Sound Transit *Sounder* Commuter Rail

The D-to-M Streets Track and Signal Improvement Project: Pacific Avenue Bridge

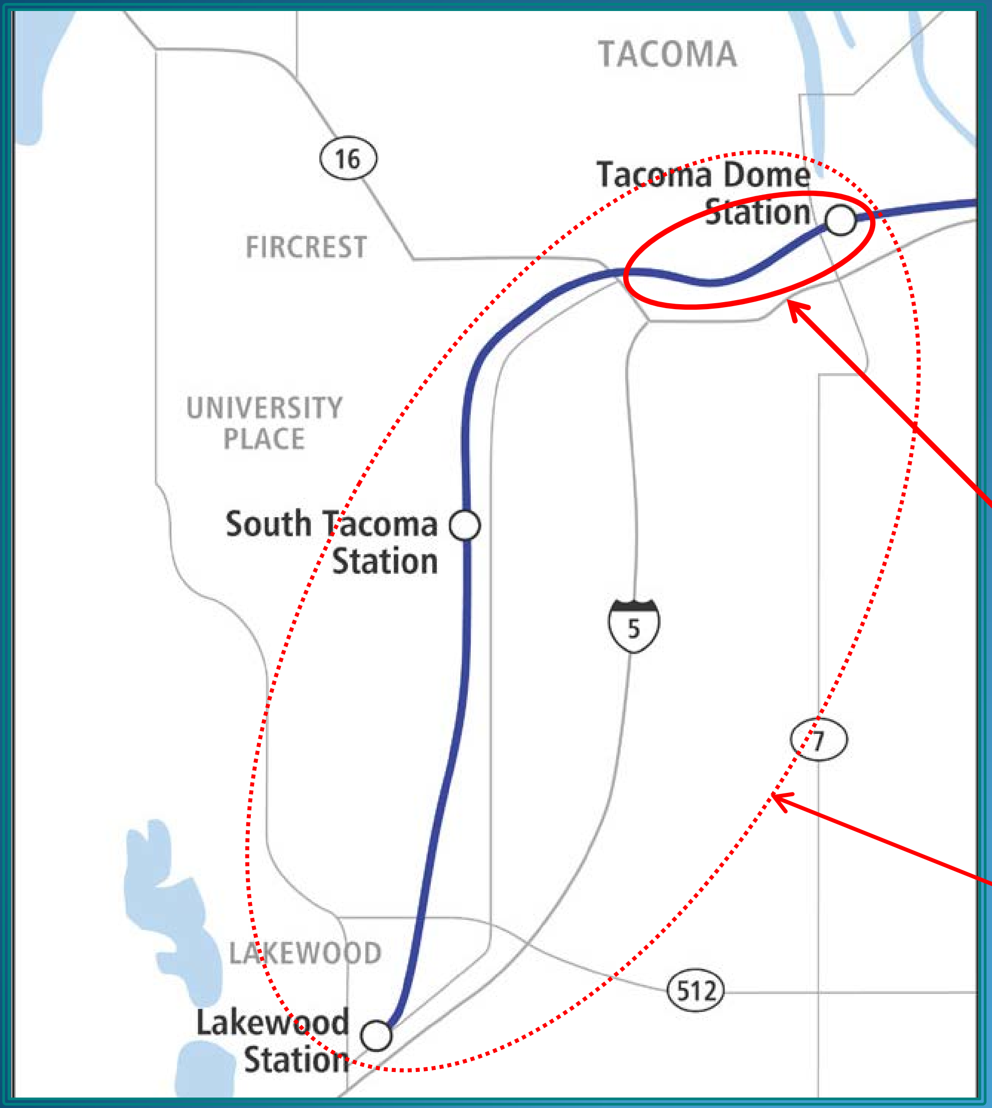
Western Bridge Engineers' Seminar
September 4-6, 2013

Sounder System Map

Everett – Seattle

Seattle - Lakewood

Tacoma to Lakewood Corridor

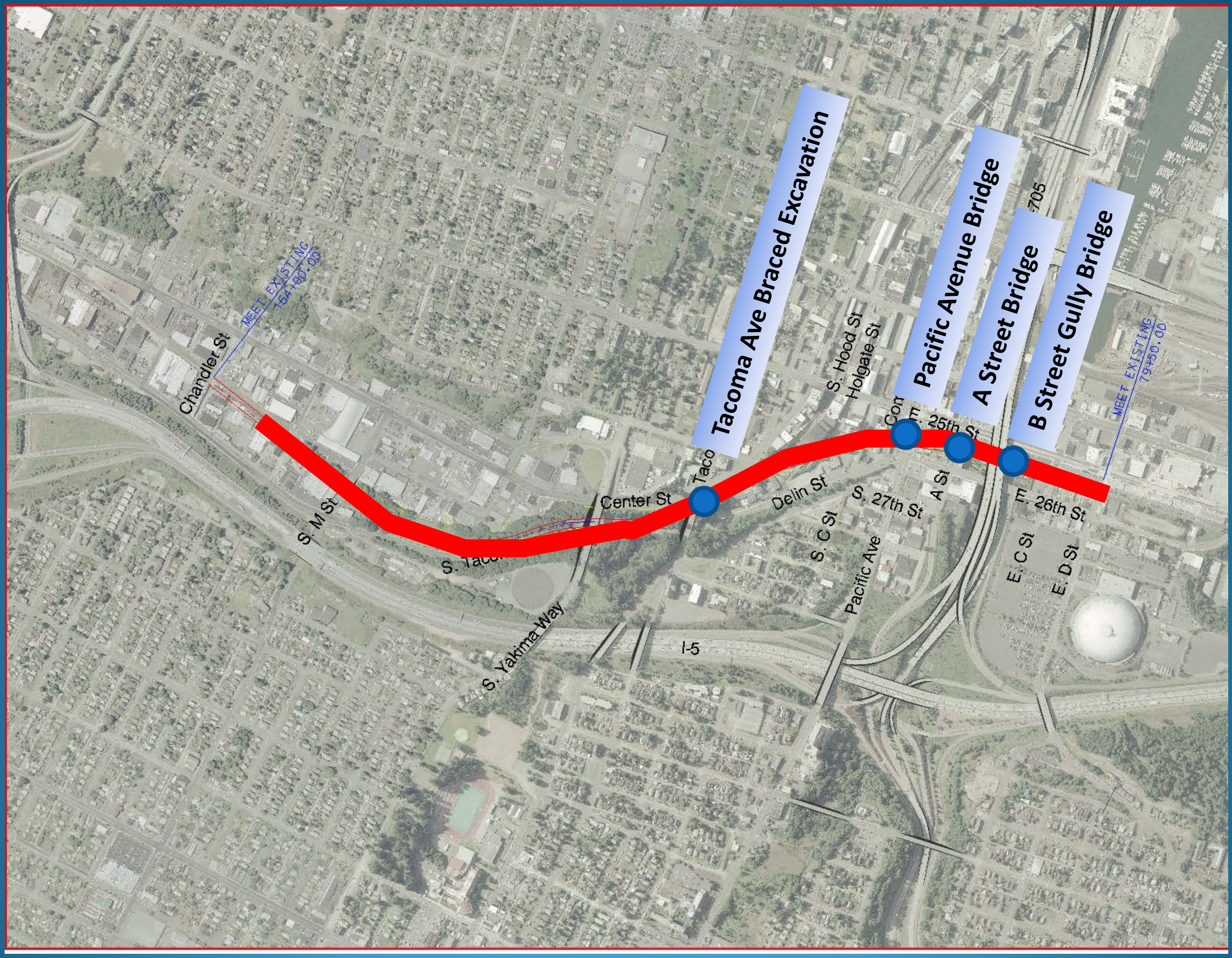


- 8.2 Miles
  - 1.4 miles of new track
  - 6.8 miles of track and signal upgrades

D to M Street

Tacoma to Lakewood

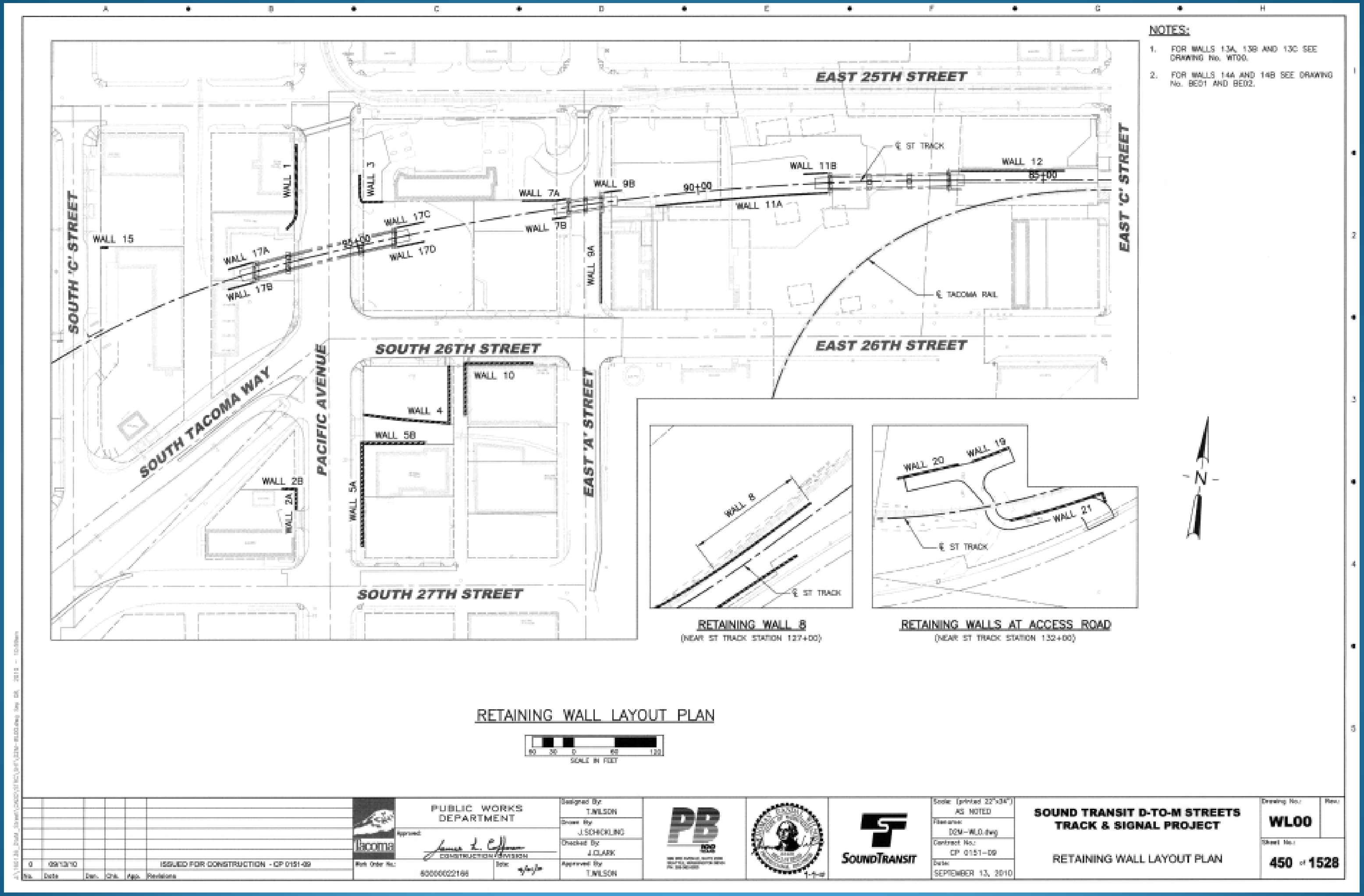
D to M Street Corridor



Project Elements

- At beginning of project (10 - 15% level of design)
  - 3 walls in downtown area
  - 1 bridge (3-span)
  - 3,500’ of cut wall
  - 1 braced excavation
- At end of project (100% level of design)
  - 22 walls in downtown area & along cut
  - 3 bridges (2ea – 3 span, 1ea – 2 span)
  - 2,400’ of soil nail wall
  - 1 braced excavation

- Wall Types: Soldier Pile, SP w/ Tiebacks, Concrete Cantilever, SEW, Soil Nails, Block walls



