

TR NEWS

November–December 2022 **NUMBER 342**

INTEGRATED FLOOD PREDICTION SYSTEM

**Know When the
Waters Are Coming and
How to Respond**

PLUS

**Decision Support for Wildlife
Crossing Programs**

**Maintaining the Global
Vaccine Supply Chain**

RESEARCH PAYS OFF
**State DOTs Measure
Public Involvement**

**NATIONAL
ACADEMIES**

Sciences
Engineering
Medicine

TRB TRANSPORTATION RESEARCH BOARD

INTEGRATED FLOOD PREDICTION SYSTEM

Know When the Waters Are Coming and How to Respond

Michael M. Stokes, Wikimedia Commons, CC BY 2.0

SERI PARK

The author is an associate professor in civil and environmental engineering at the University of Nevada, Reno.

Murky—and catastrophic—floodwaters inundated the streets of Conshohocken, Pennsylvania, brought on by the remnants of Hurricane Ida in 2021. Across the country, state departments of transportation and other state and local agencies are employing integrated flood warning and response systems. Their hope is that predicting the extent and severity of flooding will lessen economic—and human—losses.

As manifested during the Category 4 Hurricane Ida storm event in the summer of 2021, a critical issue facing state departments of transportation (DOTs) across the United States is to efficiently and precisely predict and respond to flooding. Recognizing that roadway and bridge flooding have significant economic effects, state DOTs and other state and local agencies have implemented integrated flood warning and response systems to mitigate those negative effects. In addition, accurately predicting the extent and severity of flood inundation; providing proper and timely alerts to the public about affected areas; and protecting the public from these hazards became major tasks for state DOTs and public agencies. *NCHRP Synthesis 573: Practices for Integrated Flood Prediction and Response Systems* focuses on identifying successfully implemented strategies and practices in managing critical flooding cases through a literature review, a nationwide survey sent to state DOTs, and in-depth interviews.

Literature Review Findings

A comprehensive literature review identified several issues, including data gaps in stream networks without monitoring gages, challenges in river modeling for backwater and coastal zones, and flood prediction difficulties stemming from the dynamic nature of intense runoff events increasing in frequency due to urbanization and land development.

Survey Findings

With a 94 percent survey response rate, the research team was able to identify various aspects of the approaches state DOTs are taking to address flood prediction and response systems. The survey covered the following five topic areas:

1. Current status of flood event management,
2. Flood monitoring,
3. Flood prediction,
4. Flood warning systems, and
5. Flood response systems.

The following sections present key findings in each topic area.

CURRENT STATUS OF FLOOD EVENT MANAGEMENT

Many states indicated that river flooding (e.g., overtopping banks) and surface overland flooding (e.g., due to poor drainage) are the two major types of flooding they experience. Heavy rain, storm surge, snowmelt, and sea-level rise were identified as flooding causes. Based on responses from 25 state DOT offices, overall safety enhancement (such as a reduction in death toll attributable to flood events and decreased crash frequency during heavy rain season), streamlined and collaborative interagency communication, and improved and reliable relationships were observed benefits of their successfully integrated systems.

Sharing the lessons learned from successful state DOT practices is essential for effective integration of flood prediction and response systems. In the survey, the team asked state DOTs for the top three lessons learned from their state's flooding over the past 15 years. Common responses to this question included making sure a plan is in place and being prepared for a flood event. Other common responses were ensuring good communication between agencies and being proactive, rather than reactive.

FLOOD MONITORING

When asked about the methods and practices state DOTs use for flood monitoring, the U.S. Geological Survey's National Water Information System was the most widely used. Based on responses from 30 state DOTs, improved emergency response and understanding of maintenance needs are ranked as top observed benefits of state DOT flood monitoring systems. According to 47 state DOT responses, the most common method they employed to determine the extent and severity of flooding is visual inspection. Other identified methods for assessing the extent and severity of flooding on infrastructure include public reporting, external agency reporting, and application of sonar sensor and drone footage.



