Ohio Department of Transportation

1980 West Broad Street, P.O. Box 899, Columbus, Ohio 43216-0899

September 8, 2008

To: Ohio Bridge Inspectors, Program Managers, Team Leaders and Hydraulic Engineers
From: Tim Keller, Administrator, Office of Structural Engineering
By: Mike Brokaw, Bridge Inspection Engineer
Re: Scour Plan of Action (POA)

The following is further guidance regarding scour and the scour plan of action required for those scour-critical structures (BR-87 Item #74 is 3, 2, 1 or 0). The plan of action on pages 11 through 15 is also available in word format on the Office of Structural Engineering website.

1.1. Inspection of Bridges over Water

Nationwide, more bridges are lost each year due to scour than any other reason. Many times, these bridge losses occur during regional or localized flooding and their loss from the transportation system can make recovery from the original weather event even more difficult. To combat this loss of structures from the transportation system and protect our valued infrastructure, Ohio uses a threefold approach:

First an office assessment and management priority assessment of the bridge's vulnerability to scour is made so that critical bridges can be identified for closer monitoring and scour countermeasures.

Second a field review, scour vulnerability analysis, and prioritizing of bridge substructure units are used to verify the structural condition of the underwater elements, to verify integrity of their foundations and identified for closer monitoring and anti-scour maintenance needs.

Third a detailed scour analysis of bridges very susceptible to scour is essential. Additional monitoring may be required.

Other means of an underwater inspection

1.1.1. Assessment for Bridge Scour

One of the more effective ways of preventing the loss of a bridge due to scour failure is to identify those bridges most likely to be vulnerable to scour. With this determination, called a scour assessment, the bridge inspectors and owners can concentrate inspection/monitoring efforts and remedial actions to mitigate conditions at bridges with critical vulnerability. Scour assessments are required by the NBIS because they are deemed to be a key part of a comprehensive underwater inspection program.

The main purpose of the scour assessment of an existing bridge is to determine whether the bridge is vulnerable to scour. A scour critical bridge is one whose foundation(s) has been determined to be unstable for the predicted scour conditions.

There are two areas to code for bridge scour; the Bridge Inventory Manual (Item 74, Scour Critical Bridge) and this manual in Part II, Physical Assessment, Item 40 and 48, Scour. The Inventory data in the coding manual is to be used to record the bridge's vulnerability against scour. The physical condition is to be rated

with the inspection report. The scour susceptibility has corresponding codes with respect to the Inventory form (BR-87), Item 74. The four categories and corresponding Scour Critical Susceptibility (Item 74) codes are as follows:

1. Low Scour Risk
   Item 74 corresponding codes 4, 5, 7, 8, 9
2. Scour-susceptible (Analysis needed)
   Item 74 corresponding codes 6
3. Scour-critical (Scour plan of action is required)
   Item 74 corresponding codes 0, 1, 2, 3
4. Unknown Foundations
   Item 74 corresponding codes U

The results of the scour assessment are to be used in conjunction with information from regular and underwater bridge inspections to ensure that current stream (and bridge) conditions are used to evaluate the ongoing vulnerability of the bridge. Changes in stream and streambed conditions (including, but not limited to: scour depth/location, aggradation, degradation, debris, installation of countermeasures, etc,) discovered during inspection can dramatically affect the vulnerability of a substructure unit foundation and must be considered. Accordingly, the inspection information and the scour assessment must be used together for the evaluation of the overall safety of the bridge. The inspection information is needed to validate the input parameters and results of the scour assessment. The scour assessment results are used to determine if scour poses a threat to the bridge.

The two acceptable methods of performing scour assessments are:

1. Sour evaluation-Observed Scour for Bridges Methodology
2. Scour analysis-Theoretical Scour Calculations

1.1.2. Scour Evaluation Using Observed Scour Assessment for Bridges

The Department developed an alternative method of scour assessment based upon the observance of geomorphic, hydrologic, and hydraulic features at the bridge site. This assessment is seen as a cost effective approach to meeting the NBIS requirements for evaluating existing bridges without analytical scour computations. The following approach is recommended for the development and implementation of a program to assess the vulnerability of existing bridges to scour:

Bridges which are particularly vulnerable to scour failure should be identified. These particularly vulnerable "scour-susceptible" bridges are:

1. Bridges currently experiencing scour or having a history of scour problems during past floods as identified from maintenance records, local experience, bridge inspection records, etc.