Tacoma Avenue Braced Excavation

B Street Gully Bridge - Rendering

B Street Gully Bridge

A Street Bridge - Rendering

A Street Bridge

Visualizations

- Used for:
  - Project stakeholder meetings
  - Open houses
  - City Council approval of Pacific Avenue Bridge aesthetics
- Originally limited within project scope
- Became the go-to deliverable to show engineering elements to non-engineers

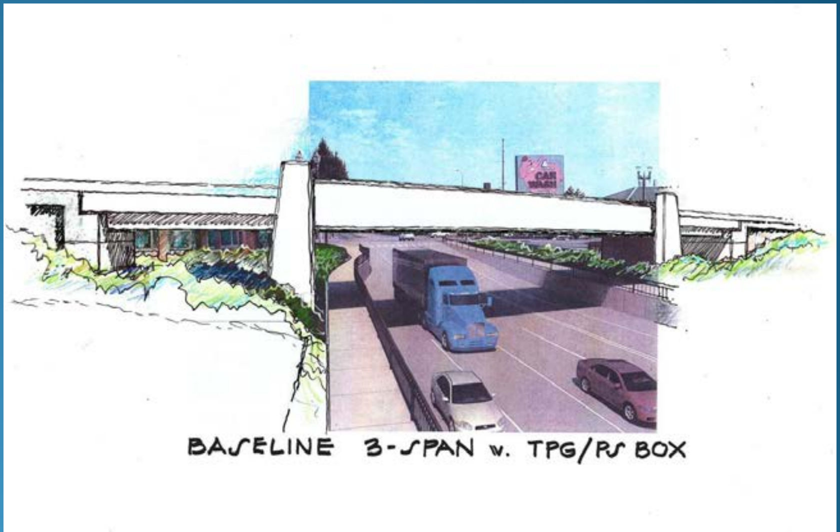
Financials

- Construction:
  - Engineers Estimate = $66M
  - Low bid by Mid-Mountain Construction= $40.8M
  - Bid + Change Orders ≈ $69M
    - Bulk of CO cost related to contaminated material discovery

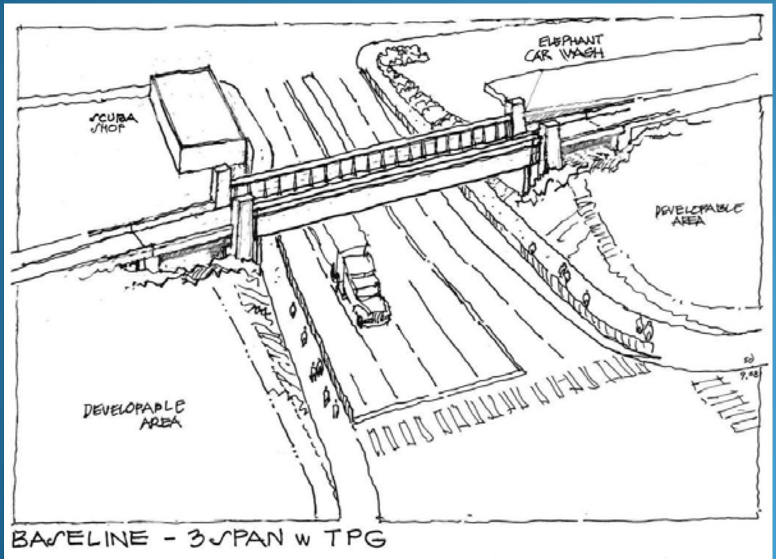
- Design + DSDC: (PB + 6 Subconsultants)
  - Total Team Budget = $14.5M
  - Design = $10.5M
  - DSDC = $4M

Pacific Ave Bridge Type Selection

- Bridge Type Study Undertaken in August 2008
  - General Criteria:
    - Feasible
    - Affordable
    - Attractive



Baseline 3-span TPG with PS Box side spans

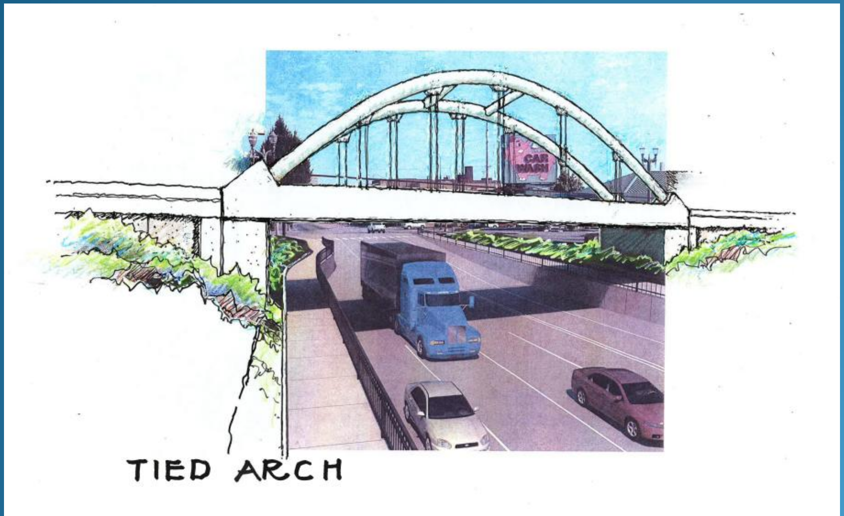


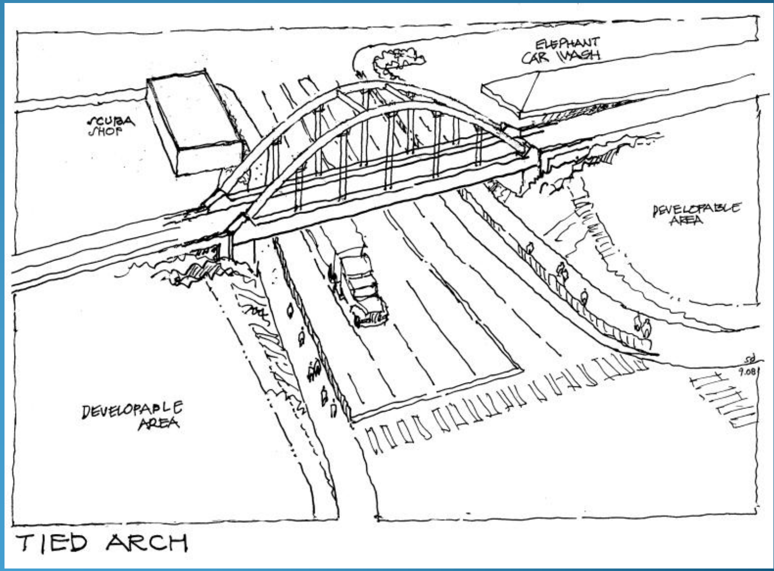
Alternatives Considered

- Cast-in-Place Thru Girder
- Thru Plate Girder
- Tied Arch
- A-Frame
- Thru Truss (Pony Truss)
- Extradosed
- Thru Steel Box Girder
- Cable-Stayed

