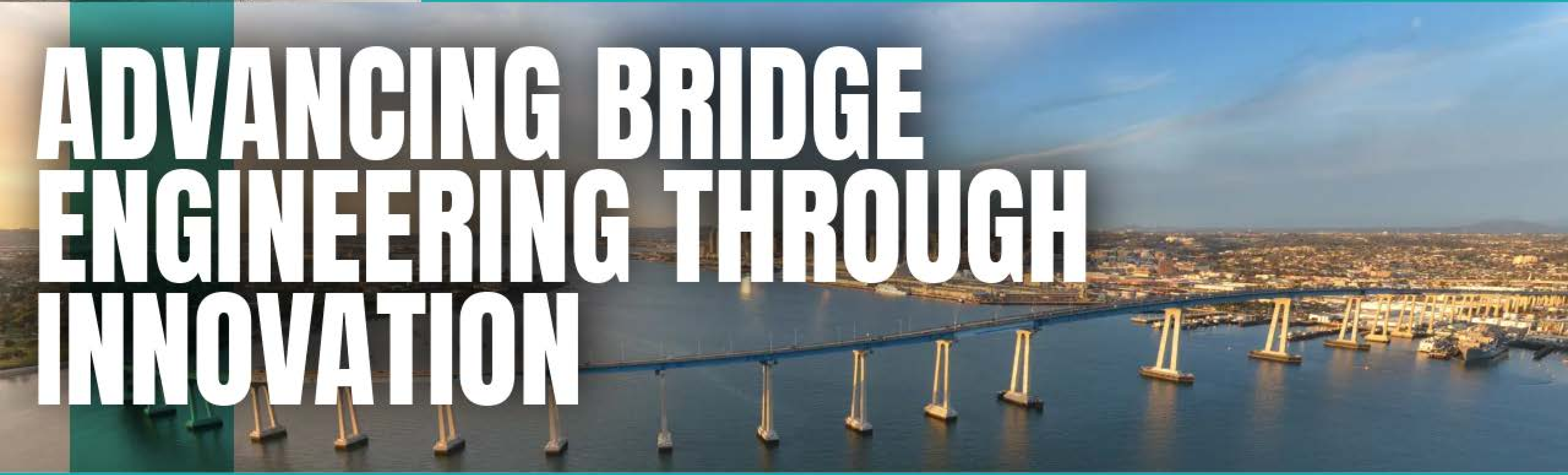
CALIFORNIA BRIDGE ENGINEERS SEMINAR

CABES



ADVANCING BRIDGE ENGINEERING THROUGH INNOVATION

CABES 2026

Presentation 10 - Bolinas Bridge: Balancing Fault Rupture and Tsunami Design

Caltrans

DES DIVISION OF ENGINEERING SERVICES

Bolinas Bridge:
Balancing Fault Rupture and Tsunami Design

Seismic Design

California Bridge Engineer Seminar

Marshall Moore, SE

Mark Thomas & Company

February 25, 3:30 PM, 2026

Session 4

MARK THOMAS

Bolinas Wye Wetland Restoration Project
Site Challenges

High PGA (0.90g)
Liquefiable soils
Fault Rupture
Tsunami

Competing interests between:
Tsunami (force based design)
Fault Rupture & Ground Motion (displacement based design)

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Fault Rupture Hazard

SLATE
GEOTECHNICAL CONSULTANTS

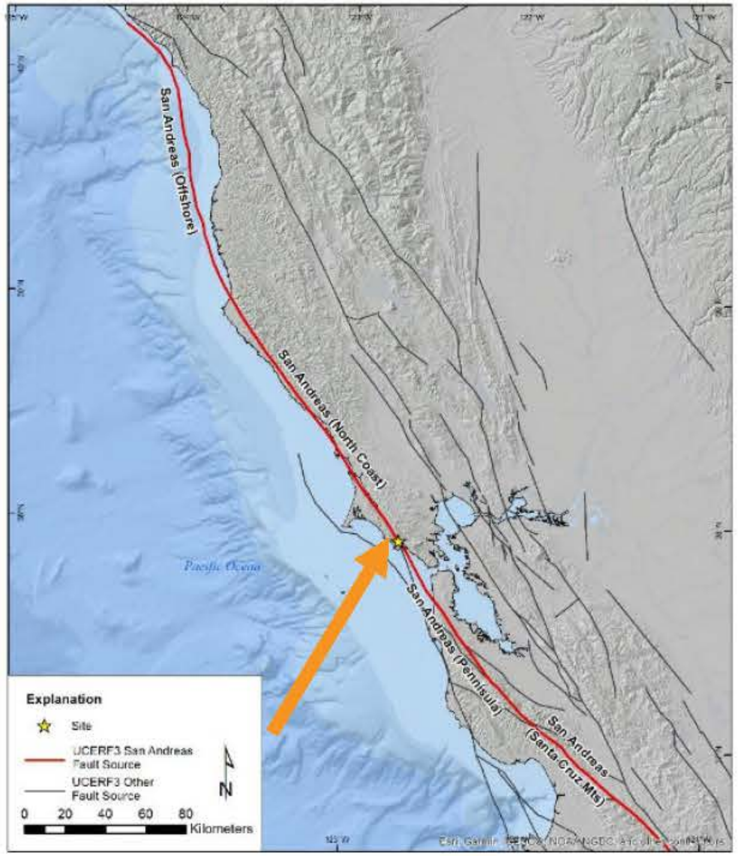


Figure 2-3. UCERF3 Fault Source Map.

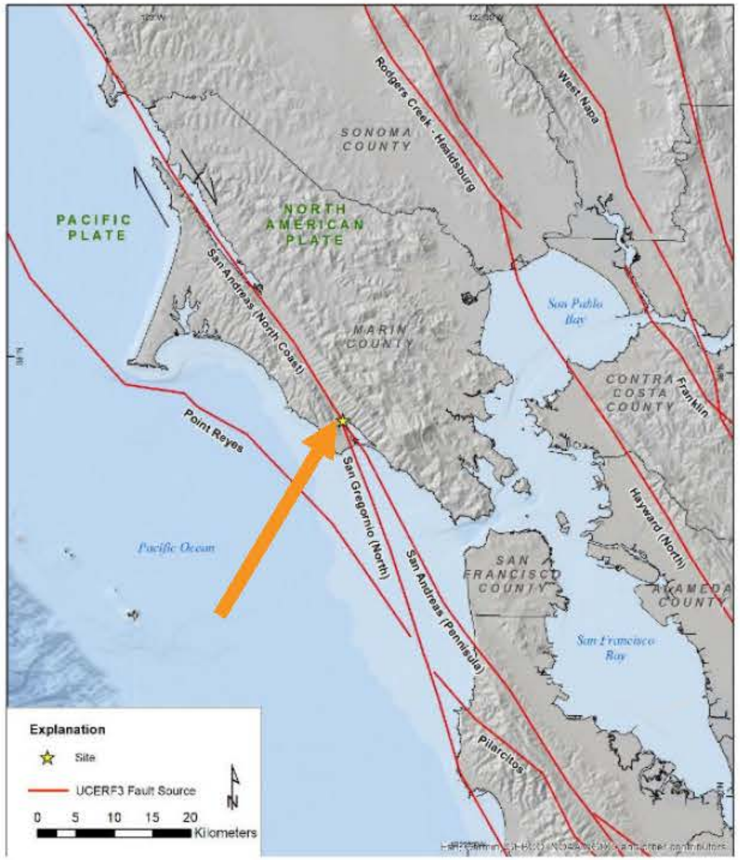
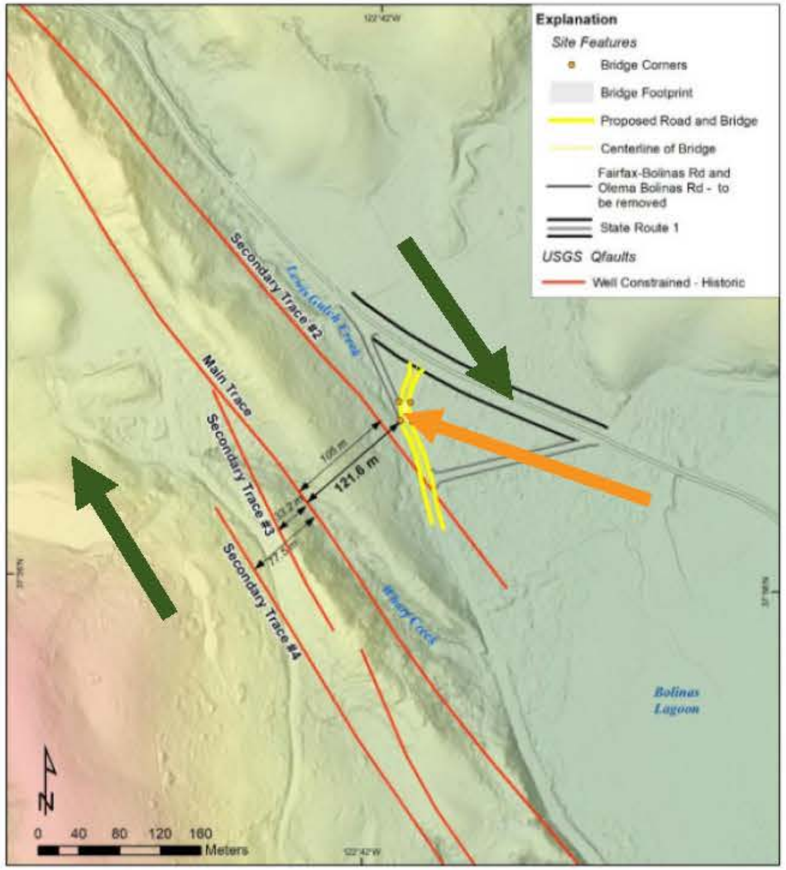


Figure 4-1. Site Location and Tectonic Setting.



