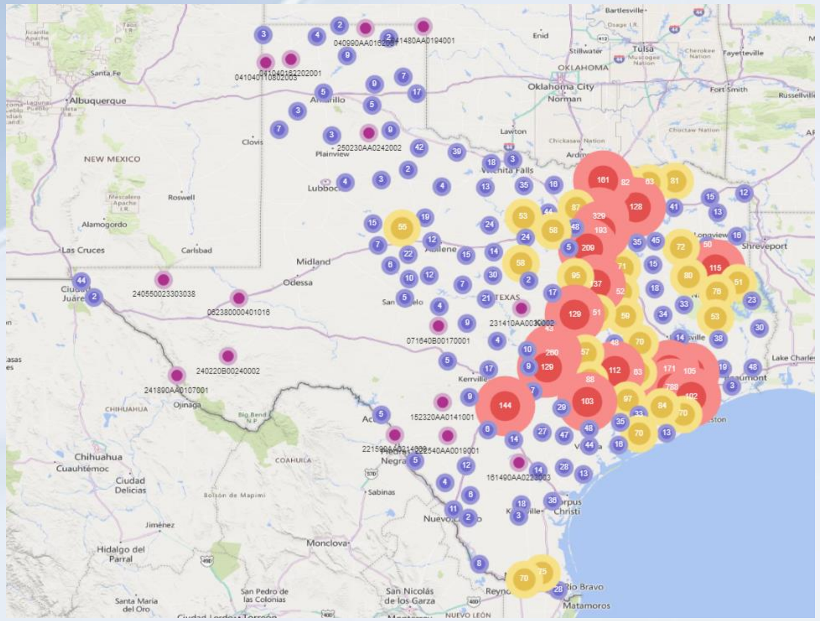
Nondestructive Testing and Evaluation For Unknown Foundations In Texas

Steven Austin, TxDOT

Shane Boone, BDI

Texas Bridge Inventory

- +56,000 bridges in Texas
  - +20,000 locally owned
  - +7,000 with unknown foundations



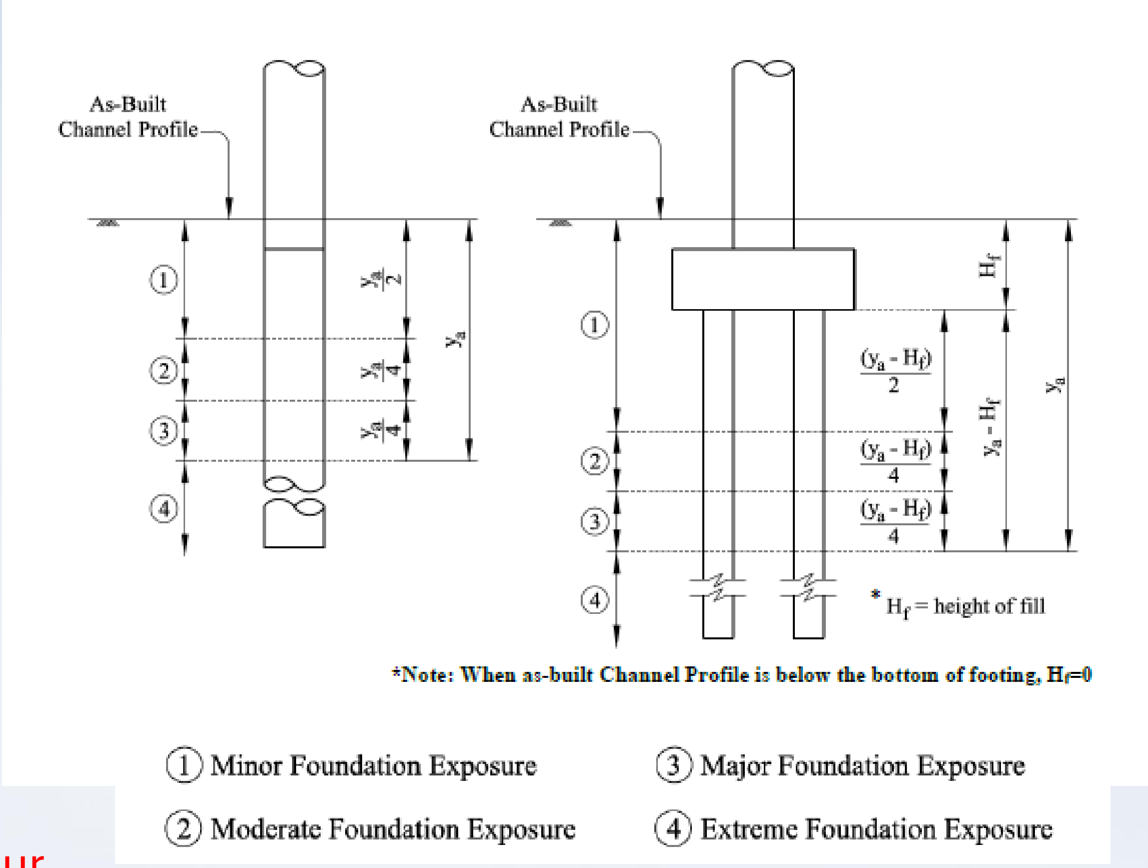
Bridge Scour Risk

- Bridges with known foundations vs bridges unknown foundations

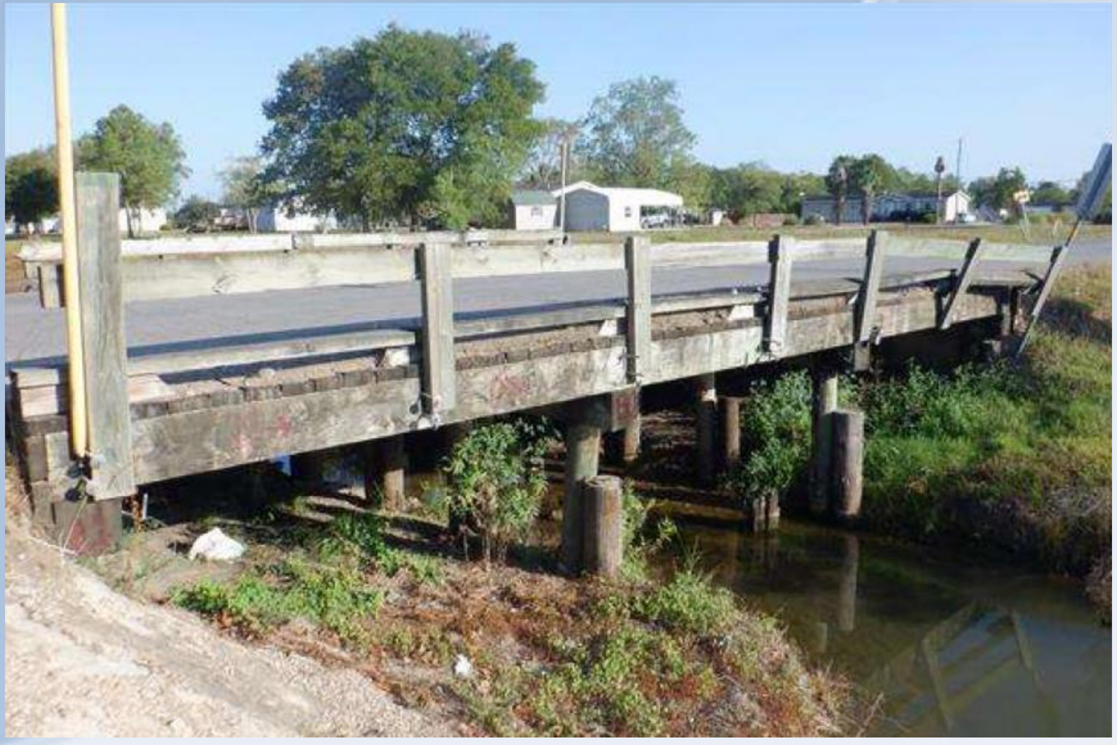
Bridge Scour Risk

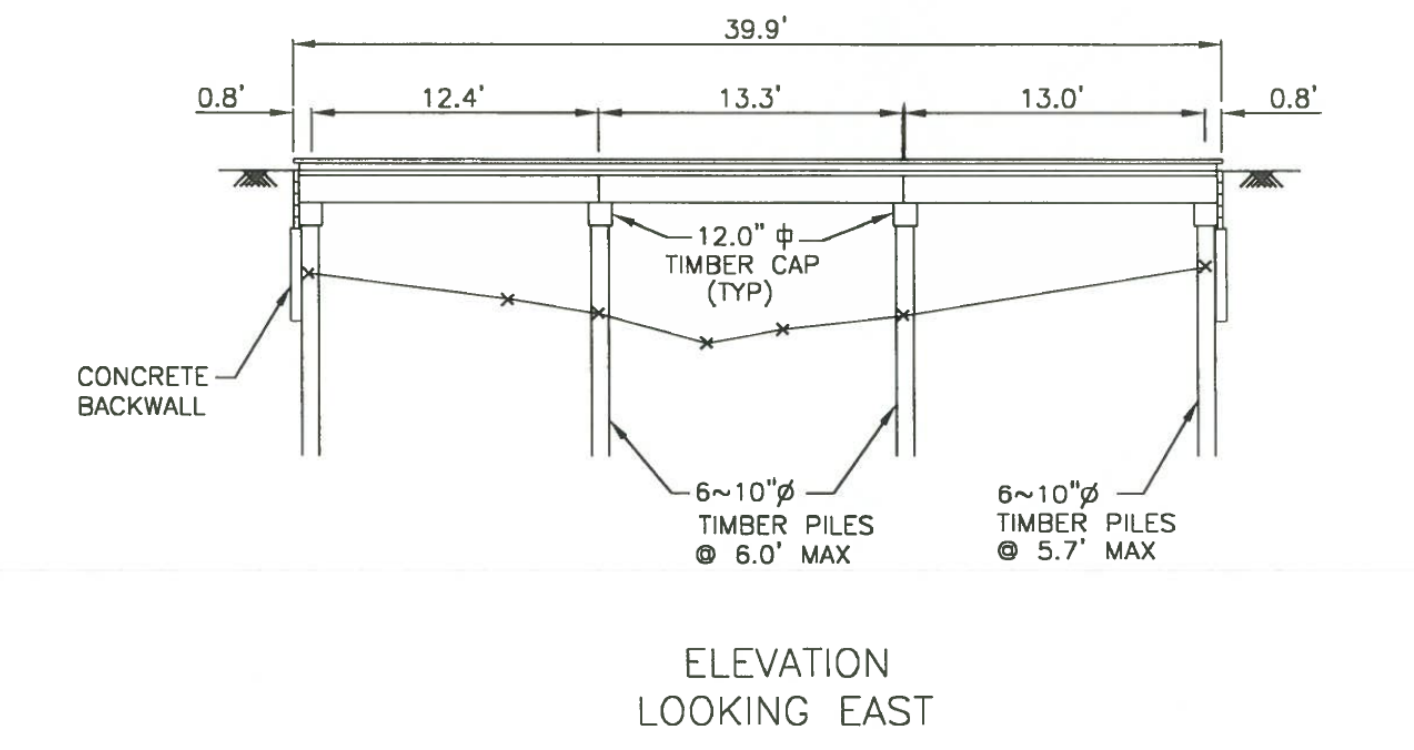
Code	Descriptions for Span Bridges
N	Bridge is not over waterway.
U	Unknown foundation and lacking scour evaluation and/or documentation.
T	Over tidal waters and lacking scour evaluation and/or documentation.
9	All foundation components, including piles or shafts, are above flood waters.
8	The calculated scour depth (if applicable) would cause minimal foundation exposure. The observed scour depth has caused minimal foundation exposure.
7	Previously observed scour has been remediated: countermeasures have been installed and are performing well.
6	Lacking scour evaluation and/or documentation.
5	The calculated scour depth would cause moderate foundation exposure. The observed scour depth causes minimal foundation exposure.
4	The observed scour has caused moderate foundation exposure. The calculated scour would cause minimal or moderate foundation exposure. Action is required to address the observed scour.
3	The calculated scour depth would cause major foundation exposure. The observed scour has caused minimal or moderate foundation exposure. A Bridge Scour Plan of Action (Form 2604) is required.
2	Observed scour has caused major foundation exposure. Immediate action is required to remediate the observed scour. A Bridge Scour Plan of Action (Form 2624) is required.
1	Observed scour exceeds the max allowable scour depth. Failure is imminent and the bridge is closed to traffic. A Bridge Scour Plan of Action (Form 2609) is required.
0	Failure has occurred, and the bridge is closed to traffic.

