Recent California Transit Tunnels

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September 29, 2020

CTES Chile

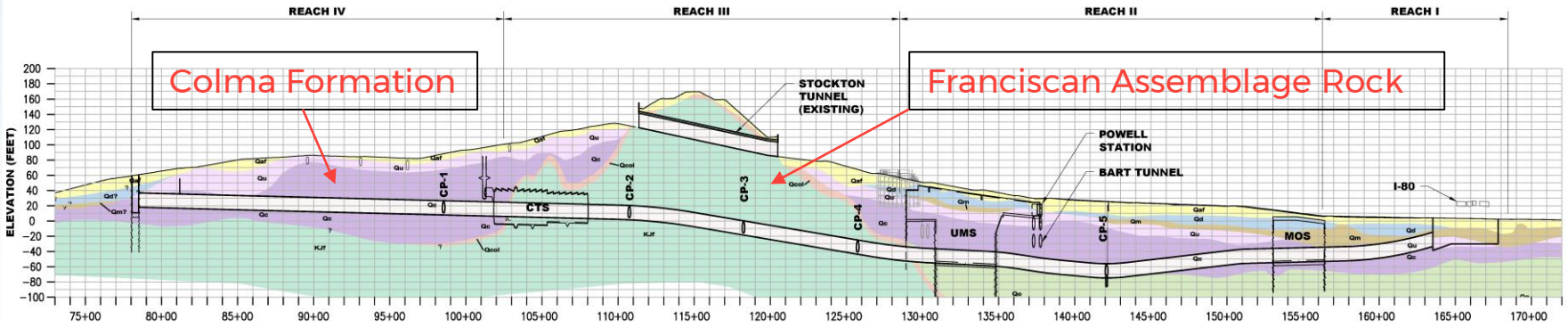
Projects

- Central Subway in downtown San Francisco
- Regional Connector in downtown Los Angeles
- Urban areas with extensive existing infrastructure
- Both excavated with soft ground EPB TBMs
- Expected to be in service in 2021

Central Subway, Downtown San Francisco

Tunnel Plan and Profile

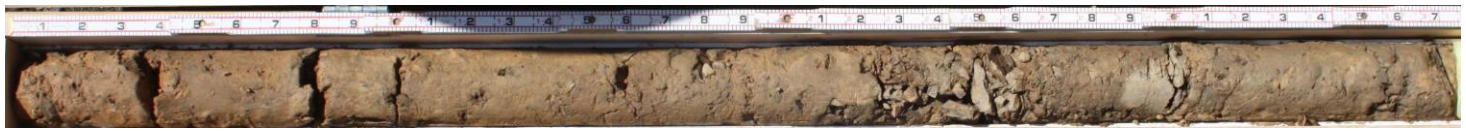
PLAN

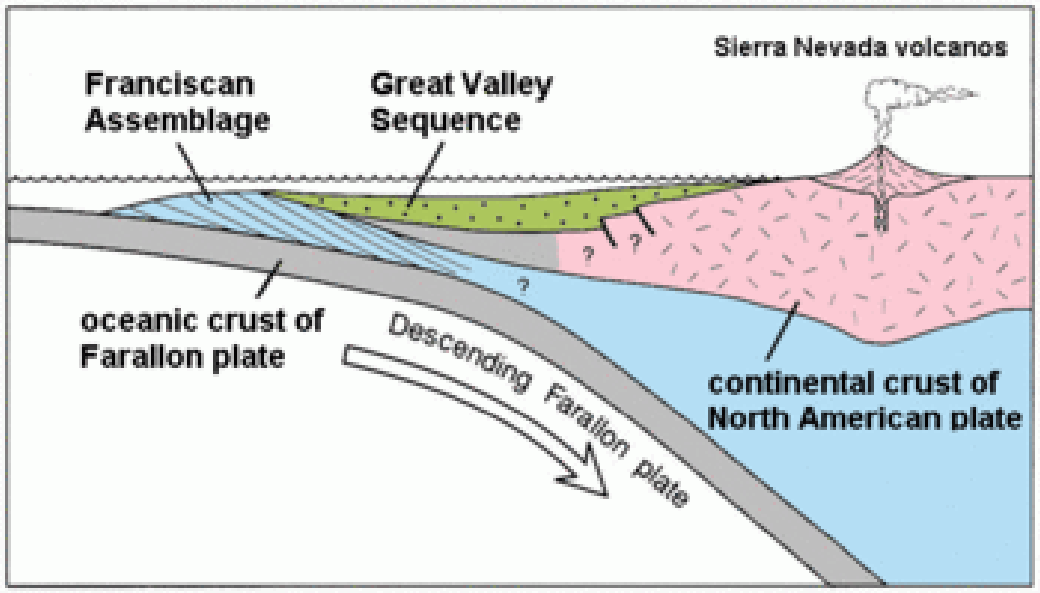


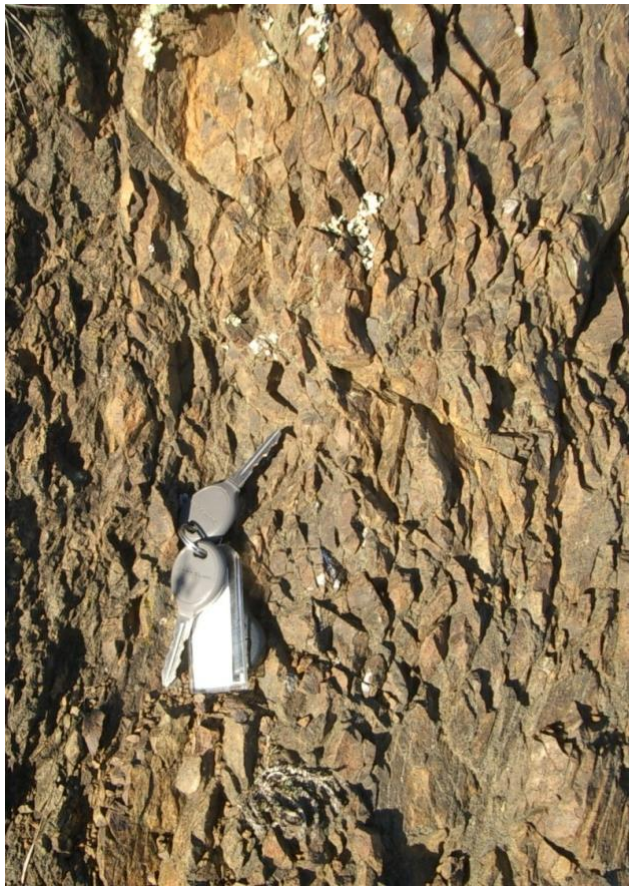
PROFILE

Colma Formation

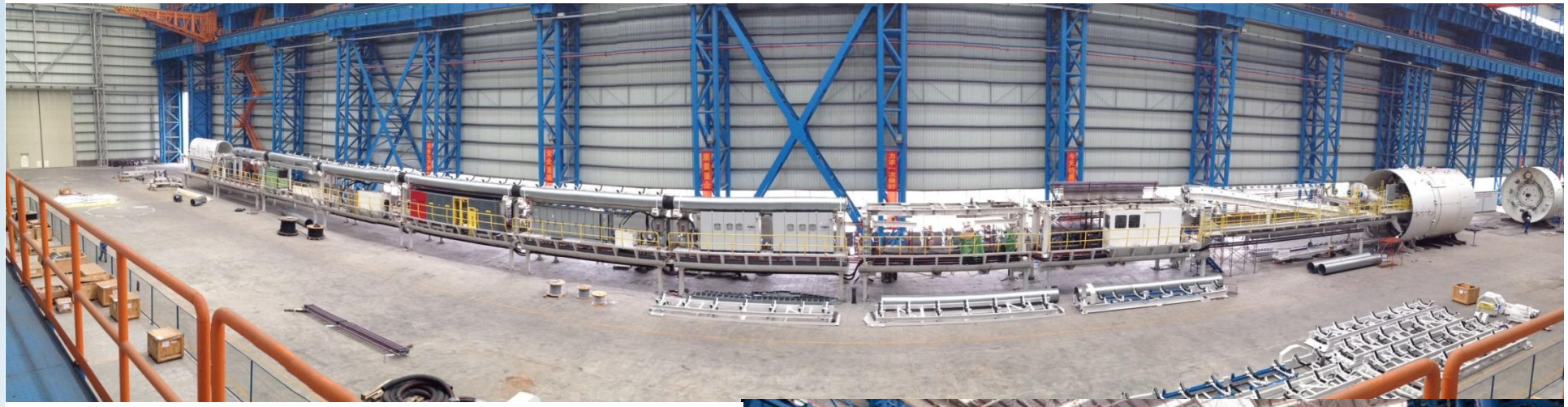
Franciscan Assemblage
(highly variable)