Sgt. Devon Bistarkey, U.S. Army National Guard, Flickr, CC BY-ND 2.0

In Ida's wake, aviators from U.S. Army National Guard North Carolina Detachment 1 Bravo Company, 2nd 151st Aviation Regiment conducted aerial search missions. As they scanned for individuals in distress in homes—such as this one, engulfed in flood waters—and other structures, they witnessed the extensive flooding along North Carolina's Cape Fear River near New Bern, Wilmington, and Lumberton.

FLOOD PREDICTION

A hydrologic/hydraulic model was identified as the most common type of flood prediction model used by state DOTs. Figure 1 shows more information about flood prediction platforms and models used by the states.

FLOOD WARNING SYSTEMS

To further understand how state DOTs evaluate the importance of information used within their flood warning systems,

they were asked to use a scale of one to eight stars, from least to highest importance, as a ranking method. Observed stream stage, bridge scour, and observed stream inundation were identified by state DOTs as the most important ranked information used in their flood warning systems. In contrast, they typically ranked model precipitation and model inundation information as relatively less important than these other factors.

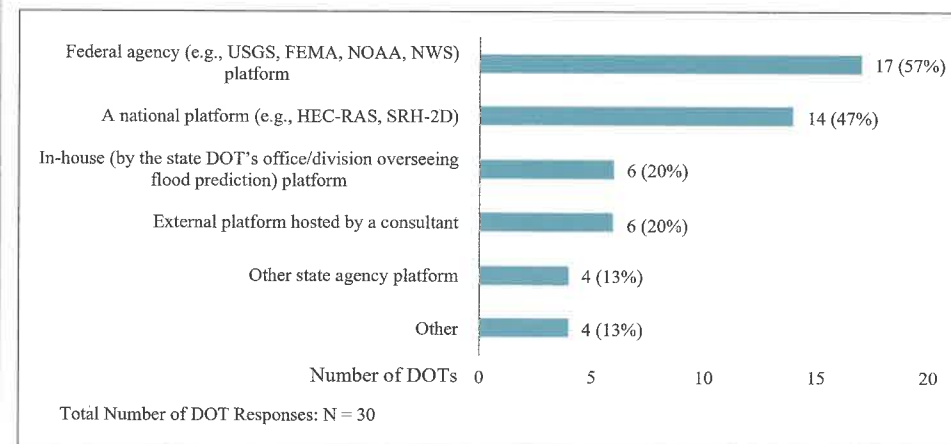


FIGURE 1 Reported flood prediction platforms and models used by states. The 30 survey respondents were allowed to select multiple answers. (Source: NCHRP Synthesis 573.)

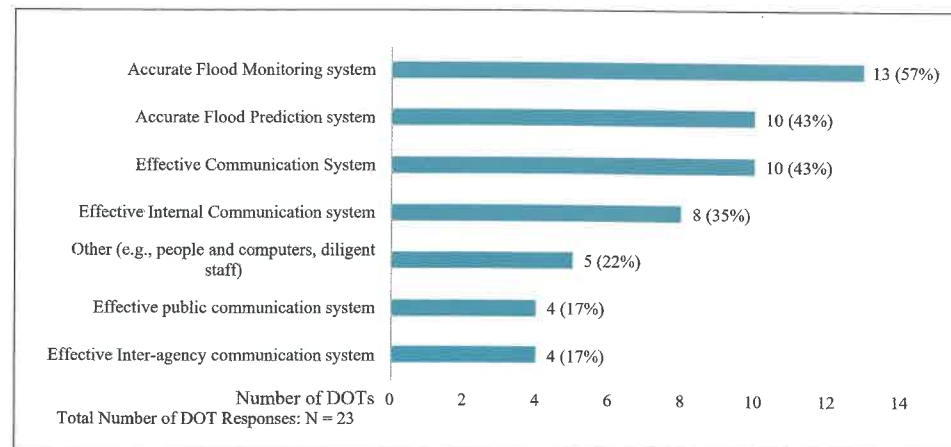


FIGURE 2 Reported key factors and attributes that have led to successful flood warning systems. The 23 survey respondents were allowed to select multiple answers. (Source: NCHRP Synthesis 573.)

Identifying the key factors and attributes that lead to a successful flood warning system was also a major task in the research project. Based on 23 responses, state DOTs reported accurate flood monitoring and prediction systems among the most essential factors and attributes for success (Figure 2).

