

APPENDIX F

Sample Documents of Practices Related to Integrated Flood Prediction and Response Systems

Idaho

BridgeWatch Reports

Iowa

Bridge Scour Management Plan – Standard Provisions
ScourWatch Data Report

New York

NYSDOT's San Diego Domestic Scan Presentation

North Carolina

Sample Memorandum of Agreement (MOA)

South Carolina

Sample Resiliency Survey spreadsheet

Texas

Streamflow Measurement at Bridges Presentation

**IDAHO TRANSPORTATION
DEPARTMENT SUPPLEMENTAL
BRIDGE WATCH REPORT
DISTRICT NO. 5**

BRIDGE KEY: 19260
STRUCTURE NO: 91843A 2.50
FEATURES INTERSECTED: SAND CREEK
LOCATION: 0.5 N. 2.3 E. FIRTH

SUBSTRUCTURE: No onsite inspection.

CHANNEL: No onsite inspection.

NOTES TO BAME: This alert was generated by NEXRAD station KSFX (Pocatello) which reported 0.84" rainfall in 1 hour at 9:39 PM on 3/22/18 exceeding the 25 yr 1 hour threshold of 0.83" (see attached).

Actual rainfall in this nearby Twin Falls was 0.34" for the day. Area stream gauges (13060000 Snake River near Shelley) did go up a bit but were still running at ¼ of a 25 year flow. This appears to be an inflated rain prediction from NEXRAD, which coupled with the small drainage basin of this bridge produced a false alarm.

No onsite inspection is necessary at this time.

MISCELLANEOUS ITEMS: None.

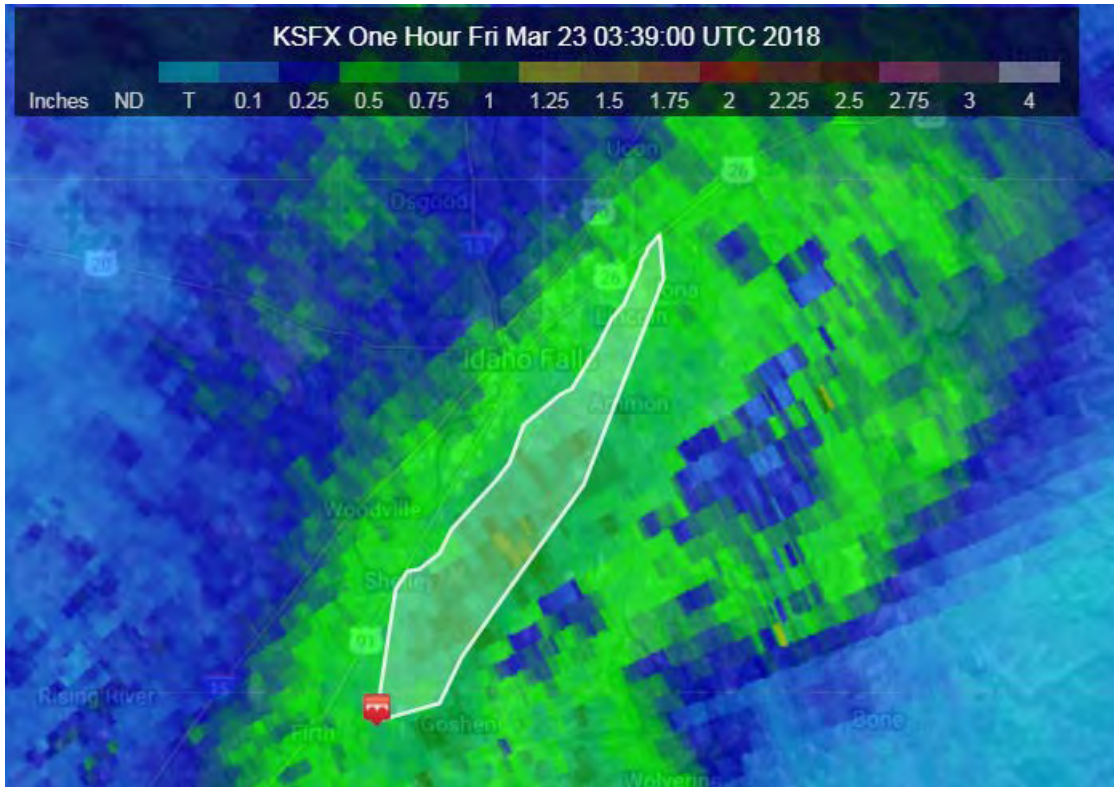
WORK ACCOMPLISHED: None.

MTCE RECOMMENDATIONS: None.

SIGNATURE:



DATE: 3-23-18



22 Rain

Actual: **61°** | **43°**
 0.34 in

Average: **55°** | **32°**
 0.04 in

**IDAHO TRANSPORTATION DEPARTMENT
SUPPLEMENTAL BRIDGE WATCH REPORT
DISTRICT NO. 6**

BRIDGE KEY: 31595
STRUCTURE NO: X995400 100.54
FEATURES INTERSECTED: PINE CREEK
LOCATION: 0.4 S. 0.5 W. PINEHURST

SUBSTRUCTURE: No onsite inspection.

CHANNEL: No onsite inspection.

NOTES TO BAME: This alert was generated by USGS gage 13112000 (Camas Creek at Camas ID) which recorded a streamflow of 1280 cfs On 3-23-18 at 10:45 PM exceeding the threshold 25 year flow of 1240 cfs(see attached map).

There was heavy rain in the area on 3-22-18 likely causing this flow spike possibly in conjunction with melting snow. The particularly high and fast water flow spike looks to me as if it might be debris affected. I spoke with Clark County who had people in the area and reported that these bridges are still under snow. The melt causing high water must have occurred lower in the drainage basin.

No onsite inspection is recommended at this time.

MISCELLANEOUS ITEMS: None.

WORK ACCOMPLISHED: None.

MTCE RECOMMENDATIONS: None

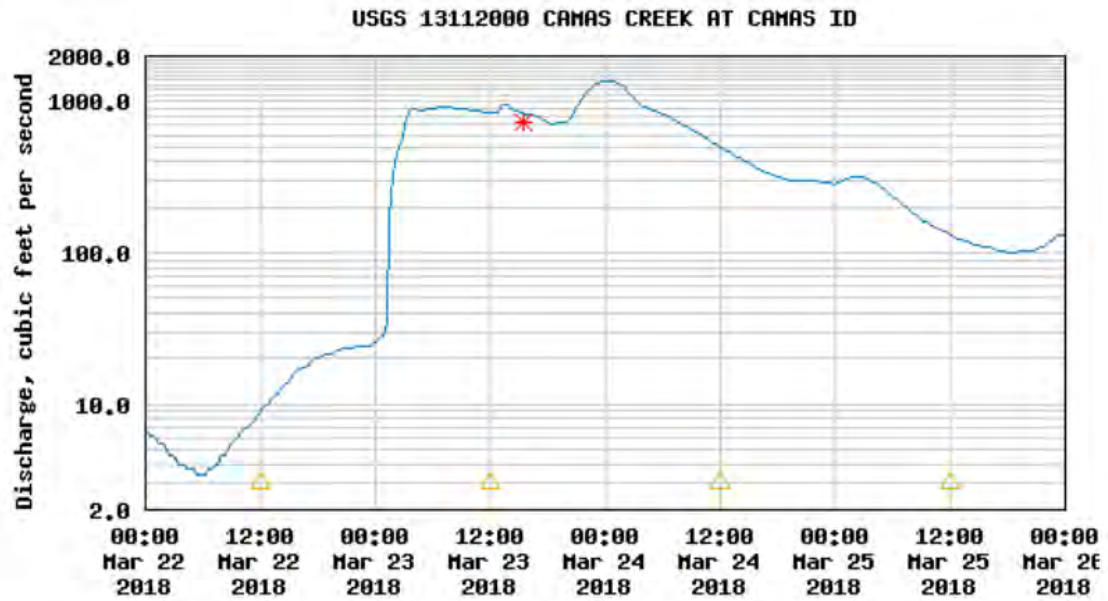
SIGNATURE:



DATE: 5-4-18

Discharge, cubic feet per second

Most recent instantaneous value: 133 03-29-2018 06:30 MDT



Bridge Scour Management Plan - Standard Provisions

1. Description

This document outlines procedures to be followed to manage scour at bridges that have been found to be scour susceptible or scour critical. These standard provisions outline procedures and provisions applicable to all bridges within a given classification. Procedures and provisions for specific bridges are contained in the 'Bridge Scour Management Plan - Bridge Specific Provisions' contained in Appendix B.

General information regarding scour and bridge monitoring is contained in "Bridge Scour Monitoring Plan for Local Roads and Streets", August 1997 and "Evaluating Scour At Bridges", FHWA HEC-18, May 2001. The procedures provided herein generally follow the guidelines in these documents.

Bridges listed in Appendix B have been found to be scour susceptible or scour critical as a result of assessment or analysis, or have unknown foundation conditions where the scour risk cannot be assessed. Structure Inventory and Appraisal (SIA) Item 113 identifies the current status of a bridge regarding its vulnerability to scour. Item 113 codes which generally require the bridge be monitored for scour during flood events are as follows:

<u>Code</u>	<u>Description</u>
U	Bridge with "unknown" foundation that has not been evaluated for scour. Until risk can be determined, a plan of action should be developed and implemented to reduce the risk to users from a bridge failure during and immediately after a flood event.
3	Bridge is scour critical; bridge foundation determined to be unstable for assessed or calculated scour conditions.
4	Bridge foundations determined to be stable for assessed or calculated scour conditions; field review indicates action is required to protect exposed foundations.
7	Countermeasures have been installed to mitigate an existing or assessed problem with scour and to reduce the risk of bridge failure during a flood event. Instructions contained in a plan of action have been implemented to reduce the risk to users from a bridge failure during or immediately after a flood event.

Specific bridges that require scour monitoring during flood events are listed in Appendix B.

Other documents regarding scour monitoring define 'monitoring' as measuring of the river bed during flood events. For the purposes of this document, monitoring refers to the entire process of managing scour susceptible or scour critical bridges during and immediately after flood events. This includes tracking the development of flood conditions, observing bridge condition during floods, making measurements of scour and waterways, implementing and removing road closures, and preparation and maintenance of records.

2. Classification

As noted in Section 1. this document outlines procedures to be followed for bridges that are scour susceptible, scour critical or have unknown foundation conditions where risk cannot be assessed. These bridges are grouped into the following classifications:

CRIT - Critical

Scour depth and/or bank erosion resulting in failure of the bridge could occur during a single flood event. The Iowa DOT has decided that in lieu of measuring scour depths during floods, or the installation of countermeasures, the bridges will simply be closed during floods which exceed the critical water surface elevation. These bridges are generally on low volume routes where countermeasures were determined to not be cost effective. *Monitoring during flood events is required.*

Bridge Scour Management Plan - Standard Provisions

ARM - Armored (Countermeasure)

Countermeasures have been installed to limit scour depth and/or bank erosion. These countermeasures should remain viable during a single major flood event in limiting scour/erosion. *Monitoring during flood events is required.*

PERM - Permanent (Countermeasure)

Similar to the Armored classification above, except that the installed countermeasures should remain viable through several major flood events in limiting scour/erosion. *Monitoring during flood events is NOT required as long as the countermeasure is substantially intact.* A inspection of the countermeasures should be considered following any significant (>25 yr.) or roadway overtopping flood events.

OTH - Other

Bridges that cannot be placed in one of the three classifications above are placed in this classification. Refer to the Bridge Specific Provisions for the monitoring procedures and provisions to be used. *Monitoring during flood events is required.*

Similar scour management procedures and provisions are used for all bridges within a given classification. Management provisions unique to each bridge are provided in the Bridge Specific Provisions.

3. Monitoring Schedule and Responsibilities

3.1 Functional Groups

Functional groups which will be involved in the monitoring process during a flood event are defined as follows:

District:

Local maintenance personnel, District Maintenance Manager and District public information personnel. This group will generally be involved in the process of monitoring the development of flooding conditions, implementing bridge closure plans, general monitoring of bridge condition during floods, and advising Bridge Inspection personnel of bridge closures.

Bridge Inspection:

The six bridge inspection teams (Ames, Manchester, Jefferson, Fairfield, Atlantic, and Cherokee) and supporting staff in the Bridge Maintenance and Inspection Unit of the Office of Bridges and Structures. This group will generally be involved in detailed bridge monitoring during and following a flood event, documenting/providing findings, and maintaining records.

Management:

Bridge Maintenance Engineer, Bridge Engineer, and the District Engineer or their representative. This group will generally be involved in the process of reopening of closed bridges.

3.2 Initiation Of Monitoring For Critical Water Surface Elevation

The Bridge Specific Provisions, Appendix B, contain the critical water surface elevation at which detailed monitoring procedures and/or bridge closures per Section 3.3 shall be initiated. This elevation is measured on the upstream side of the bridge unless noted otherwise in the Bridge Specific Provisions. The frequency (return period) of the elevation is dependent on the bridge characteristics, but generally reflects the 25 yr. (4% chance/year) event.

District personnel shall initiate monitoring upon notification by the Emergency Operations Center (EOC). The EOC is notified that the Critical Water Surface may have been exceeded by the Bridge Watch system which monitors rainfall and/or streamflow data.

Upon notification by the EOC site visits to observe water levels should be initiated. Site visits should continue at an appropriate interval until the storm event is over and the stream is receding. Since sites with a Permanent classification do not require monitoring, a site visit the next working day to evaluate if Critical Water Surface was exceeded should be adequate.

Bridge Scour Management Plan - Standard Provisions

Unusual conditions, such as excessive buildup of debris and ice, will require special consideration. Contact Bridge Inspection to determine if detailed monitoring should be initiated regardless of the water surface elevation.

3.3 Initiation Of Detailed Monitoring

Once the monitoring performed under Section 3.2 indicates that the critical water surface elevation has been reached, road closures (or detailed monitoring if appropriate) shall be commenced as follows.

3.3.1 Critical (CRIT) Bridge Classification

The bridge shall be closed. Implement the closure plan per Section 5. The following actions shall be taken following closure:

3.3.1.1 Monitoring During Closure

- A) The District shall contact Bridge Inspection to notify them of the closure and to schedule the inspection addressed in Section 3.3.1.1 (c) below prior to reopening the bridge.
- B) The District shall observe/monitor the condition of the bridge during the flood event. This monitoring should continue until the water surface has receded below the critical water surface. See Section 4.3. If the monitoring indicates a possible problem, contact Bridge Inspection to arrange for assistance in further monitoring.
- C) After the water surface elevation has receded below the critical water surface elevation Bridge Inspection shall perform the following:
 - 1) Measurement of the stream bed to estimate scour depths per Section 4.5.
 - 2) A visual inspection of the bridge site with emphasis on the items listed in Section 4.3.2.

3.3.1.2 Reopening Procedures

Upon completion of the monitoring under Section 3.3.1.1 above, Bridge Inspection shall provide findings to Management so that a decision can be made whether or not to reopen the bridge. See Section 5, Bridge Closure.

3.3.1.3 Follow-Up Monitoring

After the bridge is re-opened and water has receded into the normal channel take the following actions.

- A) Bridge Inspection shall inspect the bridge and measure the stream bed. See Section 4.6.
- B) Bridge Inspection will inform District Management of findings.

3.3.2 Armored (ARM) Bridge Classification

The bridge will remain open unless monitoring indicates a problem. The following monitoring shall be initiated.

3.3.2.1 Monitoring During Flood Event

- A) The District shall contact Bridge Inspection to notify them of the flood event and to schedule for monitoring following the flood event.
- B) The District shall observe/monitor the condition of the bridge during the flood event. This monitoring should continue until the water surface has receded below the critical water surface. See Section 4.3.
- C) If the monitoring performed under Paragraph B) above indicates a possible problem, the bridge should be closed. Perform bridge monitoring and closure per Section 3.3.1, Critical Bridge Classification, as appropriate. Contact

Bridge Scour Management Plan - Standard Provisions

Bridge Inspection to arrange for detailed inspection after the water has receded.

3.3.2.2 Follow-Up Monitoring

If no problems were noted during the flood event, take the following actions following the flood event.

- A) Bridge Inspection shall inspect the bridge and measure the stream bed as soon as practical. See Section 4.6.
- B) Bridge Inspection shall inspect the scour countermeasures. See Section 4.6.3.
- C) Bridge Inspection will inform District Management of findings.

3.3.3 Permanent (PERM) Bridge Classification

The bridge will remain open.

3.3.3.1 Monitoring During Flood Event

Monitoring during flood events is not required as long as the countermeasure is substantially intact. The District should contact Bridge Inspection to notify them of any significant (>25 yr.) or roadway overtopping flood events. The critical water surface elevation provided in the Bridge Specific Provisions, Appendix B, may be used as an indicator of a significant flood event.

3.3.3.2 Follow-Up Monitoring

Monitoring following flood events is not required as long as the countermeasure is substantially intact. Bridge Inspection should consider an inspection of the installed countermeasures within three weeks following significant or overtopping flood events. See Section 4.6.3 and 4.6.4. If problems with the countermeasure are found, contact Management to initiate reclassification of the bridge and remedial action.

3.3.4 Other (OTH) Bridge Classification

Refer to the Bridge Specific Provisions for the monitoring requirements.

4. Monitoring Procedures

This section addresses detailed monitoring procedures required per Section 3.3, Initiation Of Detailed Monitoring.

If any problems are suspected or identified that may threaten the structural integrity of the bridge, the District should close the bridge per Section 5, Closure.

4.1 Safety

Extreme care should be used while monitoring bridges during flood stages. A minimum of a two-person crew is recommended for all work beyond monitoring for the critical water surface elevation. If there is ever a question regarding the safety of the bridge or the crew, the bridge should be closed until the flood recedes and the bridge can be inspected.

4.2 Critical Water Surface Elevation

The critical water surface elevation from the Bridge Specific Provisions, Appendix B, shall be marked at the bridge site pre-flood to allow rapid visual check of the water surface in relation to the critical elevation. This elevation is measured on the upstream side of the bridge. It is recommended that this mark be made on one of the substructure units at a location easily seen.

4.3 Observation Of Bridge Condition During Flood Event

The intent is to visually observe the bridge and surrounding site for signs of distress or developing problems during an ongoing flood event.

Bridge Scour Management Plan - Standard Provisions

4.3.1 Monitoring Interval

The monitoring interval will be determined at the discretion of the monitoring personnel for specific flood events based on monitoring results and site specific data, such as bridge size, drainage area, and scour history. Refer to the Bridge Specific Provisions, Appendix B, for any site specific requirements. Recommended monitoring intervals are as follows.

Closed Bridges:

It is suggested that the bridge site be monitored at least once a day.

Open Bridges:

For lower volume roads, it is suggested that the bridge site be monitored at least twice a day. For higher volume roads and Interstate, it is suggested that the bridge site be monitored at least four times a day.

Particular attention should be given to those situations where the water level is near the bottom of the superstructure. In these instances, consideration should be given to increasing the monitoring frequency. For these bridges around-the-clock monitoring should be considered.

4.3.2 Monitoring Procedures

Refer to the Bridge Specific Provisions, Appendix B, for any site specific areas of emphasis. Particular attention should be paid to the following issues which indicate problems:

- Change in vertical or horizontal alignment of handrail or structural members such as beams.
- Shifting of channel alignment or erosion of stream banks.
- Berm slope distress such as erosion, sagging, cracks or cupping. If stream flow is adjacent to abutment berm consider the following:
 - Sounding and probing for voids at abutments.
 - Sound approach for hollow indications.
 - Inspect for voids adjacent to wing walls.
- Cracks in the soil of the banks.
- Misalignment of bridge bearings.
- Cracking or other signs of distress in approach pavement or roadway.
- Movement or cracking of bridge deck.
- Debris (and ice) buildup.

Debris buildup on scour critical bridges should be considered a serious problem. This includes bridges that are classified as Armored per Section 2. The debris can cause unpredictable scour patterns that could result in rapid failure of the bridge foundation. Bridge Inspection should be contacted immediately to coordinate detailed inspection. The District will decide whether or not to remove debris during the flood.

4.3.3 Reporting

Document and pass along to Bridge Inspection any significant observations for inclusion in the bridge documentation file for individual bridges.

4.4 Reserved

4.5 Measurement Of Stream Bed During Flood Event

The maximum scour depth in moderate to rapidly erodeable bed materials will occur at or directly following the flood peak. For less erodeable bed materials the maximum scour may

Bridge Scour Management Plan - Standard Provisions

occur some time after the flood peak. Following the flood peak, infilling of the scour hole with sediment may occur.

For bridges with a Critical classification the intent is to measure the stream bed elevation near the abutments, piers and on the berm prior to reopening the bridge. **These measurements on critical bridges will generally be made after the water surface has dropped below the critical elevation.**

For bridges with an Other classification, the Bridge Specific Provisions may require that measurements be taken directly following the flood peak in order to estimate the maximum scour that occurred. In this case, measurements should be taken as soon after the flood peak as practicable to obtain measurements before infilling of the scour hole begins.

The following procedures also apply to measuring and recording the streambed elevation following the flood per Section 4.6.2.

4.5.1 Measurement Equipment

Sonar equipment is recommended for measuring the stream bed during the flood. Sounding weights and/or poles may be practical after the flood has receded. Each bridge inspection team has a sonar unit.

4.5.2 Measurement Procedure

Measure for scour from the upstream face 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.

Take measurements of the streambed at all piers, at abutment locations, and at the toe of abutment slopes to determine if the channel bottom elevation is changing at these locations. Ensure that the measurements at piers are taken beyond the limits of the pier footings.

