Saco River Flood Hazard Reduction Study

Town of Bartlett, New Hampshire

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EXECUTIVE SUMMARY

OVERVIEW

A flood hazard reduction study of the Saco River was conducted from the Second Iron Bridge to approximately 0.9 of a mile downstream of River Street in the Town of Bartlett, NH. The study included community involvement, the collection of field data, an assessment of river morphology and stability, a flood frequency analysis, hydraulic modeling of existing conditions, and modeling of flood hazard reduction options.

The stability of the river was assessed using remote sensing and field work. Deposition of sediment was found to be the major geomorphic adjustment occurring within the study area, due to both the natural characteristics of the river and historic dredging of the channel.

A two -dimensional hydraulic computer model of the study area was used to evaluate flood inundation and hydraulic characteristics. The geometry of the channel and surrounding floodplain of the study area was based on LiDAR topography flown in November 2016 and published in 2019, as well as field-measured cross sections for channel bathymetry. Culverts and bridges were added to the model based on field measurements of the structures. The model was calibrated to the October 2017 flood event and then run for flows from the 2-year up to the 500-year events.

EXISTING FLOODING

Modeling of existing conditions provided insights into the location, frequency, and patterns of flooding. Particularly important findings include:

- **Immediately below the Second Iron Bridge**, water begins to leave the channel during the 10-year event, and there is significant risk of bank erosion.
- **At the downstream end of the Dugway**, water begins to spill onto Cobb Farm Road during approximately the 50-year event.
- **At the Cobb Farm / Stanton Road intersection**, water begins to overtop the road at the 10-year event, and vehicle passage is questionable by the 25-year event. This water flows from near the Dugway through the woods to the intersection.
- **The south berm** begins to overtop in single discrete location during approximately the 10-year event, and by the 50-year event, approximately one third of its length is overtopped.
- **River Street** floods primarily due to water overtopping the south berm. Water begins to flow over the road during the 10-year event, and by the 25-year event, much of the road is under at least a veneer of water making vehicular travel questionable.

PROPOSED FEMA BERM REPAIRS

Proposed repairs to the berms on the north and south sides of the river were evaluated. The results show that the proposed northern FEMA berm repairs reduce the frequency and extent of flooding of the Cobb Farm / Stanton Road intersection, but due to overtopping and outflanking of the berm, roadway flooding nonetheless persists for the 50-year and greater events. The proposed southern FEMA berm repair will reinforce an area damaged during the 2017 flood. There is no proposed increase in the height of the southern berm; therefore, reduction in flooding is not expected due to the repair.

ADDITIONAL FLOOD MITIGATION ALTERNATIVES

Seven potential flood hazard reduction alternatives, in addition to the North and South FEMA Berm Repairs, were identified. Sketches of each are included in Appendix D. A subset of these – Alternative #s 1, 3 and 5 – were evaluated in detail.

Alternative 1) Dredging of channel above River Street Bridge - The existing and dredged conditions were evaluated for the 100-year event. The results showed no significant difference in water surface elevations or flood extent upstream of the bridge.

Alternative 2) New Single-Span River Street Bridge (not evaluated in detail) **-** A single-span bridge would increase the hydraulic capacity and be less prone to debris blockage, but is a relatively expensive alternative with benefits that may not extend far enough upstream to eliminate all overtopping of the southern berm or prevent flooding at the location of the northern FEMA berm, without concurrent improvements at those locations. Additional analysis is necessary to evaluate the efficacy of this alternative.

Alternative 3) Taller Southern Berm -This alternative involves raising the existing South Berm continuously from River Street up to approximately Albany Brook and protecting it from erosion. The results show significant reduction in flooding on the south floodplain in Bartlett Village compared to existing conditions, but some flooding of River Street remains possible during the 50-year and larger events.

Alternative 4) Raise River Street and Install Larger Culverts (not evaluated in detail) **-** The flooding of River Street affects access to homes on the other side of the river. Raising the road and installing larger culverts has the potential to keep the road dry under a larger range of flows, but there's the risk of increased flooding of homes on the upstream side when the culvert capacity is exceeded and the higher roadway acts as a dam. Additional analysis is necessary to evaluate the efficacy of this alternative.

Alternative 5) Taller and longer Northern Berm -The intent of this alternative is to construct a berm on the north side of the river with sufficient height and length to prevent flooding of Cobb Farm Road at the Dugway and at the intersection with

Stanton Farm Road during the 100-year event. The berm would need to be taller than the proposed FEMA berm to prevent overtopping, and it would need to be extended to tie into higher ground to prevent outflanking, which would require raising a portion of Cobb Farm Road at the Dugway. The berm could be located generally on the footprint of the FEMA berm, but there are significant benefits to locating it further from the river to reduce the risk of failure due to erosion.

Alternative 6) New Bridge at Cobb Farm Road / Stanton Farm Road Intersection (not evaluated in detail) - This alternative is intended to keep the Cobb Farm Road/Stanton Farm Road intersection dry when water from the Saco flows across the northern floodplain to the intersection, as currently occurs. Additional analysis is necessary to evaluate the efficacy of this alternative.

Alternative 7) Buyouts (not evaluated in detail) - FEMA has a voluntary program to purchase and remove structures that are subject to repetitive flooding. Candidates for buyouts are often structures that are at risk for repeated flooding or damage due to erosion.

RECOMMENDATIONS

- If reconstruction of existing and former berms is pursued, they should be designed to withstand the considerable erosive forces that will continue to challenge their performance.
- If reconstruction of the North berm is pursued, consider relocating it away from the river to accommodate the down-valley movement of the meander bend and to shield it from the highly erosive forces at the river's edge, raising it to prevent overtopping, and extend it upstream to prevent it from outflanking.
- Use the flood inundation maps presented in this study to inform decisions about suitable building locations, as the flood extents differ significantly from what is shown on the FEMA Flood Insurance Rate maps.
- Consider buyouts of homes where flooding cannot be mitigated or that are prone to fluvial erosion hazards.
- Consider repairing locations on the Southern Berm that are shown to be the initial locations of overtopping (in the vicinity of Tir Na Nog Lane and at the eastern end near River Street).
- Further evaluate the benefit of additional and larger culverts on River Street, coupled with excavation upstream to better direct flow to the culverts.

1.0 INTRODUCTION

The Town of Bartlett, NH has experienced two major floods over the past decade. Flooding during tropical storm Irene (summer 2011) and the Halloween Storm (Fall 2017) storm damaged infrastructure, flooded roadways and homes, and resulted in public safety risks to residents. More than 150 residents on the north side of the river were stranded during these large flood events due to flooding of Cobb Farm Road and River Street. A number of efforts were undertaken to repair damage caused by Tropical Storm Irene including: dredging the river upstream of the River Street Bridge, rebuilding and armoring the south bank upstream of the bridge, and installing two 10 foot box culverts to provide additional capacity at the bridge. These efforts did not successfully mitigate flooding that took place during 2017. For this reason, the Board of Selectmen and town residents are seeking technical guidance on how to reduce flood hazards in Bartlett, protect properties, and improve public safety.

Berms, which were reportedly constructed by the Corps of Engineers in the late 1960s to protect properties in Bartlett Village and elsewhere, have been compromised by recent storms, and the town has applied to FEMA to repair them. Town residents, the Board of Selectmen, and the town engineer have reported the Saco River is adjusting rapidly due to recent, intense flood events. Erosion of the berm on the north side of the river below the dugway has caused flooding of the intersection of Cobb Farm Road and Stanton Farm Road making it impassable during high water. Similarly, breaching of the southern berm has exacerbated flooding in Bartlett Village. At least twice in the last decade (2011 and 2017), River Street has become impassable due to flooding.

The team of Bear Creek Environmental, LLC and Ripple Natural Resources, LLC was retained by the Town of Bartlett in June 2019 to conduct a flood hazard reduction study of a 2.9 mile study area (Figure 1), starting at the Second Iron Bridge and going downstream approximately 4,600 feet below the River Street Bridge. The study includes community involvement, collection of field data, an assessment of river morphology and stability, a flood frequency analysis, hydraulic modeling of existing conditions, and modeling of flood hazard reduction options. All of this information is being used to provide options to the community regarding flood hazard mitigation.

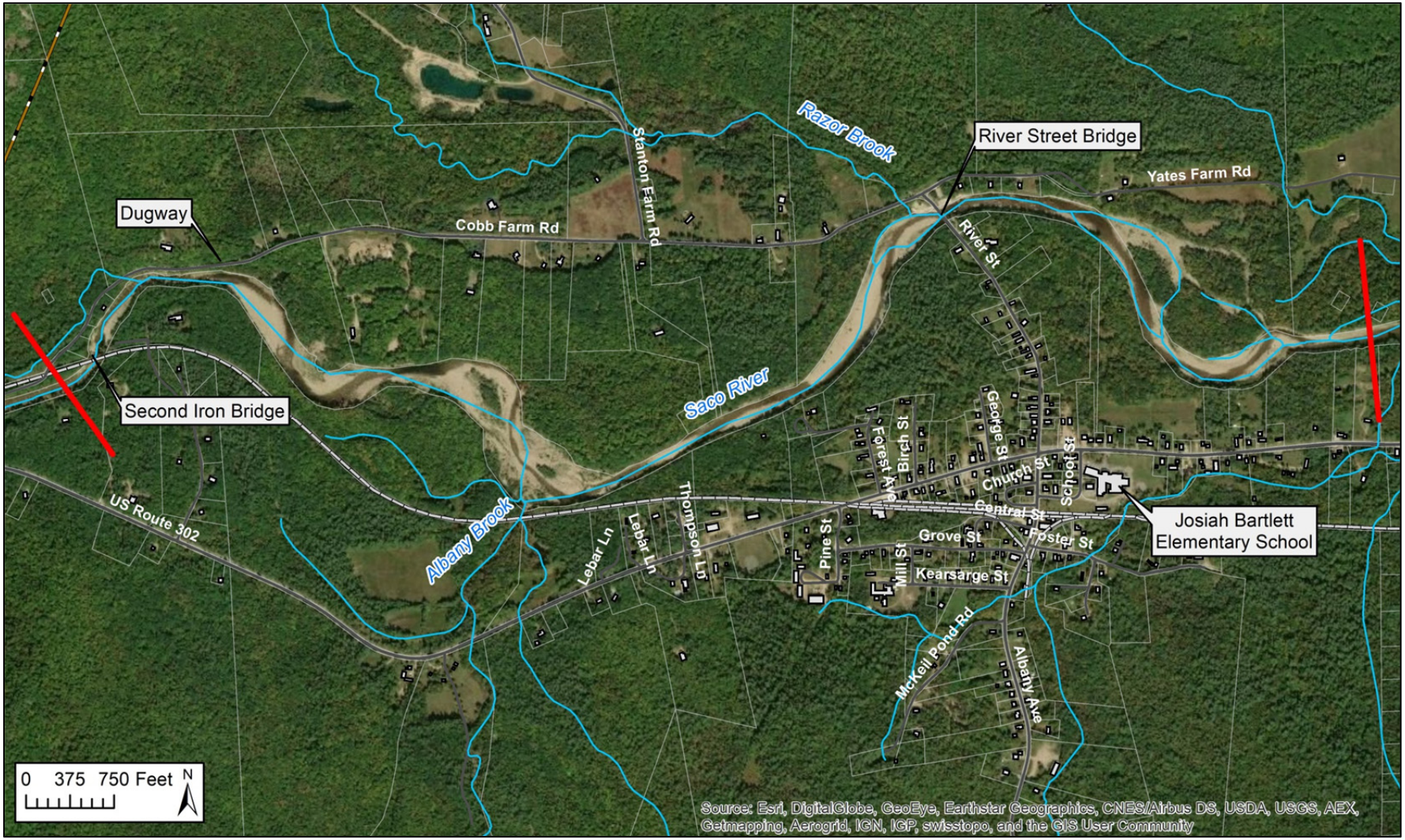


Figure 1. Map of Saco River study area. Upstream and downstream bounds denoted by red lines.

2.0 PROJECT KICKOFF

Landowner meetings and a project kickoff meeting were held at the beginning of the project to engage the community and learn more about the concerns that stakeholders have surrounding flooding and river adjustment. The announcement for the landowner meetings and public meeting is provided on page 1 of Appendix A (A1).

2.1 Landowner Meeting

Community members with concerns about future flooding on their property along the Saco River in Bartlett Village were invited to meet with project consultants hired by the Town of Bartlett to conduct the flood hazard study. The consulting team was available to meet with landowners by appointment on their property on July 22, 2019. Approximately twenty-two landowners, Travis Chick (Town of Bartlett Road Foreman) and Gene Chandler (Town of Bartlett Selectmen), met with the consulting team. The landowners who participated in the meetings were from Cobb Farm Road, Stanton Farm Road, Yates Farm Road, Tir Na Nog Lane, River Street, and US Route 302.

Valuable information was provided by landowners about historic flooding on their property, adjacent landowner properties, and on town roads. High water locations were recorded in the field using a submeter GPS unit (model LT500 manufactured by CHC). Photographs were taken by the consulting team to document areas of know flood inundation. In addition, photographs and video taken during the 2017 Halloween flood were provided to the consulting team by landowners.

2.2 Public Kickoff Meeting

A special group meeting was also held on July 22, 2019 at the Bartlett School Cafeteria in conjunction with the Bartlett Board of Selectmen's meeting. Twenty-four community members in addition to representatives from the Bartlett Board of Selectmen attended the public meeting. The purpose of the meeting was to introduce the study and for the community to ask questions and provide information to the consulting team.

3.0 EXISTING RIVER CONDITIONS

3.1 River Mapping

A stream geomorphic assessment of the Saco River within the study area was conducted by Bear Creek Environmental, LLC during August 2019. An assessment based on fluvial geomorphic science was chosen because it provides a holistic, watershed-scale approach to identifying the stressors on river ecosystem health. The stream geomorphic assessment data are valuable for focusing restoration and protection activities within the watershed and for assisting with flood resiliency planning.

Methods

Protocols recommended by the New Hampshire Department of Environmental Services (NHGS, 2012) were employed to collect river geomorphic data. Areas of active bank erosion, berm locations, gravel bars, locations of bank armoring and other important river features were mapped. Special attention was paid to mapping areas where berms are compromised and water flows within the floodplain (flood chutes). Cross section information, including bankfull stage, was collected to understand both vertical and horizontal adjustment of the river. Phase 2 Rapid Stream assessment Field Sheets were completed (A2-A7).

Results

The Saco River study reach (Second Iron Bridge to just below River Street) has a channel slope of 0.6 percent and a valley slope of 0.8 percent. The sinuosity or ratio of the stream length to the valley length is 1.32. This means the channel within the study reach meanders back and forth across its floodplain. A review of the shaded relief of LiDAR ground surface elevations shows the numerous flood chutes and historic channels across the Saco River floodplain (Figure 2).

Upstream of the study reach, the channel and valley characteristics are different in terms of slope, sinuosity, and confinement. The slope upstream of the study area is steeper, at 1.0 percent compared with 0.6 percent within the study reach. The upstream reach is straighter, with a sinuosity of 1.09 (low) compared to 1.32 (moderate). The upstream valley is narrower than the valley within the study reach, which has a natural confinement ratio of 21. We note that within the study area, roads and railroads confine the naturally broad valley, reducing its confinement ratio to 9, and the berms confine it further, to a ratio of 7, but even so it remains wide enough to be characterized as unconfined.

The active channel of the Saco River within the study area is approximately 200 feet wide based on field-collected measurements. This is significantly wider than would be expected for river channel based on drainage area, which is typically the strongest predictor of channel width. The natural valley characteristics in the study reach, including the wider valley and flatter slope compared to upstream reaches, is partly responsible for the generally wide and shallow channel within the study area. Dredging of the river to create the berms and maintenance dredging in the years since have also promoted a relatively wide and shallow channel.

Understanding the characteristics of the study area and the reach above the study area is important for understanding sediment accumulation within the study reach. As the slope drops and the natural valley widens, the sediment that is transported from upstream drops out creating large gravel bars and sediment deposition at constrictions, such as the River Street Bridge. During a one to two-year flood event, a particle size of approximately nine to ten inches is expected to be transported.

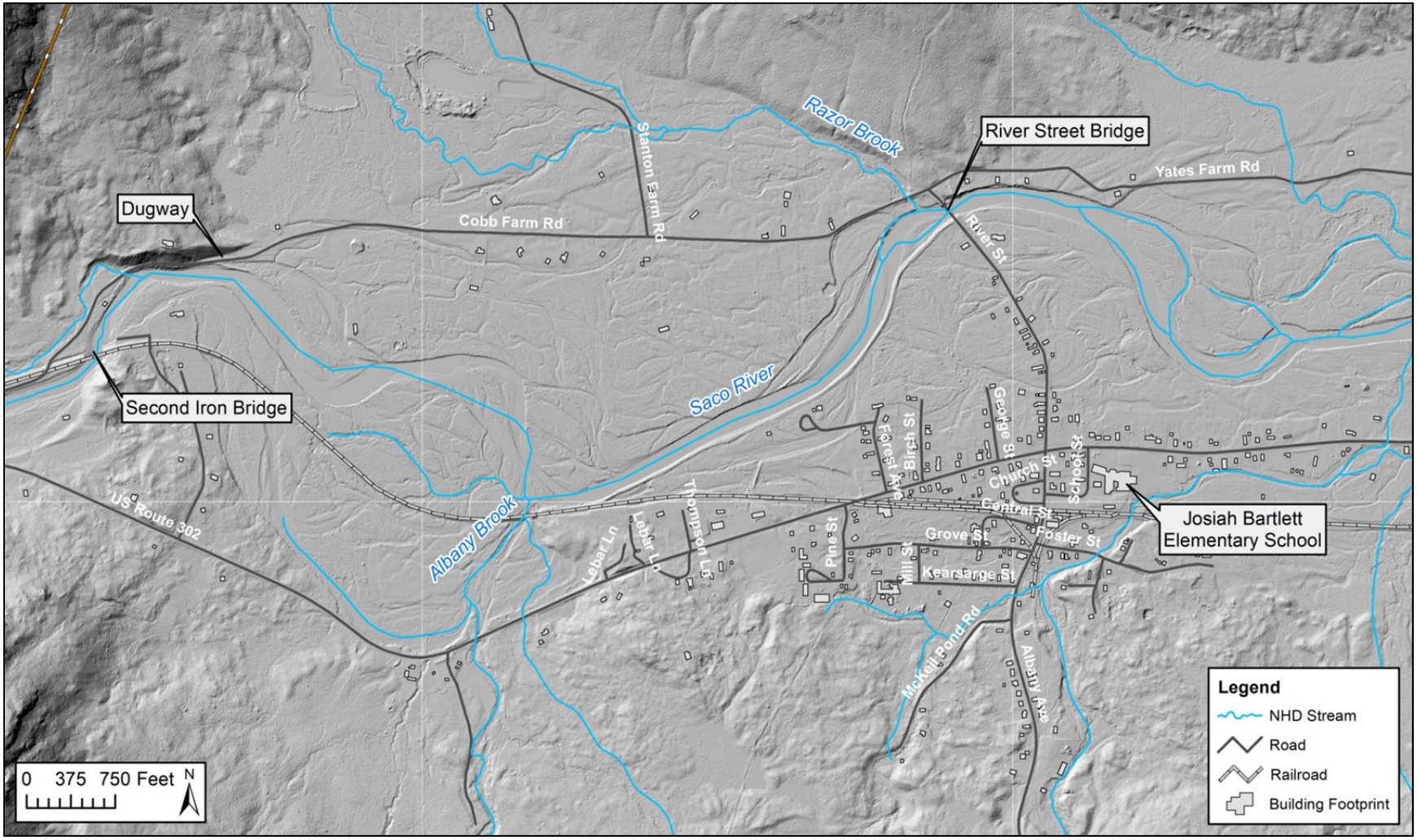


Figure 2. Shaded relief of LiDAR ground surface elevations shows the numerous flood chutes and historic channels across the Saco River floodplain.

The locations of berms, hard bank armoring (rock riprap), bank erosion, and narrow vegetated buffers (less than 25 feet in width) that were mapped during the August 2019 river assessment are provided in A8. A summary of these features is provided below in Table 1. Photographs illustrating different features are provided below in Table 2.

Table 1. Summary of River Features Measured Within Saco River Study Reach – August 2019

Feature	North Bank		South Bank	
	Length (ft)	Percent	Length (ft)	Percent
Bank armoring	1699	11	1537	10
Bank erosion	4869	32	3200	21
Berms	2010	13	3836	25
Buffers less than 25 feet in width	2204	14	497	3

Table 2. Photos of the Study Reach

Second Iron Bridge at top of study reach (looking upstream)	Breached berm on north bank
Deposition of cobbles on large bar feature (looking upstream)	Gravel bar stabilizing through growth of vegetation

Table 2. Photos of the Study Reach

Start of levy on south bank near Albany Brook	Eroding south bank near landfill

3.2 Topographic Survey

A field survey to augment LiDAR elevation data available for the site was conducted during August 2019 by Bear Creek Environmental, LLC and Ripple Natural Resources, LLC. The survey focused on riverbed topography and the geometry of bridges. Survey efforts were concentrated in the vicinity of the River Street Bridge. In addition to measuring cross sections, the dimensions, condition and location of culverts on River Street and at the intersection of Cobb Farm Road and Stanton Farm Road were noted.

Methods

River cross sections were measured with a laser level. Measurements were made from top of bank to top of bank. In the office, these relative channel elevations were adjusted to match the LiDAR georeferenced elevations.

Results

A total of 10 river cross section were measured in the field. The cross-section locations are shown on the basemap (see A8).

3.3 Historic Aerial Imagery Review

Reviewing changes in a river's course over time can provide valuable insight into where the river has been in the recent past and how it may continue to change into the future. For the Saco River study reach, historic aerial imagery was reviewed to assess lateral migration, or changes in horizontal location, of the river over time. Additionally, imagery was reviewed to identify potential changes in river planform such as major deposition and channel avulsion (new channel formation/change in main flow location). Aerial imagery from 1992, 2003, 2009, 2010, 2015, and 2017 was reviewed in this assessment. The imagery was used to digitize a centerline of flow for each year, which, when compared, allows for an assessment of changes in the river's

course over the 25-year period of available imagery. These historic centerlines are portrayed in A9 and A10.

The earliest imagery available, from 1992, shows a river centerline that is the least sinuous (meandering) of all years assessed. Between 1992 and 2003, the river in the upper half of the study area became more sinuous. Most adjustments were slight, the largest of which being an approximately 320-foot migration to the north across a depositional area. Across the twenty five year period reviewed, meander migration was consistent as the river's centerline gradually moved farther out along the outside of each bend in the river's course. This process of down valley migration in rivers is a natural process. Additional sediment appears to have accumulated on the gravel/cobble bars that have been present since 1992; however, no new major bars have formed.

3.4 Evaluation of Vertical Stability

A Phase 2 Stream Geomorphic Assessment of the Saco River study reach was completed in August 2019 (see A2-A7). Stream geomorphic assessments provide detailed data on river features and adjustment processes. One component of the study was a rapid geomorphic assessment (RGA) of the focus reach. The RGA consolidates field data into a single form that rates the condition of the reach based on active and historic adjustment processes. Included in the RGA is an evaluation of channel degradation (incision) and channel aggradation, both of which are indicators of vertical stability.

Very minor, localized evidence of channel incision was observed along the study reach of the Saco River. The primary process contributing to vertical channel stability is aggradation. The location and characteristics of this reach of the Saco River result in high levels of naturally occurring deposition. Reaches upstream of the study area are steeper in slope with narrower valleys, causing them to be primarily transport reaches for sediment. As the valley widens and slope drops in the study area, major sediment deposition occurs on the streambed as a natural part of the channel evolution process. This deposition drives other geomorphic adjustment processes such as channel widening and changes in channel planform such as the formation of flood channels and horizontal channel migration.

In addition to the decreased channel slope and wider valley, the dredging of the channel in the late 1960s to create berms also contributed to aggradation. That dredging resulted in a relatively wide and shallow channel with less ability to transport the cobble and gravel delivered from upstream.

