NCHRP 20-68A
"US Domestic Scan Program"

Domestic Scan 15-02
Bridge Scour Risk Management

Rebecca Curtis
Bridge Management Engineer
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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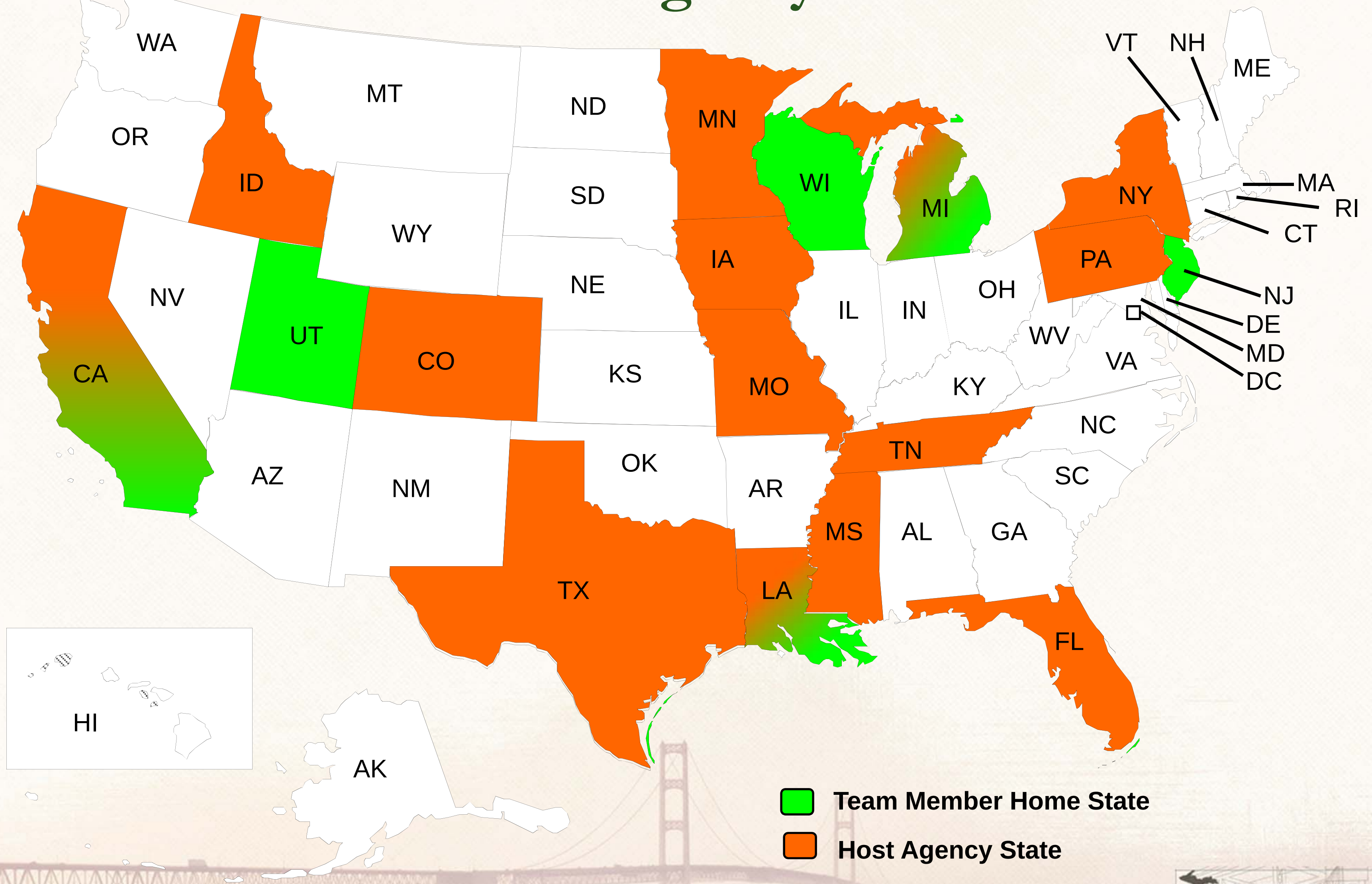
Scan 15-02 Team Members Home State and Invited Agency States



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NCHRP Panel's General Guidance to the Scan Team

"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**."*

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NCHRP Panel's General Guidance to the Scan Team (cont.)

"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. "*

NCHRP Panel's Anticipated Outcomes

"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."*

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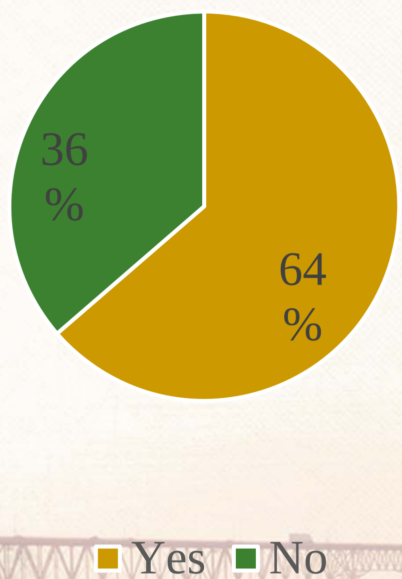
Team's Approach

- 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

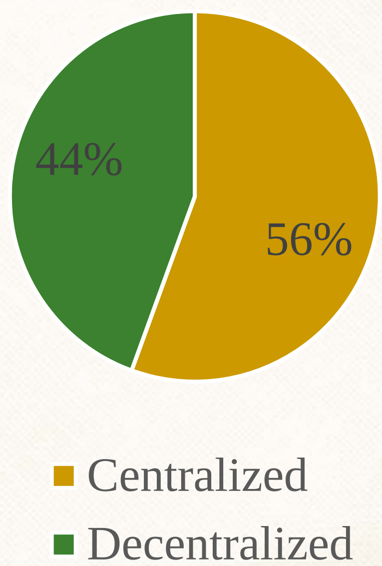
Responses to Selected Amplifying Questions

- General Information about Agency (Continued)

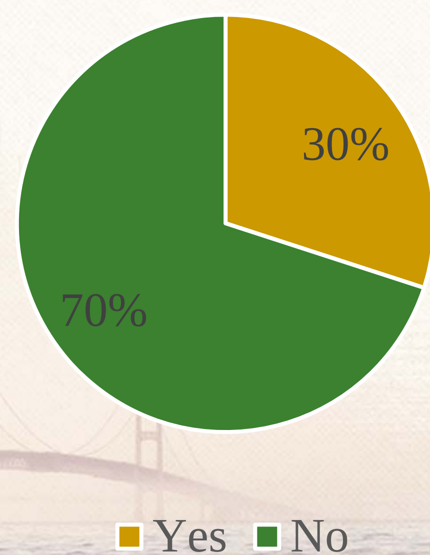
Is there a dedicated scour evaluation team?



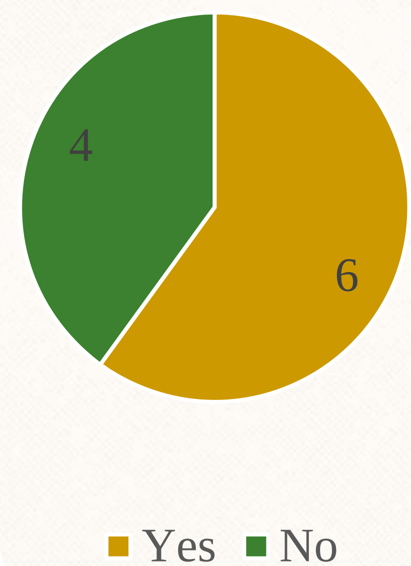
Is the evaluation team centralized or decentralized?



Is there a dedicated program with allocated funds to address scour issues such as countermeasures



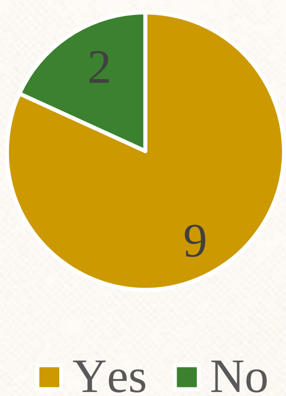
Is the evaluation team multidisciplined?



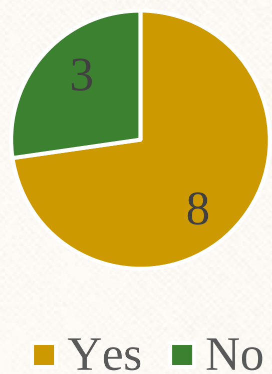
Responses to Selected Amplifying Questions

- Topic 1: General Procedures and Risk Analysis

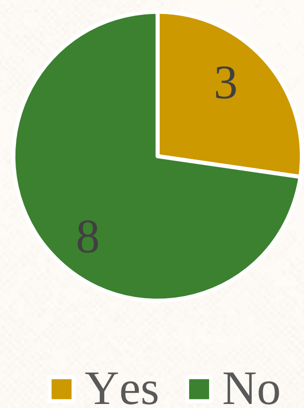
Does your agency follow FHWA's guidelines for scour design for new bridges?



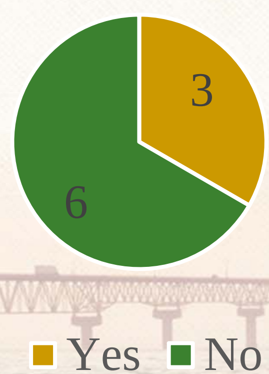
Does your agency follow FHWA's guidelines for scour countermeasures?



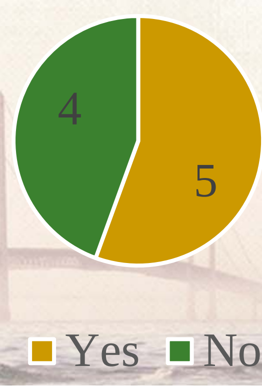
Are you considering or adopting new changes in your scour assessment and mitigation process?



Do you consider using a vulnerability index?



Are you considering adding Scour as a risk factor in your transportation asset management plan?



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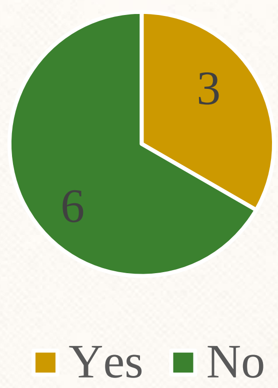
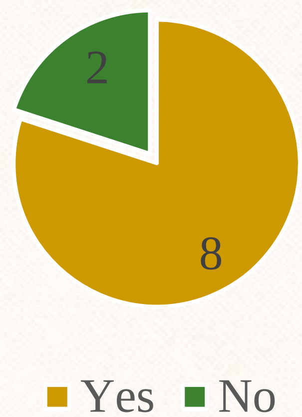
Responses to Selected Amplifying Questions

- Topic 2: Scour Modeling and Analysis

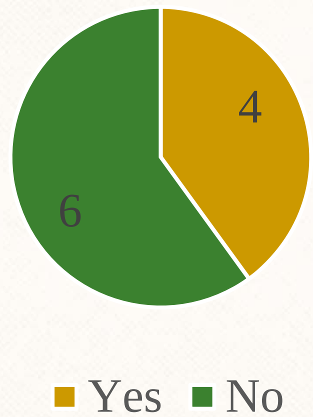
Does your agency use HEC-18 equations?



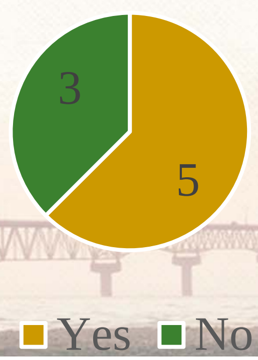
Do you perform a detailed/refined Hydraulic analysis?



Do you perform a cost-benefit analysis prior to performing structural modeling?



Do you have a case study that would demonstrate the success of the detailed hydraulic and/or structural modeling and analysis?

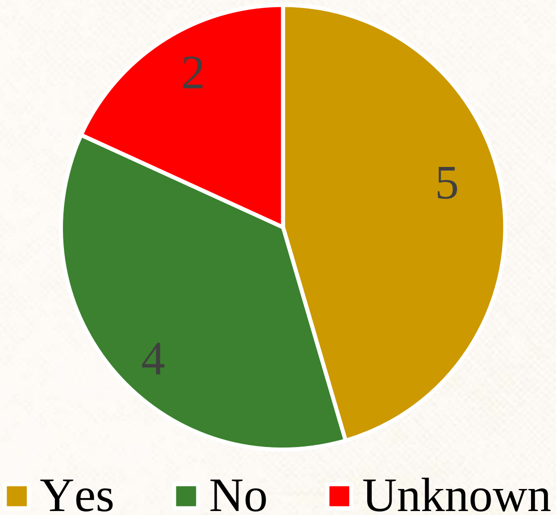


Do you use computer software for scour assessment and/or risk mitigation (e.g., SRH-2D, HEC-RAS, FB-Multiplier, etc.)?