A few of the Alternatives Evaluated

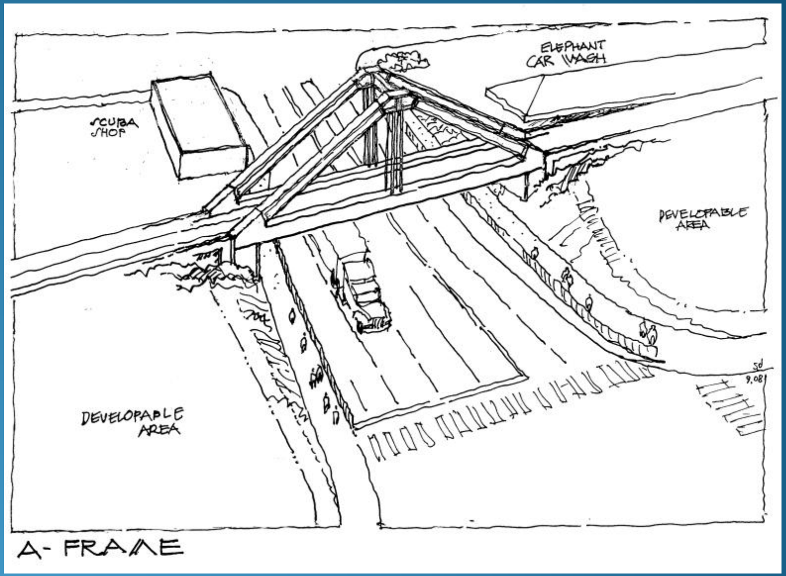
- Single Span Tied Arch

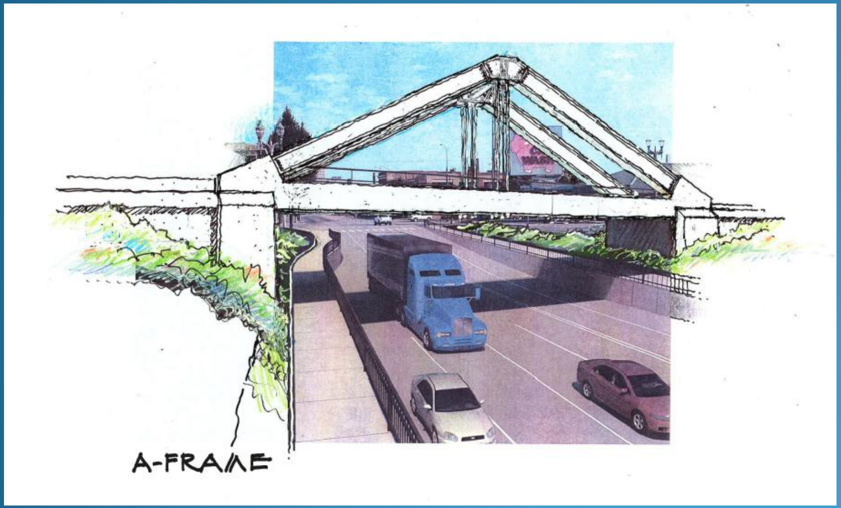




Alternatives Cont'd

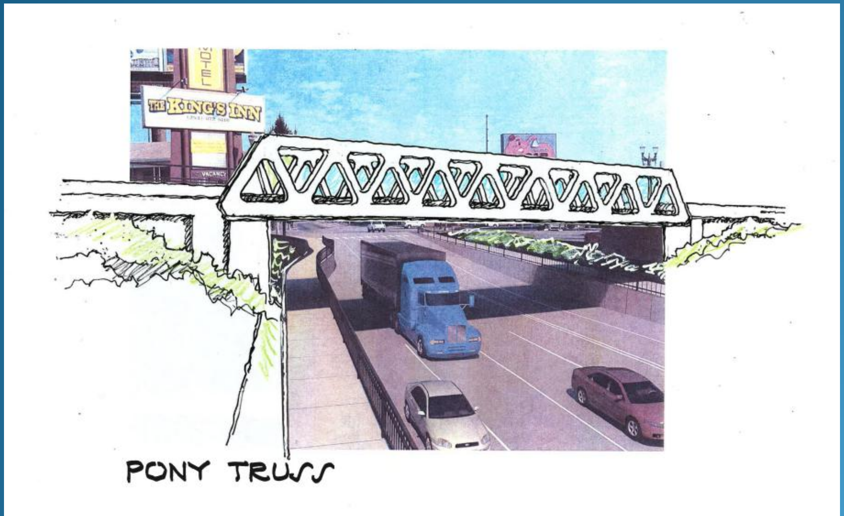
- Single Span A-Frame

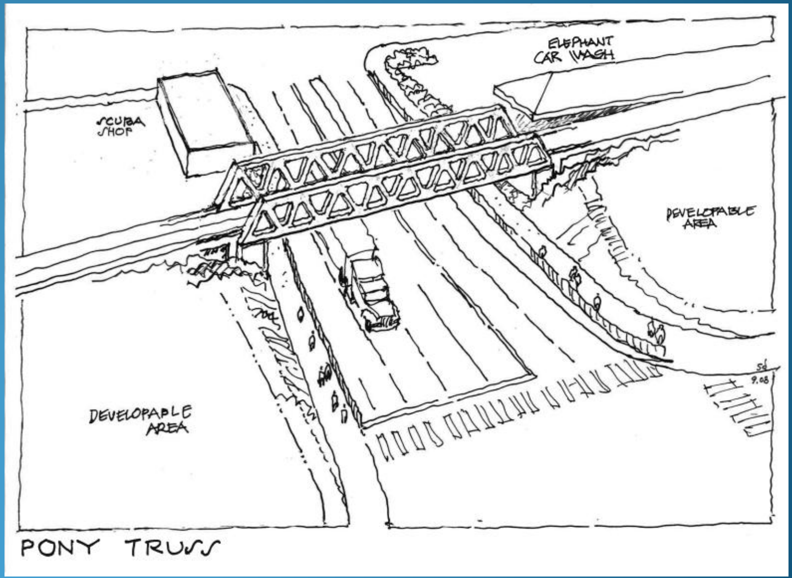




Alternatives Cont'd

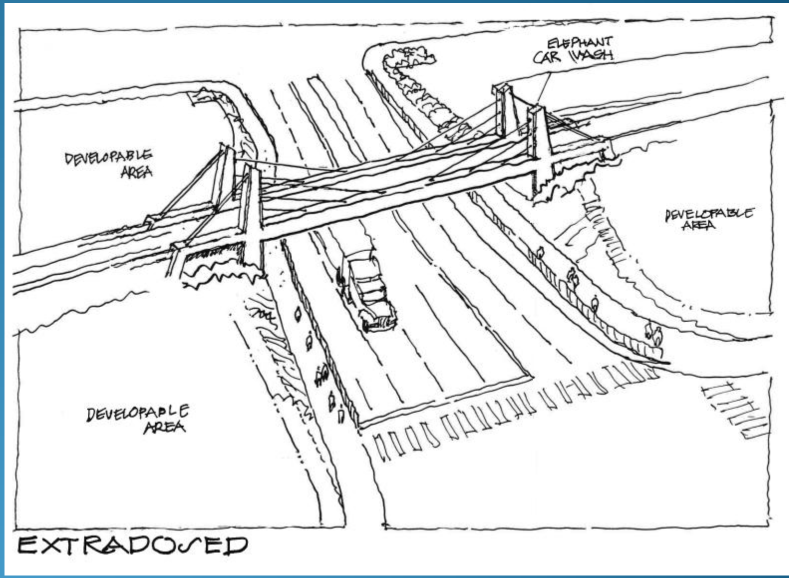
- Single Span Pony Truss

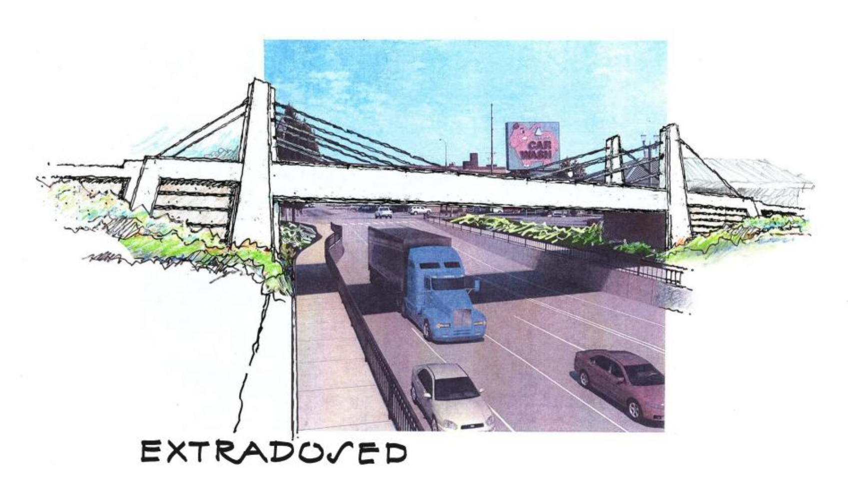




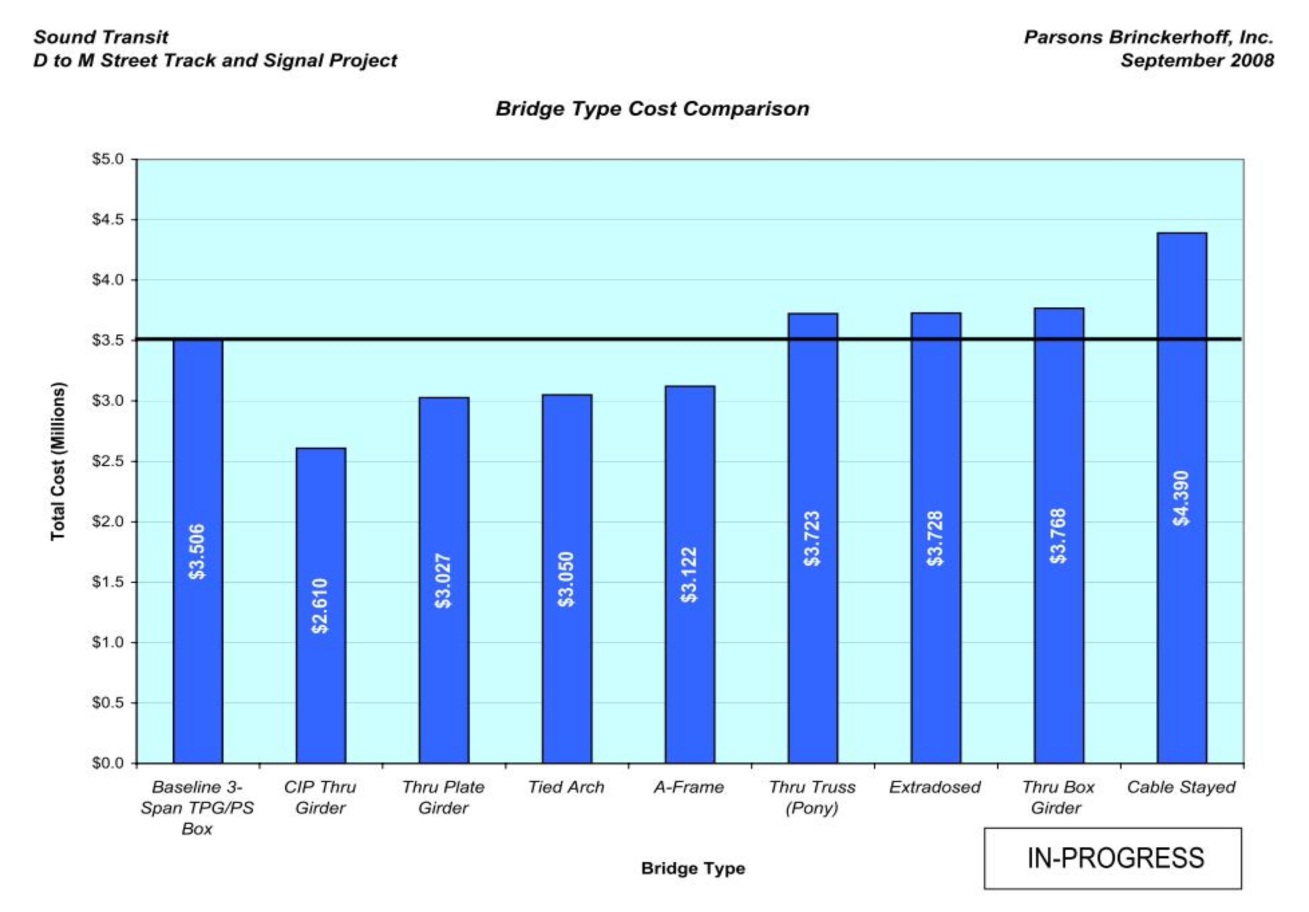
Alternatives Cont'd

- Single Span Extradosed





Bridge Type Cost Comparison



Structure Type Evaluation Matrix

A weighted criteria approach was taken using the following categories:

a) *Aesthetics*
b) *Impact to Roadway Profile*
c) *Gateway Potential*
d) *Cost*
e) *Schedule*
f) *Structural Behavior*
g) *Constructability*
h) *Durability*
i) *Inspection and Maintenance*
j) *Geotechnical / Foundations*

Weighting ranged from 1 – 5:

1 – Does not meet minimum criteria
2 – Meets minimum criteria
3 – Exceeds criteria
4 – Clearly exceeds criteria
5 – Significantly exceeds criteria

Structure Type Evaluation Matrix

D to M Street Track and Signal Project
STRUCTURE TYPE EVALUATION MATRIX

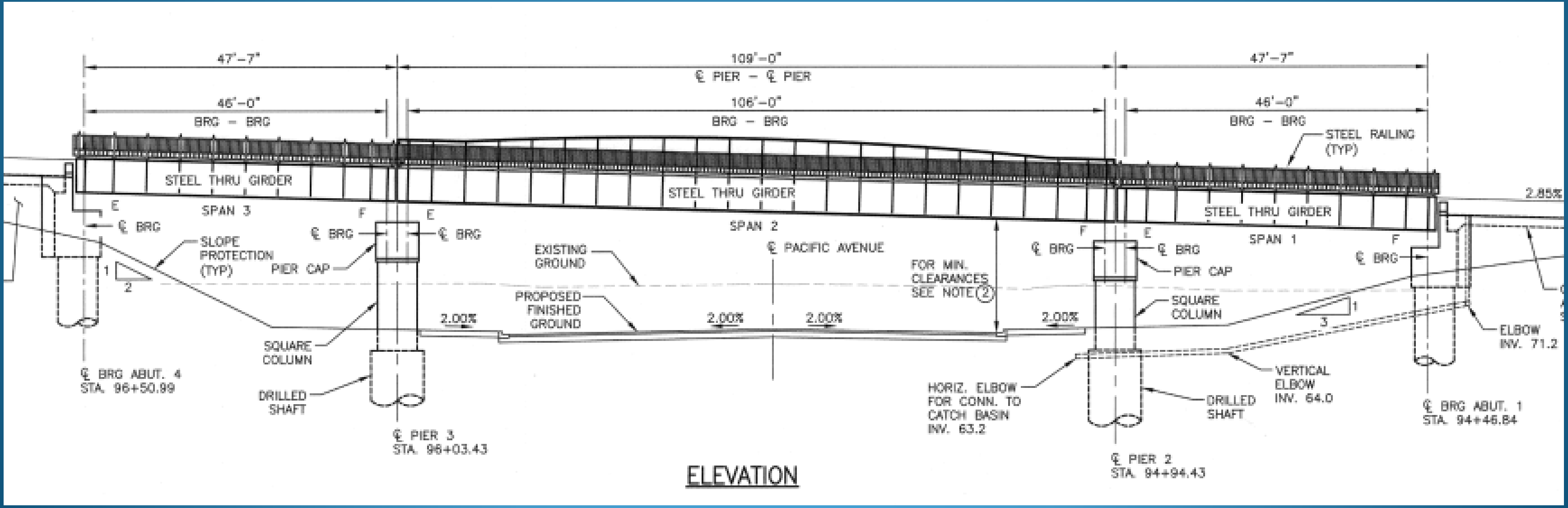
Criteria	Score Weight	STRUCTURE TYPE																			
		Baseline 3-span		A-Frame		Steel Through Girder		Concrete Through Girder		CIP Through Girder		Cable Stayed		Extradosed		Tied Arch		Through Truss	
Aesthetics	4																				
Impact to Roadway Profile	4																				
Gateway Potential	3																				
Cost	5																				
Schedule	3																				
Structural Behavior	2																				
Constructability	3																				
Durability	2																				
Inspection / Maintenance	3																				
Geotech / Foundation	2																				
Total Score			0		0		0		0		0		0		0		0		0
Ranking																					

1 – Does not meet minimum criteria
2 - Meets minimum criteria
3 - Exceeds Criteria
4 – Clearly Exceeds Criteria
5 – Significantly Exceeds Requirements

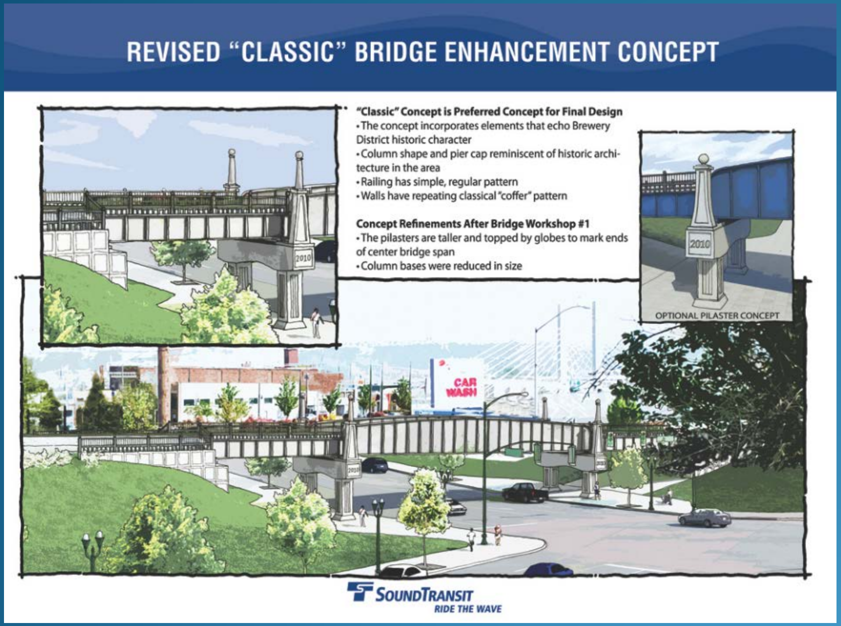
Highest score indicates most preferred structure type

Final Alternative Selection

- The single span Thru Plate Girder was preferred based on:
  - Least cost
  - Most constructible
  - Least impact to roadway
- Ultimately due to urban design concerns in the downtown area a 3-span TPG structure was selected.