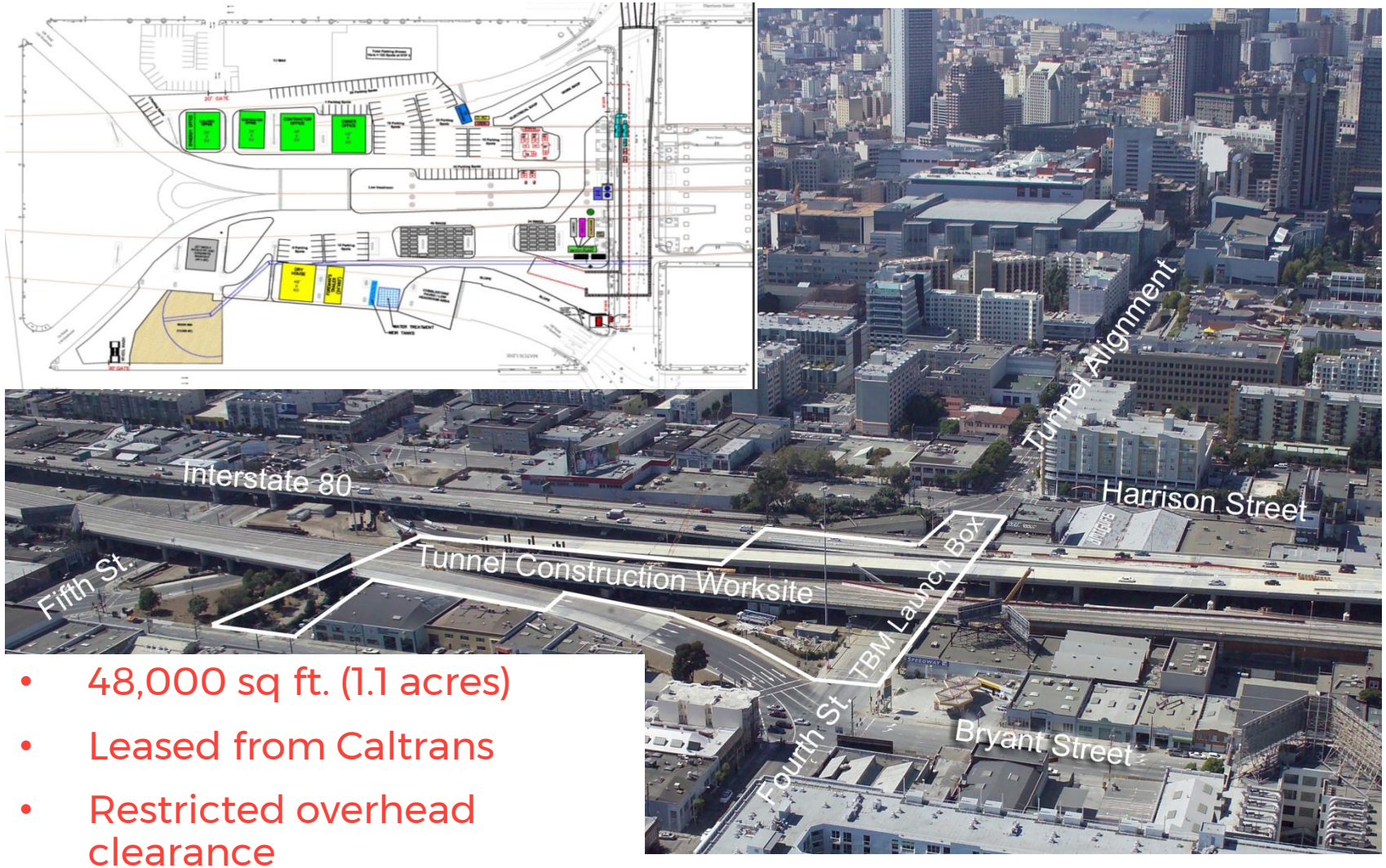


Two new TBMs built by Robbins “Mom Chung” and “Big Alma”



- Earth Pressure Balance
- 20 ft - 8 inch (6.3m) dia.
- Motors 5 x 282 Hp
- Speed 0-4.5 rpm
- Mixed ground cutterhead – disks and teeth
- Opening ratio 31%
- 4 bar max pressure
- Articulated cutterhead, 450 ft radius

Tunnel Construction Worksite



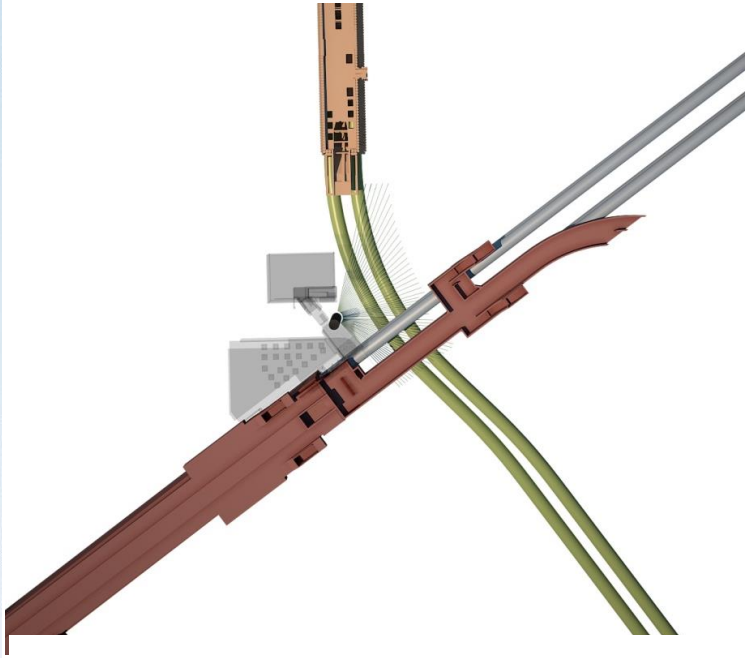
- 48,000 sq ft. (1.1 acres)
- Leased from Caltrans
- Restricted overhead clearance

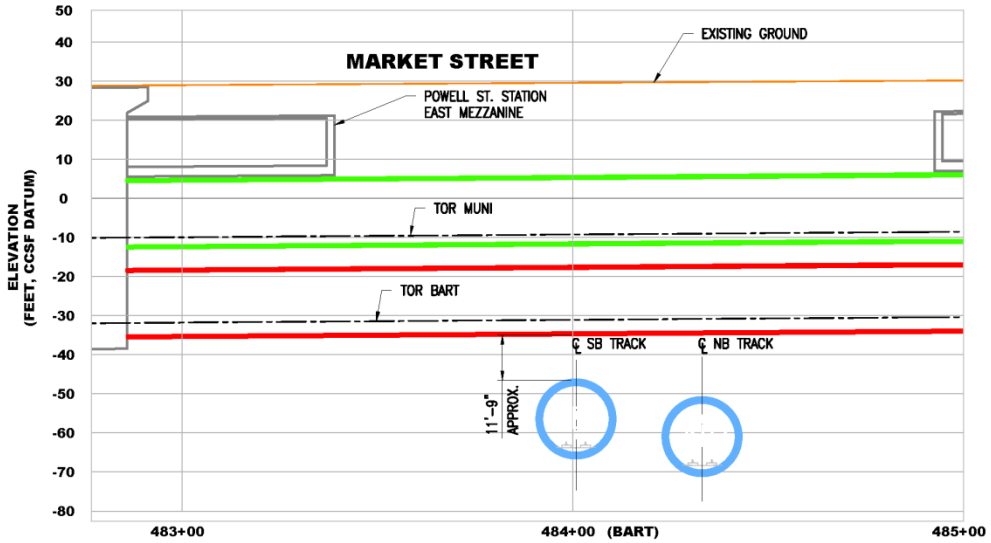
Launch Box

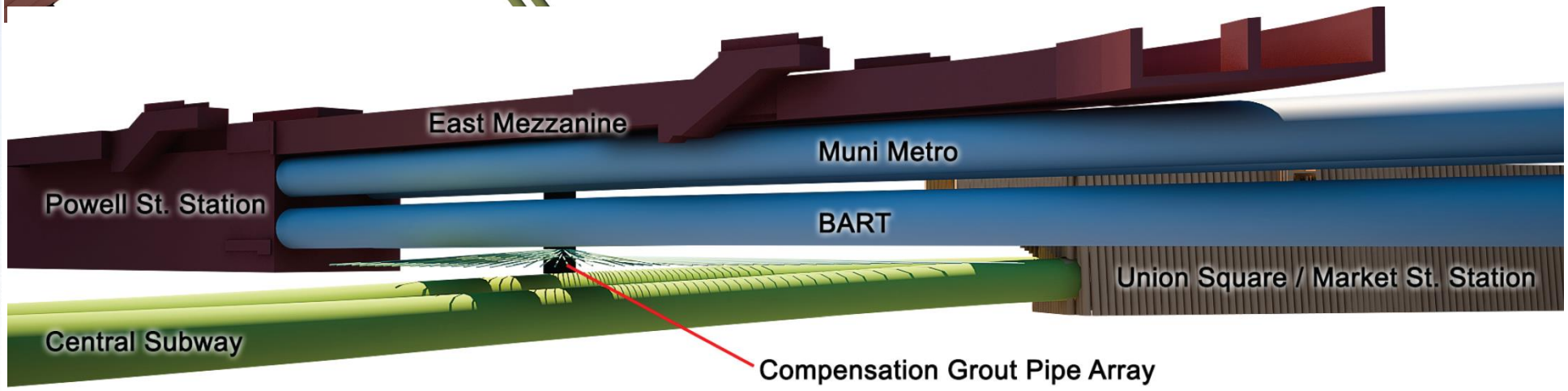
- Under Caltrans I-80 Viaduct
- Fill over compressible soils
- SSI analyses to evaluate effect of box construction on viaduct pile foundations

