NCHRP 20-68A
“US Domestic Scan Program”

Domestic Scan 15-02
Bridge Scour Risk Management

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Michigan DOT
Domestic Scan 15-02
“Bridge Scour Risk Management”

- This scan was conducted as a part of NCHRP Project 20-68A, the U.S. Domestic Scan program

- The program was requested by the American Association of State Highway and Transportation Officials (AASHTO), with funding provided through the National Cooperative Highway Research Program (NCHRP)
NCHRP 20-68A
U. S. Domestic Scan Program

- The Program is a multi year project conducting 3-4 scans per year.
- Each scan is selected by AASHTO and the NCHRP 20-68A Project Panel.
- Each scan addresses a single technical topic of broad interest to many state departments of transportation and other agencies.
- The purpose of each scan and of Project 20-68A as a whole is to accelerate beneficial innovation by:
  - facilitating information sharing and technology exchange among the states and other transportation agencies;
  - identifying actionable items of common interest.
Scan Team

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Scan 15-02 Team Members Home State and Invited Agency States

- **Team Member Home State**
- **Host Agency State**
“This scan will examine practices of states, counties, metropolitan areas, municipalities and other transportation agencies, to identify and document successful approaches to reducing bridge flooding and scour risk through appropriate use of countermeasures. The scan will also consider how innovative bridge owners assess structural vulnerability or bridge scour susceptibility.”
NCHRP Panel’s General Guidance to the Scan Team (cont.)

“The scan team would examine innovative approaches such as

- **Risk-based** decision analysis for
  - selection and installation of countermeasures
  - selection, installation, and management of monitoring systems
  - bridge replacement rather than use of countermeasures or monitoring systems

- **Inspection** procedures for scour countermeasures

- **Alert systems** to trigger inspections during flood events

- **Road-closing** and -reopening decision process

- Bridge inspection and documentation procedures during and after a flood event, including updating bridge inspection reports and the agencies’ **Scour Plan of Action**.”
“The scan team will focus on practices for inspection, monitoring, countermeasure selection and placement, and risk management for scour-critical and scour-susceptible bridges individually and in networks of varying sizes.”
“By documenting and sharing successful practices the scan team will produce a valuable resource for use by bridge owners, state and local bridge inspectors, bridge designers and bridge management staff in reducing the risk to the travelling public due to flooding and scour.”
Team’s Approach

- Perform Desk Scan and Literature review
- Identify Topics that are related to Scour Risk Management
- Produce Amplifying Questions/Survey for Participating States based on Identified Topics
- Compile Responses to Amplifying Questions
- Hold Workshop of Invited States
- Establish Findings and Recommendations
Responses to Selected Amplifying Questions

General Information about Agency (Continued)

- Is there a dedicated scour evaluation team?  
  - Yes: 64%  
  - No: 36%

- Is the evaluation team centralized or decentralized?  
  - Centralized: 56%  
  - Decentralized: 44%

- Is there a dedicated program with allocated funds to address scour issues such as countermeasures?  
  - Yes: 30%  
  - No: 70%

- Is the evaluation team multidisciplined?  
  - Yes: 4  
  - No: 6
Responses to Selected Amplifying Questions

**Topic 1: General Procedures and Risk Analysis**

- Does your agency follow FHWA’s guidelines for scour design for new bridges?  
  - Yes: 2, No: 9
- Does your agency follow FHWA’s guidelines for scour countermeasures?  
  - Yes: 3, No: 8
- Are you considering or adopting new changes in your scour assessment and mitigation process?  
  - Yes: 3, No: 8
- Are you considering adding Scour as a risk factor in your transportation asset management plan?  
  - Yes: 3, No: 6
- Do you consider using a vulnerability index?  
  - Yes: 4, No: 5
Responses to Selected Amplifying Questions

**Topic 2: Scour Modeling and Analysis**

- Does your agency use HEC-18 equations?
  - Yes: 3
  - No: 6

- Do you perform a detailed/refined Hydraulic analysis?
  - Yes: 2
  - No: 8

- Do you perform a cost-benefit analysis prior to performing structural modeling?
  - Yes: 4
  - No: 6

- Do you have a case study that would demonstrate the success of the detailed hydraulic and/or structural modeling and analysis?
  - Yes: 3
  - No: 5