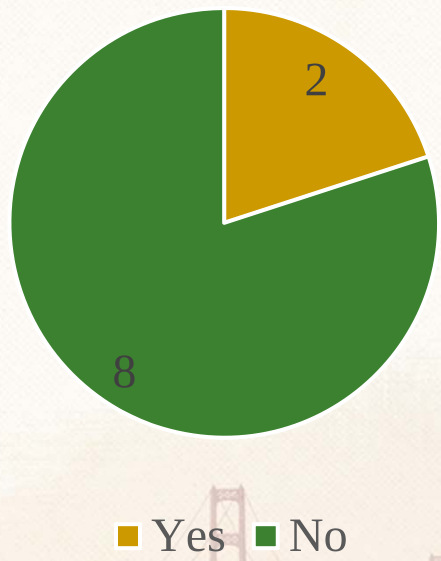
Responses to Selected Amplifying Questions

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

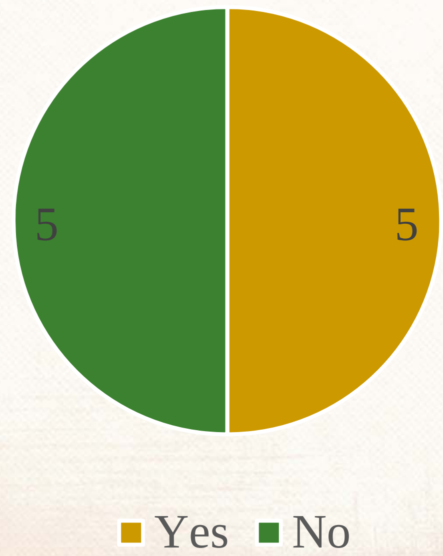
Has your state used sonar on a line rod in order to measure scour depths at some bridges on a daily basis?



Do you have state-specific criteria to reduce the frequency of field inspections for scour critical bridges?



Are you using a Network-wide web-based monitoring system for monitoring rainfall, flooding etc. and pro-active notification of personnel during flood events?



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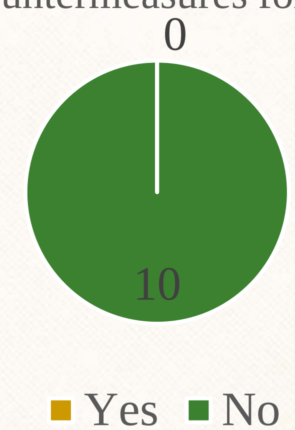
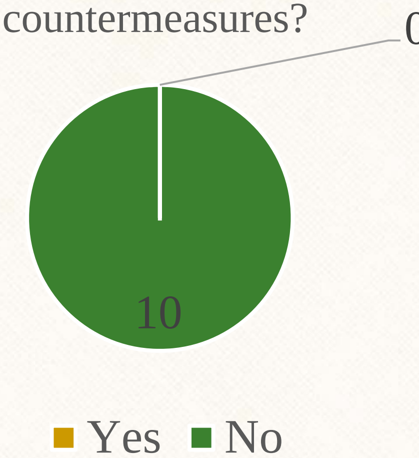
Responses to Selected Amplifying Questions

- Topic 4: Design Installation and Sustainability of Countermeasures

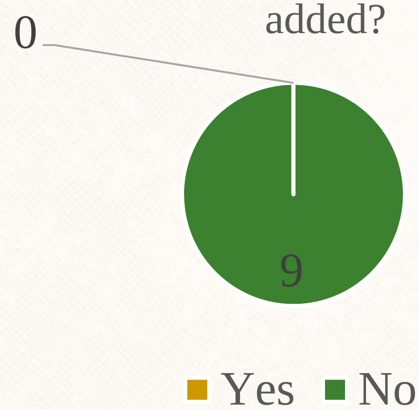
Do you have state-specific guidelines for designing and installing countermeasures for scour?



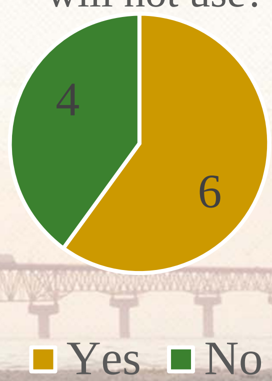
Do you have guidelines for selecting appropriate countermeasures?



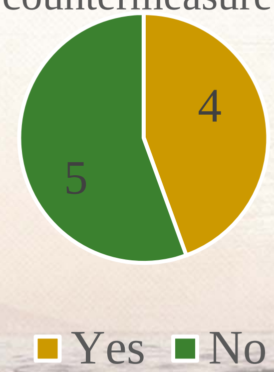
Does a criterion exist that prevents changing the 113 code after countermeasures are added?



Are there any countermeasures or foundation types that your department will not use?



Do you have agency-defined elements for your element level inspection for scour countermeasures?



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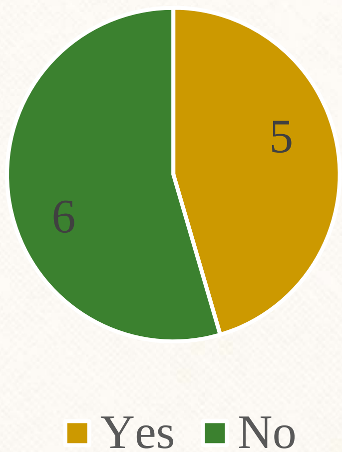
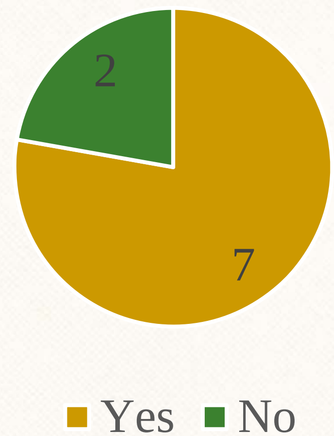
Responses to Selected Amplifying Questions

- Topic 5: Plan of Action

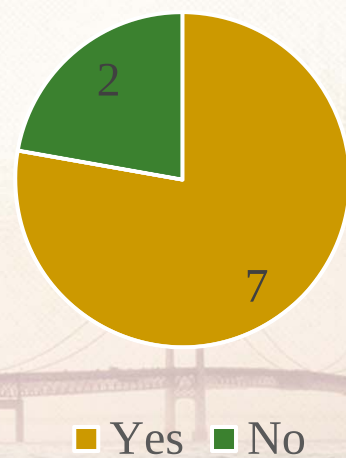
Do you have a statewide emergency response for inspection and monitoring of a large network of bridges under an extreme event?



If structural or channel improvements or installations of countermeasures have been made, do you request a re-evaluation?



Do you have emergency action protocols?



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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)

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Topic 1: General Procedures and Risk Analysis

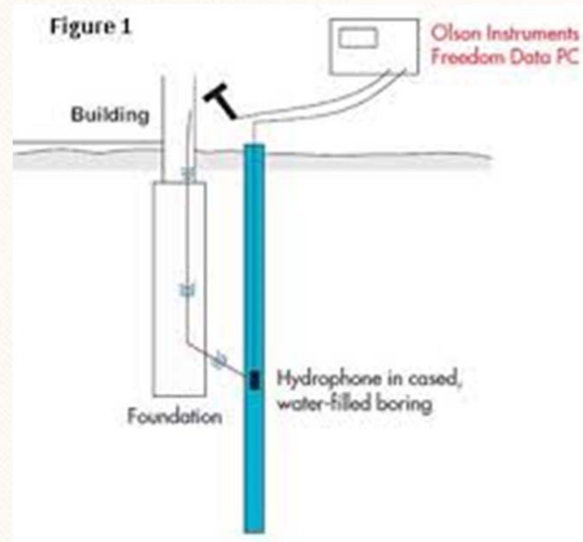
Findings:

- 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

Criteria	Rehabilitation	Replacement
Construction Cost	Lower Initial Cost = $18,790,000	Higher Initial Cost = $ 43,392,000
Life Cycle Costs	Net Present Value = $ 27,266,671 Equiv. Uniform Annual Cost = $ 1,123,598	Net Present Value = $ 47,616,837 Equiv. Uniform Annual Cost = $ 1,962,183
Functionality	Remains the same	Wider roadway deck promotes safety & accommodates center channelization lane for left turns
Long Term Reliability	Substructures would be 130 years old before bridge is replaced Additional future scour countermeasures likely required	New bridge built to current codes and requirements Scour resistant Substructure
Risk	Greater potential for unforeseen issues with major structural repairs Higher likelihood for possible issues with 80-year old substructures	Fewer unknowns with all-new construction Ability to fully considerer potential issues in new design
Constructability	Specialized & complex repairs for track and tread replacements Jacking and shoring leaves Major work during winter	Typical Movable Bridge Construction
Construction Disruption	9-Month Roadway Closure	21-Month Roadway Closure

State Practices: Louisiana DOTD

- Pile Testing-Dispersive Wave & Parallel Seismic



State Practices: Texas DOT

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

INFERENCE METHOD

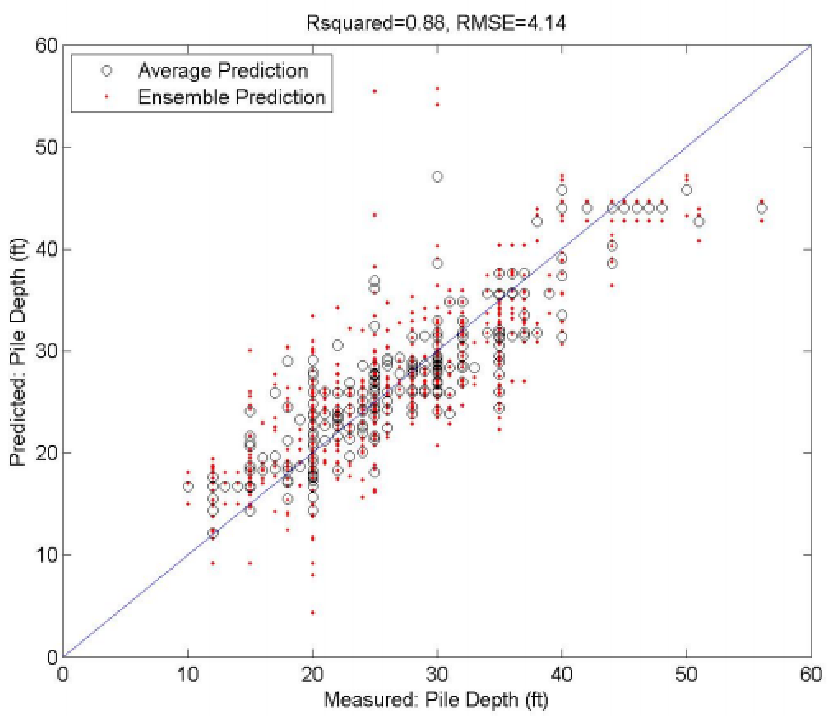


Figure 7-11. Ensemble Prediction for MLP-PL10 for Concrete Piling.

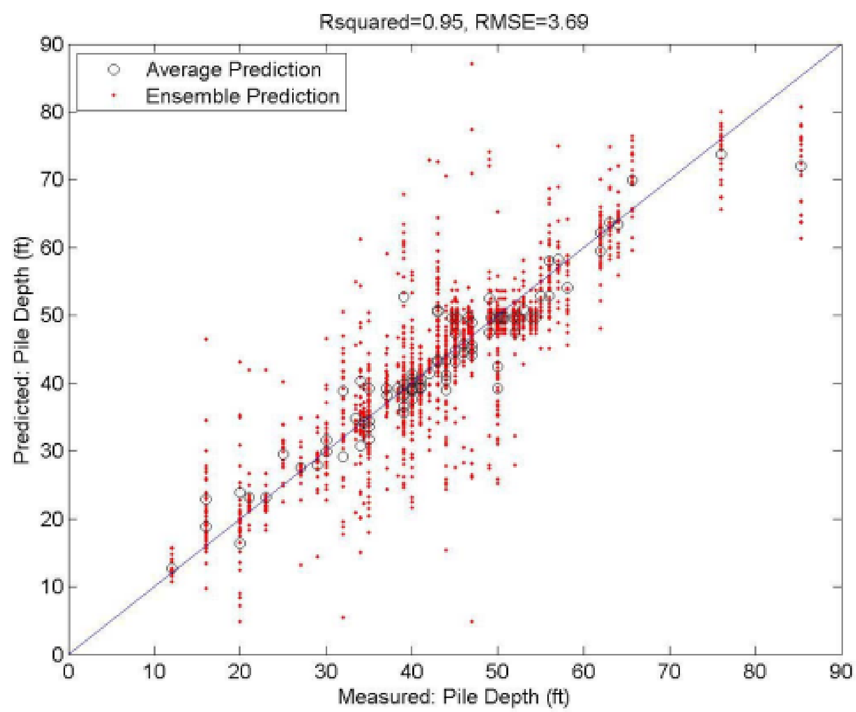


Figure 7-12. Ensemble Prediction for MLP-PL11 for Drilled Shafts.