Precast Concrete Segmental Lining

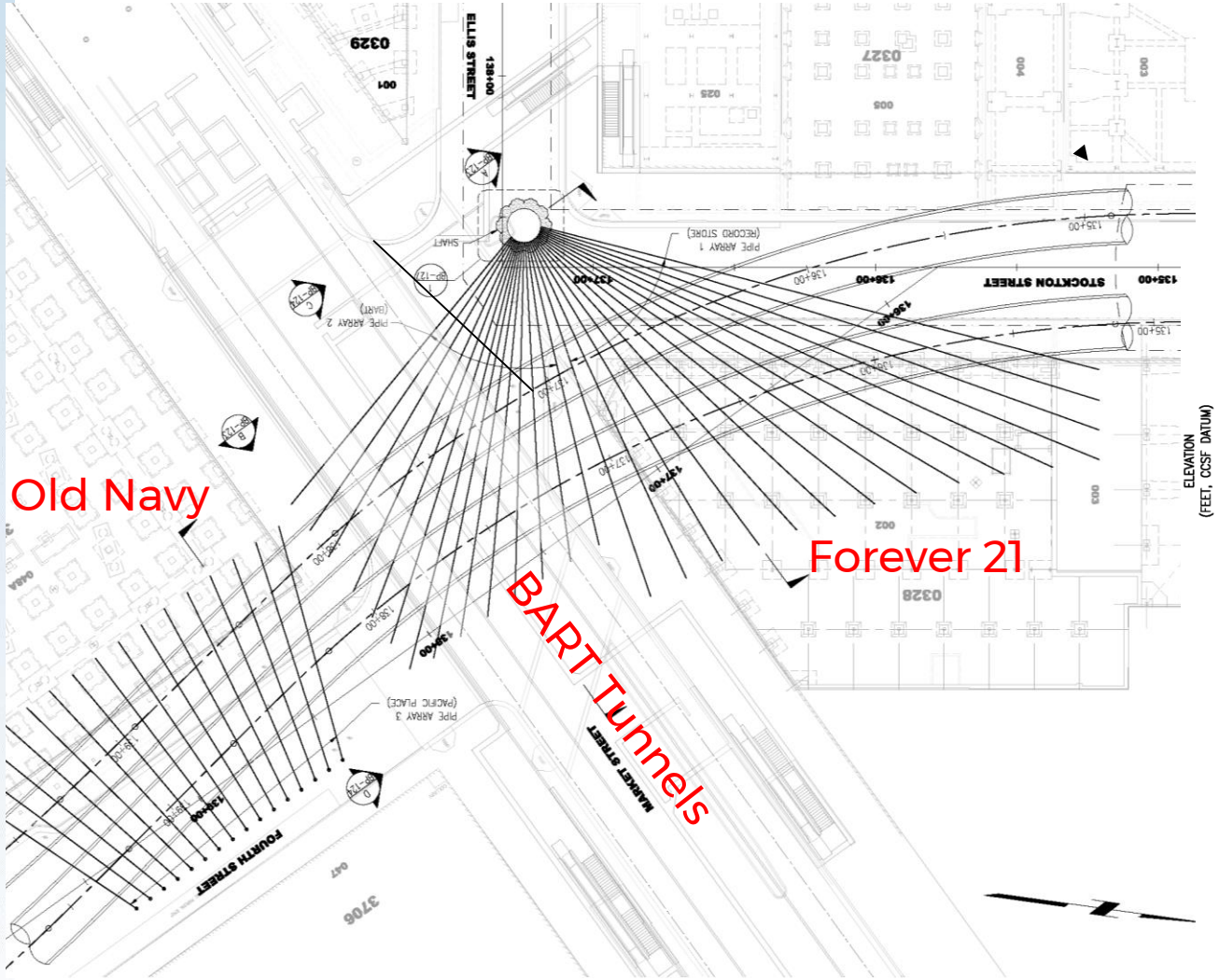
BART Crossing (12 to 15 ft clear)