Scour Critical



Timber Piles





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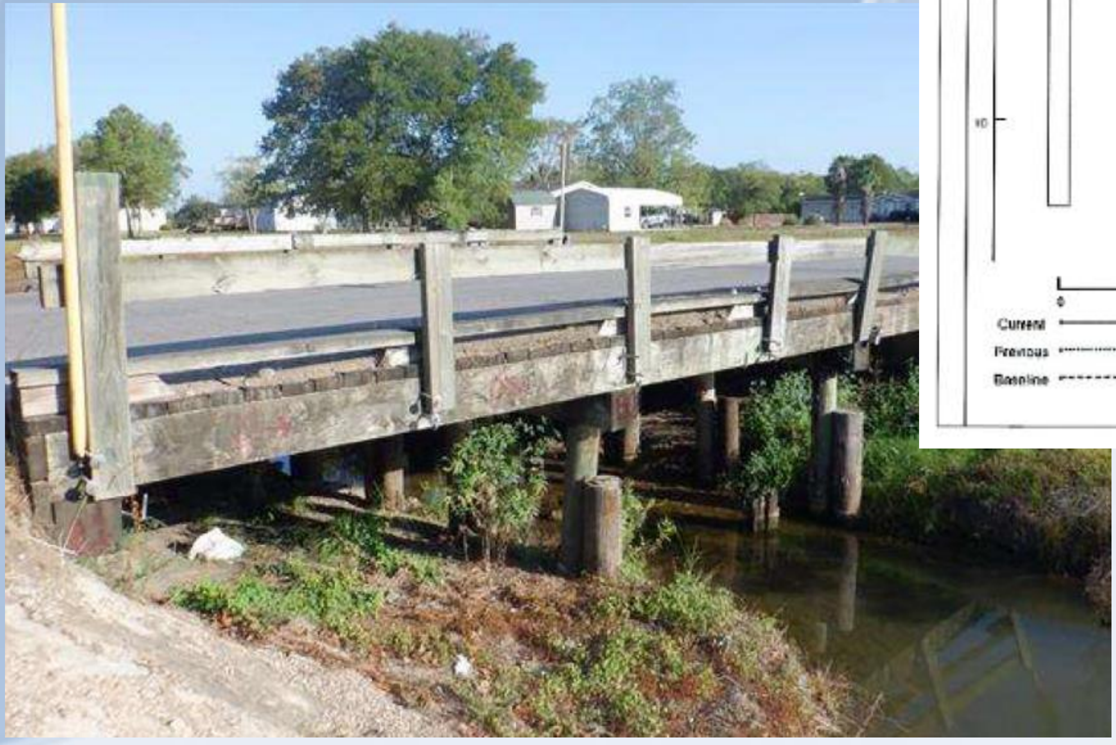
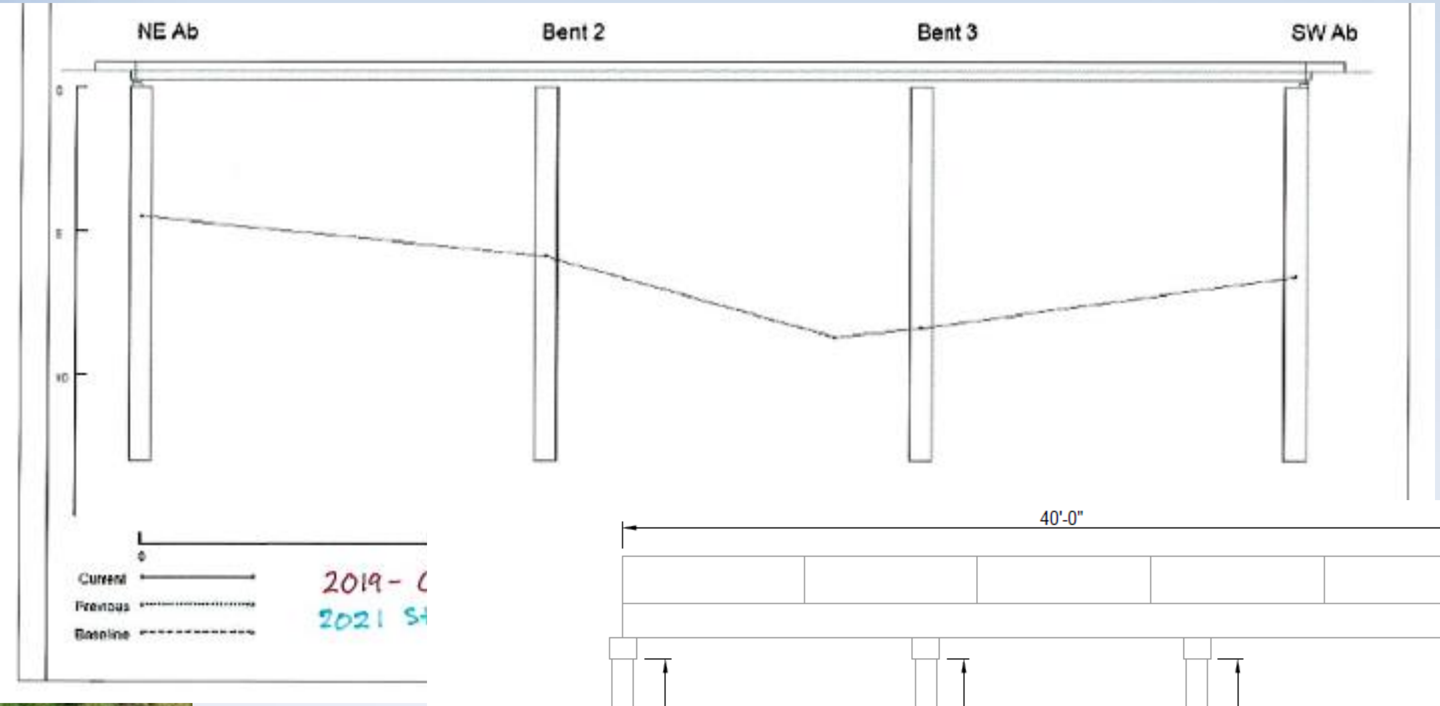
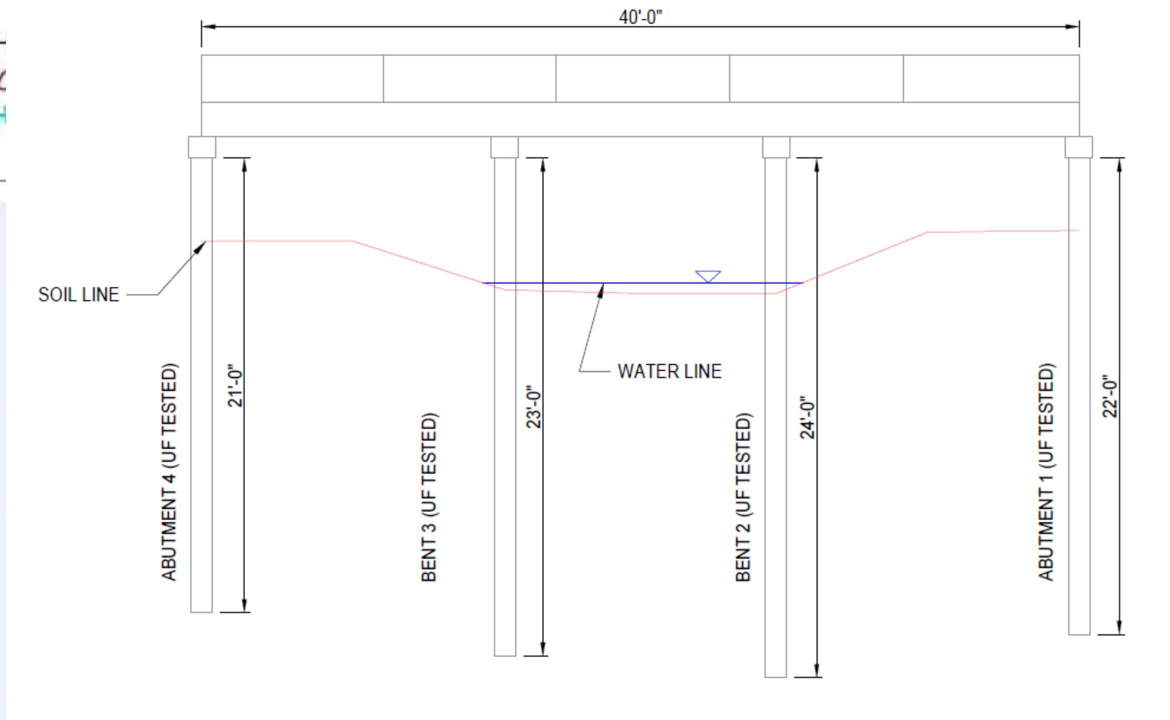
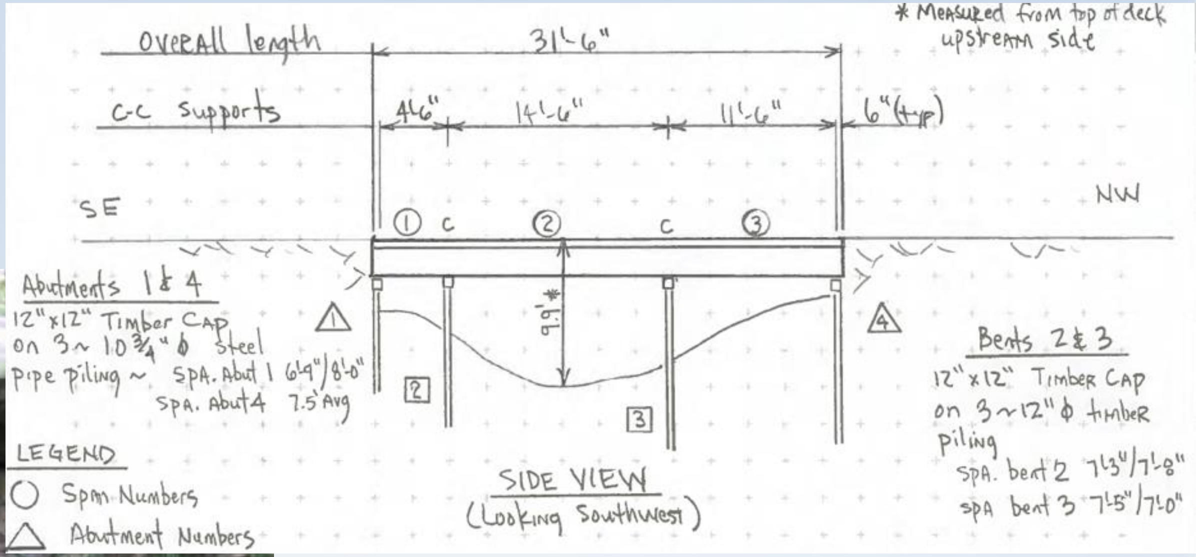
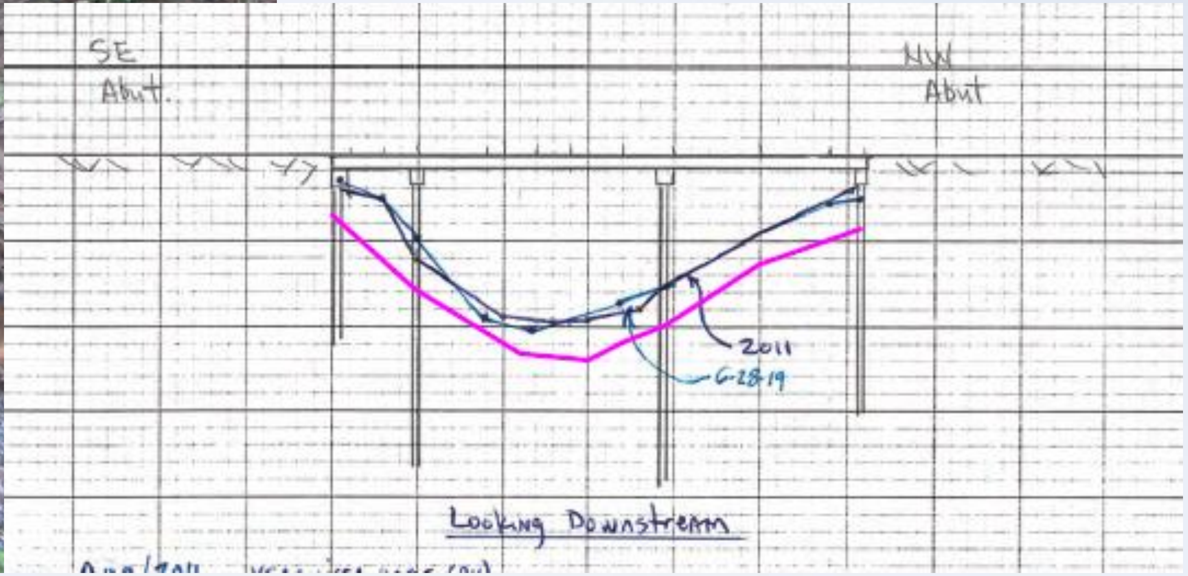




