Iowa DOT Flood Monitoring and Response Manual

CHAPTER 1

OVERVIEW AND DEFINITIONS

1.1 PURPOSE OF MANUAL

Highway infrastructure is exposed to a diverse range of hazards with flooding being one of the most common and consequential. Roadway flooding can directly affect public safety and disrupt transportation networks and the services they provide. Bridges are susceptible to scour from flooding which can expose bridge foundations reducing its structural integrity.

An operational flood forecasting system can provide support to the Iowa DOT for their immediate flood preparation and response needs as well as long-term planning efforts. With advanced warning, the DOT can prioritize limited resources to close roads, plan detours and communicate to the public before motorists are exposed to flood hazards.

The purpose of this manual is to describe Iowa DOT's flood forecasting capabilities and to document the responsibilities and procedures when flooding is anticipated to impact highway infrastructure. Flood forecasting is a way to proactively monitor, assess, and respond to flood-related hazards in real time. It involves integrating multiple sources of data, providing clear communication protocols and providing automated notifications to appropriate personnel.

The Iowa DOT's development of the Riverine Infrastructure Database (RIDB) and utilization of the BridgeWatch system provides real-time alert notifications to proactively allocate resources to vulnerable asset locations and enhance public safety during flood events.

1.2 DEFINITIONS, ABBREVIATIONS, AND ACRONYMS

1.2.1 Definitions

The following terms used in this manual are defined below:

- *Annual Exceedance Probability Discharge (AEPD)* – an estimated flood event with a flood frequency recurrence interval (e.g., 1% AEPD is a flood event with a 1% chance of being equaled or exceeded in any given year; also known as a Q100 flood)
- *BridgeWatch* – A propriety software that provides real-time flood hazard monitoring from data sources such as NWS, USGS and Iowa Flood Center with automated alert notifications to appropriate personnel at the asset level.
- *Critical Streambed Elevation* – Elevation of streambed that exposes bridge foundations which may risk structural integrity of structure or approach roadway.

- *Critical Water Surface Elevation* – As specified under the Bridge Specific Provisions, the elevation which detailed monitoring procedures shall be initiated.
- *Hillslope Link Model (HLM)* – A continuous rainfall/runoff and streamflow generation model that provides current and forecasted flowrates for streams in Iowa.
- *Iowa Flood Center (IFC)* – Created by the Iowa Legislature after the 2008 floods to provide science-based information and technology for decision-makers to improve Iowa's flood preparedness and resiliency.
- *Iowa Flood Information System (IFIS)* – a web-based platform developed by the Iowa Flood Center to provide real-time flood conditions, forecasts, inundation maps and related data to Iowa communities.
- *National Water Model (NWM)* – A hydrologic modeling framework that simulates observed and forecast streamflow over the entire continental United States.
- *NEXRAD* – A network of high-resolution Doppler weather radars operated by the NWS.
- *Rating Curve* – A graph showing the relationship between the stage (water level) of a stream and its discharge.
- *Riverine Infrastructure Database (RIDB)* - A relational GIS database for rapid assessment of infrastructure vulnerability to flooding through utilization of flow data from the Iowa Flood Center (IFC) Hillslope Link Model (HLM)
- *Scour* - Erosion of streambed or bank material due to flowing water.
- *Scour Countermeasure* – The design of stone revetment or Articulating Block Mattress (ABM) to resist the erosive forces of flooding.
- *Scour Susceptible Bridge* – Bridge foundations have been assessed or analyzed as vulnerable to scour or cannot be assessed due to unknown foundations.

1.2.2 Abbreviations and Acronyms

ABM	Articulated Block Matt
AEPD	Annual Exceedance Probability Discharge
BSB	Bridges & Structures Bureau
GIS	Geographic Information System
HLM	Hillslope Link Model
IFC	Iowa Flood Center
IFIS	Iowa Flood Information System
NEXRAD	Next-Generation Radar
NWM	National Water Model
NWS	National Weather Service
RIDB	Riverine Infrastructure Database
TMC	Traffic Management Center
USGS	U.S. Geological Survey

CHAPTER 2

FLOOD FORECASTING RESOURCES

2.1 RIVERINE INFRASTRUCTURE DATABASE (RIDB)

2.1.1 Origination and Purpose

In 2008, extensive flooding occurred in central and eastern Iowa that impacted I-80 and many other primary routes. During these flood events, it was difficult to asses and predict which highway locations had the potential for overtopping from floodwaters so that safe detour routes could be identified for the traveling public. The effort to evaluate the vulnerability of the roadway to flooding required significant staff time and resources to collect bridge and road plans, reconcile the datums of projects and correlate hydraulic information to determine accurate stage versus discharge relationships (rating curves) at specific bridge and highway locations.

Fortunately, the Iowa DOT had a bridge replacement project under construction on I-80 over the Cedar River at the time of the 2008 floods. Since the Iowa DOT had design information regarding the low roadway and detailed hydraulic information (rating curve), the Interstate was closed before floodwaters impacted the traveling public. Traffic was proactively detoured preventing significant traffic delays and diversion of traffic into the local roadway system. This event was the impetus for the development of the innovative RIDB.

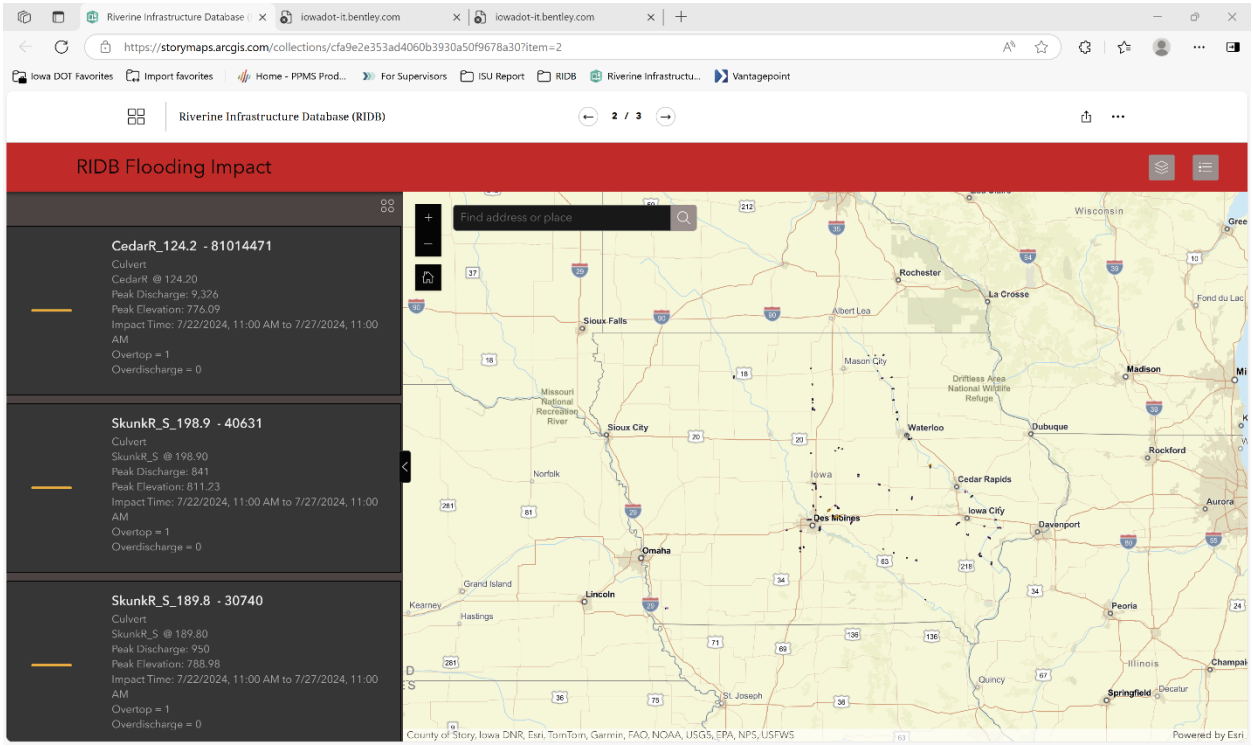
2.1.2 Development

The Iowa DOT owns approximately 2,100 bridges over streams and rivers on the primary highway system. Many of these bridges and roadways are vulnerable to flood damage and overtopping during flood events. The RIDB will provide a proactive approach to assessing the vulnerability and risk to transportation infrastructure by incorporating hydraulic (rating curve) information and infrastructure (low road and bridge beam elevations) data that will be continuously monitored with forecasted flood discharges from the Iowa Flood Center's (IFC) Hillslope Link Model (HLM).