2. Bridges over erodible streambeds and streams with design features that make them vulnerable to scour, including:

   - Piers and abutments designed with spread footings or short pile foundations
   - Superstructures with simple spans or nonredundant support systems that render them vulnerable to collapse in the event of foundation movement; and

- Bridges with inadequate waterway openings or with designs that collect ice and debris. Particular attention should be given to structures where there are no relief bridges or embankments for overtopping, and where all water must pass through or over the structure.

3. Bridges on aggressive streams and waterways, including those with:
   - Active degradation or aggradation of the streambed
   - Significant lateral movement or erosion of stream banks
   - Steep slopes or high velocities
   - In stream sand and gravel and other materials
   - Mining operations in the vicinity of the bridge
   - Histories of flood damaged highways and bridges
   - Bridges that regularly collect significant debris on piers

4. Bridges located on stream reaches with adverse flow characteristics, including:
   - Crossings near stream confluences, especially bridge crossings of tributary streams near their confluence with larger streams
   - Crossings on sharp bends in a stream

Prioritize the scour-susceptible bridges and bridges by foundation types. To determine those foundations which are stable for the scour assessment, the following guidance is provided to the substructure unit foundation:

1. For spread footing foundations:
   - If the bottom of footings is not in the flood plain - Not scour critical
   - If the bottom of footings founded on soil or erodible rock within the flood plain - Scour critical
   - If the bottom of footings is founded on rock or is socketed into hard shale within the flood plain – Not scour critical

2. For deep foundations (piles or caissons):
   - If piles or caisson are bearing or are socketed in to rock - Not scour critical
   - If the piles are friction piles, a calculated scour analysis should be performed. Field evaluation will greatly influence coding (see Physical Evaluation, Item 40, for more discussion) May become Unstable and Scour Critical

Enter the results of the scour assessment in the BMS in accordance to The ODOT's Bridge Inventory Manual. Bridges assessed as "low risk" for Item 74 (scour-critical bridges) should be coded as a 9, 8, 7, or 5.

Bridges considered scour-critical based on an evaluation should be coded as a 0, 1, 2, or 3 for Item 74

Bridges with unknown foundations (except for interstate bridges) should be coded as a "U" in Item 74, indicating that a scour evaluation/calculation has not been made. It is recommended that only those bridges with unknown foundations which have observed scour, receive scour evaluation prior to the deployment of instrumentation currently being developed to determine foundation type and depth.

1.1.3. Scour Analysis Using Theoretical Scour Calculations

A scour assessment of a bridge using the theoretical scour calculations is a method based on hydrologic and hydraulic analyses of the stream and bridge opening. The method is described in The Bridge Design Manual in section 203.3 Scour and FHWA publication NHI 01-001 "Evaluating Scour at Bridges" fourth edition. In good design practice, the bottom elevations of foundations are established considering the calculated scour depth. These design scour computations may be used for the scour assessment and should remain in the bridge inspection file.

If existing scour at the bridge is deeper than the calculated scour, the theoretical scour analysis is not correctly modeling the real conditions and the scour assessment should be re-analyzed. Any significant change in site conditions should also warrant re-visiting the scour calculations.

For the scour assessment, the following guidance is provided for checking the resultant calculated depth of the theoretical scour to the substructure unit foundation:

For spread footing foundations:

- If the calculated scour is above the bottom of footings - Not scour critical
- If the calculated scour is below the bottom of footings founded on soil or erodible rock - Scour critical

For deep foundations (piles or caissons):

- If the calculated scour is above the bottom of footings - Not scour critical
- If the calculated scour is below the bottom of footing and above the bottom of pile/caisson a structural analysis of the foundation unit is needed to determine its stability. If not stable - Scour Critical
- If the calculated scour is below the bottom of pile/caisson. Unstable- Scour Critical

1.1.4. Scour Plan of Action for Scour Critical Bridges

Bridges considered scour-critical based on an evaluation/assessment coded as a 0, 1, 2, or 3 for Item 74 shall have a Scour Plan of Action. The plan shall include:

- Timely installation of temporary scour countermeasures such as monitoring or riprap and monitoring.
- Plans for monitoring scour-critical, unknown foundation, during, and after flood events, and for blocking traffic, if needed, until scour countermeasures are installed.
- Immediate bridge replacement or the installation of permanent scour countermeasures depending upon the risk involved.

A Scour Plan of Action form is provided

1.1.4.1. Scour Plan of Action form definitions

SFN- Structural file number
Bridge No. - County-Route-Section
Owner - Name of agency who owns the Bridges.
Facility Carried - Name the road the bridge carries.

