Scour and Debris Induced Vulnerability Analysis for Riverine Bridge Structures

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Introduction

- Accumulation of floating large woody debris caused almost ¾ of bridge failures in the United States.
- Assessing the potential for major debris formation and its effects is essential for mitigating bridge failure risks and enhancing the resilience of future bridge design to withstand severe weather events.

Figure 1. *Debris-related scour damage to bridges*

Methodology

- The potential for debris generation is projected based on the susceptibility of upstream trees to windthrow or landslide events, combined with their relative proximity to the river.
- Debris entrapment probability and dimensions are predicted considering a conical cross section.
- The scour is computed from the HEC-18 guide and compared to the foundation depth.
- Monte Carlo simulation is used to evaluate the **bridge vulnerability** under different conditions.
- Case study conducted for a bridge in Vermont under Hurricane Irene (~100-year return period).

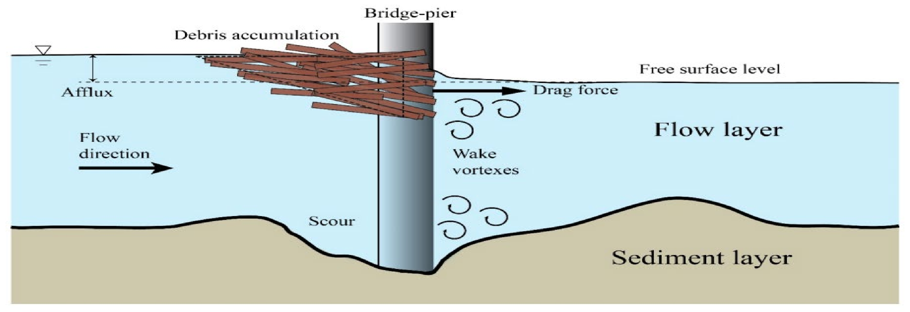

Figure 2. *(left) Schematic diagram of debris accumulation around bridge pier*

[Ref: Cantero-Chinchilla et al., "Assessing the effect of debris accumulation at river bridges", University of Southampton]

