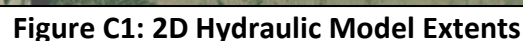


2D Hydraulic Modeling Narrative

Two-dimensional (2D), steady state hydraulic analyses were performed to analyze the existing and proposed hydraulic conditions at the Smith Brook Bridge. The software package used to develop the SRH-2D (Reference 5) model for the crossing is Aquaveo's SMS Version 13.3 (Reference 6). The program allows the user to develop a 2D hydraulic, sediment, temperature, and vegetation model that incorporates the finite volume method in conjunction with implicit first- and second-order numerical schemes to approximate a solution for the 2D depth averaged Saint Venant equations.

A topographic and bathymetric survey (Reference 12) was completed for this project and incorporated into the model as an XML file. The survey included stream thalweg data, roadway elevations, and bank geometry near the existing bridge. A LiDAR surface was used to supplement the on-the-ground survey to incorporate areas within the extents of the model that the survey did not cover. LiDAR data was downloaded from the NOAA Data Access Viewer website (Reference 7). The model extents are shown below:



The feature stamping tool was used to define the channels outside the limits of the survey using estimated water depths, streambed widths, and streambed slopes as described below. A summary of this data is included in Table C1. Bog Brook was not stamped as it would have

minimal impact on the results at Smith Brook Bridge. The survey, LiDAR, and stamp data were combined to create an existing terrain surface for the existing conditions model.

Table C1: Feature Stamp Data

Waterbody	Location	Estimated Water Depth (ft)	Streambed Width (ft)	Streambed Slope (ft/ft)
Smith Brook	Immediately US of Survey	1	16	0.002
	750' US of Survey	1	16	0.006
Mattawamkeag River (Main Channel)	DS of Survey & Immediately US of Survey	7.5	100	0.001
	3,400' US of Survey	7.5	100	0.0004
Mattawamkeag River (US East Channel)	2,000' US of Confluence w/ Smith Brook	5	80	0.0007

The type of LiDAR used in this project does not penetrate through water; therefore, the water surface elevations (WSE) are approximated by interpolation of streambank elevations across the stream. The surveyed streambed elevations were subtracted from the approximated WSEs to estimate the depth of the channel outside the limits of the surveyed stream and river. By inspecting the difference between the LiDAR water surface and the survey data, as well as observations from a field visit on June 12, 2025, the Smith Brook channel bottom was taken to be 1' below the LiDAR water surface upstream of the survey. The Mattawamkeag River main channel bottom was taken to be an average of 7.5' below the LiDAR water surface upstream and downstream of the survey. Approximately 2,000' upstream of the confluence, the Mattawamkeag River is split into two channels for a length of 2,900'; the west channel is the main channel, and the east channel was considered separately. This east channel bottom was taken to be an average of 5' below the LiDAR water surface.

The width of the streambed outside of the limits of the survey were estimated using the survey data and aerial imagery. The bottom of the streambeds were assumed to be flat, and the side slopes were created when the stamp and LiDAR data were merged. This created a rectangular shape for Smith Brook and a trapezoidal shape for the Mattawamkeag River. The streambed width of Smith Brook was estimated to be 16'. The streambed of the Mattawamkeag River was estimated to be 100' for the main channel and 80' for the upstream east channel.

The slope of the streambed was assumed to be the same as the water surface slope. The slopes of the approximated water surface for Smith Brook were calculated as 0.002 ft/ft immediately upstream of the limits of the survey and transitioned to 0.006 ft/ft approximately 750' upstream of the survey limits. The slope of the approximated water surface for the Mattawamkeag River main channel was calculated as 0.001 ft/ft downstream of the survey and immediately upstream

of the survey; the upstream main channel transitioned to 0.0004 ft/ft approximately 3,400' upstream of the survey limits. The slope of the approximated water surface for the Mattawamkeag River upstream east channel was calculated as 0.0007 ft/ft.

The existing surface was modified for the proposed conditions model to incorporate the proposed bridge and which includes the following features:

- A 90'-0" long span (skewed 20 degrees) with a clear span distance of 84'-6 7/8" from face of abutment to face of abutment;
- a streambed cross-section with a 3.5' wide shelf on each side set at an elevation of 334', side slopes of 1.75(H):1(V), and a stream-bottom with a slight V-shape between the bottom of the side slopes;
- a streambed longitudinal profile starting about 70' upstream of the proposed upstream fascia of the bridge with the following properties: an adverse slope of -0.042 ft/ft for 13'; then a slope of 0.003 ft/ft to and through the bridge, and past the downstream fascia 42' at a slope of 0.003 ft/ft; and then sloped down 0.333 ft/ft to tie into the bottom of the scour hole.

Mesh Development

The upstream limit of the model along Smith Brook is about 6,500' (measured along the stream) upstream of the crossing. The upstream limit of the model along the Mattawamkeag River is about 8,000' (measured along the river) upstream of the confluence with Smith Brook. The downstream limit is about 5,600' (measured along the river) downstream of the confluence. About 1,200' downstream of the confluence with Smith Brook, is the confluence of Bog Brook and the Mattawamkeag River. The upstream limit of the model along Bog Brook from this confluence is 7,000' (measured along the stream). Triangular mesh elements were used to model the floodplains and surrounding terrain, and a combination of triangular and quadrilateral mesh elements were used to model the stream, the river, and the roads. Triangular mesh was used in multiple locations in the stream to better represent the surveyed bathymetry. The size of the elements was adjusted based on their proximity to the bridge and stream to optimize the model.

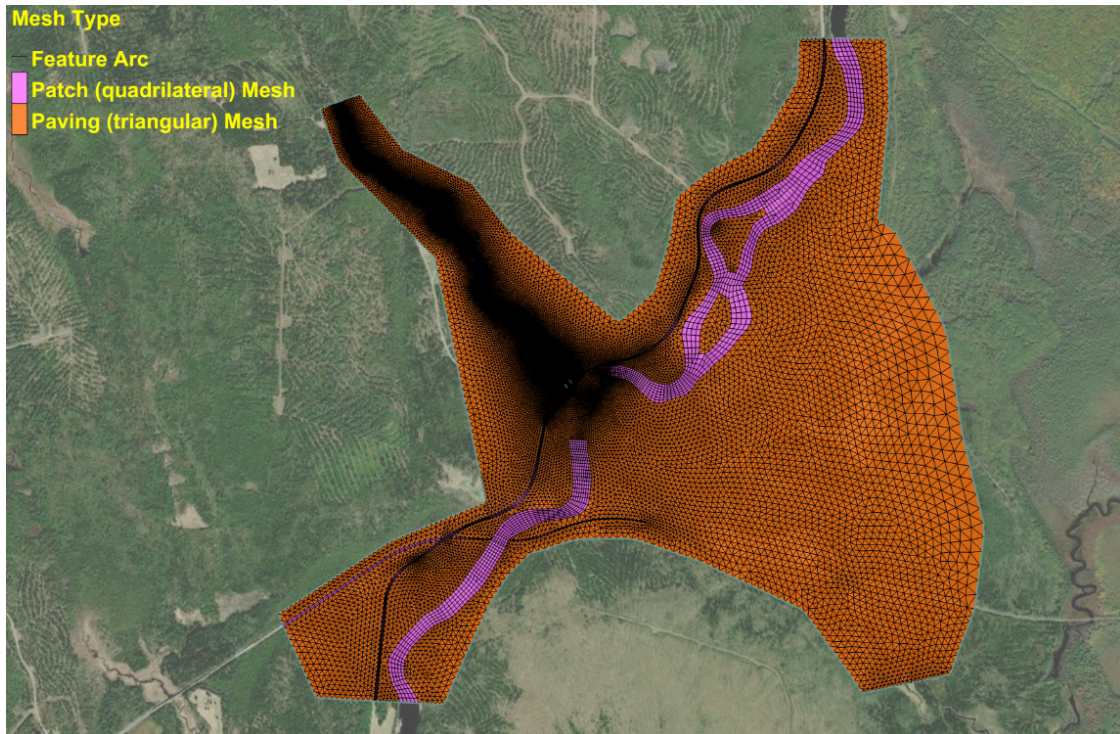


Figure C2a: Plan View of Model Domain and Mesh Elements

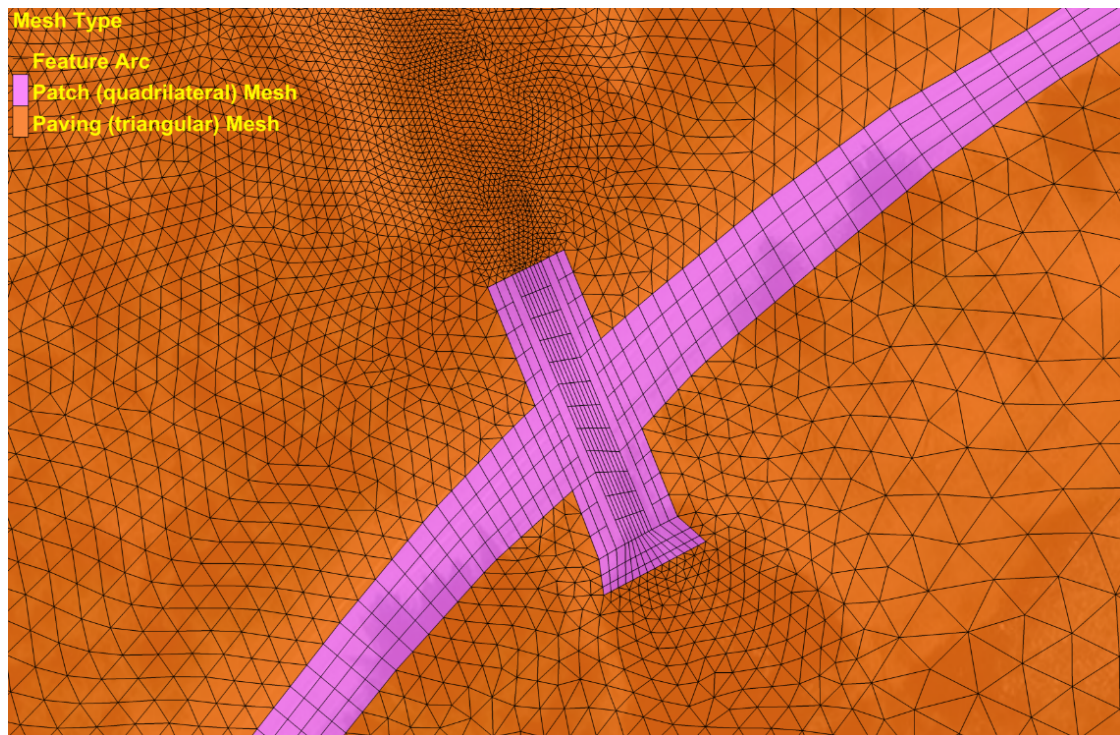


Figure C2b: Plan View of Bridge Site and Mesh Elements

Material Properties

The material properties used were based on aerial imagery and observations from field visits made on November 20, 2024 and June 12, 2025, and input as Mannings' n roughness coefficients to the Materials SMS coverage. A roughness coefficient of 0.03 was used for Smith Brook and the Mattawamkeag River. The roughness of Bog Brook was estimated to be 0.035. A proposed Materials coverage was created by modifying the existing Materials coverage to represent the increased span as well as the riprap which will be placed on the embankments around the proposed bridge.

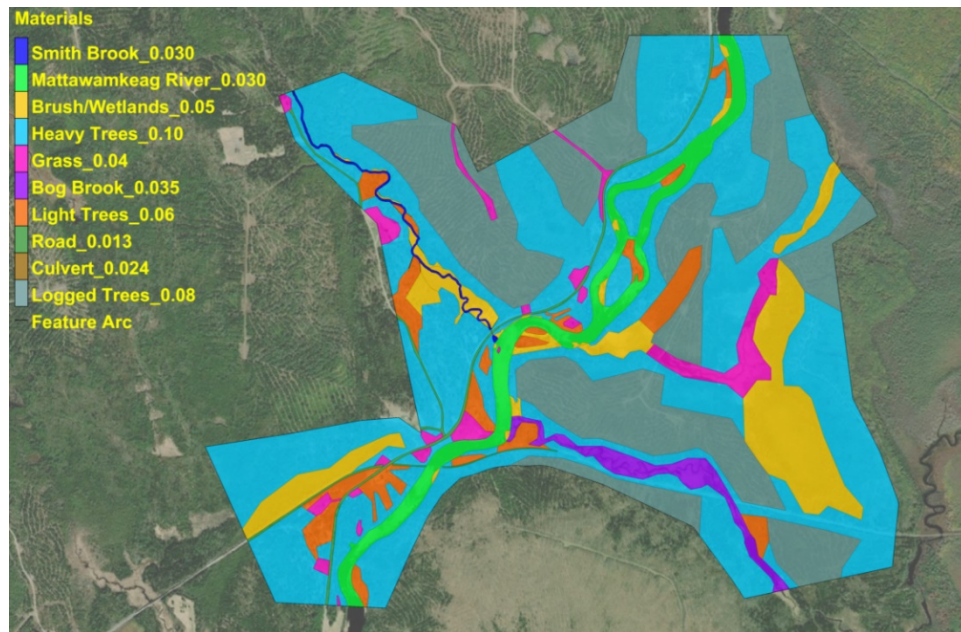


Figure C3a: Plan View of Model Domain and Existing Materials

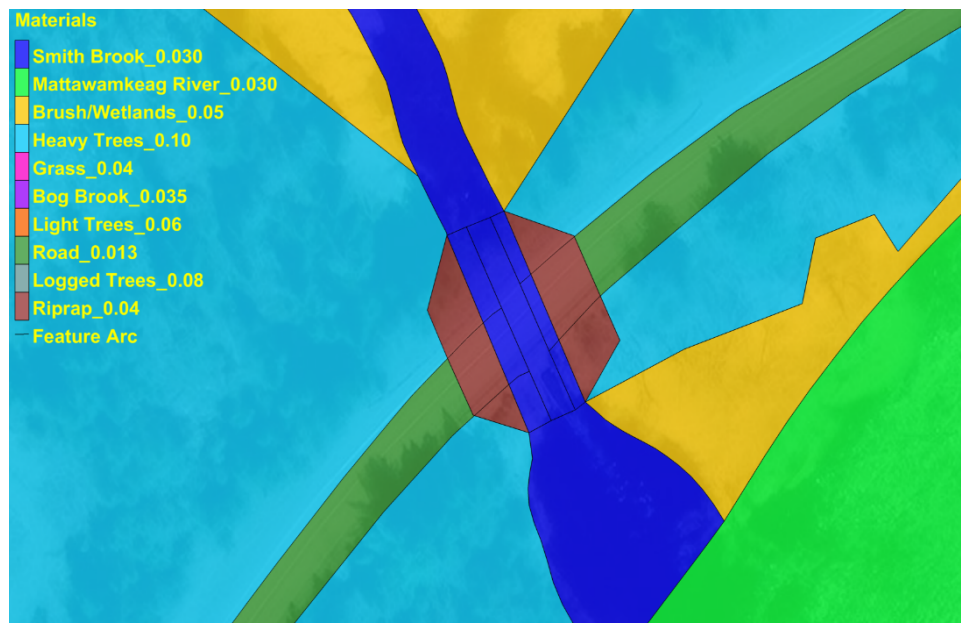


Figure C3b: Plan View of Proposed Materials at Bridge Site

Boundary Conditions

The peak flows were input as constant discharge distributed at the inlet using conveyance for the upstream boundary conditions of Smith Brook, the Mattawamkeag River, and Bog Brook. The downstream boundary conditions were input as a WSE calculated by the program based on: assuming subcritical flow and normal depth, a composite roughness coefficient of 0.040 at low flows and 0.065 at high flows, a normal slope of 0.001 ft/ft, and the total discharge. The normal slope was based on the assumption that the water surface slope is an approximation of the energy grade line slope and the streambed slope. The water surface slope was calculated using estimated elevations from the LiDAR data near the downstream boundary.

