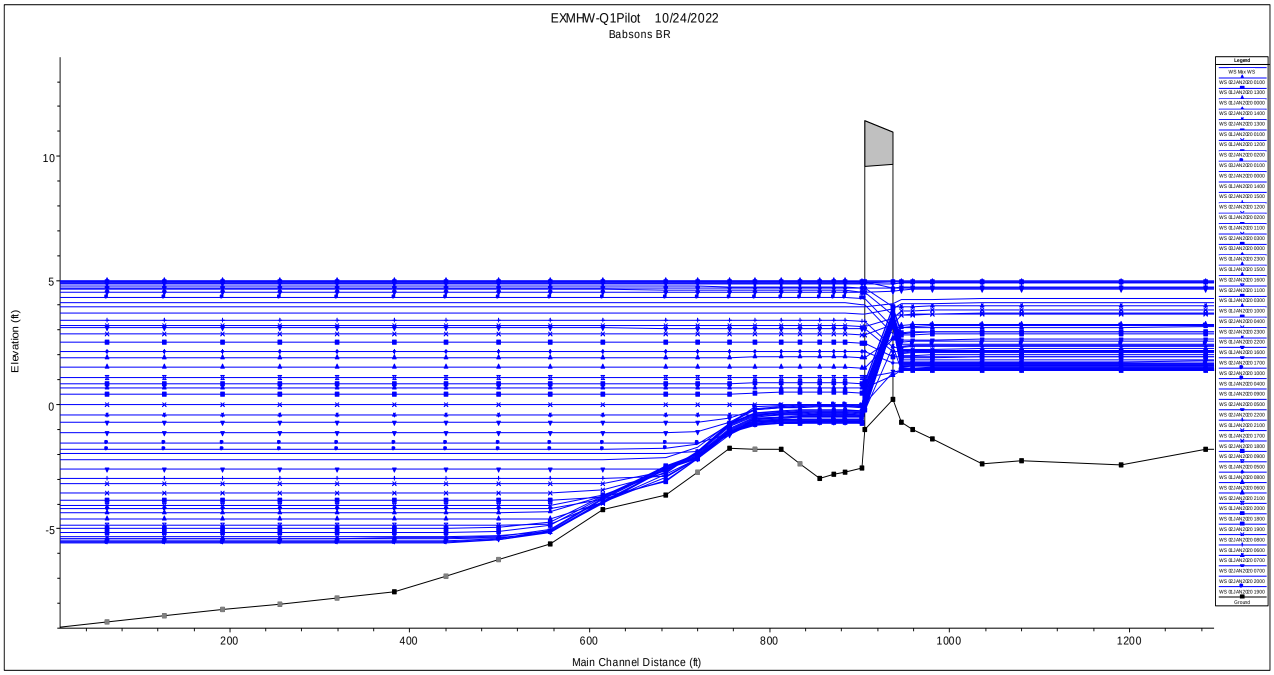


Figure 27. Existing Bridge model profile, left side is downstream, right side is upstream. This figure shows variation in water levels over a MHW to MLW cycle with minimal upland flow.

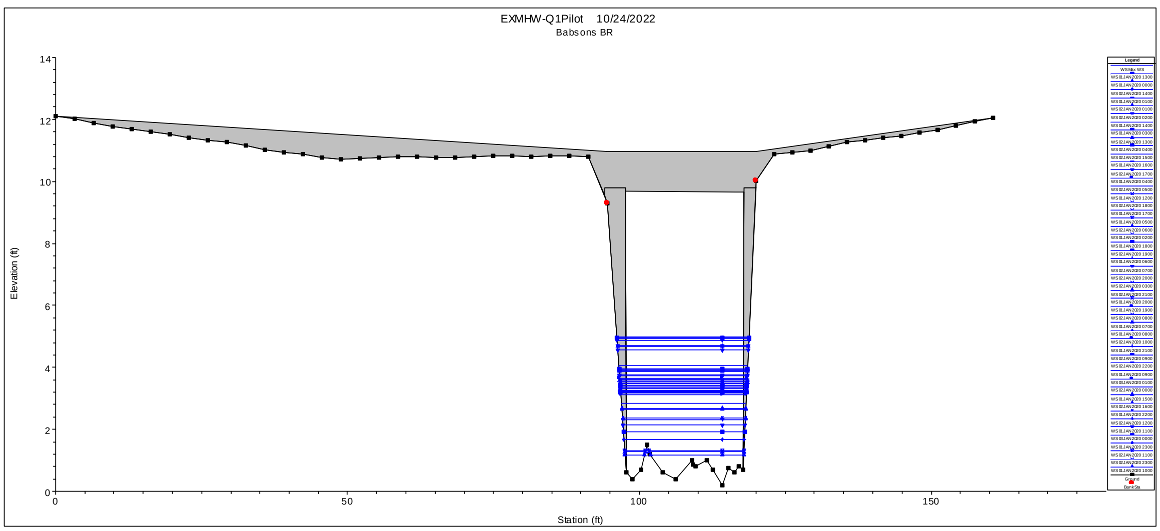


Figure 27. Existing bridge, hydraulic control point, upstream, Tide levels MHW to MLW plus typical upland flow. Upstream face. Channel bottom at hydraulic control point is based on recent survey by MaineDOT.

The proposed bridge is a 56’ single span on concrete abutments with riprap protection sloping to the existing bed with a base width of approximately 20’. The proposed bridge section as modeled in HECRAS is shown in figure 28.

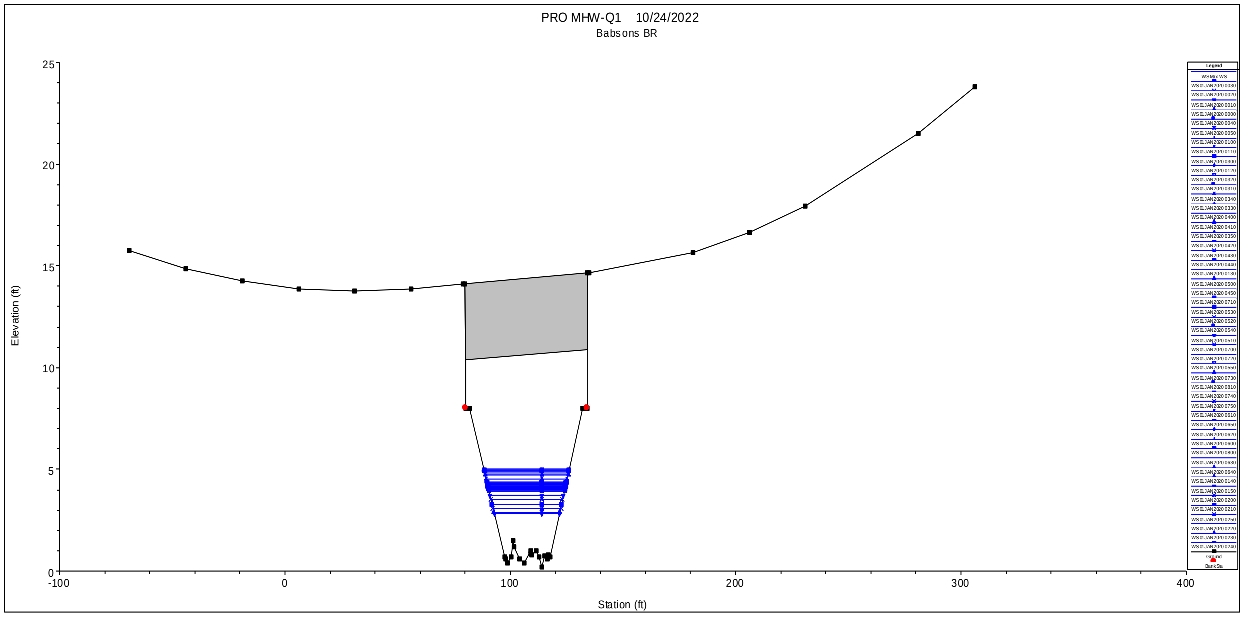


Figure 28. Proposed bridge plotted Left to Right facing downstream. MHW to MLW plus typical upland flow.

Hydraulic data is summarized in Table 6 below.