The HLM is a hydrological model that utilizes rainfall events to simulate observed and forecasted flowrates for any stream in Iowa. The RIDB ingests the HLM flowrates to perform rapid comparisons of highway asset elevations to display when a site threshold has been exceeded for potential roadway overtopping or excessive bridge scour. The RIDB does not send automated alerts to appropriate staff when a threshold is exceeded.

The RIDB will ultimately monitor approximately 1500 sites for flood flows from the IFC's HLM. The flows are compared to thresholds established for each location based on rating curve information developed from hydraulic modeling of the site. The RIDB will monitor every

vulnerable primary highway and bridge in Iowa that drains over 10 square miles (approximately 1500 additional locations).



RIDB flooding impact interface; [Riverine Infrastructure Database (RIDB)]

2.2 BRIDGEWATCH

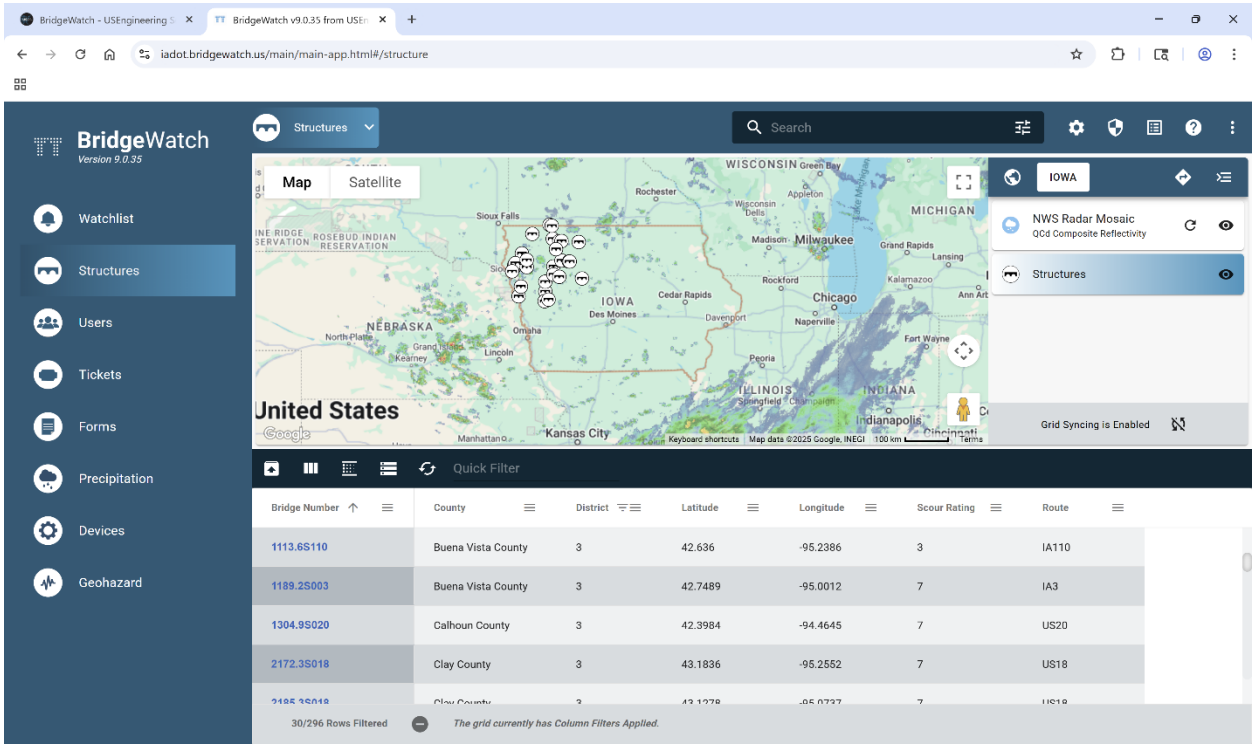
2.2.1 Capabilities

BridgeWatch is a web-based software application from USEngineering Solutions, Inc that provides real-time flood monitoring and alert notifications for infrastructure owners to identify, predict, manage and record flooding hazards for bridges and roadways. The Iowa DOT has utilized the BridgeWatch program since 2004 for monitoring scour critical bridges and overtopping of low roadways since 2016.

BridgeWatch provides proactive real-time alerts to key personnel for roadways at risk of overtopping or bridges vulnerable to scour due to flooding. The program utilizes real-time data sources such as National Weather Service (NWS) NEXRAD rainfall, USGS gages and IFC Flood Sensors to monitor infrastructure thresholds (low road and peak flood flows) established at DOT asset locations (bridges and roadways) in a geospatial format. The BridgeWatch program will also leverage the monitoring capabilities of the RIDB when alert notifications are issued by the program. BridgeWatch will send the alert notifications to appropriate personnel via text messages 24/7 when a threshold is exceeded.

The program provides a platform for on-site documentation and reporting of field observations via a ticket system. Users of BridgeWatch can access a graphical display of their geographical area, an inventory of the infrastructure being monitored and a list of sites exceeding their respective thresholds.

The BridgeWatch program is designed to be a proactive monitoring system providing meteorological and hydrological data to make informed decisions regarding hazard related responses to transportation infrastructure from any location at any time.