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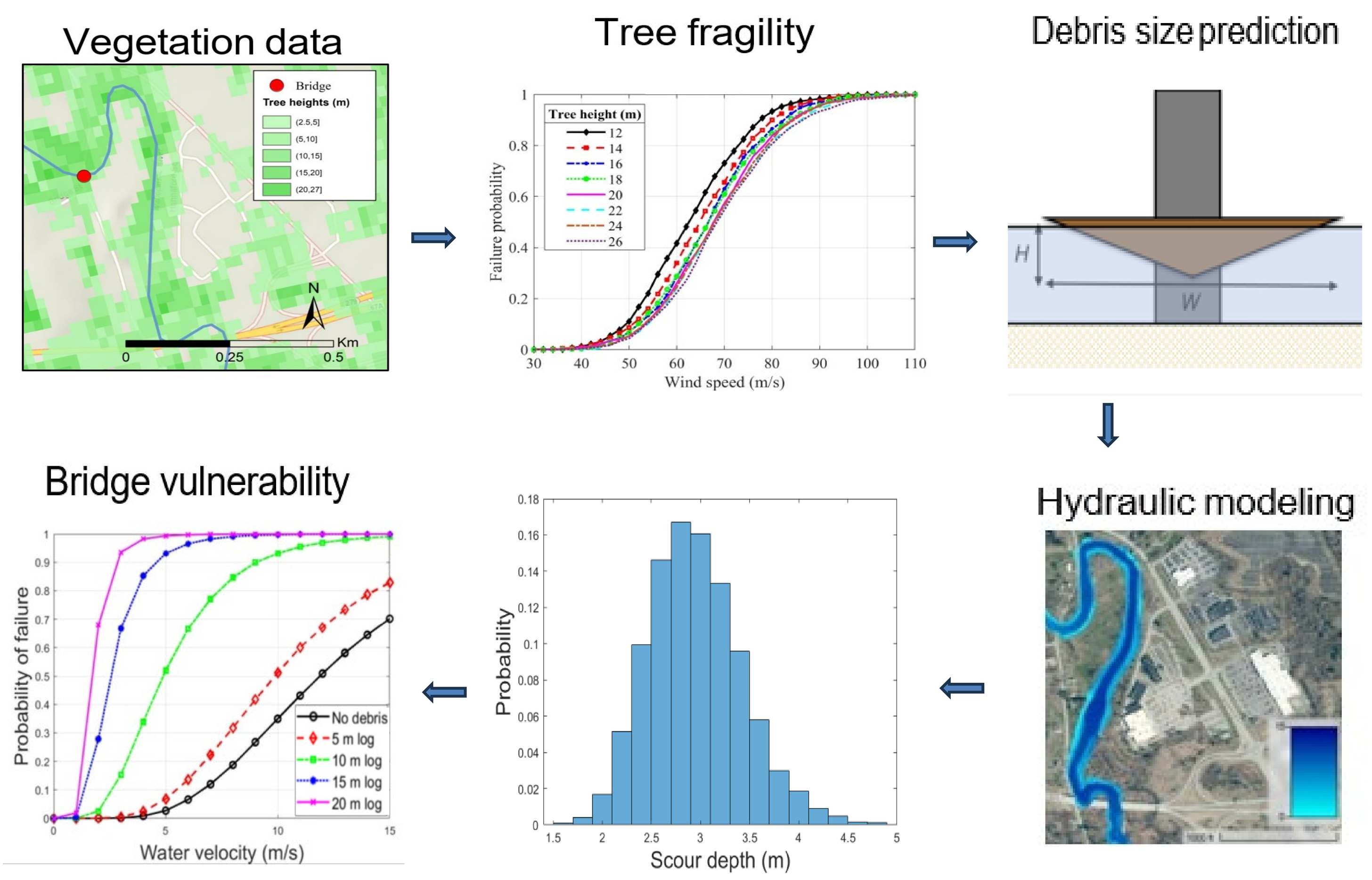

Figure 3. *Flowchart of bridge risk analysis framework*

Results

- The most debris-prone areas are highlighted (Figure 4) and the distribution of debris size is predicted (Figure 5).
- Sensitivity analysis is conducted for different debris size (Figure 6) and different flow conditions with varying foundation depths (Figure 7).
- The **importance of debris consideration** is highlighted: without debris, risk is underestimated.