Typically the maximum scour is expected to occur near the front face of the pier. If floodwater 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 upstream 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 abutment foundation is undermined, the approach fill may be endangered. Adverse flood flow alignment with the substructure units may result in points of turbulence. These locations should also be considered for measurement.

Compare the measured bed elevation to the critical bed elevation provided in the Bridge Specific Provisions, Appendix B. If the measured bed elevation is lower than the critical bed elevation, the foundation should be considered unstable thereby placing the structural integrity of the bridge in question. The bridge should therefore be closed if it is open per Section 5, Bridge Closure. Analysis and possible remedial action will be required before the foundation can be considered stable.

4.5.3 Reporting

Document inspection findings in the bridge documentation file for individual bridges.

4.6 Inspection Of Bridge/Measurement Of Stream Bed Following Flood Event

The intent is to conduct an inspection following the flood with particular emphasis on waterway features. This inspection will be conducted after the water has receded into the normal channel.

4.6.1 General Inspection Procedures

Following the flood event Bridge Inspection should conduct an inspection of the bridge and bridge site with particular emphasis on waterway features. Particular emphasis should be placed on those issues noted in Section 4.3.2.

4.6.2 Measurement Of Stream Bed

Bridge Scour Management Plan - Standard Provisions

Measure and record the stream bed similar to Section 4.5. Measure or survey stream banks as required to update any attachments to the Bridge Specific Provisions. Refer to the Bridge Specific Provisions for the critical bed elevation and other site specific criteria that indicates attention is required.

4.6.3 Countermeasure Inspection for Armored and Permanent Bridge Classifications

Refer to the Bridge Specific Provisions, Appendix B, for specific countermeasures installed at the bridge site. The inspection should verify that the countermeasures are substantially intact and appear to still be functional.

The Bridge Specific Provisions will include design plan sheets and/or inventory drawings of countermeasures that were installed. For countermeasures under water, compare the measured bed elevation to the countermeasure failure elevation provided in the Bridge Specific Provisions, Appendix B. If the measured bed elevation is lower than the countermeasure failure elevation, the countermeasure has most likely failed and is no longer functional.

If the countermeasures are damaged or otherwise made ineffective, scour or bank erosion resulting in failure of the bridge could be developed during a future single storm event. The bridge may have to be treated as a Critical (CRIT) classification until the countermeasures are repaired.

4.6.4 Reporting

Document inspection findings in the bridge documentation file for individual bridges as required. Complete a copy of the Scour Report form (Appendix D) for the bridge.

5. Bridge Closure

The Management functional group, as defined by Section 3.1, should be consulted prior to closing any bridges not having a Critical classification. The intent of this process is to solicit further expertise prior to taking the disruptive step of closing a State highway. This group should also be consulted prior to reopening a bridge classified as Critical after the flood has receded.

However, if monitoring indicates an immediate threat to the structural integrity of the bridge or approach roadway the bridge should be closed immediately. Examples of these circumstances are visible settlement of the bridge, undermining of abutments or approach slabs, or massive failure of the berm slopes.

The Management group shall also be consulted prior to reopening any bridge. Following completion of detailed monitoring, the bridge inspection team shall contact Management to brief them on the bridge condition.

The District shall prepare and maintain a closure and detour plan for all bridges with a Critical (CRIT) classification. A detour and closure plan may also be required for some Other (OTH) classification bridges. Refer to the Bridge Specific Provisions, Appendix B.

It is recommended that the District also prepare a contingency closure and detour plan for bridges with a Armored (ARM) classification in the event closure is required.

6. Inspection

During regular biennial inspections installed countermeasures for bridges classified as Armored or Permanent shall be inspected. Refer to the Bridge Specific Provisions, Appendix B, for specific countermeasures installed at the bridge site. The Bridge Specific Provisions will include design plan sheets and/or inventory drawings of countermeasures that were installed.

The inspection should verify that the countermeasures are substantially intact and appear to still be functional. If the countermeasures are damaged or otherwise made ineffective, scour or bank erosion resulting in failure of the bridge could be developed during a future single storm event. Contact Management to initiate reclassification of the bridge and remedial action. Timely contact of Management is required since the bridge may have to be treated as a Critical (CRIT) classification until the countermeasures are repaired.

Bridge Scour Management Plan - Standard Provisions

Note the condition of the countermeasures on the appropriate code sheets.

7. Records

Upon completion of post-flood monitoring or biennial inspections, Bridge Inspection will update the bridge documentation file to include the scour report form and table of bridge deck elevations if inspection results were noted on these records.

Bridge Management or their designated representative will review the bridge documentation file following inspections to determine if any remedial action or changes to the bridge specific provisions are required.

A copy of the current Scour Management Plan with all appendices/attachments in .pdf format will be maintained at the following network address:

W:\Highway\Bridge\PrelimSection\Scour\Scour_Management_Plan

Notice of any modifications to the plan that will effect monitoring procedures or bridge classification will be sent to all appropriate functional groups by e-mail.

8. Appendices

- A. Monitoring Flow Chart
- B. Bridge Specific Provisions
- C. Countermeasure Criteria
- D. Scour Report Form

Revisions:

11/15/00 - Initial Document

03/19/01 - Revision (Timing of reopening inspection, stream bed measurements)

08/20/01 - Revision (Editorial Changes)

08/12/04 - Major Revision (Added Permanent Classification)

04/28/05 – Sect. 3.2, crit. water surface meas. location per Bridge Specific Provisions

04/19/10 – Remove contact listing, remove Sect. 4.4 deck measurements, revise Sect. 3.2 to reflect EOC/bridge watch, Sect. 3.3.2.2 and Sect. 3.3.3.2 note approx. time frame for inspection.

Bridge Scour Management Plan - ScourWatch Data

0407.6S005

Bridge No.: 0407.6S005
FHWA No: 13900
SIA #113: 7 - Plan Of Action Implemented
Classification: Permanent
Countermeasure Installed, Limited Inspection Following Flood
Location: IA 005 Over Drainage Ditch, 1.9 Mi. N of Cincinnati
Type: 52' X 30' Steel Beam, Pile Bent Abuts Steel SP Backed

County: Appanoose
Route: IA 005
Stream: Drainage Ditch
District: 5 Fairfield

Comments

None

Alert Message / Special Instructions

None

Gage Data

Gage Data Not Used

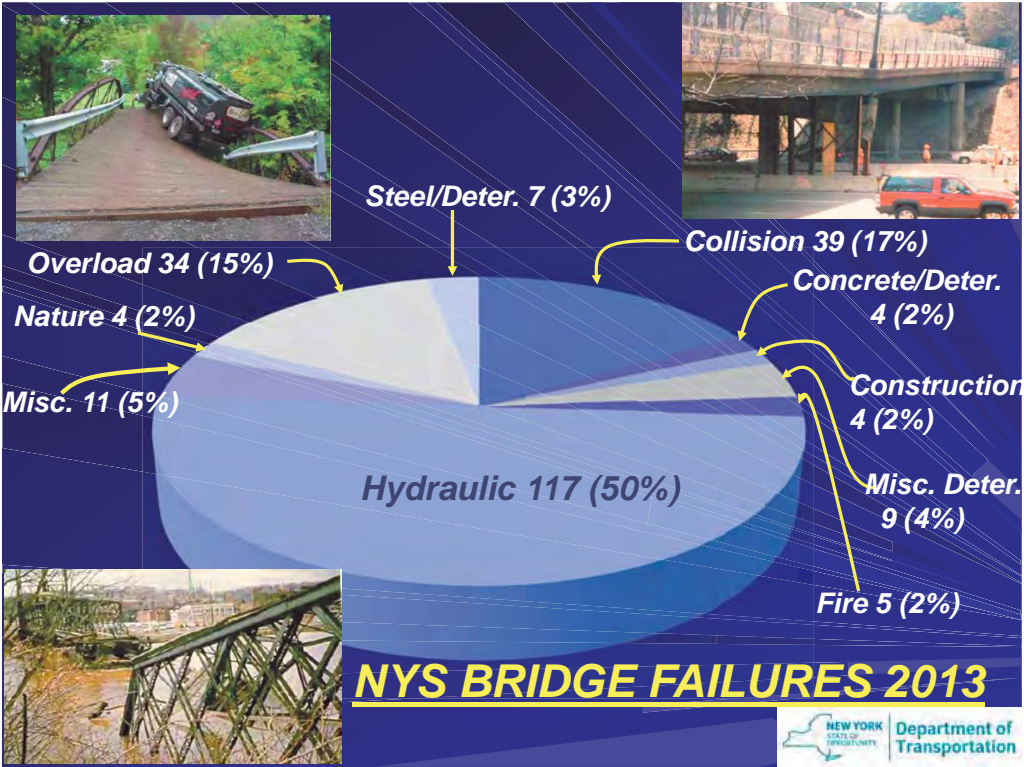
Rainfall Data

50 Yr. Upper Basin Area: 6.1 Sq.Mi. Percent Basin w/ Rainfall: 1%

Rainfall Data: 1 Hr.-3" 3 Hr.-3.8" 6 Hr.-4.5" 12 Hr.-5.2" 24 Hr.-5.9"

Contact Listing

5 District Maintenance Manager - Kenneth Morrow	Contact 1	Email	Cellphone
5 District Operations Manager - David Loving	Contact 2	Email	Cellphone
CO Asst. Bridge Maintenance Engineer - Timothy Dunlay		Email	
CO Preliminary Bridge Engineer - David Claman		Email	
CO Transportation Engineer - Bridge - William Kaufman		Email	
CO Transportation Engineer - Bridge Maint - David Jensen		Email	Home Email



NCHRP

Domestic Scan # 15-02 "Bridge Scour Risk Management"

NYSDOT Bridge Safety Assurance Program

Hydraulic Vulnerability Procedures

NEW YORK STATE OF OPPORTUNITY Department of Transportation

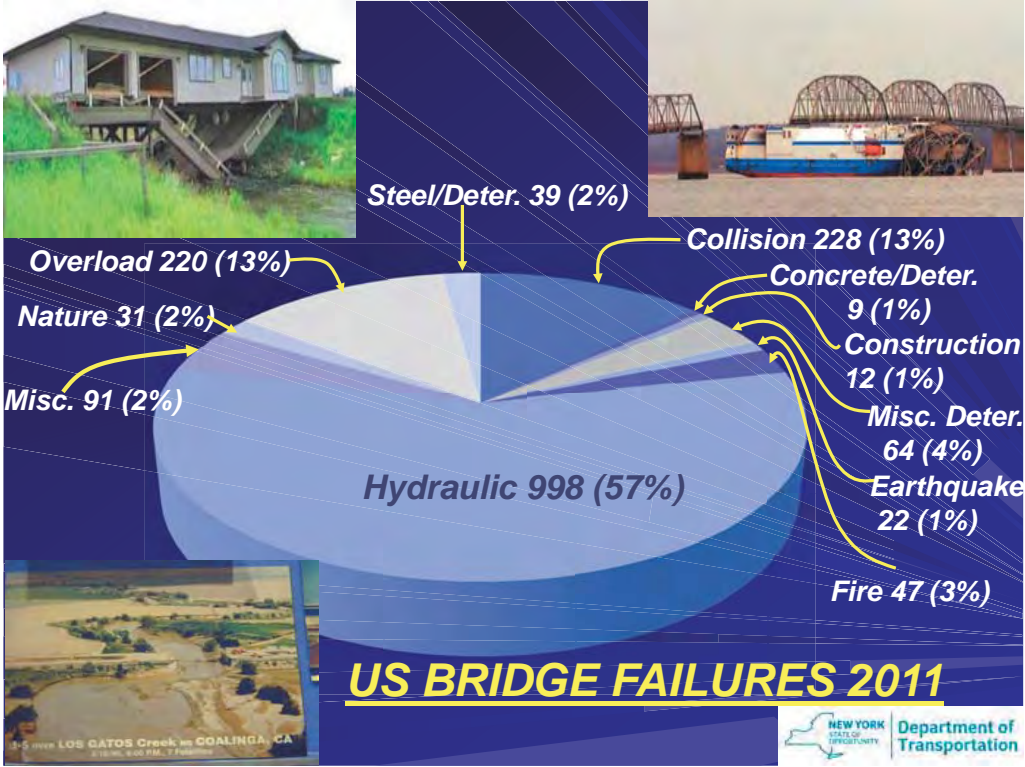
How It All Started April 5, 1987

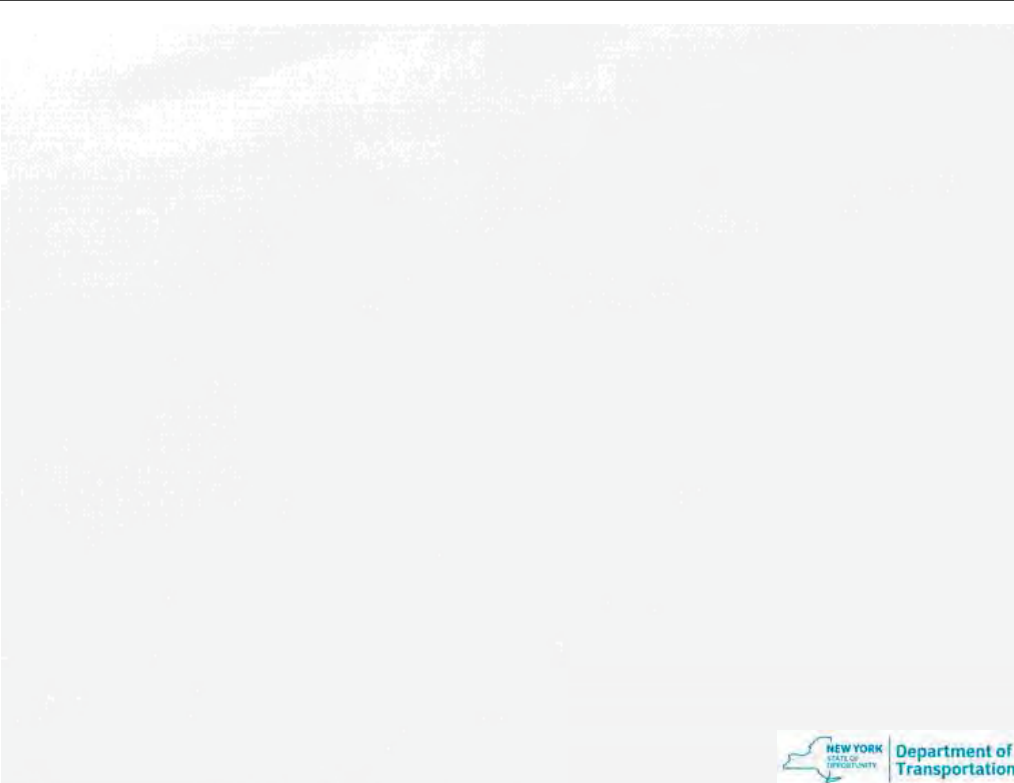
This was a 70 year flood

The worst floods were...

In 1955	73,600 CFS
In 1987	72,200 CFS
In 1996	80,200 CFS

NEW YORK STATE OF OPPORTUNITY Department of Transportation





HYDRAULIC VULNERABILITY

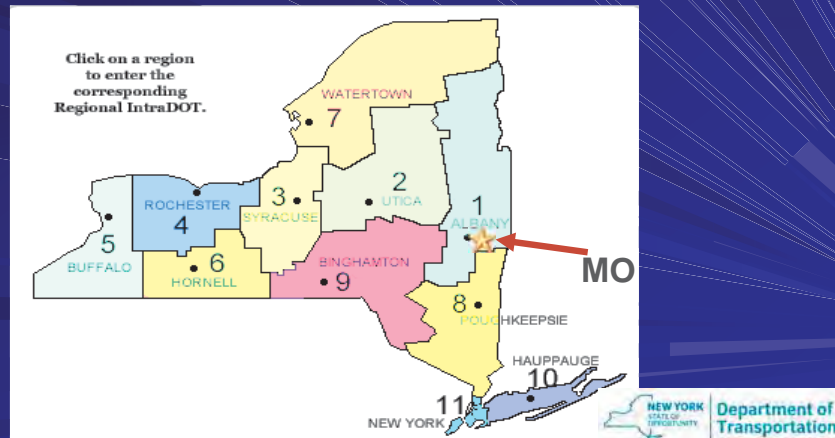
Schoharie Bridge Failure - April 1987

- Technical Advisory T 5140.20 -- 1988
- Technical Advisory T 5140.23 -- 1991
 - New bridges designed to be safe from scour
 - Evaluate existing bridges for scour
- 23 CFR 650 Subpart C 313.e.3 -- 2005 -- Plan of Action for Scour Critical Bridges



NYSDOT RESPONSE

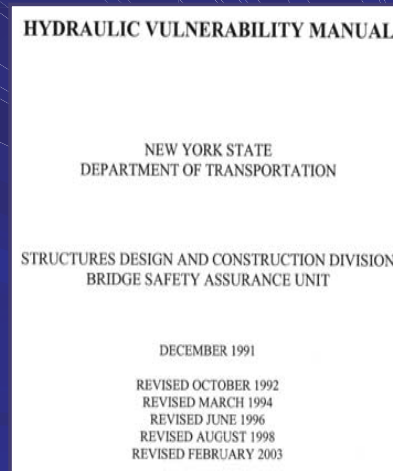
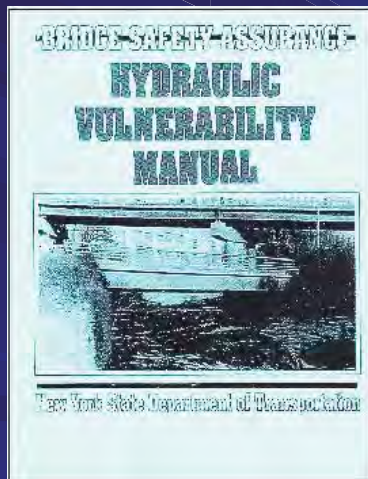
- Hydraulic and Bridge Safety Assurance (BSA) Units established
 - Separate units in the Main Office (MO)
 - Combined functions in the Regional Offices



Scour Hole on Land Pier From 1996 Flood

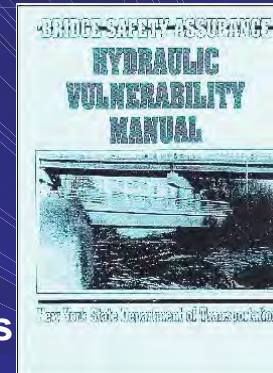


HYDRAULIC VULNERABILITY ASSESSMENT



NYSDOT RESPONSE

- Hydraulic Training programs were established:
 - NHI Training which includes:
 - HIRE
 - HEC RAS (Hec 2)
 - HEC 18, 20, 23
 - Other Hydraulic courses
 - The Hydraulic Vulnerability Assessment (HVA) Manual was developed under the BSA Unit. This was developed to evaluate existing bridges for scour.



HYDRAULIC VULNERABILITY ASSESSMENT

1. **Screening**
2. **Classifying**
3. **Rating**
4. **Monitoring**

HYDRAULIC VULNERABILITY ASSESSMENT MANUAL

Interdisciplinary Team.

