



WEATHER-RESPONSIVE MANAGEMENT STRATEGIES

CASE STUDY

Source: FHWA

Weather-Responsive Management Strategies (WRMS) for Flood Management in Iowa, Missouri, and Nebraska

Background

The Weather-Responsive Management Strategies (WRMS) initiative under the Federal Highway Administration (FHWA) Every Day Counts—Round 5 (EDC-5) program promotes the use of road weather data from mobile and connected vehicle (CV) technologies to support traffic and maintenance management strategies during inclement weather. The goal is to improve safety and reliability, as well as reduce environmental impacts on the transportation system resulting from adverse weather.

WRMS can mitigate the impact of flooding events through preparation and prediction efforts that leverage and build data, tools, and relationships. As a result, agencies are better equipped for response and recovery efforts. While experience with major flood events increases Department of Transportation (DOT) staff understanding of how to assess and respond to flood risks, flood-related WRMS enable DOT staff to better understand the consequences of specific stream gauge readings, what the impacts will be and where, who to talk to, what resources are available, and new tools and next steps required to advance practices.

This case study highlights the experiences and lessons learned from the Iowa, Missouri, and Nebraska DOTs while managing major flood events in the Missouri River Basin. The DOTs utilized similar strategies but different tactics given the various agency relationships and resources available for flood management.

Missouri River Basin Major Flooding Events

The Missouri River Basin, shown in Figure 1, typically experiences some annual flooding in the spring as a result of snowmelt from upstream areas and increased rainfall. Levees, dams, and other infrastructure are in place to help control the floods and minimize the impacts of this annual cycle. Significant flood events on the Missouri River in 2011 and 2019 caused major prolonged impacts and road closures, resulting in recovery and reconstruction efforts lasting for many months.

The 2011 flood caused over two billion dollars in damages and five fatalities in the United States. Flooding followed wetter than normal fall soils, record winter snowfall, and then record-setting spring precipitation. Numerous levees were breached along the Missouri River, flooding thousands of acres of farmland and damaging transportation infrastructure. During the event, there was flash flooding along uncontrolled tributaries and extensive mainstem river flooding, which continued for months in some locations. Extreme river levels caused hydraulic conditions, which Missouri DOT had not previously observed.¹

The 2019 flood was caused by a confluence of events. An intense storm with heavy rains and warm air in March rapidly melted much of the thick snowpack and ice that had accumulated over the winter, producing significant runoff in a short period. Large chunks of river ice, which ran against dams, levees, and other infrastructure, packed together to jam waterways, and contributed to the failure of Spencer Dam in Nebraska. Several streams and rivers reached all-time record levels in Nebraska, Iowa, and South Dakota.²

Data and Tools for Prediction and Preparation

DOTs rely on a variety of data and tools to predict and prepare for a significant flood event. Experience helps staff understand the spatial relations between the height of a roadway and how it will be impacted by a certain water level, in conjunction with models that examine inundation at various



Figure 1. The Missouri River Basin is in the north central United States (Source: Bureau of Reclamation)

river levels. However, when levees are destroyed or events are exceptional, this historic experience becomes less relevant, and staff needs to rely on available data and models to understand the resulting rise and fall of the flood water levels. Below are examples of data and tools used by DOTs:

- **River Gauge Data.** Missouri DOT actively used the National Oceanic and Atmospheric Administration (NOAA)/ National Weather Service (NWS) river gauge and hydrograph predictions to plan for closures. Notes included with the NOAA hydrograph information contain several details, such as water levels that will impact downstream bridges. This information was available to Missouri DOT supervisors on their mobile devices. It helped staff understand when water was being released from upstream dams, and where to position equipment and staff, as needed, to keep roads open for as long as possible before floodwaters crossed a road.

¹U.S. Department of Commerce, National Oceanic and Atmospheric Administration, **Service Assessment: The Missouri/Souris River Floods of May – August 2011** (May 2012)

²NASA Earth Observatory. "Historic Floods Inundate Nebraska." <https://earthobservatory.nasa.gov/images/144691/historic-floods-inundate-nebraska>

- Hydrologic Modeling.** To understand water flow, potential impacts, and road overtopping risks, analysts use a variety of hydrologic models available at DOTs and from university partners. For example, Iowa DOT utilized a 2D hydraulic model called TUFLOW[®] that determined the stages and velocities along the entire 50 river miles of the Missouri River for 32 miles of I-29 and three major highway crossings, shown in Figure 2. This provided forecasting, assessment, and response information as the U.S. Army Corps of Engineers (USACE) temporarily repaired the levee system to a 25-year flood level over the 6 months following the March 2019 flood event. Hydraulic modeling also provided detailed information for emergency relief betterment analysis to improve resiliency options for DOT infrastructure.
- LiDAR Mapping.** Iowa DOT used a light detection and ranging (LiDAR) map, accurate to within an eight-inch elevation, to model where water would pool over large areas, whether the road may act as a dam or allow water to go over the top, and where to sandbag. This data was essential to Iowa DOT for relating the Missouri River stream gauge information to potential infrastructure impacts, particularly after levee breaches caused by the March 2019 flood made infrastructure more vulnerable to subsequent flooding. The LiDAR map facilitated a proactive response that would otherwise require maintenance staff on the ground for updates.
- Data Repositories.** Iowa DOT used centralized databases with flood-related resilience and monitoring information alongside infrastructure information to

