Lamoille River Modeling and Alternatives Analysis

Hardwick Flood Mitigation

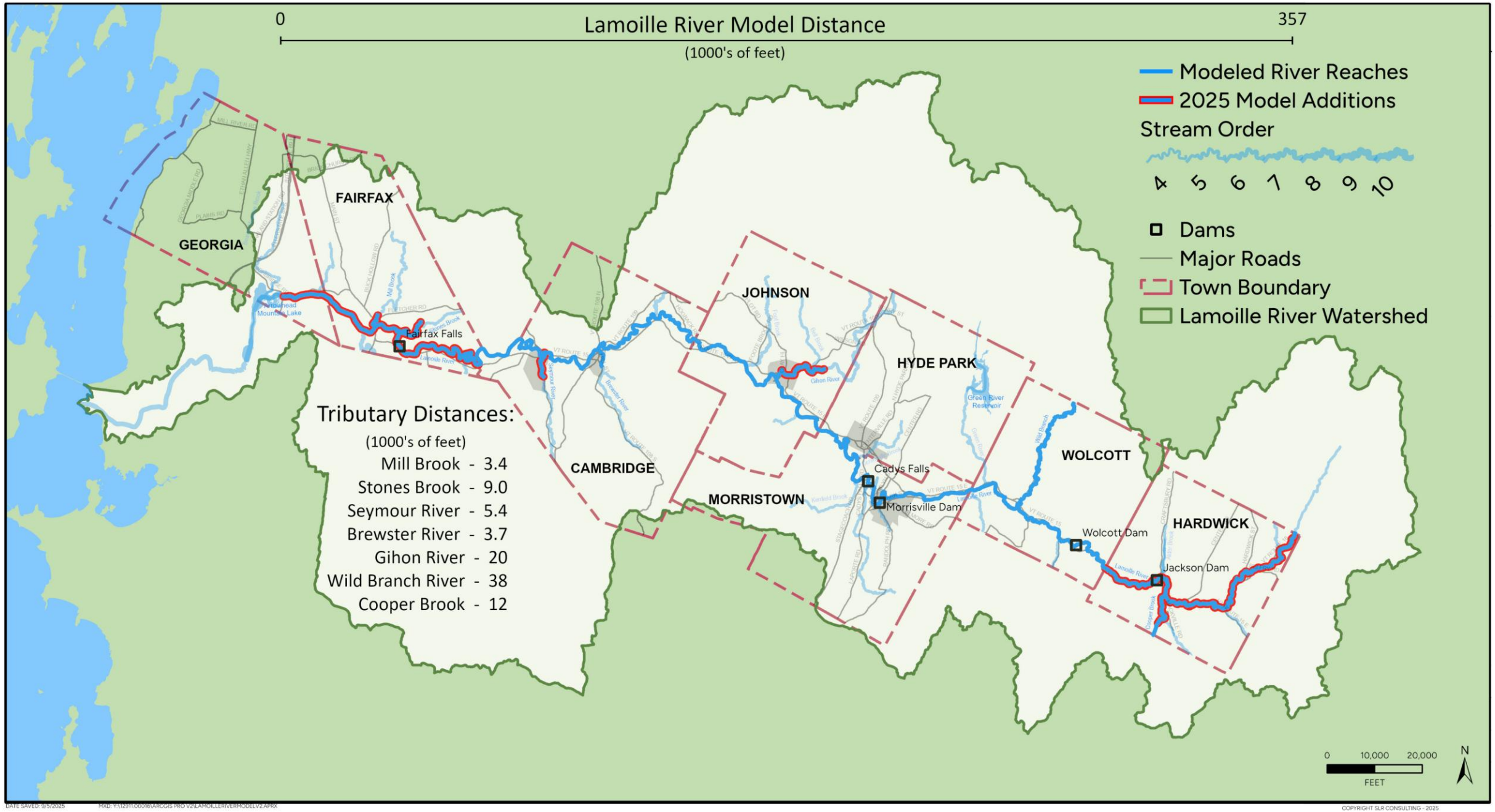
December 3, 2025

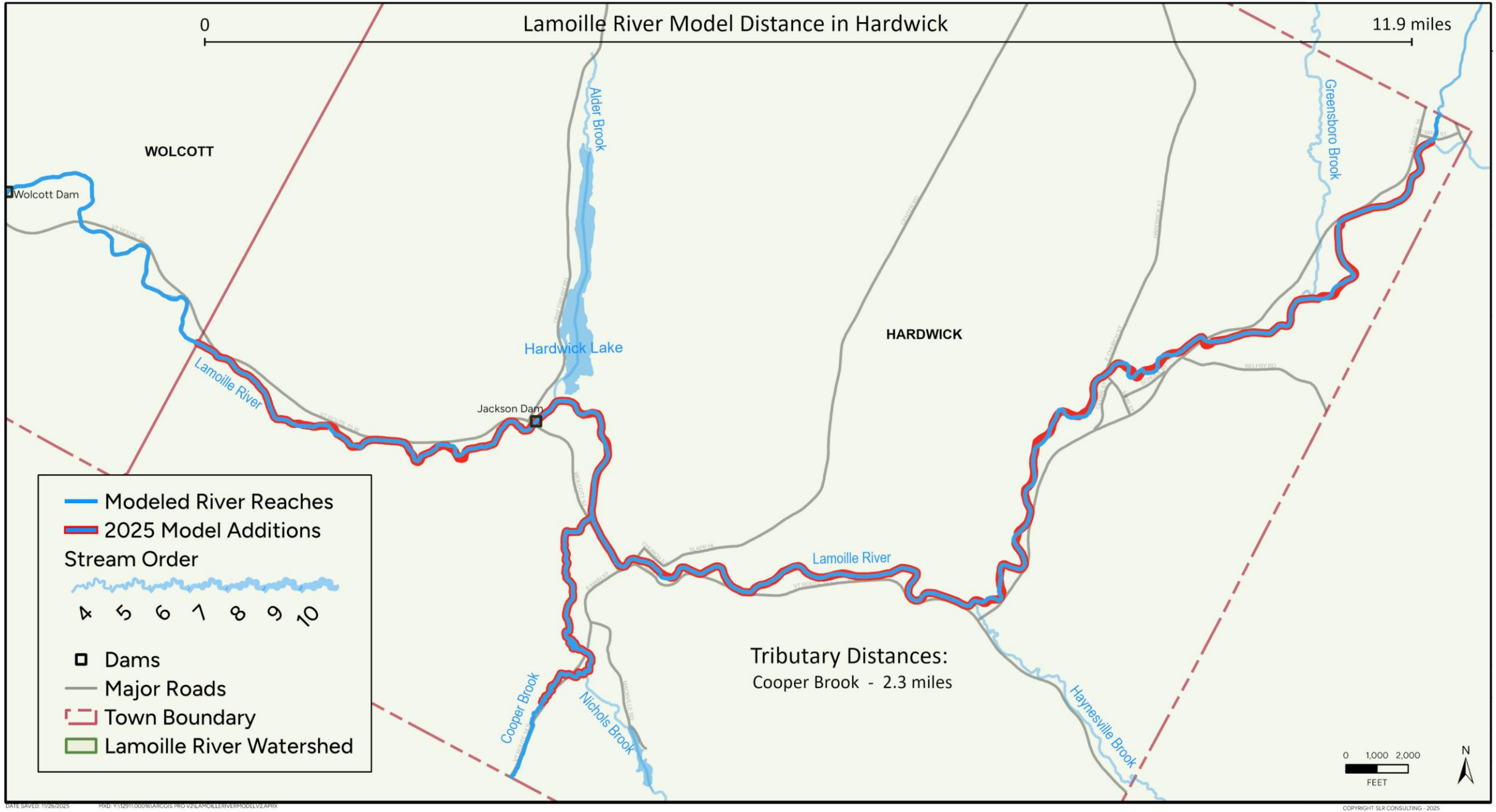
SLRCONSULTING.COM

SLR

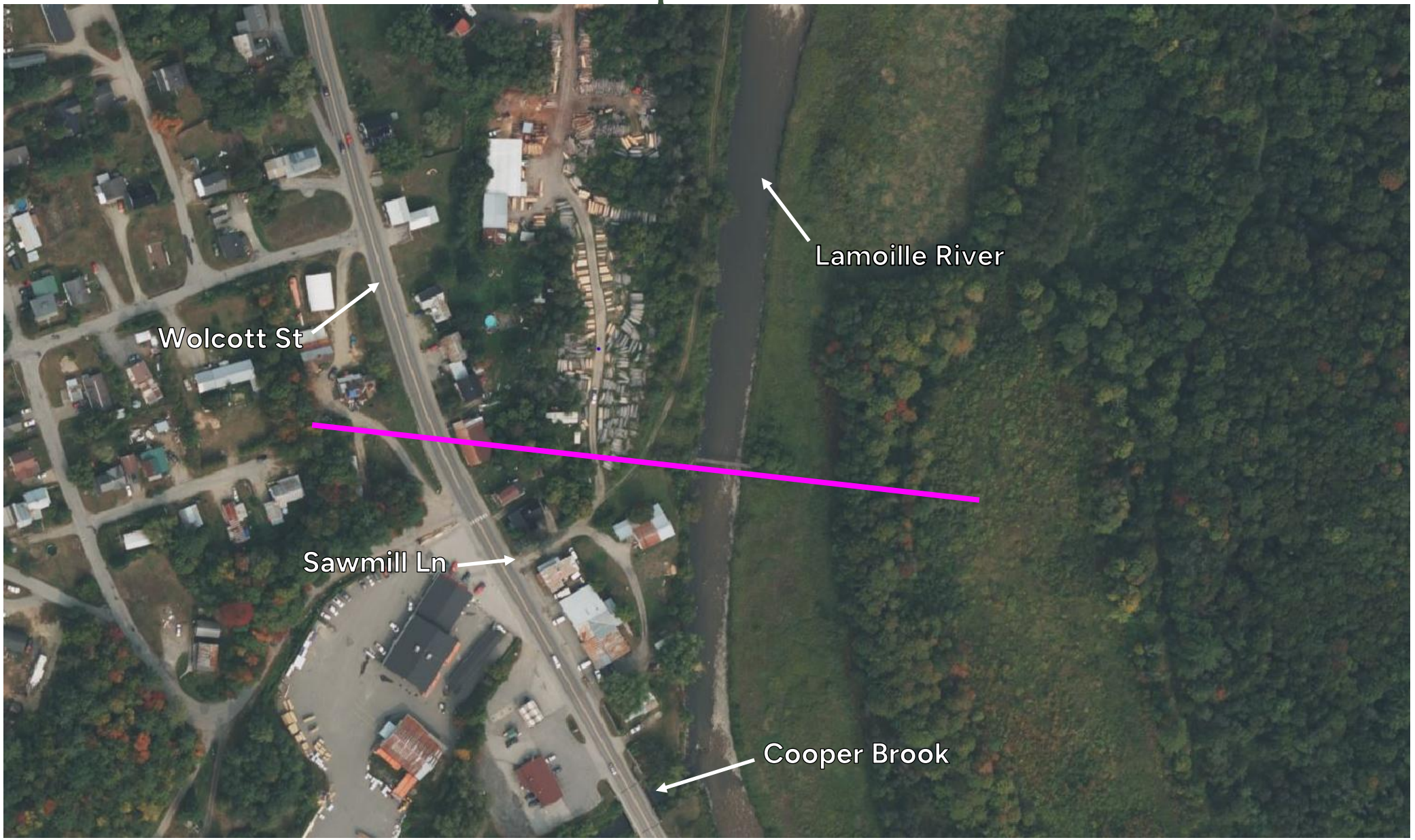
Agenda

- Model Extent
- Data Sources
- Types of Results
- Model Accuracy
- Existing Results
- Alternative Analysis

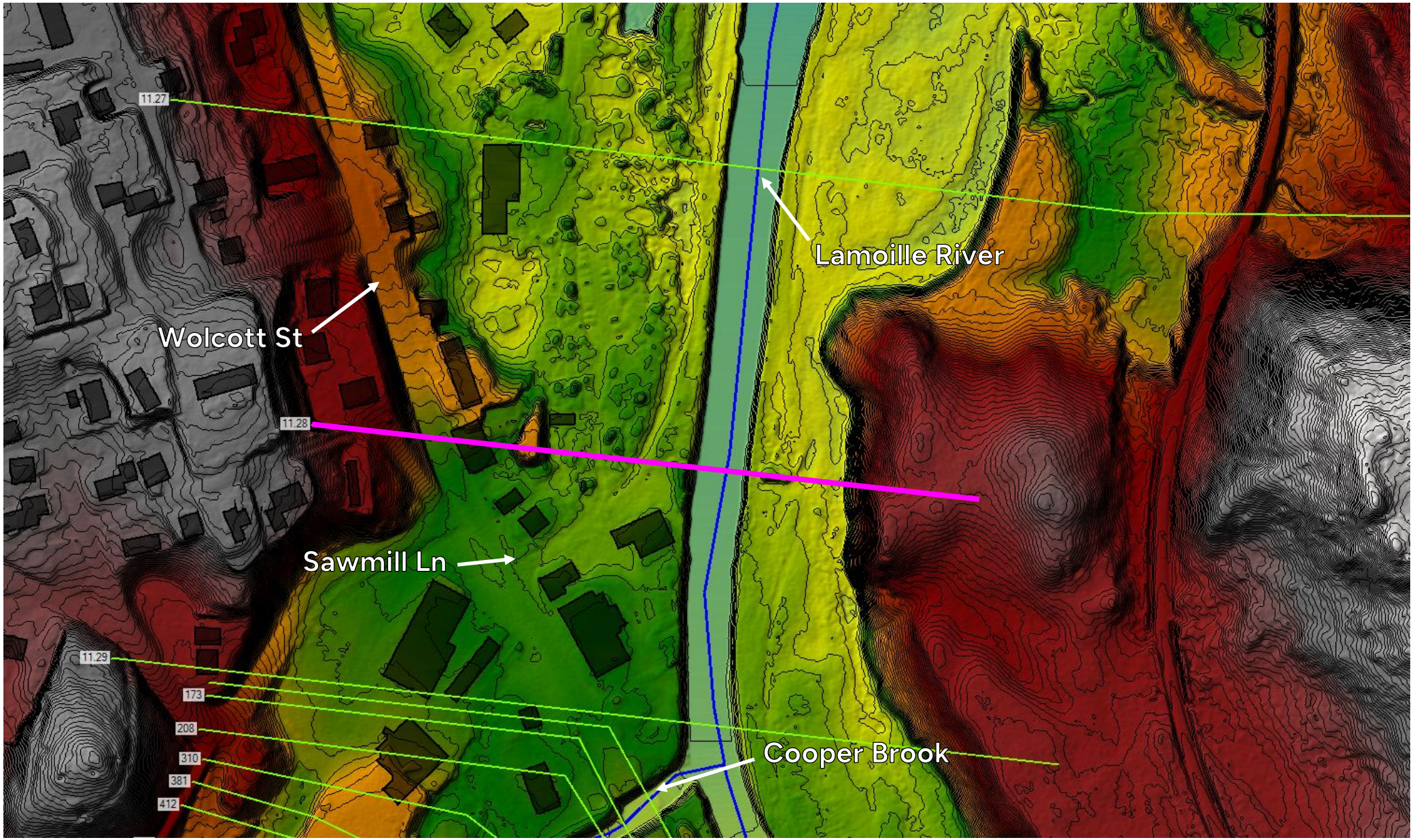




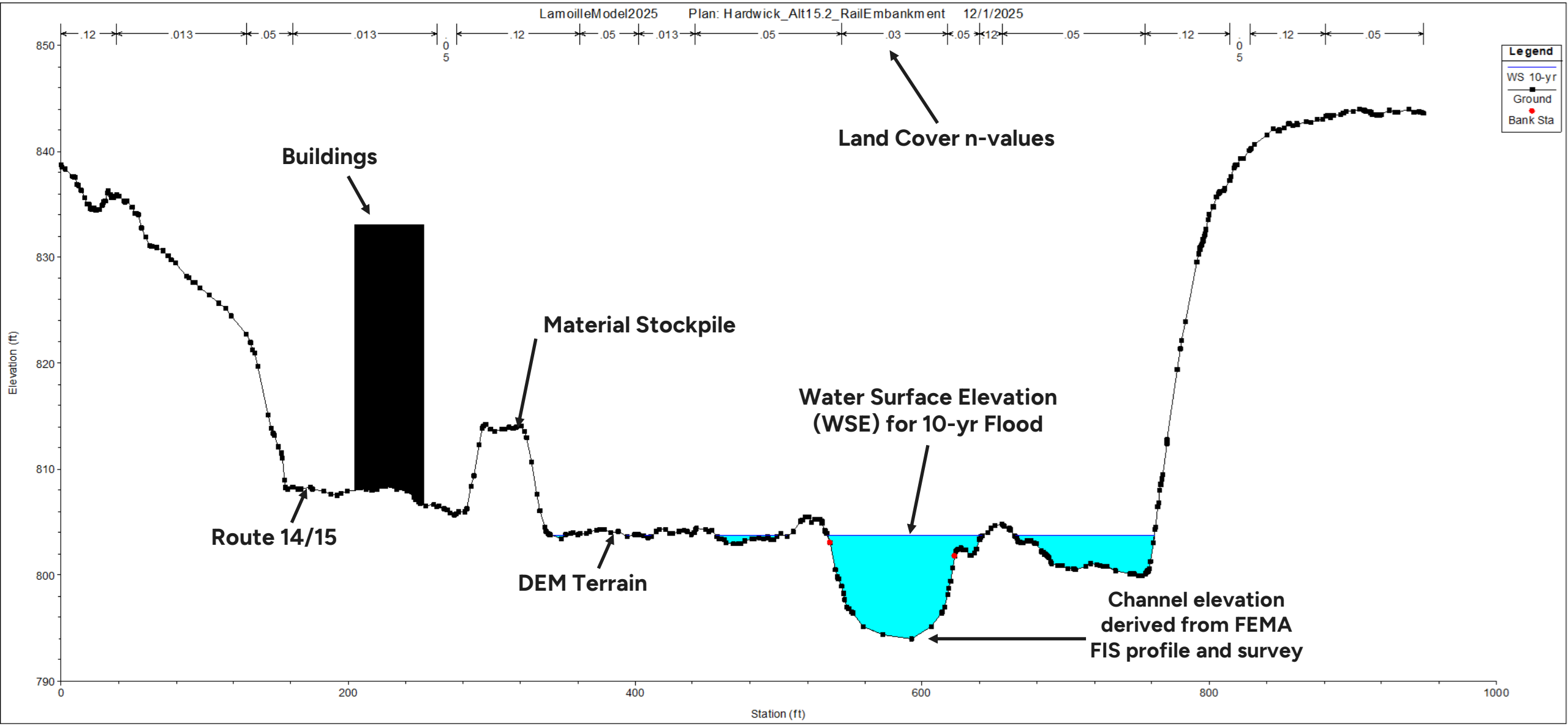
Map View



Model Terrain

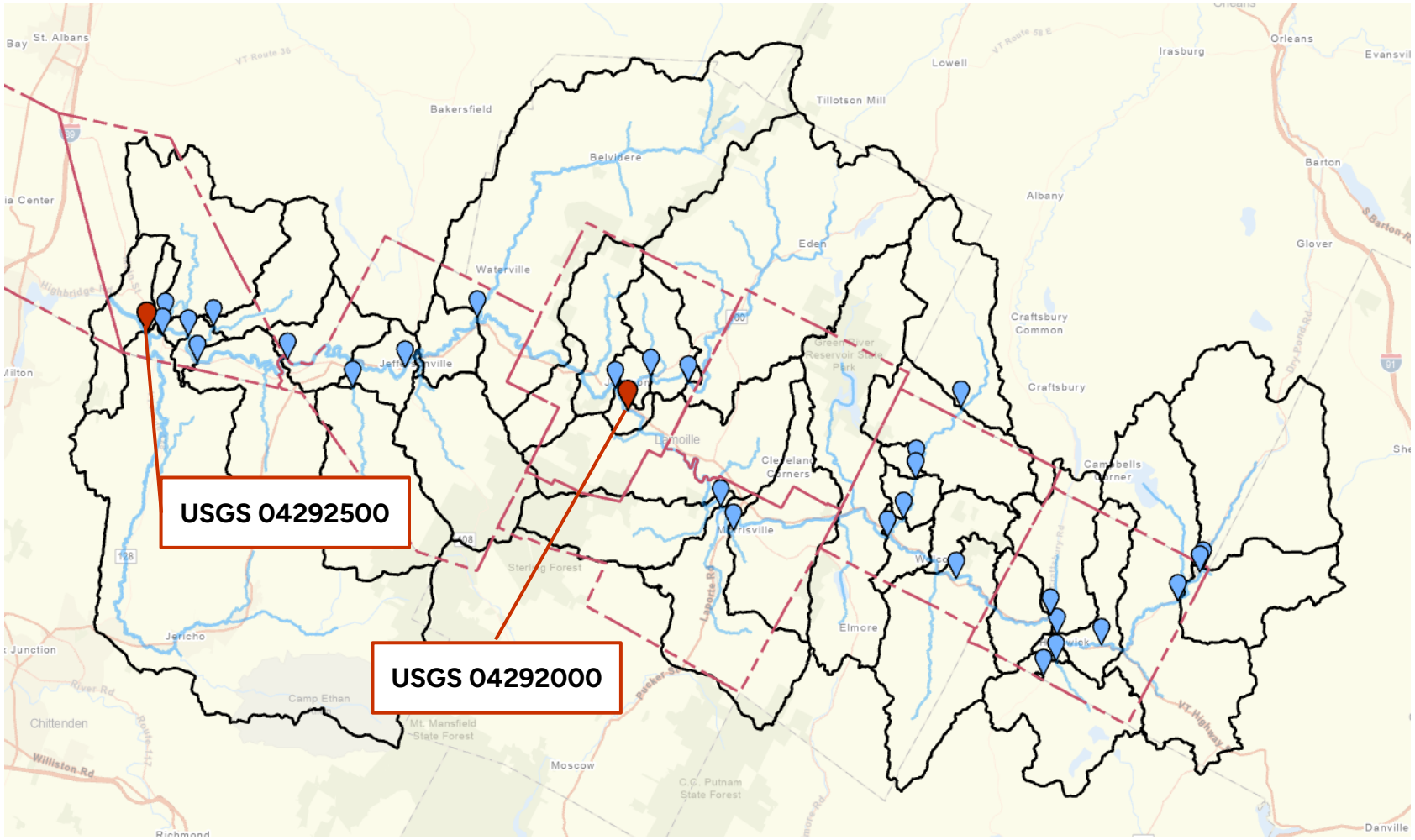


Cross Section View



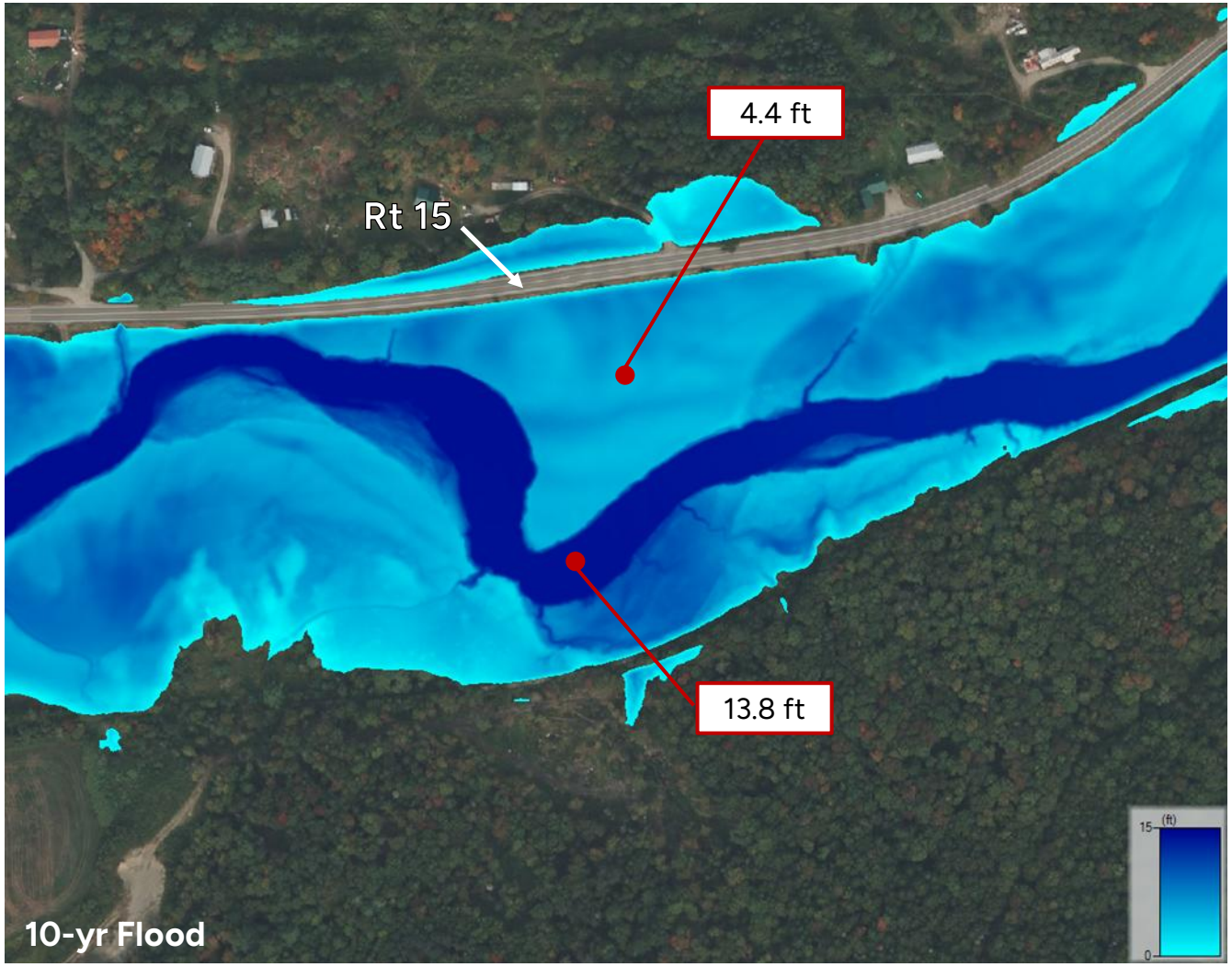
Flood Flows

- Used draft updated FEMA flood flows (July 2025).
- Flows were estimated in areas without FEMA flows
  - FEMA flow trend lines
  - Scaled flows by drainage area



What can the model tell us?

