MARYLAND STATE HIGHWAY ADMINISTRATION
OFFICE OF STRUCTURES

MANUAL FOR HYDROLOGIC AND HYDRAULIC DESIGN

CHAPTER 7
SCOUR PROGRAM FOR EXISTING BRIDGES

April 2011

Maryland State Highway Administration
Office of Structures
SCOUR PROGRAM FOR EXISTING BRIDGES

Preface

Chapter 7, Scour Program for Existing Bridges, has been extensively revised from previous versions. The primary change is that the bridge scour program for existing bridges is now being managed by the Office of Structures, Structural Inspection and Remedial Engineering.

All questions or concerns about inspecting and evaluating scour at existing bridges, including questions about Chapter 7, should be referred to Structural Inspection and Remedial Engineering.

Maryland State Highway Administration
Office of Structures
SCOUR PROGRAM FOR EXISTING BRIDGES

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A. History of Office of Structures Scour Program for Existing Bridges

1. PROGRAM INITIATION

The Office of Structures (OOS) implemented a program in the early 1990's for the inspection of bridges for the National Bridge Inspection Standards (NBIS) Item 113, Scour Critical Bridges. This program remains in effect today, and has served effectively to:

- identify bridges with actual or potential scour problems
- establish a process for taking action to minimize the scour problems and
- minimize any safety hazards to the public.

This program has been implemented for all publicly owned bridges in Maryland (SHA, federal, county and municipal bridges). The actions described below by OOS have been carried out by non-SHA bridge owners as well. Basic elements of the program include:

- Use of Interdisciplinary Scour Teams comprised of USGS Hydrologists, Structure Inspection and Remedial Engineering (SIRE) and Hydraulic Engineers and Soils and Geologists from the Office of Materials Testing.
- Scour evaluations/assessments of all bridges and subsequent rating of all bridges for Item 113, Scour Critical Bridges.
- An active inspection and monitoring program.
- Prompt actions to minimize any safety hazards to the public due to scour by a) bridge rehabilitation or replacement or b) installation of scour countermeasures.
- Training of bridge inspectors with regard to the scour program.
- An active cooperative program with county and municipal bridge owners

Early coordination and training sessions were set up with county engineers so that their process for evaluating Item 113, Scour Critical Bridges was consistent with the OOS Program. OOS also assisted in selecting and training the consultants to conduct the Item 113 scour evaluations of county bridges.

OOS has continued this cooperative program with the counties up to the present time. Primary emphasis is on maintenance of the Structural Inventory and Appraisal (SIA) data base and on general oversight of the county scour programs. OOS recognizes the value of training in the scour monitoring program by sending Bridge inspectors to periodic in-house training sessions regarding the procedures to follow and the appropriate actions to take regarding bridge inspections and follow-up actions.

2. INITIAL RATING OF ITEM 113, SCOUR CRITICAL BRIDGES

In the early 1990's OOS developed a detailed procedure for rating bridges for Item 113. The procedure consisted of a risk-based approach taking into consideration such things as:

- Bridge history and performance over its service life
- Information from the SI&A files
- Whether the bridge is on a tidal or non-tidal waterway.
- Estimated flood discharges and velocities provided by the U.S. Geological Survey
- Bridge plans, including foundation types, pile lengths, etc.

- Subsurface soils and rock, borings, etc.
- Information obtained from field inspections
- Any unusual or unique features existing at the bridge site.

Based on the above data, the Interdisciplinary Team rated each bridge as stable, low risk, or scour critical. The use of Category U, unknown foundation, was used in the item 113 evaluation primarily for bridges believed to be on spread footings. A cooperative program with the soils engineers was initiated to investigate such U.

B. Current NBIS Ratings for Item 113, Scour Critical Bridges

1. CURRENT ITEM 113 RATINGS

The Office of Structures uses the following codes for Item 113 which are based upon the FHWA Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges:

N – Bridge not over a waterway.