2. Site map including segment distances relative to the SW bridge corner and the main trace of

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Fault Rupture Study

SLATE GEOTECHNICAL CONSULTANTS

- Maximum Fault Rupture Displacement along San Andreas Fault:

- 4.31 m
- 14’-2”

How do we design a single span 60 ft long bridge for that?

Determined using Caltrans Geotechnical Manual (2017) and Guidelines for Evaluating the Hazard of Surface Fault Rupture (CGS, 2002).

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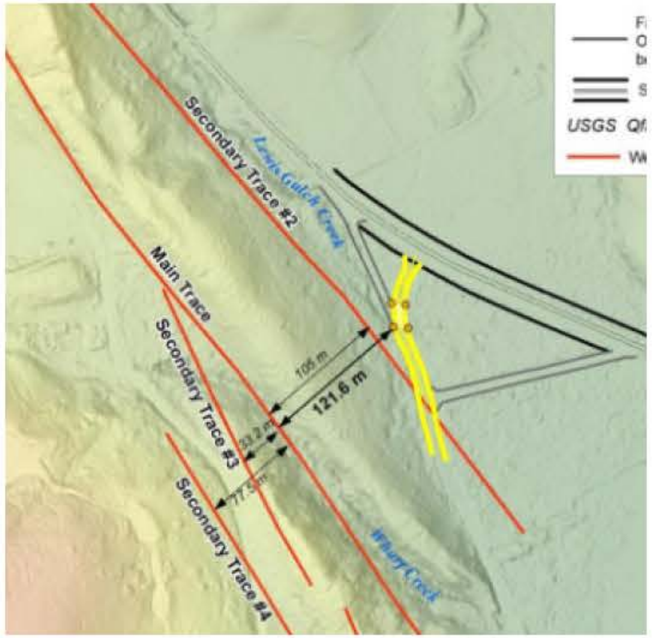
Fault Rupture Study

- Maximum Fault Rupture Displacement along San Andreas Fault:
  - 4.31 m
  - 14'-2"

Bridge is adjacent to a Secondary Trace that was assigned 10% of the total displacement.

- Design Fault Rupture Displacement at Bridge:
  - 0.43 m
  - 1'-5"

Manageable design displacement



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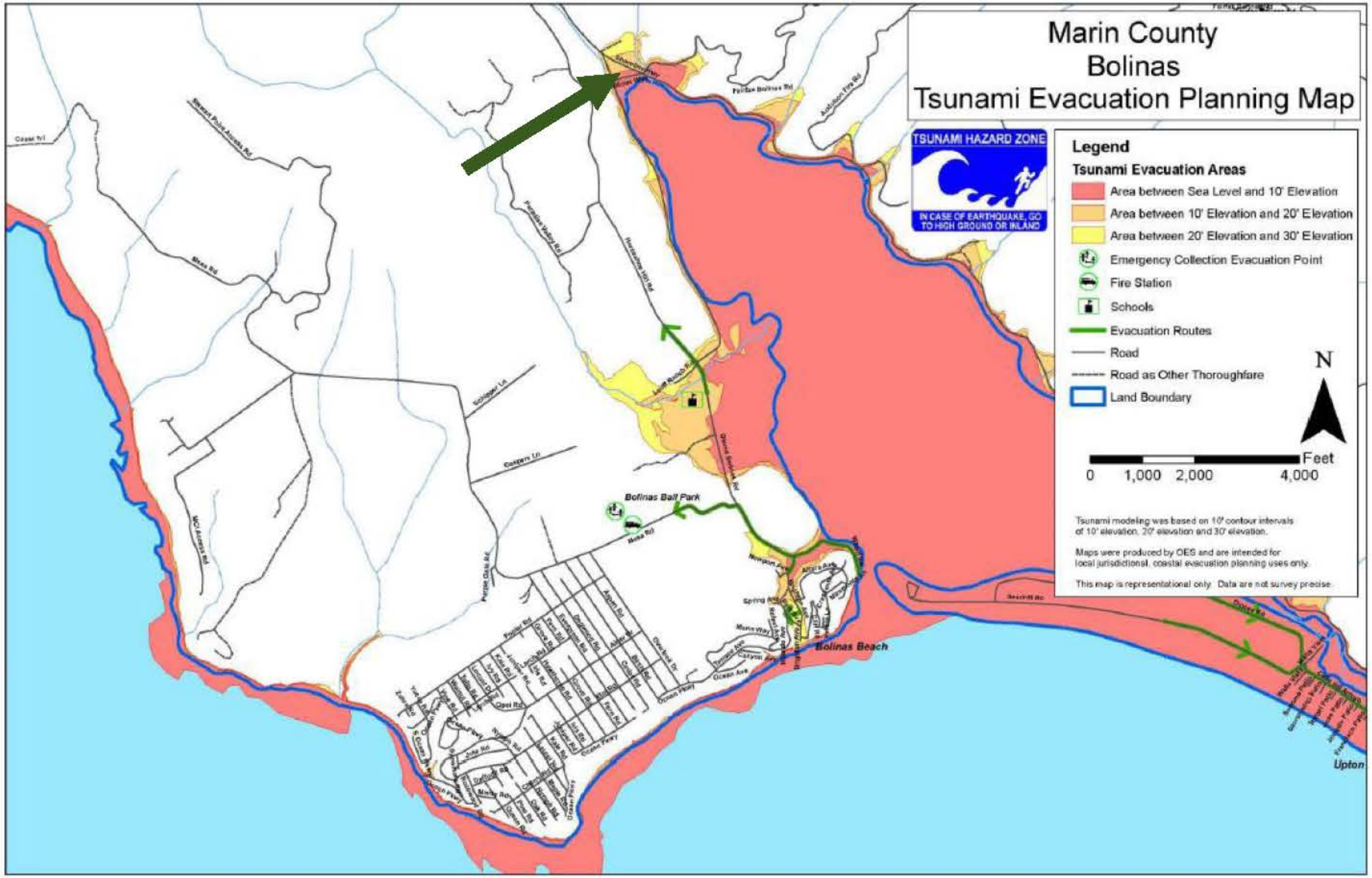
Tsunami Hazard



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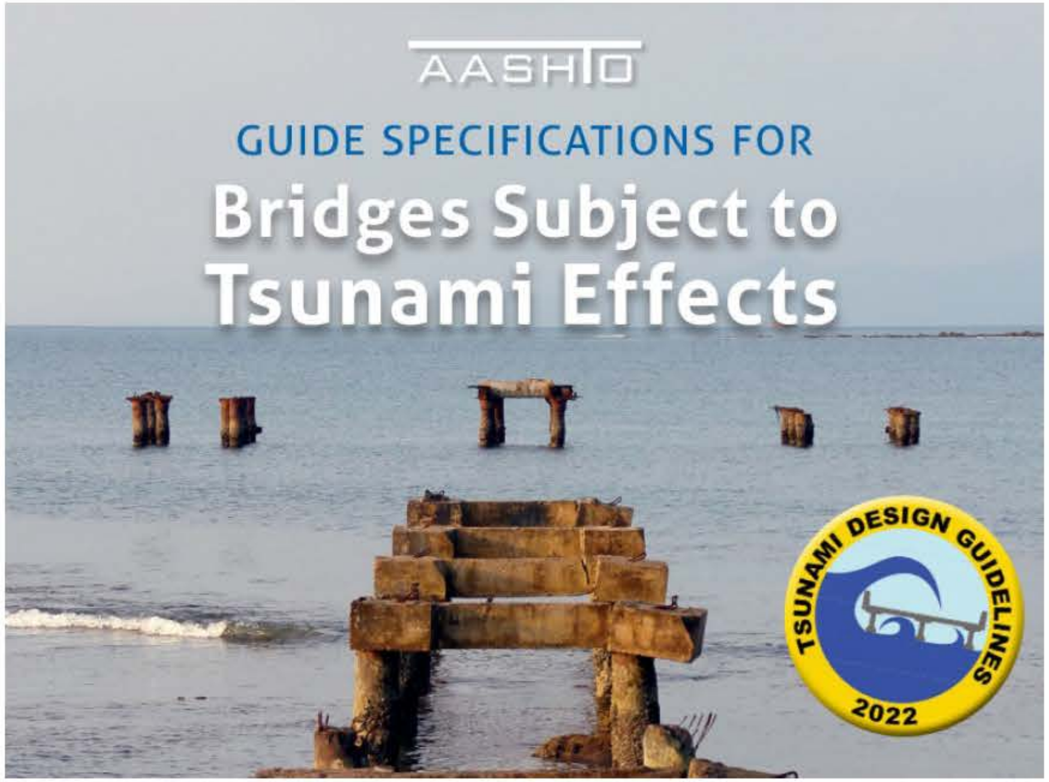
Tsunami Hazard

Design Code: *AASHTO Guide Specifications for Bridges Subject to Tsunami Effects*
(released 2022, previous design relied upon ASCE or mix of guidance)



- 7% Probability of Exceedance in 75 years ~ 1000 – year recurrence
- Horizontal & Vertical Forces on Bridge defined based upon height, speed and bridge geometry

Table 5.2-1 — Load Cases

Load Case	Flow Speed	Flow Depth	Large Debris
1	u_{max}	${}^{2}/_{3}\,\eta_{max}$	-
2	$0.8u_{max}$	η_{max}	-
3	$0.5u_{max}$	$0.5\eta_{max}$	F_{dr}