The current channel bed elevations within the study area were compared to the bed elevations reported in the 1984 FEMA Flood Insurance Study for the Town of Bartlett. The current and 1984 elevations are in reasonable agreement, suggesting that the observed aggradation has been primarily on the channel margins, with cobble/gravel bars that are getting taller over time, rather than an aggradation across the entire channel. This is consistent with anecdotal reports

from residents who acknowledge that sediment deposits in the channel are not new, but report that they've grown larger. For instance, the gravel/cobble bar on the south side of the channel immediately upstream of River Street has long been present, but residents report it grows with each major storm, and field survey confirms it did indeed get approximately two feet taller during the 2017 flood event. As long as dredging of the channel occurs after major flood events, accumulation of new material with the next large storm and possibly even with annual spring runoff can be expected. Without dredging, however, the active channel over time will narrow and the ability to transport sediment will improve, thereby moving the channel toward an equilibrium condition.

4.0 FLOOD FREQUENCY ANALYIS

A Flood Frequency Analysis (FFA) was conducted to estimate flows in the Saco River study area for storms ranging from the 50 to the 0.2 percent chance exceedance (2-year to the 500-year). An FFA is useful to define the frequency of known flood events, such as Irene and the October 2017 floods, and for use in hydraulic modeling to identify the frequency of flooding under both existing and proposed conditions. A summary of the analysis is included here, and additional documentation is included in Appendix B.

The FEMA Flood Insurance Study of the Saco River includes flow estimates based on transposition of flows measured at a Conway, NH gage (USGS Gage #01064500) to a number of locations in Bartlett. An update to that analysis was warranted because those flows were based a 1973 analysis of the Conway gage, and there are now more than 40 years of additional flow data (including significant flood events) available. Also, a flow gage has been operational at the River Street Bridge in Bartlett (USGS Gage #010642505) since 2010, which allows for local data to be included.

The Bartlett gage has only been in operation for 10 years, which is too short a record to allow for reliable statistical analysis based on this gage alone. Thus, the record was extended following the procedures in US Geological Survey Bulletin 17C (England 2019), which documents the standard methods for streamflow analysis in the United States. The FFA was then conducted using the extended data series.

For this analysis, the 10 years of annual peak flows recorded at the Bartlett gage were shown to be strongly correlated (r^2=0.91) to the flows recorded at the Conway gage. The Conway gage has 96 years of continuous records, to the Bartlett gage's 10. Using the correlation between the two gages, the Bartlett record was statistically extended by 21 years to create a 31-year record covering the period 1989 - 2019.

The FFA was then conducted using the extended data series using the US Army Corps of Engineers Hydrologic Engineering Center's Statistical Software Package (HEC-SSP) version 2.2,

again following Bulletin 17C methodology. A weighted skew (between station skew and regional skew) was used. Low-outlier screening per 17C was employed, which identified one such flow. All high flows were included, including both the 2011 (Irene) and 2017 (Halloween) floods.

The FFA results are presented in Table 3. Based on this analysis, the 2011 peak flow (Irene) of 29,100 cfs is very close to the 100-year flood event. The 2017 peak flow (Halloween) of 25,300 cfs is on the order of the 50-year event. For hydraulic modeling purposes, these flows were transposed based on drainage area from River Street to other upstream locations.

Table 3. Estimated Saco River Flows at River Street in Bartlett

Percent Annual Chance Exceedance (%)	Recurrence Interval (years)	Flow (cfs)
0.2	500	42,500
1	100	29,200
2	50	24,400
4	25	20,000
10	10	14,900
20	5	11,300
50	2	6,830

5.0 BASE HYDRAULIC MODELING

Hydraulic analysis was performed using the HEC-RAS version 5.0 computer program, developed by the US Army Corps of Engineers. HEC-RAS calculates water surface profiles for steady gradually varied flow in natural or man-made channels. HEC-RAS has the capacity to model various obstructions such as bridges, culverts, weirs, roads, and other structures. The program computes a wide range of hydraulic variables for each peak discharge simulated including water surface elevation (height of the water), velocity (speed of the water), and shear stress (force on the channel and banks).

5.1 Model Parameters and Input

The terrain, or geometry, of the channel and surrounding floodplain of the study area was based on LiDAR topography flown in November 2016 and published in 2019. The data provide

elevation data on a 0.7m grid. The LiDAR data were augmented with field survey to improve channel bathymetry.

A mesh with 100 ft by 100 ft grid cells was initially developed within the study area. That mesh was then refined with the use of smaller cells and breaklines to improve model resolution in areas of interest such as locations of roadways and berms. The final model mesh includes 35,364 cells.

A land classification data set was developed within the HEC-RAS Mapper to assign Manning's n-values within the modeled area. The land use/land cover dataset was digitized from aerial imagery in ArcGIS, using the National Land Cover Dataset (NLCD) from 2016 to verify classifications as needed. The associated Manning's n-values came from the Natural Resources Conservation Service (NRCS, 2016). The dominant land classifications and n-values are Mixed Forest (n=0.16), Developed-Low Intensity (n=0.1), Developed-Open Space (n=0.04), and Open Water (n=0.04).

Culverts and bridges were added to the model based on field measurements of the structures. Culverts were included at four locations on River Street south of the bridge. Two culverts were added under Cobb Farm Rd near Stanton Rd, and two more were added nearby on Stanton Rd. A final culvert was added under a private driveway upstream of the Cobb Farm/Stanton intersection. The River Street bridge was represented in the model as four culvert openings (the smaller twin culverts installed in 2016, and the main bridge bays on either side of the center pier).

External boundary conditions were established on the Saco River at the upstream model limits (immediately above the Second Iron Bridge), Razor Brook upstream of Stanton Road, Albany Brook upstream of the RR tracks, and on the Saco River at the downstream model limits. The river flows assigned to the boundary conditions for the Saco River upstream, Razor Brook, and Albany Brook locations were based on the computed flows at River Street (Section 4.0) transposed based on drainage area to those other locations. The boundary condition flow and the resulting Saco River flows are shown in Table 4.

Table 4. Flows (cfs) used in the Hydraulic Model							
Location	**Drainage Area (sq mi)**	**2-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**	**500-yr**
Saco River @ Second Iron Bridge	75.19	5,784	12,721	17,133	20,954	25,127	36,731
Albany Brook	6.94	553	1,155	1,521	1,829	2,162	3,066
Razor Brook	6.89	492	1,024	1,346	1,617	1,910	2,703

The model was initially run using diffusion wave equations while model refinements such as mesh adjustments and culvert conditions were made. It was then run using the Full Momentum equations for improved accuracy.

5.2 Model Calibration

The model was calibrated to the October 2017 flood event because of the relatively robust photographic and anecdotal documentation of flooding during that storm (Figure 3). Most notably, photographs exist showing the inundation limits near the intersection of Cobb Farm and Stanton Roads, on River Street, and at the River Street Bridge. In addition, locations of berm overtopping on the south side of the river and flooding on Forest Avenue were reasonably well documented by residents and field evidence. High water marks from the 2017 flood used to guide model calibration and the results of the calibrated model are shown on Map C1.

The primary calibration locations included the following:

- Cobb Farm and Stanton Road Intersection. The extent of overtopping reasonably matches observations.
- Homes Southwest of Cobb Farm / Stanton Intersection. The model shows water around and flowing behind the structures, reasonably matching photographs of the event.
- River Street. The depth of flooding (0.5 – 2.0 feet) and inundation limits are consistent with reports from residents and the Town, and the northern limit of flooding before the road climbs up to the bridge is consistent with photographs.
- River Street Bridge, the computed elevation is consistent with reports and photographs of water swirling above the inlet to the new twin culverts.
- South Berm. The model shows overtopping of the berm near Tir Na Nog Lane, consistent with anecdotal reports.
- Forest Avenue. The depth of flooding is consistent with reports from residents.

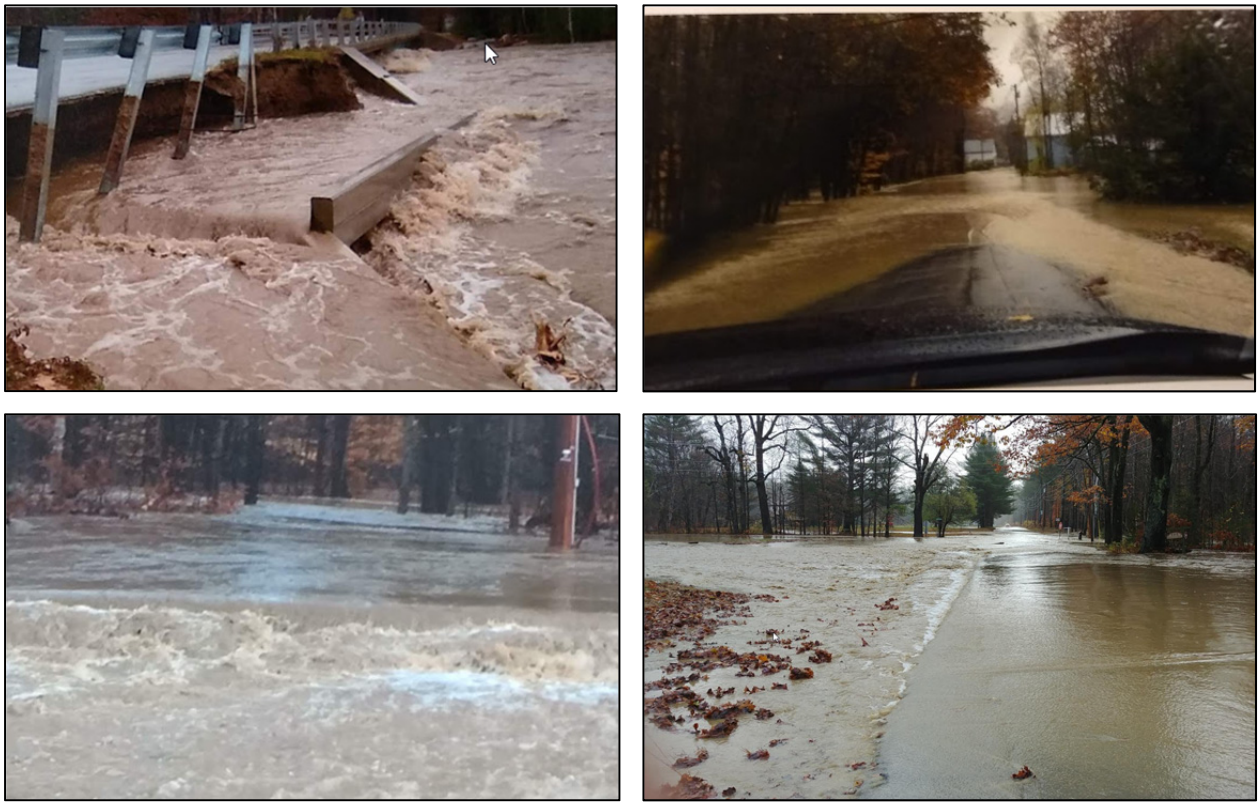


Figure 3. Selected photographs used to calibrate the hydraulic model to the 2017 flood event, including (clockwise from top left) the River Street Bridge, River Street, the Cobb Farm Rd/Stanton Farm Rd intersection (looking east), and Cobb Farm Rd (looking south).[1]

5.3 Existing Conditions

The calibrated model was run for a range of flows from the 2-year up to the 500-year. The results at four notable locations are summarized in Table 5. Maps of selected storm events are included on Maps C2 – C7. A map showing the flood inundation boundaries for the 2 year, 50 year and 100 year flood events is provided on Map C8. Hydraulic modeling results for the 100-year event are shown with FEMA flood hazard areas in Figure 4 and on Map C9.

Table 5. Model Results for Existing Conditions

Recurrence Interval	Cobb Farm Rd at the Dugway: Water on Road?	Cobb Farm at Stanton Rd: Length Overtopped / Depth Range	South Berm: Length of Overtopping	River Street: Length Overtopped / Depth Range
2 year	No	No	None	None
10 year	No	<250/<0.3’	200’	<100’/<0.2’
25 year	No	450’/0.4’-0.8’	700’	1,200’/0.5’-1’
50 year	Yes	840’/0.6’-0.9’	1,200’	1,500’/0.5’-2’
100 year	Yes	850’/0.8’-1.0’	2,400’	1,600’/1’-3’
500 year	Yes	1900’/0.9’-1.2’	3,700’	>2,000’/2.5’-4.5’

[1]Photos of River Street Bridge, River Street and Cobb Farm Road were provided by Angela Huertas. Photo of Cobb Farm Road/Stanton Farm Road intersection provided by Don Nava.

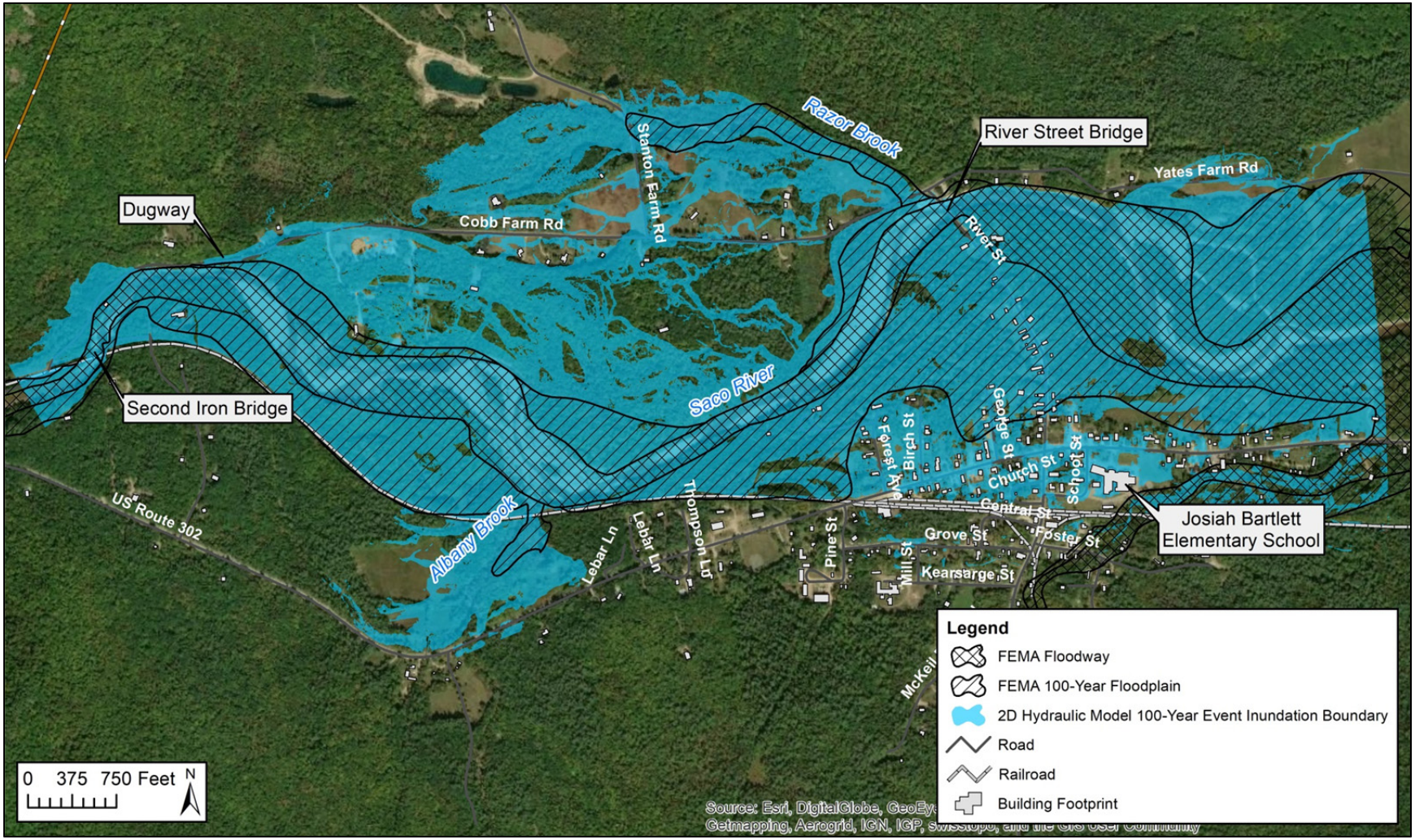


Figure 4. FEMA 100-year flood hazard zone and floodway shown overlaid on the 100-year flood inundation boundary from the Saco River hydraulic model.

The most notable results from the modeling of existing conditions, moving generally from upstream to downstream, include the following:

1. **Near the Second Iron Bridge** (upstream study limits), water begins to spill from the Saco river channel at about the 10-year flood level, resulting in isolated shallow sheet flooding near the houses located on the north bank and flow through the flood chutes on the south bank (see Map C3). With larger storm events, the extent and depth of flooding predictably increases, and at the 50-year storm and greater, Cobb Farm Road in this area is flooded and the nearby homes surrounded by water. Water velocity during the 100-year event is on the order of 15 ft/sec just downstream of the Second Iron Bridge, and nearly 18 ft/second in the Dugway, which explains the fluvial erosion observed in these locations (see Map C10).

2. At the downstream end of the **Dugway**, water is contained in the channel until approximately the 50-year flood, when it begins to overtop and a relatively small amount of water runs down and across the road (see Map C5). The volume of water leaving the channel at the Dugway predictably increases with larger storms. During the 100-year storm, velocities remain above 15 ft/sec as the river turns to the south after the Dugway, where they reduce to approximately 9 ft/sec, which is still an unusually high velocity for open channel flow in a natural river (see Map C10).

3. In the vicinity of the **Cobb Farm Road and Stanton Road intersection**, the 10-year storm event begins to put water from the Saco River onto Cobb Farm Road (see Map C3). During the 25-year and larger storm events (see Map C4), the extent and depth of Cobb Farm and Stanton Farm flooding increases. Flow velocities near the intersection are typically under 4 ft/sec, and non-erosive, though higher velocities are computed in some of the flood chutes. The culverts there are in poor condition and too small to handle any significant flow. Larger culverts might be able to keep the road dry for the 10-year and possibly the 25-year events, and bridges would likely be needed to handle larger events.

4. Water that floods the **Cobb Farm/Stanton intersection** comes from three locations. First, water spills during the 10-year and larger events from the Saco channel into the floodplain just downstream of the Dugway (see Map C3). This is reportedly the location of a former berm. Some finds its way back to the Saco, but the remainder flows toward the intersection. Second, during the 50-year and larger events, water spills onto Cobb Farm Road at the Dugway, as described above (see Map C5). It flows across and down the road and into the aforementioned floodchute, and ultimately contributes to flooding at the intersection. Third, water can flow from Razor Brook to the intersection, independent of flooding from the Saco. There's a long berm or similar elevated linear

feature extending from Stanton Farm Road upstream approximately 1,000 feet that acts as a divide between the Razor and Saco floodplains. However, at the upstream end of this feature (near a home on the north side of Cobb Farm Road), there's the potential for water from Razor to enter the Saco floodplain and flow toward the Cobb Farm/Stanton Farm intersection (see Maps C5-C7).

5. The **South Berm** on the bank of the river from near Albany Brook down to River Street contains the Saco River up to approximately the 10-year flood, at which point water begins to overtop at one location upstream of Forest Avenue where there is a break in the berm (see Map C3). During the 25-year event, a second location near River Street also overtops (see Map C4). Predictably, the length of the berm that overtops increases with larger floods, and approximately one-third and one-half of its approximate 4,000-foot length overtops during the 50 and 100-year events, respectively. We note that seepage through the berm, which is not explicitly captured in the model, could contribute additional water to the back-side of the berm, but except where the berm may be constructed in an atypically porous fashion, the quantity of seepage water would not be significant relative to the volume of overtopping water.

6. There is an **additional L-shaped berm** between the South Berm and the railroad that reduces flooding in the Village. It originates at the railroad approximately 1,100 feet west of Forest Ave, projects north into the floodplain, and then turns and runs east parallel to the river. Its effect on flood flows starts with the 10-year event when water is beginning to overtop the South Berm (see Map C3). The benefit is particularly evident during the 50-year event (see Map C5) when it can be seen to effectively kick water back toward the river and away from developed areas.

7. **River Street** flooding is generally from water that overtops the Southern Berm, collects in flood chutes, and is conveyed toward culverts under the road. When the capacity of those flood chutes and culverts is exceeded, water overtops the road. There is also the potential for overtopping near the River Street bridge due to backwater from the downstream side of the road. During the 10-year event, some of the chutes and culverts would be reaching their capacity, and a minor amount of water on the road in one or two locations is expected (see Map C3). During the 25-year event, much of the road is under at least a veneer of water, and travel by vehicle would be questionable. During the 50-year event and larger, the entire floodplain is effectively under water, and vehicular travel dangerous if even possible.

8. The **River Street Bridge** does constrict flows – as would be expected since the available flow area through the bridge and associated culverts is considerably smaller than the flow area of the natural approach channel – resulting in higher flood elevations in the

channel upstream compared to down. The constriction elevates flood levels upstream. However, because the river upstream is so steep, the elevated flood levels are relatively localized (compared to a lower slope river, where the effects of a constriction would translate much further upstream). The River Street bridge constriction appears to contribute to overtopping of the South Berm immediately above the bridge (which contributes to flooding of River Street as shown on Map C5), but overtopping of the berm at locations further upstream is independent of the bridge constriction.

6.0 FLOOD HAZARD REDUCTION ALTERNATIVES

The Town of Bartlett has applied to the Federal Emergency Management Agency (FEMA) for funding to repair damages incurred during the 2017 flood. These repairs include partial reconstruction/reinforcement of two existing berms, one on the north side of the river and one on the south. The hydraulic model developed for this study was used to evaluate these berm repairs. Additional flood hazard reduction alternatives were also identified. Three of these alternatives were modeled.

6.1 Proposed FEMA Berm Repairs

6.1.1 North FEMA Berm Repair

Engineering plans dated September 17, 2019, which were prepared by HEB Engineers out of North Conway, NH, were used to determine the height and location of the proposed FEMA berm repair for modeling purposes. The northern berm repair represents a roughly 1,100 foot long section that starts at the Dugway and extends to the east (see Map E1).

The proposed FEMA north berm repairs were modeled using the hydraulic model presented earlier. The land surface was raised in the location of the proposed berm to the elevations shown on the HEB engineering drawings. The results show that the berm reduces the amount of water exiting the channel in this location during the 100-year flood (see Map E1). However, the berm is overtopped in places and it is outflanked at the upstream end where it meets Cobb Farm Road at the dugway (Figure 5). The amount of water reaching the Cobb Farm/Stanton Rd intersection with the FEMA Berm in place is reduced by two-thirds compared to existing conditions for the 100-year event (316 cfs down to 97 cfs). Most of that water outflanked the upstream end of the FEMA berm as opposed to overtopping it. Even with the significant reduction in flow reaching the Cobb Farm/Stanton Rd intersection, the intersection and road still flood.