U – Non-Interstate bridge with "unknown" foundations that have not been evaluated for scour. This is a temporary bridge rating, and current plans are to reassess and recode all bridges with unknown foundations, in accordance with FHWA requirements, by November 2010. (See Unknown Foundations).

T – Bridge over "tidal" waters that has not been evaluated for scour, but considered low risk. This is a temporary rating that was required to be eliminated by November 2008.

9 – Bridge foundations, including piles, on dry land well above flood waters.

8P – Bridge is a culvert type structure with a paved bottom.

8L – Bridge foundations determined to be stable for the assessed or calculated scour condition. Scour is determined to be above the top of the footing (Example A) by assessment or by calculations.

7 - Countermeasures have been installed to mitigate a previously existing problem with scour and to reduce the risk of bridge failure during or immediately after a flood event. These countermeasures may or may not have experienced continued scour. Instructions contained in the Plan of Action have been implemented to reduce the risk to users from a bridge failure during or immediately after a flood event.

6 – Scour calculation/evaluation has not been made or Interstate Bridge with unknown foundations. This is a temporary bridge rating that was required to be eliminated by November 2008. (See Unknown Foundations).

5A – Bridge foundations determined to be stable due to assessment. Scour is determined to be within the limits of footings or piles (Example B). No scour has been found during any inspection of this bridge. The potential risk of failure during or immediately after a flood event is considered low. No actions are planned other than monitoring.

5B – Bridge foundations determined to be stable due to assessment of scour conditions. Scour is determined to be within the limits of footings or piles (Example B). Scour has been found during an inspection. The potential risk of failure during or immediately after a flood event is considered to be moderate. No actions are planned other than monitoring.

5C – Bridge foundations determined to be stable for calculated scour condition. Scour is determined to be within the limits of footings or piles (Example B) or by calculations.

4 - Bridge foundations determined to be stable for assessed or calculated scour conditions; field review indicates that action is needed to protect exposed foundations.

3 - Bridge is scour critical; bridge foundations determined to be unstable for assessed or calculated scour conditions. Scour within limits of footing or piles (Example B) or scour is below spread footing base or pile tips (Example C). Monitoring is to be performed until scour countermeasures are in place. (Implement Plan of Action for Installing Scour Countermeasures by April, 2010 for all counties/other agencies.)

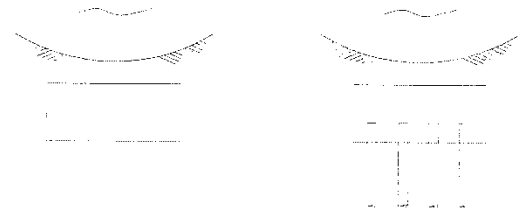
2 - Bridge is scour critical. Field review indicates that extensive scour, including undermining, has occurred at a bridge foundation. Immediate action is required to install scour countermeasures. (An evaluation will be done to determine the need to implement an individual Plan of Action until scour countermeasures are installed.)

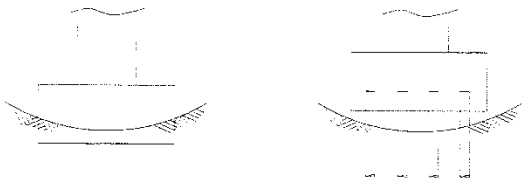
1 - Bridge is scour critical. Field review indicates that failure of piers/abutments is imminent; bridge is closed to traffic.

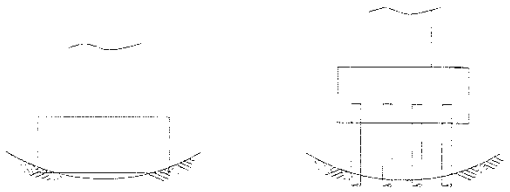
0 - Bridge is scour critical. Bridge has failed and is closed to traffic

Item 113 - Scour Critical Bridges (cont'd)

EXAMPLES:	CALCULATED OR ESTIMATED SCOUR DEPTH	ACTION NEEDED
A. Above top of footing		None – indicate rating of 8 for this item (see code)
B. Within limits of footing or piles		Conduct foundation structural analysis or evaluation.
C. Below pile tips or spread footing base		Provide for monitoring and/or scour counter-measures as necessary.