The existing bridge was modeled using a pair of pressure arcs and a feature stamp to create the culvert shape. An HY-8 boundary condition could not be used since water from the Mattawamkeag River can flow upstream through the culvert during high flows, and the HY-8 boundary condition is limited to one directional flow and would not correctly represent the hydraulics. The pressure arc ceiling was a parabolic shape that approximately matched the waterway opening of the top of the culvert, and the Manning's roughness coefficient of the ceiling was taken as 0.024. The feature stamp created the bottom half of the culvert shape that was directly incorporated into the mesh. The materials coverage at the culvert was taken as 0.024. The geometric data for the existing bridge was taken from the latest bridge inspection report (Reference 9), the existing plans (References 10 and 11), and the existing ground survey (Reference 12). The proposed bridge was also modeled using pressure arcs, but the ceiling was taken as flat with a low chord elevation of 344.6' and a Manning roughness coefficient of 0.08; the proposed low chord was revised to be 346.44' for the preliminary design, but the original value of 344.6' was left in the model since pressure flow does not occur and it does not affect the results.

Sensitivity Analysis

A sensitivity analysis of the downstream model boundary conditions was performed to verify model convergence of the water surface profile downstream of the bridge. Convergence occurs when a downstream boundary condition, roughness, or mesh resolution is changed but the solution remains similar. For this study, the WSE at the downstream boundary condition was changed for two combinations for the 100-year joint probability flood event:

1. the 100-year flood in Smith Brook and Bog Brook in conjunction with the 1.1-year flood in the Mattawamkeag River
2. the 5-year flood in Smith Brook and Bog Brook in conjunction with the 100-year flood event in the Mattawamkeag River

The WSEs were increased and decreased by 1' to try to demonstrate that the downstream boundary condition did not affect the solution at the project site. For joint probability combination #1 described above, the model converged near the confluence of Smith Brook and the Mattawamkeag River. However, for joint probability combination #2 described above, the model did not converge before the confluence and project site; the increased WSE was 0.6' above

the design WSE and the decreased WSE was 0.4' below the design WSE. The velocities had minimal differences between these models with less than 0.5 ft/sec difference.

A sensitivity analysis of Manning's roughness coefficient was also completed to verify model convergence. The roughness coefficient of the Smith Brook streambed channel and the Mattawamkeag River streambed channel were increased and decreased by 0.005, and was evaluated for the two combinations described above for the 100-year joint probability flood event. The results show that this increase and decrease results in a WSE difference of approximately 0.5' +/- for the increase or decrease of Manning's n. The velocities had small differences between these models with 1.3 ft/s difference or less.

These analyses show that the model is very sensitive to inputs and that the accuracy of the results is highly dependent on the accuracy of the inputs. There is higher confidence in the lower flow results, however there is still a degree of uncertainty. The inputs were adjusted to account for field observations and the topography and bathymetry around the bridge are based on survey data to be as accurate as possible. Even with an increase in WSE due to altering the downstream boundary condition and the Manning's n, there would still be sufficient freeboard at the 50-year joint probability flood, and the increases in velocities are small for the sensitivity analyses, so the model was not expanded to try to increase the convergence of the results. Additionally, due to the current large size of the model, it would not be practicable to attempt to improve convergence by extending the model further downstream on the Mattawamkeag River.

Scour Analysis

A scour analysis will be performed based on procedures outlined in FHWA publication HEC-18, 5th Edition (Reference 8). The 100-year and 500-year storm events will be analyzed for contraction scour and local scour at the proposed site, per the MaineDOT Bridge Design Guide (Reference 15). The Particle Size Distribution Report provided by WSP (Reference 14) reports that the D_{50} of the streambed is 6.54 mm, and the D_{50} of the overbanks ranges from 0.02 mm to 5.3 mm. The complete scour analysis will be included in the final PDR. An evaluation of the riprap placed at the proposed bridge opening is anticipated as well.

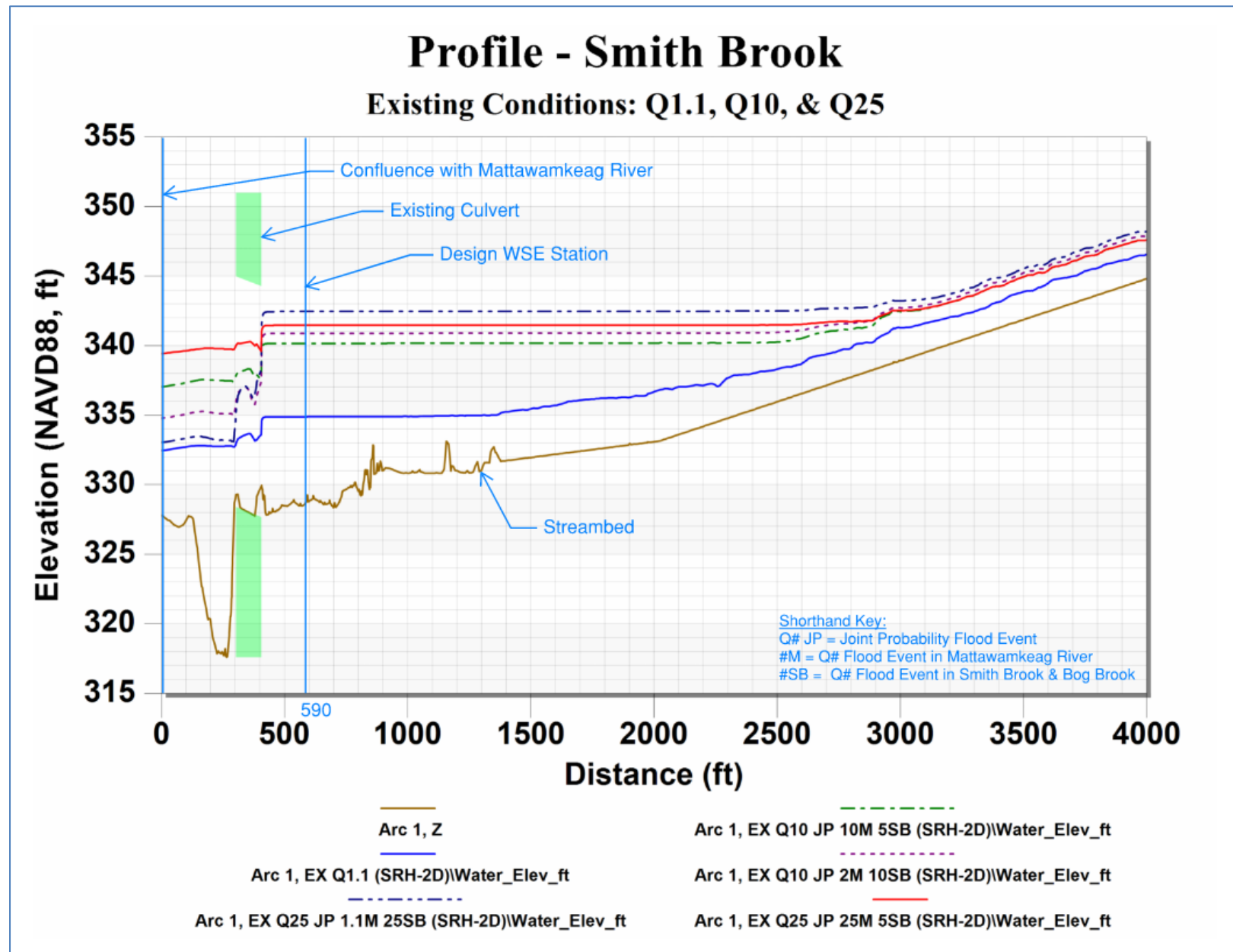
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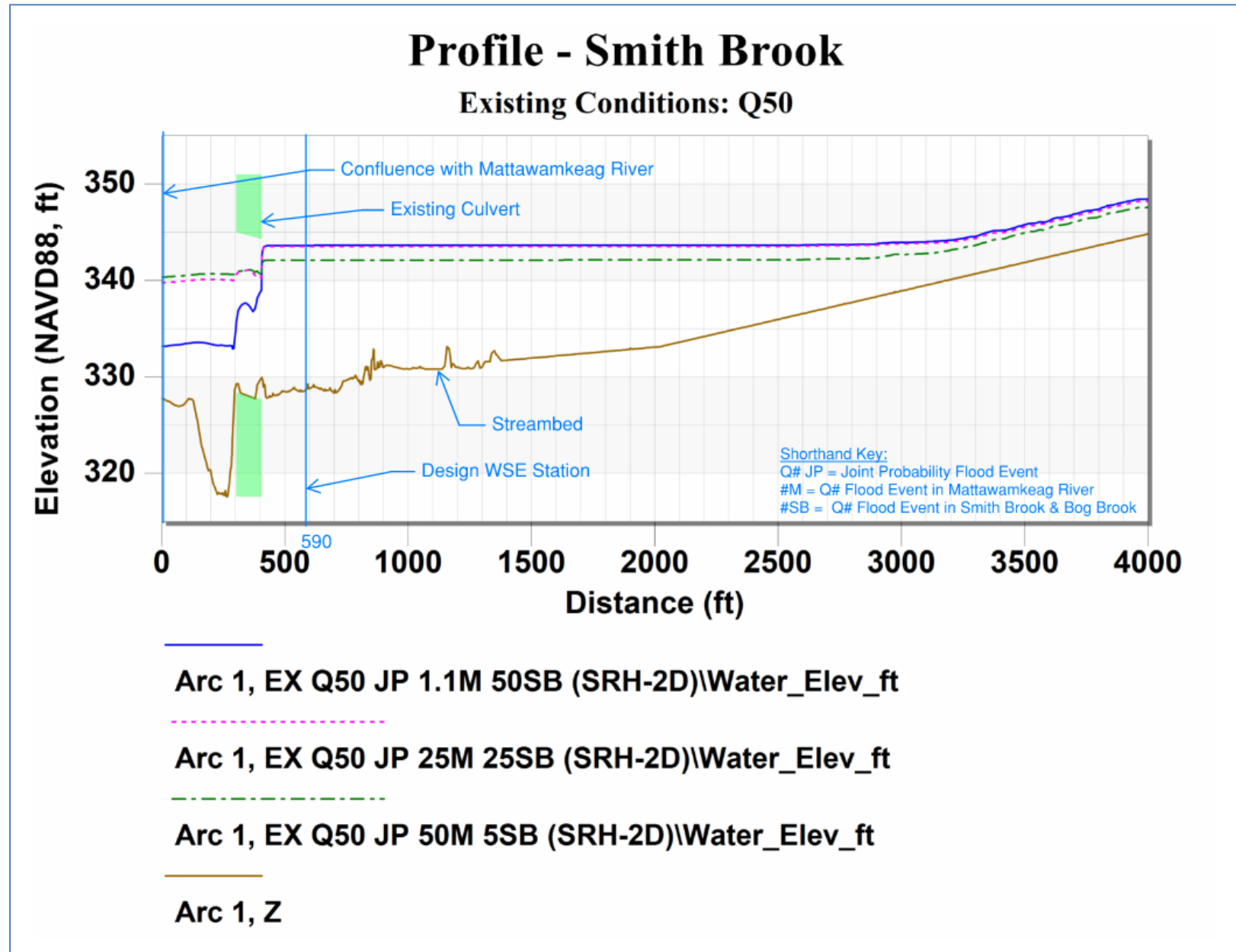
2D Hydraulic Modeling