1. **Hydraulic Engineer**
 2. **Geotechnical Engineer**
 3. **Structural Engineer**
- This team was used to develop the HVA Manual
 - Scour evaluations of new bridges are also conducted by the interdisciplinary team

HYDRAULIC VULNERABILITY ASSESSMENT

1. **Classifying** -- *Evaluates the vulnerability of a structure to scour failure.*

- *General Hydraulic Assessment*
- *Foundation Assessment*

HYDRAULIC VULNERABILITY ASSESSMENT (HVA)

1. **Screening** – *Prioritize bridges to proceed with HVA assessment.*

- *Inventory Screen*
- *Susceptible Screen*

HYDRAULIC VULNERABILITY ASSESSMENT

2. **Classifying** – *General Hydraulic Assessment*

- *Streambed Material*
- *River Slope (0-3)*
- *Historic Scour Depth (0-4)*
- *Adequate Opening (0-2)*
- *Channel Bottom – Degrading? (0-4)*
- *Channel Configuration (0-3)*
- *Backwater Effects (0-1)*
- *Depth of Flow during Storm Events (1-2)*
- *Overflow Relief (0-1)*

HYDRAULIC VULNERABILITY ASSESSMENT (HVA)

1. **Screening**

- *Was not done for local bridges*
- *All State bridges were screened but not required anymore.*
- *All new bridges are designed to withstand scour*

HYDRAULIC VULNERABILITY ASSESSMENT

2. *Classifying – Bridge Size Culverts*

- *Culvert Type (0-8)*
- *Bridge Size Culverts – Primary element Condition State (1-5)*
- *Angle of Attack (0-4)*
- *Embankment Encroachment (0-4)*
- *Sediment and/or Debris Problems (1-5)*

HYDRAULIC VULNERABILITY ASSESSMENT

2. *Classifying – Abutment & Pier Foundation Assessment*

- *Scour Countermeasure Installed (0-5)*
- *Foundation Type (0-10)*
- *Angle of Attack (0-4)*
- *Embankment Encroachment (0-4)*
- *Pile/Footing Below Streambed (1-5)*
- *Pier Width (1-5)*
- *Multiple Piers In Flood Plain (0-2)*
- *Simple Spans (0-1)*

CLASSIFICATION

Final Classification Score = General Hydraulic Assessment + Foundation Assessment Score

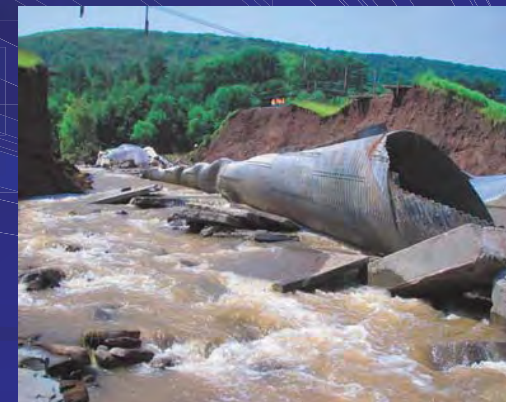
Higher of the Abutment, Pier or Culvert Scores

HYDRAULIC VULNERABILITY ASSESSMENT

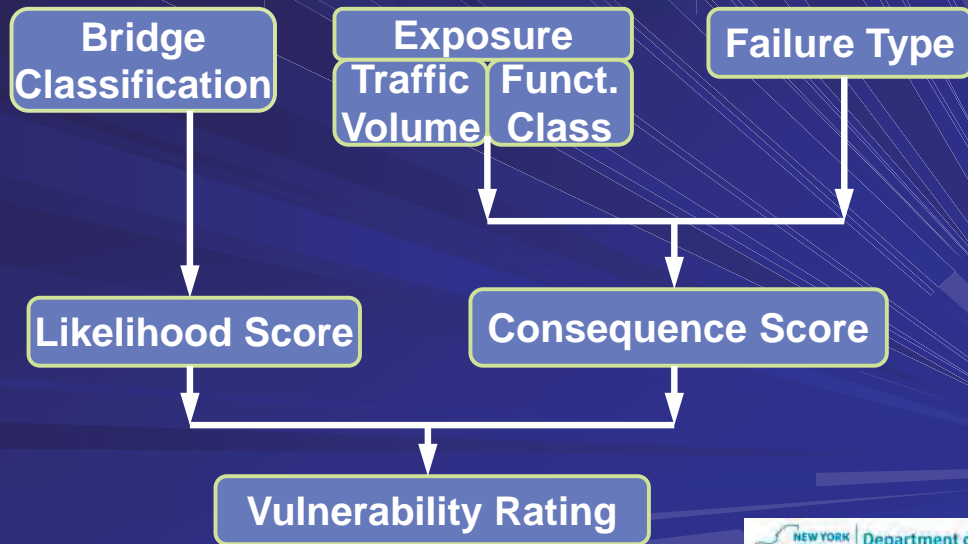
2. *Classifying – Foundation Assessment Abutments and Piers*

Culverts

- *Less susceptible to scour damage?*
- *Metal Culverts Primary Element Condition State considered*



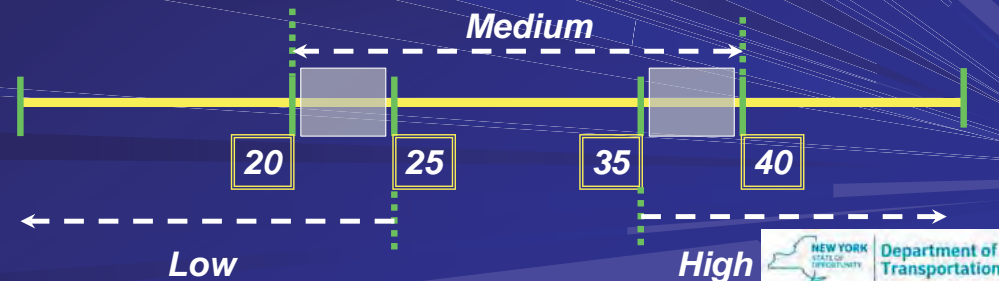
VULNERABILITY RATING PROCEDURE



HYDRAULIC VULNERABILITY ASSESSMENT

2. *Classifying – Vulnerability Class*

<i>Classification</i>	< 25	20 - 40	>35
<i>Vulnerability</i>	LOW	MEDIUM	HIGH



HYDRAULIC VULNERABILITY ASSESSMENT

Likelihood Score – The likelihood of a structure to fail due to scour. Its obtained from the results of the HVA classifying process, or a detailed hydraulic study.



HYDRAULIC VULNERABILITY ASSESSMENT

Rating – Provide a uniform measure of the structure's vulnerability to failure when compare to other structures.

- *It's basically used as a planning tool.*
- *Helps to prioritize bridges for Rehab (scour countermeasure) or Replacement*

HYDRAULIC VULNERABILITY ASSESSMENT

Failure Type – Assuming that the one or more of the substructure unit fails because of scour, what kind of a failure would the superstructure experience?

- *Catastrophic*
- *Partial Collapse*
- *Structural Damage*

HYDRAULIC VULNERABILITY ASSESSMENT

Consequence of Failure – Is evaluated on the basis of the type of failure a Structure is prone to, and the exposure to the public that a failure would cause.



HYDRAULIC VULNERABILITY ASSESSMENT

Failure Type – Some factors that are considered to evaluate superstructure failure modes are:

- *Redundancy of the Superstructure*
- *Simple Span vs. Continuous Span*
- *Bridge Type – Truss, Multi Girder, etc.*
- *Span length*
- *Support Conditions*
- *Abutments & Piers*
- *Type, Size, Height*

*Foundations, Bearing Types,
Seats widths, etc.*

HYDRAULIC VULNERABILITY ASSESSMENT

Consequence of Failure

$$\text{Consequence Score} = \text{Failure Type Score} + \text{Exposure Score}$$

VULNERABILITY RATING SCORE

Rating	Rating Score	
> 15	1	Safety Priority
13 - 16	2	Safety Program
9 - 14	3	Capital Program
< 15	4	Inspection Program
< 9	5	No Action

HYDRAULIC VULNERABILITY ASSESSMENT

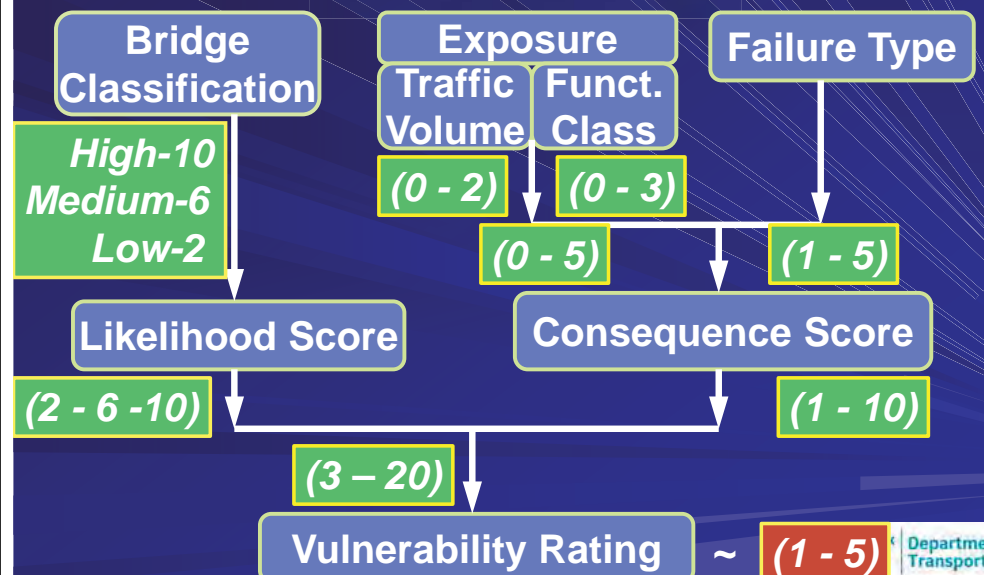
Exposure – Is a measure of the effect that a failure of a structure will have on the users of the bridge and the highway network.

$$\text{Exposure Score} = \text{Traffic Volume Score} + \text{Functional Classification Score}$$

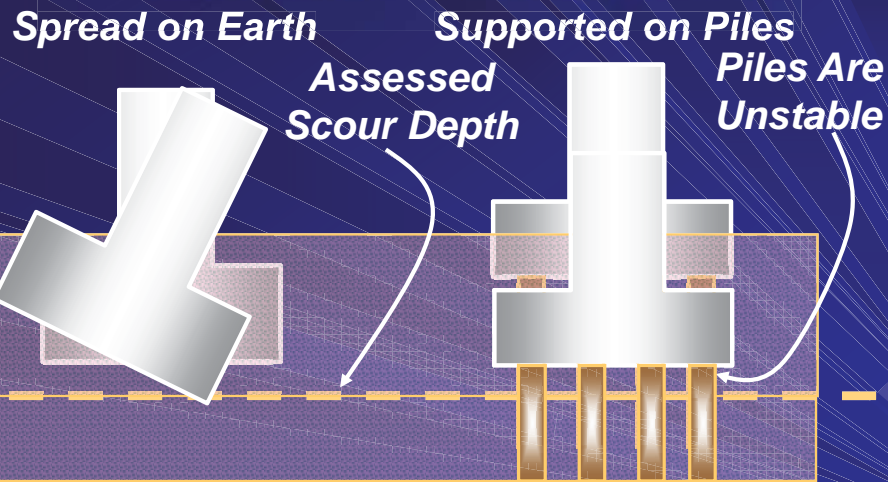
VULNERABILITY RATING SCORE

Assigning FHWA 113 Scour Critical Code based on the Hydraulic Vulnerability Assessment

VULNERABILITY RATING PROCEDURE



Hydraulic Vulnerability Classes

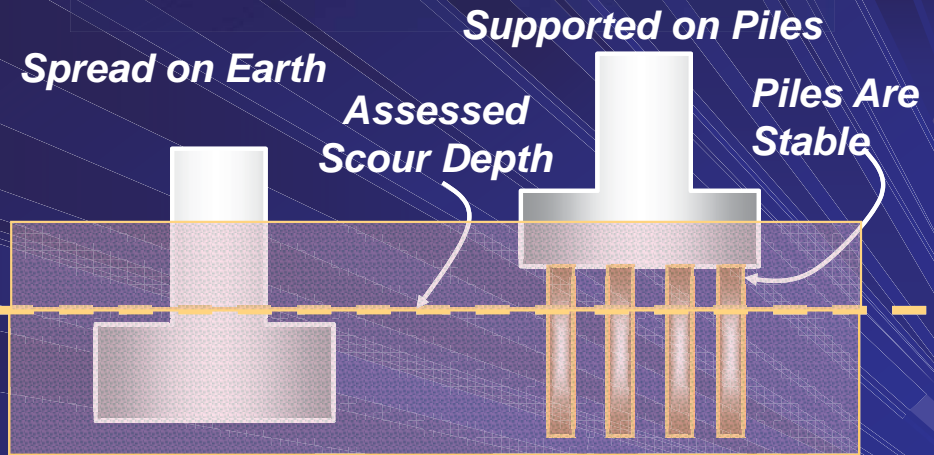


Classification – High

The occurrence of a single, intermediate or large flood could result in failure.

Assigned an FHWA 113 Code of 3, 2 or 1

Hydraulic Vulnerability Classes



Classification – Low

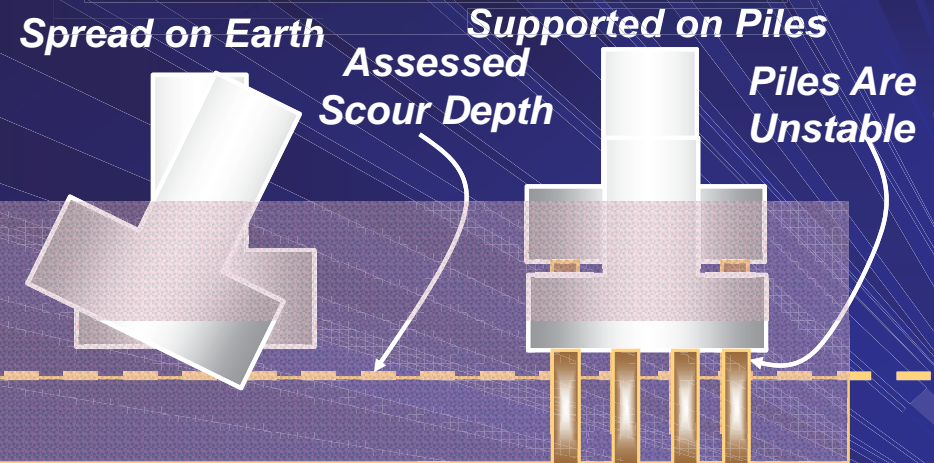
Bridge has little potential for failure
Assigned a FHWA 113 Code of 8 or 5

Scour Critical Bridges

SCOUR CRITICAL BRIDGE:

Is defined as a structure that has at least one of its substructure units (pier and/or abutment) unstable due to observed scour at the bridge or due to the scour potential determined from a **Scour Evaluation**.

Hydraulic Vulnerability Classes



Classification – Medium

There is a recognizable potential for failure from several storm events. Assigned an FHWA 113 Code of 7, 5, or 3 depending on Rating Score

Scour Critical Bridges

- There are over 20,000 Bridges in the US that are considered SCOUR CRITICAL
- There approximately 1000 Bridges in NY that are assessed as SCOUR CRITICAL:
 - 200 – State Bridges
 - 800 – Locally Owned Bridges
- All Scour Critical Bridges require a POA

Scour Critical Bridges



Scour Critical Bridges

Monitoring: Floodwatch

Post Flood Inspections

- ***NYSDOT Bridge Flood Warning Action Plan (BFWAP) – First issued in 1989***
 - *This plan establishes procedures for monitoring State owned or maintained bridges during periods of “Flood Warnings” issued by the National Weather Service*
 - *Its outlines the organizational responsibility of each department, personnel, etc. and conditions to be observed, when monitoring structures during a flood warnings.*

Scour Critical Bridges

- **Classification Score**
 - **High**
 - **Medium, based on recommendation by Regional Hydraulics Engineer (RHE)**
- **FHWA Item 113 Code**
 - **“2”**
 - **“3”**
 - **“7”**
 - **“U”**
- **Rating Score**
 - **1 and 2**
 - **3, based on RHE recommendation**

NYSDOT Plan of Action Form

- Electronic version (MS Access-based) of the POA form.
- A copy should be included in the Bridge Inspection Folder for State Own Bridges
- NYSDOT MO requires a certification from the Local Bridge Owners that a POA was completed.

NYSDOT Plan of Action (POA)

FHWA Technical Advisory

- 23 CFR 650 Subpart C 313.e.3 – 2005
 - Plan of Action for Scour Critical Bridges
 - Supplements NYSDOT Bridge Flood Warning Action Plan (BFWAP - 1989)



PLAN OF ACTION (POA)

POA is to provide guidance for bridge owners, that can be implemented for **Scour Critical Bridges** before, during, and after flood events to protect the traveling public.

The primary components of a Plan of Action are:

1. Outlines personnel and procedures for carrying out the POA
2. Instructions regarding type and frequency of inspections to be made at the bridge
3. A schedule for timely design and construction of **scour countermeasures**



NYSDOT - Plan of Action Form

Closure Instructions

Criteria for Closure: Water Level is 5 foot below the Low Beam Elevation. Can be observed by a water gage marked on the north west corner of the north abutment

Authorization for Closure: Bridge Maintenance/Bridge Management Engineer

Detour Route: NY Route 438 East (12 miles) to US Route 62 South (0.7 Miles) to NY Route 39 West (

Criteria for Re-Opening:

Bridge should be inspected by a NYS Licensed PE and certified safe before reopening to traffic



NYSDOT - Plan of Action Form

Type(s) of Inspection/Monitoring performed

Biennial Inspection Interim Inspection Post Flood Inspection
 Diving Inspection Fathometer Survey Special Inspection
 Flood Event Monitoring Scour Monitors (list type used) None

Criteria for Monitoring: Flood Warning issued from the National Weather Service

Flood Warning issued by Nation Weather Service and/or follow instructions from the NYSDOT Bridge Flood Warning Action Plan



NYSDOT - Plan of Action Form

Countermeasures

Countermeasures Considered1	Cost1	\$0.00
Countermeasures Considered2	Cost2	\$0.00
Countermeasures Considered3	Cost3	\$0.00

Countermeasures Recommended: Status:

Countermeasure Installed: None Date Installed:

Bridge Scheduled for Replacement Estimated Letting Date: 11/6/2012

Authorization

Author(s) of POA: Lallman Rambali Date Signed: 11/19/2007

Close Form



NYSDOT - Plan of Action Form

Closure Instructions

Criteria for Closure: Water Level is 5 foot below the Low Beam Elevation. Can be observed by a water gage marked on the north west corner of the north abutment

Authorization for Closure: Bridge Maintenance/Bridge Management Engineer

Detour Route: NY Route 438 East (12 miles) to US Route 62 South (0.7 Miles) to NY Route 39 West (

Criteria for Re-Opening:



Monitoring

Floodwatch & Post Flood Program

-- *What bridges?*

- *All Scour Critical Bridges*
- *Bridges flagged by inspectors for scour damage.*



HYDRAULIC VULNERABILITY ASSESSMENT

4. Plan of Action:

- *Monitoring -- Flood Watch*
- *-- Post Flood Inspection*
- *-- Scour Monitors*

Monitoring

Floodwatch & Post Flood Program

-- *When?*

- *During Flood Warning issued by the National Weather Service (NWS).*
- *During Flash Flood Warnings????*
- *Reports of flooding from local residents and/or maintenance crew.*

Plan of Action

Monitoring: Floodwatch Post Flood Inspections

- *What ?*
- *When ?*
- *Who ?*
- *Where ?*
- *How ?*

Monitoring

Floodwatch Program - How?

- **Continual Monitoring**
 - **High Risk bridges: Potential to have a sudden or catastrophic collapse.**



Monitoring

Floodwatch & Post Flood Program

-- Who?

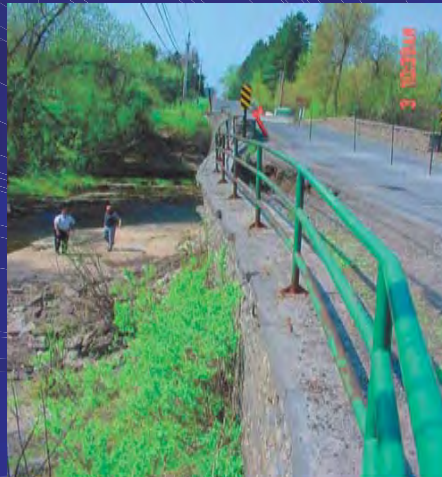
- ...determines what bridges are on the Flood Watch Program?
- ...receives notification of Flood Warnings?
- ...carries out the Flood Watch?
- ...carries out Post Flood Inspections?
- ...reopens a bridge after it was closed as a result of Flood Watch?

- **Responsibilities are outlined in the NYSDOT BFWAP**

Monitoring

Floodwatch Program - How?

- **Periodic Monitoring:**
 - **Non-High Risk bridges: Bridges that will undergo structural damage/partial collapse as a result of substructure movement.**



Monitoring

Floodwatch Program - Where?