SPREAD FOOTING (NOT FOUNDED IN ROCK)

PILE FOOTING

= Calculated or Estimated scour depth

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2. CHANGES TO ITEM 113 SCOUR RATING

If there is a significant change (two feet or more when compared to the earliest recorded soundings) observed at the bridge site, the bridge inspector shall notify the bridge manager for immediate attention. Actions may range from bridge closure to a change in the Item 113 rating code.

The interdisciplinary scour team shall be requested to review scour rating changes.

If the Item 113 rating is changed as a result of an inspection to a "2" or below, the substructure rating (Item 60) is also reevaluated and revised as appropriate.

Bridges with a rating of 3 may be monitored more frequently than the two year schedule, depending on the perceived risk and a Plan of Action (POA) must be developed. Such bridges may require further action to protect the bridge. Arrangements should be made for installing scour countermeasures. Until they are installed, monitoring could be an acceptable countermeasure. The severity of scour at a bridge should be a factor when evaluating a bridge's condition to determine if it should be replaced.

Inspection procedures include evaluation of the superstructure, substructure, riprap/scour countermeasures and measurements of the stream channel upstream, through and downstream of the bridge. Stream measurements are compared with previous inspection results. Significant changes of 2 feet or more require preparation of an engineering request and the notification of the interdisciplinary team. The amount of debris at the structure is evaluated, and recommendations are made when judged necessary for debris removal.

C. Rating Bridges with Unknown Foundations

1. INTRODUCTION:

The SHA, in cooperation with the Federal Highway Administration, county and municipal bridge owners, has undertaken the task of evaluating all bridges with unknown foundations for the purpose of deciding whether they should be rated as scour critical under the provisions of Item 113, Scour Critical Bridges.

Reference is made to a memorandum from the Federal Highway Administration (FHWA) dated January 9, 2008 and entitled "Technical Guidance for Bridges over Waterways with Unknown Foundations". (Reference 1) This memorandum has been sent in previous correspondence to all bridge owners in Maryland (References 2). The FHWA is requesting that we take action to eliminate the number of bridges in this category by (1) reevaluating the bridges, (2) providing scour protection where feasible and (3) recoding the Item 113, Scour Critical Bridges.

Up to this time, bridges with unknown foundations have been assigned a variety of different codes. Now all such bridges need to be given a temporary code of "U" (Note the exception to this rule is that Interstate bridges with unknown foundations are to be coded as a 6). By November 2010, all bridge owners will need to evaluate the unknown foundation in order to properly rate Item 113 for these bridges.

The Office of Structures will work with County and Municipal Engineers to discuss how best to go about making these decisions. The guide included in this memorandum has been developed to assist in making such judgments. SHA will provide assistance, at the bridge owner's request, to arrange for Federal bridge funds to be used to obtain technical assistance in making the analyses for these bridges. It is the responsibility of the bridge owner to obtain the necessary information and to make a judgment as to the appropriate code to be used. However, it is also the responsibility of the SHA to see to it that the inspections and ratings are made in a competent and timely manner. If necessary, SHA will take action to hold all other owners accountable for inspecting and rating these bridges.

2. PREPARATIONS FOR RATING UNKNOWN STRUCTURES

This current review is similar to the review that state, county and municipal bridge owners conducted in the early 1990's for rating scour critical bridges. The following information and procedures developed during and after the 1990's review will be helpful in conducting the current review of bridges with unknown foundations:

1. Information in the database of the Structural Inventory and Appraisal
2. Action plans for existing scour critical bridges.
3. Channel stability assessments and scour critical evaluation worksheets developed for bridge owners during the 1990's review.
4. Plans and other project information.
5. Inspection reports and any information relating to scour damage and repairs for the bridges being rated.
6. Records applicable to the repair or replacement of any bridges listed as having unknown foundations.
7. Other applicable information in the bridge owner's files.