Elevation Data reported in feet NAVD88 **Velocity Data in feet per second**	**Existing Bridge**	**Proposed Bridge**
Low Chord	9.3-9.7’	10.4’ to 10.9’
DOT tide data, 8/11/18 23:30 DS/US	7.7/7.61	7.7/7.7
DOT tide data 7/26/18 23:06	5.6 datalogger, 5.8 modeled	5.8 modeled
Headwater El. @Q10, MHW/MLW + 4’ SLR	9.0	9.0
Headwater El. @ Q50, ft NAVD, MHW/MHW + 4’SLR	9.1	9.0
Headwater El. @ Q100, ft NAVD, MHW/MHW + 4’ SLR	9.1	9.0
Discharge Velocity @ Q50, fps (At MLW)	11.6	10.5
Discharge Velocity @ Q100, fps (100-year tidal surge)	5.6	6.8
Headwater, MHW with Q1.1, ft NAVD	5.0	5.0
Discharge Velocity @ typical daily tides (calibration data-July/August-2018)	3.5/4.0 inflow	3.3/4.7
Clearance @ 50-year tidal surge	0.4-0.7’	1.4’ to 1.9’
Clearance @ 10-year upland flow, with MHW +4’ SLR	0.3-0.7’	1.4’ to 1.9’
50-year storm tide, DS, ft, NAVD	9.0	9.0
100-year storm tide DS, ft, NAVD	9.1	9.2
Bridge Opening Area, ft^2	182	442

Table 6. Summary of Hydraulic Results

Table 7 on the following page summarizes results of the steady flow models. Table 8 summarizes unsteady flow results.

Wave Action:

The project site was reviewed for potential wave action and is found not likely to experience significant waves using USACOE methodology. However, the FEMA FIS lists the downstream side of the bridge as a zone VE, meaning potential wave action greater than 3 feet.

Babson's Bridge, Unsteady Flow HECRAS Model Results.

		Existing Bridge					Proposed Bridge			Difference in WL	
Tide Level	Upland Flow Frequency	Water Level, Model Boundary	Downstream Water Level, Section 888	Upstream Water Level, Section 1013	Water Level, Model Boundary	Peak Velocity, fps	Upstream Water Level, Section 1013	Water Level, Model Boundary	Peak Velocity, fps	DH 1013 to 888 Existing	DH 1013 to 888 Proposed
MHW	1.1-year	5.0	5.0	5.0	5.0	0.6	5.0	5.0	0.4	0.0	0.0
	10-year	5.0	5.0	5.2	5.2	2.2	5.1	5.1	1.5	0.2	0.1
	25-year	5.0	5.0	5.3	5.3	2.9	5.2	5.2	1.9	0.3	0.2
	50-year	5.0	5.0	5.4	5.4	3.3	5.2	5.2	2.2	0.4	0.2
	100-year	5.0	5.0	5.5	5.5	3.8	5.3	5.3	2.6	0.5	0.3
	500-year	5.0	5.0	5.8	5.8	5.0	5.5	5.5	3.4	0.8	0.5
MLW	1.1-year	-5.6	-0.5	2.1	2.1	5.7	2.1	2.1	5.8	2.6	2.6
	10-year	-5.6	0.4	3.5	3.5	7.2	3.5	3.5	7.1	3.1	3.1
	25-year	-5.6	0.6	4.0	4.0	7.7	3.9	3.9	7.5	3.4	3.3
	50-year	-5.6	0.7	4.3	4.3	8.0	4.1	4.1	7.8	3.6	3.4
	100-year	-5.6	0.9	4.7	4.7	8.4	4.4	4.4	8.0	3.8	3.5
	500-year	-5.6	1.2	5.4	5.4	9.1	4.9	5.0	8.6	4.3	3.8
MHW+4' SLR	1.1-year	9.0	9.0	9.0	9.0	0.3	9.0	9.0	0.2	0.0	0.0
	10-year	9.0	9.0	9.0	9.0	1.1	9.0	9.0	0.6	0.0	0.0
	25-year	9.0	9.0	9.1	9.1	1.5	9.0	9.0	0.8	0.1	0.0
	50-year	9.0	9.0	9.1	9.1	1.7	9.0	9.0	0.9	0.1	0.0
	100-year	9.0	9.0	9.1	9.1	2.0	9.0	9.0	1.1	0.1	0.0
	500-year	9.0	9.0	9.2	9.2	2.6	9.1	9.1	1.4	0.2	0.1

Table 7. Mount Desert/Babsons Bridge Steady Flow Results

UNSTEADY FLOW	Existing									Proposed							
	High Water				Low Water	Peak Velocity		Peak Q		High Water				Low Water	Peak Velocity		Peak Q
	Elev		Time		Elev	Magnitude	Time	cfs		Elev		Time		Elev	Magnitude	time	
Plan	DS	US	DS	US	US	fps			Plan	DS	US	DS	US	US	fps		
.p05 MHW Q1	4.97	4.95	1330	1340	1.37	3.51/-2.79	1600	205	.p23	4.99	4.99	13:33	13:35	1.37	3.53/-3.05	16:52	215
. P28 T50 Q1	9	8.93	115	120	1.95	5.5/-3.7	445	564	.p 29 T50 Q1	9	9.02	1:05	1:05	1.93	6.83/-4.7	0:05	643
.p30 T100Q1	9.2	9.1	1:15	1:20	1.95	5.6/-3.7	445	582	.p 31 T100Q1	9.2	9.2	1:05	1:05	1.93	6.82/-4.76	0:05	657
.p 32MHWQ10	4.96	5.09	1:00	1:30	3.47	5.99/-.75	16:40	307	.p33MHWQ10	4.97	5.05	13:30	13:45	3.33	6.07/-.89	16:40	319
.p34 MHW+4Q10	8.99	9.01	13:30	13:35	3.51	6.8/-2.1	18:15	598	.p35 MHW+4Q10	8.99	9.01	13:30	13:35	3.35	6.43/-2.37	18:20	668
.p06 fullcalib									.p36 fullcalib								
.p24 8-8 to 8-15 calib	7.66	7.59	23:30	23:46	0.83	3.48/-3.98		482	.p37 8-8 to 8-15calib	7.66	7.65	23:30	23:32	0.49	3.32/-4.73		531
.p25 7-24 to 7-31 calib	5.77	5.76	0:35	0:40	0.96	3.05/-3.41		260	.p38 7-24 to 7-31 calib	5.77	5.78	0:35	0:40	0.75	3.01/-3.89		288

Table 8. Final Design Unsteady Flow Results, Existing and Proposed

Utilities:

Just upstream of the bridge, a utility line crosses the stream at a lower level than the low chord of the existing bridge as shown in figure 29.

Figure 29. Utility line just upstream of existing bridge.

The bridge low chord is 9.3 to 9.6'. MHW tide plus 4' of sea level rise with Q10 upland flow is predicted to be 9.0' under existing and proposed conditions. 100-year surge is predicted to be 9.2', all putting the utility line at risk for inundation during storm events. Such events carry the risk of rapidly flowing water in both directions over time, as well as submergence.

Summary of Significant Hydraulic Findings:

- Under current conditions, water levels upstream of Babsons Bridge are affected by structures near and in the bridge designed to pond water for firefighting and other goals.
- These structures were surveyed in as much detail as the site allowed, with some data interpretation required to compile the geometric model.
- MaineDOT indicated that a goal for the replacement bridge is to maintain the current water level regime for typical tides and for storm tides.
- The final HECRAS model showed good calibration to MaineDOT measured tide data upstream of the bridge.
- Under existing conditions, during typical daily tides, incoming high tide levels nearly equilibrate from downstream to upstream. Data loggers show a slight lag

in time from downstream to upstream peak tide, and a small drop in elevation from downstream to upstream peak tide.

- Low tide levels are controlled by the structures near the bridge and by the bridge abutments, and do not drop below about 0.8'.
- Upstream water levels due to high upland flows are predicted to be lower with the proposed bridge than with the existing bridge. The 100-year upland flood combined with MHW would be about 0.3' lower under proposed conditions.
- Velocities are predicted to be lower with the proposed bridge, although rapid flow is still predicted during times of low tide levels due to the steep channel base under and downstream of the bridge.
- The 100-year storm surge peak level upstream of the bridge is predicted to be slightly higher (0.1') under proposed conditions than under existing conditions.
- The 10-year storm against MHW plus 4' of SLR shows 0.3-0.6' of clearance under existing conditions and 1.4' to 1.9' of clearance with the proposed bridge.
- Clearance for the 50-year tidal surge is the same as the 10-year upland storm with MHW plus 4' SLR.
- The existing utility line is lower than the bridge low chord, which is slightly higher than the 50- year storm surge or high tide with potential 100-year sea level rise.

6.0 Scour Considerations:

Scour at the proposed bridge would be limited to contraction and long term bed scour. Abutments are to be protected with riprap. Bed material size distribution is based on the following sieve analyses from borings.

Boring Number	Depth of Sample	D50	D84
B 101	15-17'	1 mm	20 mm
BB 101	26-28'	.18 mm	5 mm
BB 102	1-3'	1 mm	12 mm
BB 102	15-17'	1 mm	20 mm

Contraction scour was computed using methods recommended in FHWA HEC-18. The following table summarizes contraction scour computations, with general contraction scour ranging from 4-5'if bed material is exposed at the channel bed surface.

Contraction scour would likely be limited by the large rocks and other debris within the bridge channel. However, scour was computed under worst case potential conditions, assuming no channel bed protection.