- **GIS database of Scour Critical bridges**
- **Track storms using satellite imagery**
 - **Internet**



Scour Countermeasure Design

- Identify the causes of the Vulnerability Deficiencies
- Determine the proper countermeasure that addresses these deficiencies
- Prepare a properly designed countermeasure

Scour Countermeasure Design

Design of Scour Countermeasure on Existing Structures

- **Identify the cause(s) of the Stream Instability at the Bridge**
 - *Is it Local Scour?*
 - *Is it Contraction Scour?*
 - *Is it Long Term Degradation?*
 - *Is it cause by lateral shifting/migration of the channel?*
 - *Is the Instability cause by two or more of the above?*

Scour Critical Bridges

- There are over 20,000 Bridges in the US that are considered SCOUR CRITICAL
- There approximately 1000 Bridges in NY that are assessed as SCOUR CRITICAL:
 - 200 – State Bridges
 - 800 – Locally Owned Bridges
- All Scour Critical Bridges require a POA

Design of Scour Countermeasure

• **Instability -- Contraction Scour**

- *Add Relief Structures in the floodplain*
- *Allow overtopping of the approaches*
- *Armored entire channel under bridge*

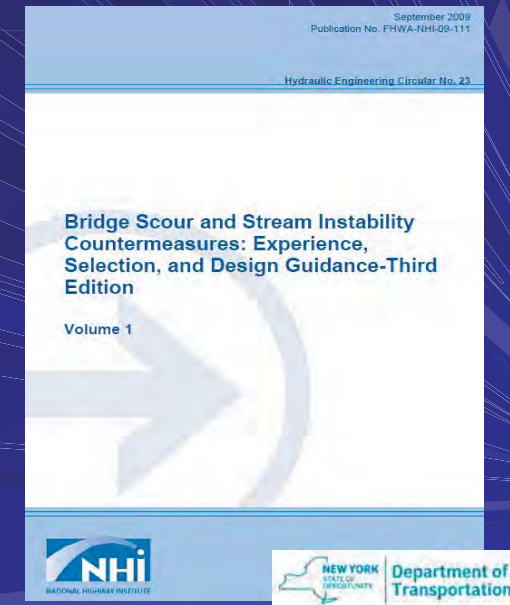
- **Riprap**
- **Gabions**
- **Concrete with Cutoff wall**
- **Articulated Concrete Mat**
- **Jack Fields**



Design Guidelines for Scour Countermeasures

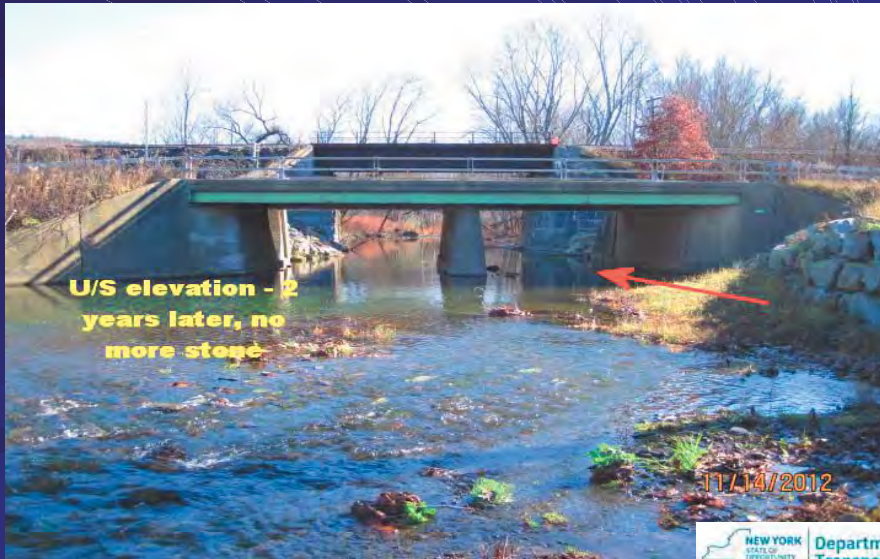
■ **FHWA HEC 23** **Bridge Scour and Stream Instability Countermeasures**

Volume 1 & 2



Design of Scour Countermeasure

• **Instability -- Contraction Scour**



Design of Scour Countermeasure

• **Instability -- Local Scour**

- **Riprap**
- **Jack Field**
- **Articulated Concrete Mat**
- **Guide Banks**
- **Gabions**



Design of Scour Countermeasure

- **Instability – Long Term Degradation**



5.14.2003 12:51

Rte. 36 / Rock Spring Creek
Inspection photo, 5/2003



Rte. 36 / Rock Spring Creek
9/2003 --- Note: Spread Footings on earth



5.14.2003 12:53

Rte. 36 / Rock Spring Creek
Inspection photo 5/2003 Looking
Downstream

Check Dams & Profile Retainers

HEC-23 DG 11

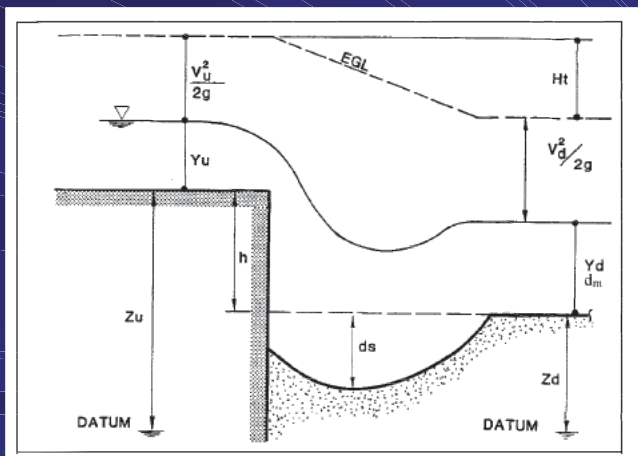
- Vertical control measure
- Purpose: arrest head cut and maintain stable stream bed elevation at bridge
- Rock riprap, sheet pile, timber, concrete
- Sediment infilling can raise the bed elevation upstream
- Energy dissipation and turbulence can cause bed erosion, and lateral bank erosion downstream



Rte. 36 / Rock Spring Creek Repairs 11/03
Grout under footings, grout-filled bags and heavy stone to fill

Check Dams

- Need to design for downstream scour hole



Rte. 36 / Rock Spring Creek Repairs 11/03
Re-built stone channel downstream to re-establish profile

Design of Scour Countermeasure

Bendway Weirs

HEC-23 DG 1

- For bank protection and lateral stability
- Re-direct flow perpendicular to weir axis, towards center of channel
- Submerged at most flows
- Sediment deposition between weirs
- Stone fill construction
- Not for degrading or sediment deficient reaches

Design of Scour Countermeasure

• Instability – Long Term Degradation

➤ Install Streambed Grade Stability Structure

➤ Sheetpile Check Dams

➤ Stone Check Dam

➤ Gabion Check dam

➤ Rock Riffle

– Consider more environmentally friendly



Design of Scour Countermeasure

Bendway Weirs vs. Rock Vanes

- Bendway Weirs suitable for channels with very wide flood plains
- Rock Vanes suitable for narrow channels with very small flood plains. Best suited for somewhat incised channels
- “Armored Scour Pools” install at the tip of Vanes/Weirs to protect from Local Scour
- Where the length of the channel is significantly shorten, “Rock Riffles” are installed to account for change in stream power. Armored scour pool install at the end of the riffle to protect it from local scour/head cut.

Design of Scour Countermeasure

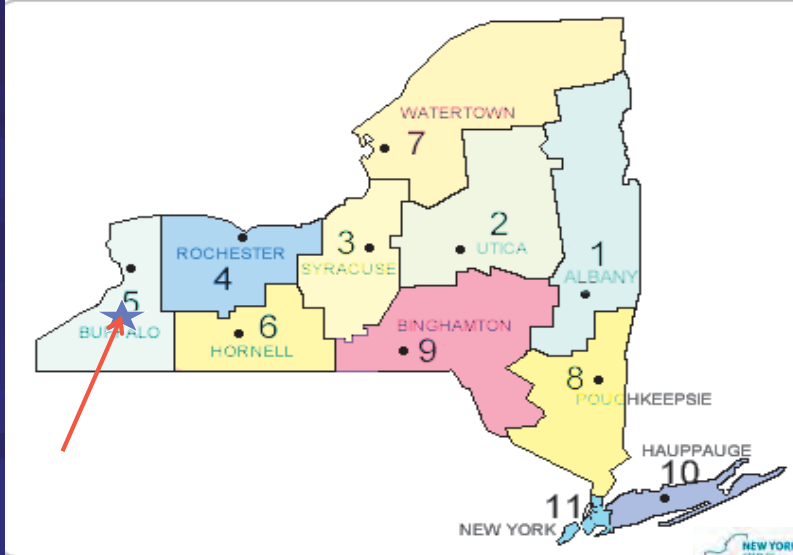
• Lateral Instability

Meandering streams affect bridge structures by:

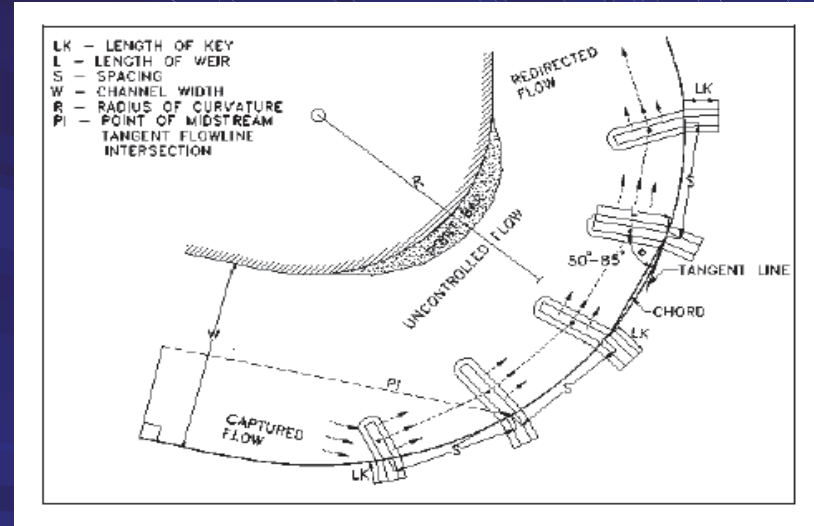
- *Changing the flow angle of attack on a pier or abutment during the design life of the bridge.*
- *Lateral shifting of the stream banks that could impact the approaches of the structure*
- *Both of the above could occur at the same time*

Design of Scour Countermeasure

- Instability – Rt16 over Cattaraugus Creek



Bendway Weirs



Typical plan

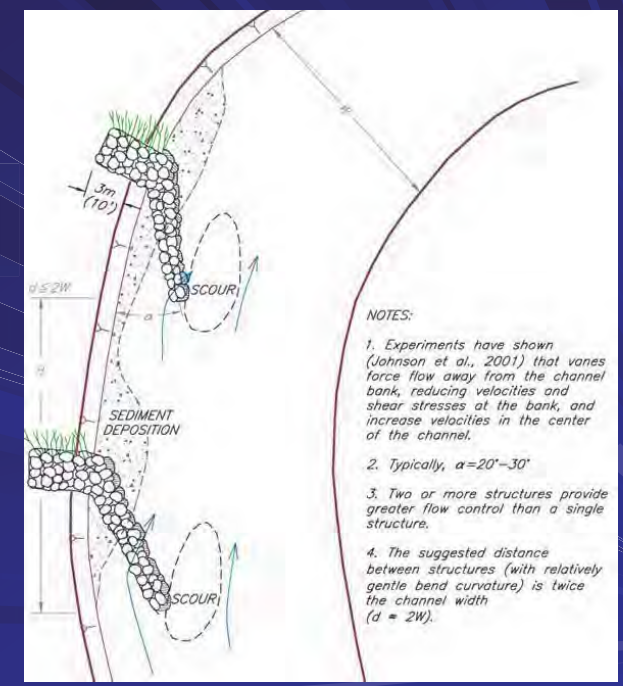
Design of Scour Countermeasure

- Instability – Lateral Channel Shifting



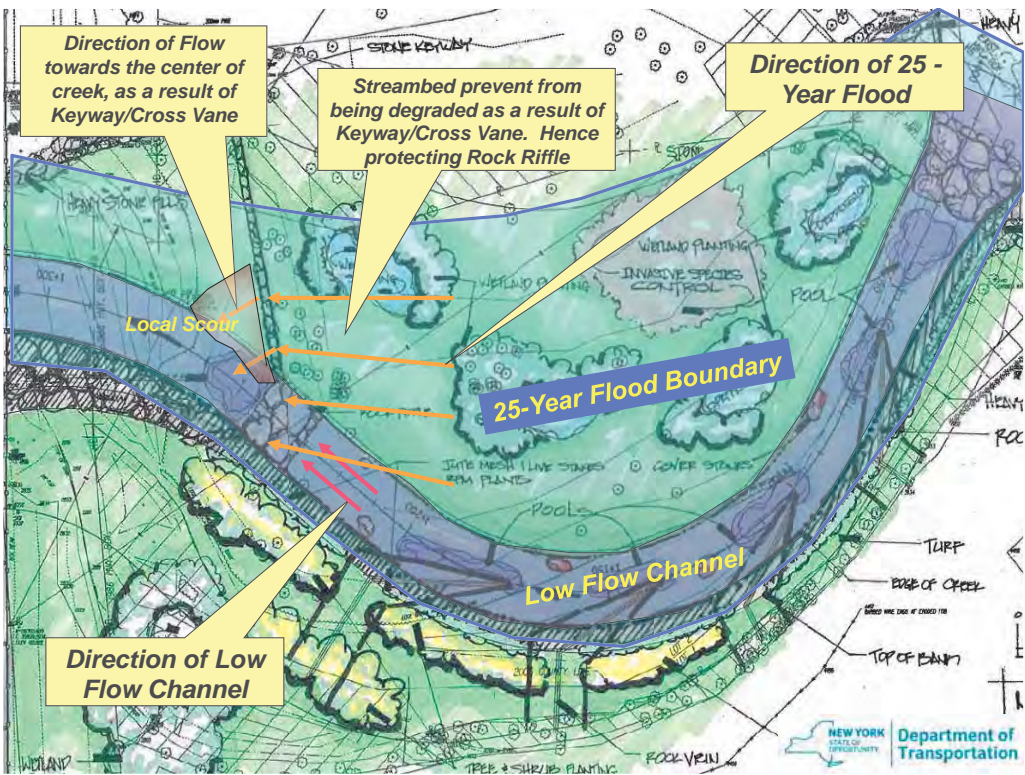
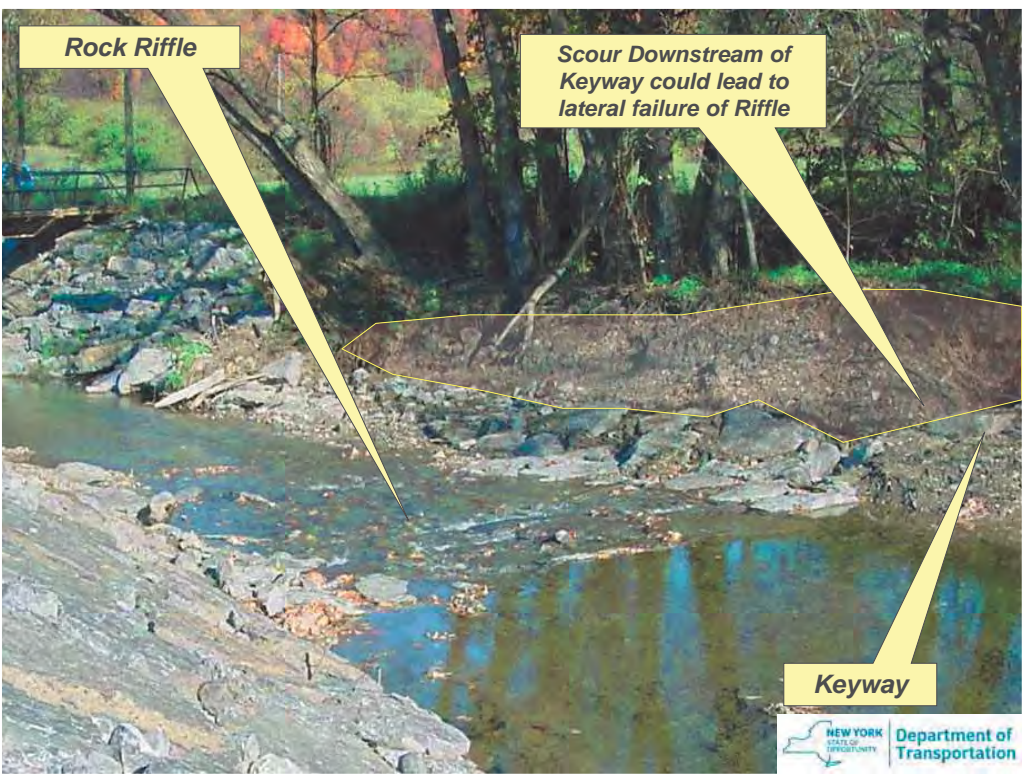
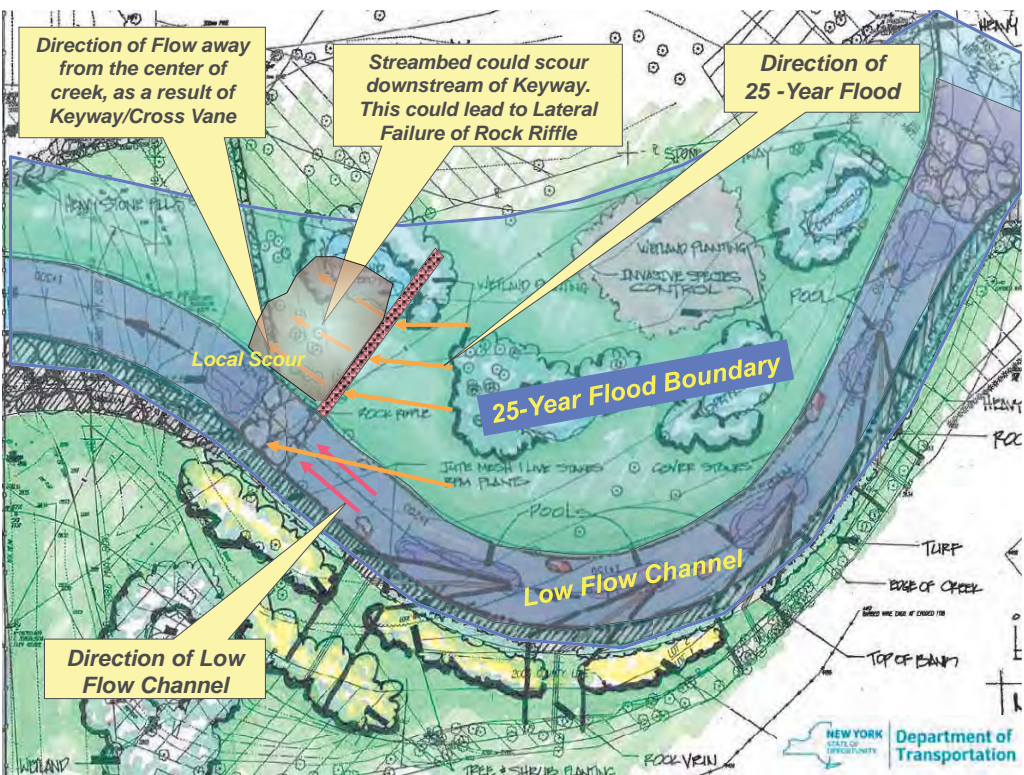
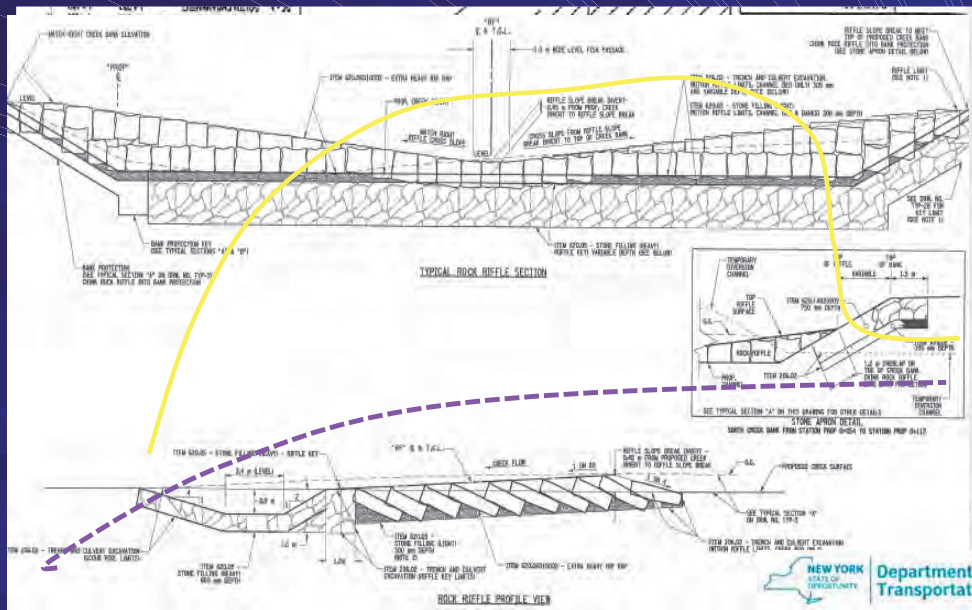
Install River Training Structures

Rock Vanes



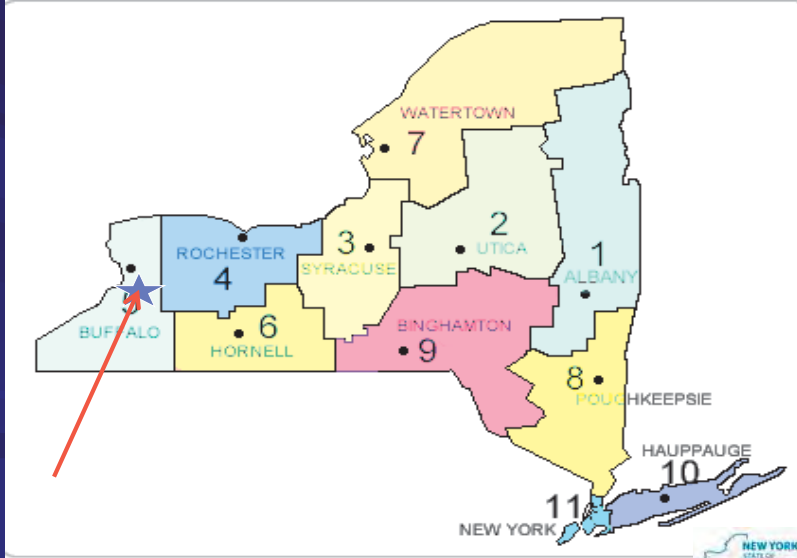
Design of Scour Countermeasure

- **Instability – Lateral Channel Shifting**



Design of Scour Countermeasure

• Instability – Rt16 over Cattaraugus Creek



Design of Scour Countermeasure

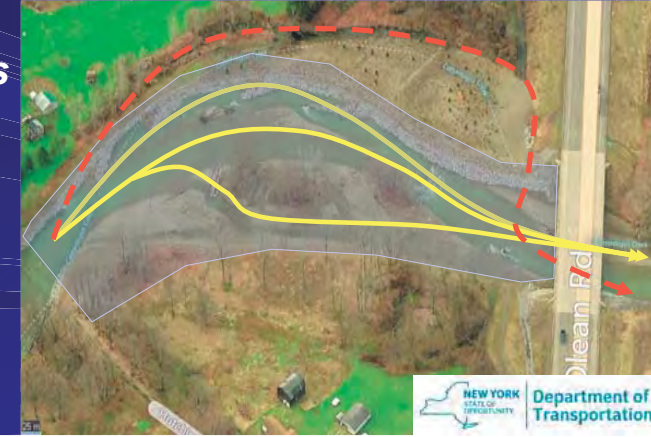
• Instability – Lateral Channel Shifting

