Evaluating, Documenting, and Remediating Scour in Texas

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Texas Department of Transportation

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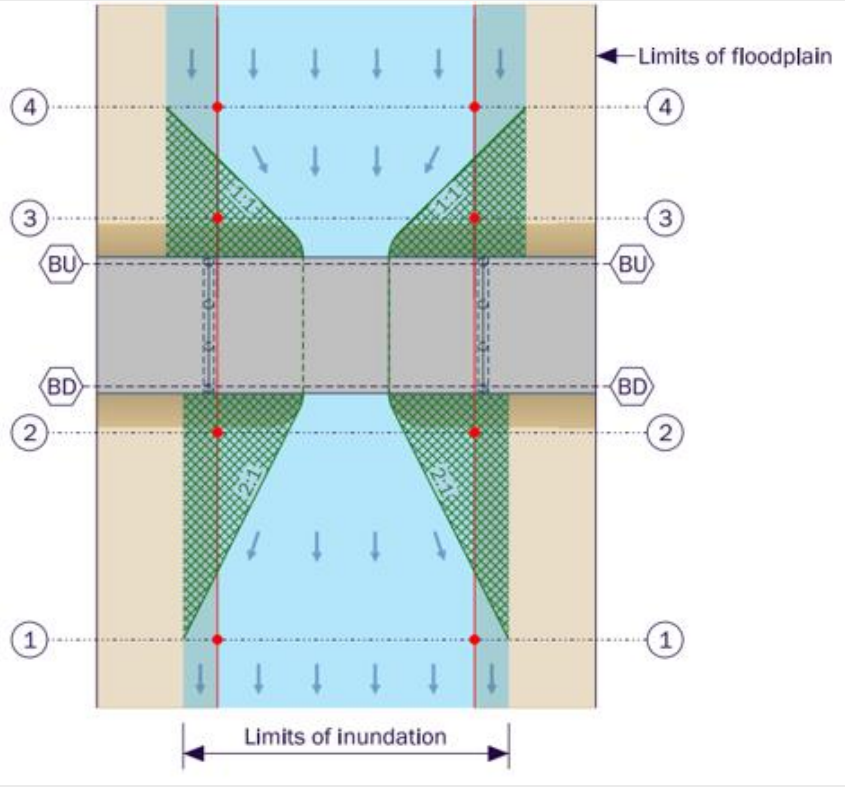
Is this a problem?

Scour at Bridges

- Erosion of streambed or bank material due to flowing water
  - Contraction scour
    - Constricting the channel at a bridge opening
  - Pier Scour
    - Obstructions to flow in the channel



Bridge Foundation Exposure

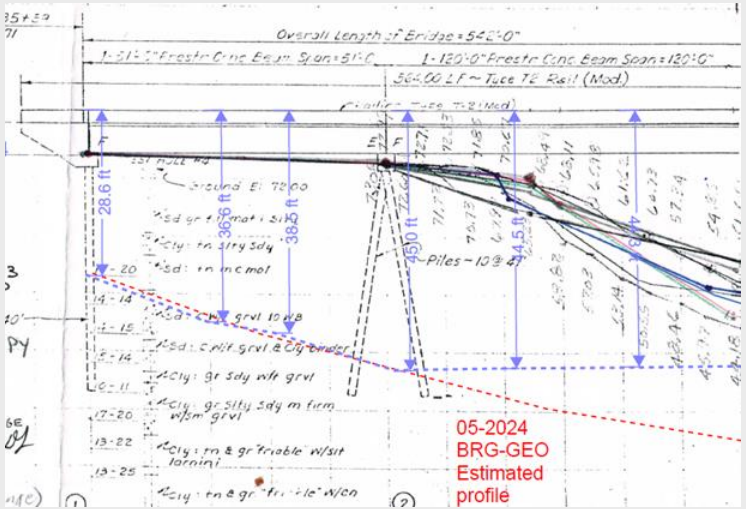
- Loss of axial and lateral capacity
- Substructure slenderness concerns

Embankment Instability

- Erosion around abutments
- Slope failures
- Undermining rigid structures

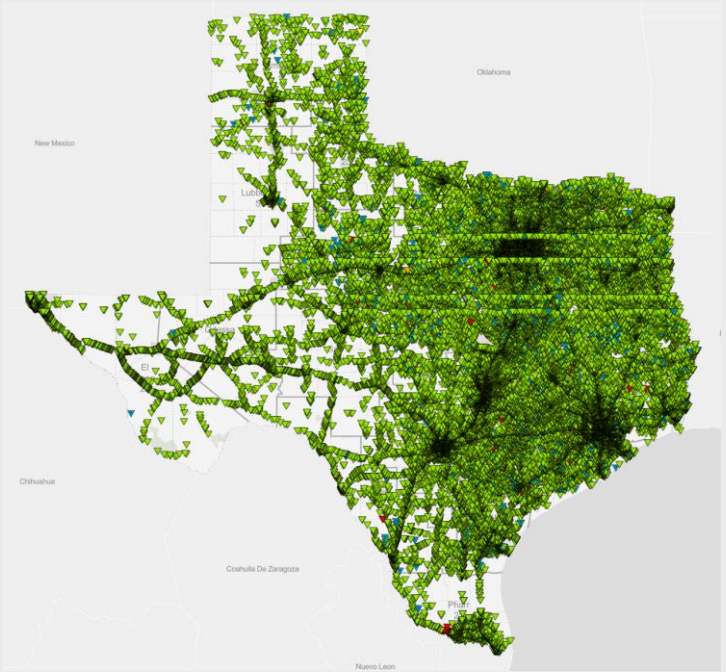
Importance of Scour

- Most common cause of bridge failures nationwide
  - Existing structures required to be evaluated for scour vulnerability
  - New bridge designs required to have a scour evaluation



TxDOT bridge inventory

- 57,588 total bridges
  - 45,703 bridges over water (79.3%)
    - Of these:
      - 20,887 bridge class culverts (45.7%)
      - 26,904 on-system (57.1%)
      - 19,609 off system (42.9%)
      - <1% scour critical

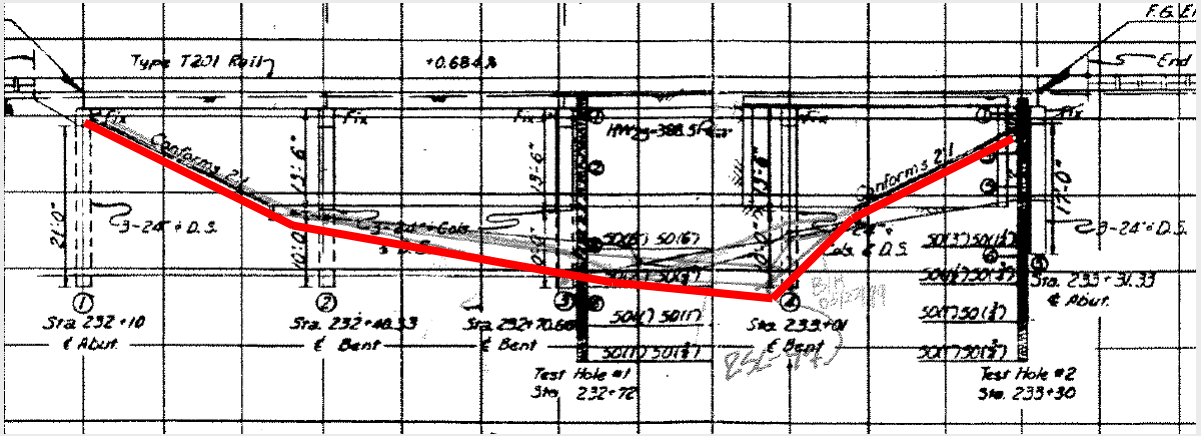


Bridge Division – Geotechnical Branch

- Office of primary responsibility for scour evaluation
- Scour is multidisciplinary
  - Geotechnical Branch
  - Bridge Inspection
  - Bridge Asset Management
  - Design Division – Hydraulics
- District bridge groups and consultants