Public Workshops (July 2009)



Aesthetic Studies

Color, Railing Type, and
Surface Treatments

Aesthetic Lighting

Pacific Ave Bridge - Rendering

Pacific Ave Bridge - Photo

Pacific Ave Bridge Characteristics

- Steel through plate girder superstructure with reinforced concrete ballast pan
  - 106' Main Span with 11'-3" deep plate girders
  - 46'-0" Approach Spans with 5'-4" deep plate girders

Pacific Ave Bridge Characteristics

- Piers
  - Reinforced concrete cap on 5'-6" square columns
  - 8'-0" diameter drilled shafts

Pacific Ave Bridge Characteristics

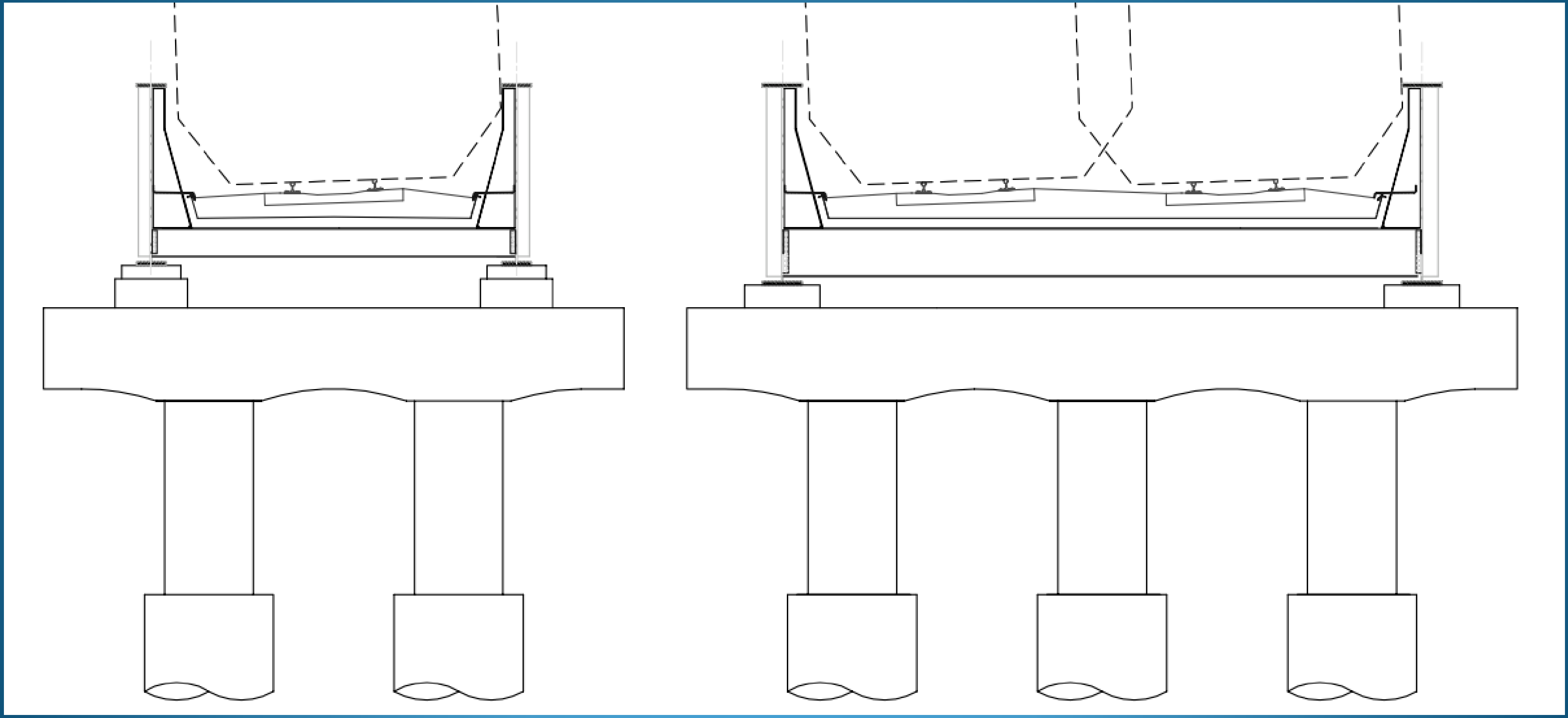
- Abutments
  - Reinforced concrete cap on 6'-0" diameter drilled shafts

Design Challenges

- Substructure design must accommodate initial single track and future double track superstructures
  - Initial single track for Sound Transit's Sounder commuter train
  - Future additional track for Amtrak passenger train
- Liquefaction potential in 10' layer of soil overlain by 30' of fill
  - Downdrag on drilled shafts due to overlying material
  - Balance ductility with rail structure stiffness requirements

Designing for Future 2nd Track

- Two column/shaft substructure designed for eventual third symmetrical column/shaft



Initial – Single Track

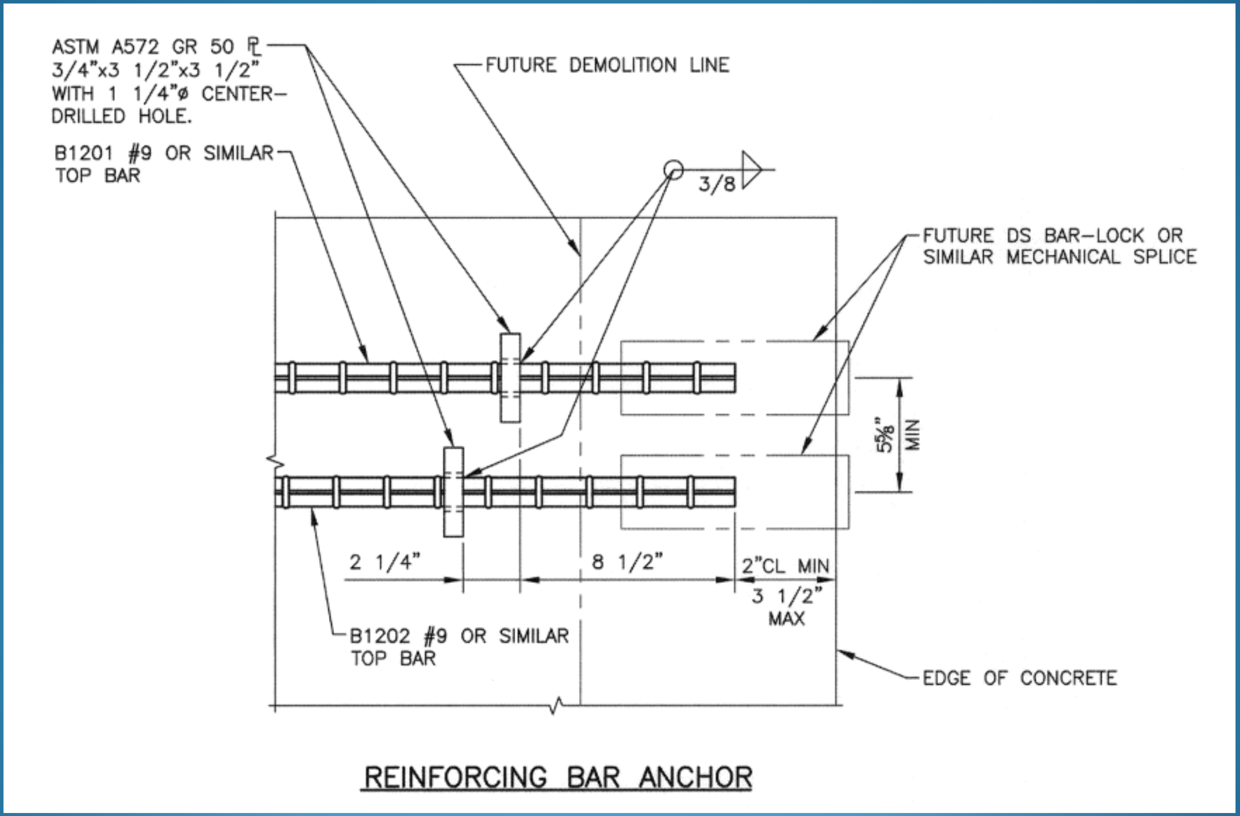
Final – Two Tracks

Designing for Future 2nd Track

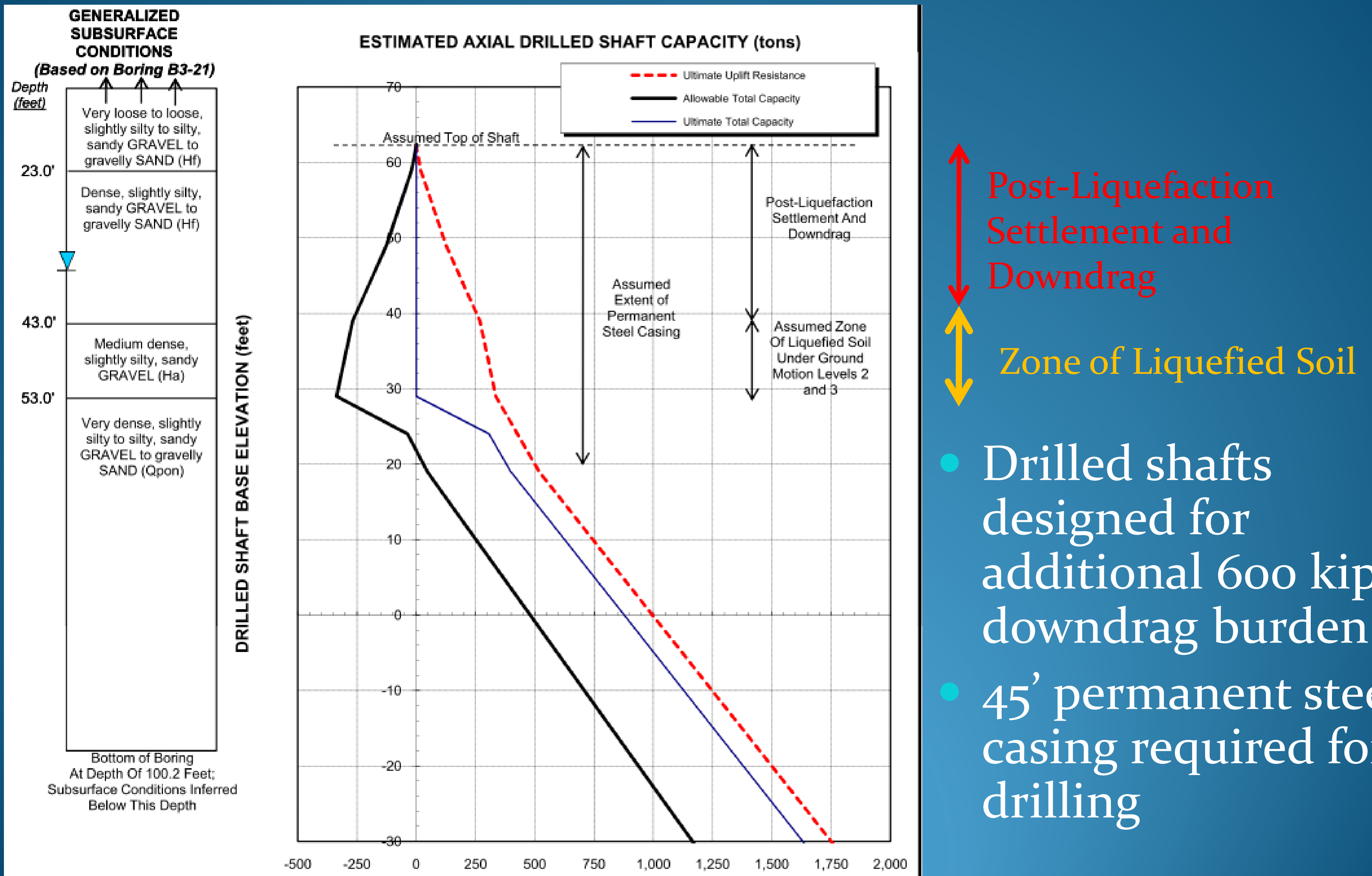
- Top of bent elevations established for two-track superstructure
  - Floorbeams 70% greater in height for future structure
  - Bearings 70% greater in height for future structure
  - Temporary pedestals for initial structure elevation