Figure 30. Photo looking upstream into the bridge showing bed protection. This protection only extends across the existing channel.

No information was found related to long term bed scour.

Predicted scour depths are shown below assuming no channel protection.

Model time	Q, frequency	Tide, frequency	Contraction Scour Depth, feet below bed
02 0450	10-year	MHW+4’	3.8
02 2320	1.1-year	100-year surge	5.1
Steady Flow	500-year	MLW	4.9

Scour projections in tidal waters are generally considered conservative. Scour computation methodologies were developed based on riverine flow conditions in one dimension. Storm surges are limited in time, occurring as a long amplitude wave, with both incoming and outgoing components. Daily tides also are long amplitude waves (12 hours from peak to peak) with both incoming and outgoing components that may shift material in either direction.

Project plans indicate that riprap abutment protection for the new bridge will extend to the current channel base width, thus protecting the existing channel bed material. The potential scour prism assuming no bed protection is shown below on the project plan section plot in figure 31.

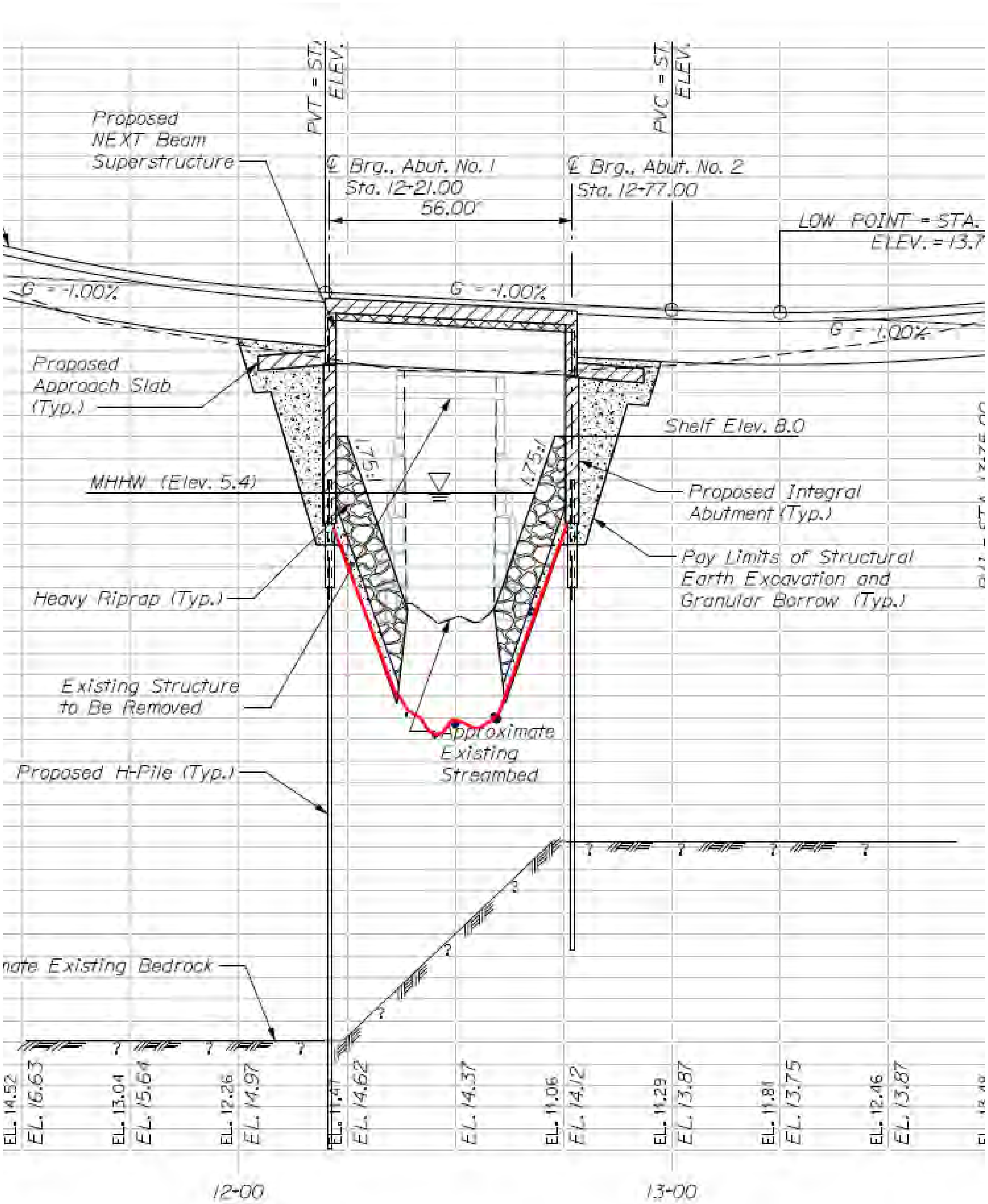


Figure 31. Proposed bridge section with scour prism assuming no channel bed protection. Red line shows predicted scour prism based on 5' of contraction scour and 2:1 side slopes for the scour prism.

Embankment piping:

During Northstar's field visit, it was noted that water appeared to flow through the roadway embankment on the westerly downstream embankment beyond the riprap that shows in figure 31 below. A close-up of the area of piping is shown in figures 32 and 33.

Figure 32. Westerly downstream embankment location of piping (red arrow)

Figure 33. Areas of active piping through embankment, flow from downstream to upstream on incoming tide.

7.0 References:

https://www.maine.gov/dacf/mgs/hazards/highest_tide_line/index.shtml

- Maine Highest Astronomical Tide Stations

Citations

Recommended citations for the project, web application, and datasets:

- **Project**
  - Maine Geological Survey, 2021, Highest Astronomical Tide Line. https://www.maine.gov/dacf/mgs/hazards/highest_tide_line/index.shtml. Accessed October 13, 2022.
- **Web Application**
  - Maine Geological Survey, 2021, Maine Highest Astronomical Tide Line WebApp. https://maine.maps.arcgis.com/apps/webappviewer/index.html?id=4c22efe50ee24459a502e619f8965a84. Accessed October 13, 2022.
- **Data**
  - Maine Geological Survey, 2022, Maine Highest Astronomical Tide Line. Department of Agriculture, Conservation and Forestry, Augusta, ME. https://mgs-maine.opendata.arcgis.com/datasets/maine-highest-astronomical-tide-line.
  - Maine Geological Survey, 2022, Maine Highest Astronomical Tide Stations. Department of Agriculture, Conservation and Forestry, Augusta, ME. https://mgs-maine.opendata.arcgis.com/datasets/maine-highest-astronomical-tide-stations.

More Help

- Memorandum from Charles Hebson, Maine DOT to Jim Wentworth, Kleinfelder Assoc, July 09, 2017. 21677 Brooklin-Sedgwick River Bridge #3216, Sea Level Rise.
- ESRI ArcMap, ArcGIS Desktop. Data added from MEGIS website, project plans and ESRI
- Federal Emergency Management Agency. Flood Insurance Study and Flood Hazard Boundary Maps, Hancock County, Maine. July 20, 2016 23009CV001A and B
- Maine Dept. of Transportation. Bridge Design Manual. August 2003, updates to July, 2017
- Maine DOT, Bridge Plans, Babsons Bridge # 5244, 1949 and 1967
- Maine DOT Bridge Inspection Reports,
- NOAA tide data: Southwest Harbor Tide Gage # 8413564
- NOAA tide data: Bar Harbor, Primary Gage, Station #8413320
- NOAA Sea Level Trends http://www.co-ops.nos.noaa.gov/sltrends/sltrends.html
- U.S. Army Corps of Engineers, Hydrologic Engineering Center. HEC-RAS River Analysis System. Version 5.06. 2018 Davis, CA
- U.S. Army Corps of Engineers. Shore Protection Manual. Volume I and II, 1984.
- U.S. Army Corps of Engineers, Updated Tidal Flood Profiles, New England Coastline, March, 2012.
- U.S. Department of Transportation. Federal Highway Administration. Evaluating Scour at Bridges, 5th edition. HEC-18. April 2012, Publication No. FHWA-HIF-12-003
- U.S. Department of Transportation. Federal Highway Administration. Bridge Scour and Stream Instability Countermeasures. HEC-23. Volume 2. September, 2009. FHWA-NHI-09-112. DG 14, Rock Riprap at Bridge Abutments and DG 4, Riprap Revetment
- U. S. Dept. of the Interior, Geological Survey, with Maine Dept. of Transportation. Estimating the Magnitude and Frequency of Peak Flows for Streams in Maine for Selected Recurrence Intervals. Water Resources Investigations Report 99-4008. https://streamstats.usgs.gov/ss/. USGS Streamstats. Beta Version 4.