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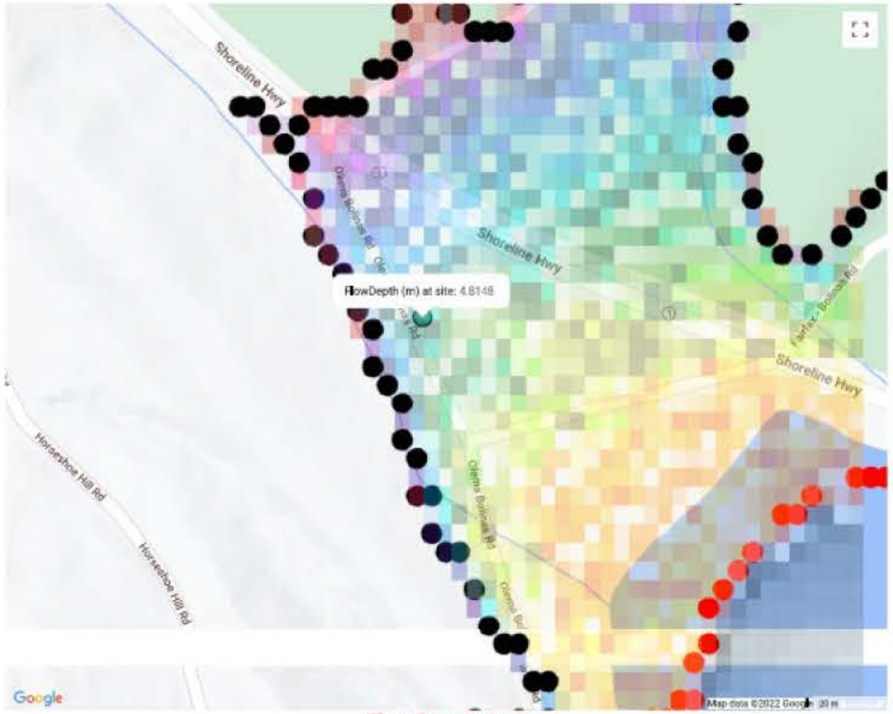
Tsunami Hazard

Natural Hazards Risks and Resiliency Research Center (NHR3) Web Portal

- Caltrans STP 2.6: Hydraulic Design for Structures over Waterways
  - 2.6.2.5: Tsunami
  - Tsunami Inundation Portal
    - Alaska, California, Hawaii, Oregon, Washington
    - Pacific Earthquake Engineering Research Center
    - http://ec2-35-167-122-9.us-west-2.copute.amazonaws.com/tsunamis/new



FlowDepth (m)

- Ground Elevation: ~13 ft
- 1000-Year Recurrence
- Flow Depth: ~16 ft
- <u>Max Flow Velocity: ~14 ft/s</u>
- Added 3.5 ft for Sea Level Rise per ***Caltrans*** STP 2.6.2.5
- <u>Max Flow Elevation: ~33 ft</u>
- <u>Bridge Deck Elevation: ~25 ft</u>

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Tsunami Hazard

Debris Load: ***<u>AASHTO Guide Specifications for Bridges Subject to Tsunami Effects</u>***
<u>ASCE 7-16: Minimum Design Loads For Building and Other Structures</u>

$$F_{dr} = \frac{\pi W u}{2 g \Delta t} \qquad \text{(C5.5-1)}$$

$$F_{dr} = \frac{W u^2}{g S} \qquad \text{(C5.5-2)}$$

$$F_{dr} = 1.3 u \sqrt{k m (1 + c)} \qquad \text{(C5.5-3)}$$

- AASHTO provides guidelines on potential debris loads
- Sensitive to anticipated duration of impact/stiffness of debris – difficult to estimate
- AASHTO provides crush load of empty shipping container of 140 kips
- This was used as a conservative upper bound

Tsunami Hazard

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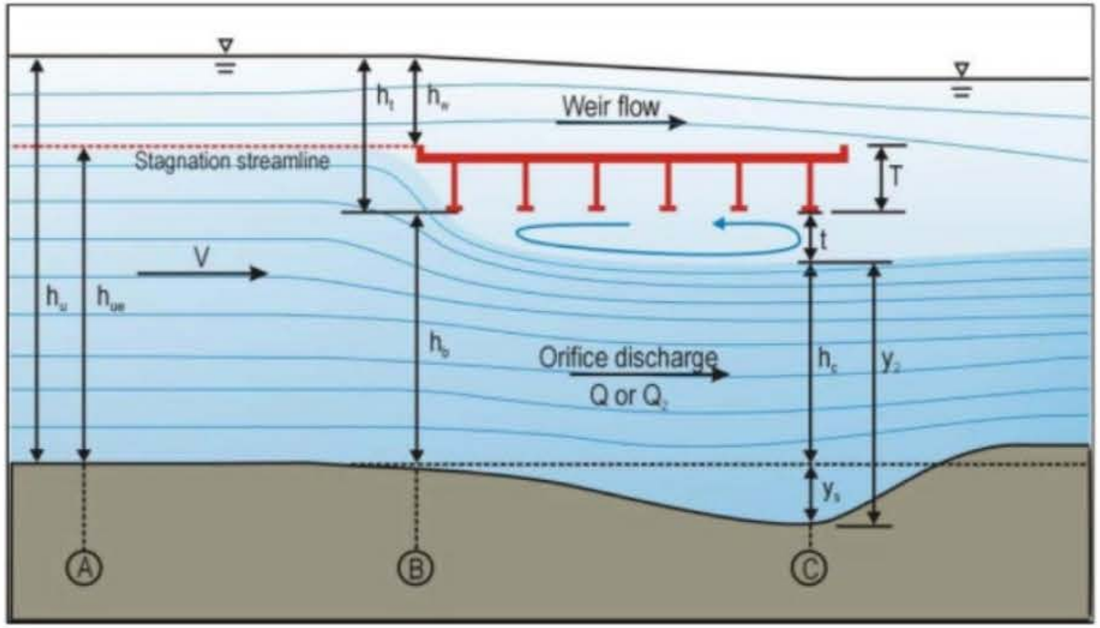
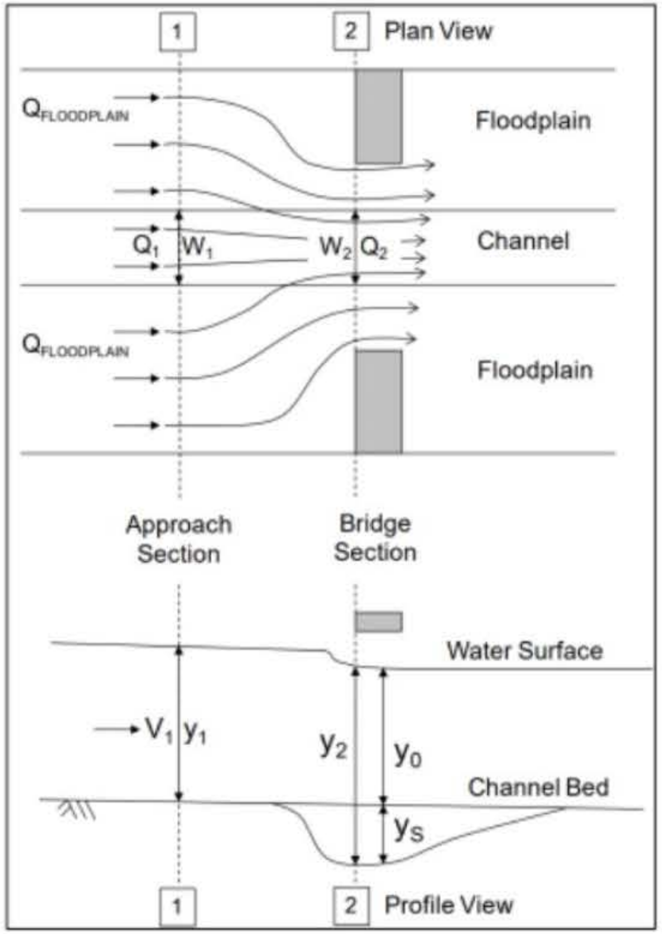
Tsunami Scour

Q_2/Q_1	Maximum total scour (feet)
1.0	29.27
1.25	44.42
1.5	48.76
2.0	52.83





Scour ranges from ~30 to 50 ft depending upon assumed extent of flow constriction

