Scour Technology Transfer

MDOT Overview

Rebecca Curtis - Bridge Management Engineer

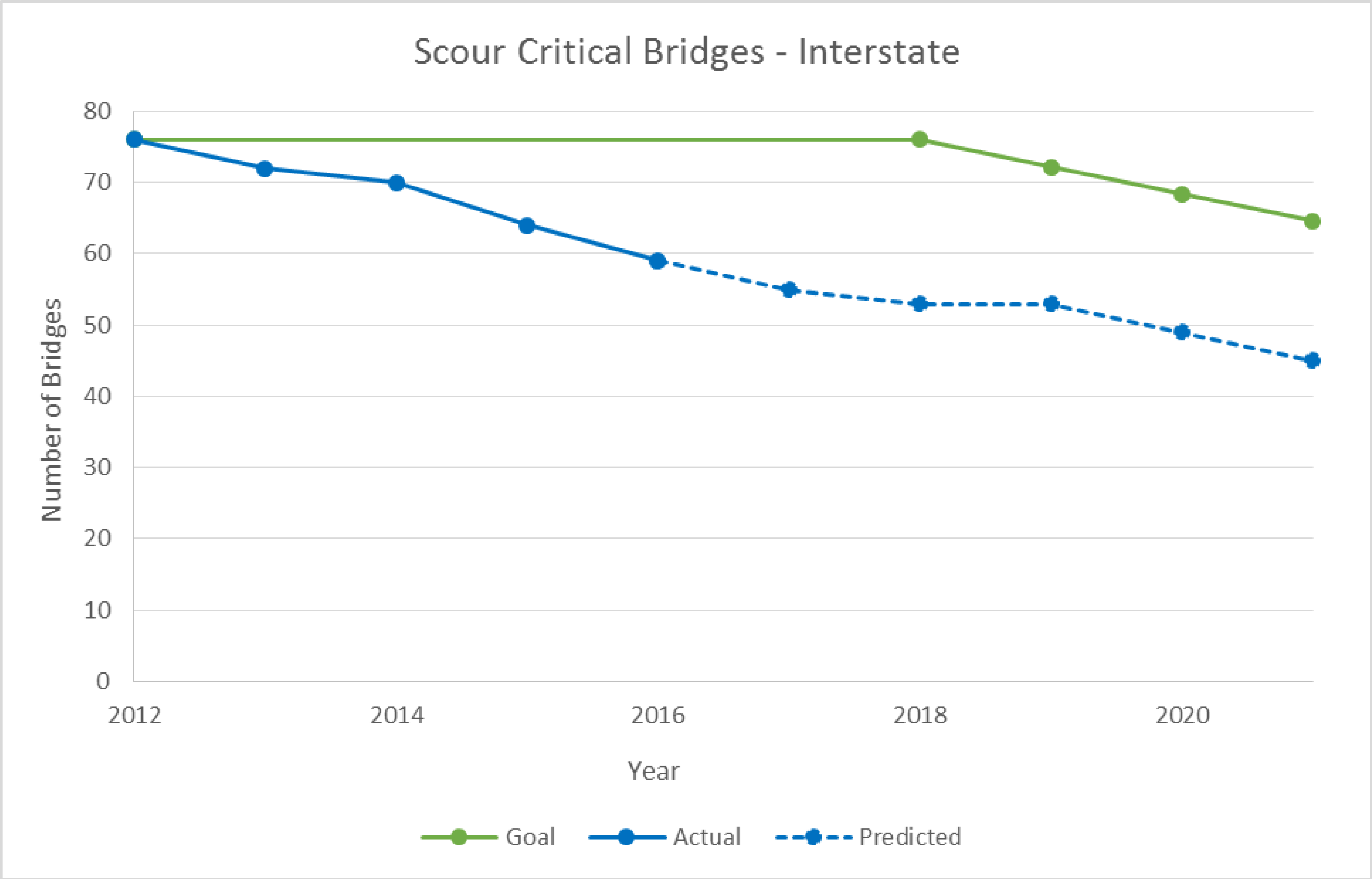
Ryan Snook – Geotechnical Engineer

Erik Carlson – Hydraulic Engineer

Performance Measures

Region	Scour Critical Interstate Bridges	2018-2022 Year Target
Superior	0	**0**
North	0	**0**
Grand	12	**3**
Bay	13	**3-4**
Southwest	13	**3-4**
University	12	**3**
Metro	6	**1-2**
Total	**56**	**14**