BridgeWatch Interface; https://usengineeringsolutions.com/bridgewatch/

2.3 EXTERNAL DATA RESOURCES

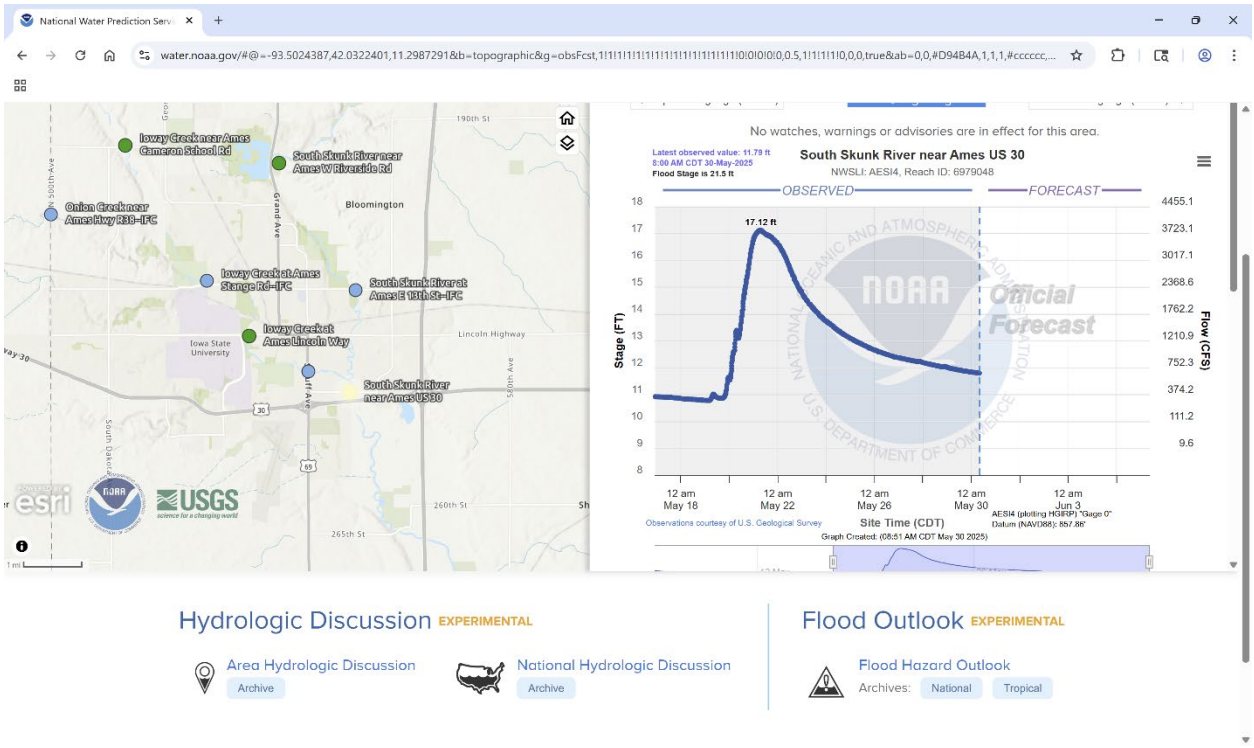
2.3.1 USGS Gages

The U.S. Geological Survey (USGS) has cooperative agreements with the Iowa DOT and other partners to provide real-time stream gage data to monitor stream flows throughout the state. The agreements help fund and maintain a stream gage network of approximately 120 gaging stations that are utilized for flood warnings and forecasts, reservoir operations, developing water related policy and the design of bridges and culverts.

The BridgeWatch program monitors USGS gages at associated bridges and roadways and will use the data source to send alerts when infrastructure is jeopardized by flooding.

2.3.2 NWS Forecasting Sites

The National Weather Service (NWS) provides flood forecasting at certain USGS gage sites. These forecasts are projections of what the gage height/flood discharge would be based on past rainfall that has occurred over the basin and any 24 hour projected rainfall amounts. Most of the gages on major streams in Iowa provide forecasted flood stages and discharges. The forecasts can be utilized to be proactive in the assessment of infrastructure impacts and whether a roadway or bridge should be closed to traffic. Initial NWS forecasts are typically conservative (over-estimates the flood) but do provide early warning of potential impacts to infrastructure to enhance public safety and possibly mitigate the impacts.



NWS Forecasting Site; https://www.weather.gov/forecastmaps/

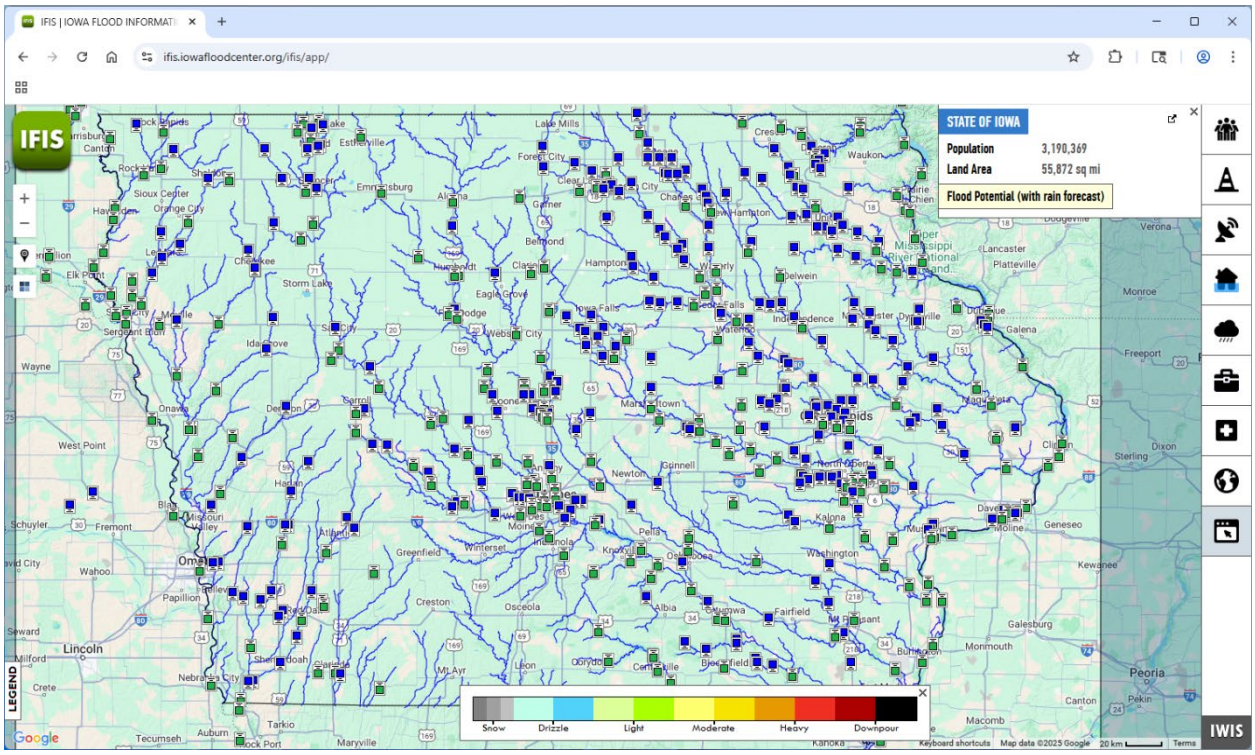
2.3.3 Iowa Flood Center

Created by the Iowa Legislature after the 2008 floods, the Iowa Flood Center (IFC) provides science-based information and technology for decision-makers to improve Iowa's flood preparedness and resiliency. The IFC is located at the University of Iowa and provides many resources for communities and asset owners to mitigate the impacts associated with flooding.

The Iowa Flood Information System (IFIS) provides real-time and forecasted streamflows for every stream in Iowa utilizing the Hillslope Link Model (HLM). Approximately 300 IFC stream-stage sensors measure river levels every 15 minutes to improve flood monitoring and forecasting for emergency managers, communities, Iowa DOT and the HLM. These stream-

stage sensors will provide monitoring for roadway overtopping at select highway locations vulnerable to flooding.

The RIDB aggregates the observed and forecasted flows of the HLM and stream-stage sensors to monitor exceedance of infrastructure thresholds (low road and bridge beam/discharges) so that alert notifications through BridgeWatch can be sent to key personnel. The BridgeWatch alerts are sent to initiate field observation of potential flooding impacts.