State Practices: Texas DOT (Cont'd)

- Inference Method

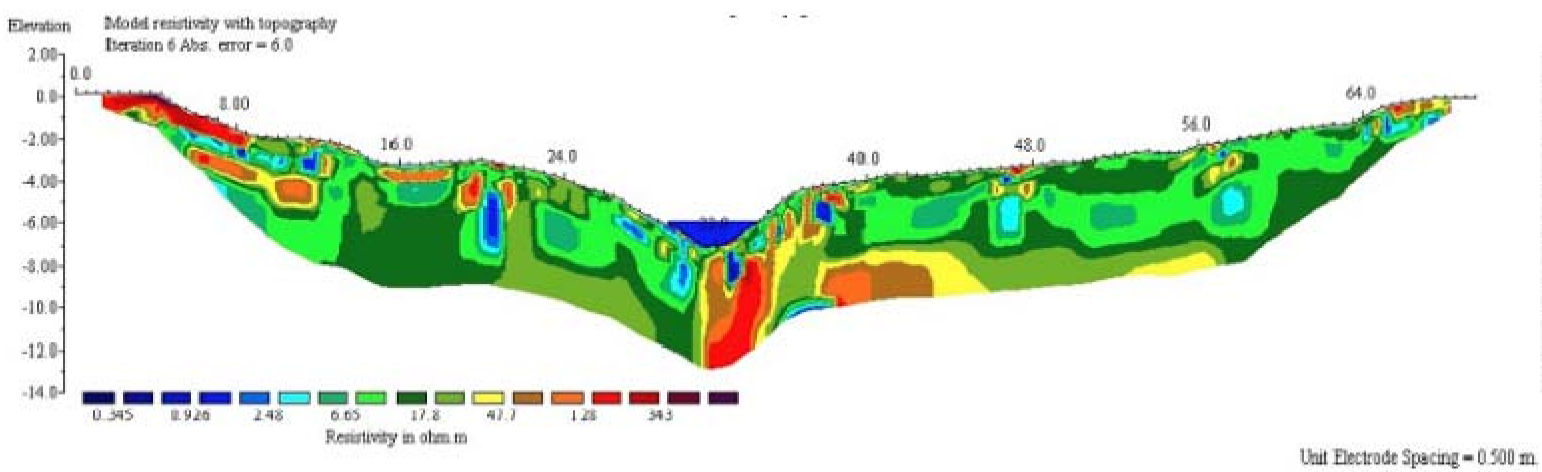
Worked for bridges with concrete piling and drilled shafts, but did not work well for timber piling.

State Practices: Texas DOT (Cont'd)

- Geophysical Method

Figure 11-6. Bridge 14 ERI Fieldwork.

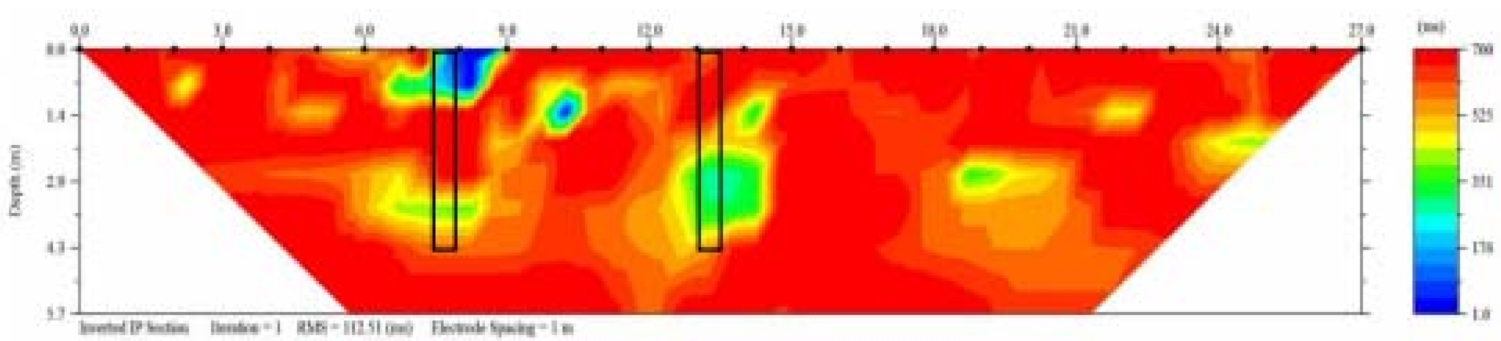
Resistivity Profiling



State Practices: Texas DOT (Cont'd)

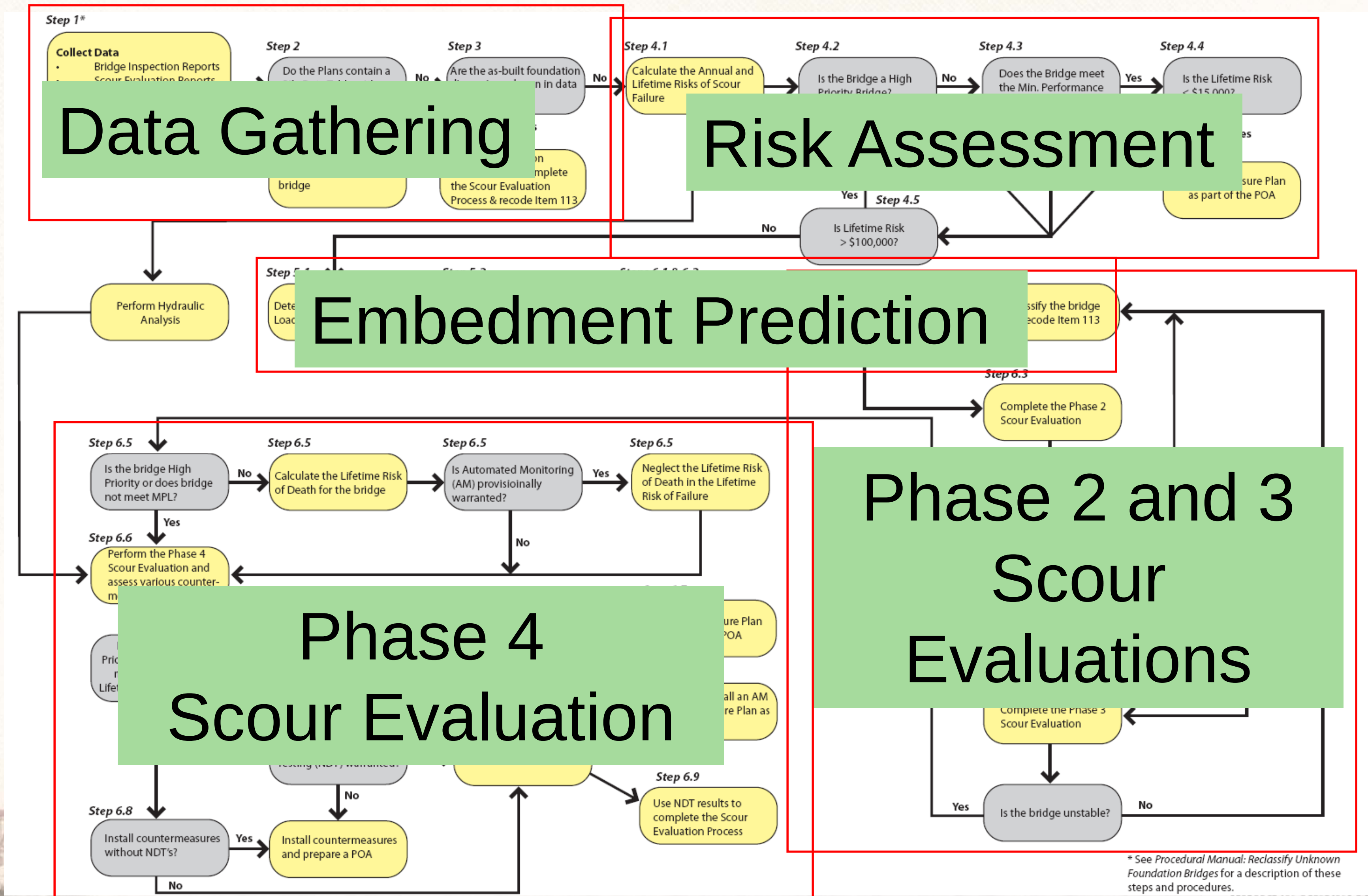
- Geophysical Method

Polarization Imaging



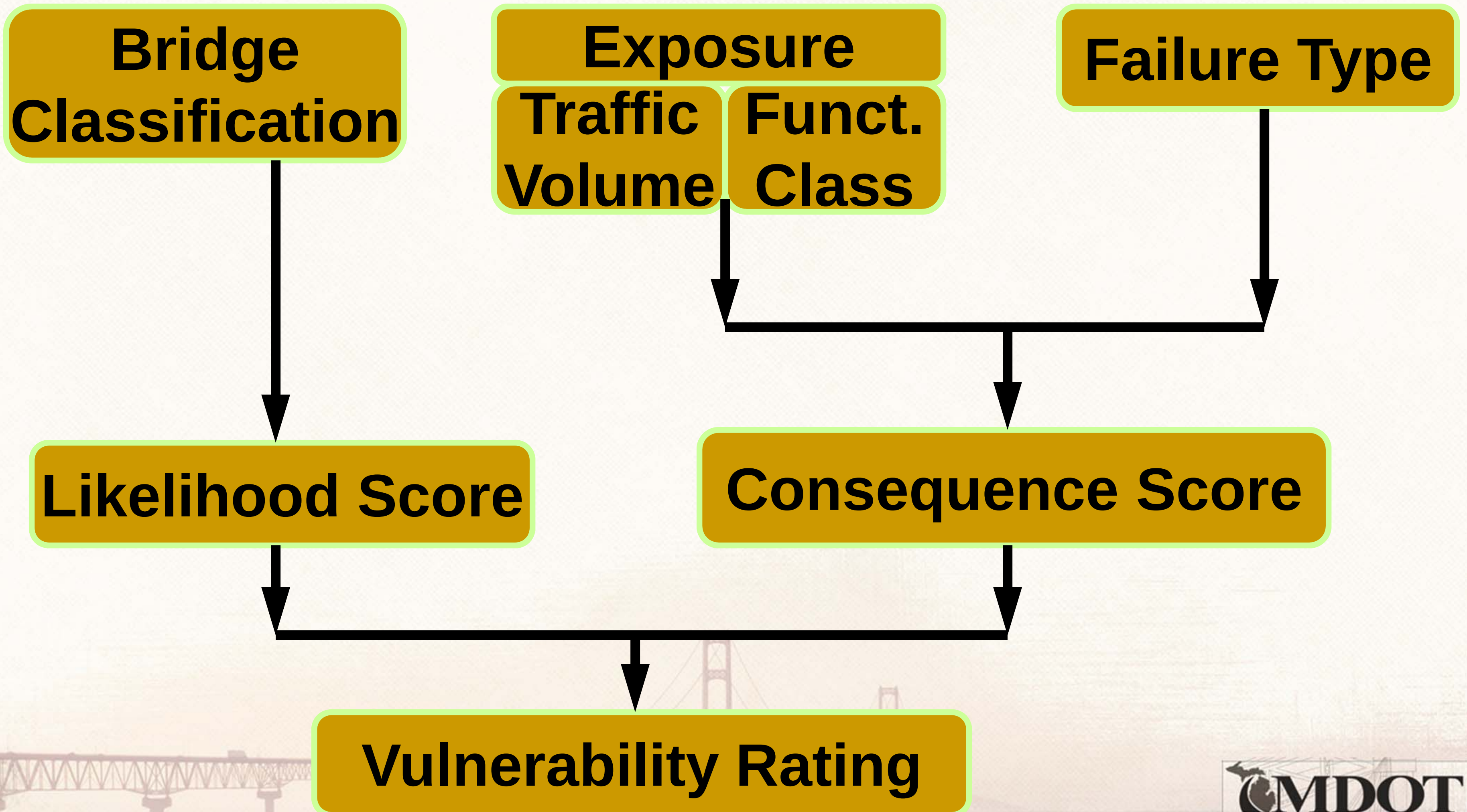
State Practices: Florida DOT

- Unknown Foundations Process



State Practices: New York State DOT

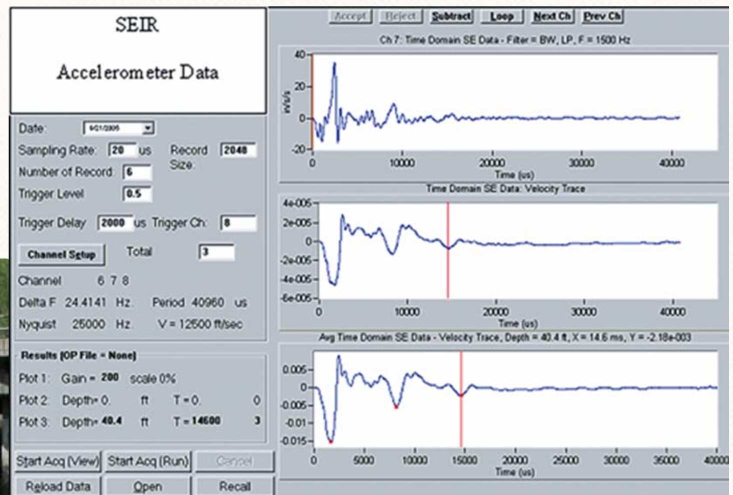
- Vulnerability Rating Procedure



State Practices: Colorado DOT

- Scour Critical Bridge Program

Data Collection → ***Scour Analysis*** → ***Recommendations*** → ***Final Report***



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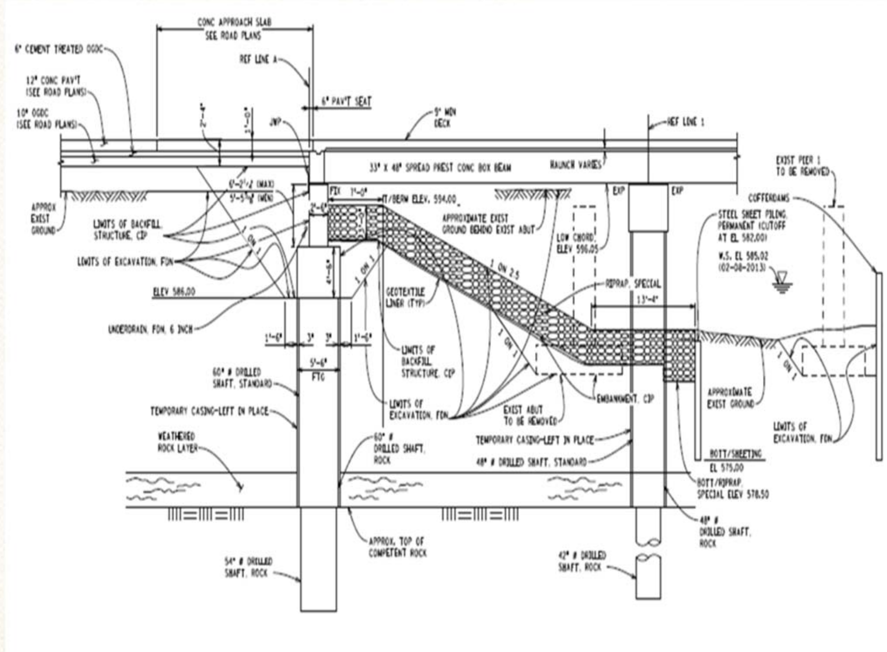
Topic 1: General Procedures and Risk Analysis

- <u>Conclusions:</u>
  - 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



ABUTMENT A & PIER 1 SECTION

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.