Appendix

Additional Bridge Survey/Model Data

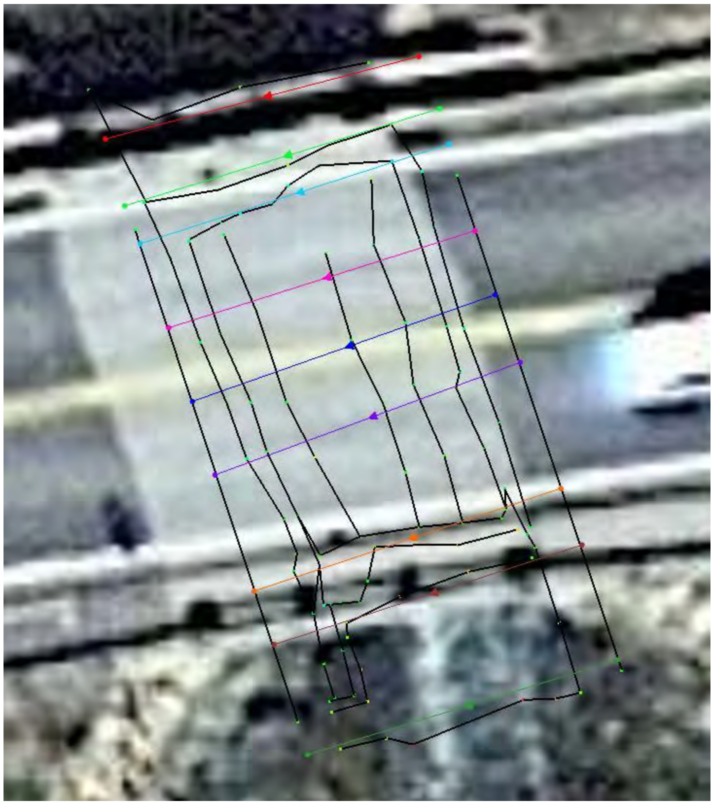
Summary of NOAA Tide Data, Mount Desert Island

Summary of Field Data, March, 2019

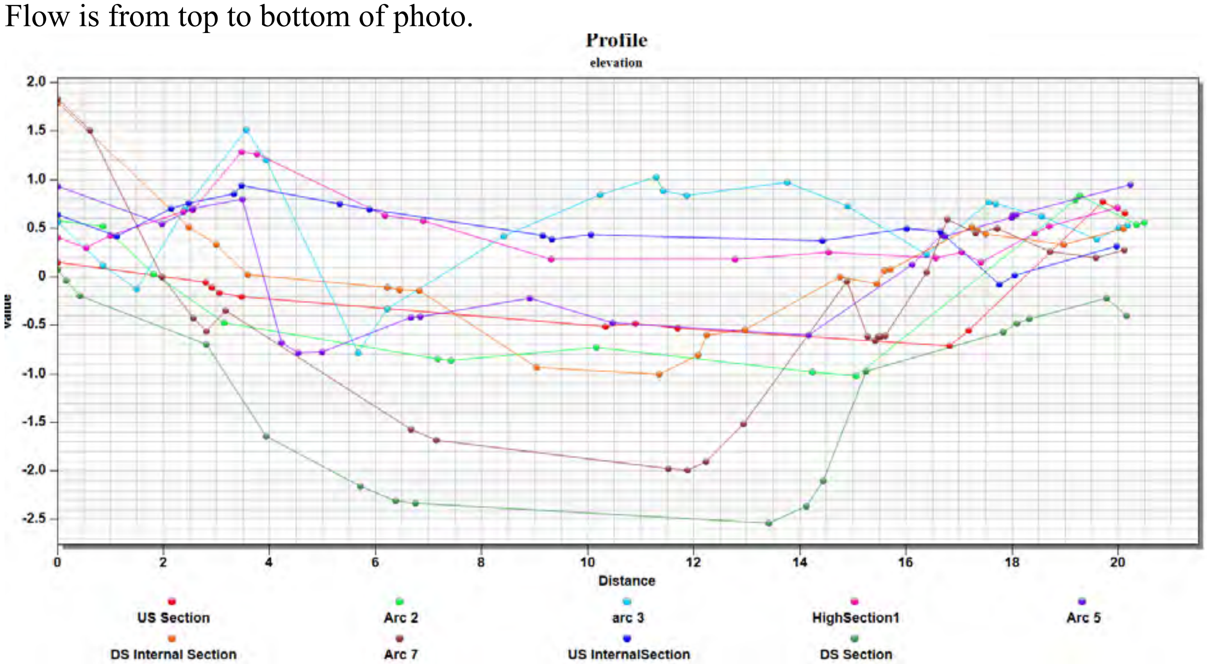
MaineDOT Bridge #5244 Hydrology Report

Maine DOT Bridge #5244 Tidal Hydrology Memorandum, 16 November, 2018

Additional Information related to bridge hydraulic model geometry



Air photo of bridge, showing cross sections in bridge. Sections are plotted below.
Flow is from top to bottom of photo.



Selected sections for hydraulic model are combination of high points in the light blue and pink lines.

Source of Data	**Bar Harbor Gage**		**Southwest Harbor**	
Type of Station	Recording Station		Subordinate Station	
Station ID	8413320		8413564	
Notes			**BH X .96 High, X.95 Low, Time offset 0 min H, -27 min Low**	
Datum	MLLW	NAVD	MLLW	NAVD
HOWL	16.21	10.24	15.56	9.83
HAT	13.69	7.72	13.14	7.41
MHHW	11.37	5.4	10.92	5.18
MHW	10.95	4.98	10.51	4.78
NAVD88	5.97	0	5.73	0.00
MSL	5.67	-0.3	5.39	-0.34
MTL	5.66	-0.31	5.38	-0.35
MLW	0.38	-5.59	0.36	-5.37
MLLW	0	-5.97	0.00	-5.73
LAT	-2.91	-8.88	-2.76	-8.50
LOWL	-2.28	-8.25	-2.17	-7.90
FEMA Storm Surge, 2016 FIS at Transect 095				
10-year		8.5		
50-year		9		
100-year		9.2		
500-year		9.7		

MDI Tides | **March 20 2019** | EO

Water Level Measurements - 15-30 minute intervals | NB

5.97 MLLW = 0.0 NAVD | 5.863 MLLW = 0.0 NAVD

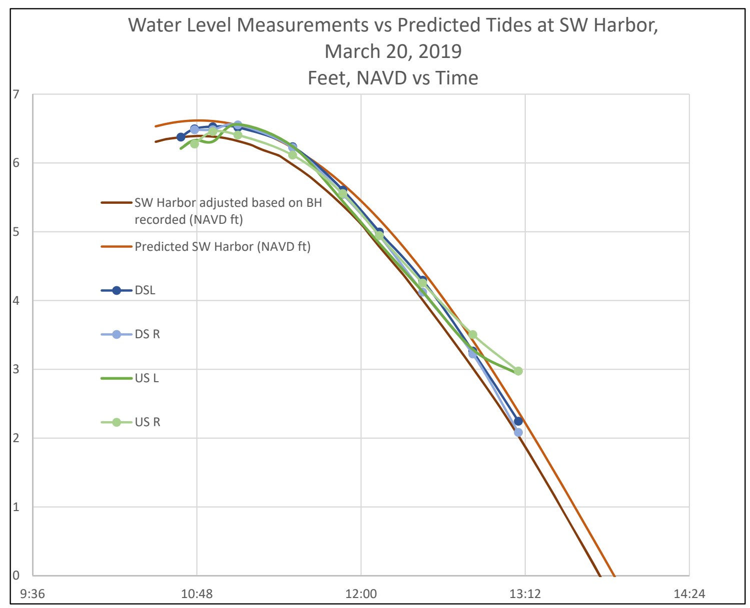
8413320	MLLW	NAVD	8413564	MLLW	NAVD
4:38 AM	-1	-6.97	4:11 AM	-0.99	-6.853
10:49 AM	12.9	6.93	10:49 AM	12.36	6.497
5:09 PM	-1.7	-7.67	4:42 PM	-1.61	-7.473
11:18 PM	12.5	6.53	11:18 PM	11.96	6.097

ADD 1.2' to tape measure distance for weight.