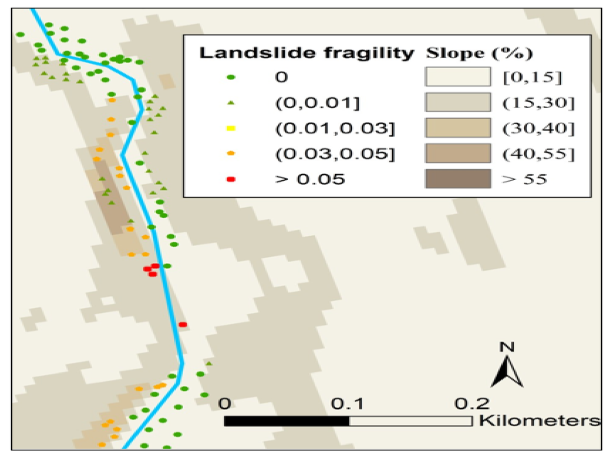

Figure 4. *Tree debris generation probabilities*

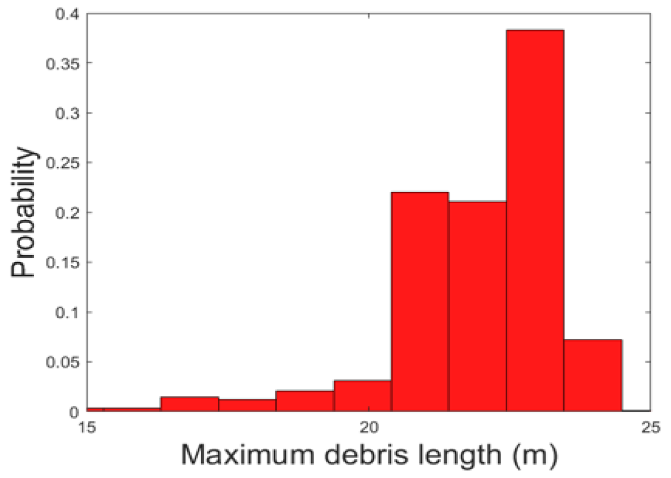

Figure 5. *Predicted debris lengths for Irene*

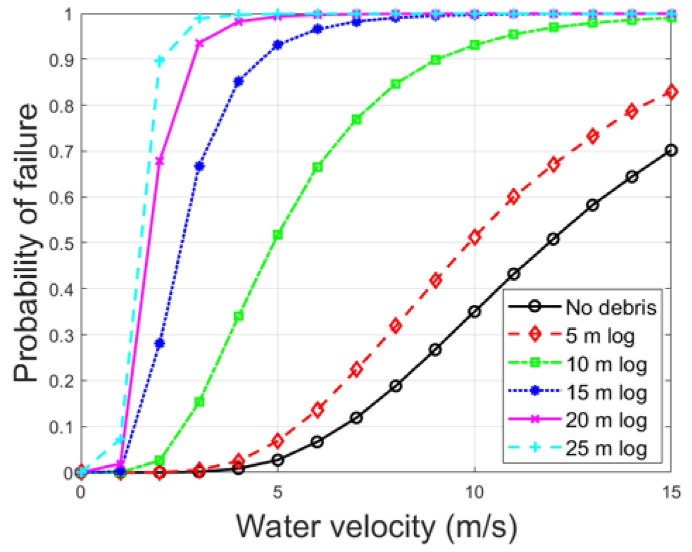

Figure 6. *Risk sensitivity to debris size*

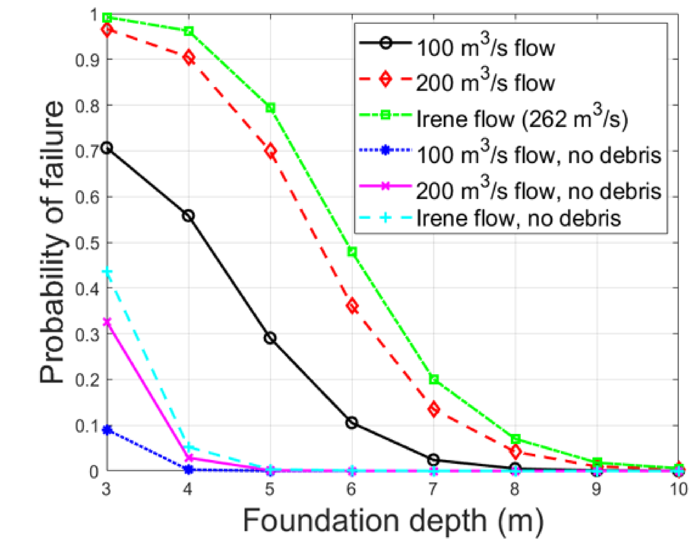

Figure 7. *Vulnerability with/without debris*

Conclusions

- Sensitivity analysis shows that 25m and 20m debris size causes 100% failure at a very lower water velocity (4-5m/s) compared to other debris size (5-15 m) .
- When the foundation depth reduces probability of failure increases more rapidly for the higher flow rate.
- When the flow rate remains constant (e.g., Irene, 262 m^3/s) & the foundation depth decreases, for the debris incorporated water probability of failure increases more rapidly (reaches 100% at foundation depth 3m) compared to the virgin water (reaches around 45%).

Future Work

- To further validate and calibrate model using empirical data and machine learning to predict and highlight effects of combined debris and scour on bridge safety.
- Will be expanded as a tool to **inform decisions** related to closing bridges before storms.

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