Importance of Documentation

- Scour vulnerability evaluation
  - Rapid evaluation in flood response
  - Prioritization of structures for replacement
  - Identify structures requiring repair



Scour Summary Sheet Contents

- Bridge information
- Engineer's seal and signature
- Countermeasure condition
- Maximum allowable scour depth
- Observed scour depth
- Trigger elevation (for reevaluation)
- Description for future action

SCOUR DEPTHS

☑ Scour depths are measured from the as-built channel profile.

☐ Scour depths are measured from:

Abutment or Bent #	Bent 2	Abut 1
y_{ab} ☑ or y_{ar} ☐	15	
y_{al}	25	
Max Allowable Scour Depth[1], y_a	15 (Elev. 200)	
Max Possible Scour Depth[2]		See Trigger
Calculated Contraction Scour	5	
Calculated Pier Scour	2.5	
Total Calculated Scour Depth	7.5	
Observed Scour Depth	10 (Elev. 195)	See below

Notes: (1) Min (y_{ar} or y_{ab}, or y_{al}). (2) ONLY applicable if a non-erodible stratum is pres

Abutment Protection Condition: (Describe below) None or Minor ☐ Moderate ☒ Major ☐ B.C.09

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TRIGGER ELEVATION & FUTURE ACTION

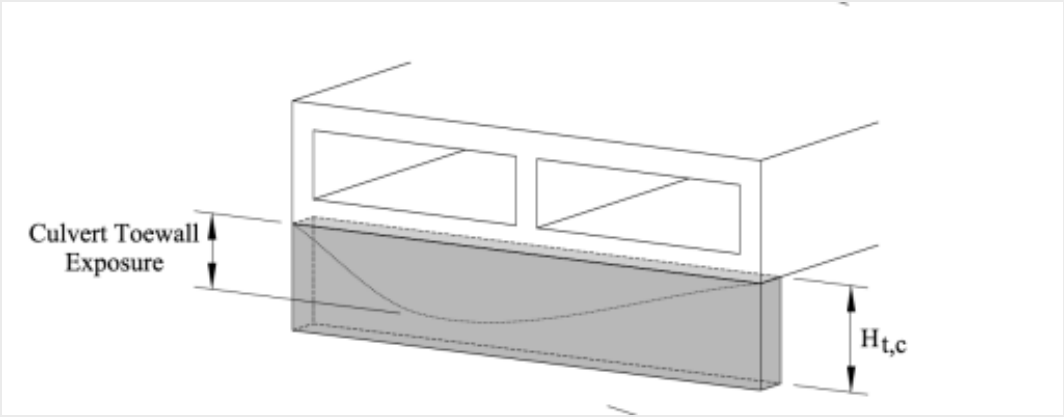
Refer to Chapter 10 of the Scour Evaluation Guide.

Current scour at abutment exposed toe wall of CRR. Considered moderate exposure condition.
Re-evaluation will be needed:
-When scour exposed the bottom of abutment cap
-When scour at Bent 2 exceeded 13 feet (Elev. 198')

Scour Summary Sheet

- Span Bridges
  - Based on vulnerability assessment/analysis and field observations
  - Must be accompanied by supporting documentation to justify coding
- Bridge Class Culverts
  - Based on field observations

Item 113 Coding	Exposure and/or Undermining Category	*Choose the Most Critical Mechanism*			
		Culvert/Pipe Undermining	Culvert/Pipe Toewall Exposure	Apron Undermining	Apron Toewall Exposure
8	Minimal	< 1 ft.	$< {}^{1}/_{3}\ H_{t,c}$	$< {}^{1}/_{5}\ L_a$	$\leq H_{t,a}$
4	Moderate	1 – 3 ft.	$\leq H_{t,c}$	${}^{1}/_{5}\ L_a - {}^{3}/_{5}\ L_a$	$> H_{t,a}$
2	Major	> 3 ft.	$> H_{t,c}$	$> {}^{3}/_{5}\ L_a$	-



Scour Evaluation Methods – Existing Structures

- Evaluations to accompany a Scour Summary Sheet
  - Screening
    - Identify low-risk structures
  - Assessment
    - Detailed evaluation based on scour history
  - Analysis
    - Detailed analytical evaluation based on hydraulic analysis

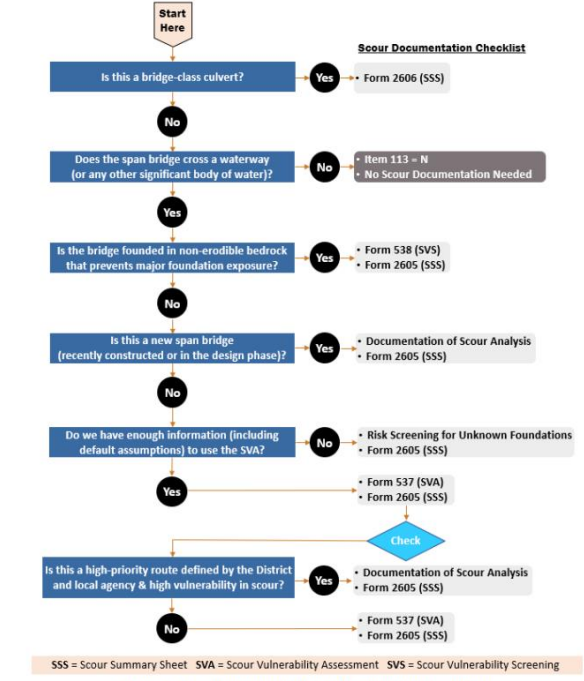
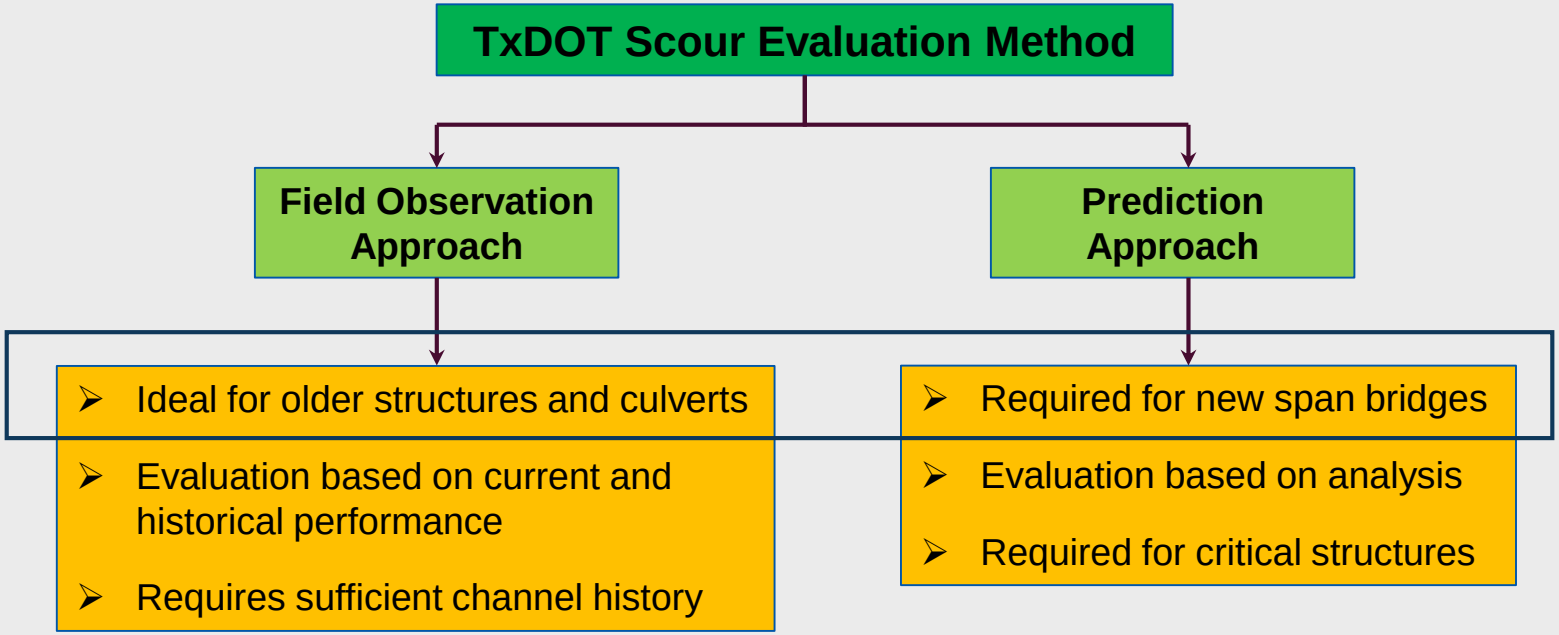