- Do you use computer software for scour assessment and/or risk mitigation (e.g., SRH-2D, HEC-RAS, FB-Multiplier, etc.)?
  - Yes: 0
  - No: 11
Responses to Selected Amplifying Questions

- **Topic 3: Monitoring and Field Inspection of Scour Critical Bridges**

  - Has your state used sonar on a line rod in order to measure scour depths at some bridges on a daily basis?
    - Yes: 2
    - No: 5
    - Unknown: 4

  - Do you have state-specific criteria to reduce the frequency of field inspections for scour critical bridges?
    - Yes: 8
    - No: 2

  - Are you using a Network-wide web-based monitoring system for monitoring rainfall, flooding etc. and pro-active notification of personnel during flood events?
    - Yes: 5
    - No: 5

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**CMDOT**
Michigan Department of Transportation
BRIDGE DEVELOPMENT
Responses to Selected Amplifying Questions

**Topic 4: Design Installation and Sustainability of Countermeasures**

- Do you have state-specific guidelines for designing and installing countermeasures for scour?
  - Yes: 0, No: 10

- Do you have guidelines for selecting appropriate countermeasures?
  - Yes: 0, No: 10

- Does a criterion exist that prevents changing the 113 code after countermeasures are added?
  - Yes: 0, No: 9

- Are there any countermeasures or foundation types that your department will not use?
  - Yes: 4, No: 6

- Do you have agency-defined elements for your element level inspection for scour countermeasures?
  - Yes: 5, No: 4
Responses to Selected Amplifying Questions

**Topic 5: Plan of Action**

Do you have a statewide emergency response for inspection and monitoring of a large network of bridges under an extreme event? **Yes** 5  **No** 6

If structural or channel improvements or installations of countermeasures have been made, do you request a re-evaluation? **Yes** 2  **No** 7

Do you have emergency action protocols? **Yes** 2  **No** 7

[Graphs and charts showing responses to questions]
Team’s Approach (Continued)

- the Scan Team identified topics that are essential for the understanding of Scour Risk Management as follows:
  - General Procedures and Risk Analysis
  - Scour Modeling and Analysis
  - Monitoring and Field Inspection of Scour Critical Bridges
  - Design, Construction, and Sustainability of Countermeasures
  - Plan of Action (POA)
Findings:

- Most states used criticality and others used Probabilistic Approaches to help perform Risk Analysis.
- A number of States perform Vulnerability analysis and table scoring to help mitigate scour.
- Many states have strong Teams of Structural, Hydraulic, and Geotechnical Engineers.
- Definition of risk and minimizing Uncertainty using various methods.
State Practices: Louisiana DOTD

- Pile Testing-Dispersive Wave & Parallel Seismic

Figure 1

- Building
- Foundation
- Hydrophone in cased, water-filled boring
- Olson Instruments Freedom Data PC
State Practices: Texas DOT

- Unknown Foundation Determination for Scour
  - Inference Method
  - Geophysical Method

**INFEERENCE METHOD**

Figure 7-11. Ensemble Prediction for MLP-PL10 for Concrete Piling.

Figure 7-12. Ensemble Prediction for MLP-PL11 for Drilled Shafts.
State Practices: Texas DOT (Cont’d)

- Inference Method

Worked for bridges with concrete piling and drilled shafts, but did not work well for timber piling.
State Practices: Texas DOT (Cont’d)

- Geophysical Method

Figure 11-6. Bridge 14 ERI Fieldwork.

Resistivity Profiling
State Practices: Texas DOT (Cont’d)

- Geophysical Method

Polarization Imaging
State Practices: Florida DOT

Unknown Foundations Process

Data Gathering

- Collect Data
  - Bridge Inspection Reports
  - Scour Evaluation Reports
- Do the Plans contain a rating system?
  - Yes
    - Proceed to the next step
  - No
    - Collect additional data

Risk Assessment

- Perform Hydraulic Analysis
- Determine load effects
  - Impact
    - Yes
      - Complete the Scour Evaluation Process & recode Item 113
      - Proceed to the next step
    - No
      - Evaluate factors
        - Does the Bridge meet the Min. Performance
          - Yes
            - Recode the bridge & proceed to the next step
          - No
            - Complete the Phase 2 Scour Evaluation

