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Assessing the Flood Reduction Benefits of On-Road Structures

tech transfer summary

Iowa communities considering the use of modified culvert systems to mitigate the impacts of flooding can benefit from geospatial datasets and visualizations that identify candidate locations and anticipated pooling and drainage areas.

Background

On-road structures (ORS) present a viable alternative to traditional culvert design and have the potential to more effectively mitigate flood impacts. ORS utilize the roadway embankment as a dam, restricting flow into the culvert to provide flood storage for significant peak flow events.

Several counties in Iowa have implemented ORS in HUC12 watersheds, and anecdotal evidence suggests that these structures have reduced the flood impacts of recent extreme rainfall events.

Problem Statement

Iowa lacks a detailed statewide geospatial database identifying which existing culverts are suitable candidates for conversion to ORS. Additionally, a HUC12-scale assessment of the potential for peak flow reductions offered by a system of ORS has not yet been conducted.

Objectives

To address these gaps, this project integrated geographic information system (GIS) and hydrologic analysis, rainfall runoff modeling, and hydroinformatics to develop tools to guide, facilitate, and enhance the adoption of ORS in Iowa. Specific objectives were as follows:

1. Construct a statewide geospatial database identifying suitable locations for the construction of ORS.
2. Develop a methodology to programmatically complete planning designs for the individual ORS locations identified in Objective 1.
3. Assess the HUC12-scale flood reduction benefits of a system of ORS.
4. Develop a web platform to communicate the results of Objectives 1 through 3.

Research Description

Locations suitable for the construction of ORS were identified through statewide GIS analyses of all of the HUC12 watersheds in Iowa. For each watershed, information on flood storage, expected pool areas, and drainage areas was generated

Planning designs for ORS in six of the HUC12 watersheds were then developed to help further identify ORS that offer significant peak flow reduction benefits. Hydrologic design and analysis was automated using Python scripts in ArcGIS to enable the programmatic design of many ORS.

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RESEARCH PROJECT TITLE
Assessing the Flood Reduction Benefits of On-Road Structures

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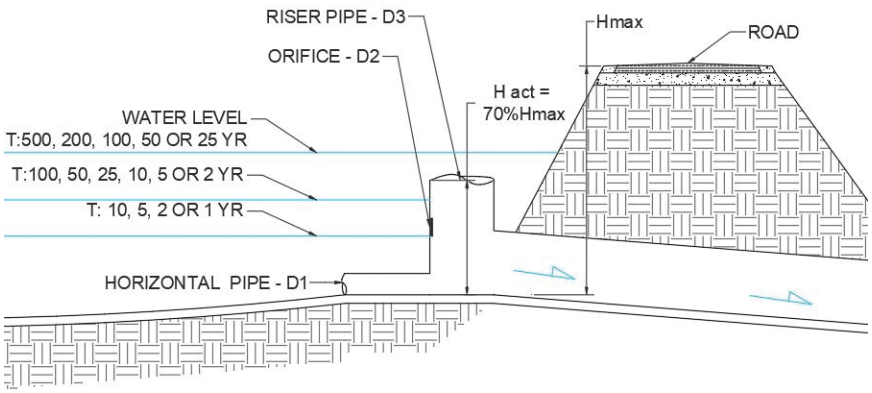