- Water Surface Elevation
- Floodplain Mapping
- **Flow Characteristics**
  - Velocity
  - **Depth**
- Channel and Water profiles
- Dam, Bridge, and Culvert Impacts
  - Backwatering
  - Overtopping
  - Scour



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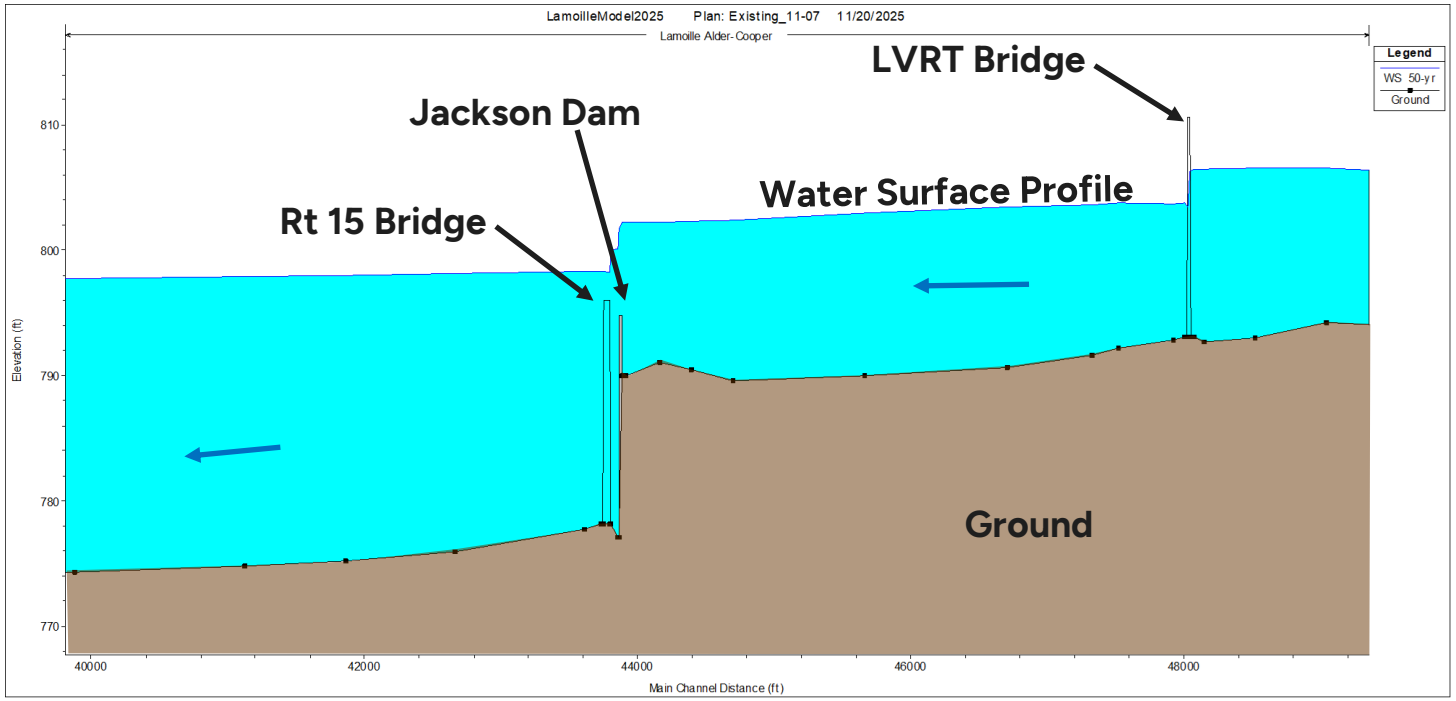
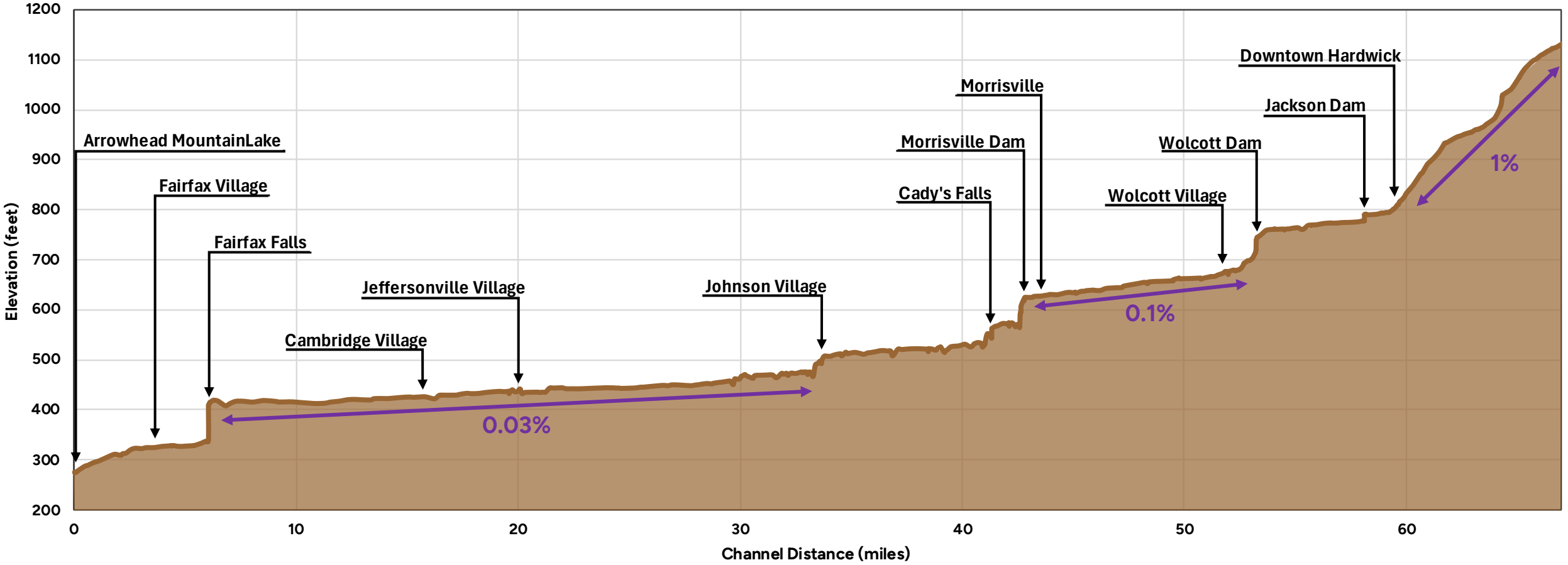
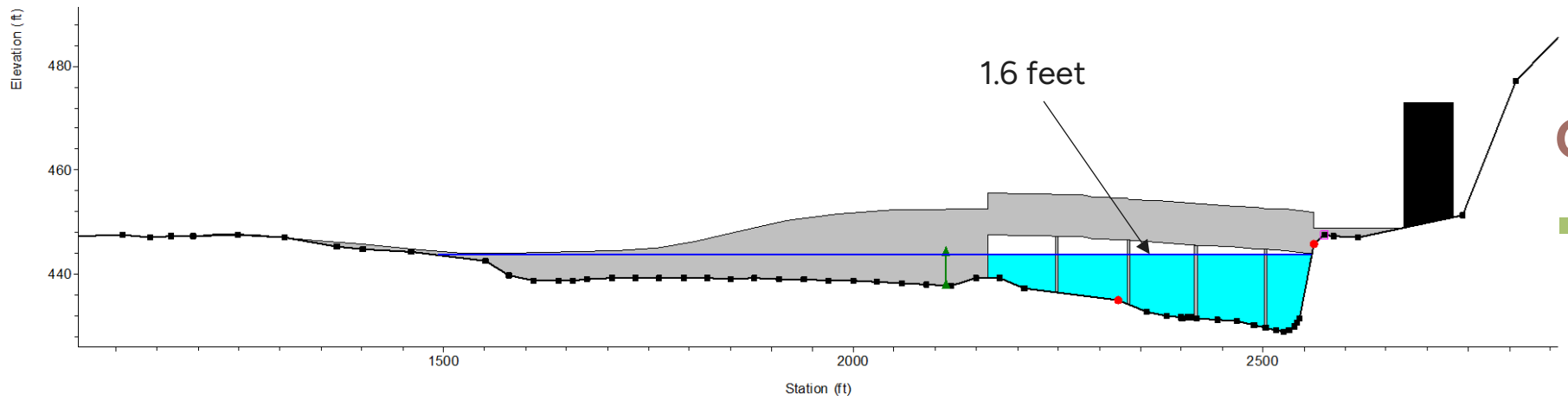


Lamoille River Long Profile

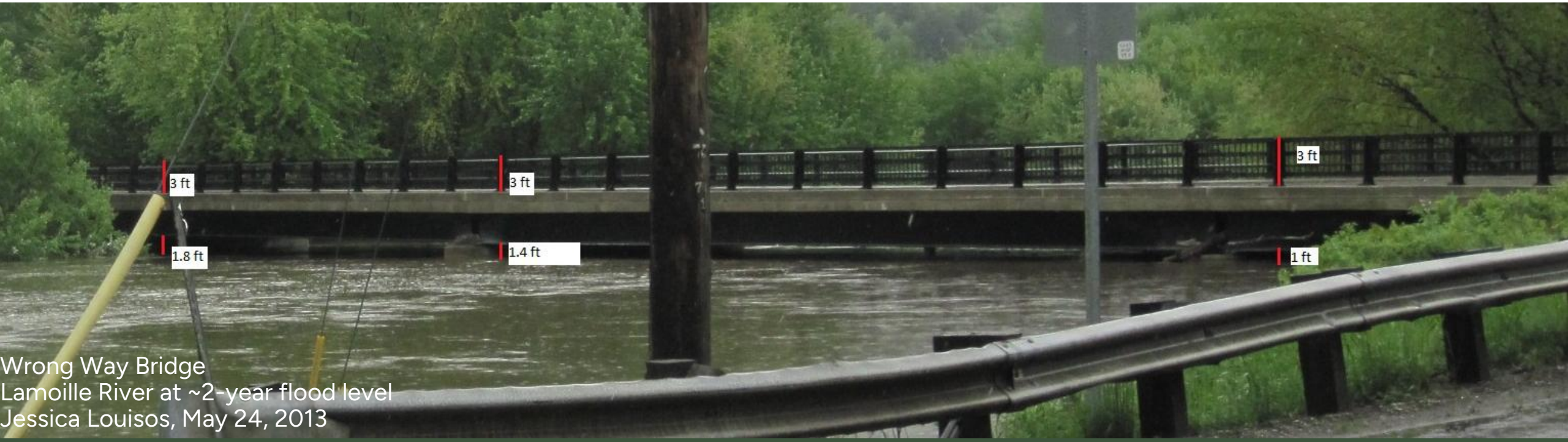


How Accurate is it?



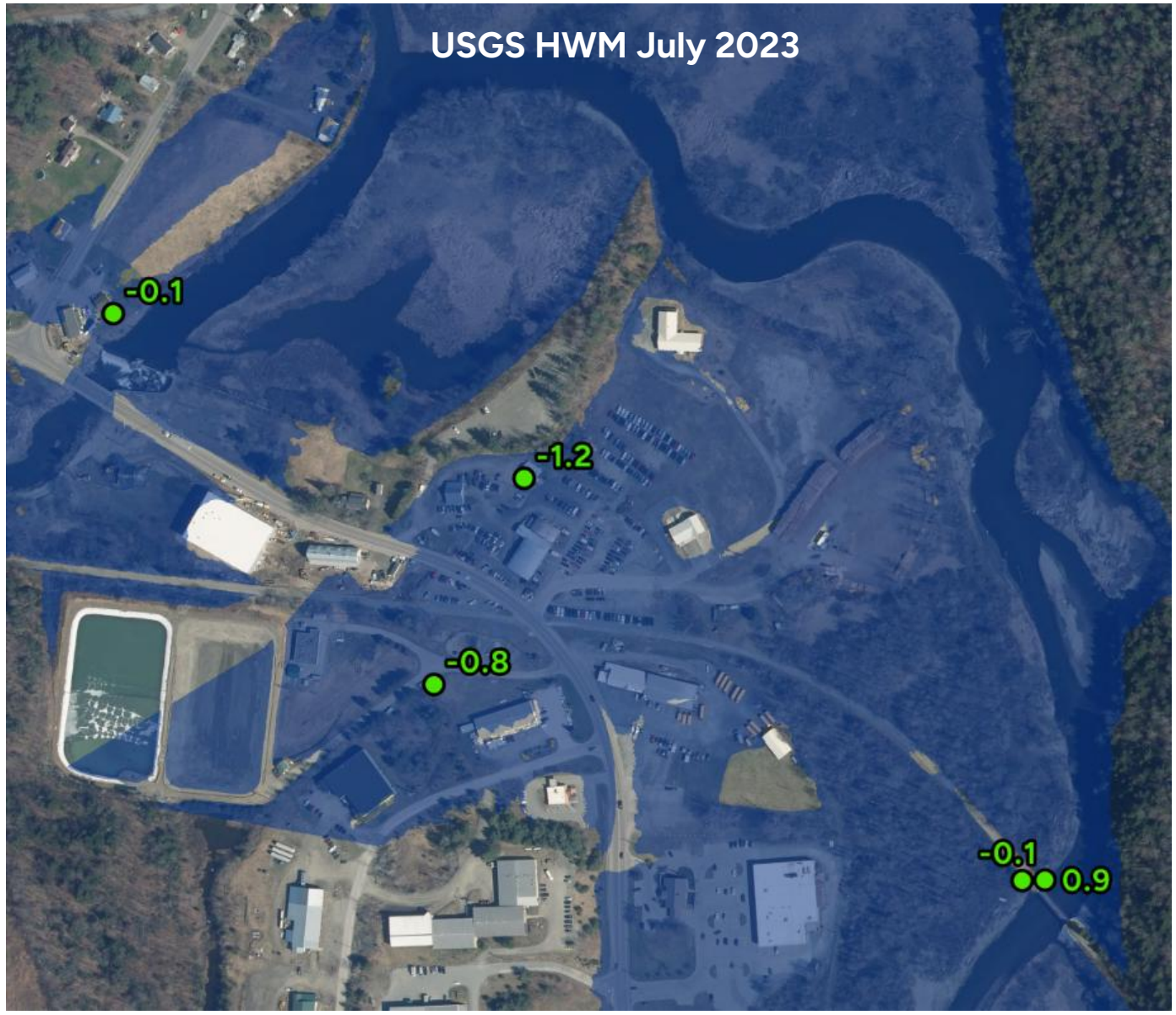
Calibration / Validation:

- Flooding Photos



Wrong Way Bridge
Lamoille River at ~2-year flood level
Jessica Louisos, May 24, 2013

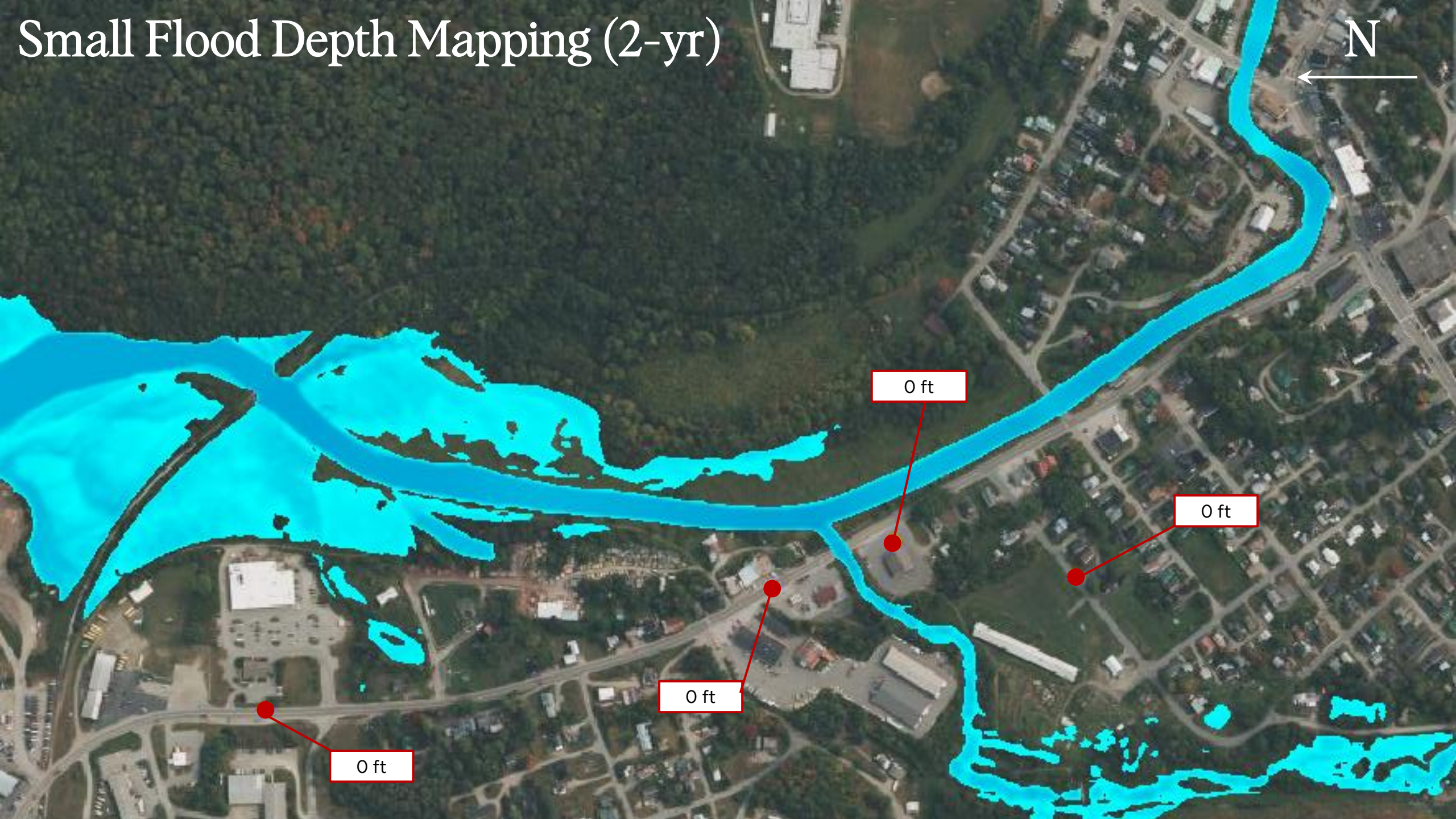
How Accurate is it?



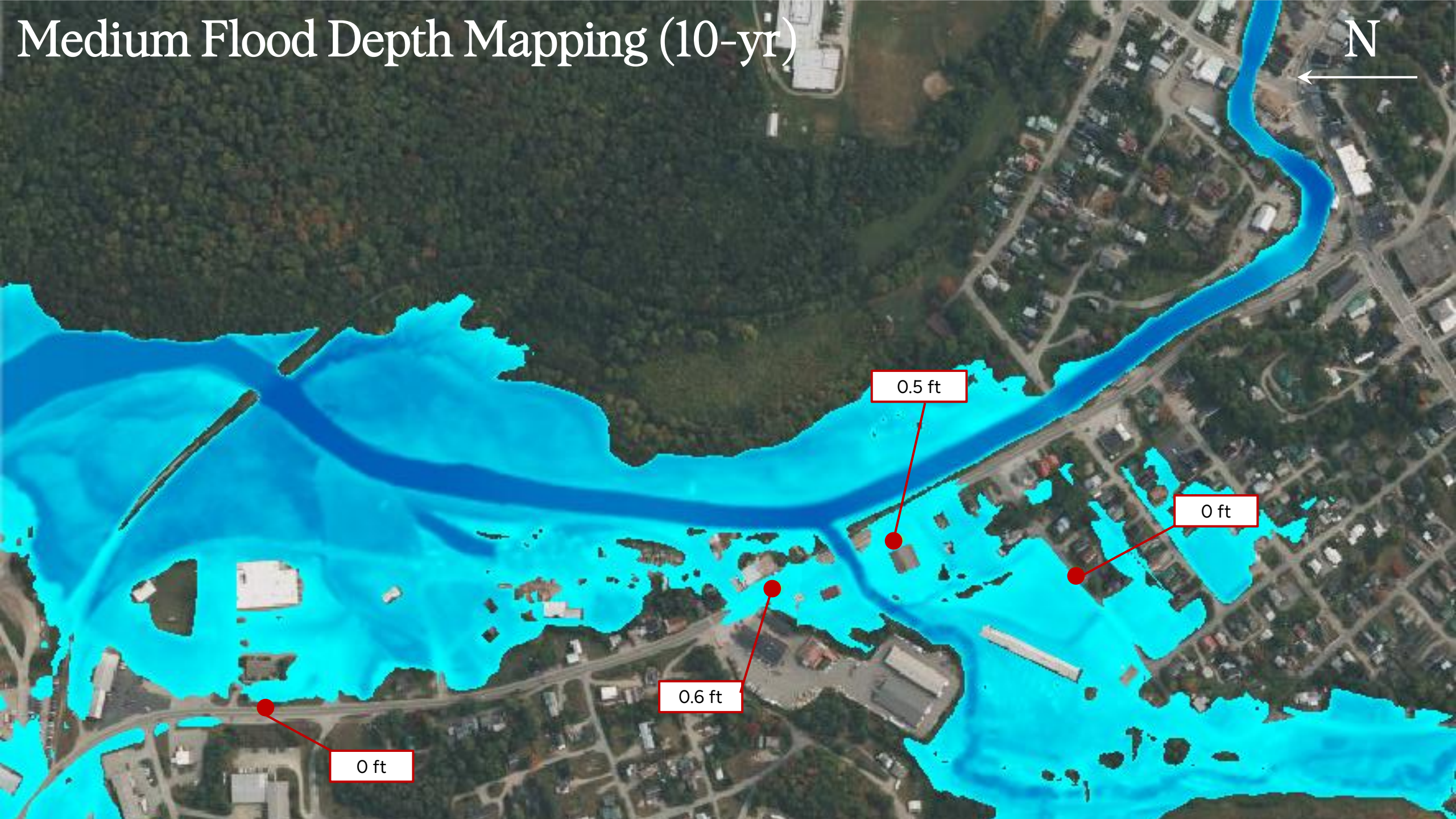
Calibration / Validation:

- High Water Marks (HWMs)
- Accuracy is within 1 ft
- Good for comparing alternatives

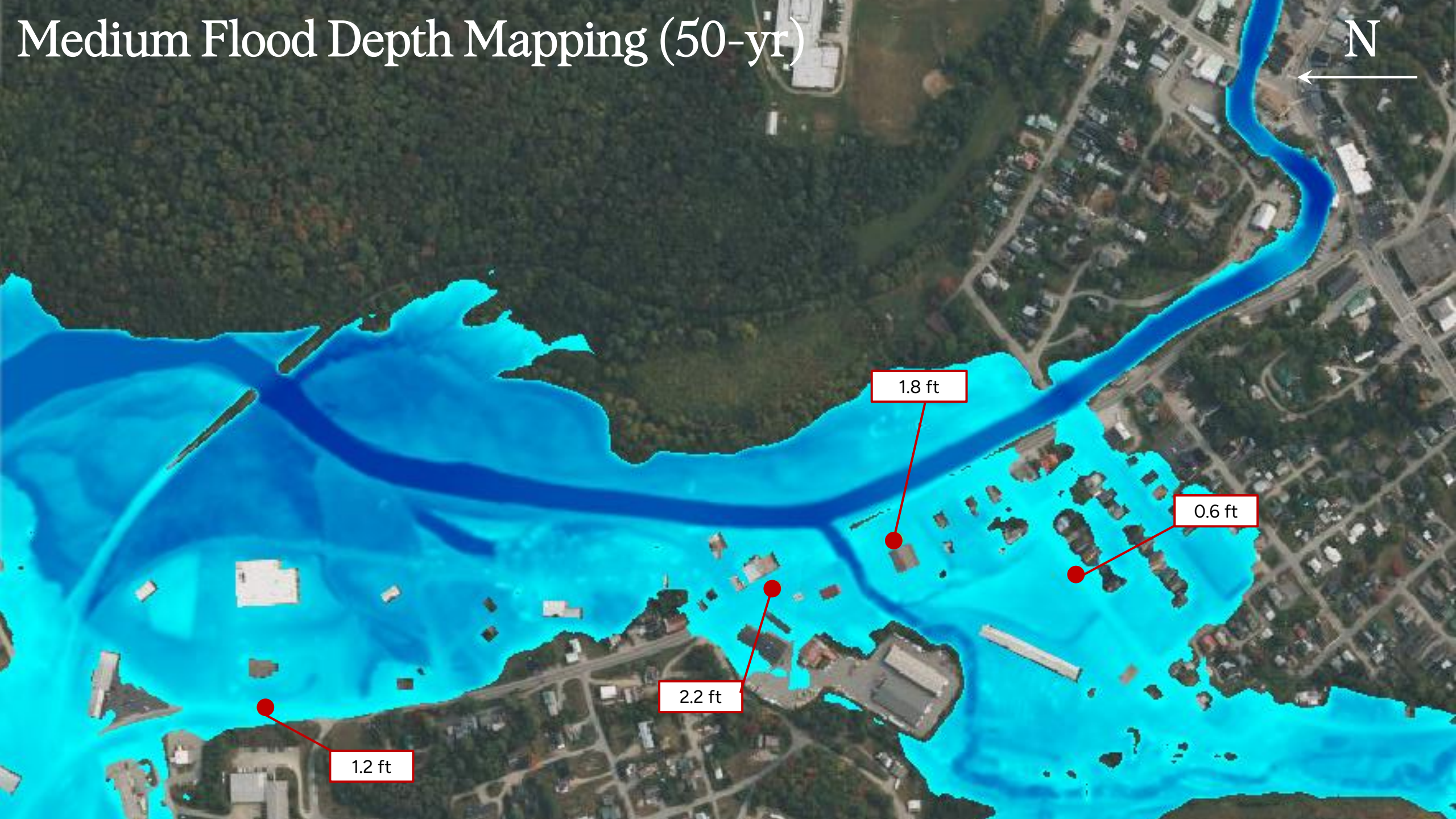
Small Flood Depth Mapping (2-yr)

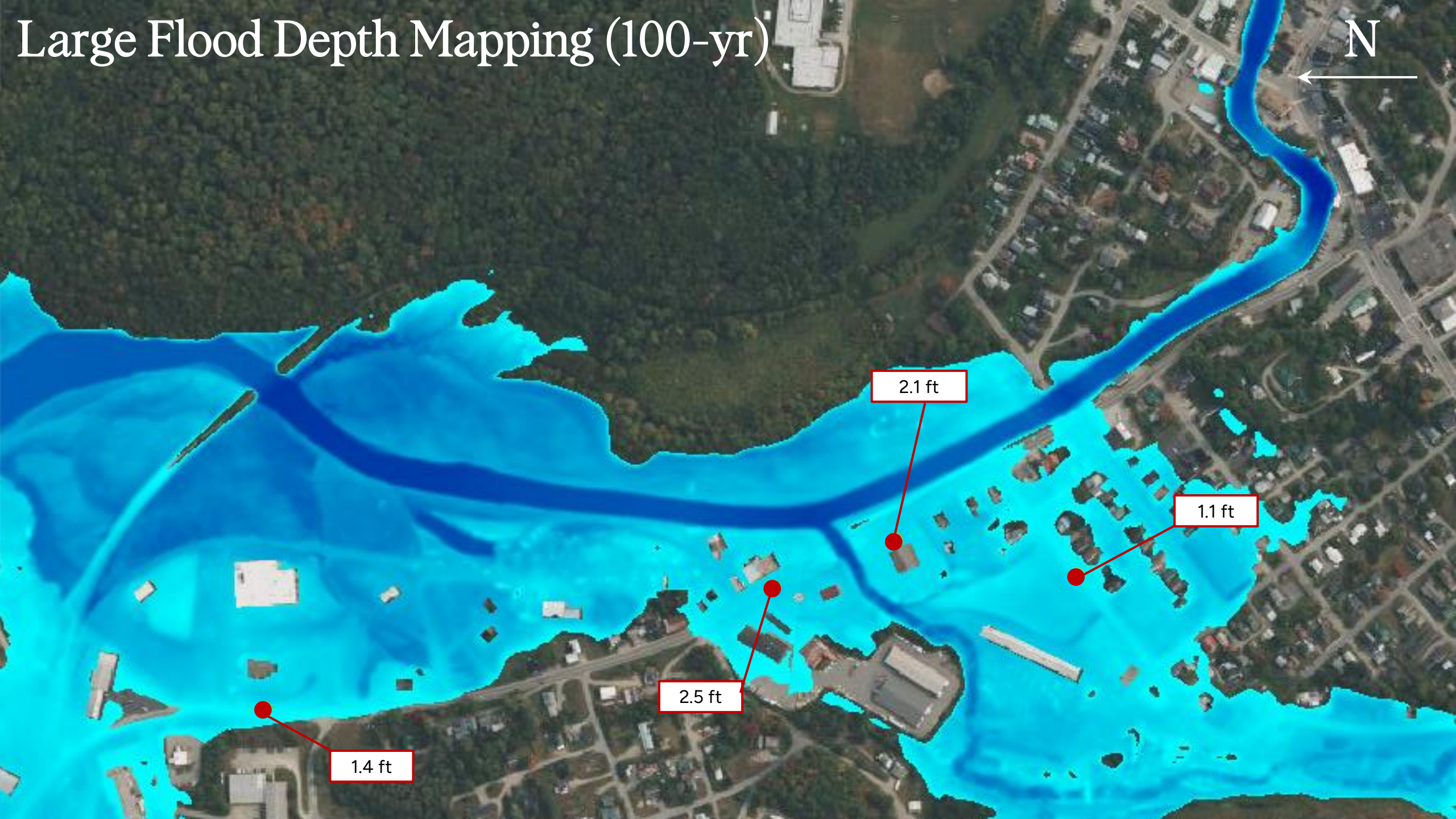


Medium Flood Depth Mapping (10-yr)



Medium Flood Depth Mapping (50-yr)