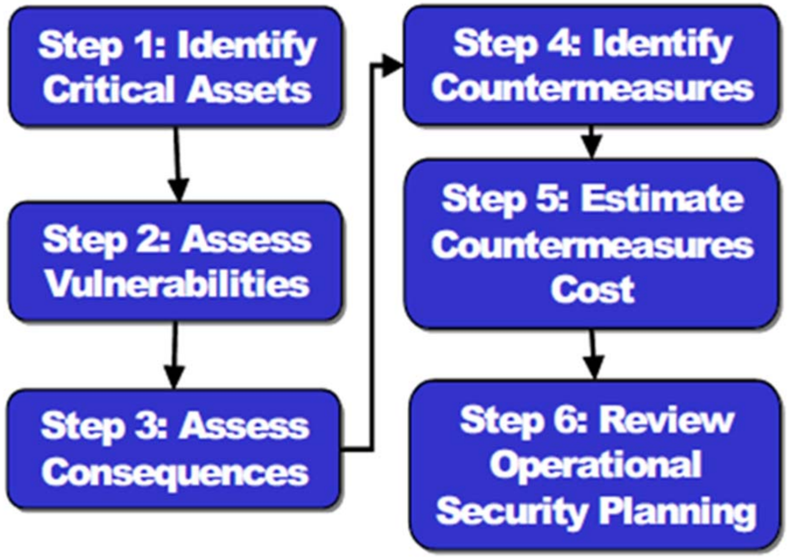


Figure 1 – Six Steps for Conducting a Vulnerability Assessment

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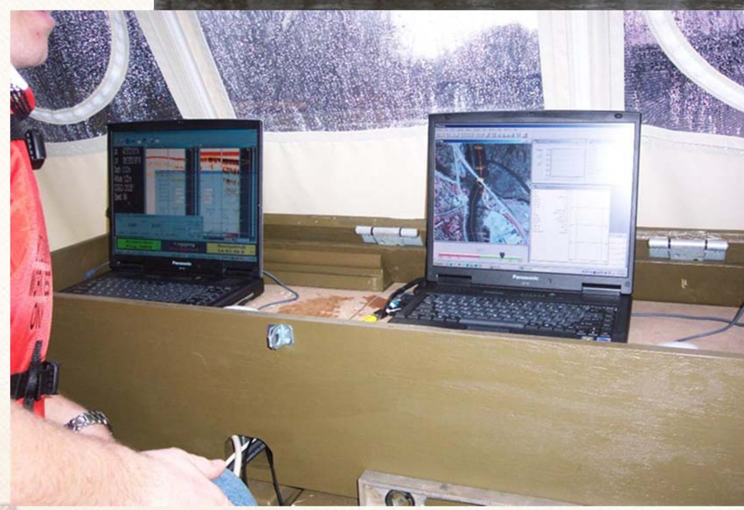
Topic 2: Scour Modeling and Analysis

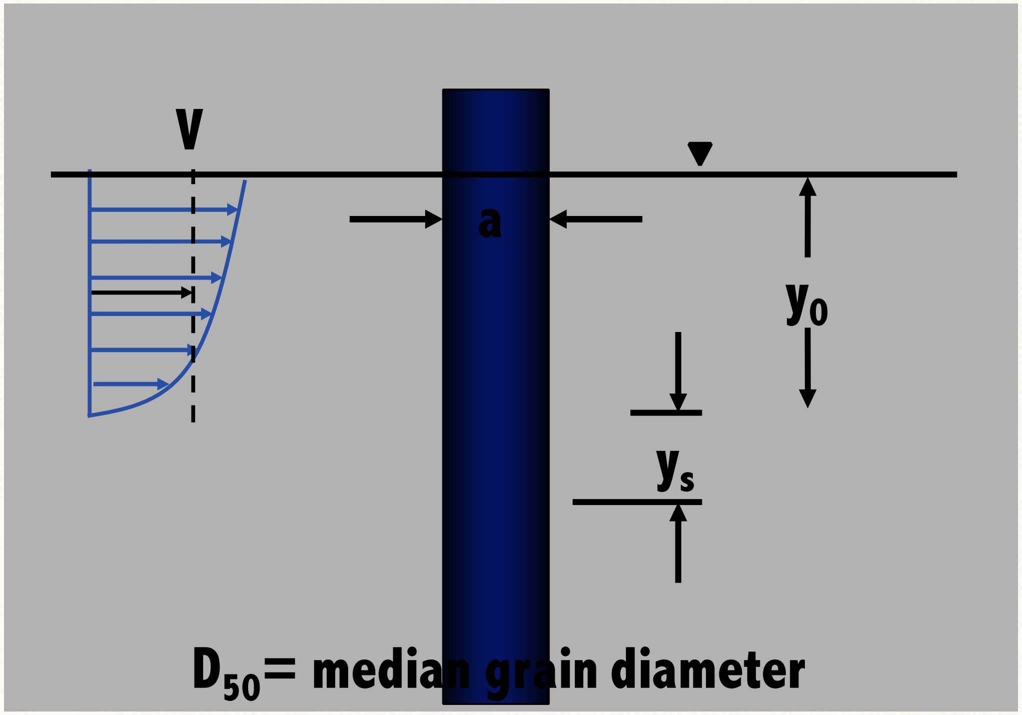
Findings:

- 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

$$0.47 \leq \frac{V}{V_c} \leq 1$$

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

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

$$0.47 \leq \frac{V}{V_c} \leq 1$$

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

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

- LIVE-BED SCOUR

$$1 \leq \frac{V}{V_c} \leq \frac{V_{lp}}{V_c}$$

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

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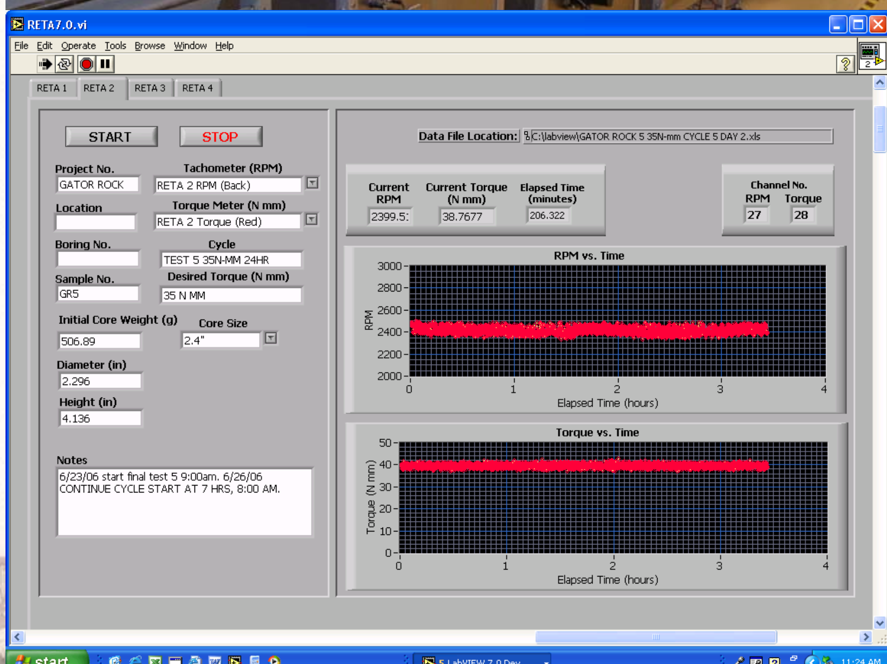
State Practices: Florida DOT

- Rock Erosion Measurements with the Rotating Erosion Test Apparatus (RETA)



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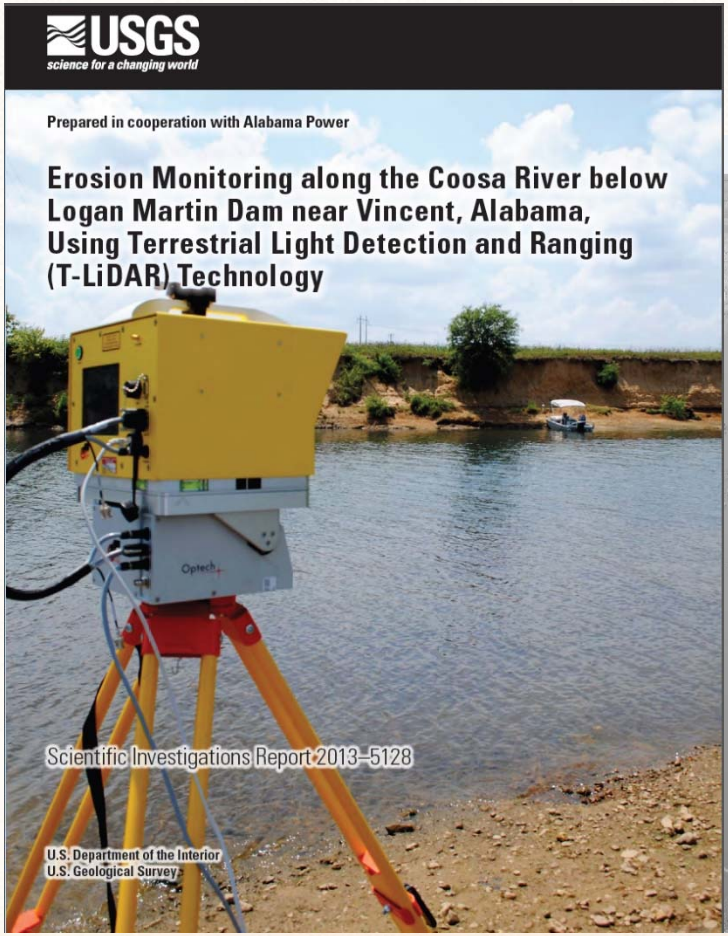
State Practices: Missouri DOT

- Streambank Stability/Lateral Migration



LiDAR Scan

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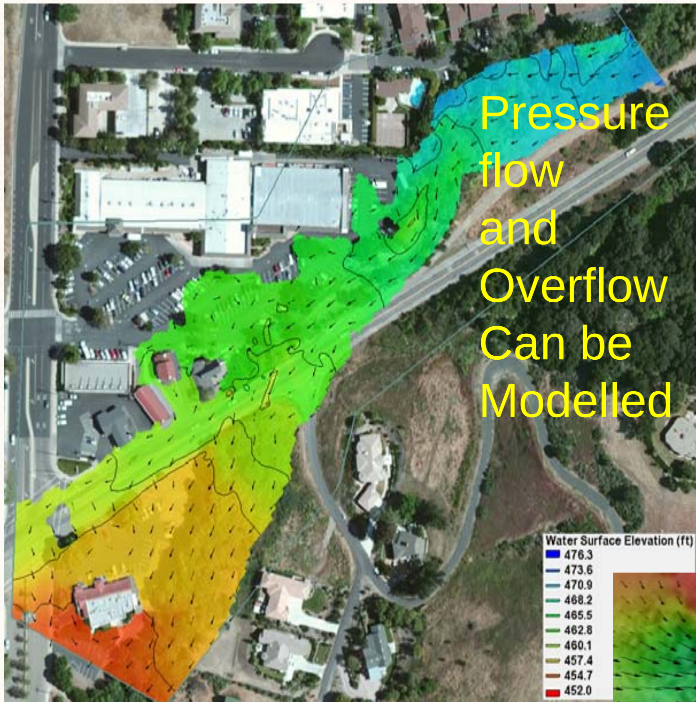
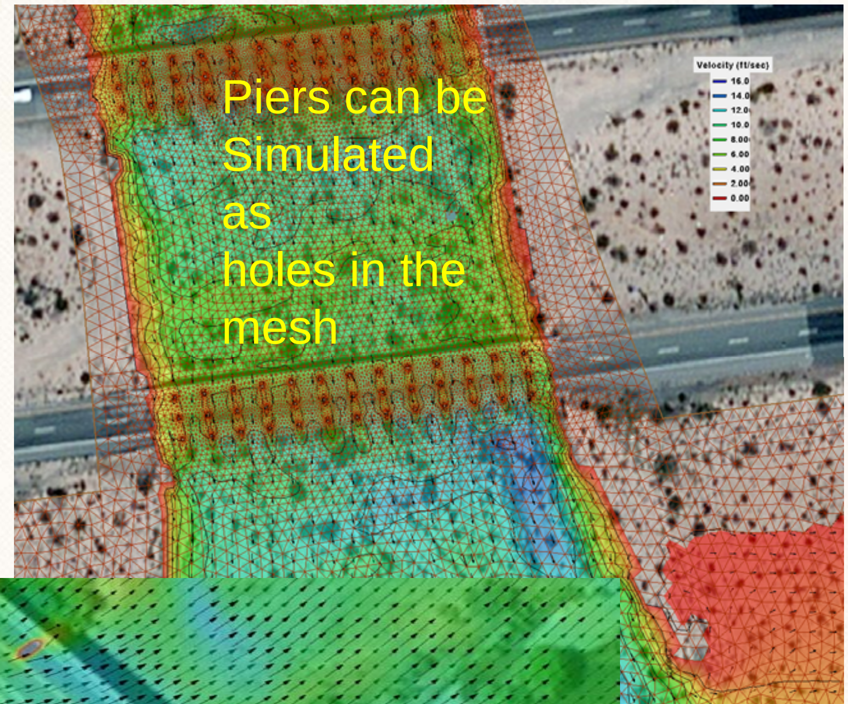
State Practices: Caltrans