facilitate quick assessment. This type of assessment is analogous to how a DOT might use PikAlert[®] or a maintenance decision support system (MDSS) during winter weather events to understand assets and resources in a single stop. Roads are surveyed to the sub-inch level, which is far more detailed than the LiDAR information. Data repositories can be used at a microscopic level to inform related hydrologic modeling efforts, since a couple inches of water can make the difference between normal operations and a closure. Similarly, Missouri DOT maintains a bridge database that contains detailed information, including plans and photos for bridges. This was especially helpful in their preparation for understanding when water would rise to critical scour points.

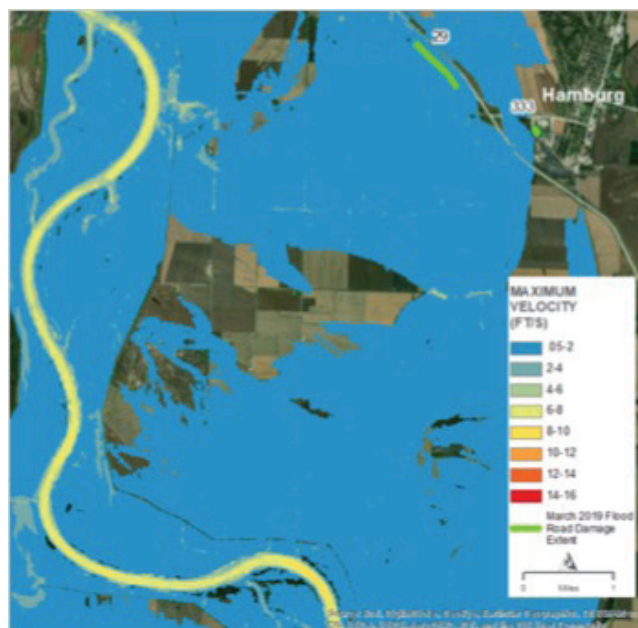


Figure 2. A velocity and inundation map from Iowa DOT's TUFLOW model of a Missouri River segment for a 10-year flood frequency event, with green areas showing where significant damage occurred, as well as flood impacts on infrastructure without the levee system permanently repaired (Source: Iowa DOT)

- **Sandbag and Barrier Systems.** Different sandbag and barriers systems are available from a variety of companies. For instance, one type of barrier is created by pumping the inside with floodwater like a large water balloon. Other examples include connected sandbags that are many feet tall and traditional hand-filled sandbags. Additionally, Iowa used LiDAR outputs to identify where to temporarily elevate roads using Jersey barriers infilled with rock, and to sandbag a non-DOT dirt road at an entry point that was narrower and easier to protect than a broader area for a downstream highway.

Intra- and Inter-Agency Partnerships

During a major flood event, State DOT personnel must coordinate and work with staff from a variety of agencies, departments, and other partners that typically conduct separate day-to-day activities. For example, Missouri DOT has participated in tabletop exercises for a variety of scenarios other than weather with the American Red Cross, hospitals, NWS, emergency managers, and other partners to help develop these relationships. Experience with previous emergency events provides a basis for understanding points of contact for assistance as different questions and issues arise. During a flood event, agencies may work with the entities listed below:

- **The United States Army Corp of Engineers** (USACE) develops plans for an upstream water release, which can increase flooding. Missouri DOT cited the challenge of issuing emergency contracts, conducting repairs and paving, and re-opening a river crossing before another flood caused by an upstream release closed it again. The USACE also inspects levees and understands where failures may be possible. This relationship and knowledge can inform DOT actions to assist people who are being displaced by flooding as a result of released water and levee breaches. During the 2011 flooding, Missouri DOT issued emergency contracts and conducted roadway repairs to reopen a major river crossing, only to close it again following an upstream water release. Coordination with the USACE can inform State DOT actions to maintain transportation surrounding flood events.
- **Railroad companies**, as well as the USACE, may use public roadways to transport heavy loads for rebuilding infrastructure damaged by floods, causing major rutting and additional damage to roads with an unclear timeline of project completion and cost for the State DOT.
- **Commercial motor carriers** support flood recovery efforts and require input from the State DOT about routes to transport recovery materials, as well as everyday goods and services.
- **Hydrology and hydraulic staff** at the State DOT, university partners, or private weather service providers work with State DOT maintenance and operations staff to run hydrology models based on observations in a cyclical execute-monitor approach, to generate a plan and messaging strategy based on understanding which bridges are at risk and whether they may be protected.
- **HazMat teams** are important during recovery, as a lot of potentially hazardous materials and refuse gets washed onto roadways and State DOT rights-of-way during floods. This may require special expertise for removal.

