MINNESOTA DEPARTMENT OF TRANSPORTATION

BRIDGE SCOUR EVALUATION PROCEDURE
FOR MINNESOTA BRIDGES

December 2009

Introduction

This document describes the policy of the Minnesota Department of Transportation (Mn/DOT) in regard to the evaluation of scour at bridges over water throughout the state. The priorities of the evaluation program are to identify bridges that may be vulnerable to scour problems in order to:

- Minimize risk to the public due to bridge failure by monitoring bridges during floods and closing if necessary.
- Maintain transportation network and protect investment in infrastructure by identifying and prioritizing bridges that require repair or replacement.
- Evaluate, monitor, repair and replace bridges using cost-effective strategies.

The methods used to minimize the risks of scour to Minnesota's transportation network include:

- Design new bridge foundations to withstand maximum predicted scour.
- Evaluate existing bridges and identify those vulnerable to scour.
- Develop and implement a plan of action to monitor, repair, or replace vulnerable bridges.
- Perform routine bridge inspection including a check for evidence of scour, comparing cross sections at bridges taken at regular intervals and underwater inspection of bridges over major waterways to be performed every five years.
- Incorporate research on predicting scour, monitoring bridges, and repairing or installing scour protection. Evaluate data collected during monitoring of state bridges in order to make better predictions.

Prior to 1988, scour was not considered in the design of new bridges over major waterways. Scour was analyzed and repairs constructed when scour problems were detected. A comprehensive evaluation program of all existing bridges began in 1988 after the issuance of Federal Highway Administration Technical Advisory T 5140.20 "Scour At Bridges". Included in the Advisory was “Interim Procedures For Evaluating Scour At Bridges”. This was superseded by T5140.23 “Evaluating Scour at Bridges” in Oct. 28th, 1991. HEC 18 “Evaluating Scour At Bridges, Fourth Edition” is the most recent guidance published. FHWA guidelines allows states considerable latitude in developing their own specific scour evaluation program in order to account for variable conditions with respect to hydrology, geomorphology, and state bridge design practices. The Mn/DOT policy has been designed to minimize risk to the citizens of Minnesota and the driving public in general while evaluating bridges in a cost effective manner.

Minnesota Bridge Scour Evaluation Program

All new bridges must be designed to be stable for predicted scour depths. Bridge scour analysis procedures are provided in FHWA Publication HEC-18 "Evaluating Scour at Bridges". The Minnesota Bridge Scour Program for existing bridges has consisted of four parts which follow procedures described in FHWA publications HEC-18, "Evaluating Scour At Bridges", HEC-20, "Stream Stability At Highway Structures" and HEC-23 "Bridge Scour and Stream Instability Countermeasures". The parts include: primary screening, secondary screening, Scour Analysis and developing and implementing a Plan of Action (POA) which may include countermeasures and/or monitoring during floods. Mn/DOT issued formal Screening Guidelines in 1990 and since that time all bridges greater than 20' in length have been screened. Many of the bridges on the Interstate and State systems (high priority bridges) have been evaluated by performing a scour analysis and where appropriate, countermeasures designed and constructed. In addition, Mn/DOT has developed a monitoring program for both emergency and regular monitoring of bridges for scour.

Each part of the existing bridge scour evaluation program is described briefly below. Detailed procedures for each part are given in the appendices.

Primary Screening

The Minnesota bridge scour program has a four step procedure that is designed to determine the scour susceptibility of existing bridges with minimal effort. The first part of the process was the primary screening. Primary screening considers the history of scour, foundation stability and protection from scour. This screening placed bridges into one of three categories: low risk (code I), unknown foundation (code G) or scour susceptible. This was an effort to identify the bridges that needed further evaluation for scour vulnerability with minimal effort. The initial primary screening has been completed for all bridges greater than 20' in length in the state.

A second primary screening needs to be done for all bridges rated "G". In the past, the FHWA exempted unknown foundations from being further evaluated due to the lack of a process and guidance. FHWA is now concerned that some bridges with a "G" code may in fact be scour critical and MnDOT has recently developed a POA template to deal with these structures until they can be evaluated, see Appendix G for guidance on dealing with "G" rated bridges. The FHWA has a target date of April 2010 for eliminating the bridges with unknown foundation codes from the National Bridge Inventory (NBI). All "G" rated bridges should be re-screened using the Coding Worksheet for "G" Rated Bridges provided in Appendix B.

If desired, a Secondary Screening or a Scour Analysis could be performed to further fine tune the coding of the bridges rated R in the Primary Screening.

Secondary Screening

Procedures for secondary screening were developed by a Bridge Scour Policy Task Force convened by the State Aid For Local Transportation Division in 1994. The Task Force consisted of Mn/DOT personnel, county engineers, and consultants. Secondary screening should be performed or supervised by a professional engineer familiar with the bridge being screened or expert in the methods of bridge scour evaluation. The worksheet has recently been modified to handle the secondary screening of bridges with unknown foundations. Secondary screening worksheets for both known and unknown foundations are found in Appendix C.

The engineer fills out a worksheet which covers several parameters related to performance of the bridge under scour conditions. The parameters considered are: historical scour performance, scour resistant foundations, debris and blockage, geomorphic conditions, hydraulic conditions, structural conditions, and special low risk conditions. Completion of the questionnaire allows the engineer to rate the bridge as low risk for failure due to scour (code I); limited risk to public-monitor in lieu of evaluation (code K); or scour critical-monitoring required (code R). Completed worksheets and any backup data are filed with the bridge owner. A copies of the worksheets and detailed instructions for its completion are provided in Appendix C.

Scour Analysis

A Scour Analysis, as described in this policy document, is a site specific study of a bridge to determine its vulnerability to foundation scour and stream stability problems at the bridge. The team performing the evaluation should be thoroughly familiar with FHWA publications HEC-18, HEC-20 and HEC 23. They should also be competent in the fields of hydraulics, geotechnical, and structural engineering.

The evaluation consists of the following 4 tasks, listed in the order of execution, including:

- office data collection
- review and evaluation of collected data
- site visit and field assessment
- scour analysis.

For the scour analysis, water surface profile modeling with a HEC-2 or HEC-RAS type computer program is performed. The hydraulic evaluation of the structure needs to be done to determine the potential scour depth. A pre-printed Minnesota DOT Scour Analysis Report Form has been developed and should be used for reporting the results of the hydraulic evaluation.

Bridge scour depths are then calculated using equations provided in FHWA Publication HEC-18 “Evaluating Scour at Bridges”. The resulting scour predictions may need to be reviewed by personnel with structural and geotechnical expertise to determine if the bridge will remain stable. For bridges with unknown foundations the engineer will have to make an educated assumption as to the foundation (see Appendix G) then code the bridge accordingly.

A copy of the Scour Analysis Report Form and instructions are provided in Appendix D. Attached to the report should be pertinent collected data, a completed pre-printed Minnesota Bridge Scour Field Assessment Form (Field Form), and any computations made to support the scour rating. See Appendix E.

Details of the study and report are left to the agency contracting the study and engineers or firms performing the study. Supporting information is located in Appendix F and J.

Plans of Action

A Plans of Action (POA) is a detailed explanation of what should be done in the event of a flood. It documents:

- what should be done, monitoring or countermeasure installation
- when it should be done and how frequently. If the bridge is too be monitored, the POA notes at what frequency or water surface elevation the monitoring should start and what the critical elevation is at each substructure
- what to do if that critical elevation is encountered.

POAs are site specific and are individually developed for each bridge rated R,U, P,K,G, and O. Definitions of these codes are located in Appendix A.

General guidelines for monitoring bridges are included in the **Mn/DOT Flood Response Plan** for State bridges and the **Bridge Scour Monitoring Plan For Local Roads** for local bridges. These plans are provided in Appendix H & I. Constructed scour countermeasure planning and implementation should proceed as appropriate and as funding allows.

Templates for POAs have been developed for use by local units of government and are located in Appendix K. They can also be downloaded from:
http://www.dot.state.mn.us/bridge/docsdown.html#hyd

APPENDICES

A. Scour Rating Codes

B. Primary Screening for “G” Rated Bridges

C. Secondary Screening

D. Scour Analysis Report Form

E. Minnesota Bridge Scour Field Assessment Form

F. Bridge Stability Guidelines

G. Guidance For “G” Rated Bridges

H. Mn/DOT Flood Response Plan

I. Bridge Scour Monitoring Plans For Local Roads

J. Design Aids
   - Roughness Coefficients
   - Sediment Grade Scale
   - Soil Triangle
   - Non-scour Velocities For Soils

K. Plan of Action Templates

L. Authors

APPENDIX A

SCOUR RATING CODES

CODE	LITERAL	DESCRIPTION
A	NON-WATERWAY	Bridge not over waterway.
B	CLOSED-SCOUR	Bridge is closed to traffic; field review indicates that failure of peirs and/or abutments due to scour is immiment or has occurred.
C	CLOSED-NOT SCOUR	Bridge is closed to traffic for reasons other than scour.
D	OBS SCOUR-IMM PROT REQ	Bridge is scour critical; field review indicates that extensive scour has occurred at bridge foundations. Immediate action is required to provide scour countermeasures.
E	CULVERT	Culvert structure. Scour calculations, evaluation, and/or screening has not been made. Should not include bottomless culverts.
F	NON EVAL-FOUND KNOWN	Bridge Structure. Scour calculation, evaluation, and/or screening has not been made. All substructure foundations are known. This code is no longer acceptable for bridges with widths 20' or greater.
G	NO EVAL-FOUND UNKNOWN	Scour calculation, evaluation and/or screening has not been made. Bridge on unknown foundations. This code is no longer acceptable for bridges with widths 20' or greater.
H	FOUND ABOVE WATER	Bridge foundations (including piles) well above flood water elevations.
I	SCREEN-LOW RISK	Bridge screened, determined to be low risk for failure due to scour.
J	SCREEN-SCOUR SUSC	Bridge screened, determined to be scour susceptible. This code is no longer acceptable for bridges with widths 20' or greater.
K	SCREEN-LIMITED RISK	Bridge screened, determined to be of limited risk to public, monitor in lieu of evaluation and close if necessary.
L	STABLE-EVAL	Scour evaluation complete, bridge judged to be low risk for failure due to scour.
M	STABLE-SCOUR ABOVE FTG	Bridge foundations determined to be stable for calculated scour conditions; calculated scour depth from the scour prediction equations is above top of footing.
N	STABLE-SCOUR IN FTG/PILE	Bridge foundations determined to be stable for calculated scour conditions; calculated scour depth from the scour prediction equations is within limits of footing or piles.
O	STABLE-ACTION REQUIRED	Bridge foundations determined to be stable for scour conditions; Scour action plan requires additional action.
P	STABLE DUE TO PROT	Countermeasures have been installed to correct a previously existing problem with scour. Bridge is no longer scour critical. Scour countermeasures should be inspected at least once every 4 years and after major flows, or as recommended in the Plan of Action. Report any changes that have occurred to countermeasures.

R	CRITICAL- MONITOR	Bridge has been evaluated to be scour critical. Scour action plan recommends monitoring the bridge during high flows and closing if necessary.
U	CRITICAL-PROT REQ	Bridge has been evaluated to be scour critical. Scour action plan recommends this bridge as a priority for installation of countermeasures. Until countermeasures are installed, monitor bridge during high flows and close if necessary.

APPENDIX B

PRIMARY SCREENING FOR “G” RATED BRIDGES

BRIDGE SCOUR SCREENING PROCEDURE FOR "G" RATED BRIDGES

Purpose of Screening:

The purpose of screening is to classify bridges that have been previously coded as "G-Unknown Foundation" as either low risk for scour problems or scour susceptible. Bridges that are scour susceptible will require further evaluation or can be rated "R- Scour Critical". After the bridge has been screened, the scour code in the bridge inventory must be updated.

Criteria for Low Risk Bridges:

The criteria for determining low risk bridges is described in the attached Screening Guidelines. The criteria are summarized below:

- No evidence of scour at the piers and abutments or of channel lowering or shifting.
- Piers, if existing, have spread footings on erosion resistant rock (granite, basalt, quartzite, or gneiss which is not highly broken or fractured).
- Abutments are on spread footings on erosion resistant rock, or have adequately maintained protection inplace.

Screening Procedure:

To determine if a bridge meets the low risk criteria inplace scour protection and scour history must be known about the bridge. Several worksheets (listed below) are included in the attachments and may be used to gather information and assign a screening code. Although these worksheets are optional, they will provide documentation of the reasons for your decision and can be filed for future reference.

- **Bridge Scour Screening - Inspection Worksheet**
  Worksheet to record information on scour history and inplace scour protection at a bridge.

- **Primary Screening for "G" Rated Bridges:**
  Provides aid in assigning scour rating code as a result of screening.

If you choose to use the worksheets, you can retain them for your records, but only the assigned scour code should be sent to Mn/DOT.

Screening Guidelines:

Screening is being used to identify bridges which can be labeled low risk without further evaluation

Low Risk Criteria For Piers

A. Pier on spread footing on erosion-resistant bedrock (granite, basalt, quartzite, or gneiss) which is not highly broken or fractured. No known scour problems.

Low Risk Criteria For Abutments:

A. Abutment foundations on spread footings on erosion-resistant bedrock (granite, basalt, quartzite, or gneiss) which is not highly broken or fractured. No known scour problems.

B. Abutments with slopes that have adequate scour protection. Adequate protection is defined as riprap equivalent to Class III random riprap (Mn/DOT Spec. 3601), grouted riprap, grouted fabric or gabions. Protection should be in good condition and require no repairs. No known scour problems.

All sub-structures must meet the low risk criteria, or the sub-structure's foundation must be well above the flood water elevation for the bridge to be rated as low-risk. All of the low-risk ratings are dependent on having no known scour problems, and may also depend on the condition of the protection. If conditions change at the site, the low risk rating should be reviewed, and possibly revised.

PRIMARY SCREENING FOR "G" RATED BRIDGES **12/10/2009**

#: ____________________ Name: ________________________________ Date: ____________________

Worksheet is an aid to complete scour screening. Prior to starting the worksheet, you need information on historical scour problems and existing scour protection. Check known foundation types of nearby bridges built during the same period of time as your bridge of interest. Historical foundation practices were very repetitive. Assume bridge was built in similar fashion.

Circle Yes or No for each question and follow the directions.