Conversion:			
US=		DS =	
add 1.2' to tape length			
Dist Measured onsite	Top Parapet tc	Top Para to Road	
USR	5.66	4.23	
USL	5.55	4.15	
	Est. Top Para t	Top Para to Sidewalk	
DSL	5.57	3.50	
DSR	5.57	3.53	

	Raw Data no Tape added						
Time Start	**Time Stop**	**Time Avg**	**DSL**	**DS R**	**US L**	**US R**	
		Elevations At Rail	**14.977**	**15.1038**	**15.2105**	**15.156**	**Add Elevation Data**
10:41 AM		10:41 AM	7.40		7.80		
10:47 AM		10:47 AM	7.28	7.42	7.68	7.68	
10:53	10:58	10:55	7.25	7.42	7.70	7.50	tidal high on ds rocks no flow
11:03 AM	11:10	11:06	7.26	7.35	7.45	7.55	starting to flow out
11:28 AM	11:31	11:30	7.54	7.68	7.77	7.84	
11:51	11:53	11:52	8.17	8.36	8.57	8.40	
12:08		12:08	8.78	8.96	9.18	9.01	Plus Velocity
12:27		12:27	9.48	9.78	9.88	9.70	
12:49		12:49	10.51	10.68	10.72	10.45	Plus Velocity
13:09		13:09	11.53	11.82	11.08	10.98	

NAVD with tape				
Time Avg	DSL	DS R	US L	US R
Elevations At Rail Measurement	14.98	15.10	15.21	15.16
LC	11.73	11.86	10.51	10.48
10:41 AM	6.38		6.21	
10:47 AM	6.50	6.48	6.33	6.28
10:55 AM	6.53	6.48	6.31	6.46
11:06 AM	6.52	6.55	6.56	6.41
11:30 AM	6.24	6.22	6.24	6.12
11:52 AM	5.61	5.54	5.44	5.56
12:08 PM	5.00	4.94	4.83	4.95
12:27 PM	4.30	4.12	4.13	4.26
12:49 PM	3.27	3.22	3.29	3.51
1:09 PM	2.25	2.08	2.93	2.98



WIN:	23515.00		**Project Name:**	
Town:	Mt Desert		**Stream Name:**	Kittredge Brook / Babson Creek
Route No.	ME-3 / ME-198		**Bridge Name:**	Babson Bridge
Asset ID:	5244		**Analysis by:**	csh
Lat:	44.369	**Long:** -68.329	**Date:**	4/9/2019

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

Enter data in blue cells only!

ver. 2018 Jul 09

	km^2	mi^2	ac	*Enter data in [mi^2]*
A	8.81	3.40	2176.0	Watershed Area *DRNAREA*
W	1.42	0.5	350.3	Wetlands area (by NWI)
P_c	554342	4914833		watershed centroid (E, N; UTM 19N; meters)
County	Hancock			*choose county from drop-down menu*
pptA				mean annual precipitation (inches; by look-up)
A (km^2)	8.81	**Conf Lvl**	0.67	
W (%)	16.10			NWI Wetlands % *STORNWI*

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

Watershed Characteristics for Monthly & Daily Flows

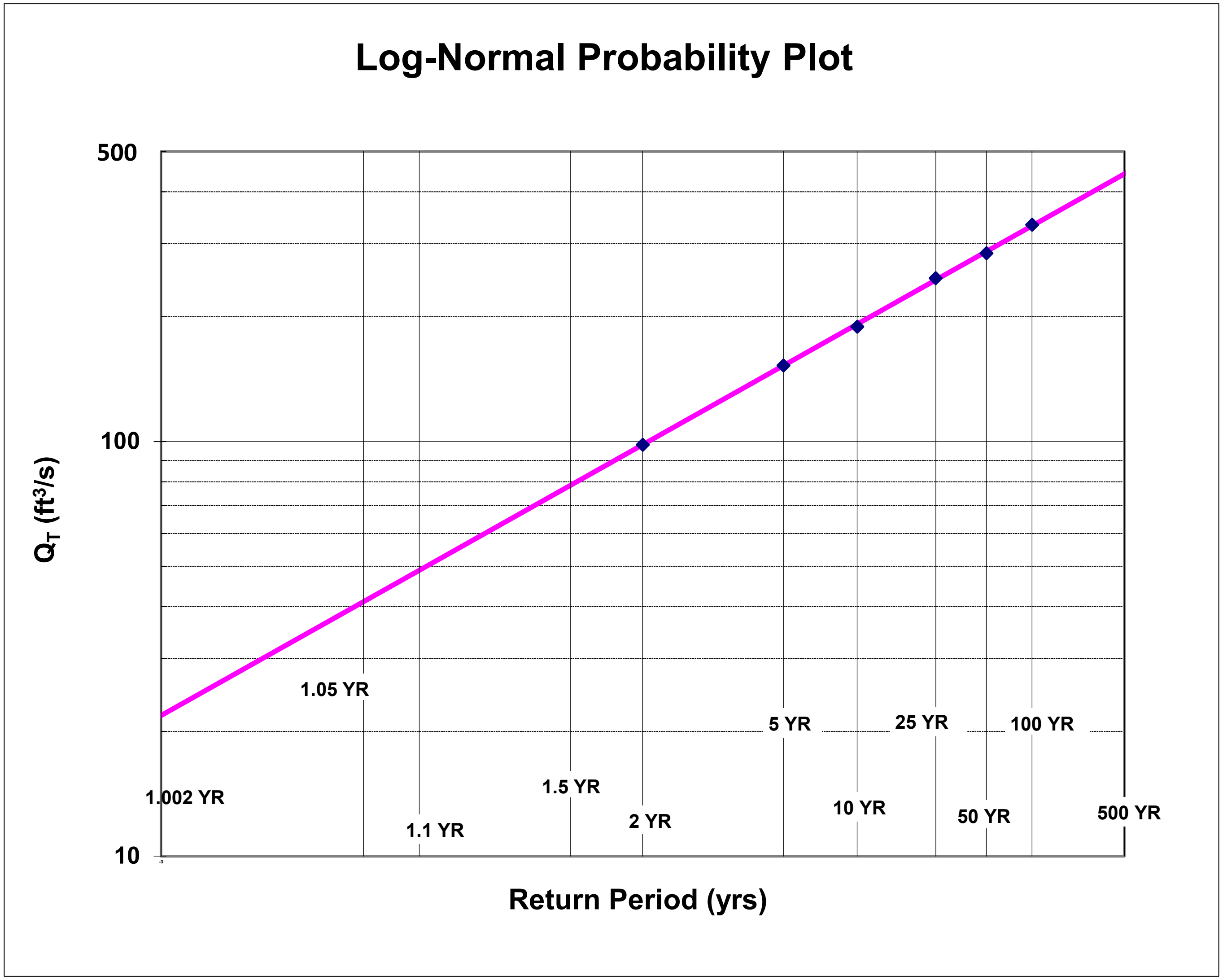
EAVG	113.5	mean basin elevation (ft)
SLOPE	8.1	mean basin slope (%)
EMAX	285.4	maximum basin elevation (ft)
WATER	0.22	percent of drainage basin land cover classified as open water
PRECIP	48.8	mean annual precipitation
SG	0.00	sand & gravel aquifer as decimal fraction of watershed A
HGA	7.8	mean basin percentage of hydrological soil group A
DIST	29.00	distance from the coast (mi)

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

Ret Pd T (yr)	Peak Flow Estimate Lower	Q_T (m^3/s)	Upper	Q_T (ft^3/s)
1.1		1.39		49.0
2	1.98	2.78	3.92	98.3
5	3.06	4.32	6.11	152.6
10	3.74	5.35	7.67	189.1
25	4.83	7.02	10.21	247.9
50	5.47	8.06	11.87	284.6
100	6.32	9.44	14.08	333.2
500	8.10	12.51	0.00	441.8

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


Log-Normal Probability Plot
500
100
10
Q_T (ft^3/s)
1.05 YR
1.002 YR
1.1 YR
1.5 YR
2 YR
5 YR
10 YR
25 YR
50 YR
100 YR
500 YR
Return Period (yrs)

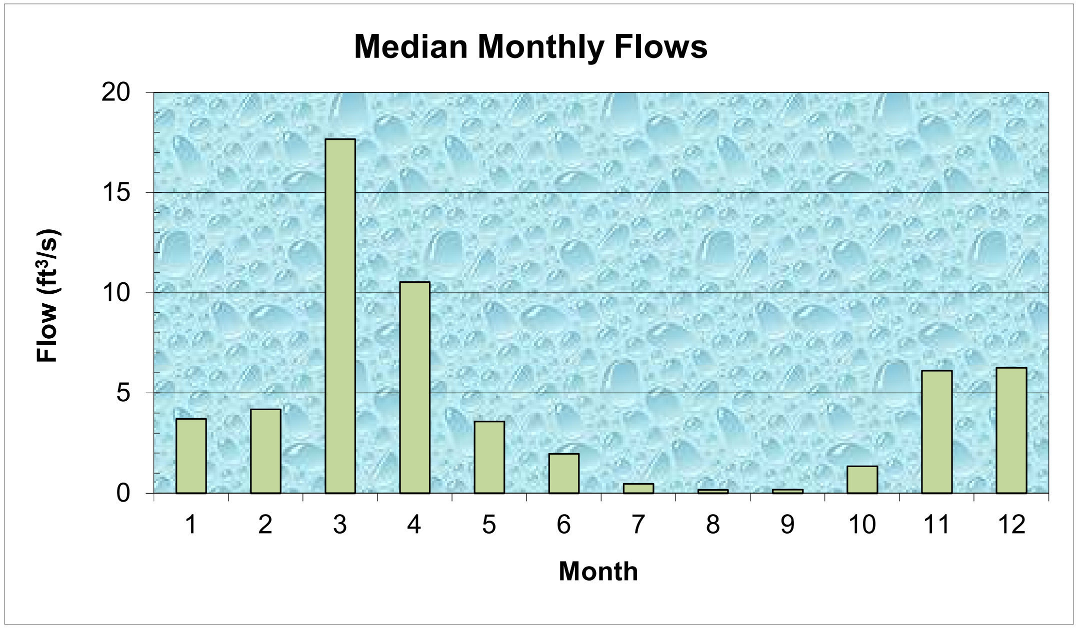
WIN:	23515.00			**Project Name:**	0
Town:	Mt Desert			**Stream Name:**	Babson Creek
Route No.	ME-3			**Bridge Name:**	Babson Bridge
Asset ID:	5244			**Analysis by:**	csh
Lat:	44.36900	**Long:**	-68.32900	**Date:**	4/9/2019