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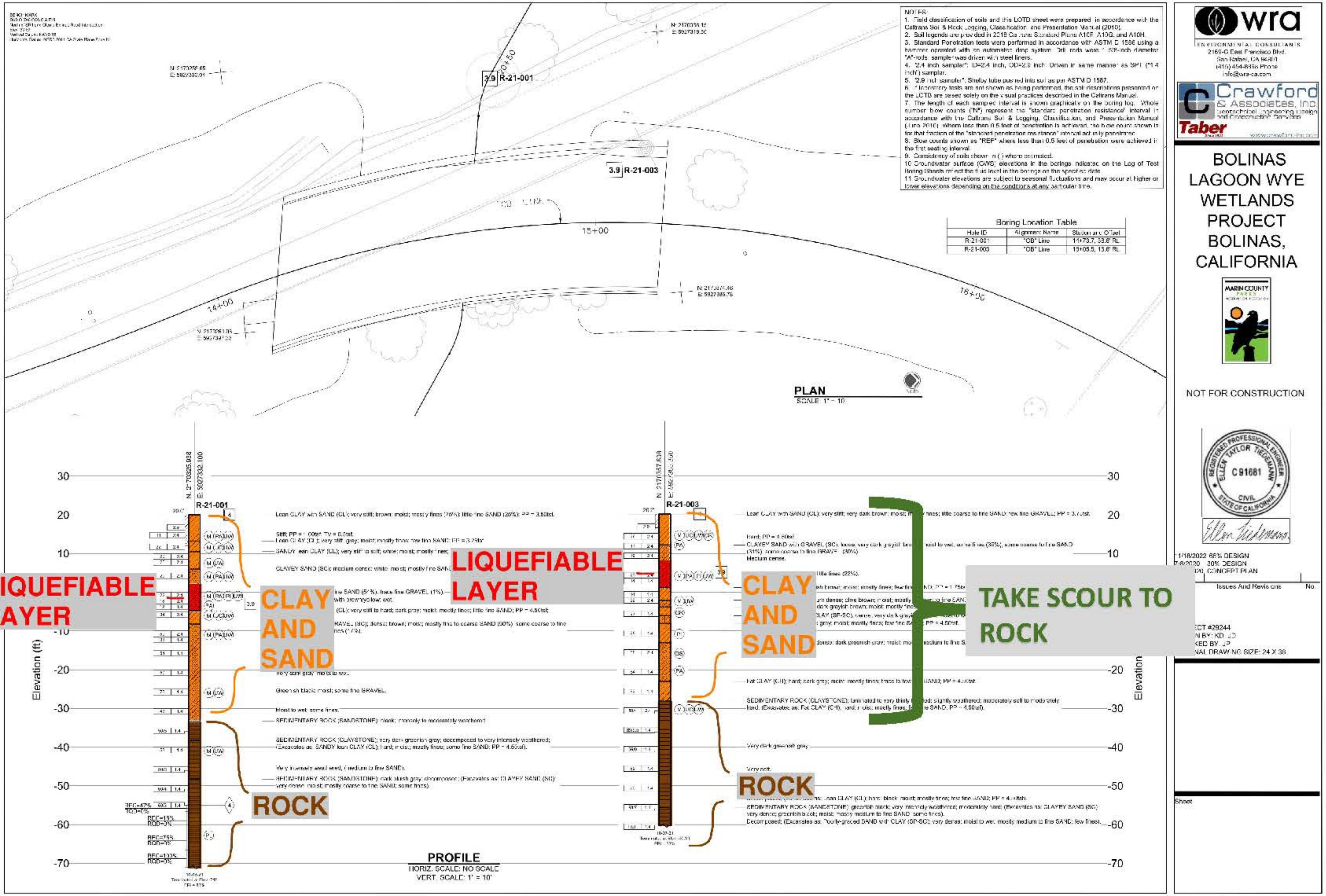
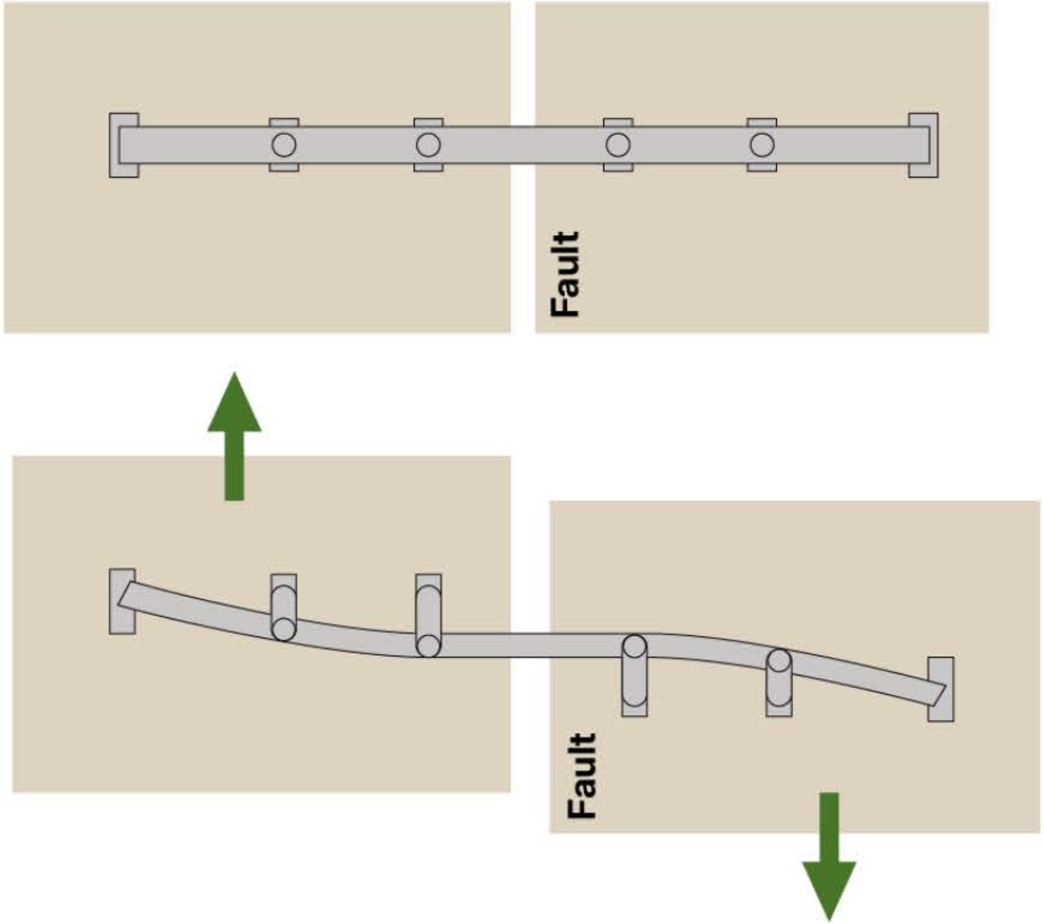


LIQUEFIABLE LAYER
CLAY AND SAND
ROCK
LIQUEFIABLE LAYER
CLAY AND SAND
ROCK
TAKE SCOUR TO ROCK
R-21-001
R-21-003
Boring Location Table
PLAN
PROFILE
HORIZ. SCALE: NO SCALE
VERT. SCALE: 1" = 10'
Elevation (ft)
wra
ENVIRONMENTAL CONSULTANTS
Crawford & Associates, Inc.
Taber
BOLINAS LAGOON WYE WETLANDS PROJECT BOLINAS, CALIFORNIA
MARIN COUNTY PARKS
NOT FOR CONSTRUCTION
C 91681
Issues And Revisions

Designing For Fault Rupture

Caltrans Structure Technical Policy 20.22: Analysis of New Bridges in Fault Rupture Zones

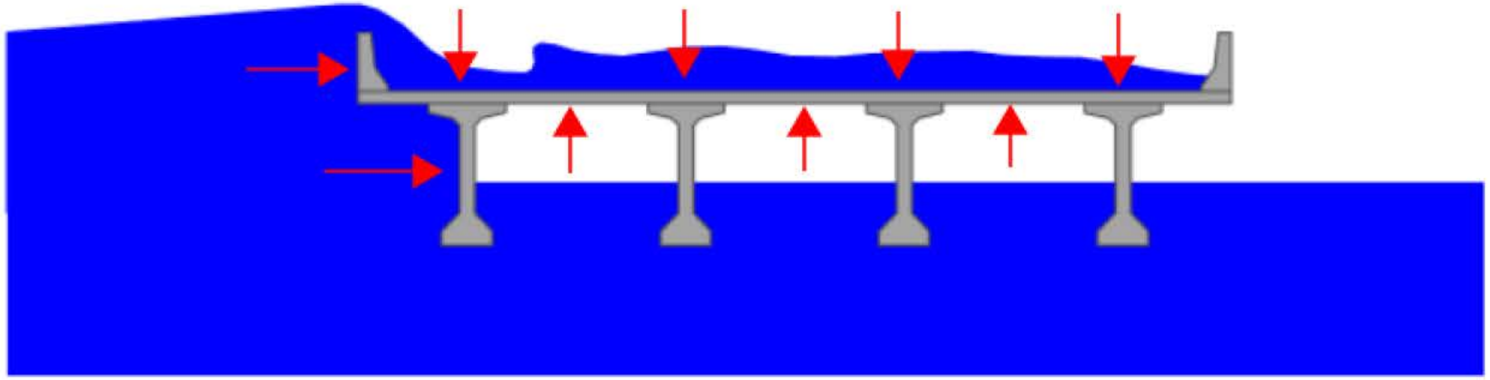
- Simplified Analysis:
  - Obtain static response due to fault offset
  - Obtain dynamic response due to ground shaking
  - Combine displacements to obtain total displacement demand



Designing For Tsunami

Caltrans Memo To Designers 20-13: Mitigating Tsunami Hazards

- Force based analysis
- Recommended Design Features:
  - Continuous Superstructure
  - Deep Foundations
  - Monolithic connections
  - Tie Dows
  - Vents
  - Open Barrier Rails
  - Fenders