Large Flood Depth Mapping (100-yr)
N
2.1 ft
1.1 ft
2.5 ft
1.4 ft

Types of Flood Mitigation Alternatives

Constriction Reduction

- Widen bridges, culverts, or other structures
- Remove fill or buildings

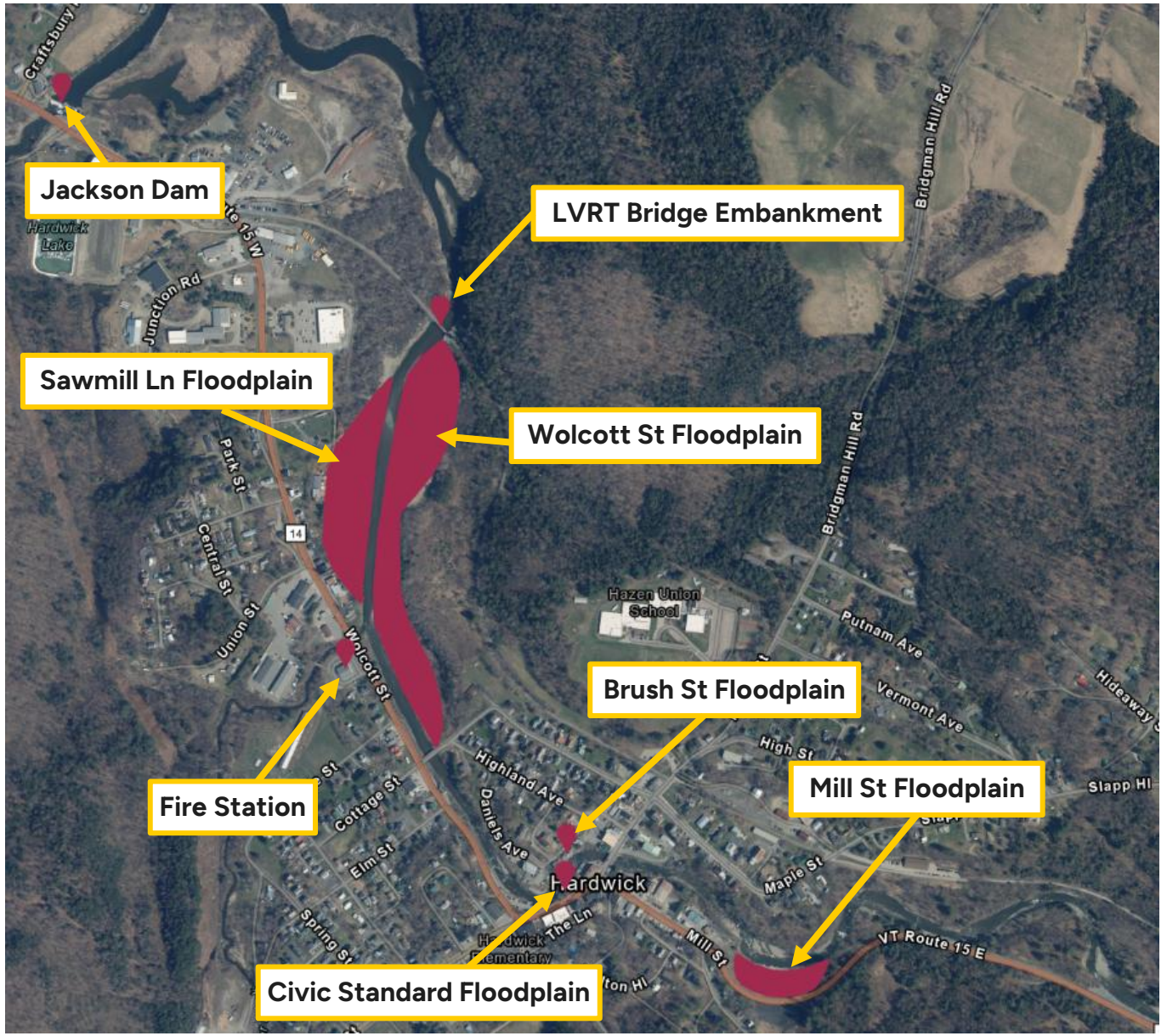
Floodplain Reconnection

- Lower floodplain
- Remove berm
- Elevate channel
- Buyouts

Infrastructure Protection

- WWTP and utilities
- Roads
- Buildings

Potential Flood Mitigation Alternatives in Hardwick



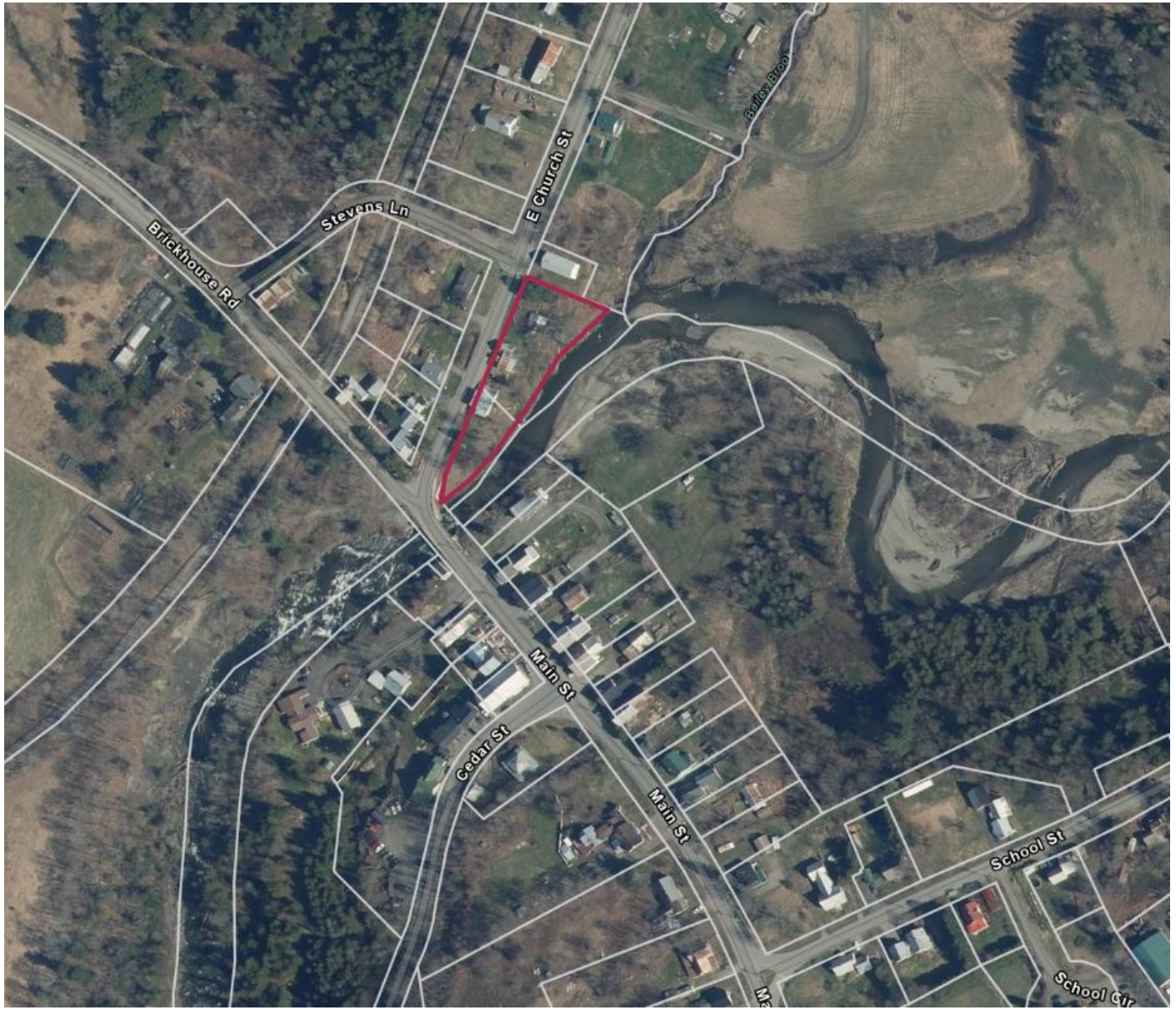
East Church Street Bridge and Floodplain

Problems

- Buyouts
- Erosion

Possible Solutions

- Bridge Replacement
- Floodplain restoration
- Slope stabilization



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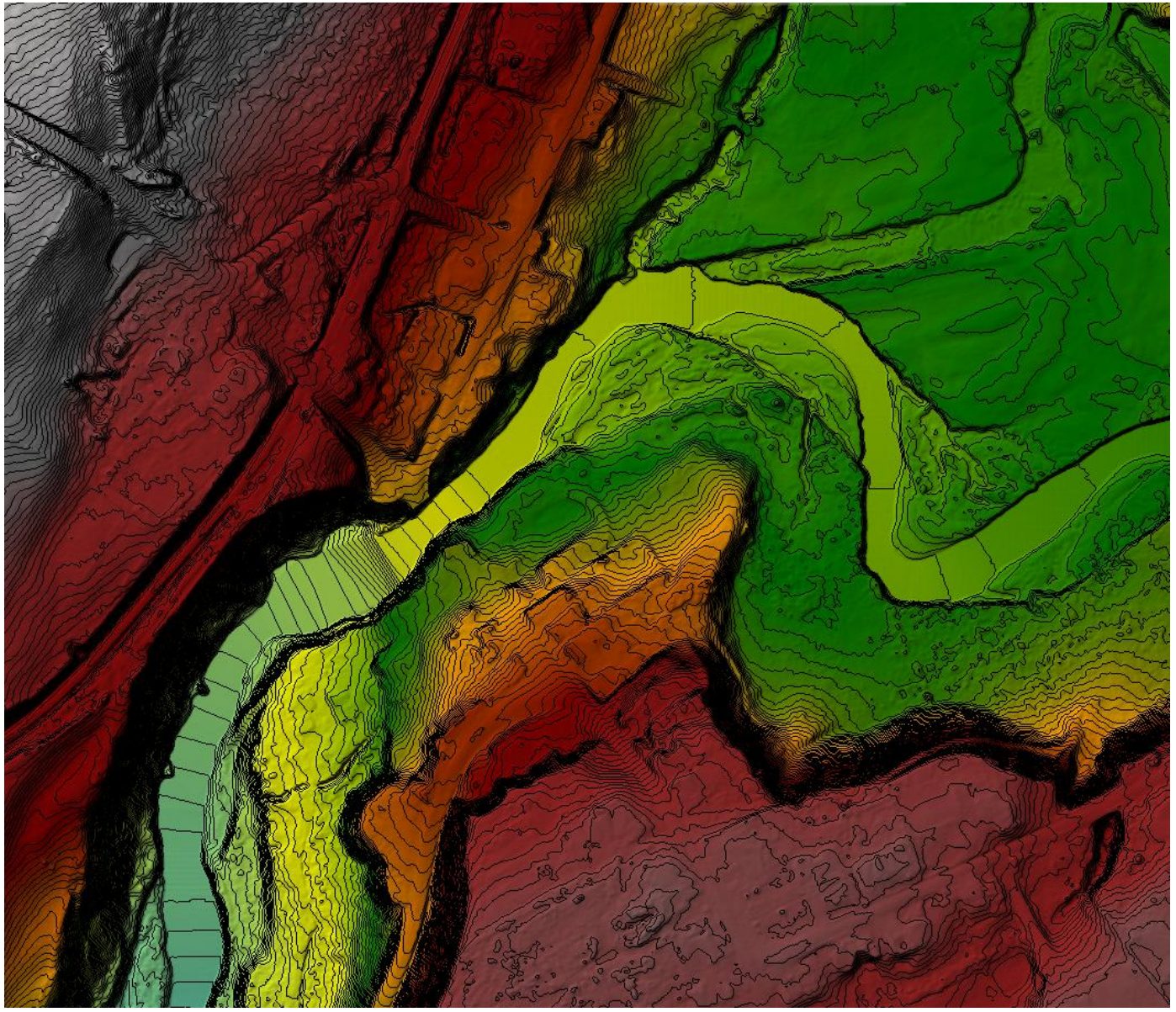

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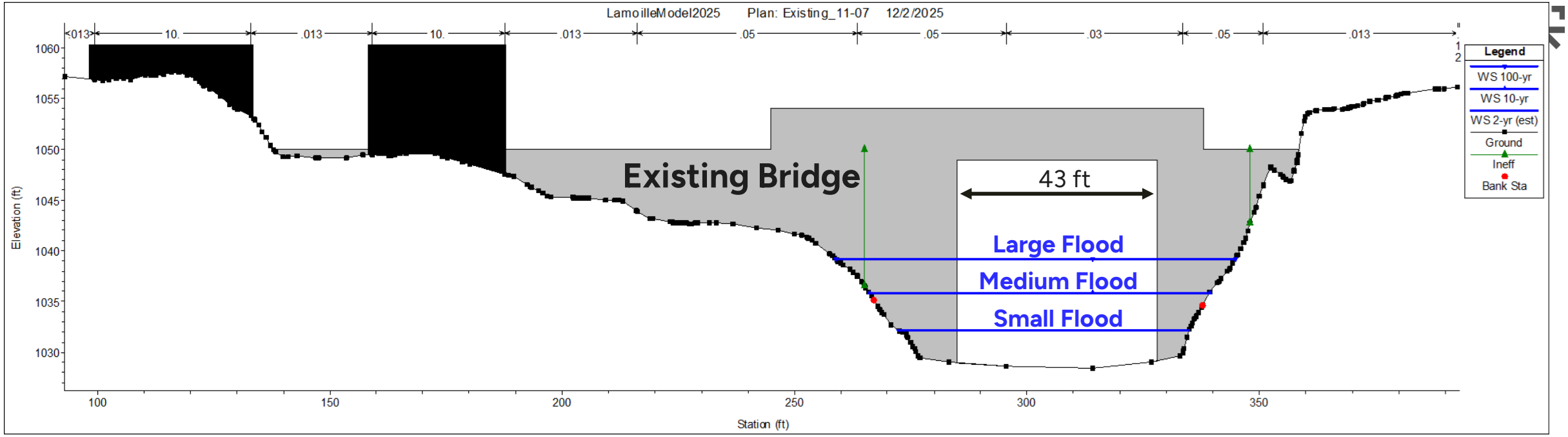
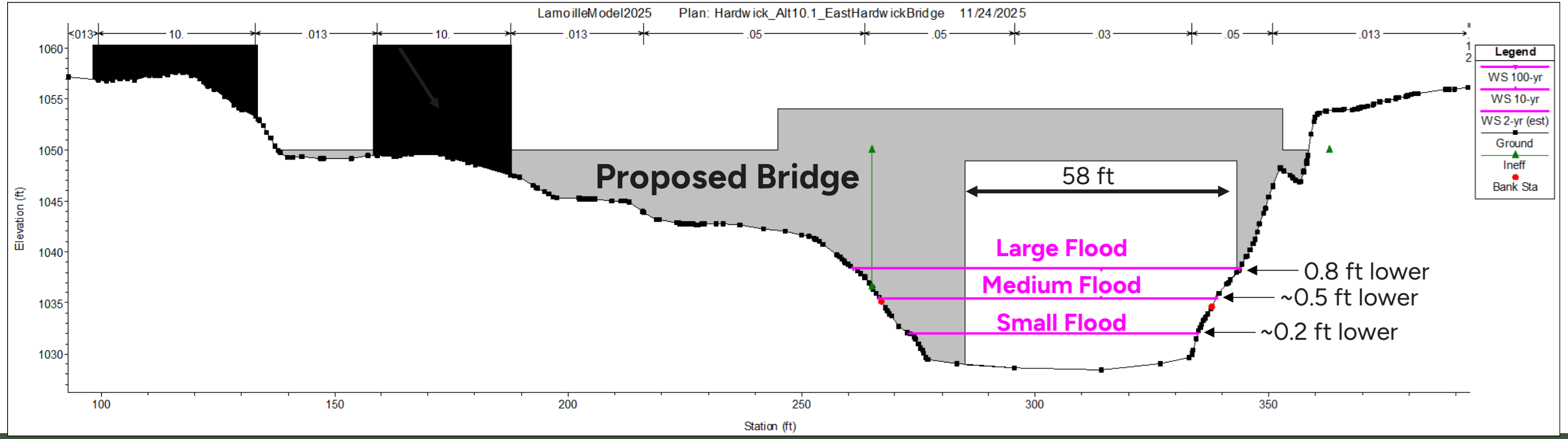
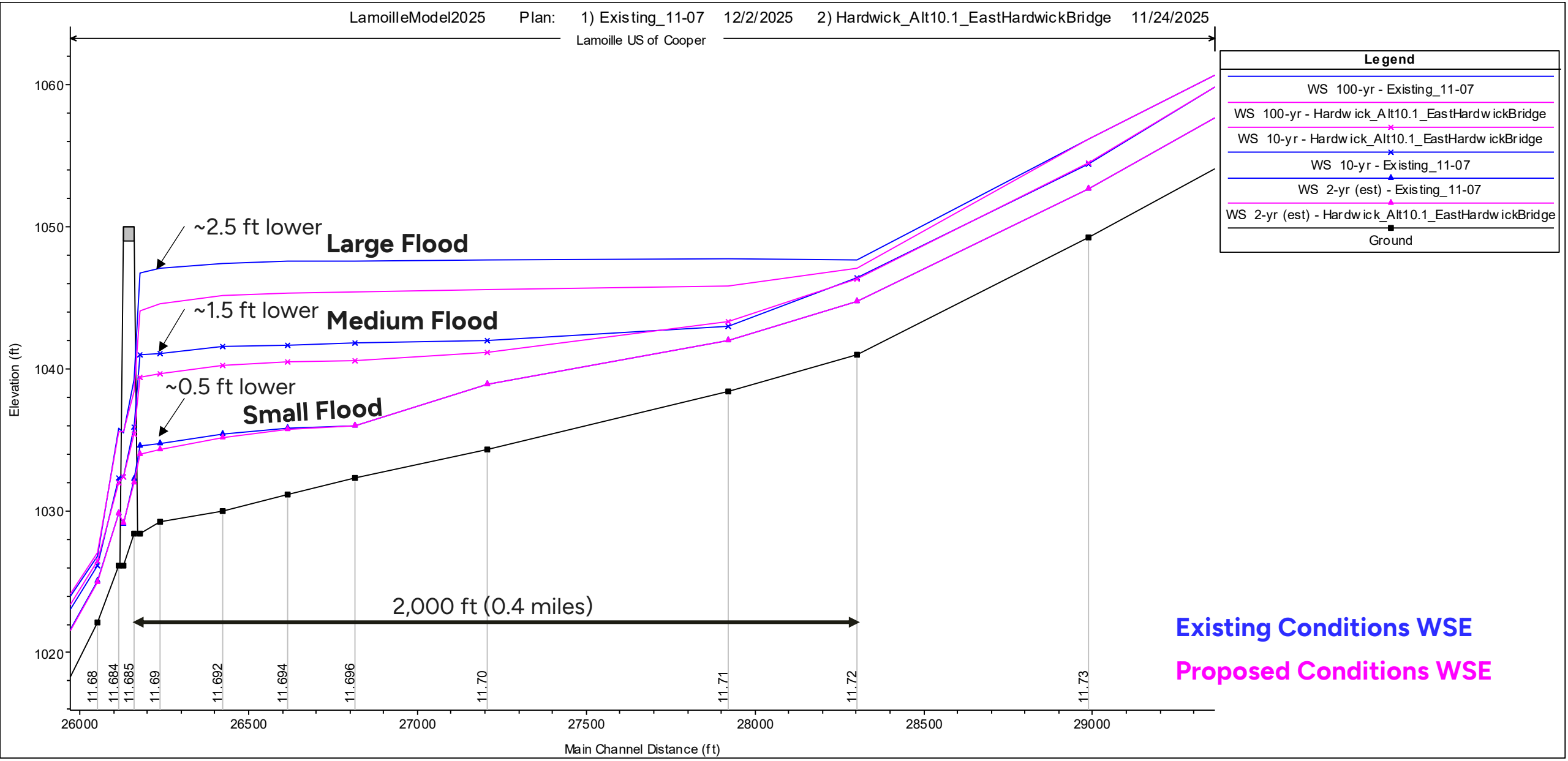

LamoilleModel2025 Plan: Existing_11-07 12/2/2025
Existing Bridge
43 ft
Large Flood
Medium Flood
Small Flood
Legend
WS 100-yr
WS 10-yr
WS 2-yr (est)
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)


LamoilleModel2025 Plan: Hardwick_Alt10.1_EastHardwickBridge 11/24/2025
Proposed Bridge
58 ft
Large Flood
Medium Flood
Small Flood
0.8 ft lower
~0.5 ft lower
~0.2 ft lower
Legend
WS 100-yr
WS 10-yr
WS 2-yr (est)
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)

Results – Lamoille River Profile



Mill Street Floodplain

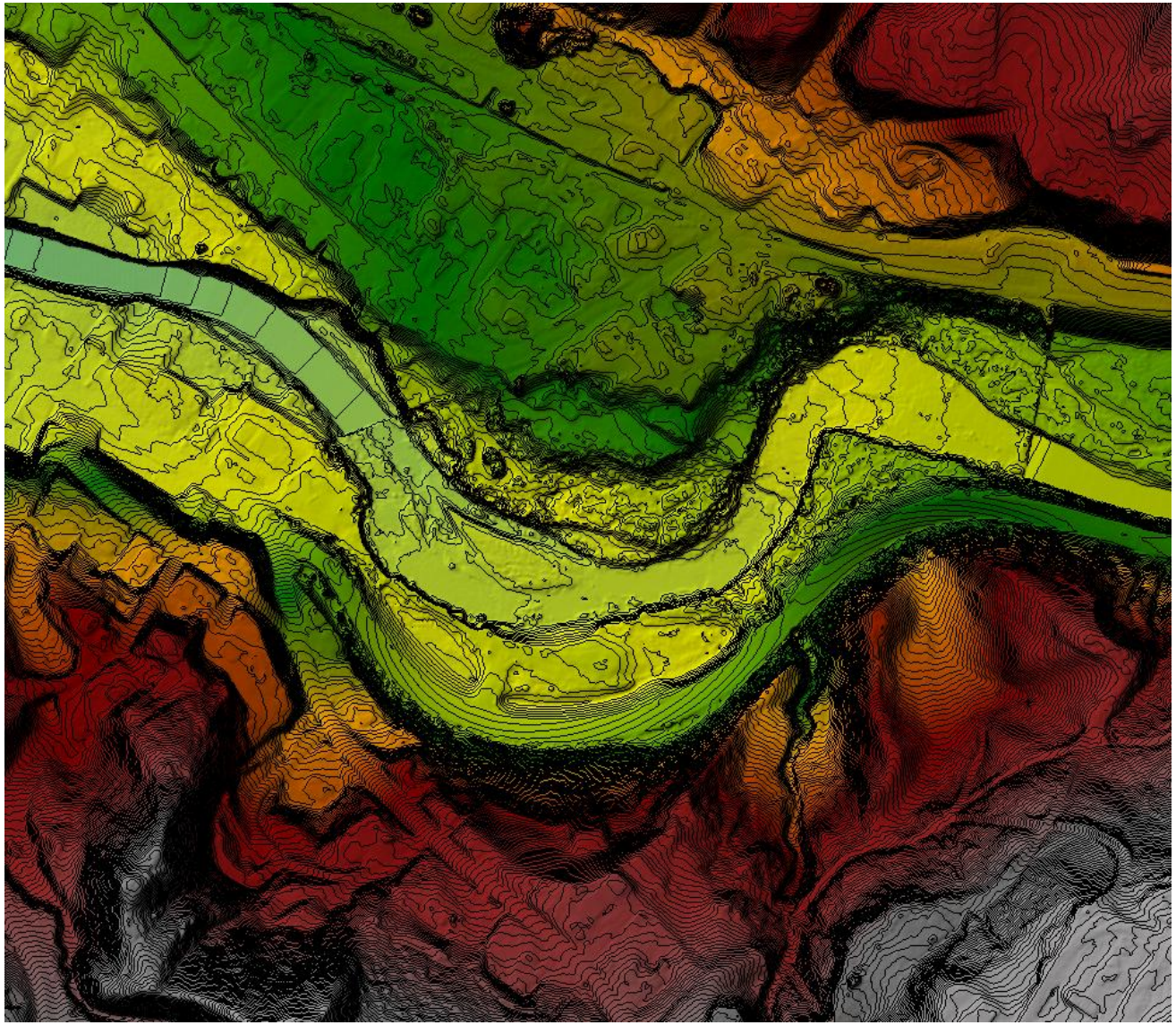
Problems

- Eroding bank
- Buyout

Possible Solutions

- Slope stabilization/bank armouring
- Floodplain restoration
  - Space for Debris and Ice Shedding

Mill Street Floodplain



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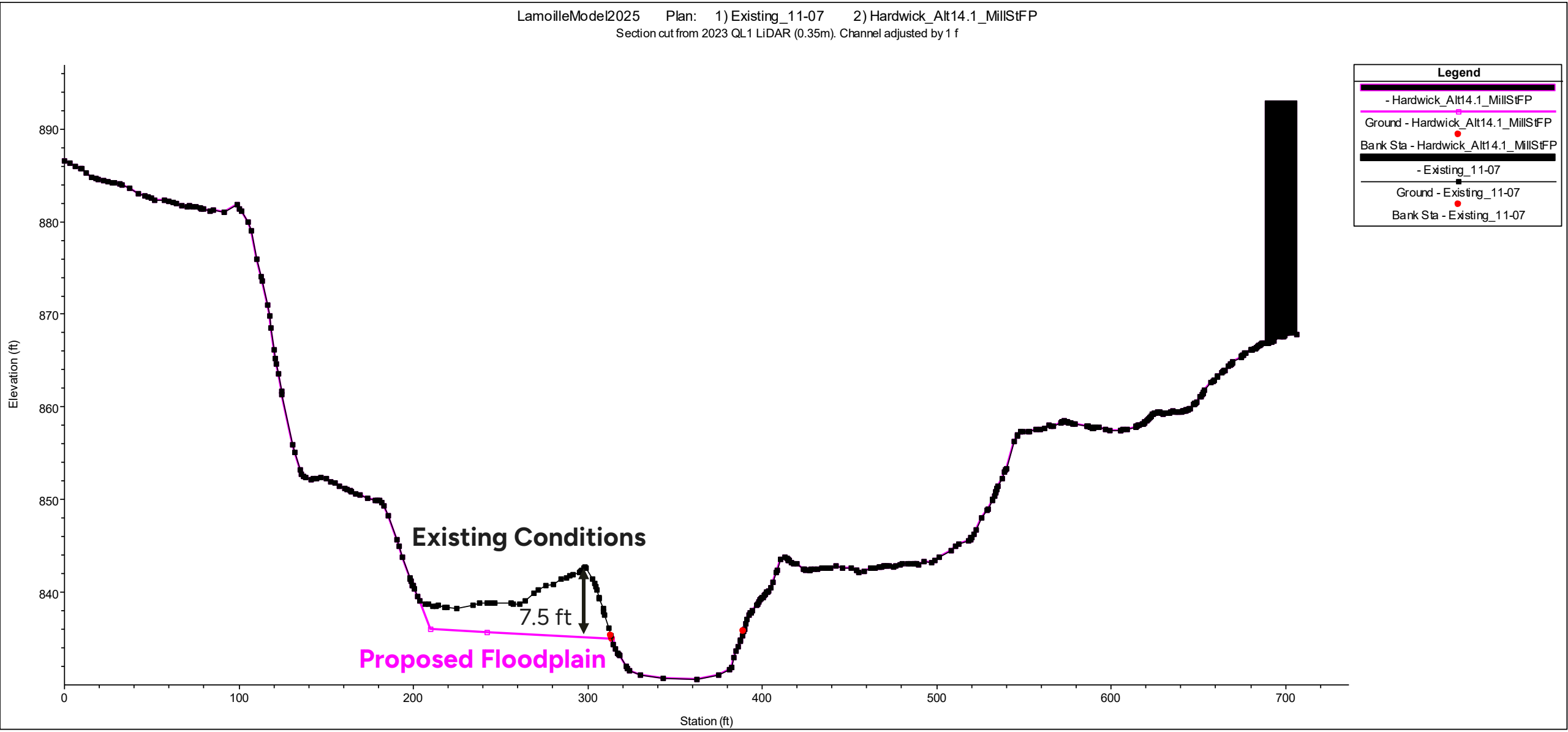
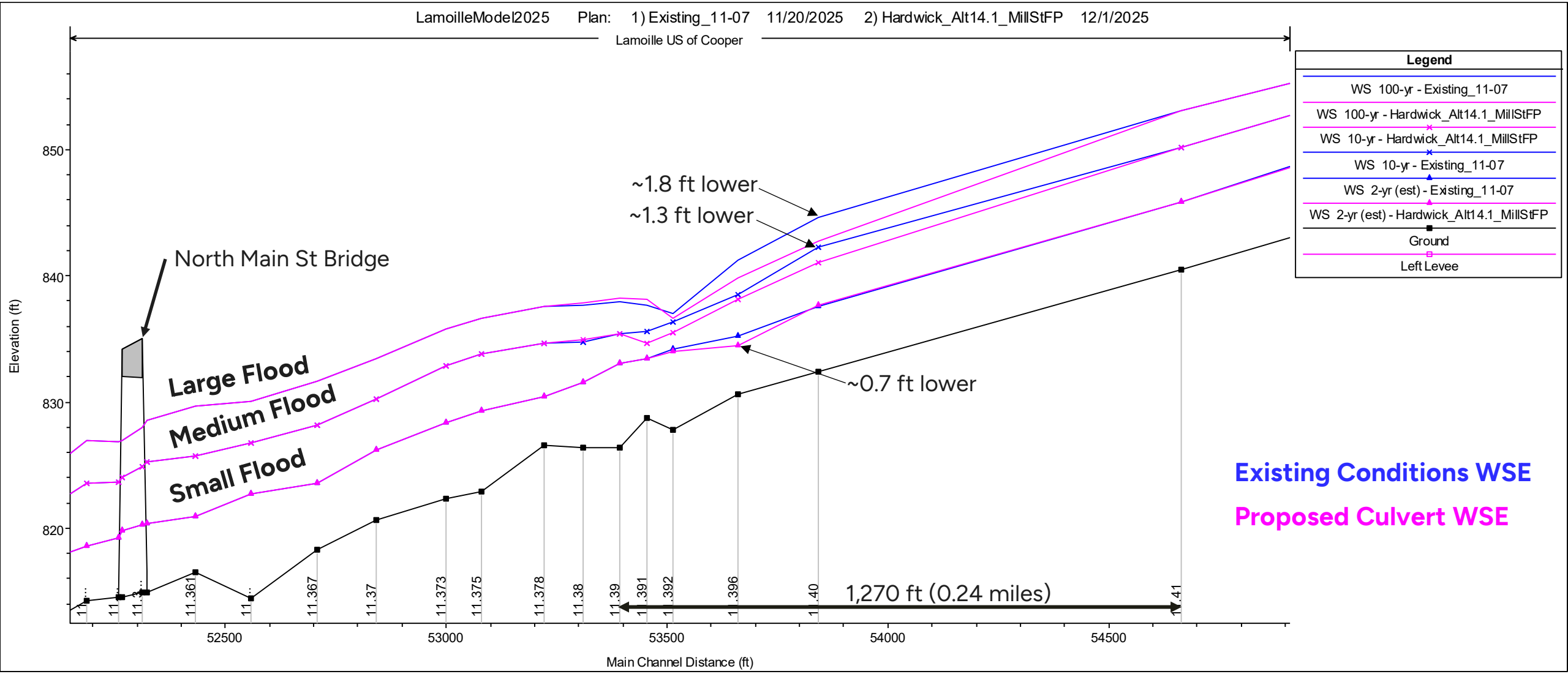
  - Space for Debris and Ice Shedding