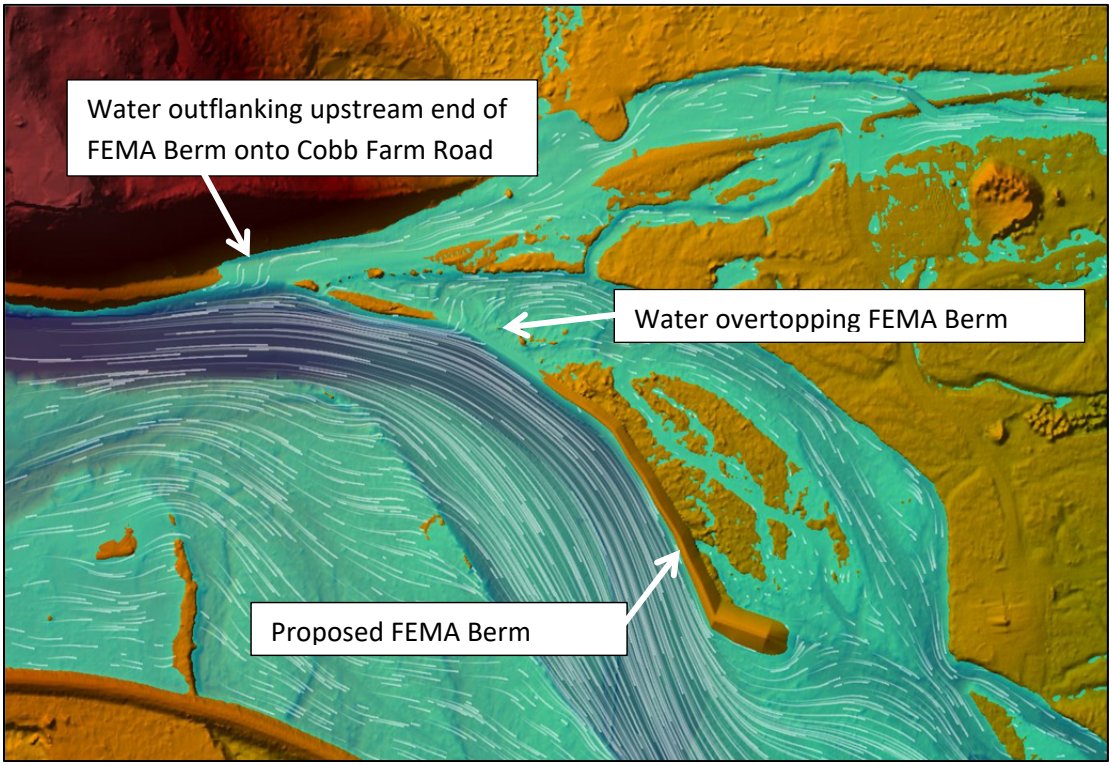


Figure 5. Results for the 100-year show that the FEMA north berm is overtopped and outflanked by floodwaters.

During the smaller 50-year flood, modeling showed similar results for the FEMA Berm. Water overtops the berm in the same location to a slightly lesser extent, and water still outflanks the upstream end and overtops Cobb Farm Road at the Dugway. In fact, there's more water reaching the road at the dugway compared to existing conditions because the FEMA berm marginally elevates the water surface in the Saco channel upstream a short distance. The Cobb Farm/Stanton Farm intersection floods during the 50-year event even with the FEMA Berm.

During the 25-year flood event, the FEMA Berm is effective at keeping water in the channel and eliminates flooding at the Cobb Farm/Stanton intersection. Thus, somewhere between the 25 and 50-year event is when water first outflanks the FEMA Berm or overtops it sending water to the Cobb Farm/Stanton Farm intersection. This is a considerable improvement over existing conditions when the intersection first starts to flood during the 10-year event.

The flow in the river at the FEMA Berm location is relatively fast and deep, and provides insight into why the former berm failed. As shown on maps C9 through C11), flow velocities are generally 10-15 feet per second adjacent to the berm (and 15-18 feet per second further out in the channel), flowing approximately 10 feet deep, and generating shear forces above 30 lb/sq-ft. Only relatively large angular rock, similar to the rock at the toe of the dugway slope that has remained stable, is capable of resisting the erosive force of such deep and fast water.

6.1.2 South FEMA Berm Repair

The proposed FEMA berm repair on the south side targets repairing an area of damage in the berm from the 2017 flood. Based on the HEB plans, the proposed repair work includes strengthening the existing berm by adding material, but no increase in the existing berm height is proposed. This reinforcement work starts about 800 feet above River Street and extends upstream about 350 feet.

Because there is no proposed increase in the height of the southern berm, there's no potential for reduction in flooding (i.e., it would overtop at the same frequency as existing conditions), and thus the berm repairs were not explicitly modeled as were the North FEMA Berm repairs. However, the hydraulic characteristics computed for existing conditions would apply under repaired conditions as well. Flow velocities are generally 5-10 feet per second adjacent to the berm (and 10-13 feet per second further out in the channel), flowing up to 16 feet deep, and generating shear forces above 30 lb/sq-ft in locations where the berm is redirecting flow (see C9-C11). While not as severe as the North FEMA Berm, these values are nonetheless characteristic of an erosive environment.

6.2 Additional Flood Hazard Reduction Alternatives

Seven potential flood hazard reduction alternatives, in addition to the North and South FEMA Berm Repairs, were identified (Map D1). These alternatives came from discussions with the Selectboard and residents, and from review of existing conditions modeling. The seven additional alternatives are:

1. Dredging of river cobble above the River Street Bridge
2. New single-span River Street Bridge
3. Enhanced Southern Berm from River Street to Albany Brook
4. Raising River Street and installing larger culverts
5. Enhanced Northern Berm
6. New Bridge on Cobb Farm Road and reconfigure the Cobb/Stanton intersection
7. Buyout of at-risk homes

A map and schematic of each alternative is included in Appendix D. The pros and cons of each are provided in Table 6. These alternatives were provided to the Bartlett Board of Selectmen on February 13, 2020. The Board chose Option #1, Option #3, and Option #5A for additional hydraulic evaluation. Modeling of these options is presented in Section 7.3.

Table 6. Saco River Potential Mitigation Alternatives (Bartlett, NH)		
Mitigation Alternative	**Pros**	**Cons**
1). Dredging of river cobble above the River Street Bridge (Map D2)	• Provides material for repair of southern berm • Offers temporary increase in channel capacity • Relatively inexpensive compared to other alternatives	• Any benefit would be temporary because channel will fill back in over time • Flood mitigation benefits are relatively small and localized
2). New single-span River Street Bridge (Map D3)	• Provides larger opening for floodwaters • Reduces debris jam potential • Could be oriented to better align with river approach	• Bridge replacement is expensive • Benefits extend relatively short distance upstream due to steep river slope
3). Taller Southern Berm from River Street to Albany Brook (Map D4)	• Reduces floodwaters to River Street and to homes in the Village on the south side of the river	• Increases erosive energy in the river channel • Relies on hard engineered solution that may fail and must be maintained
4). Raise River Street across floodplain and install larger culverts (Map D5)	• Reduces flooding of River Street during some flood events • Keeps River Street open to vehicles over a larger range of floods	• Benefits likely limited to lower flow events (e.g. 25-year storm), above which culverts are overwhelmed. • Could worsen flooding of homes on upstream side of Street when culverts are overwhelmed.
5A). Taller and Longer Northern Berm generally on existing FEMA berm repair footprint (Map D6)	• Protects numerous homes on north side of river from flooding • Protects Stanton Farm/Cobb Farm Road from flooding • May facilitate FEMA funding for rebuilding structure	• High probability of failure due to erosion • Requires raising Cobb Farm Road
5B). Taller and Longer Northern Berm set back from river and extended to prevent outflanking (Map D6)	• Provides area of floodwater attenuation (reduces energy and slows down floodwaters) relative to proposed FEMA berm repair location • Protects numerous homes on north side of river from flooding • Protects Stanton Farm/Cobb Farm Road from flooding • Less prone to failure due to erosion than proposed FEMA berm repair location	• May challenge FEMA funding protocols that frequently require rebuilding in kind. • Results in new environmental impacts • Requires raising Cobb Farm Road
6). New Bridge on Cobb Farm Road and reconfigured Cobb/Stanton Intersection (Map D7)	• Improves access to homes off of Cobb Farm Road and Stanton Farm Road during a flood	• New bridge would be relatively expensive • Would require considerable excavation to "route" floodwaters to the new bridge

Table 6. Saco River Potential Mitigation Alternatives (Bartlett, NH)		
7). Buyout of at-risk homes that are not readily protected by other mitigation measures	• Federal funding covers 75% of cost for qualified structures. • Pays pre-flood market price. • On River Street, may allow for additional raising of road to maintain vehicle access. • Eliminates risk to residents and first responders	• Reduces Town tax base • Typically a lengthy (5-year) process following a flood.

6.3 Detailed Evaluation of Selected Flood Hazard Reduction Alternatives

Alternative 1. Dredging of Channel above River Street Bridge

This alternative, shown on Map D2, entails removing the gravel and cobble on the south side of the channel upstream of the River Street Bridge that was deposited during the October 2017 storm. There was reportedly a similar deposit following Irene in 2011, and the channel was dredged to remove it. In the model, the terrain in the channel was adjusted to match the topography shown on the HEB Engineers design drawings (September 17, 2019), which reflects the existing sediment deposit. Dredged conditions were based on November 2016 elevations, which is marginally lower than the proposed dredge elevations shown on the HEB Engineers plans. The difference between existing and dredged conditions reflects approximately 4,400 cubic yards of material removed over approximately 650 feet of channel starting at the bridge.

The existing and dredged conditions were run in HEC-RAS for the 100-year event. The results showed no measurable difference in water surface elevations or flood extent upstream of the bridge (see Map E2). This result is likely a function of the bridge constriction immediately downstream; the bridge is backing up water, and the deposit of sediment would need to be considerably larger before it outweighs the influence of the bridge. The constricting effect of the bridge is immediately evident looking at the inundation limits upstream and downstream of the bridge on Map E2.

Alternative 2. New Single-Span River Street Bridge.

Not selected for evaluation. See Table 6 for summary and Map D3 for schematic. A single-span bridge would increase the hydraulic capacity and be less prone to debris blockage. The clear opening of the current bridge is approximately 144 feet, which includes the two main bridge openings and the two box culverts at the north end. A new bridge would ideally provide the 144-ft opening or more in a single span. The width of the downstream channel is approximately 150 feet, and that largely defines the size of bridge that the site can accommodate. There may be the opportunity to realign the bridge by shifting the north side in the downstream direction

(and reconfiguring the River Street/Cobb Farm Road intersection). This would increase the available span and would better orient the structure with the approach channel.

Alternative 3. Taller Southern Berm

This alternative entails raising the existing South Berm continuously from River Street up to approximately Albany Brook (Map D4). In the hydraulic model, it was coded to have a top elevation approximately 3 feet above the existing 100-year elevation, which is a common design criterion for new federal levees. This alternative also includes protection of the berm with angular rock sufficiently large to withstand the extreme erosive forces in the river channel.

The results show a significant reduction in the extent of floodwaters on the south floodplain in Bartlett Village (Map E3) compared to existing conditions. Whereas the berm overtops during the 10-year event under existing conditions, the taller berm does not generally overtop even at the 100-year event. There is no flooding of US Route 302, Forest Avenue, Birch Street, Tir Na Nog Lane, or George Street in Bartlett Village, as there is under existing conditions. However, during the 100-year event and to some extent the 50-year event, the modeling shows two potential limitations of an enhanced southern berm. First, floodwaters overtop the berm at its downstream end where it would taper down to meet the existing elevation of River Street (Figure 6, small circled area), and this water floods River Street and some of the houses on River Street. It might be possible to address this with a rigid wall at the downstream end of the berm rather than an earthen berm that tapers down to meet the road elevation. Second, during the 100-year event, there is sufficient backwater to flood at least a portion of the road from the downstream side of River Street (Figure 6, larger circle). Strategic raising of River Street in this location might address this issue.

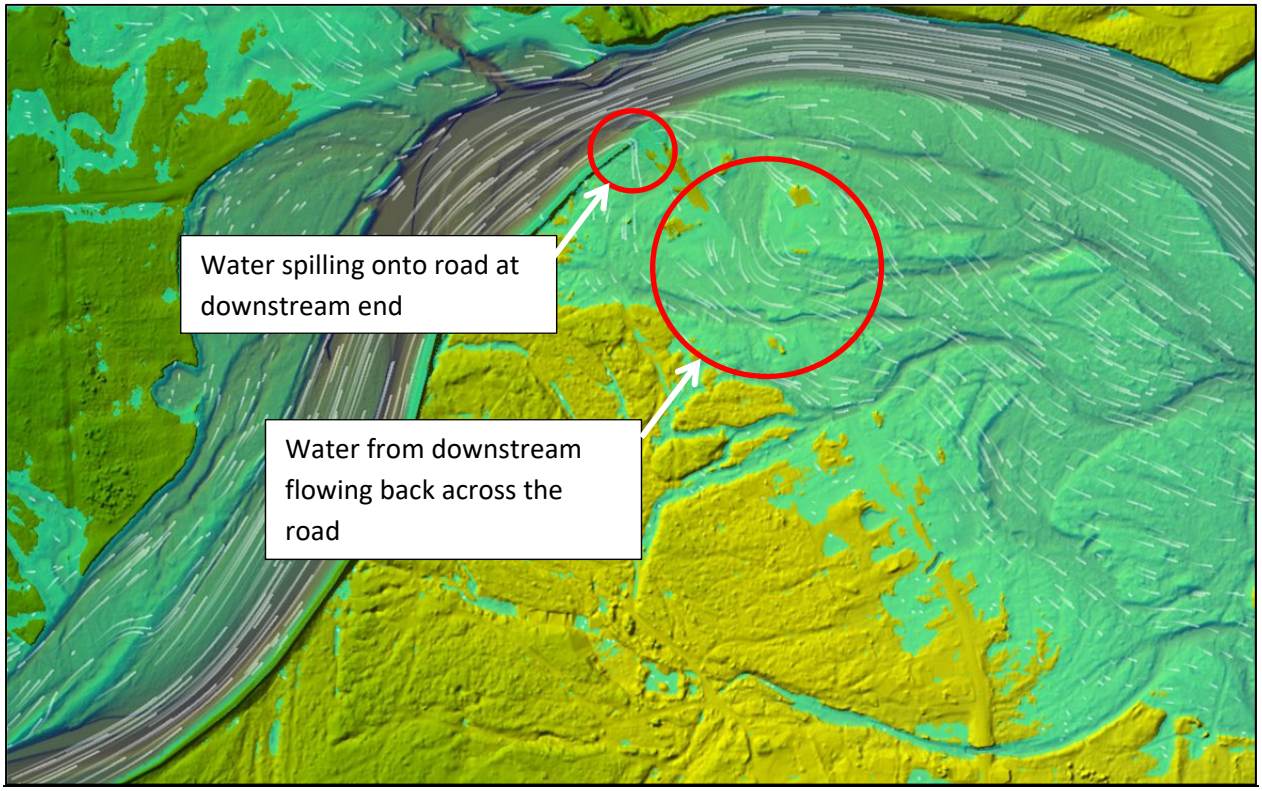


Figure 6. Results for the 100-year show water overtopping the end of the southern berm where it meets River Street, as well as water from the east flowing back across the road.

We note that this alternative does not cause a detectable shift in floodwaters to the other side of the channel, a common argument against the use of berms. This is because the amount of water that overtops the existing berm but would be contained by the taller one is relatively small compared to the total volume of floodwater, and it's not enough to cause a discernable increase in flooding elsewhere.

Alternative 4. Raise River Street and Install Larger Culverts.

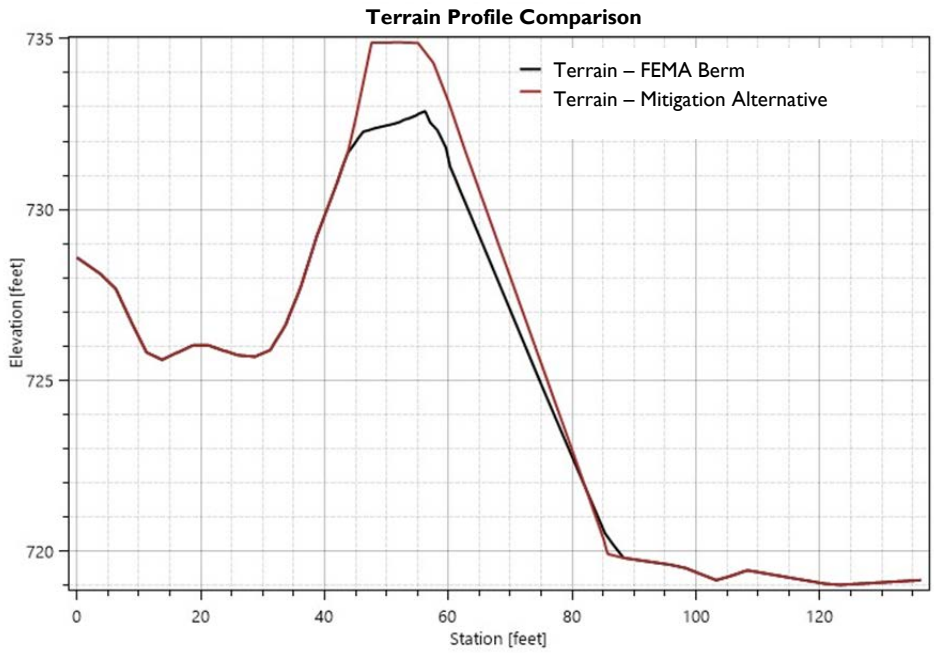
Not selected for evaluation. See Table 6 for summary and Map D5 for schematic. The flooding of River Street is a critical issue because it affects access to homes on the other side of the river. Raising the road and installing larger culverts has the potential to keep the road dry under a larger range of flows, but it has significant risk to properties on the upstream side. This alternative wasn't explicitly modeled as part of this study, but conceptually it can be seen that the road acts as a dam across the floodplain and backs up water above it. If the road is raised, adequately sized new culverts need to be installed to prevent higher water. This is typically only feasible during relatively minor flood events. During larger events when there is significantly more water flowing across the floodplain, culverts cannot reasonably be expected to handle the flow, and water backs up to the new higher road elevation. Additional and larger culverts –

without any raising of the road – can only help keep the road from flooding, and are thus worth considering. Raising the road, however, should be done only after a thorough analysis of the risks to upstream properties.

Alternative 5. Taller and longer Northern Berm

The intent of this alternative is to construct a berm on the north side of the river with sufficient height and length to prevent flooding of Cobb Farm Road during the 100-year event. Initial concepts for this alternative included a berm that extended continuously from River Street up to the Dugway. However, the hydraulic modeling of existing conditions showed that a continuous berm is unnecessary; water contributing to Cobb Farm Road flooding originates from a limited area near the Dugway, and a berm continuing downstream from this area would provide no additional benefit. Whereas the proposed North FEMA Berm may be constrained by requirements to replace the former berm with a structure of the same size in the same location, this alternative is not so constrained, and could be located back from the river to reduce erosion as shown on Map D6 and as described in Table 6 (alternative 5B).

For the purpose of hydraulic modeling, this alternative includes a berm on approximately the same footprint as the proposed FEMA North Berm, but raised to an elevation approximately 3 feet above the 100-year flood to prevent overtopping. It is also extended approximately 140 feet at the upstream end to tie into high ground to prevent being outflanked. This extension would cross over Cobb Farm Road at the eastern end of the Dugway, so in practice this alternative would entail reconstructing several hundred feet of the road to transition up and over the elevated land. A representative changes in berm dimensions from the proposed FEMA repairs to the mitigation alternative, as reflected in the model, is shown below in Figure 7.



Terrain Profile Comparison

Figure 7. Comparison of terrain profiles for proposed FEMA northern berm and northern berm mitigation alternative.

When modeled for the 100-year flood, the results show that this berm would prevent water from the Saco River from reaching Cobb Farm Rd and the Cobb Farm/Stanton Road intersection (Map E4). We note, however, that there is still the potential for water from Razor Brook to spill onto its southern floodplain and contribute to roadway flooding during the 100-year event.

While the modeled berm of this alternative was on approximately the same footprint as the proposed North FEMA Berm, there would be benefits to offsetting it from the active river channel where it would not be subject to the extreme forces that contributed to failure of the original berm. While that would clearly be beneficial from a resiliency standpoint, a tradeoff is that it would require raising Cobb Farm Road over a longer distance to prevent outflanking of the berm.

As was the case with evaluation of an enhanced southern berm, this alternative does not cause a detectable shift in floodwaters to the other side of the channel (see Map E4), a common argument against the use of berms. Here, this concern is unfounded because it is a relatively small amount of water that the berm is designed to keep in the channel. During the 2017 flood, for instance, there was approximately 25,000 cfs flowing down the Saco, and only approximately 600 cfs left the channel and caused the flooding of the Cobb Farm Road /

Stanton Road intersection. So, the berm during that event would only be pushing 600 cfs back into the channel – about 2 percent of the total flow – and that is not enough to have a discernable negative affect elsewhere.

Alternatives 3 and 5 were modeled independently as well as together to show effects of the construction of both a longer and taller northern and southern berm. The results of the alternatives combined for the 100-year event are shown on map E5.

Alternative 6. New Bridge at Cobb Farm / Stanton Intersection.

Not selected for evaluation. See Table 6 for summary and Map D7 for a schematic. This alternative is intended to keep the Cobb Farm Road/Stanton Road intersection dry when water from the Saco flows across the northern floodplain to the intersection, as currently occurs. Under existing conditions, enough water reaches the intersection that a bridge, rather than larger culverts, is likely needed to handle the flow. Because the water is dispersed in the floodplain and overtopping over a long length of road, land grading on the upstream side of the road would be needed to funnel it into the new bridge opening. Stanton Farm Road would be realigned to intersect with Cobb Farm Road further to the west to avoid the need for a second bridge.

Alternative 7. Buyouts

Not selected for evaluation. See Table 6 for summary. FEMA has a property acquisition program – referred to as buyouts -- to purchase and remove structures that are subject to repetitive flooding. It is an entirely voluntary program in which, after a disaster declaration, structures are purchased for pre-storm value with FEMA covering 75% of the cost and the state and/or local government covering the remaining 25%. In some cases, buyouts have been completed as part of a disaster mitigation plan instead of in response to the latest flood. Candidates for buyouts are often structures that are at risk for repeated flooding or are at risk of damage due to erosion.

7.0 RECOMMENDATIONS

If the Town pursues reconstruction of existing and former berms, we recommend the Town consider armoring the river side of them with appropriately-sized angular rock. As demonstrated by the hydraulic modeling presented in this report, the berms will be subject to extreme erosive forces, and it is not a reasonable expectation that gravel and cobble that the river has transported from upstream will provide for durable, flood resilient berms.

If the Town pursues reconstruction of the North berm, we recommend that it be relocated away from the river to accommodate the down-valley movement of the meander bend and to shield it from the highly erosive forces at the river's edge. We further recommend that it be extended upstream – which would entail raising a portion of Cobb Farm Road at the Dugway – to prevent it from outflanking.

We recommend the Town use the results of the hydraulic modeling presented here to inform decisions about suitable building locations, because in some locations, the extent of flooding presented in this study differs significantly from what is shown on the FEMA Flood Insurance Rate maps.

We recommend the Town consider buyouts of homes where flooding cannot be mitigated or that are prone to fluvial erosion hazards. This is particularly important on River Street if the integrity of the Southern Berm continues to deteriorate, which will result in more frequent flooding of the southern floodplain.

We recommend the Town consider repairs to the locations on the Southern Berm that are shown to be the initial locations of overtopping (in the vicinity of Tir Na Nog Lane and at the eastern end near River Street).

We recommend the Town further evaluate the benefit of additional and larger culverts on River Street, coupled with excavation upstream to better direct flow to the culverts.

REFERENCES

England, J.F., Jr., Cohn, T.A., Faber, B.A., Stedinger, J.R., Thomas, W.O., Jr., Veilleux, A.G., Kiang, J.E., and Mason, R.R., Jr., 2018, Guidelines for determining flood flow frequency—Bulletin 17C (ver. 1.1, May 2019): U.S. Geological Survey Techniques and Methods, book 4, chap. B5, 148 p., https://doi.org/10.3133/tm4B5.

HEB Engineers, Inc. 2019. Design Drawings for the October 2017 Storm Damage: Saco River located in Bartlett, New Hampshire prepared for Town of Bartlett, HEB Project # 2019-064, Issued: September 17, 2019. North Conway, NH. 20 sheets.

Natural Resources Conservation Service (NRCS) – Kansas. 2016. Manning's *n* Values for Various Land Covers to Use for Dam Breach Analyses by NRCS in Kansas. Available at: https://www.wcc.nrcs.usda.gov/ftpref/wntsc/H&H/HecRAS/NEDC/lectures/docs/Manning%92s%20n-values%20for%20Kansas%20Dam%20Breach%20Analyses%20-%20Adopted%20071216.pdf

New Hampshire Geological Survey (NHGS). 2012. Implementation of Phase 2 Geomorphology Assessments Version 1.0. New Hampshire Department of Environmental Services.

US Army Corps of Engineers. 2016. HEC-Ras River Analysis System: 2D Modeling User's Manual, Version 5.0. Hydraulic Engineering Center, Davis, CA.