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

MAINE MONTHLY MEDIAN FLOWS and HYDRAULIC GEOMETRY BY USGS REGRESSION EQUATIONS (2004, 2013, 2015)

	Value	Variable	Explanation
	3.40	*A*	Area (mi^2)
554342	4914833	P_c	Watershed centroid (E,N; UTM; Zone 19; meters)
	28.80	*DIST*	Distance from Coastal reference line (mi)
	48.8	*pptA*	Mean Annual Precipitation (inches)
	0.00	*SG*	Sand & Gravel Aquifer (decimal fraction of watershed area)

Month	Q_{median} (ft3/s)	(m^3/s)
Jan	**3.70**	0.1050
Feb	**4.18**	0.1185
Mar	**17.66**	0.5005
Apr	**10.54**	0.2986
May	**3.58**	0.1013
Jun	**1.97**	0.0557
Jul	**0.48**	0.0135
Aug	**0.17**	0.0049
Sep	**0.18**	0.0051
Oct	**1.34**	0.0381
Nov	**6.12**	0.1733
Dec	**6.27**	0.1776



Q_{bf}	**18.8**	
ann avg	**7.2**	
ann med	**3.0**	
$Q_{1.002}$	**21.9**	
$Q_{1.01}$	**29.1**	
$Q_{1.05}$	**41.1**	
Q_{bf}	**64.5**	assume v = 4ft/s

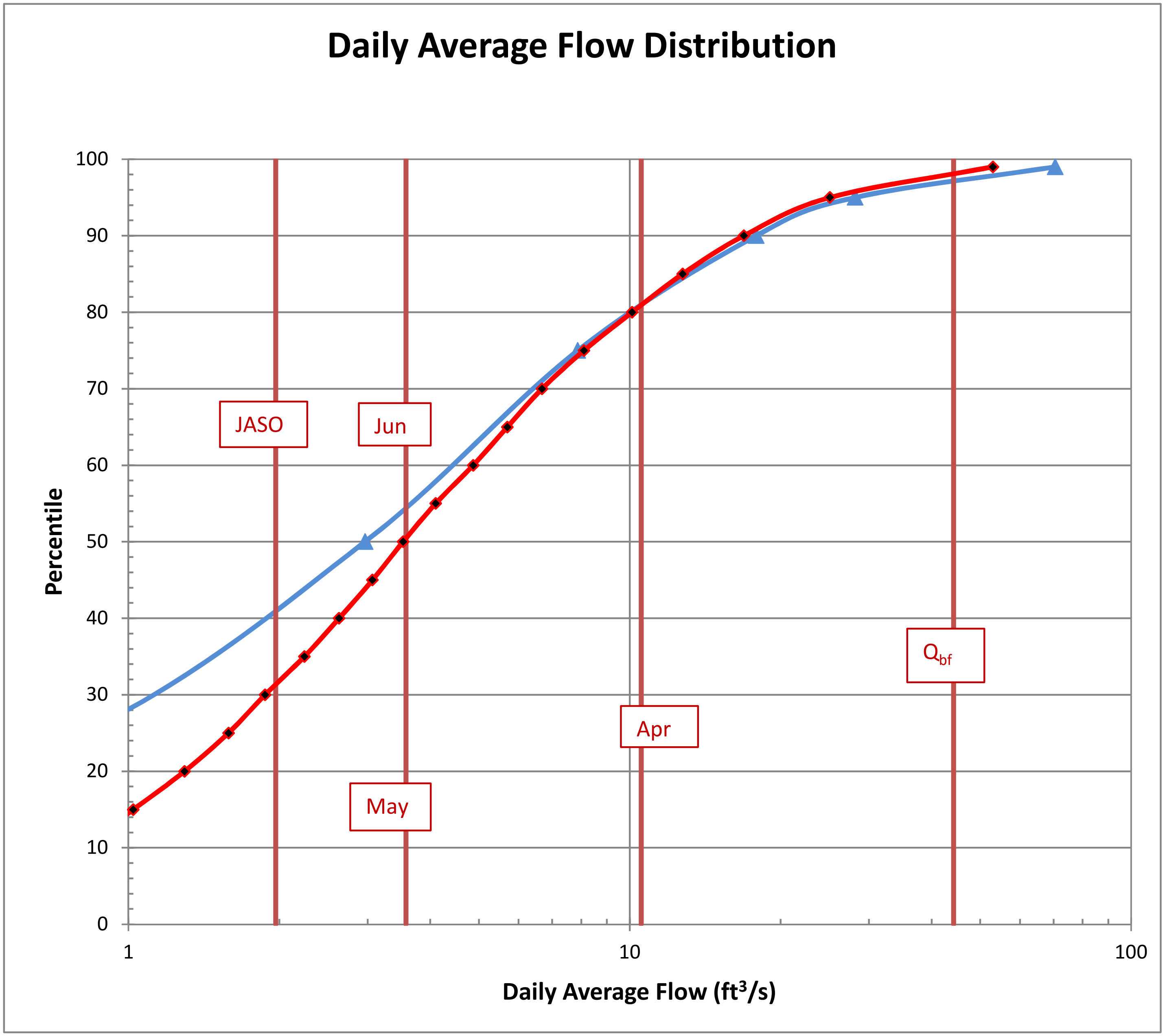
W_{bf}	**17.9**	estimated bankfull width (ft)
d_{bf}	**0.9**	estimated bankfull depth (ft)
A_{bf}	**13.0**	estimated bankfull flow area (ft^2)

References

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

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

Dudley, R.W., 2015. Regression Equations for Monthly and Annual Mean..., USGS SIR 2015-5151