Embedment Prediction

- Calculate the Annual and Lifetime Risks of Scour Failure
- Is the Bridge a High Risk Assessment Section?
  - Yes
    - Recode the bridge & proceed to the next step
  - No
    - Evaluate factors
      - Is the Lifetime Risk > $100,000?
        - Yes
          - Recode the bridge & proceed to the next step
        - No
          - Complete the Phase 2 Scour Evaluation

Phase 4 Scour Evaluation

- Is the bridge High Priority or does bridge not meet PFL?
  - Yes
    - Proceed to Step 6.4
  - No
    - Proceed to Step 6.5

- Perform the Phase 4 Scour Evaluation and assess reasonable countermeasures

- Is the bridge unstable?
  - Yes
    - Recode the bridge & proceed to the next step
  - No
    - Install countermeasures & prepare a POA

Phase 2 and 3 Scour Evaluations

- Use NDT results to complete the Scour Evaluation Process
- Complete the Phase 2 Scour Evaluation
- Complete the Phase 3 Scour Evaluation
- Prepare an Aid for the POA

*See Procedures Manual: Rectify Unknown Foundation Bridges for a description of these steps and procedures.
State Practices: New York State DOT

- Vulnerability Rating Procedure

Bridge Classification

Exposure
  - Traffic Volume
  - Funct. Class

Failure Type

Likelihood Score

Consequence Score

Vulnerability Rating
State Practices: Colorado DOT

- Scour Critical Bridge Program

**Data Collection**  **Scour Analysis**  **Recommendations**  **Final Report**
Topic 1: General Procedures and Risk Analysis

Conclusions:

- Scour Risk Management is a complex process and requires input and open communication from multiple disciplines.
- Due to limited resources, states need to prioritize risk assessment including advanced design, monitoring, and design of countermeasures.
- Prioritization appears to be based on criticality alone with limited consideration to vulnerability.
**Topic 1: General Procedures and Risk Analysis**

- **Recommendations:**
  - States need to form scour committees with interdisciplinary capabilities (i.e., Engineers from Geotechnical, Structural, and Hydraulics areas).
  - Scour is a nation-wide threat - AASHTO should create a multidisciplinary task force that would develop guidelines and specifications for scour mitigation design and to serve as a clearing house for new innovations.
  - Due to limited resources, States should consider using Risk Analysis to prioritize how to best apply their limited resources rather than using vulnerability analysis to identify scour critical bridges.

![Figure 1 – Six Steps for Conducting a Vulnerability Assessment](image-url)
Topic 2: Scour Modeling and Analysis

Findings:

- Better testing methods of soil and rock is needed. (i.e. Erosion test for site-specific type of soils, Rock Erosion/Texas Cohesive soil methods/Predictive Models)
- Use of 2D/3D hydraulic modeling to simulate stream flow
- Texas velocity chart for verifying modeling. Texas Data management for quality control/assurance. Data checks, such as in Texas case, can help provide quality control for scour predictions.
- Agencies are using Google earth to study historic stream migration patterns
- HEC-18 provides a scour methodology for cohesive soils but requires getting shear stress by testing.
State Practices: Florida DOT

- Local Scour Equations

- CLEAR-WATER SCOUR

\[
0.47 \leq \frac{V}{V_c} \leq 1
\]

\[
y_s = \frac{2.5 f_1 \left( \frac{y_0}{D^*} \right) f_2 \left( \frac{V}{V_c} \right) f_3 \left( \frac{D^*}{D_{50}} \right)}{D^*}
\]

where

\[
f_1 \left( \frac{y_0}{D^*} \right) = \tanh \left( \left( \frac{y_0}{D^*} \right)^{0.4} \right)
\]

\[
f_2 \left( \frac{V}{V_c} \right) = 1 - 1.75 \left[ \ln \left( \frac{V}{V_c} \right) \right]^2
\]

\[
f_3 \left( \frac{D^*}{D_{50}} \right) = \frac{D^*/D_{50}}{0.4(D^*/D_{50})^{1.2} + 10.6(D^*/D_{50})^{-0.13}}
\]