USGS 010642505 SACO RIVER AT RIVER STREET, AT BARTLETT, NH. Last accessed 2/17/2002 https://nwis.waterdata.usgs.gov/nh/nwis/peak/?site_no=010642505&agency_cd=USGS

USGS 01064500 Saco River near Conway, NH. Last accessed 2/17/2002 https://nwis.waterdata.usgs.gov/nwis/peak/?site_no=01064500&agency_cd=USGS

Appendix A

Data Collection

PUBLIC NOTICE
TOWN OF BARTLETT

~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~ ~

ARE YOU CONCERNED ABOUT FUTURE FLOODING ON YOUR PROPERTY ALONG THE SACO RIVER IN BARTLETT VILLAGE?

If so, you are invited to meet with consultants hired by the Town of Bartlett to conduct a flood hazard reduction study on the upper section of the Saco River in the Village.
The consultants are available to meet with landowners by appointment only on their property between 10:00AM and 4:00PM and from 6:00PM to 8:00PM on Monday, July 22, 2019. To make an appointment, send an email to: sacoriverfloodstudy@gmail.com no later than July 18.

A special group meeting will also be held on Monday, July 22, 2019 at the Bartlett School Cafeteria from 4:30-5:30PM in conjunction with the Bartlett Board of Selectmen's meeting for more discussion.

Board of Selectmen
Gene G. Chandler
David A. Patch
Vicki L. Garland

Rapid Stream Assessment Field Notes

Stream Name: Saco River
Location: Bartlett, NH
Observers: Mary Neelon, Alex Marcucci
Organization /Agency: Bear Creek Environmental
Weather: Sunny, warm
Flood history known: Y / N (date of known flood 2011, 2017)

Segment I.D: ☐ Sub-Reach
Date: 8/13/19
Town: Bartlett, NH
Segment Length: 15,186 ft.
Segment Not Assessed: W/I/N/G/B/O
Rain Storm within past 7 days: Y / N

Segment Impacted by TSI Flooding or recent flood (within last 1-5 yrs) Y/N; Segment Altered by Flood Work Y/N

1. Valley and River Corridor

1.1 Segmentation: GC/CD/SS/PS/DF/CE/BB/FS/PA/SR/VW/OT/None
1.2 Alluvial Fan (FIT): Yes/No/UK

1.3 ~~River Corridor~~ P1 valley Encroachments (FIT)	Reach or Segment Length: One Bank	Both Banks	Height from tw	1.4 Slope of the Adjacent Terrace or Hillside: Left Corridor	Right Corridor
Berms LB:	2010	3836	← RB	flat (0-3%) hilly (4-8%) steep (9-15%) very steep (16-25%) x-steep (>25%)	flat (0-3%) hilly (4-8%) steep (9-15%) very steep (16-25%) x-steep (>25%)
Roads	2443	12743		Continuous w/bank A / S / N	Continuous w/bank A / S / N
Railroads	8300			Within 1x Wbkf A / S / N	Within 1x Wbkf A / S / N
Improved Paths	0	0		Texture of Exposed Slope	Texture of Exposed Slope
Development	7631	1207	NA	till boulder/cobble gravel sand silt clay bedrock other Not Evaluated	till boulder/cobble gravel sand silt clay bedrock other Not Evaluated

1.5 Confinement	1.6 Grade Controls (FIT) ☑ none — Fill out height fields for grade controls if applicable →	Total Height (0.0 ft)	Height Above Water Surface (0.0 ft)	Photo Yes / No
Valley width / Channel width Valley Width: P1 = 4104 ☐ Gorge Estimated / Measured ☑ Human caused change in valley width P2 = 1688	**Location in Reach** (record locations on field map) Waterfall // Ledge // Dam // Weir			
Narrowly Confined (>=1 & < 2)				
Semi-confined (>2 & < 4)				
Narrow (>= 4 & < 6)				
P2 Broad (>= 6 & <10)	1688 / 195 ft = 8.65			
P1 Very Broad (>= 10)	4104 / 195 ft = 21.0			

From x-section spreadsheet

2. Stream Channel

2.1 Bankfull Width: 195.0 ft. **2.1a Wetted Width:** 37.5 ft.

2.1b Ratio (W_{wetted} / W_{bkf}): 0.19 **2.2 Max. Bankfull Depth:** 10.13 ft. **2.3 Mean Bankfull Depth:** 4.51 ft.

2.4 Floodprone Width: 3044 ft. **2.5 Recently Abandoned FP :** 11.78 ft. **2.6 Ratio W/d_{mean}:** 43.2

2.7 Entrenchment: 15.6 **2.8 Incision Ratio:** 1.16 IR_{bef} : _____ **2.9 Sinuosity:** moderate

2.10 Riffles/Steps: complete / eroded / sedimented / NA / NE **2.11 Riffle/Step Spacing:** NE ft.

Dimensions Altered by Flood Y/N ; Altered by Flood Work Y/N ; Channel Enlargement Measure = _____

2.12 Bed Substrate Composition (percent):

1 Bedrock	2 Boulder	3 Cobble	4 Gravel Course	4 Gravel Fine	5 Sand	6 Silt or Clay	Embeddedness Mean Channel	Embeddedness Mean Margin
	6	58	18	9	9	Y / N	8	34

2.13 Avg. Size of Largest Particles on: Bed: 12" Bar: 9"
circle: inches or millimeters
2.13a % Exp. Substrate: 80

2.14 Stream Type: A G F B E C D 1 2 3 4 5 6 a b c
Cascade Step-Pool Plane Bed Riffle-Pool Ripple-Dune Braided ☑ Reference Type

Stream Type: D3

3. Riparian banks, Buffers, and Corridors

3.1	Typical Bank Slope		shallow	moderate	steep	undercut	(evaluate on the higher of the two banks)			
	Bank Texture-RB	Lower	bedrock	boulder/cobble	gravel	sand	silt/clay	mix	cohesive / non-cohesive	
		Upper	bedrock	boulder/cobble	gravel	sand	silt/clay	mix	cohesive / non-cohesive	
	Bank Texture-LB	Lower	bedrock	boulder/cobble	gravel	sand	silt/clay	mix	cohesive / non-cohesive	
		Upper	bedrock	boulder/cobble	gravel	sand	silt/clay	mix	cohesive / non-cohesive	
	Bank Erosion (FIT)	Left	Length: 4869 ft.	Height: 6 ft.	Bank Revetment Type: riprap + hard bank	Length: 1699 ft.				
		Right	Length: 3201 ft.	Height: 5 ft.	Bank Revetment Type: riprap + hard bank	Length: 1537 ft.				
	Near Bank Vegetation Type	Trees	L % cover 40	Invasive 0	Conifer 0	Deciduous 100	R % cover 40	Invasive 0	Conifer 0	Deciduous 100
		Shrubs / Saps.	L % cover 20	Invasive 0	WADs 0	Saplings 100	R % cover 30	Invasive 0	WADs 0	Saplings 100
		Herbs	L % cover 20	Invasive 30	Grasses 0	Forbs 70	R % cover 50	Invasive 30	Grasses 0	Forbs 70
	Bank Canopy	Left	76 - 100%	51 - 75%	26 - 50%	1 - 25%	0%	Channel Canopy		
		Right	76 - 100%	51 - 75%	26 - 50%	1 - 25%	0%	Open	Closed	
3.2	Buffer Width (dom/sub) (FIT 0-25 ft)	Left	0 – 25 ft.	26 – 50 ft.	51 – 100 ft.	> 100 ft	none (SD).			
		Right	0 – 25 ft.	26 – 50 ft.	51 – 100 ft.	> 100 ft	none (SD).			
	Buffer Vegetation Type	Trees	L % cover 70	Invasive 0	Conifer 20	Deciduous 80	R % cover 70	Invasive 0	Conifer 20	Deciduous 80
		Shrubs / Saps.	L % cover 50	Invasive 0	WADs 0	Saplings 100	R % cover 50	Invasive 0	WADs 0	Saplings 100
		Herbs	L % cover 70	Invasive 10	Grasses 0	Forbs 90	R % cover 70	Invasive 10	Grasses 0	Forbs 90
3.3	Riparian Corridor (dom/sub)	Left	forest	shrub-sapling	crop/pasture/hay	commercial/industrial	residential	bare	none (SD)	
		Right	forest	shrub-sapling	crop/pasture/hay	commercial/industrial	residential	bare	none (SD)	

4.1 Springs or Seeps: extensive / present / minimum / none / altered **4.2 Adjacent Wetlands**: extensive / present / minimum/none/altered

4.3 Flow status: base / low / avg. **4.4 Current Debris Jams (FIT)**: # 0

Flood related jam yes/no ; If yes = Significant for (all that apply) habitat/channel adjustment / flood damage concerns

4.5 Flow Regs. & Withdrawals (FIT): TYPE: withdrawal / bypass / r-o-r / store & release / none / unk
SIZE : small / large ; **USE:** drinking / irrigation, flood-control / hydro-electric / recreation /other

4.6 Upstream/Downstream Flow Regs. : upstream / downstream / both / none

4.7 Stormwater Inputs (FIT): NE tile drain ___ / road ditch___ / urban stormwater ___ / field ditch ___/ overland flow ___

4.8 Constrictions ☐ none **menu**: instream culvert // bridge // old abutment // bedrock outcrop // other

see tally sheet

Constriction Type (from menu	Width (ft)	Photo Yes / No		channel constriction	floodprone constriction	Problems (check all that apply) deposition above	deposition below	scour above	scour below	alignment	none
RR Bridge	147	yes		☑	☑		✓				
River St. Br.	122	yes		☑	☑	✓	✓		✓		
				☐	☐						

4.9 Beaver Dams (FIT): # 0 _____ft. of the segment affected. ☐ Bridge & Culvert Assessments

5. Channel Bed and Planform Changes (5.0 to 5.3 record on tally sheet)

5.4 Stream Ford or Animal Crossing (FIT): Yes / No

5.5 Channel Alterations (FIT) (circle all that apply): dredging gravel mining commercial mining none
Length of Straightening: 12,219 (With Windrowing : Yes / No) Alteration from Flood Work Yes/No

Flood Berms : material from channel / material pushed out of field / notes also rock riprap berms

Comments:

VT RAPID GEOMORPHIC ASSESSMENT ----- UNCONFINED STREAMS

For narrow and broad to very broad valley types (confinement ratio ≥ 4) Typically Riffle-pool and Dune-Ripple Stream Types

Stream Name: Saco River
Location:

Observers: MN, AM, ZM
Organization /Agency: BCE
Reference Stream Type C3 or (D3) ☐ Modified
(If alluvial fan or naturally braided system see Handbook Protocols)

Segment I.D.:
Date: 8/13/19
Town: Bartlett
Elevation: ft.
Weather: Sunny, warm
Rain Storm within past 7 days: Y / (N)

Adjustment Process	Condition Category: Reference	Good	Fair	Poor
7.1 Channel Degradation (Incision) • Exposed till or fresh substrate in the stream bed and exposed infrastructure(bridge footings) • New terraces or recently abandoned floodplains. • Headcuts, or nickpoints that are 2-3 times steeper than typical riffle. • Freshly eroded, vertical banks. • Alluvial (river) sediments that are imbricated (stacked like dominoes) high in bank. • Tributary rejuvenation, observed through the presence of nickpoints at or upstream of the mouth of a tributary. • Bars with steep faces, usually occurring on the downstream end of a bar. localized	☐ Little evidence of localized slope increase or nickpoints.	☑ Minor localized slope increase or nickpoints.	☐ Sharp change in slope, head cuts present, and/or tributaries rejuvenating.	☐ Sharp change in slope and / or multiple head cuts present. Tributaries rejuvenating.
	☑ Incision Ratio ≥ 1.0 < 1.2 **and** Entrenchment ratio > 2.0	☐ Incision Ratio ≥ 1.2 < 1.4 **and** Entrenchment ratio > 2.0	☐ Incision Ratio ≥ 1.4 < 2.0 **and** Entrenchment ratio > 2.0	☐ Incision ratio ≥ 2.0 **OR** Entrenchment ratio ≤ 2.0
	☐ Riffle heads complete and comprised of courser sediments (≥D80). Full complement of expected bed features.	☑ Riffle heads mostly complete. Riffle lengths may appear shorter. Full complement of expected bed features.	☐ Riffles or dunes may appear incomplete; bed profile dominated by runs.	☐ Riffle-pool or ripple-dune features replaced by plane bed features.
	☐ No significant human-caused change in channel confinement or valley type.	☑ Only minor human-caused change in channel confinement but no change in valley type.	☐ Significant human-caused change in channel confinement enough to change valley type, but still unconfined.	☐ Human-caused change in valley type, unconfined or narrow changed to confined.
	☐ No evidence of historic / present channel straightening, gravel mining, dredging and/or channel avulsions.	☐ Evidence of minor bar scalping on a point bar and/or channel avulsion; but minor to no historic channel straightening, gravel mining, or dredging.	☐ Evidence of significant historic channel straightening, dredging, gravel mining and/or channel avulsions.	☑ Extensive historic channel straightening, commercial gravel mining, and/or recent channel avulsion.
Stream Type Departure ☐ **Type of STD:**	☑ No known flow alterations (i.e., increases in flow or decreases in sediment supply).	☐ Minor flow alterations, some flow increase and/or reduction of sediment load.	☐ Major historic flow alterations, greater flows and/or reduction of sediment load.	☐ Major existing flow alterations, greater flows and/or reduction of sediment load.
Score: **Historic** ☐	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
7.2 Channel Aggradation • Shallow pool depths. • Abundant sediment deposition on point bars and mid-channel bars and extensive sediment deposition at obstructions, channel constrictions, and at the upstream end of tight meander bends. Islands may be present. • Most of the channel bed is exposed during typical low flow periods. • High frequency of debris jams. • Coarse gravels, cobbles, and boulders may be embedded with sand/silt and fine gravel. ** This parameter may be a difficult to infeasible to evaluate in ripple-dune stream types **Stream Type Departure** ☐ **Type of STD:**	☐ Complete riffle heads and deep pools in riffle-pool systems.** Full complement of expected bed features.	☑ Mostly complete riffles and/or some filling of pools with fine sediment. Pools may only be slightly deeper and wider than runs.**	☐ Incomplete riffles or dunes and dominated by runs. Significant filling of pools with sediment, pools may be absent with runs prevailing.	☐ Riffle-pool or ripple-dune features replaced by plane bed features.
	☐ Minor point or delta bars present. Minor depositional features typically less than half bankfull stage in height.	☐ Single to multiple mid-channel or diagonal bars present. Minor depositional features typically less than half bankfull stage in height.	☐ Multiple unvegetated mid-channel or diagonal bars present. Major sediment buildup at the head of bendways leading to steep riffles and flood chutes.	☑ Multiple unvegetated mid-channel or diagonal bars present splitting or braiding flows even under low flow conditions.
	☑ No apparent increase in fine gravel/sand substrates (pebble count).**	☐ Some increase in fine gravel/sand substrates that may comprise over 50% of the sediments.	☐ Large incr. in fine gravel/ sand substrates that may comprise over 70% of the sediments. Sediment feels soft underfoot.	☐ Homogenous fine gravel/ sand substrates may comprise over 90% of the sediments. Sediment feels soft underfoot.
	☐ Low width/depth ratio ≤ 20 for C or B type channels ≤ 10 for E type channels	☐ Low to moderate W/d ratio >20 ≤ 30 for C or B channels >10 ≤ 12 for E channels	☐ Moderate to high W/d ratio >30 ≤ 40 for C or B channels >12 ≤ 20 for E channels	☑ High width/depth ratio >40 for C or B type channels >20 for E type channels
	☐ No known flow alterations (i.e., decrease in flow or increase in sediment supply).	☑ Minor reduction in flow and/or increase in sediment load. Flood-related sediment working through reach, seen as enlarged bars.	☐ Major historic flow alterations, reduction in flows and / or increase in sediment load.	☐ Major existing flow alterations, extreme reduction in flows and / or increase in sediment load.
	☐ No human-made constrictions causing upstream deposition.	☐ Human-made constrictions smaller than floodprone width, causing minor to moderate upstrm / dwnstrm deposition.	☑ Human-made constrictions significantly smaller than floodprone width, causing major upstrm / dwnstrm deposition.	☐ Human-made constrictions significantly smaller than bankfull width, causing extensive upstrm / dwnstrm deposition and flow bifurcation.
Score: **Historic** ☐	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1

Adjustment Process	Condition Category: Reference	Good	Fair	Poor
7.3 Widening Channel • Active undermining of bank vegetation on both sides of the channel; many unstable bank overhangs that have little vegetation holding soils together. • Erosion on both right and left banks in riffle sections. • Recently exposed tree roots (fresh roots are 'green' and do not break easily, older roots are brittle and will break easily in your hand). • Fracture lines at the top of the bank that appear as cracks parallel to the river. • Mid-channel bars and side bars may be present. • Urbanization and stormwater outfalls leading to higher rate and duration of runoff and channel enlargement.	☐ Low width/depth ratio ≤ 20 for C or B type channels ≤ 10 for E type channels	☐ Low to moderate W/d ratio >20 ≤ 30 for C or B channels >10 ≤ 12 for E channels	☐ Moderate to high W/d ratio >30 ≤ 40 for C or B channels >12 ≤ 20 for E channels	☑ High width/depth ratio >40 for C or B type channels >20 for E type channels
	☐ Little to no scour and erosion at the base of both banks at the riffle section. Negligible bank overhangs, fracture lines at top of banks, leaning trees or freshly exposed tree roots.	☑ Minimal to moderate scour and erosion at the base of both banks at the riffle section. Some overhangs, fracture lines at top of banks, leaning trees and freshly exposed tree roots.	☐ Moderate to high scour and erosion at the base of both banks at the riffle section. Many bank overhangs, fracture lines at top of banks, leaning trees and freshly exposed tree roots.	☐ Continuous and laterally extensive scour and erosion at the base of both banks at the riffle section. Continuous bank overhangs, fracture lines at top of banks, leaning trees and freshly exposed tree roots.
	☑ Incision Ratio ≥ 1.0 < 1.2 **and** Entrenchment ratio > 2.0	☐ Incision Ratio ≥ 1.2 < 1.4 **and** Entrenchment ratio > 2.0	☐ Incision Ratio ≥ 1.4 < 2.0 **and** Entrenchment ratio > 2.0	☐ Incision ratio ≥ 2.0 **OR** Entrenchment ratio ≤ 2.0
	☐ Minor point or delta bars present. Depositional features less than half bankfull stage in height.	☐ Single to multiple mid-channel or diagonal bars present. Minor depositional features typically less than half bankfull stage in height.	☐ Multiple unvegetated mid-channel or diagonal bars present. Major sediment buildup at the head of bendways leading to steep riffles and flood chutes.	☑ Multiple unvegetated mid-channel or diagonal bars present splitting or braiding flows even under low flow conditions. Many bars well veg
	☑ No known channel and / or flow alterations (i.e., increase in flow and / or change in sediment supply).	☐ Minor increase in watershed input of flows or sediment. Episodic (flood) discharges through reach resulting in short-term enlargement.	☐ Major channel and/or flow alterations, increase in flows and/or change in sediment load (increase or decrease).	☐ Major and extensive -channel and/or flow alterations, increase in flows and/or change in sediment load (increase or decrease).
Score: Historic ☐	20 19 18 17 16	15 14 13 12 11	10 9 (8) 7 6	5 4 3 2 1
7.4 Change in Planform • Flood chutes or neck cut-offs may be present. • Channel avulsions may be evident or impending. • Change or loss in bed form structure, sometimes resulting in a mix of plane bed and riffle- pool forms. • Island formation and/or multiple thread channels. • In meandering streams the thalweg, or deepest part of the channel, typically travels from the outside of a meander bend to the outside of the next meander bend. Pools are located on downstream third of the concave bends. Riffles are at the cross-over between the pools on successive bends. During planform adjustments, the thalweg may not line up with or follow this pattern. As a result of the lateral extension of meander bends, additional deposition and scour features may be in a channel length typically occupied by a single riffle-pool sequence.	☐ Low bank erosion on outside bends, little or no change in sinuosity within the reach.	☐ Low to moderate lateral bank erosion on outside bends, may include minor change in sinuosity within the reach.	☑ Moderate to high lateral bank erosion on most outside bends, may include potential neck cut-offs and moderate change in sinuosity.	☐ Extensive lateral bank erosion on most outside bends, may include impending neck cut-offs and major change in sinuosity within the reach.
	☐ Little evidence of flood chutes crossing inside of meander bends, only minor point or delta bars.	☐ Minor flood chutes crossing inside of meander bends, evidence of minor to moderate unvegetated mid-channel, delta, or diagonal bars. Some potential for channel avulsion.	☑ Historic or active flood chutes crossing inside of meander bends, evidence of channel avulsion, islands, and unvegetated mid-channel, delta, or diagonal bars.	☐ Active large flood chutes crossing inside of most meander bends, evidence of recent channel avulsion, multiple thread channels, islands, and unvegetated mid-channel, delta, or diagonal bars.
	☐ No additional deposition and scour features in the channel length typically occupied by a single riffle-pool sequence. Thalweg lined up with planform.	☐ Additional minor deposition and scour features in the channel length typically occupied by a single riffle-pool sequence.	☑ Additional large deposition and scour features in the channel length typically occupied by a single riffle-pool sequence. Thalweg not lined up with planform.	☐ Multiple sequences of large deposition and scour features in the channel length typically occupied by a single riffle-pool sequence.
	☐ No human-caused alteration of channel planform and / or the width of the floodprone area.	☐ Minor to moderate alteration of channel planform and/or width of the floodprone area resulting from floodplain encroachment, channel straightening, or dredging.	☐ Major alteration of channel planform and/or the width of the floodprone area resulting from historic floodplain encroachment, dredging, or channel straightening.	☑ Major alteration of channel planform and width of the floodprone area resulting from recent and extensive floodplain encroachment, dredging, and/or channel straightening.
	☐ Human-made constrictions causing only negligible upstream deposition.	☐ Human-made constrictions smaller than floodprone width, causing minor to moderate upstrm / downstrm deposition.	☑ Human-made constrictions significantly smaller than floodprone width, causing major upstrm / downstrm deposition.	☐ Human-made constrictions significantly smaller than bankfull width, causing extensive and major upstrm / downstrm deposition and flow bifurcation.
Score: Historic ☐	20 19 18 17 16	15 14 13 12 11	10 9 (8) 7 6	5 4 3 2 1

7.5 Channel Adjustment Scores – Stream Condition – Channel Evolution Stage

Condition / Departure	Reference N/S	Good Minor	Fair Major	Poor Extreme	STD*	Historic	Condition Rating: (Total Score / 80)	Channel Evolution Stage:
Degradation		15					0,45	F-IV
Aggradation				5				
Widening			8				**7.6 Stream Condition:** Fair	
Planform			8					

Channel Adjustment Processes: 36

7.7 Stream Sensitivity: Very Low / Low / Moderate / High / Very High / Extreme

* Channel Condition "default" to **poor** – significant flood damage (not able to get accurate channel data) **Y/N** ; or D II d ?

