Identifying Sensitive Structural and Hydraulic Parameters in a Bridge-Stream Network for Flood Mitigation Planning

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Abstract

Perturbations to hydraulic structures can have significant and far-reaching consequences, including both hazard attenuation and intensification. Quantitative analysis of the dynamic interactions between a river and its surrounding infrastructure under high-risk, transient conditions may help prioritize limited resources available for bridge and river rehabilitations, holistic design of bridges, and address stakeholder concerns raised in response to planned bridge and infrastructure alterations.

Study Area

- **Otter Creek between Rutland and Middlebury, VT**
- **12 road and 8 rail bridges**
- **75 miles of town- and state-owned road and 30 miles of state-owned rail lie within the floodplain,**
- **Several overflow bridges and more than one hundred culverts.**

Computer Model

- **Built 2D unsteady HEC-RAS model of 40mi² of the Otter Valley.**
- **Augmented LiDAR terrain model with geo-referenced sonar soundings.**
- **Calibrated to gauged Tropical Storm Irene (Q500) flows and surveyed high water marks**
- **Verified fidelity for several additional flood events.**

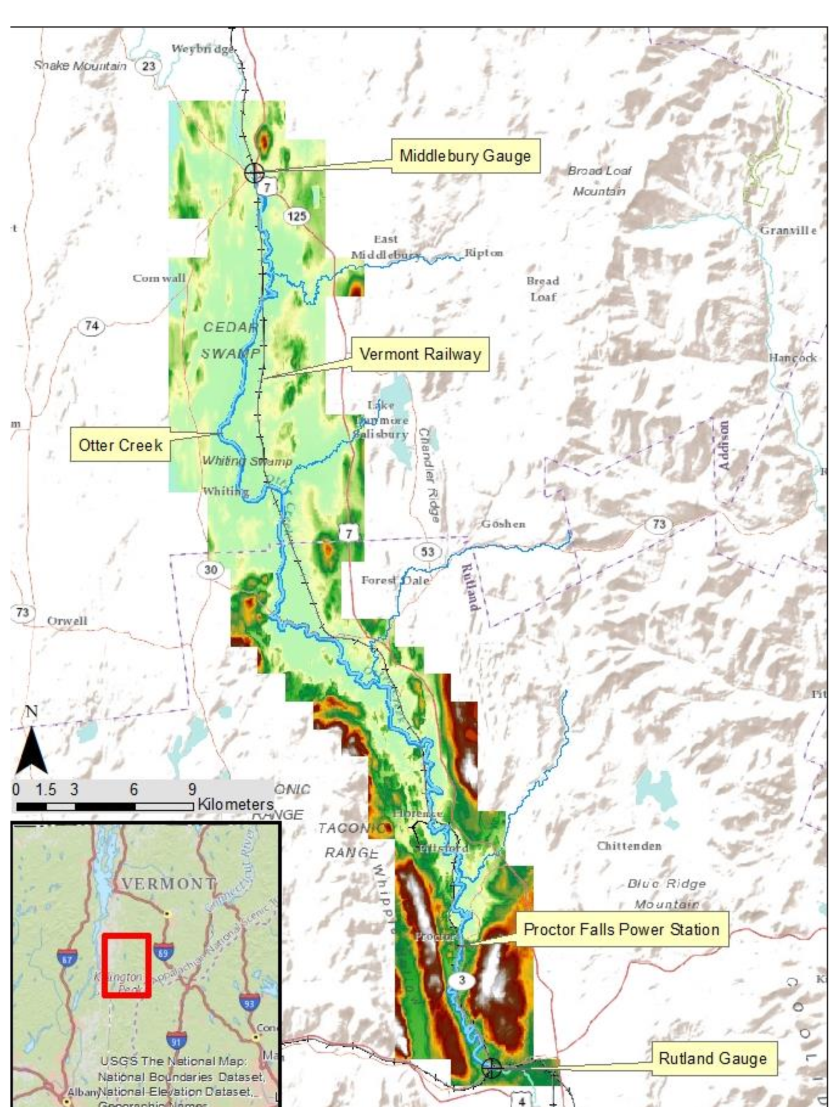

Figure 1. Otter Creek study area. The USGS operates flow gauges in Rutland and Middlebury, 46 river miles apart.