Designing for Future 2nd Track

- Cap reinforcement designed with internal headed anchorages to minimize service disruption during cap extension



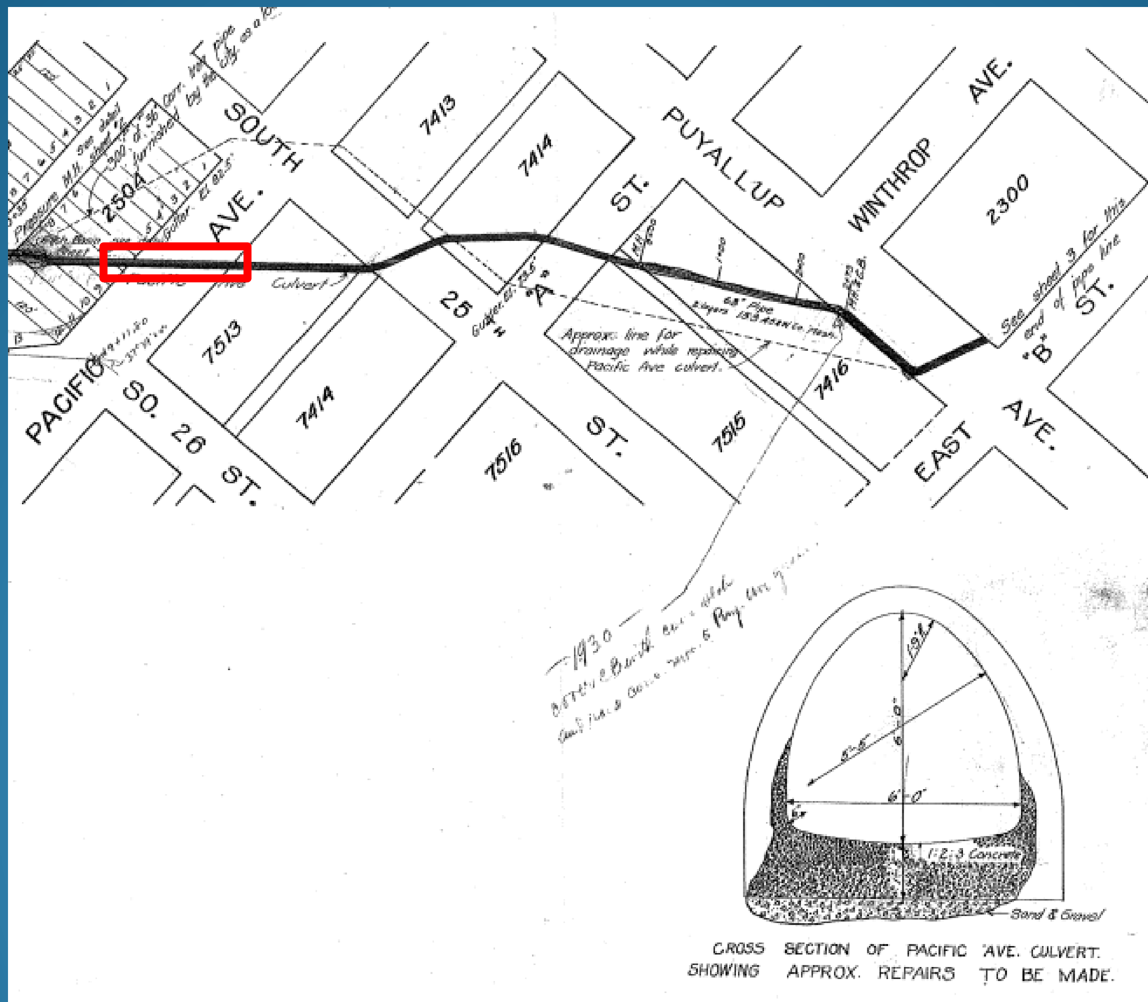
Liquefaction Hazard



- Drilled shafts designed for additional 600 kip downdrag burden
- 45’ permanent steel casing required for drilling

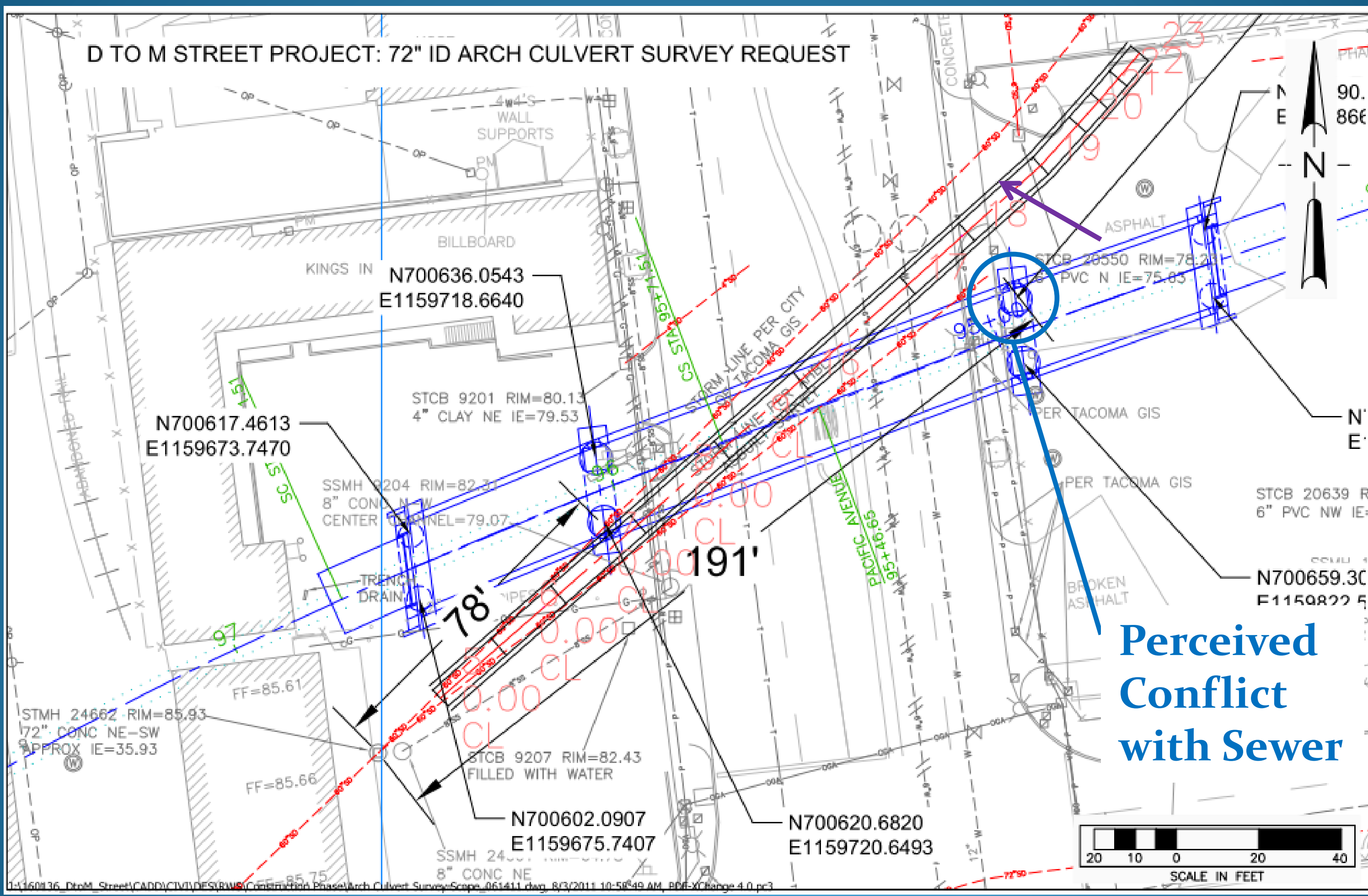
Pier 3 Drilled Shaft Conflict

- 72” diameter culvert 30’ below grade at pier 3



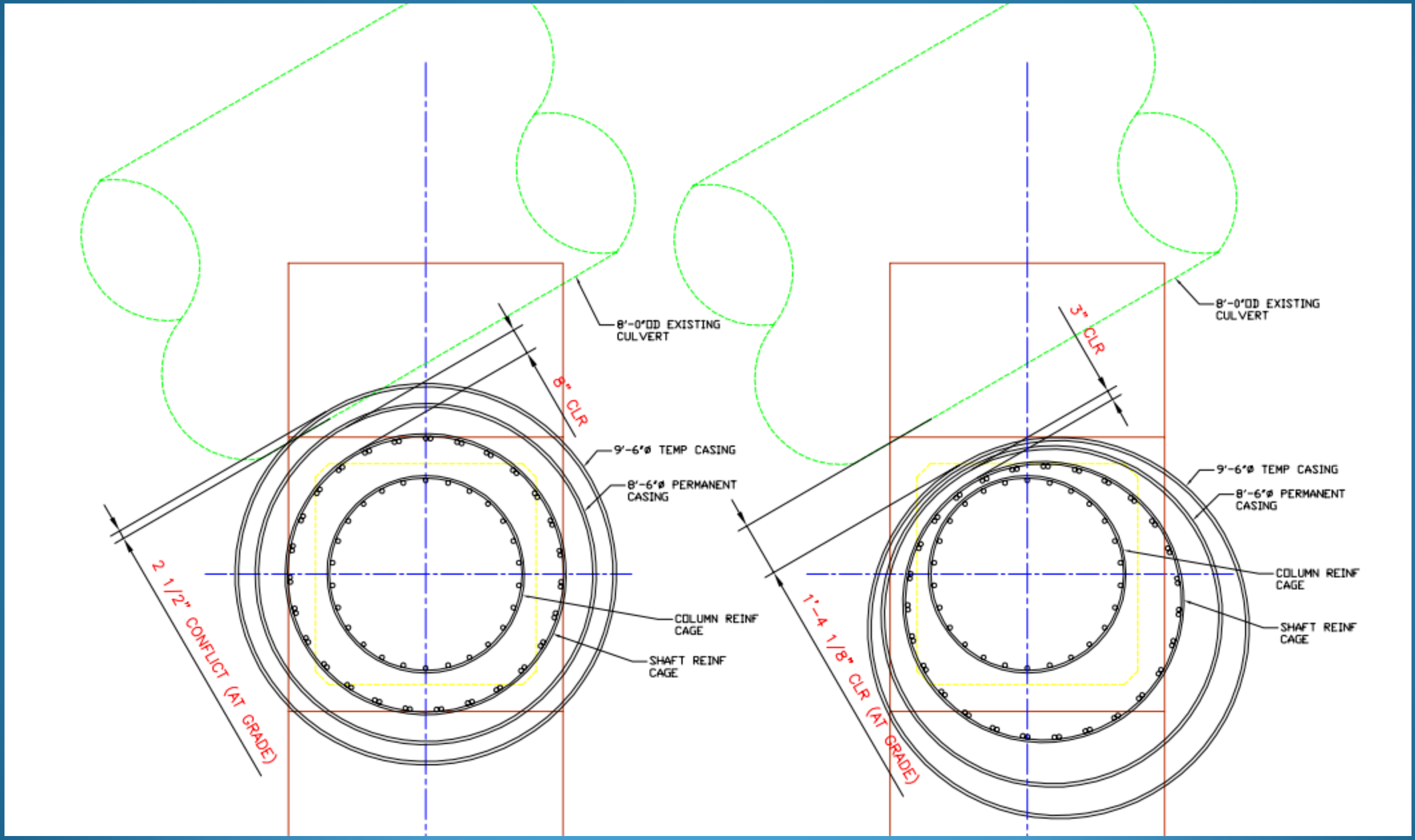
Pier 3 Drilled Shaft Conflict

- Perceived conflict of drilled shaft installation with existing existing storm sewer at Pier 2