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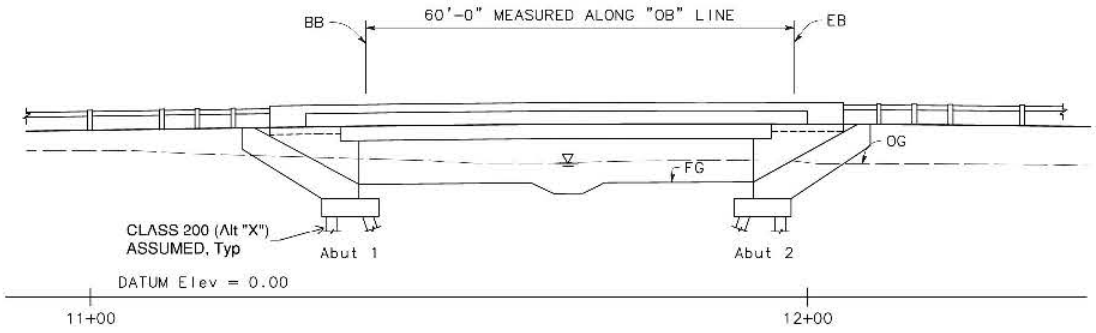
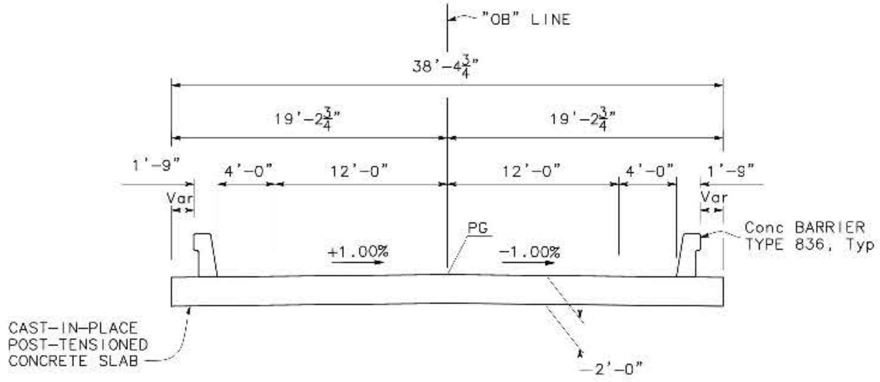
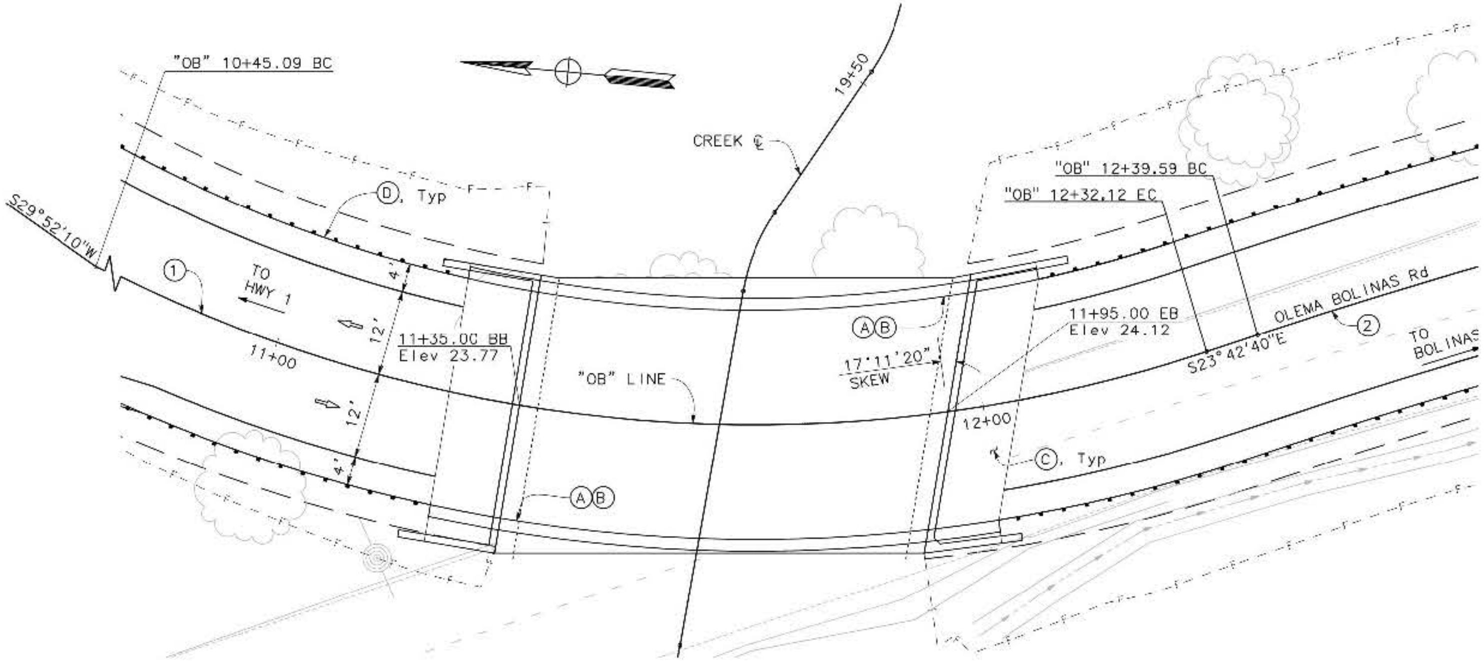
Original Base Design



ELEVATION
1"=10'





- Single Span
- Simply Supported
- Slab Bridge
- Seat Abutment
- Driven Battered Piles
- $1,300,000

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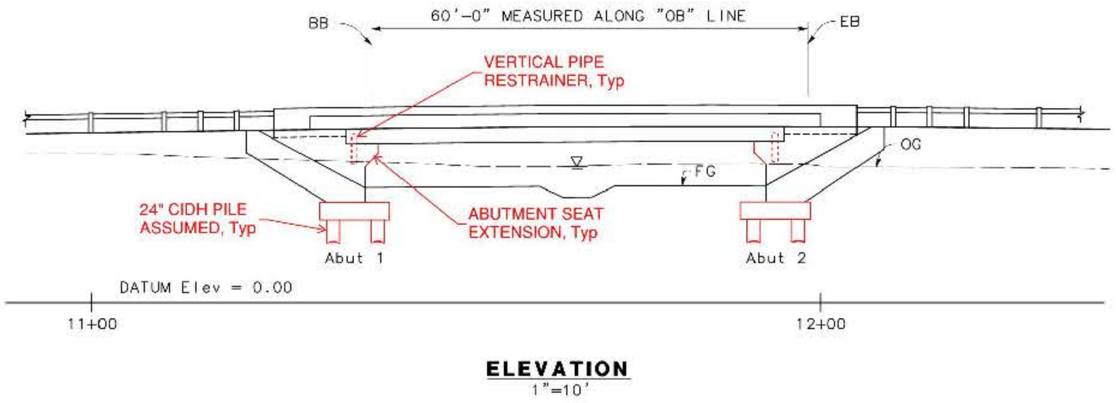
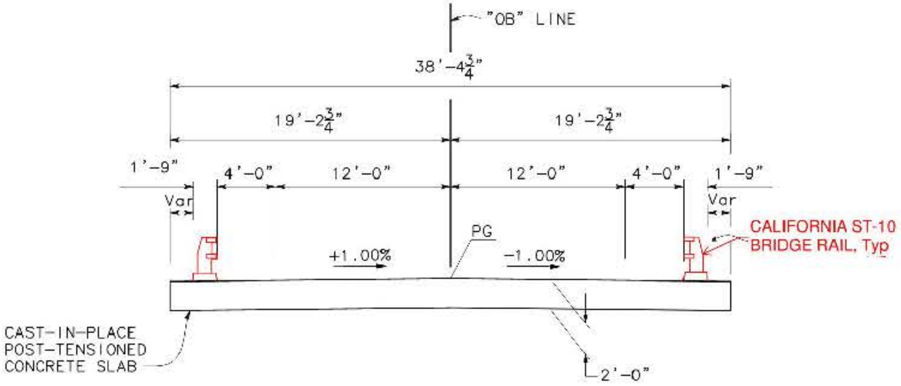
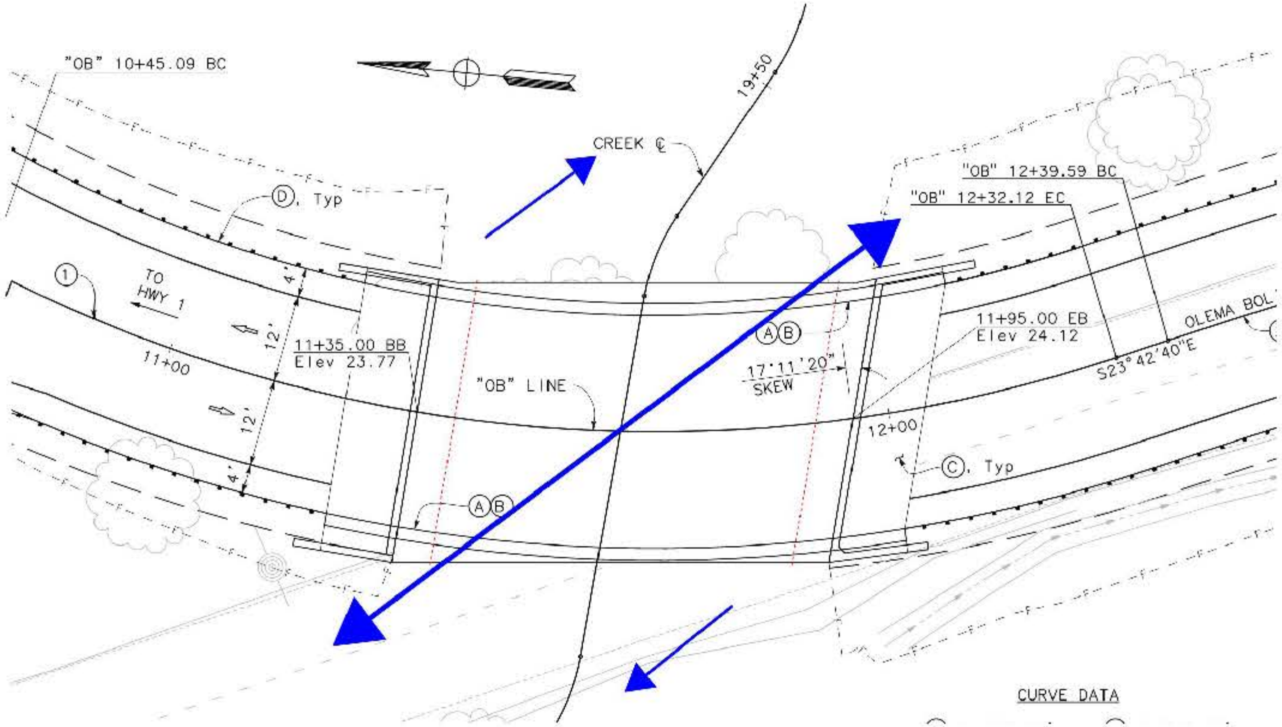
Design For Tsunami & Fault Rupture