- LIVE-BED SCOUR

\[
y_s = \frac{f_1 \left( \frac{y_0}{D^*} \right)}{D^*} \left[ 2.2 \left( \frac{V - V_c}{V_{lp} - V_c} \right) + 2.5 f_3 \left( \frac{D^*}{D_{50}} \right) \left( \frac{V_{lp} - V}{V_{lp} - V_c} \right) \right]
\]

\[
1 \leq \frac{V}{V_c} \leq \frac{V_{lp}}{V_c}
\]

\[D_{50} = \text{median grain diameter}\]
State Practices: Florida DOT

- Rock Erosion Measurements with the Rotating Erosion Test Apparatus (RETA)
State Practices: Missouri DOT

- Streambank Stability/Lateral Migration

LiDAR Scan

Erosion Monitoring along the Coosa River below Logan Martin Dam near Vincent, Alabama, Using Terrestrial Light Detection and Ranging (T-LiDAR) Technology

Scientific Investigations Report 2003-5128

U.S. Department of the Interior
U.S. Geological Survey
State Practices: Caltrans

- Improved Scour Measurements
State Practices: Caltrans (Cont’d)

- Detailed Hydraulic Modeling

  - Pressure flow and Overflow Can be Modelled
  - Piers can be Simulated as holes in the mesh
  - Skew angles Can be better estimated
Conclusions:

- Advanced methods for modeling and material testing can be used to enhance scour predictions.
- Using external data sources can enhance the quality control of scour predictions.
Topic 2: Scour Modeling and Analysis

Recommendations:

- Materials testing for cohesive soils or rocks can be performed using new techniques such as those developed by Florida DOT or FHWA.

- States are recommended to use 2D/3D models that are shown to be very useful in advanced cases. There is a need to identify the conditions or parameters when the 2D models can be applied.

- Encourage States and other agencies, involved with 2D modeling, to participate in NHI courses and other training workshops.
Topic 3: Monitoring and Field Inspection of Scour Critical Bridges

Findings:
- Improved methods to predict scour depth (i.e., 2D modeling to include better parameters for the HEC18 equations).
- Improved and safer inspection methods (i.e., Sonar versus diving). Use of 3-D Sonar in lieu of Under Water Inspection (UWI).
- A number of states have had successful relationship with USGS through contracts and partnership.
- Smart Phone Point Cloud
State Practices: Tennessee DOT

- Bridgework™ Program
  - Internet based application
  - Implemented 2004
  - Customizable with TRIMS data
  - Monitors 24 / 7 / 365
  - Default thresholds
State Practices: Idaho DOT

- Idaho Stream Gauging Locations

<table>
<thead>
<tr>
<th>Explanation - Percentile classes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
</tr>
<tr>
<td>10-24</td>
</tr>
<tr>
<td>25-75</td>
</tr>
<tr>
<td>76-90</td>
</tr>
<tr>
<td>&gt;90</td>
</tr>
<tr>
<td>High</td>
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</tbody>
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![Map of Idaho showing stream gauging locations](image)

![Example of a stream gauging station](image)
State Practices: Idaho DOT

- SNOTEL Sites in Idaho
State Practices: Iowa DOT

Remote Hydrographic Surveying System

- ECHOSOUNDER & GPS
- RADIO CONTROL
- DATA TELEMETRY
- REAL TIME MAPS
State Practices: Mississippi DOT

- Bridge Scour Monitoring

Bridge Scour Monitoring

- 24" x 24" Fiberglass Gage House
- Antennae and Solar Panel
- Pile Bent 184R
- Aluminum I-beams clamped to piers using 3" x 3" aluminum angle and 5/8" stainless steel threaded rod
- Stream velocity meter
- Channel bottom transducer
- Approximate Katrina Surge 12.7 ft elev
State Practices: Mississippi DOT (Cont’d)

- Real time scour monitoring gage (15 min interval)

02480273 Pascagoula River at Interstate 10 at Crooked Bayou

Bridge Scour Monitoring
State Practices: Michigan DOT

- 3D BRIDGE app
State Practices: Idaho DOT

- Scour Monitoring Research

Tube driven into streambed with post pounder.
State Practices: Caltrans

- Flood Monitoring System for State Bridges
State Practices: Caltrans (Cont’d)

- Monitoring
State Practices: Caltrans (Cont’d)

- SMART Rocks

- Acoustic Stage Gage
State Practices: Caltrans (Cont’d)

- Tilt Sensor Instrumentation

Feather River Bridge #18-0009
STRUCTURAL HEALTH MONITORING

ABOUT THE PROJECT
Feather River Bridge
Feather River Documents
Structural Monitoring