Cross Section View – Existing and Proposed



Results – Lamoille River Profile



Existing 100-yr Depth Mapping

Proposed 100-yr Depth Mapping

Note: Velocities decrease 1.0 – 5.0 ft/s through project area

Downtown Floodplains - Buyouts

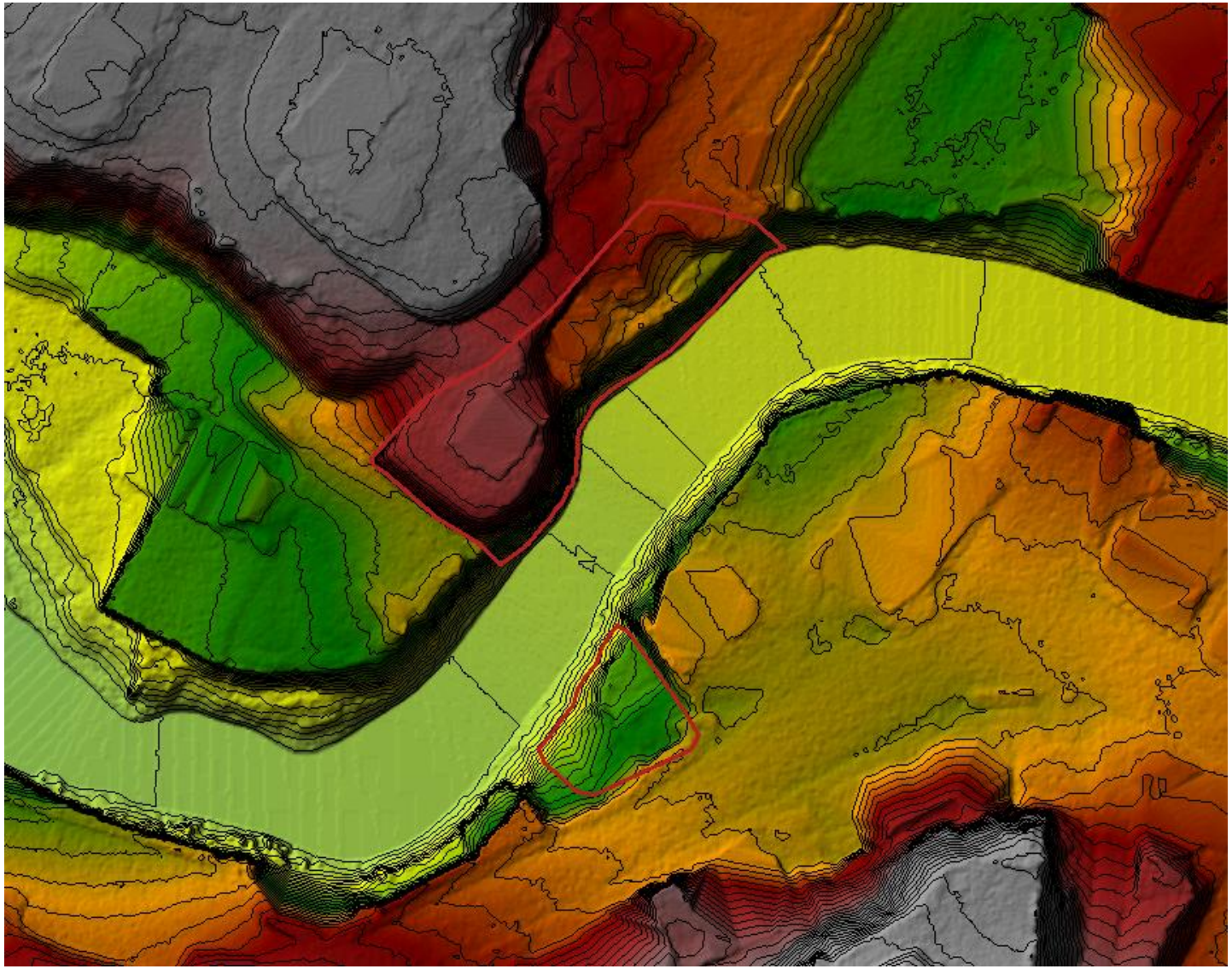
Problems

- Eroding banks
- Potential Buyouts

Possible Solutions

- Slope stabilization/bank armouring
- Floodplain restoration

Downtown Floodplains - Buyouts



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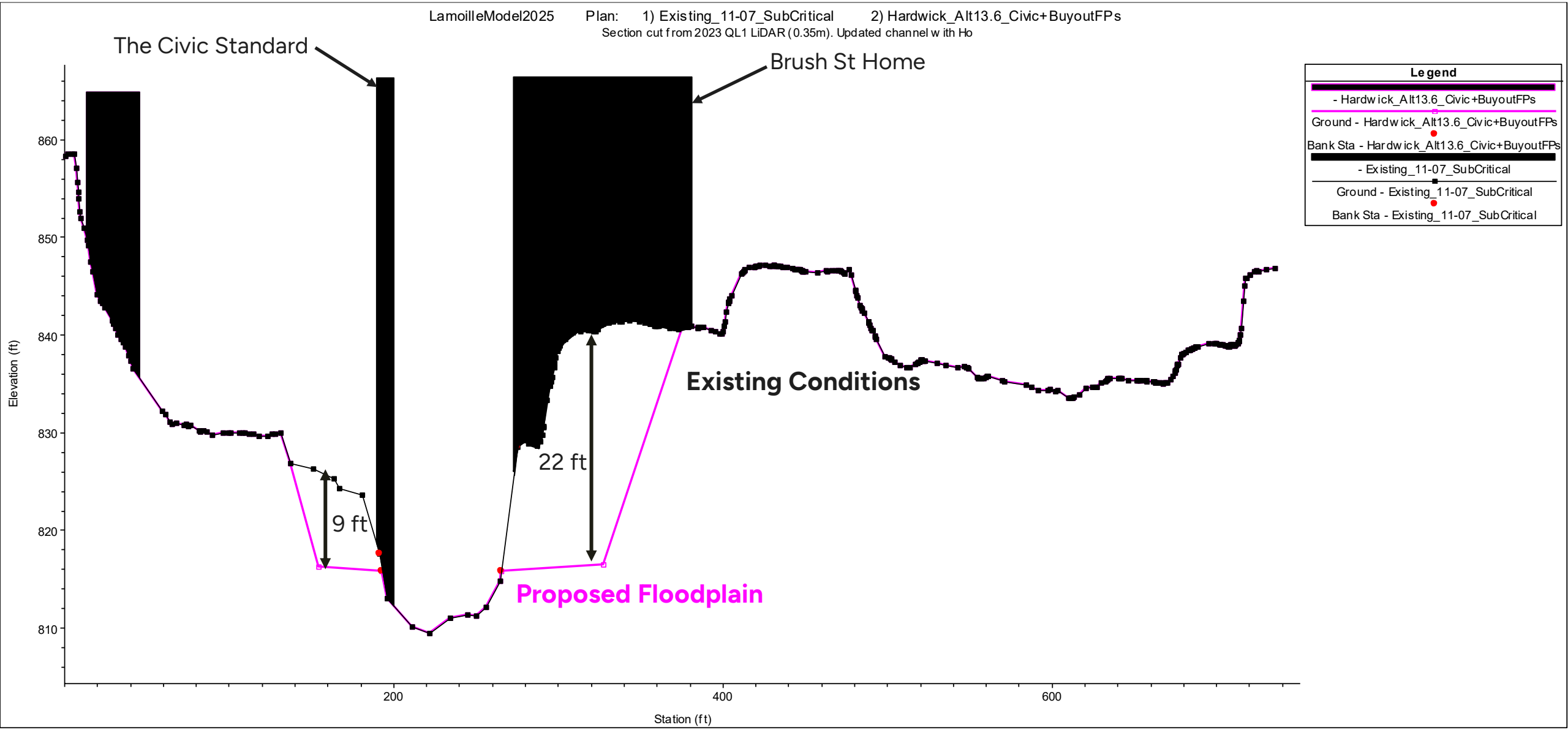
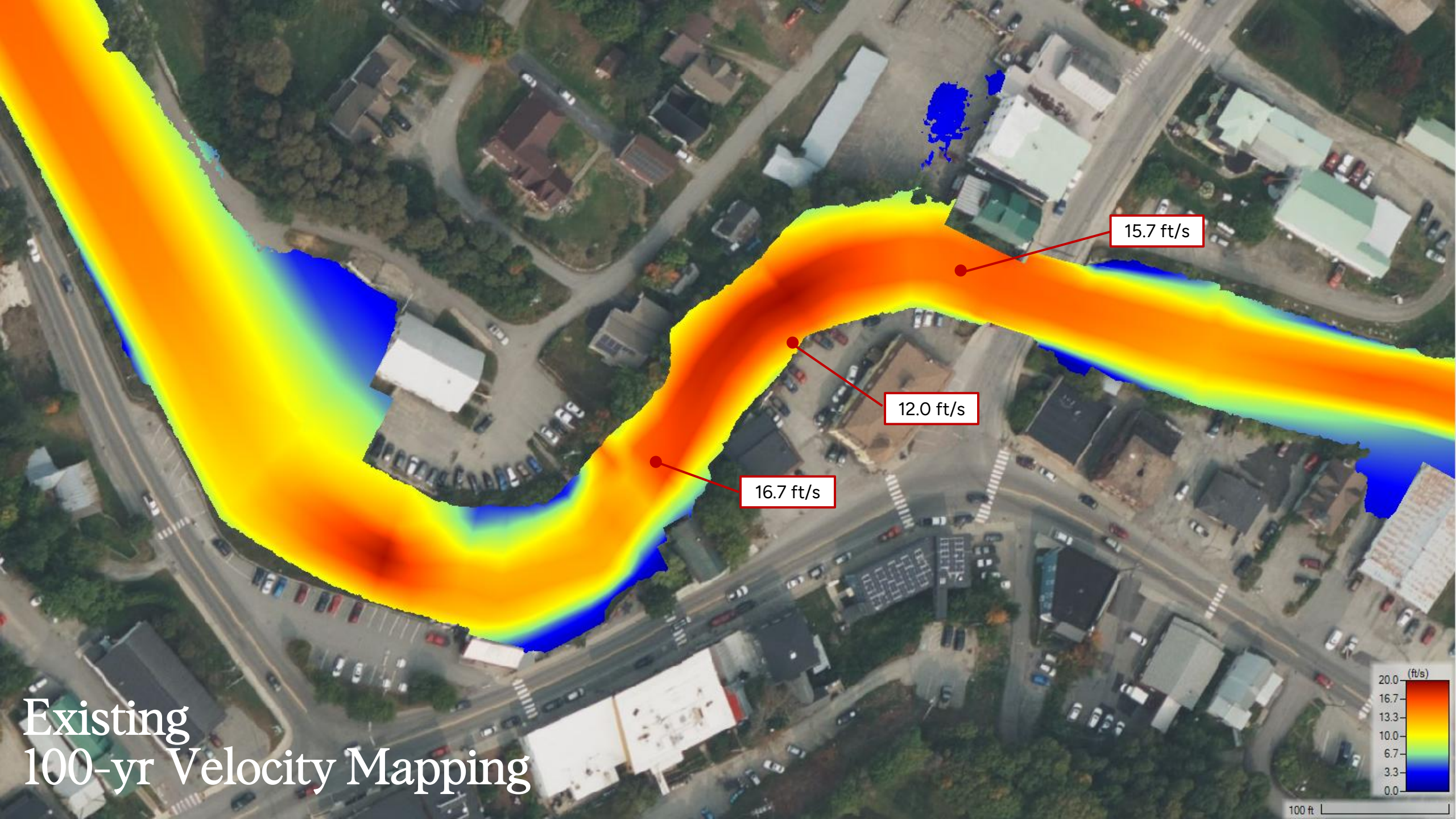
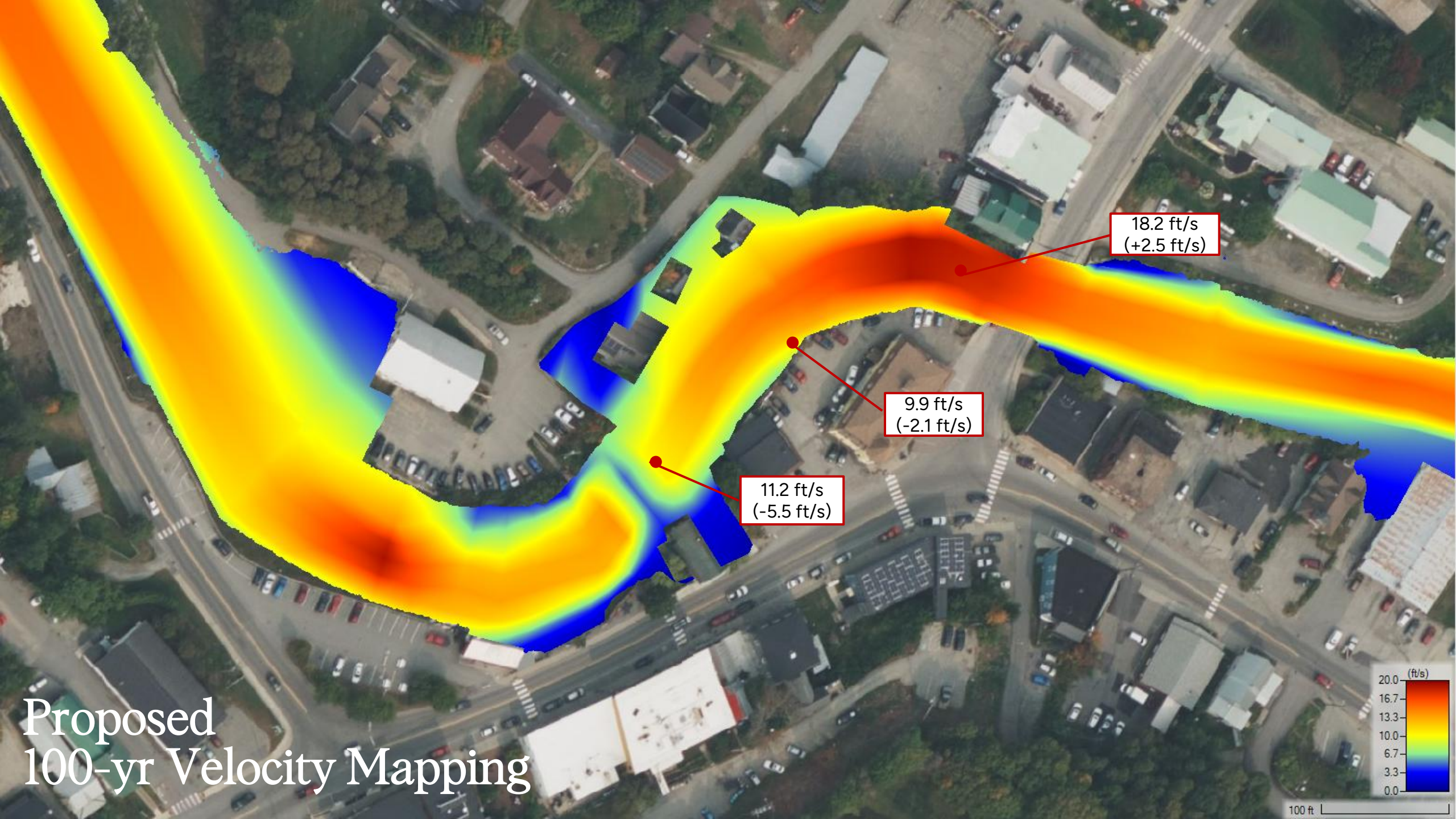




Existing 100-yr Velocity Mapping



Proposed 100-yr Velocity Mapping

Downtown Floodplains - Constrictions

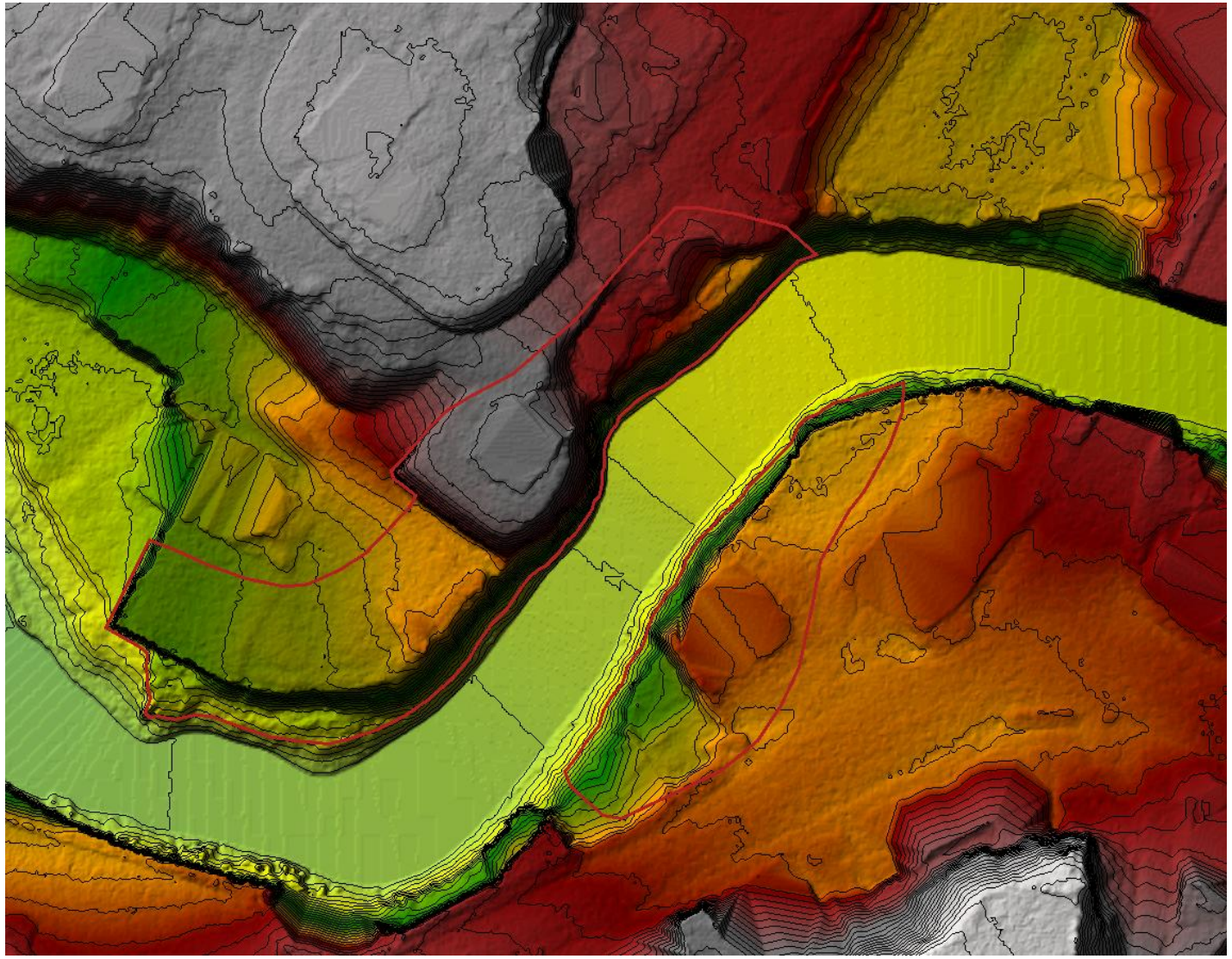
Problems

- Constrictions
- Eroding banks

Possible Solutions

- Slope stabilization/bank armouring
- Floodplain restoration

Downtown Floodplains - Constrictions



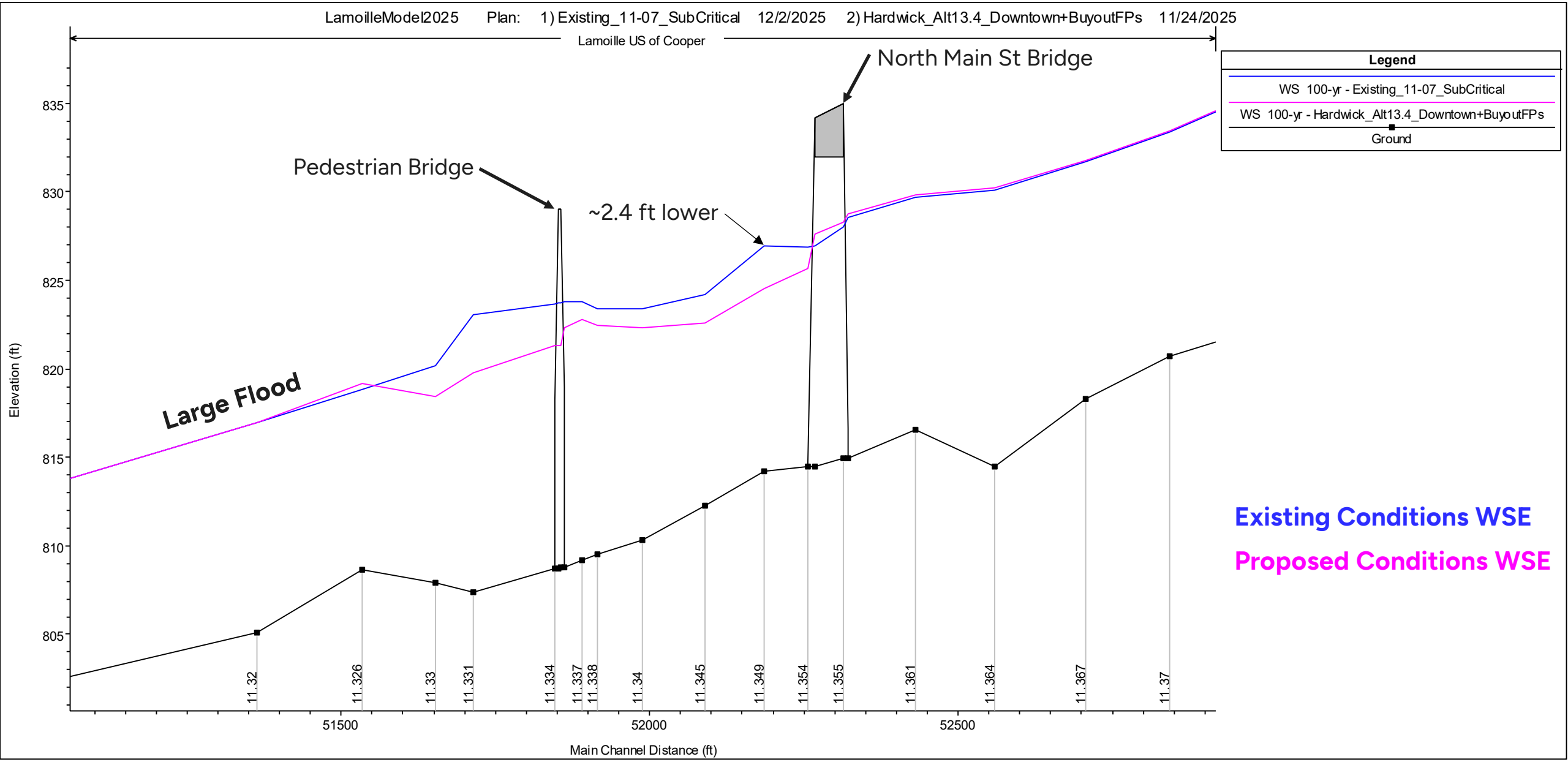
Problems

- Constrictions
- Eroding banks

Possible Solutions

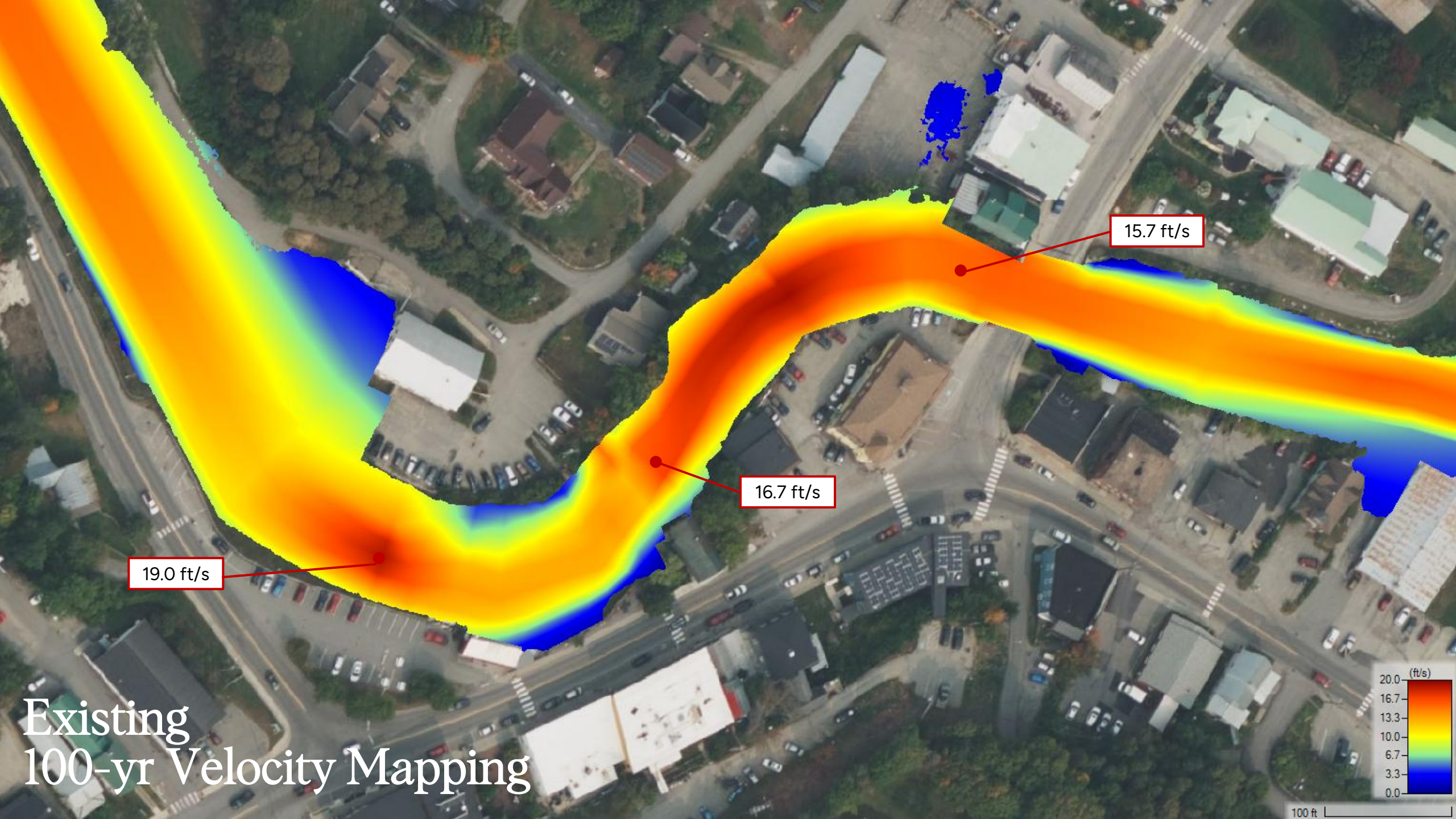
- Slope stabilization/bank armouring
- Floodplain restoration