FLOOD RESPONSE SYSTEMS

According to 34 state DOT responses, cooperation from local agencies in the state, adequate state resources for staffing and funding, and continuous public awareness campaigns regarding emergency response and warning systems were reported as key factors and attributes that have led to successful flood response systems.

Survey results also echo many challenges that state DOTs are experiencing in other areas. Many reported state resources (such as staffing, funding, and turnover), data coverage, and technical expertise as common challenges in implementing flood prediction models and flood warning systems. Survey results also show that impediments to implementing a successful flood monitoring system include these same state resources.

Interview

Based on the survey results and literature review, the team applied several criteria to select states to serve as case examples. The states' reported degrees of success

with integrated systems for flood prediction and response, geographic and physiographic distribution, differing flood causes and types, different types of land cover and development, and population densities were considered when conducting in-depth interviews. Ultimately, these selection factors yielded a diverse group of states that face a range of challenges and practice innovative solutions. Figure 3 maps the selected states and provides notable

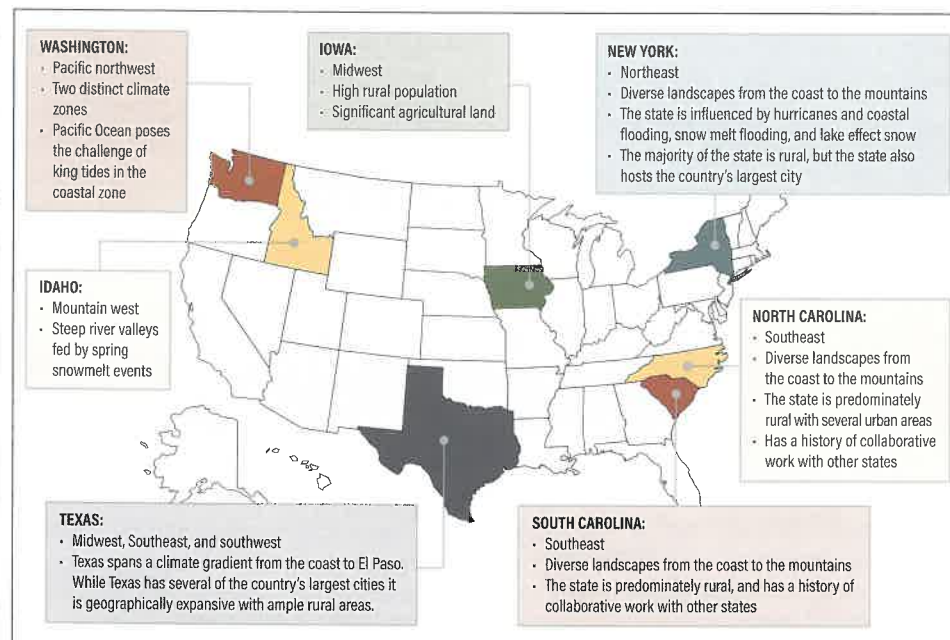


FIGURE 3 Locations and notable features of state DOTs selected as case examples. (Source: NCHRP Synthesis 573.)

features considered for selection. Through this process, seven case examples—Idaho, Iowa, New York, North Carolina, South Carolina, Texas, and Washington—were selected.

IDAHO

Key attributes for the Idaho DOT's successful flood monitoring program include the application of BridgeWatch software and efforts by the Scour Committee, a standing committee composed of a diverse group of engineering disciplines within the Idaho DOT. Notably, the interview showed that regular updating of BridgeWatch inputs and constant monitoring of its outputs contributed to success in flood management.

IOWA

The Iowa DOT has successfully implemented BridgeWatch for flood monitoring. In addition, collaboration with the Iowa Flood Center, at the University of Iowa College of Engineering, and use of the center's Iowa Flood Information System has led to a successful flood prediction program, a vital element for effective flood management.



Cathy Frye, Flickr, CC BY 2.0

When Reynolds Channel is as smooth as glass, it is hard to fathom the devastation that Hurricane Sandy brought to this same spot in Point Lookout, New York, on the eastern edge of one of Long Island's barrier islands 10 years ago. Long Island, the largest and longest island in the contiguous United States, is home to countless low-lying coastal areas just like this one—all of which are vulnerable to flooding.