LONG-TERM DATA
Past 24 Hours
Past 24 Hours
Past Week
Past Month
Past 90 Days
Full Project
Custom Date Range

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INFRASITCTURE TECHNOLOGY INSTITUTE
Michigan Department of Transportation
BRIDGE DEVELOPMENT

Hourly Data
past 72 hours - latest data taken Sat, Apr 30, 2011 17:00 PST

Feather River Stage

Per 2 Y Tilt

Master Temperature

Topic 3: Monitoring and Field Inspection of Scour Critical Bridges

Conclusions:

- Advanced technology such as sonar can be applied effectively to enhance data collection efficiency and inspector safety.
- External data sources, such as USGS generated data, are essential for the successful implementation and management of scour programs in the USA.

<table>
<thead>
<tr>
<th>CS TABLE 10 – SCOUR PROTECTION</th>
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<tbody>
<tr>
<td><strong>Defects</strong></td>
</tr>
<tr>
<td>Scour or Erosion</td>
</tr>
<tr>
<td>Material Defect (scaling, abrasion, spalling, corrosion, cracking, splitting and decay)</td>
</tr>
<tr>
<td>Damage (unraveling, displacement, separation, and sagging)</td>
</tr>
</tbody>
</table>
Recommendations:

- States should establish collaborative partnerships with USGS and other agencies to facilitate sustainable data collection for scour predictions.
- AASHTO and FHWA should establish partnerships with USGS and other agencies for innovative applications to advance the State-of-Art of flooding on highway infrastructure.
- States should work proactively with FHWA for use and acceptance of advanced technologies for underwater inspection (e.g., sonar) to improve data collection and divers’ safety.
- Continued and future research is needed to enhance the capabilities of various systems to measure real-time scour. Moreover, communication and dissemination of various research projects is needed to raise awareness of accomplishments.
Topic 4: Design, Construction, and Sustainability of Countermeasures

Findings - A number of States have had good experience with various countermeasure designs.
State Practices: Minnesota DOT

- **Countermeasure Techniques**

- (Matrix Riprap, partially grouted riprap)

- Geobags
State Practices: Missouri DOT

- Smart Rocks Scour Monitoring/Riprap Effectiveness

- Original Concepts
- 3 Monitoring Strategies

Figure 1.5 Scour Countermeasure Monitoring

Figure 4.43 Design and Prototype of Magnets and Passive Smart Rocks
Conclusions:

- States had varying levels of success in implementing the same countermeasures.
- The design and installation of countermeasures needs to be appropriate given all parameters.
- States had success in innovative techniques in applying countermeasures such as Articulated Mattresses, GeoBags, Caged Blocks, AJAX, rock riffle.
- Countermeasures have a shorter lifespan compared to the design and service life of the bridge.
Topic 4: Design, Construction, and Sustainability of Countermeasures

Recommendations:

- States are encouraged to share lessons learned based on their specific experience with countermeasure design and application (e.g., Ski, etc.)
- States should pay more attention to inspecting countermeasures during construction and routine inspections.
- Establishment of a body to help disseminate the information related to the performance of various types of countermeasures is needed.
Findings:

- Implementing inspection during significant flood events can be a strain on departmental resources.
Topic 5: Plan of Action (POA)

Conclusions:

- Only few states included information useful to the stakeholders of the POA rather than purely meeting the FHWA mandate.
- Some States are using innovative methods (e.g., BridgeWatch or ArcGIS Online) to implement POA’s
- It has been observed that during extremely large flood events, bridges that are not scour critical were also impacted.
Recommendations:

- It is recommended that States consider additional information (e.g., cross section, whether the bridges on the detour route are scour critical, etc.) to enhance their POA which could be useful to the stakeholders.

- States are recommended to develop emergency protocols for widespread flood events. (POA are bridge-specific)

- States should create risk-based prioritization for implementing POA during flood events, which could be based on specific trigger for specific bridges.
Next Steps

- Scan Team will develop a Scan Report:
  - Document “Findings” and “Conclusions”.
  - Include a Dissemination Plan.
  - Provide recommended next steps.
  - Invited states will review and approve their state’s info prior to finalizing and publishing.
Final Report and other material will be made available on the web at

www.domesticscan.org

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