Existing Conditions Results

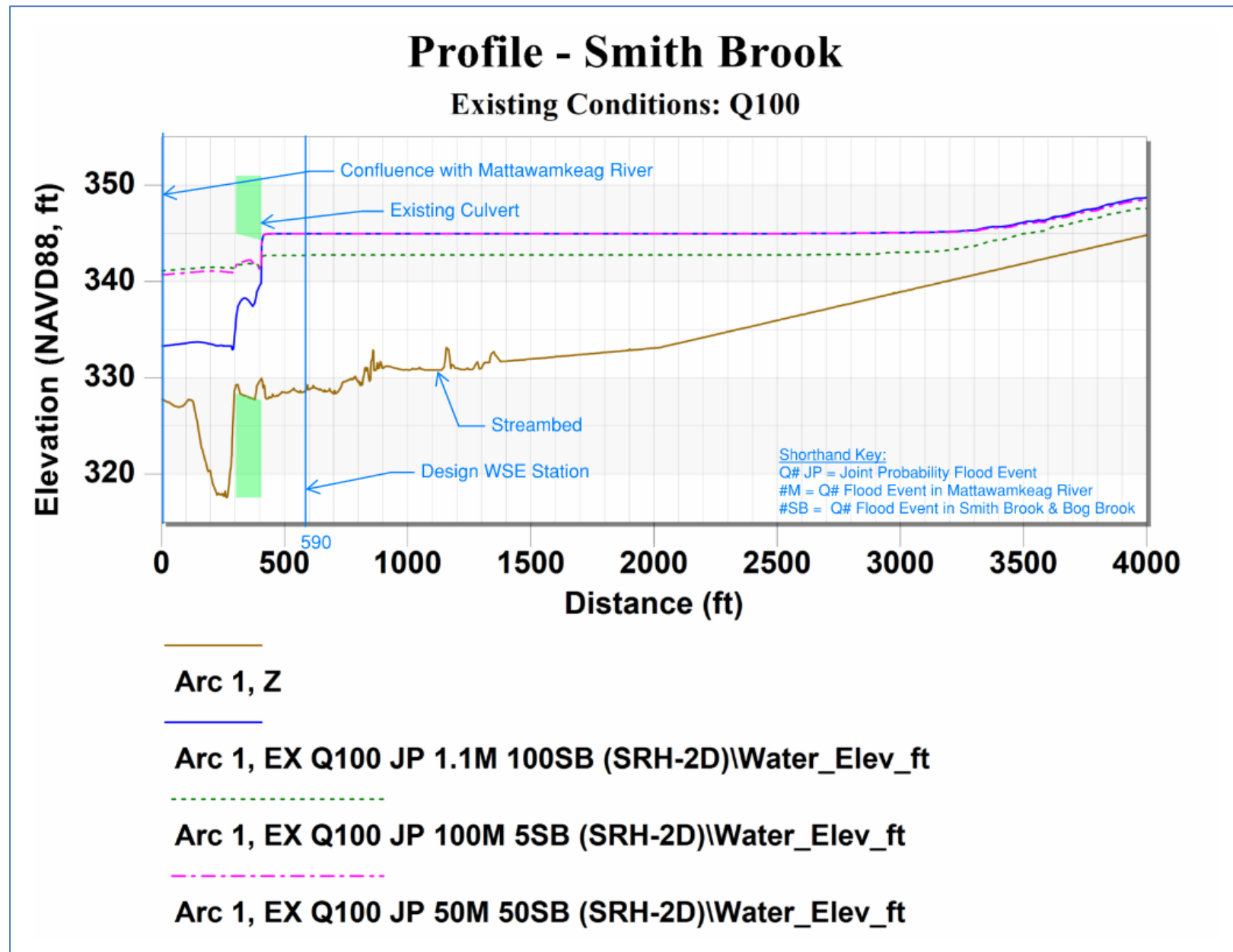
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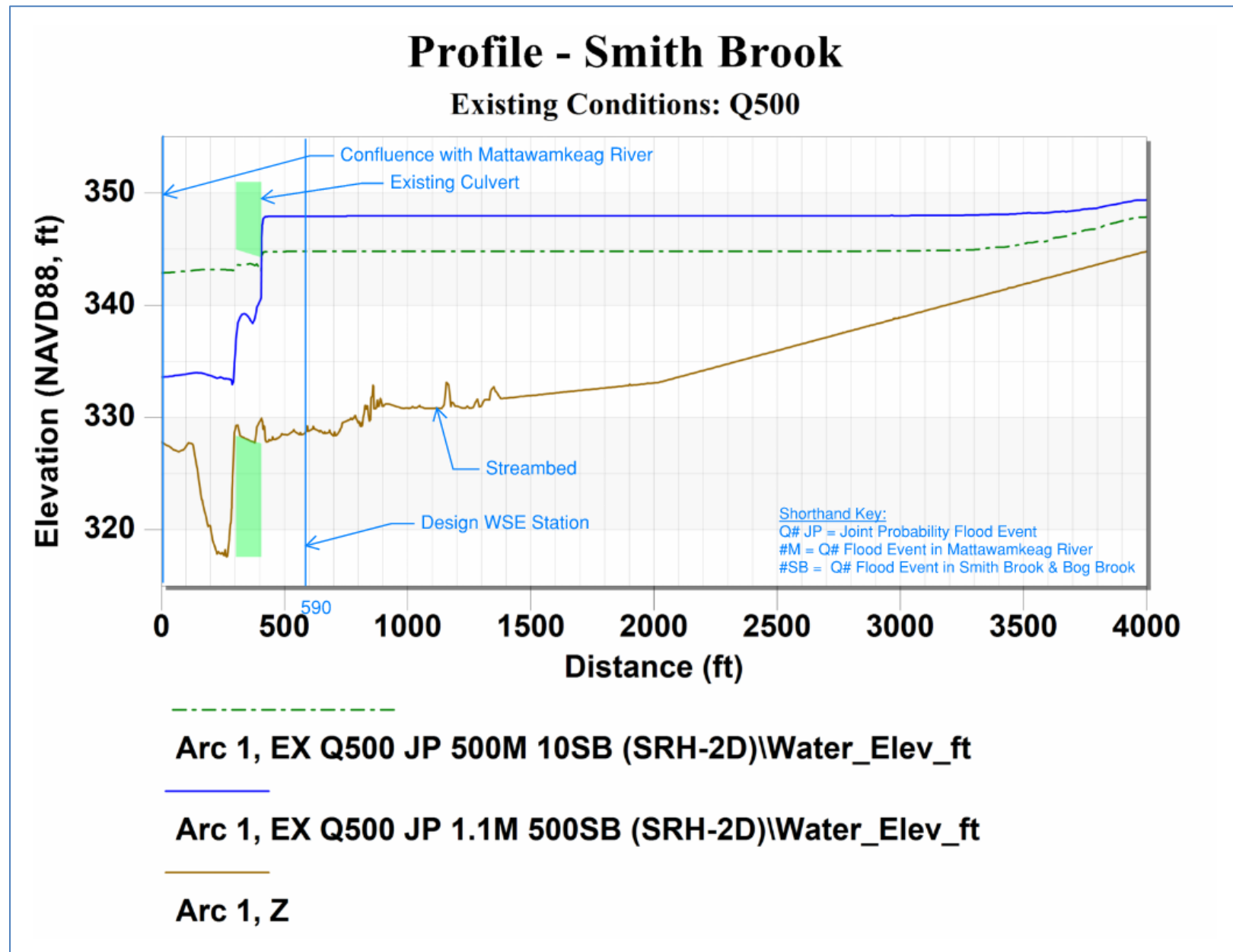
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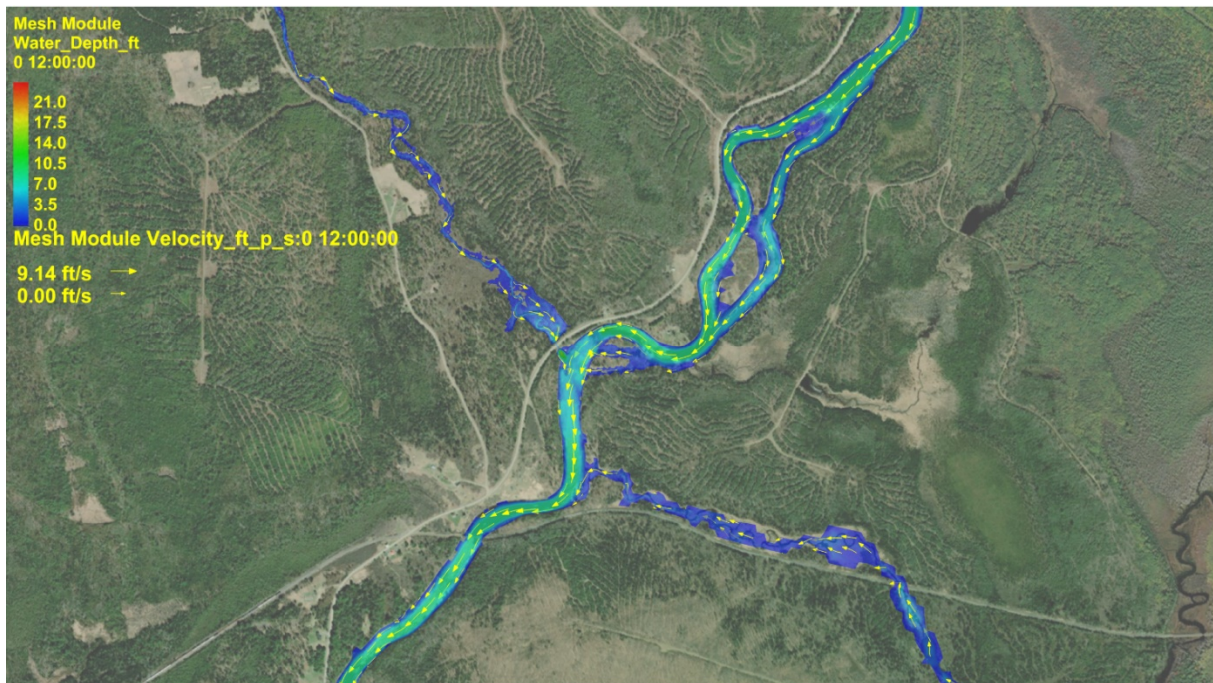
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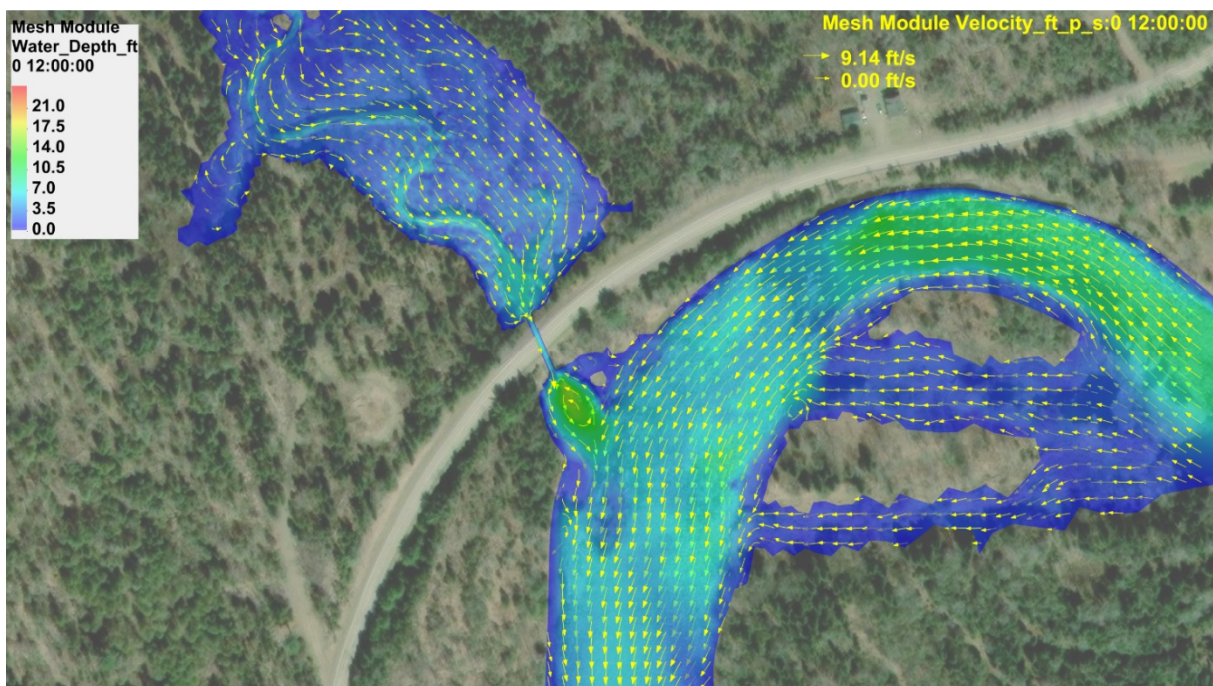
Existing Conditions Water Surface Elevation Profiles



Existing 1.1-Year Flood Event Water Depths with Flow Vectors

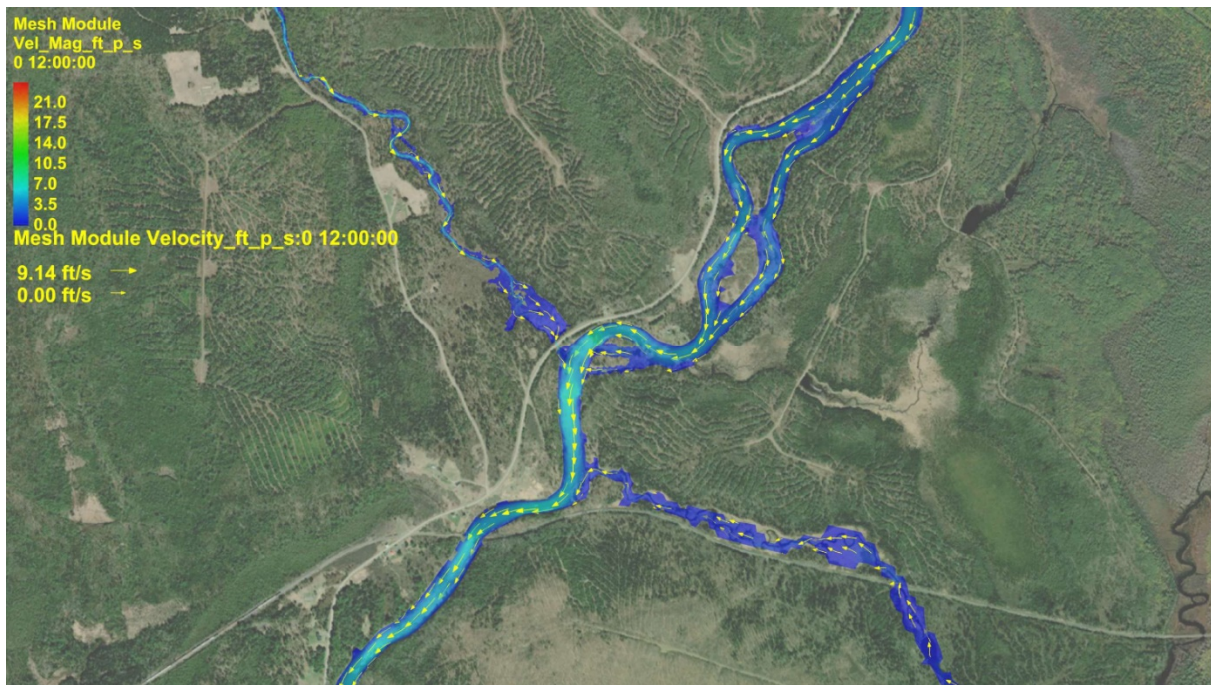


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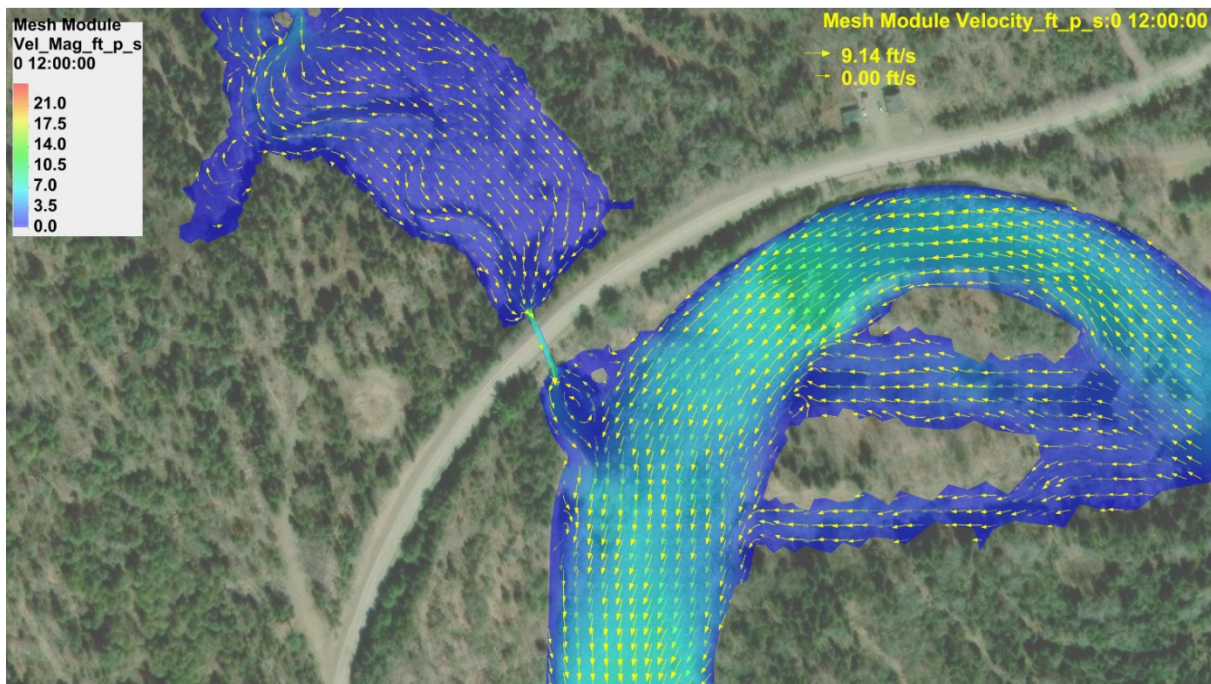