* Channel Condition default to poor - Due to channel alterations from work in channel after flood: **Y/N**

* Stream Sensitivity "default" to **poor** – significant flood damage (not able to get accurate channel data) **Y/N** ;

* Stream Sensitivity "default" to **poor** Due to channel alterations from work in channel after flood: **Y/N**

Cross-Section Worksheet

547
X 3
1641

top width 17

Stream Name: Seeco River
Reach-Segment:
Location: 1641 feet Above bridge (547 yds)
Date: 8/13/19
Observers: MW, AM

16.9
17
15.2

Cross-Section Notes Codes

LTER = Left Terrace	RTER = Right Terrace	TW = Thalweg
LFPA = Left Flood Plane	RFPA = Right Flood Plane	LPIN = Left Pin
LTOB = Left Top of Bank	RTOB = Right Top of Bank	RPIN = Right Pin
LBF = Left Bankfull Stage	RBF = Right Bankfull Stage	
LEW = Left Edge of Water	REW = Right Edge of Water	
RAF = Recently Abandoned Floodplain		

tail of riffle

Cross-sections - Number and Location Description: (bkf height = _____)

Note	Distance	Depth
hummocky	-71	15.2
	-58	15.2
top of berm	-40	16.9
	-33	15.42
Start berm	-26	14.39
	-14	13.06
LPIN free	0	12.61 -
	3	12.41 Sand dep
	9	13.13
	15	12.55
bottom of bar	20	12.14 *
	26	11.82
	33	11.79
	42	11.61

Note	Distance	Depth
	52	11.19
	66	10.11
15.42	81	9.29
	98	8.58
	112	7.98
	122	7.18
	134	6.51
	145	5.79
LEW	154	4.88
	163	3.97
	170	3.03
	176	2.65
TW	183	2.48
	186	2.79
REW	191.5	4.86
	195	7.22
RPIN	198	7.89

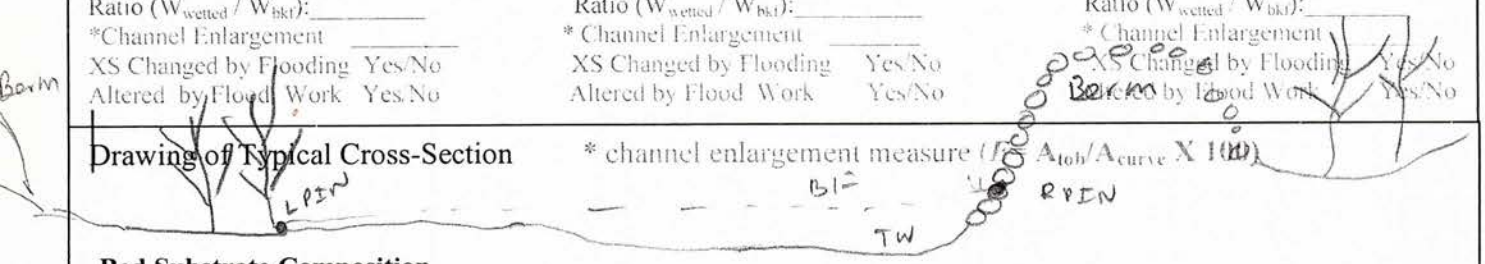
Note	Distance	Depth
Near top of berm +7	209	15.44
	~216	17.84 top berm
	228	17.24
17.5	-2.6	245.5	14.64
18	-0.7	263.5	13.94
18	+0.3	281.5	14.24

1098 sq feet

Bankfull Width	182	Bankfull Width		Bankfull Width	
Max. Depth	9.66	Max. Depth		Max. Depth	
Mean Depth	~6	Mean Depth		Mean Depth	
Floodprone Width		Floodprone Width		Floodprone Width	
Low Bank Height		Low Bank Height		Low Bank Height	
Width/depth Ratio		Width/depth Ratio		Width/depth Ratio	
Entrenchment		Entrenchment		Entrenchment	
Incision Ratio	~1.0	Incision Ratio		Incision Ratio	
IRhef		IRhef		IRhef	
Wetted Width		Wetted Width		Wetted Width	
Ratio (W_{wetted} / W_{bkf}):		Ratio (W_{wetted} / W_{bkf}):		Ratio (W_{wetted} / W_{bkf}):	
*Channel Enlargement		* Channel Enlargement		* Channel Enlargement	
XS Changed by Flooding	Yes/No	XS Changed by Flooding	Yes/No	XS Changed by Flooding	Yes/No
Altered by Flood Work	Yes/No	Altered by Flood Work	Yes/No	Altered by Flood Work	Yes/No

Drawing of Typical Cross-Section

* channel enlargement measure (Ups A_{tob}/A_{curve} X 100)



Bed Substrate Composition

Size Class	Millimeters	Inches	Relative Size	Distribution of 100 Particles	Percent
1-Bedrock	> 4096	> 160	Bigger than a VW Bug		
2-Boulder	256 – 4096	10.1 – 160	Basketball to VW Bug	1 6	
3-Cobble	64 – 256	2.5 – 10.1	Tennis ball to basketball	58	
4-Coarse Gravel	16 – 64	0.63 – 2.5	Marble to tennis ball	18	
4-Fine Gravel	2 – 16	0.08 – 0.63	Pepper corn to marble	9	
5-Sand or Smaller	< 2.00	< 0.08	Smaller than a pepper corn	9	

Embeddedness	Ch1 0	Ch2 30	Ch3 0	Ch4 10	Ch5 0	Ma1 30	Ma2 30	Ma3 70	Ma4 0	Ma5 40
Largest mobile particles	Bd1	Bd2	Bd3	Bd4	Bd5	Br1	Br2	Br3	Br4	Br5

tail of riffle → run

Fines: 5% 0% 0% 0% 5%

49
yd

Tally Sheet (page 1)

Stream Name: Saco River
Location: Top of reach

Segment I.D:
Date: 7/12/19

☐ Sub-Reach

Step 2.1 Height of bankfull above water surface

Bankfull Height	Chan. Wdth	Comments (describe indicators)

Step 5. Channel Bed and Planform Changes

Record actual number of features			Tally
5.1	Depositional Features (Bar Type)	Mid	II
		Point	III
		Side	~~IIII~~ I
		Diagonal	~~IIII~~ III
		Delta	
		Island	
5.2 FIT	Flood Chutes		~~IIII~~ ~~IIII~~ numerous
	Neck Cut-offs		
	Channel Avulsions		
	Braiding		II
	Migration		
5.3 FIT	Aggrade	Steep Riffles	~~IIII~~ ~~IIII~~ IIII
	Degrade	Head Cuts	I (channel works through sediment)
	Tributary Rejuvenation?		Yes / No

Ic higher than bankfull

Step 3.1 Bank Erosion **FIT**

Left Bank Length	Height	Right Bank Length	Height
Total:	Avg.	Total:	Avg.

Step 3.3 Mass Failures and Gullies **FIT**

Mass Fail - Length		Height	Gully - Length		Length
Left	Right		Left	Right	

Step 3.1 Bank Revetment **FIT**

Length	
Left Bank	Right Bank
Total:	Total:

Step 4.8 Channel Constrictions

	Constriction Type	Width	Photo?	GPS?	Ch. Constr.	FP. Constr.	DA	DB	SA	SB	A	None
1.)	RR Bridge	147	yes	✓	✓	✓		✓				
2.)	River St Br	122	yes	✓	✓	✓	✓	✓		✓		
3.)												
4.)												
5.)												

60
62

us. study reach?

		Tally
Step 2.12	Large Woody Debris	
Step 4.4	Debris Jams	

Step 2.11	Riffle/Step Spacing:		ALP Bar #1
Step 2.13	Avg. Largest Particle	On Bed:	On Bar: 0.8, 0.7, 0.9, 0.8, 0.75
	0.95, 1.05, 1.0, 1.05, 1.05		x̄ = 0.79' = 9.5"
	x̄ = 1.02' = 12.2"		1 + bar

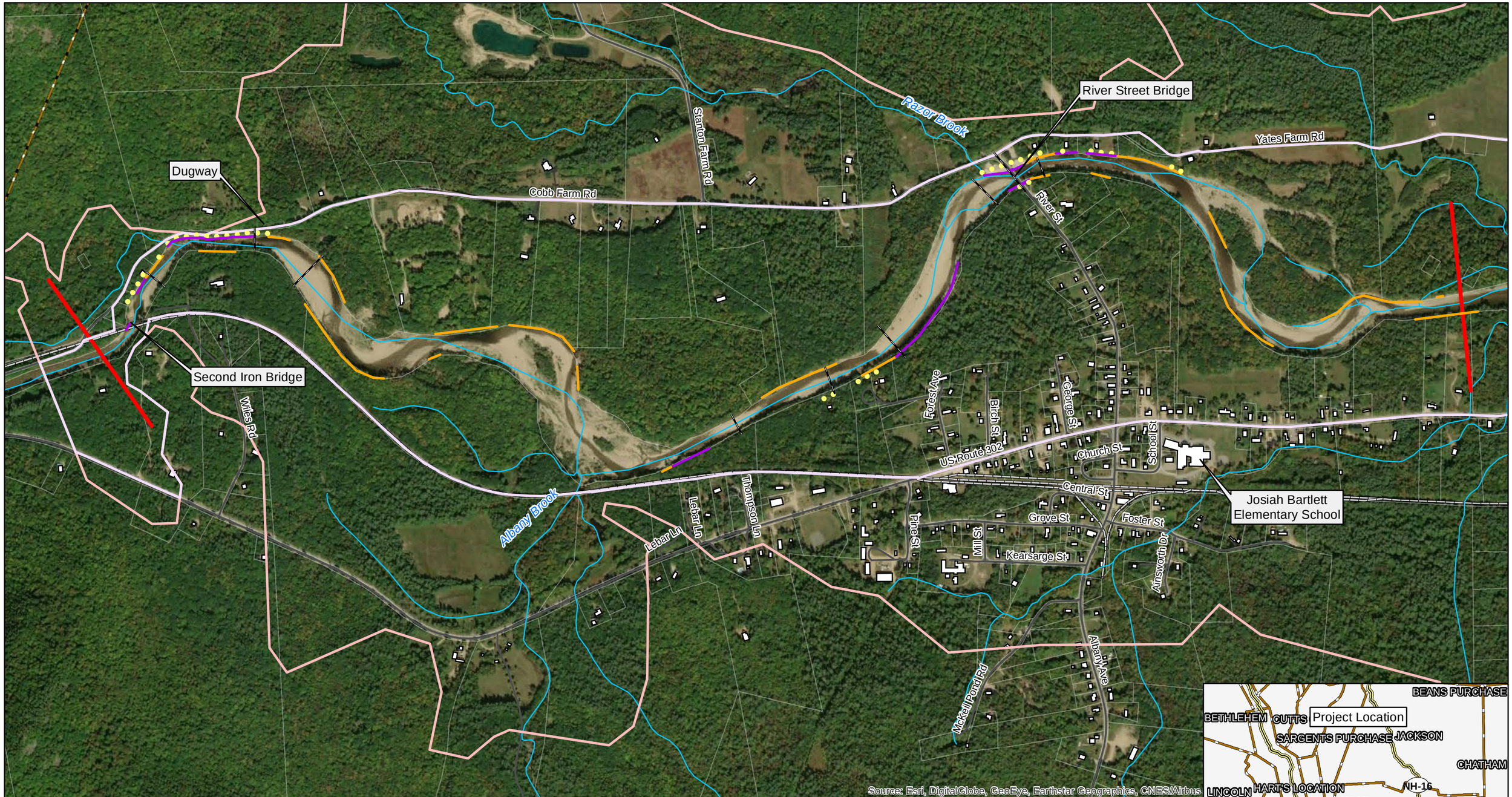
Step 1.3 River Corridor Encroachments **FIT**

Type	Length		Height of Fill
	One Side	Both Sides	
			Riffle #2
0.95 1.0	0.9 1.1	0.9	
x̄ = 0.97'			
11.6"			

Step 4.6 Stormwater **FIT**

	Tally
Field Ditch	
Overland Flow	ALP Bar #2
Road Ditch	0.7', 0.75', 0.6, 0.75, 0.7'
Tile Drain	
Urban Stormwater	x̄ = 0.7'
Other	8.4"

ALP Bar ~9" ≈ 229 mm
ALP Bed ~12" ≈ 305 mm



Stream Geomorphic Assessment Data
Saco River
Flood Hazard Reduction Study
Bartlett, NH

Bear Creek Environmental

Legend

Stream Geomorphic Assessment - Impact

- Bank Armoring
- Bank Erosion
- Buffer Less than 25 Feet
- Field Surveyed Cross Section
- NHD Stream
- Phase 2 River Valley
- Phase 1 River Valley
- Study Area Limits
- Road
- Railroad
- Building Footprint

0 750 1,500 Feet

1 inch = 750 feet

N

Spatial data sources include NH GRANIT & Bear Creek Environmental. Phase 2 Stream Geomorphic Assessment completed in August 2019. Building footprints from Microsoft. Background imagery is ESRI World Imagery. Map composed on March 16, 2020.

Dugway
Second Iron Bridge
River Street Bridge
Josiah Bartlett Elementary School
Razor Brook
Albany Brook
Cobb Farm Rd
Stanton Farm Rd
Yates Farm Rd
River St
Wiles Rd
Lebar Ln
Thompson Ln
Forest Ave
Birch St
George St
Church St
School St
US Route 302
Central St
Grove St
Foster St
Pine St
Mill St
Kearsarge St
Ainsworth Dr
Albany Ave
Mckell Pond Rd

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus

BEANS PURCHASE
BETHLEHEM
CUTTS
Project Location
SARGENTS PURCHASE
JACKSON
CHATHAM
LINCOLN
HART'S LOCATION
NH-16
HADLEYS PURCHASE
US-302
BARTLETT
UNORGANIZED TERRITORY
HALES LOCATION
CONWAY
ALBANY
WATERVILLE VALLEY

Saco River Historic Stream Centerline
Flood Hazard Reduction Study
Bartlett, NH

Bear Creek Environmental

Legend

- NHD Stream
- Study Area Limits
- Road
- Railroad
- Building Footprint

Historic Stream Centerline by Year

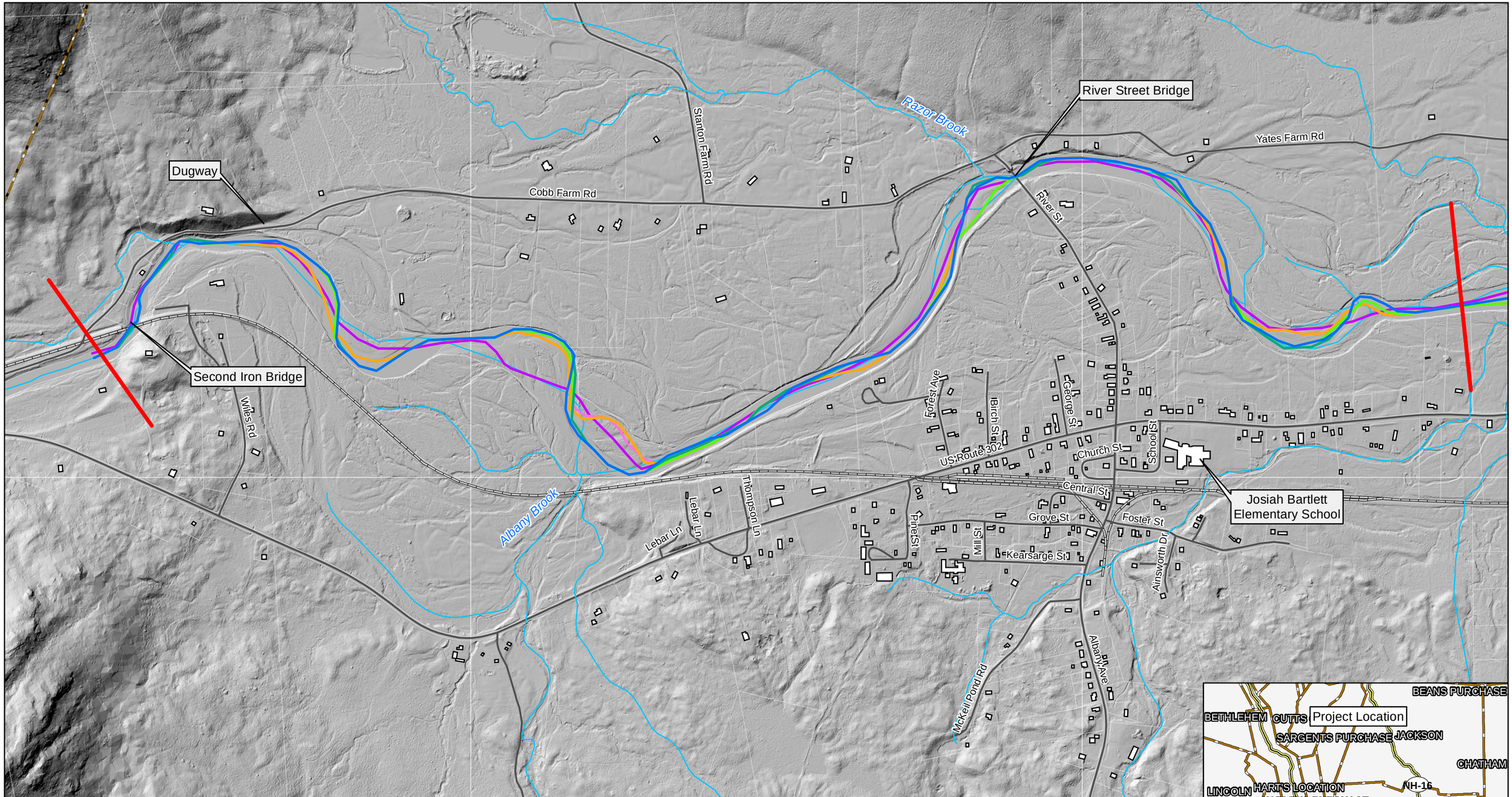
- 1992
- 2003
- 2009
- 2010
- 2015
- 2017

- Parcel Boundary
- Town Boundary

0 750 1,500 Feet
1 inch = 750 feet

N

Spatial data sources include NH GRANIT & Bear Creek Environmental. Historic stream centerline digitized from aerial imagery. Building footprints from Microsoft. Background imagery is ESRI World Imagery. Map composed on March 13, 2020.



Saco River Historic Stream Centerline
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Appendix B

Flood Frequency Analysis

RIPPLE
Natural Resources LLC

FROM: Matt Murawski, PE
TO: Mary Nealon, Bear Creek Environmental
DATE: February 18, 2020

SUBJECT: Saco River Flood Mitigation Study
Flood Frequency Analysis

A Flood Frequency Analysis (FFA) was conducted to estimate streamflow in the Saco River at River Street in Bartlett, NH for storms ranging from the 0.2 to 50 percent chance exceedance (500-year to 2-year). The results are as follows:

Percent Annual Chance Exceedance (%)	Recurrence Interval (years)	Flow (cfs)
0.2	500	42,500
1	100	29,200
2	50	24,400
4	25	20,000
10	10	14,900
20	5	11,300
50	2	6,830

There is a flow gage at the location of interest – Saco River at River Street at Bartlett NH (USGS 010642505) – but it has only been operation for 10 years, meaning some augmentation of the data is warranted to improve the accuracy of the analysis. In this case, the10-year record was extended based on correlation with a gage having a longer record, following the procedures in US Geological Survey Bulletin 17C (England 2019), which documents the standard methods for streamflow analysis in the United States. The FFA was then conducted using the extended data series. A summary of the steps follow, and input and output data are attached.

METHODOLOGY

Step 1. Annual peak flow data are available for the Saco River at River Street at Bartlett NH for the 10-year period from 2010 to 2019. The Saco River near Conway, NH gage (USGS 01064500) was selected for use in extending the Bartlett data. The Conway gage has 96 years of continuous data, including the most recent 10 years that coincide with the Bartlett gage, and 86 years of previous data.

Step 2. The statistical properties of both the short site (Bartlett) and long site (Conway) were investigated, and found to be strongly correlated. The computed Correlation Coefficient for the annual peak flows during the 10 years of corresponding records is

0.953, which is well above the 0.8 threshold above which this gage extension method is suitable.

Step 3. Following the methodology of 17C, an effective record length of 31 years was computed, meaning 21 additional years of data could be developed to augment the 10 years of actual flow measurements at the Bartlett gage.

Step 4. Using the statistical relationships between the two gages, 21 additional annual peak flows, for the years 1989 to 2009, were estimated. Combining those with the actual measured data for years 2010 to 2019, results in an extended data set with annual peak flows for a 31-year period from 1989 to 2019.

Step 5. The HEC-SPP program was used to perform a FFA on the 31 years of data following 17C methodology. A weighted skew (between station skew a regional skew) was used. The low-outlier screening per 17C was employed, which identified one such flow. All high flows were included, including both the 2011 (Irene) and 2018 (Halloween) events.

REFERENCES

England, J.F., Jr., Cohn, T.A., Faber, B.A., Stedinger, J.R., Thomas, W.O., Jr., Veilleux, A.G., Kiang, J.E., and Mason, R.R., Jr., 2018, Guidelines for determining flood flow frequency—Bulletin 17C (ver. 1.1, May 2019): U.S. Geological Survey Techniques and Methods, book 4, chap. B5, 148 p., https://doi.org/10.3133/tm4B5.

USGS 010642505 SACO RIVER AT RIVER STREET, AT BARTLETT, NH. Last accessed 2/17/2002 https://nwis.waterdata.usgs.gov/nh/nwis/peak/?site_no=010642505&agency_cd=USGS

USGS 01064500 Saco River near Conway, NH. Last accessed 2/17/2002 https://nwis.waterdata.usgs.gov/nwis/peak/?site_no=01064500&agency_cd=USGS

ATTACHMENTS

1. Annual Peak Flows Saco River at River Street at Bartlett NH
2. Annual Peak Flows Saco River near Conway NH
3. Gage Extension Interim Calculations (following 17C)
4. Flood Frequency Report from HEC-SSP

Annual Peak Flows
Saco River at River Street at Bartlett NH

	Year	Date	Flow (cfs)
Measured gage record	2019	Apr. 20, 2019	7,490
	2018	Oct. 30, 2017	25,300
	2017	Jul. 02, 2017	8,500
	2016	Feb. 25, 2016	3,840
	2015	Apr. 21, 2015	3,100
	2014	Apr. 15, 2014	11,300
	2013	Oct. 30, 2012	9,290
	2012	Nov. 30, 2011	6,530
	2011	Aug. 28, 2011	29,100
	2010	Jan. 25, 2010	7,390
Extended Gage Record	2009		2,840
	2008		4,180
	2007		7,790
	2006		4,310
	2005		8,870
	2004		10,600
	2003		2,840
	2002		7,590
	2001		6,430
	2000		5,780
	1999		8,500
	1998		15,400
	1997		7,740
	1996		11,800
	1995		976
	1994		5,330
	1993		6,570
	1992		4,140
	1991		9,390
	1990		5,200
	1989		7,840

Annual Peak Flows
Saco River near Conway NH

Year	Date	Flow (cfs)
2019	Apr. 21, 2019	21,700
2018	Oct. 30, 2017	48,700
2017	Jul. 02, 2017	14,800
2016	Feb. 25, 2016	11,000
2015	Apr. 21, 2015	10,900
2014	Apr. 16, 2014	31,900
2013	Oct. 30, 2012	19,200
2012	Jun. 03, 2012	20,000
2011	Aug. 29, 2011	58,200
2010	Jan. 26, 2010	16,300
2009	Oct. 26, 2008	11,700
2008	Apr. 29, 2008	15,200
2007	Oct. 29, 2006	23,100
2006	Jan. 19, 2006	15,500
2005	Apr. 24, 2005	25,200
2004	Dec. 18, 2003	28,400
2003	Aug. 10, 2003	11,700
2002	Apr. 14, 2002	22,700
2001	Dec. 18, 2000	20,300
2000	Apr. 09, 2000	18,900
1999	Sep. 17, 1999	24,500
1998	Jun. 14, 1998	36,500
1997	Oct. 22, 1996	23,000
1996	Nov. 12, 1995	30,600
1995	Jan. 17, 1995	5,710
1994	Nov. 29, 1993	17,900
1993	Apr. 17, 1993	20,600
1992	Oct. 07, 1991	15,100
1991	Dec. 24, 1990	26,200
1990	Aug. 11, 1990	17,600
1989	12-May-89	23,200
1988	Apr. 29, 1988	22,900
1987	Apr. 01, 1987	46,600
1986	Jan. 28, 1986	29,500
1985	Sep. 28, 1985	9,310
1984	Apr. 06, 1984	24,300
1983	Mar. 20, 1983	13,600
1982	Apr. 27, 1982	12,000
1981	Feb. 21, 1981	16,000
1980	Apr. 10, 1980	16,400