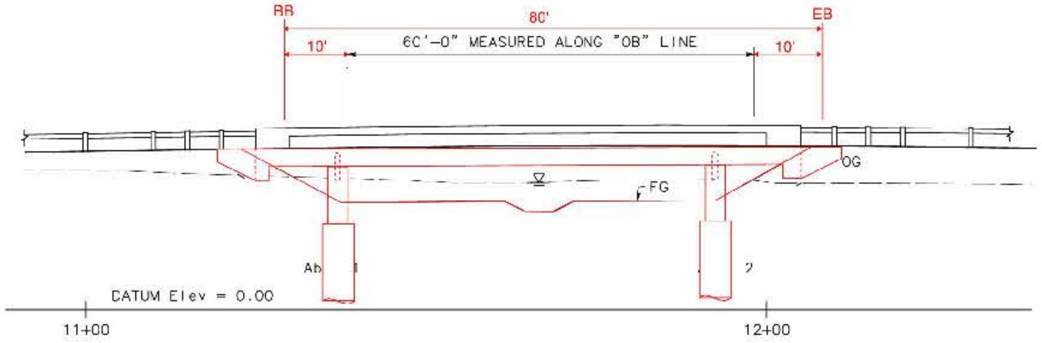




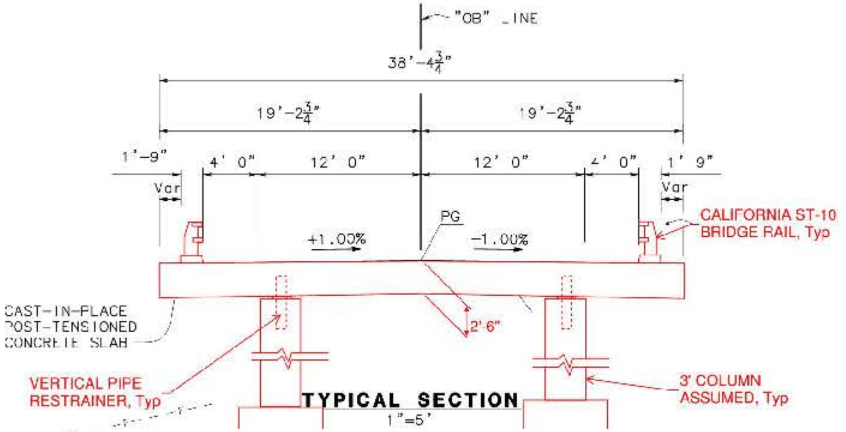


- Pipe Restrainers
- Drilled Piles W/ Rock Socket
- Open Barriers
- Seat Extensions
- $2,000,000

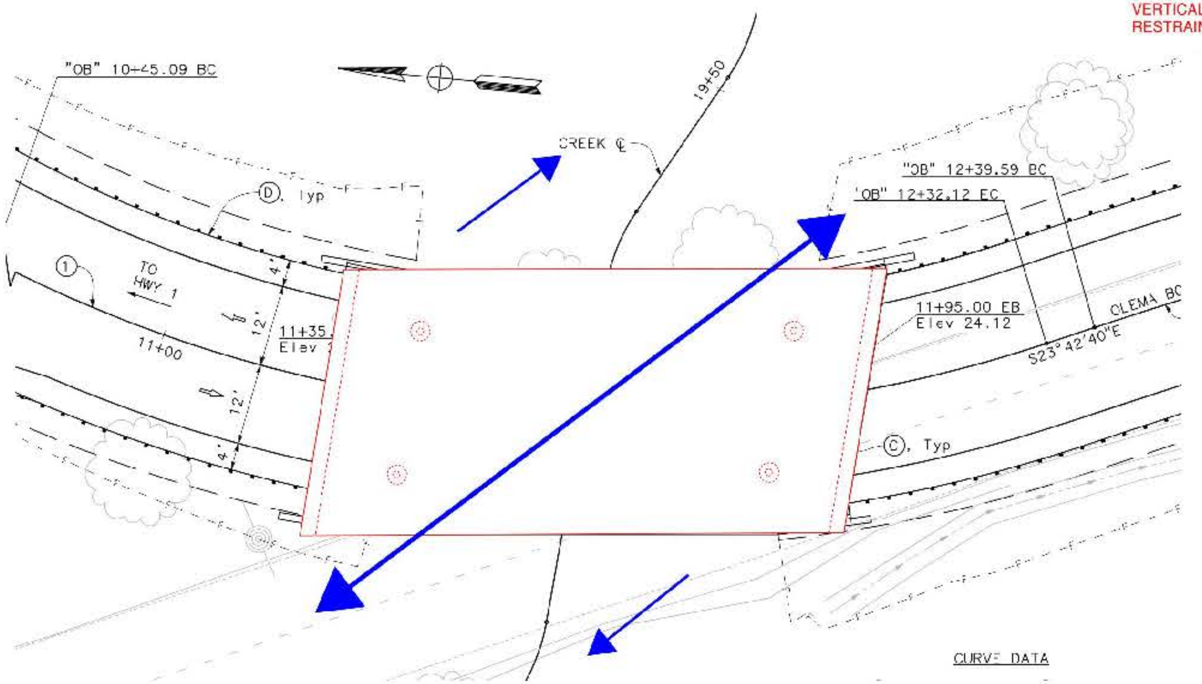
Alternative Design: Tsunami & Fault Rupture



ELEVATION
1"=10'



TYPICAL SECTION
1"=5'



- Multi-Span Bridge
- Large Diameter Piles
- Pinned Column Connections
- Vertical Pipe Restrainer
- $1,900,000