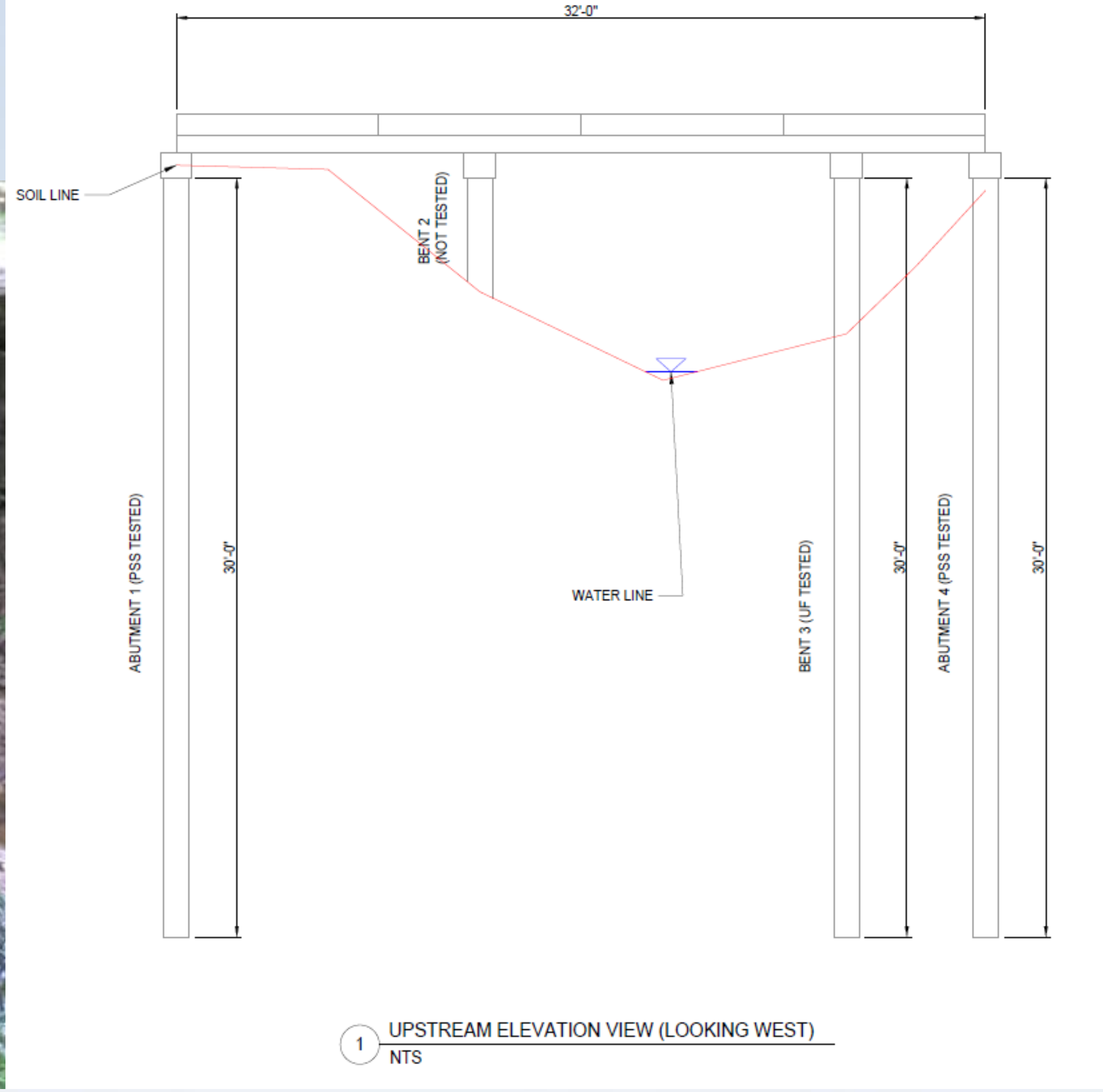


Timber Piles

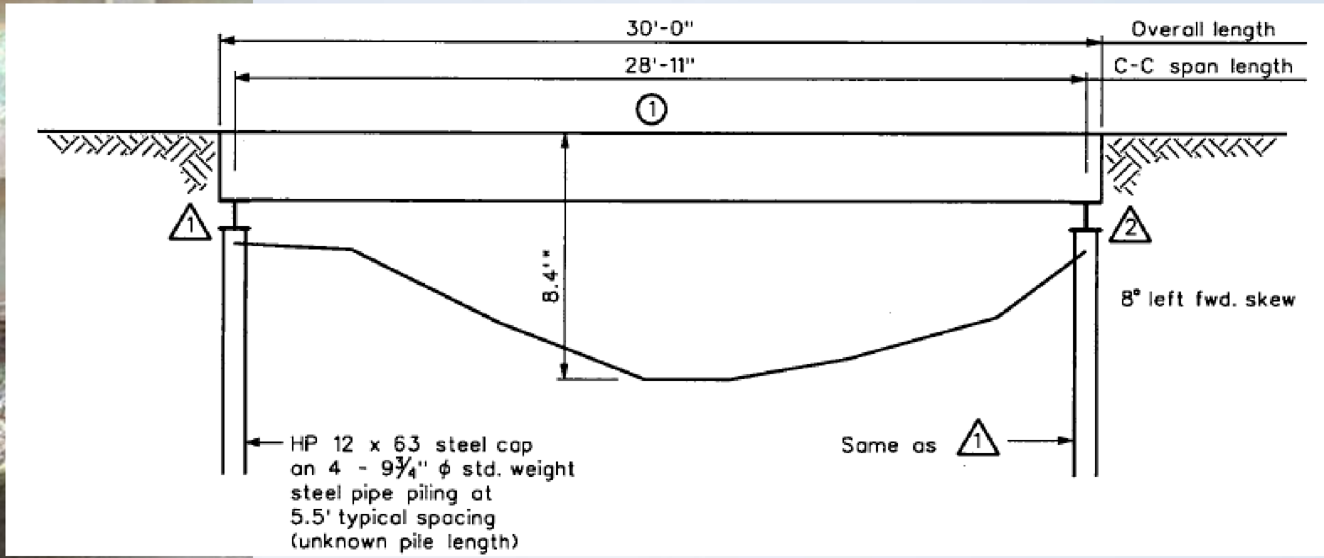




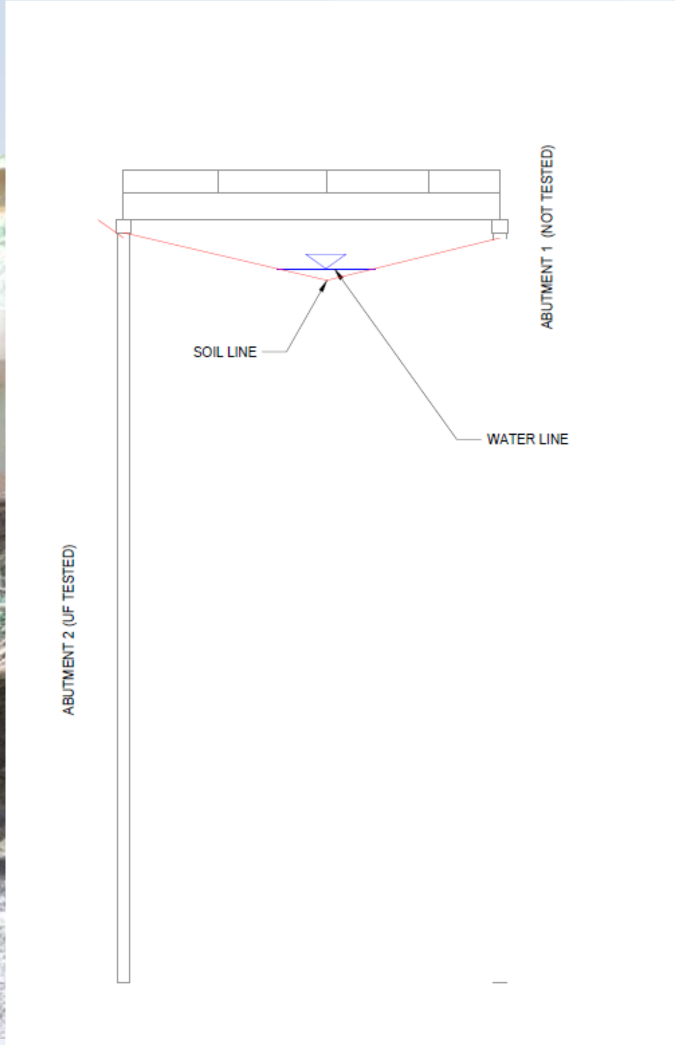
Timber Piles



Steel Piles

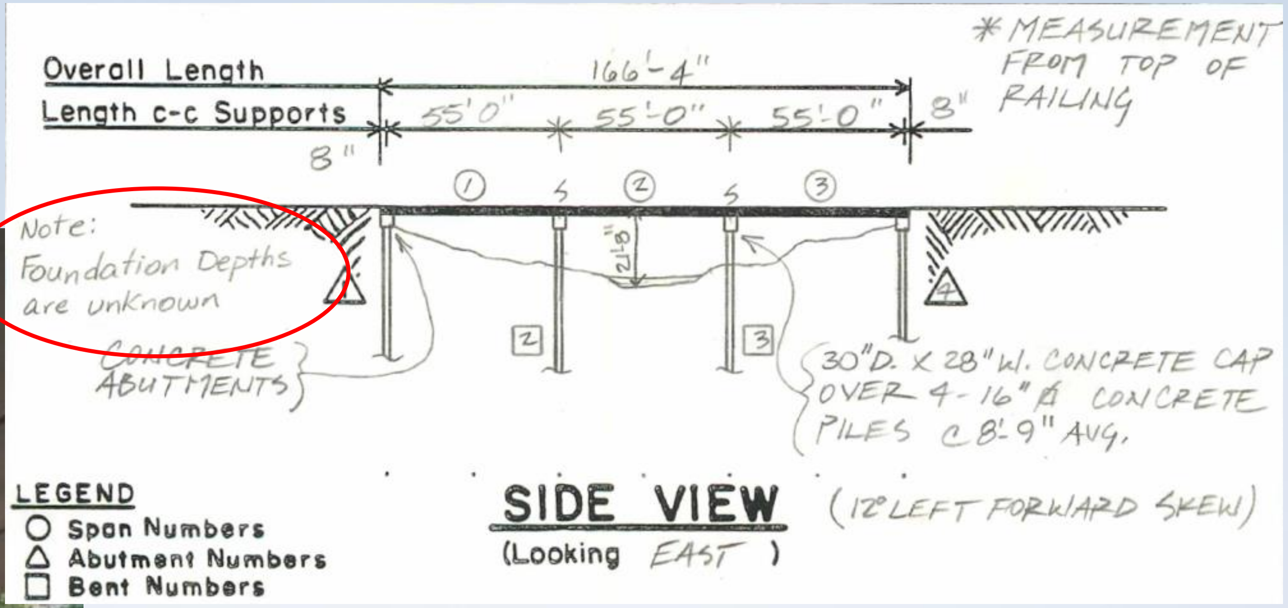

30'-0"
Overall length
28'-11"
C-C span length
1
8.4'
8° left fwd. skew
HP 12 x 63 steel cap
on 4 - 9¾" ϕ std. weight
steel pipe piling at
5.5' typical spacing
(unknown pile length)
Same as 1
2

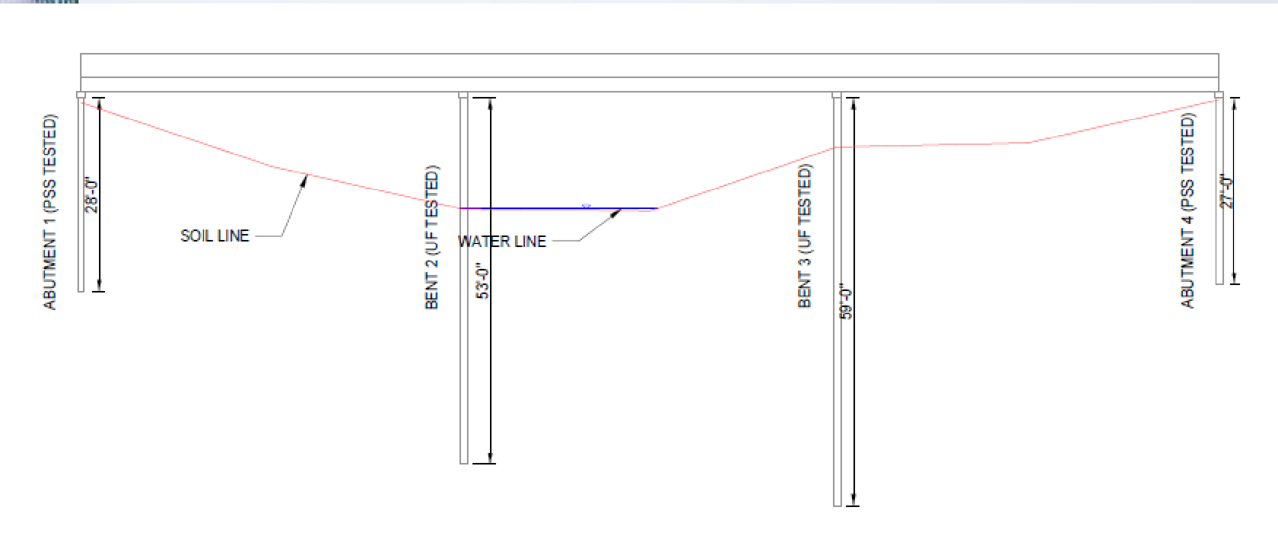
Steel Piles


ABUTMENT 1 (NOT TESTED)
SOIL LINE
WATER LINE
ABUTMENT 2 (UF TESTED)


PILE CAP
2'-8"
2'-6"
SOIL LINE
PILE 3 (NOT TESTED)
PILE 4 (NOT TESTED)
PILE 1 (UF TESTED)
PILE 2 (UF TESTED)
59'-0"
58'-0"

Concrete Piles





Concrete Piles

Scour Summary Sheet for Span Bridges

Form 2605 (rev. 8/20) Page 1 of 2

DISTRICT: HOUSTON
COUNTY: HARRIS
PSN: [redacted]

FEATURE CARRIED: IMPERIAL VALLEY SB
FEATURE CROSSED: GREENS BAYOU
CSJ: B336-25

Recommended Scour Coding(s)

Item 113 - Scour Critical Bridges	3
Item 113.1 - Scour Plans of Action	
Item 113.2 - Unknown Foundations	U

Engineer of Record for the Recommended Scour Coding(s)
[redacted]

Date of Recommendation: Sep 20, 2021

SCOUR EV

Date of Scour Evaluation: Sep

Engineer of Record for Scour Evaluation: [redacted]

Scour Evaluation Method ☐

☑
☐
☐

Scour Summary Sheet for Span Bridges

DISTRICT: HOUSTON
COUNTY: HARRIS
NBI#: [redacted]

FEATURE CARRIED: IMPER
FEATURE CROSSED: GREE
CSJ: B336-

Recommended Scour Coding(s)

Item 113 - Scour Critical Bridges	8
Item 113.1 - Scour Plans of Action	
Item 113.2 - Unknown Foundations	

Engineer of Record for the Recommended Scour Coding(s)
[redacted]