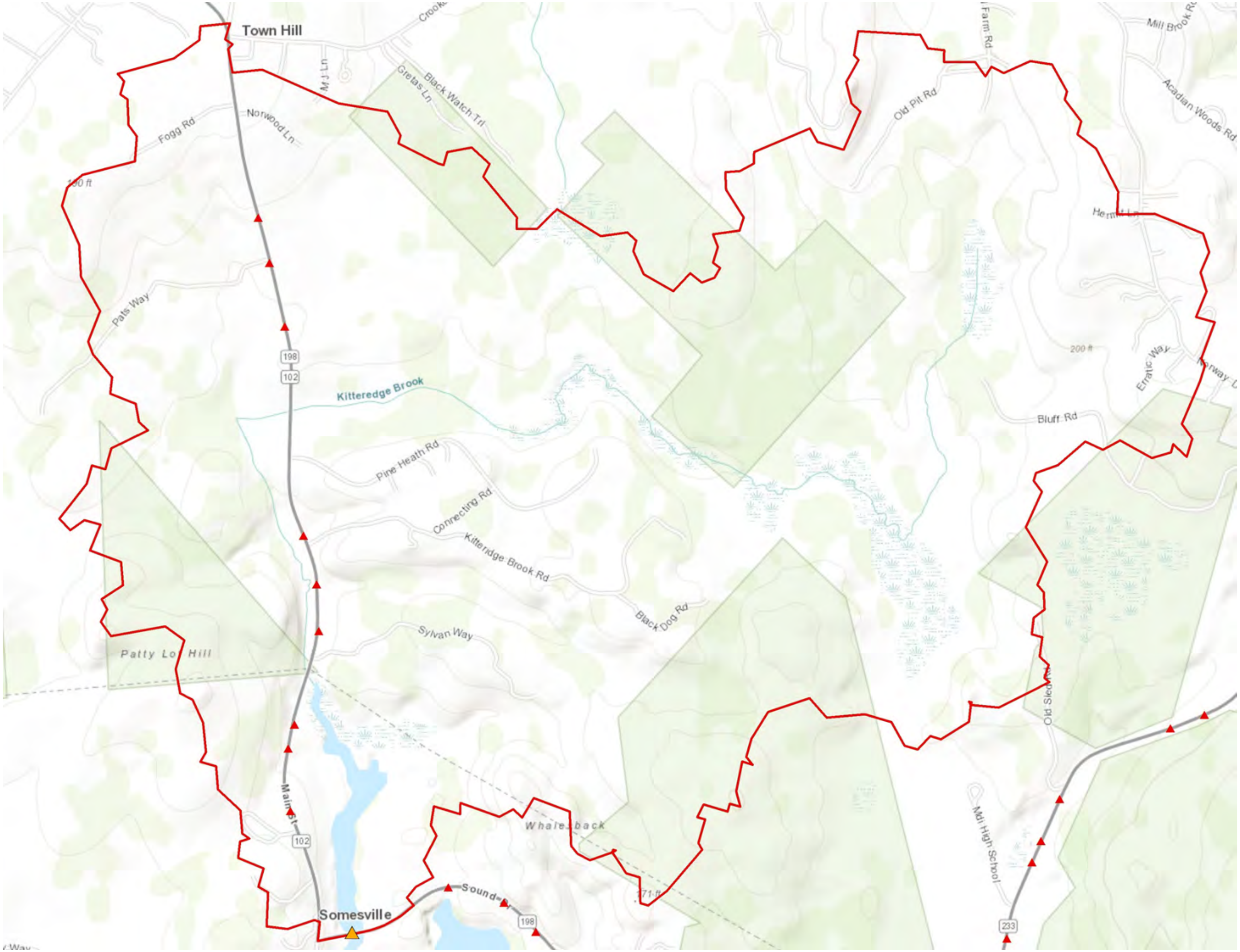
Daily Avg Flow Dist

A_{ws} = (mi^2) 3.4

Q (ft^3/s)

Pctl	Median	84^{th} pctl
1	0.29	0.52
5	0.54	0.86
10	0.79	1.20
15	1.02	1.49
20	1.29	1.81
25	1.58	2.12
30	1.87	2.42
35	2.24	2.76
40	2.63	3.18
45	3.07	3.59
50	3.53	4.24
55	4.10	4.93
60	4.87	5.79
65	5.70	6.75
70	6.68	7.87
75	8.10	9.47
80	10.11	11.30
85	12.75	14.49
90	16.89	19.45
95	25.07	30.25
99	53.01	69.79

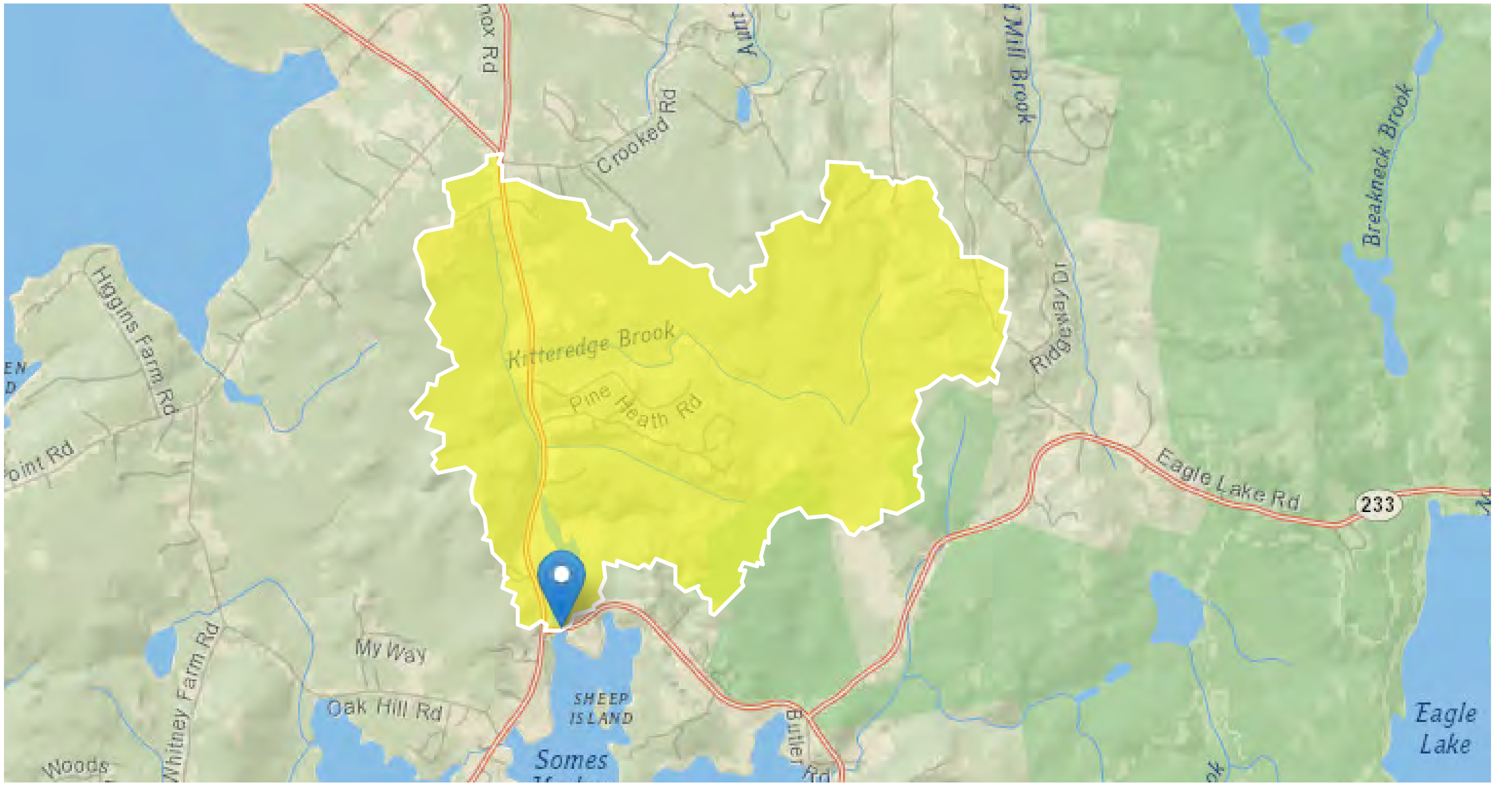
Q_{bf}	18.8
$Q_{1.002}$	21.9
$Q_{1.1}$	49.0
Q_2	98.3



Appendix 9
Mount Desert Babsons Bridge #5244
Northstar Hydro, Inc.

Mt Desert 23515.00 Babson Bridge ME-3 over Babson Creek

Region ID: ME
Workspace ID: ME20190408133733670000
Clicked Point (Latitude, Longitude): 44.36905, -68.32902
Time: 2019-04-08 09:37:47 -0400



Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	3.4	square miles
STORNWI	Percentage of storage (combined water bodies and wetlands) from the National Wetlands Inventory	16.1	percent
SANDGRAVAF	Fraction of land surface underlain by sand and gravel aquifers	0	dimensionless
ELEV	Mean Basin Elevation	113.5	feet
BSLDEM10M	Mean basin slope computed from 10 m DEM	8.07	percent
CENTROIDX	Basin centroid horizontal (x) location in state plane coordinates	554341.9	feet
CENTROIDY	Basin centroid vertical (y) location in state plane units	4914833.23	feet
COASTDIST	Shortest distance from the coastline to the basin centroid	29	miles
ELEVMAX	Maximum basin elevation	285.4	feet
LC06WATER	Percent of open water, class 11, from NLCD 2006	0.22	percent
LC11DEV	Percentage of developed (urban) land from NLCD 2011 classes 21-24	7.52	percent
LC11IMP	Average percentage of impervious area determined from NLCD 2011 impervious dataset	2.04	percent
PRECIP	Mean Annual Precipitation	48.8	inches
SANDGRAVAP	Percentage of land surface underlain by sand and gravel aquifers	0	percent
STATSGOA	Percentage of area of Hydrologic Soil Type A from STATSGO	7.78	percent

General Disclaimers

The delineation point is in an exclusion area. Warning! Coastal/Tidal areas are outside the hydrologic region defined by the study. Accuracy of regression equations is not defined.