Performance Measures



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 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."*

Scan Team

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Bridge Management Engineer
Michigan DOT

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New Jersey Department of Transportation

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Rutgers, The State Univ. of New Jersey

Kevin Flora
Senior Bridge Engineer, Structure Maintenance and Investigations
California Department of Transportation (CALTRANS)

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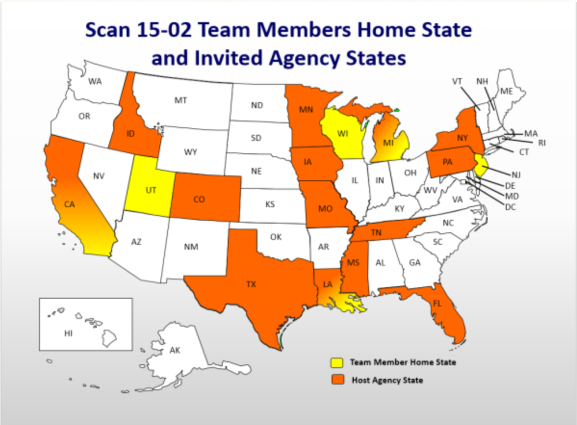
Geotechnical Engineer Specialist
Utah Department of Transportation

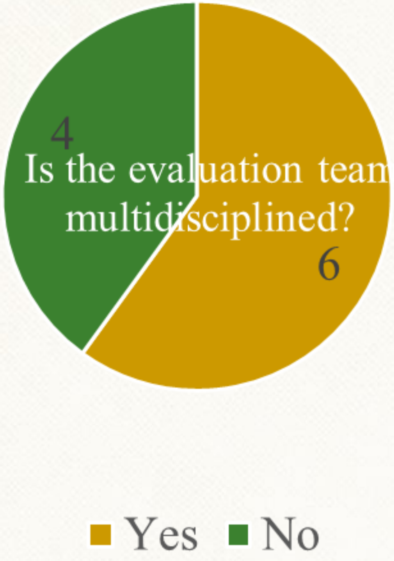
Rick Marz
The head of Wisconsin Inspection Program
Bureau of Structures Maintenance Chief
Wisconsin DOT

Stephanie Cavalier, P.E.
Bridge Scour Manager
Louisiana Department of Transportation and Development (LADOTD)

Team's Approach



Desk Scan, Literature Search, Identify Agencies and prepare questions.