Date of Recommendation: 9/13/2023

SCOUR EVALUATION DETAILS

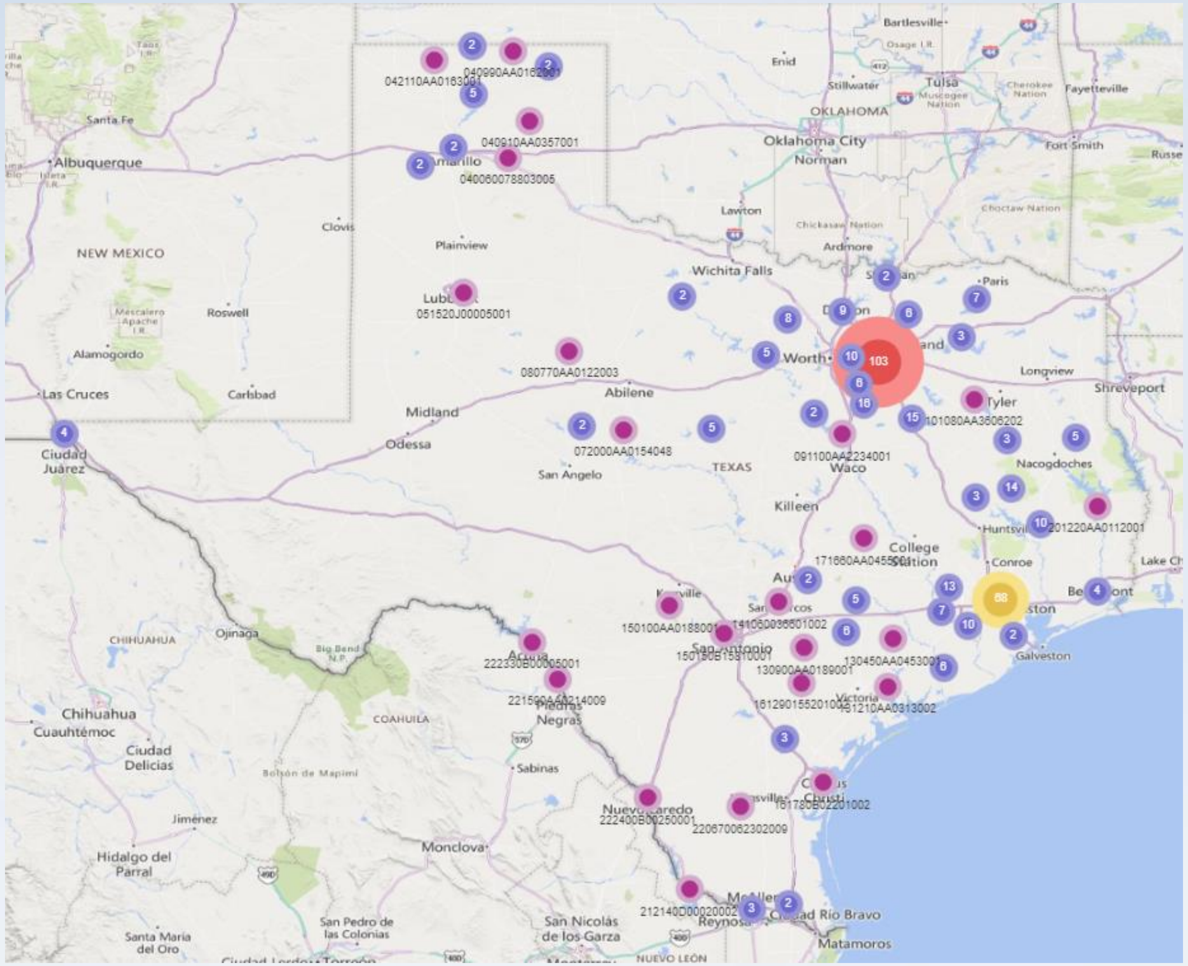
Date of Scour Evaluation: 9/13/2023

Engineer of Record for Scour Evaluation: [redacted]

Scour Evaluation Method
- ☐ Detailed Hydraulic Analysis (indicate me
  - ☐ Traditional HEC-18
  - ☐ FDOT Pier Scour
  - ☐ SRICOS
  - ☐ HEC-18 Reduction (for clayey soi
  - ☐ Annandale's Erodibility Index
  - ☐ Other:
- ☑ Scour Vulnerability Assessment
- ☐ Scour Vulnerability Screening
- ☐ Other:

Texas’ Next Steps for Unknown Foundations

- Complete scour risk assessments.
- Prioritize bridges based on scour risk.
    - Scour coding of 1, 2, or 3
        - <u>**< 400 bridges**</u>



Nondestructive Testing and Evaluation

- Background
- Methods of Testing and Analysis
- Validation

NCHRP 21-5

NCHRP
National Cooperative Highway Research Program

RESEARCH RESULTS DIGEST

December 1996 Number 213

These **Digests** are issued in the interest of providing an early awareness of the research results emanating from projects in the NCHRP. By making these results known as they are developed, it is hoped that the potential users of the research findings will be encouraged toward their early implementation in operating practices. Persons wanting to pursue the project subject matter in greater depth may do so through contact with the Cooperative Research Programs Staff, Transportation Research Board, 2101 Constitution Ave., N.W., Washington, D.C. 20418.

Subject Areas: IIC Bridges, Other Structures, and Hydraulics and Hydrology; IIIA Soils, Geology and Foundations; and IIIB Materials and Construction

Responsible Senior Program Officer: Lloyd R. Crowther

Nondestructive Testing of Unknown Subsurface Bridge Foundations—Results of NCHRP Project 21-5

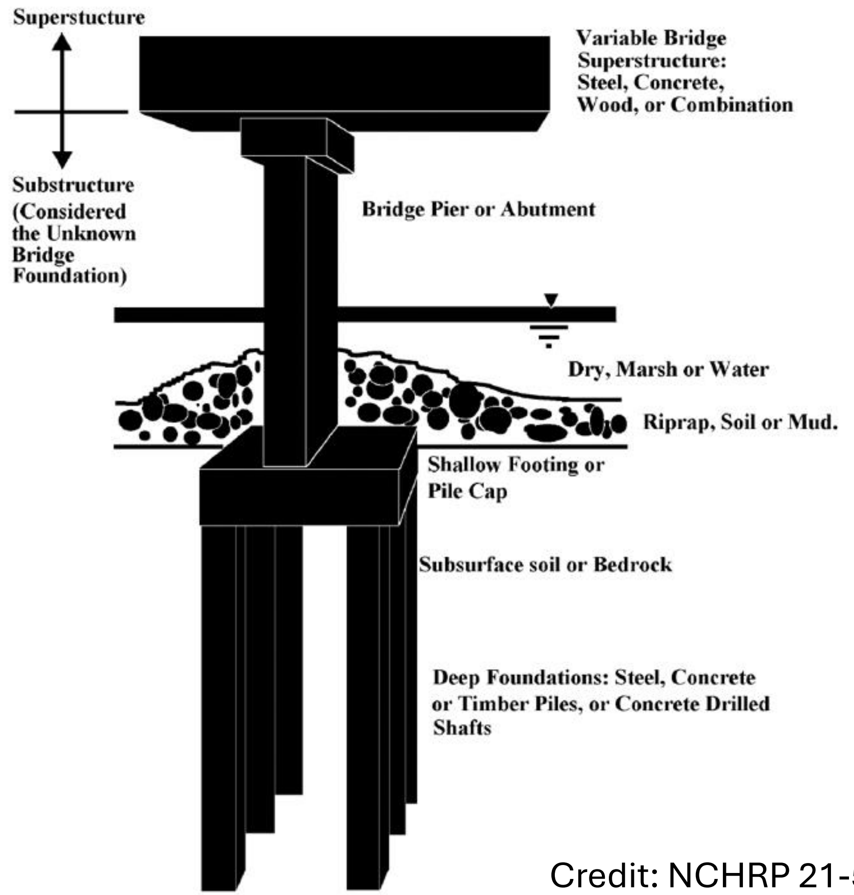
This NCHRP digest presents the findings of NCHRP Project 21-5, "Determination of Unknown Subsurface Bridge Foundations," which evaluates existing and new technologies for use in determining unknown subsurface bridge foundation characteristics. A continuation project (NCHRP Project 21-5(2) is underway, which will research and develop equipment, field technologies, and analysis methods for those new technologies with the most promising application to nondestructive testing of unknown subsurface bridge foundations. This digest was prepared by the staff of Olson Engineering, Inc. The Principal Investigator for the project is Larry D. Olson of Olson Engineering, Inc.

INTRODUCTION

This digest contains information about the feasibility of using nondestructive test (NDT) methods for the determination of unknown depths of bridge foundations. This will be of interest to bridge and other structural engineers; soils, geology, and foundation engineers; and materials and construction engineers.

Of the approximately 580,000 highway bridges in the National Bridge Inventory, many of the older, non-federal-aid bridges have no design plans available. Therefore, no information is available regarding the type, depth, geometry, or material incorporated in the foundations (Elias, 1992; Watson, 1990; Baguelin, et al. 1980). The current best estimate of the population of bridges over water with unknown foundations is 106,000, with 25,000 of the bridges being on-state systems and 81,000 bridges being off-state systems. These unknown bridge foundations pose a significant problem to the departments of transportation (DOTs) of the various states because the Federal Highway Administration (FHWA) is requiring state DOTs to screen and evaluate all bridges to determine their susceptibility to scour. Foundation depth information, in particular, is needed for performing an accurate scour evaluation at each bridge site, along with as much other information on foundation type, geometry, materials, and subsurface conditions as can be obtained.

NCHRP Project 21-5, "Determination of Unknown Subsurface Bridge Foundations," was introduced to evaluate and develop existing and new technologies that could determine subsurface bridge foundation characteristics, where such information was unavailable. The project was carried out in two stages. The first stage consisted of the review and evaluation of existing and proposed technologies having promise for use in determining unknown subsurface bridge foundation characteristics such as depth, type, geometry, and materials; this was followed by development of a research plan. The second stage of the project consisted of evaluating and testing as many of the



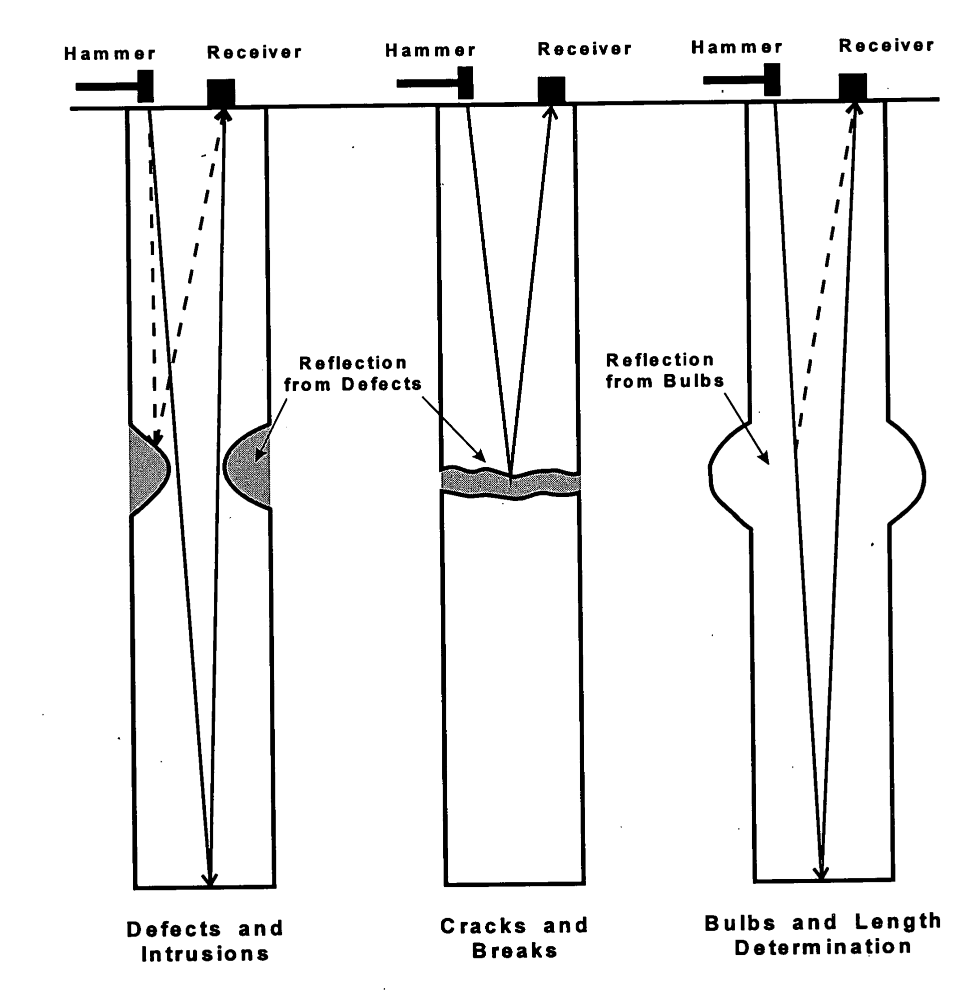
Credit: NCHRP 21-5

NDT-E Primary Methods

- Sonic Echo / Impulse Response
  - Designated by ASTM D5882 – Standard Method for Low Strain Impact Integrity Testing of Deep Foundations
- Ultraseismic Vertical Profiling
  - Developed as part of NCHRP 21-5, "Determination of Unknown Subsurface Bridge Foundations."
- Parallel Seismic Survey
  - One of the oldest, most reliable methods for determining the embedded depth of unknown foundations.
  - Typically used for foundations where access to the pile is restricted (pile caps).