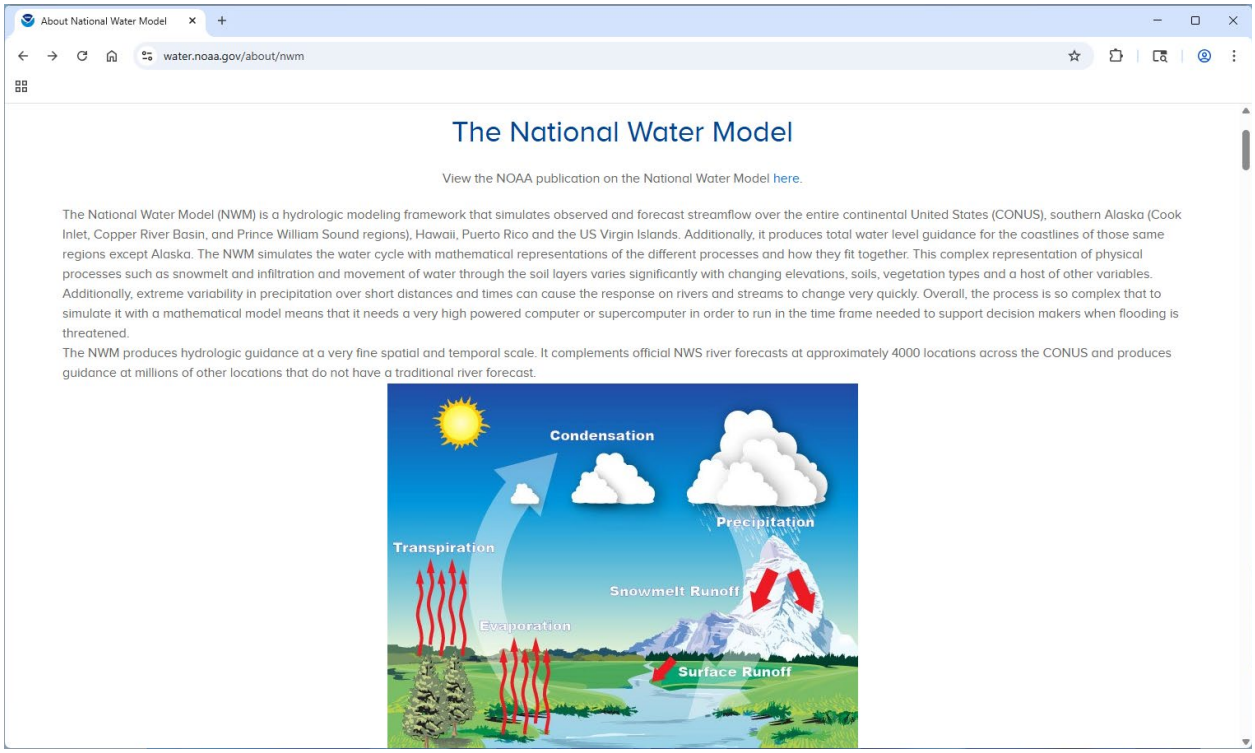
Iowa Flood Information System (IFIS) https://ifis.iowafloodcenter.org/ifis/app/

2.3.4 National Water Model

The National Water Model (NWM) was introduced in 2016 to provide the capability to simulate and monitor hydrological behavior across the entire United States. The model is equipped to simulate important hydrological cycle components such as rainfall, infiltration, streamflow (runoff), and evaporation among others. The NWM has short, medium and long-range weather forecasting capabilities and uses a supercomputer to generate existing and forecasted streamflows anywhere in the continental U.S.

Several studies have evaluated the effectiveness of the NWM to estimate streamflow. One of the studies found that the NWM can be a reliable tool for forecasting flood in rural areas. However, its efficacy depends on the data quality used to generate the forecasts. While the NWM is a promising tool for forecasting floods, it requires additional research and calibration at specific locations and applications to ensure its effectiveness in diverse weather situations.

The NWM is currently undergoing extensive validation and verification to identify where scientific updates to the model can make the most improvement and new versions are planned for release on a regular basis. The NWM output provides supplemental guidance to NWS forecasters and should not be considered an official NWS river forecast.



National Water Model; https://water.noaa.gov/about/nwm

CHAPTER 3

FLOOD MONITORING AND REPONSIBILITES

3.1 FLOOD MONITORING

The Iowa DOT is uniquely positioned to provide real-time monitoring for its infrastructure due to the development of the RIDB and other resources available (BridgeWatch, IFIS and NWM) to assess the flooding impacts of its bridges and roadways. A flood monitoring plan identifies the personnel responsible for assessing the assets for forecasted flood events, and establishes roles and communication channels between the Central and District offices.

Flood forecasts can support a coordinated and proactive approach to hazard response operations by providing better lead time for events, enabling more efficient use of resources and supporting faster response in the field.

3.1.1 Bridge Monitoring Plan – Standard Provisions

The Iowa DOT has monitoring plans for each scour susceptible bridge on the primary highway system and several Iowa DNR state parks. There are approximately 70 bridges that are classified as scour susceptible on the highway network. Most of those structures have been designed with scour countermeasures (revetment or ABM) that limits scour or erosion during a flood event to an acceptable level. This allows the bridges to remain open during a flood event.

Monitoring is still required for these structures due to their potential risk. Bridge monitoring intervals and procedures should be followed according to the Standard and Specific Bridge Monitoring Provisions.

Once a scour critical water surface elevation has been reached, monitoring should be performed until the flood elevation recedes and there are no signs of scour or distress.

Bridges have been grouped into four different scour classifications according to their scour susceptibility:

Critical – A bridge classified as scour critical does not have a countermeasure for protection against the potential erosive forces of a flood. There are a few bridges that the Iowa DOT has decided not to protect with a countermeasure (mostly DNR Park structures) and will be closed during a flood which exceeds the critical water surface elevation. Monitoring during flood event is required.

Armored – Countermeasure has been installed to limit scour depth/bank erosion. The countermeasure is typically revetment which should remain viable in limiting scour/erosion during a major flood event. Monitoring during flood event is required.

Permanent – Countermeasure should remain viable for several major flood events in limiting scour/erosion. This countermeasure is typically an articulated block mat (ABM) and does not require monitoring during a flood event as long as the countermeasure is substantially intact. Verification of countermeasures should be considered following any significant (>25 yr. flood) or roadway overtopping events.

Other – Temporary crossings, runarounds or bridges with current scour/erosion issues would be classified as Other and can be added to the monitoring plan. Information for monitoring procedures and provisions would be specified under the Bridge Monitoring Plan - Specific Provisions. Monitoring during a flood event is required.

3.1.2 Bridge Monitoring Plan – Specific Provisions

Each scour susceptible bridge has information on the critical water surface elevation and critical scour depths that could jeopardize the integrity of the structure or approach roadway. Each bridge has a mark or painted line on a substructure unit depicting the critical water surface elevation to allow rapid visualization of the current water surface relative to the critical elevation.

The Bridge Monitoring Plan - Specific Provisions includes information on the scour classification, bridge plans, critical water surface elevation, critical streambed elevations and scour countermeasure plans. The Bridge Monitoring Plan - Specific Provisions can be found on the W drive at:

W:\Highway\Bridge\PrelimSection\Scour\Scour_Management_Plan_Work\ Bridge Monitoring Plan_SpecificProvisions\Active

It is recommended that District personnel responsible for monitoring scour susceptible bridges obtain a hard copy of the Bridge Monitoring Plan - Specific Provisions for reference if the critical water surface elevation mark is not visible or has been exceeded during a flood.

3.1.3 Roadway Overtopping and Low Beam Monitoring

In addition to monitoring scour susceptible bridges, the Iowa DOT's flood forecasting system provides early warning of roadway overtopping and inundation of the bridge low beam elevation. The inundation of a beam can cause pressure flow which magnifies the scouring effect during a flood. A steel beam bridge will typically be closed when flood waters inundate the superstructure or experiences significant debris accumulation. Concrete beam bridges can better resist flood water inundation and debris buildup.

The alert notifications will be sent when the estimated flood elevation is one foot below the low road or low beam of the structure. The alert notification may be more conservative (greater than one foot below the low road or bridge beam) if the basin is small (< 100 sq. mi.) to allow adequate response time before a peak elevation is achieved.

Debris accumulation on scour susceptible bridges can cause unpredictable scour patterns that could result in rapid failure of bridge foundations, bridge berms or approach roadway. Continuous monitoring should be considered when a bridge beam is inundated by flood waters or has significant debris buildup.

3.2 RESPONSIBILITES

The Iowa DOT has experienced significant flood events over the years which has impacted the traveling public and our highway infrastructure throughout the state. In order to provide a reliable flood forecasting system, actionable information as well as a proactive and coordinated response to flooding events is needed. This can be accomplished by providing clear roles and responsibilities for an effective implementation of monitoring plans and actions.

3.2.1 Districts

District personnel monitor bridges and roadway conditions during flood events to ensure the safety of the traveling public. When flooding is forecasted and a threshold is exceeded for a scour susceptible bridge or potential overtopping of a roadway, an automated alert notification from the BridgeWatch program will be sent via text message to key personnel. The text message will identify the bridge and/or roadway site that is potentially threatened due to flood waters.