Figure 2-1 – Scour Evaluation and Documentation Flowchart

Existing Structures

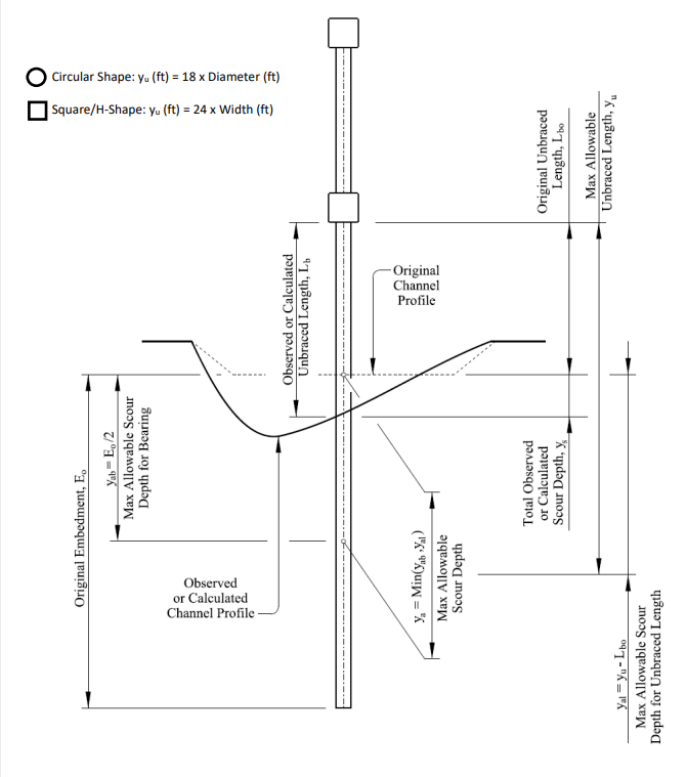


Maximum Allowable Scour – Span Bridges

- Amount of scour that can occur before a bridge foundation becomes unstable due to:
  - Bearing capacity
  - Lateral support
  - Rotational stiffness
  - Other applicable failure modes

Maximum Allowable Scour – Deep Foundations

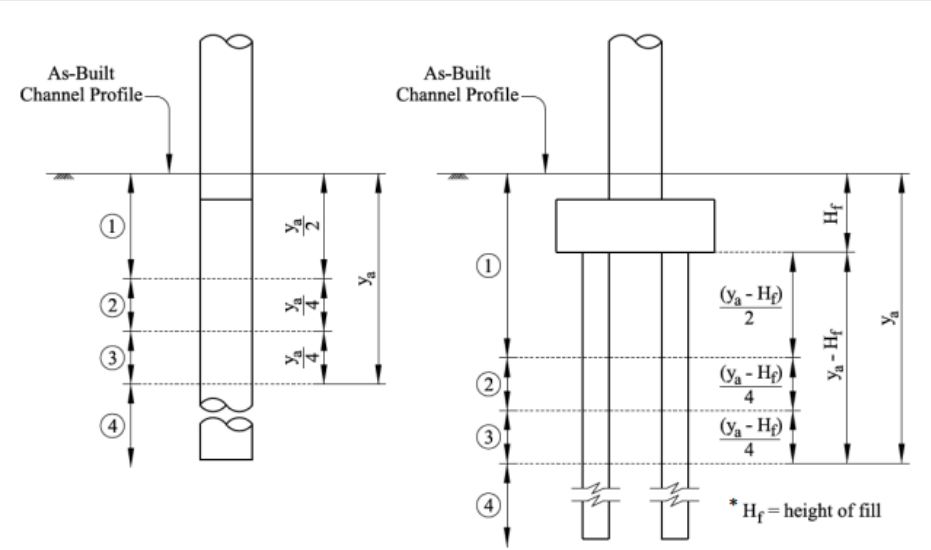
- Geotechnical capacity assumptions
  - Factor of safety of 2 from original embedment
  - Uniform material along full length of element
  - End-bearing neglected
  - No disregard depth from original channel profile



Exposure Categories - Deep Foundations

① Minor Foundation Exposure
② Moderate Foundation Exposure
③ Major Foundation Exposure
④ Extreme Foundation Exposure

y_a = Max Allowable Scour Depth (Refer to Ch. 2 in the Scour Evaluation Guide)



