Using Geospatial Analysis to Evaluate Stream Crossing Replacements in New Hampshire

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Overview

- Floods are a global issue that can damage property and threaten life
- Undersized culverts and bridges can fail during floods, leading to road closures that can interfere with home access and emergency response and degrade aquatic habitat
- We were tasked by the New Hampshire Geological Survey (NHGS) to analyze stream crossings that have been recently replaced to determine whether the new structures were better than the old structures at passing flood flows

Fig. 1: Culvert failure during large flood in Freeport, Maine, in August 2008

Culvert Locations

- There are 20,367 culverts in the New Hampshire database
- For this project, we selected stream crossings that were:
  - Located in New Hampshire
  - Part of the Merrimack or Piscataqua River watersheds
  - Reconstructed in the past 10 years
  - Had incomplete data post-reconstruction

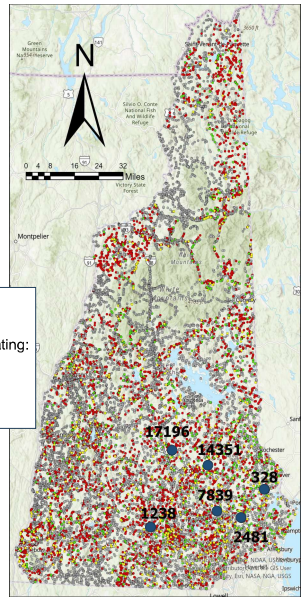


Fig: 2: All culverts in the New Hampshire Geological Survey database colored by hydraulic rating for the 100-year flood. Large circles show study sites labeled with crossing ID

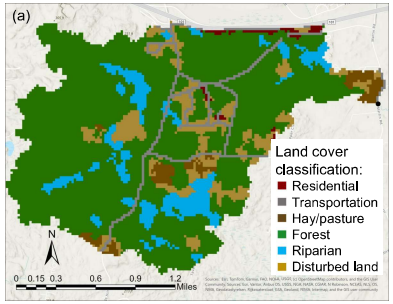
Geospatial Analysis

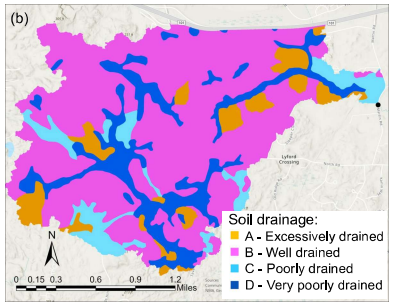
Following NHGS guidelines and using ArcGIS Pro with ArcHYDRO:

- Delineated the watershed upstream of each study culvert based on drainage direction
- Integrated land cover, soil drainage class, wetland fraction, and precipitation data to generate values for peak discharge flowing into each culvert using the Soil Conservation Service method:

$$Q = \frac{(P - 0.2\,S_r)^2}{P + 0.8\,S_r}$$

where:
Q = runoff depth
P = extreme precipitation depth
S_r = watershed retention





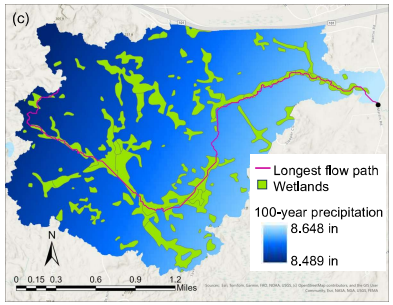


Fig. 3: Brown Brook watershed. (a) Watershed land cover (NH Land Cover Assessment, 2001). (b) Soil drainage class (NRCS Soil Survey Geographic Database, SSURGO, 2009). (c) 100-year precipitation (Northeast Regional Climate Center, 2010) and wetland coverage data (National Wetland Inventory)

Hydraulic Ratings

- Using a Microsoft Excel template from the NHGS, we compared peak discharges for 2, 10, 25, 50, and 100 year precipitation events to what the culvert can pass to determine the hydraulic rating before reconstruction (and we plan to eventually recalculate after culvert reconstruction)

Table 1: Pre-reconstruction stream hydraulic ratings for three sites with complete geospatial analysis. All three of these sites were improved in the past 10 years. Although the Fremont site passed the flood tests, concern arose from a structural safety perspective

General Information					Pre-reconstruction Hydraulic Rating				
Crossing ID	Town	Road	Stream	Drainage area	2-yr	10-yr	25-yr	50-yr	100-yr
17196	Canterbury	Morrill Rd	Hayward Brook	3.26 mi²	Overtop	Overtop	Overtop	Overtop	Overtop
7839	Raymond	Roy St	Unnamed	0.16 mi²	Pass	Vulnerable	Overtop	Overtop	Overtop
2481	Fremont	Martin Rd	Brown Brook	3.20 Mi²	Pass	Pass	Pass	Pass	Pass

Field Work

- When in the field, we measured and photographed elements of the reconstructed culvert that affect flood capacity. These measurements included width, height, slope, and stream size. We also noted features such as beveled entryways, angled wingwalls, reinforcements, and sloped sidewalls
- The type and shape of the structure, as well as the undercutting, pooling, drop-off, or damming were also noted as these factors affect flood control as well as geomorphic compatibility and aquatic organism passage

Fig. 4: Culvert in Barrington where we conducted field measurements. (a) Prior to reconstruction, this culvert regularly backed up and overtopped during large rain events. 2023 archive photo by NHGS. (b) Following reconstruction, the culvert tripled in size and was reinforced with wingwalls. The black pipe was a temporary redirection of flow and will be removed following construction. Photo by Connor Paul.

Future Research

- Geospatial analysis and field observations can be repeated for the more than 50 culverts in New Hampshire that have recently been reconstructed
- Field observations from reconstructed culverts will be used to recalculate hydraulic ratings
- The NHGS will use these data to update their website which provides information to the public about the stream crossings in New Hampshire
- We also plan to work with the NHGS to create an online story map that uses before and after photos and hydraulic analysis to demonstrate to taxpayers the importance of these reconstructions

Fig. 5: Seb Eid and Connor Paul measuring water depth at Brown Brook in Fremont. Photo by Brian Hauschild.

Acknowledgments

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