Sonic Echo / Impulse Response (SE/IR)

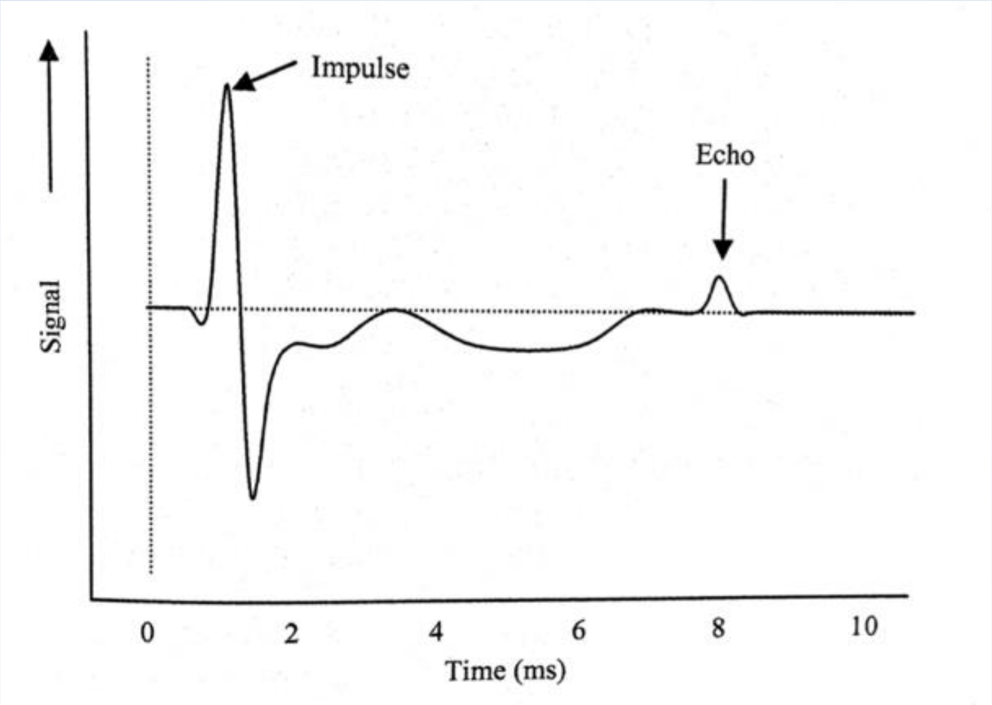
- ASTM D5882
  - Standard Method for Low Strain Impact Integrity Testing of Deep Foundations
- Requires access to the top of the pile or a method to induce compression (P) waves.



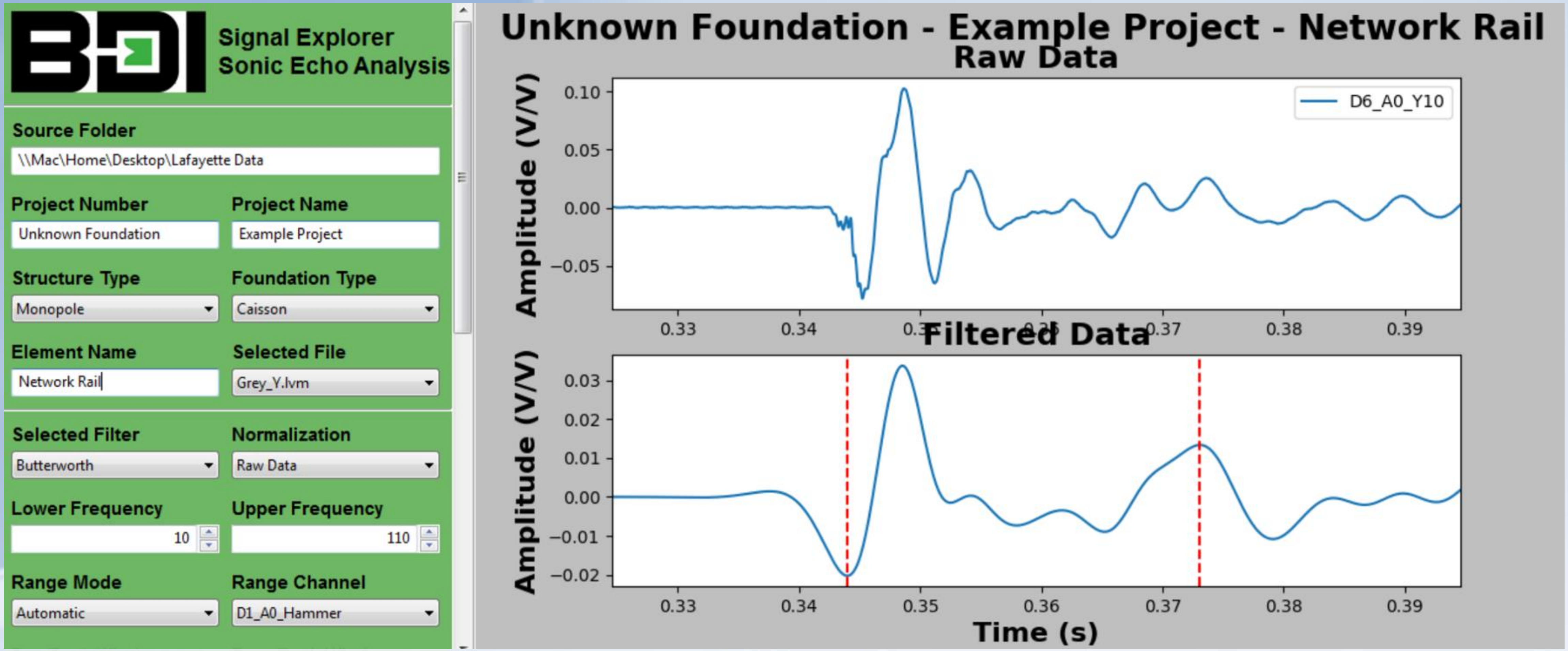
Credit: NCHRP 21-5

SE/IR Analysis

- Data is analyzed in the time domain to identify the impulse and echo of the wave generated.
- With wave speeds measured in the field, the depth is calculated.



Credit: Rashidyan et al., 2016

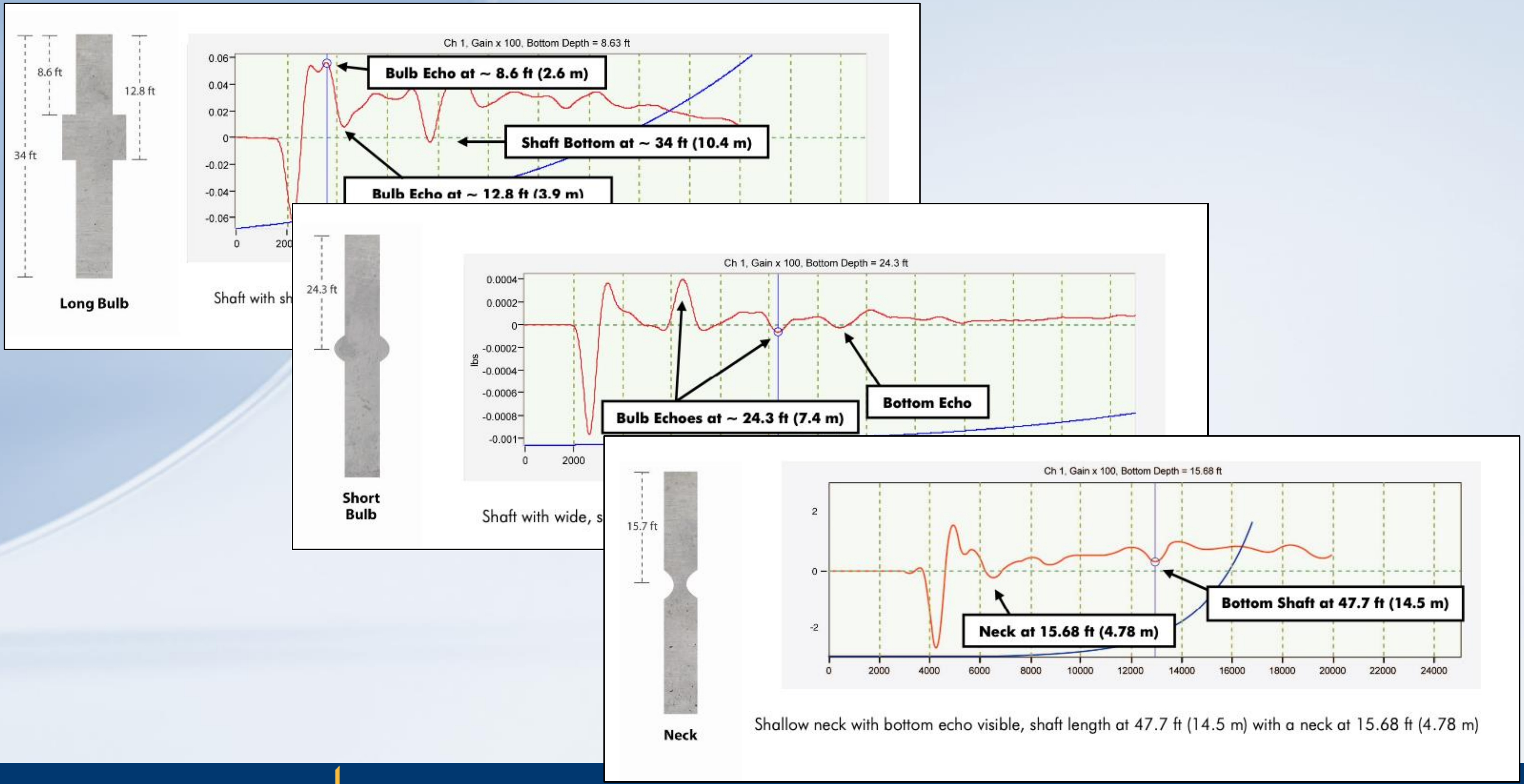

Signal Explorer
Sonic Echo Analysis
Source Folder
\\Mac\Home\Desktop\Lafayette Data
Project Number
Unknown Foundation
Project Name
Example Project
Structure Type
Monopole
Foundation Type
Caisson
Element Name
Network Rail
Selected File
Grey_Y.lvm
Selected Filter
Butterworth
Normalization
Raw Data
Lower Frequency
10
Upper Frequency
110
Range Mode
Automatic
Range Channel
D1_A0_Hammer
Unknown Foundation - Example Project - Network Rail
Raw Data
D6_A0_Y10
Amplitude (V/V)
Filtered Data
Time (s)

Pile Inspection

- Not all piles are perfectly uniform.
- Multiple boundary conditions exist that can cause the reflection analysis to be difficult.