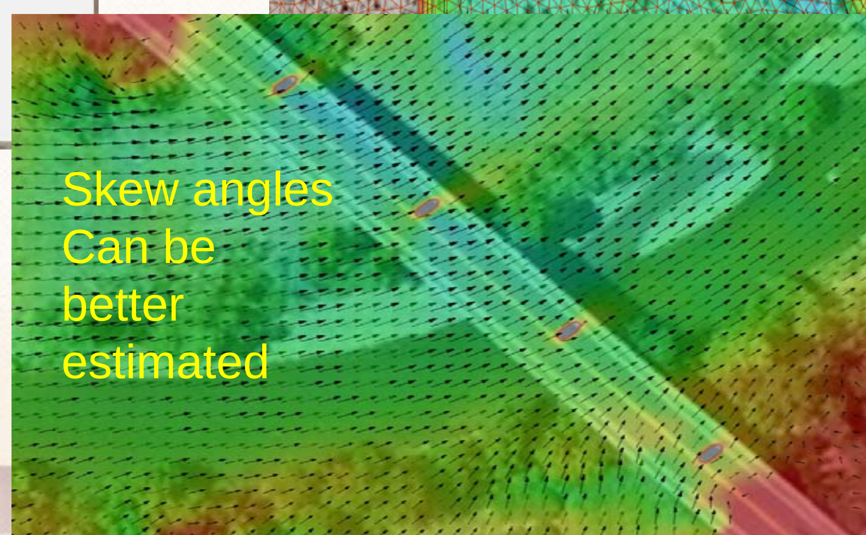
- Improved Scour Measurements

State Practices: Caltrans (Cont'd)

- Detailed Hydraulic Modeling



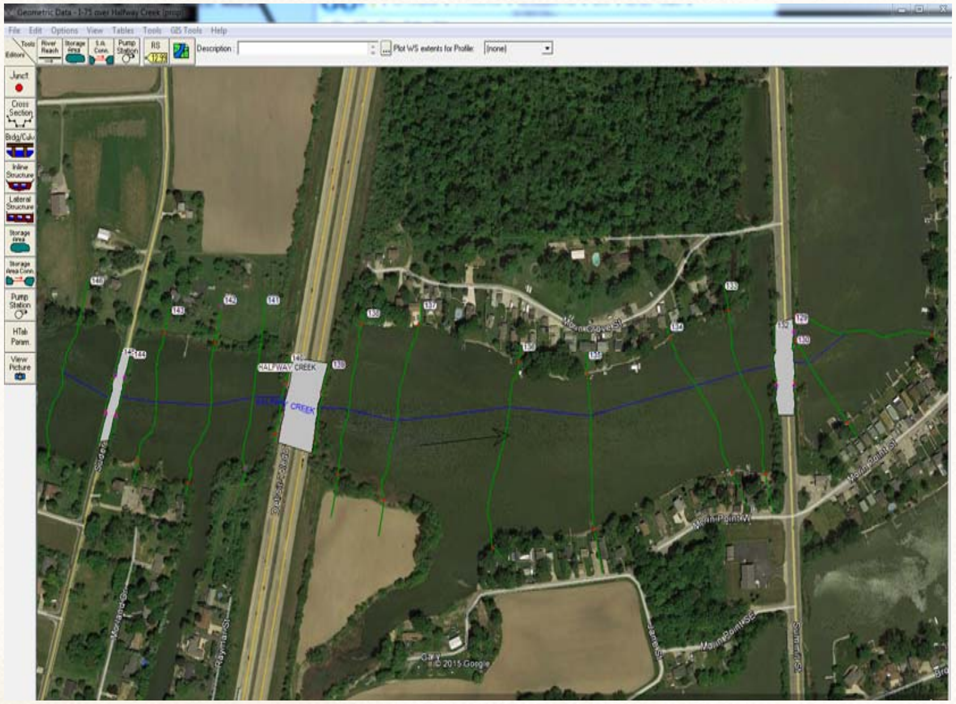




Topic 2: Scour Modeling and Analysis

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.



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Topic 2: Scour Modeling and Analysis

Recommendations:

- Materials testing for cohesive soils or rocks can 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

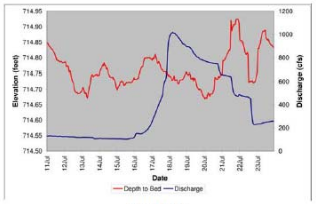
<u>Findings:</u>

- 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

SCOUR MONITORING (ea.)

Description: This element defines scour monitoring systems applied to substructure elements.			
No.	Name	CS Table	Description
838	Scour Monitoring	12	Scour monitoring systems.
Quantity Calculation: The quantity for this element is measured per bridge and includes all devices attached to the bridge for monitoring velocity or scour depths.			

Scour Monitoring Device



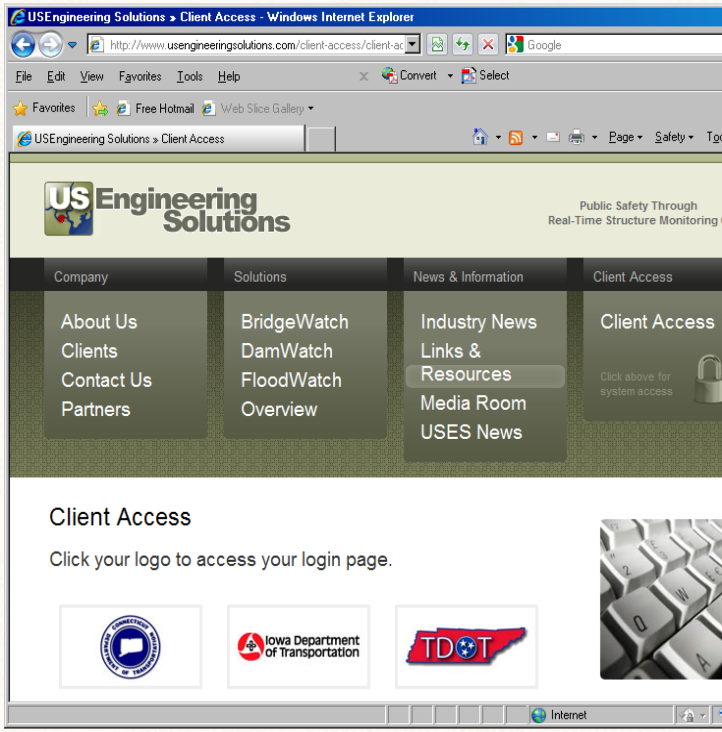
Sour Data

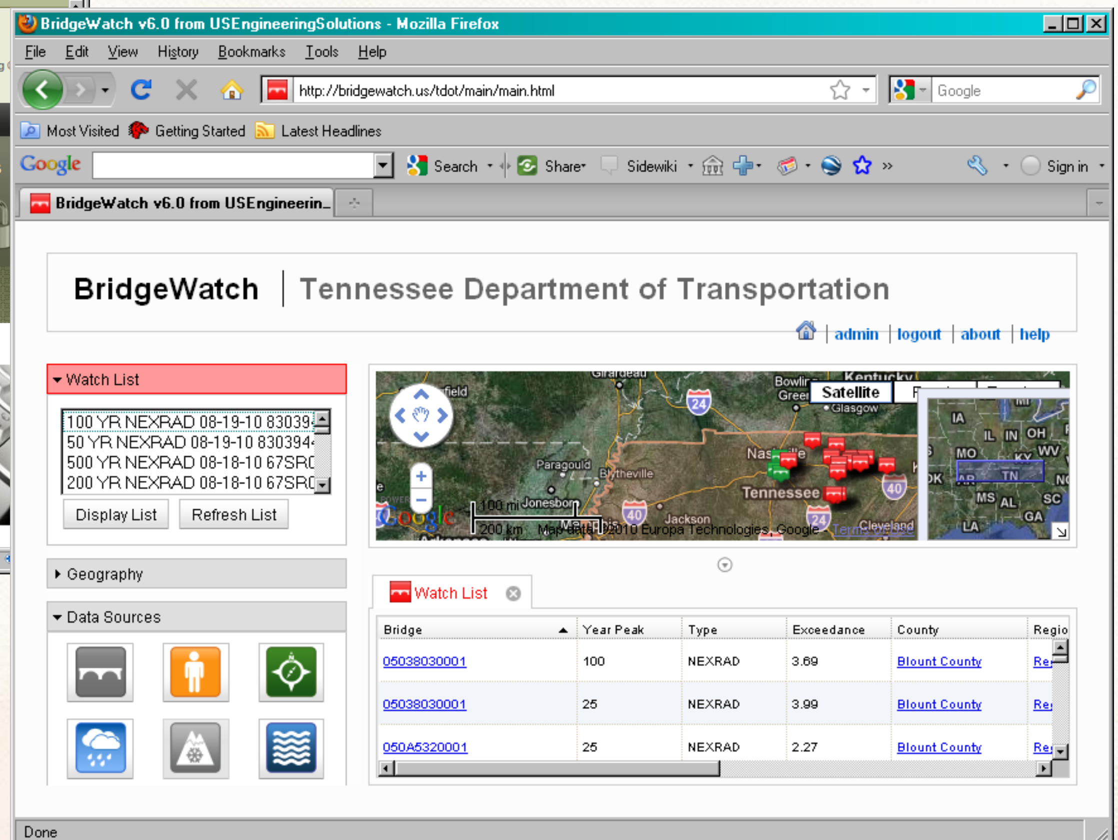
State Practices: Tennessee DOT

- Bridgewatch™ Program

Internet based application

Implemented 2004





Customizable with TRIMS data

Monitors 24 / 7 / 365

Default thresholds

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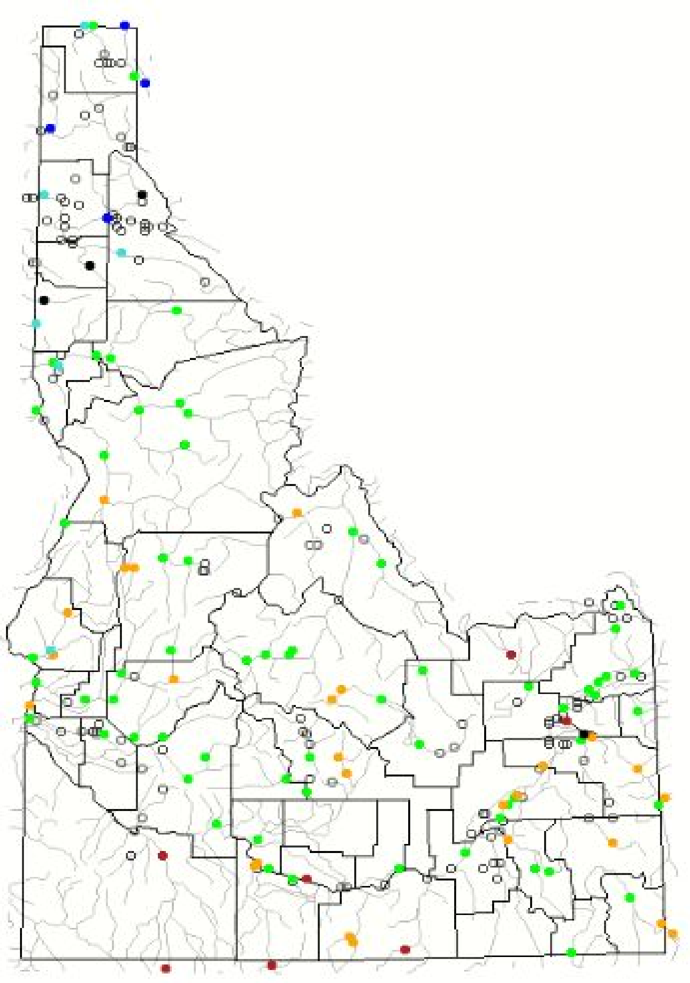
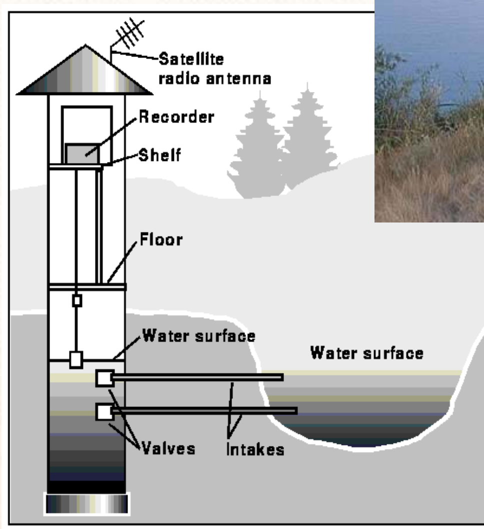
State Practices: Idaho DOT