The State DOT may contact a variety of other agencies to support flood preparation and recovery efforts, depending on the resources required in specific locations. For example, Iowa DOT noted that the Department of Corrections was engaged in advance of a flood event to provide labor to fill sandbags. The National Guard helped supply aid to a Nebraska community that could not be accessed by road due to flood waters. The 2019 flood also prompted Nebraska DOT to engage the Game and Parks Department to use airboats and officer operators to inspect flood damage. The State DOT may also engage county agencies, the Department of Agriculture, and the U.S. Geological Survey to support flood-related efforts.

Response and Recovery

A key lesson learned for agencies experiencing a major flood event is that the State DOT often serves as a major resource to other people, cities, and agencies for emergency operations—devoting State DOT staff and equipment to provide support on top of standard duties to care for roadways. As a result, State DOT maintenance groups tend to be extremely short-staffed during floods, because they are helping others as approved by emergency operations, even as staff are shifted internally to support the impacted area. Additionally, State DOT office staff help to organize emergency efforts from different offices and District areas. Further, State DOT maintenance garages are often used as emergency distribution hubs to provide sandbags, supply water, or collect garbage.

The Iowa, Missouri, and Nebraska DOTs all emphasized the importance of knowledge, experience, and relationships when responding to major flood events. Experience gives a basis for understanding past successes

Bridge Re-opening Challenges after Major Flooding

In the seven months after the March 2019 flood, the U.S.-59 Amelia Earhart Bridge across the Missouri River was fully closed on three separate occasions for multiple weeks at a time. This was necessary because of subsequent flooding resulting from impacted, vulnerable infrastructure and dams releasing water. This bridge also serves as a major route for commuters from Missouri into Atchison, Kansas. The shortest alternate route adds over 30 miles in one direction. Missouri DOT used temporary traffic signals when only one lane of the highway could be opened. Staff monitored flood water on-site to keep the route open as long as possible, and used extensive community outreach to keep the public informed and minimize impacts from the detour.

and failures, and the various tactics used in a situation. As such, the bigger struggle is what to plan for, based on the prediction of what to actually expect.

During recovery, State DOT staff must inspect the damage caused by flooding to determine whether roadways can be reopened or require repair—which can be a major challenge when roadways are closed and inaccessible. For example, 3,000 miles of roads were closed in Nebraska following the 2019 flood. District staff immediately began assessments and continued inspections over the following weeks to determine there were 27 damaged bridges and 200 miles of roadway requiring repairs. Nebraska DOT maintenance staff conducted the majority of cleanup and initial repairs, and then hired contractors to begin major repair work.

Meanwhile, there were over 470 road closures in Missouri. Compounding the problem, 180 breaches in Missouri levees were not repaired by the USACE until a year after the flood, with some roads remaining underwater in the interim. This created a need for the DOT to understand the recovery process and timeline set by other agencies so DOT staff could access flooded areas to assess damage and set a timeline and approach for recovery.

Given similar damage, Missouri DOT cited constraints on the District budget caused by major flood events. For instance, the State DOT spent about \$11 million for flood recovery efforts in 2011. The repairs were completed by contract, and the 80 percent reimbursement came back into the District's State Transportation Improvement Program (STIP) budget for contracting 8 years later.

Additionally, assessing the economic impact of closures is a major challenge for justifying investments, faster response, and preparations for future flood events. A similar challenge, noted by Nebraska DOT, is that bridges reconstructed using Federal Emergency Management Agency funds must be built according to the original design and cannot be upgraded to anticipate future flood events. Missouri DOT is generating benefit-cost ratios and examining the likelihood of flooding on roadways impacted by significant and recurring floods to determine whether additional mitigation treatments (like raising the roadway or armoring shoulders) should be implemented with other repairs. Missouri DOT is also considering the installation of permanent gates on I-29, which would allow them to

close the highway as warranted by future flooding and severe winter weather.

Conclusion

The experiences by Iowa, Missouri, and Nebraska DOTs during major flood events provide a number of valuable lessons learned, especially for agencies that may have limited experience with flood events. Developing and maintaining relationships with partners will help agencies understand contacts and available resources when they are needed, as well as the various data and tools that may support prediction and response efforts. After a flood event, recovery efforts may last for months and are often beyond the State DOT's control, depending on timelines of other agencies and availability of funding.

Available Resource

FHWA's EDC-5 WRMS Resource Toolkit:
<https://collaboration.fhwa.dot.gov/dot/fhwa/RWMX/SiteAssets/WRMS/home.aspx>

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