*Note: When as-built Channel Profile is below the bottom of footing, H_f=0

Exposure Categories - Abutments

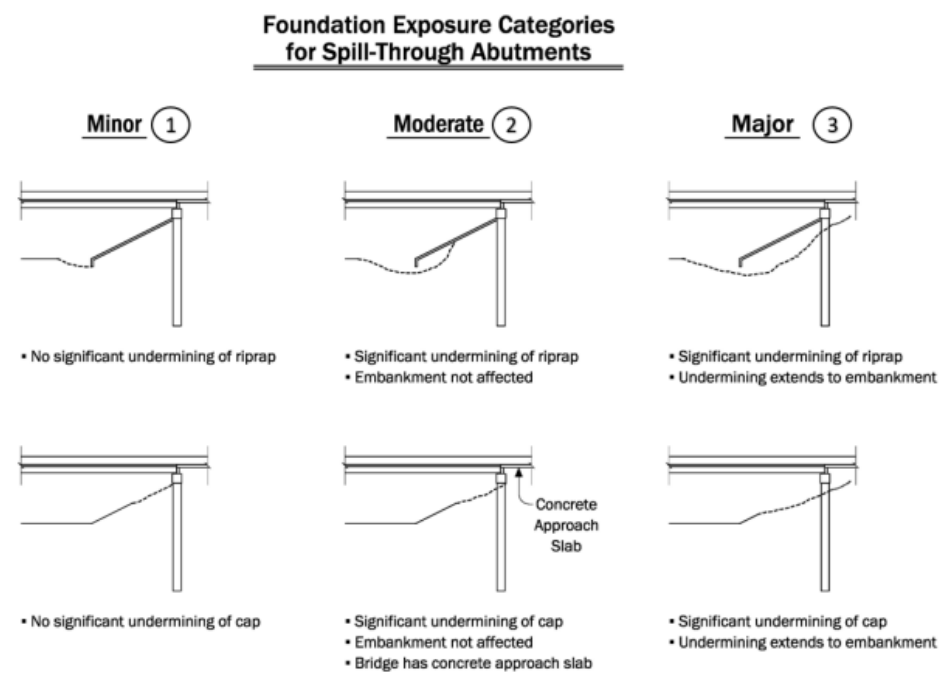
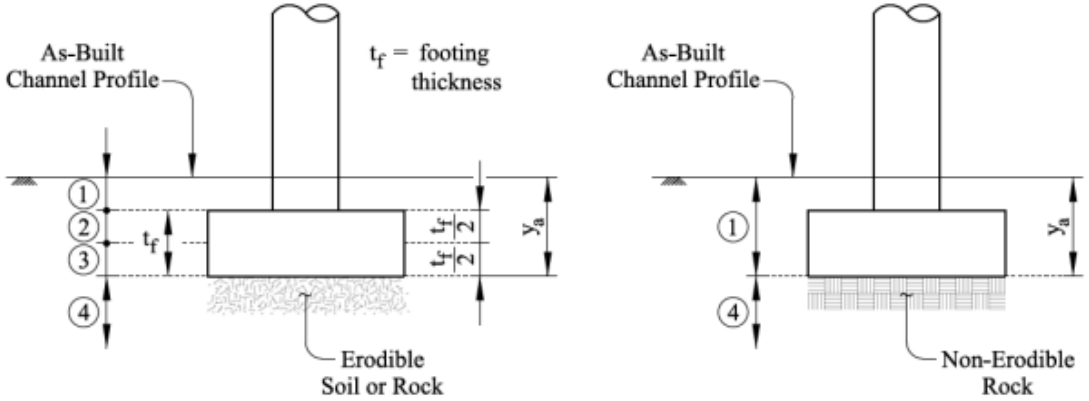


Figure 8-2 – Foundation Exposure Categories for Spill-Through Abutments

Maximum Allowable Scour – Shallow Foundations

① Minor Foundation Exposure
② Moderate Foundation Exposure
③ Major Foundation Exposure
④ Extreme Foundation Exposure

y_a = Max Allowable Scour Depth (Refer to Ch. 2 in the Scour Evaluation Guide)

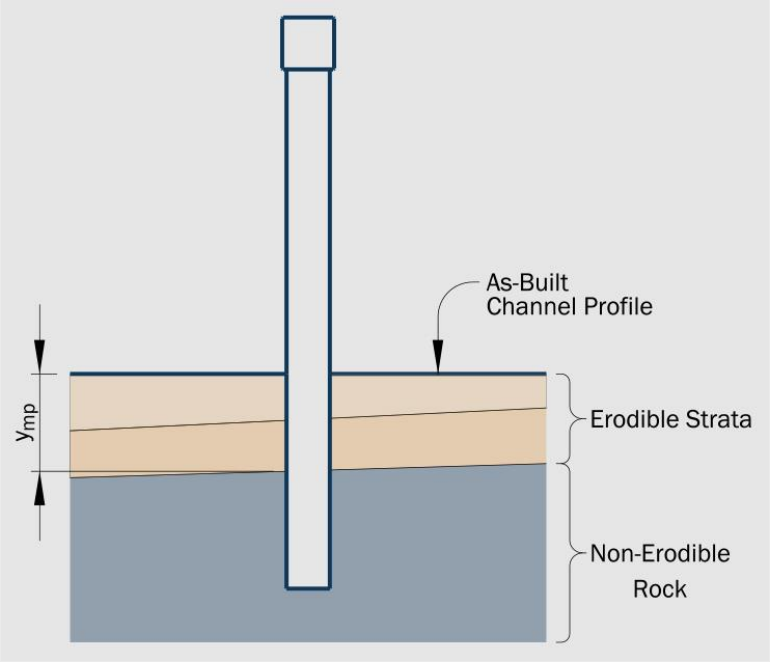


Screening Evaluation

- Bridges founded in non-erodible stratum
- Evaluate bents at maximum possible scour depth

Table 4-1 – Channel Materials and Scour Vulnerability

Material	Sub-Category	TCP Values or Equivalent Strength Data	Scour Vulnerability
Rock	Hard (granite, limestone, shale)	< 4 in./100 blows	Non-Erodible
	Soft (shale, sandstone)	< 12 in./100 blows	Mildly Erodible
Clay	Hard (redbed, shaley clays, very stiff clays)	< 12 in./100 blows	Mildly Erodible
	Soft to Medium	> 12 in./100 blows	Erodible
Sand	All	All	Very Erodible



Scour Vulnerability Assessment

- Determine risk factors to identify scour vulnerability class

	Channel Material Score
+	Channel Condition Score
+	Scour History Score
+	Channel Migration History Score
	Total Score

- From boring (sand, clay, rock, etc.)
- NBI Item 61 coding
- Exposure Category
- Amount of impact on bents

Total Score = Sum of Risk Factor Scores = 3

Scour Vulnerability Class (Check One)**:**

☐ Normal (Total Score < 3) ☑ Enhanced (Total Score >= 3)

Scour Coding – Existing Structures

- Maximum allowable scour
  - Based on controlling foundation or structural capacity
- Compared to evaluated scour
  - Observed scour
    - Assessment vulnerability category
  - Or calculated scour

Table 8-5 – SVA Scour Coding Table

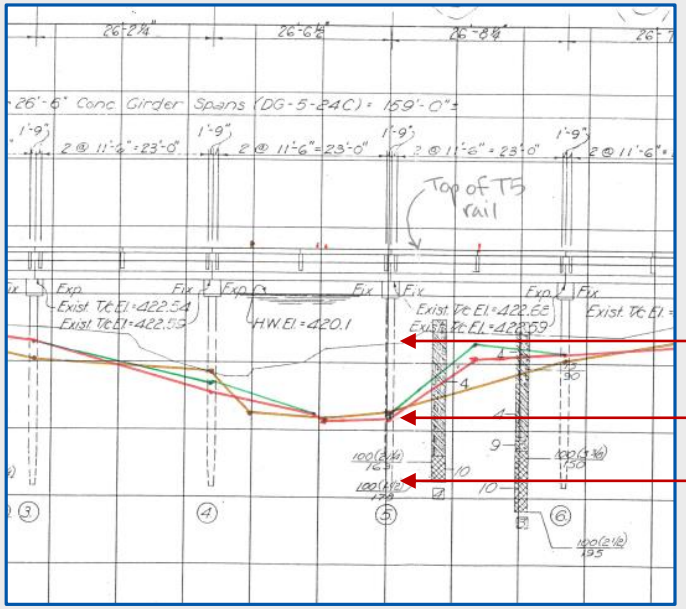
Current Scour Condition Refer to Figures 8-1 and 8-2 for Definitions of Foundation Exposure Categories	Recommended Scour Coding			
	Scour Vulnerability Class			
	Normal	Enhanced	Normal	Enhanced
	Item 113		SNBI Item B.C.11 & (Item B.AP.03)	
Countermeasures Installed & Functioning	8	8	4 to 9 (B)	4 to 9 (B)
Minor Foundation Exposure	8	5	6, 7, 8, 9 (A)	6 or 7 (A)
Moderate Foundation Exposure	4	3	4, 5, 6 (A)	4, 5, 6 (C or D)
Major Foundation Exposure	2	2	2 or 3 (C or D)	2 (C or D)
Bridge Closed	1	1	1 (C or D)	1 (C or D)
Bridge Failed	0	0	0	0