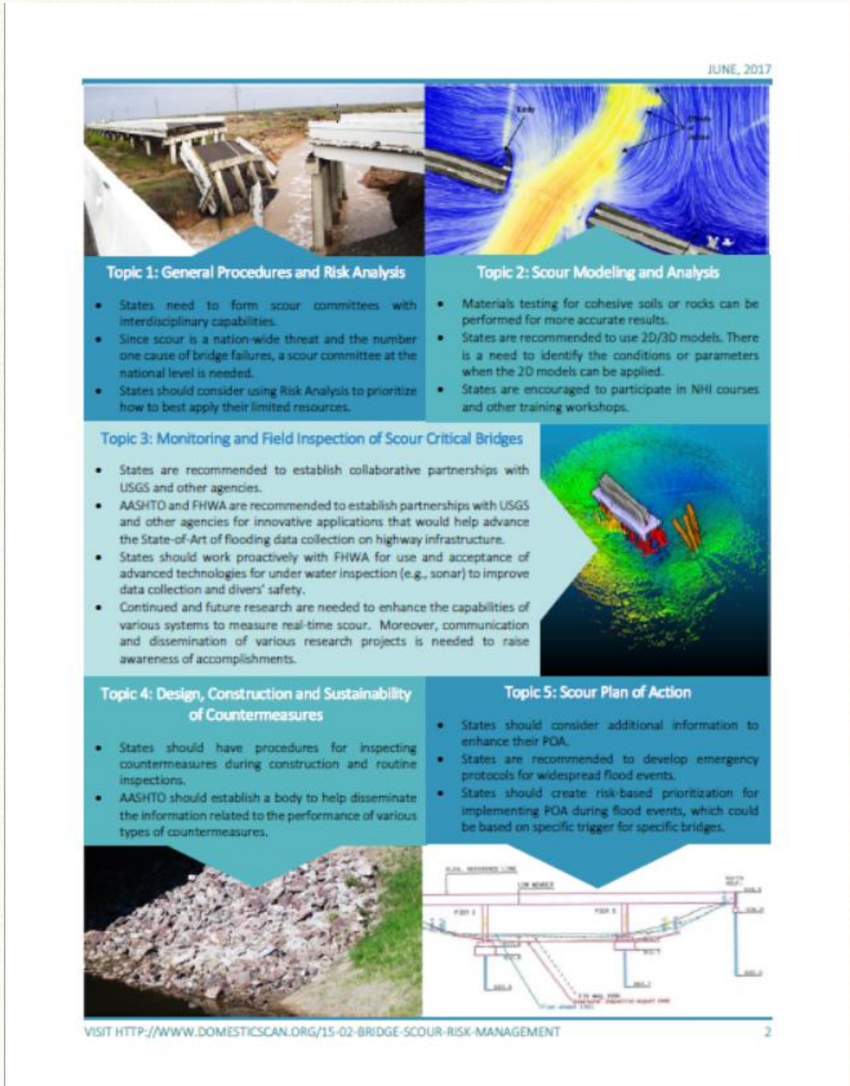


Combine Responses

Host Workshop

Scan Recommendations

- General Procedures and Risk Analysis
- Scour Modeling and Analysis
- Monitoring and Field Inspection
- Design, Construction and Sustainability of Countermeasures
- Scour Plans of Action



JUNE, 2017

Topic 1: General Procedures and Risk Analysis

- States need to form scour committees with interdisciplinary capabilities.
- Since scour is a nation-wide threat and the number one cause of bridge failures, a scour committee at the national level is needed.
- States should consider using Risk Analysis to prioritize how to best apply their limited resources.

Topic 2: Scour Modeling and Analysis

- Materials testing for cohesive soils or rocks can be performed for more accurate results.
- States are recommended to use 2D/3D models. There is a need to identify the conditions or parameters when the 2D models can be applied.
- States are encouraged to participate in NHI courses and other training workshops.

Topic 3: Monitoring and Field Inspection of Scour Critical Bridges

- States are recommended to establish collaborative partnerships with USGS and other agencies.
- AASHTO and FHWA are recommended to establish partnerships with USGS and other agencies for innovative applications that would help advance the State-of-Art of flooding data collection 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 are 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

- States should have procedures for inspecting countermeasures during construction and routine inspections.
- AASHTO should establish a body to help disseminate the information related to the performance of various types of countermeasures.