- Idaho Stream Gauging Locations

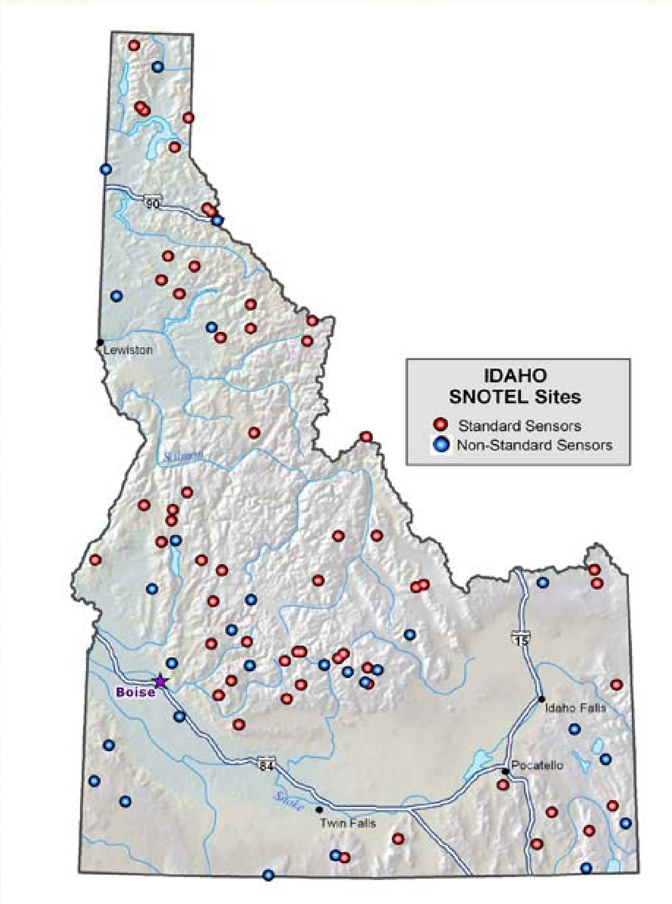


Explanation - Percentile classes							
Low	<10 Much below normal	10-24 Below normal	25-75 Normal	76-90 Above normal	>90 Much above normal	High	Not-ranked

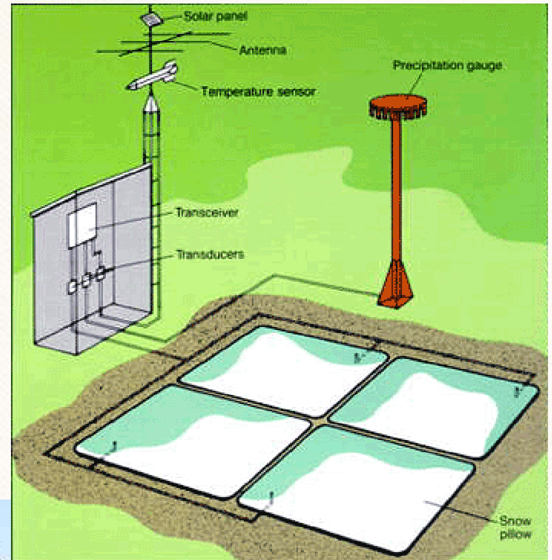


State Practices: Idaho DOT

- SNOTEL Sites in Idaho

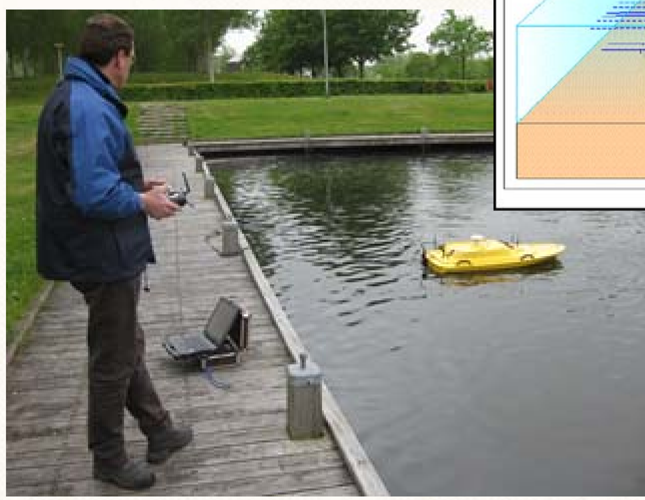


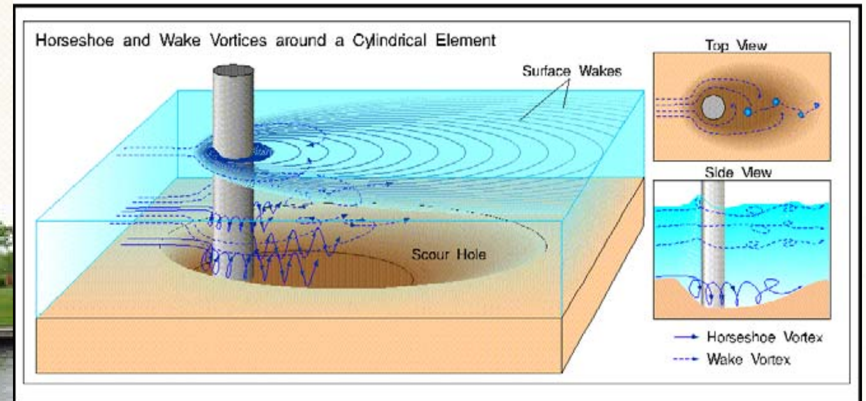
NRCS
Natural Resources
Conservation Service

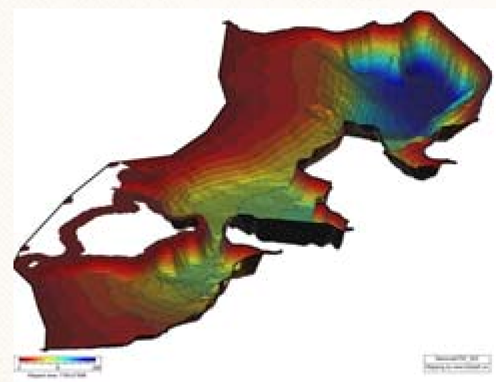


State Practices: Iowa DOT

- Remote Hydrographic Surveying System



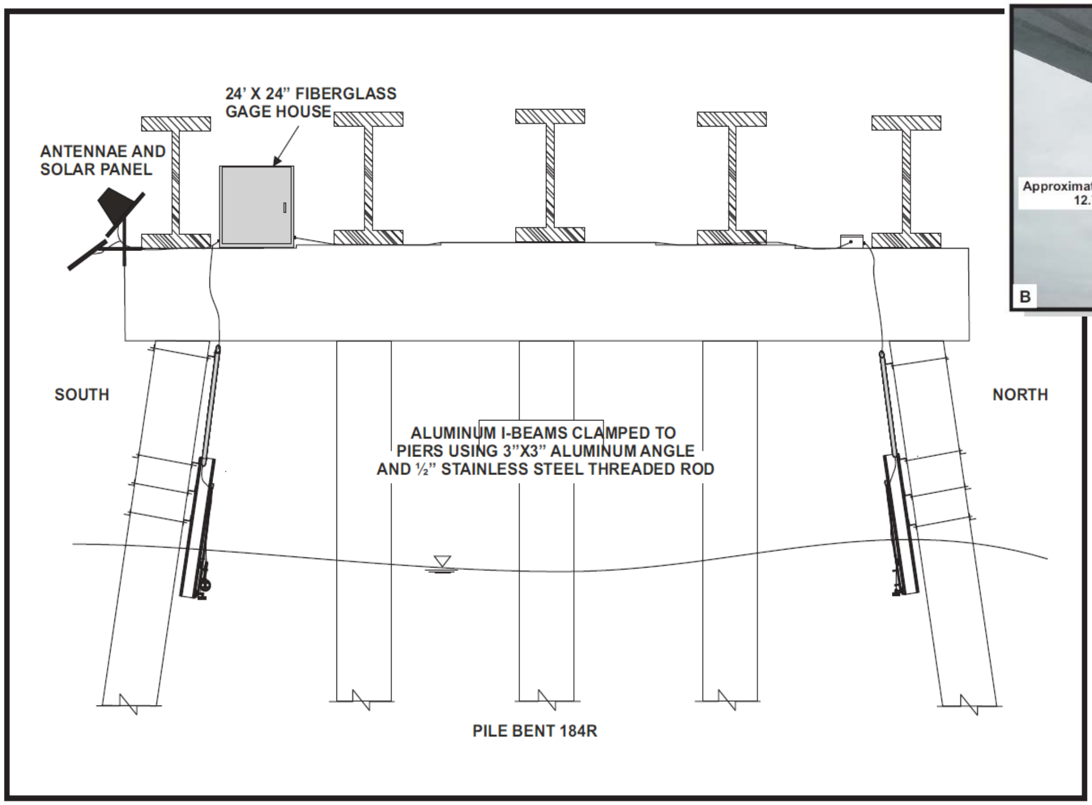




ECHOSOUNDER & GPS + RADIO CONTROL + DATA TELEMETRY ⟹ REAL TIME MAPS

State Practices: Mississippi DOT

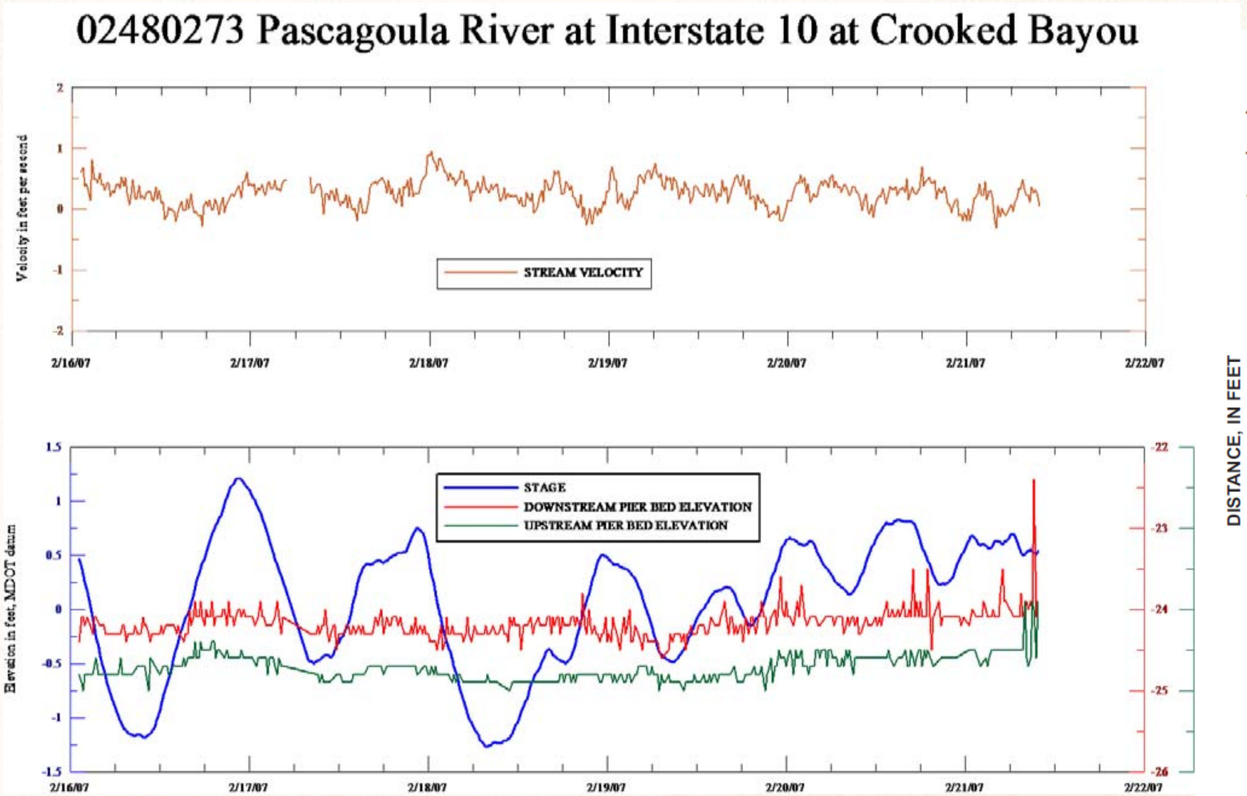
- Bridge Scour Monitoring

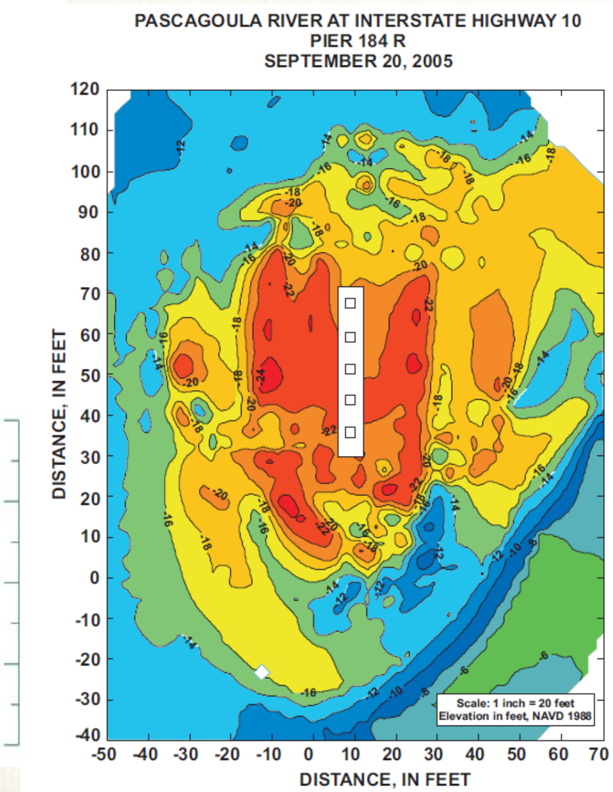


Bridge Scour Monitoring

State Practices: Mississippi DOT (Cont'd)