Scour Critical Bridges

- Classification for a bridge that is unstable or may become unstable, as determined by a scour appraisal
  - Item 113 coded as a 3, 2, or 1
    - Observed scour depth in the “Major” scour category
    - Calculated scour depth in the “Extreme” scour category
- Requires a Plan of Action
- Requires back-calculation to confirm scour critical results

In-Depth Capacity Analysis

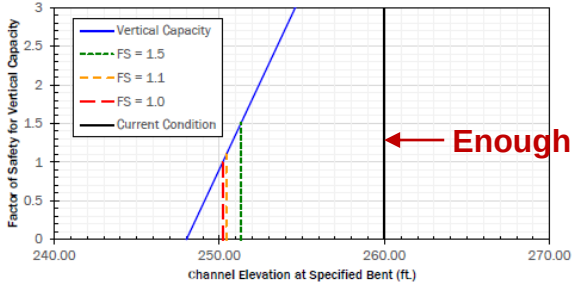
- Bridged determined to be scour critical from previous assumptions



BENT NO.	6	DATE DRIVEN	7-9-62	PILE SIZE	15" Sq.	DESIGN LOAD	33 Tons
A	37	37.00		20.42	.050	100 ✓
B	37	37.00		20.20	.000	150 ✓
C	37	37.00		20.40	.050	100 ✓
D	37	35.86	1.14	19.13	.000	150 ✓
E		37.00	18.48			

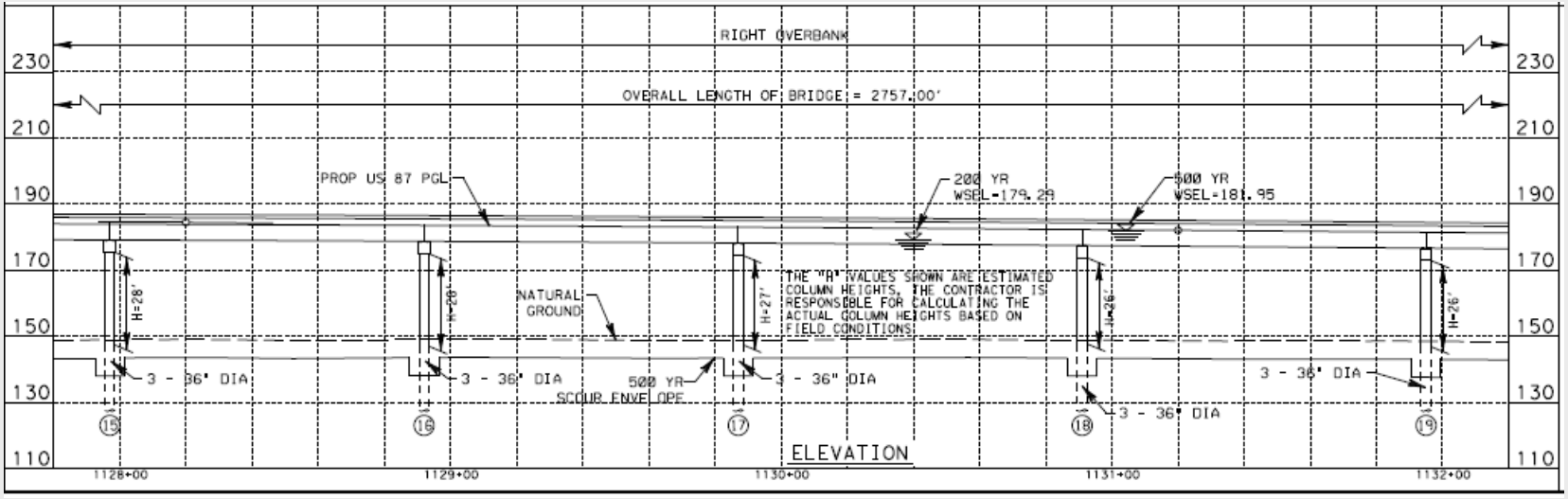
Intersection:
Bent:
Pile:
NBI #:
CCSJ:

Factor of Safety	Channel Elev. (ft.)
1.5	251.3
1.1	250.4
1	250.2



New Structures

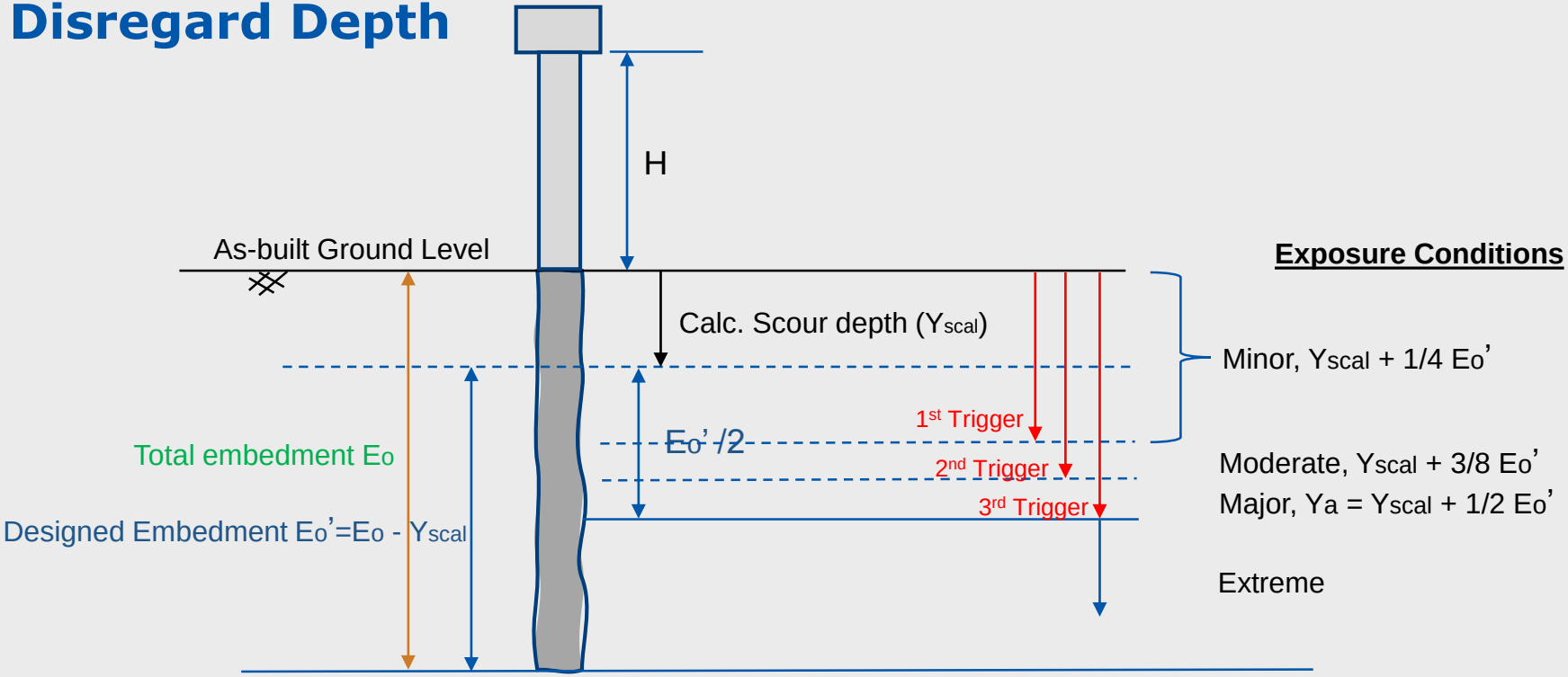
- Scour Analysis based on hydraulic and hydrologic analysis **required** for all bridges
- Bridges designed to resist damage resulting from the scour design flood