Waterway - Name the creek/river that intersects the bridge**.**
Completed By - Name of agency that is responsible for completing the Plan of Action.
Date - Provide the date of when the Scour Plan of Action form was completed.

Section 1 - Scour Vulnerability Rating.
The evaluations should provide the details as to why the bridge is considered scour critical

- **Scour Evaluation Summary -** Summarize why the bridge became/is scour critical and provide some details of the present hydraulic concerns at the bridge site.
- **Scour History -** Report any known history of scour problems, drift/debris problems at the bridge site, channel meandering, bank erosion, approach washout, or any channel degradation and mining operation in proximity to site, etc.
- **Foundation type -** Identify the bridge foundation type.
- **Foundation material.** Identify the foundation material as best as possible. Foundation Reports and/or Log of Test Borings are a good source for this information. The county may also want to do a field visit to assess the ground material. This entry also can be left unknown.
- **Scour review** - Provide any known past hydraulic studies
- **Structural assessment** - Provide any known past structural assessment studies in relation to the scour potential and the date done at the bridge site.
- **Critical Elevation** - If any study provides an elevation in which the bridge becomes unstable, provide that information.
- **Geotechnical Assessment -** Provide any known past geotechnical assessment studies and the date done at the bridge site.
    - **Critical Elevation** - If any study provides an elevation in which the bridge foundation becomes unstable, provide that information.

Section 2 - Scour Countermeasure Recommendation
Provide countermeasures in accordance with guidelines from Hydraulic Engineering Circular 18 and 23 (HEC 18 and HEC 23) published by the Federal Highway Administration.

- **Completed Scour Countermeasure** - Indicate and give details and dates of any recent scour countermeasure that has been implemented in regards to addressing the current scour critical status of the bridge. All applicable studies, lead agencies, and as-built should be noted.
- **Proposed Scour Countermeasures**
    - **Countermeasures Not Required** - Indicate and provide details as to why no scour countermeasures are required at this time.
    - **Install Scour Countermeasures -** Indicate and provide details and dates including reference to any hydraulic, structural or geotechnical studies that have been completed for the purpose of scour mitigation.
- **Close Bridge** - Provide dates, details and detour.

Section 3 – Countermeasure Implementation Schedule
Identifies the installation of the proposed countermeasures to be preformed by contract work or work to be done by in-house maintenance forces. An estimated date of completion should be given.

Section 4 – Monitoring Plan
Monitoring is an option of providing scour countermeasure at a bridge site. It can be used as the scour mitigation proposal or as a supplement to a more permanent scour countermeasure. Monitoring a bridge for

scour encompasses a large and varied amount of options. It can be as simple as inspecting the bridge for hydraulic damage on a regular interval and/or after a significant hydraulic event, or as complex as monitoring the bridge at different discharge levels using various monitoring devices. A monitoring plan could be the precipitous leading to Bridge Closure.

- **Monitoring Plan Summary** - Provide details of the extent of monitoring. What information the monitoring will provide, and what action will be implemented if the information indicates a scour problem?
- **Monitoring Authority** - Identify responsible agency for implementation and action of monitoring. Indicate who is in charge of overseeing and carrying out the monitoring plan.
- **Regular Inspection program** - Indicate the frequency of the monitoring and will cross sections and comparison of historical cross sections be required. Indicate the items to watch for.
- **Increased Inspection Interval** - Indicate the need for and increased interval and items to watch for.
- **Fixed Monitoring Devices** - Identify the type of instrument. This type of monitoring can be dependent on increasing channel flows and an identified discharge that could potential cause scour concerns. The monitoring or interval is usually increased as discharge increases.
- **Other Monitoring Program** - Identify any other methods of monitoring.

Section 5 – Bridge Closure Plan

- **Closure Plan Summary** - Provide summary of closure.
- **Scour Monitoring Criteria for Considering Bridge Closure** - Should be filled out if monitoring is used in consideration for bridge closure.
- **Person Responsible for Closure** - Identify responsible person/position responsible for closure.
- **Contact People** - Identify responsible person/position in charge of the bridge during closure.
- **Responsible for re-opening after inspection** - Identify responsible person/position responsible for re-opening the bridge.

Section 6 – Detour Route

- **Detour Route Description -** Provide a map with a viable detour in case of bridge closure/failure.
- **Length of Detour** - Provide length of detour in miles. A list of signs needed for closure and locations on detour map.
- **Bridges on Detour Route** - Provide a list of Bridges along the detour that are over water.
- Bridges Number
    - **Waterway** - Identify the waterway beneath the bridge.
    - **Load Rating or other restriction**

1.1.4.2. Evaluation of Scour Countermeasures

The Department's coding instructions for BMS Item indicate that the scour countermeasures are to be properly designed or verified through analysis before they can be considered as effective against scour.