Year	Date	Flow (cfs)
1979	Apr. 27, 1979	27,600
1978	Jan. 09, 1978	20,400
1977	Mar. 14, 1977	40,500
1976	Apr. 02, 1976	17,900
1975	Mar. 18, 1975	11,300
1974	Dec. 21, 1973	26,900
1973	Jun. 30, 1973	35,000
1972	7-May-72	9,440
1971	4-May-71	14,800
1970	Dec. 27, 1969	17,000
1969	Apr. 19, 1969	15,300
1968	Apr. 25, 1968	29,300
1967	Nov. 03, 1966	28,500
1966	20-May-66	5,110
1965	Nov. 26, 1964	7,990
1964	Nov. 08, 1963	25,500
1963	Oct. 07, 1962	21,600
1962	Apr. 08, 1962	9,470
1961	10-May-61	5,820
1960	Oct. 24, 1959	43,800
1959	Apr. 20, 1959	5,390
1958	Dec. 21, 1957	19,500
1957	Apr. 21, 1957	6,430
1956	Jan. 10, 1956	10,100
1955	Oct. 16, 1954	14,800
1954	9-May-54	24,900
1953	Mar. 27, 1953	47,200
1952	Jun. 02, 1952	22,700
1951	Nov. 26, 1950	32,800
1950	Apr. 21, 1950	19,600
1949	Dec. 31, 1948	11,300
1948	Apr. 02, 1948	12,800
1947	Apr. 12, 1947	10,600
1946	Aug. 03, 1946	12,200
1945	Mar. 30, 1945	12,500
1944	Nov. 09, 1943	21,000
1943	12-May-43	9,950
1942	Apr. 26, 1942	8,760
1941	Apr. 16, 1941	7,100
1940	3-May-40	20,000

Year	Date	Flow (cfs)
1939	Dec. 06, 1938	11,200
1938	Sep. 21, 1938	20,800
1937	7-May-37	18,800
1936	Mar. 19, 1936	44,500
1935	Dec. 02, 1934	8,640
1934	Apr. 13, 1934	15,900
1933	Apr. 18, 1933	11,900
1932	Sep. 17, 1932	16,400
1931	Jun. 09, 1931	15,400
1930	Apr. 07, 1930	15,800
1909	Apr. 14, 1909	16,800
1908	Nov. 03, 1907	29,100
1907	1-May-07	11,500
1906	Apr. 16, 1906	8,200
1905	Jul. 31, 1905	15,300
1904	Apr. 30, 1904	11,400

Gage Extension following 17C MOVE Method
Equations refer to 17C Appendix 8

	n1	10				
	n2	86				
	y1	3.945	mean of logs for concurrent period			
	x1	4.334	mean of logs for concurrent period			
	x2	4.225	mean of logs for nonconcurent			
	Sy1	0.308	stnd dev of logs for short			
	Sx1	0.249	stnd dev of logs for long site, concurrent period			
	Sx2	0.224	stnd dev of logs for long site, nonconcurrent period			
	Corr Coef	0.9533				
	Corr	0.9089				
	alpha sq	0.9756303				
eq 8-10	Bhat	1.179788				
eq 8-9	phat	0.953338				
eq 8-7 (augmented mean)	u-haty	3.8303	mean			
eq 8-8 (augmented variance)	O-hatsqy	0.08058	variance			
eq 8-14	A	-214.9143				
eq 8-15	B	49.828571				
eq 8-16	C	17.307937				
eq 8-19	ne + n1	31.408226				
	ne	21.408226				
use	ne	21				
eq 8-21	xe	4.2856				
eq 8-22	Sxe sq	0.0310				
eq 8-23	a	3.7757				
eq 8-24	b sq	2.2085				
	b	1.4861				
1st Yr of Extension		2009				
		log of flow	flow (cfs)	Year		Rounded
eq 8-20	yin1+1	3.4526		2,835	2009	2,840
	yin1+2	3.6215		4,183	2008	4,180
	yin1+3	3.8916		7,791	2007	7,790
	yin1+4	3.6341		4,306	2006	4,310
	yin1+5	3.9478		8,867	2005	8,870
	yin1+6	4.0249		10,591	2004	10,600
	yin1+7	3.4526		2,835	2003	2,840
	yin1+8	3.8803		7,592	2002	7,590
	yin1+9	3.8082		6,430	2001	6,430
	yin1+10	3.7621		5,782	2000	5,780
	yin1+11	3.9296		8,503	1999	8,500
	yin1+12	4.1869		15,377	1998	15,400
	yin1+13	3.8888		7,741	1997	7,740
	yin1+14	4.0731		11,833	1996	11,800
	yin1+15	2.9896		976	1995	976
	yin1+16	3.7270		5,333	1994	5,330
	yin1+17	3.8177		6,572	1993	6,570
	yin1+18	3.6172		4,142	1992	4,140
	yin1+19	3.9729		9,395	1991	9,390
	yin1+20	3.7161		5,201	1990	5,200
	yin1+21	3.8944		7,841	1989	7,840

Bulletin 17C (Java) Frequency Analysis
18 Feb 2020 10:35 AM

--- Input Data ---

Analysis Name: Saco at Bartlett FFA
Description: FFA using 31 year extended record for Saco at Barlett

Data Set Name: SACO at Bartlett Extended
DSS File Name: C:\Users\Matt Murawski\Documents\PROJECTS\2019005 Saco River\Flows\Saco_at_River_St_at_Bartlett_FFA\Saco_at_River_St_at_Bartlett_FFA.dss
DSS Pathname: /SACO RIVER/RIVER STREET, AT BARTLETT, NH/FLOW-ANNUAL PEAK/01jan1900/IR-CENTURY/Save Data As: SACO at Bartlett Extended/

Report File Name: C:\Users\Matt Murawski\Documents\PROJECTS\2019005 Saco River\Flows\Saco_at_River_St_at_Bartlett_FFA\Bulletin17Results\Saco_at_Bartlett_FFA\Saco_at_Bartlett_FFA.rpt
XML File Name: C:\Users\Matt Murawski\Documents\PROJECTS\2019005 Saco River\Flows\Saco_at_River_St_at_Bartlett_FFA\Bulletin17Results\Saco_at_Bartlett_FFA\Saco_at_Bartlett_FFA.xml

Start Date:
End Date:

Skew Option: Use Weighted Skew
Regional Skew: -0.1
Regional Skew MSE: 0.298

Plotting Position Type: Hirsch-Stedinger

Upper Confidence Level: 0.05
Lower Confidence Level: 0.95

Use non-standard frequencies
Frequency: 0.2
Frequency: 1.0
Frequency: 2.0
Frequency: 4.0
Frequency: 10.0
Frequency: 20.0
Frequency: 50.0

Display ordinate values using 1 digits in fraction part of value

--- End of Input Data ---

<< EMA Representation of Data >>
SACO at Bartlett Extended

		Value		Threshold		
Year	Peak	Low	High	Low	High	Type
1989	7,840.0	7,840.0	7,840.0	2,840.0	1.0E99	Syst
1990	5,200.0	5,200.0	5,200.0	2,840.0	1.0E99	Syst
1991	9,390.0	9,390.0	9,390.0	2,840.0	1.0E99	Syst
1992	4,140.0	4,140.0	4,140.0	2,840.0	1.0E99	Syst
1993	6,570.0	6,570.0	6,570.0	2,840.0	1.0E99	Syst
1994	5,330.0	5,330.0	5,330.0	2,840.0	1.0E99	Syst
1995	976.0	1.0E-6	2,840.0	2,840.0	1.0E99	Syst
1996	11,800.0	11,800.0	11,800.0	2,840.0	1.0E99	Syst
1997	7,740.0	7,740.0	7,740.0	2,840.0	1.0E99	Syst
1998	15,400.0	15,400.0	15,400.0	2,840.0	1.0E99	Syst
1999	8,500.0	8,500.0	8,500.0	2,840.0	1.0E99	Syst
2000	5,780.0	5,780.0	5,780.0	2,840.0	1.0E99	Syst
2001	6,430.0	6,430.0	6,430.0	2,840.0	1.0E99	Syst
2002	7,590.0	7,590.0	7,590.0	2,840.0	1.0E99	Syst
2003	2,840.0	2,840.0	2,840.0	2,840.0	1.0E99	Syst
2004	10,600.0	10,600.0	10,600.0	2,840.0	1.0E99	Syst
2005	8,870.0	8,870.0	8,870.0	2,840.0	1.0E99	Syst
2006	4,310.0	4,310.0	4,310.0	2,840.0	1.0E99	Syst
2007	7,790.0	7,790.0	7,790.0	2,840.0	1.0E99	Syst
2008	4,180.0	4,180.0	4,180.0	2,840.0	1.0E99	Syst
2009	2,840.0	2,840.0	2,840.0	2,840.0	1.0E99	Syst
2010	7,390.0	7,390.0	7,390.0	2,840.0	1.0E99	Syst
2011	29,100.0	29,100.0	29,100.0	2,840.0	1.0E99	Syst
2012	6,530.0	6,530.0	6,530.0	2,840.0	1.0E99	Syst
2013	9,290.0	9,290.0	9,290.0	2,840.0	1.0E99	Syst
2014	11,300.0	11,300.0	11,300.0	2,840.0	1.0E99	Syst
2015	3,100.0	3,100.0	3,100.0	2,840.0	1.0E99	Syst
2016	3,840.0	3,840.0	3,840.0	2,840.0	1.0E99	Syst
2017	8,500.0	8,500.0	8,500.0	2,840.0	1.0E99	Syst
2018	25,300.0	25,300.0	25,300.0	2,840.0	1.0E99	Syst
2019	7,490.0	7,490.0	7,490.0	2,840.0	1.0E99	Syst

Fitted log10 Moments	Mean	Variance	Std Dev	Skew
EMA at-site data w/o regional info	3.842801	0.063663	0.252315	0.398752
EMA w/ regional info and B17b MSE(G)	3.842204	0.064316	0.253605	0.181758

EMA w/ regional info and specified MSE(G) 3.842204 0.064316 0.253605 0.181758

EMA Estimate of MSE[G at-site] 0.195417
MSE[G at-site systematic] 0.195417
Equivalent Record Length [G at-site] 31.000000
Equivalent Record Length [Syst+Hist-LowOutl] 30.000000
Grubbs-Beck Critical Value 2,840.000000

--- Final Results ---

<< Plotting Positions >>
SACO at Bartlett Extended

Events Analyzed		Ordered Events		
	FLOW	Water	FLOW	H-S
Day Mon Year	CFS	Rank	Year	CFS	Plot Pos
25 Jan 1989	7,840.0	1	2011	29,100.0	3.12
25 Jan 1990	5,200.0	2	2018	25,300.0	6.24
25 Jan 1991	9,390.0	3	1998	15,400.0	9.37
25 Jan 1992	4,140.0	4	1996	11,800.0	12.49
25 Jan 1993	6,570.0	5	2014	11,300.0	15.61
25 Jan 1994	5,330.0	6	2004	10,600.0	18.73
25 Jan 1995	976.0	7	1991	9,390.0	21.85
25 Jan 1996	11,800.0	8	2013	9,290.0	24.97
25 Jan 1997	7,740.0	9	2005	8,870.0	28.10
25 Jan 1998	15,400.0	10	2017	8,500.0	31.22
25 Jan 1999	8,500.0	11	1999	8,500.0	34.34
25 Jan 2000	5,780.0	12	1989	7,840.0	37.46
25 Jan 2001	6,430.0	13	2007	7,790.0	40.58
25 Jan 2002	7,590.0	14	1997	7,740.0	43.70
25 Jan 2003	2,840.0	15	2002	7,590.0	46.83
25 Jan 2004	10,600.0	16	2019	7,490.0	49.95
25 Jan 2005	8,870.0	17	2010	7,390.0	53.07
25 Jan 2006	4,310.0	18	1993	6,570.0	56.19
25 Jan 2007	7,790.0	19	2012	6,530.0	59.31
25 Jan 2008	4,180.0	20	2001	6,430.0	62.43
25 Jan 2009	2,840.0	21	2000	5,780.0	65.56
25 Jan 2010	7,390.0	22	1994	5,330.0	68.68
28 Aug 2011	29,100.0	23	1990	5,200.0	71.80
30 Nov 2011	6,530.0	24	2006	4,310.0	74.92
30 Oct 2012	9,290.0	25	2008	4,180.0	78.04
15 Apr 2014	11,300.0	26	1992	4,140.0	81.17
21 Apr 2015	3,100.0	27	2016	3,840.0	84.29

25 Feb 2016	3,840.0	28	2015	3,100.0	87.41
01 Jul 2017	8,500.0	29	2009	2,840.0	90.53
30 Oct 2017	25,300.0	30	2003	2,840.0	93.65
01 Jan 2019	7,490.0	31	1995	976.0*	97.77

* Outlier

* Low outlier plotting positions are computed using Median parameters.

<< Frequency Curve >>

SACO at Bartlett Extended

Computed Curve FLOW, CFS	Variance Log(EMA)	Percent Chance Exceedance	Confidence Limits 0.05 FLOW, CFS	0.95
42,485.3	0.02498	0.200	115,115.4	27,441.1
29,230.3	0.01339	1.000	57,957.5	20,915.3
24,401.7	0.00979	2.000	42,760.9	18,166.8
20,028.2	0.00697	4.000	31,305.4	15,458.0
14,850.7	0.00435	10.000	20,439.2	11,922.8
11,300.5	0.00311	20.000	14,465.2	9,279.4
6,831.6	0.00226	50.000	8,260.8	5,695.7

<< Multiple Grubbs-Beck Test P-Values >>

SACO at Bartlett Extended

Number Of Low Outliers	P-Values
1	2.115E-2
2	6.842E-1
3	3.400E-1
4	2.502E-1
5	6.025E-1
6	6.236E-1
7	4.126E-1
8	2.813E-1
9	7.759E-1
10	6.964E-1
11	8.337E-1
12	9.719E-1
13	9.545E-1
14	9.072E-1
15	9.934E-1

```
|----------------|-------------|
* = p-value corresponds to a zero flow value.


<< Systematic Statistics >>
SACO at Bartlett Extended
-----------------------------------------------------------------
|       Log Transform:        |                              |
|         FLOW, CFS           |       Number of Events       |
|-----------------------------|------------------------------|
|  Mean                3.842  |  Historic Events          0  |
|  Standard Dev        0.254  |  High Outliers            0  |
|  Station Skew        0.399  |  Low Outliers             1  |
|  Regional Skew      -0.100  |  Zero Events              0  |
|  Weighted Skew       0.182  |  Missing Events           0  |
|  Adopted Skew        0.182  |  Systematic Events       31  |
|-----------------------------|------------------------------|

--- End of Analytical Frequency Curve ---
```

Appendix C

Base Hydraulic Modeling

Dugway

Intersection flooded

House surrounded by water

River Street Bridge

Water lapping at edge of bridge

Road flooded

Second Iron Bridge

Road flooded

House surrounded by water

Josiah Bartlett Elementary School

Razor Brook

Albany Brook

Cobb Farm Rd

Stanton Farm Rd

Yates Farm Rd

River St

Tir Na Nog Ln

Forest Ave

Birch St

Church St

Central St

Grove St

Foster St

Kearsarge St

Mill St

Pines St

Ainsworth Dr

Albany Ave

McKeil Pond Rd

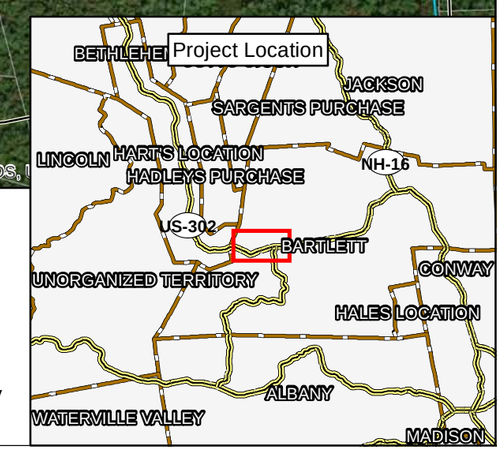
Lebar Ln

Thompson Ln

Wiles Rd

US Route 302

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS,



2017 Flood Extent
Saco River
Flood Hazard Reduction Study
Bartlett, NH

Bear Creek Environmental

Legend

2017 Flood - Water Depth (ft)

High : 19.2

Low : 0.001

HEC-RAS 2D Flow Area

NHD Stream

High Water Mark

Road

Railroad

Building Footprint

Parcel Boundary

Town Boundary

0 750 1,500 Feet

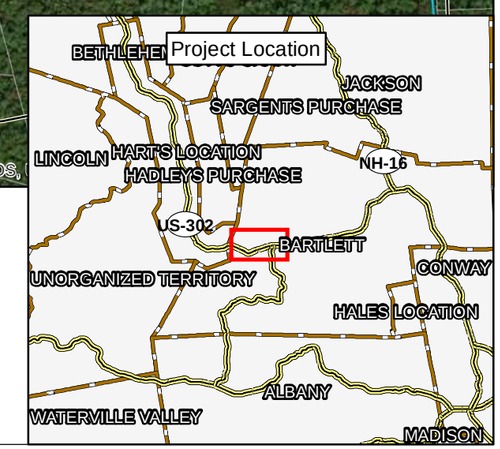
1 inch = 750 feet

N

Spatial data sources include NH GRANIT & Bear Creek Environmental. High water marks and notes about flooding from field reconnaissance and meetings with landowners and Bartlett officials. These flood notes and others were used to calibrate flood model. Building footprints from Microsoft. Background imagery is ESRI World Imagery. Map composed on March 16, 2020.

Dugway
Second Iron Bridge
River Street Bridge
Josiah Bartlett Elementary School
Razor Brook
Albany Brook
Cobb Farm Rd
Stanton Farm Rd
Yates Farm Rd
River St
Tir Na Nog Ln
Forest Ave
Birch St
George St
Church St
School St
Central St
Grove St
Foster St
Kearsarge St
Mill St
Pine St
Ainsworth Dr
Albany Ave
McKeil Pond Rd
Thompson Ln
Lebar Ln
Wiles Rd
US Route 302

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS,



2-Year Flood Extent
Saco River
Flood Hazard Reduction Study
Bartlett, NH

Bear Creek Environmental

Legend

2-Year Event - Water Depth (ft)
High : 11.7
Low : 0.001

HEC-RAS 2D Flow Area
NHD Stream
Road
Railroad
Building Footprint
Parcel Boundary
Town Boundary

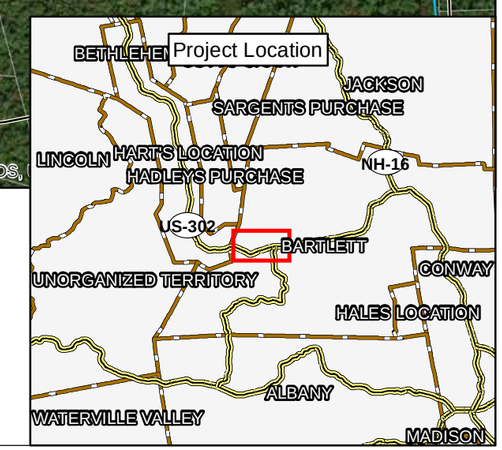
0 750 1,500 Feet
1 inch = 750 feet

N

Spatial data sources include NH GRANIT & Bear Creek Environmental. Building footprints from Microsoft. Background imagery is ESRI World Imagery. Map composed on March 4, 2020.

Dugway
Second Iron Bridge
River Street Bridge
Josiah Bartlett Elementary School
Razor Brook
Albany Brook
Cobb Farm Rd
Stanton Farm Rd
Yates Farm Rd
River St
Tir Na Nog Ln
Forest Ave
Birch St
George St
Church St
School St
Central St
Grove St
Foster St
Kearsarge St
Mill St
Pine St
Ainsworth Dr
Albany Ave
McKeil Pond Rd
Thompson Ln
Lebar Ln
Wiles Rd
US Route 302

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS,



10-Year Flood Extent
Saco River
Flood Hazard Reduction Study
Bartlett, NH

Bear Creek Environmental

Legend

10-Year Event - Water Depth (ft)
High : 16.0
Low : 0.001
HEC-RAS 2D Flow Area
NHD Stream
Road
Railroad
Building Footprint
Parcel Boundary
Town Boundary

0 750 1,500 Feet
1 inch = 750 feet

N

Spatial data sources include NH GRANIT & Bear Creek Environmental. Building footprints from Microsoft. Background imagery is ESRI World Imagery. Map composed on March 4, 2020.

25-Year Flood Extent
Saco River
Flood Hazard Reduction Study
Bartlett, NH

Bear Creek Environmental

Legend

25-Year Event - Water Depth (ft)

High : 18.1

Low : 0.001

HEC-RAS 2D Flow Area

NHD Stream

Road

Railroad

Building Footprint

Parcel Boundary

Town Boundary

0 750 1,500 Feet

1 inch = 750 feet

N

Spatial data sources include NH GRANIT & Bear Creek Environmental. Building footprints from Microsoft. Background imagery is ESRI World Imagery. Map composed on March 4, 2020.

Dugway

Second Iron Bridge

River Street Bridge

Josiah Bartlett Elementary School

Razor Brook

Albany Brook

Cobb Farm Rd

Stanton Farm Rd

Yates Farm Rd

River St

Tir Na Nog Ln

Forest Ave

Birch St

George St

Church St

Schools St

Central St

Grove St

Foster St

Kearsarge St

Mill St

Pine St

Ainsworth Dr

Albany Ave

McKeil Pond Rd

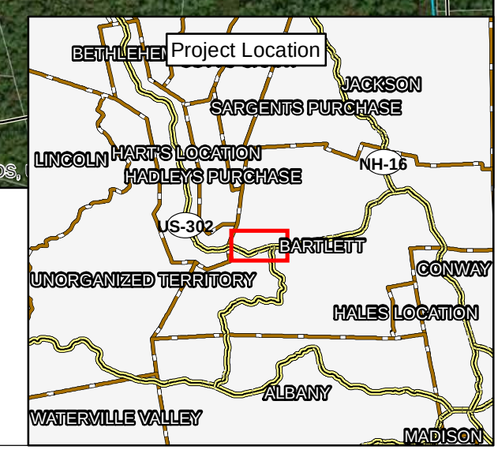
Thompson Ln

Lebar Ln

Wiles Rd

US Route 302

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS,



50-Year Flood Extent
Saco River
Flood Hazard Reduction Study
Bartlett, NH

Bear Creek Environmental

Legend

50-Year Event - Water Depth (ft)

High : 19.1

Low : 0.001

HEC-RAS 2D Flow Area

NHD Stream

Road

Railroad

Building Footprint

Parcel Boundary

Town Boundary

0 750 1,500 Feet

1 inch = 750 feet

N

Spatial data sources include NH GRANIT & Bear Creek Environmental. Building footprints from Microsoft. Background imagery is ESRI World Imagery. Map composed on March 4, 2020.

Dugway

Second Iron Bridge

River Street Bridge

Josiah Bartlett Elementary School

Razor Brook

Albany Brook

Cobb Farm Rd

Stanton Farm Rd

Yates Farm Rd

River St

Tir Na Nog Ln

Forest Ave

Birch St

George St

Church St

Spooner St

Central St

Grove St

Foster St

Kearsarge St

Mill St

Pine St

Ainsworth Dr

Albany Ave

McKeil Pond Rd

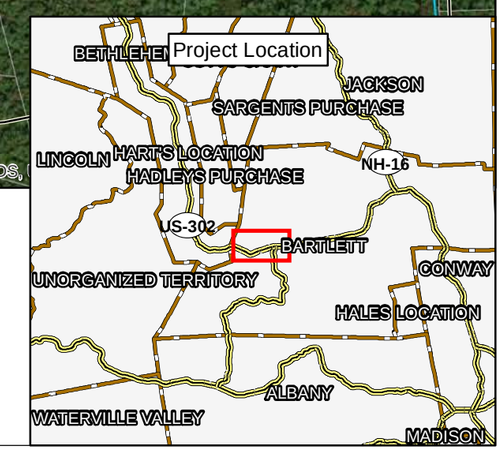
Thompson Ln

Lebar Ln

Wiles Rd

US Route 302

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS,



100-Year Flood Extent
Saco River
Flood Hazard Reduction Study
Bartlett, NH

Bear Creek Environmental

Legend

100-Year Event - Water Depth (ft)

- High : 19.9
- Low : 0.001

HEC-RAS 2D Flow Area

NHD Stream

Road

Railroad

Building Footprint

Parcel Boundary

Town Boundary

0 750 1,500 Feet

1 inch = 750 feet

N

Spatial data sources include NH GRANIT & Bear Creek Environmental. Building footprints from Microsoft. Background imagery is ESRI World Imagery. Map composed on March 4, 2020.