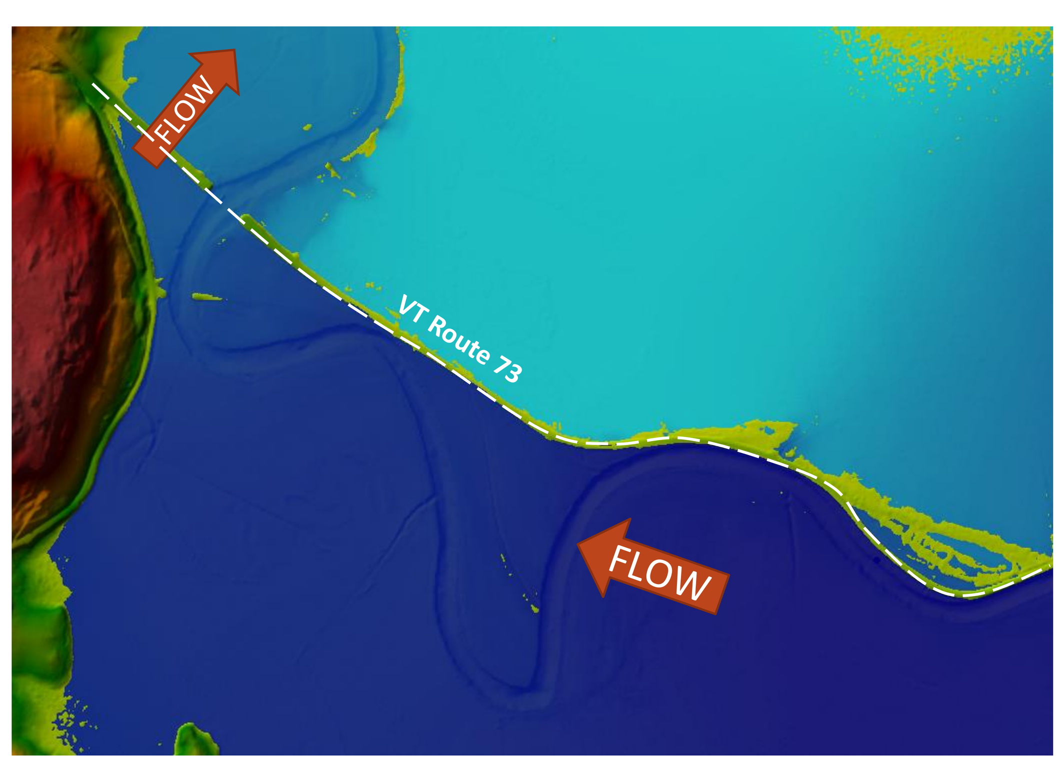

Figure 2. Backwaters can extend far upstream. Here, Rt. 73 increases WSE at 2 upstream bridges, 3.75 and 5.25 mi away, by 0.3 and 0.5ft, respectively. This can be alleviated by an increased bridge span or relief structures. The road grade can then be raised to eliminate overtopping.

Analysis

Sensitive structural and hydrogeological features are determined by simulation of various perturbations, including raising roadway grades, increasing bridge span lengths, and removal of encroaching structures. Local changes can impact the response of the entire watershed.