1.) Are there any existing or historical scour problems: a.) Scour at any pier. b.) Movement, scour, or erosion at either abutment. c.) Channel lowering or lateral movement.	YES NO
2.) Do both abutments meet any of the following criteria: a.) Adequate scour protection: Riprap (class III or larger), grouted riprap, or gabions, in good condition. b.) Spread on erosion resistant bedrock: Granite, basalt, gabbro, quartzite, or gneiss (not highly broken or fractured).	YES NO
3.) Do all piers meet any one of the following criteria: a.) Spread on erosion resistant bedrock: Granite, basalt, gabbro, quartzite, or gneiss (not highly broken or fractured). b.) No Piers.	YES NO
4.) If you answered NO to 1, YES to 2 and 3: Rate Bridge "I" If this criteria is not met: • Place Adequate scour protection at piers and abutments, Rate Bridge "P" and write Plan of Action (POA) for "P" rated Bridge OR • Rate Bridge "R"- Critical and write POA for "R" rated Bridge A Secondary Screening or a Scour Analysis can be done on Bridges rated "R" to see if they qualify for a different scour code.	Rating ________________________

APPENDIX C

SECONDARY SCREENING

- **INSTRUCTIONS**
- **WORKSHEET FOR BRIDGES WITH KNOWN FOUNDATIONS**
- **WORKSHEET FOR BRIDGES WITH UNKNOWN FOUNDATIONS**

INSTRUCTIONS FOR PERFORMING
SECONDARY SCREENING OF MINNESOTA BRIDGES

The Minnesota Department of Transportation, State Aid for Local Transportation Division, has funded the development of a secondary screening procedure in order to reduce the time and cost of evaluating bridges over water for foundation scour. The screening procedure presented herein is meant to provide guidance in evaluating existing bridges for vulnerability to scour and not an exact procedure to determine the safety of a bridge against the potential ravages of scour. The variableness of river geometry, scourability of bed materials, and magnitude and duration of floods make an exact analysis virtually impossible with the tools currently available. To streamline this complex process into a secondary screening procedure is difficult; however, with the use of engineering judgement and common sense, we believe a secondary screening can be helpful in reducing the number of bridges requiring a detailed analysis. Annual or biennial inspections to observe the dynamic nature of river geomorphics over time and to record the changes so they can be utilized as comparison during future inspections is essential.

This secondary screening is intended to reduce the number of bridges requiring a bridge scour analysis by examining several parameters related to performance of the bridge under scour conditions. The parameters considered are: historical scour performance, scour resistant foundations, debris and blockage, geomorphic conditions, hydraulic conditions, structural conditions, and special low risk conditions.

It is intended that a bridge will be screened by one or more professional engineers familiar with the bridge or expert in the subject of bridge scour, by answering the questions on a pre-printed form/questionnaire entitled Secondary Screening of Minnesota Bridges or the Secondary Screening of Minnesota Bridges with Scour Code "G". Information required to perform a secondary screening includes: structure inventory sheet, USGS quadrangle map showing the water course at least one mile upstream and one mile downstream of the bridge, plan and elevation drawings of the bridge, bridge photographs, and bridge inspection reports. Additional information that is recommended when available are soil information/boring logs and hydraulic design data. Although a field review may not be necessary if the engineer doing the screening is familiar with the bridge, in many cases a field review is recommended because it allows the engineer to see and document the conditions as they exist currently. The engineer(s) performing the screening should fill out the Screening Form according to the following instructions.

Complete the questionnaire in consecutive order (one for each parameter) by answering "yes", "no", or "unknown" to each question. Responses to questions in the various sections may result in rating the bridge without completing the questionnaire in total. Place an **X** by the appropriate **scour screening rating code** on the first page. Possible bridge scour ratings include:

I Bridge screened, determined to be low risk for failure due to scour. *Additional evaluation will not be done at this time. Inspection of the channel under the bridge during the annual or biennial routine inspection must supply sufficient information about the channel and protection to maintain the low risk rating. If conditions change, the bridge should be evaluated and re-coded if necessary.*

K Bridge screened, determined to be of limited risk to public, monitor in lieu of evaluation and close if necessary. *Monitoring should be completed in accordance with the* ***bridge's Scour Plan of Action (POA).***

O Bridge screened stable for scour, but action required. *The action required can include the annual or biennial inspection providing a front face cross section is taken and compared with previous cross sections. It may also include other actions that may not normally be checked during the routine inspection. Activities such as keeping an eye on lateral stream migrations, unstable stream banks, vegetation in the floodplain which can change the flow patterns, formation of islands or bars in the vicinity of the bridge, availability of debris in upstream channel, nearby upstream tributaries that may contribute substantial amounts of sediment, and other factors that may influence the flow distribution and flow patterns. Probing may be necessary to determine if erodible bed rock is still inplace after major floods. A site specific Plan of Action should be on file informing monitoring staff what concerns were noted at the bridge and which actions to take.*

U Bridge has experienced scour. A Scour Plan of Action (POA) shall be on file recommending the installation of countermeasures. In the interim, the bridge will be monitored during high flows and closed if necessary. *The POA should detail the what, when, where, & how of monitoring. Countermeasures should be designed and installed when feasible. After installation of countermeasures, bridge shall be rated "P".*

R Bridge has been evaluated to be scour critical. A Scour Plan of Action (POA) shall be on file, recommending monitoring the bridge during high flows and closing the bridge if necessary. *The POA should detail the what, when, where, & how of monitoring. A system of recording the data so it will be available for comparison with future data is very important.*

Each of the sections is described below.

1. HISTORICAL SCOUR PERFORMANCE: The intent of this section is to have the reviewer consider foundation or substructure undermining which is specifically attributed to pier scour, abutment scour, contraction scour, channel vertical degradation, or channel lateral migration, which has not been corrected by properly designed and constructed scour countermeasures. Minor changes to the bridge's "designed and constructed condition", such as minor channel cross section changes or the need for riprap replenishment, which should be addressed by normal maintenance, are not at issue. If the bridge has continuing scour problems, a scour evaluation study or a monitoring program is required.

State the primary screening code. This should be available from a computer printout of scour codes from data that has been submitted to the Mn/DOT Bridge Management Engineer by the bridge owner. Answer "yes", "no", or "unknown", to whether the bridge ever experienced scour causing foundation undermining that has not been adequately corrected. If the answer is "yes", Rate the Bridge "U- Critical, Protection Required. If "no" or "unknown", go to 2.

2. SCOUR RESISTANT FOUNDATIONS: (This section was eliminated in the Secondary Screening for Minnesota Bridges with Scour Code “G”) The intent of this section is to give the reviewer a second chance to rate the bridge as low risk (I) in the event the opportunity was missed during the primary screening. Bridges of any size which are founded on erosion resistant bedrock such as granite, basalt, gabbro, quartzite and gneiss, provided it is not highly broken or fractured, can be rated as low risk for failure due to scour.

Certain foundation materials or foundations protected by scour countermeasures may be considered as stable for scour when used in streams with relatively small drainage areas. The specific conditions considered under this section for bridges with drainage area less than 400 square miles include: abutments protected by properly designed riprap, piers or abutments on piles with pile tips more than 40 feet below the lowest channel bottom, or pile foundations located in stiff clay with an unconfined compressive strength greater than 4000 psf (shear strength of 2000 psf). (Note, there is no reference to piling length in the stiff clay criteria.) It is necessary that the stiff clay classification be determined from soil boring data as recorded on the bridge plan or other soil boring logs and located in the approximate location and elevation of the foundation elements. A Standard Penetration Test in cohesive soils of approximately 15 blows per foot has been published in the literature as being correlated with an unconfined compressive strength of approximately 4000 lbs/ft^2. Caution should be exercised when interpreting blow counts because wide variations in unconfined compression strength may exist for the same blow count. Sounding rod tests with a 50 lb hammer are not appropriate for determining the existence of stiff clay soils.

If all the substructure units of the bridge are founded on scour resistant material or protected by countermeasures, the bridge can be rated as low risk for scour without performing a scour evaluation study. Answer the four (4) questions for each substructure unit as "yes", "no", or "unknown". Place the answer in the table on page 2 of the Screening Form. If there is at least one "yes" in each column in the table, rate the bridge as "**I**" and proceed no further. If any column does not contain a yes, then go to 3.

3. DEBRIS AND BLOCKAGE: The obstruction of a bridge opening by debris and ice is a serious problem which can have grave consequences for the bridge by partially damming the water course and raising the head differential from one side of the bridge to the other and therefore raising the water velocity through the bridge. These conditions are difficult to predict quantitatively and therefore any possibility of blockage must be treated as a potential scour problem and the bridge will require a scour evaluation study or a monitoring program.

Answer the questions regarding debris and ice blockage. If the answer to either question is "yes" or "unknown", go to 7. If the answer to both questions is "no", go to 4.

4. GEOMORPHIC CONDITIONS AFFECTING SCOUR RESISTANCE: The reviewer must consider geomorphic conditions which may indicate a potential scour problem at the bridge. Comparing current channel bottom elevations with the bottom elevations shown on the bridge plan can reveal that degradation of the channel or contraction scour has occurred under the bridge. Observed bank erosion; channel and bridge geometry which might aggravate scour conditions such as significant channel bends upstream of the bridge; piers or abutments which are skewed to the direction of flow; and significant constriction of flood flows can all be indicative of potential scour problems. If such conditions exist at the bridge site, a scour evaluation study or a monitoring program is required.

Answer the five questions regarding geomorphic conditions. If the answer to any of the questions is "yes" or "unknown", go to 7. If the answer to all the questions is no, go to 5.

5. HYDRAULIC CONDITIONS AFFECTING SCOUR RESISTANCE: Water courses with small hydraulic gradients (and without the scour aggravating conditions discussed in Sections 1 through 4 above) should not develop velocities sufficient to cause serious scour problems. The reviewer should consider the channel slope in the vicinity of the bridge and observed flood velocities which indicate non-scouring conditions. In general, if the average cross sectional velocity through the bridge during significant flood events is less than 3 fps (and 5 fps in clay bed streams) the bridge can be considered low risk for scour and no scour evaluation study is required. The questions in this section are designed to identify low velocity conditions.

For water courses where the floodway width is less than 5 times the total bridge length, answer the four (4) questions related to water depth, slope, and flood peak discharge average velocity. If the answer to any of the questions is "yes", rate the bridge as "**I**" and proceed no further. If the answer to all of the questions is "no" or "unknown", go to 6.

6. STRUCTURAL CONDITIONS AFFECTING SCOUR RESISTANCE: Certain structural features of single span bridges provide a demonstrated toughness against scour problems. These features include concrete abutments on piles and timber abutments less than 6 feet high on piles. In addition, man made drainage ditches designed to allow low velocities, have also been demonstrated to be non-threatening to single span bridges. If the reviewer can identify these conditions without the aggravating scour conditions discussed in Sections 1 through 5 above, the bridge can be considered low risk for scour and a scour evaluation study is not required.

If the bridge is a single span and the effective flood plain width is less than 5 times the span length, answer the three (3) questions related to foundation structural details. If the answer to any of the questions is "yes", rate the bridge as "**I**" and proceed no further. If the answer to all 3 questions is "no" or "unknown", go to 7.

7. MONITORED REDUCED RISK BRIDGES: The bridge must meet one of the following criteria to be monitored as a reduced risk bridge: Scheduled for replacement or installation of constructed scour countermeasures within 5 years; road classified as a Local Road or with an estimated ADT of less than 25; or overtopping the bridge or adjacent roadway on the average of every 5 years or less. This section is designed to identify bridges for which a monitoring program is a logical economic choice instead of continued scour evaluation studies. Bridges that are being monitored for scour can be considered to have a reduced risk to the general public. If a monitoring program is not in existence or will not be implemented, a scour evaluation study is required.

Other bridges that may not require a scour analysis are bridges that are founded on erodible or semi-erodible bedrock. These bridges are difficult to analyze because the tools are not available at this time. It is expected that bedrock will erode at a much slower rate than non-cohesive material, so that a close scrutiny during the routine inspection should be adequate to insure the integrity of the bedrock. Probing to determine the top of rock may be necessary to determine if there has been any change due to potential scour. Documenting the cross section taken at the bridge is recommended.

Answer the first three (3) questions related to risk. If the answer to any of the questions is "yes", and the local professional engineer having jurisdiction over the bridge inspection directs a monitoring program for the bridge, rate the bridge as "**K**" and monitor in accordance with the Scour Monitoring Plan. If the answer to (d) is yes, rate the bridge as "**O**", scour safe but action required in accordance with the above instructions. If the answer to all 4 questions is "no" or "unknown" rate the bridge "**R**" and monitor.

SECONDARY SCREENING OF MINNESOTA BRIDGES WITH KNOWN FOUNDATIONS

Date:____

Signature of Professional Engineer performing Screening:________________________
Registration Number:________________________

Bridge Location:

Bridge Number:_________________________________
County:_______________________________________
Township:_____________________________________
Roadway:______________________________________
Stream:_______________________________________

Complete the following questionnaire consisting of 7 sections, in consecutive order, and place an **X** by the appropriate **scour screening rating code** listed below. Responses to questions in the various sections may result in rating the bridge without completing the questionnaire in total.

_____Low risk for failure due to scour, Scour Code = **I**

_____Limited risk to public, monitor in lieu of evaluation, Scour Code = **K**

_____Scour safe, but action required, Scour Code = **O**

_____Scour Critical, Monitoring required, Scour Code = **R**

_____Scour Critical, Protection required, Scour Code = **U**

1. HISTORICAL SCOUR PERFORMANCE:

a. What is the Primary Screening Code:_________
b. Has the bridge ever experienced scour which caused foundation undermining that has not been adequately corrected?_______

If the answer to (b) is "yes", Rate Bridge "U". If "no" or "unknown", go to 2.

2. SCOUR RESISTANT FOUNDATIONS:

Answer the following questions for each substructure unit. Place the answer in the table on the next page.

a. Are the foundations embedded in scour resistant rock such as basalt, gabbro, granite, gneiss, or quartzite, if not highly weathered, broken or fractured, based upon record drawings or construction records? Rock type is ________.

(b), (c) and (d) are only for bridges with drainage areas less than 400 mi^2 :

b. For the foundations with piling, are the piling embedded in stiff clay (a clay with a shear strength greater than 2000 psf)?
c. Abutments only: are there adequately designed and functioning scour countermeasures in good stable condition protecting the abutments? (typical scour countermeasures include riprap, gabions, concrete paving)
d. Piers only: Is the average bottom of the pile tips more than 40 feet below the lowest river bottom elevation at the bridge site?

	Left Abutment	Pier No. ___	Pier No. ___	Pier No. ___	Pier No. ___	Right Abutment
a.						
b.						
c.		N.A.	N.A.	N.A.	N.A.	
d.	N.A.					N.A.

If there is at least one "yes" in each column in the above table, rate the bridge as "**I**" and proceed no further. If "no" or "unknown", go to 3.

3. DEBRIS AND BLOCKAGE:

a. Does debris collect or build up at the bridge and block at least 10% of the flow cross section? ____________________

b. Does ice collect or build up at the bridge and block at least 10% of the flow cross section?____________________

If the answer to either of the above 2 questions is "yes" or "unknown", go to 7. If the answer to both questions is "no", go to 4.

4. GEOMORPHIC CONDITIONS AFFECTING SCOUR RESISTANCE:

a. Is the stream bed degrading? _____________________

b. For natural streams, are there channel bends of greater than 30 degrees within a distance of 4 times the channel width upstream of the bridge? _______

c. Are the stream banks unstable? ________

d. Are the bridge abutments or piers skewed to the direction of flow? _____

e. Is the effective flow width (width of flow during the 100 year flood) greater than 5 times the total bridge span or 5 times the bank full channel width?_________

If the answer to **any** of the above 5 questions is "yes" or "unknown", go to 7. If the answer to all the above questions is no, go to 5.