Results – Lamoille River Profile

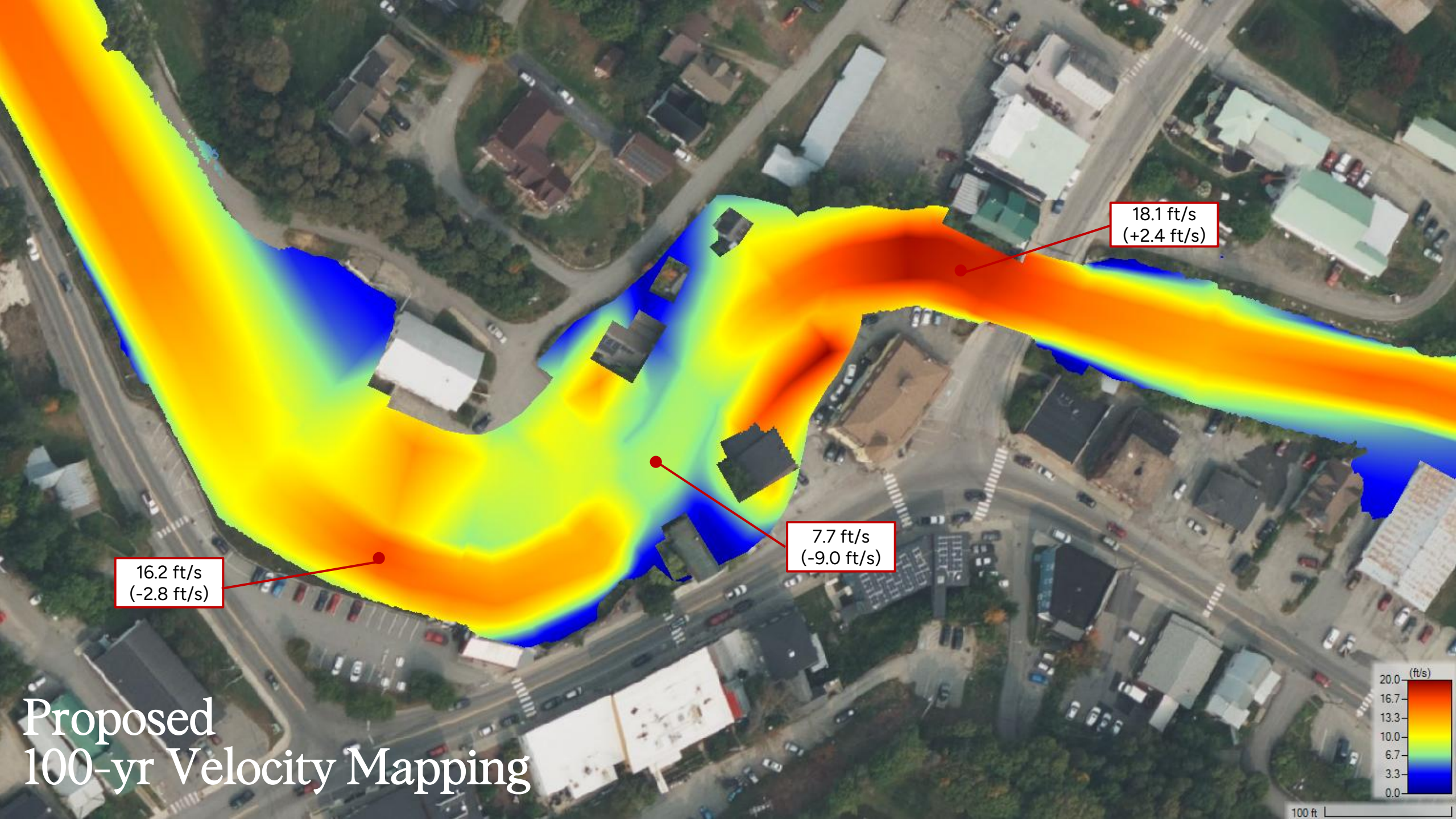


Existing Conditions WSE

Proposed Conditions WSE



Existing
100-yr Velocity Mapping



Proposed 100-yr Velocity Mapping

Wolcott Street and Sawmill Lane Floodplains

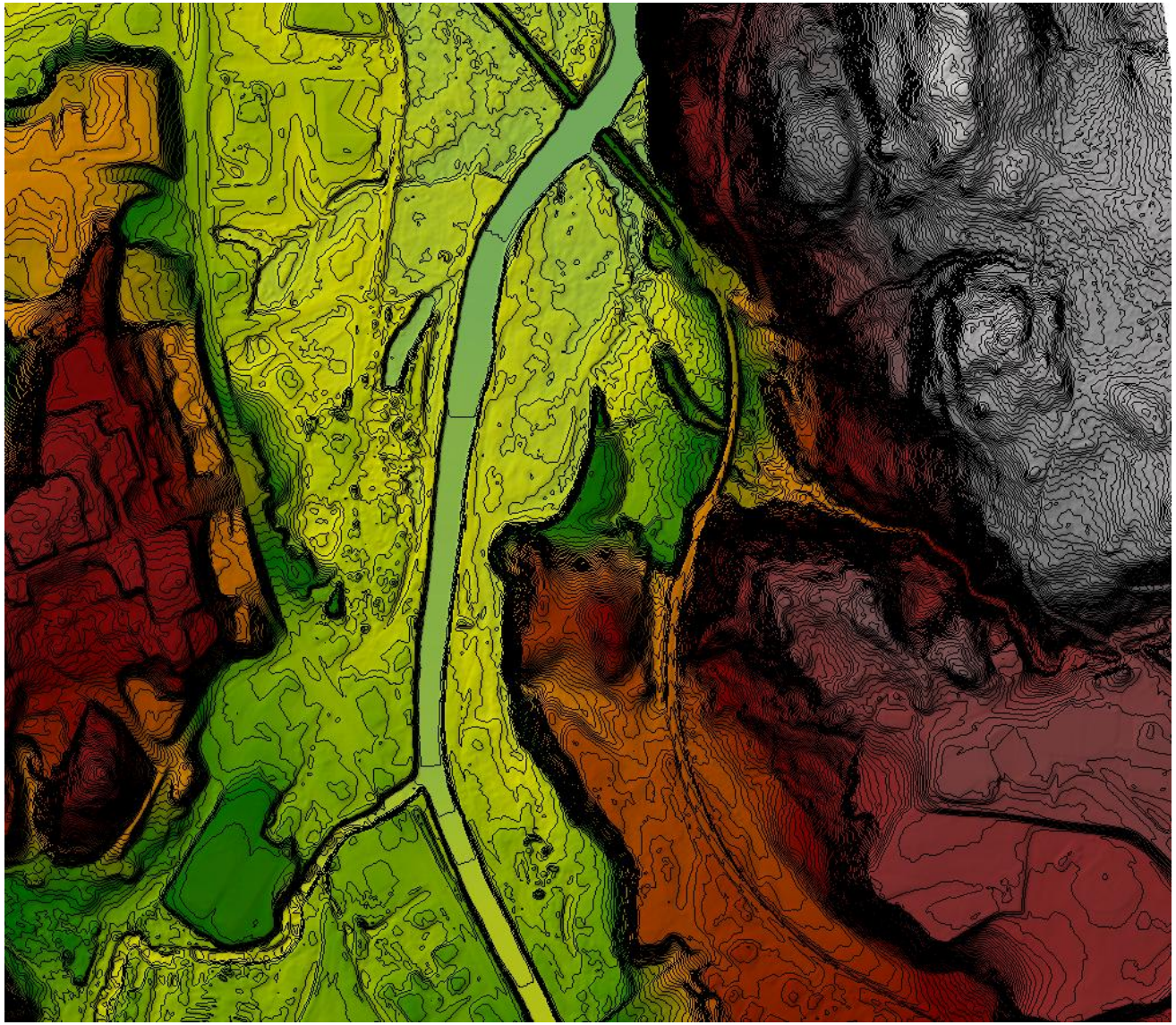
Problems

- Sediment deposition
- Inundation flooding
- Possible buyouts

Possible Solutions

- Floodplain restoration opportunity

Wolcott Street and Sawmill Lane Floodplains



Problems

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- Inundation flooding
- Possible buyouts

Possible Solutions

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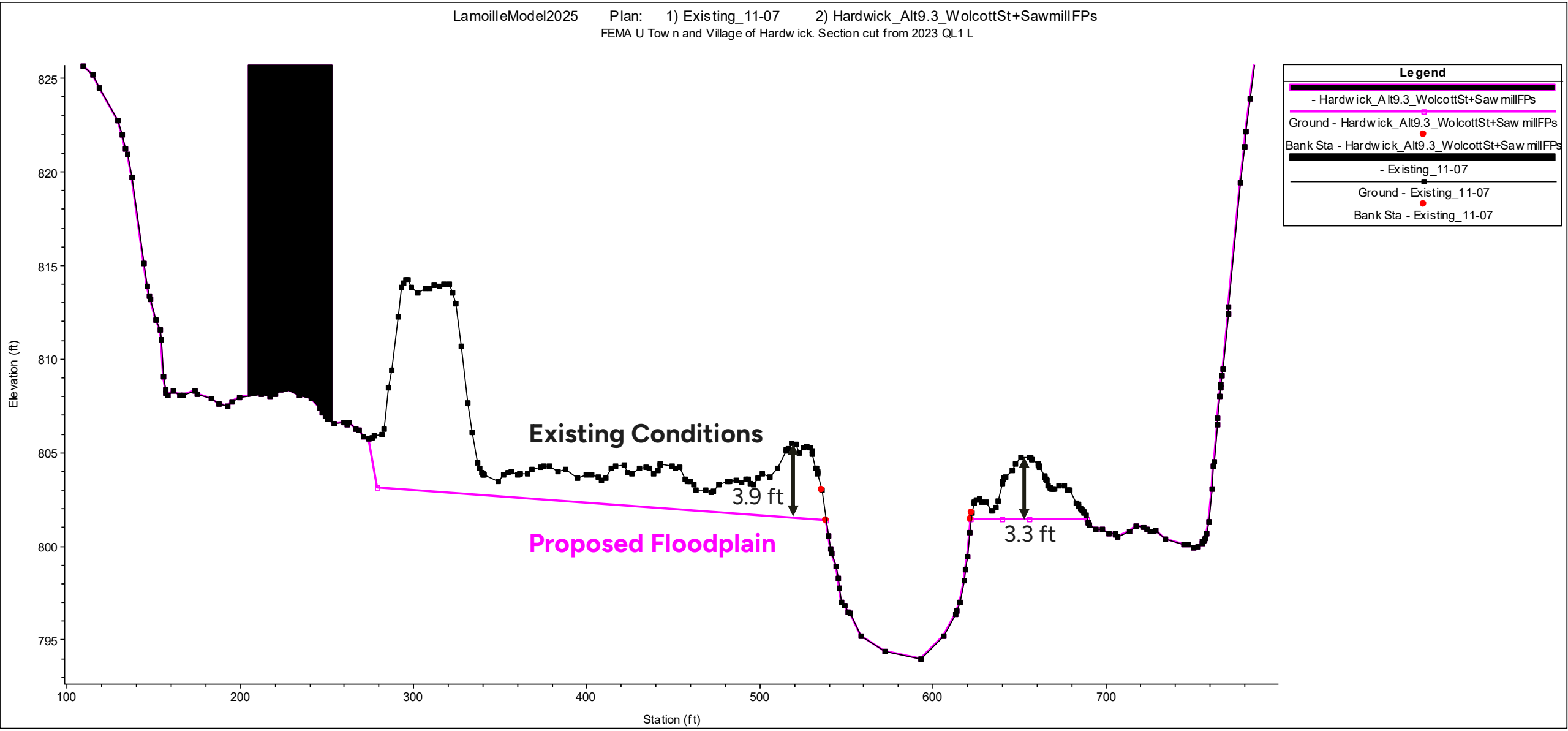
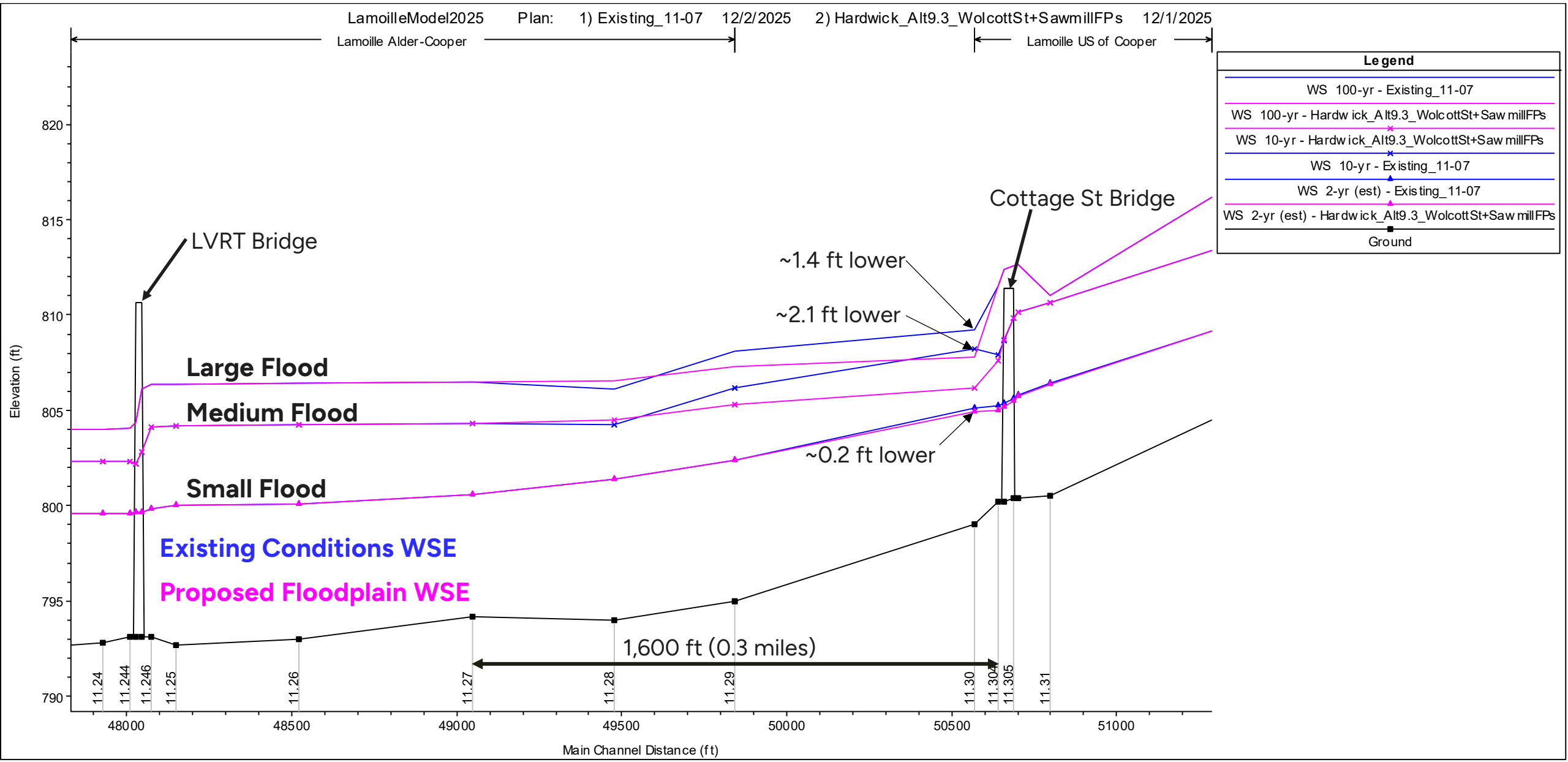
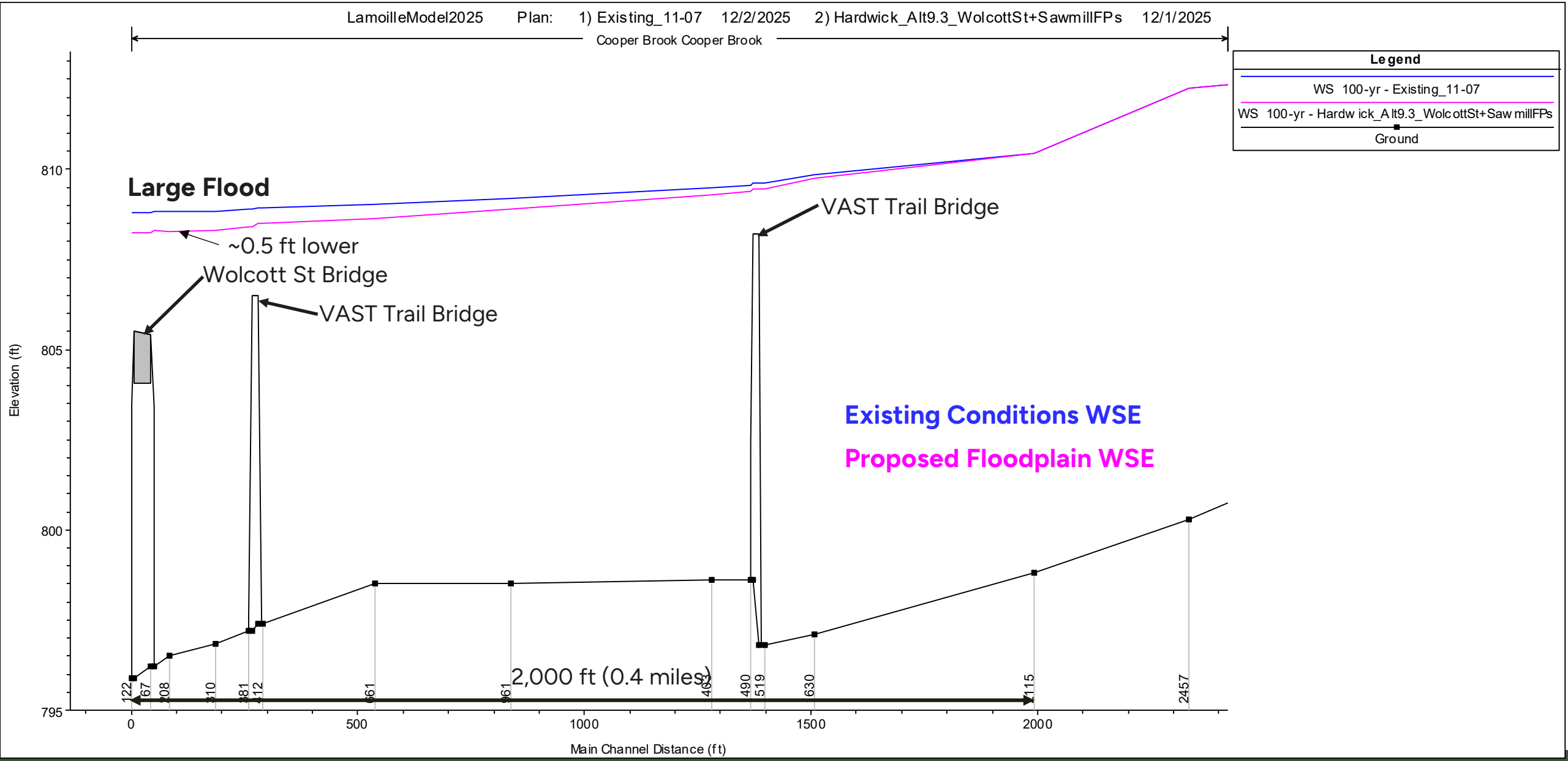
Cross Section View – Existing and Proposed