We now have 15 years of additional experience in inspecting, evaluating and rating scour critical bridges which should help to facilitate and streamline our approach to rating bridges with unknown foundations. In addition, the number of these bridges is small in comparison with our total inventory of bridges over waterways so the scope of this work is less than it was for the original scour critical evaluation study.

3. WORKSHEETS FOR RATING BRIDGES WITH UNKNOWN FOUNDATIONS

This Office has prepared four basic forms or worksheets for rating bridges with unknown foundations:

- Table 1:Piers with no installed scour countermeasures
- Table 2:Piers with installed scour countermeasures
- Table 3:Abutments with no installed scour countermeasures
- Table 4:Abutments with installed scour countermeasures

Every bridge may have certain unique features that will have a bearing on how it is to be rated. The worksheets prepared by the Office of Structures do not contain all the information needed to rate every bridge. However, the worksheets do provide basic guidance on a conservative approach to judging which bridges should be considered as

scour critical. The final decision for each bridge, including the evaluation of any unique site-specific conditions, must be made by the bridge owner.

If there is an existing condition (or significant potential) for ongoing scour, degradation, channel movement or damage to the foundation, rate the pier or abutment as scour critical and select the scour critical rating code (3 or below) that is appropriate for the degree of the perceived risk. The Item 113 rating for the bridge should be selected as the lowest rating of the various pier and abutment elements of the bridge.

UNKNOWN FOUNDATIONS
TABLE 1: PIERS WITH NO INSTALLED SCOUR COUNTERMEASURES

Bridge No and Description._____ Date _____

Inspection Date_____ Date of Last Underwater Inspection, If Applicable _____

Table 1 pertains to a pier with no installed scour countermeasures and with little or no information available about the pier's foundation. The table provides guidance as to whether the pier should be coded a 3 or less (scour critical) or 5A, 5B, 5C, or 8 for item 113.			
Steps:		Pier #	Pier #
1	Is the pier founded on a footing? -If no, (ex. pile bent) go to step 3. -If yes, go to step 2.		
2	Is the top of the footing exposed or has it ever been exposed during previous inspections or can the top of footing be located by field inspection methods? -If yes to any of the three, the following options are available: • Determine through field investigations that the footing is founded on scour resistant material (rock) and code an 8L for item113. • Perform scour analysis and determine the footing is stable for the calculated scour condition and code a 5C for item 113. • Go to step 3 to determine if the foundation could be assess as being stable and code a 5A or 5B for item 113.Otherwise, code the pier a 3 or less (scour critical) for item113. - If no, go to step 3.		
3	The interdisciplinary scour team should make an assessment of the scour condition and determine what the scour rating should be taking into account the available information from plans, inspection reports, flood history data and other historical data. Is the channel (item 61) rated as 6 or below? Is there a significant angle of attack of flood flows on the pier? Is there evidence of on-going changes to the stream such as local or contraction scour, lateral movement or downstream degradation that could threaten the stability of the bridge foundations? Does the bridge overtop on a frequent basis with resulting damage to the approach fills or channel? Code item 113 according to the coding guide.		