5. HYDRAULIC CONDITIONS AFFECTING SCOUR RESISTANCE:

Based upon known topographic information and water surface profile calculations or historical records or profession judgment, answer the following questions:

a. Is the flood depth less than 3 feet and stream slope, within a mile of the bridge, less than 5 feet per mile?_______

b. Is flood depth less than 10 feet and stream slope, within a mile of the bridge, less than 1 foot per mile? ________

c. Is flood depth less than 20 feet and stream slope, within a mile of the bridge, less than 0.5 feet per mile? ______

d. For floods of magnitude greater than 50 years, is the average velocity through the bridge less than 3 fps in sand bed water courses or less than 5 fps in clay bed water courses? ______

If the answer to any of the above 4 questions is "yes", rate the bridges as "**I**" and proceed no further. If the answer to all of the above questions is "no" or "unknown", go to 6.

6. STRUCTURAL CONDITIONS AFFECTING SCOUR RESESTANCE:

If the bridge is multiple span, go to 7. If the bridge is a single span and the effective flood plain width is less than 5 times the span length, answer the following 3 questions. Otherwise, go to 7.

a. Is the bridge supported by concrete abutments on piles? ______

b. Is the bridge supported by timber abutments less than 6 feet high on piles?______

c. Is the bridge a single span with concrete abutments over a man made ditch with slope of less than 5 feet per mile or average ditch velocity less than 3 fps for a flood of magnitude 50 years or greater? _____

If the answer to any of the above 3 questions is “yes”, rate the bridge as “**I**” and proceed no further. If the answer to **all** 3 questions is “no” or “unknown”, go to 7.

7. MONITORED REDUCED RISK BRIDGES:

a. Is the bridge scheduled for replacement or installation of constructed scour countermeasures within 5 years? ______

b. Is the road classified as a Local Road or is the estimated average daily traffic (ADT) over the bridge less than 25? _____

c. Does the bridge or adjacent roadway overtop more often than on average every 5 years, requiring closure and therefore inspection before reopening?_____

d. Is the bridge supported by spread footings on rock and can the rock condition be adequately examined during a routine inspection? _____

If the answer to either: a, b or c is “yes”, and the local professional engineer having jurisdiction over the bridge inspection directs a monitoring program for the bridge, rate the bridge as “**K**”. If the answer to d is “yes”, rate the bridge as “**O**”, scour safe but action required in accordance with the instructions. If the answer to all 4 questions is “no” or “unknown”, rate the bridge as "**R**" and monitor. A Scour Analysis can be done on Bridges rated “R” to see if they qualify for a different scour code.

SECONDARY SCREENING OF MINNESOTA BRIDGES
WITH SCOUR CODE "G"

Date:

Signature of Professional Engineer performing Screening:________________________

Registration Number:________________________

Bridge Number:________________________________
County:_______________________________________
Township:_____________________________________
Roadway:______________________________________
Stream:_______________________________________

Assume a foundation:
The FHWA has issued guidance Risk-Based Management Guidelines for Scour at Bridges with Unknown Foundations . See Chapter 5 for Scour Risk Management Guidelines which include guidance for Inferring Foundations and Screening Bridges According to Risk. The following are common assumptions that are noted in Chapter 5 for bridges with unknown foundations:

i. Older structures (built before 1960) were usually built on timber piling.
ii. Depth of piles can be assumed as at least 10 feet for bridges with unknown foundations.
iii. If rock is near the surface, spread foundations can be assumed.
iv. The top of a typical spread footing can be assumed to be 3 feet below the top of the soil and the bottom 7 feet below the top of the soil.

Technical Guidance for Bridges over Waterways with Unknown Foundations has the following suggestions: Check known foundation types of bridges built during the same period of time as your bridge of interest. Historical foundation practices were very repetitive and rather simple in concept.

Complete the following questionnaire consisting of 6 sections, in consecutive order, and place an X by the appropriate scour screening rating code listed below. Responses to questions in the various sections may result in rating the bridge without completing the questionnaire in total.

RESULTS:

_____Low risk for failure due to scour, Scour Code = **I**

_____Limited risk to public, monitor in lieu of evaluation, Scour Code = **K**

_____Scour safe, but action required, Scour Code = **O**

_____Scour Critical, Monitoring required, Scour Code = **R**

_____Scour Critical, Protection required, Scour Code = **U**

1. HISTORICAL SCOUR PERFORMANCE:

a. What is the Primary Screening Code:_________

b. Has the bridge ever experienced scour which caused foundation undermining that has not been adequately corrected?_______

If the answer to (b) is "yes", Rate Bridge "U". If "no" or "unknown", go to 2.

2. DEBRIS AND BLOCKAGE:

c. Does debris collect or build up at the bridge and block at least 10% of the flow cross section? ___________________

d. Does ice collect or build up at the bridge and block at least 10% of the flow cross section?___________________

If the answer to either of the above 2 questions is "yes" or "unknown", go to 6. If the answer to both questions is "no", go to 3.

3. GEOMORPHIC CONDITIONS AFFECTING SCOUR RESISTANCE:

f. Is the stream bed degrading? ____________________

g. For natural streams, are there channel bends of greater than 30 degrees within a distance of 4 times the channel width upstream of the bridge? _______

h. Are the stream banks unstable? ________

i. Are the bridge abutments or piers skewed to the direction of flow? _____

j. Is the effective flow width (width of flow during the 100 year flood) greater than 5 times the total bridge span or 5 times the bank full channel width?_________

If the answer to any of the above 5 questions is "yes" or "unknown", go to 6. If the answer to all the above questions is no, go to 4.

4. HYDRAULIC CONDITIONS AFFECTING SCOUR RESISTANCE:

Based upon known topographic information and water surface profile calculations or historical records or profession judgment, answer the following questions:

e. Is the flood depth less than 3 feet and stream slope, within a mile of the bridge, less than 5 feet per mile?_______

f. Is flood depth less than 10 feet and stream slope, within a mile of the bridge, less than 1 foot per mile? ________

g. Is flood depth less than 20 feet and stream slope, within a mile of the bridge, less than 0.5 feet per mile? ______

h. For floods of magnitude greater than 50 years, is the average velocity through the bridge less than 3 fps in sand bed water courses or less than 5 fps in clay bed water courses? ______

Is the answer to any of the above 4 questions is “yes”, rate the bridge as “I” and proceed no further. If the answer to all of the above questions is “no” or “unknown”, go to 5.

5. STRUCTURAL CONDITIONS AFFECTING SCOUR RESESTANCE:

If the bridge is multiple span, go to 6. If the bridge is a single span and the effective flood plain width is less than 5 times the span length, answer the following 3 questions. Otherwise, go to 7.

d. Is the bridge supported by concrete abutments on piles (see above for foundation assumption)? ______

e. Is the bridge supported by timber abutments less than 6 feet high on piles?______

f. Is the bridge a single span with concrete abutments over a man made ditch with slope of less than 5 feet per mile or average ditch velocity less than 3 fps for a flood of magnitude 50 years or greater? _____

If the answer to any of the above 3 questions is “yes”, rate the bridge as “I” and proceed no further. If the answer to all 3 questions is “no” or “unknown”, go to 6.

6. MONITORED REDUCED RISK BRIDGES:

a. Is the bridge scheduled for replacement or installation of constructed scour countermeasures within 5 years? ______

b. Is the road classified as a Local Road or is the estimated average daily traffic (ADT) over the bridge less than 25? _____

c. Does the bridge or adjacent roadway overtop more often than on average every 5 years, requiring closure and therefore inspection before reopening?_____

d. Is the bridge supported by spread footings on rock and can the rock condition be adequately examined during a routine inspection? _____

If the answer to either: (a), (b) or (c) is "yes", and the local professional engineer having jurisdiction over the bridge inspection directs a monitoring program for the bridge, rate the bridge as "K". If the answer to (d) is "yes", rate the bridge as "O", scour safe but action required in accordance with the instructions. If the answer to all 4 questions is "no" or "unknown", rate the bridge as "R" and monitor. A Scour Analysis can be done on Bridges rated "R" to see if they qualify for a different scour code.

APPENDIX C

SCOUR ANALYSIS

- **INSTRUCTIONS**
- **REPORT FORM**

INSTRUCTIONS FOR PERFORMING MINNESOTA DOT SCOUR ANALYSIS

Instructions are provided below for performing a bridge scour analysis in accordance with FHWA guidelines and Minnesota specific conditions reflected in the development of the Minnesota Department of Transportation Bridge Scour Evaluation Procedures. A scour analysis entails performing a site specific qualitative study of a bridge to determine it's vulnerability to conditions which cause foundation scour and stream stability problems at the bridge. The team performing the review should be thoroughly familiar with FHWA publications HEC-18, HEC-20 and HEC-23. They should also be competent in the fields of hydraulics, geotechnical, and structural engineering.

A scour analysis consists of the following 4 tasks, listed in the order of execution, including: office data collection, review and evaluation of collected data, site visit and field assessment, and scour evaluation. The pre-printed Minnesota DOT Scour Report Form (Report Form) should be used for reporting the results of scour evaluations. Attached to the report should be pertinent collected data, a completed pre-printed Minnesota Bridge Scour Field Assessment Form (Field Form), and any computations made to support the scour rating. A description of each task is given below.

OFFICE DATA COLLECTION

The first task to be performed in a scour analysis is the collection of available data related to geology, hydrology, and sediment transport in the drainage area upstream and in the vicinity of the bridge. This data should include: a bridge general plan and elevation with foundations depicted, topographic maps of the water course and drainage area, aerial photographs from different years for comparison, soil boring logs, pile driving records, soils/geologic maps, stream gage data, bridge hydraulic recommendation, bridge inventory sheet, bridge inspection reports, underwater inspection reports, hydrologic and hydraulic studies or other studies of the water course, and other appropriate data. All of the information collected should be identified on the first page of the form.

Peak flood discharges and approximate stages should be estimated for the 100 and 500 year floods, prior to the site visit. The discharge estimates help make the field observations more meaningful by allowing visualization of flow conditions for these extreme events.

REVIEW AND EVALUATION OF THE DATA COLLECTED

In general, all of the information collected should be reviewed prior to a site visit and field assessment. The data which is used in rating the scour susceptibility of the bridge should be attached to the Report Form. Specific items of data should be reviewed as follows:

1. Review the plan and elevation of the bridge to determine the depth to the bottom of the footings and their orientation with respect to the flow direction.

2. Review the aerial photographs for lateral migration of the water course. The photographs compared should be the most recent available and preferably one taken at least 20 years earlier, if available.

3. Review the soils and geologic information to determine the ability of the bed and bank materials to resist scour. Also assess the drainage area susceptibility to soil erosion and therefore a continuing source of material for bed load and scour infilling. Soil boring information and pile driving records should be reviewed for stratigraphic and grain size information.

4. Review bridge inventory sheet, inspection reports, and underwater inspection reports for historical problems related to scour and stream stability.

5. Review available stream gage data, bridge hydraulic recommendations, FEMA floodway information, and other hydraulic/hydrologic studies and reports for information regarding flood hydrographs and peak discharges, water surface profiles, and associated channel velocities.

Answer the 7 questions on page 2 of the Report Form or summarize this information in narrative form. On USGS topographic maps, delineate the area tributary to the bridge. Use maps of an appropriate scale. Digitize or planimeter the area to determine its approximate size. Note that the tributary area map will be used to help determine land use, vegetation type, and land and water course slope, which in turn will provide background for assessing the potential for debris or ice problems. Prior to making a site visit, determine 100 year and 500 year flood peak discharges by analyzing gage records for the water course, transposing records from another water course, estimating flows from Minnesota regression equations or flood insurance studies. If there is no information available for Q_{500}, use $1.7*Q_{100}$. Write the discharges in the space provided on page 2 of the Report Form. Attach discharge calculations to the scour evaluation report form.

SITE VISIT AND FIELD REVIEW

Plan site visits to minimize travel time and cost. Equipment required should include: camera, sounding pole or equivalent, tape measure, hand auger, shovel, and notebook including the Minnesota Bridge Scour Field Assessment Form. Notes are easily made on copies of the bridge plan and elevation. It is recommended that the notebook taken to the field contain site specific information from the office data collection. Water surface elevation at the time of the site visit should be noted and referenced to a known elevation on the bridge. Depth and approximate velocity measurements should be taken at the upstream fascia. If measurements indicate the stream bed has lowered at the bridge, it may be necessary to profile the thalweg upstream and downstream in an effort to determine if degradation is localized or not. Visualize the angle of attack on the piers and abutments during bank full and flood stage. Note the potential for and location of roadway overtopping and the possibility of pressure flow under the bridge. Photograph the bridge from upstream and downstream and photograph the water course looking upstream and downstream from the bridge. Evaluate the site upstream and downstream of the bridge. Take one cross section downstream and one upstream, at the bridge. Take one cross approximately one bridge length upstream including the overbank area. Cross section should “close”. Meaning, cross section should begin and end at whatever high water marks are noted at site or previously calculated. Note the presence of any erosion or scour at foundation units or elsewhere. Summarize observed conditions at the bridge related to scour in the space provided on page 2 of the Report Form. Attach field notes, photographs, and Field Form. Draw a cross section of the channel and flood plain and note bank heights, bottom width, side slopes, roughness coefficients, etc.

SCOUR EVALUATION

Upon completion of the site visit and field review, a preliminary estimate of scour depth should be made. The following step by step procedure is recommended:

1. Determine Q_{100}, Q_{500}, and $Q_{overtopping}$ (Q_{OT}), if appropriate. (This may have been done prior to the site visit.) Utilize the USGS regression equations, gaging data, Flood Insurance Studies and other studies as available. If Q_{OT} is less than Q_{500} or Q_{100}, the Q_{OT} will usually generate the highest average velocity through the bridge which needs to be evaluated.

2. Determine appropriate "n" values from field notes and photographs. (See Table 8-1 from the AASHTO Model Drainage Manual in appendix I)

3. Determine slope from quadrangle map or other source.

4. Utilize an appropriate computer program such as HEC-RAS, enter in the cross section data obtained in field. Run for a range of discharges including Q_{100}, Q_{500}, and Q_{OT}. Using the flow distribution feature in HEC-RAS note the main channel and the overbank flow at the approach section. This information is necessary for the contraction scour calculation, found in HEC 18.

6. Calculate the mean velocity through the bridge by dividing the appropriate discharge by the area bounded by the surveyed channel bottom elevation at the front face of the bridge and the estimated or calculated water surface elevation, or read the value from the HEC-RAS output. If part of the discharge is overtopping the road, this quantity must be deducted from the quantity flowing under the bridge.

7. Calculate contraction scour by utilizing both the live bed and the clear water contraction scour equations as given in HEC 18 and select the smaller scour depth. With stratified bed materials (See Appendix J), the depth of scour can be determined by using the clear water scour equation and successive mean diameter of the bed material layers.

8. Calculate pier scour using the CSU equation given in HEC 18. The average velocity should be adjusted as follows: (a) If the pier is located in the outside of a bend, use 1.7 V_{ave} or (b) for other locations, use 1.25 V_{ave}. If the footing is exposed, use the guidance given in HEC 18.

9. Check the adequacy of the existing riprap on the abutments, using the criteria from HEC-23 to determine if it is stable for the calculated discharges. If there is no riprap inplace, or existing riprap is not adequate, determine the size of riprap required by the HEC-23 criteria.

10. Plot the predicted contraction scour and pier scour on a cross section of the bridge.

11. Evaluate the bridge for structural stability. The memo from Don Flemming, State Bridge Engineer, entitled **Guidelines for Evaluation of Stability of Existing Pile Foundations When Exposed by Scour** and included in Appendix F, can be utilized in this evaluation.