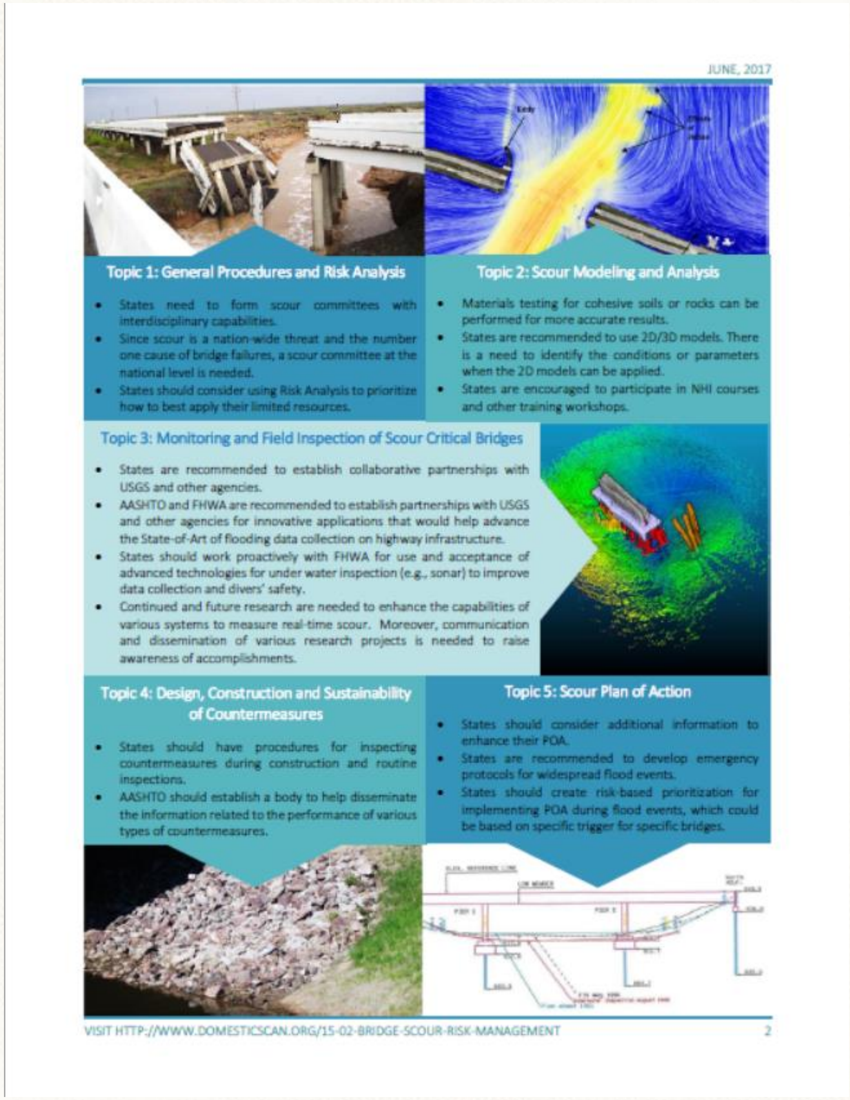
Topic 5: Scour Plan of Action

- States should consider additional information to enhance their POA.
- States are recommended to develop emergency protocols for widespread flood events.
- States should create risk-based prioritization for implementing POA during flood events, which could be based on specific trigger for specific bridges.

VISIT HTTP://WWW.DOMESTICSCAN.ORG/15-02-BRIDGE-SCOUR-RISK-MANAGEMENT 2

Scan Recommendations

- Final Report will be available on the web at www.domesticscan.org later this summer



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General MDOT Overview

			PAGE 1 OF 9
MDOT Michigan Department of Transportation	GUIDANCE DOCUMENT	IDENTIFIER	EFFECTIVE DATE
		10231	06/04/14
		SUPERSEDES	DATED
		NEW	06/04/14
RESPONSIBLE ORGANIZATION:	Bureau of Highway Development – Design – Bridge Development		
SUBJECT:	Coding and Managing Bridges for Scour Vulnerability		

Purpose

The purpose of this policy is to identify MDOT and local agencies' responsibilities for the management of bridges vulnerable to scour. MDOT's goals for management of scour susceptible bridges are:

- Ensure the safety of individual bridges and bridge approaches crossing waterways.
    - Perform Scour Evaluations following procedures listed in HEC -18.
    - Develop and implement Plan of Actions (POA).
    - Address critical findings by initiating follow up actions such as scour monitoring, mitigation, or replacement.
- Reduce the network wide risk of bridge scour and minimize future flood damage to bridges.
    - Utilize data driven, risk-based asset management. See MDOT Scour Risk Assessment, or Local Agency Scour Risk Assessment documents
    - Prioritize scour mitigation and countermeasures given fiscal resources and constraints.
    - Design and place countermeasures to reduce the risk of bridges that are scour critical.
    - Consider bridge replacement as an option for mitigation if one of the following conditions are met:
        - The structure is a replacement candidate due to condition.
        - The structure is ranked both highly critical and highly vulnerable during the risk assessment and countermeasures will not reduce the risk to acceptable levels.
        - Countermeasures are not feasible due to cost, constructability, environmental constraints or backwater concerns.