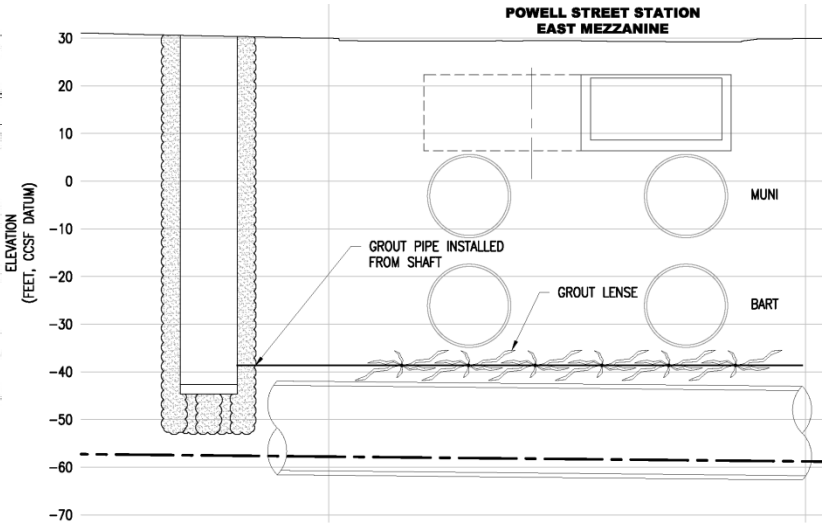






Compensation Grouting Plan

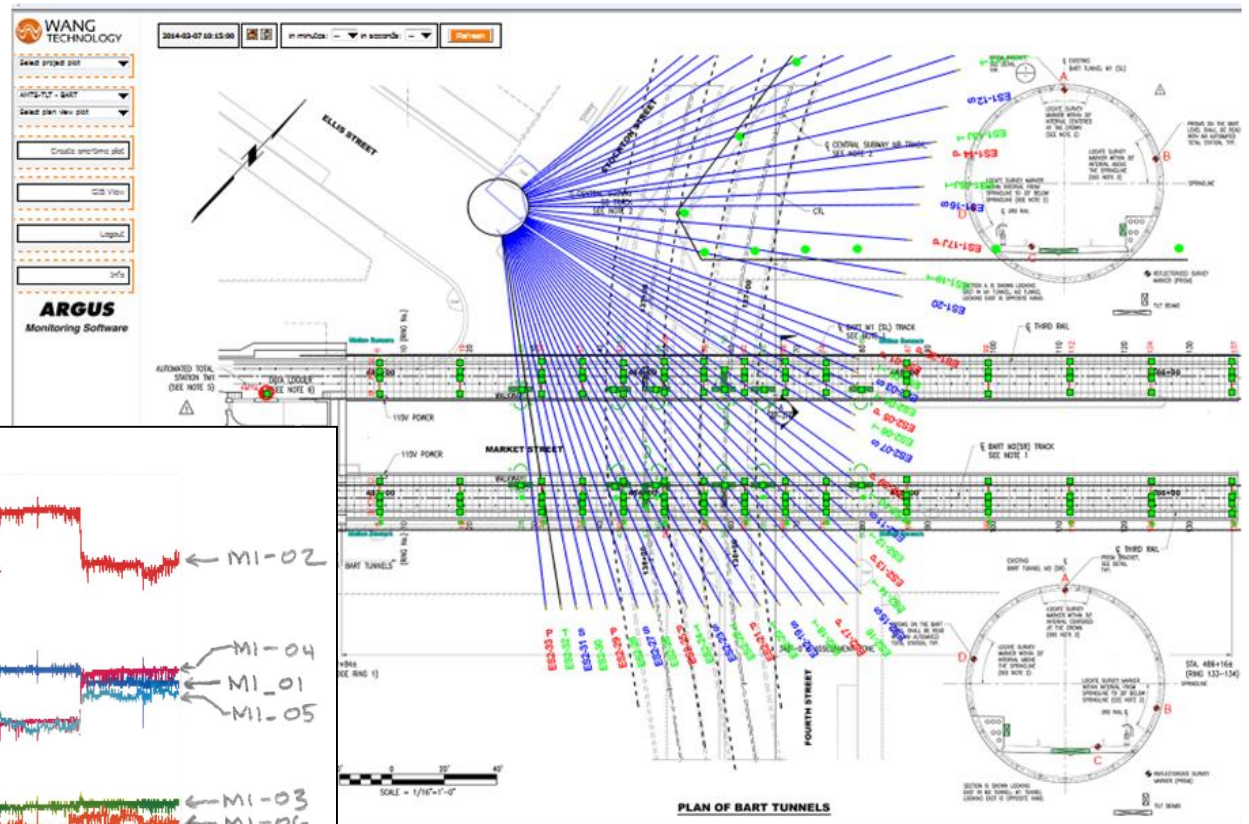


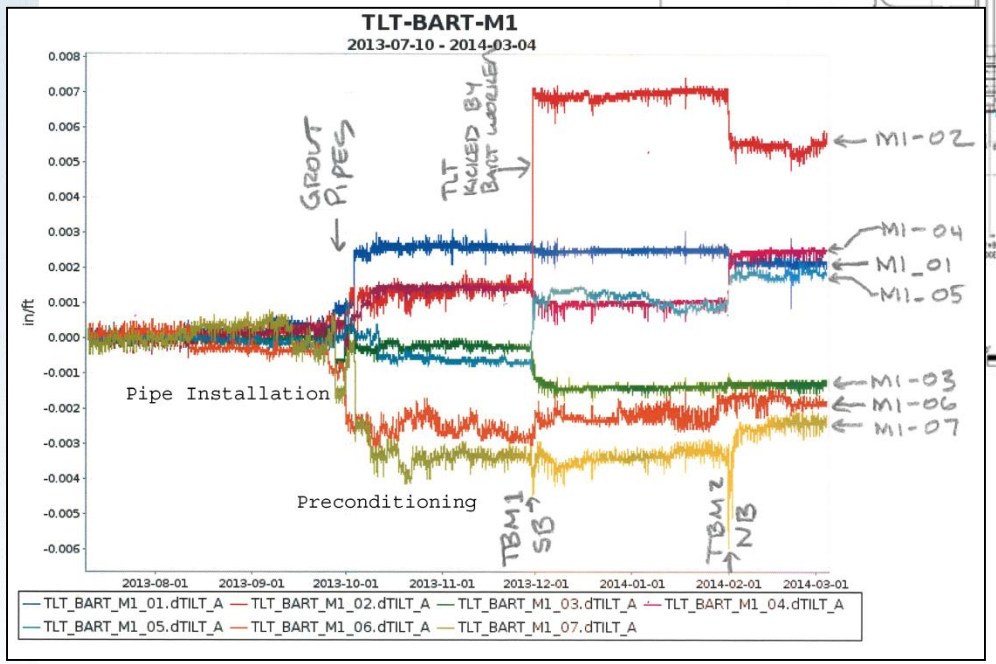


Ellis Street Grouting Shaft

BART Crossing Results

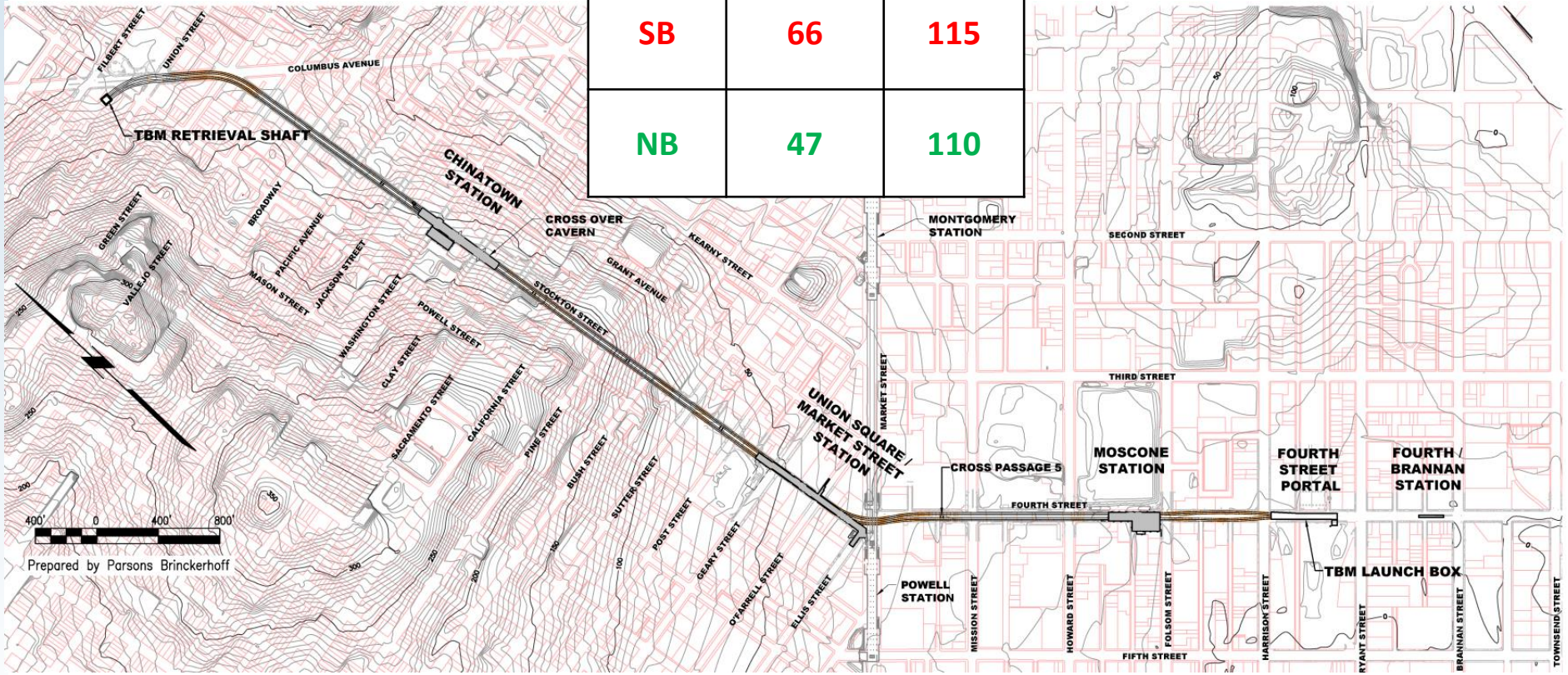
- Rail survey results
- Max settlement:
  - M1 tunnel 0.36 in
  - M2 tunnel 0.12 in
- Max change in slope 0.005





TBM Progress Rates

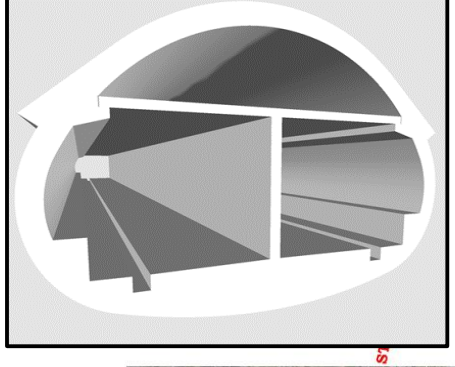
TBM	Average (Ft/day)	Best Day (Ft)
SB	66	115
NB	47	110



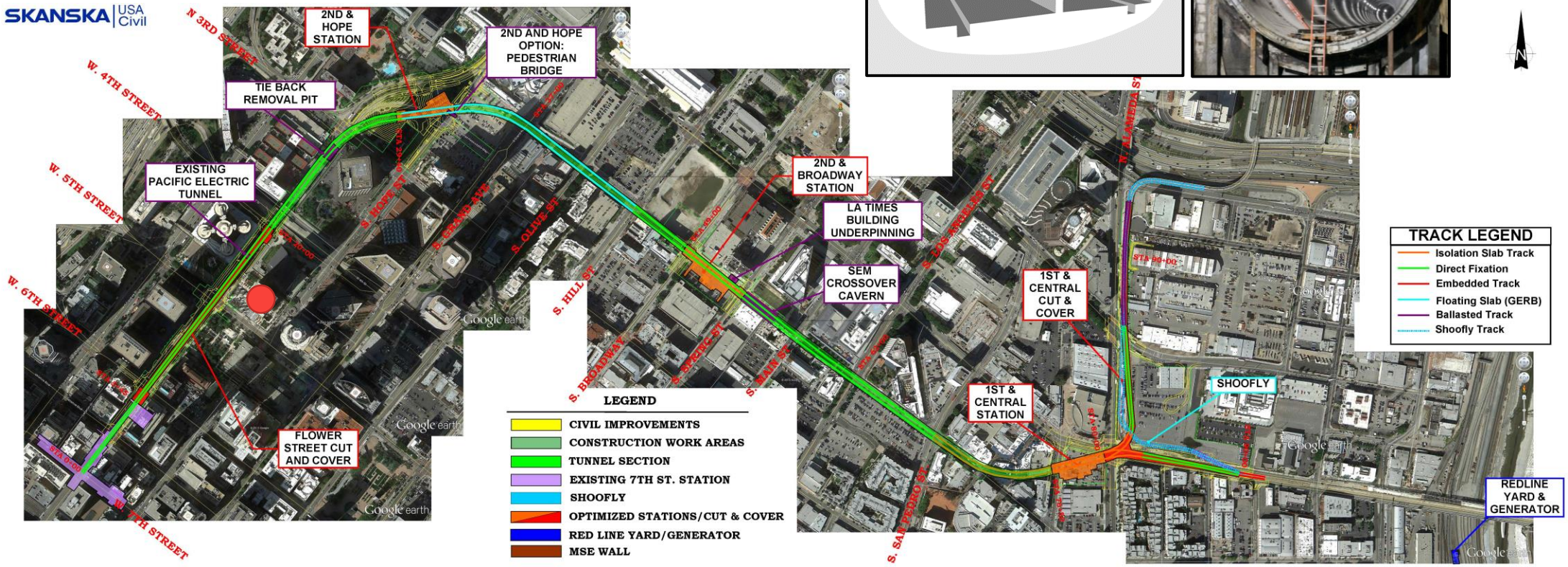
Regional Connector Transit Project: Connects Gold, Blue and Expo Lines