➤ Install River Training Structures

➤ Spur Dikes

➤ Rock Vanes

➤ Bendway Weirs



HVA Review – 2004 Inspection

Spread footing on earth & Footing undermined

FHWA 113 Code 2



Design of Scour Countermeasure

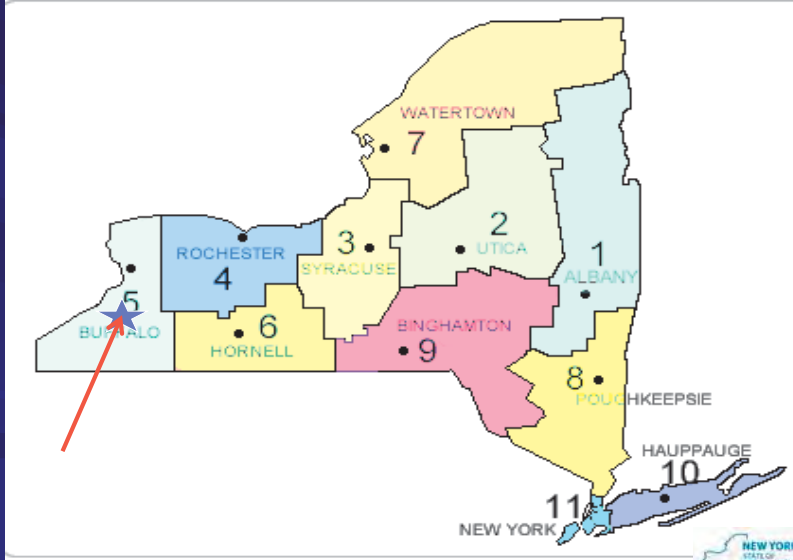
• Instability – Lateral Channel Shifting



08/13/2015 12:53

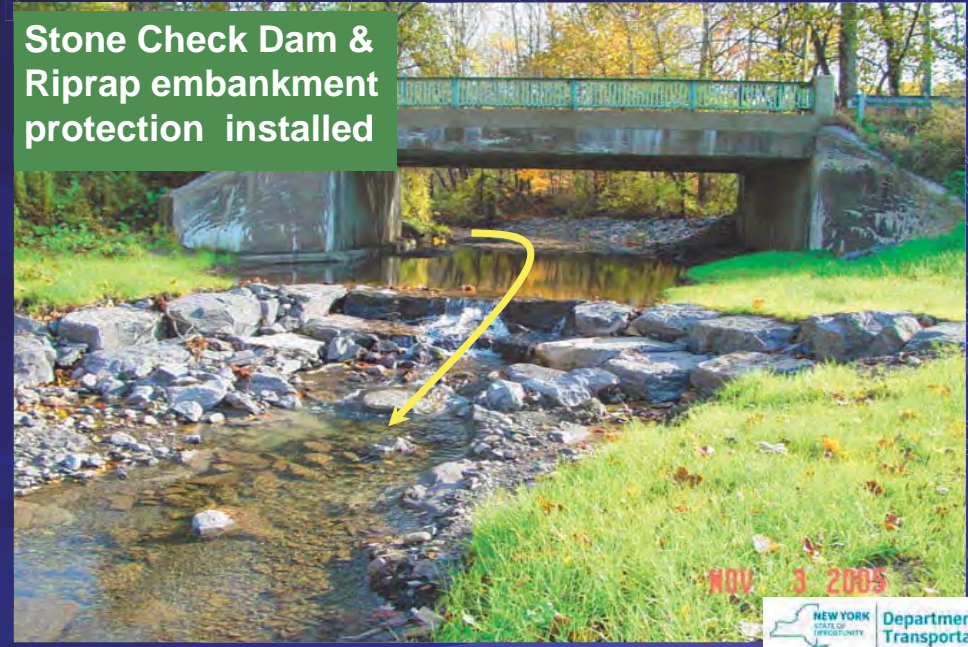
Design of Scour Countermeasure

• **Instability – Rt 240 over Cazenovia Creek**



HVA Review – 2005 Scour Retrofit

Stone Check Dam & Riprap embankment protection installed



HVA Review Case Study

2004 Inspection

FHWA 113 Code – 3
Foundation is unstable for the assessed Scour depth – (Short Timber Piles)

Yellow Flag issued for undermining of End Abutment and Wingwall

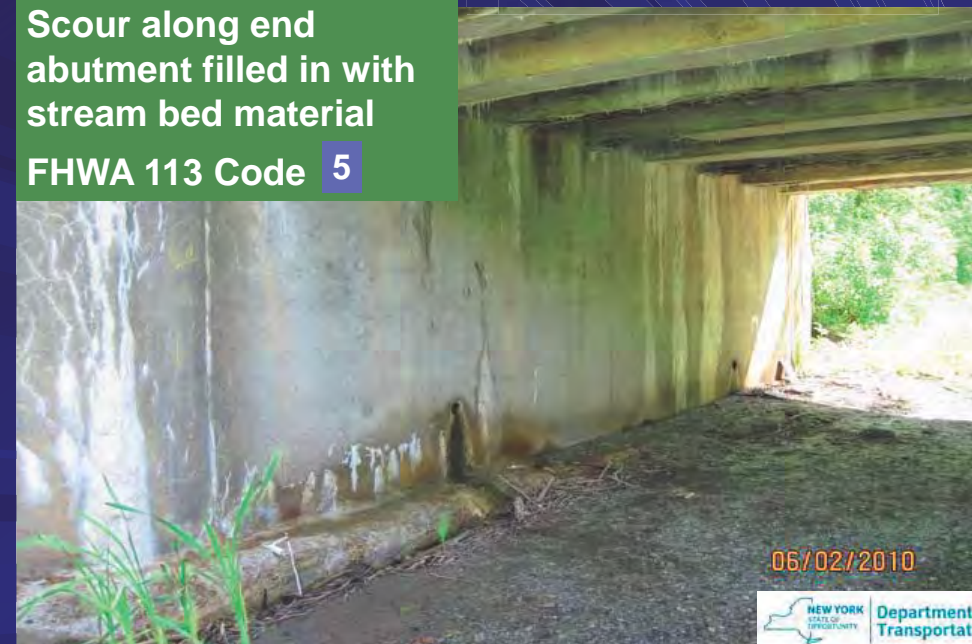
FHWA 113 Code – 2



HVA Review – 2010 Inspection

Scour along end abutment filled in with stream bed material

FHWA 113 Code 5



Hydraulic Vulnerability Re-Assessment

HVA Re-assessment is carried out based on information obtained through the Biannual Bridge Inspection Process

Items Rated during Inspection

- **800 Scour**
 - Wingwalls
 - Abutments, Piers
- **801 Stream Hydraulics**
 - Channel Alignment
 - Channel Scour
 - Bank Protection
 - Bank Erosion
 - Debris Near Bridge
 - Countermeasure Installed
 - Waterway Opening



HVA Review Case Study

2006 Inspection

FHWA 113 Code – 2
Scour countermeasure installed to correct scour deficiencies

- Riprap Bank Protection
- Stone Check Dam

Yellow Flag Removed for the undermining of End Abutment and Wingwall

FHWA 113 Code – 2



Element 800 – SCOUR

This element is used to evaluate the loss of the material next to, and under a substructure (Unit = ft)

Condition	Condition State 1	Condition State 2	Condition State 3	Condition State 4
	GOOD	FAIR	POOR	SEVERE
Scour (6000)	None	Exists within tolerable limits or has been arrested with effective countermeasures.	Exists that exceeds tolerable limits but is less than the critical limits determined by scour evaluation but does not warrant structural review.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or bridge; OR a structural review has been completed and the defects impact strength or serviceability of the element or bridge.

HVA Review Case Study

2012 Inspection

FHWA 113 Code – 2
Foundation is unstable for the assessed Scour depth – (Short Timber Piles)

Stone fill placed in Scour Hole to address an existing scour problem

FHWA 113 Code – 5



Element 800 – SCOUR



Element 801 – STREAM HYDRAULICS

This element is used to evaluate the condition of stream hydrology & hydraulics and countermeasures condition.

Unit = Each (Single Rating)

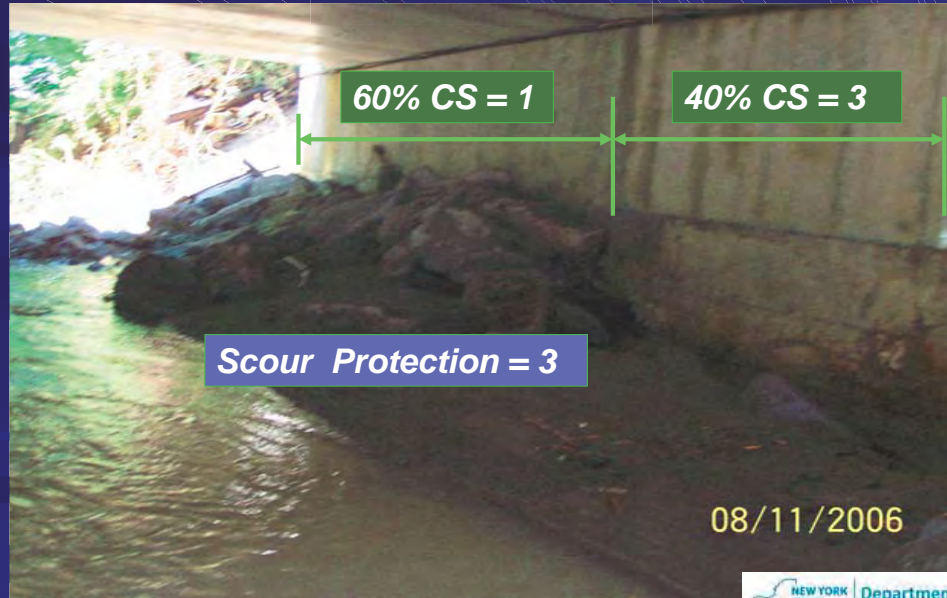
Element 800 – SCOUR



Element 801 – STREAM HYDRAULICS (Unit = Each)

Condition State Definitions				
Condition	Condition State 1 GOOD	Condition State 2 FAIR	Condition State 3 POOR	Condition State 4 SEVERE
Channel Alignment (6120)	Water approaches bridge, generally perpendicular.	Minor alignment issues, but flow generally unimpeded.	Flow directed toward Substructure elements.	This condition warrants a detailed review by the Hydraulics Engineer, to determine the effects and serviceability of hydraulic conditions near and through the bridge. The condition of the defect is deemed worse than what is described under Condition State 3. An HVA request form should be completed.
Channel Scour (6130)	Channel bottom stable. Little change in drop line readings over time.	Drop lines have displayed minor fluctuations over time.	Drop lines have displayed significant fluctuations over time.	
Waterway Opening (6140)	Plenty of room for high water to pass through structure.	Horizontal opening is somewhat restricted, but adequate.	Vertical opening restricted. Minor impacts to superstructure.	
Scour Protection (6150)	Present and in good condition.	Minor displacement or damage to protection, but still adequate.	Significant washing away or displacement of scour protection material.	
Bank Protection (6160)	Bank protection in like-new condition.	Minor displacement in bank protection material.	Significant washing away or displacement of bank protection material.	
Bank Erosion (6165)	None present within 250'.	Minor erosion within 250'	Banks near structure show significant erosion.	
Debris Near Bridge (6180)	Channel clear of gravel build-up or woody debris within 250'.	Vegetation overhanging channel, small gravel bars present.	Large gravel bars or choked woody debris is starting to restrict or redirect flow.	
Grade Control / Countermeasures (6190)	In like-new condition.	Minor displacement at grade control, rock or cross vane material – still functions well.	Significant displacement of Countermeasure material. Flanking appears possible.	

Element 800 & 801 – Scour and Stream Hydraulics



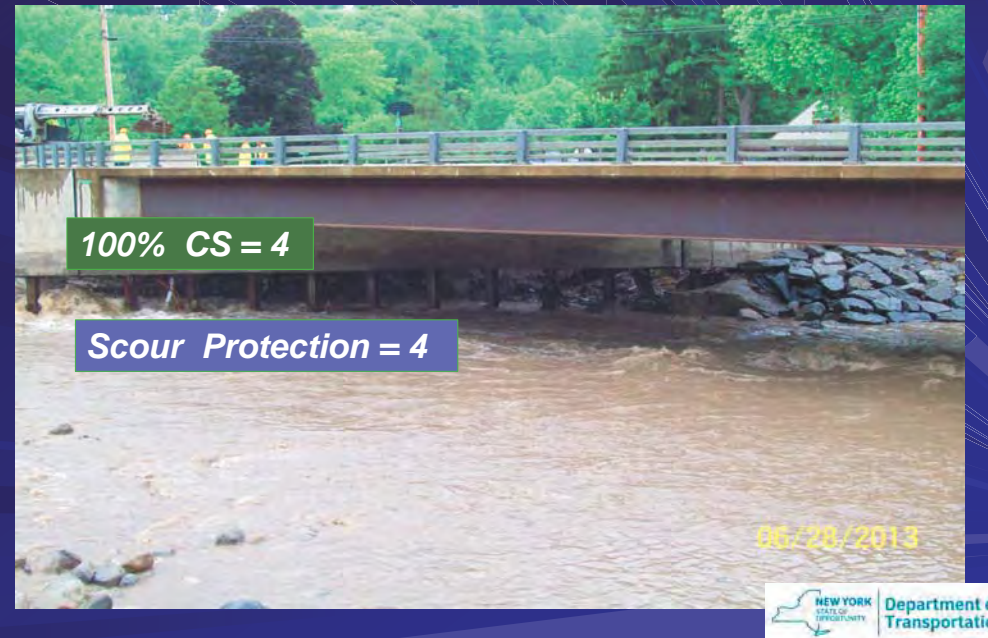
Element 800 – SCOUR



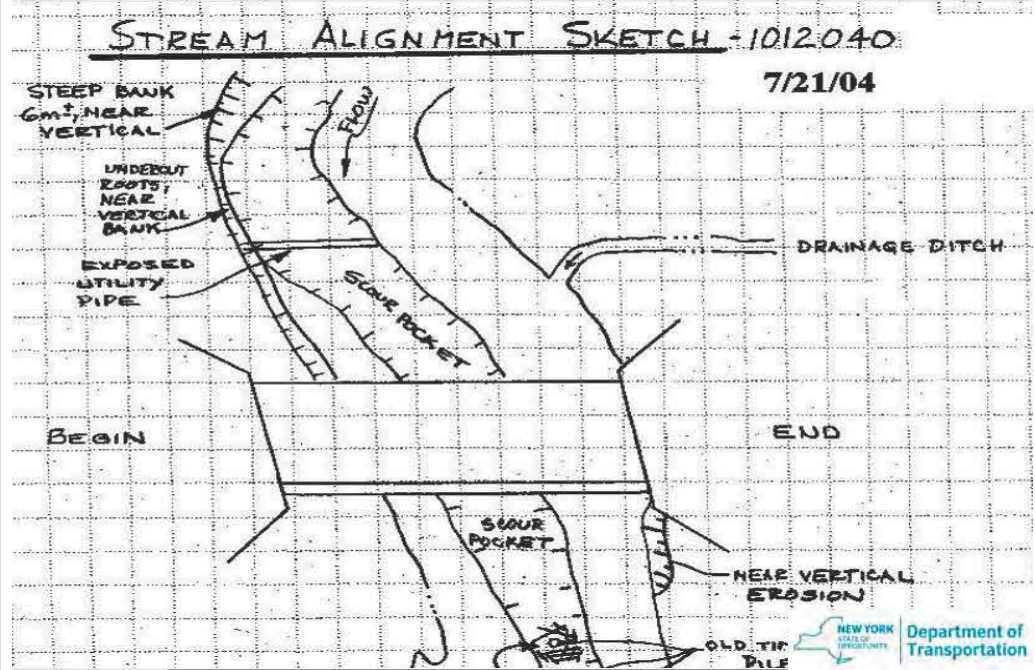
Element 800 – SCOUR



Element 800 – SCOUR



Element 801 – STREAM HYDRAULICS



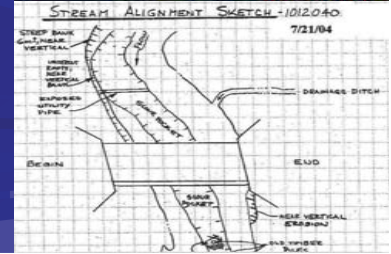
When Should an HVA Re-Assessment be completed??

- There is a New Bridge – May not always cause a change in FHWA 113 Scour Critical Code
- Any condition at the structure that may cause a change in the FHWA 113 Scour Critical Code
- Any Scour Item (800) rated 3 or 4 for more than 20% of the substructure
- Any Stream Channel Item (801) rated 4.
- If there is a change in condition state of any of the Scour (800) and/or Stream Hydraulics (801) or combination of items by ± 4 .



Element 801 – STREAM HYDRAULICS

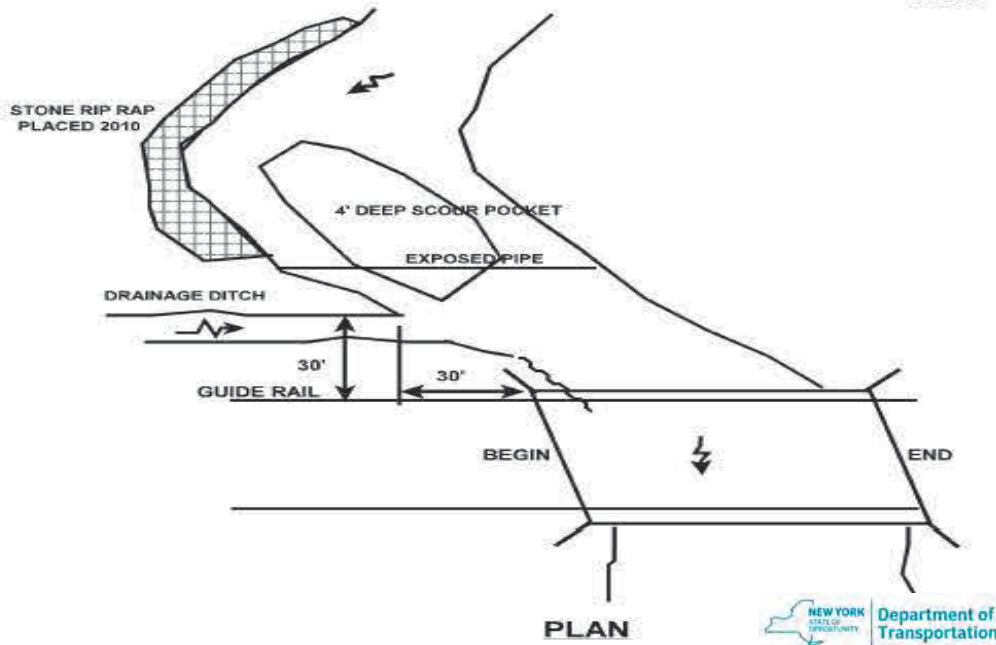
- Stream Alignment -- **2**
- Channel Scour -- **1**
- Waterway Opening -- **1**
- Scour Protection --
- Bank Protection --
- Bank Erosion -- **1**
- Debris Near Bridge -- **1**
- Countermeasure --



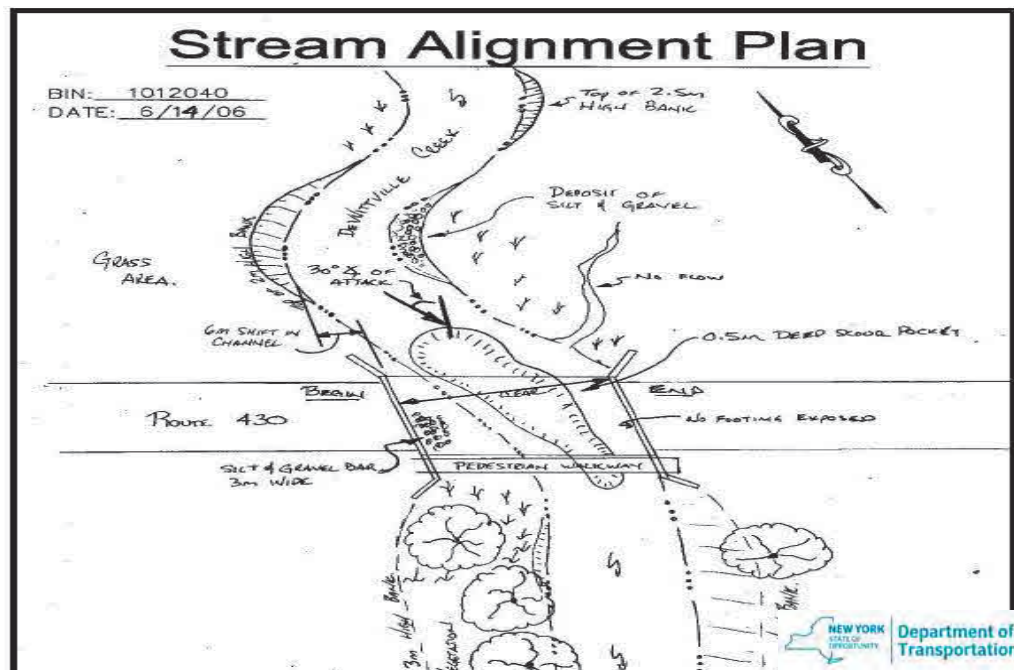
HVA REVIEW FORM

ELEMENT	DEFECT	Initial Assessed	Previous Inspection	Current Inspection	HVA REQUIRED (?)		
		5/13/2002	6/15/2012	8/4/2014			
1	800	6000	Substructure Scour <i>(Report worst CS when more than 10% of substructure has CS 3 and 4)</i>	1	1	1	
2	801	6120	Channel Alignment	2	3	4	YES
		6130	Channel Scour	1	1	1	
		6140	Waterway Opening	1	1	1	
		6150	Scour Protection				
		6160	Bank Protection		1	2	
		6165	Bank Erosion	1	1	2	
		6180	Debris Near Bridge	1	1	1	
		6190	Countermeasures				
Sum of Change(s) of (-/+ 4) in 800 and/or 801 Elements							YES
3	Is recent stream work evident or have scour countermeasure been installed?			NO			
4	Is there any reason the current FHWA 113 Code should be changed?			NO			
5	Has a hydraulic-related flag(s) been issued or removed?			NO			

Element 801 – STREAM HYDRAULICS

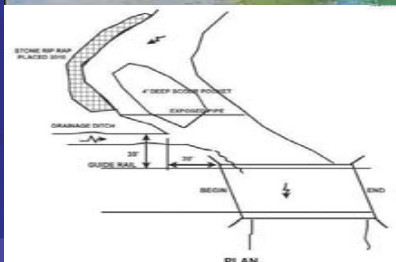


Element 801 – STREAM HYDRAULICS



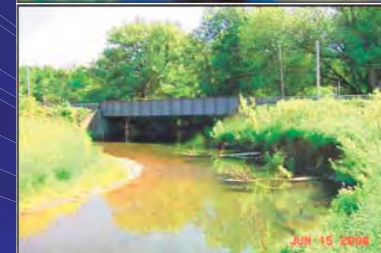
Element 801 – STREAM HYDRAULICS

Stream Alignment	--	3
Channel Scour	--	1
Waterway Opening	--	2
Scour Protection	--	0
Bank Protection	--	1
Bank Erosion	--	1
Debris Near Bridge	--	1
Countermeasure	--	0



Element 801 – STREAM HYDRAULICS

Stream Alignment	--	4
Channel Scour	--	1
Waterway Opening	--	2
Scour Protection	--	0
Bank Protection	--	0
Bank Erosion	--	4
Debris Near Bridge	--	1
Countermeasure	--	0



Element 801 – STREAM HYDRAULICS

- Stream Alignment -- **4**
- Channel Scour -- **1**
- Waterway Opening -- **2**
- Scour Protection -- **0**
- Bank Protection -- **2**
- Bank Erosion -- **4**
- Debris Near Bridge -- **2**
- Countermeasure -- **0**



HVA REVIEW FORM

	ELEMENT	DEFECT	CONDITION STATES (CS)			HVA REQUIRED (?)
			Initial Assessed 7/21/2004	Previous Inspection 6/14/2006	Current Inspection 7/6/2011	
1	800	6000 Substructure Scour <i>(Report worst CS when more than 10% of substructure has CS 3 and 4)</i>	2	2	2	
2	801	6120 Channel Alignment	2	4	3	
		6130 Channel Scour	1	1	1	
		6140 Waterway Opening	1	2	2	
		6150 Scour Protection				
		6160 Bank Protection			1	
		6165 Bank Erosion	1	3	1	
		6180 Debris Near Bridge	1	1	1	
		6190 Countermeasures				
Sum of Change(s) of (-/+ 4) in 800 and/or 801 Elements						YES
3	Is recent stream work evident or have scour countermeasure been installed?		YES			YES
4	Is there any reason the current FHWA 113 Code should be changed?		NO			
5	Has a hydraulic-related flag(s) been issued or removed?		NO			

Inspector's Comment: Stone protection placed along end right (upstream right) eroded channel bank.