PLAN OF ACTION AND SCOUR COUNTERMEASURES

Scour countermeasures are needed at the bridge to make it less vulnerable to either damage or failure from scour. The plan of action should be developed among the hydraulic, geotechnical, and structural engineers. Examples include the following:

- Monitor for scour during regular bridge inspection
- Increase monitoring frequency
- Temporary countermeasures - riprap and monitor
- Selection of scour countermeasures
- Scheduling of scour countermeasure construction

For existing bridges, recommended countermeasures should be based upon the risk associated with potential scour:

- Riprap at piers and/or abutments with monitoring after flood events (visual and /or cross sections),
- Installation of instrumentation during and after flood events
- Guide banks
- Channel improvements
- Strengthening bridge foundations
- Relief bridges (structures used to handle the overflow)

1.1.5. Underwater Inspections

Just as regularly scheduled Routine Inspections include the inspection and evaluation of all pertinent bridge components to ensure that the structure continues to satisfy present safety and service requirements. The purpose of underwater inspections is to provide similar information on underwater portions of a bridge to evaluate their overall safety and, especially, to assess the risk of failure due to scour.

1.1.5.1. Description of Underwater Inspections

During periods of low flow, underwater members will be inspected visually and by feel using probing rods, sounding lines, or other hand tools. When the physical condition of the substructure members or the integrity of their foundations cannot be determined using the probing tools due to high water, high flow, turbidity, etc., inspection by divers is required. New technology, including ground sensing radar, ultrasonic techniques, remote video recorders, and others are proven alternative methods for underwater inspections of substructure foundations for limited situations.

Key information to be determined in every underwater inspection (either by probing or diving) is the top of streambed relative to the elevation of the substructure foundations. Because scour can vary significantly from one end of a footing to the other, a single probing reading is not sufficient. Baseline streambed conditions should be established by waterway opening cross sections and by a grid pattern of probing readings around the face of a substructure unit. This baseline information is essential for future monitoring and assessment. The current streambed conditions and changes since the last inspection are critical inputs to the bridge scour assessment.

Each bridge should have local benchmarks established near each substructure unit to enable inspectors to quickly and accurately determine the depth of adjacent scour. These benchmarks can be as simple as a painted line or PK survey nail driven into the wall in a place visible during high water. The location of

these scour-monitoring benchmarks should be referenced in the inspection records. Use previously established benchmarks when possible to provide a long-term record of scour conditions. If new benchmarks need to be established, provide conversion from new to old datum.

During Routine Inspections, particular attention should be given to foundations on spread footings where scour or erosion can be much more critical than at deep foundations on piles or caissons. However, be aware that scour and undercutting of a pier or abutment on a deep foundation can also be quite serious. The foundation's vertical support capacity normally will not be greatly affected unless the scour is excessively severe, but the horizontal stability may be jeopardized. This condition becomes particularly unstable when erosion has occurred on only one face of the substructure unit, leaving solid material on the opposite face. Horizontal loads may also have debris, or rock fills piled against or adjacent to substructure units whose loads were obviously not provided for in the original design. Such unbalanced loading can produce an unstable condition, requiring corrective action.

BMS AND UNDERWATER INSPECTIONS: The Bridge Management System uses the data items to record each underwater inspection and to verify Ohio‘s compliance with the underwater inspection reporting requirements of NBIS. The date of the underwater inspection must be entered into the BMS.

1.1.5.2. Maximum Intervals for Underwater Inspections

Underwater inspections are intended to investigate two critical issues regarding the condition of bridge substructures located in water:

- The condition of structural components (including pier shaft, abutment walls, footings, etc.) under water.

- The integrity of the substructure foundation (including underlying soil, piles, caissons, etc.) against scour at each substructure unit in water.

The inspection of the foundation of a substructure unit and the determination of its ongoing resistance to scour is critical for the overall safety of the bridge. Because the integrity of the foundation against scour can suddenly and dramatically change in a relatively short time (as compared to physical condition of the structure components), shorter intervals for inspection of the foundation are warranted. The recommended intervals for underwater inspection of the foundation of substructure units for bridges over water are based upon a scour assessment of each unit.

The condition of the structural components can routinely be verified during the investigation of the foundation material. All bridges with substructure elements submerged greater than five feet in depth are to have an underwater inspection. The frequency of underwater inspection of a substructure unit is not to exceed 5 years (60 months).