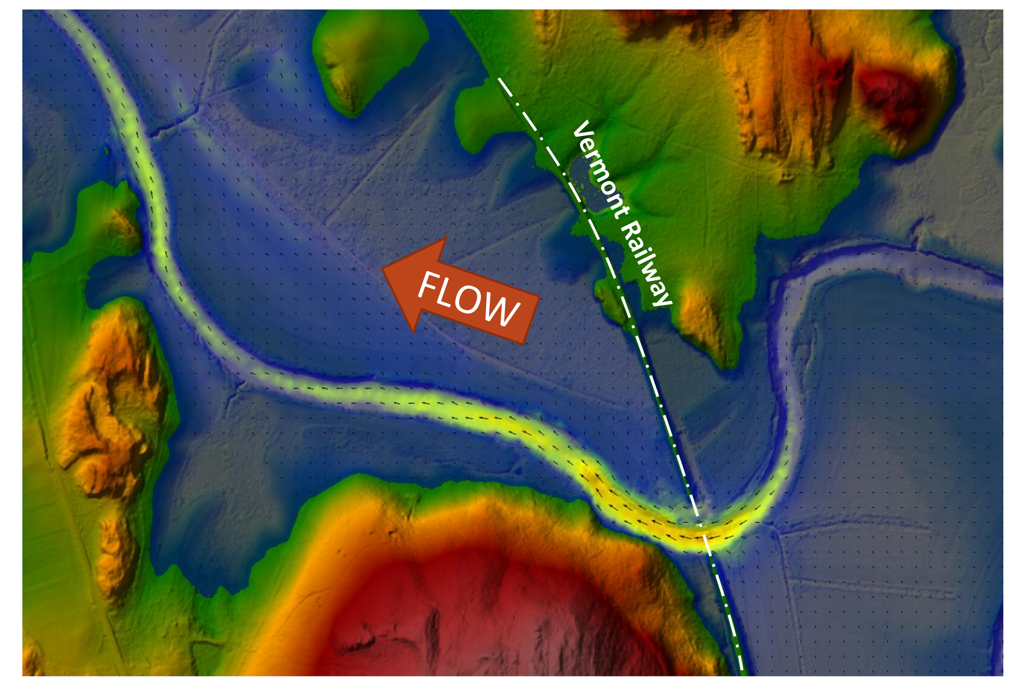

Figure 3. Velocity is increased by 225% from constriction at VT Railway Bridge 220 in Pittsford (compared to no bridge). Higher velocities propagate to the next crossing, 0.9 miles downstream, and cause a >4% increase in peak stream power at the Syndicate Rd bridge.

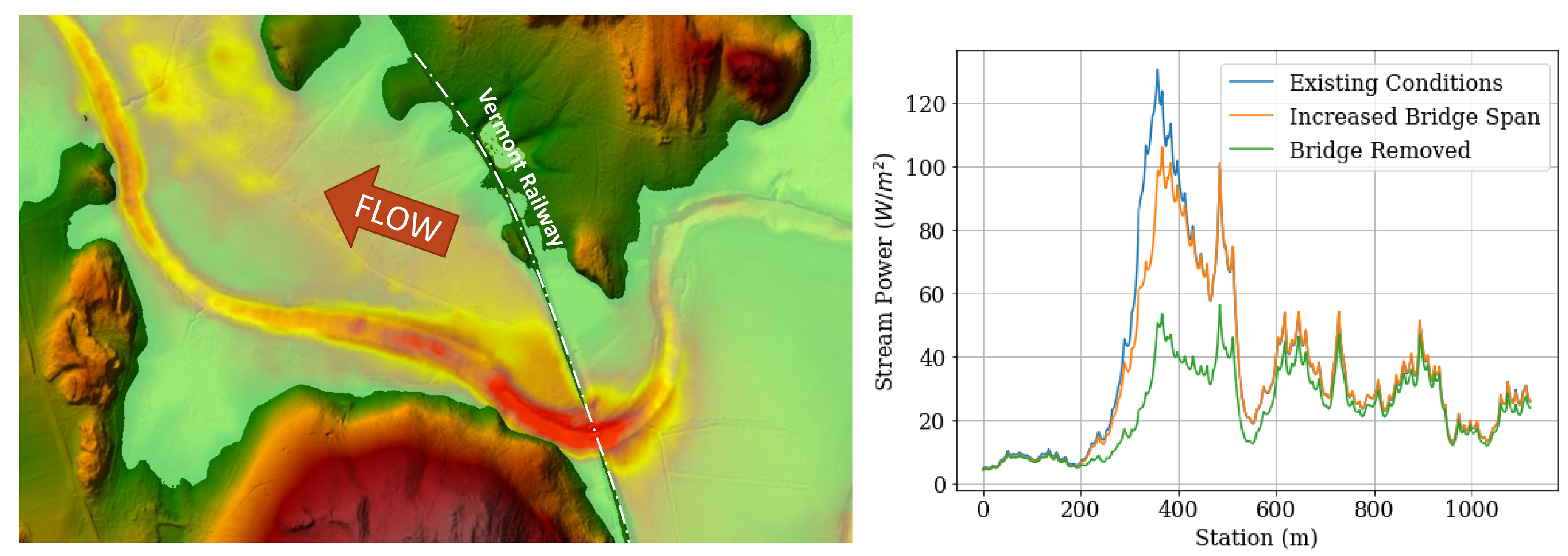

Figure 4. Stream power through VTRR bridge 220 (left). Doubling the length of the span reduces peak by 20% (right).