Project Elements

Crossover Cavern



TBM Tunnel



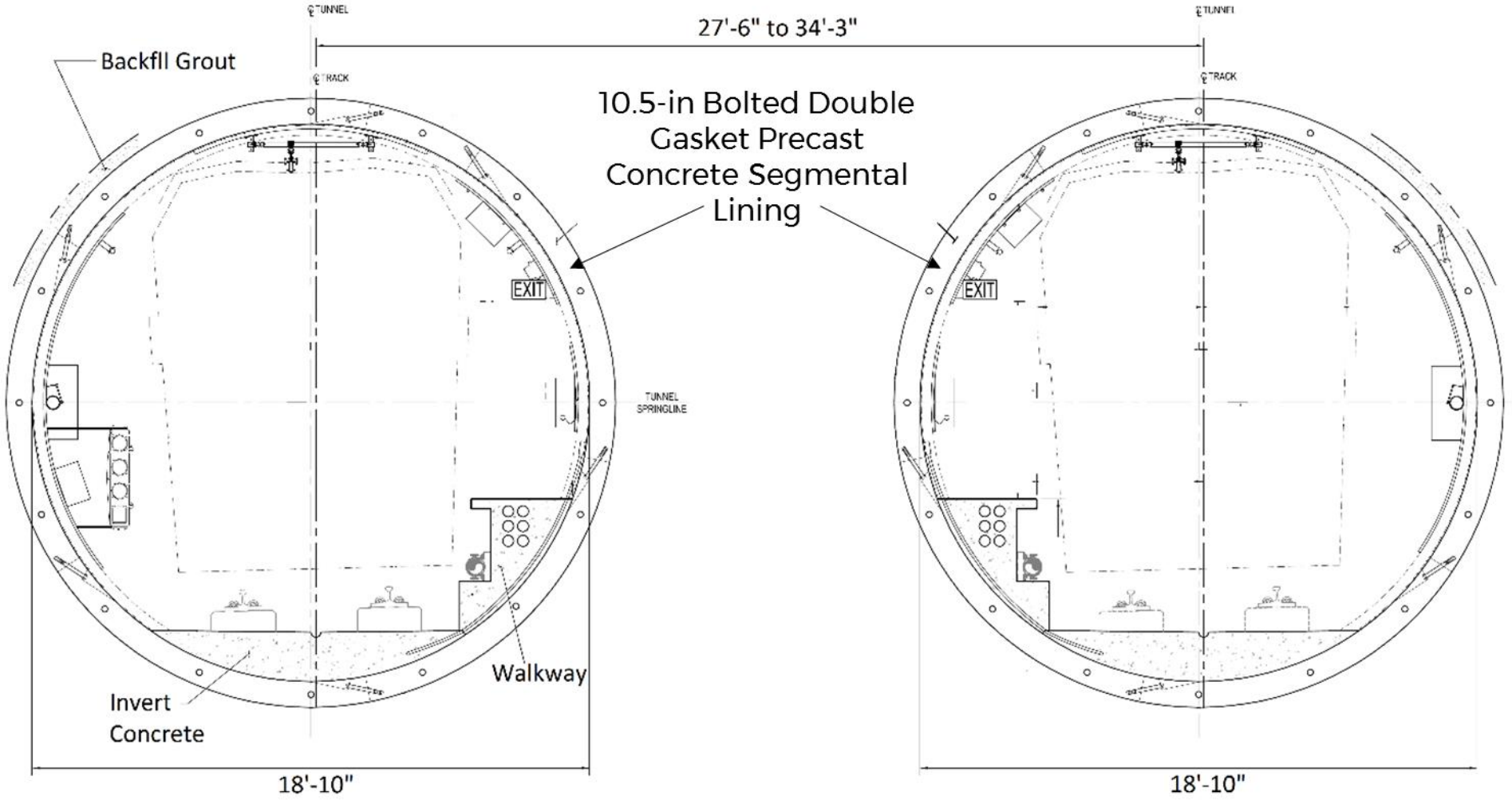
Flower Street Box Tunnel

2nd/Hope Station

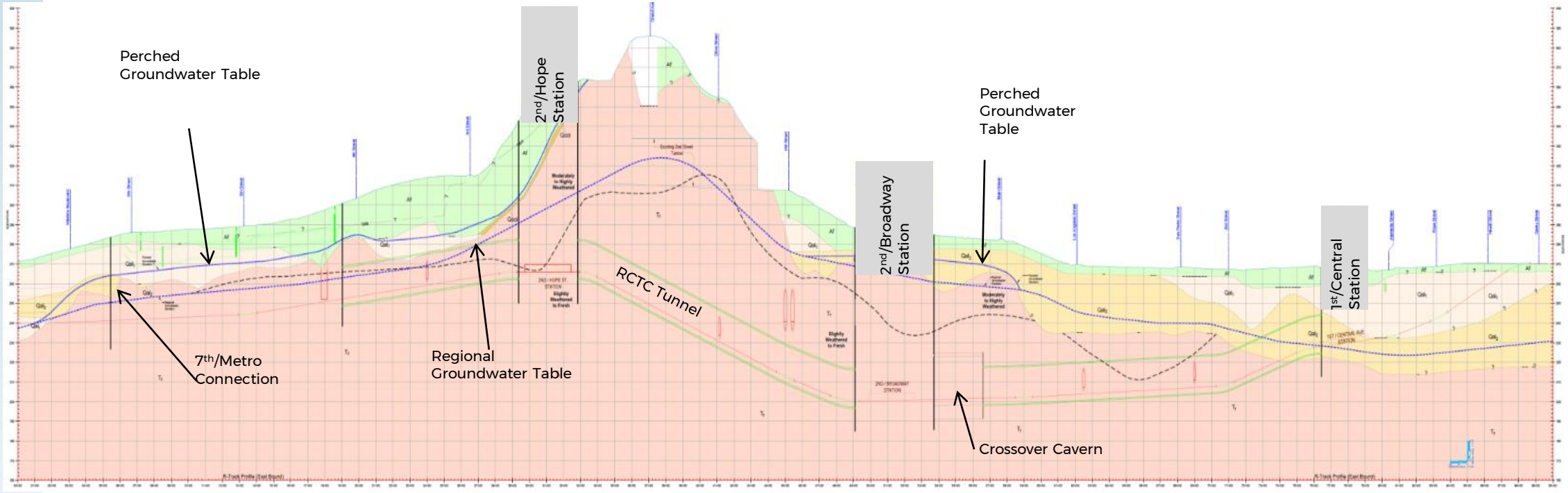
2nd/Broadway Station

1st/Central Station

Typical Tunnel Section



Geologic Conditions



Fill

- Gravel, sand, silt, and clay
- Construction debris

Alluvium

- Fine to coarse sand
- Gravel, cobbles, and boulders

Fernando Formation

- Siltstone or claystone
- Extremely to very weak

Tunneling Challenges – Overview

Japanese Village Plaza

- Low ground cover/under existing buildings

Crossover Cavern