Pier 3 Drilled Shaft Conflict

- Larger auger size vs. tolerance for plan location and plumbness for shaft resulted in potential conflict
- Explore shaft construction tolerance to avoid culvert

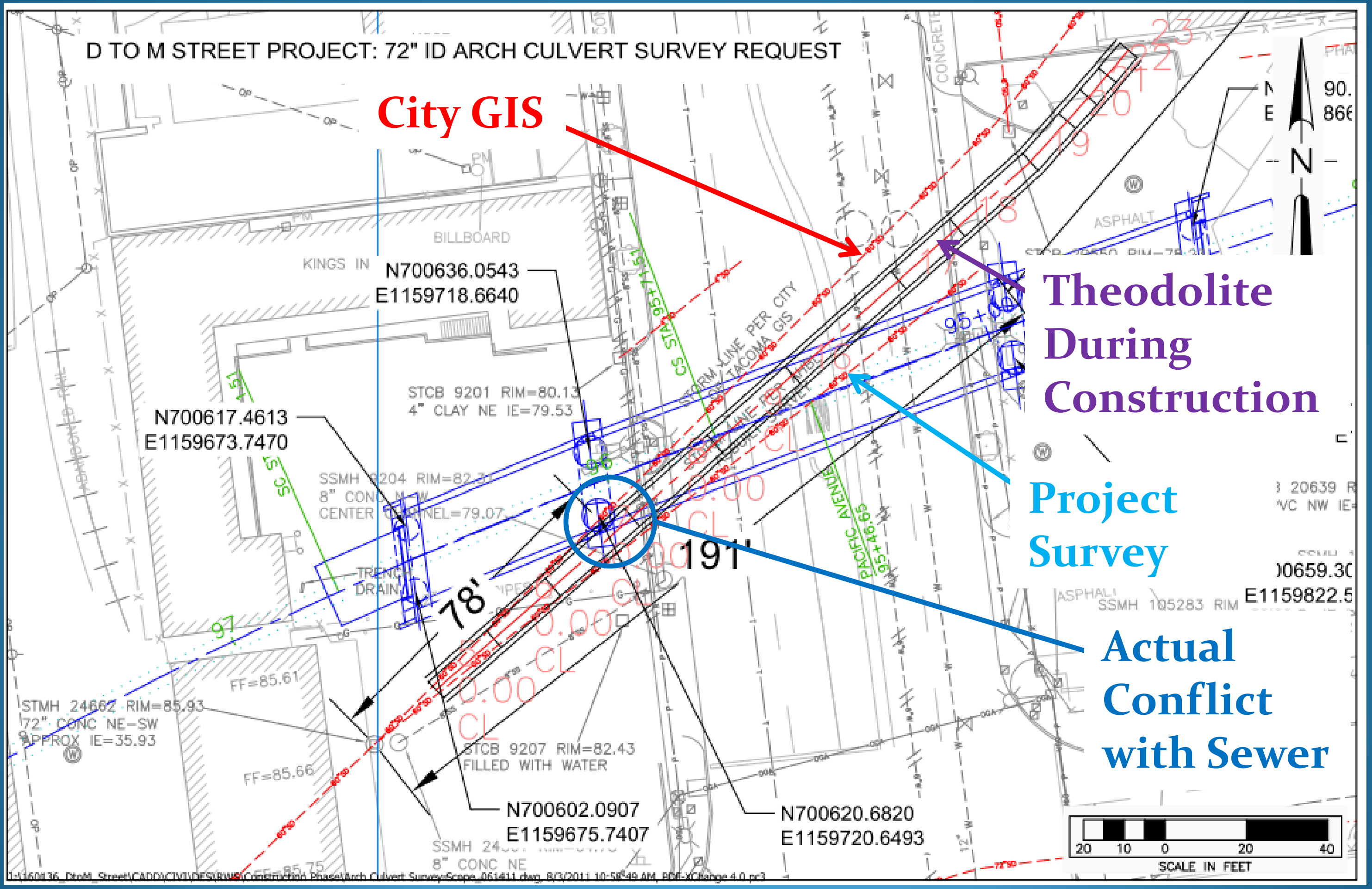


Pier 3 Drilled Shaft Conflict

- Culvert still too close for comfort. Eventual use of a gyroscopic theodolite below surface provided the desired confidence in location

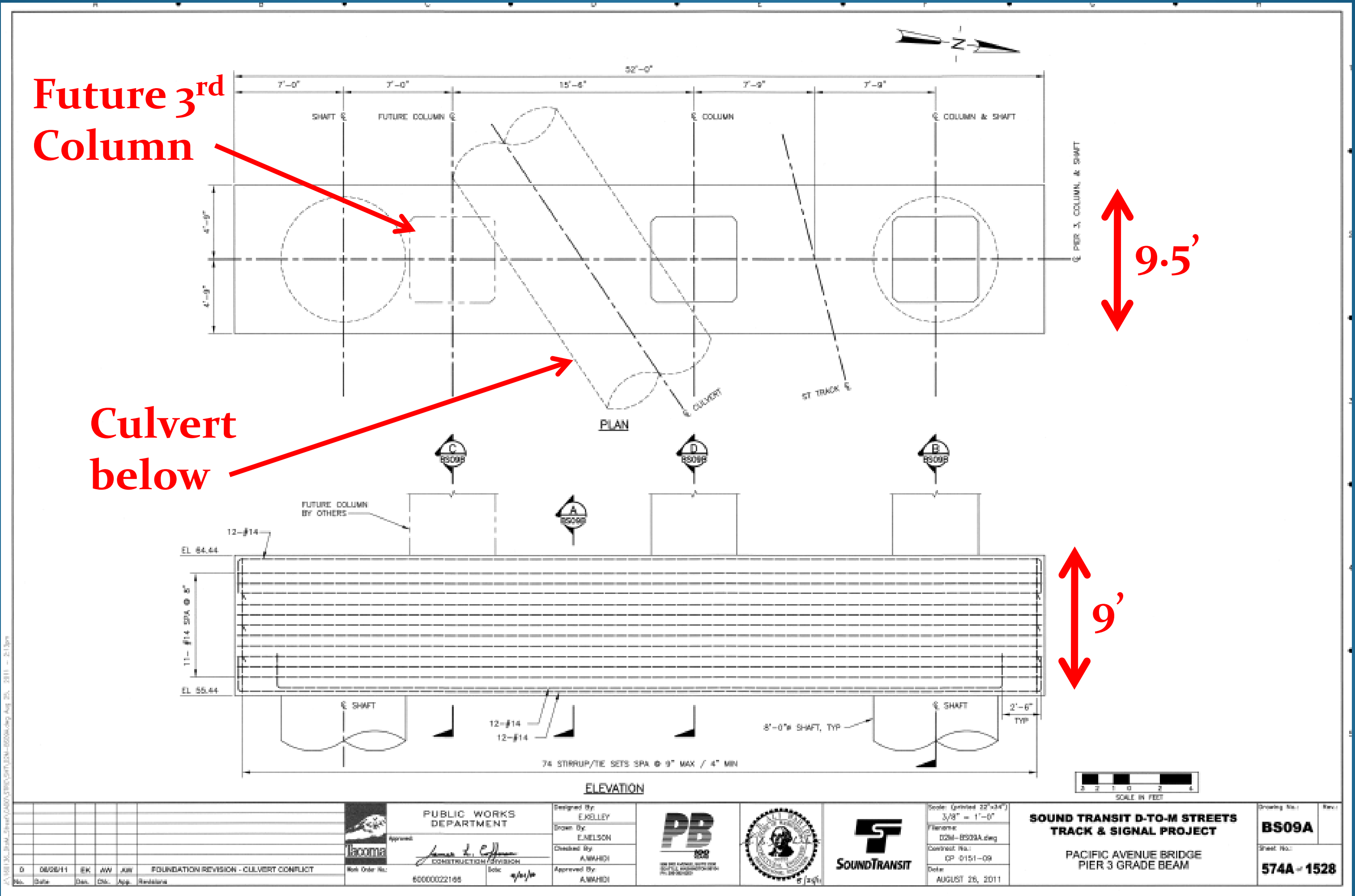
Pier 3 Drilled Shaft Conflict

- City GIS vs. surface survey vs. gyroscopic theodolite survey
- Theodolite investigation revealed actual conflict at Pier 3



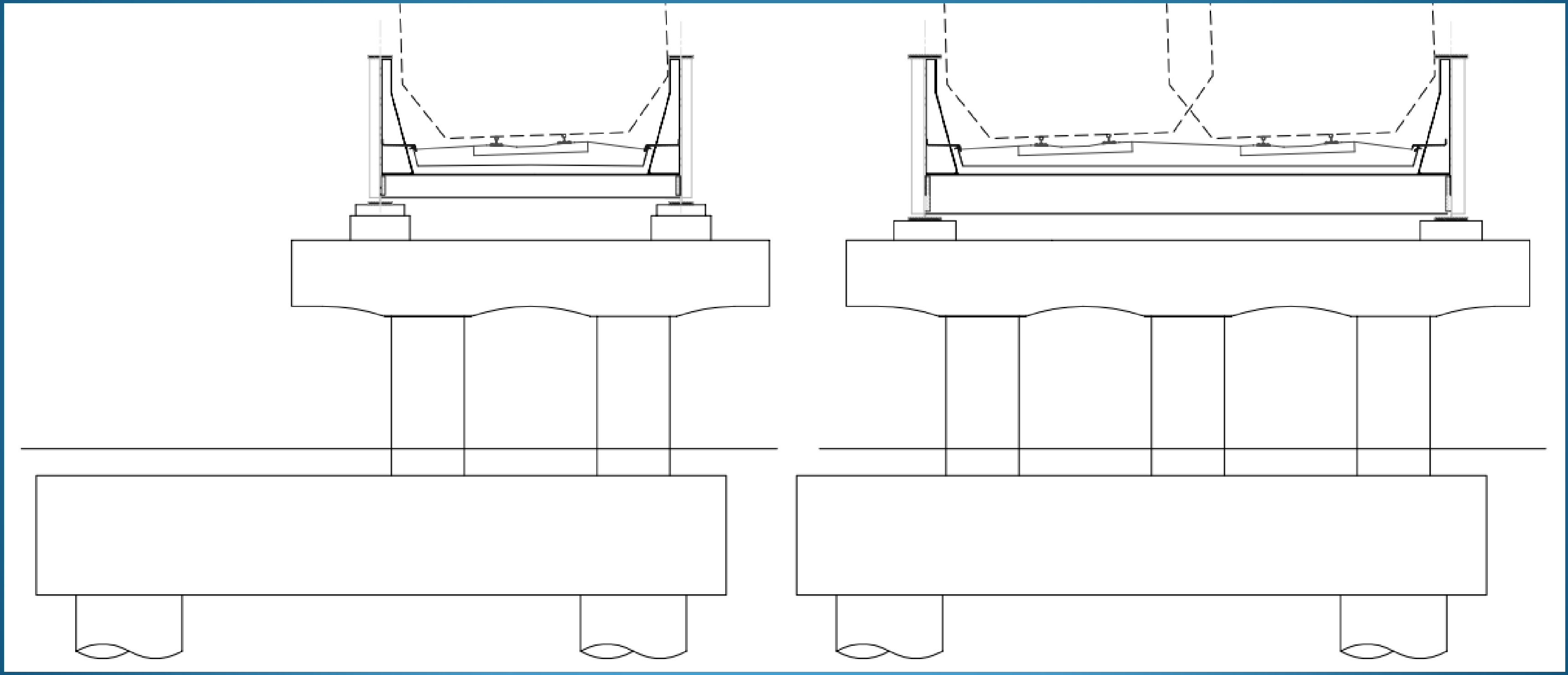
Pier 3 Drilled Shaft Conflict

- Redesign pier 3 using grade beam to avoid culvert



Pier 3 Drilled Shaft Conflict

- Design revision utilized existing 8' diameter drilled shaft reinforcing cages.
- Reinforcing cages were extended approximately 50' using mechanical couplers