MDOT Michigan Department of Transportation BRIDGE DEVELOPMENT

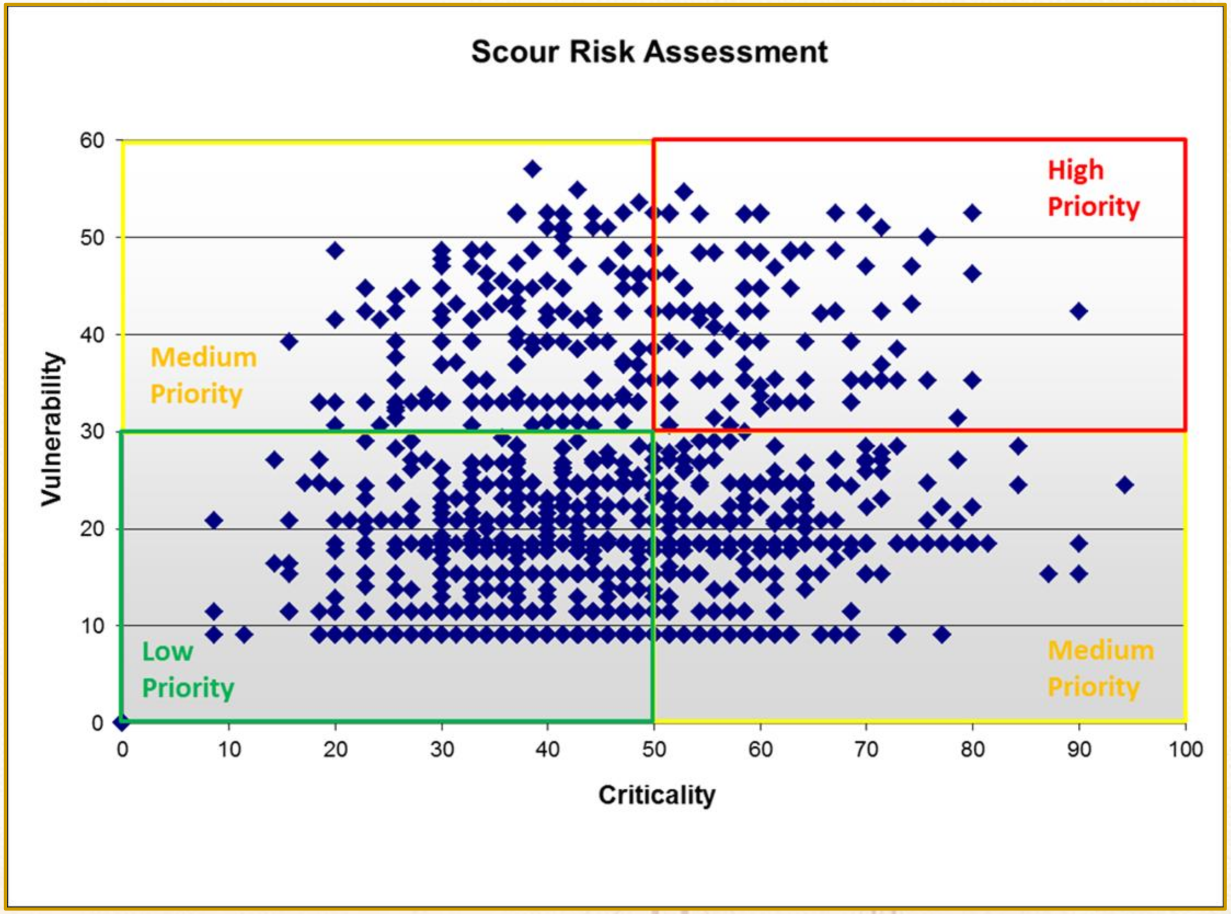
Risk Management

- Vulnerability Categories
  - Skew
  - Channel Protection
  - Footing Type
  - Number of Substructure Units
  - Scour Rating (NBI 113)
  - Soil Type
  - Scour Remediation
  - Presence of scour during inspection
  - Waterway Adequacy