Credit: Olson Instruments, Inc.

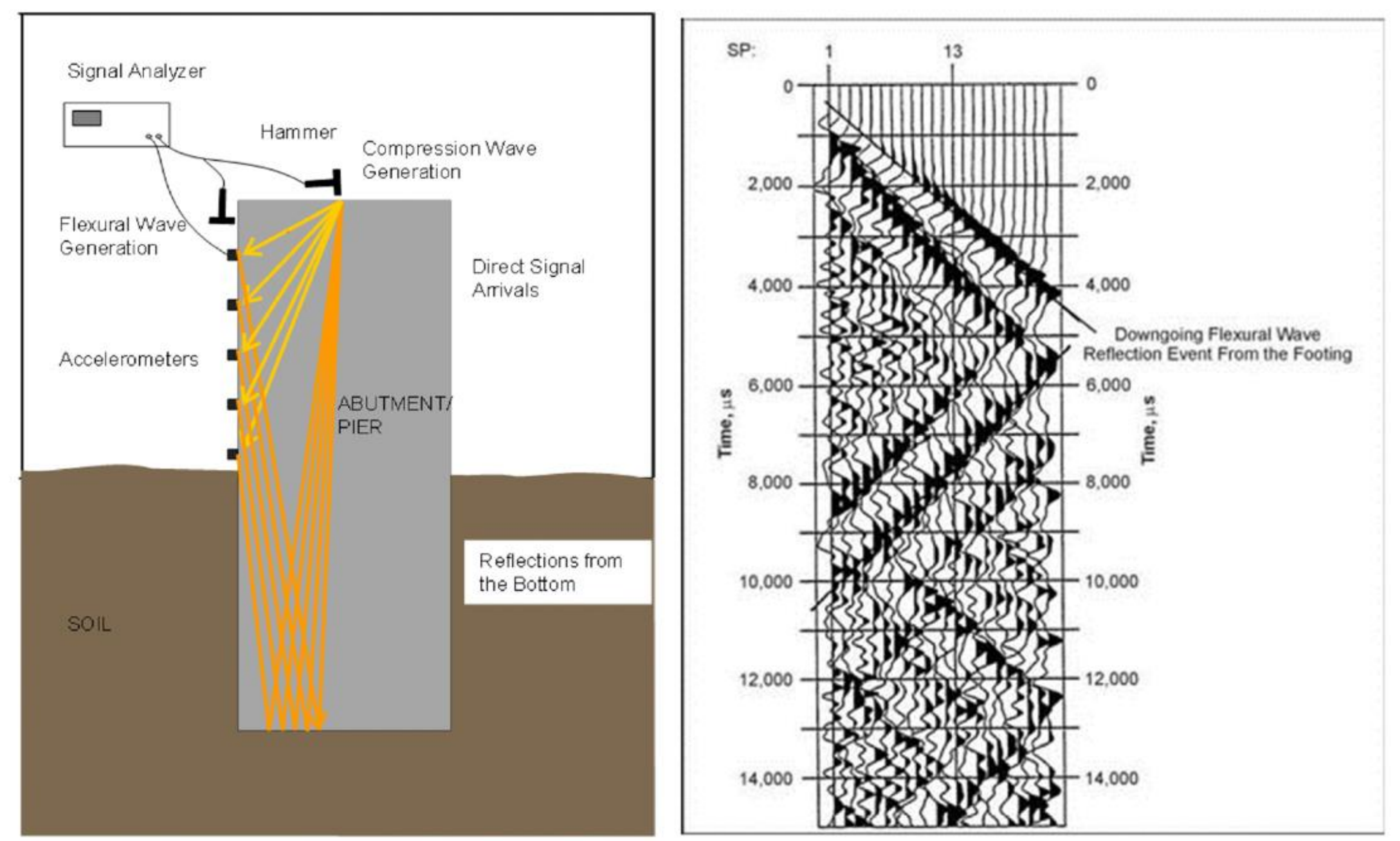
Potentially Difficult Analysis Cases



Credit: Olson Instruments, Inc.

Ultraseismic Vertical Profiling

- Developed during NCHRP 21-05 as an improved method for depth determination when piles are accessible
- Multiple vertical and lateral transducers mounted
- Vertical and lateral impacts to pile



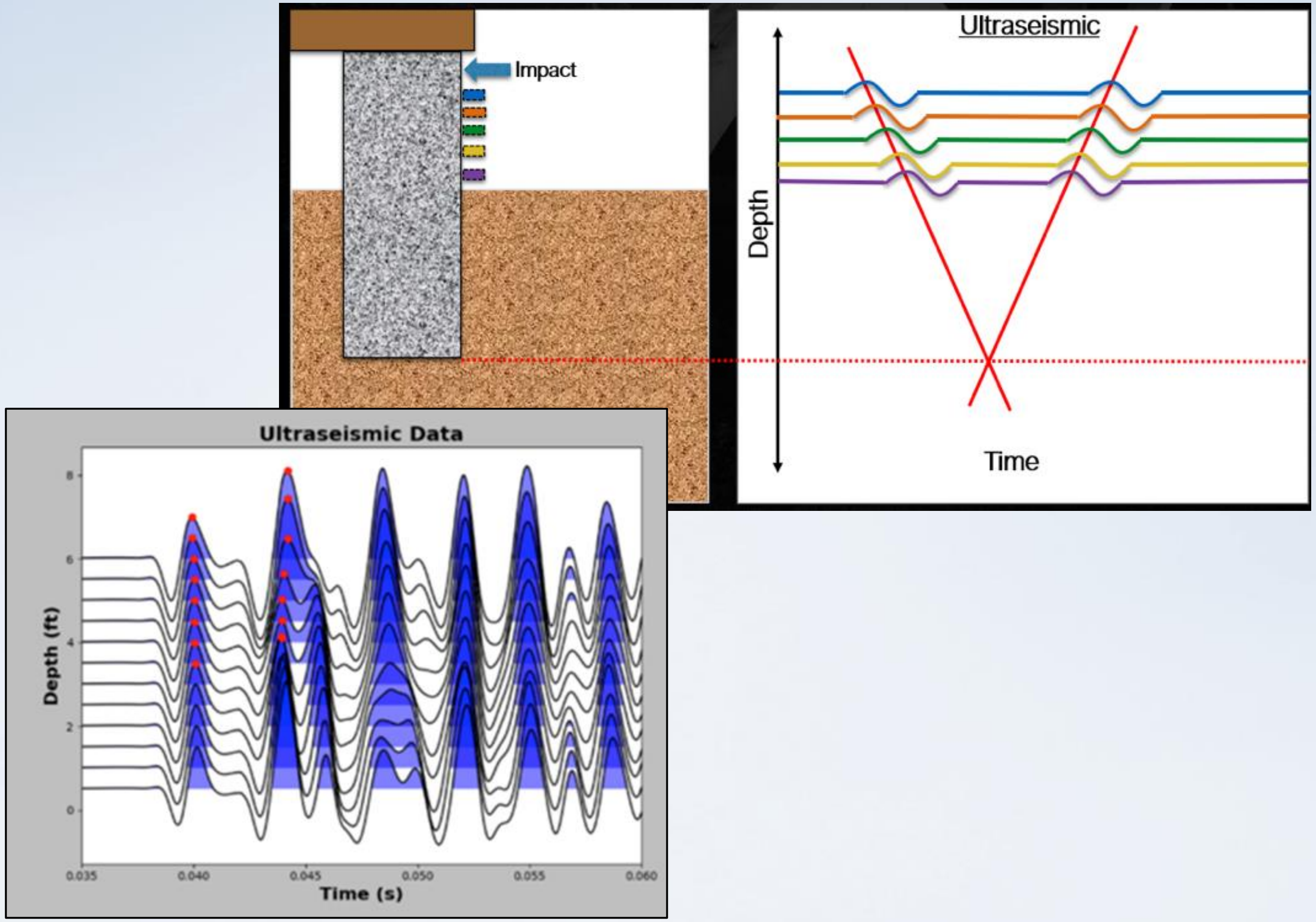
Credit: Jalinoos et al., 2017

Ultraseismic Vertical Profiling Setup

- BDI US setup typically uses 12 mounting locations with 24 total accelerometers with a spacing of 1’ or less.
- Multiple instrumented hammers are utilized to generate dynamic impacts into the pile vertically and laterally.