- Large size cavern

Metro Red/Purple Line Crossing

- Tunneling close to existing tunnel

Flower Street

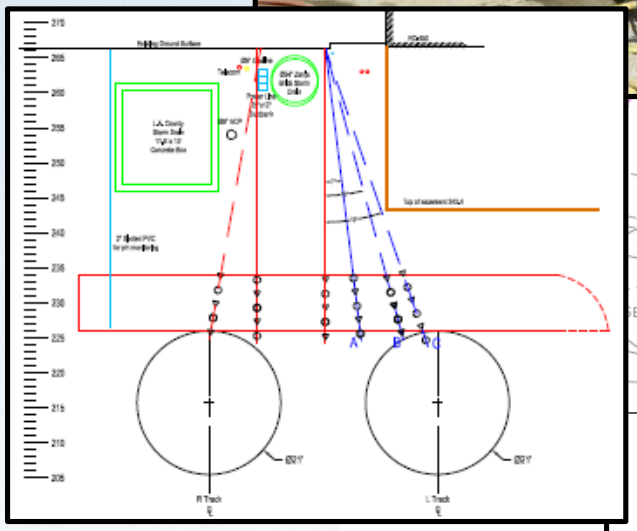
- Existing tiebacks

4th Street Bridge

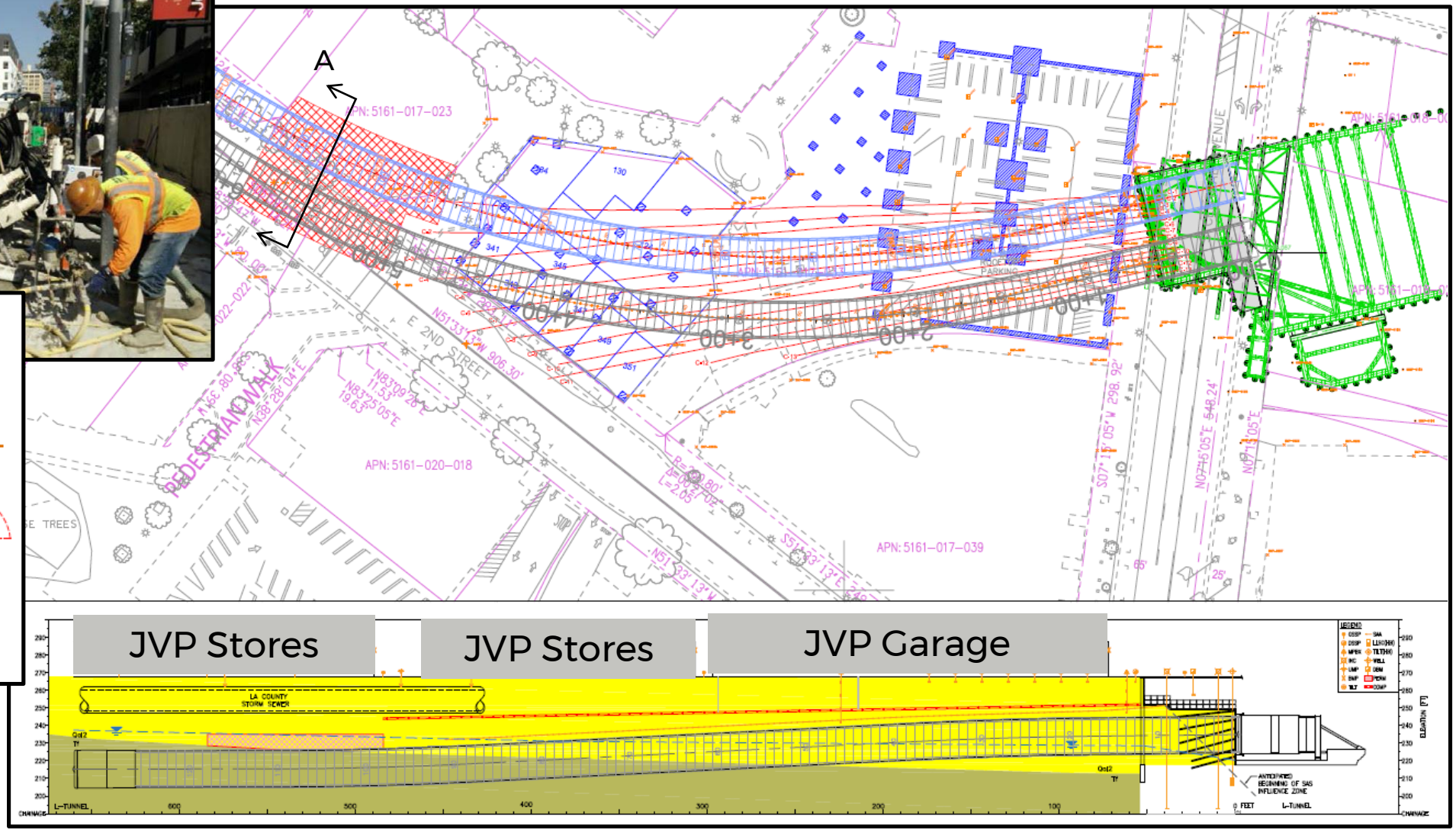
- Tunneling close to existing piles

TBM Selection Considerations

Tunneling Challenges – Japanese Village Plaza (JVP) Permeation and Compensation Grouting Program



Section A



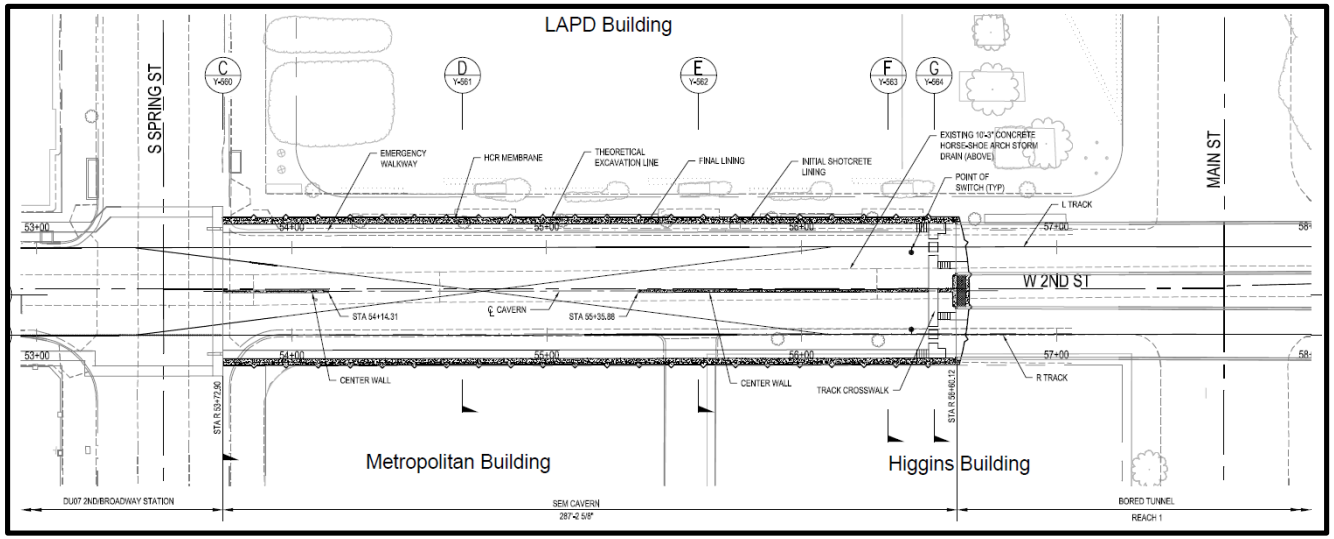
Tunneling Challenges – Crossover Cavern

Dimensions

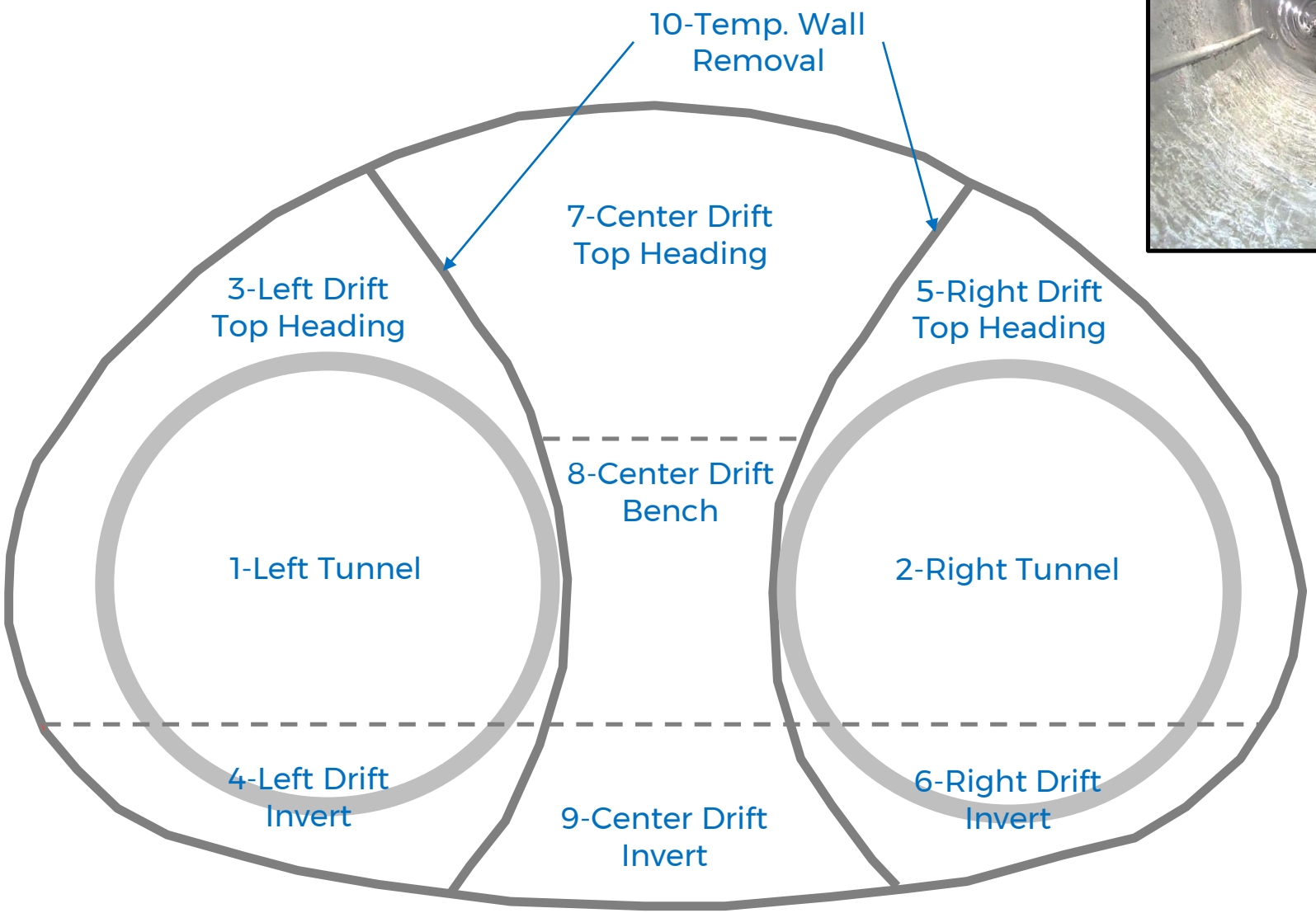
- *Width – 58’*
- *Height – 36’*
- *Length – 290’*