When a text message alert has been received, the response for monitoring a site is dependent upon the type of alert. There are three types of alerts for Iowa DOT infrastructure. A scour susceptible bridge, roadway overtopping or low beam inundation.

3.2.1.1 Scour Susceptible Bridges

The BridgeWatch program monitors NEXRAD rainfall or USGS gage information to assess the thresholds for scour susceptible bridges. Once a rainfall or gage threshold is exceeded, a text message alert is sent to the District for monitoring. Essentially, every scour critical bridge is protected with a countermeasure to mitigate scour during a flood event. If an alert is received late in the evening or in the middle of the night, monitoring of the structure and roadway can be delayed until the next morning due to the lag in peak discharge and protection of the bridge foundations with a countermeasure.

District personnel will inspect the site to determine if a critical water surface elevation has been exceeded for a scour susceptible bridge or if flood waters continue to rise warranting further monitoring of the bridge and roadway. If flood waters have peaked without reaching the critical water surface or overtopping of the road, District staff should inform the Bridges & Structures Bureau (BSB) of their findings via email or BridgeWatch App for documentation in the BridgeWatch program and future refinement of flood forecasting and alert thresholds. The peak flood elevation should be measured referenced from the low beam or low roadway.

Once flood waters exceed the critical water surface of a scour susceptible bridge, the monitoring procedures in the Bridge Monitoring Plan should be followed [see Bridge Monitoring Plan – Standard Provisions (Appendix A)]. Coordination with the BSB should be initiated during the flood event to assess the uncertainty in flood forecasting, provide validation of field conditions and to coordinate decision-making actions.

When monitoring a site, particular attention should be made to the following conditions:

- Change in vertical or horizontal alignment of handrail or structural members such as beams or barrier rail.
- Shifting of channel or erosion of stream banks.
- Berm slope erosion, sagging or cracks.
- Cracks or signs of distress in the approach pavement or road embankment.
- Movement or cracking of bridge deck.
- Debris accumulation.
- Bridge beam inundation.

Once the flood waters recede, an inspection by the Bridge Inspection Team may be warranted to verify the integrity of the bridge foundations and countermeasures.

3.2.1.2 Roadway Overtopping and Low Beam Inundations

The roadway overtopping and low beam elevation information resides in the RIDB. The RIDB utilizes the Flood Center's Hydrologic Link Model (HLM) to assess when a low road or beam elevation will be impacted by potential flooding. When a projected flood discharge from the HLM predicts a flood elevation within a foot of overtopping a roadway or inundation of the bridge beam, a threshold attribute is created for that site. When a threshold attribute is created, the BridgeWatch program will use that information to send a text alert notification to the District.

Once a site is monitored for overtopping or beam inundation, the District shall coordinate with the BSB to provide current water surface information relative to the low roadway and/or bridge beam elevations. Vertical measurements of the water surface elevation relative to the edge of shoulder or low beam should be made and conveyed to the BSB. BSB will use this information to assess the timing of potential impacts to the infrastructure based on the stream projections from the HLM or NWS. Monitoring intervals will be based on the rate of rise of flood waters and the current threat to infrastructure. Smaller streams may require continuous monitoring.

Once a bridge or roadway is closed to traffic, documentation of the peak flood event should include photos as well as marking the peak flood elevation on the bridge or roadway pavement to survey for future reference. This information is important for adjusting the site's rating curve and thresholds to improve future forecasting of flood events. A roadway overtopping form should be filled out to provide feedback on the alert notification and document the peak

overtopping elevation and impacts associated with the flood [Roadway Overtopping Form (Appendix C)]. This information will be stored in the BridgeWatch program for future reference.

Closing a bridge or roadway due to flooding should be a collaborative decision by the District and Central Office. Information will be sent to the Traffic Management Center (TMC) to coordinate traffic detours and signage for traffic management.

3.2.2 Bridge & Structures Bureau

The Bridge & Structures Bureau provides support to the Districts regarding flood forecasting information, post-flood data collection protocols and improved monitoring and response thresholds for future flood events. The BSB will be the gatekeeper for data management of the RIDB and BridgeWatch program and will document all alert and ticket notifications.

3.2.2.1 Inspection of Scour Susceptible Bridges

The Bridge Maintenance and Inspection Section of BSB will be notified by the District if the scour critical elevation is exceeded for a scour susceptible bridge. Inspection of a bridge should be performed after the peak discharge has occurred. Use sonar along the upstream face of the bridge to determine if the streambed has been lowered significantly as compared to the latest channel cross section documented in SIIMS.

Measurements should be taken at all piers and abutment locations, the middle of each span and the toe of abutment slopes. The Bridge Specific Provisions includes information on the critical streambed elevations for comparison with the channel cross section.

A scour inspection checklist [Scour Report Form (Appendix B)] will be completed by BSB Bridge Inspection Team to assess the conditions of the scour countermeasures, streambanks, approach roadway and bridge berms. Any irregularities found during the inspection will be reported to the appropriate personnel for review and possible remedial action.

3.2.2.2 Roadway Overtopping and Low Beam Inundations

If a structure has experienced pressure flow (beam inundation) or significant debris accumulation during a flood event, the Bridge Inspection Team should use sonar measurements of the streambed to assess any significant scour as described for monitoring scour susceptible bridges. Even though a bridge may not be designated as scour susceptible, erosion/scour can occur and jeopardize the approach roadway, bridge berms or other aspects of the bridge foundations. It is especially important to inspect a bridge when it has experienced a significant flood event.

3.2.3 Traffic Management Center

The Traffic Management Center (TMC) provides real-time 24/7 traffic management for Iowa's primary roadway system. During major flood events, the TMC provides emergency management for a systematic, coordinated approach to managing emergencies. An effective emergency response requires collaboration and coordination within the Iowa DOT, emergency

responders and other key agencies. The TMC will receive notifications from BridgeWatch when a threshold has been exceeded for a bridge or roadway based on forecasted flood waters. This will allow early warning to the TMC and provide awareness in case of closure of a highway or bridge. The TMC will assist Districts with determining detours and signage when a bridge is closed or water overtops a highway due to flooding.

3.3 SUMMARY

The Iowa DOT has a real-time flood forecasting system that will monitor flooding impacts to its infrastructure 24/7. The RIDB correlates hydrologic data sources (NEXRAD rainfall, USGS gages, IFC HLM, NWM) with hydraulic data (rating curves) of vulnerable assets (bridges and roadways). The BridgeWatch program provides actionable alert notifications to District and key personnel of the potential flooding of scour susceptible bridge and highway overtopping due to floods. The forecasting system will monitor approximately 1500 sites along streams draining more than 10 square miles in Iowa.

The Iowa DOT will collaborate and coordinate with emergency responders and other key agencies so that a proactive response to flooding and allocation of resources can be accomplished efficiently and effectively to enhance public safety.

3.4 APPENDICES

A. Bridge Monitoring Plan – Standard Provisions
B. Scour Report Form
C. Roadway Overtopping Form

Bridge Monitoring Plan - Standard Provisions

1. Description

This document outlines procedures to be followed to manage scour at bridges that have been found to be scour susceptible or scour critical. These standard provisions outline procedures and provisions applicable to all bridges within a given classification. Procedures and provisions for specific bridges are contained in the Bridge Monitoring Plan - Specific Provisions.

General information regarding scour and bridge monitoring is contained in "Bridge Scour Monitoring Plan for Local Roads and Streets", August 1997 and "Evaluating Scour At Bridges", FHWA HEC-18, April, 2013. The procedures provided herein generally follow the guidelines in these documents.