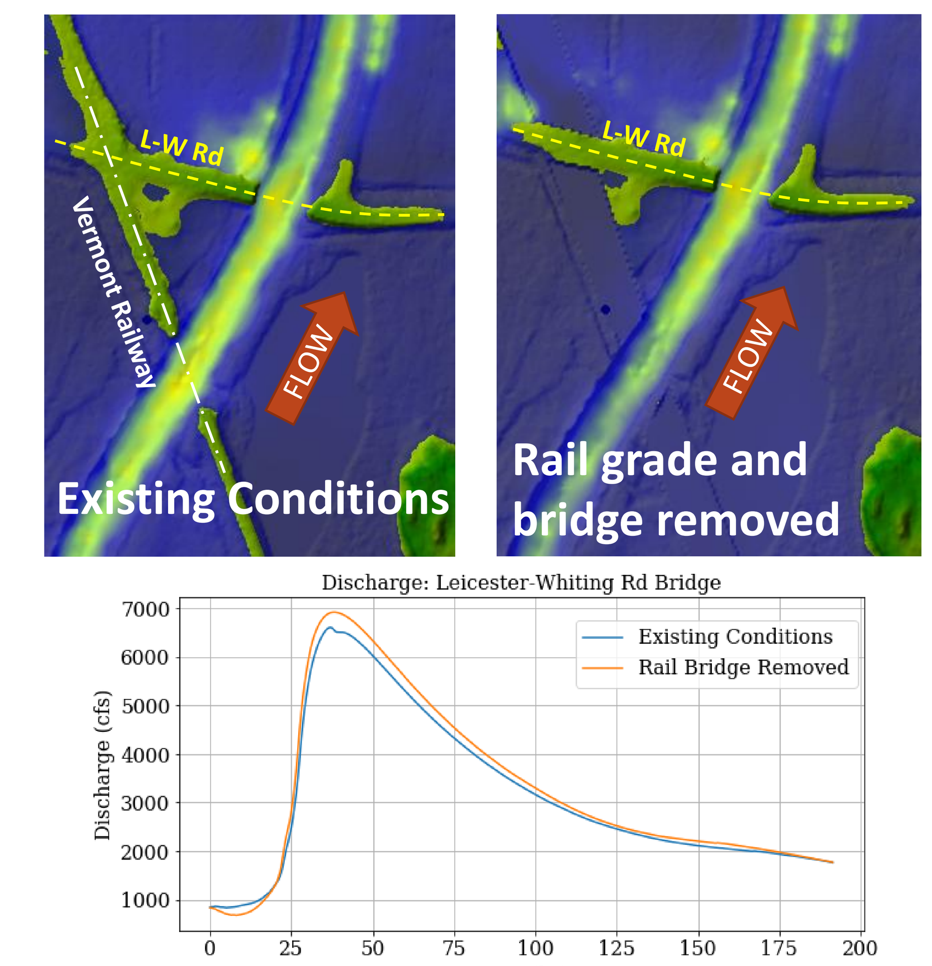

Figure 5. Structures in close proximity have significant interaction. Here, simulated removal of a railroad grade and bridge 400' upstream of a road bridge results in a 16% increase in peak discharge, and 11% increase in stream power through the 2nd bridge.

Conclusions and Ongoing Research

- **Analysis indicates alterations could have both positive and negative consequences within the corridor. The Tropical Storm Irene model showed attenuation of peak discharge by 5 hrs and 500 cfs (8%) in Middlebury, but an average increase in inundation duration of 20 hrs and additional flood depths of 0.25 ft throughout the basin.**
- **Individual perturbations to bridges intended to improve local hydraulics may result in a reduction of backwater flooding, while also allowing faster flood wave propagation through the adjusted structure. This especially may have undesirable consequences if downstream structures rely on the retardation effects of upstream structures for resiliency.**
- **A forthcoming sensitivity analysis will identify the types of structures and features to which the bridge-stream network is most responsive, which may be valuable for flood mitigation planning.**

Acknowledgments

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