Scour Analysis Methods

- Contraction Scour
  - Traditional HEC-18 method
    - Sandy Soils
  - SRICOS method
    - Clay and soft rock
  - Pressure method
    - Water above bridge low chord
- Pier Scour
  - Traditional HEC-18 method
    - Sandy Soils
  - SRICOS method
    - Clay and soft rock
  - Annandale's Erodibility Index method
    - Fractured/jointed rock

Disregard Depth

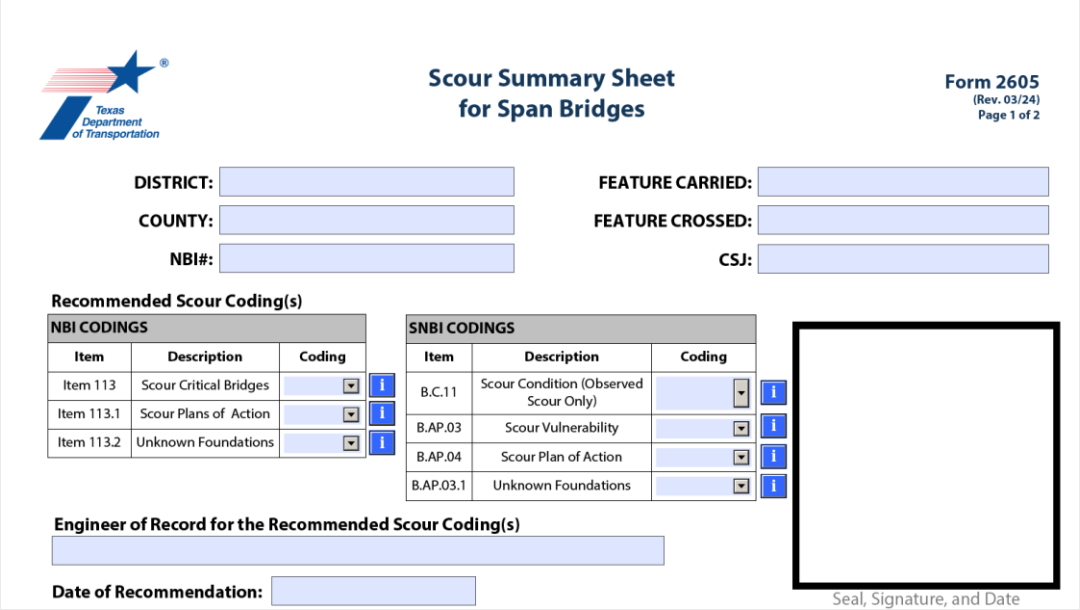


Inspection Database Information

- Scour Summary Sheet
  - Trigger elevation
  - Observed scour depth
  - Maximum allowable scour depth
  - Evaluation notes
  - Maintenance history
- As-built plans
  - Soil borings
  - Foundation Depth
- Inspection Reports
  - Channel profile
  - Inspector notes
- Inspection Photos
  - Channel Condition

Scour Summary Sheet

- Bridge inspectors check if scour exceeds trigger elevation
  - Structure is flagged for reevaluation



Texas Department of Transportation

Scour Summary Sheet for Span Bridges

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DISTRICT: | FEATURE CARRIED:
COUNTY: | FEATURE CROSSED:
NBI#: | CSJ:

Recommended Scour Coding(s)

NBI CODINGS

Item	Description	Coding
Item 113	Scour Critical Bridges	
Item 113.1	Scour Plans of Action	
Item 113.2	Unknown Foundations	

SNBI CODINGS

Item	Description	Coding
B.C.11	Scour Condition (Observed Scour Only)	
B.AP.03	Scour Vulnerability	
B.AP.04	Scour Plan of Action	
B.AP.03.1	Unknown Foundations	

Engineer of Record for the Recommended Scour Coding(s)

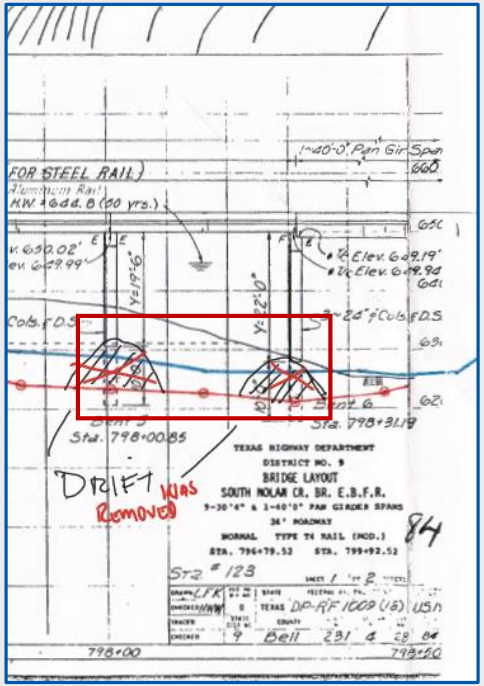
Date of Recommendation:

Seal, Signature, and Date

Evaluation Examples

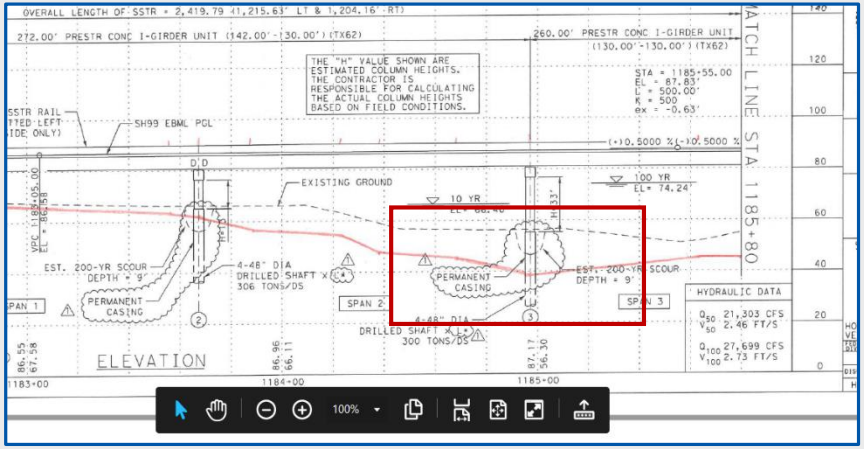
PHOTO 10

Description 10_Bent 5 drilled shafts are exposed 3 ft high (Looking South)