UNKNOWN FOUNDATIONS
TABLE 2: PIERS WITH INSTALLED SCOUR COUNTERMEASURES

Bridge No and Description._____ Date _____

Inspection Date_____ Date of Last Underwater Inspection, If Applicable _____

Table 2 pertains to a pier with installed scour countermeasures and with little or no information available about the pier's foundation. The table provides guidance as to whether the pier should be coded a 3 or less (scour critical) or 7 (installed scour countermeasures to reduce risk) for item 113.			
Steps:		Pier #	Pier #
1	Pier type and location (channel, flood plain)		
2	Description of countermeasure: material used, geometry, etc.		
3	Date installed. Has the scour countermeasure been in service for more than four years?		
4	Does the scour countermeasure protect the entire pier foundation?		
5	Has the scour countermeasure always been reported as being stable since it was installed? (If no, explain.)		
6	A risk assessment should be made and a scour rating should be determined by the interdisciplinary scour team, taking into account the available information. Is the channel (item 61) rated as 6 or above? Is there a significant angle of attack of flood flows on the pier? Is there evidence of on-going changes to the stream such as local pier or contraction scour, lateral movement or downstream degradation that could threaten the stability of the countermeasure or the bridge foundation? Does the bridge overtop on a frequent basis with resulting damage to the approach fills or channel.		
7	If the responses to questions 1-6 indicate that: • the countermeasure has been in place for at least two inspection cycles; • the countermeasure and channel have remained stable since its installation, • the countermeasures protect the entire substructure from potential scour and • there is no evidence of on-going or potential significant scour, degradation or channel movement that could threaten the pier; then consider coding the pier a 7 for item 113.		
8	If there is an existing condition (or significant potential) for ongoing scour, degradation, channel movement or damage to the countermeasure code the pier a 3 or less (scour critical) for item 113.		

UNKNOWN FOUNDATIONS
TABLE 3: ABUTMENT WITH NO INSTALLED SCOUR COUNTERMEASURES

Bridge No and Description._____ Date _____

Inspection Date_____ Date of Last Underwater Inspection, If Applicable _____

Table 3 pertains to an abutment with no installed scour countermeasures and with little or no information available about the abutment's foundation. The table provides guidance as to whether the abutment should be coded a 3 or less (scour critical) or 5A, 5B, 5C, or 8 for item 113.			
Steps:		Left Abut. (Looking downstream)	Right Abut. (Looking downstream)
1	Is the abutment founded on a footing? If no, go to step 3. If yes, go to step 2.		
2	Is the top of the footing exposed or has it ever been exposed during previous inspections or can the top of footing be located by field inspection methods? -If yes to any of the three, the following options are available: • Determine through field investigations that the footing is founded on scour resistant material (rock) and code an 8L for item 113. • Perform scour analysis and determine the footing is stable for the calculated scour condition and code a 5C for item 113. • Go to Step 3 to determine if the foundation could be assessed as being stable and code a 5A or 5B for item 113. • Otherwise, code the abutment a 3 or less (scour critical) for item 113. - If no, go to step 3.		
3	The interdisciplinary scour team should make an assessment of the scour condition and determine what the scour rating should be taking into account the available information from plans, inspection reports, flood history data and other historical data. Is the channel (item 61) rated as 6 or below? Is there a significant angle of attack of flood flows on the abutment? Is there evidence of on-going changes to the stream such as local or contraction scour, lateral movement or downstream degradation that could threaten the stability of the bridge foundations? Does the bridge overtop on a frequent basis with resulting damage to the approach fills or channel? Code item 113 according to the coding guide.		

UNKNOWN FOUNDATIONS
TABLE 4: ABUTMENTS WITH INSTALLED SCOUR COUNTERMEASURES

Bridge No and Description._____ Date _____

Inspection Date_____ Date of Last Underwater Inspection, If Applicable _____

Table 4 pertains to an abutment with scour countermeasures and with little or no information available about the abutment's foundation. The table provides guidance as to whether the abutment should be coded a 3 or less (scour critical) or 7 (installed scour countermeasures to reduce risk) for item 113.

Steps:		Left Abut. (Looking downstream)	Right Abut. (Looking downstream)
1	Abutment type and location (edge of channel or set back on flood plain)		
2	Description of countermeasure, material used, geometry, etc.		
3	Date installed. Has the scour countermeasure been in service for more than four years?		
4	Does the scour countermeasure protect the entire pier foundation?		
5	Has the scour countermeasure always been reported as being stable since it was installed?		
6	A risk assessment should be made and a scour rating should be determined by the interdisciplinary scour team, taking into account the available information. Is the channel (item 61) rated as 6 or below? Is there evidence of on-going changes to the stream such as local or contraction scour, lateral movement or downstream degradation that could threaten the stability of the bridge foundation? Does the bridge overtop on a frequent basis with resulting damage to the approach fills or channel?		
7	If the responses to questions 1-6 indicate that: • the pier is located in the channel or flood plain, • the countermeasure has been in place for at least two inspection cycles; • the countermeasure and channel have remained stable since its installation, • the countermeasures protect the entire substructure from potential scour and • there is no evidence of actual or potential significant scour, degradation or channel movement that could threaten the abutment, then consider coding the abutment a 7 for item 113.		
8	If there is an existing condition (or significant potential) for ongoing scour, degradation, channel movement or damage to the countermeasure, code the abutment a 3 or less (scour critical) for item 113.		