Regional Hydraulics Engineer's Comment: HVA was updated based on the stream alignment and new bank protection placed along the end right (upstream right) channel embankment.

HVA REVIEW FORM

	ELEMENT	DEFECT	CONDITION STATES (CS)			HVA REQUIRED (?)
			Initial Assessed 7/21/2004	Previous Inspection 6/14/2011	Current Inspection 7/6/2014	
1	800	6000 Substructure Scour <i>(Report worst CS when more than 10% of substructure has CS 3 and 4)</i>	2	2	2	
2	801	6120 Channel Alignment	2	3	4	YES
		6130 Channel Scour	1	1	1	
		6140 Waterway Opening	1	2	2	
		6150 Scour Protection				
		6160 Bank Protection	1	1	2	
		6165 Bank Erosion	1	1	4	YES
		6180 Debris Near Bridge	1	1	2	
		6190 Countermeasures				
Sum of Change(s) of (-/+ 4) in 800 and/or 801 Elements						YES
3	Is recent stream work evident or have scour countermeasure been installed?		NO			
4	Is there any reason the current FHWA 113 Code should be changed?		NO			
5	Has a hydraulic-related flag(s) been issued or removed?		NO			

Inspector's Comment: Stone protection placed along end right (upstream right) eroded channel bank in 2011 show sign of failing and the stream alignment has caused erosion along the end approach embankment

Regional Hydraulics Engineer's Comment: HVA was updated based on the stream alignment that is now causing erosion along the end approach embankment and the failing bank protection along the end right (upstream right) channel embankment.

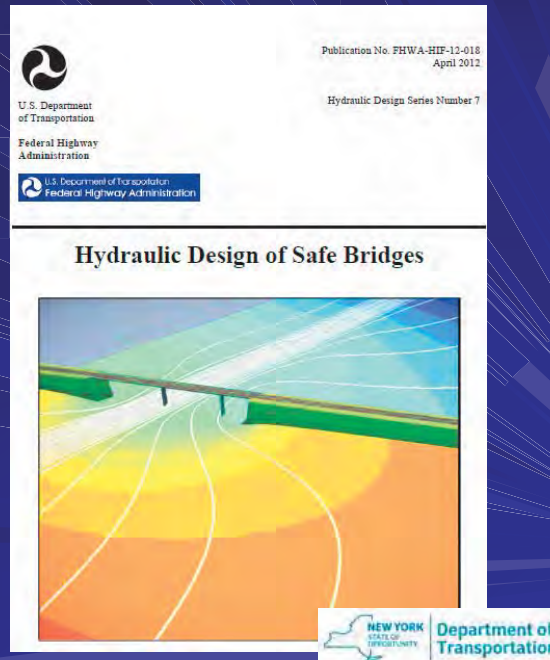
Element 801 – STREAM HYDRAULICS



08/04/2014

HVA - References

FHWA HDS 7 Hydraulic Design of Safe Bridges



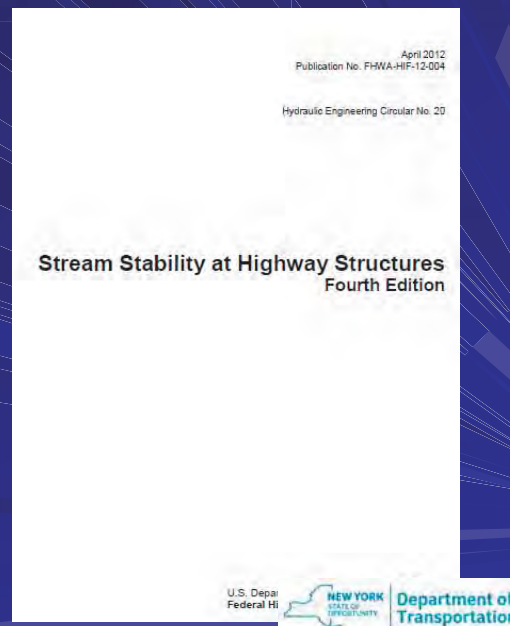
HYDRAULIC VULNERABILITY ASSESSMENT

- **Schoharie Bridge Failure – 1987**
- **FHWA Technical Advisory T 5140.20 (1988)**
- **NYSDOT Bridge Flood Warning Action Plan (1989)**
- **FHWA Technical Advisory T 5140.23 (1991)**
- **NYSDOT HVA Manual (1991)**
- **HVA Completed on all NYSDOT Bridges (1996)**
- **FHWA 113 Scour Critical Codes
Plan of Action for Scour Critical Bridges
(2005)**
- **HVA's Reassessment**



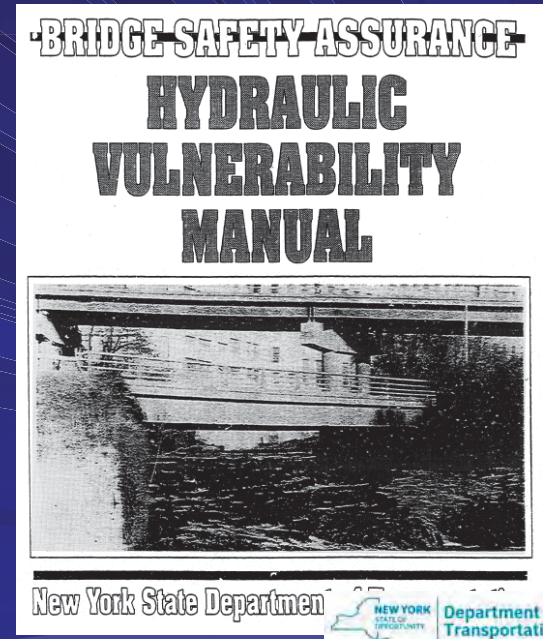
HVA - References

FHWA HEC 20 Stream Stability at Highway Structures



HVA - References

NYSDOT Hydraulic Vulnerability Manual.



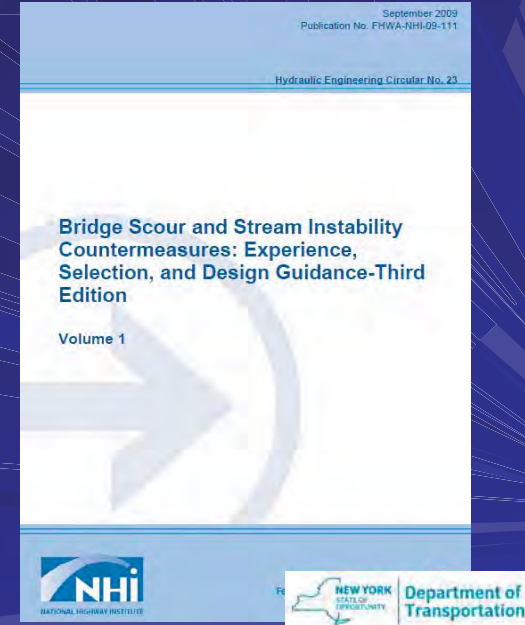
MAIN OBJECTIVE Public Safety



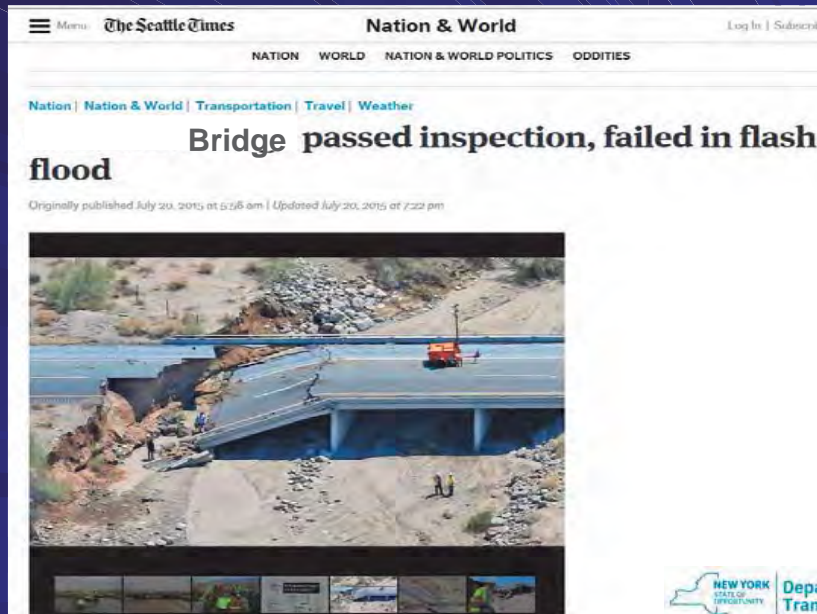
HVA - References

FHWA HEC 23 **Bridge Scour and** **Stream Instability** **Countermeasures**

Volume 1 & 2



MAIN OBJECTIVE Prevent these headlines



QUESTIONS ???

**NORTH CAROLINA
WAKE COUNTY**

MEMORANDUM OF AGREEMENT

BETWEEN

NORTH CAROLINA
DEPARTMENT OF
TRANSPORTATION

and

NORTH CAROLINA
FLOODPLAIN MAPPING
PROGRAM

This **MEMORANDUM OF AGREEMENT**, hereinafter referred to as the “MOA” or “Agreement,” made and entered into the 12th day of August, 2016, between the Department of Transportation, an agency of the State of North Carolina, hereinafter referred to as the “**Department**,” and the North Carolina Floodplain Mapping Program, an office within Emergency Management in the Department of Public Safety of the State of North Carolina, hereinafter referred to as the “**NCFMP**.”

WITNESSETH:

WHEREAS, in May 1977, the President of United States issued Executive Order 11988, in which it directed Federal Agencies to take certain steps to avoid adverse impacts associated with the occupancy and modification of floodplains; and,

WHEREAS, in 1982, the Federal Highway Administration (FHWA) entered a Memorandum of Understanding with Federal Emergency Management Agency (FEMA) entitled “Procedures for Coordinating Highway Encroachments on Floodplains with the Federal Emergency Management Agency (FEMA),” in which it provides guidance to highway design engineers in regard to complying with National Flood Insurance Program (NFIP) standards for Federal-aid highway actions involving regulatory floodways; and,

WHEREAS, in 1989, the North Carolina General Assembly created the North Carolina Highway Trust Fund for the construction and improvement of North Carolina roadways and bridges; and,

WHEREAS, in July 1990, the Governor of North Carolina issued State Executive Order 123, in which it directed the Department to work directly with the Federal Department of Transportation and FEMA to apply appropriate standards and management to comply with the Floodplain Management Policy relevant to highway construction within floodplains; and,

WHEREAS, in September 1992, the FHWA issued NS 23 CFR Part 650A, Transmittal 5, in which it provides highway design engineers with guidance regarding highway crossings that encroach on floodplains where a Detailed Study has been performed, but no regulatory floodway designated, resulting in an increase of no more than 1 foot in Base Flood Elevation (BFE); and,

WHEREAS, in September 2000, FEMA delegated the responsibility to the NCFMP in the Division of Emergency Management within the North Carolina Department of Public Safety to update and maintain the Special Flood Hazard Areas (SFHAs), Digital Flood Insurance Rate Maps (DFIRMs), and all the Letter of Map Changes (LOMCs) in North Carolina; and,

WHEREAS, on August 17, 2006, the FHWA Resource Center and North Carolina Division, the FEMA Region IV, the NCDOT Hydraulics Unit and the NCFMP staff met in Raleigh, North Carolina to discuss the compliance requirements for the NFIP; and,

WHEREAS, both the Department and the NCFMP recognize the need to function as a cooperative team in order to effectively deliver the Department's multi-modal transportation programs that include road, bridge and culvert construction or repair, maintenance facilities, ferry facilities, greenways, railroad, etc.; and,

WHEREAS, the Department and the NCFMP mutually agree this Agreement allows for efficient use of both agencies' resources and has been developed in a manner to streamline project reviews and construction schedules in a cost effective way; and,

WHEREAS, on June 8, 2008 the Department and the NCFMP signed, and later modified on March 18, 2009, this Agreement to satisfy the NFIP requirements and to keep the NCFMP's DFIRMs current in regards to the Department's projects; and,

WHEREAS, in November 2011, the FHWA issued to the Department a review report entitled "Process Review of the Hydraulics Program of the North Carolina Department of Transportation," in which it expressed concern over the Non-Encroachment Areas being treated as floodways by the NCFMP, which consequently results in the construction of longer bridges than necessary on Department projects across the state. It directed the Department to adhere to the FHWA's 23 CFR 650A guidelines and work with the NCFMP to resolve this issue; and,

WHEREAS, on April 22, 2013, the Department and the NCFMP modified this Agreement to address FHWA's comments listed above. Under the modified MOA the two agencies added MOA Types 2d and 2e for the BFE increases on the Limited Detailed Studied streams; and,

WHEREAS, on January 30, 2015, the President of the United States issued Executive Order 13690, establishing a Federal Flood Risk Management Standard and a Process for Further Soliciting and Considering Stakeholder Input, which amended Executive Order 11988, Floodplain Management, issued in 1977; and,

WHEREAS, on Feb 5, 2015, the Department and the NCFMP modified this Agreement to include the delegation of authority to the Department's State Hydraulics Engineer for approvals of MOA Types 1, 2a and 2d. MOA Type 2f was also added to this Agreement. Both agencies agree that this delegation further streamlines the MOA process while still ensuring appropriate reviews, and coordination continues to occur between the two agencies; and,

WHEREAS, the Department and NCFMP, in accordance with the provisions hereinafter set forth propose to modify this Agreement to include one modification of an existing process and two new processes that are necessary when:

- i. there exist alternative methods or applications that result in more scientifically or technically correct estimates of flood elevations regulated under the NFIP;
- ii. proposed conditions would result in an increase in the Base Flood Elevation that remains solely within the Department's Rights of Way;
- iii. the As-built survey deviates from the design reports and engineering models.

Both agencies agree these changes will further support continued compliance with FEMA's NFIP.

NOW, THEREFORE, the two agencies hereto, each in consideration of the promises and undertakings of the other, as herein provided, do hereby covenant and agree, each with the other, as follows:

1. The Department shall coordinate with, and provide the information to the NCFMP as follows:

Type 1 Provide design data and map updates to the NCFMP for projects that result in No-Rise, as defined in Exhibit A;

Type 2a Provide design data and map updates to the NCFMP for projects that result in Minor Impacts, as defined in Exhibit A;

Type 2b Provide design data and map updates to the NCFMP for projects that result in Measurable Impacts, as defined in Exhibit A;

Type 2c Provide design data and map updates to the NCFMP for projects that are in the FEMA flood study areas with missing or erroneous data, as defined in Exhibit A;

Type 2d Provide design data and map updates to the NCFMP for projects that result in an increase of greater than 0.1 foot, but less than 0.5 feet in the Base Flood Elevation (BFE), in a Limited Detailed Study stream, as defined in Exhibit A;

Type 2e Provide design data and map updates to the NCFMP for projects that result in an increase of 0.5 feet or greater, but no greater than one (1) foot in the BFE in a Limited Detailed Study stream, as defined in Exhibit A;

Type 2f Provide design data and map updates to the NCFMP for projects that result in an increase of greater than one (1) foot in the BFE in a Limited Detailed Study stream, provided the increase stays within the Department's rights of way and impact no private properties or buildings, as defined in Exhibit A;

Type 2g Provide design data and map updates to the NCFMP for projects that result in an increase in the BFE in a Detailed Study stream, provided the BFE increase and floodway modifications stay within the Department's Rights of Way and impact no private properties or buildings, as defined in Exhibit A;

Type 3a Provide the As-built plans to the NCFMP, as a requirement for Department's prior Conditional Letter of Map Revision (CLOMR) approvals after the projects are completed. These apply only to FEMA's Flood Insurance Study

(FIS) and flood maps, which remain unchanged since the issuance of CLOMRs, as defined in Exhibit A;

Type 3b Provide the As-built plans to the NCFMP, as a requirement for Department's prior CLOMR approvals after the projects are completed. These apply to FEMA's FIS and flood maps, which have been restudied and/or updated since the issuance of CLOMRs, as defined in Exhibit A.

Type 3c Conduct pre-application consultation with the NCFMP on projects that require CLOMR approval or alternative hydrologic and hydraulic engineering methods prior to their submittals. The consultation may include, but is not limited to, guidance on hydrology, data sources, hydraulic modeling/design issues, encroachment widths, and mitigation.

Type 4a Provide the As-built plans, revised design reports and flood models to the NCFMP for the projects that were not constructed in accordance with the design, which may result in a BFE and MOA type changes and LOMR, as defined in Exhibit A.

2. Exhibit A denotes the criteria and associated process fees for the twelve (12) MOA types previously listed.
3. Exhibit B denotes the submittal contents and schedule of the MOA deliverables to the NCFMP. It should be noted that NFIP compliance requires certified As-built plans to be submitted within 180 days (six months) of completion of construction. This applies to all MOA types listed in Exhibit A.
4. The Department and the NCFMP shall share design and survey data, including hydrologic and hydraulic designs and engineering models. The Department shall provide to the NCFMP, at no cost, the hydrologic and hydraulic design reports for the bridges and culverts across the state, prior to the commencement of construction, as well as the as-built plans, after the construction. The NCFMP shall provide the Department, at no cost, the FIS flood data and hydraulic models.
5. The NCFMP representatives shall meet at least once per month with the Hydraulics Unit staff to review the eligibility and schedule of candidate MOA and CLOMR projects. Under no circumstance may the Department's contract consultants directly contact the NCFMP staff for meetings or consultation. Instead, their requests shall go through the Hydraulics Unit staff. The review may include the following: hydrologic and hydraulic modeling issues, training needs, emergency repairs, consultation on CLOMRs, etc. It is the Department's responsibility to make the MOA submittals to the NCFMP in a timely manner to avoid delay of project construction.
6. The NCFMP Director shall meet once per month with the State Hydraulics Engineer to review this program to ensure its full compliance with the Federal regulations and the FHWA's guidance, to resolve issues of dispute, and to review/approve recommendations for improvement. The fee schedule may be reviewed and adjusted when the NCFMP Director deems it necessary.