Initial – Single Track Final – Two Tracks

Pier 3 Drilled Shaft Conflict

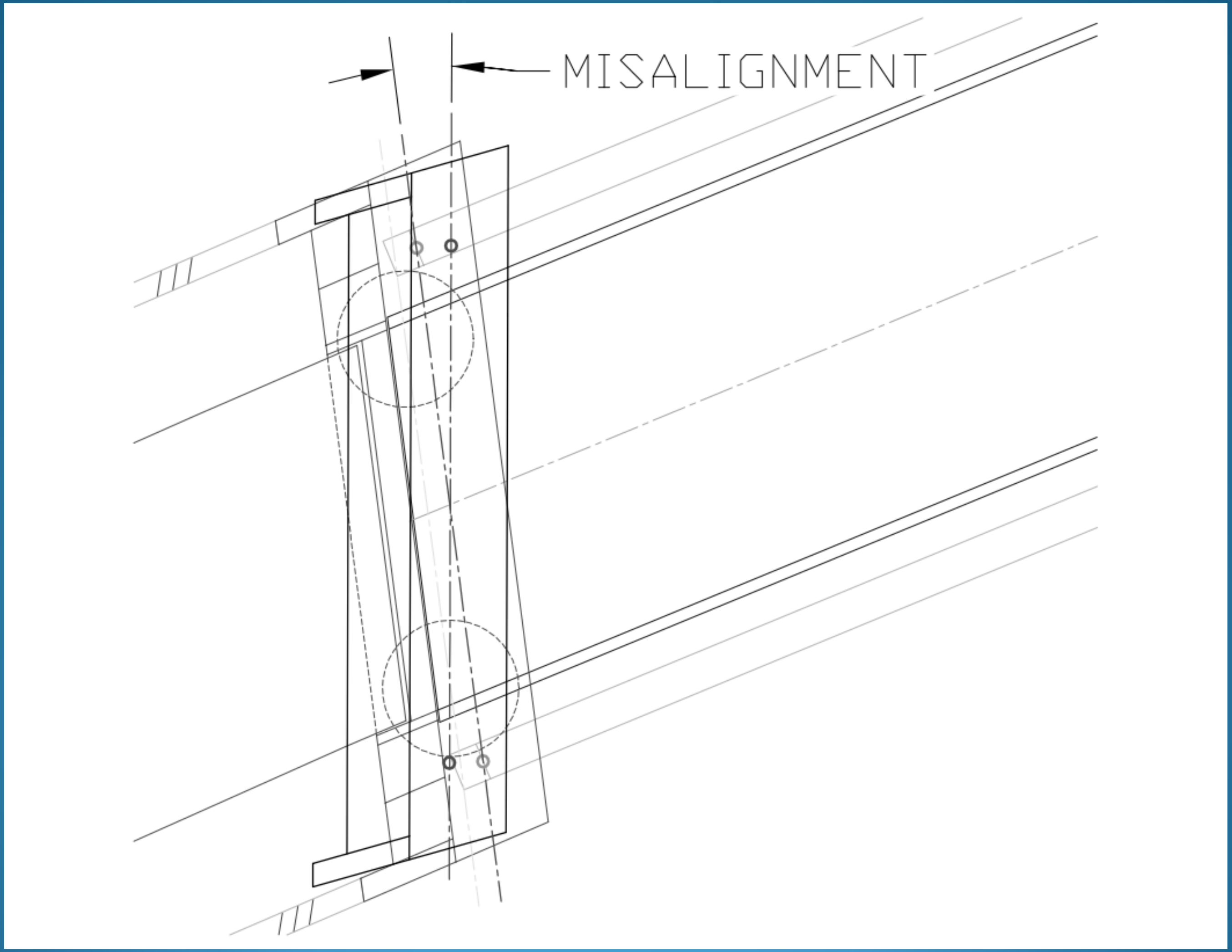
- Excavation for grade beam installation

Pier 3 Drilled Shaft Conflict

- Shaft and grade beam reinforcing

Abutment Misalignment

- Bent 4 placed incorrectly



Abutment Misalignment

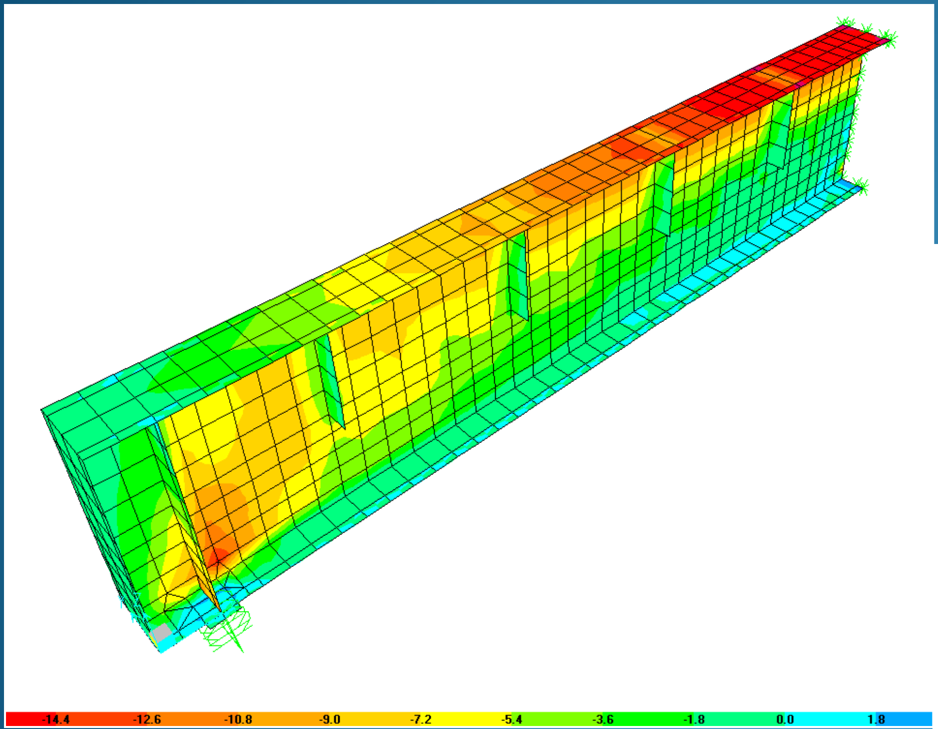
- Abutment 4 bearing stiffeners offset from bearing

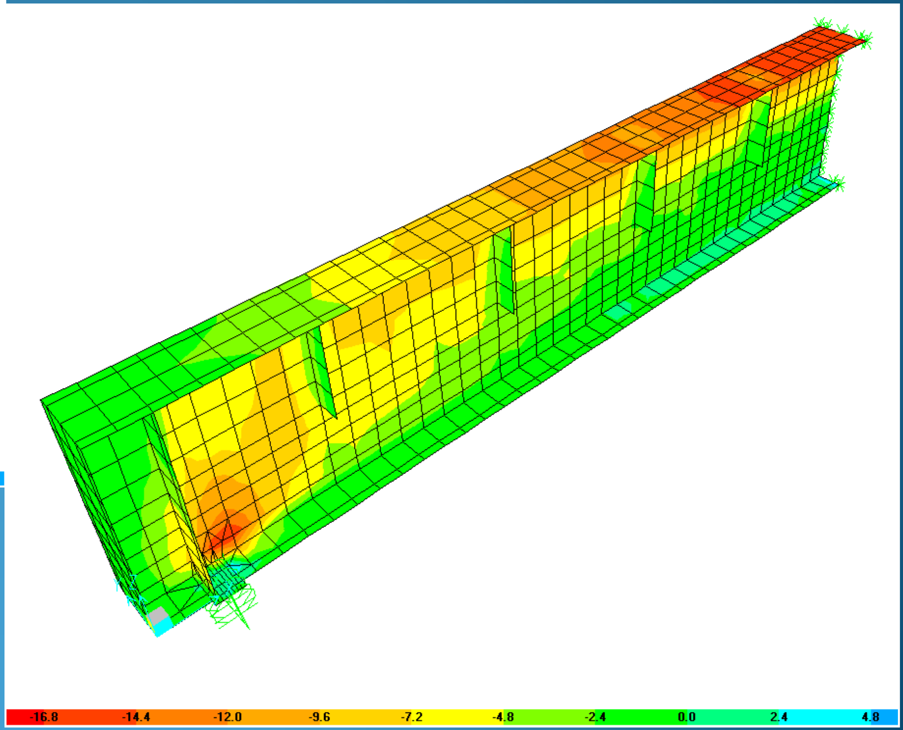
South Misalignment

North Misalignment

Abutment Misalignment

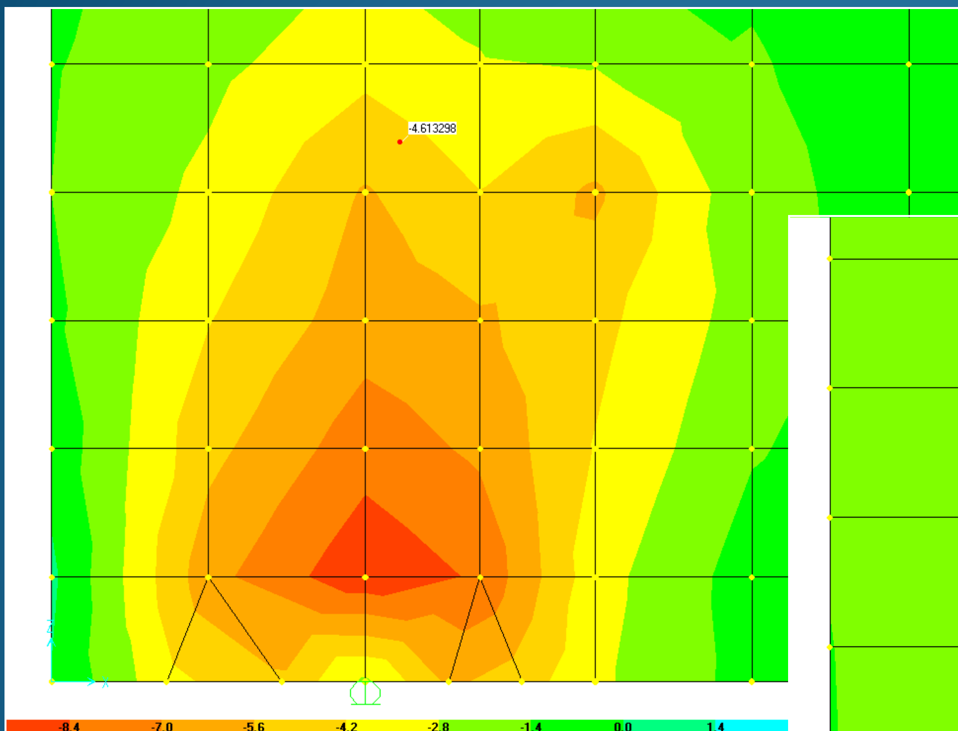
- Web stress comparison between design and as-constructed for north girder