Bridges have been found to be scour susceptible or scour critical as a result of a scour assessment, analysis, or have unknown foundation conditions where the scour risk cannot be assessed. The Specifications for the National Bridge Inventory (SNBI) identifies a bridge's vulnerability to scour under Item B.AP.03. Listed below are Item B.AP.03 codes which generally describe the vulnerability of a bridge to scour due to flood events:

Code	Description
0	Scour appraisal has not been completed.
A	Scour appraisal completed. Bridge determined to be stable for scour.
B	Scour appraisal completed. Bridge determined to be stable for scour, dependent upon designed and functioning countermeasures.
C	Scour appraisal completed. Bridge could become unstable for scour. Temporary (not designed) countermeasure installed to mitigate scour. Bridge is scour critical.
D	Scour appraisal completed. Bridge is, or may become, unstable for scour. Bridge is scour critical.
E	Scour appraisal has not been completed. Temporary (not designed) countermeasure installed to mitigate scour.
U	Scour appraisal has not been completed due to unknown foundations.

Bridges coded as B under the SNBI Scour Vulnerability that are classified as having a Permanent Countermeasure should remain viable through several major flood events in limiting scour/erosion. Monitoring during flood events is NOT required as long as the countermeasure is substantially intact. An inspection of the countermeasures should be considered when the critical water surface elevation is exceeded or roadway overtopping flood events.

Bridges coded as C or D under the SNBI Scour Vulnerability that are classified as having an Armored Countermeasure should remain viable during a single major flood event in limiting scour/erosion. Monitoring during flood events IS required.

Specific bridges that require monitoring or during flood events are listed on the W: Drive (W:\Highway\Bridge\PrelimSection\Scour\Scour_Management_Plan_Work\Bridge Monitoring Plan_SpecificProvisions\Active) and within the BridgeWatch program.

Other documents regarding scour monitoring define 'monitoring' as measuring of the river bed during flood events. For the purposes of this document, monitoring refers to the entire process of managing scour susceptible or scour critical bridges during and immediately after flood events. This includes tracking the development of flood conditions, observing bridge conditions during floods, making measurements of scour and waterways, implementing and removing road closures, and preparation and maintenance of records.

2. Classification

As noted in Section 1. this document outlines procedures to be followed for bridges that are scour susceptible, scour critical or have unknown foundation conditions where risk cannot be assessed. These bridges are grouped into the following classifications:

CRIT - Critical

Scour depth and/or bank erosion resulting in failure of the bridge could occur during a single flood event. The Iowa DOT has decided that in lieu of measuring scour depths during floods,

or the installation of countermeasures, the bridges will simply be closed during floods which exceed the critical water surface elevation. These bridges are generally on low volume routes where countermeasures were determined to not be cost effective. *Monitoring during flood events is required.*

ARM - Armored (Countermeasure)

Countermeasures have been installed to limit scour depth and/or bank erosion. These countermeasures should remain viable during a single major flood event in limiting scour/erosion. *Monitoring during flood events is required.*

PERM - Permanent (Countermeasure)

Similar to the Armored classification above, except that the installed countermeasures should remain viable through several major flood events in limiting scour/erosion. *Monitoring during flood event is NOT required as long as the countermeasure is substantially intact. Verification of the peak flood elevation is required to determine if the critical water surface elevation is exceeded.* An inspection of the countermeasures should be considered when the critical water surface elevation is exceeded, low beam is inundated or roadway overtopping flood events.

OTH - Other

Bridges that cannot be placed in one of the three classifications above are placed in this classification. Refer to the Bridge Specific Provisions for the monitoring procedures and provisions to be used. *Monitoring during flood events is required.*

Similar scour monitoring procedures and provisions are used for all bridges within a given classification. Monitoring provisions unique to each bridge are provided in the Bridge Specific Provisions.

3. Monitoring Schedule and Responsibilities

3.1 Functional Groups

Functional groups which will be involved in the monitoring process during a flood event are defined as follows:

District:

Local maintenance personnel, District Maintenance Manager and District public information personnel. This group will generally be involved in the process of monitoring the development of flooding conditions, implementing bridge closure plans, general monitoring of bridge condition during floods, and advising Bridge Inspection personnel of bridge closures.

Bridge Inspection:

The six bridge inspection teams (Ames, Manchester, Jefferson, Fairfield, Atlantic, and Cherokee) and supporting staff in the Bridge Maintenance and Inspection Unit of the Office of Bridges and Structures. This group will generally be involved in detailed bridge monitoring during and following a flood event, documenting/providing findings, and maintaining records.

Management:

Bridge Maintenance Engineer, Bridge Engineer, and the District Engineer or their representative. This group will generally be involved in the process of reopening of closed bridges.

3.2 Initiation Of Monitoring For Critical Water Surface Elevation

The Bridge Specific Provisions contain the critical water surface elevation at which detailed monitoring procedures and/or bridge closures per Section 3.3 shall be initiated. This elevation is measured on the upstream side of the bridge unless noted otherwise in the Bridge Specific Provisions. The frequency (return period) of the elevation is dependent on the bridge characteristics, but generally reflects the 25 yr. (4% chance/year) event.

District personnel shall initiate monitoring upon notification via text message from the BridgeWatch program. The District is notified that the Critical Water Surface may have been exceeded by the BridgeWatch system which monitors rainfall and/or streamflow data.

Upon notification by BridgeWatch, site visits to observe water levels should be initiated. Site visits should continue at an appropriate interval until the storm event is over and the stream is

receding. Since sites with a Permanent classification do not require monitoring, a site visit the next day to evaluate if the Critical Water Surface Elevation was exceeded should be adequate.

Unusual conditions, such as excessive buildup of debris and ice, will require special consideration. Contact Bridge Inspection to determine if detailed monitoring should be initiated regardless of the water surface elevation.

3.3 Initiation Of Detailed Monitoring

Once the monitoring performed under Section 3.2 indicates that the critical water surface elevation has been reached, road closures (or detailed monitoring if appropriate) shall be commenced as follows.

3.3.1 Critical (CRIT) Bridge Classification

The bridge shall be closed. Implement the closure plan per Section 5. The following actions shall be taken following closure:

3.3.1.1 Monitoring During Closure

A) The District shall contact Bridge Inspection to notify them of the closure and to schedule the inspection addressed in Section 3.3.1.1 (c) below prior to reopening the bridge.

B) The District shall observe/monitor the condition of the bridge during the flood event. This monitoring should continue until the water surface has receded below the critical water surface. See Section 4.3. If the monitoring indicates a possible problem, contact Bridge Inspection to arrange for assistance in further monitoring.

C) After the water surface elevation has receded below the critical water surface elevation Bridge Inspection shall perform the following:

1) Measurement of the stream bed to estimate scour depths per Section 4.5.

2) A visual inspection of the bridge site with emphasis on the items listed in Section 4.3.2.

3.3.1.2 Reopening Procedures

Upon completion of the monitoring under Section 3.3.1.1 above, Bridge Inspection shall provide findings to Management so that a decision can be made whether or not to reopen the bridge. See Section 5, Bridge Closure.

3.3.1.3 Follow-Up Monitoring

After the bridge is re-opened and water has receded into the normal channel take the following actions.

A) Bridge Inspection shall inspect the bridge and measure the stream bed. See Section 4.6.

B) Bridge Inspection will inform District Management of findings.

3.3.2 Armored (ARM) Bridge Classification

The bridge will remain open unless monitoring indicates a problem. The following monitoring shall be initiated.

3.3.2.1 Monitoring During Flood Event

A) The District shall contact Bridge Inspection to notify them of the flood event and to schedule for monitoring following the flood event.

B) The District shall observe/monitor the condition of the bridge during the flood event. This monitoring should continue until the water surface has receded below the critical water surface. See Section 4.3.

C) If the monitoring performed under Paragraph B) above indicates a possible problem, the bridge should be closed. Perform bridge monitoring and closure per Section 3.3.1, Critical Bridge Classification, as appropriate. Contact

Bridge Inspection to arrange for detailed inspection after the water has receded.

3.3.2.2 Follow-Up Monitoring

If no problems were noted during the flood event, take the following actions following the flood event.

