U.S. Department of Transportation
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Actionable Flood Warnings Based On Ground-Truth Data To Support Iowa Dot Bridgewatch Platform Functionality

tech transfer summary

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Research Project Title
Actionable Flood Warnings Based On Ground-Truth Data To Support Iowa DOT Bridgewatch Platform Functionality

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About
IIHR—Hydroscience & Engineering is an internationally-renowned laboratory where researchers are solving some of our world's greatest fluids-related challenges.

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Background
The expectation of improved flood warnings has become critical for many agencies and communities at a time when flooding is increasingly severe and widespread. In order to proactively protect Iowa bridges at risk during flooding, the Iowa Department of Transportation (IDOT) have enhanced the BridgeWatch™ web-based bridge monitoring software to include flood hazard predictions in its decision-support functionality. The reliability of flood warnings is directly dependent on the model skills and the quality of the input data used for the modeling and on the specialized analyses involved. In general, flood warnings are highly uncertain. This research project presents an innovative path to improve the flood-warning formulation with focus on transportation infrastructure and resource allocation during flooding.

Problem Statement
The evaluation of the existing floodplain maps is an important step in gaining confidence in streamflow forecasting on which the BridgeWatch warnings are based. Up to now, there are limited systematic studies to assess the accuracy of the streamflow forecasts and flood mapping using ground-truth information. The often-invoked reason for this status quo is the complexity and high cost of such a quality control process. Taking advantage of the high-resolution satellite maps (HRSM) made recently available for various purposes, an opportunity exists to use them for evaluating the quality of conventional flood maps that are difficult to validate using other means.

Goals and Objectives
The main objectives of this research are:

- Assess the quality of the statewide floodplain mapping at selected bridges across the state (with and without BridgeWatch warnings) using quantitative information from HRSM available from third-party sources.
- Develop a long-term plan to apply flood map validation to flood-prone Iowa bridges at gaged and ungagged sites and extend the BridgeWatch functionality for increasing the protection for the statewide road network against the direct and indirect adverse flood impacts, including the loss of access to essential services needed during floodings by combining the real-time data provided by the IFC bridge sensor network with HRSM-based information in a seamless integrated digital environment.

Research Description

The research activities of this project include two pilot explorations to demonstrate the usefulness of commercial HRSM imagery to capture flood inundation scope independently. In particular, we investigated the quality of manual flood maps as well as those generated from a recently introduced structured automated water extent extraction workflow called Quantile-based Filling & Refining (QFR). Flood maps generated from those two approaches were compared visually and quantitatively against the 100-year reference flood map in two pilot sites (Fredericksburg and Traer) in Iowa.

Additionally, results from those two approaches were compared against each other to learn the advantages and disadvantages of both methods. Figures 1 below shows the manual delineation of flood extent and how consistent they are compared to the reference flood map at the Fredericksburg site.

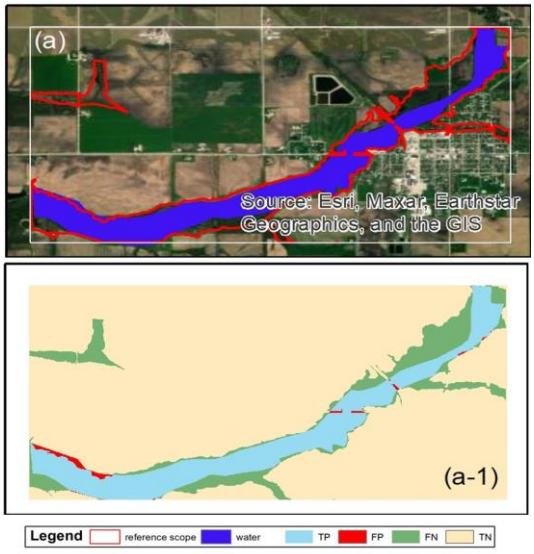

Figure 1. Manual delineation of flood extent (a) and its evaluation against the reference (a-1) in Fredericksburg site.

Similarly, Figures 2 show the automated flood extent generated by the QFR workflow. Table 1 lists the quantitative evaluation results of comparing the manual delineation against the reference and the automated delineation against the reference, respectively.