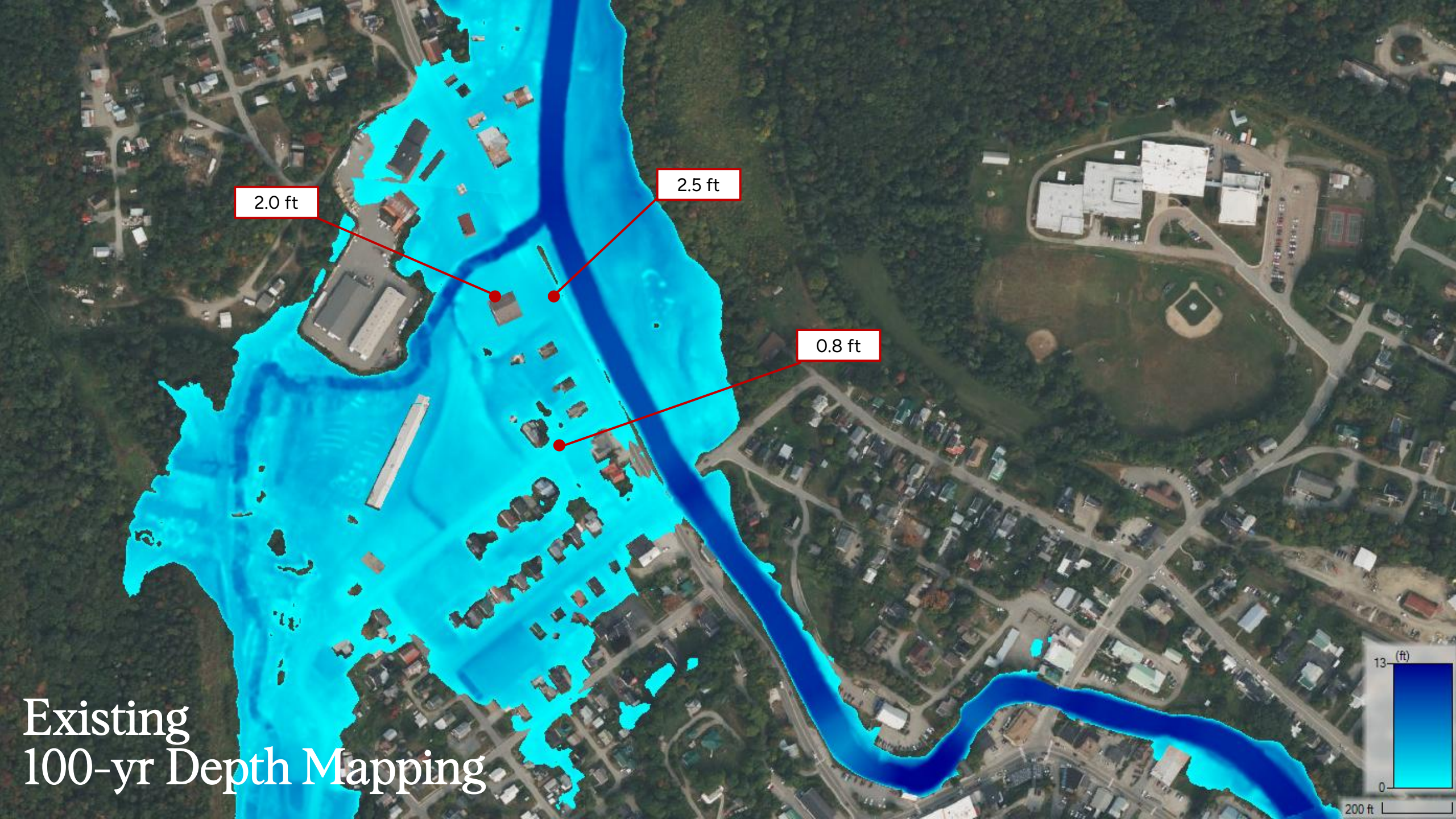


Results – Lamoille Profile

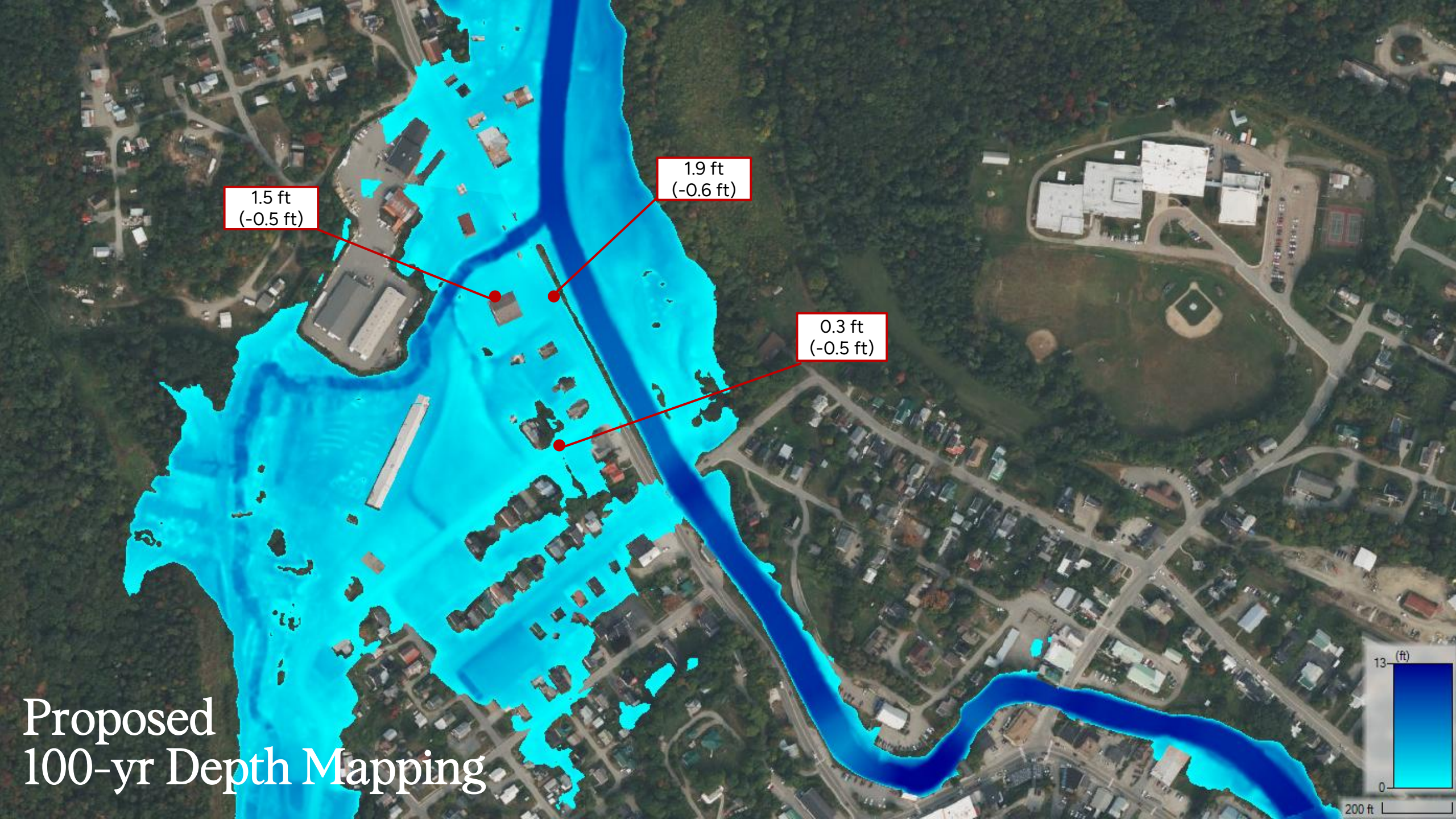


Results – Cooper Brook Profile



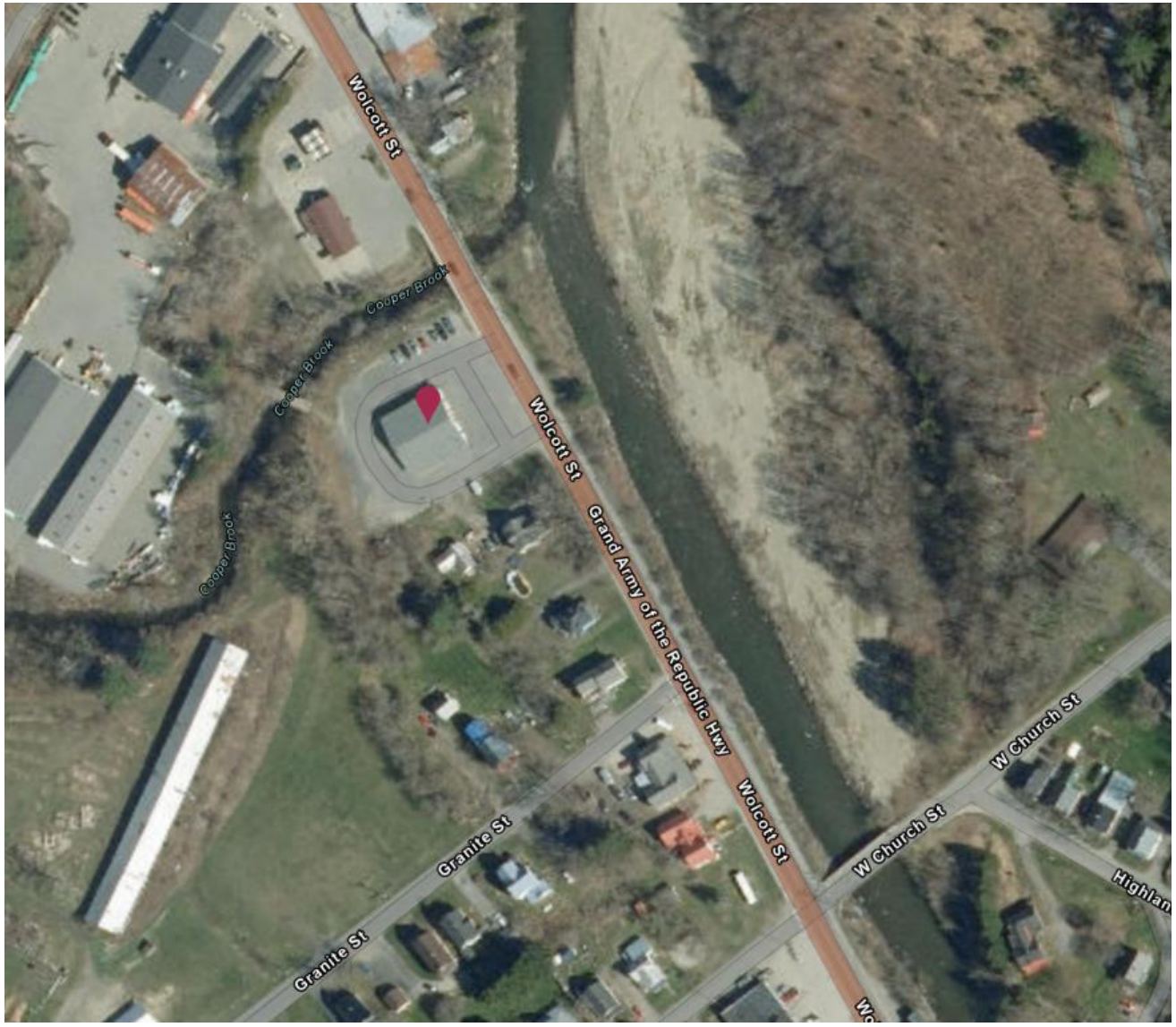


Existing 100-yr Depth Mapping



Proposed 100-yr Depth Mapping

Hardwick Fire Station



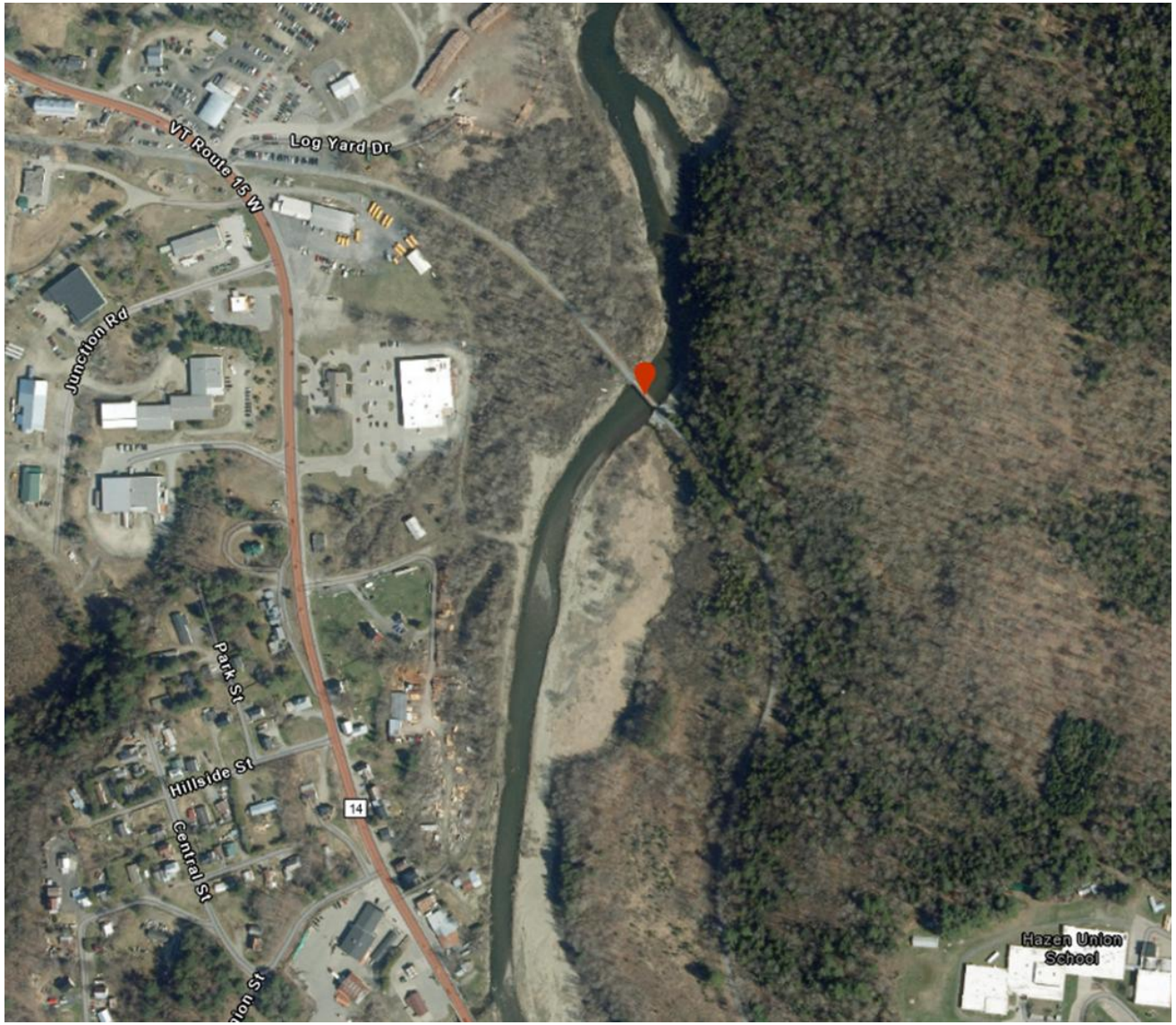
Problems

- Inundation Flooding
- Impact to emergency services

Possible Solutions

- Elevate ~4 ft (increases WSE ~0.01 ft)
- Relocation

LVRT Embankment



Problems

- LVRT Bridge is a constriction and backs up flow
- Embankment fully blocks floodplain

Possible Solutions

- Lower Embankment / Planned Overflow
- Widen Bridge

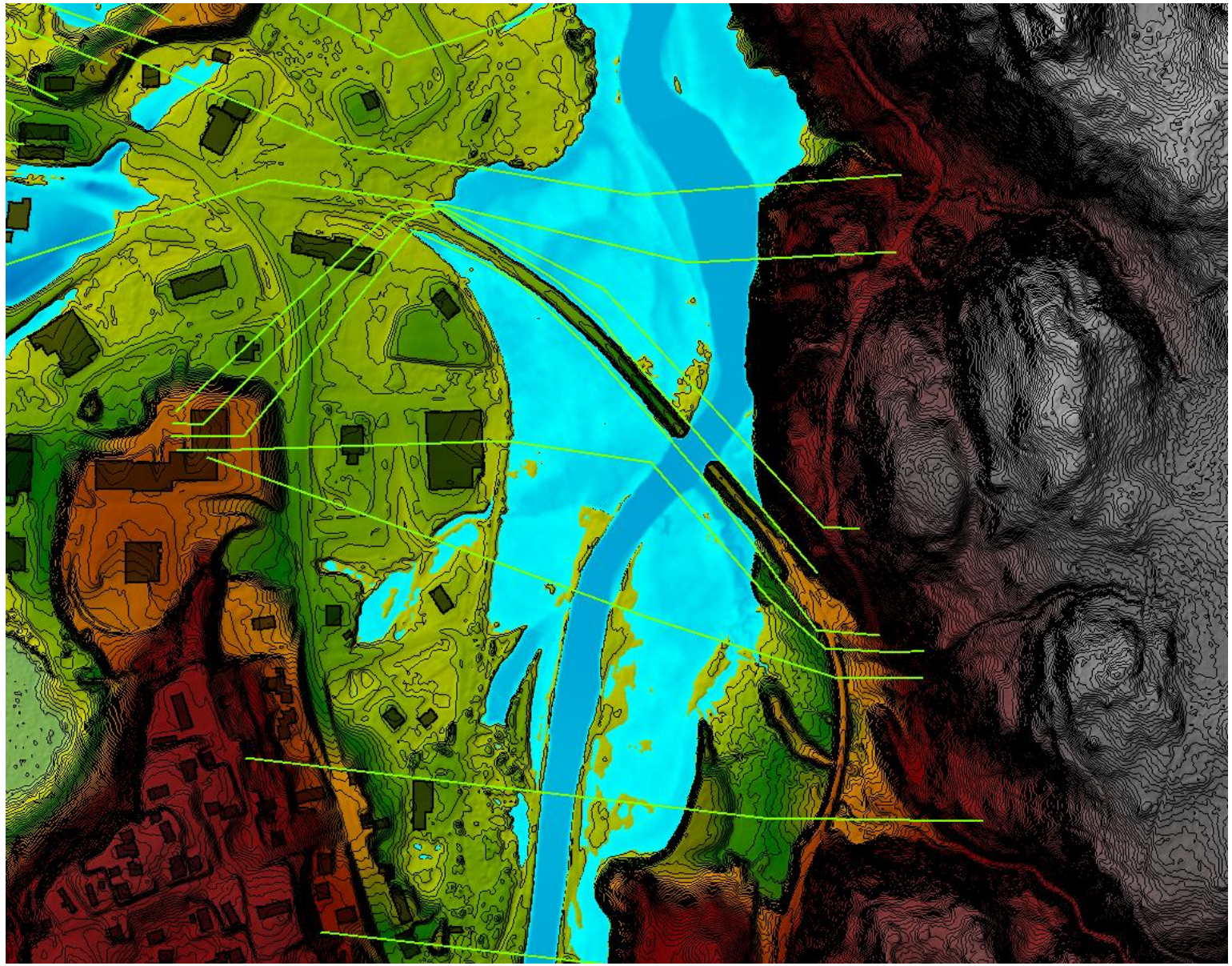
Small Flood (2-yr)

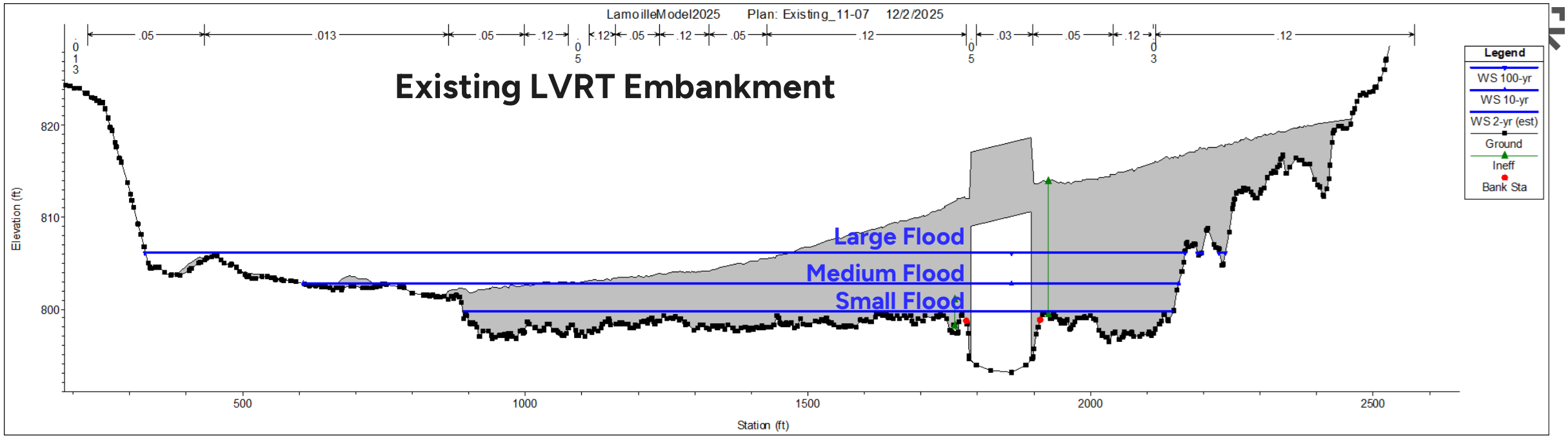
Model Cross Sections

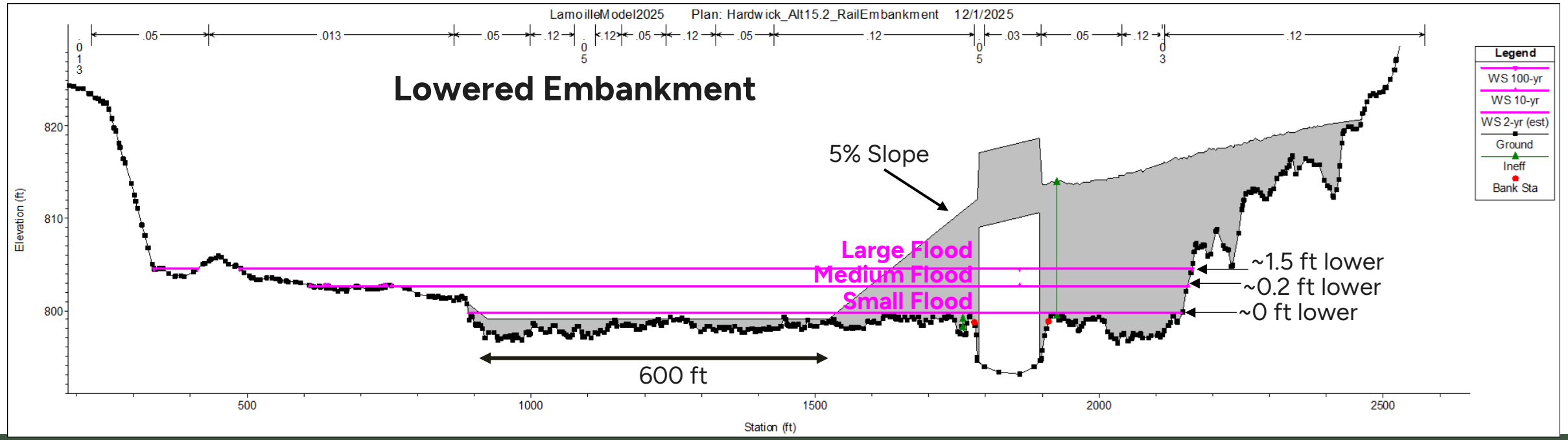
Terrain (2-ft contour)

Buildings

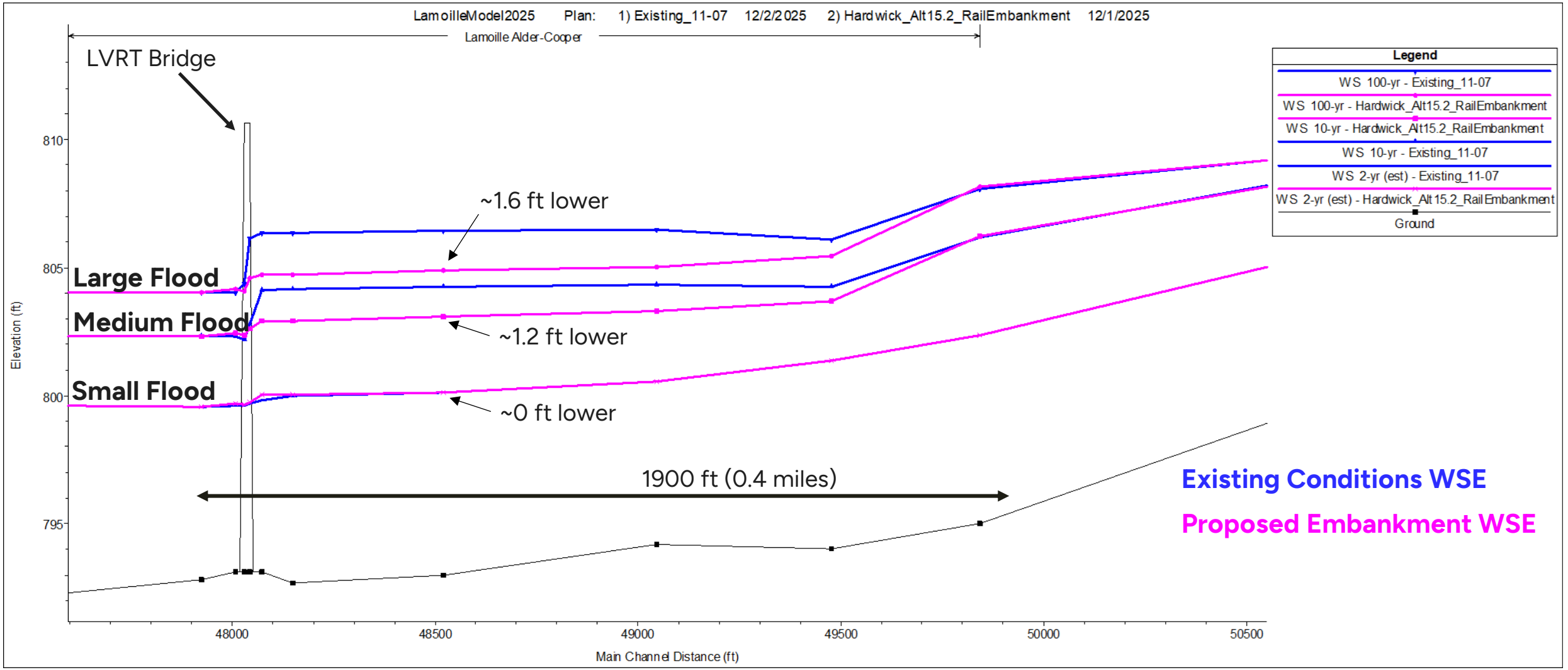
Water Depth



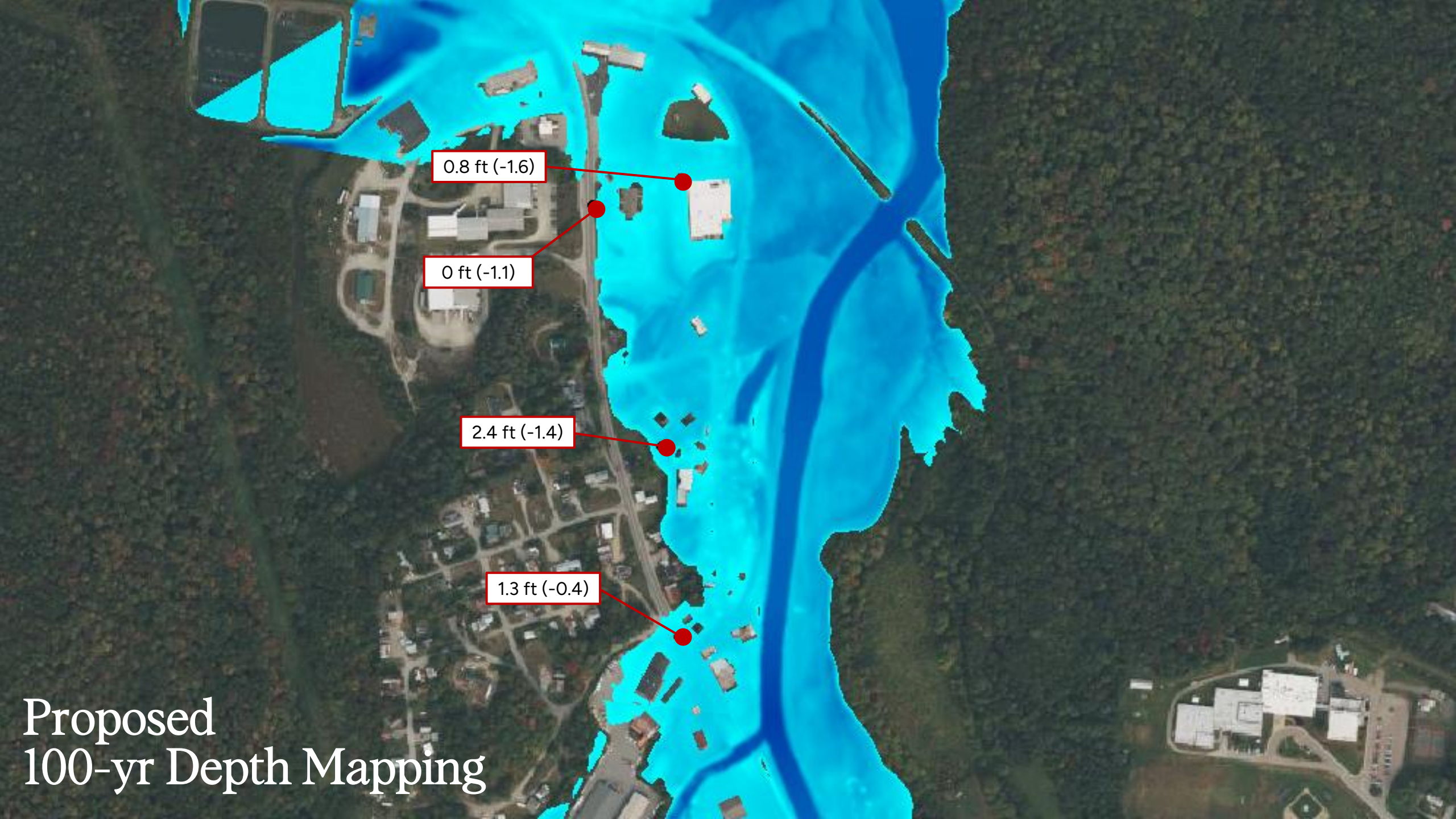

LamoilleModel2025 Plan: Existing_11-07 12/2/2025
Existing LVRT Embankment
Large Flood
Medium Flood
Small Flood
Legend
WS 100-yr
WS 10-yr
WS 2-yr (est)
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)


LamoilleModel2025 Plan: Hardwick_Alt15.2_RailEmbankment 12/1/2025
Lowered Embankment
5% Slope
Large Flood
Medium Flood
Small Flood
~1.5 ft lower
~0.2 ft lower
~0 ft lower
600 ft
Legend
WS 100-yr
WS 10-yr
WS 2-yr (est)
Ground
Ineff
Bank Sta
Elevation (ft)
Station (ft)