Risk Management

- Criticality Categories
  - Highway Classification
  - Traffic Volume
  - Detour Length
  - Deck Area
  - Economic Importance (Truck Traffic and Marine Navigation)

Risk Management



MDOT – Hydraulic Unit
Scour Process

- Original process developed through the Scour Committee in the 1990's.
- Level I analysis conducted for all structures with spans greater than 20 feet.
- Level II analysis conducted for all structures not coded 8 for item 113.
- Majority of original analysis done by Consultant contract in the 1990's.
- Scour analysis/rating often re-reviewed with any associated bridge rehabilitation and/or CPM work.
- New Item 113 coding guidance document developed by the Scour Committee in 2014.

MDOT – Hydraulic Unit
Scour Process – Level I

- Level I forms originally developed with guidance from FHWA's HEC-18 and HEC-20 manuals.
- Approved through the MDOT Scour committee in the 1990's.
- Overall scour and stream stability through site visit, aerial photographs, construction records, etc.
- Many single span structures rated 8 off original Level I analysis through engineering judgement, which we often re-review at project level.
- Construction records often required to verify pile length or if piles were even constructed.

MICHIGAN DEPARTMENT OF TRANSPORTATION
LEVEL ONE SCOUR ANALYSIS WORKSHEET

Date:_______ By:__________ Structure No:____ Control Section:_______

Job No.________ Route:__________ Watercourse:_______________________

All references are to HEC-20, 3rd Edition.

Data Collection

____ Plans
____ Bridge Inspection Reports (Maintenance Division)
____ Underwater Inspection Reports (Maintenance Division)
____ Review existing items 60, 61, 71, 92, 93, and 113 of the NBIS
____ Review available construction, design, and maintenance files for repair and maintenance work done on structure

Field Investigation Date:__________

____ Channel bottom width approximately one bridge span upstream = _______ feet

____ Overbank and channel Manning's roughness coefficients

________ Left _________ Channel _________ Right

____ Is there sufficient riprap? Abutments ________ Piers _________

____ Photographs

____ Cross sections at upstream and downstream faces of bridge

Comments:

Stream Characteristics

___ Complete the attached Figure 2.6 from HEC-20.

Comments:

Land Use: Identify the existing and past land use of the upstream watershed:

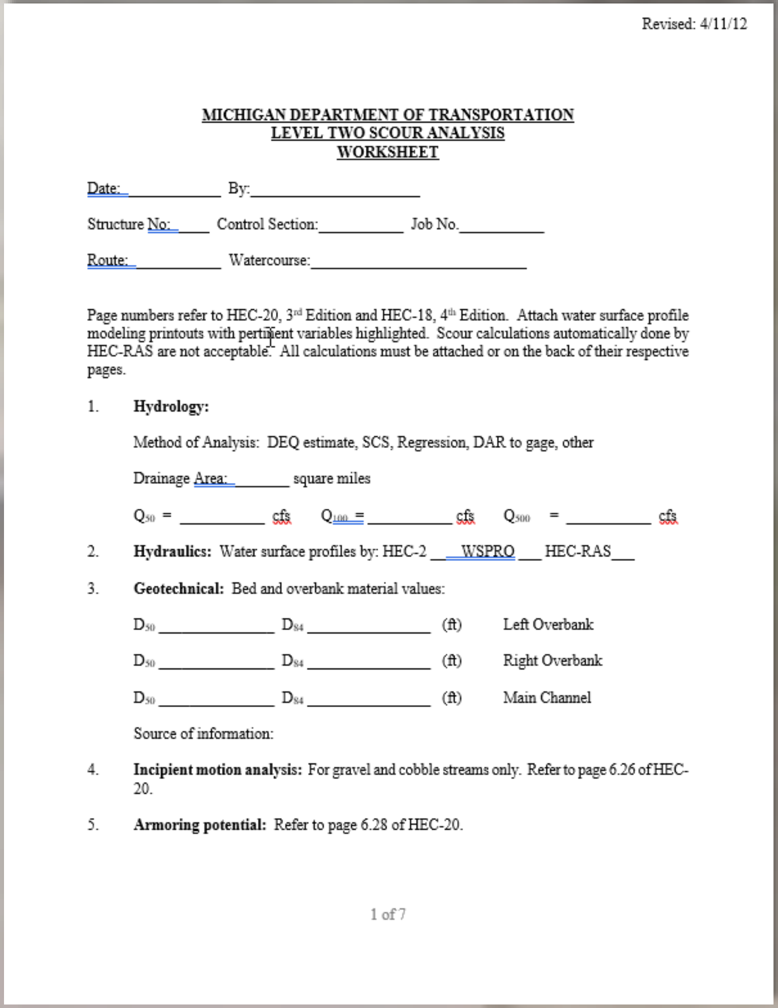
Urban Area Yes__No__ Comments:
Sand and Gravel Mining Yes__ No__ Comments:
Undeveloped Land Yes__No__ Comments:

1 of 3

MDOT – Hydraulic Unit

Scour Process – Level II

- Most of the older analysis were done with HEC-2 or WSPRO.
- Many of the analysis were performed prior to DEQ providing discharge information.
- Countermeasure design and recommendations provided with the Level II analysis.



Revised: 4/11/12

MICHIGAN DEPARTMENT OF TRANSPORTATION
LEVEL TWO SCOUR ANALYSIS
WORKSHEET

Date:__________ By:__________________

Structure No:____ Control Section:_________ Job No._________

Route:_________ Watercourse:______________________

Page numbers refer to HEC-20, 3rd Edition and HEC-18, 4th Edition. Attach water surface profile modeling printouts with pertinent variables highlighted. Scour calculations automatically done by HEC-RAS are not acceptable. All calculations must be attached or on the back of their respective pages.

1. **Hydrology:**

   Method of Analysis: DEQ estimate, SCS, Regression, DAR to gage, other

   Drainage Area:______ square miles

   Q_{50} = _________ cfs Q_{100} = _________ cfs Q_{500} = _________ cfs

2. **Hydraulics:** Water surface profiles by: HEC-2 __ WSPRO __ HEC-RAS__

3. **Geotechnical:** Bed and overbank material values:

   D_{50} ____________ D_{84} ____________ (ft) Left Overbank

   D_{50} ____________ D_{84} ____________ (ft) Right Overbank

   D_{50} ____________ D_{84} ____________ (ft) Main Channel

   Source of information:

4. **Incipient motion analysis:** For gravel and cobble streams only. Refer to page 6.26 of HEC-20.

5. **Armoring potential:** Refer to page 6.28 of HEC-20.

1 of 7

MDOT – Hydraulic Unit
Scour Process – MiBridge RFA

- Unit often consulted with items noted in routine bridge inspection through RFA process.
- We may re-evaluated Item 113 rating, if applicable.

MDOT – Hydraulic Unit
Scour Process – Bridge Rehabilitation/CPM

- In-house PM's generally ask unit to review for countermeasure placement with any rehab/CPM work.
- We may re-evaluated Item 113 rating, if applicable.
- Perform site visit to verify if countermeasures are in place and assess overall stream stability. Will make countermeasure recommendations, as necessary.

MDOT – Hydraulic Unit
Scour Process – Bridge Rehabilitation/CPM

- With new Item 113 coding guidelines, there has been a stronger push to place more robust countermeasures to adjust ratings to either 7 or 8 for scour critical structures.
- Articulating Concrete Block (ACB) has been used at multiple single span structure locations to change rating to at least a 7.

MDOT – Hydraulic Unit

Scour Process – Bridge Rehabilitation/CPM - Countermeasure Evaluation

- Noticed problems with rock riprap dissolution, specifically with pure limestone riprap.
- Sulfate durability testing adding to our SP in 2016.

MDOT – Hydraulic Unit
Scour Process – Bridge Rehabilitation/CPM - Countermeasure Evaluation

- Noticed issues with ACB installations.
- ACB has very tight construction and failure tolerances.