D. Plan of Action (POA) for Scour Critical Bridges

An individual Plan of Action (POA) is required for all bridges identified as scour critical. Scour critical bridges are those with Item 113 coded as 0, 1, 2, or 3. Included is the FHWA POA template that shall be used for each scour critical bridge. You can also download this template from:

http://www.fhwa.dot.gov/engineering/hydraulics/bridgehyd/poaform.cfm

A copy of each POA and all updates shall be submitted to MD SHA. The bridge manager shall be responsible to ensure each of the POAs is followed.

E. Flood Response Program

Flood events can cause a significant increase in scour that could impact the stability of scour critical bridges. They can also significantly impact any previous scour countermeasures that were installed to reduce the scour susceptibility of a bridge. For this reason, all bridges having Items 113 rated as U, 0, 1, 2, 3, 4, 5A, 5B, 6, or 7 should have a follow up as a result of a flood event. A flood event can be a region-wide event such as major storms and hurricanes, a storm that has caused a flood warning to be issued for a given area, or a localized event that has caused a bridge to be overtopped or nearly overtopped that has resulted in a closure of the structure due to engineering judgement.

The following should be a part of all Flood Response Programs:

- Pre-event preparation: Impending major storms and hurricanes are tracked by SHA's Homeland Security Office. In addition, various other weather web sites can be used to track storms. For any type of region-wide storm, there is usually ample time to mobilize inspection teams.

- All bridges requiring a flood response, Item 113 rated as U, 1, 2, 3, 4, 5A, 5B, 6, or 7, should be identified ahead of time and detailed scour information and plans gathered for inspection teams to have on site during all follow up inspections.

- Good communication methods with law enforcement officers, maintenance operations, engineers and if necessary public information offices should be established ahead of time for quick response and determination of problem bridges. Both maintenance operations and law enforcement officers are usually the most knowledgeable of the bridges which typically overtop or nearly overtop. Their monitoring of the area is typically the first indication of problem bridges during a flood event.

- Close the bridge if the bridge or the highway approaches are overtopped. The maintenance personnel in consultation with law enforcement officials, when appropriate, normally decide when to close the bridge. If a bridge has a history of flooding and scour, the engineer may decide to close the bridge before it overtops. This is a matter of engineering judgment based on existing conditions and

performance of the bridge during past flood events, considering the degree of observed scour, high velocity flow, extent of debris build-up and other factors. A threshold condition for the closure of such bridges is often the inundation of the low chord of the bridge. If the engineer at the site considers current conditions, as described above, to represent a risk to the traveling public, recommended practice is to maintain frequent patrols to the bridge until either the bridge is closed or the flood risk subsides.

- Provide detour routes around the bridge. Detours are normally determined by the maintenance personnel, selecting alternative routes that are not flooded. For some cases, it is helpful and efficient to establish pre-planned detour routes for bridges that flood on a regular basis.

- Inspect the bridge after flood waters recede. All bridges in the flood response program that overtop or are within the flood warning area shall be inspected.

- Maryland is a relatively small state in which all of the bridges can be reached by inspection personnel in a matter of a few hours. Inspection teams should be well organized and maintain close communications via cell phones with all those involved with responding to flood events.

- The key elements of an effective flood response plan of action include (1) preparation, (2) experienced inspectors who are knowledgeable about the bridges assigned to them, and (3) continuing coordination between the inspectors in the field, maintenance personnel, law enforcement and the engineers.