SCOUR DEPTHS		
☑ Scour depths are measured from the as-built channel profile.		
☐ Scour depths are measured from:		
Abutment or Bent #	Bent #5	Bent #6
y_{ab}	8.6'	8.5'
y_{al}	19.6'	17.8'
Max Allowable Scour Depth[1]	8.6'	8.5'
Max Possible Scour Depth[2]	6.1'	6.3'
Calculated Contraction Scour	-	-
Calculated Pier Scour	-	-
Total Calculated Scour Depth		
Observed Scour Depth	5.7'	5.8'

Evaluation Examples



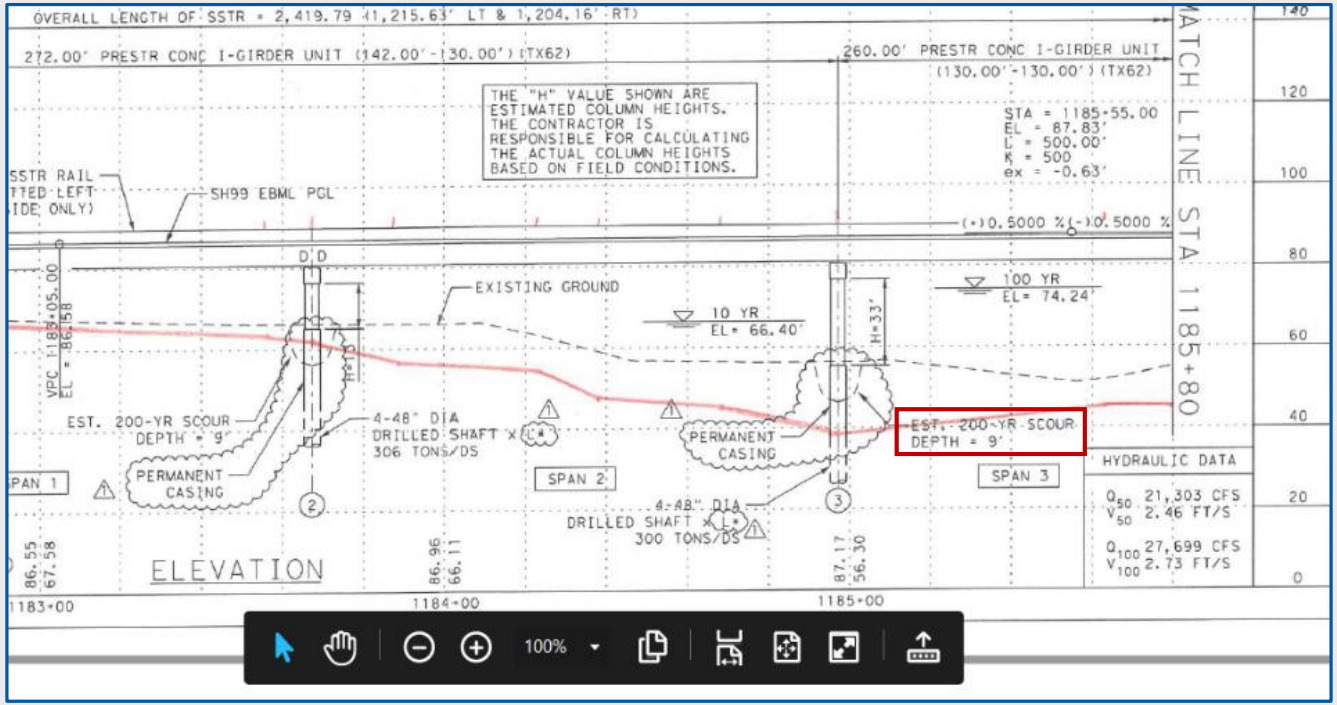
Latest Inspection Channel Profile

- As-built survey at Center Line, Inspection measured Downstream

Latest Inspection Photo:
New bridge with no Scour

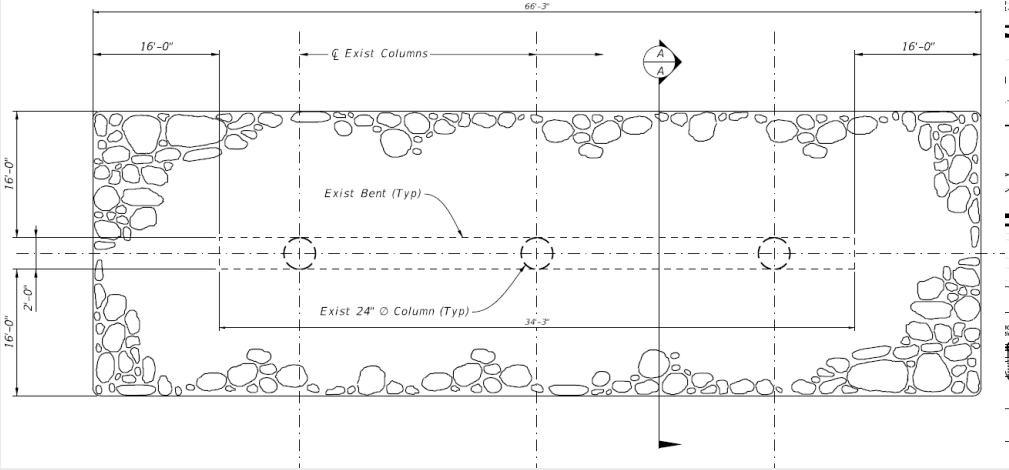
Evaluation Examples

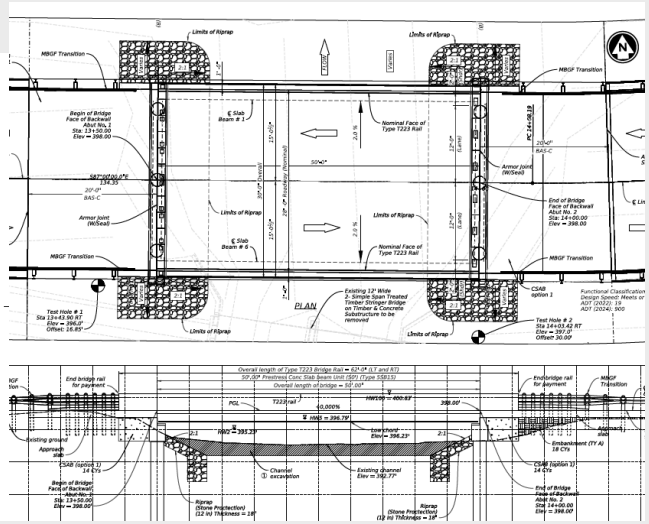
- Scour depth assumed in design



Designed Countermeasure

- Detail sheet including fully detailed plan
- Calculations in accordance with design in HEC 23 and based on calculated hydraulic data (flow velocity) at the bridge