Results – Lamoille River Profile



Existing
100-yr Depth Mapping



Proposed 100-yr Depth Mapping

Jackson Dam

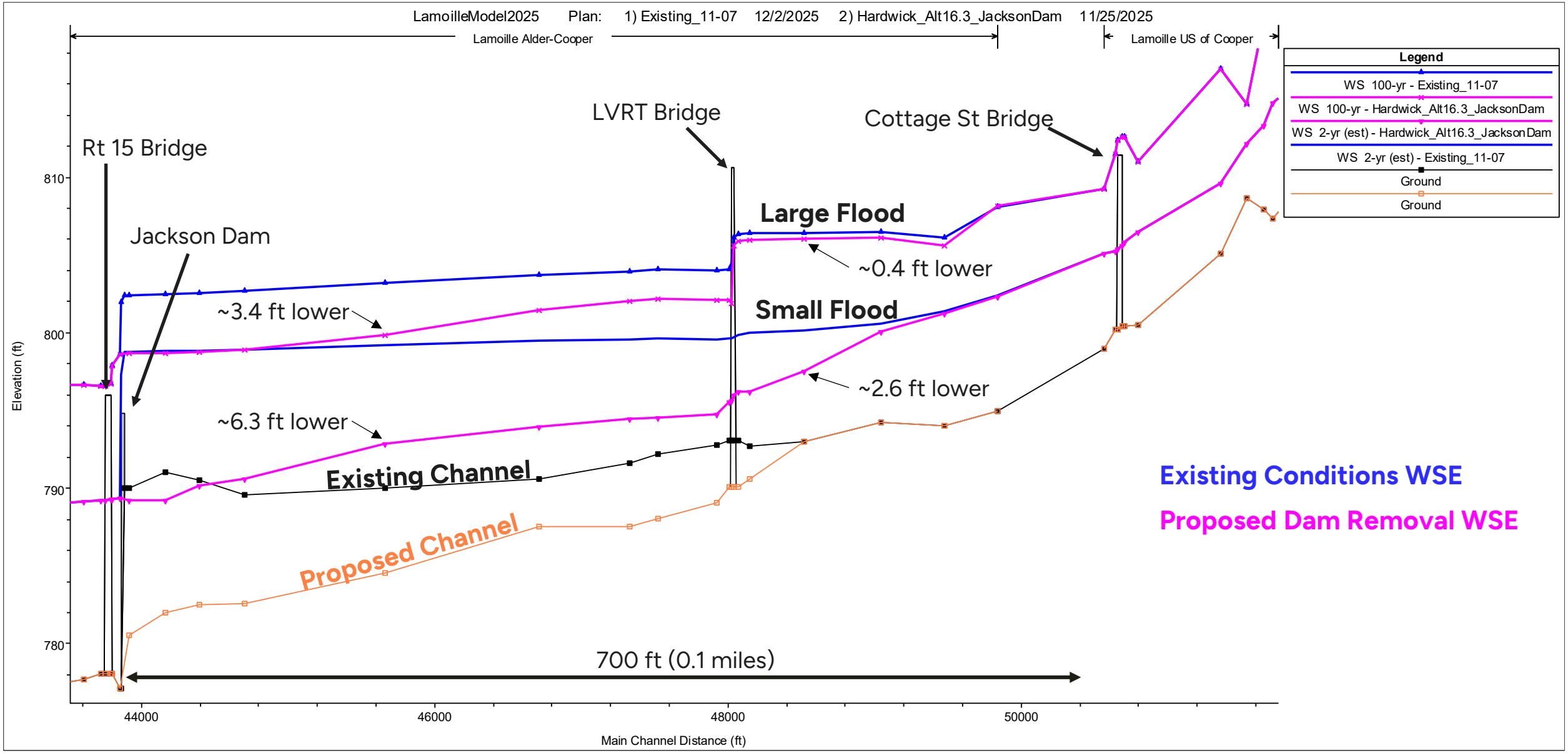
Problems

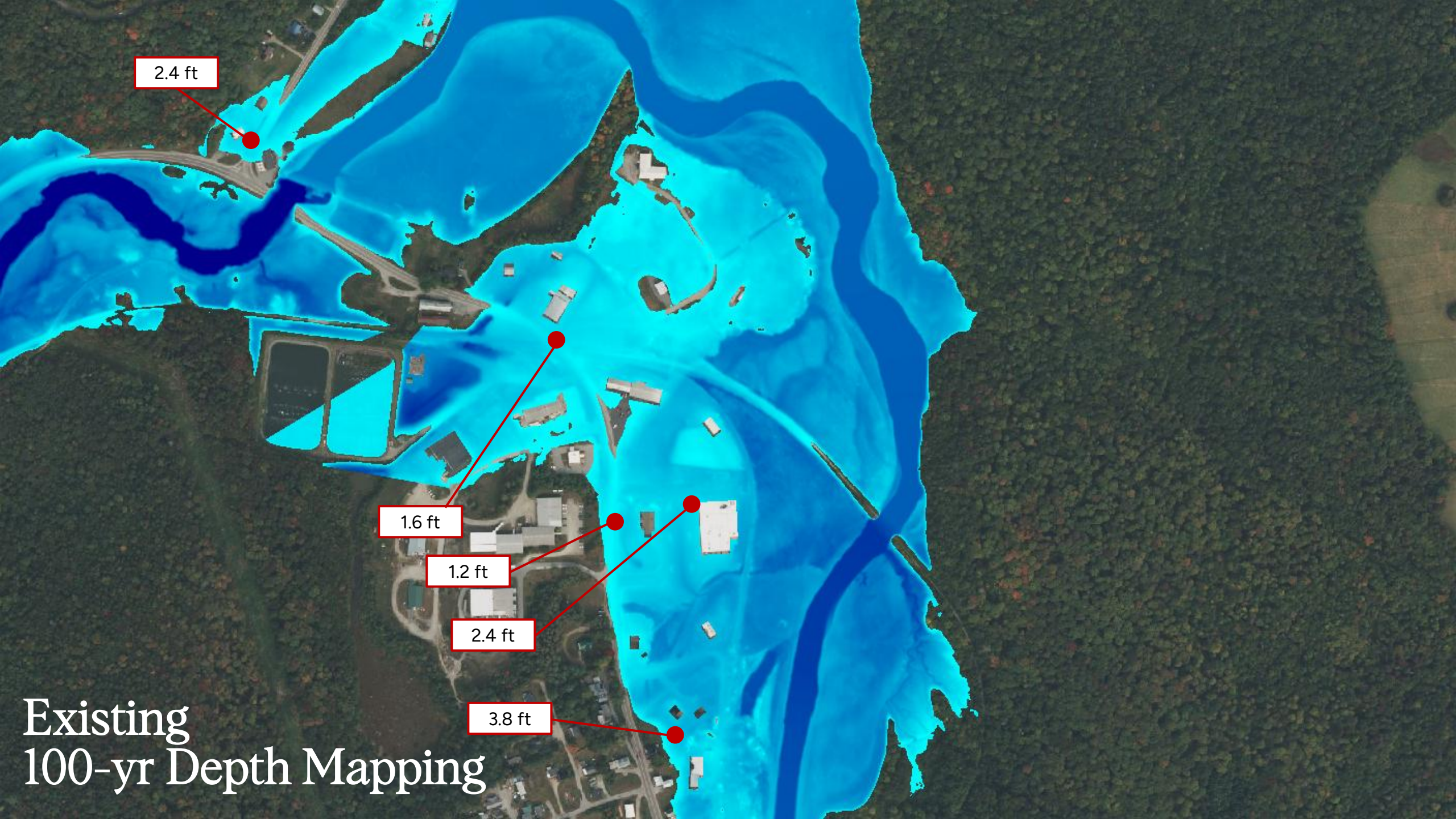
- Barrier in River

Possible Solutions

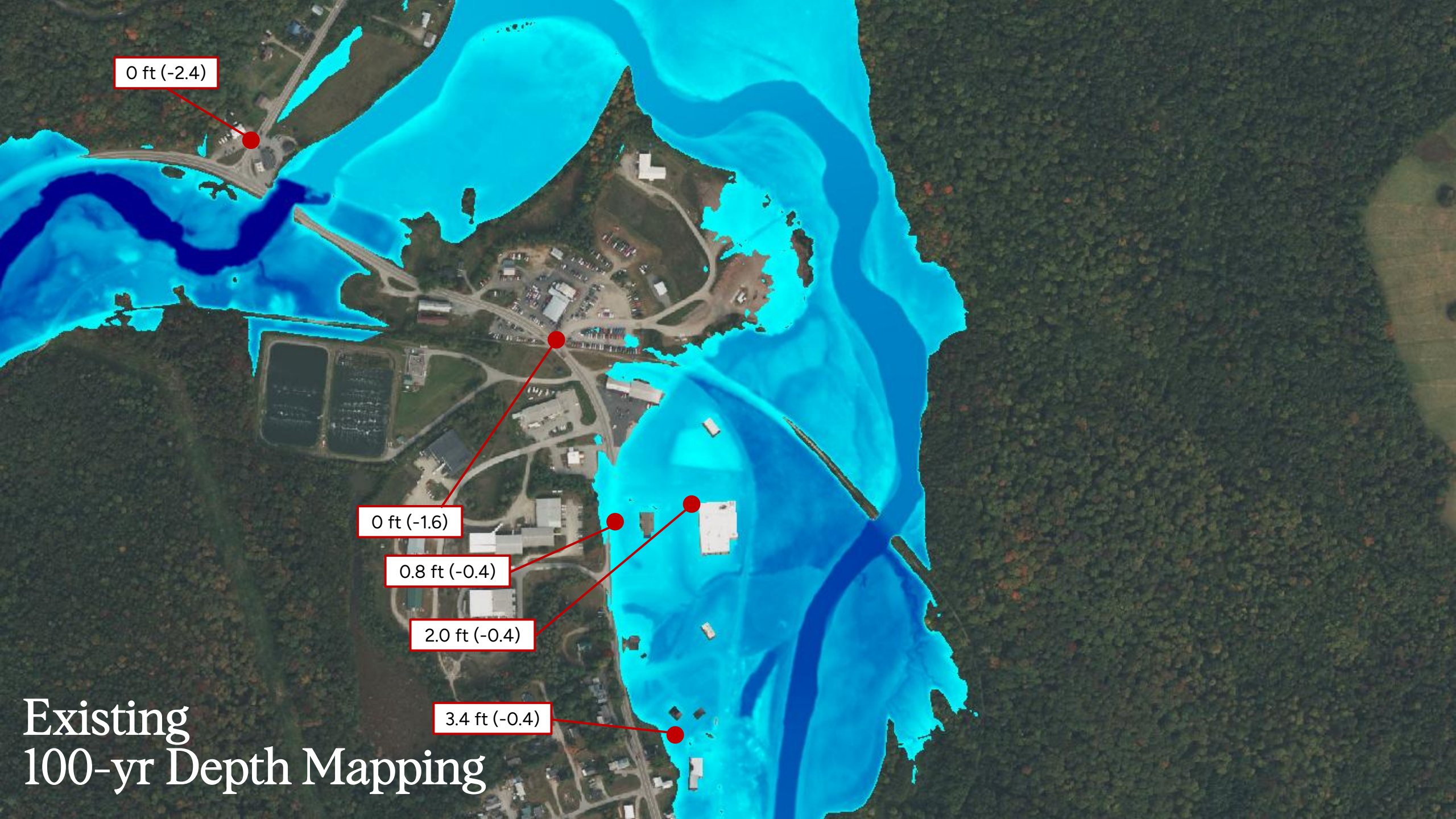
- Dam removal
- Permanent drawdown

Results – Lamoille River Profile



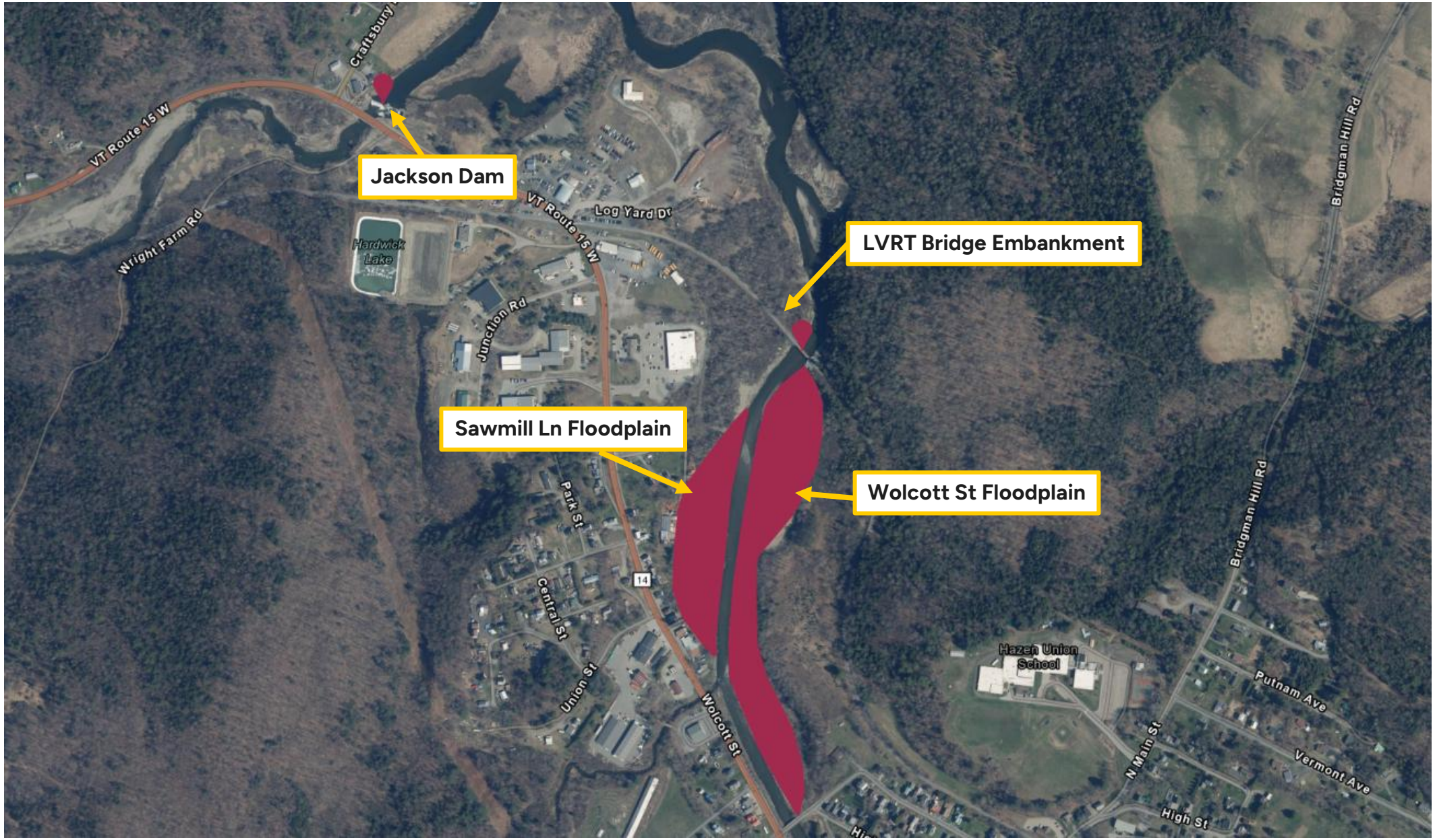


Existing 100-yr Depth Mapping

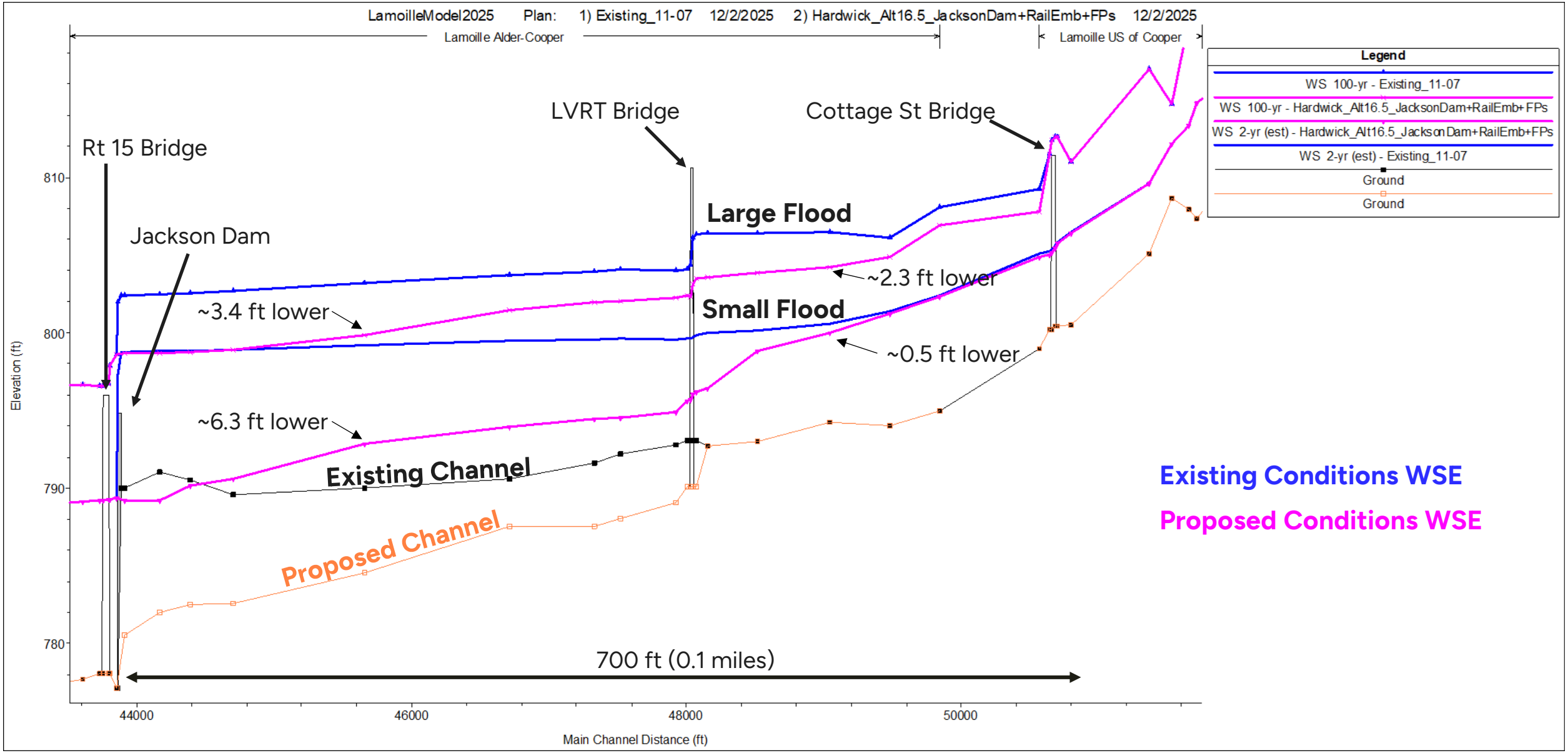


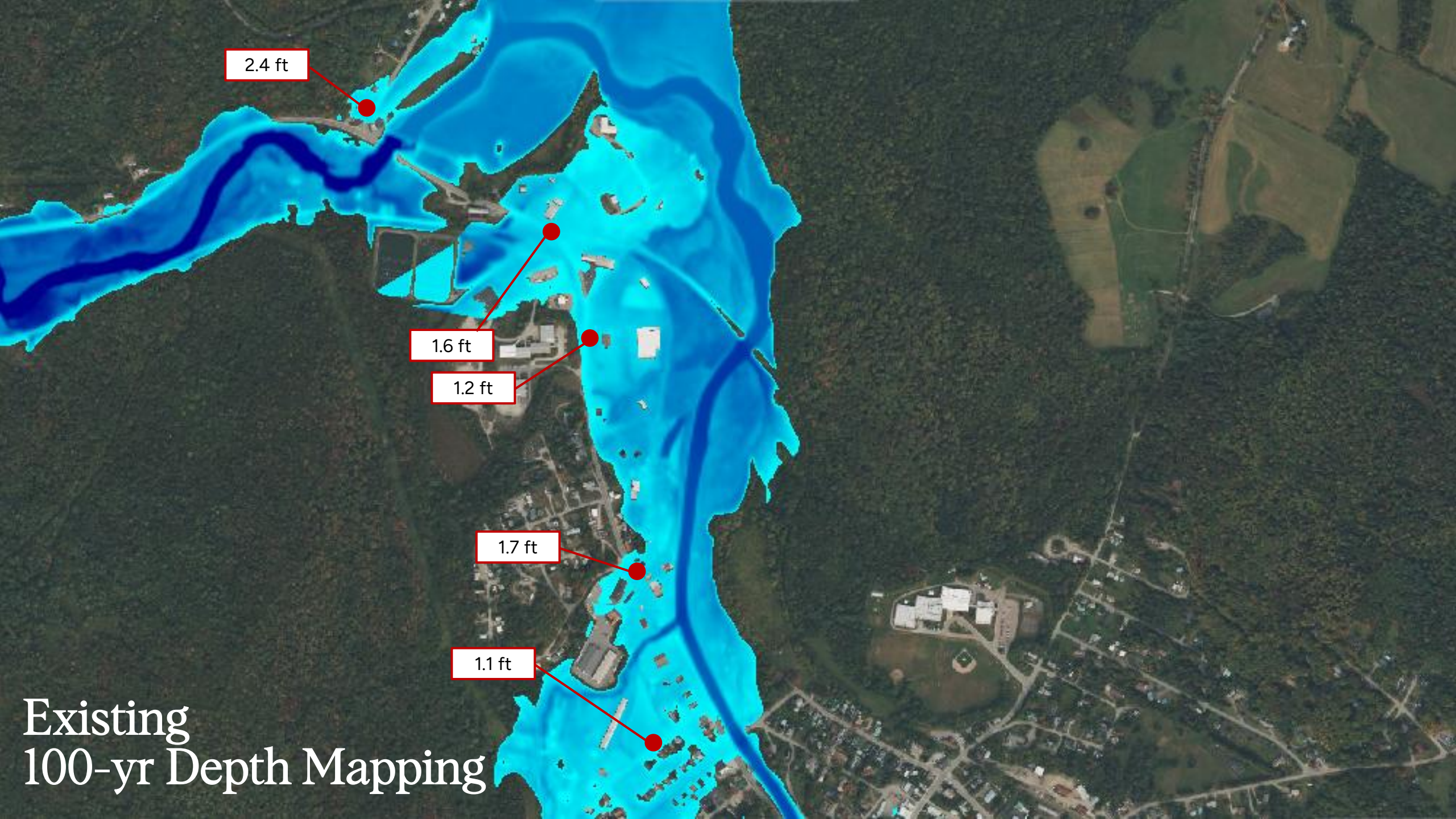
Existing 100-yr Depth Mapping

Combined Flood Mitigation Alternatives

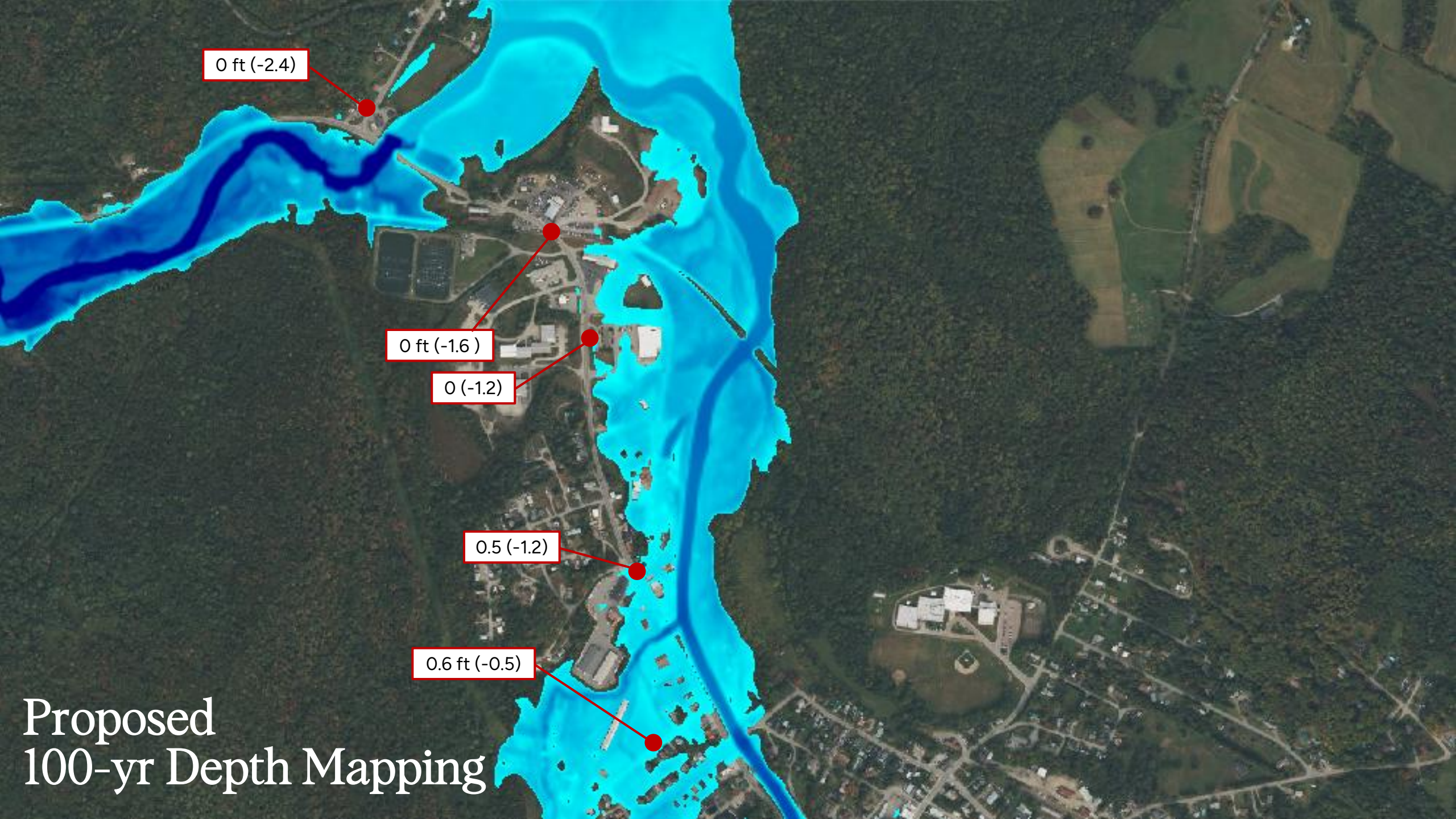


Results – Lamoille River Profile





Existing 100-yr Depth Mapping



Proposed 100-yr Depth Mapping

Questions?

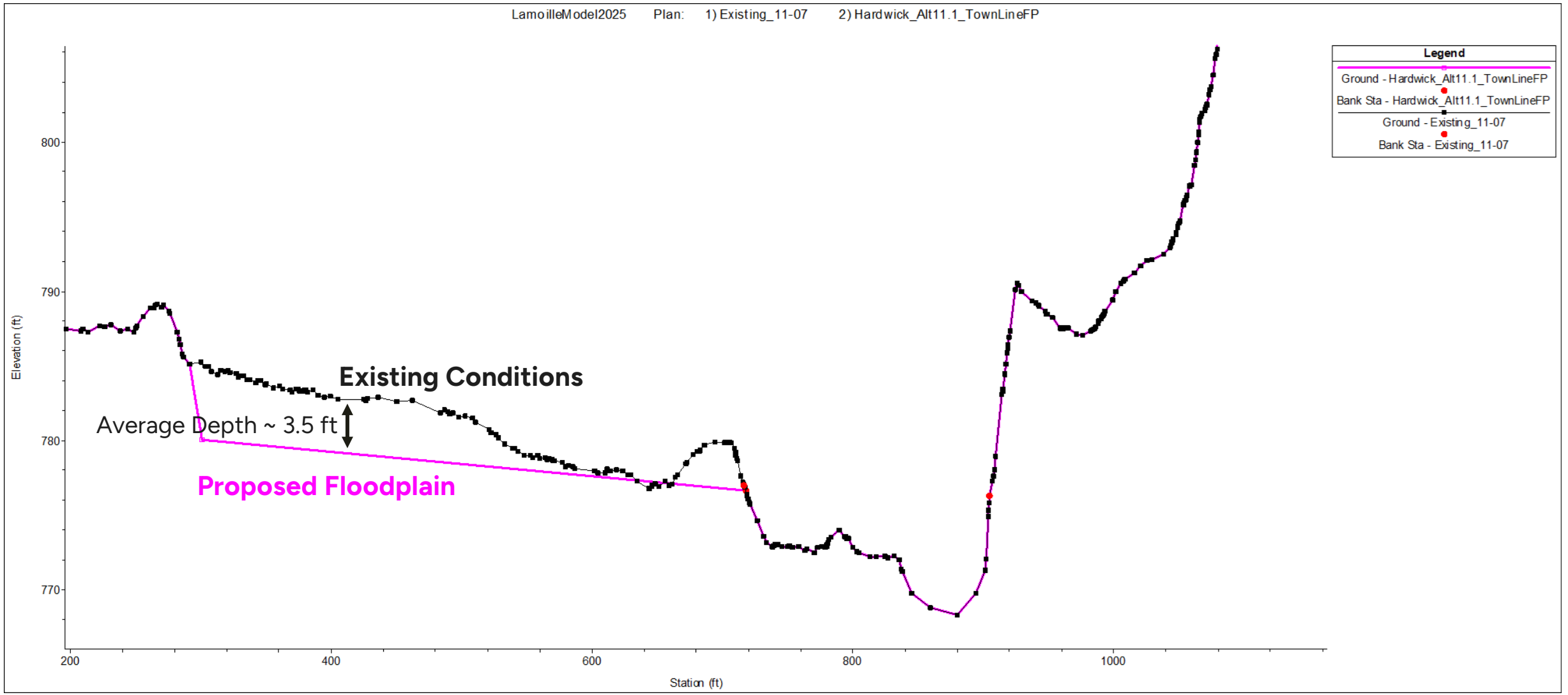
Extra Slides

(Civil Air Patrol, 7/12/2023)

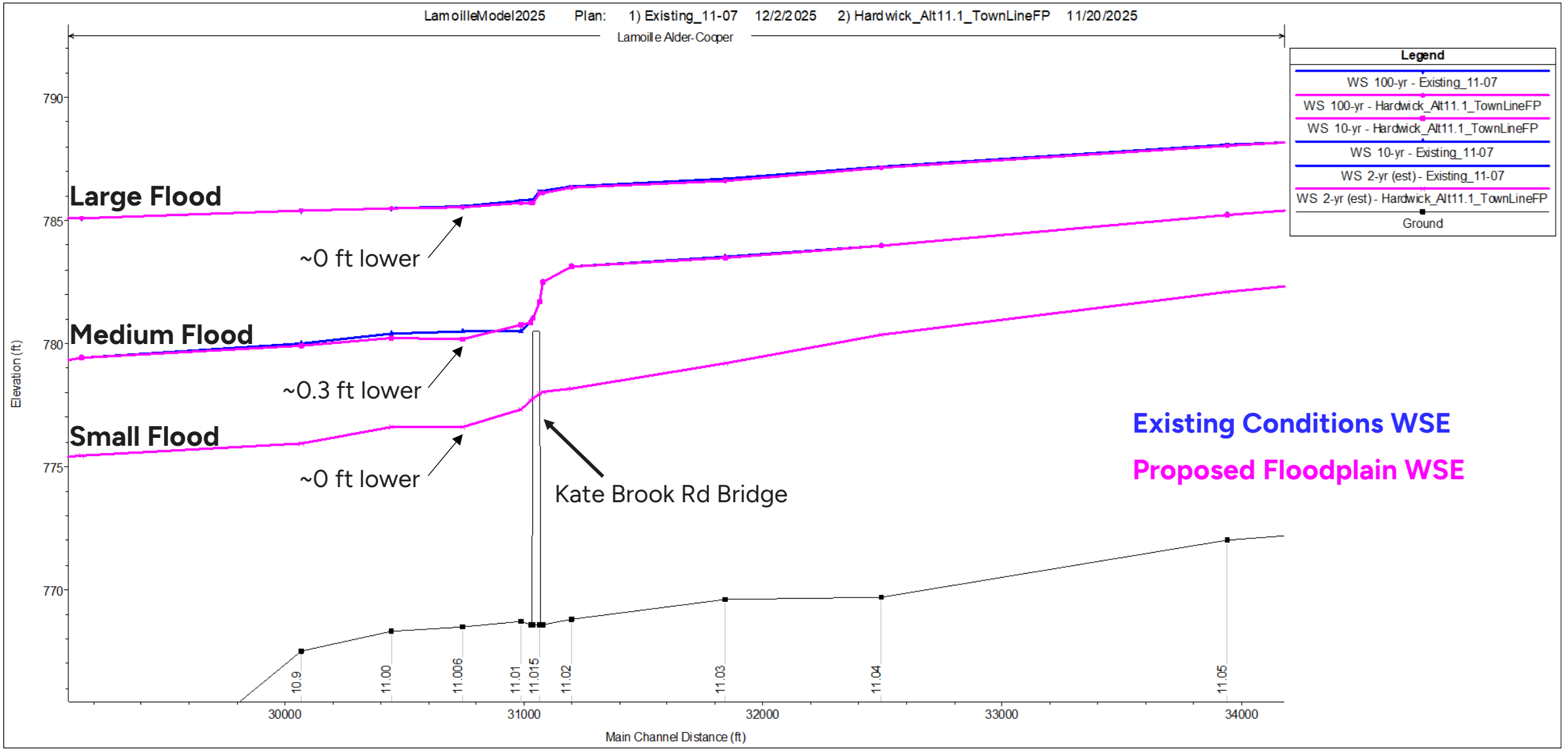
Town Line Floodplain

- Floodplain restoration (~10 ac)