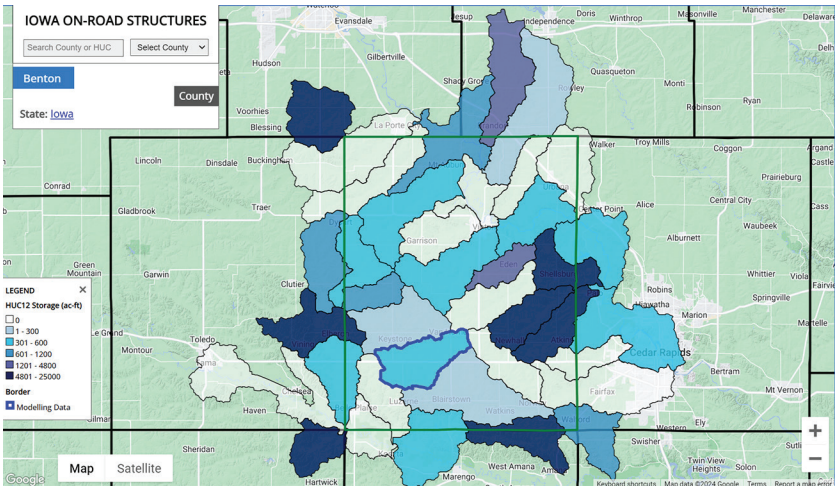
Typical ORS planning design featuring three outlets, their activation levels, and the different storms considered during the design process

For the six HUC12 watersheds, the peak flow reduction benefits of a system of ORS were quantified at the watershed scale using Generic Hydrologic Overland-Subsurface Toolkit (GHOST), a rainfall runoff model extensively validated across various watersheds in Iowa. The model's ability to predict peak flows was assessed by comparing modeled outputs against data from StreamStats Version 4.

A web-based information platform called Iowa Department of Transportation (DOT) On-Road Structures (IDOT-ORS) was developed to facilitate access to data generated in this research and, for the six HUC12 watersheds, the results of the planning designs.

Key Findings

- The statewide GIS analyses identified approximately 250,000 potential ORS implementation sites with a combined storage capacity of 2 million acre-feet and a pool area covering 900,000 acres, representing about 2.7% of Iowa.
- For a 50-year storm event, the evaluated ORS systems provided, on average, an 18% peak flow reduction at the outlets of the selected watersheds.
- Given that the hydrologic models developed in this research tested only a subset of the ORS identified through the statewide GIS analyses, there is potential for greater peak flow reduction if more structures are evaluated.
- The modeling results suggest that a larger number of ORS does not necessarily correlate with additional peak flow reductions. A metric better correlated with peak flow reduction at larger spatial scales is the percentage of the watershed regulated by the ORS.
- The IDOT-ORS information platform (https://hydroinformatics.uiowa.edu/lab/idot-ors/) allows various stakeholders to view research outcomes, including ORS locations, expected pool and drainage areas, structure designs, and inflow and outflow hydrographs.



https://hydroinformatics.uiowa.edu/lab/idot-ors/

IDOT-ORS information platform, showing aggregated flood storage at the HUC12 level

Recommendations for Future Development

- Extend the planning design scripts beyond the six selected HUC12 watersheds to cover the approximately 1,600 HUC12 watersheds in Iowa, enhancing the selection of ORS that can provide optimal peak flow reduction benefits.
- Introduce a hybrid modeling approach combining hydrologic modeling with machine learning techniques, allowing efficient assessment of more HUC12 watersheds.
- Coordinate additional research efforts with ongoing flood resiliency planning initiatives in Iowa.
- Conduct economic analyses, such as loss-avoidance or benefit-cost analyses, to provide communities with the data necessary to secure funding for enhancing flood resilience.
- Explore the water quality impacts of ORS, particularly the potential for ORS to reduce the amount of phosphorus from agricultural fields that reaches bodies of water.

Implementation Readiness and Benefits

The outcomes of this research are accessible through the IDOT-ORS web platform (https://hydroinformatics.uiowa.edu/lab/idot-ors/), which helps stakeholders understand the potential of ORS to mitigate flood impacts.

The geospatial datasets created in this project are a valuable resource for those considering ORS implementation in Iowa. These datasets provide information on ORS locations, expected pool areas, and the drainage areas associated with the structures, offering a comprehensive foundation for planning and decision-making.

The scope of the research outcomes can be broadened through additional work addressing critical aspects of flood mitigation, economic feasibility, and environmental impacts related to ORS implementation in Iowa.