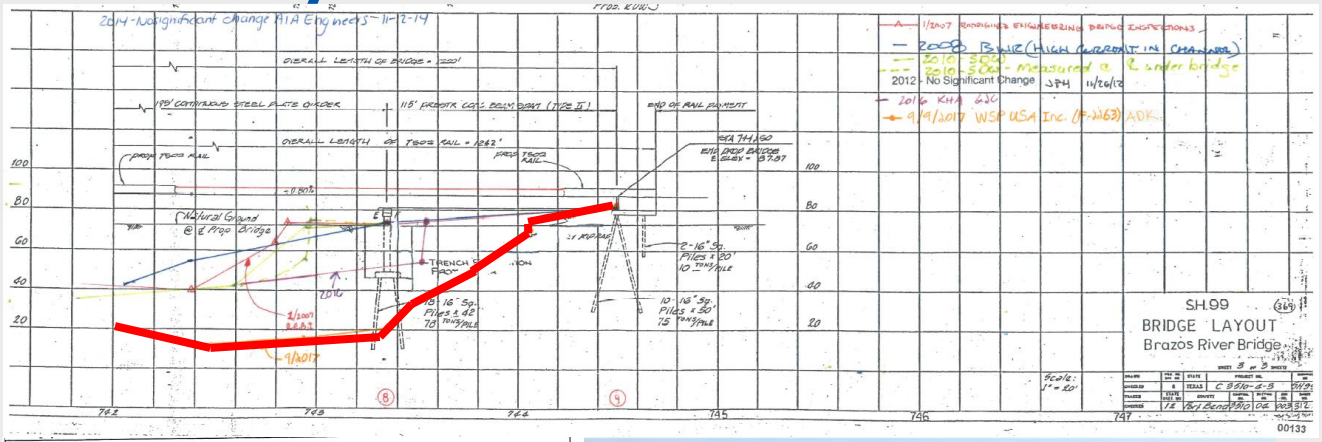


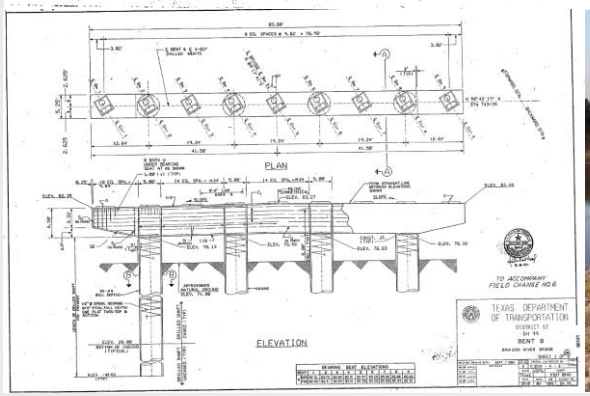


Not-Designed Countermeasure

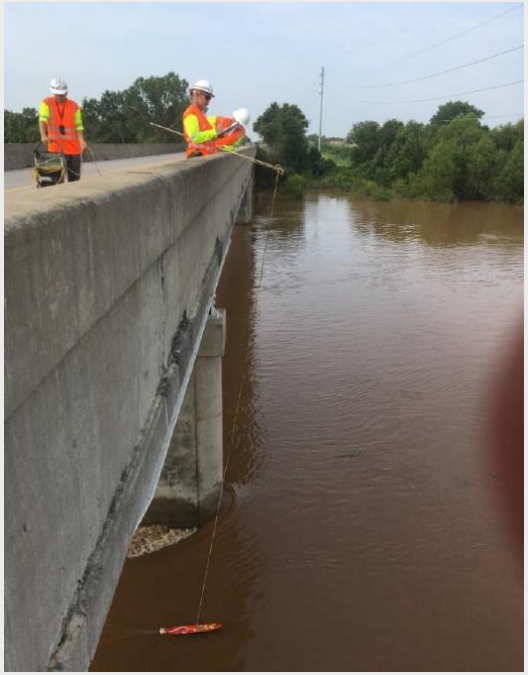
- Countermeasure may not be able to handle common flows
- Countermeasures can have a negative effect on structure if effects are not evaluated
- May not fully arrest the scour

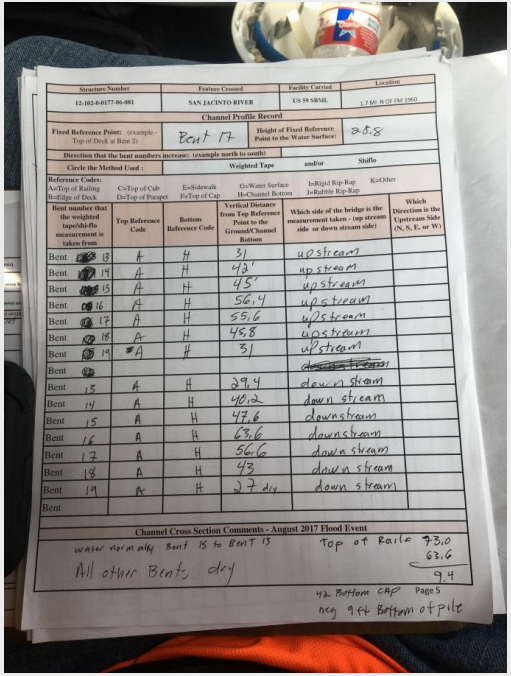
As-Built Accuracy





Scour Response Efforts





Structures Number: 12-102-0-0177-06-081 | Feature Crossed: SAN JACINTO RIVER | Facility Carried: US 59 SBNL | Location: 1.7 MI N OF FM 1960

Channel Profile Record

Fixed Reference Point: (example: Top of Deck at Bent 2): Bent 17 | Height of Fixed Reference Point to the Water Surface: 20.8

Direction that the bent numbers increase: (example north to south)

Circle the Method Used: Weighted Tape and/or Shiflo

Reference Codes: A=Top of Railing, B=Edge of Deck, C=Top of Cub, D=Top of Parapet, E=Sidewalk, F=Top of Cap, G=Water Surface, H=Channel Bottom, I=Rigid Rip-Rap, J=Rubble Rip-Rap, K=Other

Bent number that the weighted tape/shi-flo measurement is taken from	Top Reference Code	Bottom Reference Code	Vertical Distance from Top Reference Point to the Ground/Channel Bottom	Which side of the bridge is the measurement taken - (up stream side or down stream side)	Which Direction is the Upstream Side (N, S, E, or W)
Bent 13	A	H	31	upstream	
Bent 14	A	H	42'	upstream	
Bent 15	A	H	45'	upstream	
Bent 16	A	H	56.4	upstream	
Bent 17	A	H	55.6	upstream	
Bent 18	A	H	45.8	upstream	
Bent 19	A	H	31	upstream	
Bent					
Bent 13	A	H	29.4	down stream	
Bent 14	A	H	40.2	down stream	
Bent 15	A	H	47.6	downstream	
Bent 16	A	H	63.6	downstream	
Bent 17	A	H	56.6	down stream	
Bent 18	A	H	43	down stream	
Bent 19	A	H	27 dry	down stream	
Bent					

Channel Cross Section Comments - August 2017 Flood Event

water normally Bent 15 to Bent 13 Top of Raile 73.0 63.6 9.4

All other Bents dry

42 Bottom CAP Page 5

neg 9 ft Bottom of pile

Conclusions

- Required documentation should be tailored to:
  - Optimize emergency response
  - Determine when reanalysis is required
  - Prioritize structures to be replaced
  - Determine which structures need repair
- Prior preparation is essential to ensure public safety and minimize traffic disruption

Questions?

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