Complete the summary tables on page 3 and 4 of the Report Form and rate the bridge in accordance with scour rating codes below. If coded L, M, or N, scour stable, no further action is required. If coded R, U, K, O, P, Plan of Action (POA) is required.

	Scour Rating Code	Description
L	STABLE-EVAL	Scour evaluation complete, bridge judged to be low risk of failure due to scour.
M	STABLE-SCOUR ABOVE FOOTING	Bridge foundations determined to be stable for calculated scour conditions; calculated scour depth from the scour prediction equations is above top of footing.
N	STABLE - SCOUR IN FTG OR PILE	Bridge foundations determined to be stable for calculated scour conditions; calculated scour depth from the scour prediction equations is within limits of footing or piles.
O	STABLE - ACTION REQUIRED	Bridge foundations determined to be stable for predicted scour conditions; Scour action plan requires additional action.
P	STABLE DUE TO PROTECTION	Countermeasures have been installed to correct a previously existing problem with scour. Bridge is no longer scour critical. Scour countermeasures should be inspected at lease once every 4 years and after major flows, or as recommended in the scour action plan. Report any changes that have occurred to countermeasures.
R	CRITICAL - MONITOR	Bridge has been evaluated to be scour critical. Scour action plan recommends monitoring the bridge during high flows and closing if necessary.

U	CRITICAL-PROT REQUIRED	Bridge has been evaluated to be scour critical. Scour action plan recommends this bridge as a priority for installation of countermeasures. Until countermeasures are installed, monitor the bridge during high flows and close if necessary.

Complete a Report Form. Attach office data, field notes including Field Assessment Form, and calculations. File as part of the permanent scour evaluation record.

MINNESOTA DOT SCOUR EVALUATION REPORT FORM

Bridge Number:____________________________
County: _________________________________
Township:_________________________________
Roadway:_________________________________
Stream: __________________________________

This bridge has been evaluated for scour and is rated as:______________________________

The action recommended for this bridge is:____

Signature of Professional Engineer: ______________________________ Date:______________

This form presents the background data, evaluation parameters, and appropriate preliminary calculations to determine the susceptibility of the subject bridge to foundation scour in accordance with a phased approach recommended in Federal Highway Administration guidelines.

OFFICE DATA COLLECTION

The following information has been collected and is attached as part of this scour evaluation (place an **X** adjacent to the items obtained). The information should be reviewed prior to a site visit and field review.

_____ Bridge general plan and elevation with foundations depicted
_____ Topographic maps of the water course and tributary area
_____ Aerial photographs, years ________________________
_____ Soil boring logs
_____ Pile driving reports
_____ Soils/geologic maps
_____ Stream gage data
_____ Bridge Hydraulic Recommendation
_____ Bridge Inventory Sheet
_____ Bridge inspection reports
_____ Underwater inspection reports
_____ Hydraulic/hydrologic or other studies of the water course as follows __________
____
____
____
____
_____ Other appropriate data (describe)_______________________________________
____
____
____

REVIEW AND EVALUATION OF THE DATA COLLECTED

Are the piers or abutments supported by piles or caissons?___________________________
Is the bridge perpendicular to the water course? __________________________________
Are the piers or abutments parallel to the flow or at a skew?__________________________
Has there been any lateral migration of the stream in the vicinity of the bridge?____________

____
What is the evidence of lateral migration?____

____
Is there a history of scour problems at the bridge?____________________________________

____
Are the footings founded on a material resistant to scour, such as rock or stiff clay?_________

____

Hydrologic conditions at the bridge are as follows (attach backup or calculation) :

Q(100)= ____________ cfs Stage _____________
Q(500)= ____________ cfs Stage _____________
Q(Overtopping)____________ cfs Stage _____________

SITE VISIT AND FIELD REVIEW

Briefly summarize observed conditions at the bridge related to scour. Attach Minnesota Bridge Scour Field Assessment Form.____

____
____
____
____

HYDROLOGIC AND HYDRAULIC SUMMARY			
Drainage Area			
Flood Frequency (YR)			
Discharge (cfs)			
W.S. Elevation			
Maximum depth (ft)			
Average velocity (fps)			
Pier scour (ft)			
Contraction scour (ft)			
Total scour (ft)			

FOUNDATION SUMMARY SHEET				
Structure Name[1]				
Type of Foundation				
Type of Piling				
Pile Diameter (inches)				
Located in Main channel (Yes/No)				
Original Ground Elev. Date:______				
Current Ground Elev. Date:______				
Thalweg Elevation Date:________				
Top of Footing Elevation				
Bottom Footing/Pile Cap Elevation				
Average Bottom of Pile Elevation				
SCOUR SUMMARY SHEET				
Flow Frequency & Event	Q ________ = ______________cfs			
Calculated Contraction Scour (feet)				
Calculated Local Scour (feet)				
Total Scour (feet)				
Contraction Scour Elevation				
Total Scour Elevation				
Length of Pile Exposed (feet)				
Length of Pile Embedded (feet)				

[1] Use structure name identified on the bridge plan sheet. ie. North Abutment, Pier 1

The bridge is rated as ______________________ (see detailed ratings in instructions). If coded L, M, or N, scour stable, no further action is required. If coded R, U, K, P, or O a Plan of Action is required.

Attach office data, Field Assessment Form, survey notes, and calculations and file as part of the permanent scour evaluation record.

APPENDIX D

MINNESOTA BRIDGE SCOUR

FIELD ASSESSMENT FORM

Minnesota Bridge Scour Field Assessment Date:________________ Crew:________________
01/06/95 ________________

Bridge No.________________ Route: ____________________ County: ______________________
Stream: _________________________________ Location:___________________________________

Bridge:
Does bridge geometry differ from plan:_Yes/No_ If so, explain on back of sheet.

Take Cross-Section at Upstream Face of Bridge: at minimum, measure elevation (to nearest .5') at pier foundations, abutments foundations, toe of abutment slope & thalweg. Additional measurements between foundations are recommended. Attach sketch.
Water surface elevation: ________________

Abutment Direction as on plan	Location (ft) Set Back, At Bank, or In Channel & Distance from Bank	Protection Type, Size Condition & Extent	Existing Scour None, Local Scour Footing Exposed, Piles Exposed	Guide Banks Yes/No

Pier Number as on plan	Location (ft) In Channel, At Bank or on Flood Plain	Angle of Attack		Debris type/amount none, brush, branches, trees	Protection Type, Size Condition & Extent	Existing Scour None, Local Scour Footing Exposed, Piles Exposed
		Low Flow	High Flow			

Piers numbered ______ to ______
Additional Comments: ____
____
____

Are there observed or potential scour problems at bridge, describe any problems.

Yes	No	
☐	☐	Abutments tilting/moving in:________________________________
☐	☐	Approach panel cracking or settlement:
☐	☐	Slopes washing in/sloughing:________________________________
☐	☐	Scour holes near abutments/piers:___________________________
☐	☐	Bed deposits downstream:___________________________________
☐	☐	Damage to riprap/abutments/piers:___________________________
☐	☐	Bridge Railing Sagging:____________________________________
☐	☐	Debris potential:____
☐	☐	Ice problem potential:_____________________________________
☐	☐	Highwater Mark:____
☐	☐	Other:____

Channel

		Manning n	Channel/Floodplain Material & Cover Description
Channel			
Upstream Flood plain			
Downstream Flood plain			

Channel Bed Material: Type (silt/clay, sand, gravel, cobble/boulder, bedrock) & Size (fine, medium, coasrse)		
Upstream:	Under Bridge:	Downstream:

Circle conditions that apply:

River Form: Straight ● Meandering ● Braided ● Man Made ● ____________________

Stream Size: Small (<100 ft) ● Medium (100-500 ft) ● Large (>500 ft)

Flow Characteristic: Intermittent ● Perennial

Check yes for any conditions that apply and describe

Yes	No	
☐	☐	Bridge located near bend: upstream/downstream/in bend
☐	☐	Evidence of lateral migration: ____________________
☐	☐	Evidence of bank mass wasting: ____________________
☐	☐	Islands/bars: upstream/downstream/under bridge
☐	☐	Angle of Attack on bridge: Flood Flow: ________ Normal Flow: ________
☐	☐	Evidence of aggradation: ____________________
☐	☐	Evidence of degradation: ____________________
☐	☐	Nearby bridges/culverts: ____________________
☐	☐	Nearby dam/control structure: ____________________
☐	☐	Channel Modification: ____________________
☐	☐	Nearby tributaries: ____________________
☐	☐	Nearby confluence: ____________________

Banks		Bank Height	Bankfull Channel Width	Vegetation/ Cover	Material silt/clay, sand, gravel, cobbles, boulders, bedrock	Protection	Erosion none, mass wasting, fluvial
Up-stream							
Down-stream							

Circle conditions that apply:
Roadway overtopping potential: None ● ____ approach ● ____ approach ● Bridge
Roadway overtopping frequency: Frequent ● Rare
Overbank flow: None ● ____ floodplain __________ ft. ● ____ floodplain __________ ft.
Bridge length:____________
Relief structures:____

Water surface elevation required for pressure flow at bridge:________________
Current water depth under bridge at thalweg:________________
Water depth upstream: same ● deeper ● shallower
Water depth downstream: same ● deeper ● shallower

Direction of flow:_____ to _____

Summary of Conditions at Site with regards to Scour:

____
____
____
____
____
____
____

Photographs:

Roll	Exposure	Description
____	_______	Top of road over bridge
____	_______	Upstream channel, bridge from upstream & downstream,
____	_______	Downstream channel
____	_______	Bridge piers & abutments
____	_______	Inplace countermeasures
____	_______	Bridge from upstream
____	_______	______________________________
____	_______	______________________________
____	_______	______________________________
____	_______	______________________________
____	_______	______________________________
____	_______	______________________________

Sketch:
Draw plan view of bridge and river. Show approximate location of any countermeasures, existing erosion or scour, debris, islands/bars/river bends, direction of flow, and/or other nearby structures.

APPENDIX F

BRIDGE STABILITY GUIDELINES

DEPARTMENT : Transportation
Office of Bridges and Structures

STATE OF MINNESOTA
Office Memorandum

DATE : January 10, 1995

TO : Engineering Personnel
Office of Bridges and Structures

FROM : Donald J. Flemming
State Bridge Engineer

PHONE : 582-1100

SUBJECT : Guidelines for Evaluation of Stability of Existing Pile Foundations when Exposed by Scour

The following guidelines may be used with discretion by registered engineers for determination of stability of existing bridge substructure units supported by pile foundations (see attached diagrams showing pile and scour parameters for various types of piers) if estimated scour depths are sufficient to expose piling. Estimated scour depths to be used are those furnished by the Hydraulics Engineer for the lesser of overtopping or 500 year flood.

(1) For pile bent piers or abutments and for piers or abutments on footings supported by friction piling, the substructure unit should be classified as stable with respect to scour if scour depth will not expose more than 50% of the embedded piling, and the unsupported pile length is not more than more than 24 times the diameter of a "CIP" pile, 24 times the nominal section depth of an "H" pile, or more than 16 times the average diameter of a timber pile.

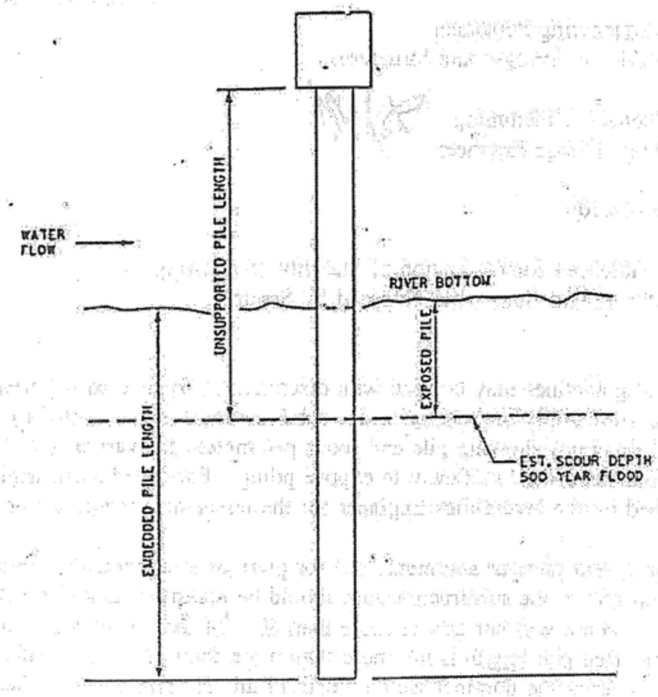
(2) For pile bent piers or abutments and for piers or abutments on footings supported by end bearing piling, the substructure unit should be classified as stable with respect to scour if at least 5 feet of the pile will remain embedded in dense material and the unsupported pile length meets the criteria in (1) above.

The substructure unit shall be considered stable if the foundation satisfies one of the above criteria.

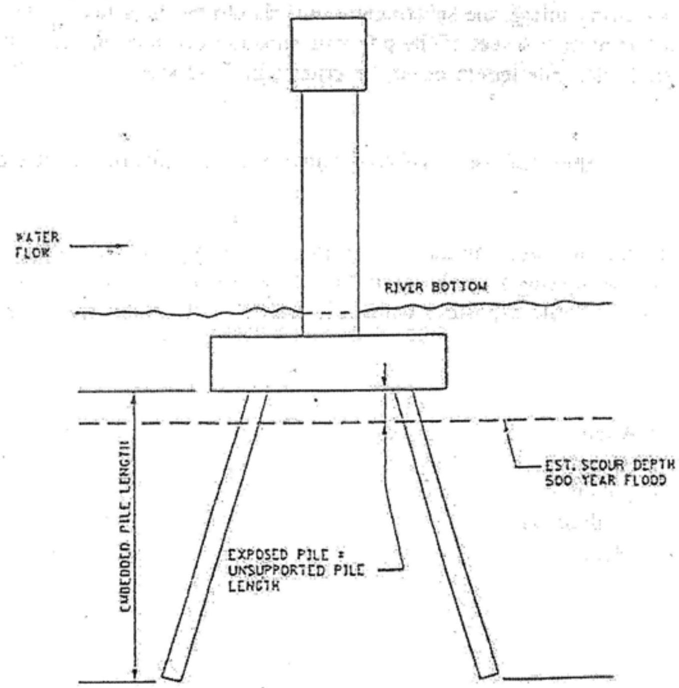
These guidelines are based on the concept that countermeasures should (and will) be taken where inspection reveals scour holes in the vicinity of pile bents or below the bottom of concrete footings. Pile exposures without lateral support will therefore be of relatively short duration.

cc: J. R. Allen
D. L. Dorgan
G. D. Peterson
D. V. Halvorson
General File

PILE BENT PIER



PIER ON PILE SUPPORTED FOOTING



Appendix G

Guidance for “G” rated bridges

Guidance for "G" rated bridges

G	NO EVAL-FOUND UNKNOWN	Scour calculation, evaluation and/or screening has not been made. Bridge on unknown foundations.

Bridges were rated "G" during our initial screening process. This was done when our scour program was in its early stages and a large number of bridges had to be categorized so the most urgent would get attention first. As "G" meant that we knew nothing about the foundations, these were set aside with the understanding we would address them at a future date. Well, that time has come.