7. The Department's personnel shall consult with the Hydraulics Unit staff to assess the need for a review by the NCFMP for maintenance or construction activities that may have the potential to result in flooding. Examples are pipe replacement/enhancement, temporary encroachment in the floodway, etc. Upon request, the NCFMP shall meet within four (4) weeks with the Department and develop action plans consistent with FEMA's NFIP goals and objectives.
8. For emergency repairs, the State Hydraulics Engineer may request ad hoc meetings with the NCFMP representatives to review and develop action plans. Upon concurrence from the NCFMP, the Department may proceed with the emergency repairs and prepare the design data and documents after the repairs are implemented.
9. Upon request, the NCFMP may assist the Department with internal review and approvals for the MOA Types 1, 2a and 2d projects. The responsibility for these approvals has been delegated to the Department's State Hydraulics Engineer.
10. The NCFMP shall conduct a semi-annual audit on those projects to ensure Department's full compliance with the Federal and State rules and regulations. The results of audits shall be shared with the Department for further process improvement. At the May and November Department / NCFMP Coordination Meetings, the Department shall provide a listing of MOA projects reviewed by the Department's in-house staff and contract consultants. NCFMP shall review at least 10% of the projects and provide the audit results at the following Coordination Meeting.
11. The NCFMP shall provide to the Department training as needed on the NFIP compliance requirements including checklists, hydrologic and hydraulic modeling, Community Floodplain Manager Certification, training for the Department's Operations forces, etc. The Department will reimburse the NCFMP for training and other associated cost.
12. With the assistance of NCFMP staff, the Department shall provide annual NFIP awareness training for all of the Department's personnel and contractors involved in design, construction, and maintenance activities. This training shall cover general flooding-related issues, appropriate coordination with FEMA and/or NCFMP on issues of compliance, mitigation, etc.
13. The Department and the NCFMP understand and agree that proper administration of this MOA ensures that the Department is consistent with FEMA's NFIP Regulations as well as FHWA's guidance of NS 23 CFR Part 650A.
14. Projects that result in an increase in the Base Flood Elevation (BFE) of 1 foot or less in a Limited Detailed Study stream shall be processed through this MOA, provided they do not adversely impact properties or buildings, and are approved by the State Hydraulics Engineer.
15. Projects that result in an increase in the BFE in the Detailed or Redelineated Detailed Flood studies shall follow the NFIP Regulations and this MOA to obtain approval prior to project construction.

16. The NCFMP shall invoice the Department monthly for the approved projects. The Department shall pay within 30 days after receipt of the invoice. The NCFMP shall be responsible for maintaining appropriate records in accordance with State accounting procedures and regulations.
17. All design and modeling work shall be performed in accordance with Federal regulations, policies and guidelines, as well as the Department's *Guidelines for Drainage Studies and Hydraulic Design*. All reviews and approvals of the hydraulic design reports and engineering flood models shall be performed by Professional Engineers registered in the State of North Carolina.
18. This Agreement shall remain in effect from the date of execution of this Agreement unless cancelled in writing as provided below. It is anticipated that this Agreement may be reviewed annually, or at a time mutually agreed upon by both parties. In the event either party to this Agreement should choose to terminate this Agreement, written notification must be given to the Director of the NCFMP and the Chief Engineer of the Department ninety (90) days prior to withdrawal.

IN WITNESS WHEREOF, this MOA has been executed, in duplicate, the day and year heretofore set out, on the part of the Department and the NCFMP by authority duly given.

**NORTH CAROLINA DEPARTMENT OF
PUBLIC SAFETY – EMERGENCY
MANAGEMENT – FLOODPLAIN MAPPING
PROGRAM**

ATTEST:

BY: *A. W. R.*

TITLE: Chief of Geospatial Survey

DATE: 8-10-16

BY: *John Kay Doman*

TITLE: Asst. EMD Director for Risk Mgmt

DATE: 8-10-16

Remittance Address:

North Carolina Department of Public Safety –
Floodplain Mapping Program
4105 Reedy Creek Road, Raleigh, NC 27607

30-0712287
Federal Tax Identification Number

N.C.G.S. § 133-32 and Executive Order 24 prohibit the offer to, or acceptance by, any State Employee of any gift from anyone with a contract with the State, or from any person seeking to do business with the State. By execution of any response in this procurement, you attest, for your entire organization and its employees or agents, that you are not aware that any such gift has been offered, accepted, or promised by any employees of your organization.

NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

BY: *Mike Adair*

TITLE: CHIEF ENGINEER

DATE: 8/11/16

BY: *R. R. C.*

TITLE: Director Technical Services

DATE: 8/12/16

To the extent this Agreement is a “Cooperative Agreement,” as that term is defined by N.C.G.S. § 143B-24, and to the extent approval of the Department of Administration is required; based on the assurances from the parties to this Agreement, approval is hereby given as indicated below by the signature of the Secretary of the Department of Administration.

DEPARTMENT OF ADMINISTRATION

BY: *Kathryn Johnston*

TITLE: Secretary

DATE: August 11, 2016

APPROVED BY BOARD OF TRANSPORTATION ITEM O: 8/4/16 (Date)

EXHIBIT A: MOA Types and Fees Schedule

Through this Agreement, the Department and the NCFMP mutually agree that the data sharing agreements and services provided herein are conducive to efficient cooperation and project timelines for the two agencies. Twelve (12) distinct MOA types are identified as services to be provided by the NCFMP as part of this Agreement:

Type 1 For a project that results in the BFE change of 0.1 foot, or less, the State Hydraulics Engineer shall review the Hydrologic and Hydraulic (H&H) designs and issue a No Rise or No Impact certification. The State Hydraulics Engineer shall notify the NCFMP of the certification along with the MOA design packet.

The NCFMP shall incorporate these data and the associated As-built plans into its future flood map studies and Digital Flood Insurance Rate Map (DFIRM) updates.

There is no review fee made to the NCFMP for a Type 1 project. The Department agrees to coordinate biannually with the NCFMP to evaluate cost share with NCFMP in processing its future map maintenance study.

Type 2a For a project that results in the BFE decrease of greater than 0.1 foot, but less than 0.5 feet (Minor Impact), the State Hydraulics Engineer shall review the H&H designs and issue a Minor Impact certification. The State Hydraulics Engineer shall notify the NCFMP of the certification along with the MOA design packet.

The NCFMP shall incorporate these data and the associated As-built plans into its future flood map studies and DFIRM updates.

There is no review fee made to the NCFMP for a Type 2a project. The Department agrees to coordinate biannually with the NCFMP to evaluate cost share with NCFMP in processing its future map maintenance study.

Type 2b For a project that results in the BFE decrease of 0.5 feet, or greater (Measurable Impact), the Department shall submit the H&H design packet to the NCFMP for review and approval. After the project is completed, the Department shall consult with the NCFMP in preparing and processing a Letter of Map Revision (LOMR).

After the project is completed, the Department shall submit the As-built plans and consult with the NCFMP in preparing and processing a Letter of Map Revision (LOMR).

The review fee made to the NCFMP for a Type 2b project is \$3,000. The Department agrees to cost share with the NCFMP in processing a LOMR and/or its future map maintenance study.

Type 2c The NCFMP will review projects involving FEMA-regulated streams in the FIS, for which missing data or major errors were encountered in the original models, resulting in major hydraulic modeling difficulty.

Examples: Effective FIS hydraulic models are not available, have missing or illegible data, FIS model output does not match the published data, missing or incorrect structures/cross sections, major discrepancies/errors in topographic data, erroneous hydrologic analysis, etc.

With the prior consultation and concurrence of the NCFMP, the Department may opt to develop H&H design reports using its own field survey data and a minimum of six (6) section analysis and develop the BFE comparison table for the existing and proposed conditions.

The proposed upstream BFE is not required to match within one-half foot of the published the BFE. The Department shall submit the H&H design data to the NCFMP for review and approval.

The NCFMP shall incorporate this data and the associated As-built plans into its future map maintenance studies and DFIRM updates.

The review and process fee made to the NCFMP for a Type 2c project is \$14,000.

Type 2d For a project that results in the BFE increase of greater than 0.1 foot, but less than 0.5 feet, over a Limited Detailed Study stream, the State Hydraulics Engineer shall review the H&H designs and issue a Minor Impact certification. The design engineer shall follow Department's *Guidelines for Drainage Studies and Hydraulic Design* to assess flood risk and impacts to properties as well as the safety of the traveling public. The State Hydraulics Engineer shall notify the NCFMP of the certification along with the MOA design packet.

The NCFMP shall incorporate this data and the associated As-built plans into its future map maintenance studies and DFIRM updates.

There is no review fee made to the NCFMP for a Type 2d project. The Department agrees to coordinate biannually with the NCFMP to evaluate cost share with NCFMP in processing its future map maintenance study.

Type 2e The NCFMP shall review a project that is over a Limited Detailed Study stream which results in the BFE increase of 0.5 feet or greater, but no greater than one (1) foot. The design engineer shall follow the Department's *Guidelines for Drainage Studies and Hydraulic Design* to assess flood risk and impacts to the adjoined properties as well as the traveling public.

After the project is completed, the Department shall submit the As-built plans and consult with the NCFMP in preparing and processing a Letter of Map Revision (LOMR).

The review fee made to the NCFMP for a Type 2e project is \$3,000. The Department agrees to cost share with the NCFMP in processing a LOMR and/or its future map maintenance study.

Type 2f The NCFMP shall review a project that is over a Limited Detailed Study stream that results in the BFE increase greater than one (1) foot; the increase shall stay within the Department's Rights of Way, to include areas obtained by easement, and has no impact to private properties or buildings. The design engineers shall follow the Department's *Guidelines for Drainage Studies and Hydraulic Design* to assess flood risk and impacts to the properties as well as the traveling public. This requires a special approval from both the State Hydraulics Engineer and the NCFMP Director. The Department shall submit all pertinent H&H design data and documentation that are outlined in 44CFR 65.12.a. After the project is completed, the Department shall consult with the NCFMP in preparing and processing a Letter of Map Revision (LOMR).

The NCFMP shall incorporate this data into and the associated As-built plans into its future map studies and DFIRM updates.

The review fee made to the NCFMP for a Type 2f project is \$3,000. The Department agrees to cost share with the NCFMP in processing a LOMR and/or its future map maintenance study.

Type 2g The NCFMP shall review a project that is over a Detailed Study stream that results in a BFE increase and/or increase and modification to the regulatory floodway that remains solely within the Department's Rights of Way, to include areas obtained by easement, and has no impact to private properties or buildings. The design engineers shall follow the Department's *Guidelines for Drainage Studies and Hydraulic Design* to assess flood risk and impacts to the properties as well as the traveling public. This requires special approval from both the State Hydraulics Engineer and the NCFMP Director. The Department shall submit all pertinent H&H design data and documentation that are outlined in 44CFR 65.12.a. After the project is completed, the Department shall consult with the NCFMP in preparing and processing a Letter of Map Revision (LOMR).

The NCFMP shall incorporate this data into and the associated As-built plans into its future map maintenance studies and DFIRM updates.

The review fee made to the NCFMP for a Type 2g project is \$3,000. The Department agrees to cost share with the NCFMP in processing a LOMR and/or its future map maintenance study.

Type 3a For the approved CLOMR projects, the Department shall submit, after project completion, the As-built plans with its design models and data to the NCFMP for its inclusion in the future DFIRM mapping needs. This applies to streams for which DFIRM mapping is still current after the issuance of CLOMR approval.

The review fee made to the NCFMP for a Type 3a project is \$3,000. The Department agrees to cost share with the NCFMP in processing a LOMR and/or its future map maintenance study.

Type 3b For the approved CLOMR projects, the Department shall submit, after project completion, the As-built plans with its design models and data to the NCFMP for its inclusion in the future DFIRM mapping needs. This applies to streams for which H&H models were restudied and FIRM mapping modified since the issuance of CLOMR approval.

The review fee made to the NCFMP for a Type 3b project is \$3,000. The Department agrees to cost share with the NCFMP in processing a LOMR and/or its future map maintenance study.

Type 3c When a project is determined to require a CLOMR approval, or the published flood elevations are scientifically or technically incorrect, due to error in application of hydrologic and hydraulic methods, the Department's design engineer may initiate a pre-application consultation to discuss with an NCFMP representative the hydrologic and hydraulic design issues, such as interpretation of the NFIP regulations, model source data, hydrology, hydraulic design, flood maps, risk analysis, encroachments, etc.

This process enables the NCFMP to provide guidance to the Department during the design process through its representatives and/or contract consultant. It includes the assistance from the NCFMP on consultation with FEMA on behalf of the Department, data search/verification, flood model review, technical guidance and CLOMR data pre-reviews.

There is no fee made to the NCFMP for a Type 3c project.

Type 4a For a project that was previously approved as an MOA or CLOMR and its field survey data from the As-built plans deviate from the design plans and flood models. It may result from unanticipated field conditions during construction, such as bedrock, utilities, etc. The Department shall submit the As-Built plans, revised design reports and flood models to the NCFMP for review and acceptance.

The review fee made to the NCFMP for a Type 4a project is \$3,000. The Department agrees to cost share with the NCFMP in processing a LOMR, if warranted.

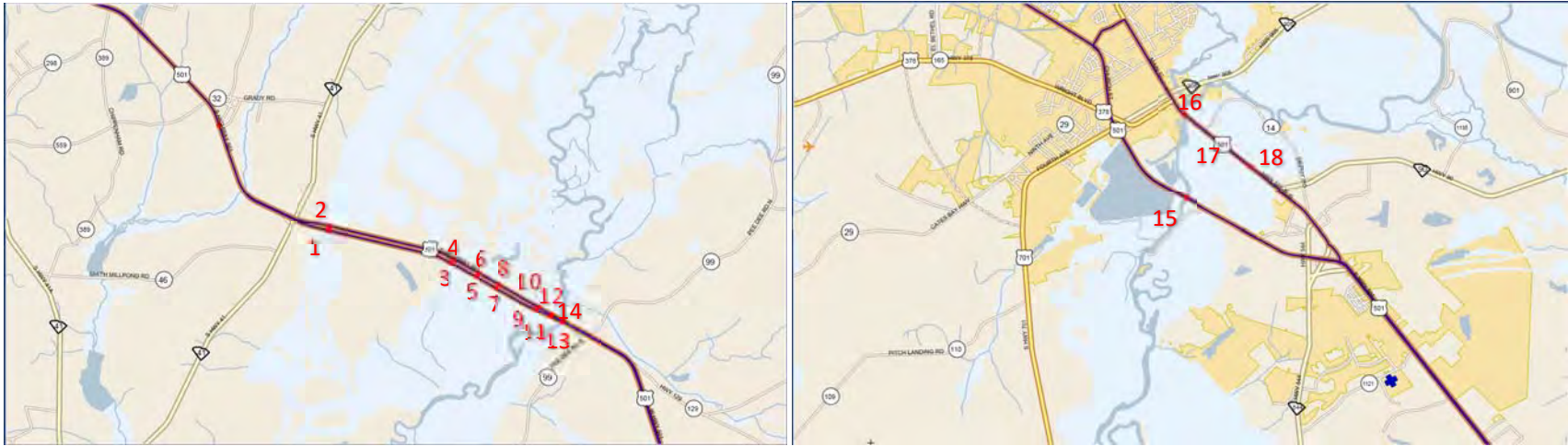
EXHIBIT B: MOA Data Deliverables and Submittal Schedule by NCDOT

DELIVERABLES	MOA TYPES											
	1	2a	2b	2c	2d	2e	2f	2g	3a	3b	3c	4a
FEMA Coordination Form	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
MOA Transmittal Form	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Title Sheet or Vicinity Map	✓	✓	✓	✓	✓	✓	✓	✓			✓	
Micro-Station (CADD) files (mapping, etc.)	✓	✓	✓	✓	✓	✓	✓	✓			✓	
Bridge /Culvert Survey Report(s) (PDF)	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓
Effective Hydraulic Model	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓
Project Hydraulic Models (HEC-RAS)	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓
Hydraulic Modeling Narrative	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓
Output Comparison Table (Excel format)	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓
No Rise Certification	✓											
Parcel/Property Owner Information (in CADD)			✓			✓	✓	✓			✓	✓
Documentation of NCFMP Concurrence				✓							✓	
"As-Built" Plans (PDF, Final submittal)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

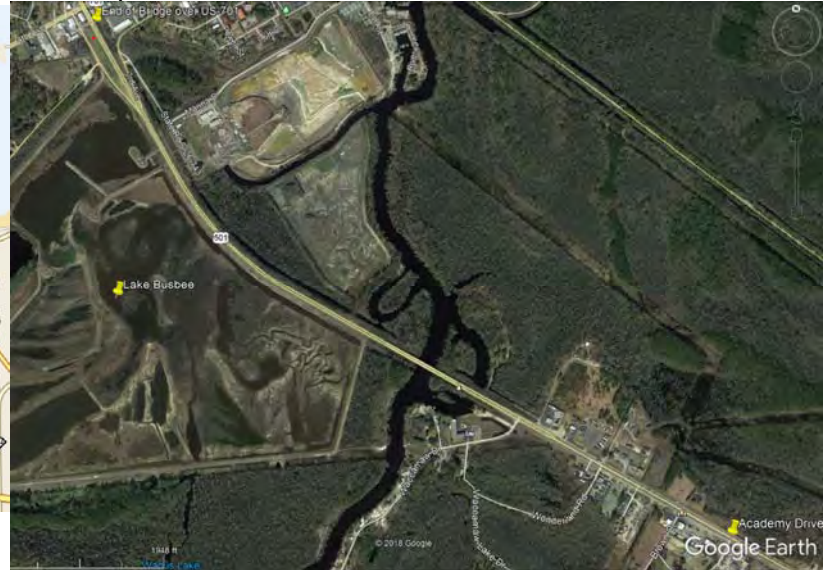
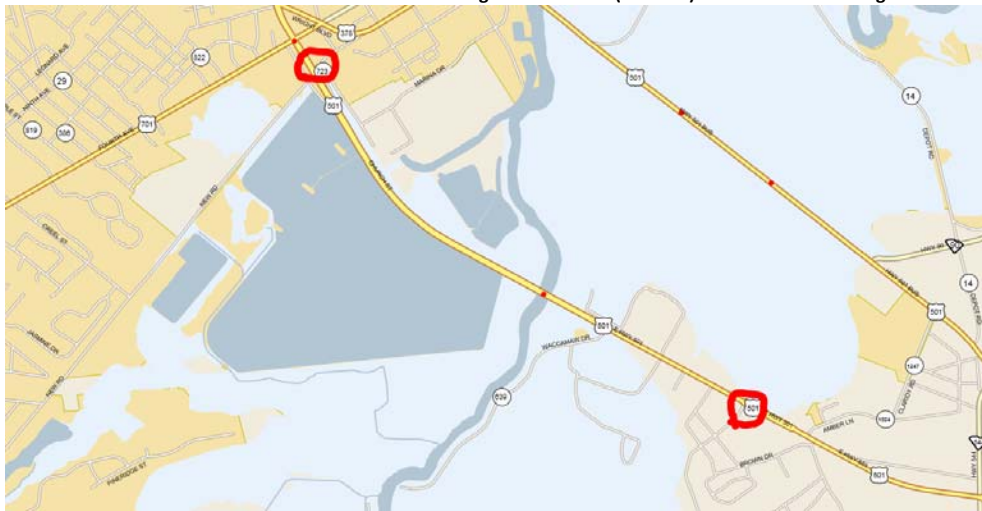
SUBMITTAL SCHEDULE													
INITIAL , minimum days before project construction	90	90	90	90	90	60	90	90	N/A	N/A	90	N/A	
FINAL, within days following project completion	180	180	180	180	180	180	180	180	180	180	180	180	

US-501 RESILIENCY CORRIDOR SURVEY

Number	MP	Details	Structure Number	Asset Number	Stream Crossing	Bridge Low Chord (ft)	Begin Bridge C.L. Elev.(ft) West	End Bridge C.L. Elev.(ft) East	Begin Bridge Right West Edge(ft)	Begin Bridge Left West Edge(ft)	End Bridge Right East Edge(ft)	End Bridge Left East Edge(ft)
US-501 (34) MARION DIST 5						NAVD 88 Datum						
1	20.52		3420050130600	560	BACK SWAMP	43.43	45.50	45.29	45.19	45.26	44.99	45.05
2	20.514		3420050110600	6543	BACK SWAMP	43.55	45.66	45.70	45.27	45.14	45.26	45.15
3	22.047		3420050130700	561	LITTLE PEE DEE SWP -1	43.38	45.25	45.35	44.94	45.00	45.03	45.10
4	22.05		3420050110700	6544	LITTLE PEE DEE SWP -1	43.56	45.55	45.56	45.14	45.06	45.17	45.09
5	22.388		3420050130800	562	LITTLE PEE DEE SWP -2	43.53	45.29	45.44	45.03	45.09	45.12	45.22
6	22.391		3420050110800	6545	LITTLE PEE DEE SWP -2	43.31	45.35	45.42	44.92	44.84	44.95	44.86
7	22.661		3420050130900	563	LITTLE PEE DEE SWP -3	43.65	45.49	45.41	45.18	45.24	45.12	45.20
8	22.663		3420050110900	6546	LITTLE PEE DEE SWP -3	43.15	45.36	45.43	44.97	44.85	44.88	44.77
9	23.199		3420050131000	564	LITTLE PEE DEE SWP -4	43.43	45.28	45.72	44.98	45.05	45.41	45.49
10	23.201		3420050111000	6547	LITTLE PEE DEE SWP -4	43.61	45.64	45.60	45.23	45.09	45.22	45.11
11	23.38		3420050131100	565	LITTLE PEE DEE SWP -5	43.92	45.81	45.80	45.51	45.56	45.50	45.59
12	23.38		3420050111100	6548	LITTLE PEE DEE SWP -5	43.53	45.52	44.45	45.07	44.94	45.08	44.98
US-501 (26) HORRY DIST 5						NAVD 88 Datum						
13	0.004		2620050130100	546	LITTLE PEE DEE RIVER	43.10	45.80	44.89	45.49	45.56	44.58	44.64
14	0.004		2620050110100	6512	LITTLE PEE DEE RIVER	43.43	45.43	45.46	45.03	44.92	45.03	44.91
15	20.741	STRUCTURE	2620050105200	2753	US-501 BYP. - WACCAMAW RIVER	24.09	28.20	27.99	27.86	27.78	27.54	27.53
16	1.922		2620050103100	793	US-501 BUSINESS - WACCAMAW RIVER	23.35	31.26	25.41	31.49	31.04	25.40	25.34
17	2.5		2620050103200	794	US-501 BUSINESS - WACCAMAW BACKWATER #1	16.01	17.92	17.92	17.65	17.66	17.66	17.63
18	2.904		2620050103300	795	US-501 BUSINESS - WACCAMAW BACKWATER #2	16.09	18.02	18.03	17.77	17.77	17.76	17.77