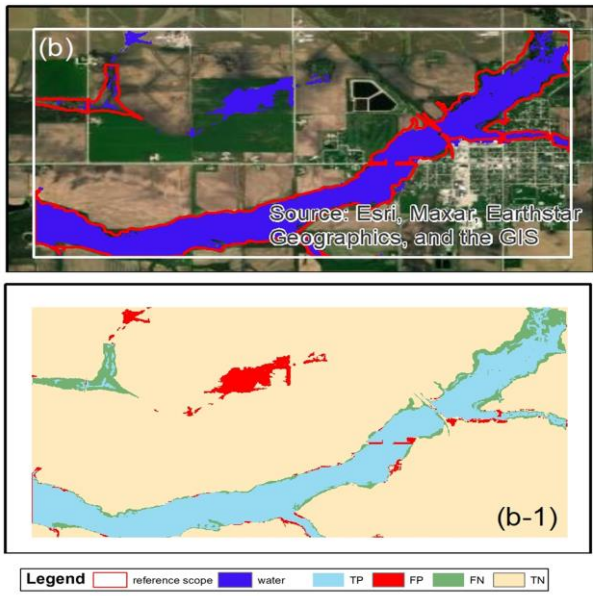

Figure 2. Automated flood map with the QFR postprocessing (b) and its evaluation against the reference (b-1) in Fredericksburg site.

Table 1. The quantitative evaluation of the manual flood map and automated maps in Fredericksburg, where Accuracy, H, and F1 explain the goodness of results from different perspectives whereas Bias shows whether the model is more inclined toward underestimations or overestimations.

	Accuracy	H	F1	Bias
Manual	0.92	0.60	0.74	0.63
QFR	0.94	0.80	0.84	0.92

Key Findings

Comparison between flood maps generated with the manual delineation and the QFR workflow and the evaluation of those resulting maps against the reference map leads to the following findings:

- The manual delineation generates acceptable results and is not unacceptably time-consuming for a small number of sites. The major issue of the manual delineation on the production level is the poor scalability.
- The major challenge of those manual flood maps from the results' quality perspective is that they are prone to systemic errors. Specifically, persistent under- or overestimation may occur due to personal preference when hand-drawing those boundaries.

- The automated water extent extraction workflow can generate better results compared to manual delineations and are more consistent with the reference.
- The automated water body extraction workflow significantly improves scalability and can work for a large number of sites following the same procedure without a significantly increased demand for auxiliary data or computational resources.

The results revealed the potential of the automated QFR water extent extraction workflow to be applied to create flood maps in data-scarce areas for Iowa using HRSM images.

Implementation Readiness and Benefits

The following steps can be taken to make the BridgeWatch platform a unique resource for flood mitigation:

- Refine and implement an automated process for extraction of the flooding extent from GRSM-based maps.
- Identify flood-prone areas critical for transportation network in the state along with adjacent stage sensors.
- Develop a data-driven approach to link legacy time series of stages recorded at IFC bridge-sensors with stage indicated by the IFC flood mapping verified with HRSM.
- Evaluate the flood impact on the transportation infrastructure (i.e., bridges, roads, culverts) using a suite of data analytic products for food damage assessment (direct and indirect economic analysis) and disruptions (rerouting, evacuation, accessing amenities, etc.)
- Develop a decision-support system to identify and forecast potential risk levels at the transportation infrastructure and recommend priorities for management of resources during flooding.
- Develop intelligent communication tools to timely and widely disseminate the outputs from the platform to public and transportation staff using voice recognition and artificial intelligence.

The exploratory work carried out in the initial stage of this research prepares the ground for automation and extension of the BridgeWatch functionality.

The practical benefits of a fully developed platform entails:

- Added value of the HRSM usability for flood mitigation
- Possibility to verify the quality of the currently used inundation maps obtained with numerical simulations.
- Use of the IFC bridge sensors in data-driven approaches for supporting monitoring and forecasting functions.
- Informing decision-makers on the potential risk levels for accessing, intervening, and securing the fluency of the traffic for the management of resources during flooding in the vicinity.