- Real time scour monitoring gage (15 min interval)





Bridge Scour Monitoring

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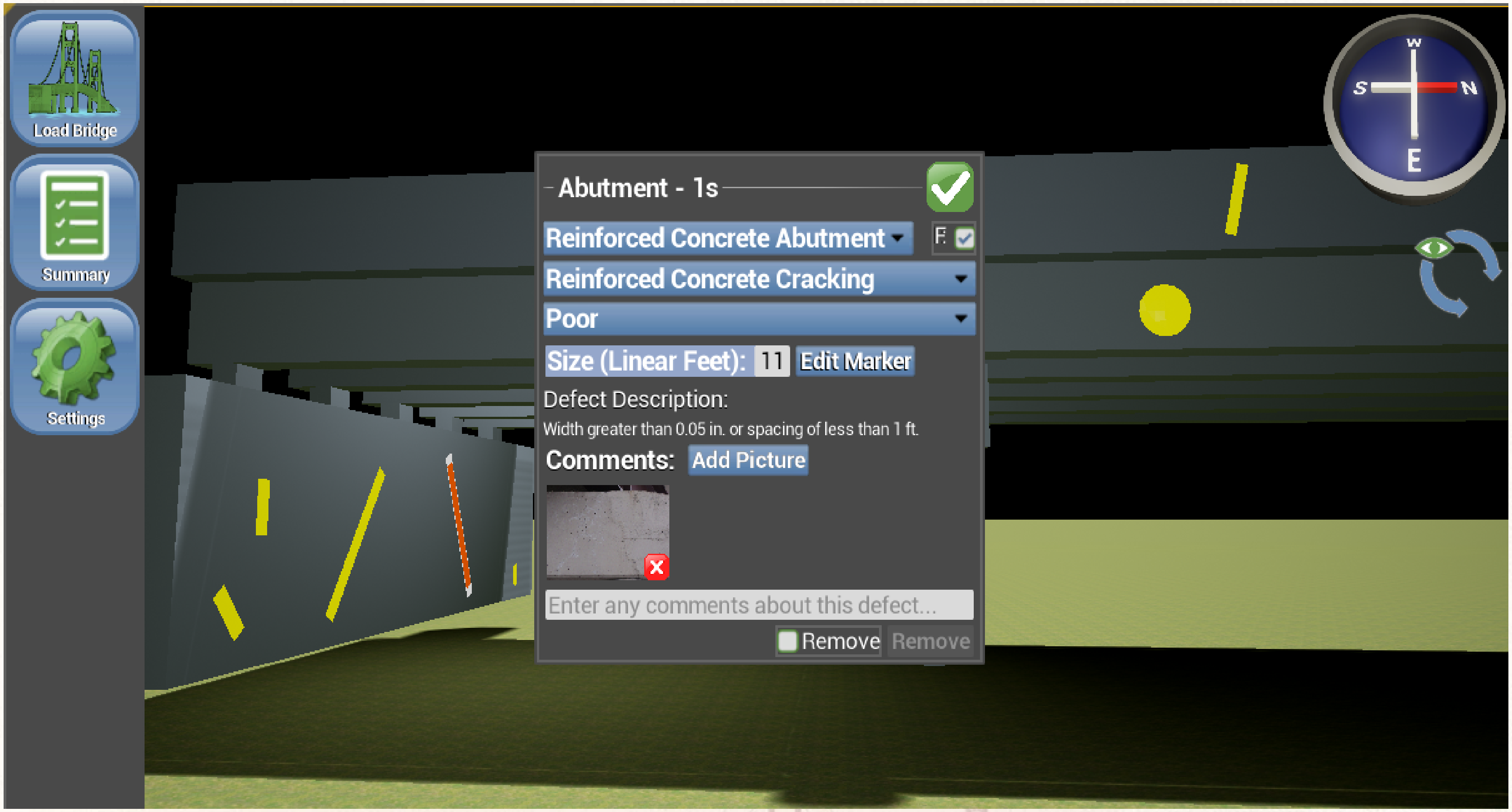
State Practices: Michigan DOT

- 3D BRIDGE app



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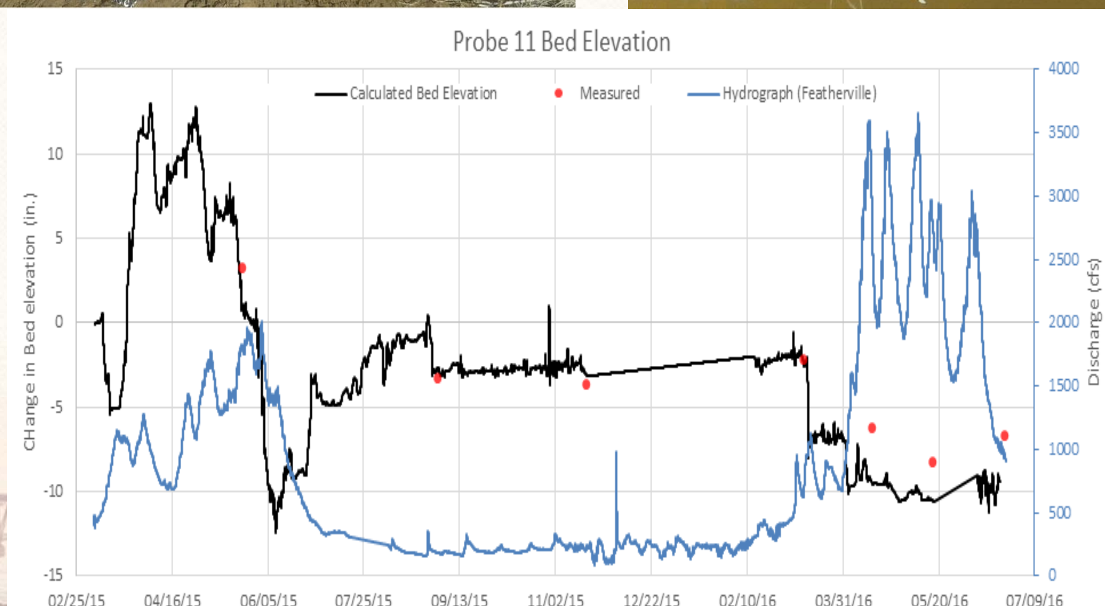
State Practices: Idaho DOT

- Scour Monitoring Research



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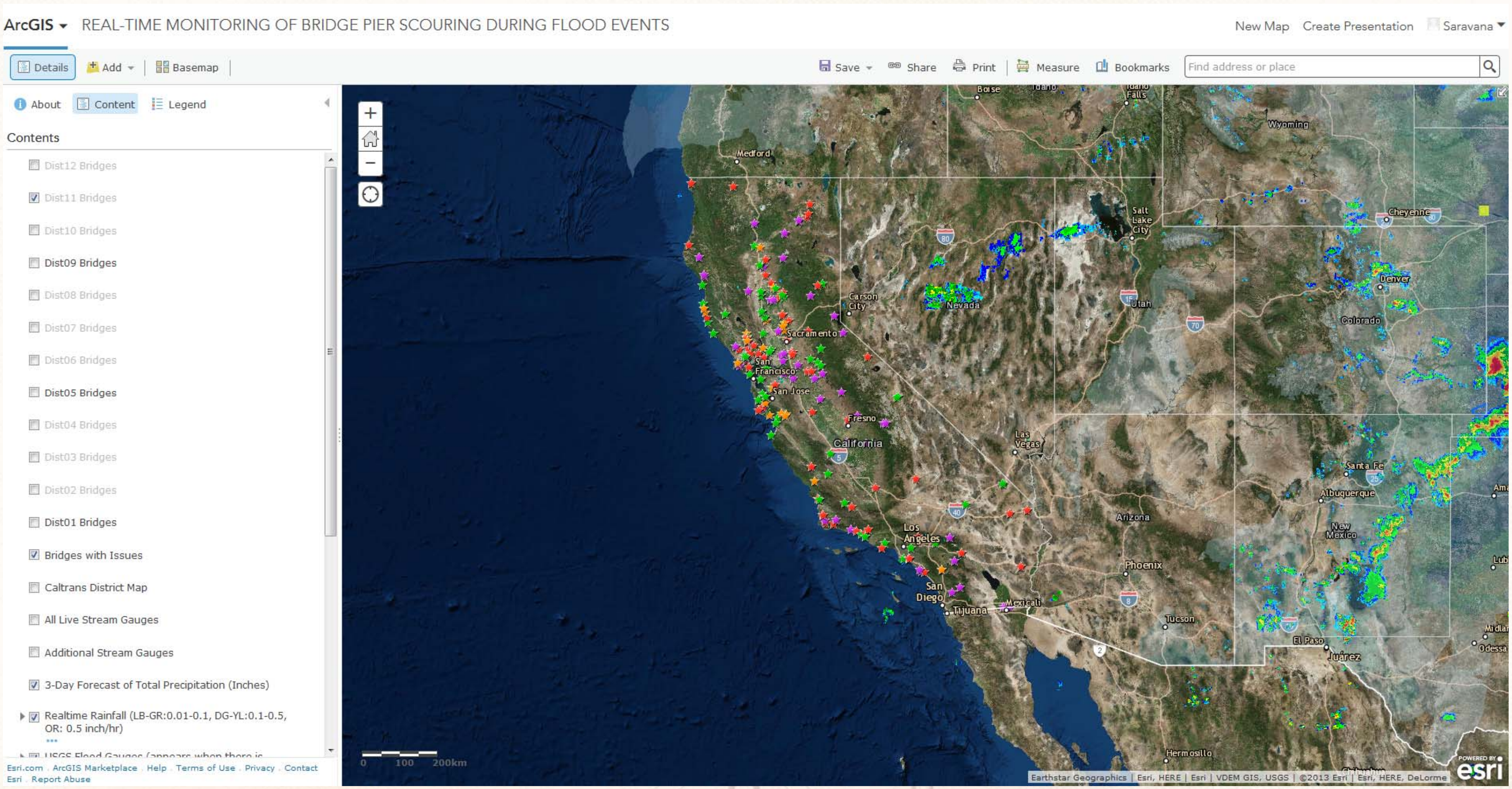
State Practices: Caltrans

- Flood Monitoring System for State Bridges



State Practices: Caltrans (Cont'd)

- Monitoring

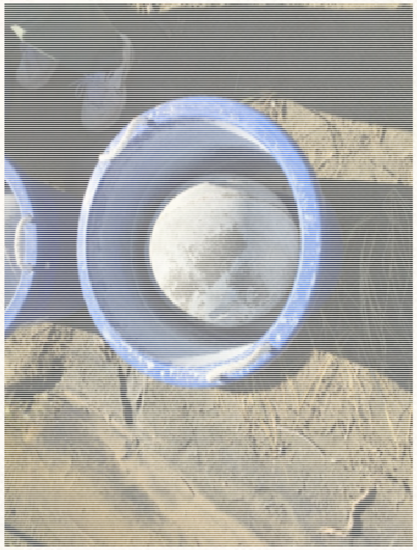






State Practices: Caltrans (Cont'd)