Sequential Excavation Method

- *Bore Tunnels*
- *Two side drifts*
- *Center drift*
- *Temporary wall removal*
- *Round Length – 3’-4”*



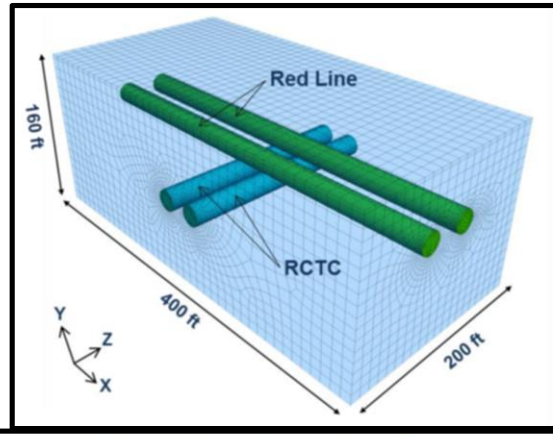
Tunneling Challenges – Crossover Cavern Excavation Sequence

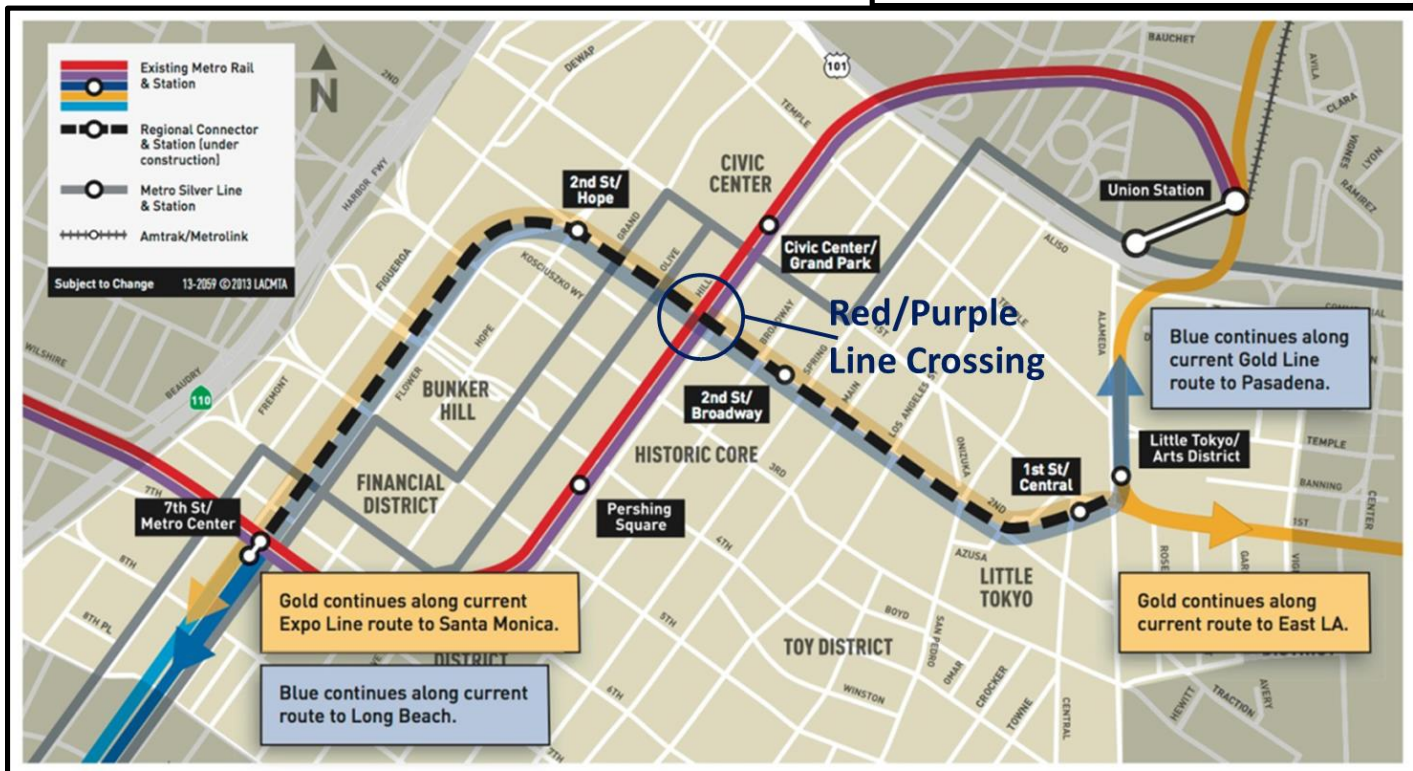


Tunneling Challenges – Metro Red/Purple Line Crossing

Issues:

- TBM drive directly under existing Metro Red Line Tunnels
- Stability of existing tunnels in operation
- No interruption to Metro operation





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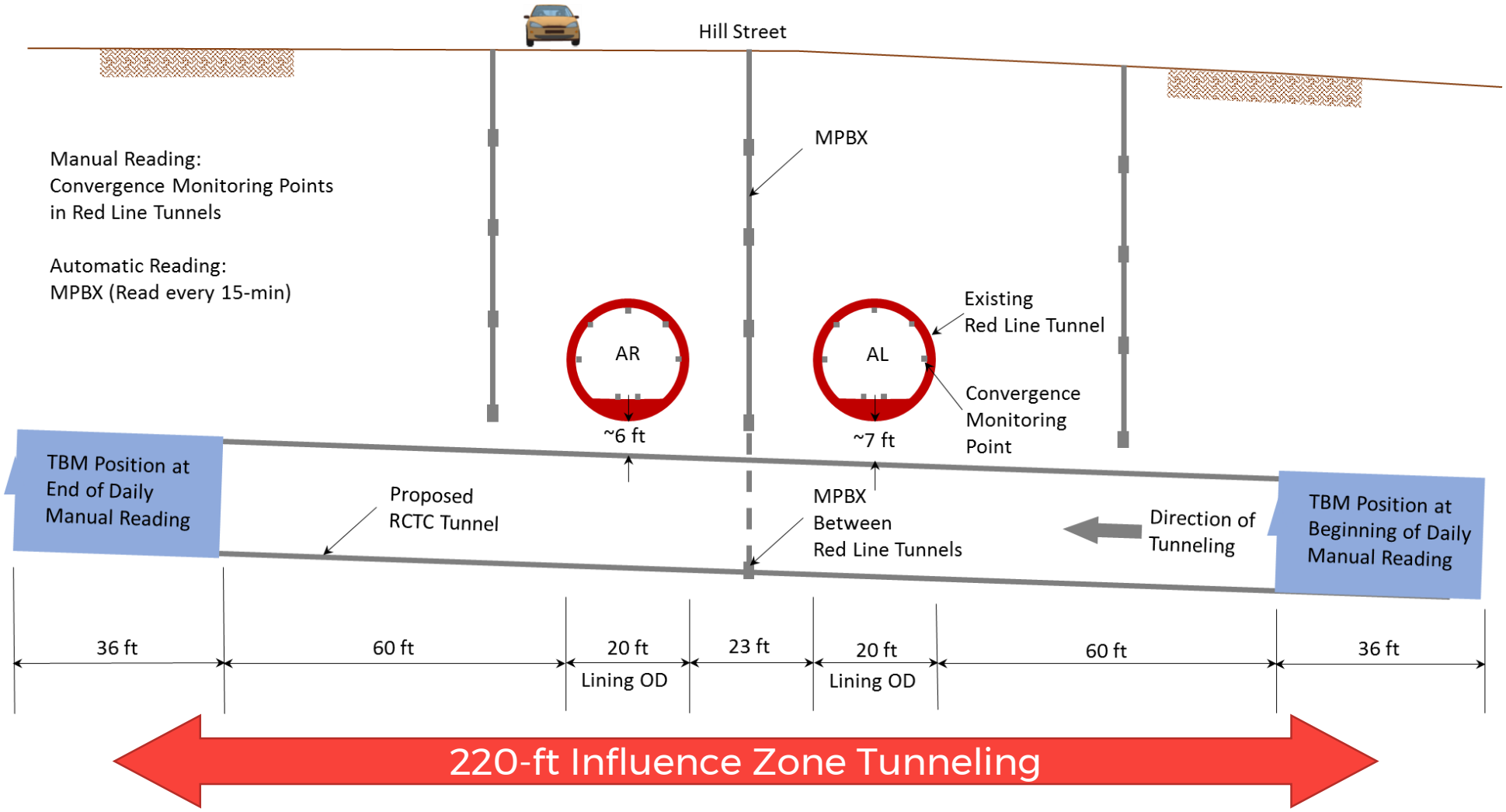
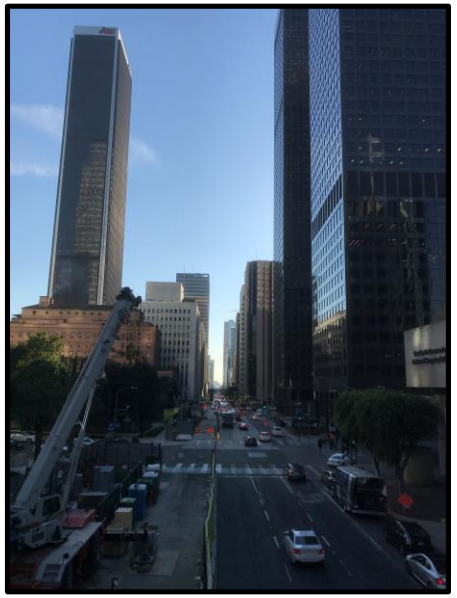
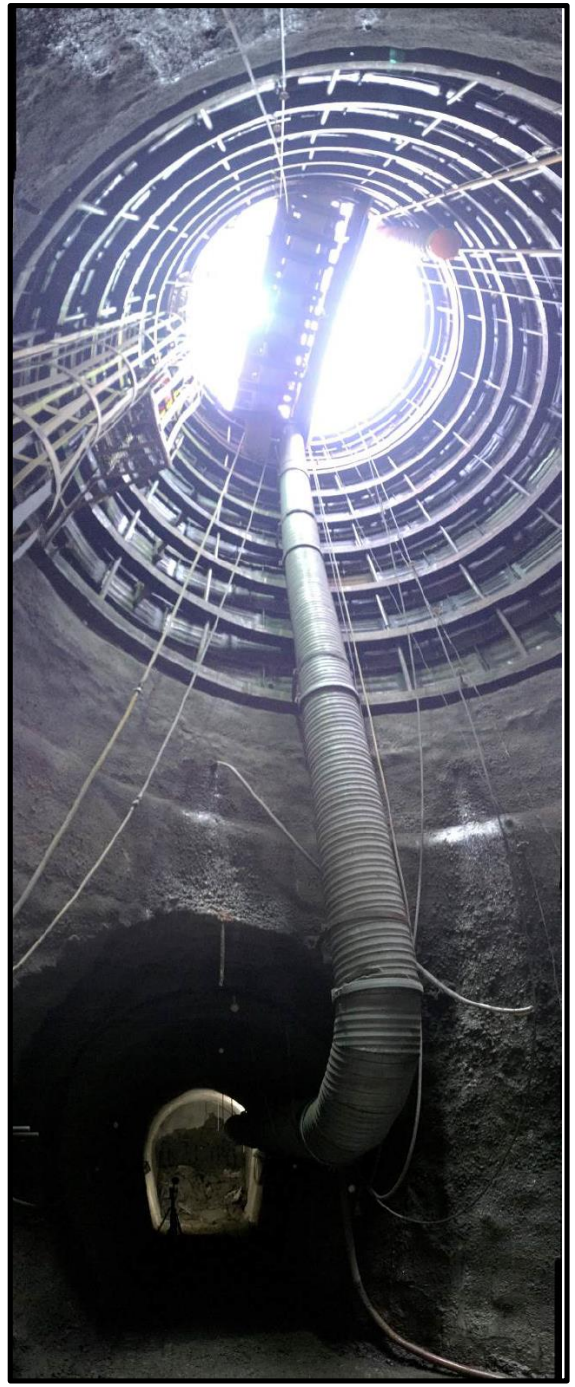