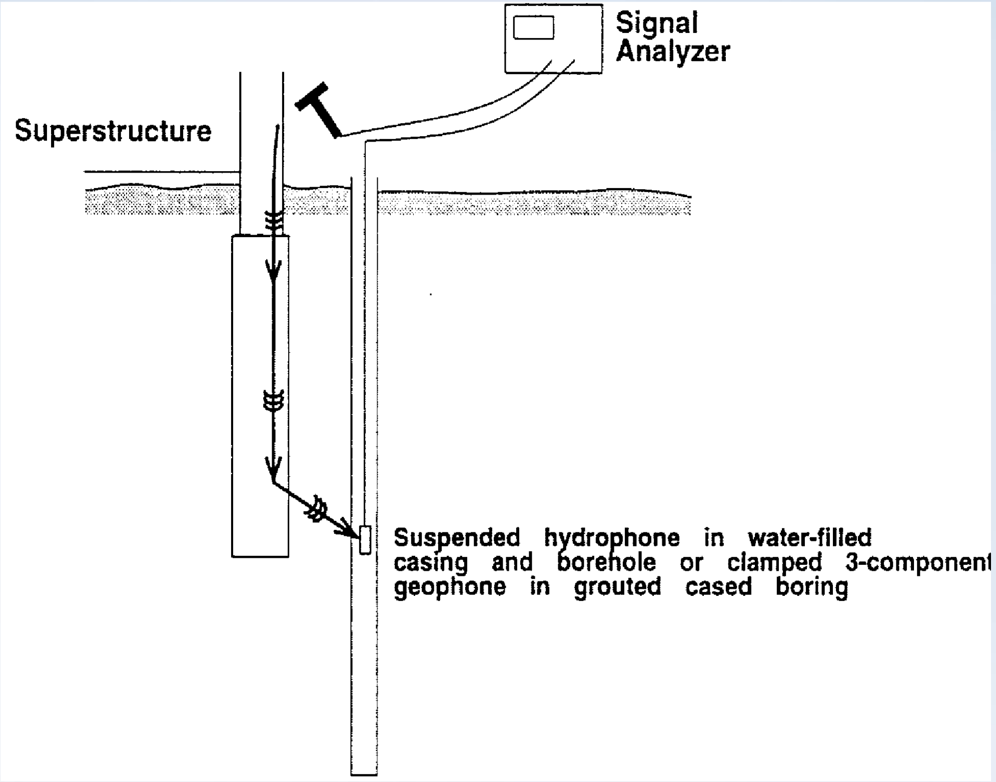
Ultraseismic Vertical Profiling

- Multiple wave reflections allow for the identification of the bottom of the pile
- Typically analyze compression (P) waves as flexural waves have been found to be unreliable (difficult) to analyze in soil of varying strata.



Parallel Seismic Survey

- Typically utilized when access to the pile is not available (pile caps, etc.)
- One of the oldest and most reliable methods to determine embedded depth of unknown foundations.



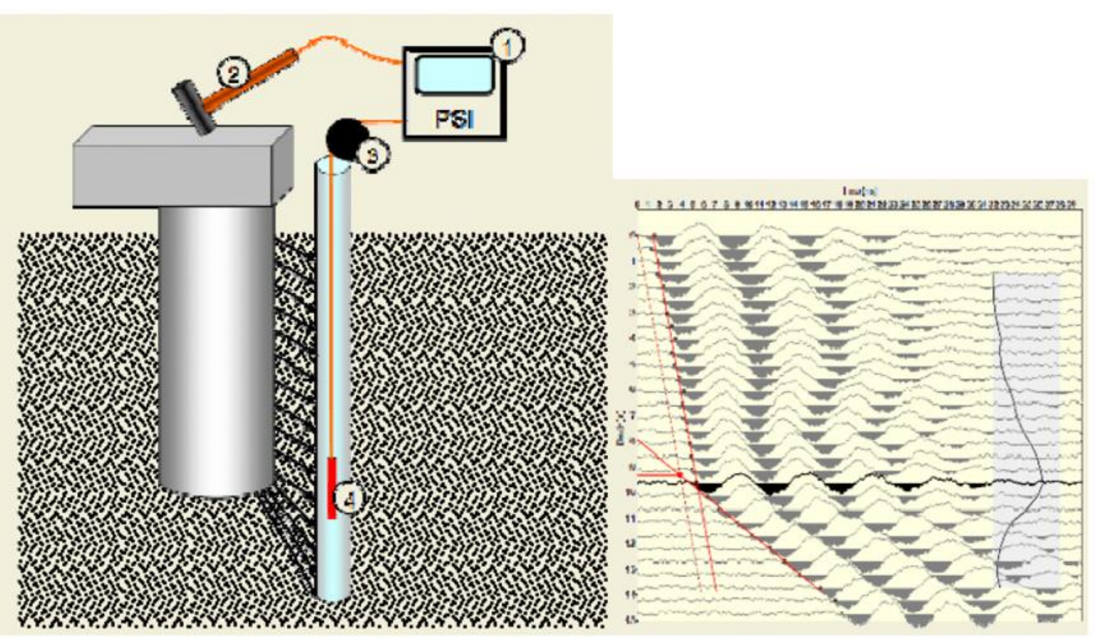
Credit: NCHRP 21-5

Parallel Seismic Survey

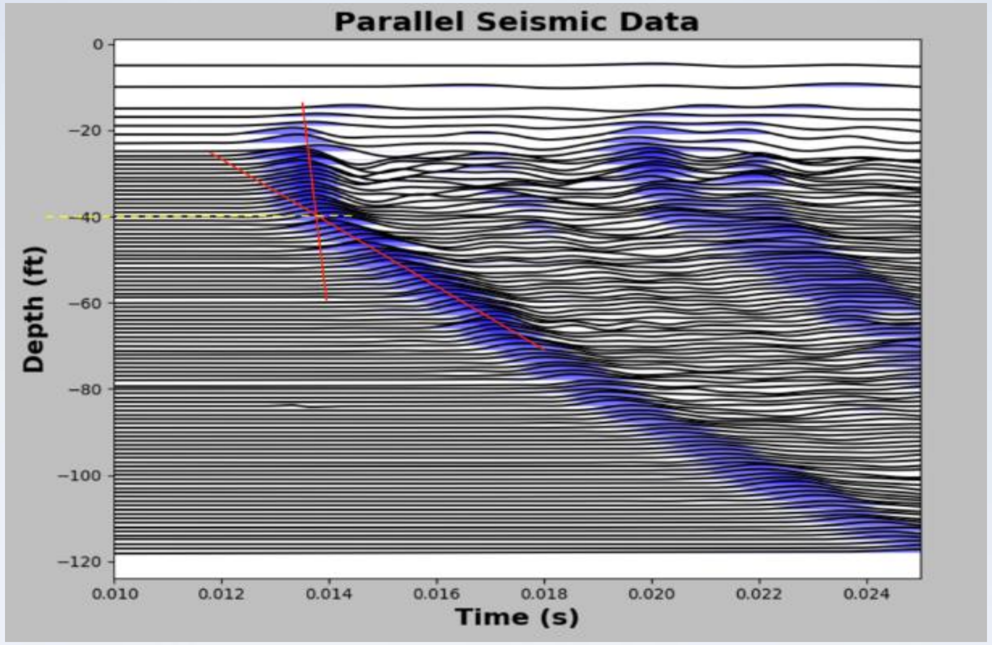
- Hydrophone lowered in 1’ increments into a grout cased borehole.
- Instrumented hammer records time of impact and hydrophone records travel time.

Parallel Seismic Survey

- A change in slope of the wave arrival indicates the bottom of the pile.



Credit: Rybak and Schamowicz, 2008

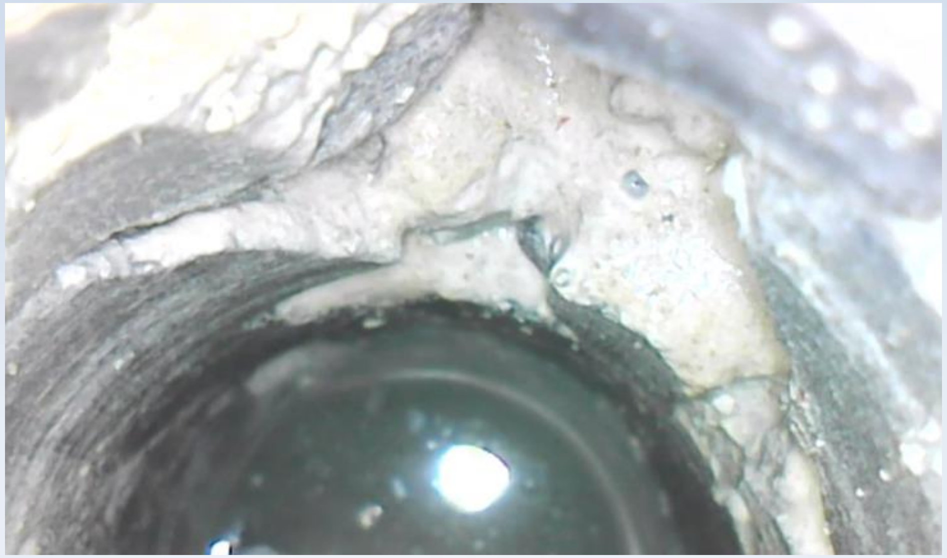


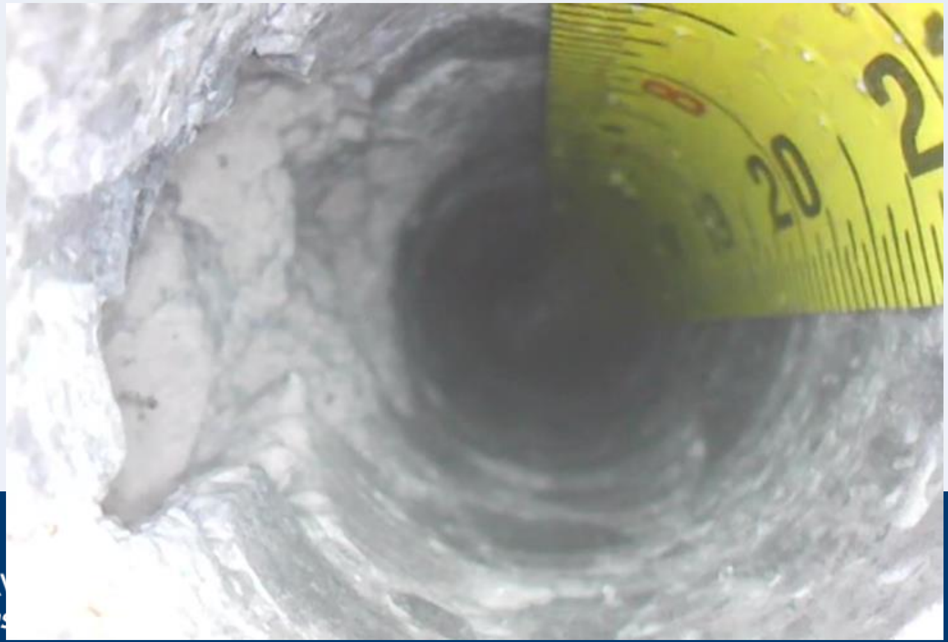
Validation Efforts

- Blind validation study as part of LADOTD Retainer Contract for Determination of Unknown Foundations Statewide
  - 6 bridges; 18 piles tested and recorded within +/- 10%
- ~165 bridges (3 piles each typ.) tested subsequently that have been found to have known depths
  - US methodology within 5%

Validation

- Boring to validate cracking / lack of consolidation.
- Borescope utilized to identify exact cause of integrity issue.





Thank You

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