There are several things that can be done:

2.) Re-Screen the Bridge to see if it qualifies for an "I":

I	SCREEN-LOW RISK	Bridge screened, determined to be low risk for failure due to scour

Bridges can be rated "I" if:

- Bridge has not had a history of scour

AND

- Both abutments have adequate scour protection; Riprap (Class III or larger), grouted riprap or gabions in good condition.

AND

- The bridge has no piers.

3.) Re-rate the bridge as "R":

R	CRITICAL- MONITOR	Bridge has been evaluated to be scour critical. Scour action plan recommends monitoring the bridge during high flows and closing if necessary.

The bridge is "R" as the foundations are unknown. Develop a more rigorous action plan (templates are available) and monitor or close during floods.

4.) Design adequate protection for the bridge, install and re-rate as "P":

P	STABLE DUE TO PROTECTION	Countermeasures have been installed to correct a previously existing problem with scour. Bridge is no longer scour critical. Scour countermeasures should be inspected at least once every 4 years and after major flows, or as recommended in the scour action plan. Report any changes that have occurred to countermeasures.

"P" rated bridges also require an action plan but not one as rigorous as an "R" rated bridge (again, templates are available).

4.) If you want to try to eliminate as many "R" rated bridges from your system as possible as they require monitoring during flooding, you can do the following:

- Do a secondary screening. If this still has the bridge rated "R" you can go on to a Scour Analysis.

- Do a Scour Analysis: Make assumptions as to foundation type (see below), calculate scour depths using HEC 18 (this will require calculating the flow rates to the structure and developing a model of the bridge with current cross sections), and rate the bridge accordingly.

The FHWA has issued guidance: "Risk-Based Management Guidelines for Scour at Bridges with Unknown Foundations" (http://144.171.11.107/Main/Public/Blurbs/157792.aspx). See Chapter 5 for Scour Risk Management Guidelines which include guidance for Inferring Foundations and Screening Bridges According to Risk. The following are common assumptions that are noted in Chapter 5 for bridges with unknown foundations:

i. Older structures (built before 1960) were usually built on timber piling.
ii. Depth of piles can be assumed as at least 10 feet for bridges with unknown foundations.
iii. If rock is near the surface, spread foundations can be assumed.
iv. The top of a typical spread footing can be assumed to be 3 feet below the top of the soil and the bottom 7 feet below the top of the soil.

"Technical Guidance for Bridges over Waterways with Unknown Foundations" (http://www.fhwa.dot.gov/engineering/hydraulics/policymemo/20080109.pdf) has the following suggestions: Check known foundation types of bridges built during the same period of time as your bridge of interest. Historical foundation practices were very repetitive and rather simple in concept.

Links to both of these documents are embedded in their addresses. Please review these documents to understand the limitations of the suggestions noted above.

APPENDIX H

MN/DOT FLOOD RESPONSE PLAN

TRUNK HIGHWAY BRIDGES FLOOD RESPONSE PLAN

Purpose

Bridges are vulnerable to damage and failure during flooding. Scour may undermine the bridge foundations or remove the protection from the abutment slopes. To protect the public and the bridges, bridges should be monitored during flooding. Monitoring generally requires measuring the river bed elevation at the bridge. Monitoring may indicate that the bridge should be closed, corrective action should be taken immediately (such as removing debris), or that protection should be installed as soon as practical.

Each district is responsible for monitoring their bridges. This Flood Response Plan contains recommendations to the Districts on monitoring bridges and the support available from the Bridge Office.

Priority

Monitoring is recommended for all bridges during significant flooding. However, the extent, frequency, and the flood stage to begin monitoring will vary. The District is responsible to determine which bridges will be monitored; the Bridge Office recommendations are as follows:

Bridge Monitoring Recommendations			
Priority	Bridge Description	Scour Code	Recommended Action
High	Scour critical with action plan	R, U	Follow Plan Of Action (POA)
High	Limited Risk, Monitor in lieu of evaluation	K	Follow POA
High	Known scour problems with no POA	Any Code	Follow general guidelines
High	Others with POA	O, P	Follow POA
Secondary	Stable and low risk bridges	H, I, L, M, N	Follow general guidelines

POAs have been prepared for scour critical bridges and contain details on monitoring a specific bridge site. The POA is on file in the District and at the Bridge Office. Bridges that do not have a POA should be monitored using the following general guidelines.

General Guidelines

Monitoring Tools

Sounding weights and/or sonar are normally used to monitor the river bed elevations at the bridge. Both methods are usually used from the bridge deck. However, the measurements taken along the bridge fascia may not be located at the site of maximum scour which is usually close to the pier or abutment. Ice and debris may limit the locations and can cause inaccurate readings.

Each District should have at least one sonar unit. Three portable winches with 35 and 100 pound weights are available. They are located in the Metro Division, District 1 – Duluth, District 6 – Rochester and the Bridge Office. If one of these units is needed, the scour coordinator from that District should be contacted.

If Mn/DOT is unable to monitor a certain bridge, the United States Geological Survey may be able to assist in monitoring that bridge with their equipment. Contact the Bridge Office Flood Coordinator if this is necessary.

A boat may be required to monitor pier scour at bridges over major rivers. Since safety of the operating personnel is a prime consideration, the boat must be of sufficient size and equipped properly to navigate around piers during flood stage.

Pre-flood Preparation

The District must be prepared to monitor when flooding occurs. Personnel who will monitor the bridges must have access to the necessary equipment and have adequate training. The District should have a plan for checking water surface elevations after rainfall or snowmelt, and notification procedures must be defined.

The District should conduct a pre-flood site investigation on all bridges with a high monitoring priority. The purpose of the pre-flood investigation is to prepare the bridge for monitoring and would include:

- Mark the locations at which measurements will be taken and measure baseline river bed elevations.
- Mark and survey a reference point elevation to measure the water surface elevation.
- Mark the water surface elevation at which monitoring should begin. Use Bridge Scour Monitoring Sign symbol.

Monitoring Frequency

Flooding that warrants monitoring of trunk highway bridges may occur any year. The District is responsible for determining if bridges are undergoing flooding conditions that require monitoring. The Bridge Office Flood Coordinator can be contacted by the District to assist in determining when monitoring shall commence and be suspended.

Action plans give the beginning flood stage at which monitoring is recommended. General guidelines are:

Begin monitoring:

- Scour Critical Bridges: As recommended in action plan
- Limited Risk and Scour Susceptible Bridges:
  - During significant flooding (water nears design high water elevation)
  - River nears elevation that has caused problems in past
  - Unusual conditions (such as large amount of debris)
- Stable or low risk Bridges:
  - River nears historic high water or design high water elevation
  - Unusual conditions (such as large amount of debris)

Initial Monitoring:

Compare the measured bed elevation to the base line elevation. Determine if the bed has lowered significantly, a significant bed change is defined as:

- 5 ft: Large rivers (river channel over 100' wide)
- 2 ft: Medium/small rivers (river channel less than 100' wide)

Continued Monitoring:

- Significant bed changes are not detected: monitor once per day until flood crest begins to recede.
- Significant bed changes are detected: monitor a minimum of twice per day and contact the District Scour Coordinator or Bridge Office Flood Coordinator.
- Monitor continuously if river bed nears the critical scour elevation.

Monitoring Procedure

Monitor all critical piers and abutments to determine if the channel bottom elevation is changing.

- Maximum pier scour is expected to occur near the front face of the pier. If flood water is attacking the pier at a skew angle, the deepest scour is expected on the front or side that the flow impacts.

- Maximum abutment scour typically occurs at the toe of the abutment slope or the upstream corner of a vertical abutment.

- Bridges with abutment slopes should be monitored both at the toe of the abutment slope and next to the abutment foundation. If the foundation is undermined, the approach fill may be endangered.

- Foundations protected by countermeasures should be monitored. Riprap is not typically designed to withstand a 100 year or 500 year flood event. Monitor to verify that the riprap remains in place.

Measure for scour from the upstream face of the bridge, if possible. However, if this is not possible due to ice or debris, measure from the downstream face. The notes should state where monitoring was taken and if ice or debris were present (since they can increase the amount of scour).

To measure river bed elevations:
- Measure the water surface elevation by measuring down from the bridge
- Determine bed elevation from water depth and known water surface elevation
- Record data. Include a water surface elevation, reference locations from a pier or the end of bridge. Elevations should be tied to MSL datum.

Action

For bridges with monitoring Plan of Action (scour code R, K, O, P or U), follow the plan recommendation to close the bridge if the riverbed lowers to the critical scour elevation. For bridges without a POA, close the bridge if scour threatens the bridge stability.
- Notify the proper authorities
- Detour traffic (use Trunk Highways where practical)
- Review bridges on detour route for scour code and monitor if necessary.
- Check bridges after flood recedes/make recommendations for repair/protection

If large amounts of debris are at the bridge, remove the debis as soon as possible. If scour occurs at the bridge consult the Bridge Office to see if protection should be installed.

Reporting

Report results of monitoring to the District Scour Coordinator daily. If scour reaches the critical river bed elevation, the monitoring personnel should take appropriate action and contact the District Scour Coordinator.

The District Scour Coordinator and Bridge Office personnel should regularly contact the Bridge Office Flood Coordinator to notify him of the flood monitoring results. The Flood Coordinator is responsible for coordinating all Bridge Office responses. In the event of wide spread flooding, the Bridge Office Flood Coordinator will provide the State Bridge Engineer with daily status reports.

After flooding has subsided, the District Scour Coordinator should summarize the bridges that were monitored and the results for the Bridge Office Flood Coordinator. The District may request that the Bridge Office review a specific bridge(s).

Bridge Office Services to the Districts

- The Bridge Office Flood Coordinator will monitor the following data sources to detect flooding which may affect Mn/DOT bridges.

  - River Flood Forecasts issued by the River Forecast Center.

  - Weekly Precipitation Maps issued by the Minnesota DNR.

  - Contact with other State and Federal agencies, including: National Weather Service; River Forecast Center; Corps of Engineers; Minnesota DNR; State Climatologist; United States Geological Survey.

- Contact District as soon as flooding is probable to alert them of flooding potential, offer our services and set up a line of communication.

- Act in an advisory capacity to provide technical expertise on flood monitoring techniques, identify bridges that should be monitored, analyze flood monitoring results, and determine bridge stability.

- Provide additional flood monitoring resources when available, including: staff, equipment and use of consultants through contracts.

- Provide on-going investigation of new technologies to improve monitoring efforts.

- Provide on-going training to District personnel.

Contact People:

BRIDGE OFFICE

3485 Hadley Avenue North Oakdale, MN 55128	FAX: (651) 366-4497 M.S.: 610
Flood Coordinator	WORK: (651) 366-4473
State Bridge Engineer	WORK: (651) 366-4500
State Hydraulic Engineer	WORK: (651) 366-4466
North Regional Construction Engineer	WORK: (651) 366-4561
South Regional Construction Engineer	WORK: (651) 366-4562
Metro Regional Construction Engineer	WORK: (651) 366-4563
Assistant Bridge Inspection Engineer	WORK: (651) 366-4567

Mn/DOT Bridge Hydraulics Scour Contacts				Updated 12/10/09
District	**Name**	**Title**	**Location**	**Phone**
D-1	Perry Colins	District Scour Coordinator District Bridge Engineer	Duluth	Work: (218) 725-2827 Cell: (218) 269-5770
D-2	Roger Hille	District Scour Coordinator District Bridge Engineer	Bemidji	(218) 277-7963
D-3				
D-3B	Gary Dirlam	Bridge Supervisor S. D3 Scour Coordinator	St. Cloud	(320) 223-6558
D-3A	Dan Anderson	Bridge Foreman N. D3 Scour Coordinator	Brainerd	(218) 828-5725
D-4	Dan Kuhn	District Scour Coordinator	Morris	(320) 208-7010
D-6	Eric Evens	District Scour Coordinator Bridge Inspection Sup.	Rochestor	(507) 286-7623 (507) 251-0134 (C)
D-7	Scott Morgan	Operations Engineer Bridge Scour Coordinator		(507) 304-6210
East D-7A	Larry Cooper	East Bridge Inspection Supervisor	Mankato	(507)-304-6220
West D-7B	Jay Spencer	West Bridge Supervisor	Windom	(507) 831-8019
D-8	Jim Stoutland	District Scour Coordinator District Bridge Engineer	Marshall	(507) 537-2050
	Geri Vick	Bridge Safety Inspector (primary scour contact)	Willmar	(320) 214-6364

APPENDIX I

BRIDGE SCOUR MONITORING PLANS

FOR LOCAL ROADS

BRIDGE SCOUR MONITORING PLAN FOR LOCAL ROADS

PURPOSE

Bridges are vulnerable to damage and failure during flooding due to scour. Scour may undermine the bridge foundations or remove the protection from the abutment slopes. To protect the public and the bridges, federal safety standards require all bridges over 20' in length be monitored for scour, closed during flooding, or evaluated for scour. The scour evaluation may include two levels of screening and a detailed analysis when necessary. There are three scour rating codes which indicate monitoring for scour during flooding is necessary. These ratings are as follows:

K Bridge screened, determined to be of limited risk to public, monitor in lieu of evaluation and close if necessary.

R Bridge has been evaluated and determined to be scour critical. The Plan Of Action (POA) recommends monitoring the bridge during high flows and closing if necessary.

U Bridge has been evaluated and determined to be scour critical. The POA recommends this bridge as a priority for installation of countermeasures. Until countermeasures are installed, monitor bridge during high flow and close if necessary.

P Bridge has countermeasures installed to prevent scour from damaging the bridge. After flooding, protection needs to be inspected to verify that it is still viable as protection.

Monitoring generally requires measuring the river bed elevation near the footings and abutments. It could indicate that a bridge should be closed due to scour.
Each road authority is responsible for monitoring its bridges. This Bridge Scour Monitoring Plan for Local Roads contains guidelines to the road authority on procedures to be used to monitor bridges and the technical support that might be available. If a POA for a specific bridge has been developed, it may contain some of the general requirements of this plan.

PRIORITY

As indicated above, bridges rated K, R, and U are required to be monitored during flooding events. In addition, monitoring is recommended for all bridges during significant (25 year frequency and greater) flooding or when debris and ice buildup at the bridge. The extent, frequency, and the flood stage to begin monitoring may vary with each bridge. The road authority is responsible to determine when bridges will be monitored. For bridges rated R and U, a POA based on a hydraulic evaluation must be prepared and contain details on monitoring each specific bridge site. The POA for each bridge should be on file with the county and with the township and readily available to the personnel charged with doing the monitoring.

MONITORING TOOLS

Sounding weights and/or sonar are normally used to monitor the river bed elevations at the bridge, a pole may be possible on shallow streams. Scour measurements are usually taken from the bridge deck along the upstream and downstream sides of the bridge. Measurements taken along the bridge fascia (railing) may not be located at the site of maximum scour which is usually close to the pier or abutment, but should be accurate enough to indicate if problems exist. Ice and debris may limit the locations or could cause inaccurate readings.

The County or the Minnesota Department of Transportation District Office may be able to assist in monitoring some bridges with their equipment upon request. If you are unable to monitor a specific bridge, the road should be closed during flooding.

SAFETY

Extreme care should be used while monitoring bridges during flood stages. A minimum of a two person crew is recommended.