MDOT – Hydraulic Unit

Scour Process – New Bridge Construction

- Level II scour evaluation done for all new bridge construction.
- Hydraulic analysis performed in 1D HEC-RAS.
- Scour calculations typically done in Microsoft Excel spreadsheets or MathCAD.
- Countermeasure design and recommendations done for all new structures, however, foundation depths do not rely on countermeasures.
- Scour memo provided to Bridge PM and Geotechnical Unit Supervisor.
- Structure re-coded (if applicable) at post-construction inspection.

COMPUTE 100 YR SCOUR (1% CHANCE) FOR PROPOSED STRUCTURE:

Compute 100 yr. Contraction Scour:

LIVE BED or CLEAR WATER?

$V_c = K_u y^{1/6} D^{1/3}$ (HEC-18, Eq. 6.1)

K_u =	11.17		(English)
y =	23.41	ft.	(Hyd. Depth, Sect. 40)
D = D_{50} =	5.91E-04	ft.	(Soil Boring B-8, G2 Consulting Group)
V =	4.75	ft/s	(Avg. Vel., Sect. 40)

V_c = 11.17 * 23.41 $^{(1/6)}$ * 5.91E-04 $^{(1/3)}$ = 1.59 ft/s

V_c < V TRUE

==> LIVE BED

USE SECTION 50 AS 1[st] FULL DEVELOPED CROSS-SECTION:

Q_1 =	22539.67	cfs	
A_1 =	4746.41	sft.	
W_1 =	190.26	ft.	
y_1 =	A_1/W_1 =	24.95	ft.

BRIDGE SECTION DOWNSTREAM

Q_2 =	27313.15	cfs	
A_2 =	5241.60	sft.	(Bridge open area)
W_2 =	228.91	ft.	(Bridge width)
y_0 =	A_2/W_2 =	22.90	ft.

FIND EXPONENT, K_1:

$V^* = (g y_1 S_1)^{1/2}$ (HEC-18, pg. 6.10)

g =	32.2	ft/s²	
y_1 =	24.95	ft.	(Hydraulic Depth, Sect. 50)
S_1 =	0.00013	ft./ft.	(Energy Slope, Sect. 50)

V^* = (32.2 ft/s² * 24.95 ft. * 0.00013 ft/ft) $^{1/2}$ = **0.32** **ft/s**

MDOT – Geotechnical Services Section

- Request for geotechnical investigation/engineering is initiated from Bridge Design
- What is the scope of work?
  - Scour protection retrofit of existing structure?
  - Replacement?
- Evaluate the existing information
  - Is it available?
  - If so, is it adequate or is more field investigation needed?
- Need to get the preliminary scour depths/elevations from the Hydraulics Unit

MDOT – Geotechnical Services Section
Field Investigation

- Where are the existing substructures?
- Where are the proposed substructures?
- Where can we drill?
  - Lane restrictions
- How deep are the footings?
- What type of foundation is anticipated?
  - Deep foundation typically needed for scour critical structures (piles, drilled shafts, micropiles)
- If pile supported, what is the preliminary factored resistance needed for the replacement bridge?

MDOT – Geotechnical Services Section
Field Investigation

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MDOT – Geotechnical Services Section

- Laboratory Testing
  - Grain size analysis, with hydrometer
  - Results sent to the Hydraulic Unit
- The Hydraulic Unit then reanalyzes their scour analysis
- If necessary, the scour analysis results are then discussed in an interdisciplinary meeting with Hydraulics, Bridge Design and Geotechnical

MDOT – Geotechnical Services Section

- The scour results are then used in the geotechnical analysis for the foundation
  - Geotechnical analysis at design flood (100 year event) and check flood (500 year event)
  - Evaluate lateral pile capacity, buckling, nominal pile driving resistance and minimum pile penetration elevation for piles first.
  - If piles aren’t an option then look to drilled shafts or micropiles, depending on site conditions.
- Constructability aspects of scour countermeasures are also evaluated.
  - If a scour retro fit, will the installation of the countermeasures affect/compromise the existing structure
  - How will the countermeasures be constructed? Is it feasible?