Bridge

Existing 1.1-Year Flood Event Velocities with Flow Vectors

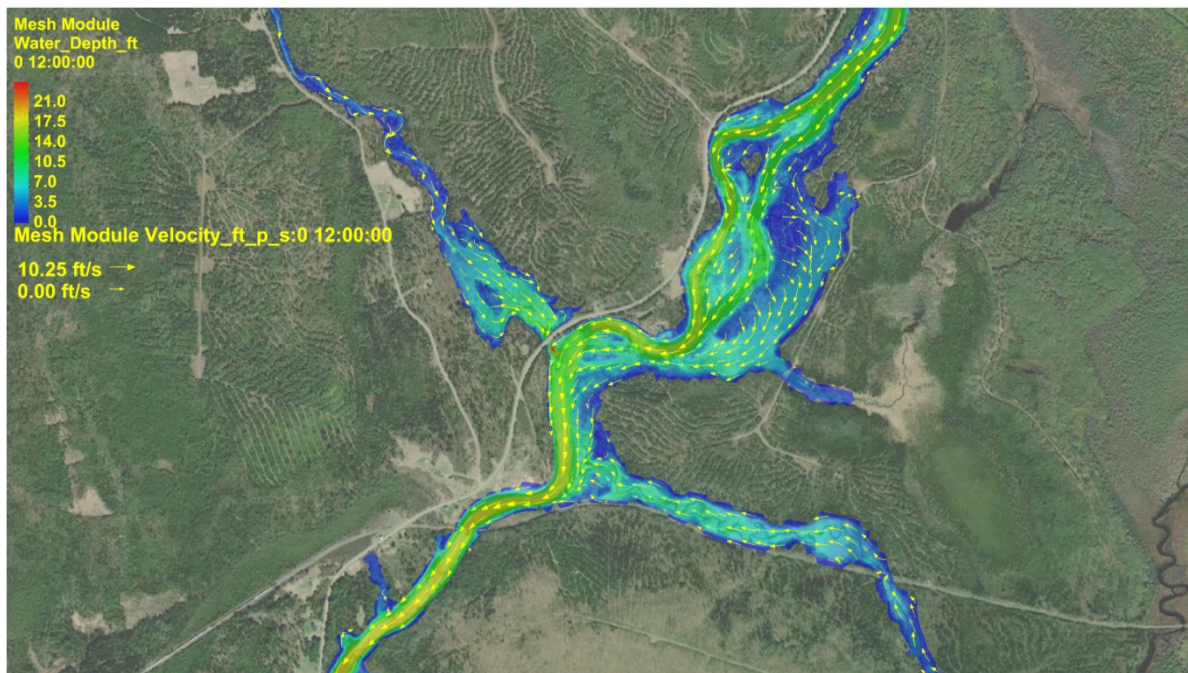


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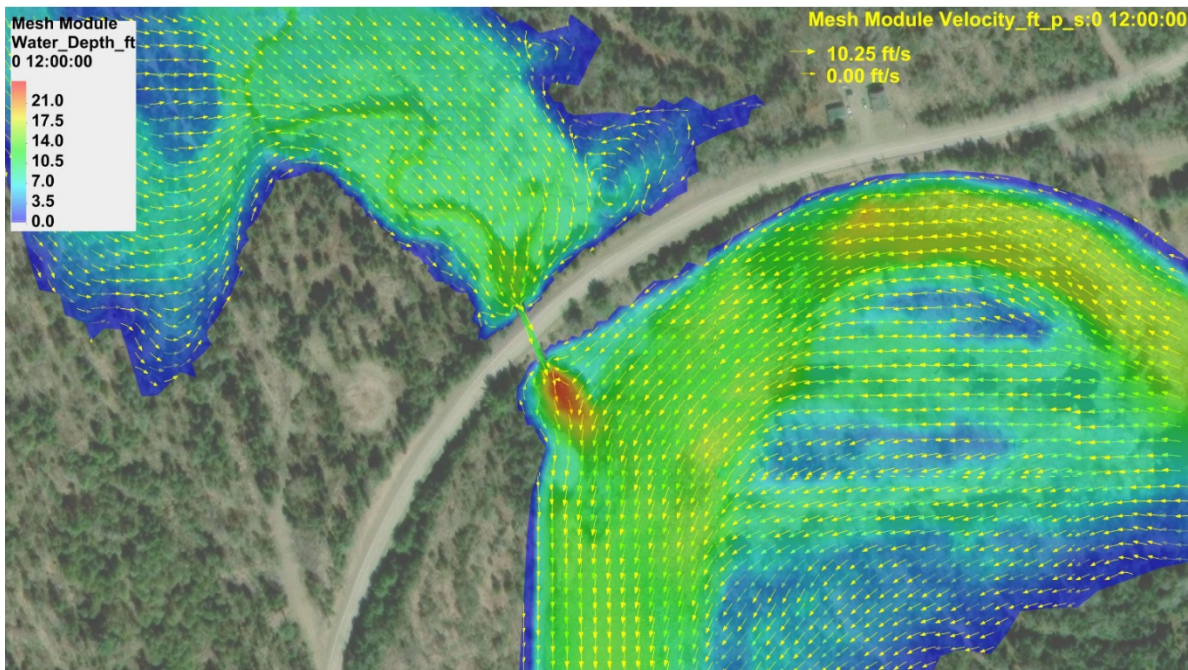


Bridge

Existing 50-Year Joint Probability Flood Event
Water Depths with Flow Vectors for Maximum Water Surface Elevation Combination:
5-Year Flood in Smith Brook & 50-Year Flood in Mattawamkeag River

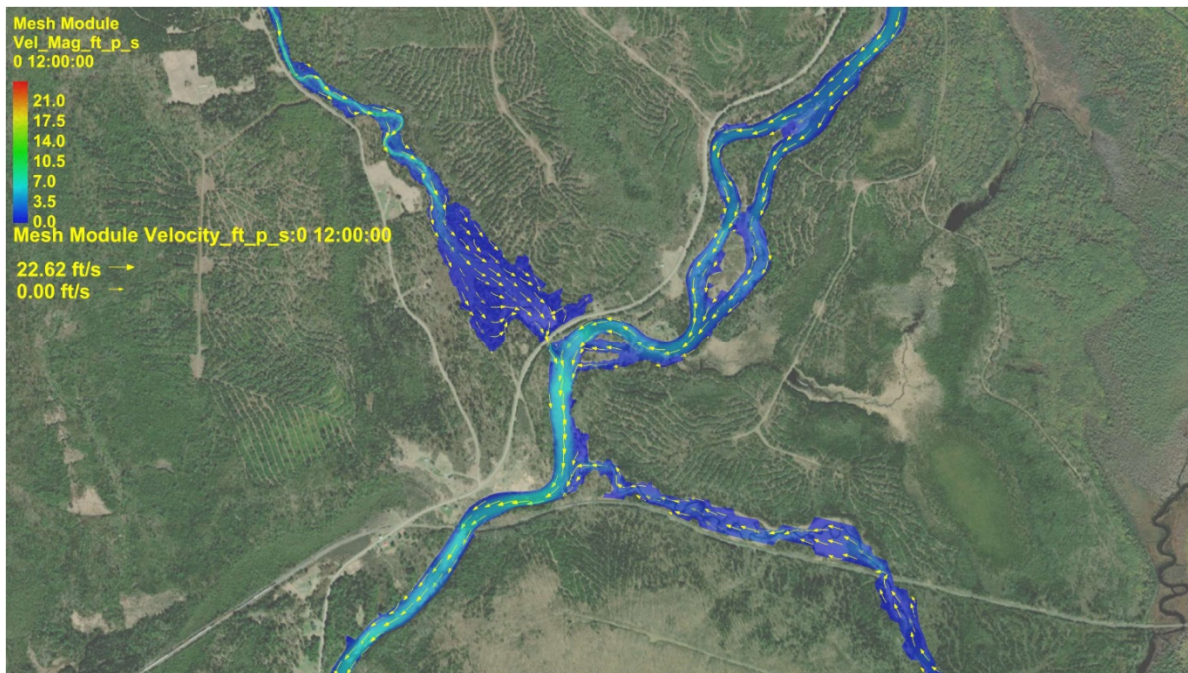


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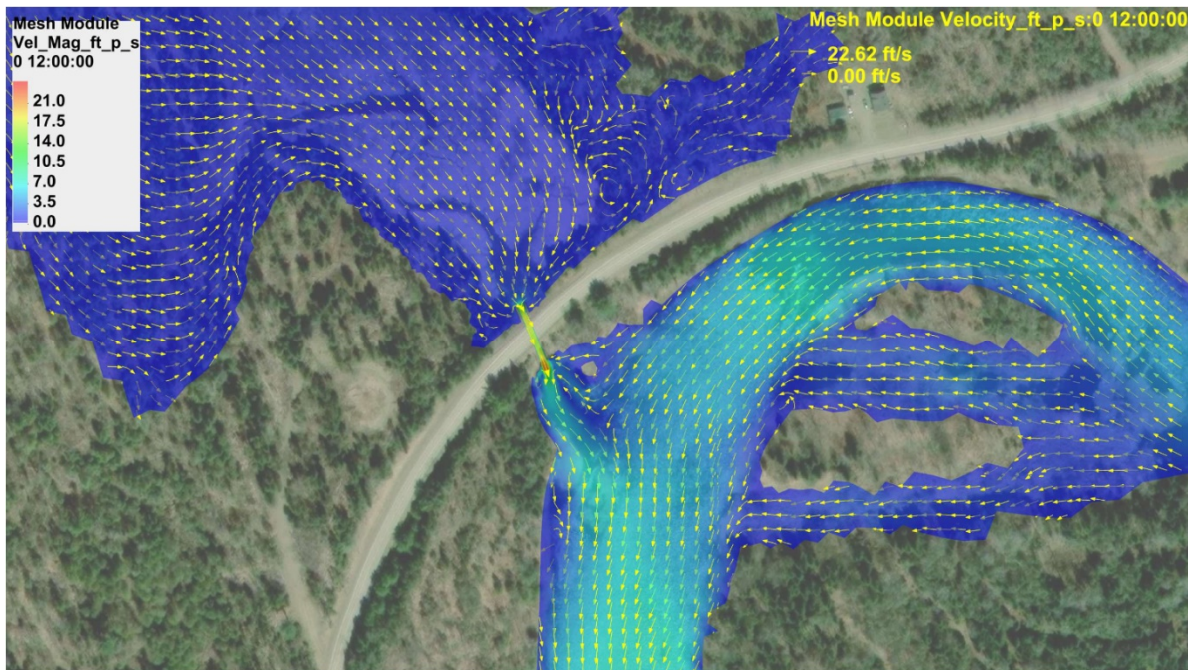


Bridge

Existing 100-Year Joint Probability Flood Event
Velocities with Flow Vectors for Maximum Velocity Combination:
100-Year Flood in Smith Brook & 1.1-Year Flood in Mattawamkeag River