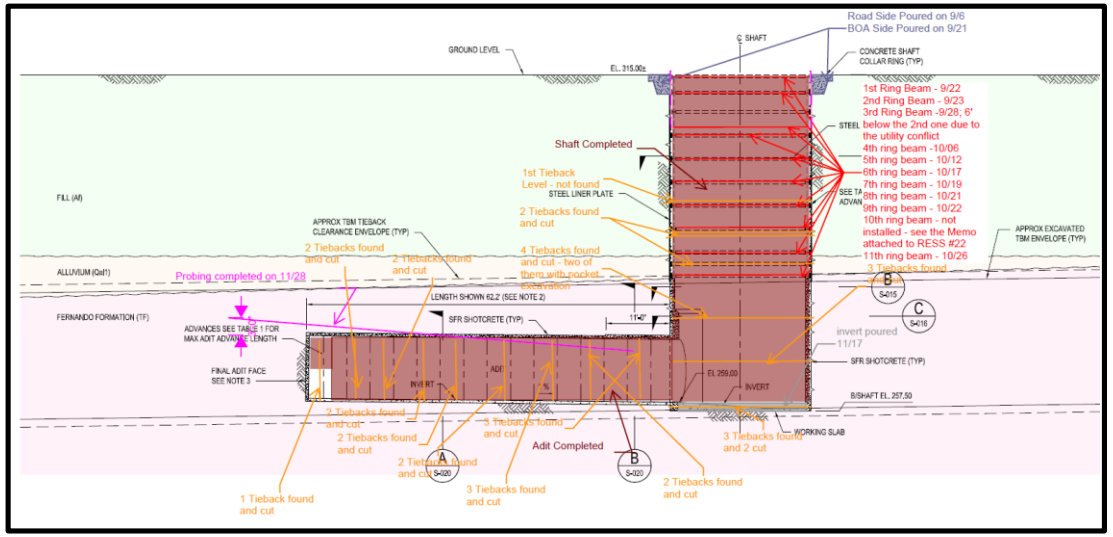
Tunneling Challenges – Tieback Removal

Issues:

- TBM encountering steel tieback rods
- TBM down times and job delay
- Tieback removal shaft and tunnel
  - *30’ dia. shaft*
  - *10’W x 11’H horseshoe shaped tunnel, 60’ long*



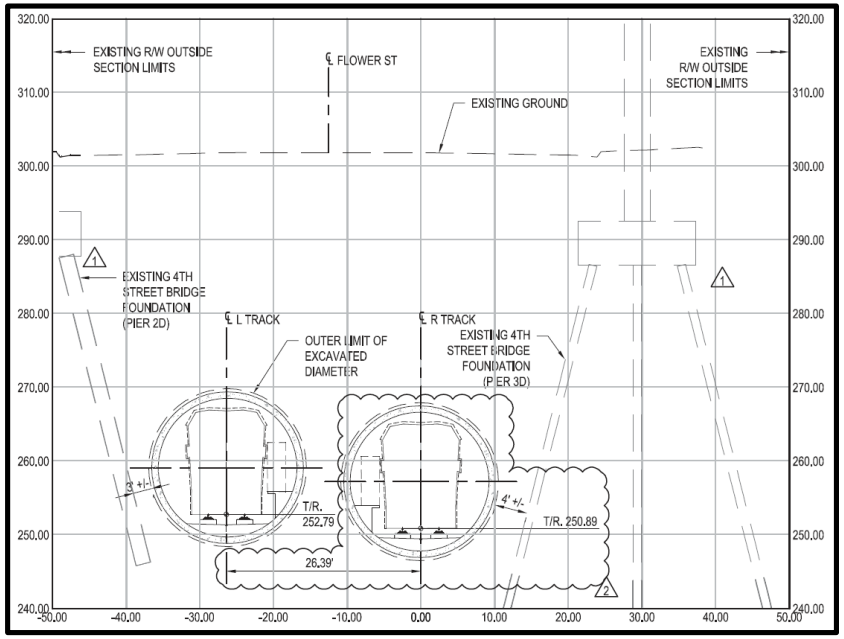


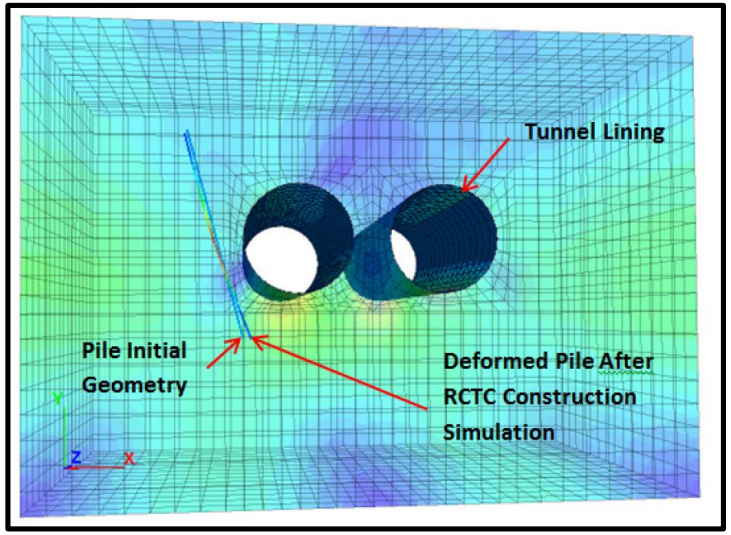


Tunneling Challenges – 4th Street Bridge

Issues:

- TBM passes between bridge foundations
- Stability of bridge foundation
- Numerical modeling and design analyses
- Instrumentation and monitoring





Conclusions

- *Urban transit tunnels can be very challenging*
- *Modern state-of-the-art tunneling methods provide better solutions for difficult situations*
- *Thorough engineering evaluations are required including:*
  - Geotechnical investigations
  - As-built records
  - Previous tunneling experience
  - Engineering analyses
  - Numerical modeling
- *Practical and effective instrumentation and monitoring program is critical for checking ground movements*
- *Contingency planning is critical to adjust methods if impacts are observed*
- *Efforts of a qualified, motivated contractor cannot be understated*

Thank You!

Questions?