US-501 RESILIENCY CORRIDOR SURVEY
Edge of Pavement (Lt. & Rt.) from East End of Bridge over US-701 to Academy Drive



US National Water Model



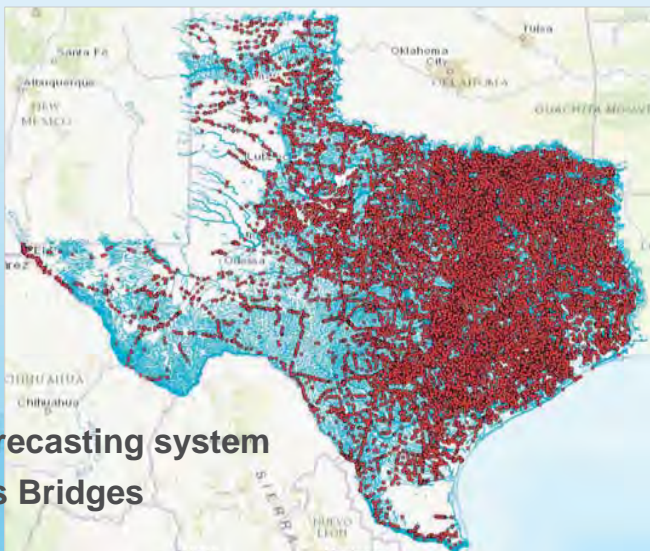
Streamflow Measurement at Bridges

Prepared by David R. Maidment
Center for Water and Environment
University of Texas at Austin

Prepared for
TxDOT Project 5-9054-01
Streamflow Measurement at TxDOT Bridges

Presented to Sommer Messtechnik
17 May 2019

27,000 Texas bridges on 15,700 stream reaches forecast by the National Water Model

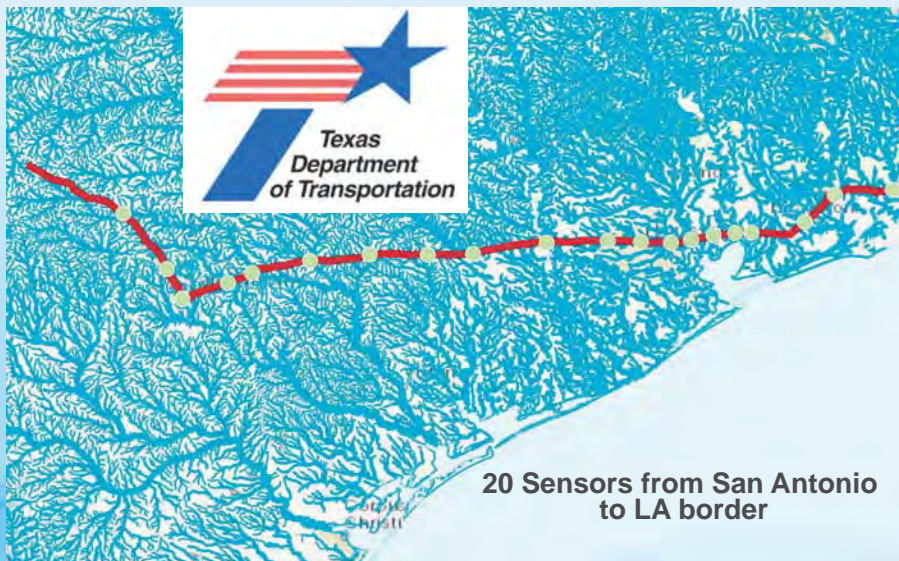


**Flood forecasting system
for Texas Bridges**

Steps in Establishing a Measurement Site

- Step 1 – Gage installation – Kisters or Hydrological Services America
- Step 2 – LIDAR measurement of stream cross-section – UT Austin
- Step 3 – Local measurement of stream cross-section and discharge – FishView
- Step 4 – Bridge Imagery – FishView
- Step 5 – Cross-section monitoring – TxDOT
- Step 6 – Gage maintenance – USGS

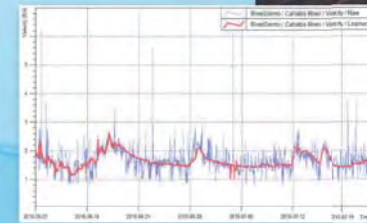
Radar Streamflow Measurement on I-10



Radar Measurement of Discharge

Prototype on Cahaba River Near Centreville, AL, 2016

Measure water surface elevation and velocity at one point on water surface



Highway Transects and Flow Correlation Zones



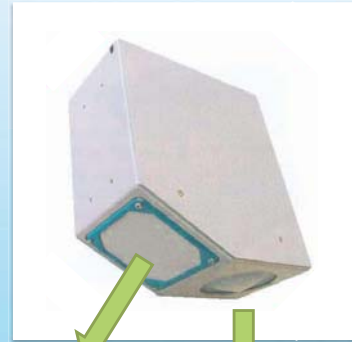
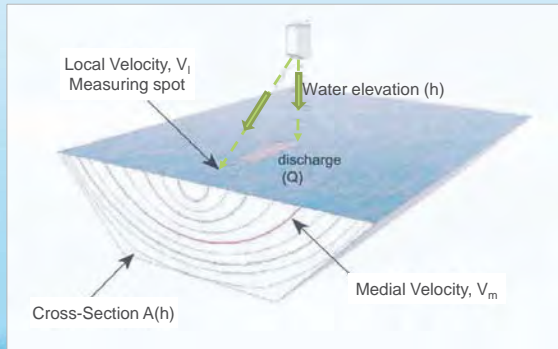
Instrumenting the Interstates as “Picket Lines” for storms passing across Texas



Radar Measurement of Water Elevation and Velocity



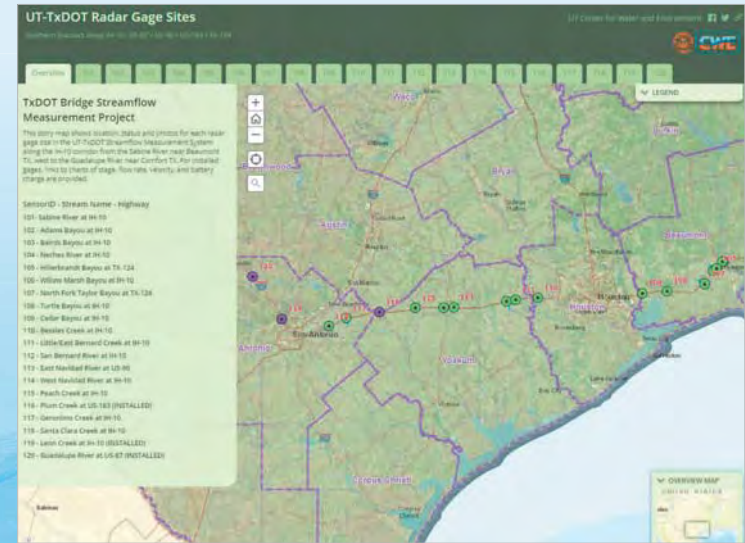
RQ-30



Velocity
Water elevation (h)

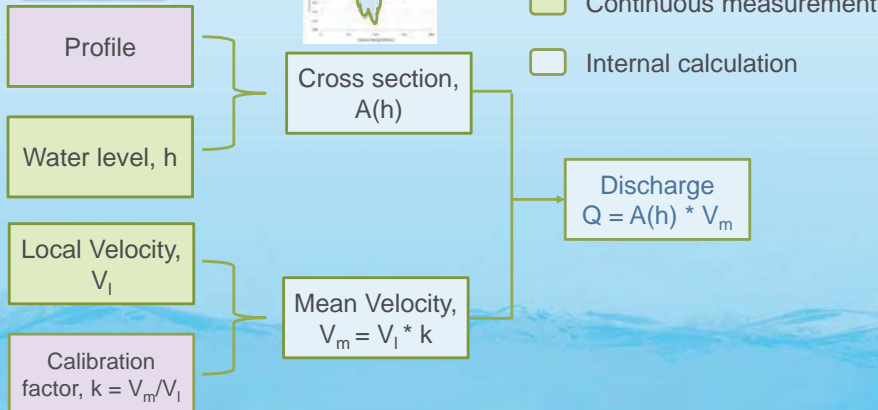
$$V_m = V_1 * k \quad k = \text{calibration factor at site}$$

Step 1. Installation of Bridge Sensors Story Map by David Arctur (CWE)



TxDOT Radar Gages story map

Automated Data Processing (Kisters)



Sensors on Guadalupe River at Comfort

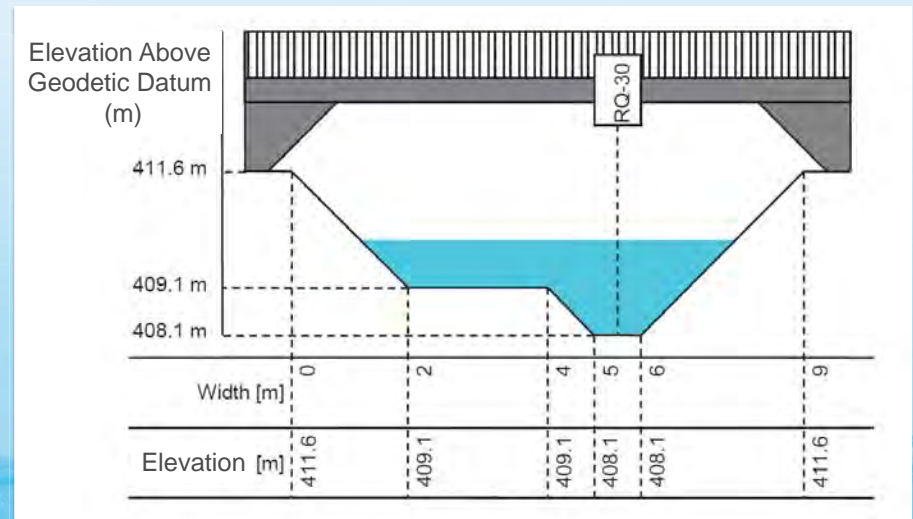


1057 Bridge Spans Extracted for Austin Area from 1m LIDAR Point Cloud Data

Gert Van Maren (ESRI)



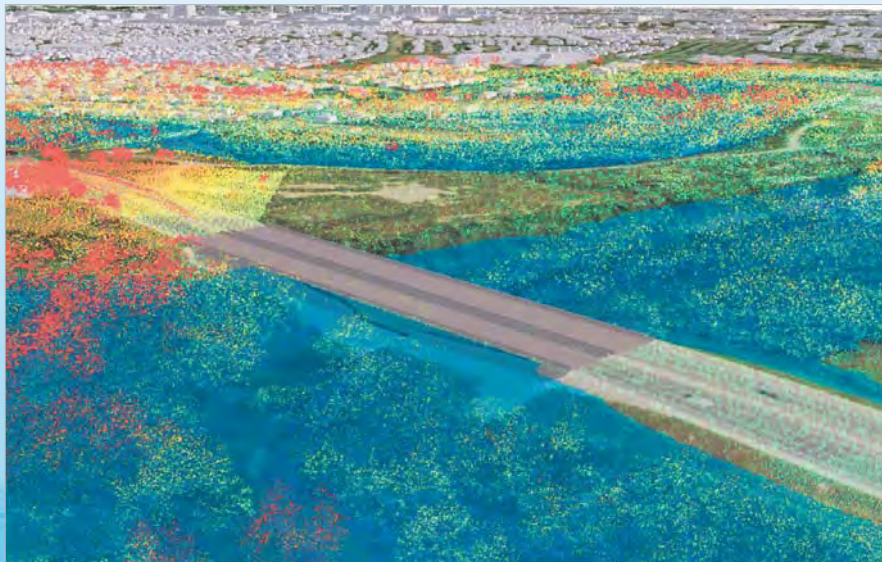
Step 2: LIDAR Measurement of the Stream Cross-Section



Source: RQ-30 User Manual (2018), p. 20

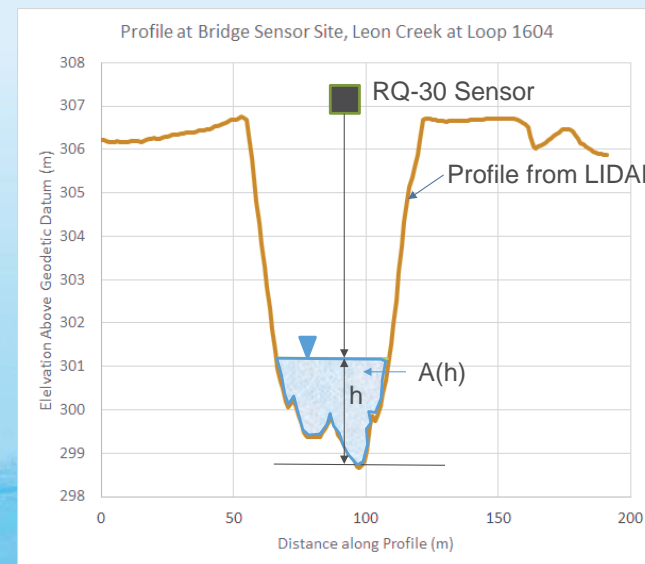
Bridge over Onion Creek at William Cannon Dr

Gert van Maren (ESRI)

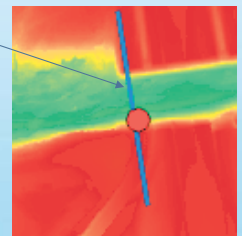


<http://www.arcgis.com/home/webscene/viewer.html?webscene=3455af9be32141569da41f42d880d022>

Cross-Section Profile from LIDAR



Referenced to geodetic datum



Local datum is the stream bed. If channel erodes or degrades, new profile is used and local datum changes

3D Bridge and Building Identification from 1m LIDAR point cloud data

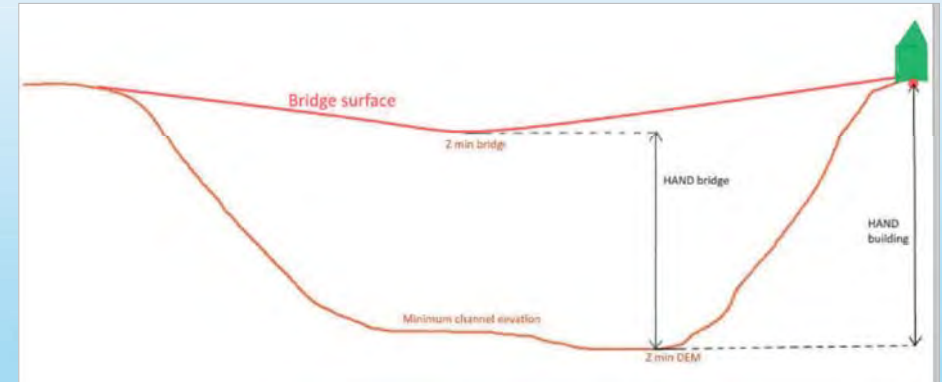
Gert van Maren (ESRI)



<http://www.arcgis.com/home/webscene/viewer.html?webscene=3455af9be32141569da41f42d880d022>

Automated Bridge Profile Extraction

Gert Van Maren (ESRI)



Step 3: Calibration of the Sensor “K-factor”

$$Q = A(W) \cdot k(W) \cdot v_t$$

For the RQ-30 radar sensor a discharge table is generated based on the cross section areas $A(W)$ and the k-factors $k(W)$ in relation to the water level W . This table is deposited in the radar sensor and is the basis for the discharge calculation. It is essential that the water levels of the discharge table correspond to the same datum as the level measurement of the radar sensor "Level (W)".

4.3.2. k-Factors

The k-factors depend on the conditions of the measurement site and have to be determined individually for every measurement site.

The k-factors are determined by modeling with a numeric hydraulic model. The k-factors depend on the water level, the shape of the cross section, the roughness assigned to the cross sectional profile and the position of the radar sensor. The advantages of modeling are the instant availability of a measured discharge right from the start and coverage of the complete water level range.

Roughness

An estimation of the roughnesses in the cross sectional profile is necessary to model the k-factors. The roughness is specified as absolute roughness k_s , Strickler coefficient K_{st} or Manning coefficient n . For the software "QCommander" a description of the condition at the border in the form "Bed of sand" or "Brick stone walls" is sufficient to constitute the roughness coefficients.

Onion Creek at William Cannon Dr

Gert Van Maren (ESRI)



Step 4. Bridge Profile Imagery



The k-factors are determined by modeling with a numeric hydraulic model. The k-factors depend on the water level, the shape of the cross section, the roughness assigned to the cross sectional profile and the position of the radar sensor. The advantages of modeling are the instant availability of a measured discharge right from the start and coverage of the complete water level range.

Using Stream Gaging to get K-factor

Stream Gaging with Current Meter
(Shallow rivers)



Stream Gaging with Acoustic Doppler Current Profiler
(Shallow rivers)

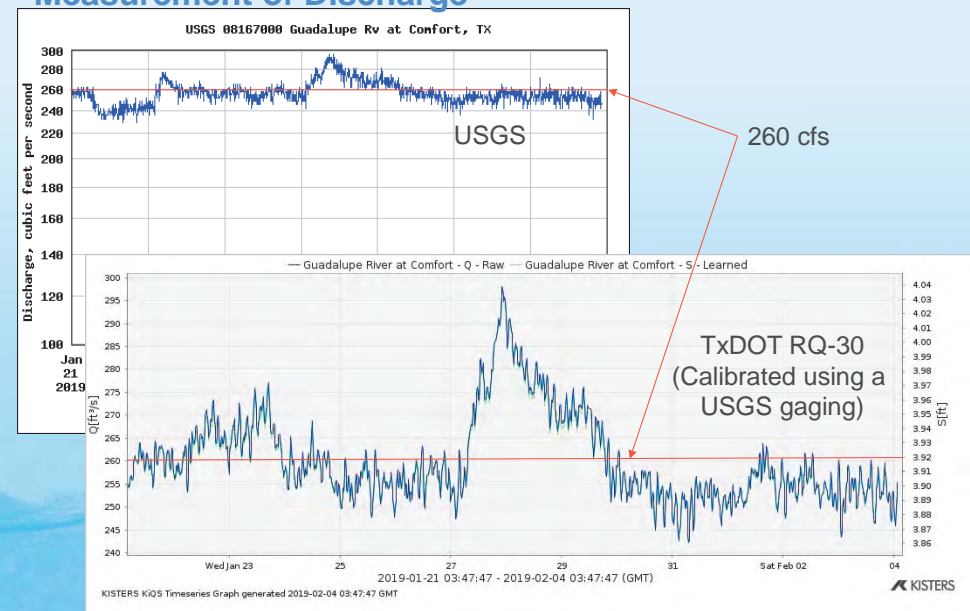


Bridge Alarming

TxDOT closes bridges if the water is at risk of hitting the beams supporting the road. This means we need to know the Low Chord Elevation of the bridge and its vertical height difference from the sensor.

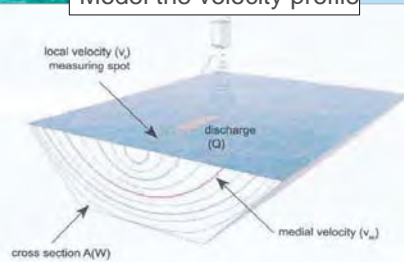
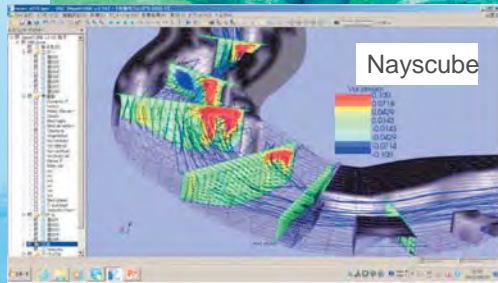


Guadalupe River at Comfort: Calibration using Local Measurement of Discharge

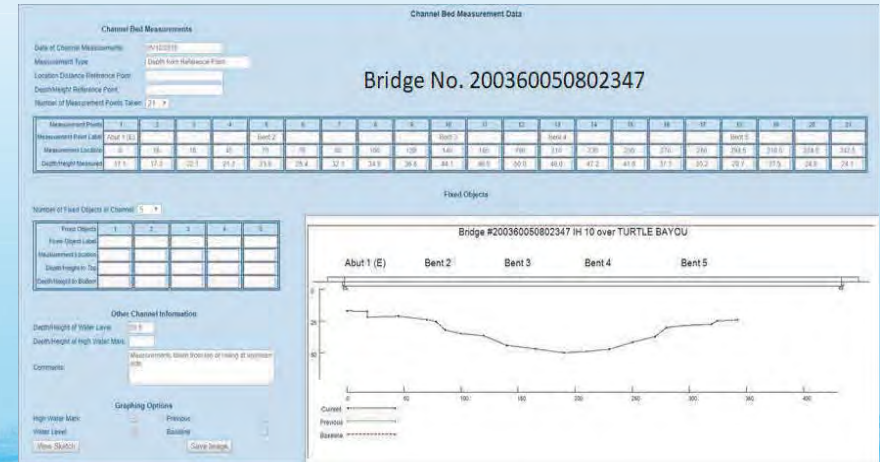




Model the velocity profile



Step 5. Monitoring of Stream Cross-Section



Once per two years. If cross-section changes, then recalibrate gage.

Step 6. Gage Maintenance (USGS)

Two visits per year by USGS

Repair and replacement of equipment when necessary

UT has two spare instruments