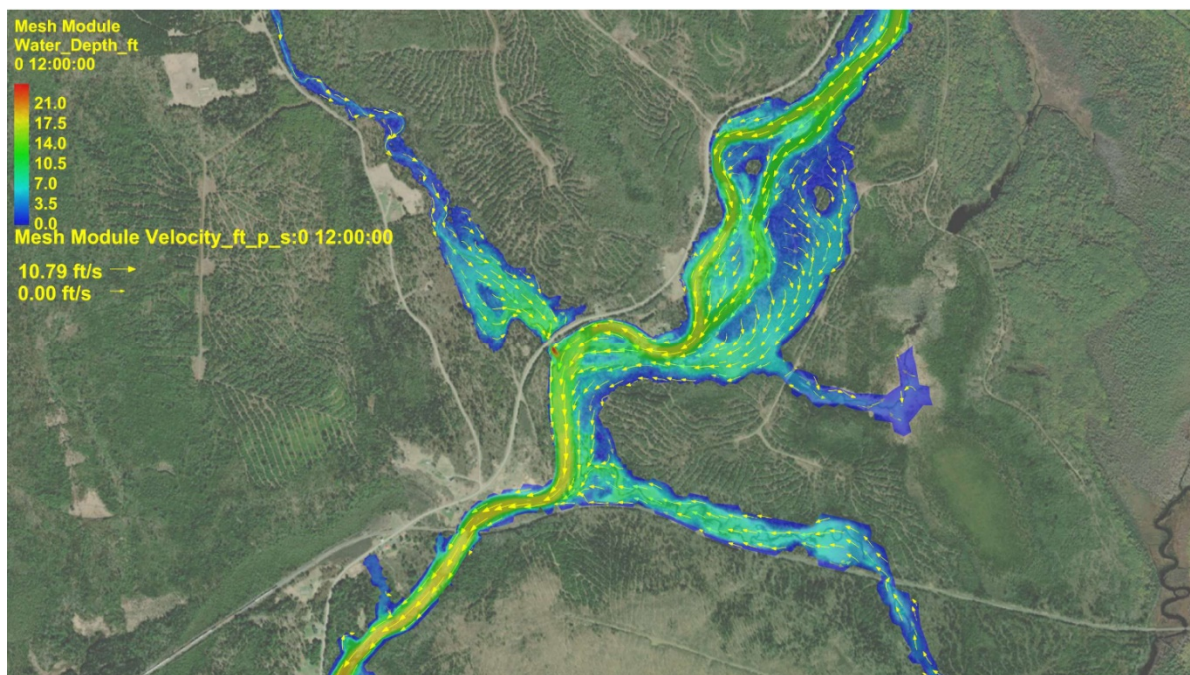


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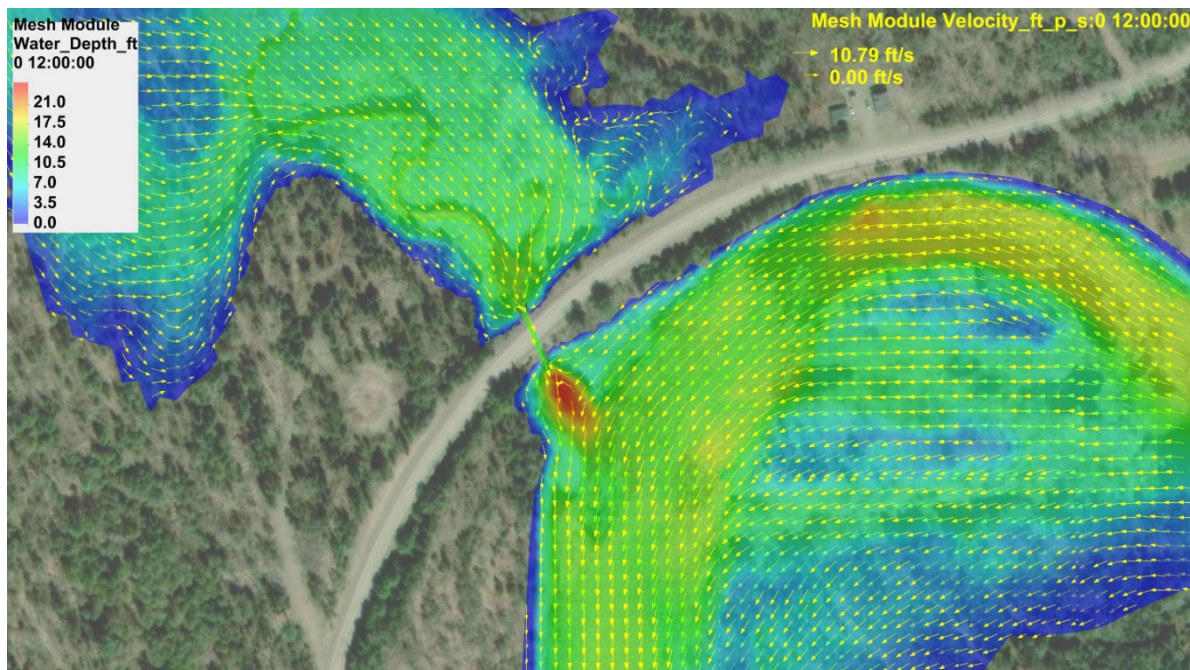


Bridge

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Velocities with Flow Vectors for Maximum Velocity Combination:
100-Year Flood in Smith Brook & 1.1-Year Flood in Mattawamkeag River

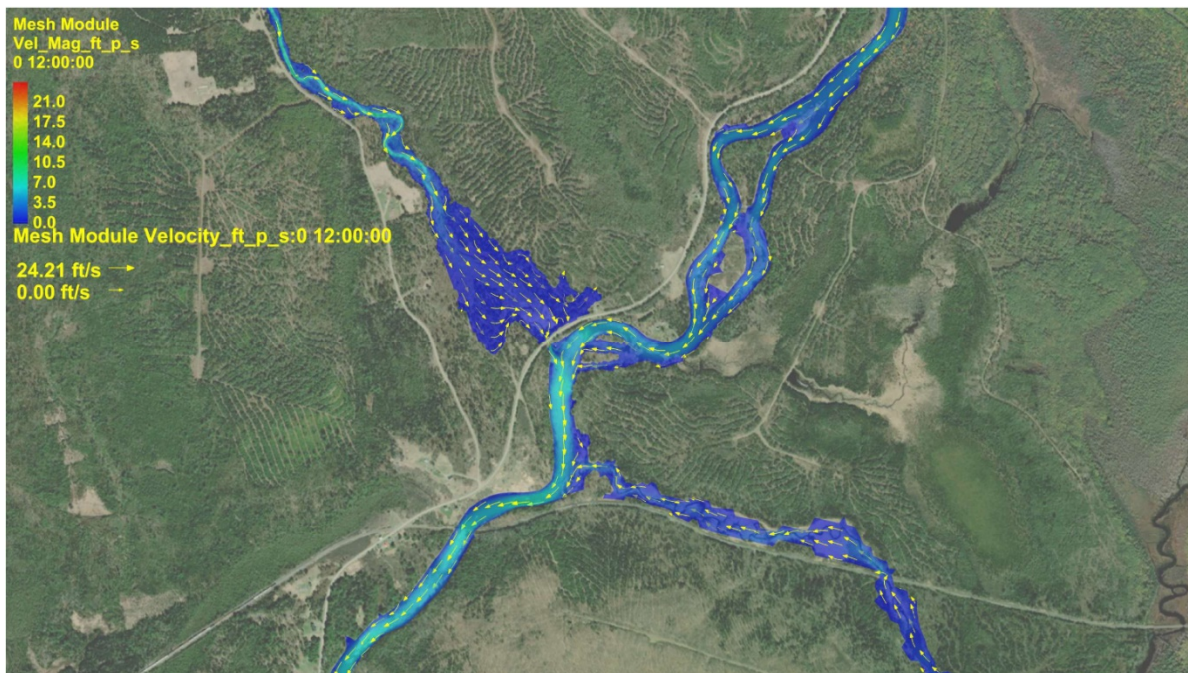


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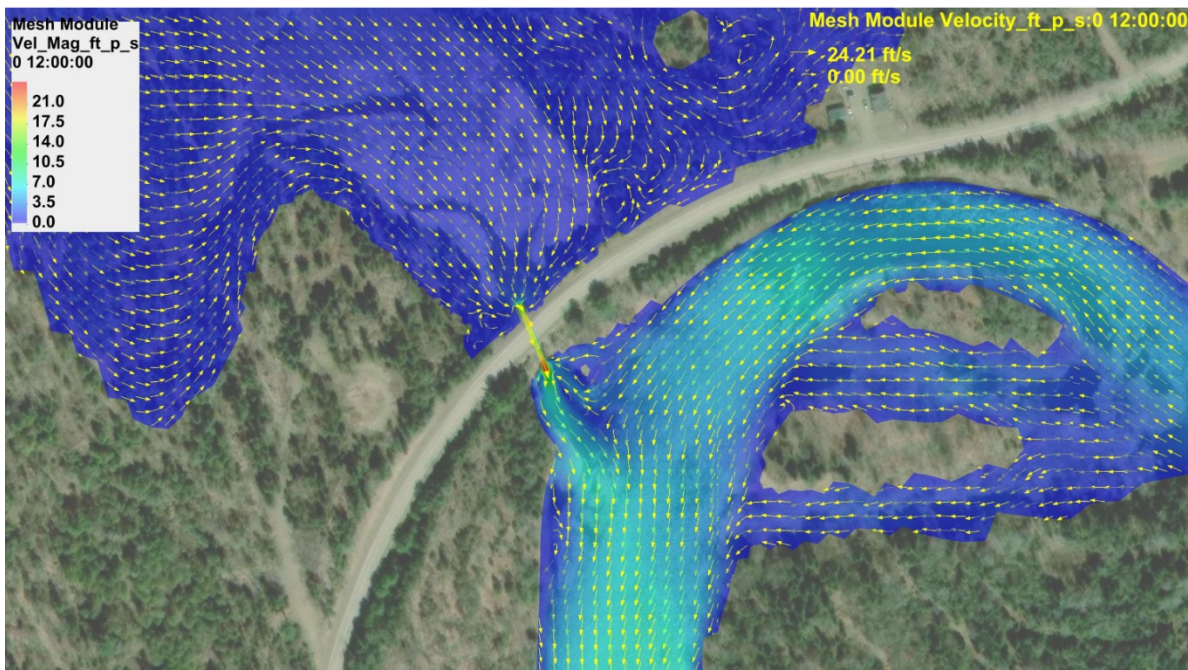


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Existing 100-Year Joint Probability Flood Event
Velocities with Flow Vectors for Maximum Velocity Combination:
100-Year Flood in Smith Brook & 1.1-Year Flood in Mattawamkeag River



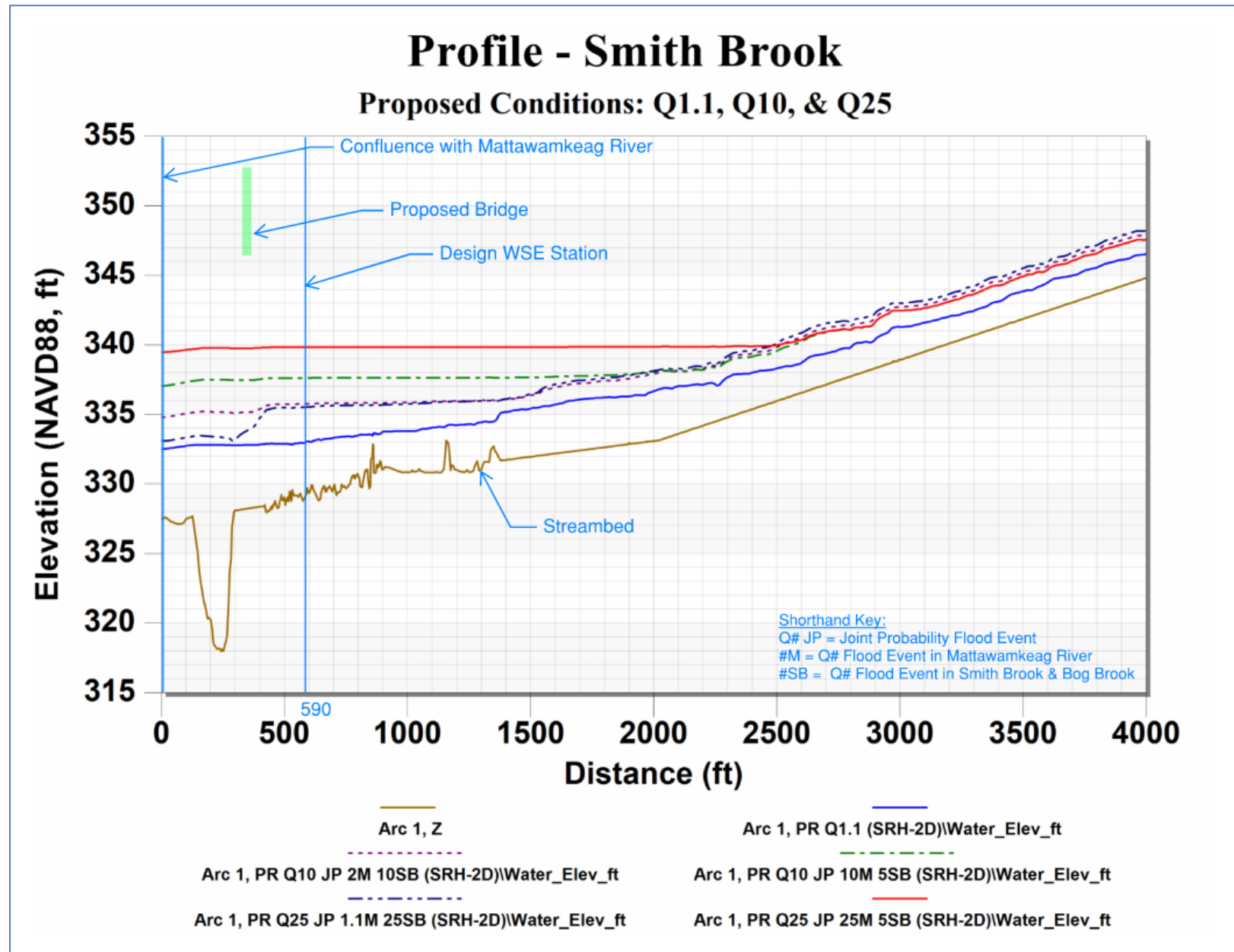
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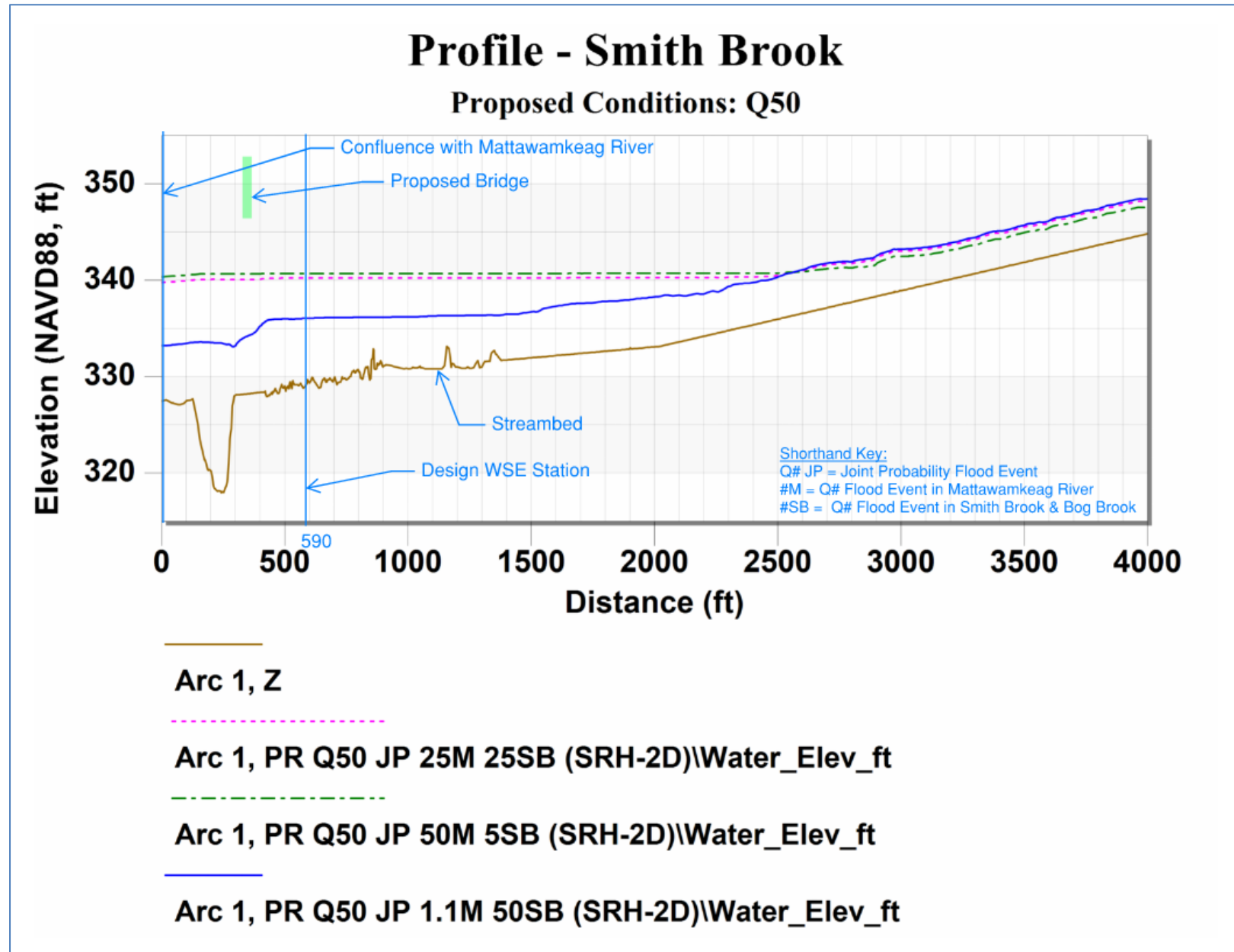
Bridge