Bankfull Statistics Parameters [Central and Coastal Bankfull 2004 5042]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	3.4	square miles	2.92	298

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

Statistic	Value	Unit
Bankfull Streamflow	18.8	ft^3/s
Bankfull Width	14.5	ft
Bankfull Depth	0.901	ft
Bankfull Area	13	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 DA LT 12sqmi 2015 5049]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	3.4	square miles	0.31	12
STORNWI	Percentage of Storage from NWI	16.1	percent	0	22.2

Peak-Flow Statistics Flow Report [Statewide Peak Flow DA LT 12sqmi 2015 5049]

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

Statistic	Value	Unit	SEp
1.01 Year Peak Flood	29.9	ft^3/s	38
2 Year Peak Flood	98.2	ft^3/s	34
5 Year Peak Flood	153	ft^3/s	35
10 Year Peak Flood	189	ft^3/s	37
25 Year Peak Flood	248	ft^3/s	39
50 Year Peak Flood	284	ft^3/s	41
100 Year Peak Flood	333	ft^3/s	42
250 Year Peak Flood	371	ft^3/s	44
500 Year Peak Flood	441	ft^3/s	47

Peak-Flow Statistics Citations

Lombard, P.J., and Hodgkins, G.A.,2015, 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, 12 p. (http://dx.doi.org/10.3133/sir20155049)

Annual Flow Statistics Parameters [Statewide Annual SIR 2015 5151]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	3.4	square miles	14.9	1419
SANDGRAVAF	Fraction of Sand and Gravel Aquifers	0	dimensionless	0	0.212
ELEV	Mean Basin Elevation	113.5	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	7.25	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)

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

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	3.4	square miles	14.9	1419
SANDGRAVAF	Fraction of Sand and Gravel Aquifers	0	dimensionless	0	0.212
ELEV	Mean Basin Elevation	113.5	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	0.00673	ft^3/s
5 Percent Duration	0.047	ft^3/s
10 Percent Duration	0.141	ft^3/s

Statistic	Value	Unit
25 Percent Duration	0.807	ft^3/s
50 Percent Duration	2.96	ft^3/s
75 Percent Duration	7.87	ft^3/s
90 Percent Duration	17.9	ft^3/s
95 Percent Duration	28.2	ft^3/s
99 Percent Duration	70.5	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)

Application Version: 4.3.0

Environmental Office – Hydrology Section
16 State House Station
Augusta ME 04333-0016
207.557.1052
Charles.Hebson@maine.gov

Maine Department of Transportation

Memo

To: Kristen Chamberlain, Eric Ham

From: Charles Hebson

CC:

Date: 16 November 2018

Re: 23515 Mt Desert – Babson Bridge #5244 – Tidal Hydrology

Executive Summary
Tidal stage data was collected upstream and downstream of Bridge #5244, Babson Bridge, for the period 11 July – 23 August 2018. The data suggest the presence of a restriction at the bridge. Grade control beneath the bridge surely plays a part in this; the opening of the bridge may also be a factor.

Discussion
Grade control at the bridge has created a tidal flat-water impoundment upstream labeled as Kittredge Brook on maps. The upstream data logger was placed at a boulder just off the embankment, as shown in Figure 1. The downstream logger was placed in a rock cluster near the east bank, as shown in Figure 2. Figure 3 shows the grade control at the bridge inlet. Approximately 200-ft downstream of the bridge is a second grade control in the channel, shown in Figure 4. At the time of data collection, survey control had not yet been established at the site, so all elevations are to an arbitrary local datum created for this purpose. The datum has been marked and noted, so that it can be converted to NAVD88 in the future once survey control has been set.

Tidal stage is graphed for the August spring tide period in Figure 5A. At peak high tide there is a very small head drop across the bridge, $\Delta h < 0.2'$ (2.4”). The time lag between peak tides is about 30 minutes; the lag on the rising tide can be as large as 54 minutes. At lower tides (Figure 5B) the difference is smaller to non-existent. The effect of the grade controls is evident in both sets of tides. The upstream falling limb displays the shape typical of reservoir / pond drainage. This may be due to a bridge opening restriction as well as the grade control, since the drainage shape is apparent as soon as the tide turns and even when the downstream tide is still above the elevation control at the bridge. The downstream falling limb follows a typical tidal shape until tide falls below the downstream control elevation.

Figure 6 shows a portion of the spring tide for better illustration. There is a small time lag between downstream peak and upstream peak, with the corresponding small head difference between peaks. At any given instant, there is a noticeably larger head difference over the course of the rising limb once the downstream tide rises above the bridge grade control. This is probably due to a combination of grade control as well as opening restriction. Once the upstream tide turns, the upstream water level is always higher than downstream, again due to the restriction at the bridge; the upstream water level remains higher than downstream until the next incoming tide rises above bridge grade control.

Figure 1. Location of Upstream Data Logger, East Side of Bridge

Figure 2. Location of Downstream Data Logger, East Bank

Figure 3. Grade Control at Bridge

Figure 4. Downstream Grade Control

Figure 5a. Tidal Hydrographs Upstream & Downstream of Bridge – Spring

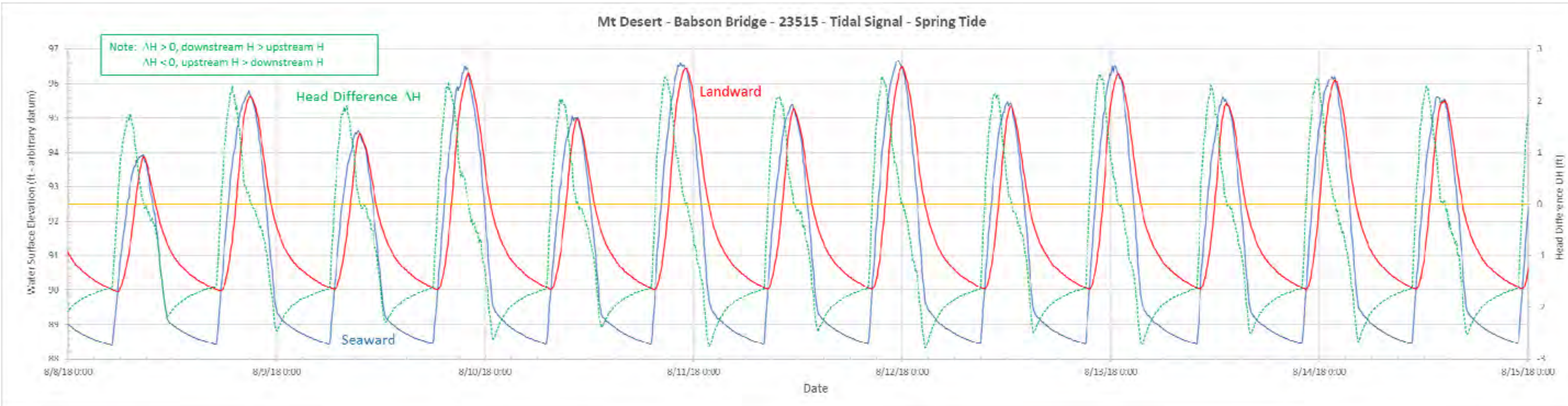


Figure 5b. Tidal Hydrographs Upstream & Downstream of Bridge – Lower Tides

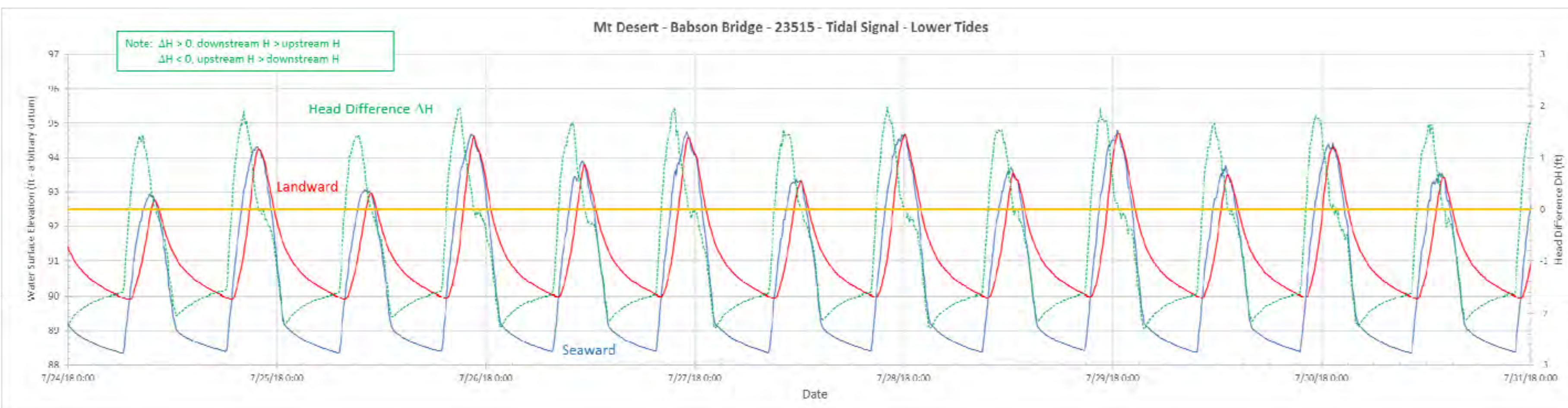


Figure 6. Illustration of Head Drop Across Bridge