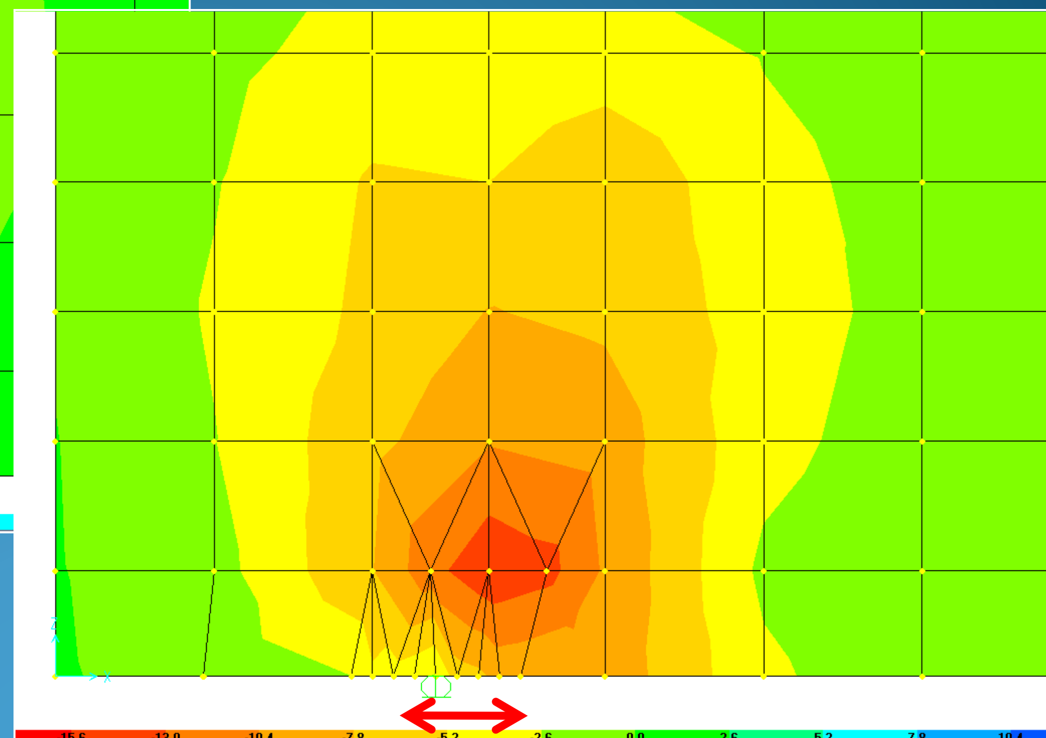
Abutment Misalignment

- Web Compressive Stress Detail



9.5 ksi Design Stress
(Aligned)

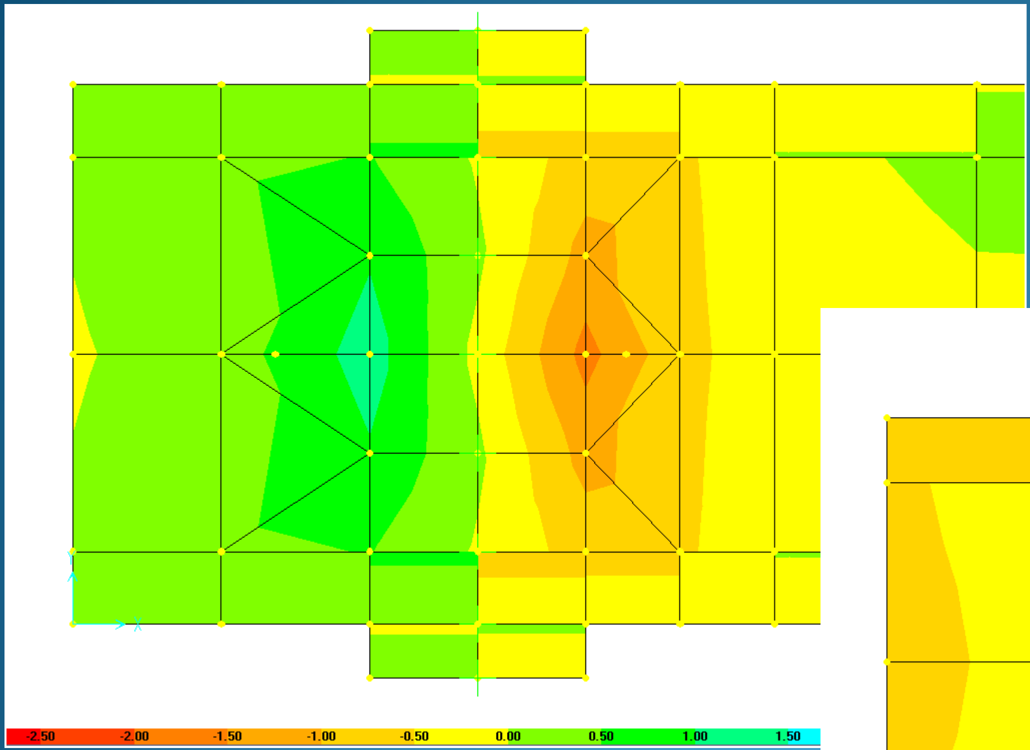
15.1 ksi As Constructed
(Misaligned 3”)



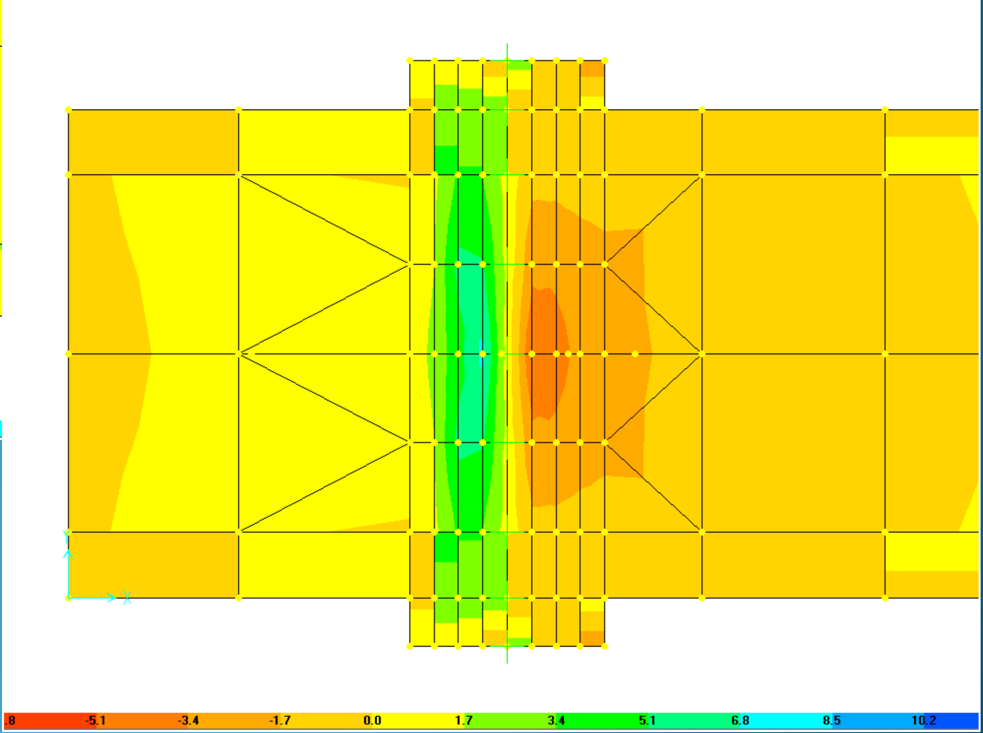
17.5 ksi Allowable Okay

Abutment Misalignment

- Rocker Plate Weld Stress Investigation

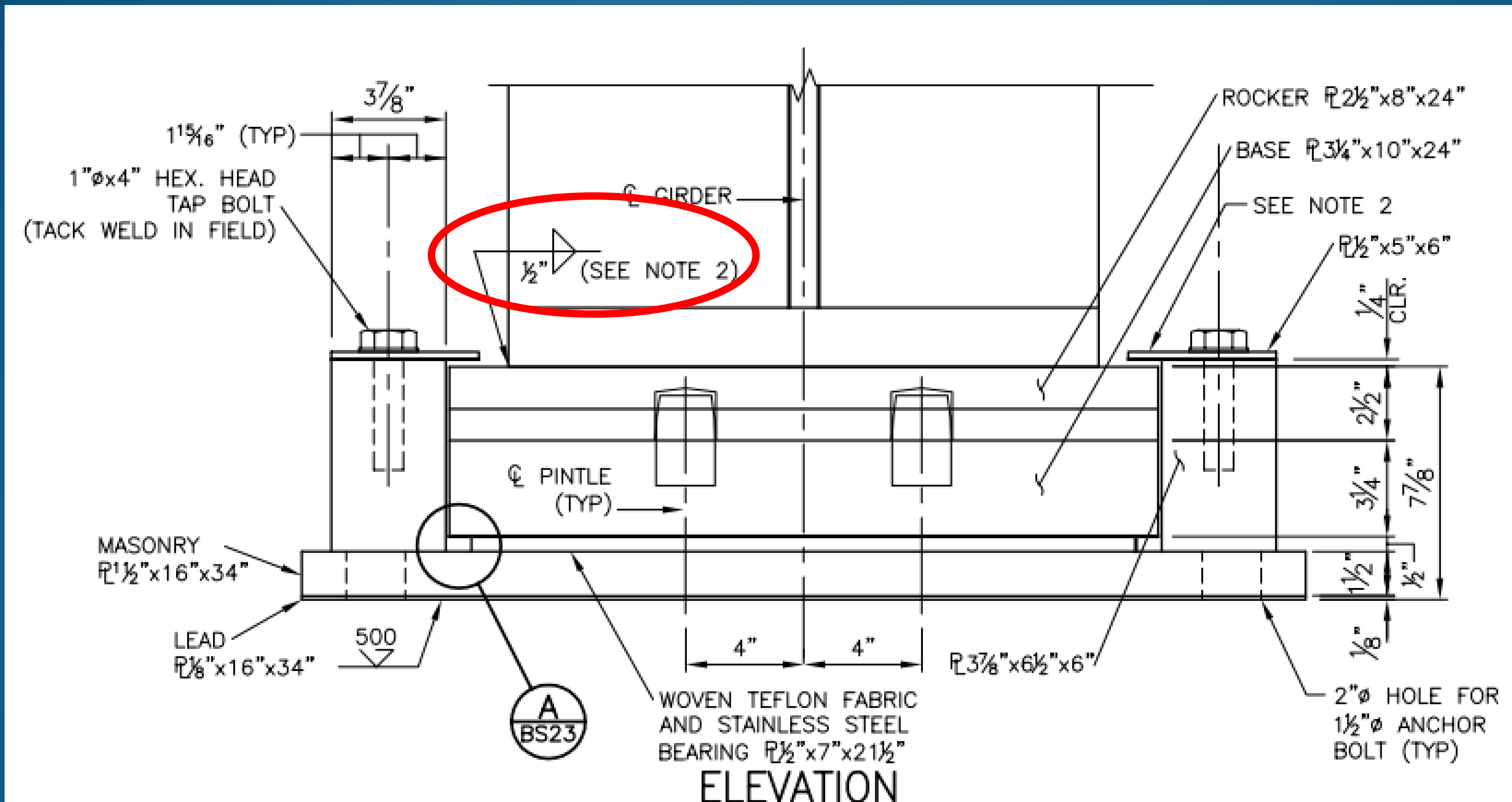


Misalignment created increase in weld stress for fatigue loading



Abutment Misalignment

- Increase flange to rocker plate weld size to ¾”



2. AT ABUTMENT 4, GIRDER "F" & "E", TRIM THE BEARING KEEPER PLATES 1/2" AND INCREASE THE SIZE OF THE LONGITUDINAL WELDS BETWEEN THE BOTTOM FLANGE OF THE GIRDER AND THE ROCKER PLATE FROM 1/2" TO 3/4".

Pacific Ave Bridge - Preconstruction

Pacific Ave Bridge - Construction

Pacific Ave Bridge - Final

Thanks to:

- Sound Transit
- Parsons Brinckerhoff
- D to M Streets Team:
  - Shannon & Wilson
  - Cosmopolitan Engineering
  - AHBL
  - GHL
  - Enviroissues
  - William Ott Construction Consultants

Questions?