1.1.6. High Water Inspections

The program manager is to establish an internal procedure to monitor scour critical bridges during or immediately after periods of high water. The following elements are recommended for consideration as part of the procedures:

- A list and, preferably a map, of scour critical bridges that are to be monitored during periods of high water. Other bridges that are not classified as scour critical but that may have scoured previously or that may be susceptible to debris and aggradation should be considered for inclusion.
- Because high stream flows can be very localized and information about its severity and extent may not be immediately available, a method of reporting the occurrence and extent of high water is needed. Many times the first responders are maintenance forces; they can be trained to report high water events to the program manager. This method is useful for prioritizing structures to be checked by bridge inspectors.
- Local benchmarks established at scour critical bridges can enable non-bridge inspectors to record and report the height of water. The list of scour critical bridges could also indicate the location of the benchmarks and the water heights at which scour inspections are warranted. In addition, the benchmarks enable inspectors to quickly gauge the progress of scour at a substructure.
- A high water inspection plan can improve the program manager's response, especially in times of area-wide flooding where inspection resources may be limited.

SCOUR PLAN OF ACTION

BRIDGE SCOUR PLAN OF ACTION				
SFN	**Bridge No.**	**Owner**	**Facility Carried**	**Waterway**

Plan of Action Completed By:	**Date of Completion**:

1. SCOUR VULNERABILITY RATING
Scour Evaluation Summary:
Scour History:
a. **Foundation Type** ☐ Spread footing ☐ Pile Extension ☐ Footing on Piles ☐ Unknown
b. **Foundation Material** ☐ Known _____ ☐ Unknown
Scour Review: Done By: Date:
Structural Assessment: Done By: Date: Critical Elevation: _____
Geotechnical Assessment: Done By: Date: Critical Elevation: _____

3. SCOUR COUNTERMEASURE RECOMMENDATION

Completed Countermeasures:

Proposed Countermeasures:

☐ **Countermeasures Not Required. (Please explain)**

☐ **Install Scour Countermeasures** (See 4 and 5)

	Estimated Cost
___Riprap with monitoring program	$
___Guide bank	$
___Spurs	$
___Relief bridge / Culvert	$
___Channel improvements	$
___Monitoring	$
___Monitoring device	$
___Check Dam	$
___Substructure Modification	$
___Bridge replacement	$
___Other _____	$

3. COUNTERMEASURE IMPLEMENTATION SCHEDULE

Countermeasure Implementation Project Type:

☐ Proposed Construction Project

Lead Agency

☐ Maintenance Project

Sale Date:

Other scheduling information:

4. MONITORING PLAN

Monitoring Plan Summary:

Monitoring Authority:

☐ **Regular Annual Inspection Program** ☐w/surveyed cross sections
Items to Watch:

☐ **Increased Inspection Interval of _____ mo.** ☐w/surveyed cross sections
Items to Watch:

☐ **Underwater Inspection Program** **Frequency _____ mo.**
Items to Watch:

☐ **Fixed Monitoring Device**
Type of Instrument:
Installation location(s):
Scour-critical discharge:_____
Action required if scour-critical elevation detected:

☐ **Other Monitoring Program**
Type: ☐ Visual
☐ Instrument
☐ Portable ☐ Geophysical ☐ Sonar
☐ Other gages

Flood monitoring required: ☐ Yes ☐ No

Flood monitoring event defined by:
☐ Discharge over _____
☐ Stage _____
☐ Elev. measured from _____

Frequency of flood monitoring: ☐1 hr. ☐3 hr. ☐6 hrs. ☐ Other
Scour critical elevation:
Action required if scour-critical elevation detected:

5. BRIDGE CLOSURE PLAN

Closure Plan Summary

Scour Monitoring Criteria for Consideration of Bridge Closure:

- ☐ Water surface elevation reaches _____
- ☐ Overtopping road or structure
- ☐ Scour Measurement Results / Monitoring Device
- ☐ Loss of Riprap
- ☐ Observed amount of Settlement
- ☐ Loss of Road Embankment
- ☐ Debris Accumulation
- ☐ Other _____

Person / Area Responsible for Closure:

Contact People (Name & Phone No.):

Responsible for re-opening after inspection:

6. DETOUR ROUTE

Detour route description (route number, from - to, etc.) – attach map.

Detour length

Signs required for closure:

Bridges on Detour Route:

Structural File Number	Bridge Number	Waterway	Load Rating Other restrictions