2D Hydraulic Modeling Proposed Conditions Results

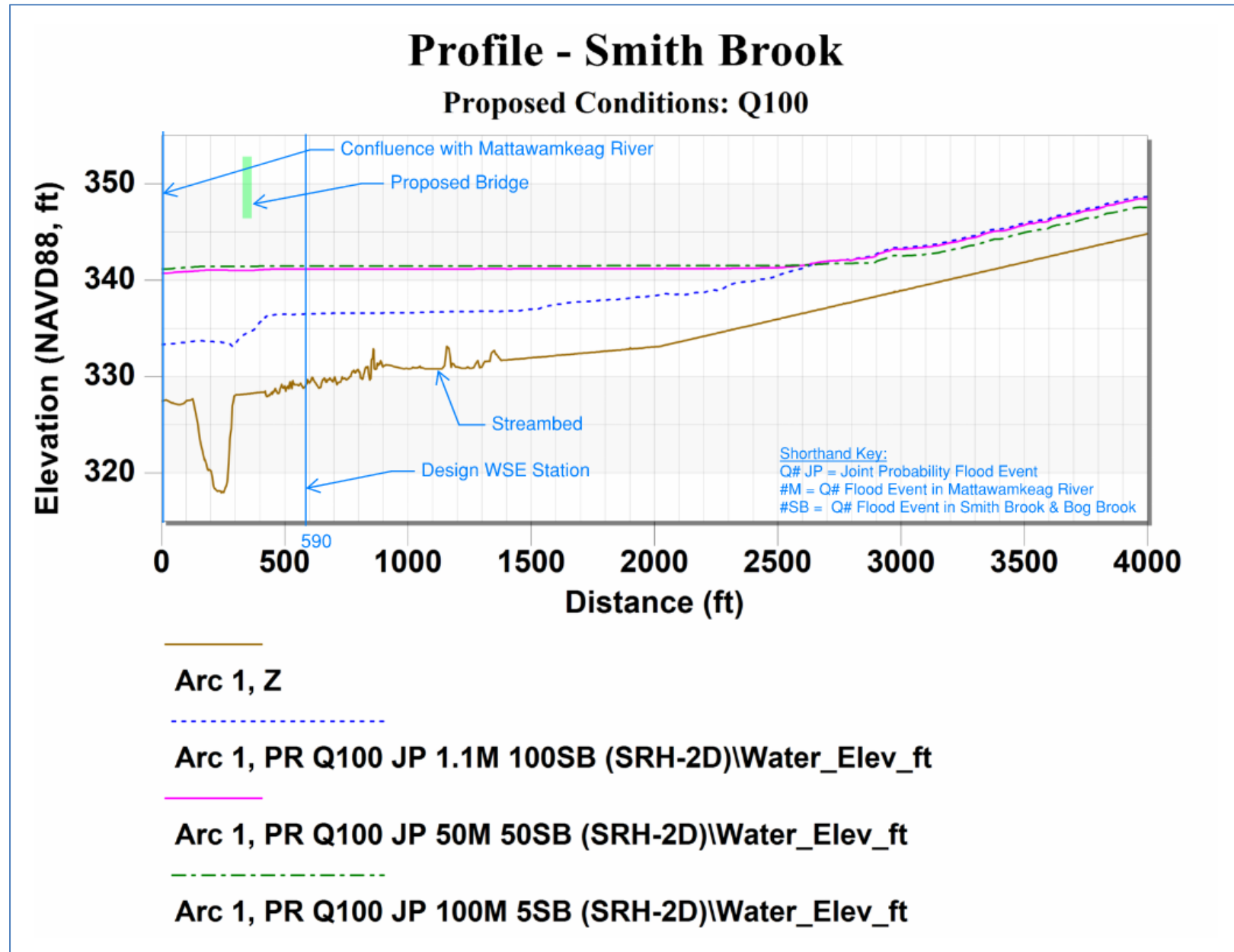
Proposed Conditions Water Surface Elevation Profiles



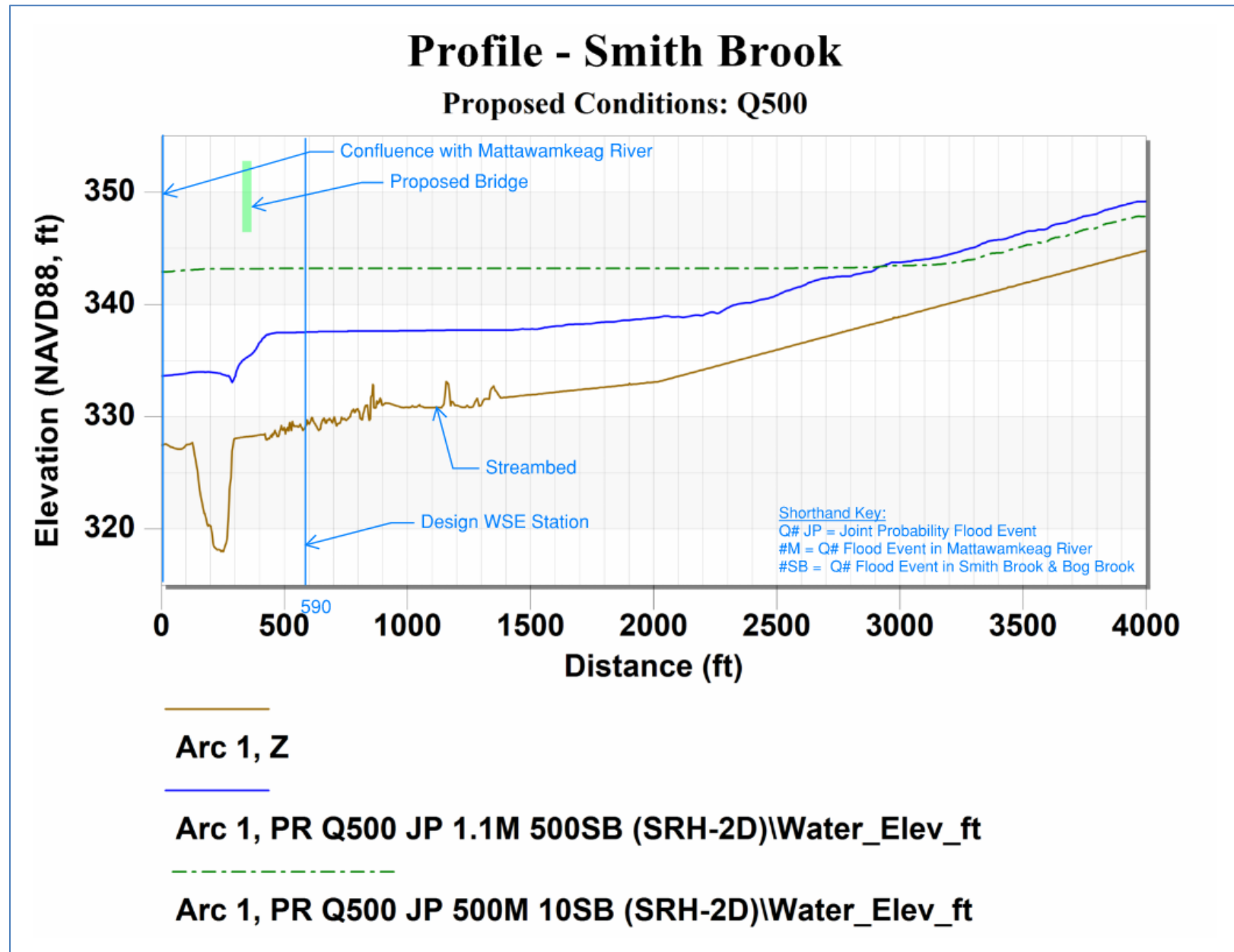
Proposed Conditions Water Surface Elevation Profiles



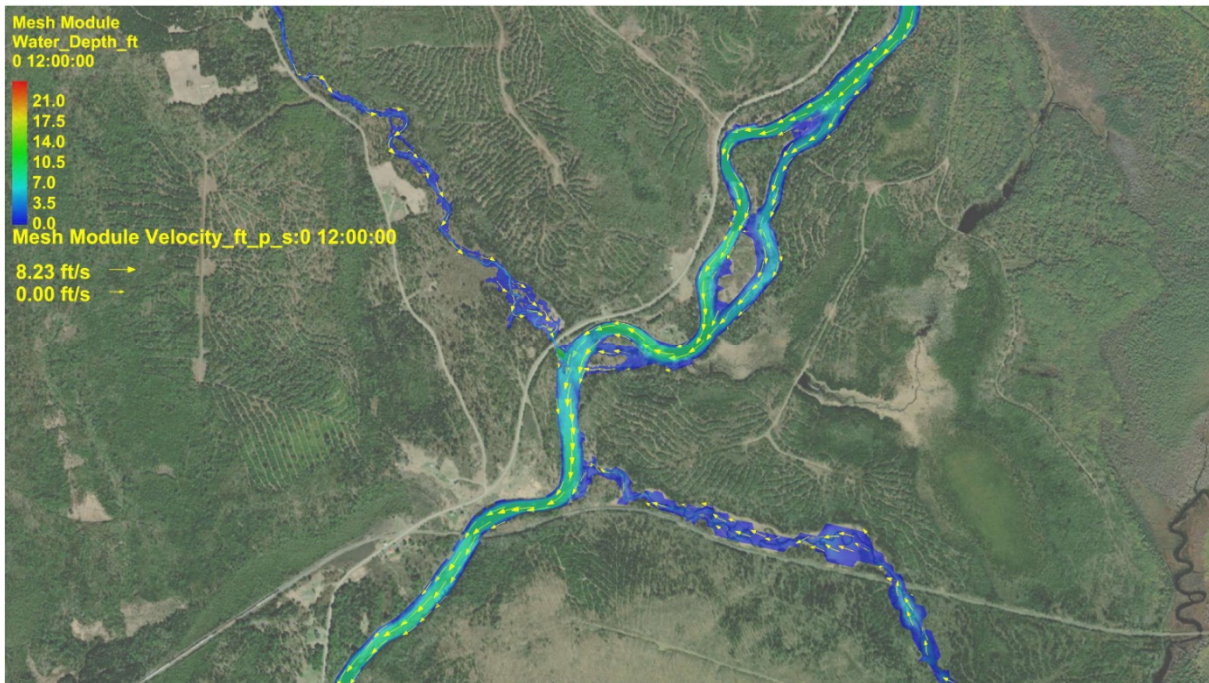
Proposed Conditions Water Surface Elevation Profiles



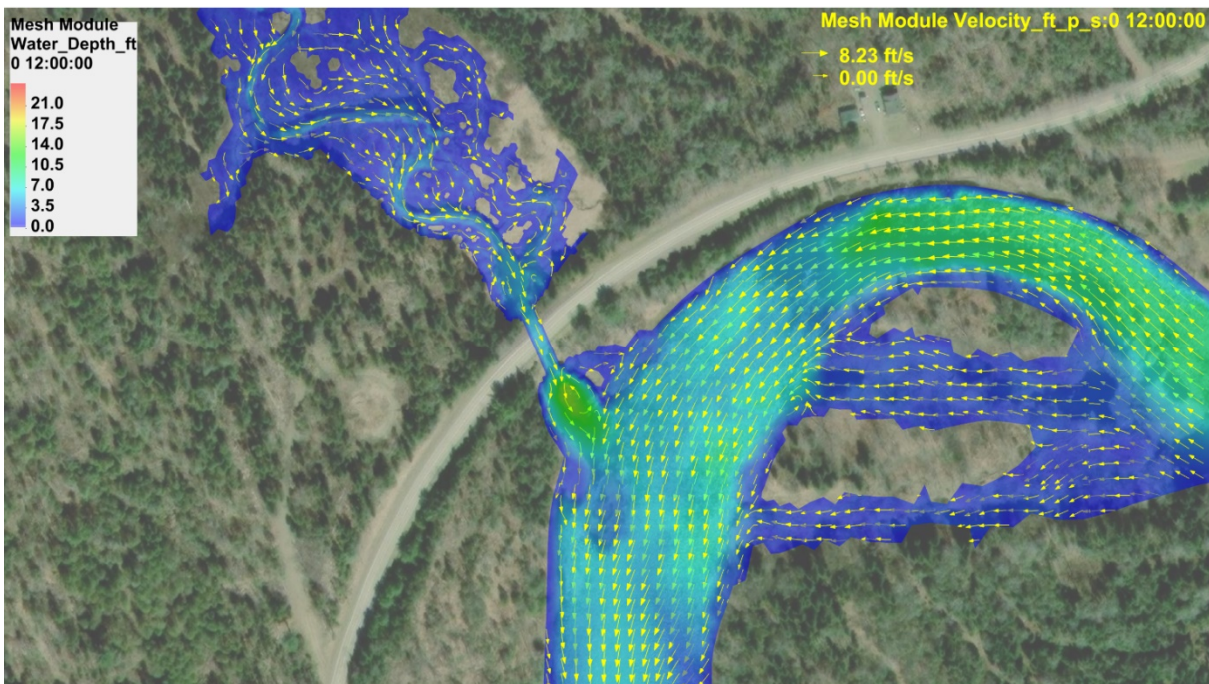
Proposed Conditions Water Surface Elevation Profiles