PRE-FLOOD PREPARATION

The road authority must be prepared to monitor when flooding occurs. Personnel who will monitor the bridges must be informed, trained, and have access to the necessary equipment. The road authority should check water surface elevations after heavy rainfall or snow melt being alert for significant flooding.

The road authority should conduct a pre-flood site investigation on all bridges identified for monitoring or subject to debris or ice buildup. The following actions should be taken:

> Mark the locations on the bridge at which measurements will be taken and measure baseline river bed elevations at these locations
>
> Determine the water surface elevation at which monitoring should begin, usually at or below the highest flood of record or design high water if known

MONITORING METHODS

Monitoring can be accomplished at the discretion of the local road authority using any combination, or all of the following methodologies:

1. Visual Observation by checking

   -Approach roadway and abutment slopes for erosion
   -Bridge rails (sags or bends)
   -Water action (noticeable changes, eddies, etc.)

2. Measurement of channel bed elevations at piers or abutments using

   -Sonar (depth finders)
   -Probes/measuring rods
   -Cable and weights

Compare the measured bed elevation to the base line stream bed elevation taken prior to the flooding. Determine if the bed has lowered significantly. A significant bed change is defined as the depth identified in the POA or established by the County Engineer or as set by the road authority or if these are not available, the following general guide can be used.

- 5 feet: Large rivers (river channel greater than 100' wide).
- 2 feet: Medium/small rivers (river channel less than 100' wide).

Records of channel bed measurements can provide a valuable documented record of the monitoring. The records may be used to adjust the frequency of monitoring in the future.

MONITORING FREQUENCY

Flooding that warrants monitoring of bridges may occur at any time any year.

As a general guide monitoring is recommended when:

1. River nears historic high water.
2. The design high water elevation is reached (if known).
3. Unusual conditions (such as large amount of debris affects 10% of opening).
4. Prior to opening the bridge if closed.

If significant bed changes are not detected: monitor once per day until flood crest begins to recede.

If significant bed changes are detected: contact the County Engineer and monitor a minimum of twice per day.

MONITORING LOCATIONS

Measure for scour from both the upstream and downstream face of the bridge, if possible. The notes should be kept on file. The notes should include the date and if ice or debris were present (since they can increase the amount of scour). A sample monitoring form is attached.

Monitor the stream bed at the middle of each span and at all piers and abutments locations and at the toe of abutment slopes to determine if the channel bottom elevation is changing at these locations.

- Maximum pier scour is expected to occur near the front face of the pier. If flood water is attacking the pier at a skew angle, the deepest scour is expected on the front or side that the flow impacts.

- Maximum abutment scour typically occurs at the toe of the abutment slope or the upstream corner of a vertical abutment.

- Bridges with abutment slopes should be monitored both at the toe of the slope and next to the abutment. If the foundation is undermined, the approach fill may be endangered.

APPROPRIATE ACTION

Close the bridge if the riverbed erosion exceeds the maximum allowed depth; there are signs of bridge movement; riprap shows signs of disturbance; or inspector is uncertain about danger.

- Install proper road closed signs.
- Notify the proper authorities (including the county highway department).
- Detour traffic (if necessary).
- Review bridges on detour route for scour and monitor (if necessary).
- Check bridge after flood recedes/make recommendations for repair/protection.

During flooding, if large amounts of debris are at bridge, remove the debris if possible. If scour occurs at the bridge, consult with your County Engineer to see if protection should be installed.

REPORTING

Report results of monitoring to the County Engineer. If scour reaches a critical point, the monitoring personnel should take appropriate action including closing the bridge and contacting the County Engineer.

YOUR COUNTY ENGINEER

The County Engineer is responsible for bridge safety inspections and can act in an advisory capacity to provide technical expertise on flood monitoring techniques, identify bridges that should be monitored, analyze flood monitoring results and determine bridge stability.

The engineer may provide additional flood monitoring resources when available including: staff, equipment, or suggest the use of consultants through contracts. The engineer may know of new technologies related to improve monitoring efforts.

BRIDGE NO.	____________
DISTRICT	____________
COUNTY	____________
TOWNSHIP	____________
CITY	____________
ROUTE	____________
STREAM	____________

BRIDGE SCOUR MONITORING GUIDE PLAN

FOR SPECIFIC BRIDGE

Bridge: Use Channel Diagram for Specific Bridge

Critical monitoring points have been labeled alphabetically beginning at A and ending at I. The bridge channel bed elevation (or depths) during normal conditions have been determined at mid span along the bridge fascia (railing) and at the critical monitoring points at abutments and piers as indicated above. During monitoring, these channel bed elevations (or depths) are to be measured and compared on the monitoring form attached. For reference the MN DOT Structural Inventory is also enclosed.

Channel Bed Depths (From Low Steel), (Top of Rail), (Bridge Deck), or (__________)

Points	A	B	C	D	E	F	G	H	I	Etc.
Location*	2	25	30	45	60	75	90	95	118	
Normal Depth**	4	12	12	12	12	12	12	12	4	
Maximum Allowed	9	17	17	17	17	17	17	17	9	

*Distance from right end of bridge looking upstream.
(Distance measured from ________________________________)

**Depth measured from (Top of Railing), (Bridge Deck), (Top of Curb),
(Low Steel), Other ____________________________)

SAMPLE LETTER

REGARDING BRIDGE SCOUR MONITORING

Name
Chairman, _____________ Township

RE: Monitoring for Bridge Scour

Dear Chairman:

The Federal Government requires that all bridges over 20 feet in length be inspected and evaluated for scour (stream bed or channel erosion during flooding). There have been several catastrophic bridge failures in the nation due to scour. There are many bridges in Minnesota that have already been determined to be scour susceptible and are either having scour preventive measures installed or are being monitored during periods of flooding.

The State has developed a bridge scour screening process and scour rating system. The common ratings for bridges with known foundations which require monitoring are:

K Bridge screened, determined to be of limited risk to public, monitor in lieu of evaluation and close if necessary.

R Bridge has been evaluated and determined to be scour critical. Scour Action Plan recommends monitoring the bridge during high flows and closing if necessary.

U Bridge has been evaluated and determined to be scour critical. Scour Action Plan recommends this bridge as a priority for installation of countermeasures. Until countermeasures are installed, monitor bridge during high flow and close if necessary.

P Bridge has countermeasures installed to prevent scour from damaging the bridge. After flooding, protection needs to be inspected to verify that it is still viable as protection.

The County, using State guidelines, has determined the rating for the following township bridges. These ratings require monitoring of each bridge during flooding to protect the public.

SAMPLE LETTER (CONTINUED)

Bridge No.	Scour Code	Foundation Type	Maximum Scour Depth Footing Abutment

Use the Plan Of Action (POA) for each of the above listed bridges rated R, or U. We have estimated the maximum depth of scour that should be allowed at each pier or abutment for the above listed bridges. If scour, as determined by monitoring, exceeds this maximum allowable depth, the bridge will have to be closed until flood waters recede and an inspection can be made. It is the Township's responsibility to monitor these bridges during flooding. By monitoring bridges and closing them if there is the danger of failure, the road authority can minimize the risk to the public. The Bridge Scour Monitoring Plan for Local Roads dated January 1, 1995 has been developed as a guide for bridge monitoring.

The local road authority may perform a complete hydraulic evaluation on any bridge rated K if they desire. An evaluation may result in an official recommendation to monitor for scour or to install additional scour protection. On many low volume roads, monitoring the bridge is a cost effective method of protecting the public.

Sincerely,

County Engineer

BRIDGE NO. ____________
DISTRICT ____________
COUNTY ____________
TOWNSHIP ____________
CITY ____________
ROUTE ____________
STREAM ____________

SAMPLE BRIDGE SCOUR MONITORING FORM

FOR LOCAL ROADS

POINT	A	B	C	D	E	F	G	H	I						*** WATER	DEBRIS
LOCATION*	2	25	30	45	60	75	90	95	118							Y/N
NORMAL DEPTH**	4	12	12	12	12	12	12	12	4							
MAXIMUM ALLOWED	9	17	17	17	17	17	17	17	9							
DATE __________																
DATE __________																
DATE __________																
DATE __________																
DATE __________																
DATE __________																
DATE __________																
DATE __________																

* Distance from right end of bridge looking upstream (distance measured from __________).
** Depth measured from (top of railing), (bridge deck), (top of curb), (low steel), other ____________________.
*** Depth measured from above to water.

APPENDIX J

DESIGN AIDS

- Roughness Coefficients
- Sediment Grade Scale
- Soil Triangle
- Non-scour Velocities For Soils

Open Channel Flow (continued)

Table 8-1

UNIFORM FLOW

Values of Roughness Coefficient n (Uniform Flow)

Type Of Channel and Description	Minimum	Normal	Maximum
EXCAVATED OR DREDGED			
a. Earth, straight and uniform	0.016	0.018	0.020
1. Clean, recently completed	0.018	0.022	0.025
2. Clean, after weathering	0.022	0.025	0.030
3. Gravel, uniform section, clean	0.022	0.027	0.033
b. Earth, winding and sluggish			
1. No vegetation	0.023	0.025	0.030
2. Grass, some weeds	0.025	0.030	0.033
3. Dense Weeds or aquatic plants in deep channels	0.030	0.035	0.040
4. Earth bottom and rubble sides	0.025	0.030	0.035
5. Stony bottom and weedy sides	0.025	0.035	0.045
6. Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-excavated or dredged			
1. No vegetation	0.025	0.028	0.033
2. Light brush on banks	0.035	0.050	0.060
d. Rock cuts			
1. Smooth and uniform	0.025	0.035	0.040
2. Jagged and irregular	0.035	0.040	0.050
e. Channels not maintained, weeds and brush uncut			
1. Dense weeds, high as flow depth	0.050	0.080	0.120
2. Clean bottom, brush on sides	0.040	0.050	0.080
3. Same, highest stage of flow	0.045	0.070	0.110
4. Dense brush, high stage	0.080	0.100	0.140
NATURAL STREAMS			
1. Minor streams (top width at flood stage < 100 ft)			
a. Streams on Plain			
1. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
2. Same as above, but more stones and weeds	0.030	0.035	0.040
3. Clean, winding, some pools and shoals	0.033	0.040	0.045
4. Same as above, but some weeds and some stones	0.035	0.045	0.050
5. Same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055

Open Channel Flow (continued)

Table 8-1 (CONTINUED)

UNIFORM FLOW

Values of Roughness Coefficient n (Uniform Flow)

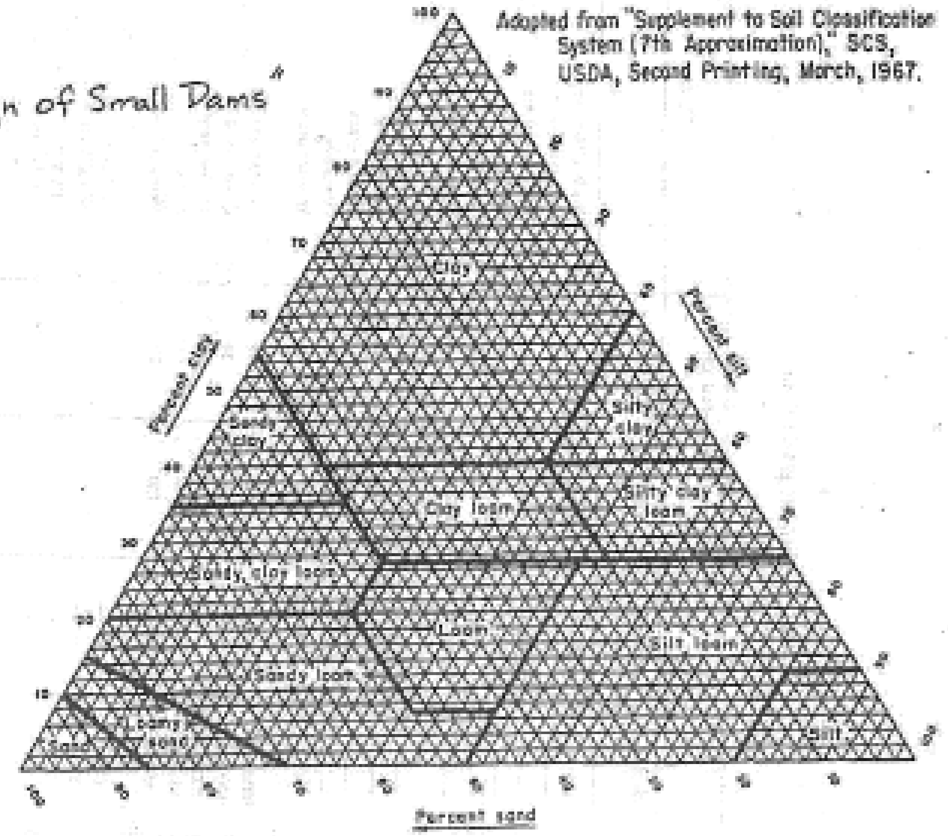
Type Of Channel and Description	Minimum	Normal	Maximum
6. Same as 4, but more stones	0.045	0.050	0.060
7. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
8. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
b. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
1. Bottom: gravels, cobbles, and few boulders	0.030	0.040	0.050
2. Bottom: cobbles with large boulders	0.040	0.050	0.070
2. Flood Plains			
a. Pasture, no brush			
1. Short grass	0.025	0.030	0.035
2. High grass	0.030	0.035	0.050
b. Cultivated area			
1. No crop	0.020	0.030	0.040
2. Mature row crops	0.025	0.035	0.045
3. Mature field crops	0.030	0.040	0.050
c. Brush			
1. Scattered brush, heavy weeds	0.035	0.050	0.070
2. Light brush and trees in winter	0.035	0.050	0.060
3. Light brush and trees, in summer	0.040	0.060	0.080
4. Medium to dense brush, in winter	0.045	0.070	0.110
5. Medium to dense brush, in summer	0.070	0.100	0.160
d. Trees			
1. Dense Willows, summer, straight	1.110	0.150	0.200
2. Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
3. Same as above, but with heavy growth of sprouts	0.050	0.060	0.080
4. Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120
5. Same as above, but with flood stage reaching branches	0.100	0.120	0.160

Table 1. Sediment grade scale.

SIZE				Approximate Sieve Mesh Openings per Inch		CLASS
Millimeters		Microns	Inches	Tyler	U.S. Standard	
4000-2000	--------	--------	160-80	--------	--------	Very large boulders
2000-1000	--------	--------	80-40	--------	--------	Large boulders
1000-500	--------	--------	40-20	--------	--------	Medium boulders
500-250	--------	--------	20-10	--------	--------	Small boulders
250-130	--------	--------	10-5	--------	--------	Large cobbles
130-64	--------	--------	5-2.5	--------	--------	Small cobbles
64-32	--------	--------	2.5-1.3	--------	--------	Very coarse gravel
32-16	--------	--------	1.3-0.6	--------	--------	Coarse gravel
16-8	--------	--------	0.6-0.3	2-1/2	--------	Medium gravel
8-4	--------	--------	0.3-0.16	5	5	Fine gravel
4-2	--------	--------	0.16-0.08	9	10	Very fine gravel
2-1	2.00-1.00	2000-1000	--------	16	18	Very coarse sand
1-1/2	1.00-.050	1000-500	--------	32	35	Coarse sand
1/2-1/4	0.50-0.25	500-250	--------	60	60	Medium sand
1/4-1/8	0.25-0.125	250-125	--------	115	120	Fine sand
1/8-1/16	0.125-0.062	125-62	--------	250	230	Very fine sand
1/16-1/32	0.062-0.031	62-31	--------			Coarse silt
1/32-1/64	0.031-0.016	31-16	--------			Medium silt
1/64-1/128	0.016-0.008	16-8	--------			Fine silt
1/128-1/256	0.008-0.004	8-4	--------			Very fine silt
1/256-1/512	0.004-0.0020	4-2	--------			Coarse clay
1/512-1/1024	0.0020-0.0010	2-1	--------			Medium clay
1/1024-1/2048	0.0010-0.0005	1-0.5	--------			Fine clay
1/2048-1/4096	0.0005-0.0002	0.5-0.24	--------			Very fine clay

"Design of Small Dams"

Adapted from "Supplement to Soil Classification System (7th Approximation)," SCS, USDA, Second Printing, March, 1967.