Dugway

Second Iron Bridge

River Street Bridge

Josiah Bartlett Elementary School

Razor Brook

Albany Brook

Cobb Farm Rd

Stanton Farm Rd

Yates Farm Rd

River St

Tir Na Nog Ln

Forest Ave

Birch St

George St

Church St

School St

Central St

Grove St

Foster St

Kearsarge St

Mill St

Pines St

Ainsworth Dr

Albany Ave

McKeil Pond Rd

Thompson Ln

Lebar Ln

Wiles Rd

US Route 302

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS,

Project Location

BETHLEHEM

JACKSON

SARGENTS PURCHASE

LINCOLN

HART'S LOCATION

HADLEYS PURCHASE

NH-16

US-302

BARTLETT

CONWAY

UNORGANIZED TERRITORY

HALES LOCATION

ALBANY

WATERVILLE VALLEY

MADISON

500-Year Flood Extent
Saco River
Flood Hazard Reduction Study
Bartlett, NH

Bear Creek Environmental

Legend

500-Year Event - Water Depth (ft)

High : 21.1

Low : 0.001

HEC-RAS 2D Flow Area

NHD Stream

Road

Railroad

Building Footprint

Parcel Boundary

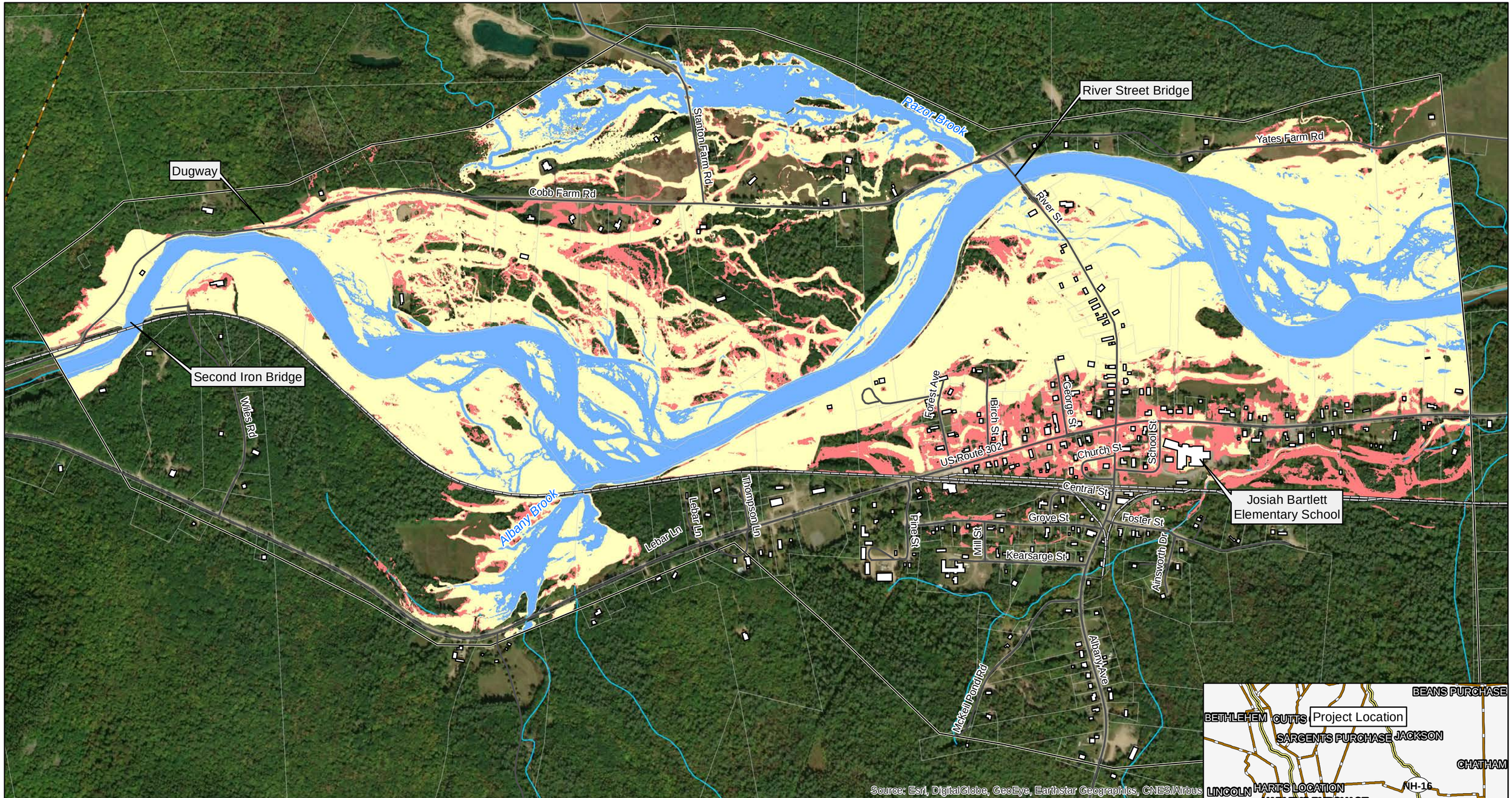
Town Boundary

0 750 1,500 Feet

1 inch = 750 feet

N

Spatial data sources include NH GRANIT & Bear Creek Environmental. Building footprints from Microsoft. Background imagery is ESRI World Imagery. Map composed on March 4, 2020.



2, 50, and 100-Year Flood Extents
Saco River
Flood Hazard Reduction Study
Bartlett, NH

Bear Creek Environmental

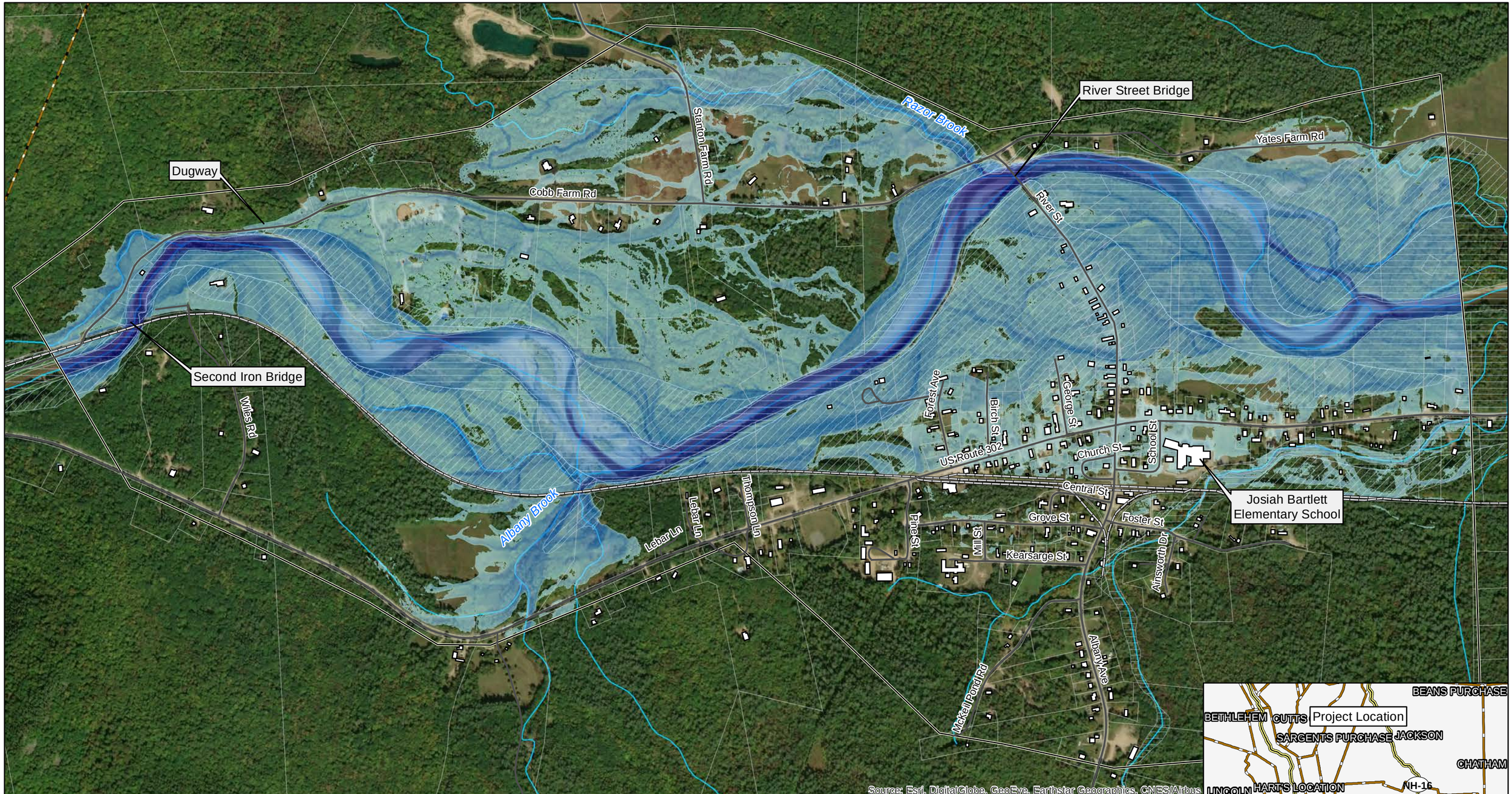
Legend

- 2-Year Event - Inundation Boundary
- 50-Year Event - Inundation Boundary
- 100-Year Event - Inundation Boundary
- HEC-RAS 2D Flow Area
- NHD Stream
- Road
- Railroad
- Building Footprint
- Parcel Boundary
- Town Boundary

0 750 1,500 Feet
1 inch = 750 feet

N

Spatial data sources include NH GRANIT & Bear Creek Environmental. Building footprints from Microsoft. Background imagery is ESRI World Imagery. Map composed on March 4, 2020.



100-Year Flood - Water Depth
Saco River
Flood Hazard Reduction Study
Bartlett, NH

Bear Creek Environmental

Legend

100-Year Event - Water Depth (ft)

High : 19.9

Low : 0.001

HEC-RAS 2D Flow Area

NHD Stream

FEMA Floodway

FEMA 100-Year Floodplain

Road

Railroad

Building Footprint

Parcel Boundary

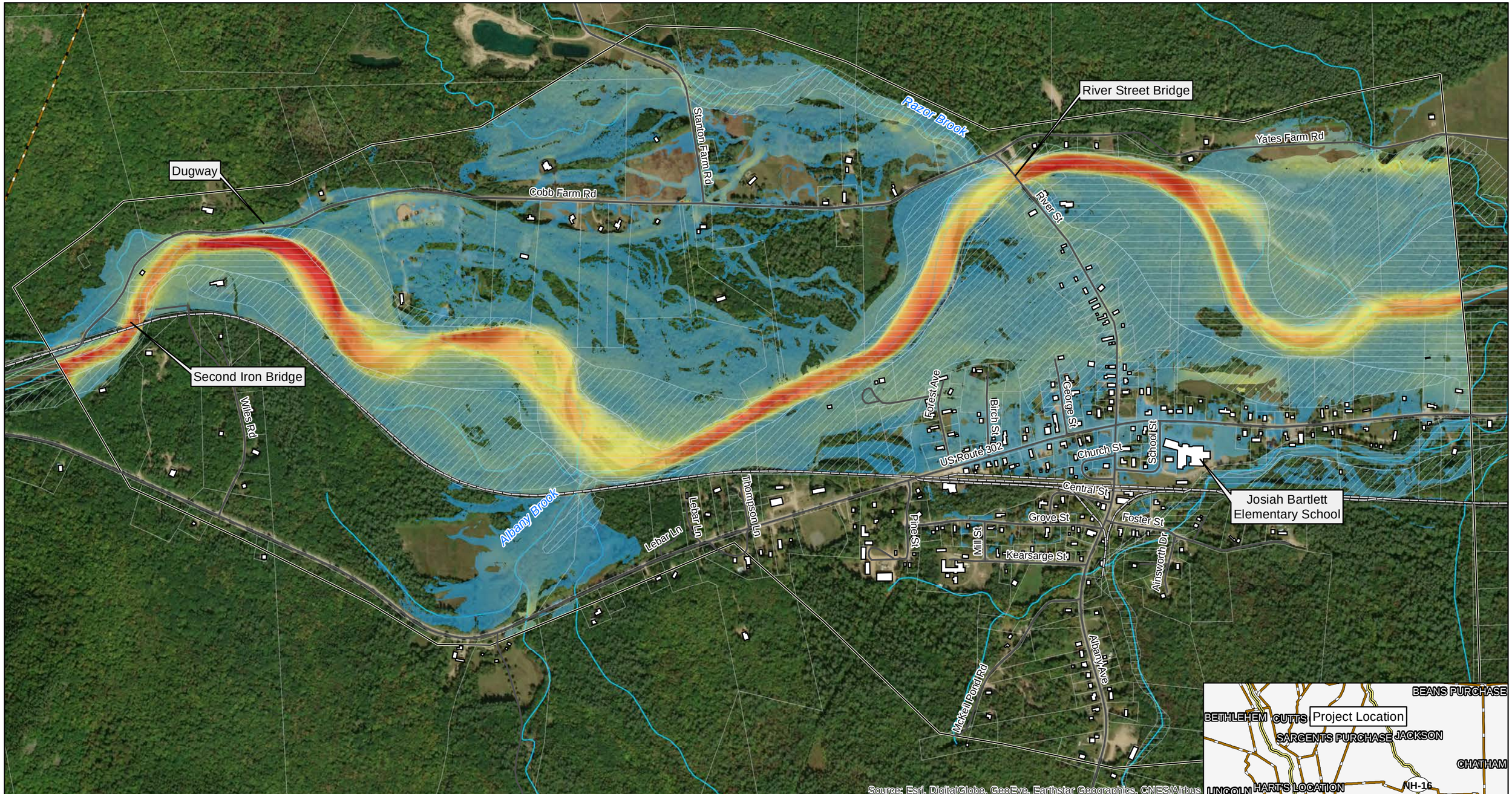
Town Boundary

0 750 1,500 Feet

1 inch = 750 feet

N

Spatial data sources include NH GRANIT & Bear Creek Environmental. Building footprints from Microsoft. Background imagery is ESRI World Imagery. Map composed on March 13, 2020.



100-Year Flood - Water Velocity
Saco River
Flood Hazard Reduction Study
Bartlett, NH

Bear Creek Environmental

Legend

100-Year Event - Water Velocity (ft/sec)

High : 18.2

Low : 0

HEC-RAS 2D Flow Area

NHD Stream

FEMA Floodway

FEMA 100-Year Floodplain

Road

Railroad

Building Footprint

Parcel Boundary

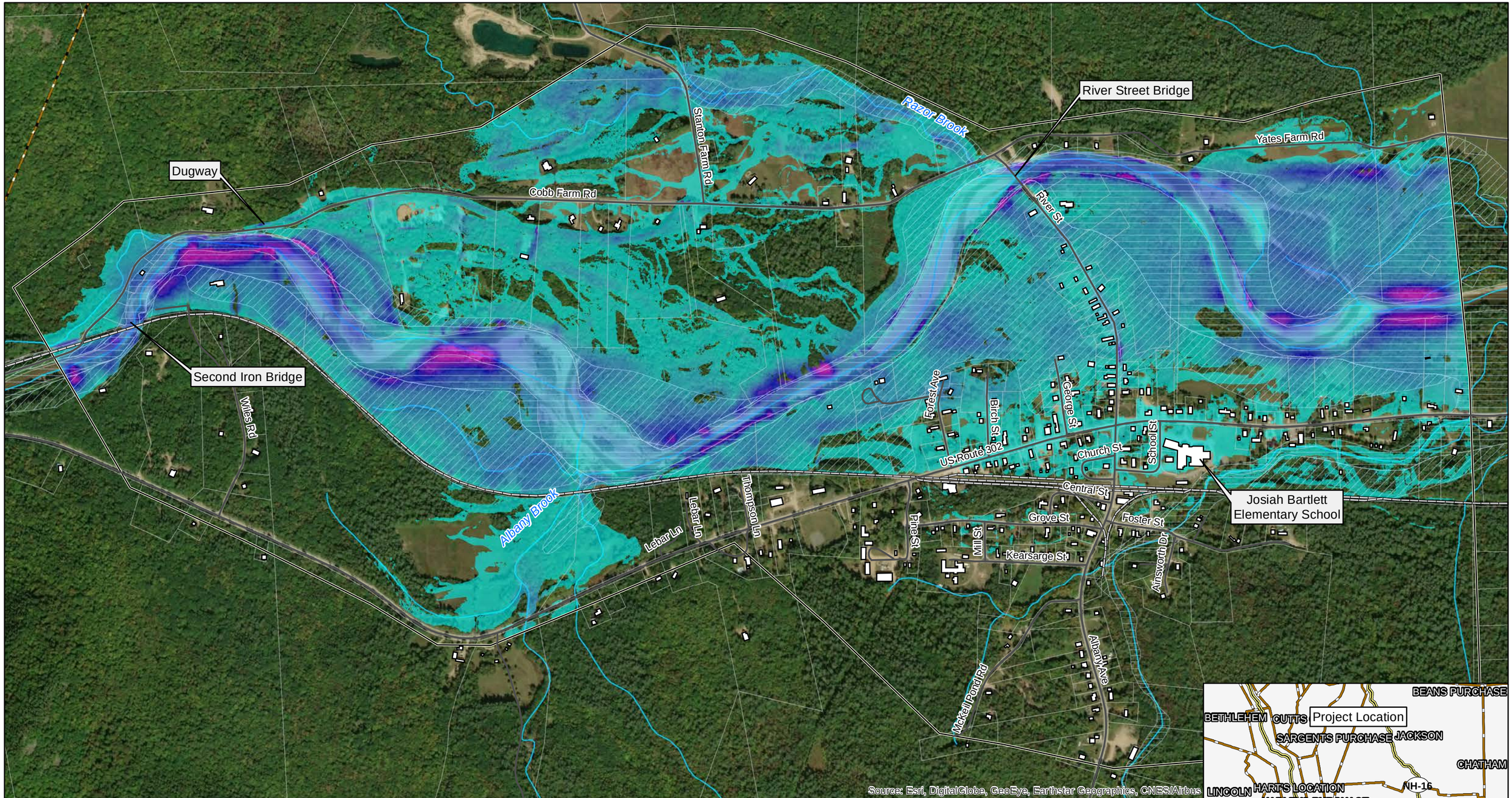
Town Boundary

0 750 1,500 Feet

1 inch = 750 feet

N

Spatial data sources include NH GRANIT & Bear Creek Environmental. Building footprints from Microsoft. Background imagery is ESRI World Imagery. Map composed on March 13, 2020.



100-Year Flood - Shear Stress
Saco River
Flood Hazard Reduction Study
Bartlett, NH

Bear Creek Environmental

Legend

100-Year Event - Shear Stress (lbs/sqft)

High : 38.2

Low : 0

HEC-RAS 2D Flow Area

NHD Stream

FEMA Floodway

FEMA 100-Year Floodplain

Road

Railroad

Building Footprint

Parcel Boundary

Town Boundary

0 750 1,500 Feet

1 inch = 750 feet

N

Spatial data sources include NH GRANIT & Bear Creek Environmental. Building footprints from Microsoft. Background imagery is ESRI World Imagery. Map composed on March 13, 2020.

Appendix D

Flood Hazard Reduction Schematics

Install new bridge under Cobb Farm Road and reconfigure Cobb/Stanton intersection

New single-span River Street Bridge

Razor Brook

Yates Farm Rd

Dredging of river cobble

Dugway

Build taller, continuous berm on north side of river

Cobb Farm Rd

Stanton Farm Rd

River St

Raise River Street across floodplain

Second Iron Bridge

Wiles Rd

Forest Ave

Birch St

George St

US Route 302

Church St

School St

Build taller, continuous berm on south side of river

Central St

Josiah Bartlett Elementary School

Albany Brook

Lebar Ln

Thompson Ln

Pine St

Mill St

Grove St

Foster St

Kearsarge St

Ainsworth Dr

Albany Ave

Mckell Pond Rd

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus

BEANS PURCHASE
BETHLEHEM
CUTTS
Project Location
SARGENTS PURCHASE
JACKSON
CHATHAM
LINCOLN
HART'S LOCATION
NH-16
HADLEYS PURCHASE
US-302
BARTLETT
UNORGANIZED TERRITORY
HALES LOCATION
CONWAY
ALBANY
WATERVILLE VALLEY

Flood Hazard Mitigation Alternatives
Conceptual Map
Flood Hazard Reduction Study
Saco River - Bartlett, NH

Bear Creek Environmental

Legend

- Proposed FEMA Berm Repair Location

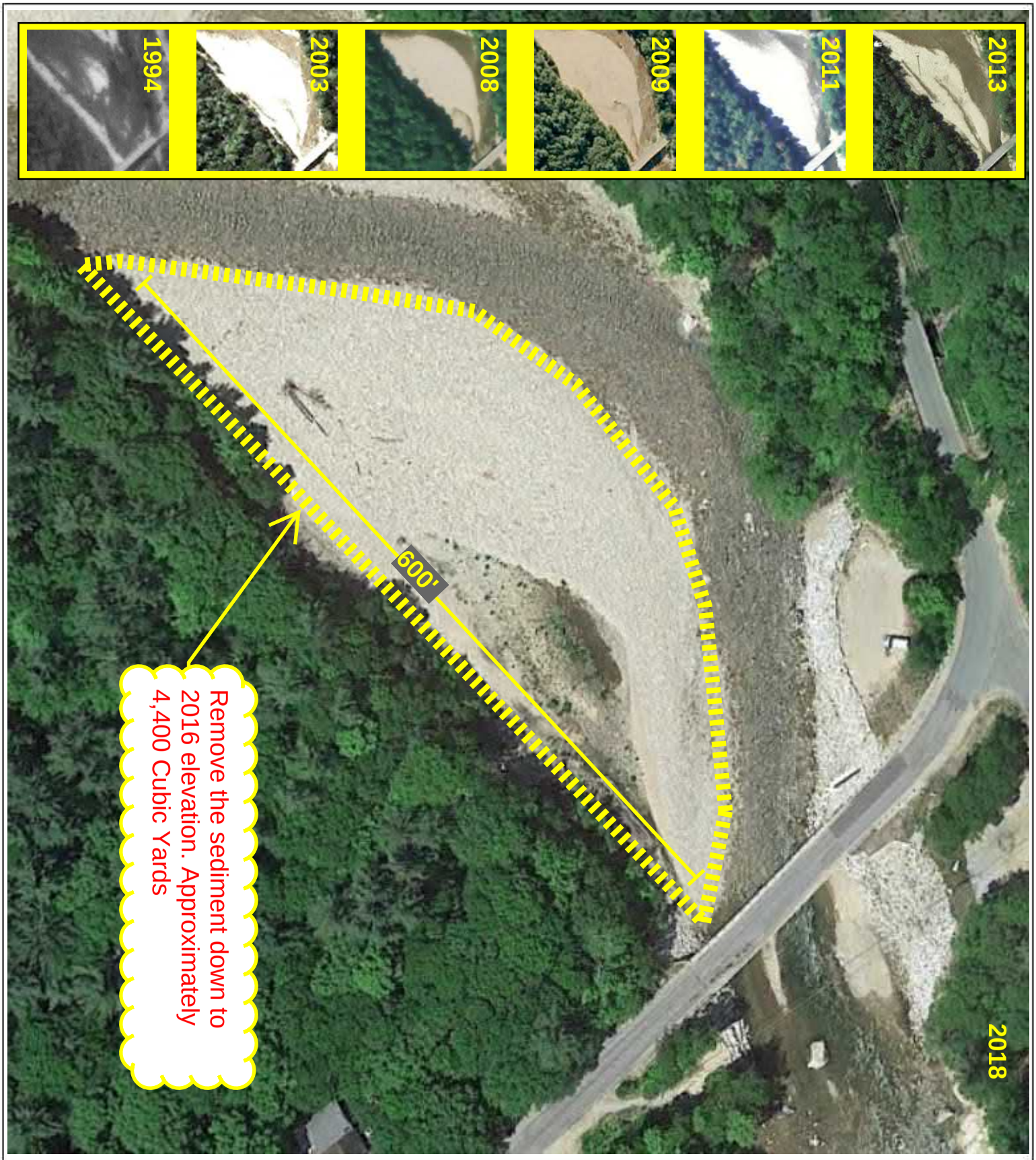
Mitigation Alternative

- Road Relocation
- Bridge or Culvert Replacement
- Berm Construction
- Raise Road
- Dredging of River Cobble
- NHD Stream
- Road
- Railroad
- Building Footprint
- Parcel Boundary
- Town Boundary