Proposed 1.1-Year Flood Event Water Depths with Flow Vectors

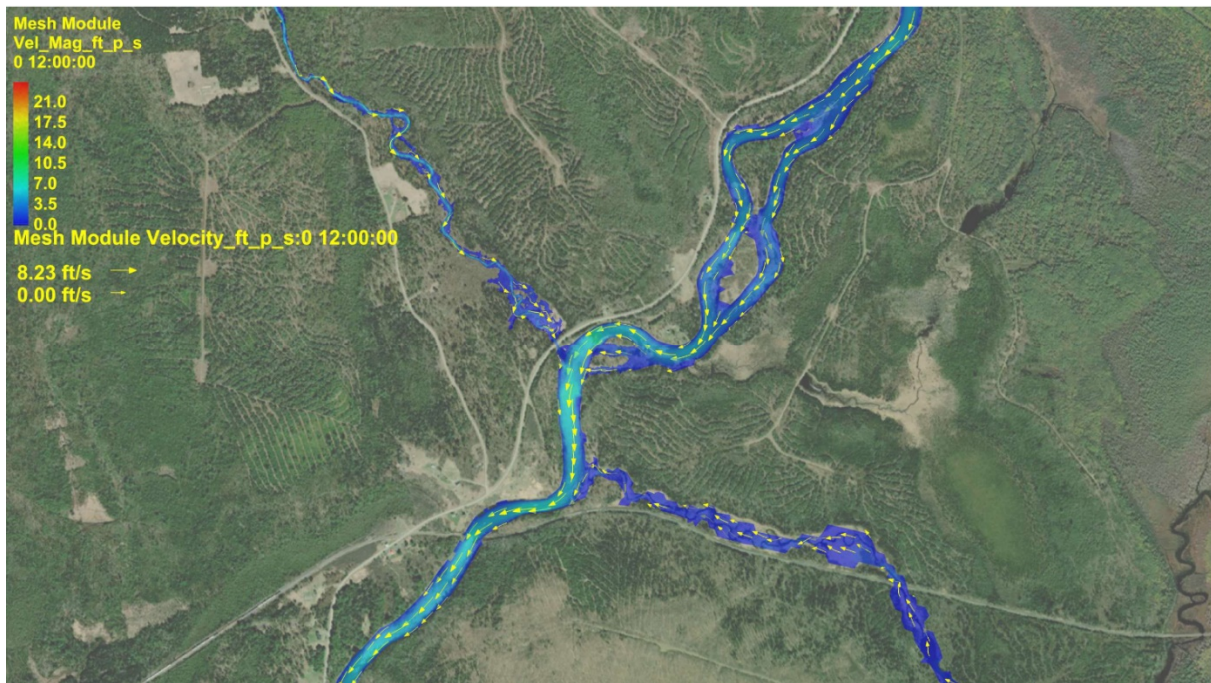


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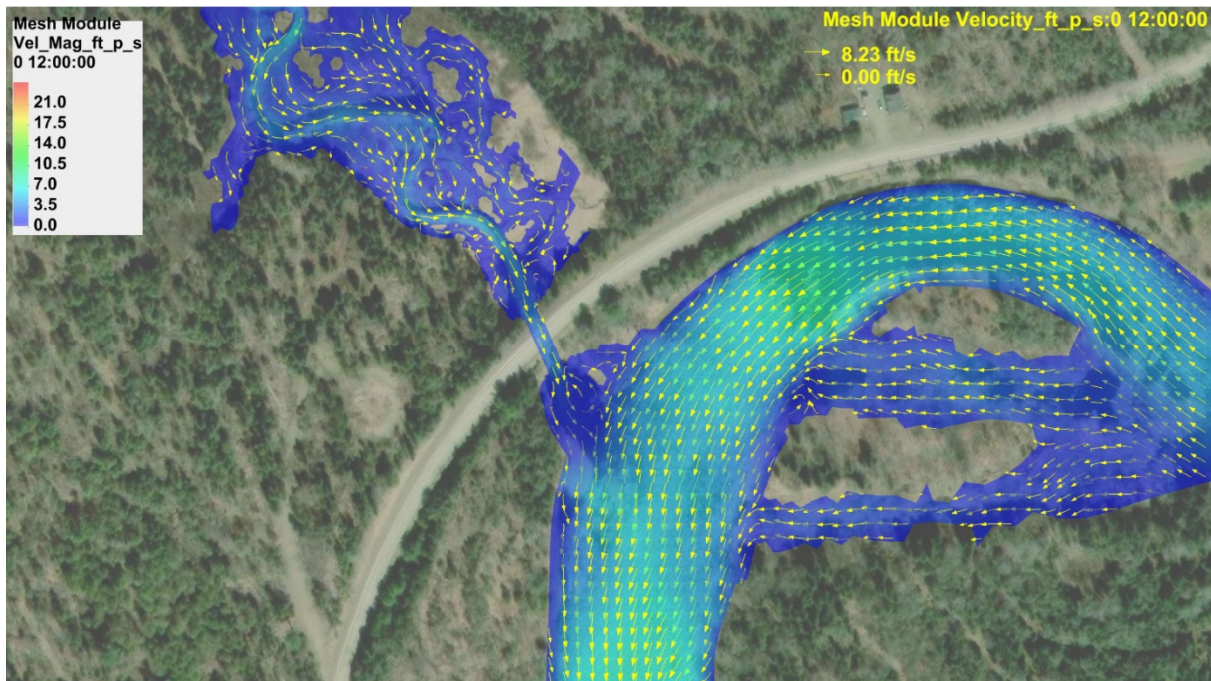


Bridge

Proposed 1.1-Year Flood Event Velocities with Flow Vectors

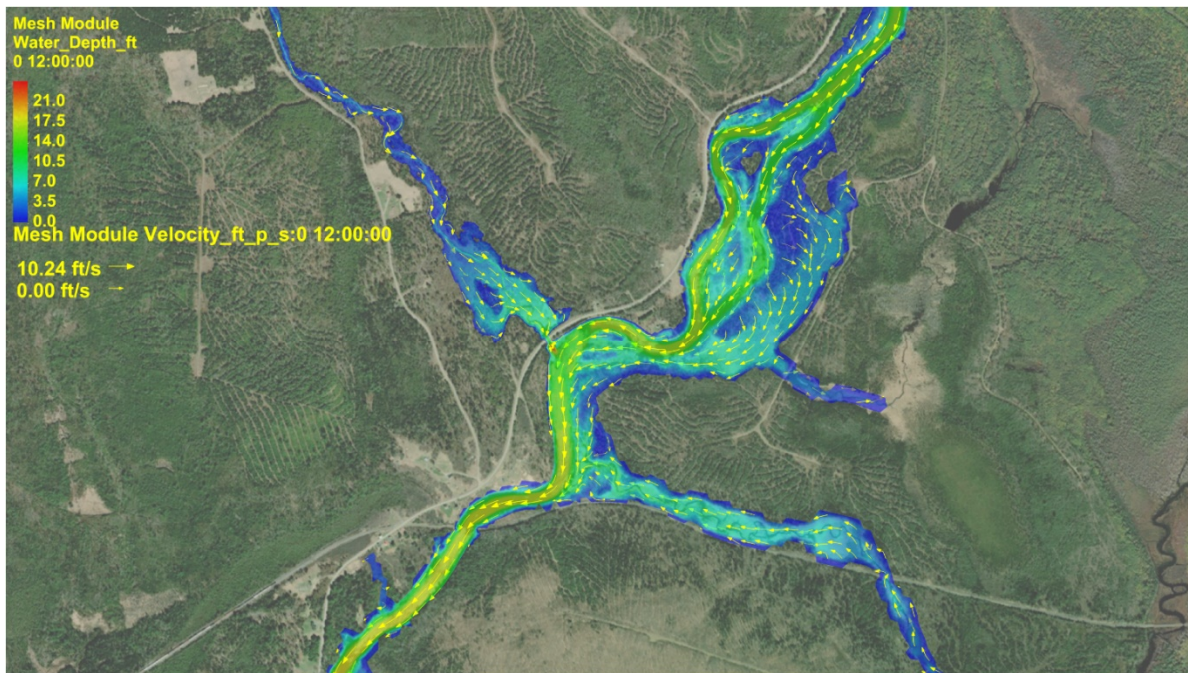


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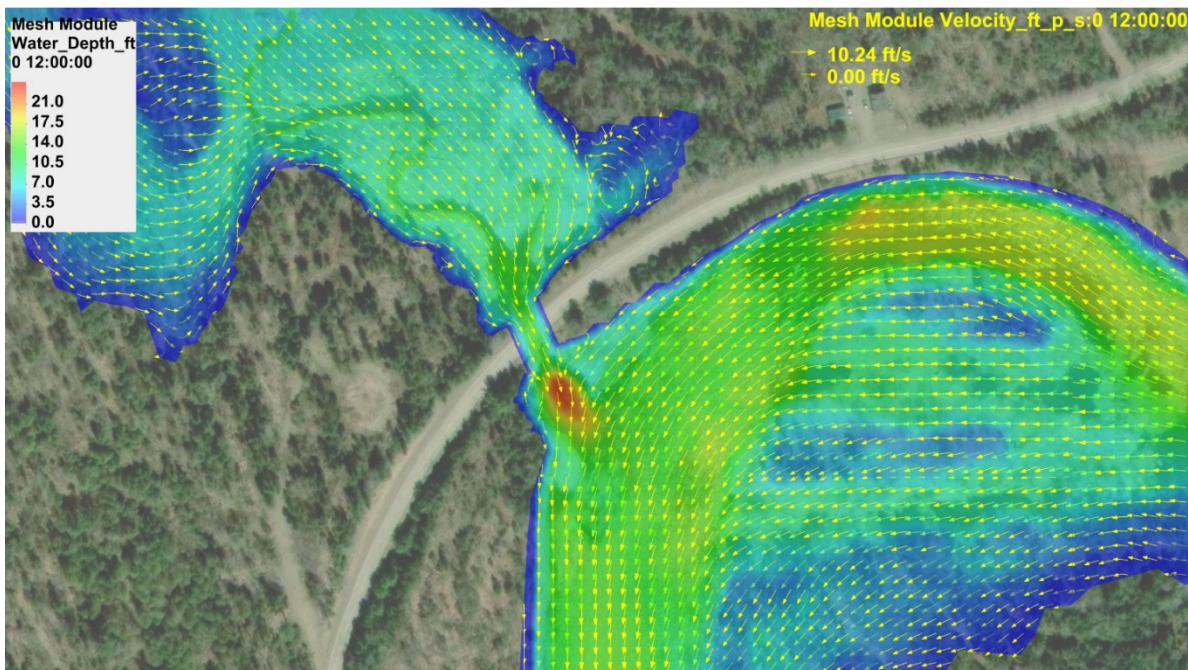


Bridge

Proposed 50-Year Joint Probability Flood Event
Water Depths with Flow Vectors for Maximum Water Surface Elevation Combination:
5-Year Flood in Smith Brook & 50-Year Flood in Mattawamkeag River



Domain

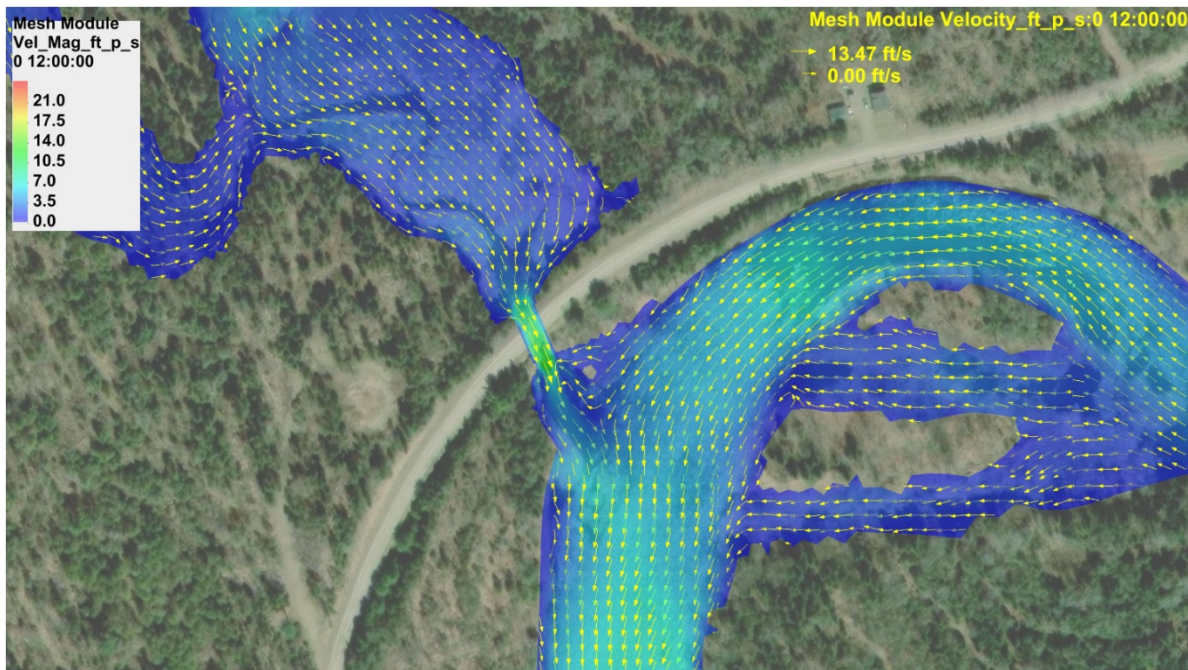


Bridge

Proposed 100-Year Joint Probability Flood Event
Velocities with Flow Vectors for Maximum Velocity Combination:
100-Year Flood in Smith Brook & 1.1-Year Flood in Mattawamkeag River