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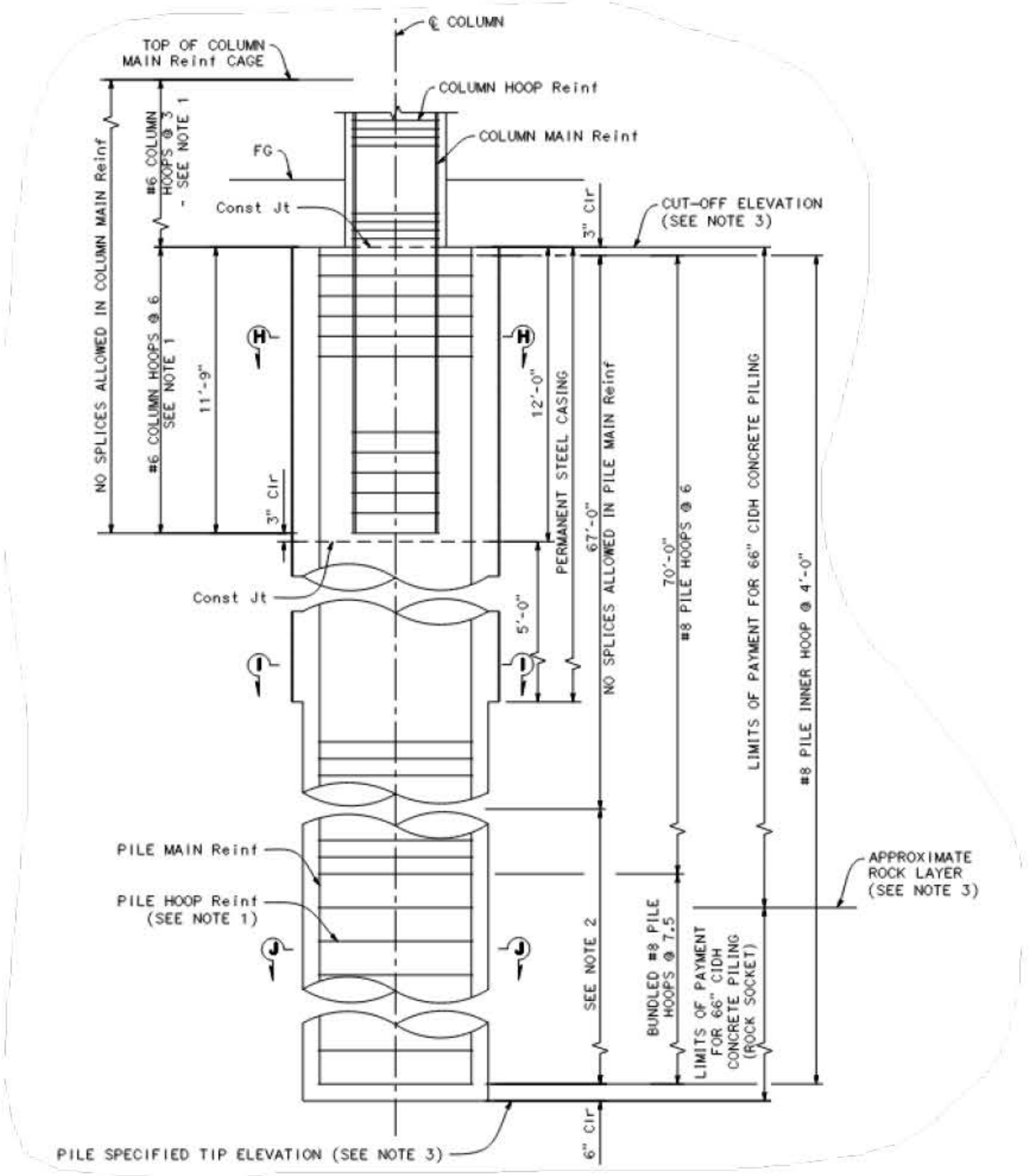
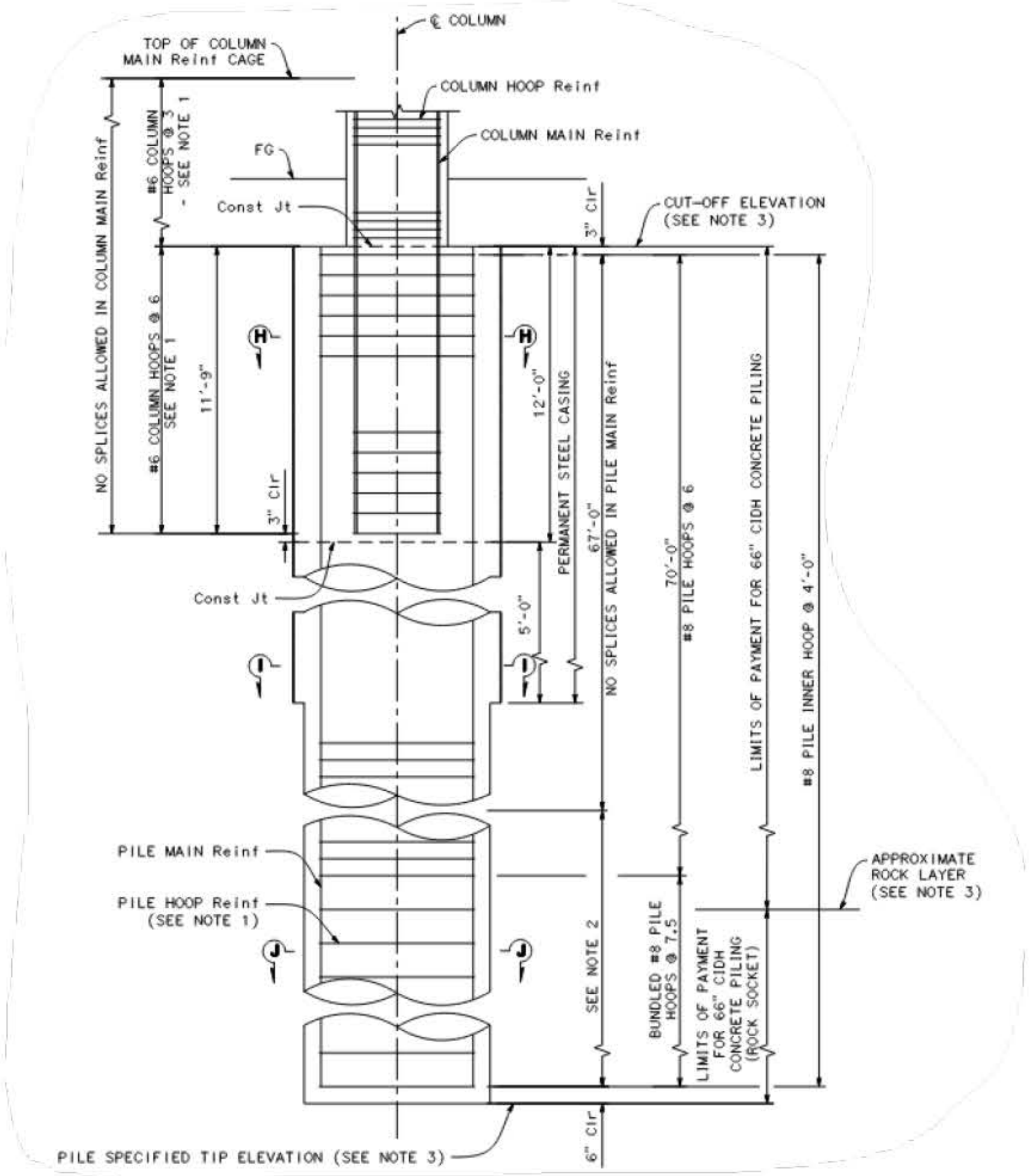
Design Details: CIDH Pile & Rock Socket



Design Details: CIDH Pile & Rock Socket



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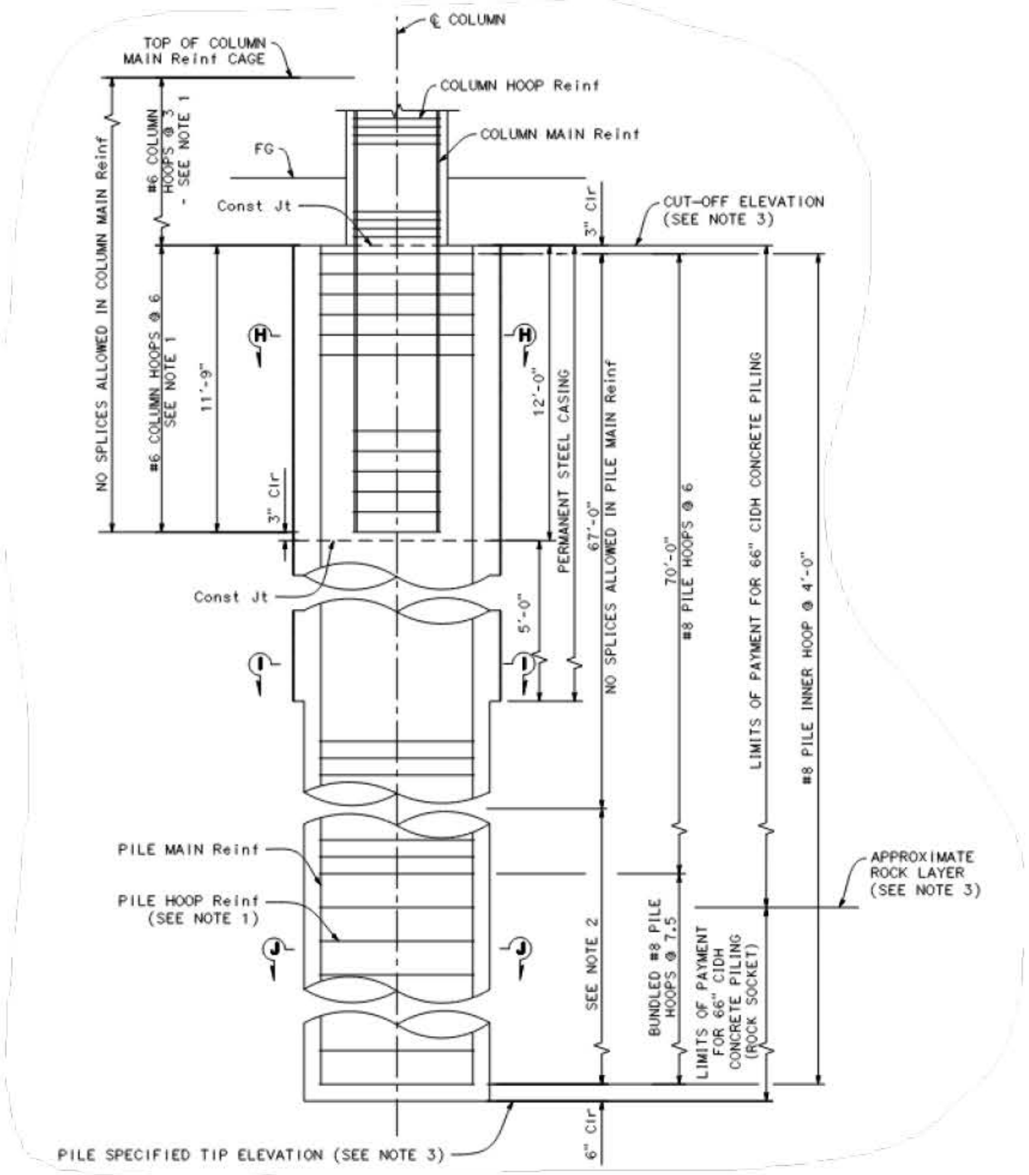
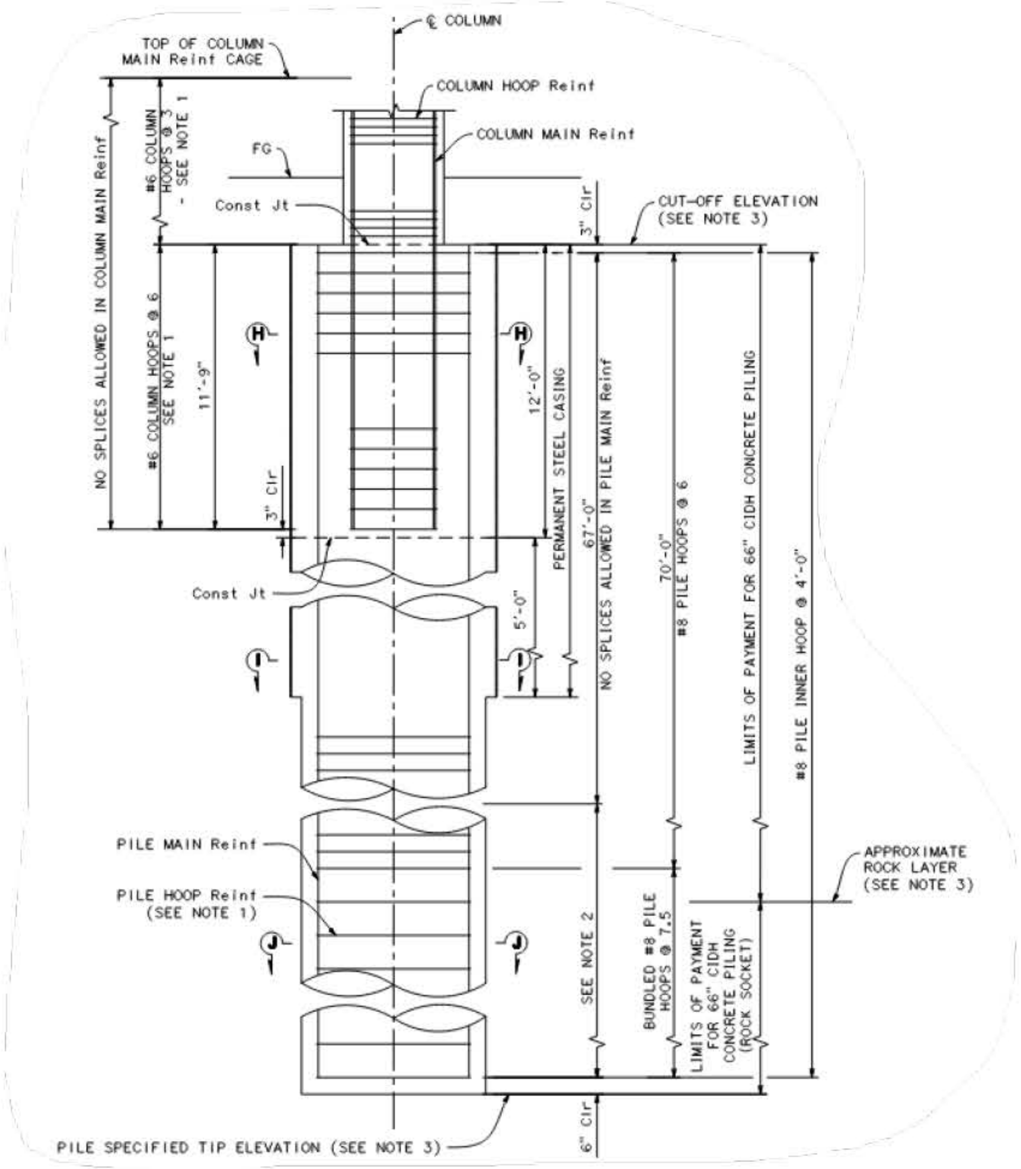
Design Details: CIDH Pile & Rock Socket