COMPARISON OF PARTICLE-SIZE SCALES

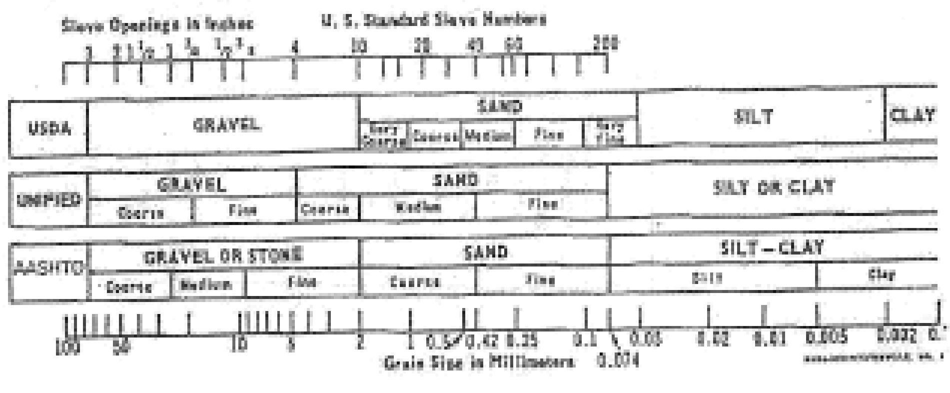


Figure 5-4.—Soil triangle of the basic soil textural classes. (U.S. Soil Conservation Service). 288-D-2782.

NON-SCOUR VELOCITIES FOR SOILS

Soil Type	Grain Dimensions		Approximate Non-scour Velocities (fps)			
			Mean Depth (ft)			
	mm	feet	1.3	3.3	6.6	9.8
For non-cohesive soils						
Boulders	> 256	>0.840	15.1	16.7	19.0	20.3
Large cobbles	256-128	0.840-0.420	11.8	13.4	15.4	16.4
Small cobbles	128-64	0.420-0.210	7.5	8.9	10.2	11.2
Very course gravel	64-32	0.210-0.105	5.2	6.2	7.2	8.2
course gravel	32-16	0.105-0.0525	4.1	4.7	5.4	6.1
Medium gravel	16-8.0	0.0525-0.0262	3.3	3.7	4.1	4.6
Fine gravel	8.0-4.0	0.0262-0.0131	2.6	3.0	3.3	3.8
Very fine gravel	4.0-2.0	0.0131-.00656	2.2	2.5	2.8	3.1
Very course sand	2.0-1.0	0.00656-0.00328	1.8	2.1	2.4	2.7
Coarse sand	1.0-0.5	0.00328-0.00164	1.5	1.8	2.1	2.3
Medium sand	0.5-0.25	0.00164-0.000820	1.2	1.5	1.8	2.0
Fine sand	0.25-0.125	0.000820-0.000410	0.98	1.3	1.6	1.8
For compact cohesive soils						
Sandy loam (heavy)			3.3	3.9	4.6	4.9
Sandy loam (light)			3.1	3.9	4.6	4.9
Loess (settled)			2.6	3.3	3.9	4.3

Derived from "Highways in the River Environment" FHWA-HI-90-016 Table 3.5.2

APPENDIX K

Plan of Action Templates

Link to Download Templates:
http://www.dot.state.mn.us/bridge/docsdown.html#hyd

U – Critical, Protection Required

MnDOT District: X

This template is provided as a starting document for development of a Plan of Action (POA). The document must be customized for each bridge. Optional comments, template instructions are provided in blue font and should be removed for the final POA product.

In general the POA should be streamlined (2-3 pages long) and focus on providing information that the inspector needs to know when out in the field. We are assuming the inspector has access to a bridge plan, previous inspection reports (including the inventory sheet), historical cross-section and other data.

The POA consists of several sections, General Information, History and Recommended Action. Depending on the scour code the Recommended Action may have sub-section labeled Monitoring Plan and Countermeasure Plan.

POAs should be reviewed periodically and updated as needed.

Route:	TH X	Location:	XX Miles Southeast of XX
Stream:	XXXXX River	County:	XXXX

Scour Code:	**U – Critical, Protection Required**	
Prepared:	preparers name x/x/2008	
Approved:	________________________	County Engineer
	________________________	County Bridge Engineer/Supervisor
	Sign and date approvals	

HISTORY

Insert brief history if relevant. Consider if any of the following items should be included:

- *Source of critical scour code: observed, assessed, calculated, other*
- *Year built, year rebuilt*
- *Foundation type*
- *Number of spans, type of structure*
- *Scour history, any problems related to scour or erosion.*
- *Additional consideration or critical issue such as road overtopping, debris potential, etc.*

RECOMMENDED ACTION

This bridge structure has been determined to be scour critical. There is a possibility during large floods that the abutment footings and/or pier piling could be undermined resulting in possible settlement or loss of the approach embankment fill and/or the piers. During regularly scheduled inspections look for evidence of scour or migration of the channel. Check condition of riprap or other scour countermeasures. Take cross-sections at the upstream and downstream fascias at intervals not to exceed four years. A record of these cross-sections shall be kept and results compared over time. During a flood the County should monitor this bridge as follows:

Flood Monitoring Plan

- **Start:** When water elevation rises to XXX.X on the upstream side of the bridge (approximate XX year flood elevation).
  - *Alternatives in defining when to start include: stage, discharge, elevation measured from, rainfall, stream gage reading, high water marks.*

- **Frequency:** Daily, if during monitoring it is determined that the channel bottom is lowering or the water elevation is increasing. Monitoring may be halted once water elevation begins to recede, if no critical scour is noted.
  - *Increase monitoring frequency if warranted, may be as often as hourly.*

- **Procedure:** Using sonar, 100 lb. weights (approx.), or other means, measure the channel elevation across the bridge opening. Look for evidence of scour at the foundations, erosion of fill near the bridge, settlement of the roadway, or any other evidence of possible scour related damage to the roadway or bridge.

- Weights needed are computed as depth x velocity

- Select method for taking measurements: fixed instrumentation, visual inspection or portable devices (either weights and/or sonar).

- Consider need for optional text if there are special procedures i.e. Because the railing overhangs the edge of footings by approximately x.x feet it will be necessary with sonar to use a transducer on a float in order to obtain readings near the edge of the footings.

- **Action:** When critical scour elevation is reached or washout of approaches is imminent, immediately notify the designated district contacts listed below to initiate bridge closure and detour installation. The County will determine if the bridge is safe to be reopened. If reopened, the bridge should be continuously monitored until there is no potential for additional scour.

- **Traffic Control:** Provide traffic control needed for riverbed elevation monitoring according to: Layout 43 Shoulder Closure, Temporary Traffic Control Layout Field Manual.

- Could require lane closure alternative

Structure	Top of Railing Elevation	Bottom of Footing Elevation	Bottom of Piling Elevation	Critical **Scour Elevation**
North Abutment	XXX.X	XXX.X	XXX.X	XXX.X
Pier 1	XXX.X	XXX.X	XXX.X	XXX.X
Pier 2	XXX.X	XXX.X	XXX.X	XXX.X
South Abutment	XXX.X	XXX.X	XXX.X	XXX.X

Datum: *provide elevation datum*

- Add and delete rows in table as necessary
- Reference may be top of rail or top of curb
-Typical accuracy of elevations to tenth of a foot i.e. 900.2

Make sure to have bridge closure plan on a separate page from the rest of the POA. This page may need to be updated more frequently as phone numbers change.

Bridge Closure Plan

If riverbed in vicinity of foundation reaches critical scour elevation immediately notify the designated district contacts listed below to initiate bridge closure and detour installation.

Notification contacts and phone numbers for a bridge closure should be provided by the county.

District Scour Notification:

County Engineer	(###) ###-####
…..	(###) ###-####
…..	(###) ###-#### (24 hour)

Detour: *Insert route description and/or map*
- Consider stability of bridges located on the detour route.

Closure Plan Notification:

List of people that should be notified about a bridge closure, this may include county staff responsible for the bridge, bridge inspection, those responsible for installing a detour, also staff responsible for notifying the public about the closure.

County Engineer	(###) ###-####
…	(###) ###-####
…	(###) ###-####
…	(###) ###-####
State Patrol Dispatch	(###) ###-#### (24 hour)

Countermeasure Plan

Place information on what countermeasures are planned, and the schedule of when countermeasures will be installed.

Once countermeasures are installed review scour code and update as appropriate.

G – Foundation Unknown

County: X

This template is provided as a starting document for development of a Plan of Action (POA). The document must be customized for each bridge. Optional comments, template instructions are provided in blue font and should be removed for the final POA product.

In general the POA should be streamlined (2-3 pages long) and focus on providing information that the inspector needs to know when out in the field. We are assuming the inspector has access to a bridge plan, previous inspection reports (including the inventory sheet), historical cross-section and other data.

The POA consists of several sections, General Information, History and Recommended Action. Depending on the scour code the Recommended Action may have sub-section labeled Monitoring Plan and Countermeasure Plan.

POAs should be reviewed periodically and updated as needed.

This template should not be used if there is a history of scour. Use template provided for scour code "R – critical monitor" if scour has been observed at the site.

Before leaving a bridge rated "G – unknown foundation" every effort should be made to determine if a more appropriate code is available and the bridge should be recoded if possible.

Route:	TH X	Location:	XX Miles Southeast of XX
Stream:	XXXXX River	County:	XXXX

Scour Code: **G – Foundation Unknown**
Prepared: preparers name x/x/2008
Approved: ________________________ County Engineer
________________________ County Bridge Engineer/Supervisor
Sign and date approvals

HISTORY

Insert brief history if relevant. Consider if any of the following items should be included:

- *Source of critical scour code: observed, assessed, calculated, other*
- *Year built, year rebuilt*
- *Foundation type*
- *Number of spans, type of structure*
- *Scour history, any problems related to scour or erosion.*
- *Additional consideration or critical issue such as road overtopping, debris potential, etc.*

RECOMMENDED ACTION

This bridge structure has been determined to have unknown foundations. Since foundation data is not available it is not possible to determine if the bridge is stable for predicted scour. There is a possibility during large floods that the abutment footings and/or pier piling could be undermined resulting in possible settlement or loss of the approach embankment fill and/or the piers.

The bridge should be inspected during routine inspections, during major flood events and before reopening the road if it is overtopped during major flood events. During regularly scheduled inspections look for evidence of scour or migration of the channel. Check condition of riprap or other scour countermeasures. Take cross-sections at the upstream and downstream fascias at intervals not to exceed four years. A record of these cross-sections shall be kept and results compared over time. Look for scour holes, evidence of settlement of the roadway, erosion of fill near the bridge, or any other evidence of possible damage to the roadway. Since it is unknown when the bridge becomes scour critical any evidence of scour should be reported and evaluated by the County Engineer.

During a flood the County should monitor this bridge as follows:

Flood Monitoring Plan

- **Start:** When water elevation rises to XXX.X on the upstream side of the bridge (approximate XX year flood elevation).
  - *Alternatives in defining when to start include: stage, discharge, elevation measured from, rainfall, stream gage reading, high water marks.*

- **Frequency:** Daily, if during monitoring it is determined that the channel bottom is lowering or the water elevation is increasing. Monitoring may be halted once water elevation begins to recede, if no critical scour is noted.
  - *Increase monitoring frequency if warranted, may be as often as hourly.*

- **Procedure:** Using sonar, 100 lb. weights (approx.), or other means, measure the channel elevation across the bridge opening. Look for evidence of scour at the foundations, erosion of fill near the bridge, settlement of the roadway, or any other evidence of possible scour related damage to the roadway or bridge.

- Weights needed are computed as depth x velocity

- Select method for taking measurements: fixed instrumentation, visual inspection or portable devices (either weights and/or sonar).

- Consider need for optional text if there are special procedures i.e. Because the railing overhangs the edge of footings by approximately x.x feet it will be necessary with sonar to use a transducer on a float in order to obtain readings near the edge of the footings.

- **Action:** When scour is observed or washout of approaches is imminent, immediately notify the County Engineer. The County Engineer will determine if bridge closure is necessary and will initiate bridge closure and detour installation. The County will determine when the bridge is safe to be reopened. If reopened, the bridge should be continuously monitored until there is no potential for additional scour.

- **Traffic Control:** Provide traffic control needed for riverbed elevation monitoring according to: Layout 43 Shoulder Closure, Temporary Traffic Control Layout Field Manual.

- Could require lane closure alternative

Structure	Top of Railing Elevation	Approximate Ground Elevation	Bottom of Footing Elevation	Estimated Critical Scour Elevation
North Abutment	XXX.X	XXX.X	XXX.X	XXX.X
Pier 1	XXX.X	XXX.X	XXX.X	XXX.X
Pier 2	XXX.X	XXX.X	XXX.X	XXX.X
South Abutment	XXX.X	XXX.X	XXX.X	XXX.X

Datum: *provide elevation datum*

- Add and delete rows in table as necessary
- Reference may be top of rail or top of curb
-Typical accuracy of elevations to tenth of a foot i.e. 900.2
The Critical Scour Elevation must be estimate using a conservative assumption of the scour elevation at which the bridge could become unstable. Since the foundation is unknown this will not be a significant amount of scour.

Make sure to have bridge closure plan on a separate page from the rest of the POA. This page may need to be updated more frequently as phone numbers change.

Bridge Closure Plan

If riverbed in vicinity of foundation reaches critical scour elevation immediately notify the designated district contacts listed below to initiate bridge closure and detour installation.

Notification contacts and phone numbers for a bridge closure should be provided by the county.

District Scour Notification:

County Engineer	(###) ###-####
…..	(###) ###-####
…..	(###) ###-#### (24 hour)

Detour: *Insert route description and/or map*
- Consider stability of bridges located on the detour route.

Closure Plan Notification:
List of people that should be notified about a bridge closure, this may include county staff responsible for the bridge, bridge inspection, those responsible for installing a detour, also staff responsible for notifying the public about the closure.

County Engineer	(###) ###-####
…	(###) ###-####
…	(###) ###-####
…	(###) ###-####
State Patrol Dispatch	(###) ###-#### (24 hour)

K – Limited Risk, Monitor in Lieu of Evaluation

County: X

This template is provided as a starting document for development of a Plan of Action (POA). The document must be customized for each bridge. Optional comments, template instructions are provided in blue font and should be removed for the final POA product.