0 750 1,500 Feet
1 inch = 750 feet

N

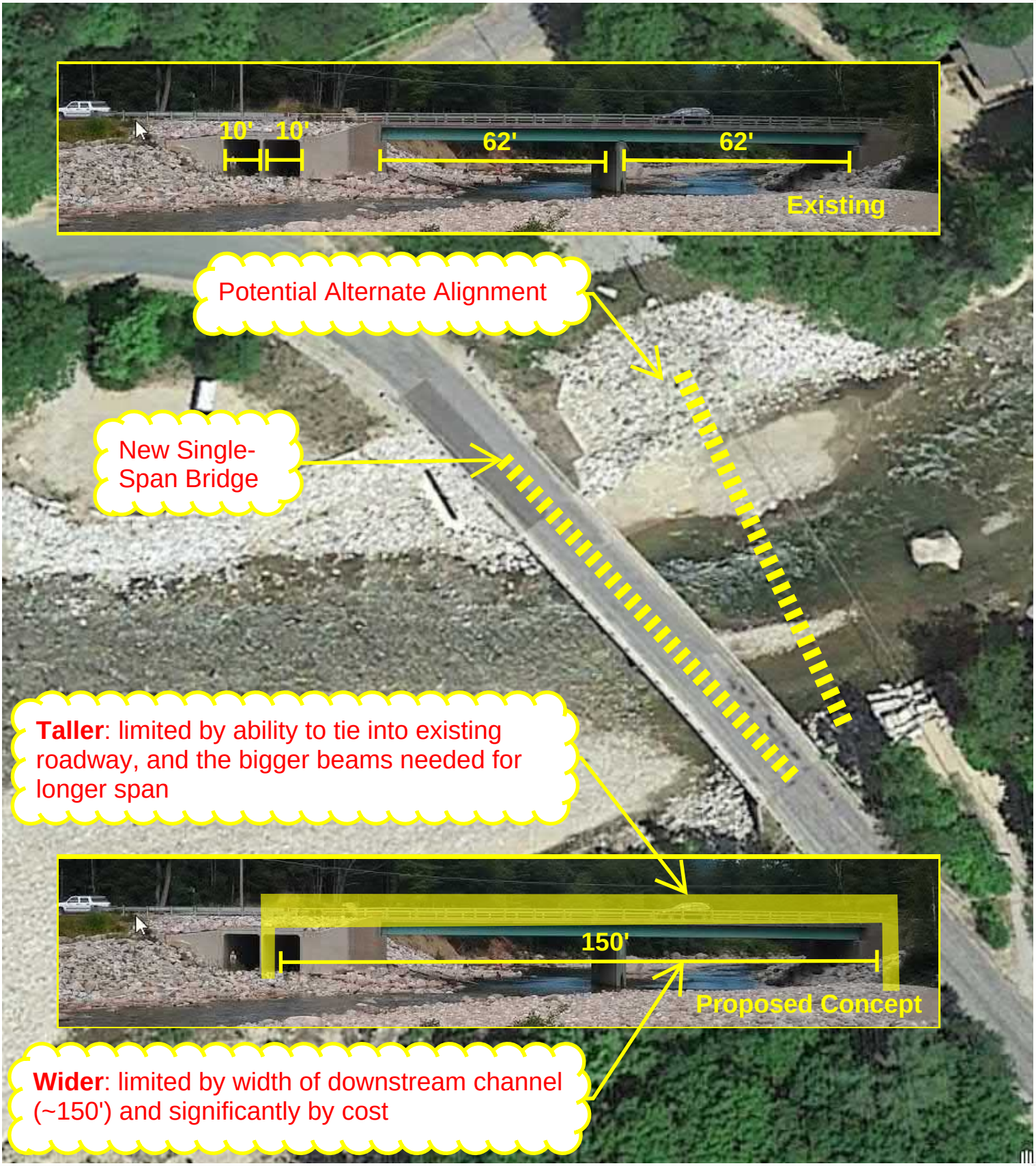
Spatial data sources include NH GRANIT & Bear Creek Environmental. Building footprints from Microsoft. Background imagery is ESRI World Imagery. Map composed on March 27, 2020.



PROJECT & LOCATION:	CLIENT:		
Saco River Flood Mitigation	Town of Bartlett, New Hampshire		
SHEET TITLE:	DATE:	DRAWN BY:	CHECKED BY:
Alt #1. Dredge Channel Upstream of Bridge	4/8/20	MTM	

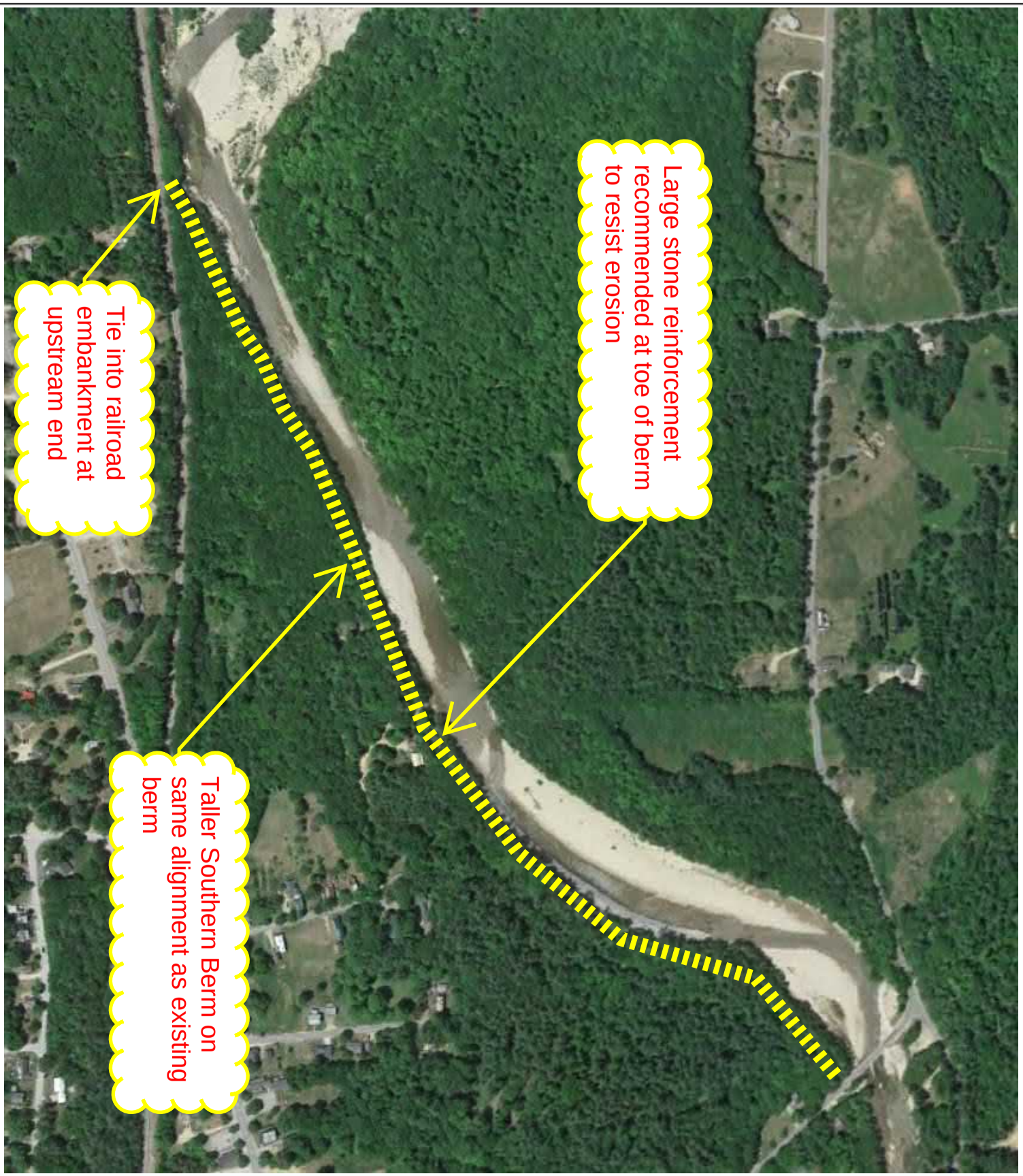
RIPPLE
Natural Resources LLC
PO Box 292 • Randolph, VT 05060
802.522.3473 • www.RippleNR.com

D2



PROJECT & LOCATION:	CLIENT:		
Saco River Flood Mitigation	Town of Bartlett, New Hampshire		
SHEET TITLE:	DATE:	DRAWN BY:	CHECKED BY:
Alt #2. Single-Span River Street Bridge	4/8/20	MTM	

RIPPLE
Natural Resources LLC
PO Box 292 • Randolph, VT 05060
802.522.3473 • www.RippleNR.com



PROJECT & LOCATION: Saco River Flood Mitigation	CLIENT: Town of Bartlett, New Hampshire		RIPPLE Natural Resources LLC PO Box 292 • Randolph, VT 05060 802.522.3473 • www.RippleNR.com
SHEET TITLE: Alt #3. Enhanced Southern Berm	DATE: 4/8/20	DRAWN BY: MTM	CHECKED BY:

PROJECT & LOCATION:	CLIENT:		
Saco River Flood Mitigation	Town of Bartlett, New Hampshire		
SHEET TITLE:	DATE:	DRAWN BY:	CHECKED BY:
Alt #4. Raise River Street	4/8/20	MTM	

RIPPLE
Natural Resources LLC
PO Box 292 • Randolph, VT 05060
802.522.3473 • www.RippleNR.com

RIPPLE
Natural Resources LLC
PO Box 292 • Randolph, VT 05060
802.522.3473 • www.RippleNR.com

CLIENT: Town of Bartlett, New Hampshire

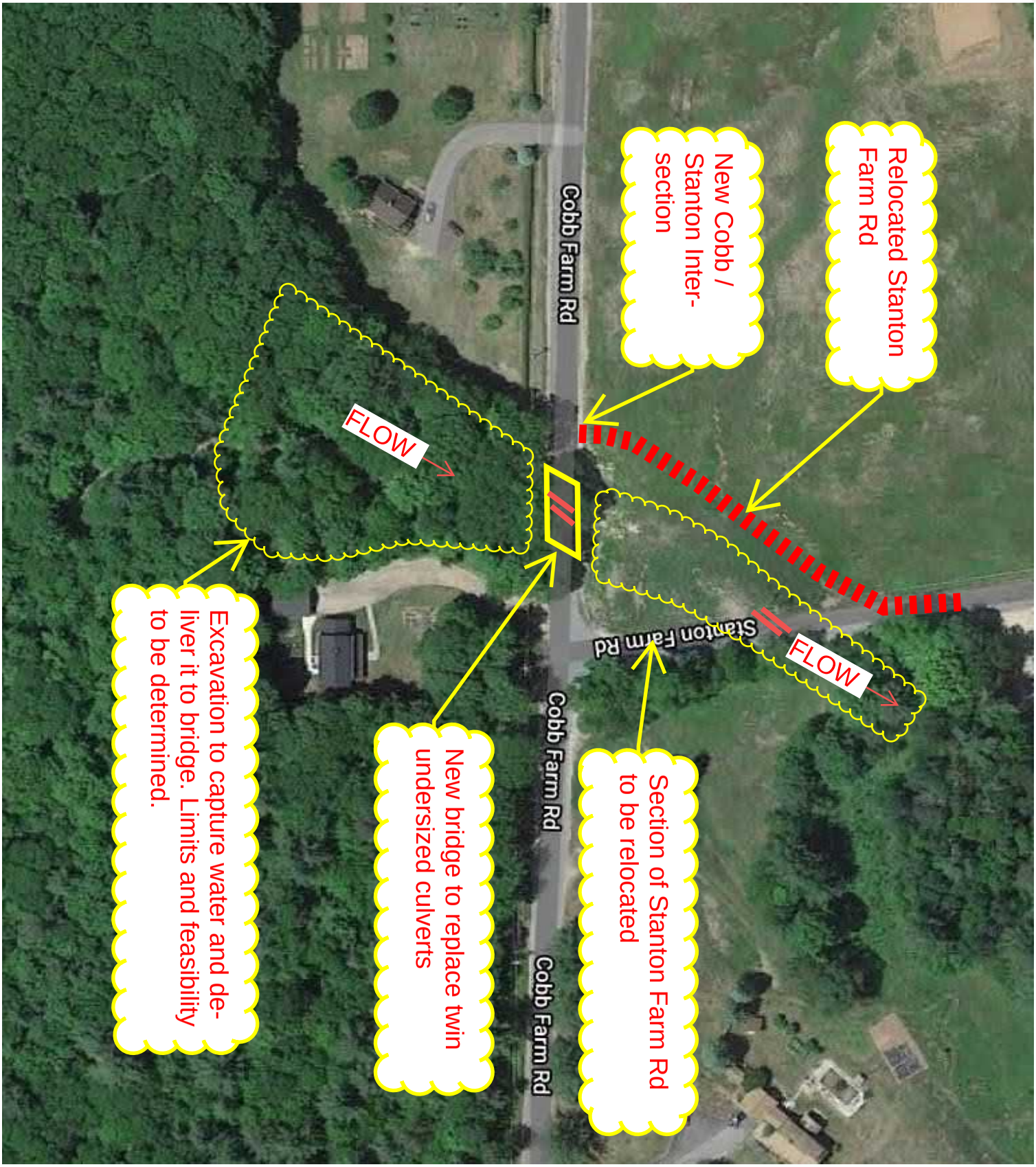
PROJECT & LOCATION: Saco River Flood Mitigation

SHEET TITLE: Alt #5. Enhanced Northern Berm

DATE: 4/8/20

DRAWN BY: MTM

CHECKED BY:



PROJECT & LOCATION:	CLIENT:		
Saco River Flood Mitigation	Town of Bartlett, New Hampshire		
SHEET TITLE:	DATE:	DRAWN BY:	CHECKED BY:
Alt #6. New Cobb Farm Rd Bridge	4/8/20	MTM	

RIPPLE
Natural Resources LLC
PO Box 292 • Randolph, VT 05060
802.522.3473 • www.RippleNR.com

Appendix E

Flood Hazard Reduction Modeling

Dugway

Second Iron Bridge

River Street Bridge

Josiah Bartlett Elementary School

Razor Brook

Albany Brook

Cobb Farm Rd

Stanton Farm Rd

Yates Farm Rd

River St

Wiles Rd

Lebar Ln

Thompson Ln

Forest Ave

Birch St

George St

US Route 302

Church St

School St

Central St

Pine St

Mill St

Grove St

Foster St

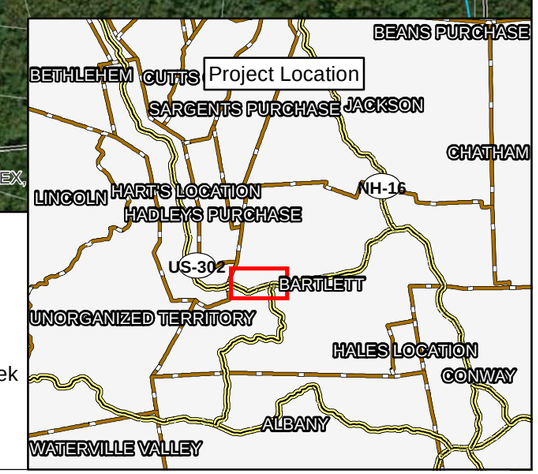
Kearsarge St

Ainsworth Dr

Albany Ave

Mckell Pond Rd

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Community



100-Year Flood Extent
Proposed FEMA Berm Repairs
Flood Hazard Reduction Study
Saco River - Bartlett, NH

Bear Creek Environmental

Legend

- 100-Year Event - Inundation Boundary with FEMA Berm Repair
- 100-Year Event - Inundation Boundary, Existing Conditions
- NHD Stream
- HEC-RAS 2D Flow Area
- Potential Berm Location
- Road
- Railroad
- Building Footprint
- Parcel Boundary
- Town Boundary

0 750 1,500 Feet

1 inch = 750 feet

N

Spatial data sources include NH GRANIT & Bear Creek Environmental. Building footprints from Microsoft. Background imagery is ESRI World Imagery. Map composed on March 16, 2020. Revised April 3, 2020.

100-Year Flood Extent
Dredging Above River St. Alternative
Flood Hazard Reduction Study
Saco River - Bartlett, NH

Bear Creek Environmental

Legend

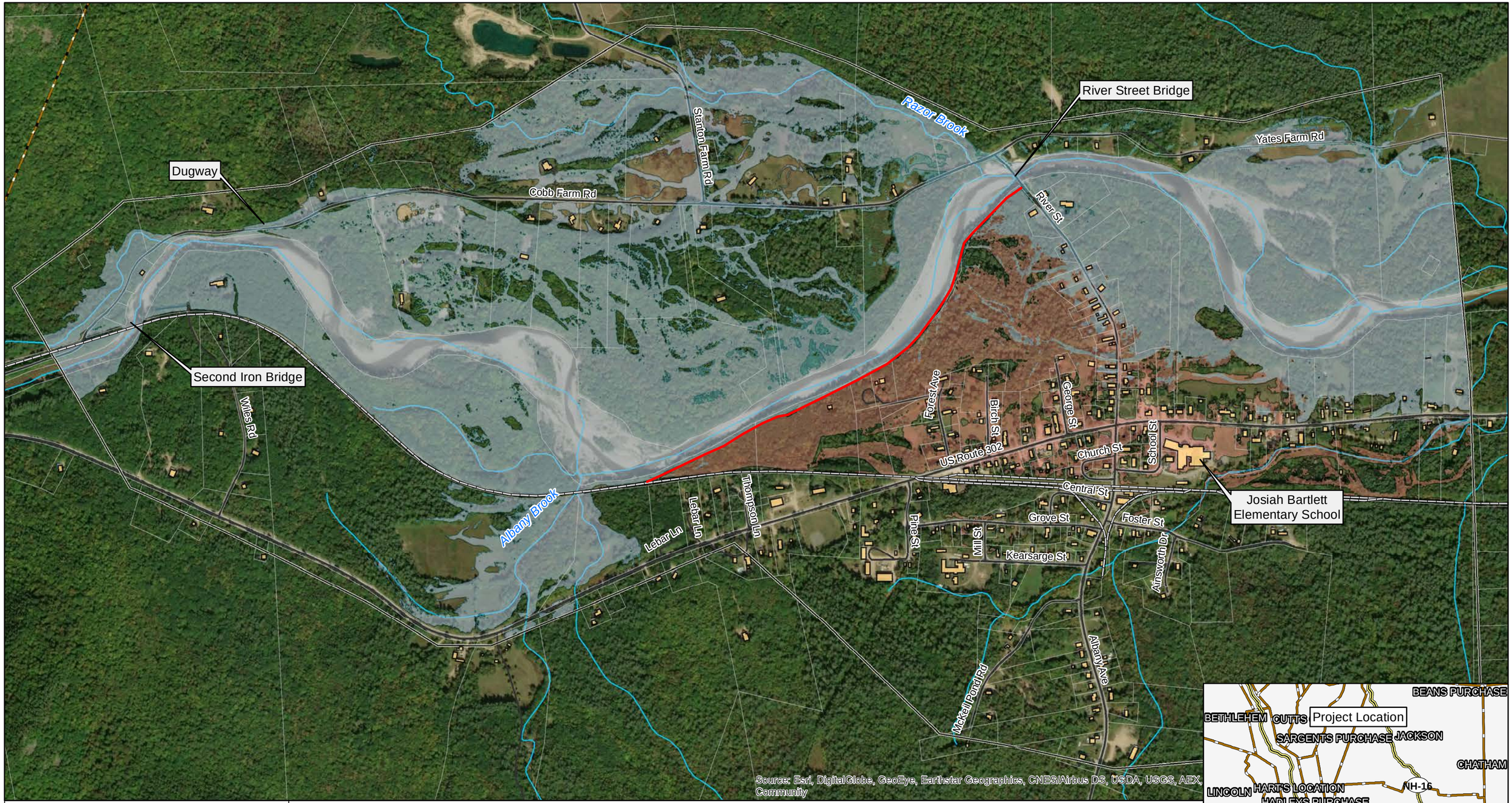
- 100-Year Event - Post-dredge Inundation Boundary
- 100-Year Event - Pre-dredge Inundation Boundary
- HEC-RAS 2D Flow Area
- NHD Stream
- Road
- Railroad
- Building Footprint
- Parcel Boundary
- Town Boundary

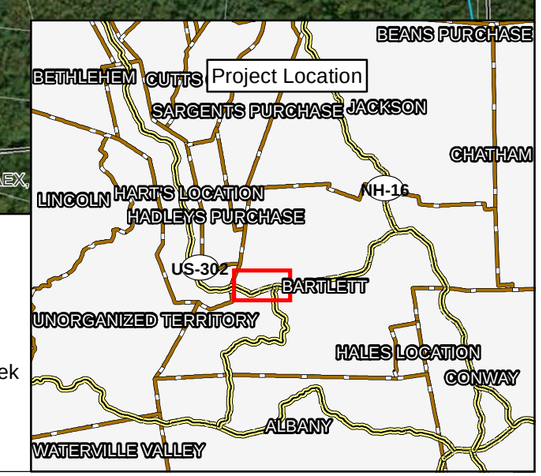
0 750 1,500 Feet

1 inch = 750 feet

N

Spatial data sources include NH GRANIT & Bear Creek Environmental. Pre-dredge conditions reflect current channel dimensions. Post-dredge conditions reflect channel dimensions altered to remove sediment from the deposition immediately upstream of the River Street bridge. Building footprints from Microsoft. Background imagery is ESRI World Imagery. Map composed on March 16, 2020. Revised April 3, 2020.





100-Year Flood Extent
South Berm Alternative
Flood Hazard Reduction Study
Saco River - Bartlett, NH

Bear Creek Environmental

Legend

- 100-Year Event - Inundation Boundary with South Berm
- 100-Year Event - Inundation Boundary, Existing Conditions
- NHD Stream
- Potential Berm Location
- HEC-RAS 2D Flow Area
- Road
- Railroad
- Building Footprint
- Parcel Boundary
- Town Boundary

0 750 1,500 Feet
1 inch = 750 feet

N

Spatial data sources include NH GRANIT & Bear Creek Environmental. Building footprints from Microsoft. Background imagery is ESRI World Imagery. Map composed on March 9, 2020. Revised April 3, 2020.

100-Year Flood Extent
North Berm Alternative
Flood Hazard Reduction Study
Saco River - Bartlett, NH

Bear Creek Environmental

Legend

- 100-Year Event - Inundation Boundary with North Berm
- 100-Year Event - Inundation Boundary, Existing Conditions
- NHD Stream
- Potential Berm Location
- HEC-RAS 2D Flow Area
- Road
- Railroad
- Building Footprint
- Parcel Boundary
- Town Boundary

0 750 1,500 Feet
1 inch = 750 feet

N

Spatial data sources include NH GRANIT & Bear Creek Environmental. Building footprints from Microsoft. Background imagery is ESRI World Imagery. Map composed on March 9, 2020. Revised April 3, 2020.

100-Year Flood Extent
North & South Berm Alternative
Flood Hazard Reduction Study
Saco River - Bartlett, NH

Bear Creek Environmental

Legend

- 100-Year Event - Inundation Boundary with North & South Berms
- 100-Year Event - Inundation Boundary, Existing Conditions
- NHD Stream
- Potential Berm Location
- HEC-RAS 2D Flow Area
- Road
- Railroad
- Building Footprint
- Parcel Boundary
- Town Boundary

0 750 1,500 Feet
1 inch = 750 feet

N

Spatial data sources include NH GRANIT & Bear Creek Environmental. Building footprints from Microsoft. Background imagery is ESRI World Imagery. Map composed on March 9, 2020. Revised April 3, 2020.