Cross Section View – Existing and Proposed

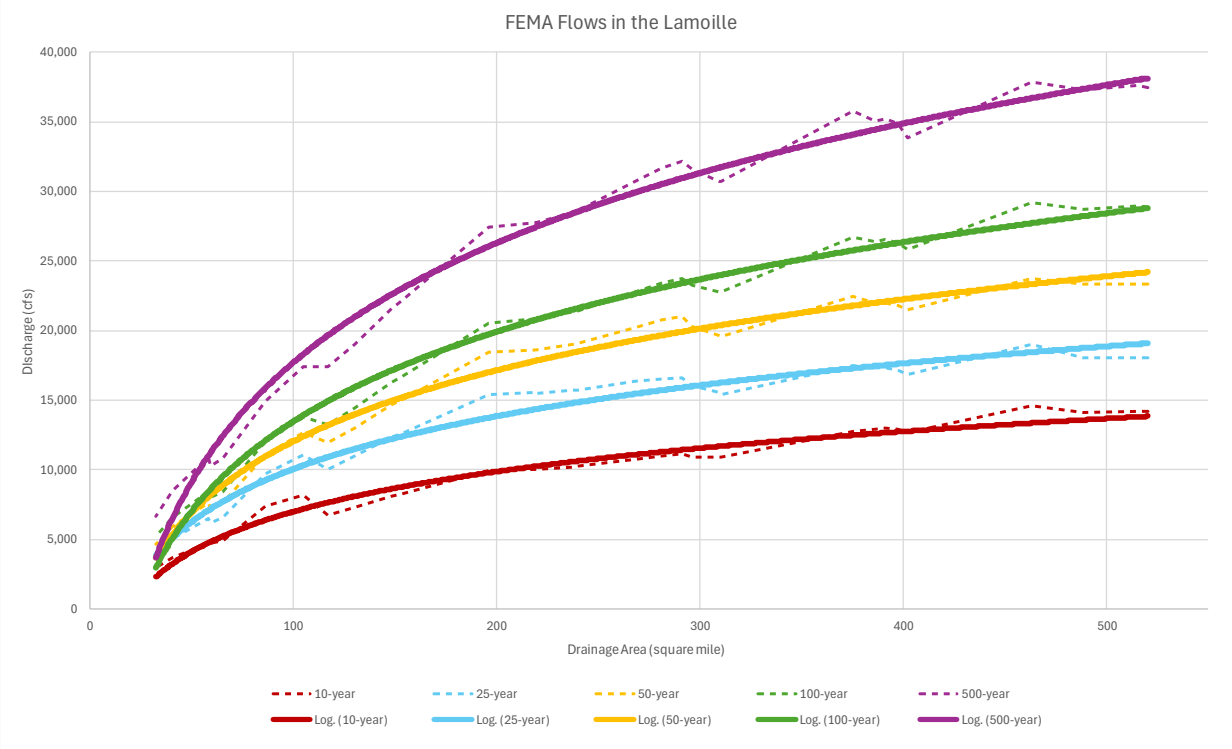


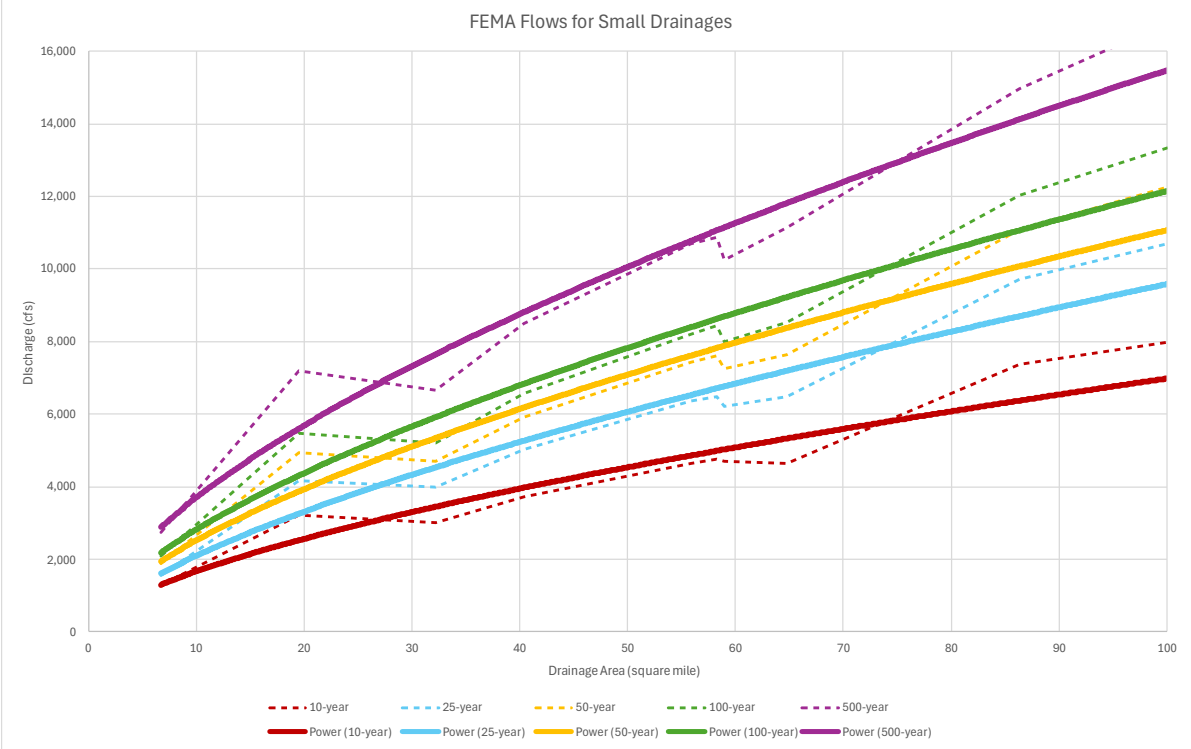
Results – Lamoille Profile



Flood Flows

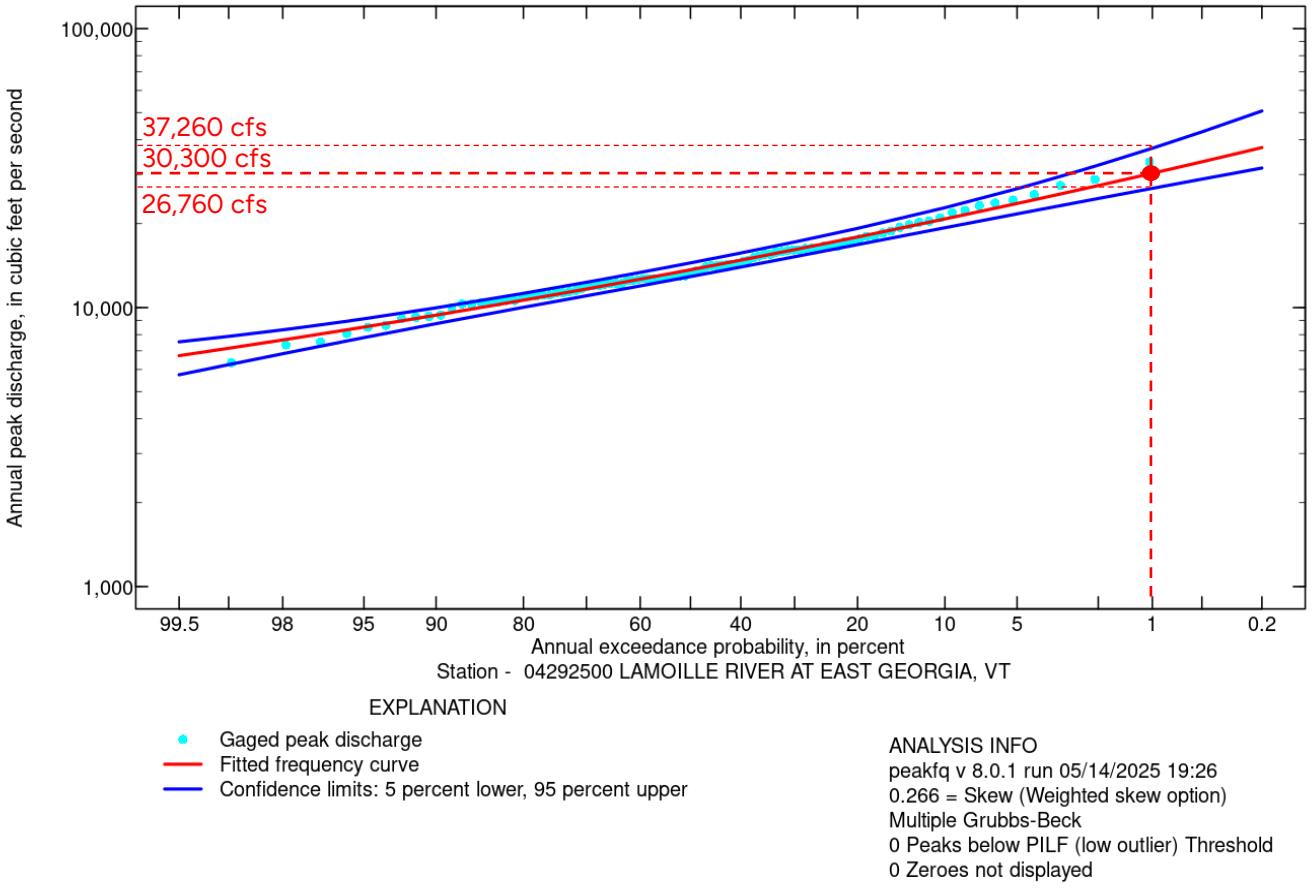
- The FEMA hydrologic study was limited to the mainstem of the Lamoille and a few tributaries
- Flows were estimated in areas without FEMA flows
  - FEMA flow trend lines
  - Scaled flows by drainage area





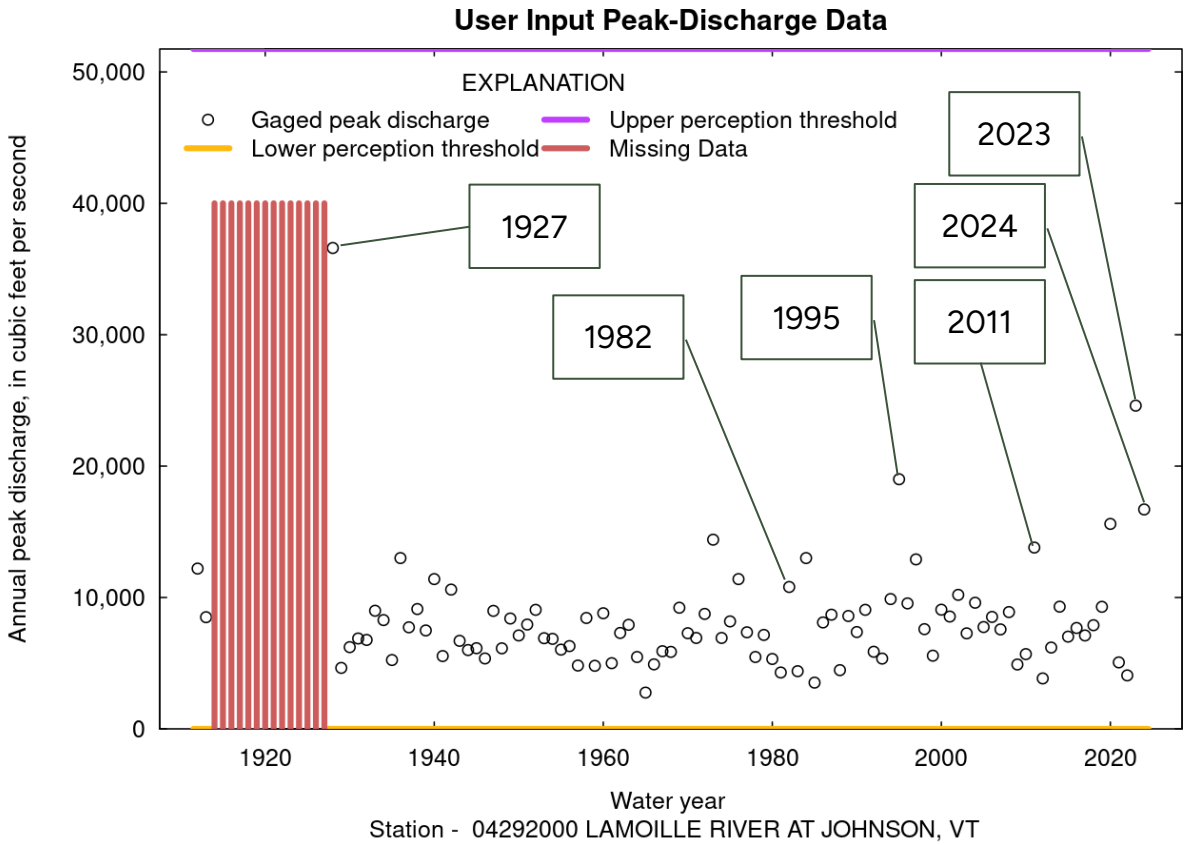
What is the 100-Year Flood?

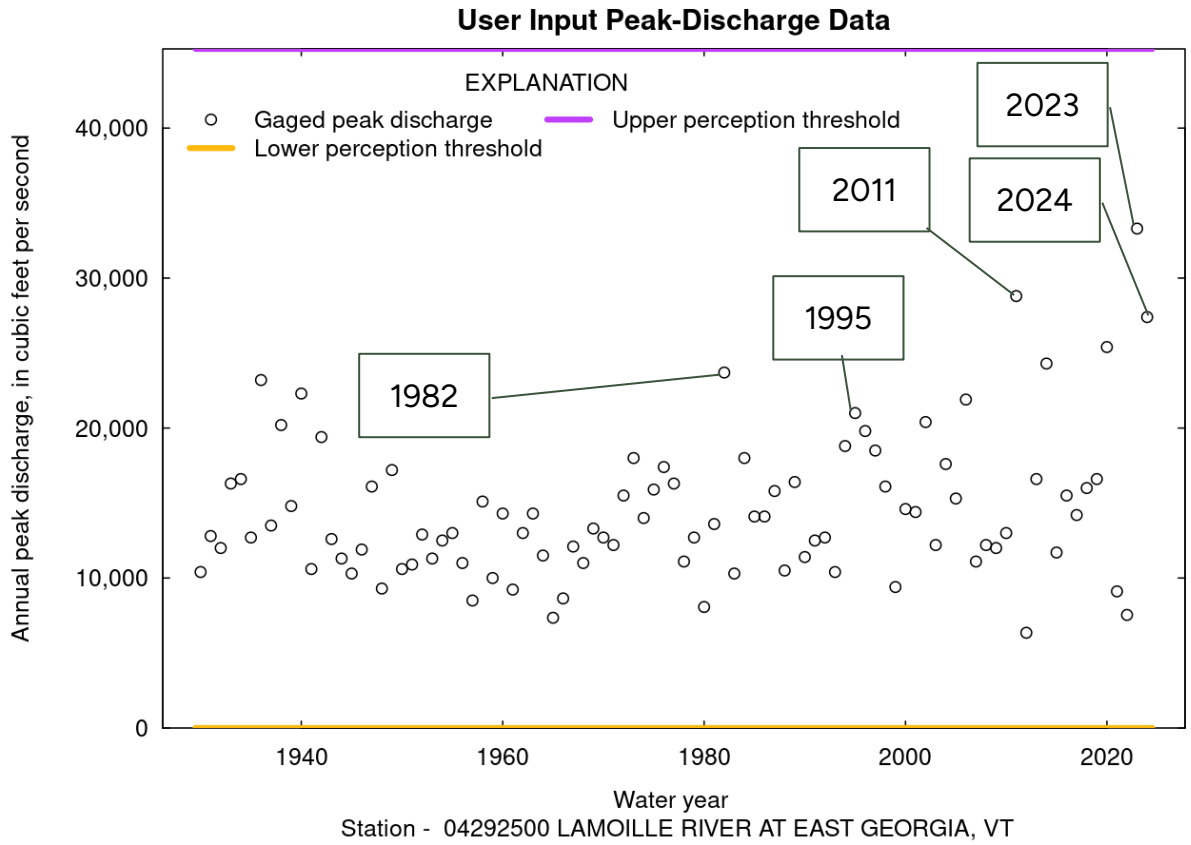
- The 100-year flood has a 1% chance of being equaled or exceeded in any 1-year.
- The 100-year flood has an average recurrence interval of 100 years.
- Chosen in the 1960's as the basis for the National Flood Insurance Program.
- The 1-percent annual exceedance probability (AEP) was "thought to be a fair balance between protecting the public and overly stringent regulation."



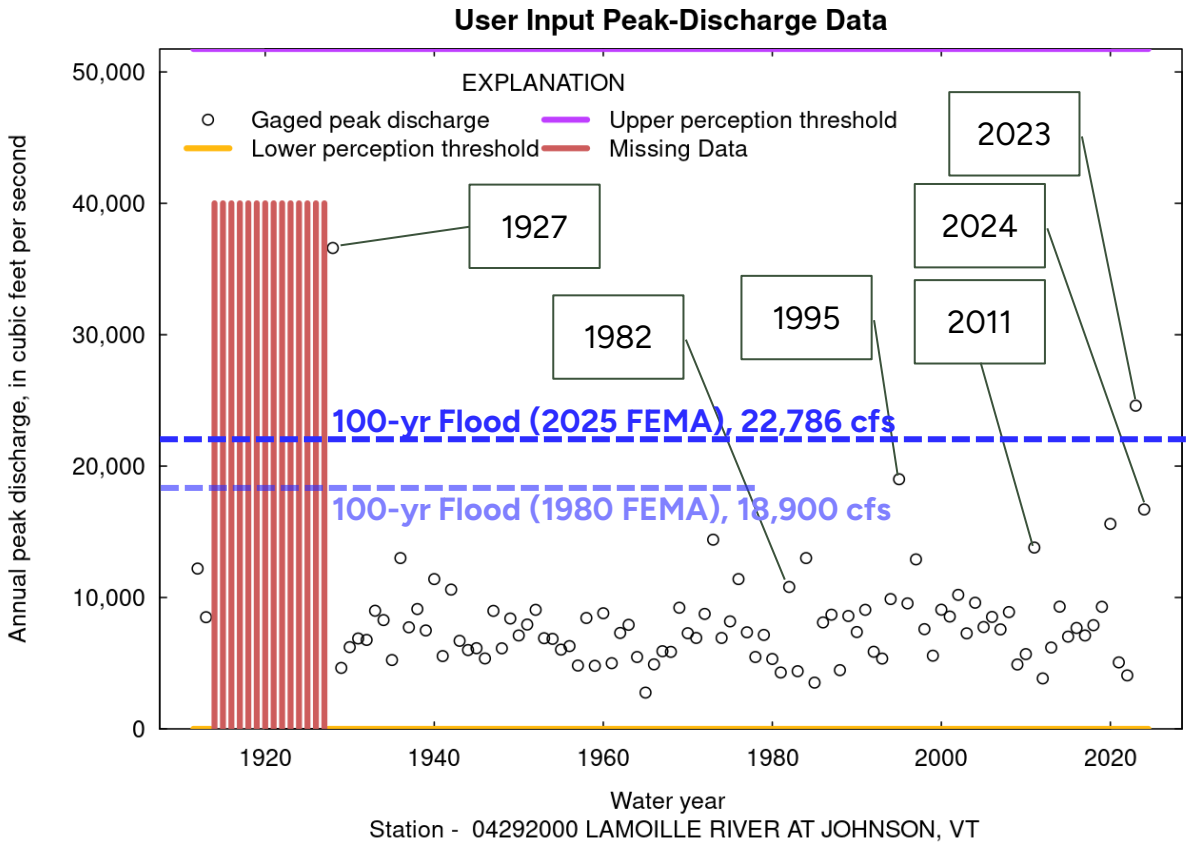
Source: Floods and Recurrence Intervals – USGS.gov

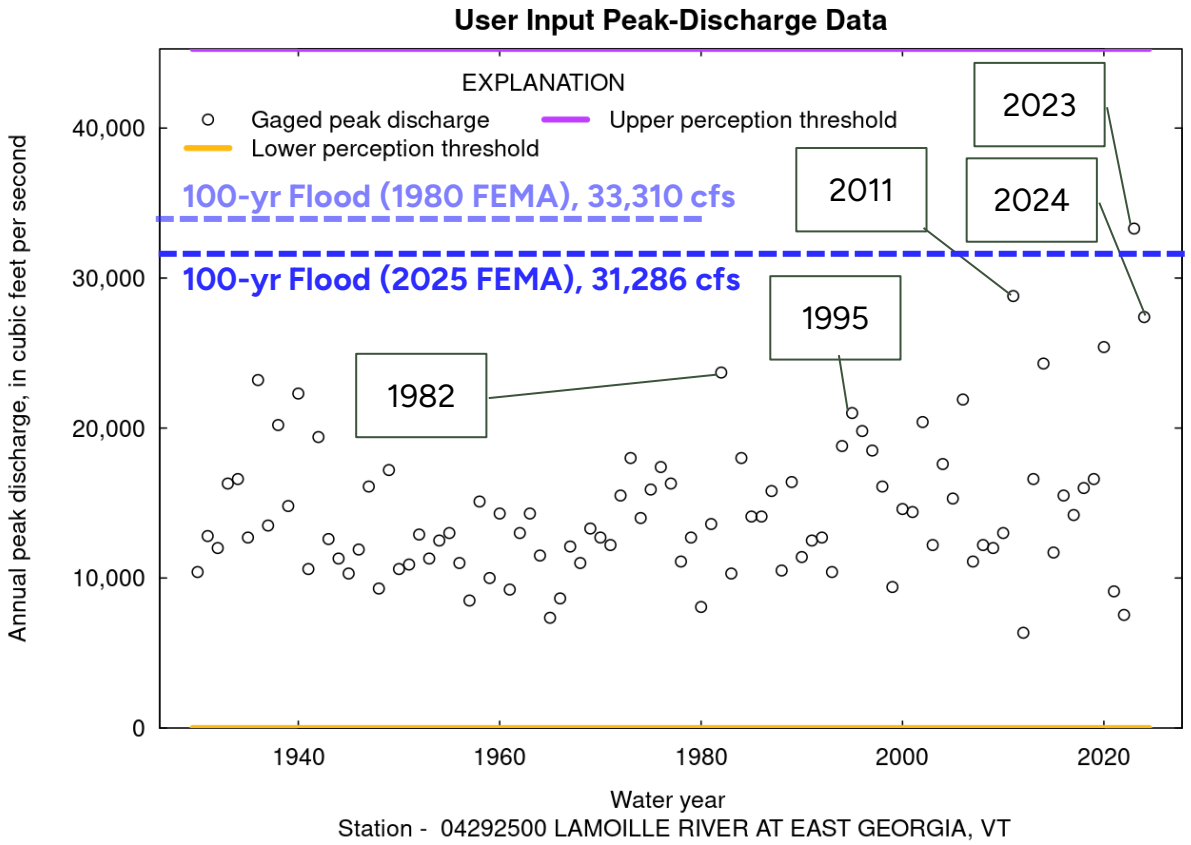
Hydrology


User Input Peak-Discharge Data
EXPLANATION
Gaged peak discharge
Lower perception threshold
Upper perception threshold
Missing Data
1927
1982
1995
2011
2024
2023
Annual peak discharge, in cubic feet per second
50,000
40,000
30,000
20,000
10,000
0
1920
1940
1960
1980
2000
2020
Water year
Station - 04292000 LAMOILLE RIVER AT JOHNSON, VT


User Input Peak-Discharge Data
EXPLANATION
Gaged peak discharge
Lower perception threshold
Upper perception threshold
1982
1995
2011
2024
2023
Annual peak discharge, in cubic feet per second
40,000
30,000
20,000
10,000
0
1940
1960
1980
2000
2020
Water year
Station - 04292500 LAMOILLE RIVER AT EAST GEORGIA, VT

Hydrology


User Input Peak-Discharge Data
EXPLANATION
Gaged peak discharge
Lower perception threshold
Upper perception threshold
Missing Data
1927
1982
1995
2011
2023
2024
100-yr Flood (2025 FEMA), 22,786 cfs
100-yr Flood (1980 FEMA), 18,900 cfs
Annual peak discharge, in cubic feet per second
50,000
40,000
30,000
20,000
10,000
0
1920
1940
1960
1980
2000
2020
Water year
Station - 04292000 LAMOILLE RIVER AT JOHNSON, VT


User Input Peak-Discharge Data
EXPLANATION
Gaged peak discharge
Lower perception threshold
Upper perception threshold
1982
1995
2011
2023
2024
100-yr Flood (1980 FEMA), 33,310 cfs
100-yr Flood (2025 FEMA), 31,286 cfs
Annual peak discharge, in cubic feet per second
40,000
30,000
20,000
10,000
0
1940
1960
1980
2000
2020
Water year
Station - 04292500 LAMOILLE RIVER AT EAST GEORGIA, VT

Flood Flows

- Used draft updated FEMA flood flows (July 2025).
- Flows were estimated in areas without FEMA flows
  - FEMA flow trend lines
  - Scaled flows by drainage area

Table 1: Flood Flows at USGS Gage 04292000 in Johnson

Recurrence Interval (years)	Updated 2025 FEMA Flows (cfs)	1980 FEMA FIS Flows (cfs)
10	10,890	10,800
25	15,430	n/a
50	19,546	16,050
100	22,786	18,900
500	30,717	27,200

Table 2: Flood Flows at USGS Gage 04292500 in East Georgia

Recurrence Interval (years)	Updated 2025 FEMA Flows (cfs)	1980 FEMA FIS Flows (cfs)
10	14,956	19,100
25	20,553	n/a
50	26,168	28,300
100	31,286	33,310
500	41,448	48,330

What is the 100-Year Flood?

- The 100-year flood has a 1% chance of being equaled or exceeded in any 1-year.
- The 100-year flood has an average recurrence interval of 100 years.
- Chosen in the 1960's as the basis for the National Flood Insurance Program.
- The 1-percent annual exceedance probability (AEP) was "thought to be a fair balance between protecting the public and overly stringent regulation."

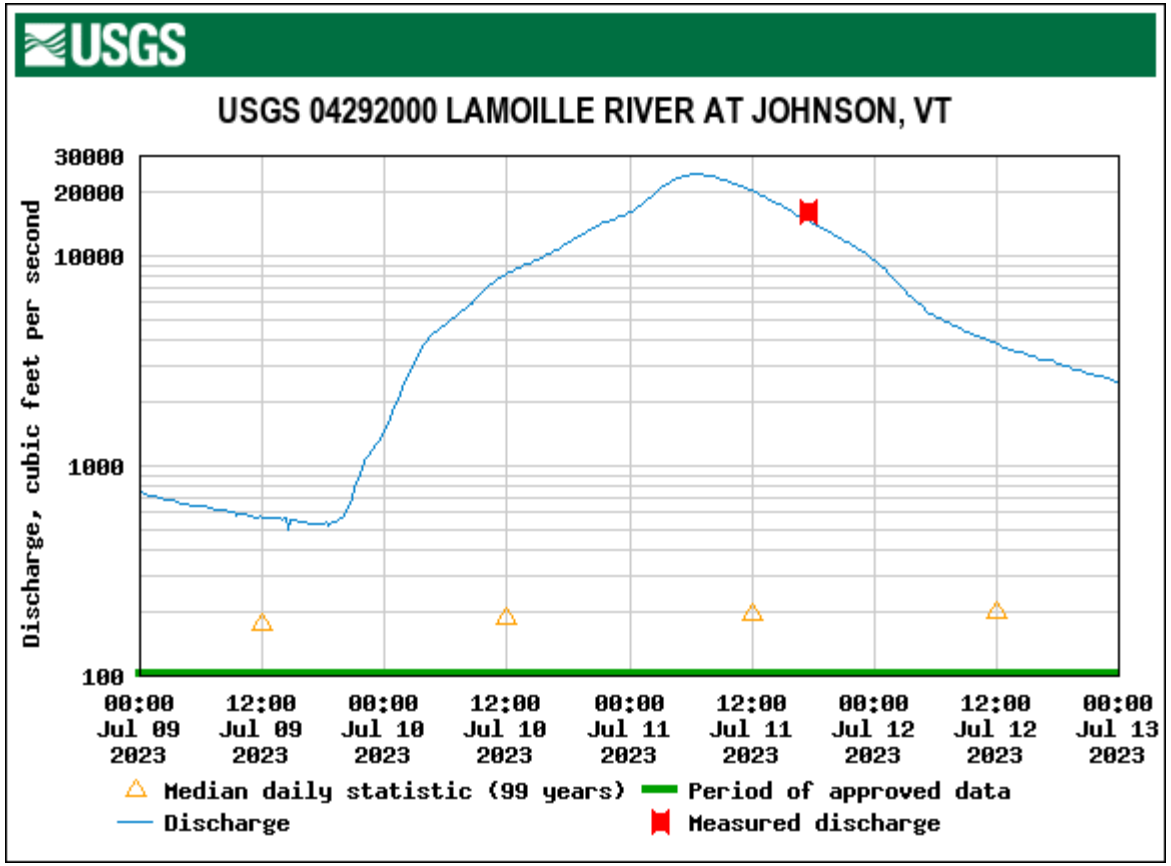
Recurrence Interval (years)	Annual Exceedance Probability
2	50%
10	10%
25	4%
50	2%
100	1%
500	0.2%

Source: Floods and Recurrence Intervals – USGS.gov

Hydrology

- **How much water is in the river?**
  - Rainfall Amount, Duration, and Intensity
  - Topography
  - Land Cover
  - Soil Moisture
  - Etc.

- **Calculating Flood Flows**
  - Gauge Analysis
  - Rainfall-Runoff Modeling
  - Regional Regression



Greenway Trail Bridge Replacement– Jeffersonville

Removed constriction

- An undersized bridge and unused abutments were removed
- Larger bridge installed
- Opened up floodplain under bridge

Dog River Floodplain Restoration – Northfield

Removing buildings, people, & infrastructure from vulnerable locations

- Remove 7 damaged homes
- Remove 9,000 CY fill in floodplain & lower land average 4 feet over 3 acres
- Remove berm
- Plant restored floodplain with native vegetation

Route 15 Bypass Culverts – Cambridge

Provide additional capacity under highway embankment

- Large culvert installed under road
- Floodwater trapped behind road embankment can flow out of village
- Road overtops less
- Buildings flooded less