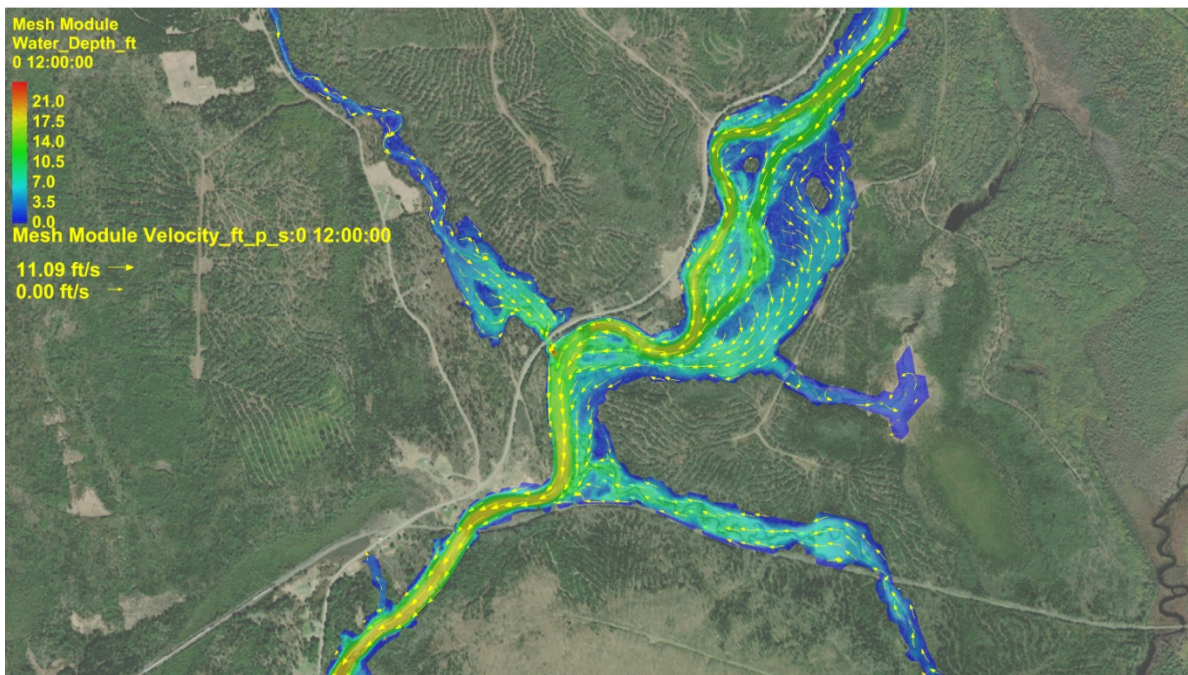


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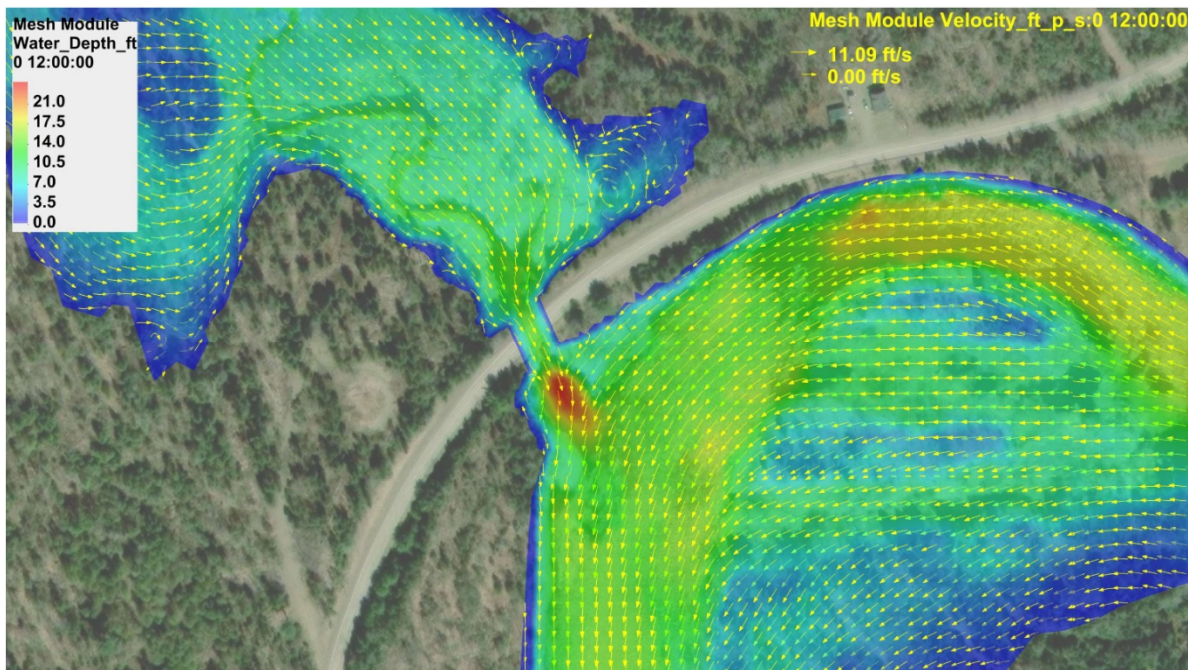


Bridge

Proposed 100-Year Joint Probability Flood Event
Velocities with Flow Vectors for Maximum Velocity Combination:
100-Year Flood in Smith Brook & 1.1-Year Flood in Mattawamkeag River

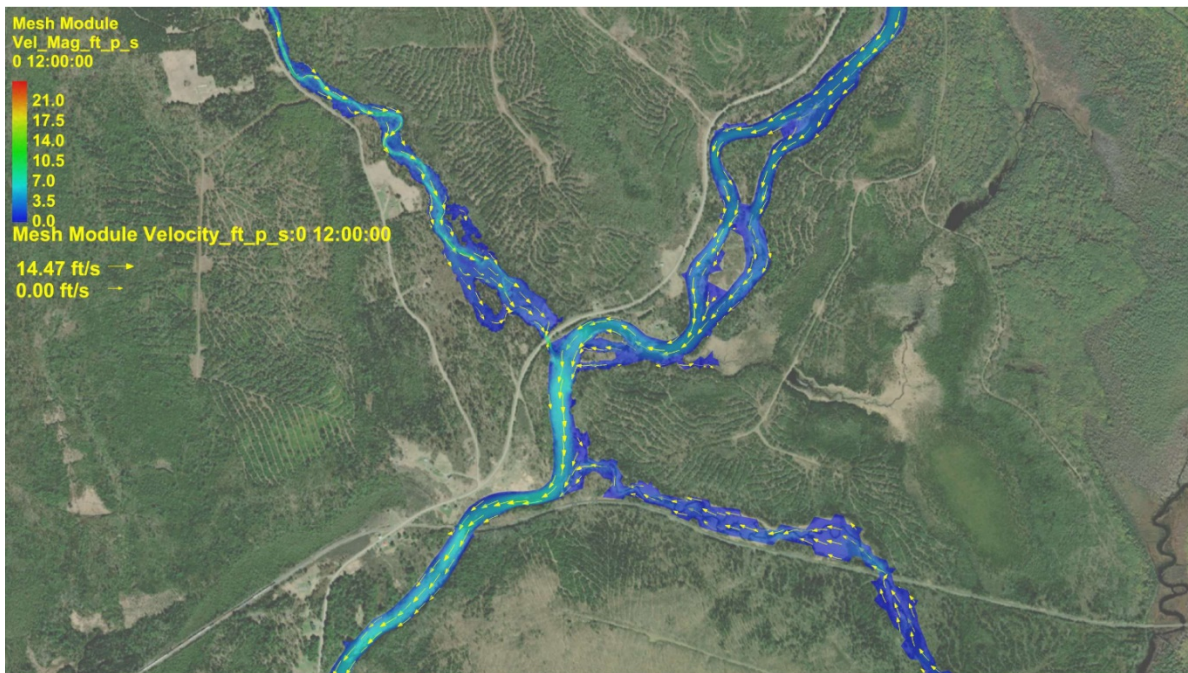


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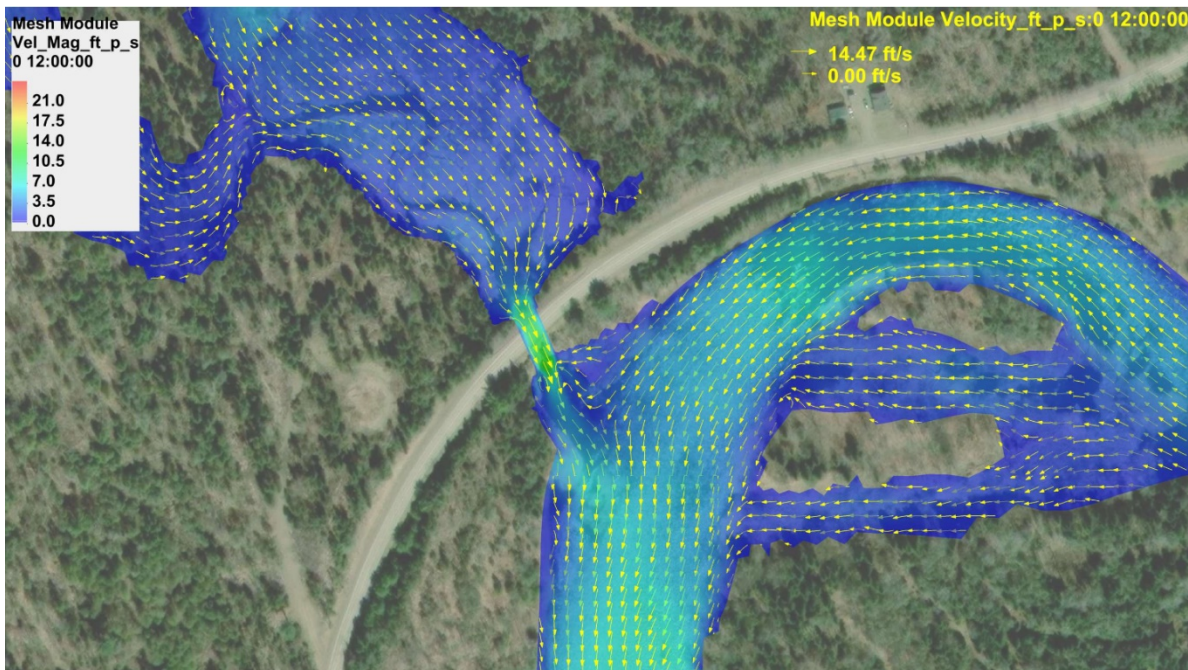


Bridge

Proposed 100-Year Joint Probability Flood Event
Velocities with Flow Vectors for Maximum Velocity Combination:
100-Year Flood in Smith Brook & 1.1-Year Flood in Mattawamkeag River

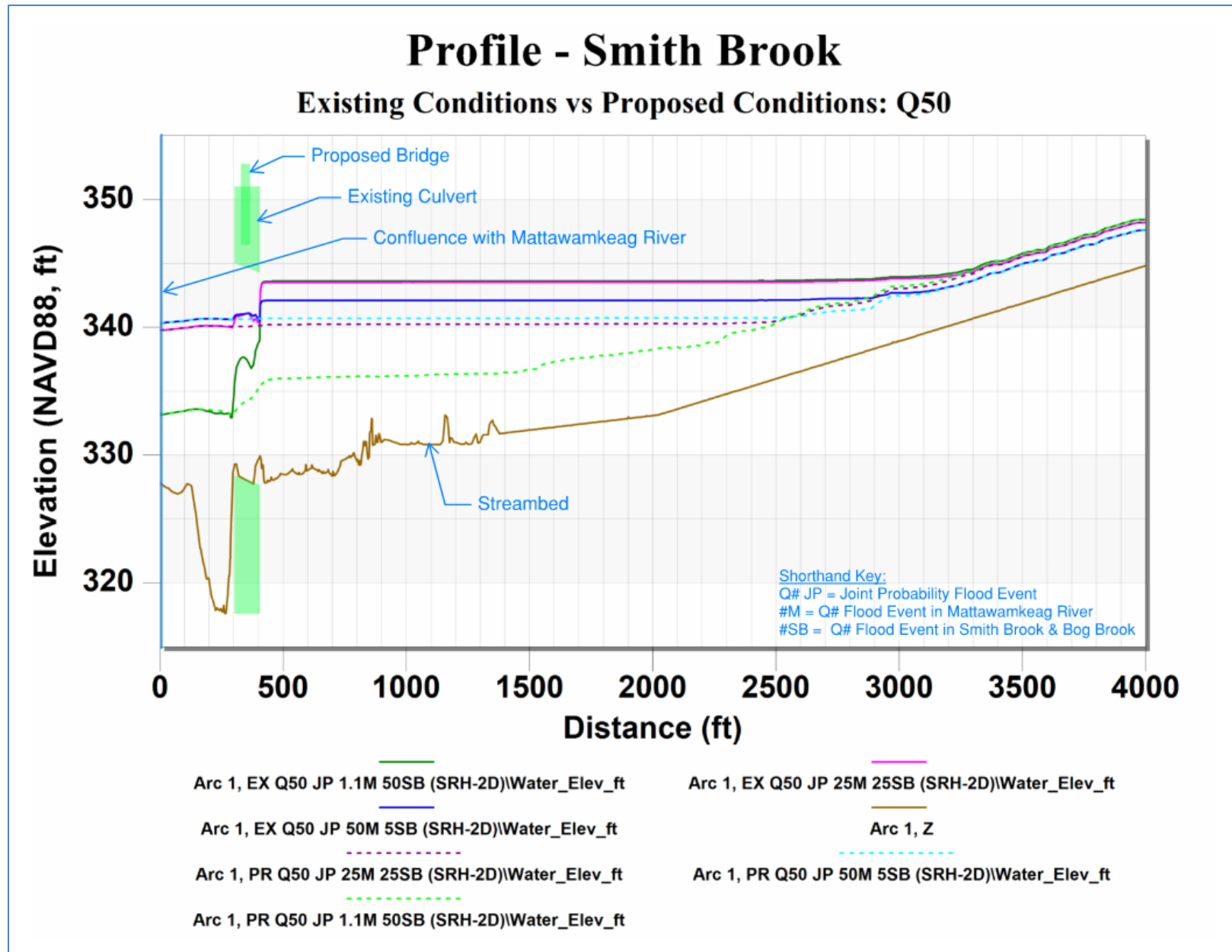


Domain



Bridge

Existing Conditions vs Proposed Conditions Water Surface Elevation Profiles



Existing Conditions vs Proposed Conditions Water Surface Elevation Profiles