In general the POA should be streamlined (2-3 pages long) and focus on providing information that the inspector needs to know when out in the field. We are assuming the inspector has access to a bridge plan, previous inspection reports (including the inventory sheet), historical cross-section and other data.

The POA consists of several sections, General Information, History and Recommended Action. Depending on the scour code the Recommended Action may have sub-section labeled Monitoring Plan and Countermeasure Plan.

POAs should be reviewed periodically and updated as needed.

Route:	TH X	Location:	XX Miles Southeast of XX
Stream:	XXXXX River	County:	XXXX

Scour Code: **K – Limited Risk, Monitor in Lieu of Evaluation**
Prepared: preparers name x/x/2008
Approved: ______________________ County Engineer
______________________ County Bridge Engineer/Supervisor
Sign and date approvals

HISTORY

Insert brief history if relevant. Consider if any of the following items should be included:

- *Source of critical scour code: observed, assessed, calculated, other*
- *Year built, year rebuilt*
- *Foundation type*
- *Number of spans, type of structure*
- *Scour history, any problems related to scour or erosion.*
- *Additional consideration or critical issue such as road overtopping, debris potential, etc.*

RECOMMENDED ACTION

This bridge structure has been determined to have limited risk and will be monitored in lieu of evaluation. There is a possibility during large floods that the abutment footings and/or pier piling could be undermined resulting in possible settlement or loss of the approach embankment fill and/or the piers.

The bridge should be inspected during routine inspections, during major flood events and before reopening road if it is overtopped during major flood events. During regularly scheduled inspections look for evidence of scour or migration of the channel. Check condition of riprap or other scour countermeasures. Take cross-sections at the upstream and downstream fascias at intervals not to exceed four years. A record of these cross-sections shall be kept and results compared over time. Look for evidence of settlement of the roadway, erosion of fill near the bridge, or any other evidence of possible damage to the roadway.

When scour is observed or washout of approaches is imminent, immediately notify the County Engineer. The County Engineer will determine if bridge closure is necessary and will initiate bridge closure and detour installation.

During a flood the County should monitor this bridge as follows:

Flood Monitoring Plan

- **Start:** When water elevation rises to XXX.X on the upstream side of the bridge (approximate XX year flood elevation).
    - *Alternatives in defining when to start include: stage, discharge, elevation measured from, rainfall, stream gage reading, high water marks.*

- **Frequency:** Daily, if during monitoring it is determined that the channel bottom is lowering or the water elevation is increasing. Monitoring may be halted once water elevation begins to recede, if no critical scour is noted.
    - *Increase monitoring frequency if warranted, may be as often as hourly.*

- **Procedure:** Using sonar, 100 lb. weights (approx.), or other means, measure the channel elevation across the bridge opening. Look for evidence of scour at the foundations, erosion of fill near the bridge, settlement of the roadway, or any other evidence of possible scour related damage to the roadway or bridge.

- Weights needed are computed as depth x velocity
- Select method for taking measurements: fixed instrumentation, visual inspection or portable devices (either weights and/or sonar).
- Consider need for optional text if there are special procedures i.e. Because the railing overhangs the edge of footings by approximately x.x feet it will be necessary with sonar to use a transducer on a float in order to obtain readings near the edge of the footings.

- **Action:** When critical scour elevation is reached or washout of approaches is imminent, immediately notify the designated district contacts listed below to initiate bridge closure and detour installation. The County will determine if the bridge is safe to be reopened. If reopened, the bridge should be continuously monitored until there is no potential for additional scour.

- **Traffic Control:** Provide traffic control needed for riverbed elevation monitoring according to: Layout 43 Shoulder Closure, Temporary Traffic Control Layout Field Manual.

- Could require lane closure alternative

Structure	Top of Railing Elevation	Bottom of Footing Elevation	Bottom of Piling Elevation	Critical **Scour Elevation**
North Abutment	XXX.X	XXX.X	XXX.X	XXX.X
Pier 1	XXX.X	XXX.X	XXX.X	XXX.X
Pier 2	XXX.X	XXX.X	XXX.X	XXX.X
South Abutment	XXX.X	XXX.X	XXX.X	XXX.X

Datum: *provide elevation datum*

- Add and delete rows in table as necessary
- Reference may be top of rail or top of curb
-Typical accuracy of elevations to tenth of a foot i.e. 900.2

Make sure to have bridge closure plan on a separate page from the rest of the POA. This page may need to be updated more frequently as phone numbers change.

Bridge Closure Plan

If riverbed in vicinity of foundation reaches critical scour elevation immediately notify the designated district contacts listed below to initiate bridge closure and detour installation.

Notification contacts and phone numbers for a bridge closure should be provided by the county.

District Scour Notification:

County Engineer	(###) ###-####
…..	(###) ###-####
…..	(###) ###-#### (24 hour)

Detour: *Insert route description and/or map*
- Consider stability of bridges located on the detour route.

Closure Plan Notification:

List of people that should be notified about a bridge closure, this may include county staff responsible for the bridge, bridge inspection, those responsible for installing a detour, also staff responsible for notifying the public about the closure.

County Engineer	(###) ###-####
…	(###) ###-####
…	(###) ###-####
…	(###) ###-####
State Patrol Dispatch	(###) ###-#### (24 hour)

O – Scour Stable, Action Required

County: X

This template is provided as a starting document for development of a Plan of Action (POA). The document must be customized for each bridge. Optional comments, template instructions are provided in blue font and should be removed for the final POA product.

In general the POA should be streamlined (2-3 pages long) and focus on providing information that the inspector needs to know when out in the field. We are assuming the inspector has access to a bridge plan, previous inspection reports (including the inventory sheet), historical cross-section and other data.

The POA consists of several sections, General Information, History and Recommended Action. Depending on the scour code the Recommended Action may have sub-section labeled Monitoring Plan and Countermeasure Plan.

POAs should be reviewed periodically and updated as needed.

Route: TH X
Stream: XXXXX River

Location: XX Miles Southeast of XX
County: XXXX

Scour Code: **O – Scour Stable, Action Required**
Prepared: preparers name x/x/2008
Approved: ________________________ County Engineer
________________________ County Bridge Engineer/Supervisor
Sign and date approvals

HISTORY

Insert brief history if relevant. Consider if any of the following items should be included:

- *Reason why requiring POA even though rated as stable. Stable for existing conditions but some concern that conditions may change such as lateral migration, bed lowering or heavy debris.*
- *Year built, year rebuilt*
- *Foundation type*
- *Number of spans, type of structure*
- *Scour history, any problems related to scour or erosion.*
- *Additional consideration or critical issue such as road overtopping, debris potential, etc.*

RECOMMENDED ACTION

Customize section adding specific language of what inspector needs to look for.

The bridge has been determined to be stable for predicted damage to the structure. There is a possibility during large floods that the abutment footings and/or pier piling could be undermined resulting in possible settlement or loss of the approach embankment fill and/or the piers. During regularly scheduled inspections look for evidence of scour or migration of the channel. Check condition of riprap or other scour countermeasures. Take cross-sections at the upstream and downstream fascias at intervals not to exceed four years. A record of these cross-sections shall be kept and results compared over time.

When critical scour elevation is reached or washout of approaches is imminent, immediately notify the County Engineer.

Structure	Top of Railing Elevation	Bottom of Footing Elevation	Average Bottom of Piling Elevation	Critical **Scour Elevation**
North Abutment	XXX.X	XXX.X	XXX.X	XXX.X
Pier 1	XXX.X	XXX.X	XXX.X	XXX.X
Pier 2	XXX.X	XXX.X	XXX.X	XXX.X
South Abutment	XXX.X	XXX.X	XXX.X	XXX.X

Datum: *provide elevation datum*

- Add and delete rows in table as necessary
- Reference may be top of rail or top of curb
-Typical accuracy of elevations to tenth of a foot i.e. 900.2

P – Stable Due To Protection

County/City: X

This template is provided as a starting document for development of a Plan of Action (POA). The document must be customized for each bridge. Optional comments, template instructions are provided in blue font and should be removed for the final POA product.

In general the POA should be streamlined (1-2 pages long) and focus on providing information that the inspector needs to know when out in the field. We are assuming the inspector has access to a bridge plan, previous inspection reports (including the inventory sheet), historical cross-section and other data.

The POA consists of several sections, General Information, History and Recommended Action.

POAs should be reviewed periodically and updated as needed.

Route: TH X
Stream: XXXXX River

Location: XX Miles Southeast of XX
County: XXXX

Scour Code: **P – Stable Due To Protection**
Prepared: preparers name x/x/2008
Approved: ________________________ County Engineer
________________________ County Bridge Engineer/Supervisor
Sign and date approvals

HISTORY

Provide scour countermeasure information:

- *Type of protection, description of countermeasure, date protection installed,*
- *Reason protection needed, explanation of any scour or other damage that resulted in the need for protection.*

Insert additional history if relevant. Consider if any of the following items should be included:

- *Source of critical scour code: observed, assessed, calculated, other*
- *Year built, year rebuilt*
- *Foundation type*
- *Number of spans, type of structure*
- *Scour history, any problems related to scour or erosion.*
- *Additional consideration or critical issue such as road overtopping, debris potential, etc.*

RECOMMENDED ACTION

This bridge structure has been determined to be stable due to protection. There is a possibility that protection could deteriorate over time or fail during large floods. The riprap for the bridge should be inspected during routine inspections and after major flood events. Evaluate the condition and extent of protection to determine if repairs are necessary. Take cross-sections at the upstream and downstream fascias at intervals not to exceed four years. A record of these cross-sections shall be kept and results compared over time.

If riprap is determined to be missing or critical scour elevation is reached, immediately contact the County Engineer. Develop repair recommendations. The following information is provided when monitoring during or after a flood:

Customize headings

Structure	Top of Railing Elevation	*To p of Footing Elevation or Bottom of Planking Elevation*	*Bottom of Footing Elevation or Bottom of Piling Elevation*	Critical **Scour Elevation**	**Top of Riprap Elevation**
North Abutment	XXX.X	XXX.X	XXX.X	XXX.X	Variable[1]
Pier 1	XXX.X	XXX.X	XXX.X	XXX.X	XXX.X
South Abutment	XXX.X	XXX.X	XXX.X	XXX.X	Variable[1]

Datum: *provide elevation datum*

[1] Riprap is installed on a slope. Take a baseline cross-section, use to compare against future measurements.

- Add and delete rows in table as necessary
- Reference may be top of rail or top of curb
-Typical accuracy of elevations to tenth of a foot i.e. 900.2

R - Critical Monitor

Route: X
Stream: XXXXX River

Location: XX Miles Southeast of XX
County: XXXX

Scour Code: **R - Critical Monitor**
Prepared: preparers name x/x/2008
Approved: ______________________ County Engineer
______________________ County Bridge Engineer/Supervisor
Sign and date approvals

HISTORY

Insert brief history if relevant. Consider if any of the following items should be included:

- *Source of critical scour code: observed, assessed, calculated, other*
- *Year built, year rebuilt*
- *Foundation type*
- *Number of spans, type of structure*
- *Scour history, any problems related to scour or erosion.*
- *Additional consideration or critical issue such as road overtopping, debris potential, etc.*

RECOMMENDED ACTION

This bridge structure has been determined to be scour critical. There is a possibility during large floods that the abutment footings and/or pier piling could be undermined resulting in possible settlement or loss of the approach embankment fill and/or the piers. During regularly scheduled inspections look for evidence of scour or migration of the channel. Check condition of riprap or other scour countermeasures. Take cross-sections at the upstream and downstream fascias at intervals not to exceed four years. A record of these cross-sections shall be kept and results compared over time. During a flood the County should monitor this bridge as follows:

Flood Monitoring Plan

- **Start:** When water elevation rises to XXX.X on the upstream side of the bridge (approximate XX year flood elevation).
  - *Alternatives in defining when to start include: stage, discharge, elevation measured from, rainfall, stream gage reading, high water marks.*

- **Frequency:** Daily, if during monitoring it is determined that the channel bottom is lowering or the water elevation is increasing. Monitoring may be halted once water elevation begins to recede, if no critical scour is noted.
  - *Increase monitoring frequency if warranted, may be as often as hourly.*

- **Procedure:** Using sonar, 100 lb. weights (approx.), or other means, measure the channel elevation across the bridge opening. Look for evidence of scour at the foundations, erosion of fill near the bridge, settlement of the roadway, or any other evidence of possible scour related damage to the roadway or bridge.

- Weights needed are computed as depth x velocity
- Select method for taking measurements: fixed instrumentation, visual inspection or portable devices (either weights and/or sonar).
- Consider need for optional text if there are special procedures i.e. Because the railing overhangs the edge of footings by approximately x.x feet it will be necessary with sonar to use a transducer on a float in order to obtain readings near the edge of the footings.

- **Action:** When critical scour elevation is reached or washout of approaches is imminent, immediately notify the designated district contacts listed below to initiate bridge closure and detour installation. The County will determine if the bridge is safe to be reopened. If reopened, the bridge should be continuously monitored until there is no potential for additional scour.

- **Traffic Control:** Provide traffic control needed for riverbed elevation monitoring according to: Layout 43 Shoulder Closure, Temporary Traffic Control Layout Field Manual.

- Could require lane closure alternative

Structure	Top of Railing Elevation	Bottom of Footing Elevation	Bottom of Piling Elevation	Critical **Scour Elevation**
North Abutment	XXX.X	XXX.X	XXX.X	XXX.X
Pier 1	XXX.X	XXX.X	XXX.X	XXX.X
Pier 2	XXX.X	XXX.X	XXX.X	XXX.X
South Abutment	XXX.X	XXX.X	XXX.X	XXX.X

Datum: *provide elevation datum*

- Add and delete rows in table as necessary
- Reference may be top of rail or top of curb
-Typical accuracy of elevations to tenth of a foot i.e. 900.2

Make sure to have bridge closure plan on a separate page from the rest of the POA. This page may need to be updated more frequently as phone numbers change.

Bridge Closure Plan

If riverbed in vicinity of foundation reaches critical scour elevation immediately notify the designated district contacts listed below to initiate bridge closure and detour installation.

Notification contacts and phone numbers for a bridge closure should be provided by the county.

District Scour Notification:

County Engineer	(###) ###-####
…..	(###) ###-####
…..	(###) ###-#### (24 hour)

Detour: *Insert route description and/or map*
- Consider stability of bridges located on the detour route.

Closure Plan Notification:
List of people that should be notified about a bridge closure, this may include county staff responsible for the bridge, bridge inspection, those responsible for installing a detour, also staff responsible for notifying the public about the closure.

County Engineer	(###) ###-####
…	(###) ###-####
…	(###) ###-####
…	(###) ###-####
State Patrol Dispatch	(###) ###-#### (24 hour)

APPENDIX L

Authors

1994 TASK FORCE MEMBERS

Minnesota Bridge Scour Task Force Members:

Steve Blanchard	Donald J. Flemming	Alan Forsberg
Mark Gieseke	Dave Halvorson	Andrea Hendrickson
Chuck Howe	Gene Isakson	W. Robert Ivarson
Bruce Iwen	Richard Larson	James McCutcheon
Gary Person	Gary Peterson	Mike Rardin
Lisa Sayler	Joel Toso	

Chairman: Mark Gieseke

Facilitator: W. Robert Ivarson

2009 Update Author

Petra DeWall