- SMART Rocks


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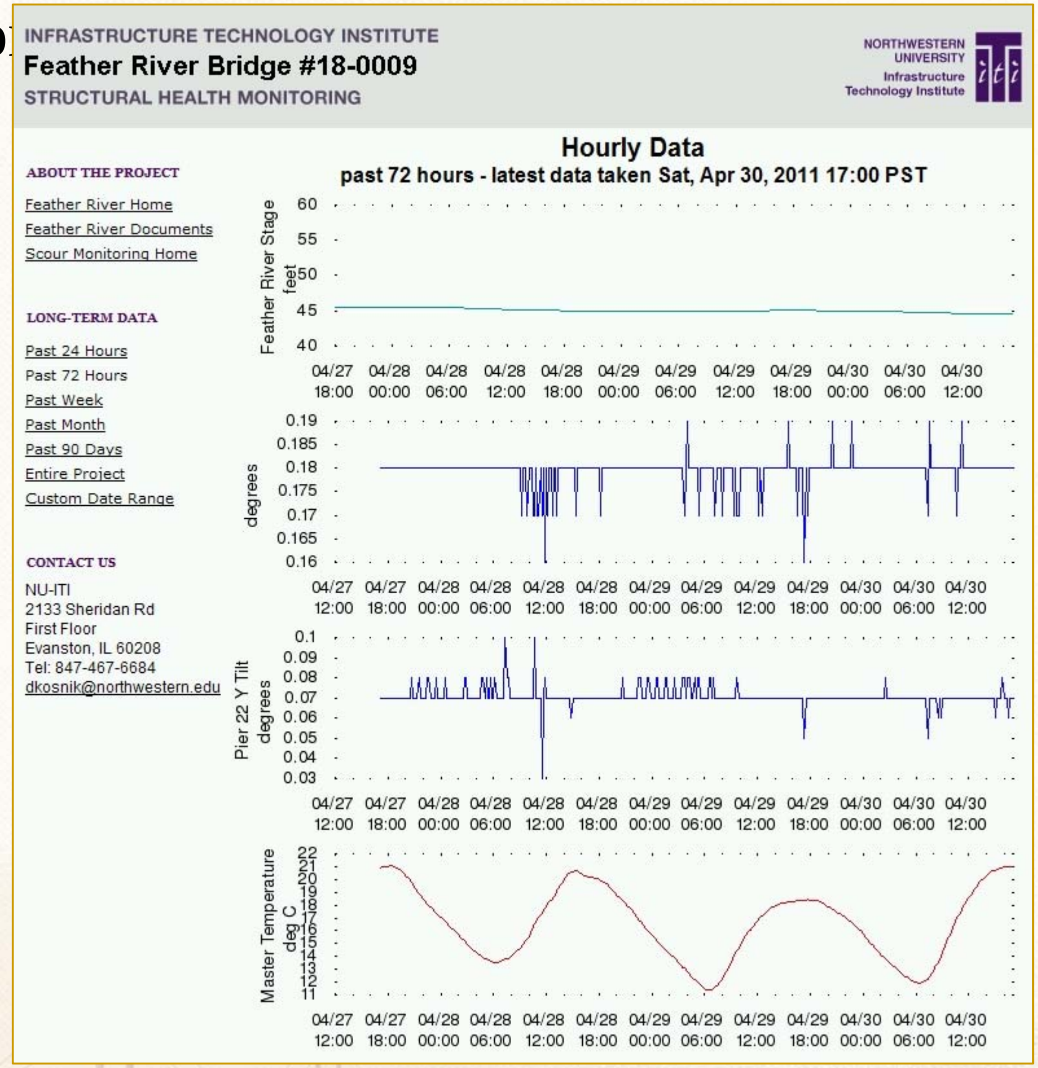
State Practices: Caltrans (Cont'd)

- Tilt Sensor Instrumentation



Topic 3: Monitoring and Field Inspection of Scour Critical Bridges

Conclusions:

- Advanced technology such 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

Michigan Bridge Element Inspection Manual

CS TABLE 10 – SCOUR PROTECTION

Defects	Condition State 1 GOOD	Condition State 2 FAIR	Condition State 3 POOR	Condition State 4 SEVERE
Scour or Erosion	None.	Countermeasure is substantially effective. Scour or Erosion exists without undermining.	Countermeasure device has limited effectiveness Erosion may be evident with undermining of countermeasure.	The channel protection device or scour countermeasure are unstable, missing or no longer effective.
Material Defect (scaling, abrasion, spalling, corrosion, cracking, splitting and decay)	Insignificant or minor defects.	Countermeasure device is substantially effective. Extensive minor to isolated advanced defects.	Scour countermeasures have limited effectiveness. Extensive advanced to major defects.	
Damage (unraveling, displacement, separation, and sagging)	Insignificant or minor damage.	Countermeasure device is substantially effective. Extensive minor to isolated advanced damage.	Scour countermeasures have limited effectiveness. Extensive advanced to major damage.	

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Topic 3: Monitoring and Field Inspection of Scour Critical Bridges

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 under water 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.

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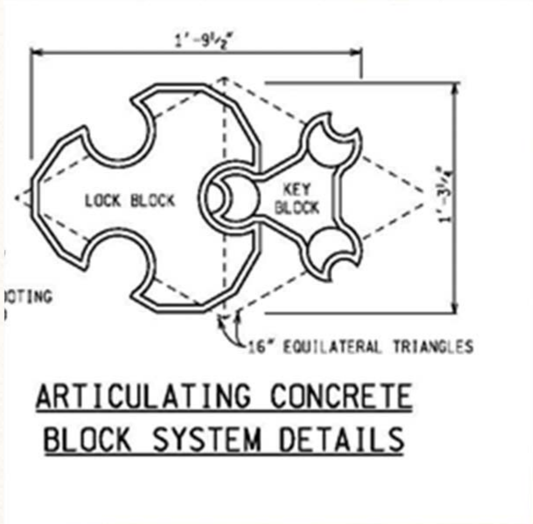
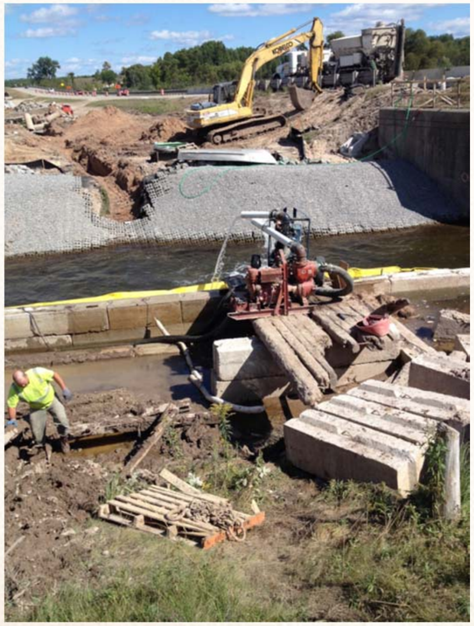
Topic 4: Design, Construction, and Sustainability of Countermeasures

Findings - A number of States have had good experience with various countermeasure designs.





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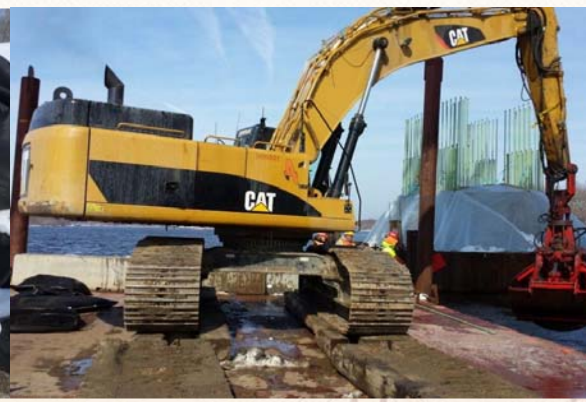
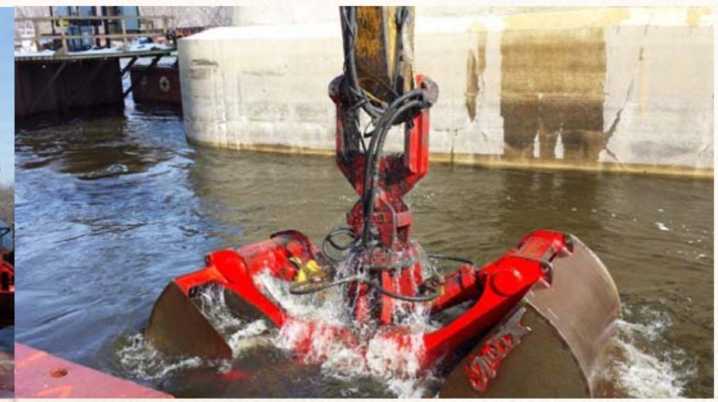
State Practices: Minnesota DOT

- Countermeasure Techniques

(Matrix Riprap, partially grouted riprap)

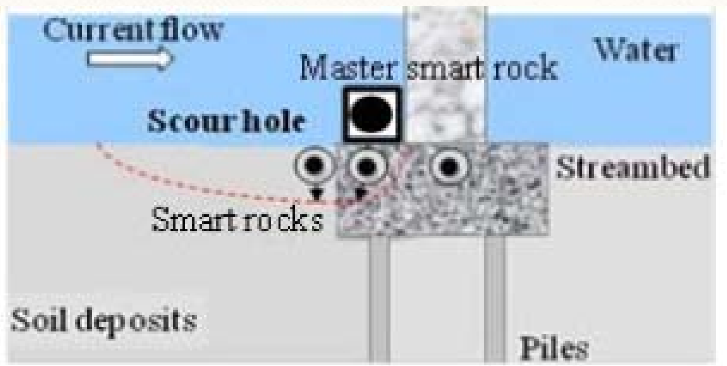




Geobags

State Practices: Missouri DOT

- Smart Rocks Scour Monitoring/Riprap Effectiveness
  - Original Concepts
  - 3 Monitoring Strategies



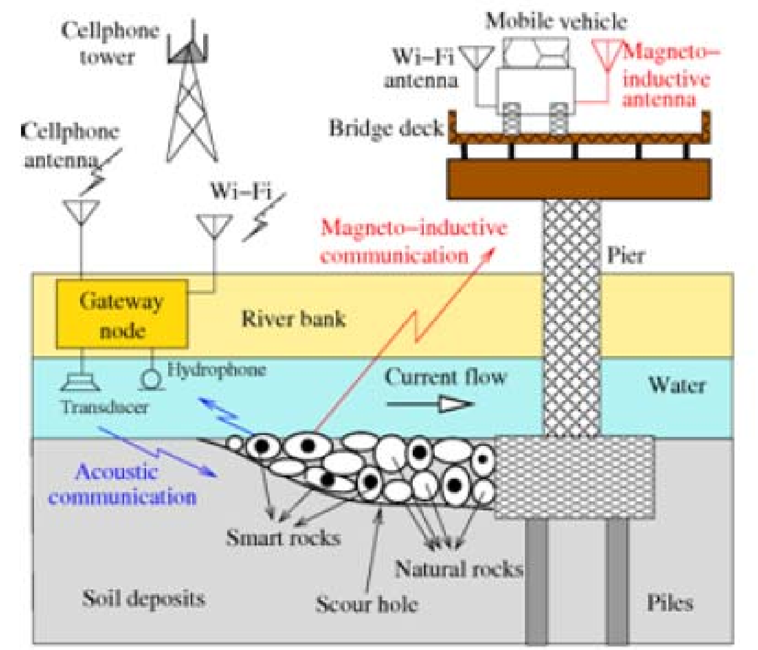
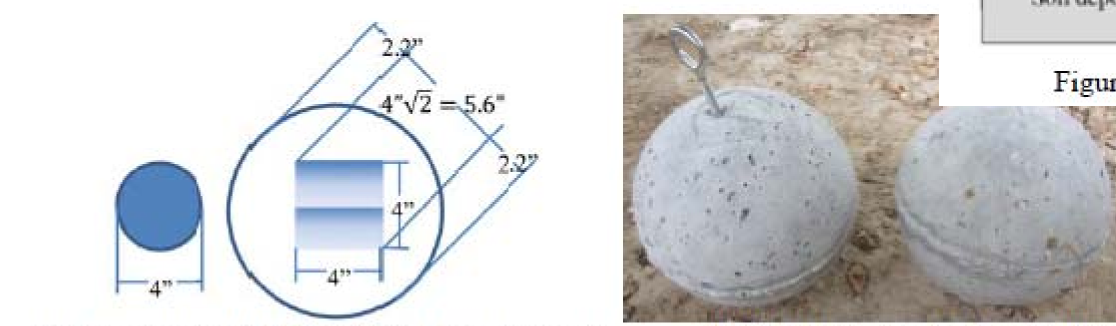


Figure 1.5 Scour Countermeasure Monitoring



(a) Geometry of Magnets and Encasement (b) Prototype in Spherical Shape

Figure 4.43 Design and Prototype of Magnets and Passive Smart Rocks

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Topic 4: Design, Construction, and Sustainability of Countermeasures

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.

Topic 5: Plan of Action (POA)

Findings:

- Implementing inspection during significant flood events can be a strain on departmental resources.

SCOUR EVALUATION

Item 113	Scour Criticality	3 SC - Unstable	Source of Item 113	Assessed
Item 71	Waterway Adequacy	7 Above Minimum		
Level I Assessment		Yes		
Level II Analysis		Yes		

Document Date	Document Name	Document Type
03/07/2016	MDOT Level Two Example.pdf	Level II
03/07/2016	MDOT Level One Example.pdf	Level I

Calculated Values

Scour Analysis Frequency	25 Year	50 Year	100 Year	500 Year	Comments
Anticipated Surface Elevation (ft)	581.75	585.63	600.21	602.3	
Distance Below Bottom Chord (ft)	5.0	4.5	0.0	0.0	Pressure Flow at the 100 Year
Anticipated Flow (cubic ft/sec)	150.0	180.0	200.5	225.24	
Anticipated Pressure Flow (Y/N)	N	N	Y	Y	

Topic 5: Plan of Action (POA)

<u>Conclusions:</u>

- 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.

Topic 5: Plan of Action (POA)

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. .

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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

2017

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