A) Bridge Inspection shall inspect the bridge and measure the stream bed as soon as practical. See Section 4.6.

B) Bridge Inspection shall inspect the scour countermeasures. See Section 4.6.3.

C) Bridge Inspection will inform District Management of findings.

3.3.3 Permanent (PERM) Bridge Classification

The bridge will remain open.

3.3.3.1 Monitoring During Flood Event

Monitoring during flood events is not required as long as the countermeasure is substantially intact. The District should contact Bridge Inspection to notify them of any significant (>25 yr.) or roadway overtopping flood events. The critical water surface elevation provided in the Bridge Specific Provisions may be used as an indicator of a significant flood event.

3.3.3.2 Follow-Up Monitoring

Monitoring following flood events is not required as long as the countermeasure is substantially intact. Bridge Inspection should consider an inspection of the installed countermeasures within three weeks following significant or overtopping flood events. See Section 4.6.3 and 4.6.4. If problems with the countermeasure are found, contact Management to initiate reclassification of the bridge and remedial action.

3.3.4 Other (OTH) Bridge Classification

Refer to the Bridge Specific Provisions for the monitoring requirements.

4. Monitoring Procedures

This section addresses detailed monitoring procedures required per Section 3.3, Initiation Of Detailed Monitoring.

If any problems are suspected or identified that may threaten the structural integrity of the bridge, the District should close the bridge per Section 5, Closure.

4.1 Safety

Extreme care should be used while monitoring bridges during flood stages. A minimum of a two-person crew is recommended for all work beyond monitoring for the critical water surface elevation. If there is ever a question regarding the safety of the bridge or the crew, the bridge should be closed until the flood recedes and the bridge can be inspected.

4.2 Critical Water Surface Elevation

The critical water surface elevation from the Bridge Specific Provisions shall be marked at the bridge site pre-flood to allow rapid visual check of the water surface in relation to the critical elevation. This elevation is measured on the upstream side of the bridge. It is recommended that this mark be made on one of the substructure units at a location easily seen.

4.3 Observation Of Bridge Condition During Flood Event

The intent is to visually observe the bridge and surrounding site for signs of distress or developing problems during an ongoing flood event.

4.3.1 Monitoring Interval

The monitoring interval will be determined at the discretion of the monitoring personnel for specific flood events based on monitoring results and site specific data, such as bridge size, drainage area, and scour history. Refer to the Bridge Specific Provisions for any site specific requirements. Recommended monitoring intervals are as follows.

Closed Bridges:
It is suggested that the bridge site be monitored at least once a day.

Open Bridges:
For lower volume roads, it is suggested that the bridge site be monitored at least twice a day. For higher volume roads and Interstate, it is suggested that the bridge site be monitored at least four times a day. District should coordinate with Preliminary Bridge Engineer to assess when the peak flood elevation will occur.

Particular attention should be given to those situations where the water level is near the bottom of the superstructure or overtopping of the road. In these instances, consideration should be given to increasing the monitoring frequency. For these bridges and roadways, around-the-clock monitoring should be considered.

4.3.2 Monitoring Procedures

Refer to the Bridge Specific Provisions for any site specific areas of emphasis. Particular attention should be paid to the following issues which indicate problems:

- Change in vertical or horizontal alignment of handrail or structural members such as beams.
- Shifting of channel alignment or erosion of stream banks.
- Berm slope distress such as erosion, sagging, cracks or cupping. If stream flow is adjacent to abutment berm consider the following:

  Sounding and probing for voids at abutments.

  Sound approach for hollow indications.

  Inspect for voids adjacent to wing walls.
- Cracks in the soil of the banks.
- Misalignment of bridge bearings.
- Cracking or other signs of distress in approach pavement or roadway.
- Movement or cracking of bridge deck.
- Debris (and ice) buildup.

  Debris buildup on scour critical bridges should be considered a serious problem. This includes bridges that are classified as Armored per Section 2. The debris can cause unpredictable scour patterns that could result in rapid failure of the bridge foundation. Bridge Inspection should be contacted immediately to coordinate detailed inspection. The District will decide whether or not to remove debris during the flood.

4.3.3 Reporting

Document and pass along to Bridge Inspection any significant observations for inclusion in the bridge documentation file for individual bridges.

4.4 Reserved

4.5 Measurement Of Stream Bed During Flood Event

The maximum scour depth in moderate to rapidly erodeable bed materials will occur at or directly following the flood peak. For less erodeable bed materials the maximum scour may

occur some time after the flood peak. Following the flood peak, infilling of the scour hole with sediment may occur.

For bridges with a Critical classification the intent is to measure the stream bed elevation near the abutments, piers and on the berm prior to reopening the bridge. **These measurements on critical bridges will generally be made after the water surface has dropped below the critical elevation.**

For bridges with an Other classification, the Bridge Specific Provisions may require that measurements be taken directly following the flood peak in order to estimate the maximum scour that occurred. In this case, measurements should be taken as soon after the flood peak as practicable to obtain measurements before infilling of the scour hole begins.

The following procedures also apply to measuring and recording the streambed elevation following the flood per Section 4.6.2.

4.5.1 Measurement Equipment

Sonar equipment is recommended for measuring the stream bed during the flood. Sounding weights and/or poles may be practical after the flood has receded. Each bridge inspection team has a sonar unit.

4.5.2 Measurement Procedure

Measure for scour from the upstream face of the bridge. Measurements taken along the bridge fascia (railing) may not be located at the site of maximum scour (which is usually close to the pier or abutment), but should be accurate enough to indicate if problems exist.

Take measurements of the streambed at all piers, at abutment locations, and at the toe of abutment slopes to determine if the channel bottom elevation is changing at these locations. Ensure that the measurements at piers are taken beyond the limits of the pier footings.

Typically the maximum scour is expected to occur near the front face of the pier. If floodwater is attacking the pier at a skew angle, the deepest scour is expected on the front or side that the flow impacts. Maximum abutment scour typically occurs at the upstream toe of the abutment slope or the upstream corner of a vertical abutment. Bridges with abutment slopes should be monitored both at the toe of the slope and next to the abutment. If the abutment foundation is undermined, the approach fill may be endangered. Adverse flood flow alignment with the substructure units may result in points of turbulence. These locations should also be considered for measurement.

Compare the measured bed elevation to the critical bed elevation provided in the Bridge Specific Provisions. If the measured bed elevation is lower than the critical bed elevation, the foundation should be considered unstable thereby placing the structural integrity of the bridge in question. The bridge should therefore be closed if it is open per Section 5, Bridge Closure. Analysis and possible remedial action will be required before the foundation can be considered stable.

4.5.3 Reporting

Document inspection findings in the bridge documentation file for individual bridges.

4.6 Inspection Of Bridge/Measurement Of Stream Bed Following Flood Event

The intent is to conduct an inspection following the flood with particular emphasis on waterway features. This inspection will be conducted after the water has receded into the normal channel.

4.6.1 General Inspection Procedures

Following the flood event Bridge Inspection should conduct an inspection of the bridge and bridge site with particular emphasis on waterway features. Particular emphasis should be placed on those issues noted in Section 4.3.2.

4.6.2 Measurement Of Stream Bed

Measure and record the stream bed similar to Section 4.5. Measure or survey stream banks as required to update any attachments to the Bridge Specific Provisions. Refer to the Bridge Specific Provisions for the critical bed elevation and other site specific criteria that indicates attention is required.

4.6.3 Countermeasure Inspection for Armored and Permanent Bridge Classifications

Refer to the Bridge Specific Provisions for specific countermeasures installed at the bridge site. The inspection should verify that the countermeasures are substantially intact and appear to still be functional.

The Bridge Specific Provisions will include design plan sheets and/or inventory drawings of countermeasures that were installed. For countermeasures under water, compare the measured bed elevation to the countermeasure failure elevation provided in the Bridge Specific Provisions. If the measured bed elevation is lower than the countermeasure failure elevation, the countermeasure has most likely failed and is no longer functional.