NEW YORK

New York has applied hydraulic vulnerability assessments, flood warnings, flood watches, and post-flood inspection programs to maintain safe bridges during flooding events. Another notable feature is the state's work with the U.S. Geological Survey on developing and updating equations in geospatial application StreamStats to account for the differences in geology and groundwater present on Long Island.

NORTH CAROLINA

Developed by the North Carolina Emergency Management Division, the Flood Risk Information System aids in the collection and storage of flood data used statewide by more than 650 municipalities and state agencies. Furthermore, the Flood Inundation Mapping and Alert Network (FIMAN) System, used by North Carolina DOT, is recognized as one of the most robust surface transportation flood warning systems in the United States. The best illustration of North Carolina DOT's efforts to manage flooding, FIMAN provides critical statewide information in real time for first responders and recovery efforts.

FIMAN-T—the transportation-specific version—is currently under development. This application will leverage FIMAN's success to provide a similar enhancement to North Carolina DOT's operational emergency preparedness and response capabilities.

SOUTH CAROLINA

Between 2015 and 2018, South Carolina experienced major storm events such as Hurricane Matthew in 2016 and Hurricane Florence in 2018. In response, South Carolina DOT enhanced its inter-agency communication, data sharing, and event management collaboration, thus gaining a deeper understanding of other agencies' activities, data, and tools for flood management. Furthermore, the use of BridgeWatch software allowed South Carolina DOT to view its bridge locations in a geospatial format with rainfall event and rainfall prediction data.

TEXAS

Texas DOT has made a well-coordinated effort to address emergency flood management. To better ensure emergency responders' safety, Texas DOT provides an application programming interface

data feed for emergency response agencies, which improves coordination and acceleration of flood management efforts. Texas DOT also is engaging in research to improve streamflow measurement at its bridges, as well as to explore improved predictive modeling based on methods from the National Oceanic and Atmospheric Administration's National Water Model.

WASHINGTON

By incorporating climate predictions into their design criteria, Washington State DOT aims to anticipate flood events. It is also committed to improving its database management to clarify content and ownership for facilitating data sharing. Through a statewide Watch List, Washington State DOT oversees critical flooding locations that are monitored by region-specific maintenance crews.

Lessons Learned and Research Roadmap

The literature review, state DOT survey, and interviews provided a sound understanding regarding the practices that support effective flood prediction and

response systems, key components of flood management. BridgeWatch; National Water Information System; and close working relationships among state DOT divisions, other state agencies, and

federal offices often are cited as common tools for success. Furthermore, sharing a coordinated and updated asset inventory document with key state DOT personnel is a vital approach to keeping departments

informed. Many state DOTs also reported that continual advances in technology (e.g., data models, sensors, and geographic information systems) have made data collection and communication between stakeholders easier and improved the coordination of model prediction efforts.

Other observed challenges include hurdles to data collection and sharing because of siloed data and other data issues. Consequently, there is a need for research that explores novel opportunities to facilitate database sharing and integration. NCHRP Synthesis 573 also points to the need for improvement in real-time flood model predictions, especially for backwater flow conditions and hydrologically complex areas [e.g., snowmelt flooding or King Tides (the highest of high tides)]. Real-time monitoring systems at state DOTs could be enhanced with more widespread adoption of BridgeWatch or similar software.

Although this article highlights key content from the synthesis, the report findings will need future updates, in light of the evolving nature of data collection and information technology.



Eric, Flickr, CC BY 2.0

King Tides occur when the orbits and alignment of the Earth, Moon, and Sun combine to produce the greatest tidal effects of the year. These highest of high tides can routinely cause coastal flooding, as shown here in Sausalito, California, on December 4, 2021.

V O L U N T E E R V O I C E S

“Marine transportation was not my area, but it’s fascinating! The ability to link continents and countries by ship, cargo, and people is a technological wonder humans have developed since the start of civilization. There have been no such great technology developments for other modes of transportation. Nowadays, marine transportation doesn’t normally get any news coverage—except recently, with the logistics difficulties we are currently having.

—ALFONSO CORREDOR

Senior Policy Advisor (Retired)
Toronto, Ontario, Canada



Appendix P