Design Details: CIDH Pile & Rock Socket



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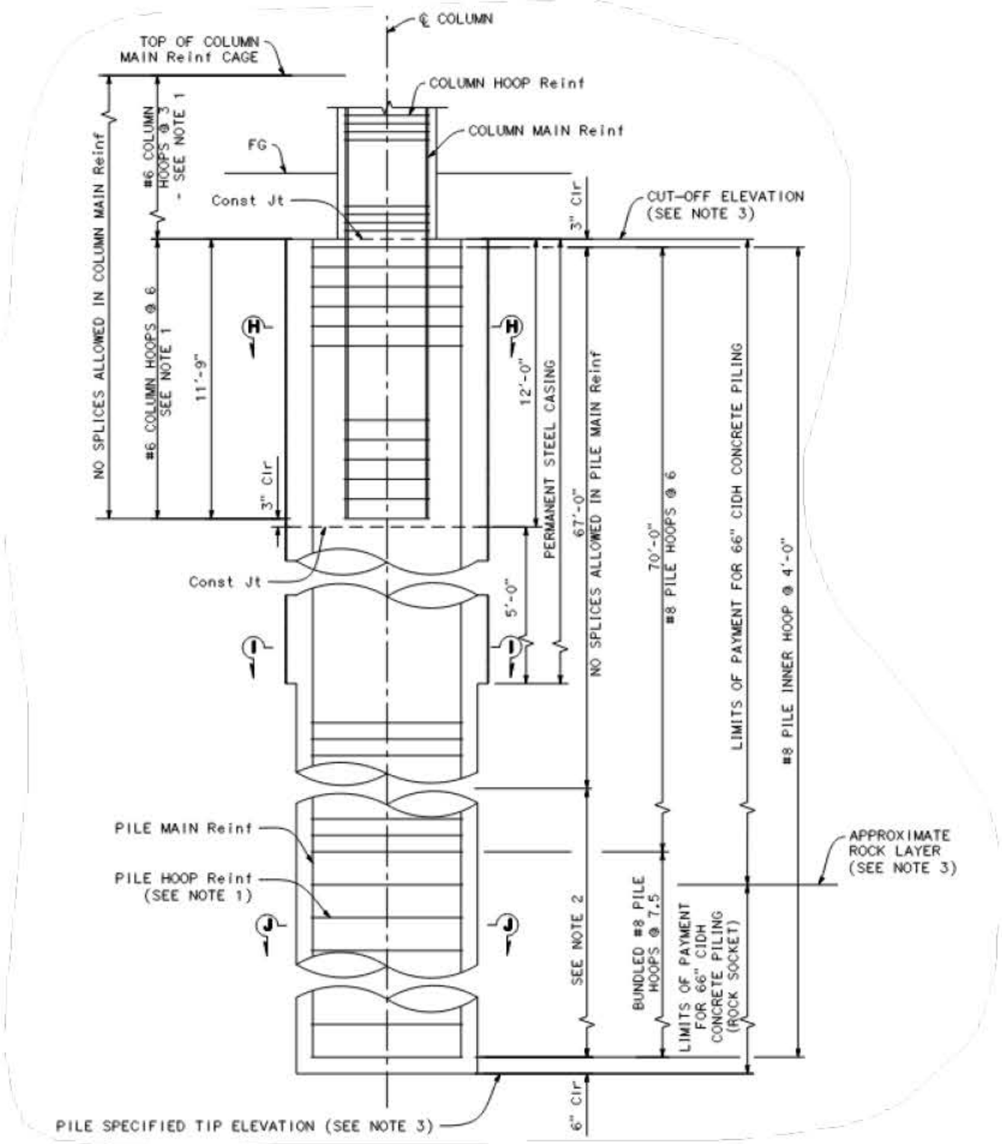
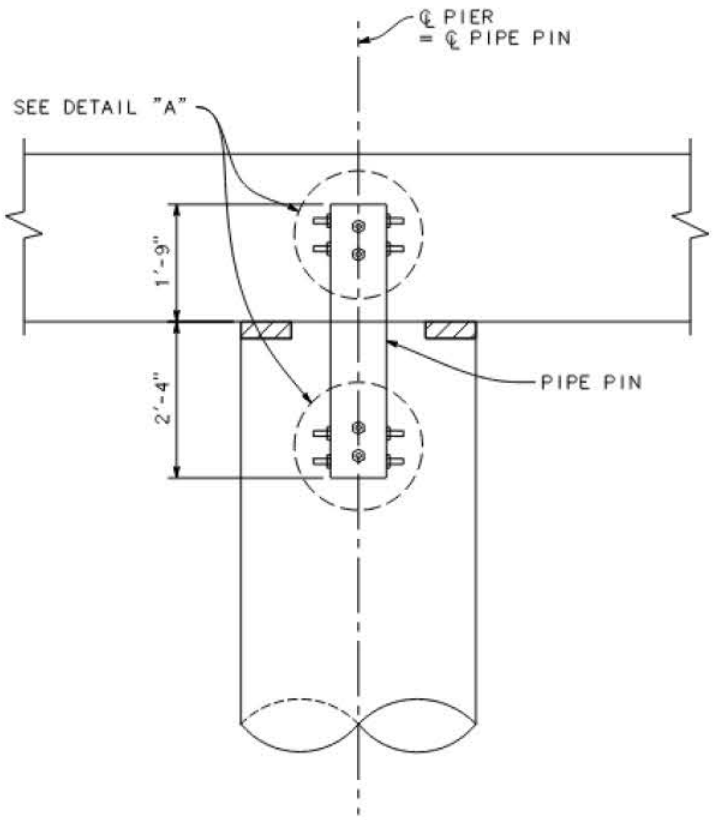
Design Details: CIDH Pile & Rock Socket



Design Details: Column Pin



PIPE PIN DETAIL AT PIERS
3/4" = 1'-0"

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Summary

- Tsunami
  - Force Based Design
  - Monolithic Connections and/or Tie Downs
  - Account for Tsunami Scour and combine with Tsunami loading
- Fault Rupture
  - Displacement Based
  - Add Flexibility/Allow Displacement
  - Fault Study may be able to significantly decrease design displacement
- Combined Design:
  - Separate design aspects (Tsunami is not expected to occur with a fault rupture event)

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Resources

- Tsunami
  - NHR3 Web Portal:
    http://ec2-35-167-122-9.us-west-2.compute.amazonaws.com/tsunamis/new
  - AASHTO Guide Specifications for Bridges Subject to Tsunami Effects
  - Caltrans:
    - Memo To Designers 20-13: Tsunami Hazard Guidelines
    - Structure Technical Policy 2.6: Hydraulic Design for Structures over Waterways

- Fault Rupture
  - Caltrans:
    - Structure Technical Policy 20.22: Analysis of New Bridges in Fault Rupture Zones
    - Memo To Designers 20-10: Fault Rupture

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Questions?

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