If the countermeasures are damaged or otherwise made ineffective, scour or bank erosion resulting in failure of the bridge could be developed during a future single storm event. The bridge may have to be treated as a Critical (CRIT) classification until the countermeasures are repaired.

4.6.4 Reporting

Document inspection findings in the bridge documentation file for individual bridges as required. Complete a copy of the Scour Report form (Appendix B) for the bridge.

5. Bridge Closure

The Management functional group, as defined by Section 3.1, should be consulted prior to closing any bridges not having a Critical classification. The intent of this process is to solicit further expertise prior to taking the disruptive step of closing a State highway. This group should also be consulted prior to reopening a bridge classified as Critical after the flood has receded.

However, if monitoring indicates an immediate threat to the structural integrity of the bridge or approach roadway the bridge should be closed immediately. Examples of these circumstances are visible settlement of the bridge, undermining of abutments or approach slabs, or massive failure of the berm slopes.

The Management group shall also be consulted prior to reopening any bridge. Following completion of detailed monitoring, the bridge inspection team shall contact Management to brief them on the bridge condition.

The District shall prepare and maintain a closure and detour plan for all bridges with a Critical (CRIT) classification. A detour and closure plan may also be required for some Other (OTH) classification bridges. Refer to the Bridge Specific Provisions.

It is recommended that the District also prepare a contingency closure and detour plan for bridges with a Armored (ARM) classification in the event closure is required.

6. Inspection

During regular biennial inspections installed countermeasures for bridges classified as Armored or Permanent shall be inspected. Refer to the Bridge Specific Provisions for specific countermeasures installed at the bridge site. The Bridge Specific Provisions will include design plan sheets and/or inventory drawings of countermeasures that were installed.

The inspection should verify that the countermeasures are substantially intact and appear to still be functional. If the countermeasures are damaged or otherwise made ineffective, scour or bank erosion resulting in failure of the bridge could be developed during a future single storm event. Contact Management to initiate reclassification of the bridge and remedial action. Timely contact of Management is required since the bridge may have to be treated as a Critical (CRIT) classification until the countermeasures are repaired.

Note the condition of the countermeasures on the appropriate code sheets.

7. Records

Upon completion of post-flood monitoring or biennial inspections, Bridge Inspection will update the bridge documentation file to include the scour report form and table of bridge deck elevations if inspection results were noted on these records.

Bridge Management or their designated representative will review the bridge documentation file following inspections to determine if any remedial action or changes to the bridge specific provisions are required.

A copy of the current Bridge Monitoring Plan – Standard Provisions with all appendices/attachments in .pdf format will be maintained at the following network address:

W:\Highway\Bridge\PrelimSection\Scour\Flood Preparedness and Response Manual

Notice of any modifications to the plan that will effect monitoring procedures or bridge classification will be sent to all appropriate functional groups by e-mail.

8. Appendices

B. Scour Report Form

Revisions:

11/15/00 - Initial Document

03/19/01 - Revision (Timing of reopening inspection, stream bed measurements)

08/20/01 - Revision (Editorial Changes)

08/12/04 - Major Revision (Added Permanent Classification)

04/28/05 – Sect. 3.2, crit. water surface meas. location per Bridge Specific Provisions

04/19/10 – Remove contact listing, remove Sect. 4.4 deck measurements, revise Sect. 3.2 to reflect EOC/bridge watch, Sect. 3.3.2.2 and Sect. 3.3.3.2 note approx. time frame for inspection.

09/17/25 - Revised NBI scour codes to SNBI Scour Vulnerability. Revised reference to Appendix B. Eliminated references to Appendix C & D.

INSPECTION CHECKLIST FOR BRIDGES

Bridge No. _____ Area No. _____ FHWA No. _____

a _____' X _____' _____

carrying _____ over _____

located in _____

and/or ____.____ mi. _____ of _____

Scour Inspection by Team No. _____ Date inspected: _____

Date Received in Office: _____

To Bridges & Structures: _____

Returned from Br & Str: _____

This report contains:
Comments ____ Yes ____ No
Sketches ____ Yes ____ No
Photos ____ Yes ____ No

A follow-up inspection/site visit was made on: _____

Item No.	Yes, No, or *(Not visible)	Description
1.	____	Is there a significant build-up of debris?
2.	____	Is there a change in the horizontal alignment of the handrail or structure members such as beams?
3.	____	Is there any indication of vertical movement of the superstructure?
4.	____	Is there shifting of the channel alignment or erosion of the stream banks? Also, are there cracks in the soil of the banks parallel to the stream?
5.	____	Is there a significant change in the alignment of the exterior bearings?
6.	____	Are there cracks or other signs of distress in the approach pavement?
7.	____	Is the water currently on the superstructure?
8.	____	Are the berm slopes steeper than **2:1** from the toe of the scour to the roadway?
9.	____	Do scour measurements indicate: (Place an "**X**" by all that apply.)

_____A. that the streambed is two or more feet below the bottom of pier footings which are supported on piles?
_____B. scour below the bottom of spread footings?
_____C. scour below the bottom of high abutment footings?
_____D. that the streambed has scoured five feet or more below the original streambed elevation at pier bents?

INSPECTION CHECKLIST FOR BRIDGES

(Continued)

Bridge No. _____

The following item applies to bridges listed in Appendix B of the Scour Monitoring Plan (Refer to Code Sheet 2, Waterway,Scour Classification Type).

SIA#113 ____ Scour Classification _____

If Armored or Permanent classification, refer to the Bridge Specific Provisions, Appendix B, for specific countermeasures installed at the bridge site. The inspection should verify that the countermeasures are substantially intact and appear to still be functional.

10. ____ Have the countermeasures been damaged or otherwise made ineffective?

Notes:

Streambed sounding data is to be documented.

A streambed profile should be done on the upstream side of all bridges. If Item #9 is yes, then a profile on the downstream side of the bridge should also be done in the scoured area. If the downstream profile also indicates a problem, then soundings should be made under the bridge if possible.

If "No" is the answer to all of the items in the checklist, no further action will be necessary.

If "Yes" is the answer to any items on the checklist, contact the Office for further instructions.

An "*" indicates the item is not visible.

Comments:_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Completed on _____ By _____

SCOUR REVIEW by the OFFICE of BRIDGES and STRUCTURES

Bridge No. _____ FHWA No. _____
Reviewed by _____ Date reviewed _____
Is a follow-up inspection recommended? _____ Yes _____ No

Comments/Recommendations:_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

ESTIMATED REPAIR COSTS

1. Removal of debris: ……$_____
2. Riprap berms &/or banks: ……$_____
3. Reshape berms &/or banks: ……$_____
4. Footing/pier protection: ……$_____
5. Channel protection/retards/jetties: ……..$_____
6. Other: ……..……$_____

Total estimated cost: ……..…..$_____

Total final cost: ……..….$_____

Roadway Overtopping Form

Bridge

Inspector

Date Created

Garage Supervisor Evaluation Form for Highway Overtopping Sites

County

Route

Milepost

Date and Time of Overtopping

Peak Water Surface Elevation/Depth

Was the alert provided in a timely fashion?

Remarks:

Was road overtopped when you inspected?

Remarks:

What elevation or vertical depth to the low roadway was the peak water surface elevation?

Provide picture(s)

Were resources deployed? If yes please complete further questions below

Remarks:

Number of employees

Signs needed

Detour Route designated

Other

Was the alert useful and accurate? (Alerts based on a peak discharge one foot below low road)

Remarks:

Do you feel BridgeWatch Alert provided a benefit by saving time that would otherwise be dedicated to monitoring?

Remarks:

Do you feel that the alerts enhanced public safety?

Remarks:

Do you recommend any changes to the alerts? (e.g., earlier to provide time to investigate?)

Remarks: