BESSAC

SVCW - Gravity Pipeline Project

Webinaire
« Regards croisés sur la pratique de la géotechnique à l'international - 2ème édition »

CFMS

09-Mai-2023

TABLE OF CONTENTS

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1. PROJECT DETAILS

Owner : Silicon Valley Clean Water.
Joint Powers Authority

SVCW
Silicon Valley Clean Water

Contractor : Barnard Bessac Joint Venture

- Barnard : 70%
- Bessac : 30%

Engineer : ARUP North America.

Progressive Design and Build.

Initial Contract Amount : $ 212 302 346
Expected Contract Amount: ~ $225 000 000

CM / OA Team

TANNER PACIFIC
Kennedy Jenks
JCK UNDERGROUND
MOTT MACDONALD

PDB Team

BARNARD
BESSAC
ARUP

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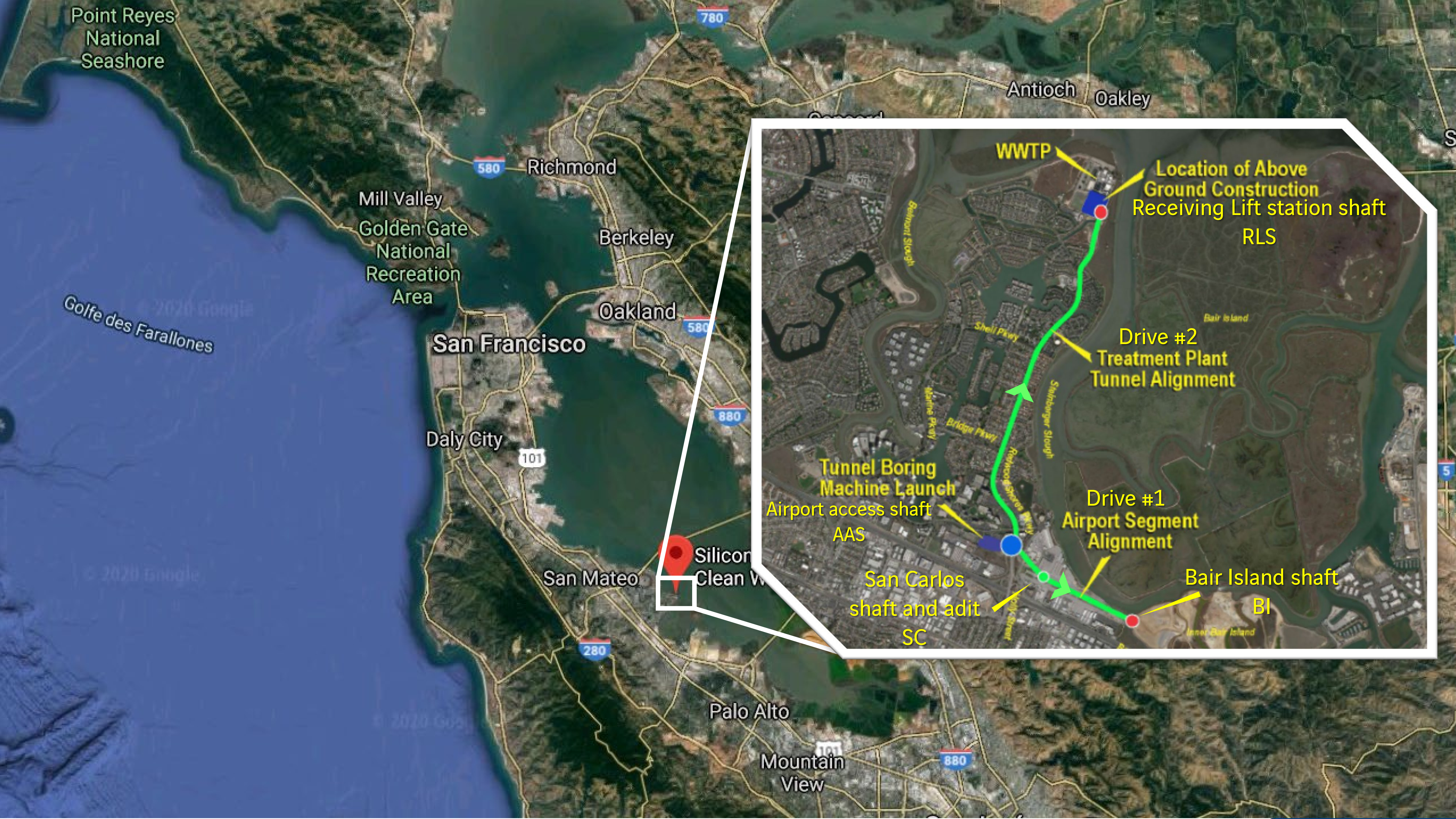
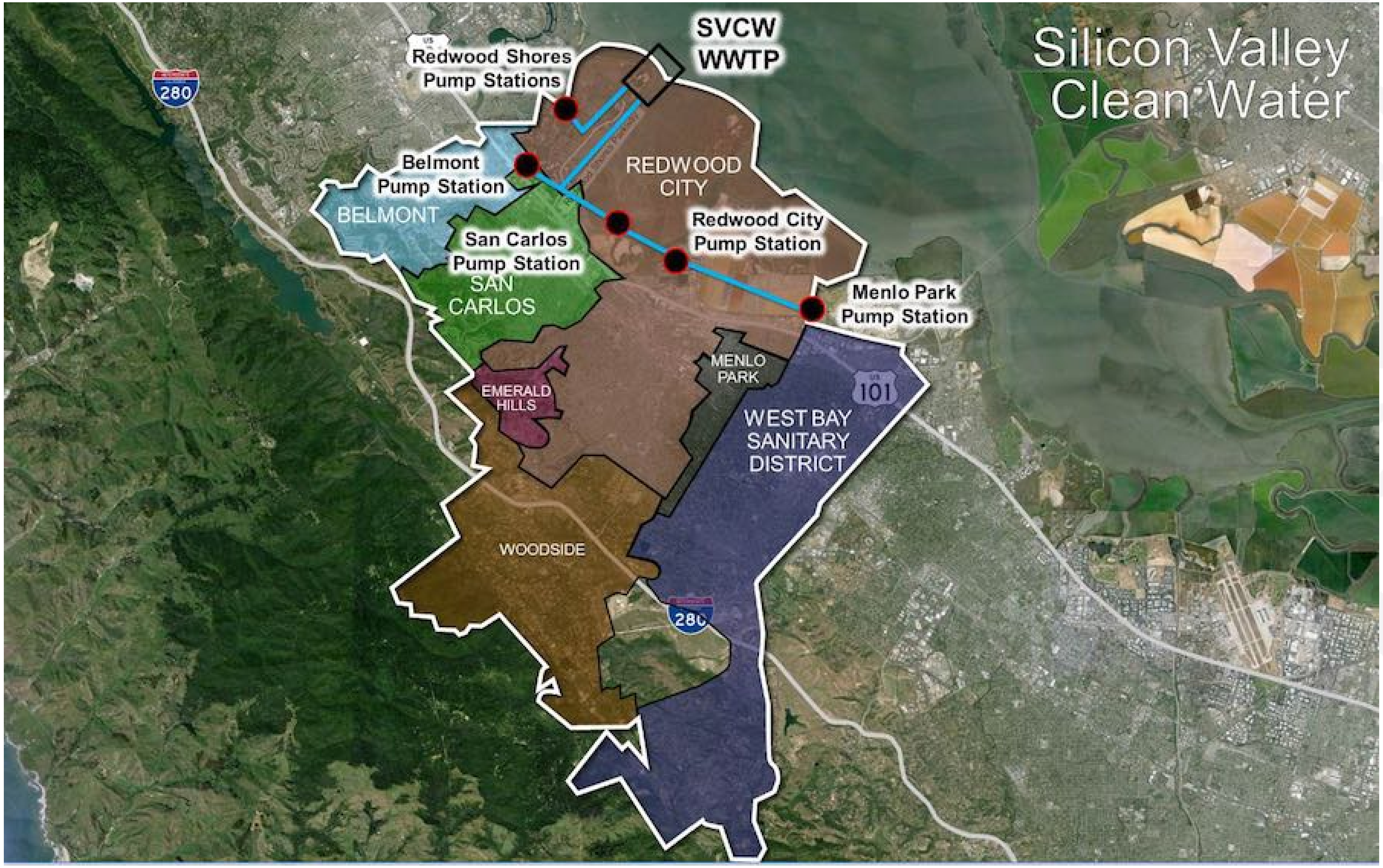

Point Reyes National Seashore
780
Antioch
Oakley
580
Richmond
Mill Valley
Golden Gate National Recreation Area
Berkeley
Golfe des Farallones
Oakland
580
San Francisco
880
Daly City
101
San Mateo
Silicon
Clean W
280
Palo Alto
Mountain View
880
WWTP
Location of Above Ground Construction
Receiving Lift station shaft
RLS
Belmont Slough
Shell Pkwy
Bair Island
Drive #2
Treatment Plant
Tunnel Alignment
Marine Pkwy
Bridge Pkwy
Steinberger Slough
Tunnel Boring Machine Launch
Airport access shaft
AAS
Drive #1
Airport Segment Alignment
San Carlos shaft and adit
SC
Bair Island shaft
BI
Inner Bair Island

1. PROJECT DETAILS



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1. PROJECT DETAILS

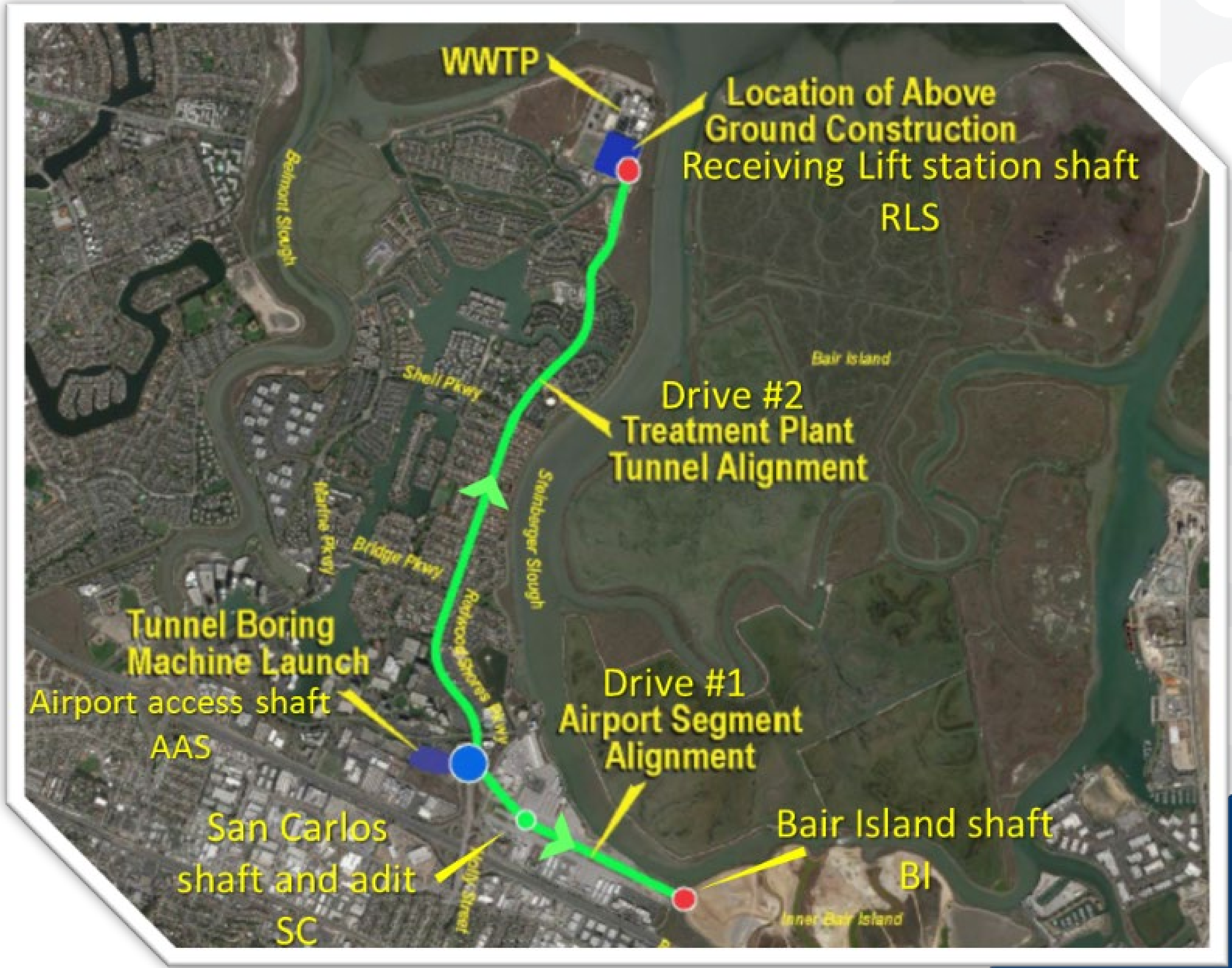
SCOPE OF WORK:

Gravity sewer/ rainstorm large tunnel replacing an aging 60" ID RC gravity pipe converted into a force main with 64 ruptures.

1. PROJECT DETAILS

SCOPE OF WORK:

- Construction of AAS Shaft
- Construction of BI Shaft
- Boring and lining of Drive 1 to BI (5125 LF / 1562 m)
- Boring and lining of Drive 2 to RLS (12307 LF / 3751 m)
- Construction of SC shaft and adit
- Supply / install / grout FRPM pipes
- Connection between the existing Reinforced concrete pipe at BI and the FRPM pipe with a Vortex type drop structure
- Connection between the SC pump station and the FRPM pipes with a Baffle drop structure



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1. PROJECT DETAILS – PROGRESSIVE DESIGN & BUILD

Type of Contract : *Progressive design and Build in 2 stages*

- RFQ and Award based on a 10% Design
- Stage 1 : Design up to 60% - Alternative Proposal – Permitting – Open Book cost estimate.

- Stage 2 : Design to 100% - Construction services and construction for the completion of the Project.

- At the end of the stage 1, 3 possibilities:
    - Award for a Guaranteed Maximum Price (T&M + Overhead and Profit).
    - Award on a Lump Sum basis.
    - Rejection of the DB proposal.

- Stage 1 was performed under the GMP type of contract.
- Stage 2 was awarded to BBJV on a Lump Sum Basis.

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1. PROJECT DETAILS – PROGRESSIVE DESIGN & BUILD

Procurement

- ✓ Team selection
- ✓ Qualifications
- ✓ Project approach
- ✓ Price component

Stage 1: Design

- ✓ Collaborative design
- ✓ Deliverables: BODR, 30%, 60%
- ✓ Cost estimates at major milestones

Stage 2: Final Design and Construction

- ✓ Final design
- ✓ Construct facilities
- ✓ Startup, testing, and joint operation

1. PROJECT DETAILS – PROGRESSIVE DESIGN & BUILD

PROGRESSIVE DESIGN AND BUILD:

Practically:

- Promote collaboration between the client, the CM, the contractor and the EOR
- Develop alternative designs to achieve :
  - ✓ 1 year faster on schedule,
  - ✓ 20% minimum cost reduction,
  - ✓ 100 years design life

Evaluation Criteria	Maximum Possible Points (Proposal / Interview)
Qualification and Experience	10 / 10
Understanding of Key Issues / Challenges	15 / 15
Project Approach	20 / 20
Innovative / Alternative Ideas	20 / 20
Schedule	10 / 10
Pricing Approach	5 / 5
Approach to Consideration of Lifecycle Cost	5 / 5
Fee Scoring	
Stage 1 Cost Proposal	6
Stage 2 Mark Up Percentages	14
Indicative Cost Estimate	10
Total Possible Points	200

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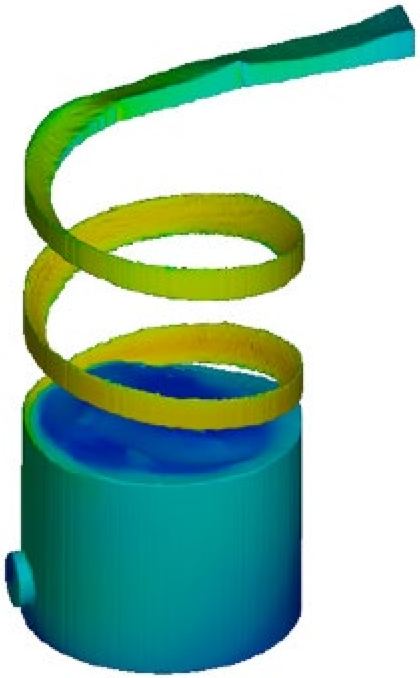
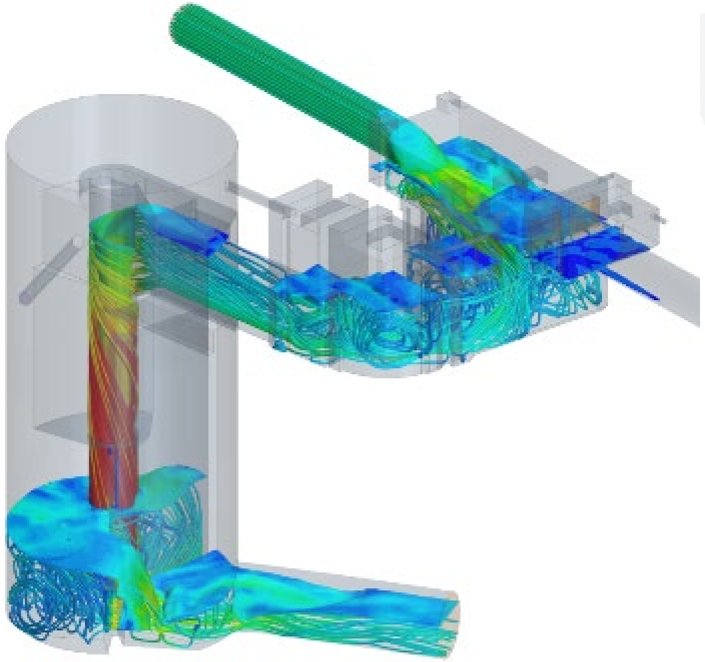
1. PROJECT DETAILS – PROGRESSIVE DESIGN & BUILD

BBJV main alternatives :

1. Multiple layers of defense (ventilation, odor control; turbulence control)





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1. PROJECT DETAILS – PROGRESSIVE DESIGN & BUILD

2. Replacing HOBAS pipe with HDPE liner or Combi segment

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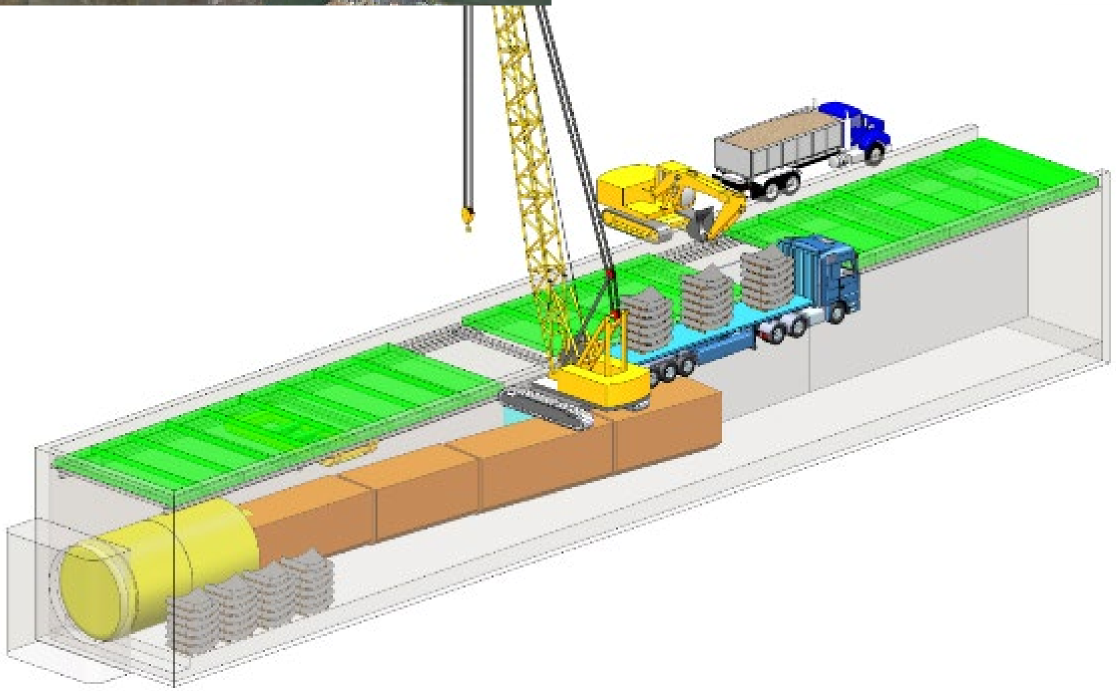
1. PROJECT DETAILS – PROGRESSIVE DESIGN & BUILD

3. Cancelling temp launching shaft (launch from Bair island, change tunnel alignment)



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1. PROJECT DETAILS – PROGRESSIVE DESIGN & BUILD

4. Overlap design and construction

- Order TBM, mould, precast, shaft during Stage 1
- Issue construction and environmental permits during stage 1
- Reschedule Key design elements based on critical path,

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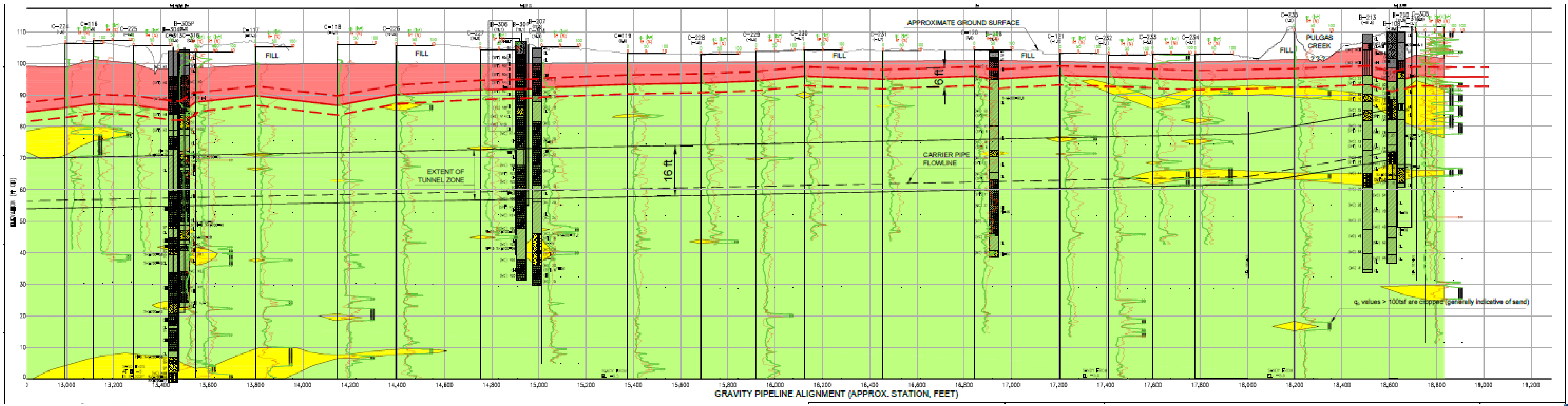
2. GEOLOGICAL CONTEXT

GEOLOGY CODE:

- Fill [FILL]
- Young Bay Mud [YBM]
- Alluvial & Marine Deposits [ULS/OBD CLAY]
- Sandy Layer [ULS/OBD SAND]



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2. GEOLOGICAL CONTEXT

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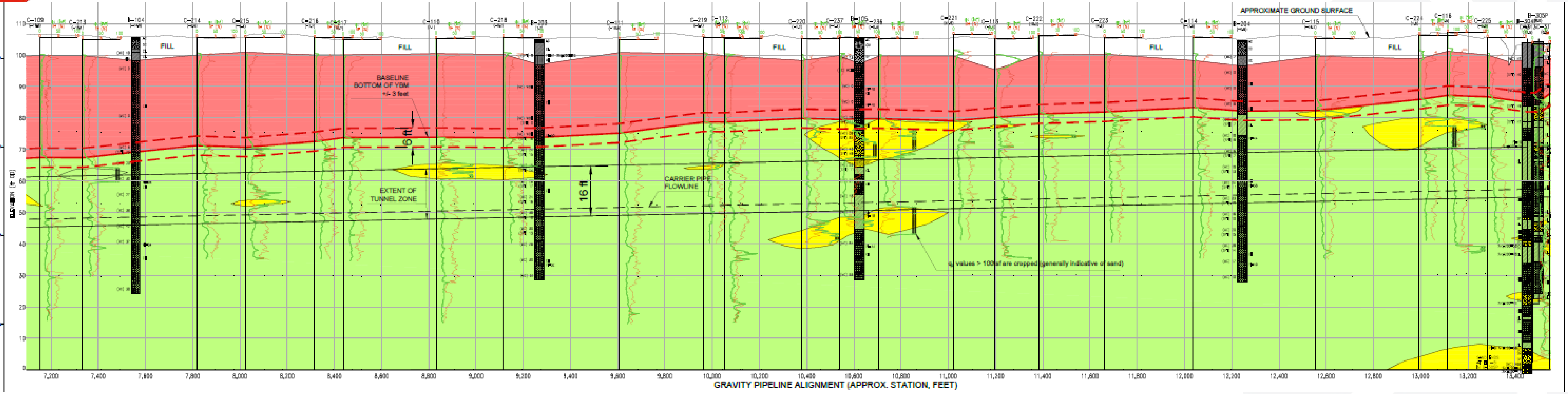

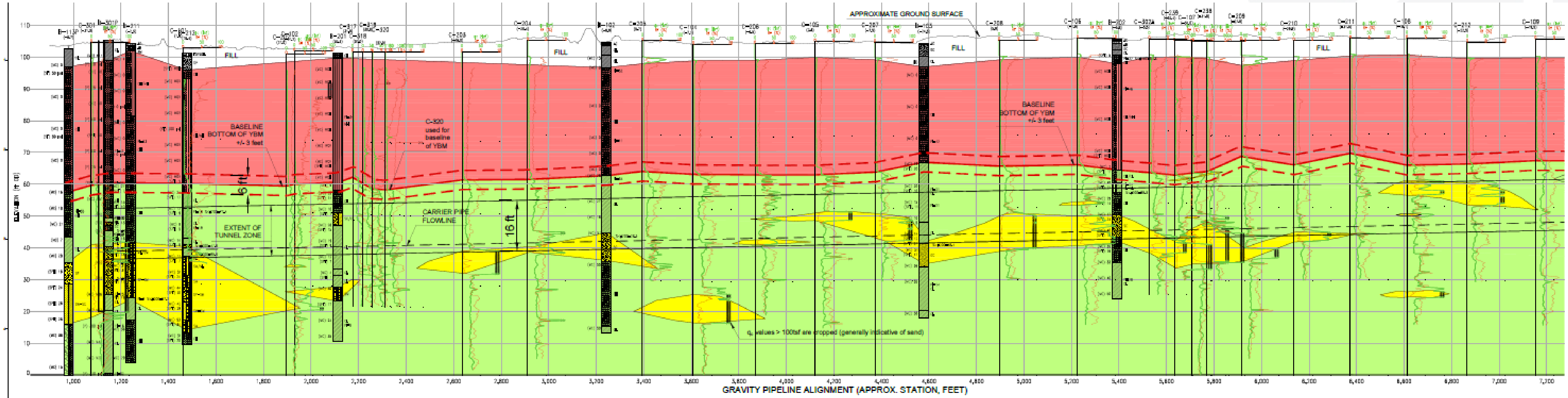

2. GEOLOGICAL CONTEXT

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2. GEOLOGICAL CONTEXT

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2. GEOLOGICAL CONTEXT

2.1 *FOCUS ON GEOTECHNICAL DATA*

Geotechnical Data Report (GDR)

A Geotechnical Data Report (GDR) is a compilation of factual subsurface data collected during a project investigation. Data are collected during borehole drilling, laboratory testing, test pit excavation, geophysical survey, geologic mapping, literature review, and other means that provide quantitative or objective data about the subsurface. The GDR contains factual data only. The GDR provides objective data that a GBR author uses to interpret subsurface conditions.(*Robin Dornfest, Nate Soule & Ryan Marsters, Lithos Engineering*)

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2. GEOLOGICAL CONTEXT

2.1 *FOCUS ON GEOTECHNICAL DATA*

Geotechnical Baseline Report (GDR)

The GBR provides information about the anticipated subsurface, discussion of similar nearby projects if available, and a section on feasible construction methods and the potential problems these methods may encounter during construction. However, the GBR's "baseline statements" ("baselines") make the document unique. The baselines are a set of contractual assumptions about ground conditions and behavior. (Robin Dornfest, Nate Soule & Ryan Marsters, Lithos Engineering)

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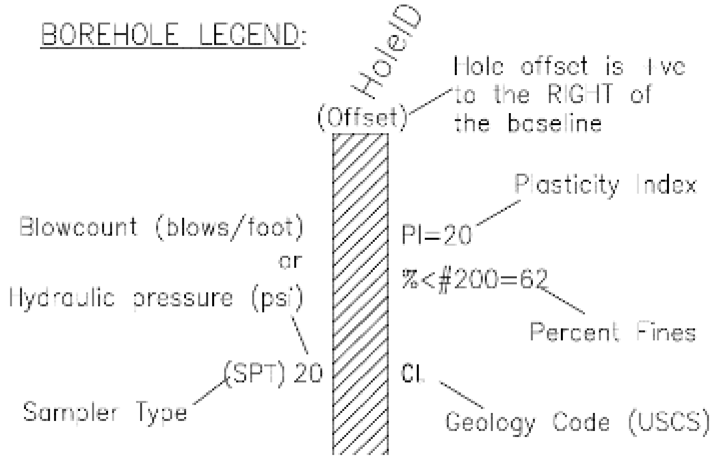
2. GEOLOGICAL CONTEXT

2.1 *FOCUS ON GEOTECHNICAL DATA*



SOIL TYPE (USCS):

- CH – Fat clay
- MH – Elastic silt
- CH/MH – Fat Clay/Elastic Silt
- CL – Lean clay
- ML – Silt
- CH/CL – CLAY
- CL–CH – Lean to Fat Clay
- CL–ML – Silty clay
- CL_S – Sandy Clay
- SC/CL – Clayey sand/Sandy clay
- CL–SC – Sandy clay to Clayey sand
- ML/SM – Sandy silt to Silty sand
- SP–SC – Sand to Clayey sand
- SC – Clayey sand
- SM – Silty sand
- SP–SM – Silty sand to Sand
- SP – Sand, poorly graded
- GC/CH – Clayey gravel to Fat clay
- GC – Clayey gravel
- GW – Gravel, well graded
- GP – Gravel, poorly graded

2. GEOLOGICAL CONTEXT
2.1 *FOCUS ON GEOTECHNICAL DATA*

Soil groups from Boreholes

Boreholes yield physical soil samples for visual inspection and selective testing in a soils laboratory. Soil samples were visually classified in accordance with the Unified Soil Classification System (USCS) as recorded in borehole log records.

Table 4 Definition of Soil Groups based on USCS

Soil Group		USCS Soil Classification[1]	General Characteristics
Fine	Fines-Fat	CH, MH	Greater than 50% passing #200 sieve; Liquid Limit > 50.
Fine	Fines-Lean	CL, ML	Greater than 50% passing #200 sieve; Liquid Limit < 50.
Coarse	Mixed-Finer	SC, SM, SC-SM	12% < % passing #200 sieve > 50%; % Sand > % Gravel
Coarse	Mixed-Coarser	GM, GC, GC-GM	12% < % passing #200 sieve > 50%; % Gravel > % Sand
Coarse	Sands	SP, SP-SM, SP-SC, SW, SW-SM, SW-SC	Less than 12% passing #200 sieve; % Sand > % Gravel
Coarse	Gravels	GP, GP-GM, GP-GC, GW, GW-GM, GW-GC	Less than 12% passing #200 sieve; % Gravel > % Sand

[1] Unified Soil Classification System defined for visual classification (ASTM D2488, 2017b) and laboratory classification (ASTM D2487, 2017a)

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2. GEOLOGICAL CONTEXT
2.1 *FOCUS ON GEOTECHNICAL DATA*

Soil Behavior Types from CPTs

CPTs have been utilized to evaluate subsurface conditions along the proposed alignment. CPTs do not provide physical soil samples for inspection and classification; however, the data obtained are nearly continuous through the soil column and provide an indication of soil behavior. Classification of soil from CPT data is referred to as soil behavior type (SBT) and is often processed and presented as normalized soil behavior type, or SBTn.

Table 5 Definition of CPT-based Soil Behavior Types after Robertson (2010)

Soil Group	Normalized Soil Behavior Type (SBT_n)	
	Soil Behavior Type No. (SBT_n)	SBT_n Descriptions
Fine Behavior	1	Sensitive, fine-grained
	2	Organic soils – clay
	3	Clay – silty clay to clay
	4	Silt mixtures – clayey silt to silty clay
Coarse Behavior	5	Sand mixtures – silty sand to sandy silt
	6	Sands – clean sand to silty sand
	7	Gravelly sand to dense sand
	8	Very stiff sand to clayey sand
	9	Very stiff, fine-grained[1]

[1] Heavily overconsolidated or cemented, behavior may vary.

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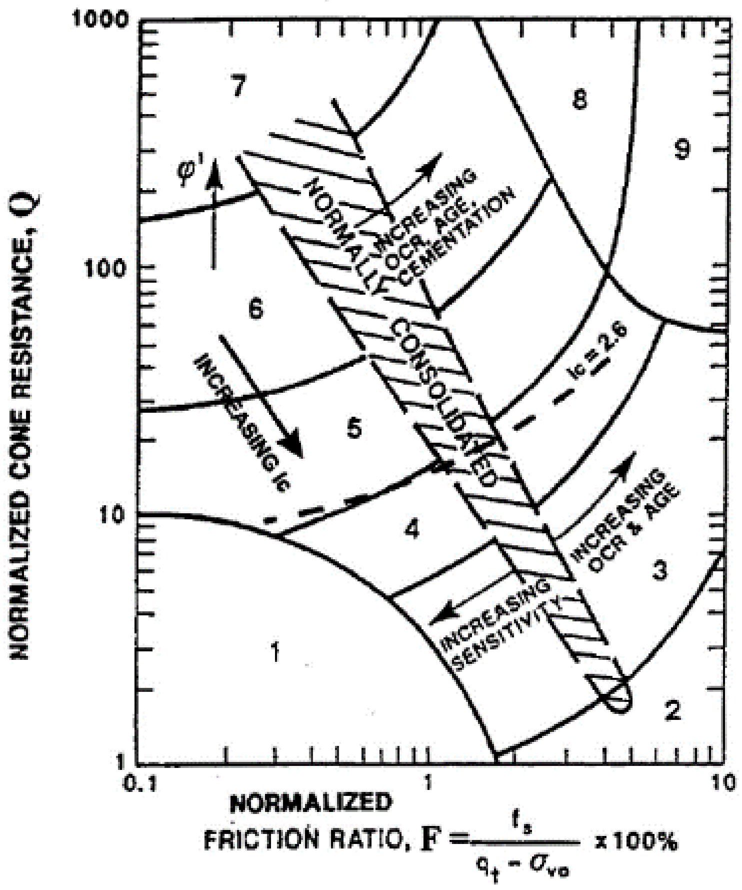
2. GEOLOGICAL CONTEXT
2.1 *FOCUS ON GEOTECHNICAL DATA*

Soil Behavior Types from CPTs

CPTs have been utilized to evaluate subsurface conditions along the proposed alignment. CPTs do not provide physical soil samples for inspection and classification; however, the data obtained are nearly continuous through the soil column and provide an indication of soil behavior. Classification of soil from CPT data is referred to as soil behavior type (SBT) and is often processed and presented as normalized soil behavior type, or SBTn (Robertson, 1990).



1. Sensitive, fine grained
2. Organic soils - peats
3. Clays - silty clay to clay
4. Silt Mixtures - clayey silt to silty clay
5. Sand Mixtures - silty sand to sandy silt
6. Sands - clean sand to silty sand
7. Gravelly sand to dense sand
8. Very stiff sand to clayey sand*
9. Very stiff, fine grained*

* *Heavily overconsolidated or cemented*

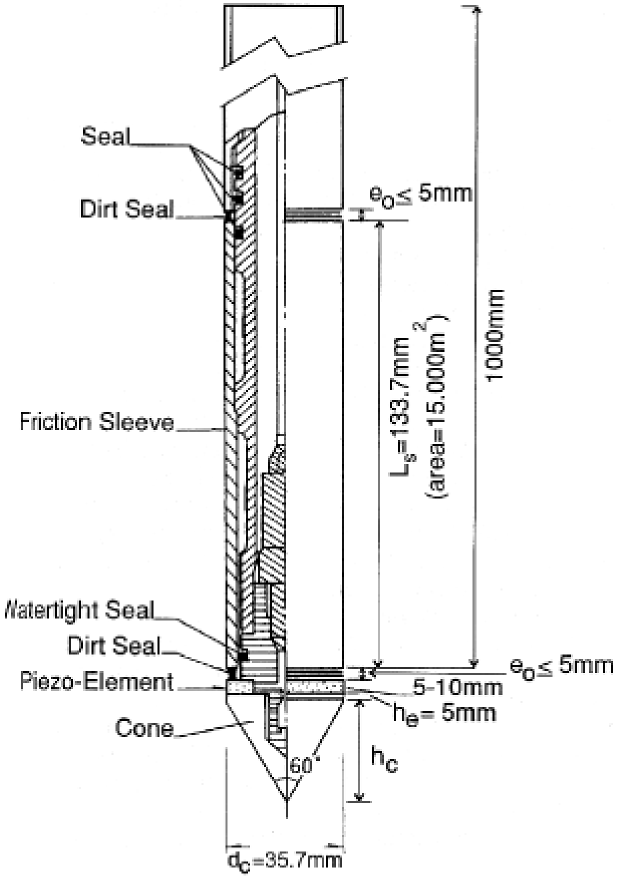
2. GEOLOGICAL CONTEXT
2.1 *FOCUS ON GEOTECHNICAL DATA*

Soil Behavior Types from CPTs

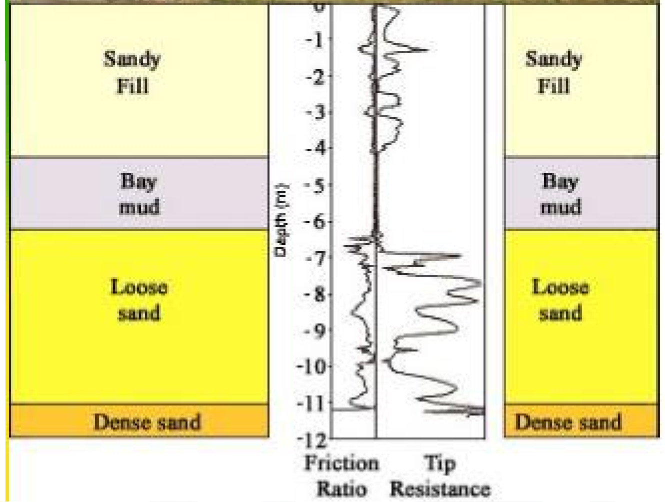
The tip resistance (Qc) is measured by load cells located just behind the tapered cone.

The tip resistance is theoretically related to undrained shear strength of a saturated cohesive material, while the sleeve friction is theoretically related to the friction of the horizon being penetrated.

J. David Rogers, Ph.D., P.E., R.G, Fundamentals of CONE PENETROMETER TEST (CPT) SOUNDINGS



Example of a Reference Penetrometer With a Fixed Cone and With Friction Sleeve



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2. GEOLOGICAL CONTEXT
2.1 *FOCUS ON GEOTECHNICAL DATA*

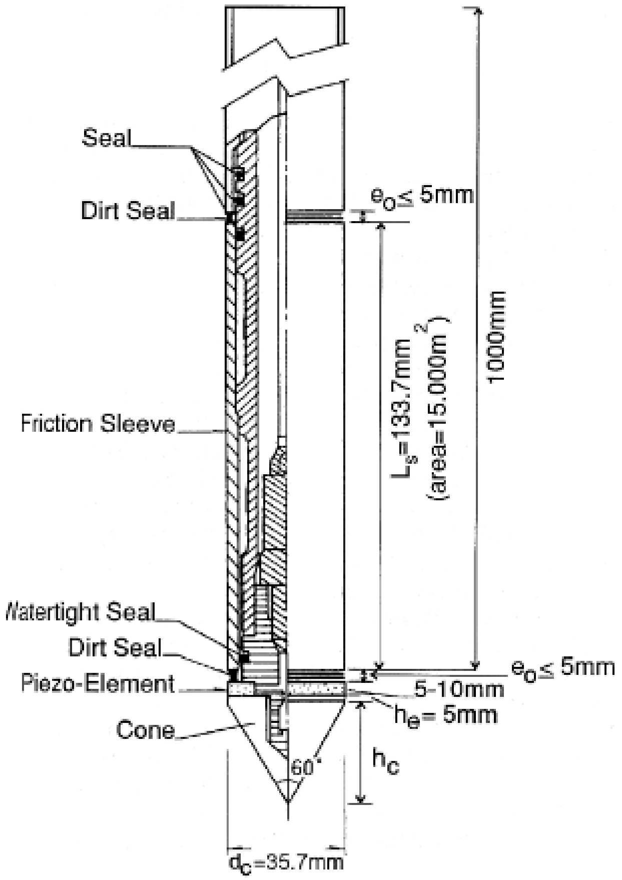
Soil Behavior Types from CPTs

The friction ratio is given in percent. It is the ratio of skin friction divided by the tip resistance (both in tsf).

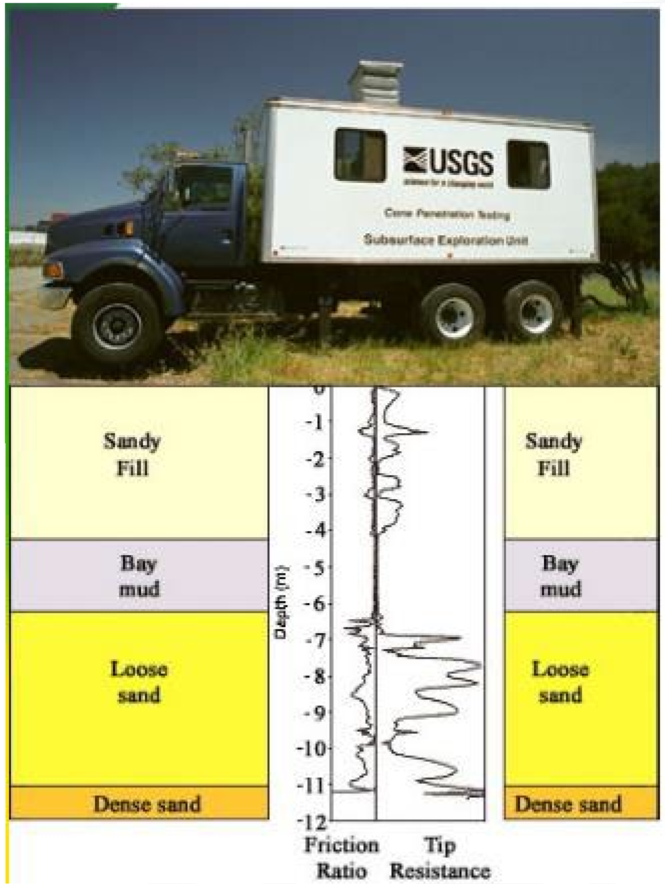
It is used to classify the soil, by its behavior, or reaction to the cone being forced through the soil.

High ratios generally indicate **clayey materials** (high c, low Ø) while **lower ratios** are typical of **sandy materials** (or dry desiccated clays).

J. David Rogers, Ph.D., P.E., R.G, Fundamentals of CONE PENETROMETER TEST (CPT) SOUNDINGS



Example of a Reference Penetrometer With a Fixed Cone and With Friction Sleeve



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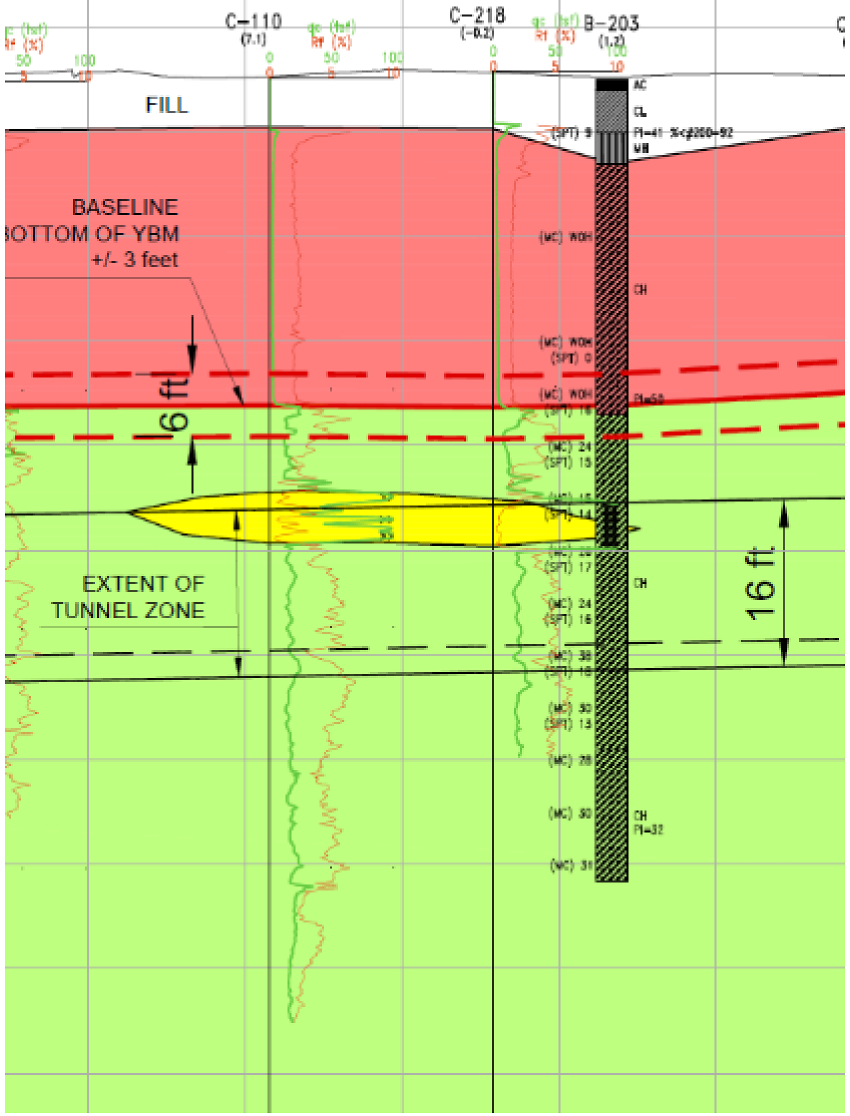
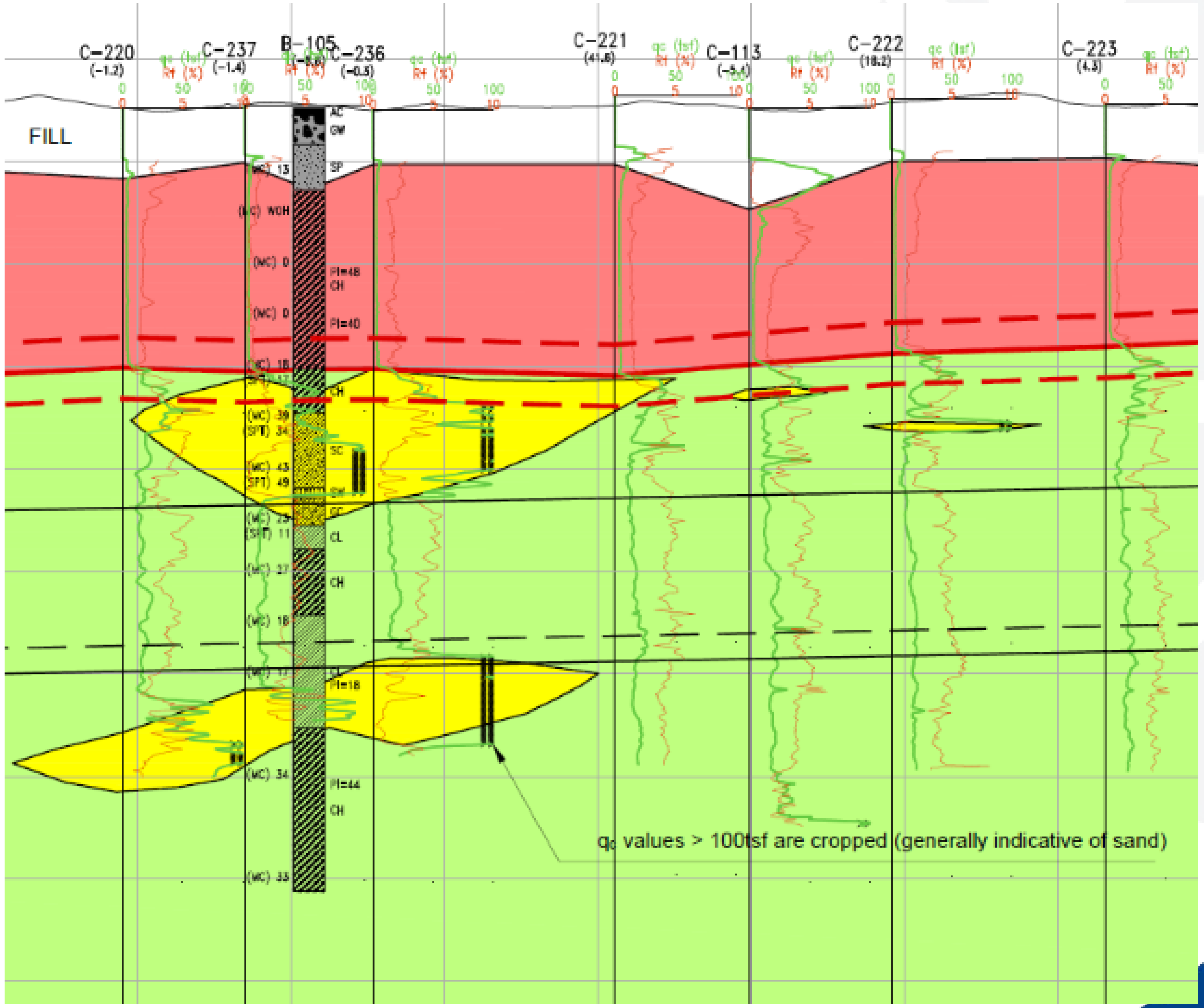
2. GEOLOGICAL CONTEXT

2.1 *FOCUS ON GEOTECHNICAL DATA*





2. GEOLOGICAL CONTEXT
2.1 *FOCUS ON GEOTECHNICAL DATA*

Soil Shear Strength correlation from CPT

Cone tip resistances can be used to estimate numerous soil parameters such as Shear Strength.

- For coarse-grained soils within the tunnel zone, cone tip resistances on the order of 50 tsf and 200+ tsf suggest internal friction angles of 30 to 36º, respectively. (Mayne, 2007). Note that the correlated friction angles were reduced by 5 degrees to account for the high fines content of the sands (Iowa DOT, 2015).

- For fine-grained soils within the tunnel zone, undrained shear strengths were estimated from cone tip resistances for fine-grained ULS per the correlation from Lunne et al. (1997). The Nkt parameter utilized in the correlation was set to 18 project-wide, which calibrated to available field and laboratory testing data, mainly from the shaft locations.

Table 14 Summary of Shear Strength Parameters in Tunnel Zone by Reach

Tunnel Reach	Average Shear Strength Parameters	
	Fines – S_u (psf)	Coarse – φ' (°)
AAS-TRS 1 (TRS to STA 38+00)	1507	33
AAS-TRS 2 (STA 38+00 to 75+50)	1787	34
AAS-TRS 3 (STA 75+50 to AAS)	1702	33
AAS-BIS 1 (AAS to STA 168+50)	1761	30
AAS-BIS 2 (STA 168+50 to BIS)	1834	36

Psf (pounds per square foot)
1000 psf = 48 kPa

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2. GEOLOGICAL CONTEXT
2.1 *FOCUS ON GEOTECHNICAL DATA*

Soil Abrasivity

Table 15 Laboratory Test Results on Soil Abrasion Test Samples

Sample Location and Depth	USCS Soil Classification	Moisture Content, %	Specific Gravity	LL/PL/PI, %	% Fines (Passing #200)	SAT, *Test#1* *Test#2* Avg
B-301P 56 – 59	CL	29		37/18/19	97	*12.5* *9.8* 11.2
B-301P 65 – 67.5	SC-SM	23	2.82	23/16/7	36	*23* *23.3* 23.1
B-302P 40 – 42.5	CL	29	2.90	48/21/27	98	*3.2* *3.4* 3.3

The Soil Abrasion Test (SAT) provides measurement of an abrasion index (Nilsen et al., 2006). Lower SAT values are less abrasive than higher SAT values. A soil with a SAT value less than 7 is considered to have low abrasivity while a soil with a SAT value greater than 22 is considered to have high abrasivity. A soil with SAT values between 7 and 22 is considered to have medium abrasivity. The results indicate a wide range of abrasivity from low to high.

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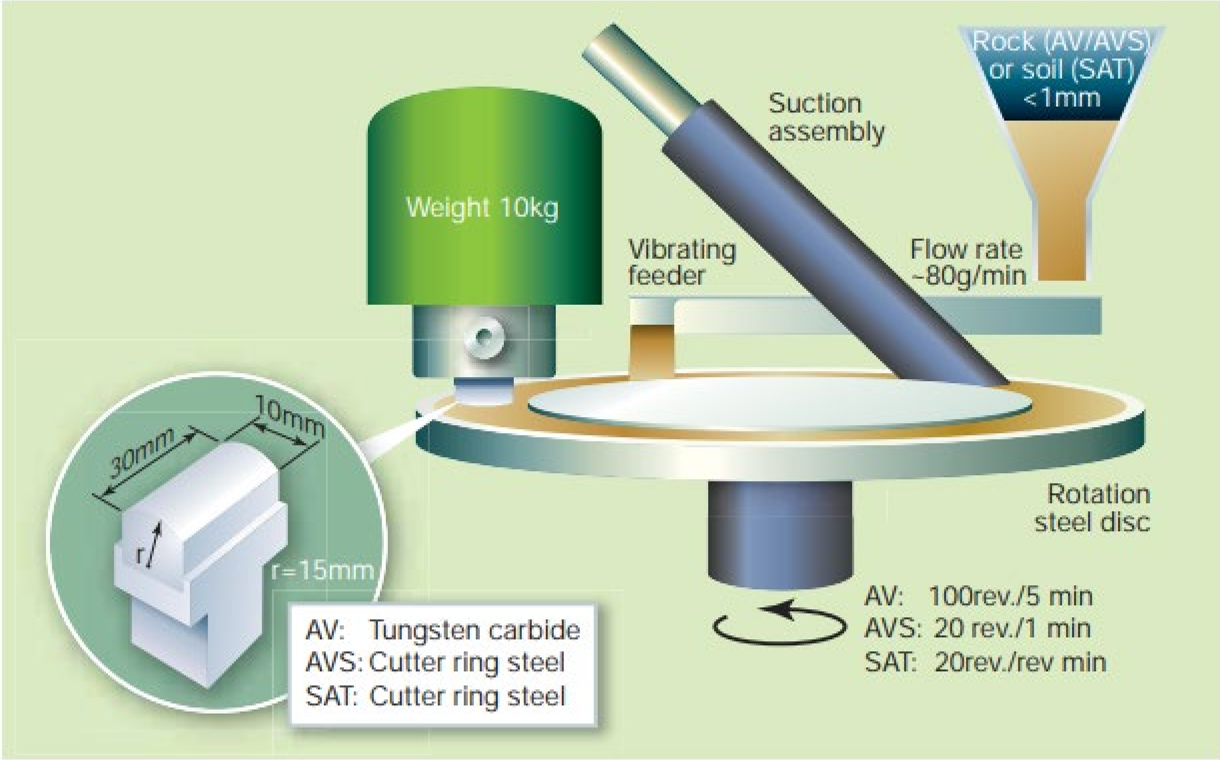
2. GEOLOGICAL CONTEXT
2.1 *FOCUS ON GEOTECHNICAL DATA*

Soil Abrasivity

Fig 3 - Principle sketch of the NTNU abrasion test



B Nilsen of Norwegian University of Science and Technology (NTNU), F Dahl of SINTEF Rock and Soil Mechanics, J Holzhäuser, of Babendererde Ingenieure, and P Raleigh, of Babendererde Engineers

Lower SAT values are less abrasive than higher SAT values.

A soil with a SAT value **less than 7** is considered to have **low abrasivity.**

A soil with a SAT value **greater than 22** is considered to have **high abrasivity**.

A soil with SAT **values between 7 and 22** is considered to have **medium abrasivity**.

Nilsen et al., 2006

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2. GEOLOGICAL CONTEXT

2.1 *FOCUS ON GEOTECHNICAL DATA*

Table 6 Baseline Soil Properties by Unit

Soil Property/ Parameter	Fill	YBM	ULS (Tunnel Zone)[1]			
			Fine Soil Groups		Coarse Soil Groups	
			Fines-Fat	Fines-Lean	Mixed-Finer	Sands
Total Unit Weight (pcf) Lowest/Mean/Highest Standard Dev/No. Tests **Baseline Range**	122/130/133 5/5 **120 – 135**	70.5/92/97 5/60 **80 – 97**	88/120/133 9/58 **110 – 130**	102/128/138 6/73 **115 – 135**	118/132/142 6/16 **120 – 135**	123/132/140 7/5 **125 – 140**
Water Content (%) Lowest/Mean/Highest Standard Dev/No. Tests **Baseline Range**	–	71/95/281 31/62 **71 – 120**	20/34/112 15/44 **20 – 60**	15/24/61 6/83 **15 – 40**	14/18/23 3/18 **12 – 25**	–
Liquid Limit (%) Lowest/Mean/Highest Standard Dev/No. Tests **Baseline Range**	–	50/89/144 18/44 **60 – 120**	50/66/105 12/55 **55 – 85**	20/38/50 7/58 **25 – 47**	23/28/41 7/7 **20 – 40**	–
Plastic Limit (%) Lowest/Mean/Highest Standard Dev/No. Tests **Baseline Range**	–	23/38/59 6/44 **25 – 45**	18/25/48 5/55 **20 – 30**	13/18/24 2/58 **15 – 20**	14/17/21 2/7 **10 – 25**	–
Plasticity Index (%) Lowest/Mean/Highest Standard Dev/No. Tests **Baseline Range**	–	27/51/99 13/44 **35 – 75**	26/41/65 9/55 **35 – 55**	4/20/34 7/58 **10 – 27**	2/11/23 7/7 **7 – 25**	–
Fines (%)[1] Lowest/Mean/Highest Standard Dev/No. Tests	–	–	71.5/90/96 10.5/5	52/714.5/98 15/34	12/29/49 12/39	8/10/12 1/13
Saturated Hydraulic Conductivity (m/s) **Baseline Range**[2]	–	$\leq 1 \times 10^{-8}$	$\leq 1 \times 10^{-7}$	$\leq 1 \times 10^{-7}$	1×10^{-7} to 1×10^{-4}	1×10^{-5} to 1×10^{-3}
Soil Strength	*Refer to Section 5.3 for Tunnels and Section 6.2 for Shafts*					

[1] Refer to particle size distribution in Section 4.5 for discussion on data. Statistical summary utilizes the entire ULS/OBD data set; results are representative of the tunnel zone. Baselines for Mix Coarser and Gravels are not provided due to lack of data (soil types rarely encountered). Refer to Section 4.7 for baseline of possible obstructions.

[2] Hydraulic Conductivities are based on limited test data and correlation with soil descriptions. The in-situ permeability at the AAS breakouts were subject to packer testing and baseline average steady-state hydraulic conductivity at these specific locations shall be taken as $k \leq 1 \times 10^{-7}$ m/s.

Pcf (pounds per cubic foot)
100 pcf = 1602 kg/m³

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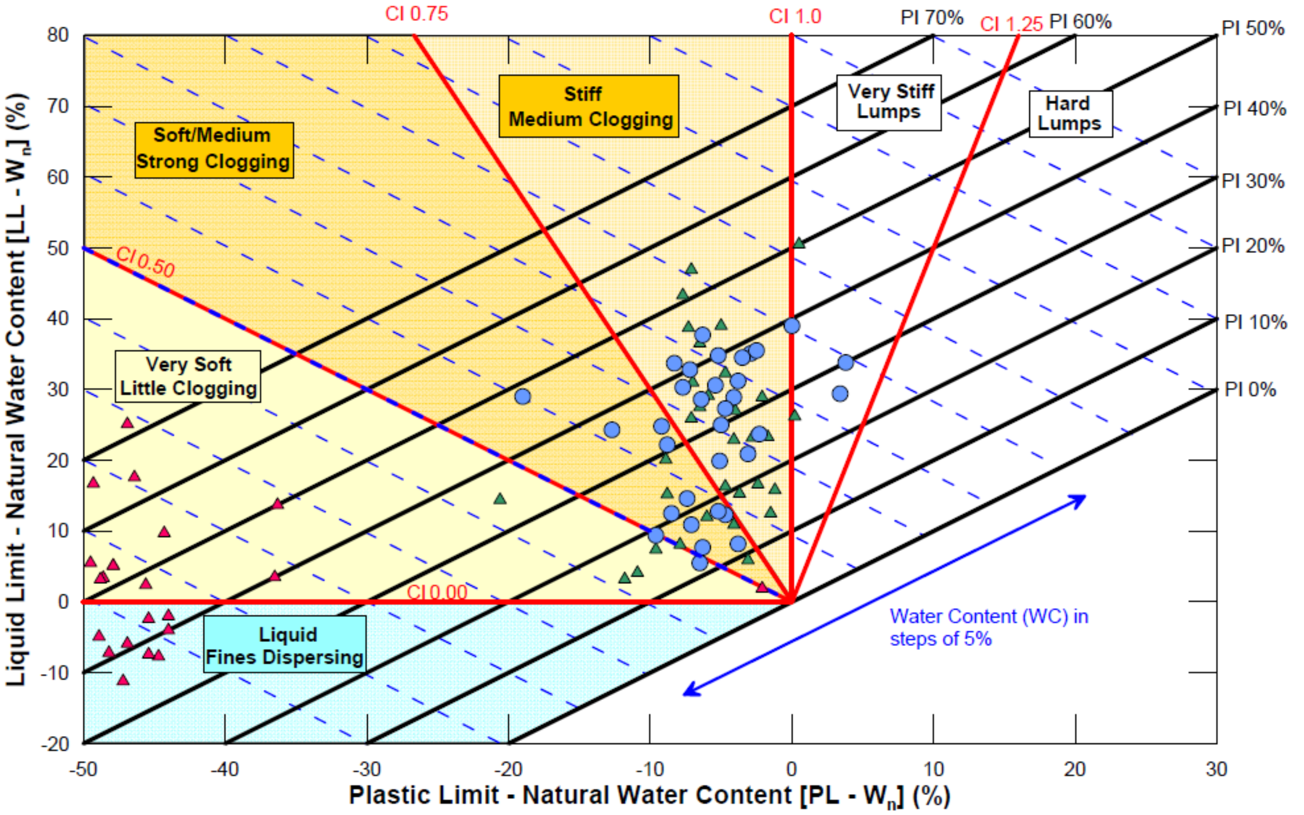
2. GEOLOGICAL CONTEXT

2.1 *FOCUS ON GEOTECHNICAL DATA*



Notes:
1. Chart adapted from Hollmann and Thewes (2013)
2. Consistency Index (CI) = (LL - W_n)/PI
3. W_n = natural (in-situ) water content
4. Hollman and Thewes indicate that for a given PI, by changing the the water content (WC), it is possible to alter the clogging potential of the soil. Each soil 'moves' downwards and to the left with increasing WC, starting with W_n.
5. All Young Bay Mud tests plot as Very Soft or Liquid.
6. Not all Young Bay Mud data points shown for clarity of scale.

- ▲ Index Data - YBM
- ▲ Index Data - ULS Clay
- ● Index Data - Tunnel Zone

SOIL CLOGGING POTENTIAL CHART

Silicon Valley Clean Water Gravity Pipeline Project
Geotechnical Baseline Report - Project-Wide
Silicon Valley Clean Water District
Redwood City, California

March 2019

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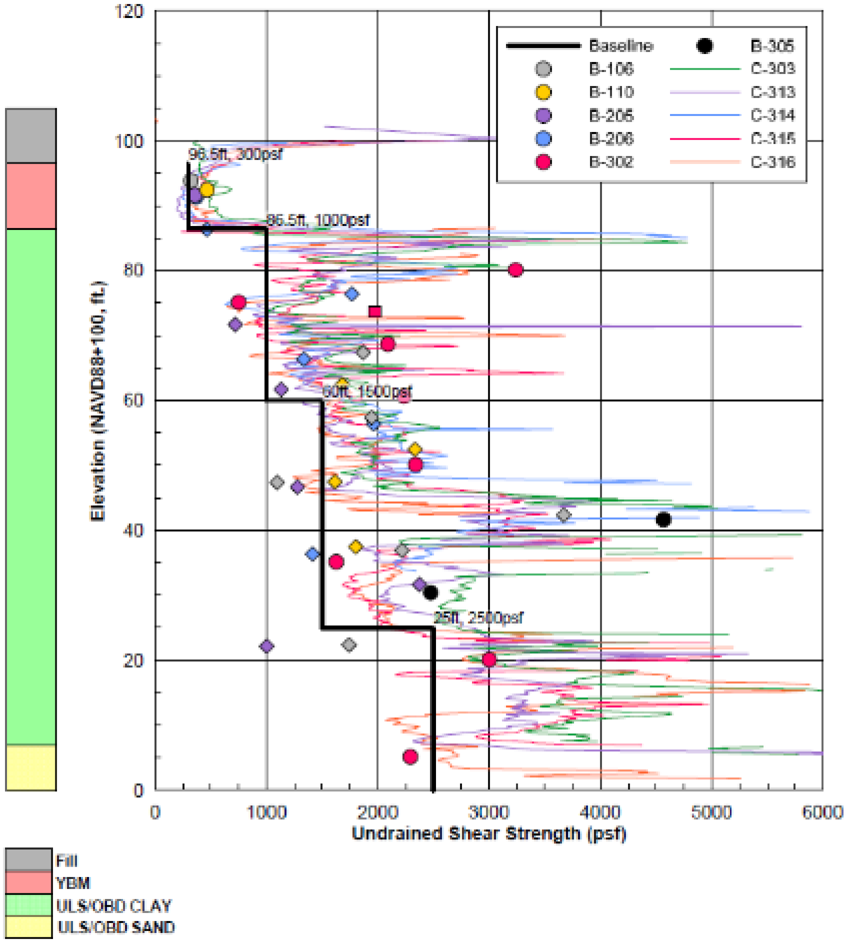
FIGURE 36

2. GEOLOGICAL CONTEXT

2.1 *FOCUS ON GEOTECHNICAL DATA*



Note: Color differentiates boring and symbol differentiates test type
- ◆ Unconfined Compression
- ● TXUU
- ■ TXCU

UNDRAINED SHEAR STRENGTH
AIRPORT ACCESS SHAFT

Silicon Valley Clean Water Gravity Pipeline Project
Geotechnical Baseline Report - Project-Wide
Silicon Valley Clean Water District
Redwood City, California

March 2018

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FIGURE 30

Psf (pounds per square foot)
1000 psf = 48 kPa

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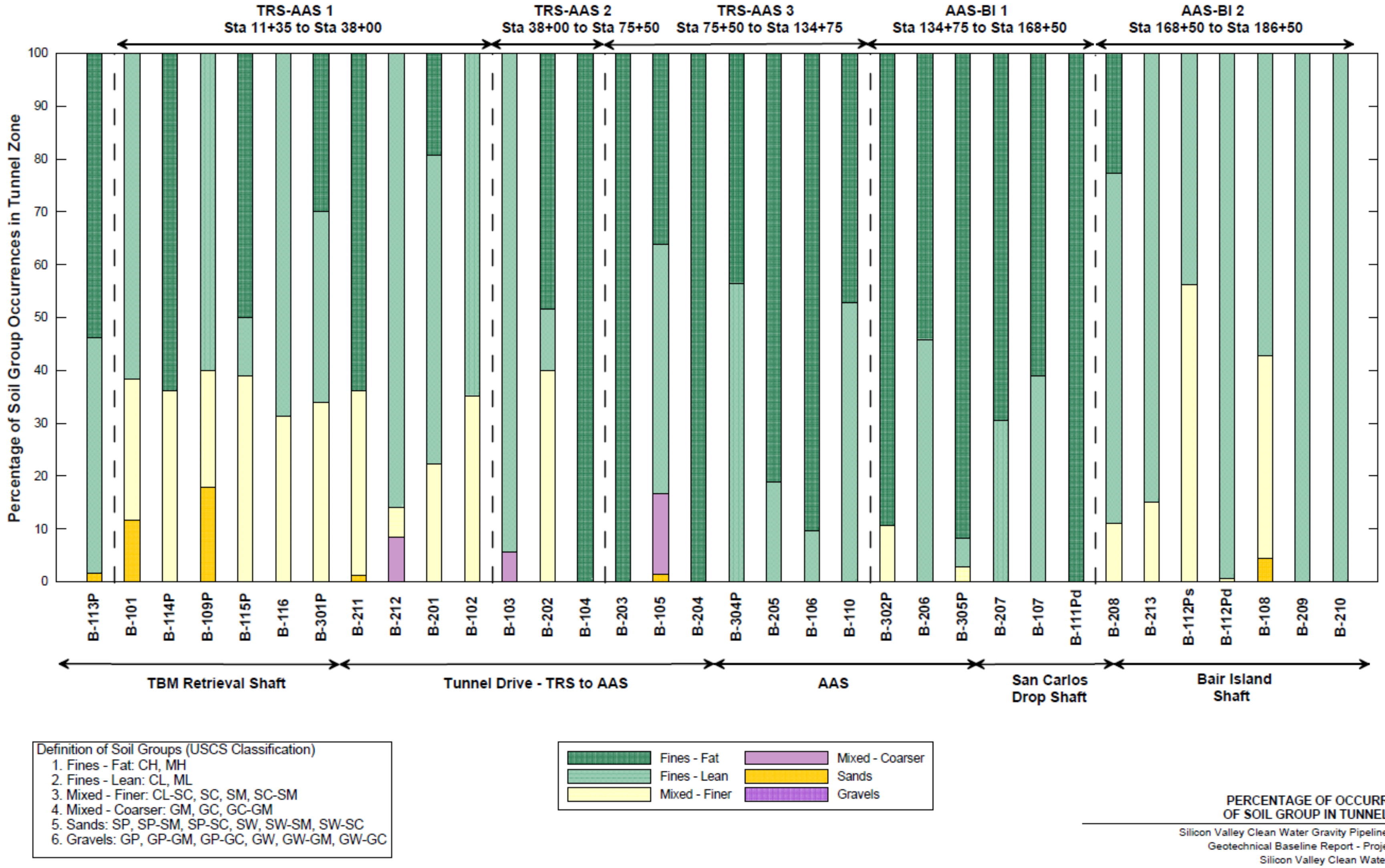
2. GEOLOGICAL CONTEXT

2.1 *FOCUS ON GEOTECHNICAL DATA*



PERCENTAGE OF OCCURRENCE OF SOIL GROUP IN TUNNEL ZONE

Silicon Valley Clean Water Gravity Pipeline Project
Geotechnical Baseline Report - Project-Wide
Silicon Valley Clean Water District
Redwood City, California

March 2019

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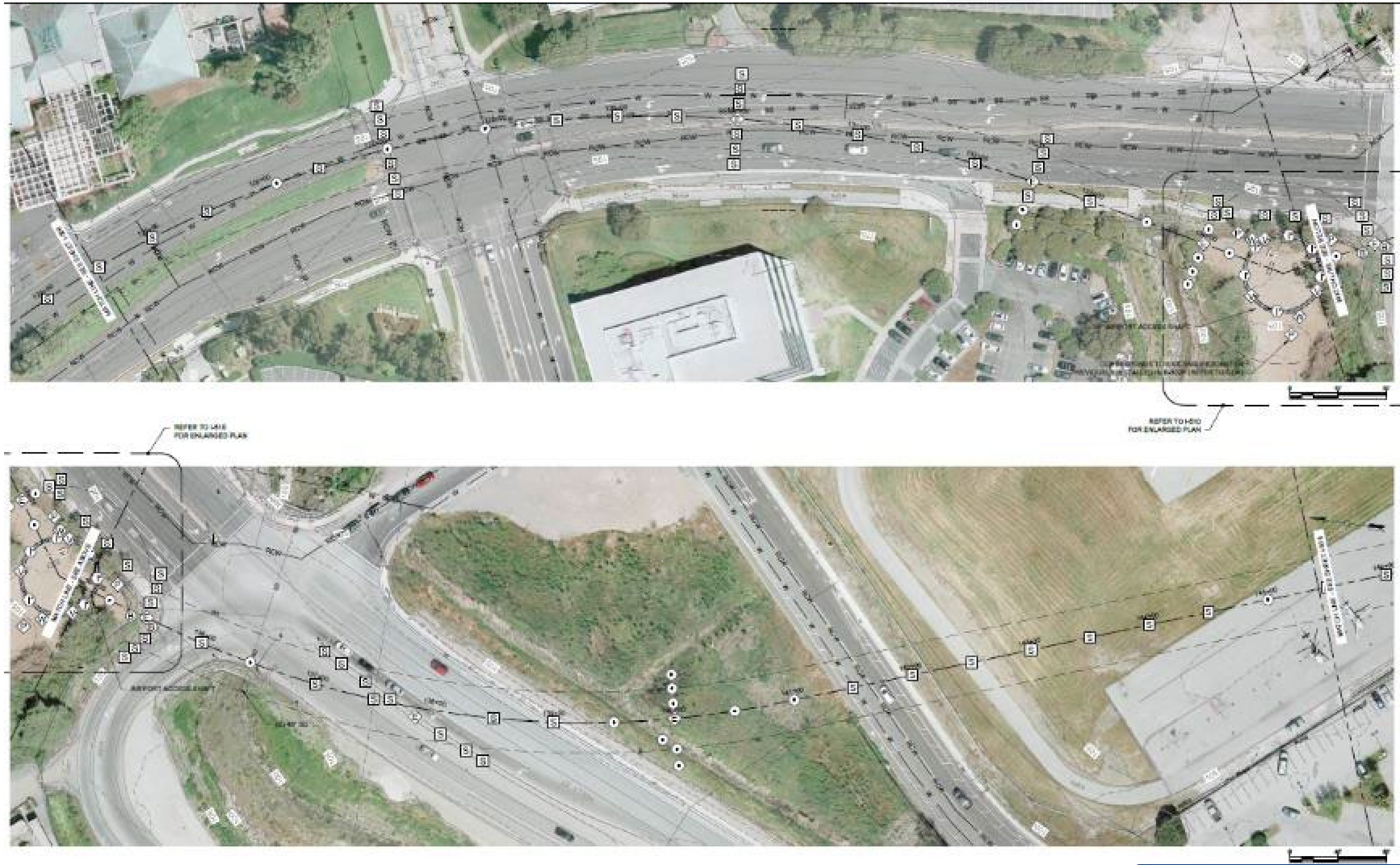
FIGURE 21

2. GEOLOGICAL CONTEXT
2.1 *FOCUS ON GEOTECHNICAL DATA*

Settlements



Warning value: 1/4in = 6 mm
Limit value: 1/2in = 12 mm

Classic 2D FEM (Finite Element Method)

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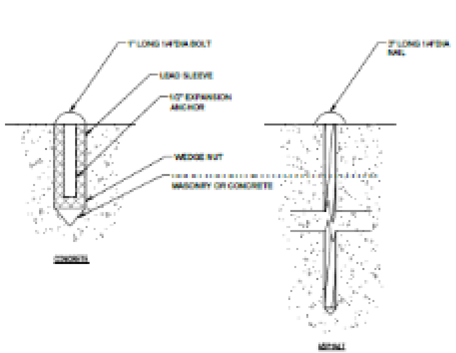
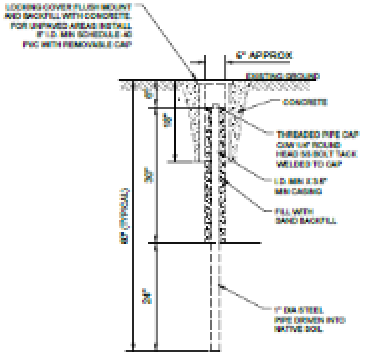
2. GEOLOGICAL CONTEXT

2.1 *FOCUS ON GEOTECHNICAL DATA*

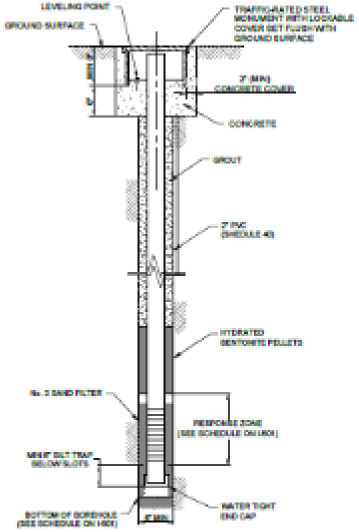
Settlements



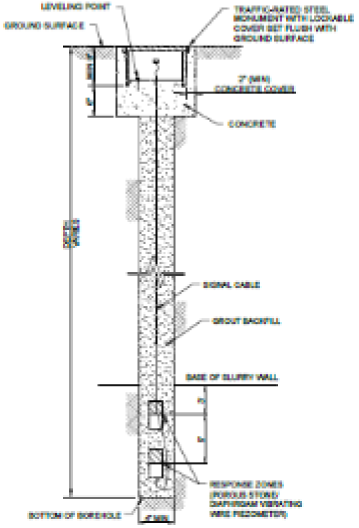
1 SURFACE SETTLEMENT POINT (SSP)
NTS



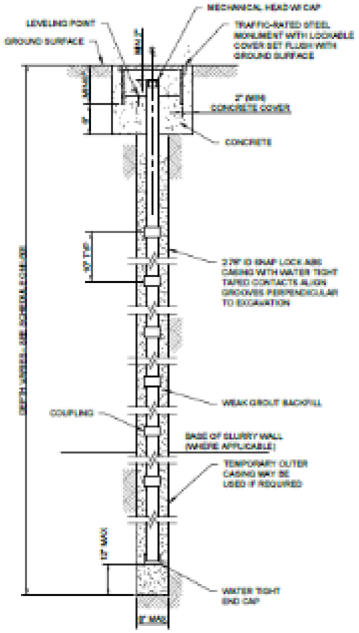
2 SURFACE MONITORING POINT FOR UNPAVED AREAS (SMP)
NTS



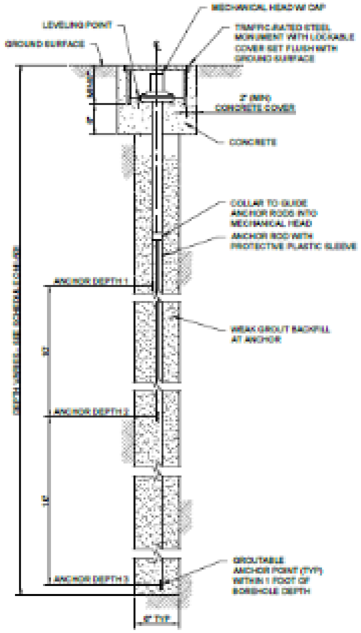
3 STANDPIPE PIEZOMETER (PZM)
NTS



4 MULTI-LEVEL VIBRATING WIRE PIEZOMETER (VWP)
NTS



5 INCLINOMETER (INC)
NTS



3 MULTI-POINT BOREHOLE EXTENSOMETER (MPBX)
NTS

3. SHAFTS – LAUNCHING SHAFT

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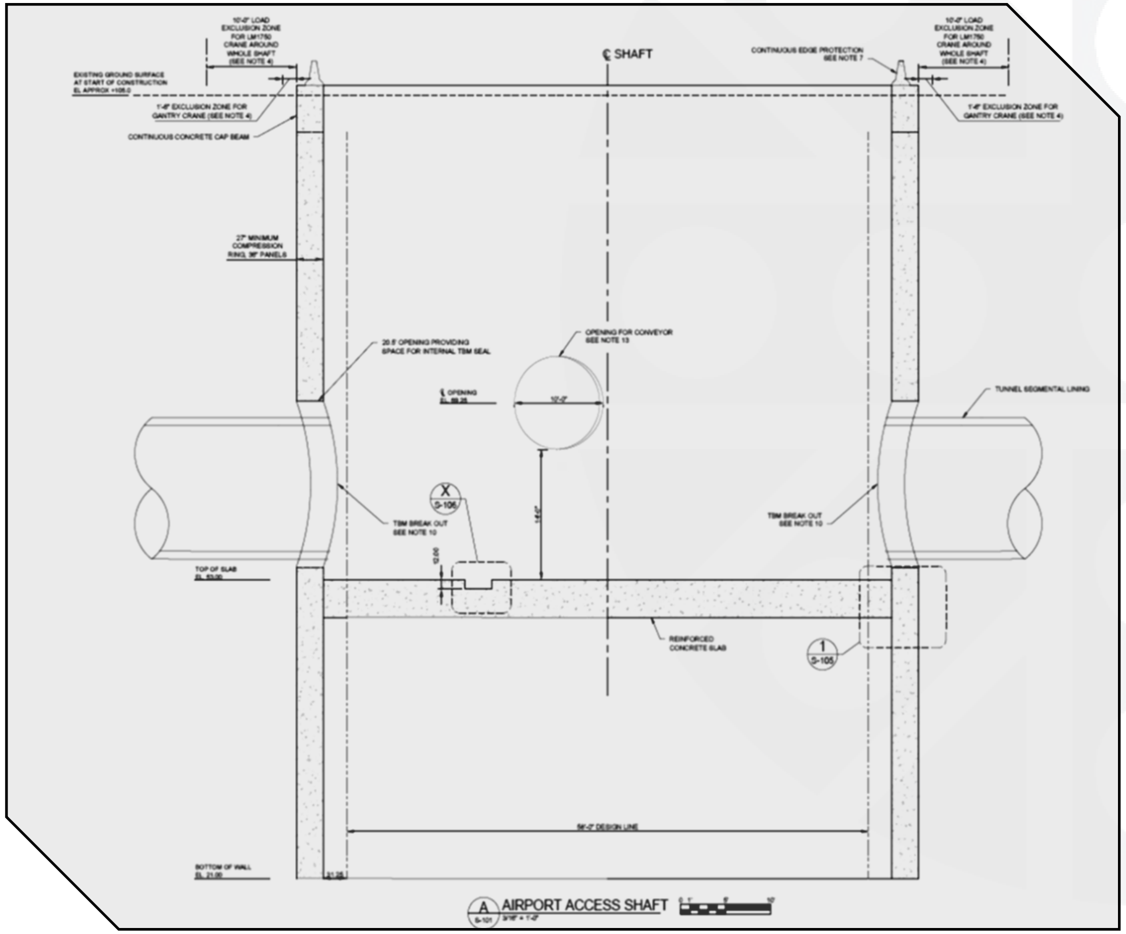
3. SHAFTS – LAUNCHING SHAFT

Main information:

- Internal diameter = 58’ / 17,67m
- Depth (excavation) = 56,5’ / 17,22m
- Bottom slab thickness = 4’ / 1,22m
- Cut Off depth compare to ground level: 84’ / 25,60 m
- Geology:
  - El 105 to 99: Imported fill material.
  - El 99 to 85: Young Bay Mud.
  - El 85 to 49: Stiff clay (Upper Layer Sediment)
- 2 depressurizations wells have been installed in order to reduce the pressure in the sandy layer. Depth 125 Feet and screened between El -18 and +7.



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3. SHAFTS – LAUNCHING SHAFT

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3. SHAFTS – LAUNCHING SHAFT

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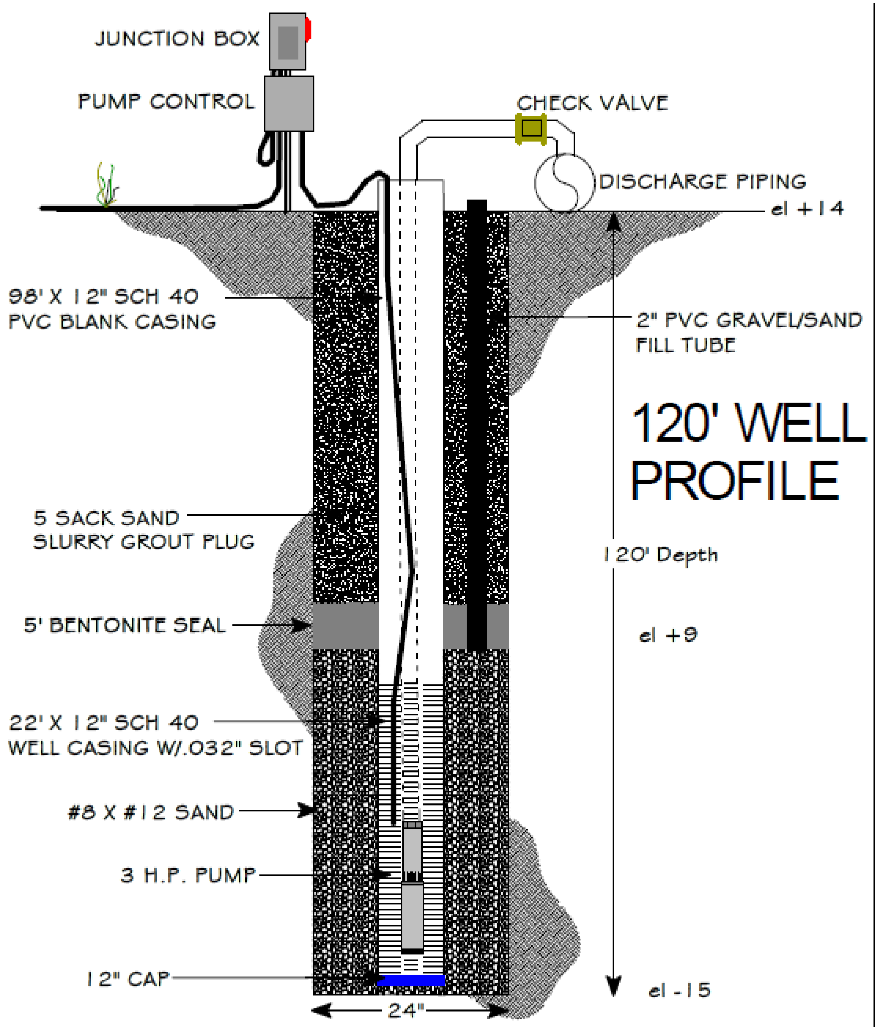
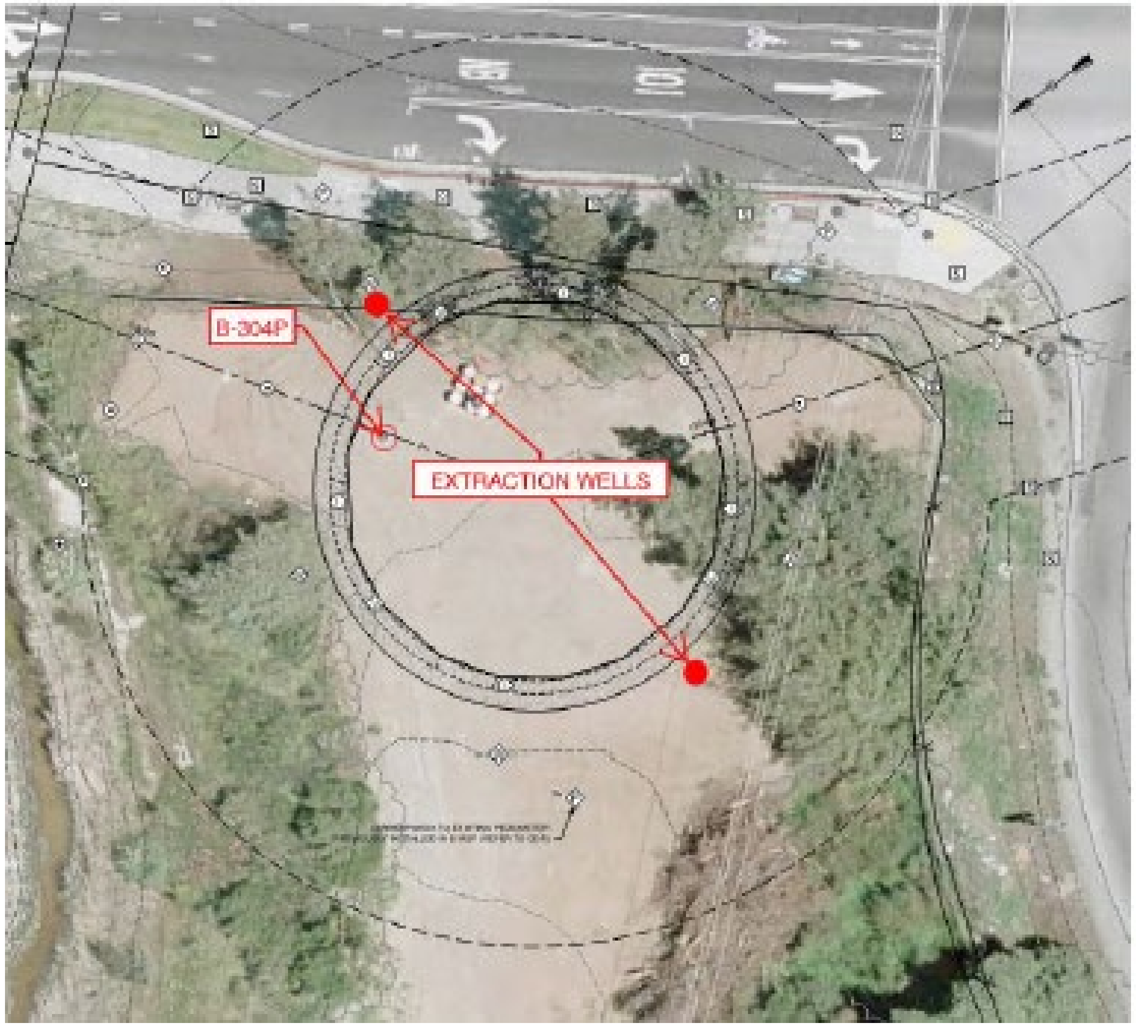
3. SHAFTS – LAUNCHING SHAFT





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3. SHAFTS – LAUNCHING SHAFT

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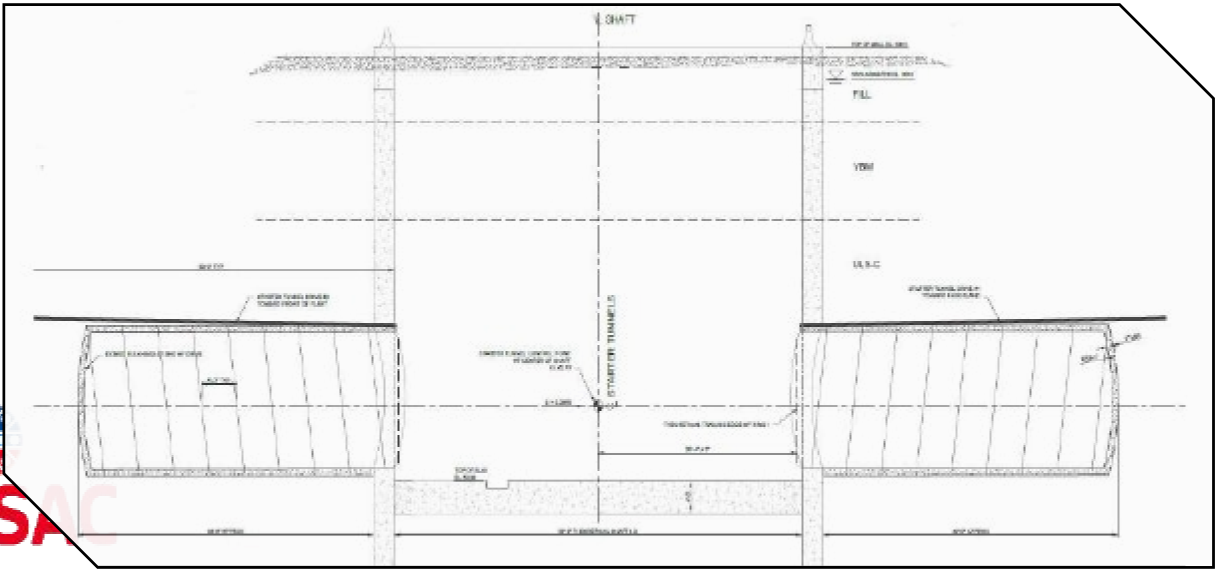
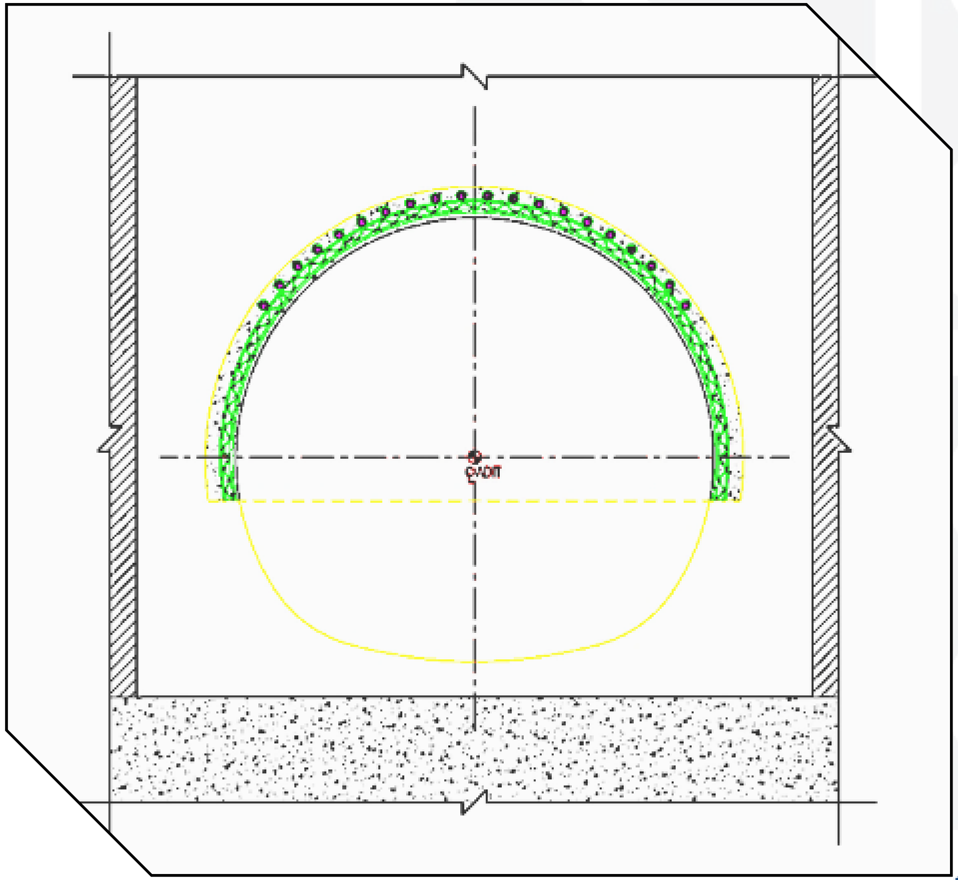
3. SHAFTS – LAUNCHING SHAFT (STARTER TUNNELS)

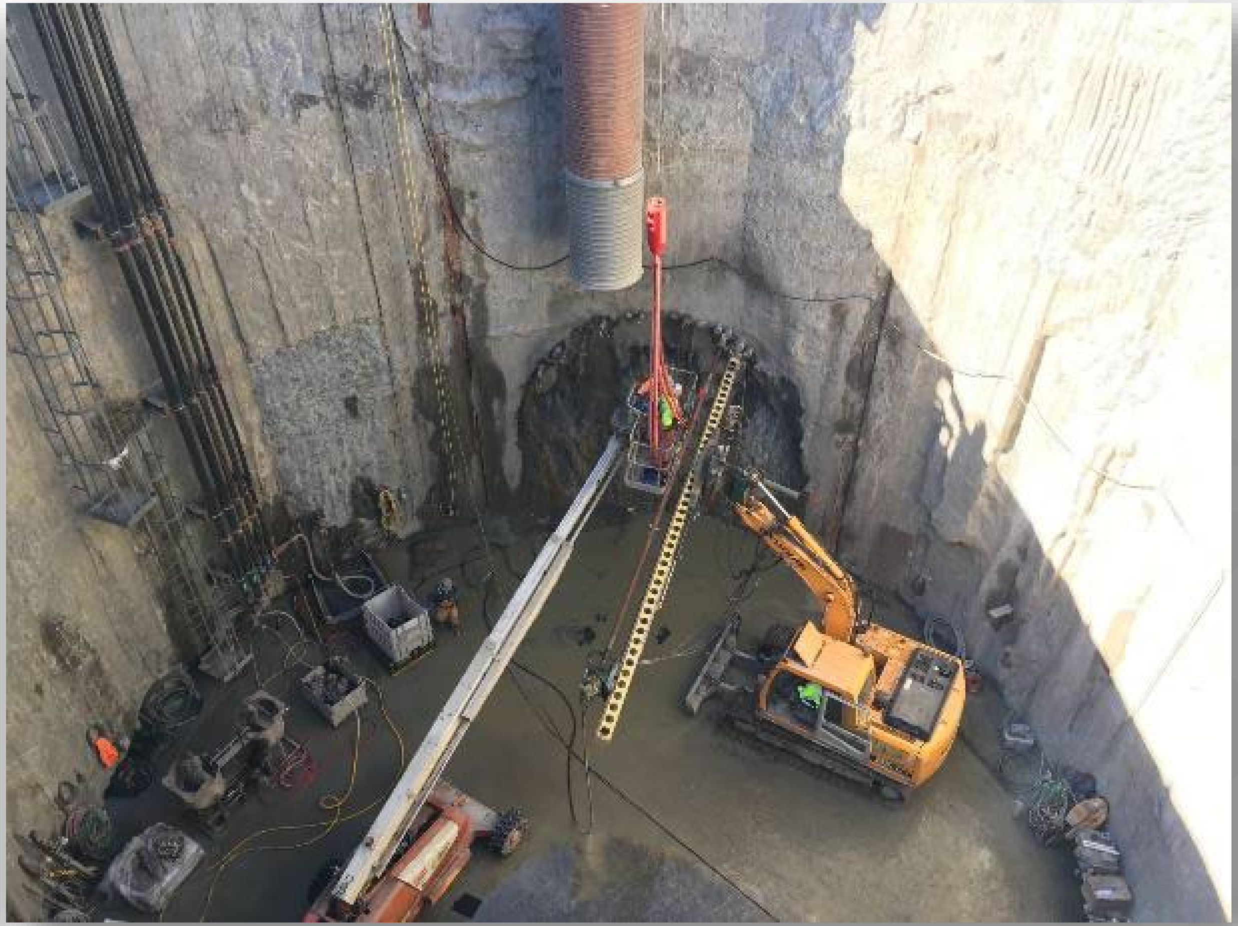
Two starter galleries for both drives, each being 42' long to be able to assembly, prior mining, the TBM and the gantry 1.

For the launching sequence, steel half rings were installed on the cradle to create the shifting way and we used a muck pump to bring muck from TBM to inclined conveyor.





3. SHAFTS – LAUNCHING SHAFT (STARTER TUNNELS)



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3. SHAFTS – LAUNCHING SHAFT (STARTER TUNNELS)

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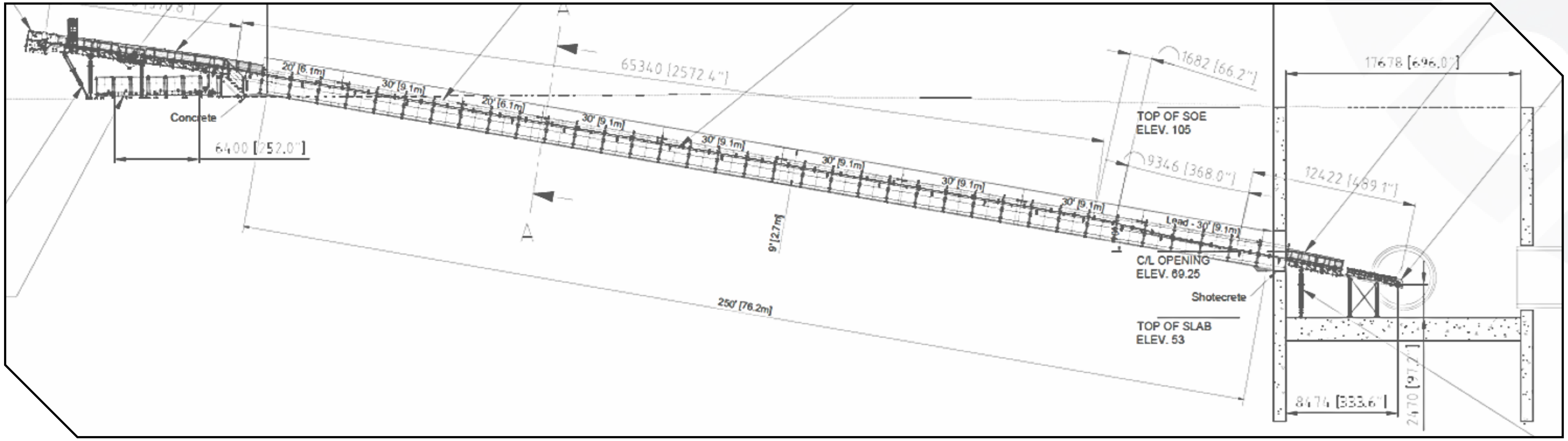
3. SHAFTS – LAUNCHING SHAFT (STARTER TUNNELS)

3. SHAFTS – LAUNCHING SHAFT (INCLINED TUNNEL)

An inclined conveyor made by H+E is used to extract the muck produced by the TBM from the launching shaft to the storage area. With a slope of 10º, it rolls through a steel inclined tube 9' / 2.74m in diameter and 250'/75 ml long.



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3. SHAFTS – LAUNCHING SHAFT (INCLINED TUNNEL)

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3. SHAFTS – LAUNCHING SHAFT (INCLINED TUNNEL)

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3. SHAFTS – RECEIVING SHAFT (BAIR ISLAND)

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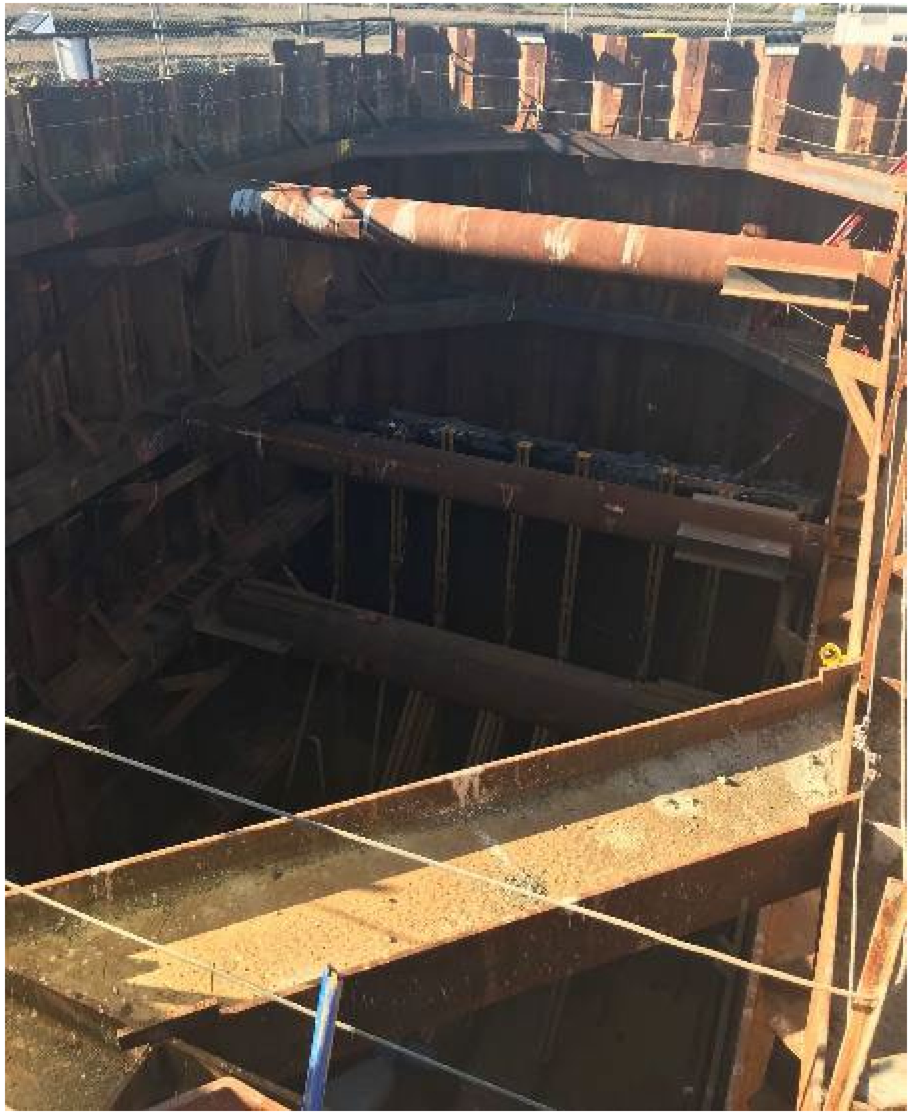
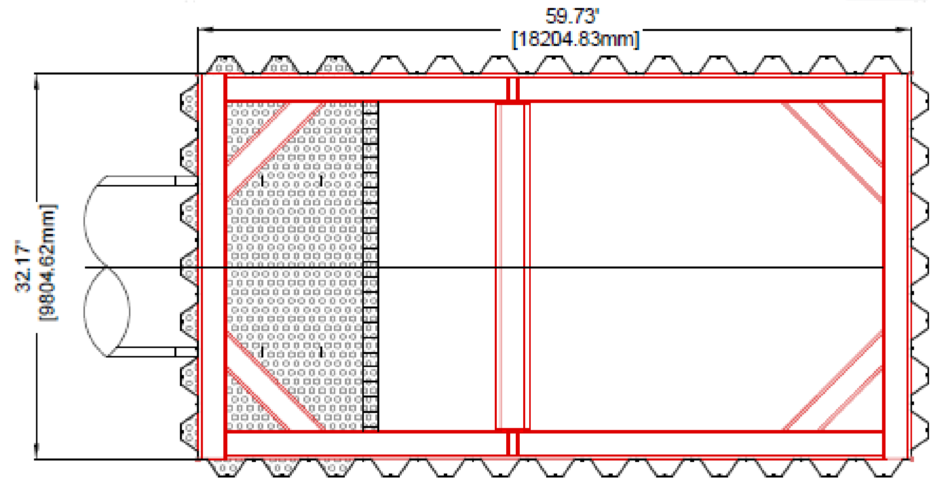
3. SHAFTS – RECEIVING SHAFT (BAIR ISLAND)





Main information: The support of excavation is made of sheet piles, struts and walers.

- Length = 59.73’ / 18.21m
- Width = 32.17’ / 9.81m
- Depth (excavation) = 48’ / 14.63m
- Bottom slab thickness = 3’ / 0.91m

3. SHAFTS – RECEIVING SHAFT (BAIR ISLAND)

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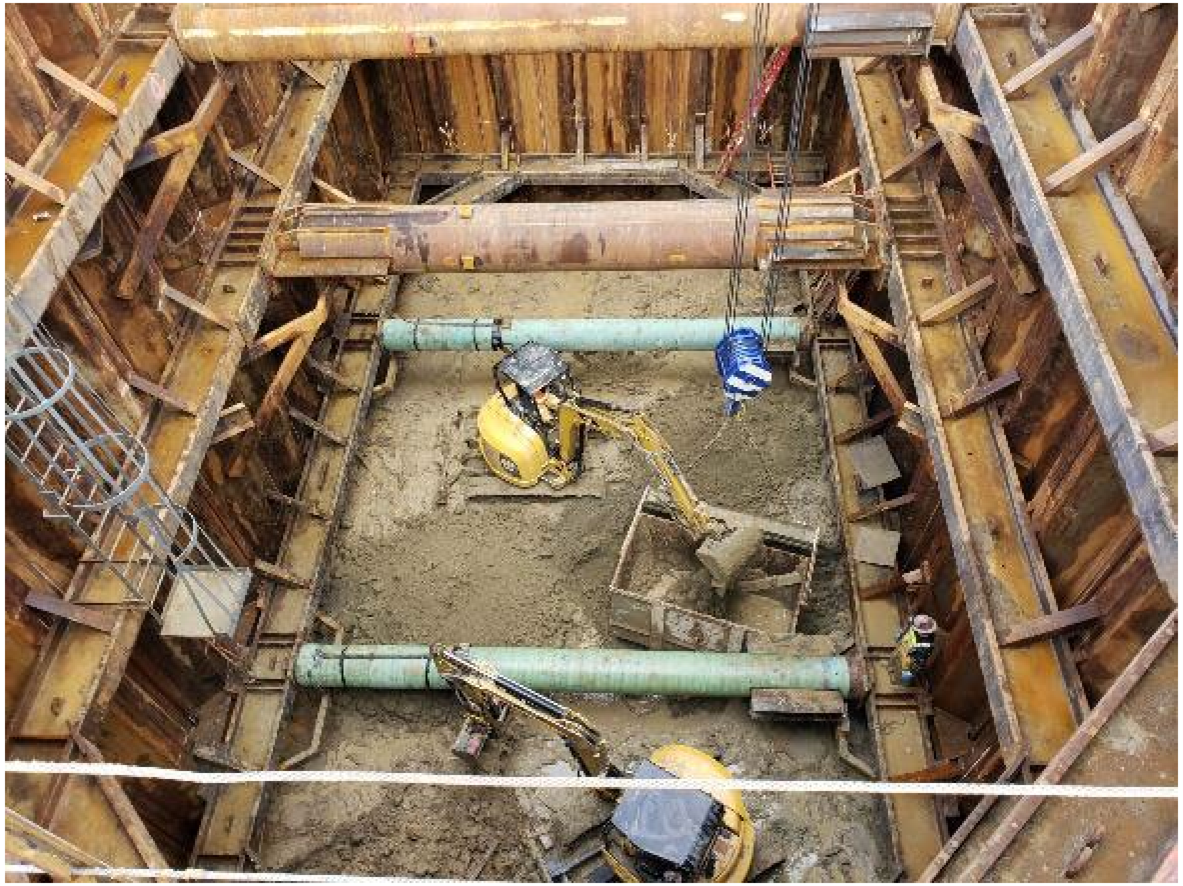
3. SHAFTS – RECEIVING SHAFT (BAIR ISLAND)



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3. SHAFTS – RECEIVING SHAFT (SFS)

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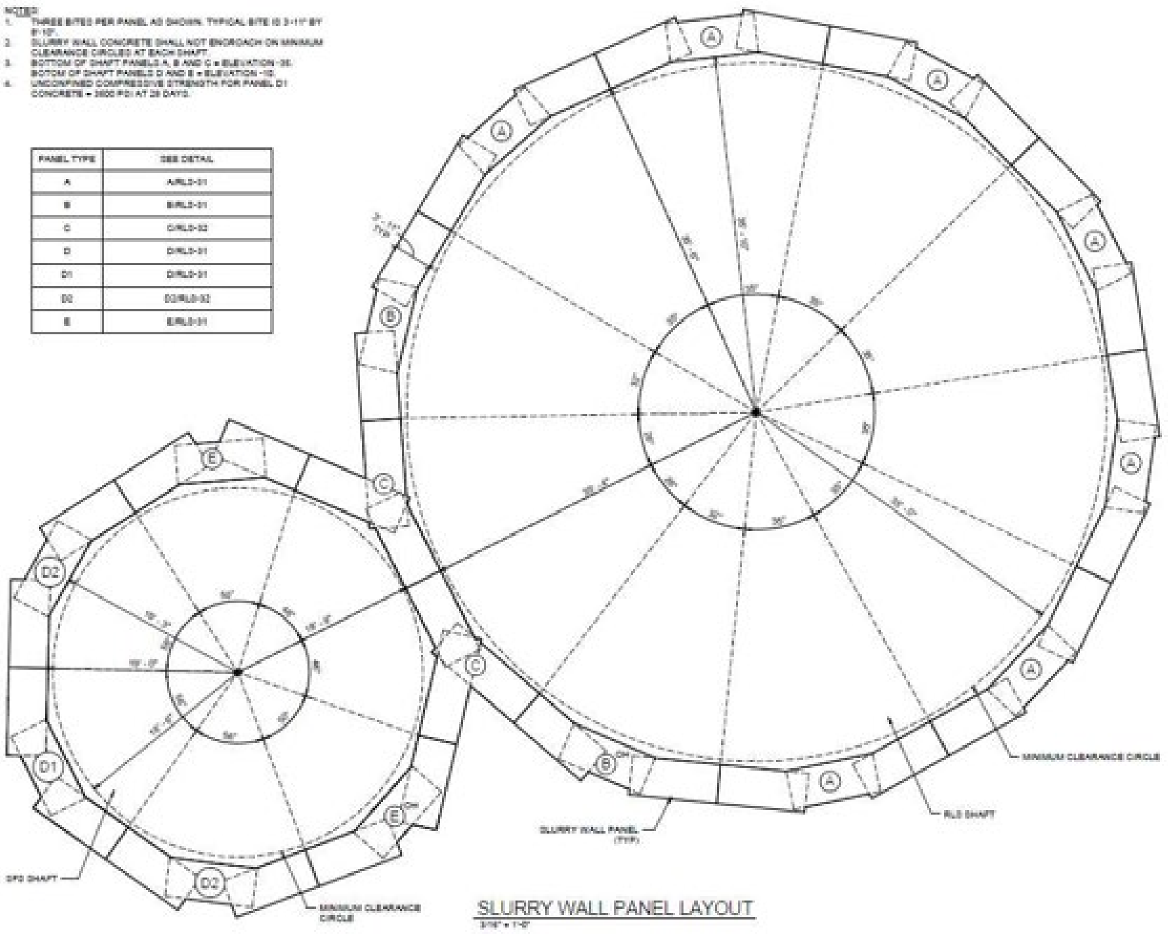
3. SHAFTS – RECEIVING SHAFT (SFS)

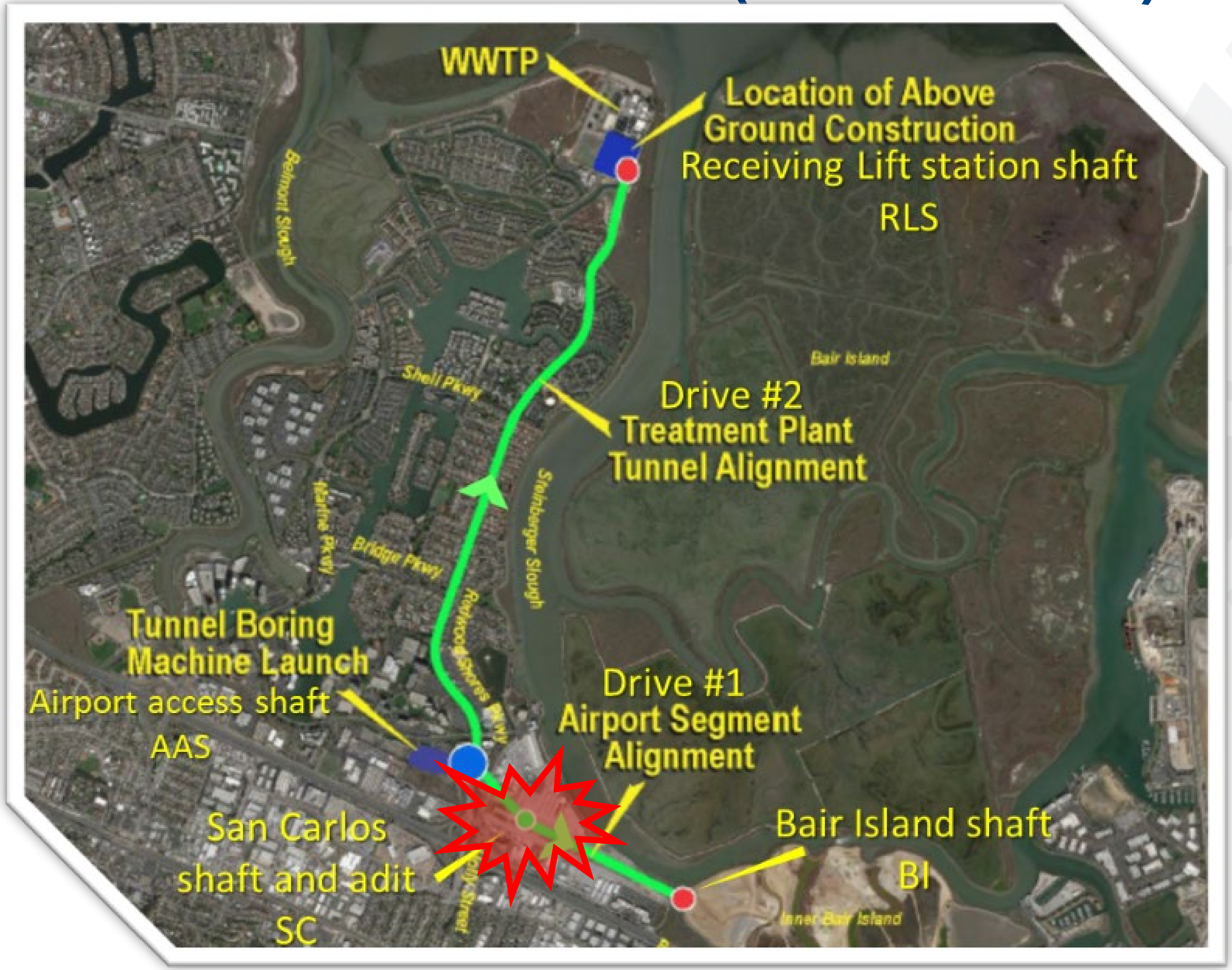
The construction of this shaft is outside our scope of work.



Main information: The support of excavation is made of concrete diaphragm walls.

- Wall thickness = 4ft / 1,2 m
- Strength = 13,000 psi / 90MPa
- Shaft Diameter = 37’ / 11 m
- Depth (slab) = 80’ / 24 m

3. SHAFTS – OTHER SHAFT (SAN CARLOS)



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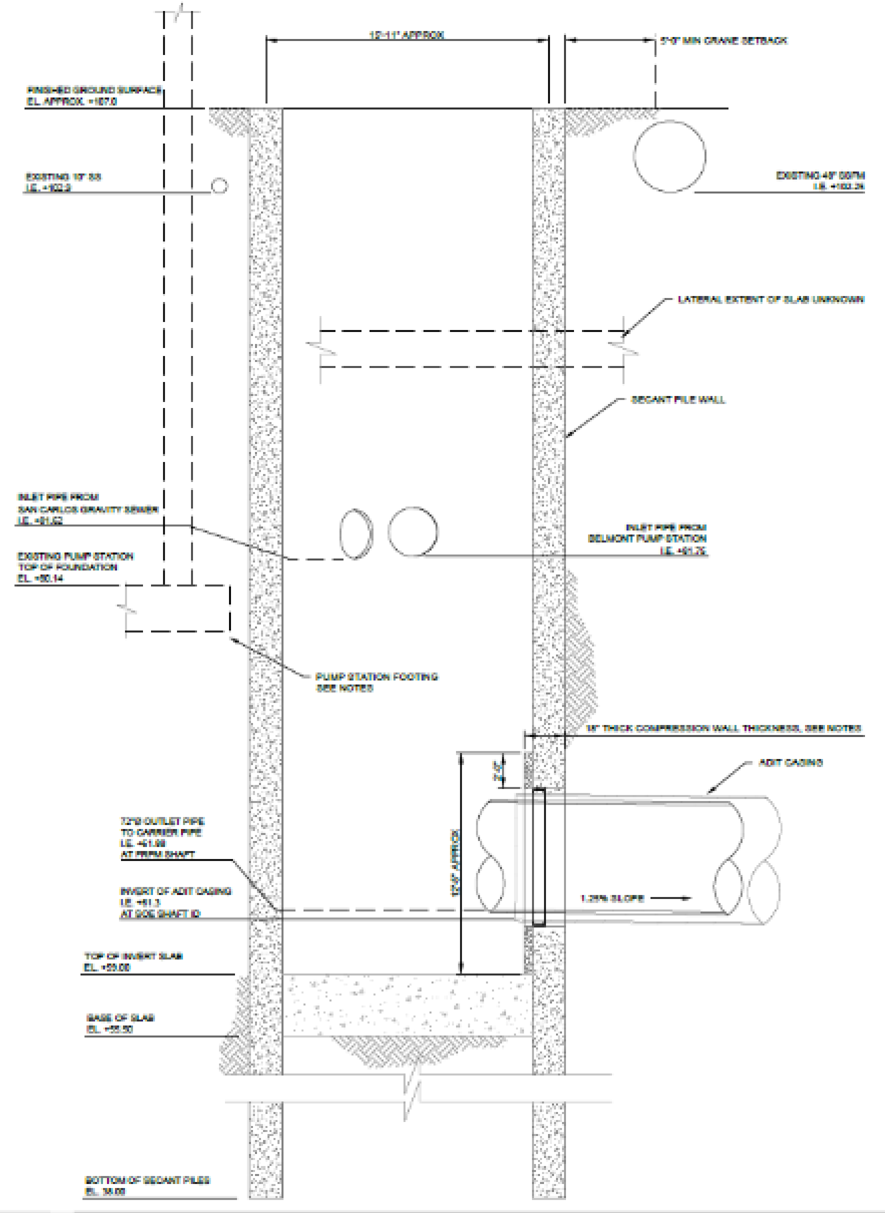
3. SHAFTS – OTHER SHAFT (SAN CARLOS)

<u>**Main information:**</u> The support of excavation is made of secant piles.

- Piles Diameter = 2,8’ / 880 mm
- Shaft Diameter = 15’ / 4,5 m
- Depth (excavation) = 48’ / 14.63m
- Bottom slab thickness = 3,5’ / 1m



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3. SHAFTS – OTHER SHAFT (SAN CARLOS)

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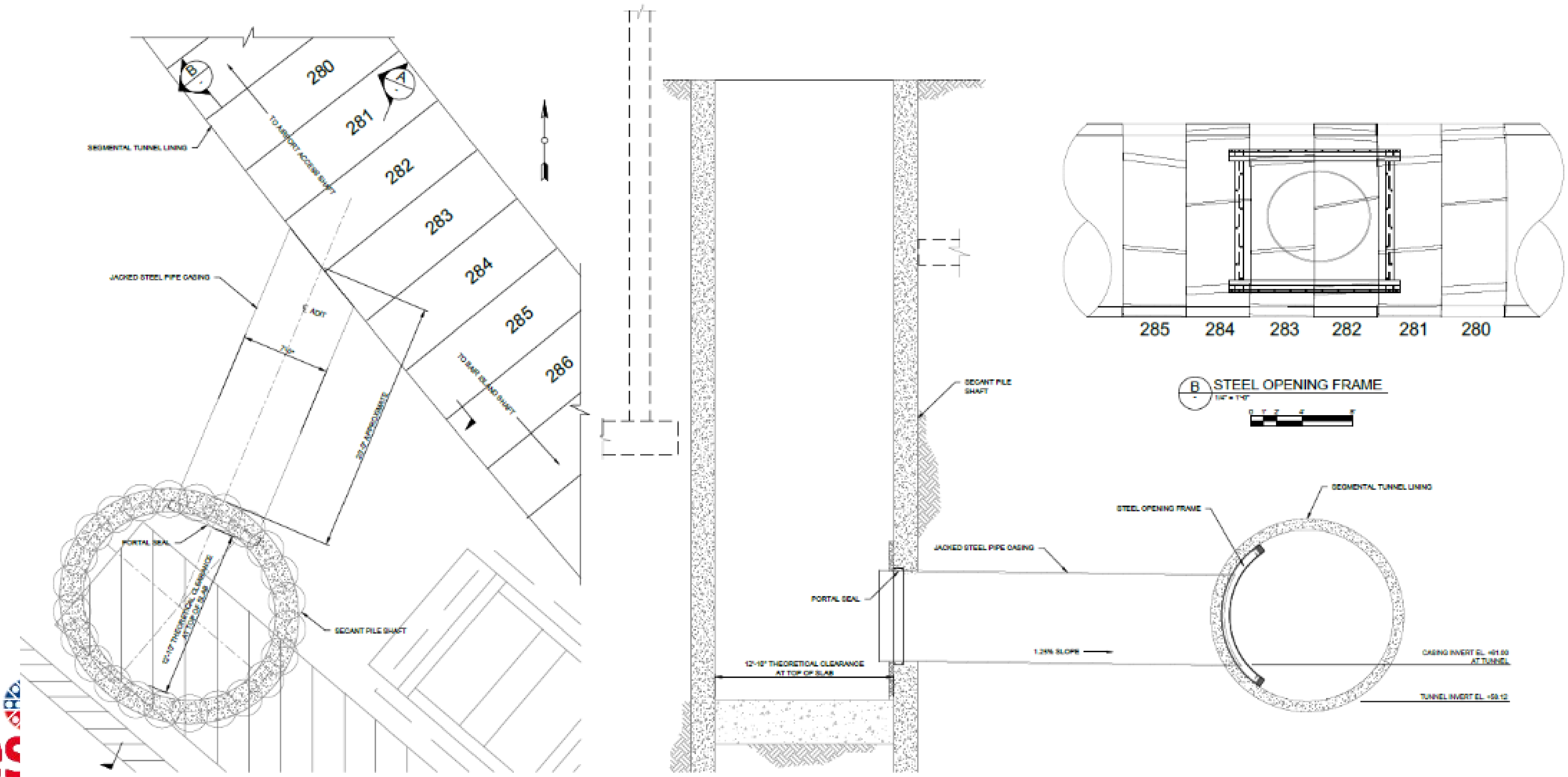

3. SHAFTS – OTHER SHAFT (SAN CARLOS)



3. SHAFTS – OTHER SHAFT (SAN CARLOS)

4. TUNNELING WORKS - TBM

TBM is an HK EPB machine 4 910 mm diameter designed:

- To cope with 650 LF radius curve
- For a maximum advance speed of 4 inches/mn
- 100 mm/mn
- For the concrete lining described on the next slide
- For excavated material transport
  - with muck pump for launching.
  - with continuous conveyor belt
- For stacking 2 full rings with quick unloader
- For ring erection with mechanical lifting table
- The backup is made of 17 gantries, i.e. 620 LF / 190 m.
- Annular void injection by Bi-Component grout.

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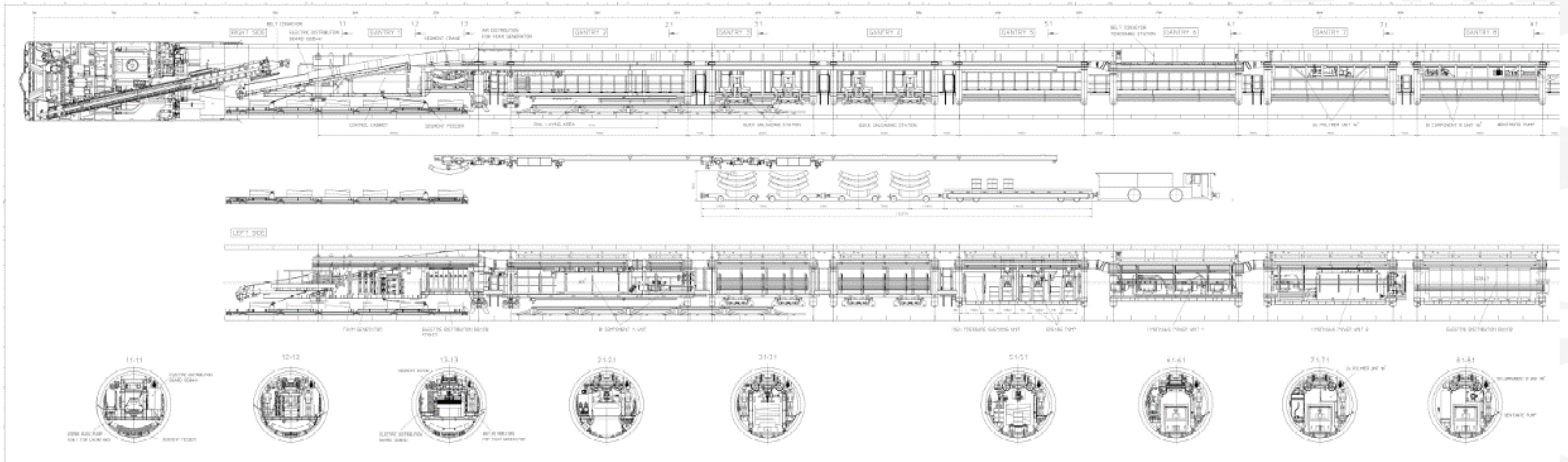
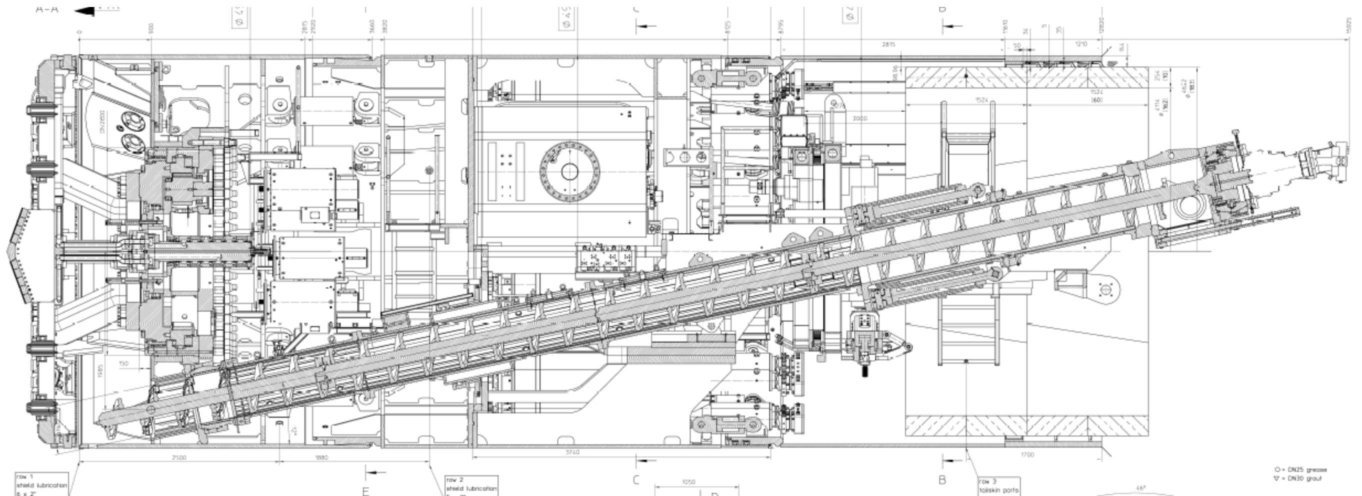
4. TUNNELING WORKS – TBM





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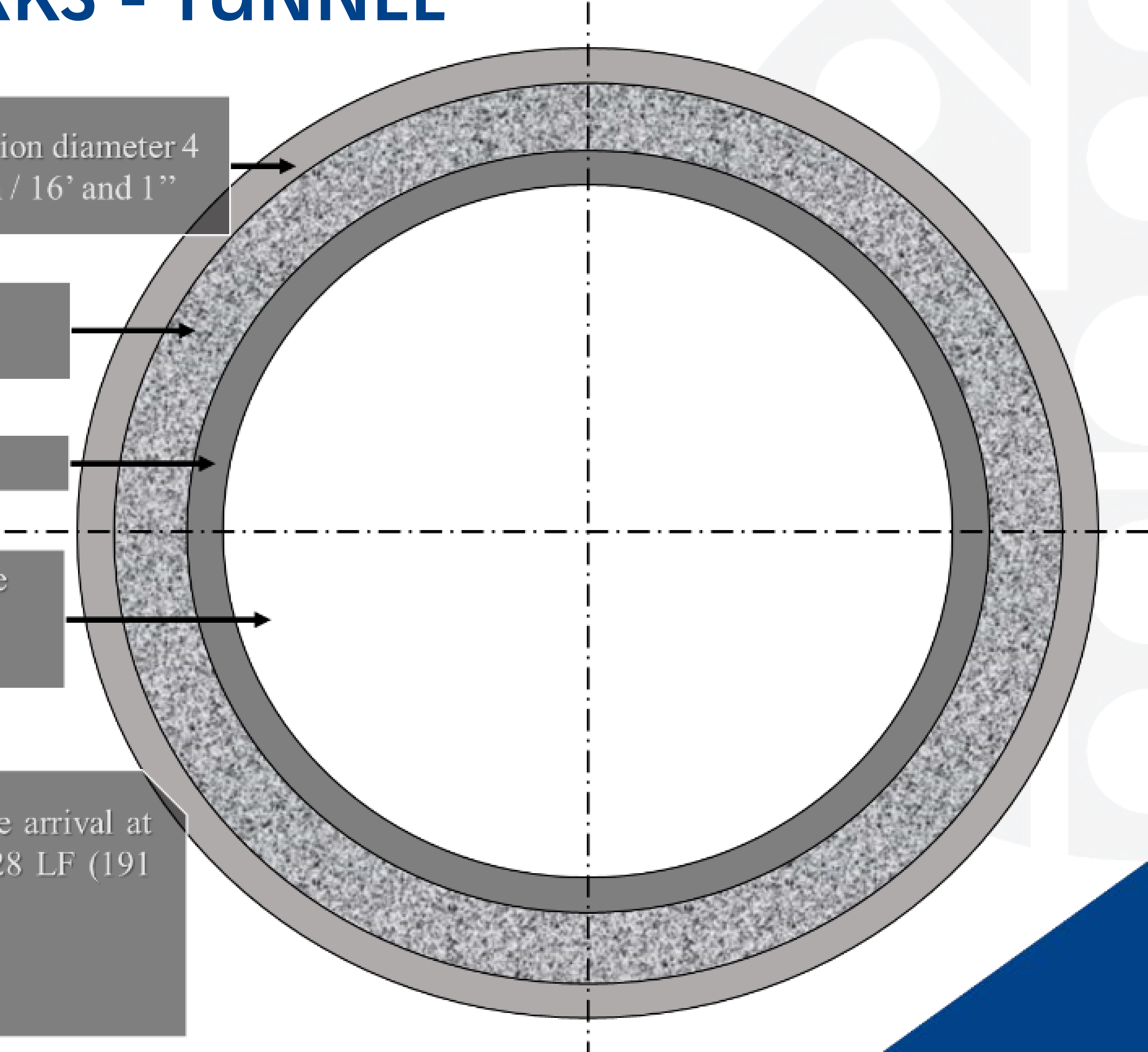
4. TUNNELING WORKS - TUNNEL

Excavation diatmeter 4 910 mm / 16' and 1"

Precast concrete segments
13' and 6" inner diameter

Cellular grout

Fiberglass Reinforced Polymer Mortar Pipe (FRPM pipe)
10' and 11' inner diameter



The maximum gradient is 0,15% except at the arrival at BI where the gradient increase to 1,3% on 628 LF (191 m).

The maximum curve is 800 LF (244 m).

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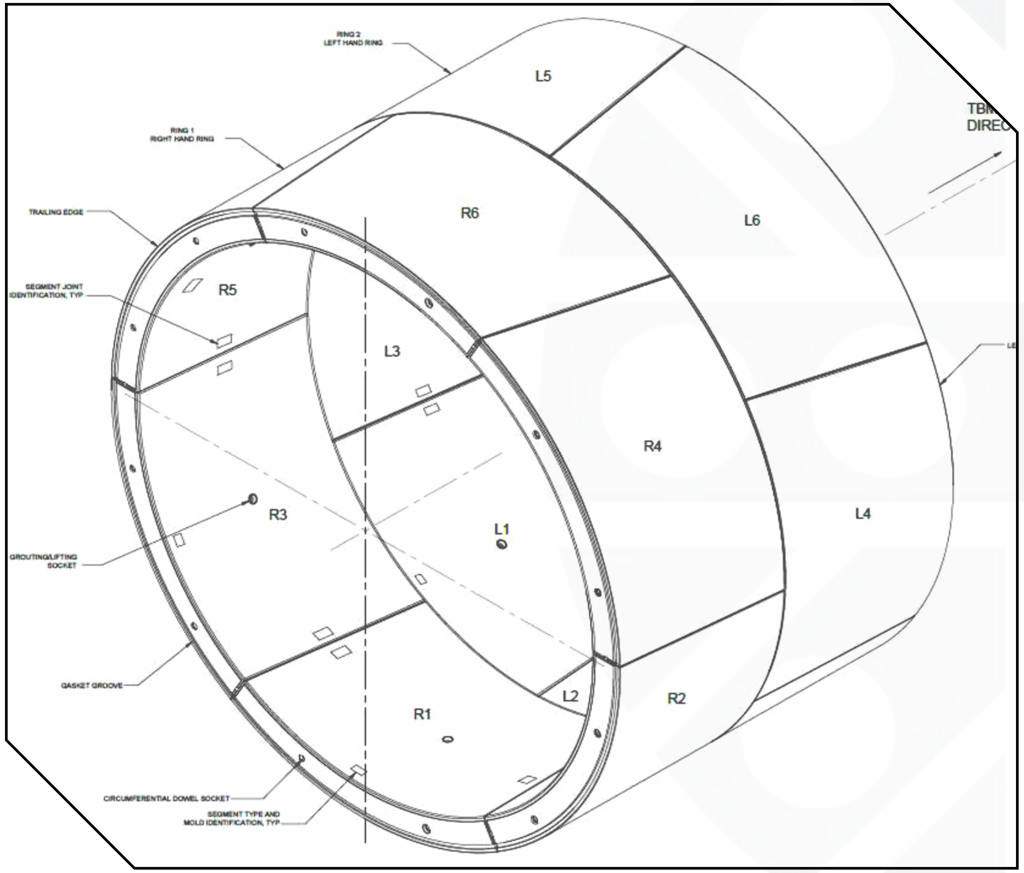
4. TUNNELING WORKS - TUNNEL

4. TUNNELING WORKS – TUNNEL (SEGMENTS)

Rings are Universal type and have been designed with Left and Right type to erect rings bottom up for safety reason.

Main characteristics:

- Outside diameter: 182 inches / 4623 mm
- Inside diameter: 162 inches / 4115 mm
- Segment thickness: 10 inches / 254 mm
- Segment length: 5 feet / 1524 mm
- Weight: 2,2 T / 4,800 lbs
- Ring distribution: 5+1
- Steel fiber reinforced concrete (50lb/CY – 29,6kg/m3)
- Compressive strength: design 6000psi/41,3MPa, actual 8644 psi/59,6 Mpa.



Cal Portland Type II Cement (75%):	573 lbs
Headwaters Type F Flyash (21%):	160 lbs
Mississippi Silicon Silica Fume (4%)	31 lbs
Teichert Waterford C33 Sand:	1333 lbs
Teichert Waterford 3/8" Rock:	1644 lbs
Bekaert Maccaferri 4D Steel Fibers:	50 lbs
Glenium 3400:	Approx 7oz/cwt
W/C Ratio:	0.29 - 0.31
Desired Slump:	0" to 3"

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4. TUNNELING WORKS – TUNNEL (SEGMENTS)

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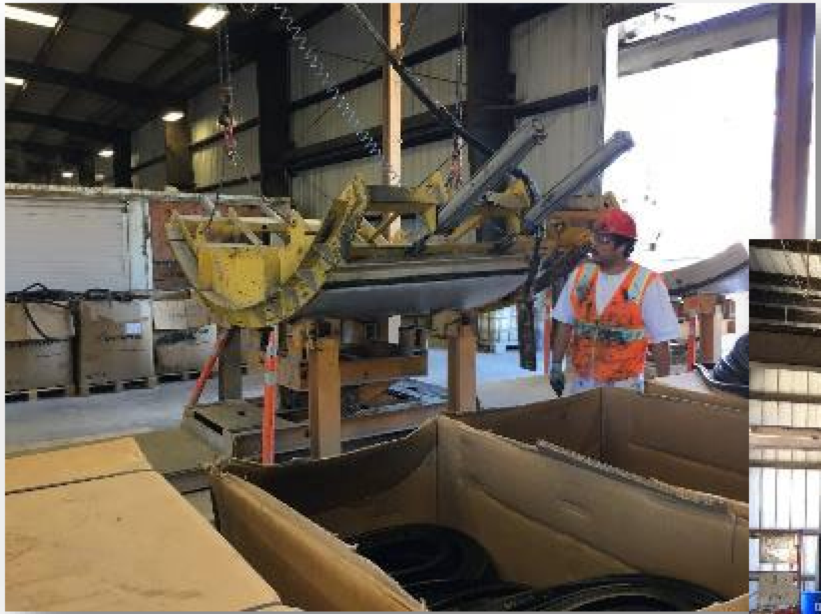

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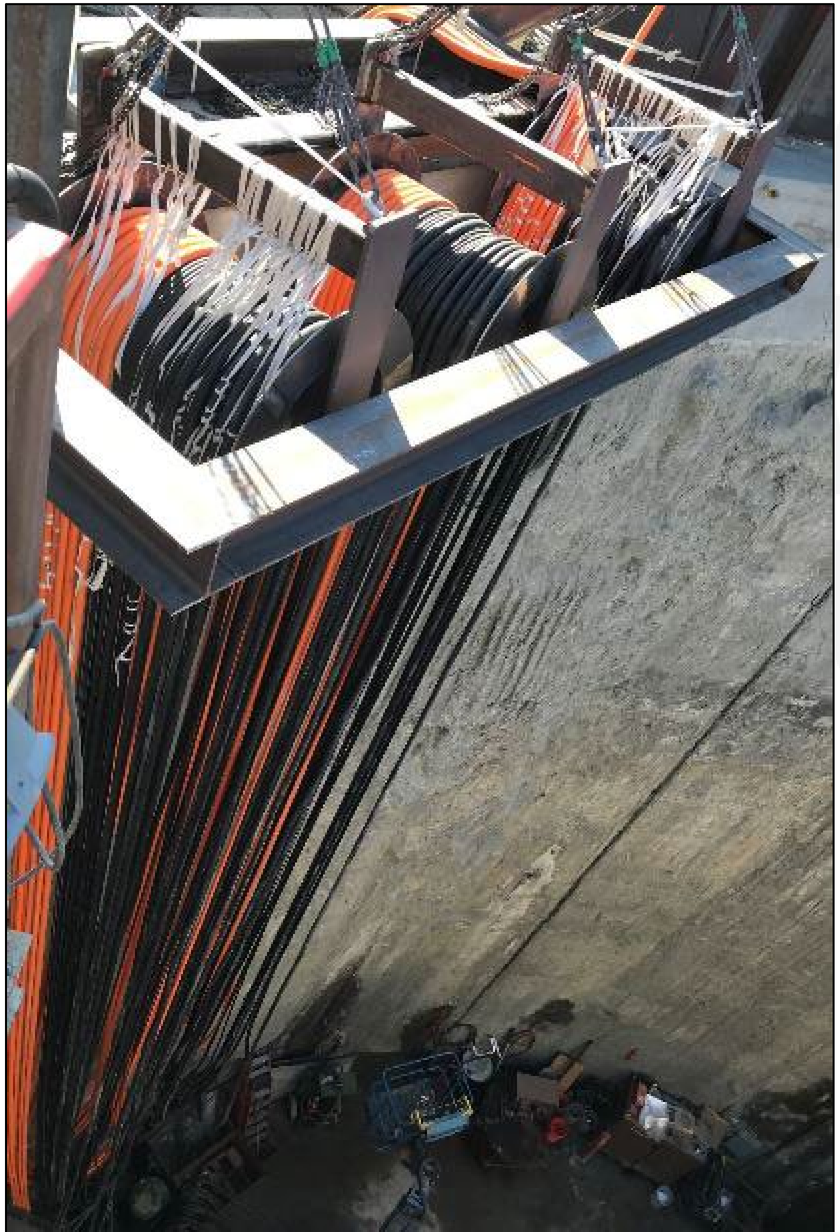
4. TUNNELING WORKS – LAUNCHING

<u>Stage 1 :</u> Break-out and excavation from the ASS for a distance of 240 LF / 73 m, 48 installed rings. Install umbilical's connection for power supply, hydraulic, communication and utilities with the backup gantries 2 to 15 installed and assembled at the surface on rails.

A muck pump was used. to extract the excavated muck from the TBM.

Then, first extended TBM stoppage to install gantries 2 through 8.



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4. TUNNELING WORKS – LAUNCHING

4. TUNNELING WORKS – LAUNCHING

4. TUNNELING WORKS – LAUNCHING

Stage 3: Excavation of an additional 90 LF / 27,5 m, 118 installed rings.
Third extended TBM stoppage to install gantries 16 through 17.

Stage 4: Excavation of an additional 310 LF / 94,5 m, 180 installed rings.
TBM stoppage for installation of continuous conveyor and California switch.

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4. TUNNELING WORKS – EXCAVATION

DRIVE 1 AAS-BI:

- In final configuration:
  - Excavation of 1 272 m in 41 days → 31 m per day (10h/shift, 2 shift per day, 5 days a week)
  - Max production → 42 rings in 24 hours, 63 m.

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4. TUNNELING WORKS – EXCAVATION

DRIVE 2 AAS-SFS:

- Launching method improved, 2 weeks saved.

- In final configuration:
    - Harder clay encountered at first: high torque on CH and clogging issues at the conveyor transitions
    - Excavation of 3 367 m in 185 days ➔ 18,2 m per day (10h/shift, 2 shift per day, 5 days a week)
    - Max production ➔ 34 rings in 20 h, 51 m

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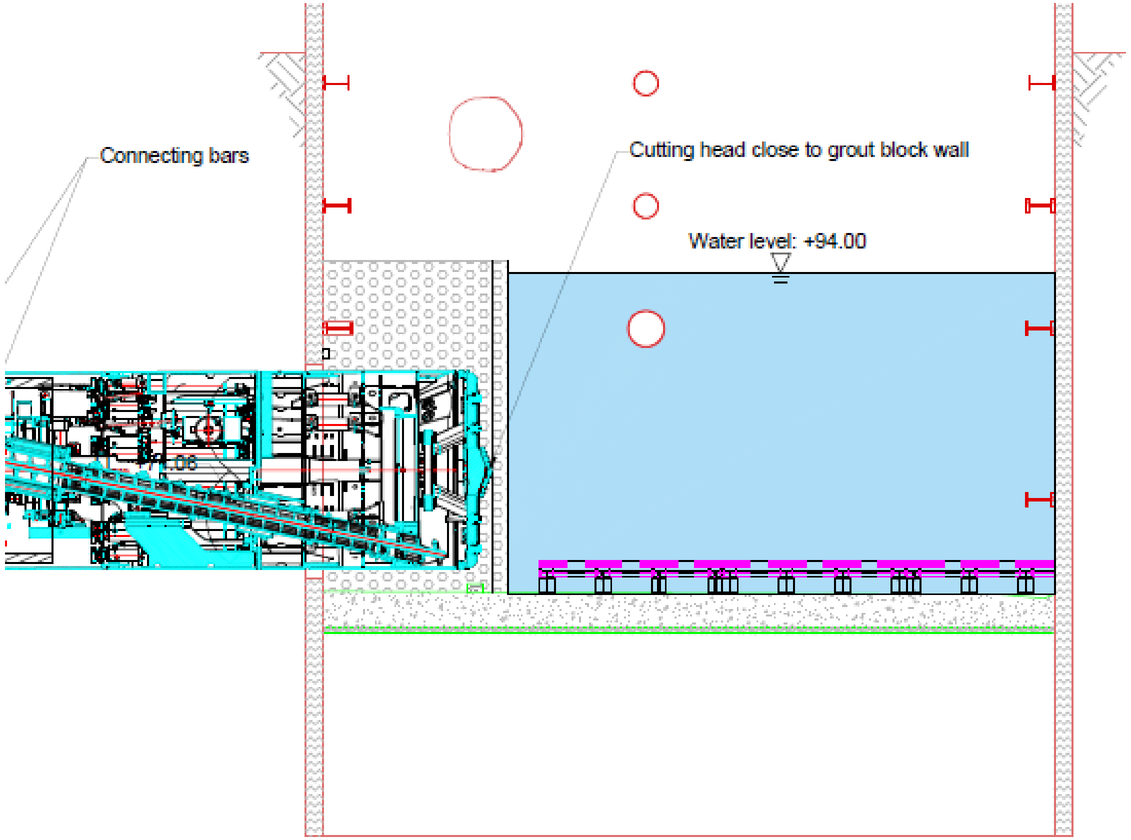
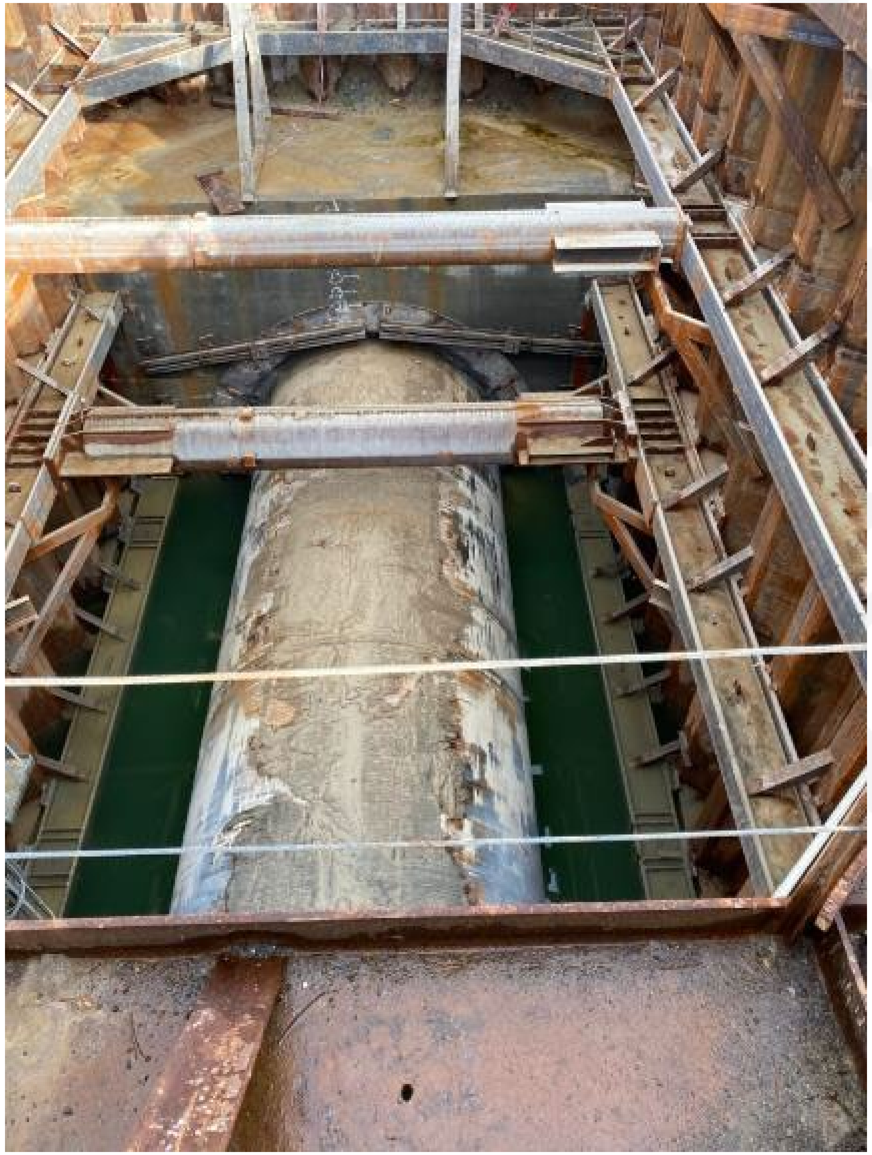
4. TUNNELING WORKS – BREAKOUT (BAIR ISLAND)





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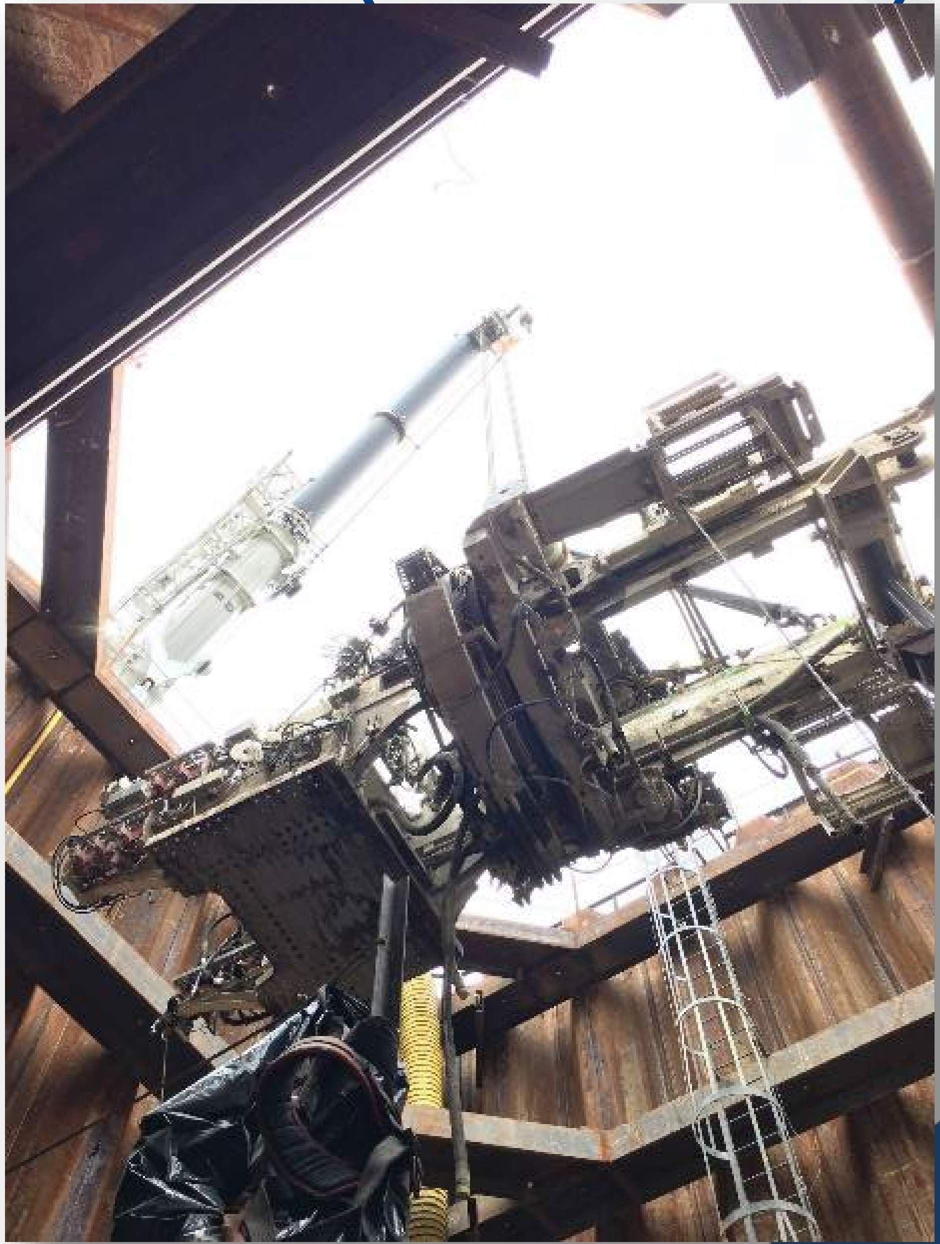
4. TUNNELING WORKS – BREAKOUT (BAIR ISLAND)



4. TUNNELING WORKS – BREAKOUT (BAIR ISLAND)

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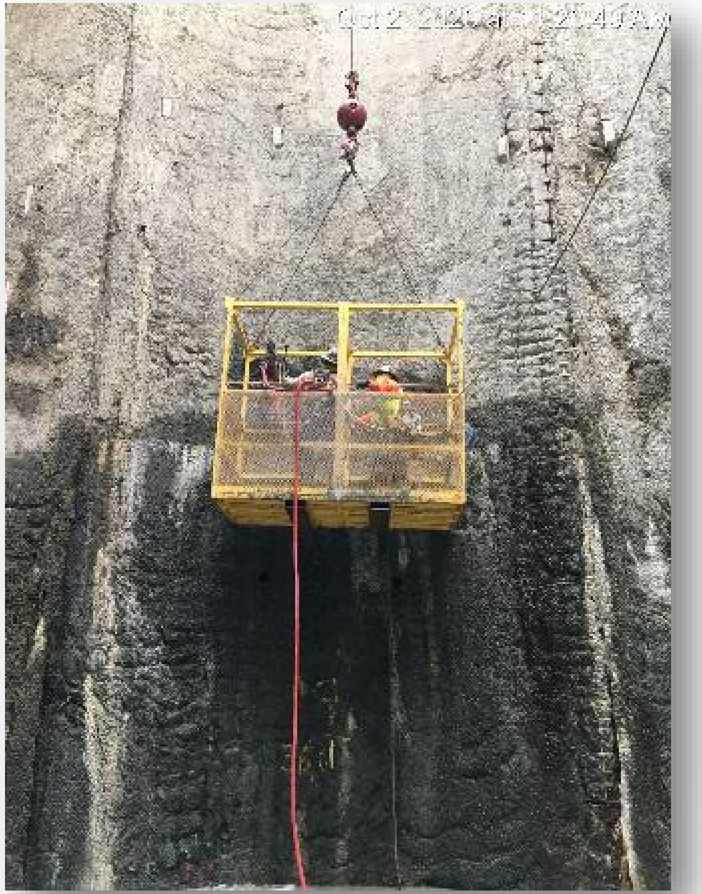
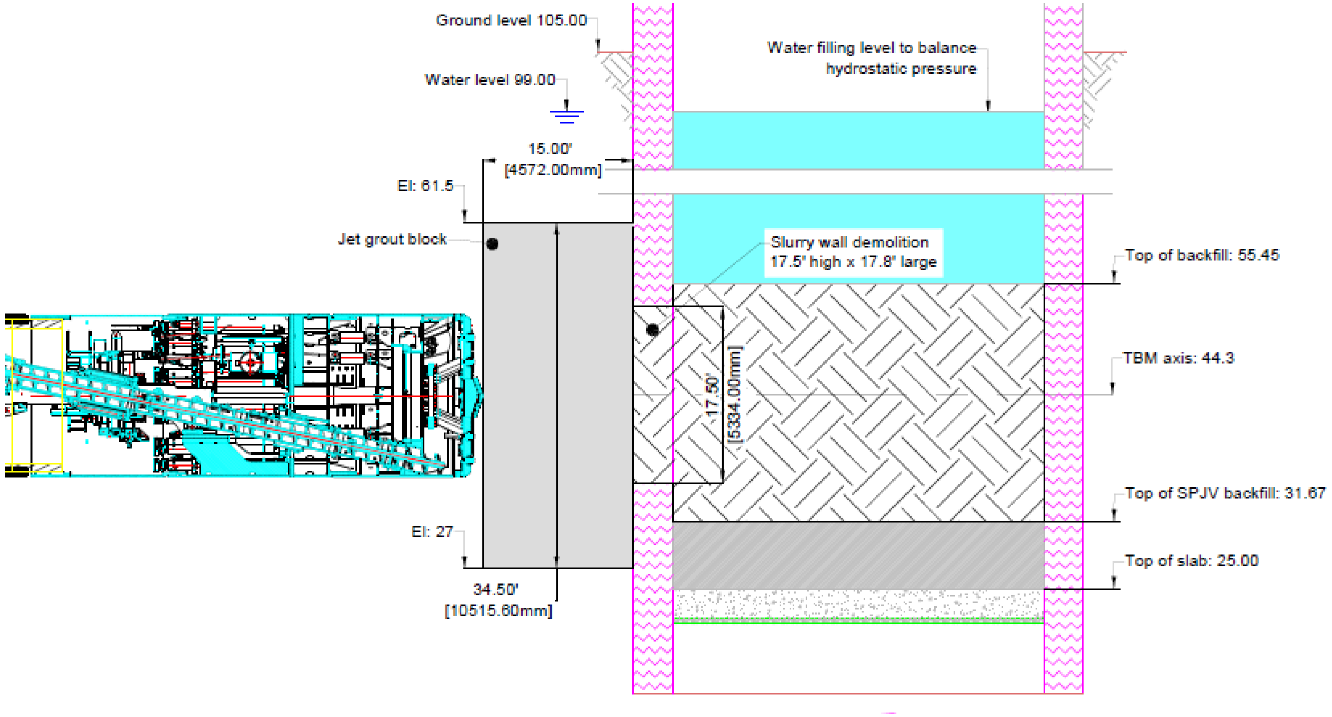
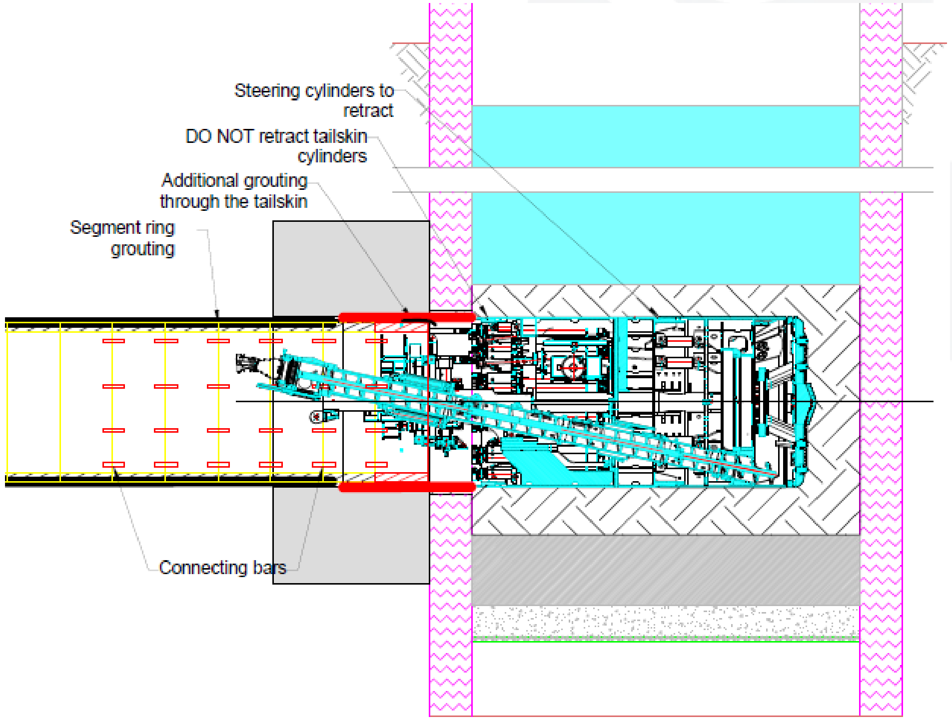
4. TUNNELING WORKS – BREAKOUT (SFS)



13,000 psi concrete ! (90 Mpa)

4. TUNNELING WORKS – BREAKOUT (SFS)





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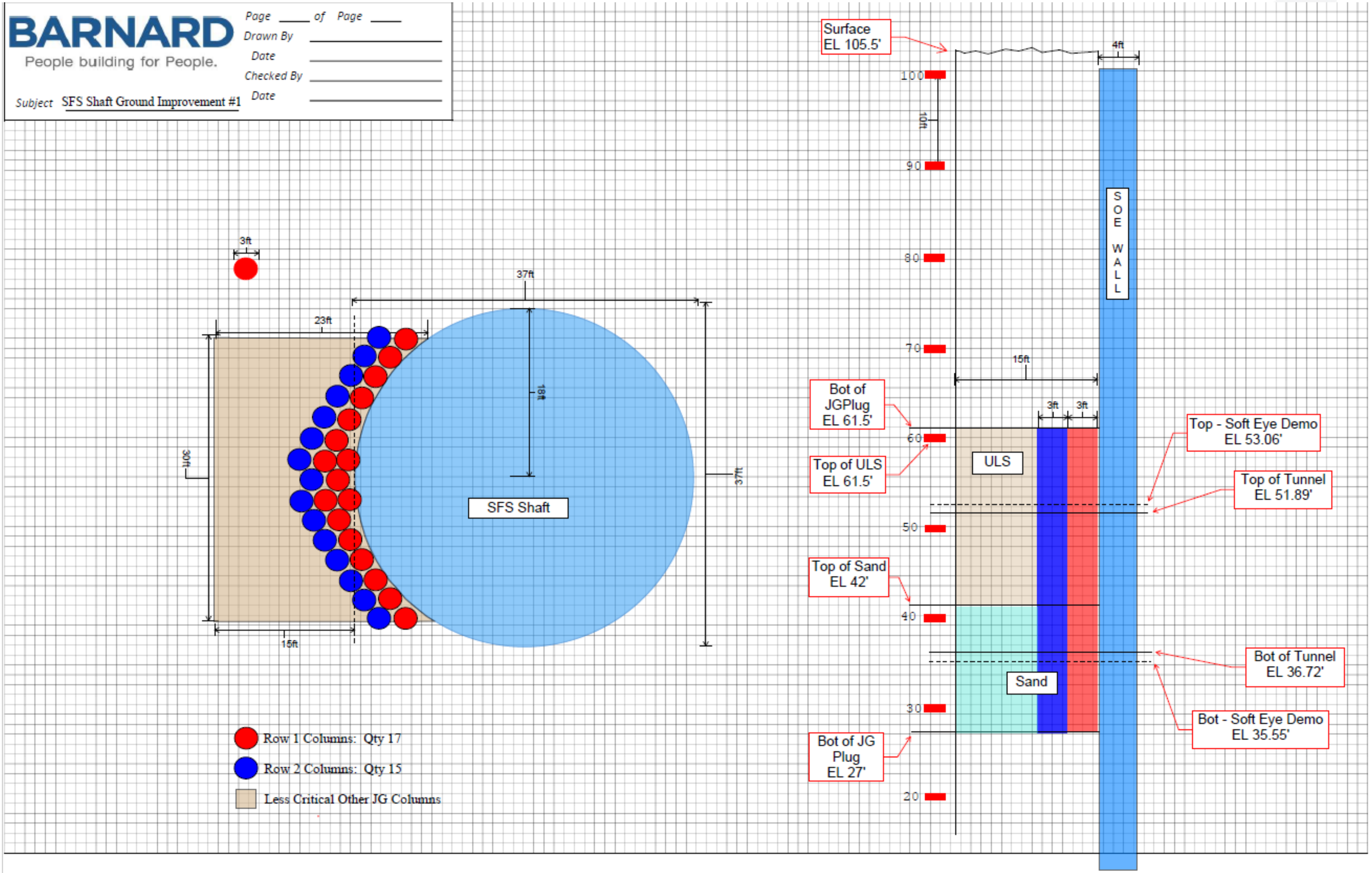

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4. TUNNELING WORKS – BREAKOUT (SFS)

JET GROUTING

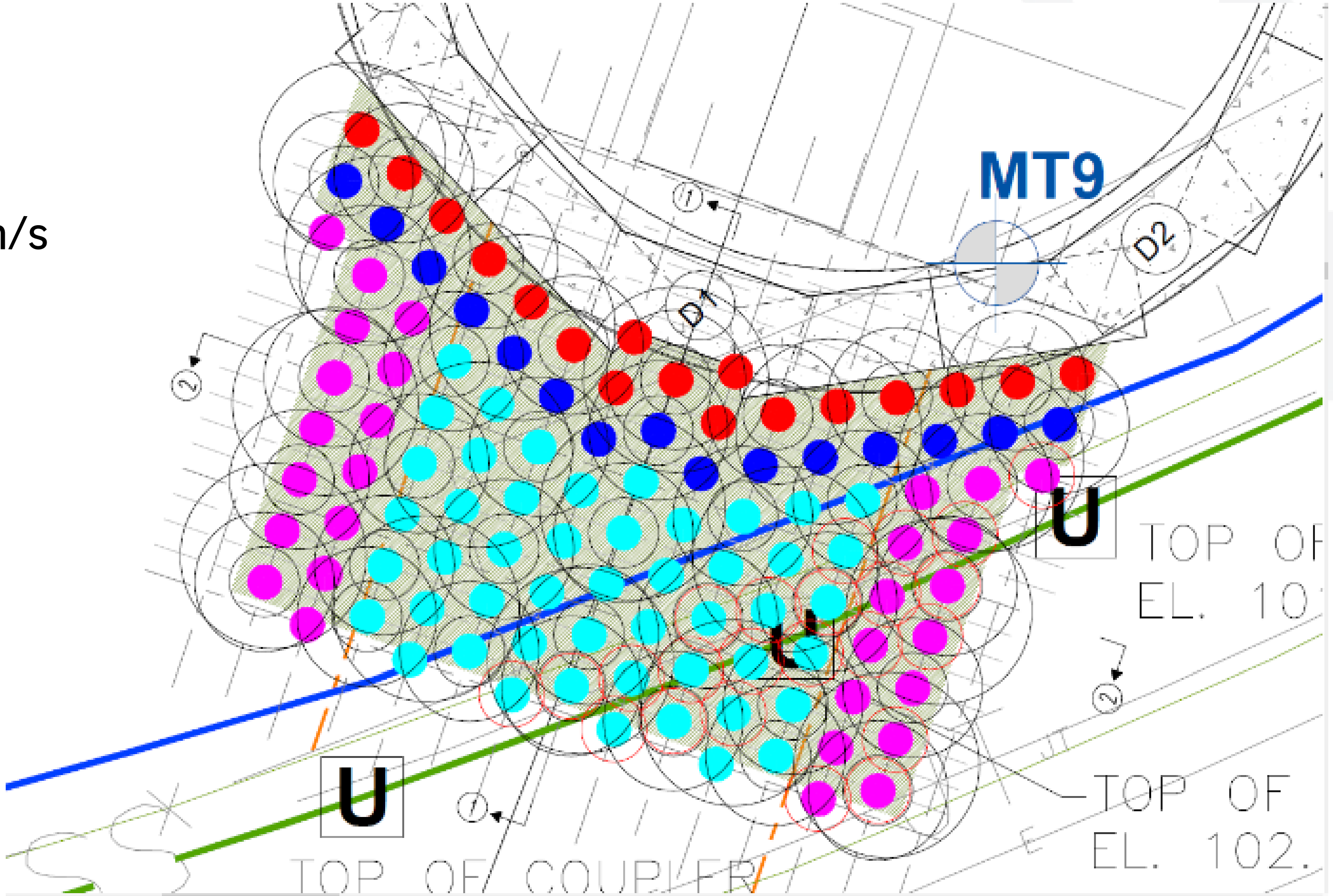
- *Block dimension:* *17ft x 15ft x 34,5ft*
- *Columns*: 3ft diameter, 2,33ft on center
- *Target:* 450 psi @ 28days (3MPa), $1x10^{-5}$ cm/s

Production Columns:

- Double Fluid jetting full length
- Jetting w/c=1.4
- 5mm nozzle
- Lift rate = 8"/min Elev. 27.05 to Elev. 61.55
- 8 to 10 RPM

Pre-Treatment Holes:

- Drill to 46 feet below ground surface (approx. Elev. 60)
- Single Fluid jetting from Elev. 60 to Elev. 95.
- Jetting w/c=1.4
- 6 mm nozzle
- Lift rate = 8"/min
- 8 RPM



4. TUNNELING WORKS – BREAKOUT (SFS)

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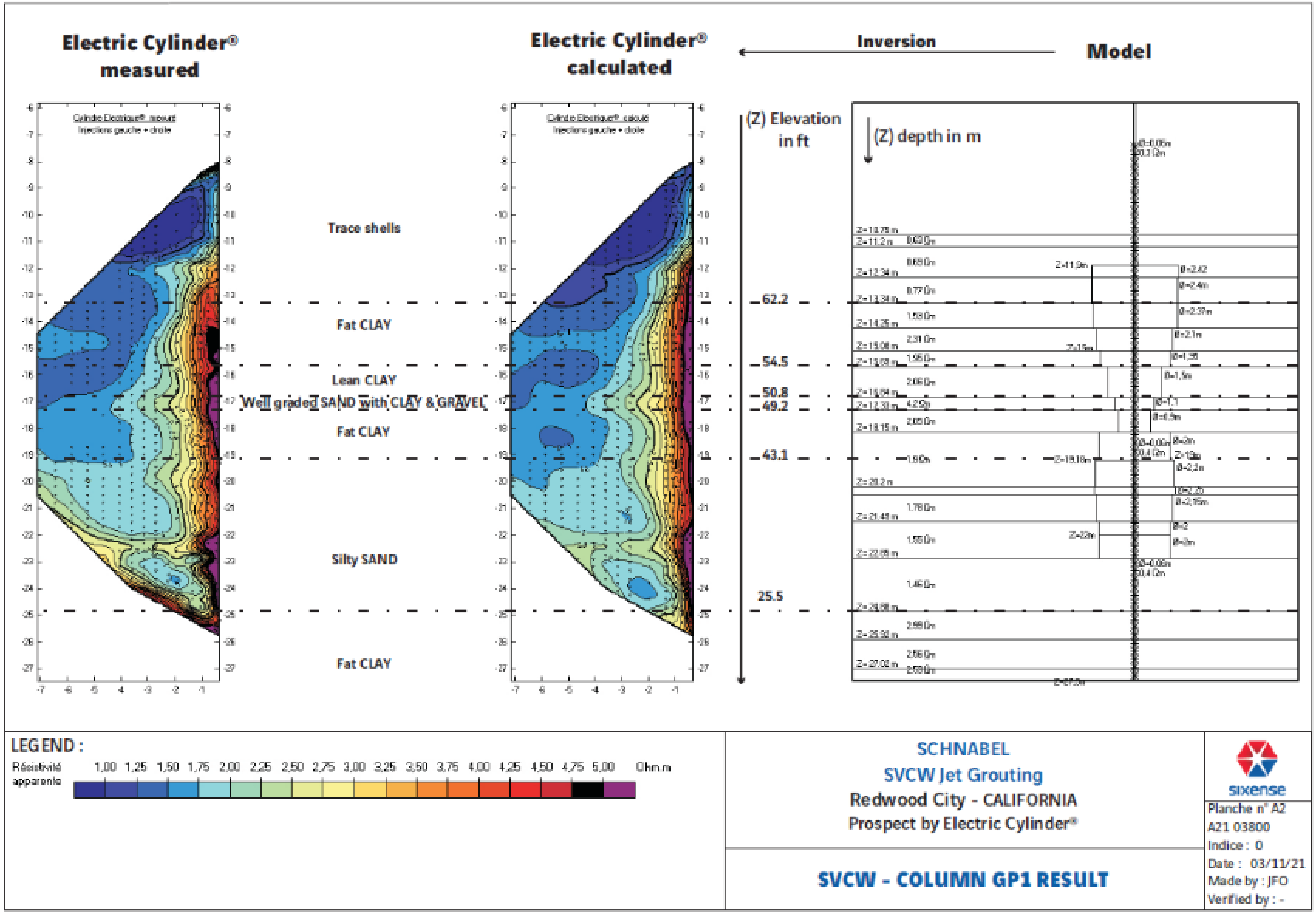

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4. TUNNELING WORKS – BREAKOUT (SFS)

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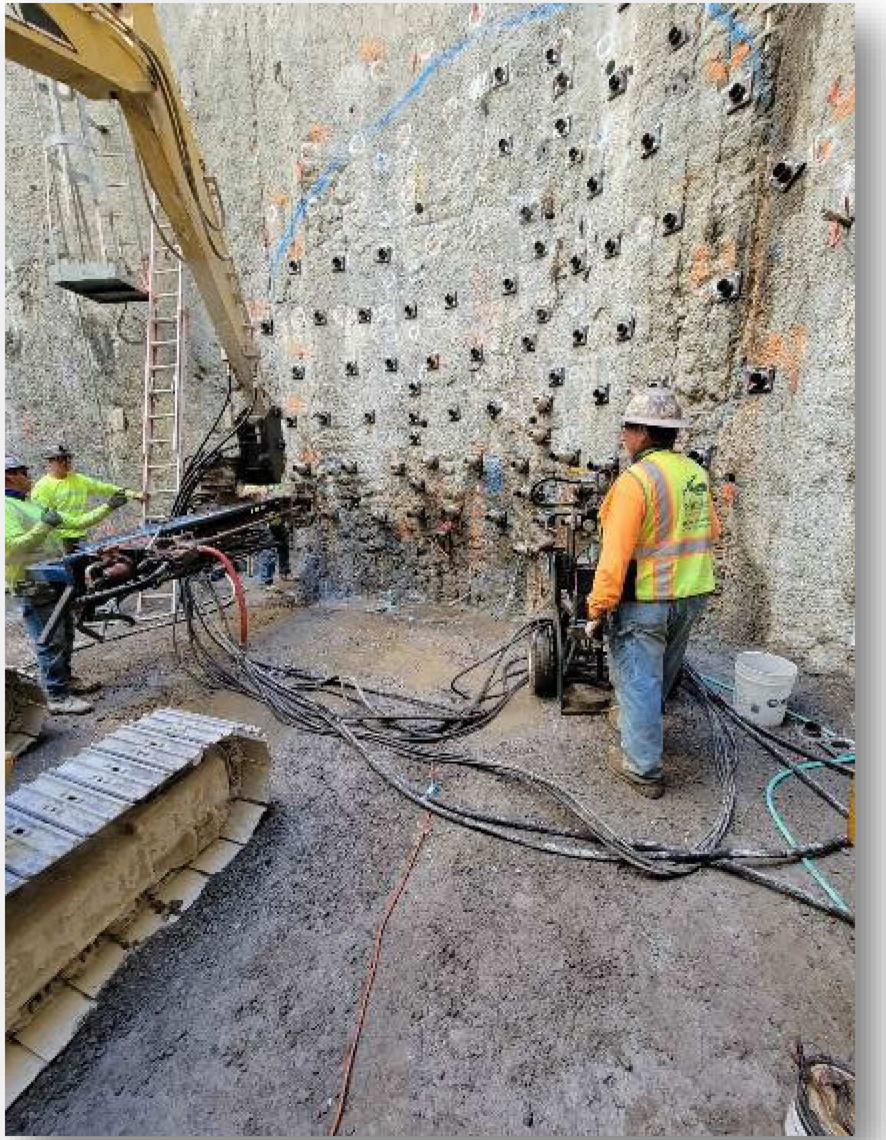

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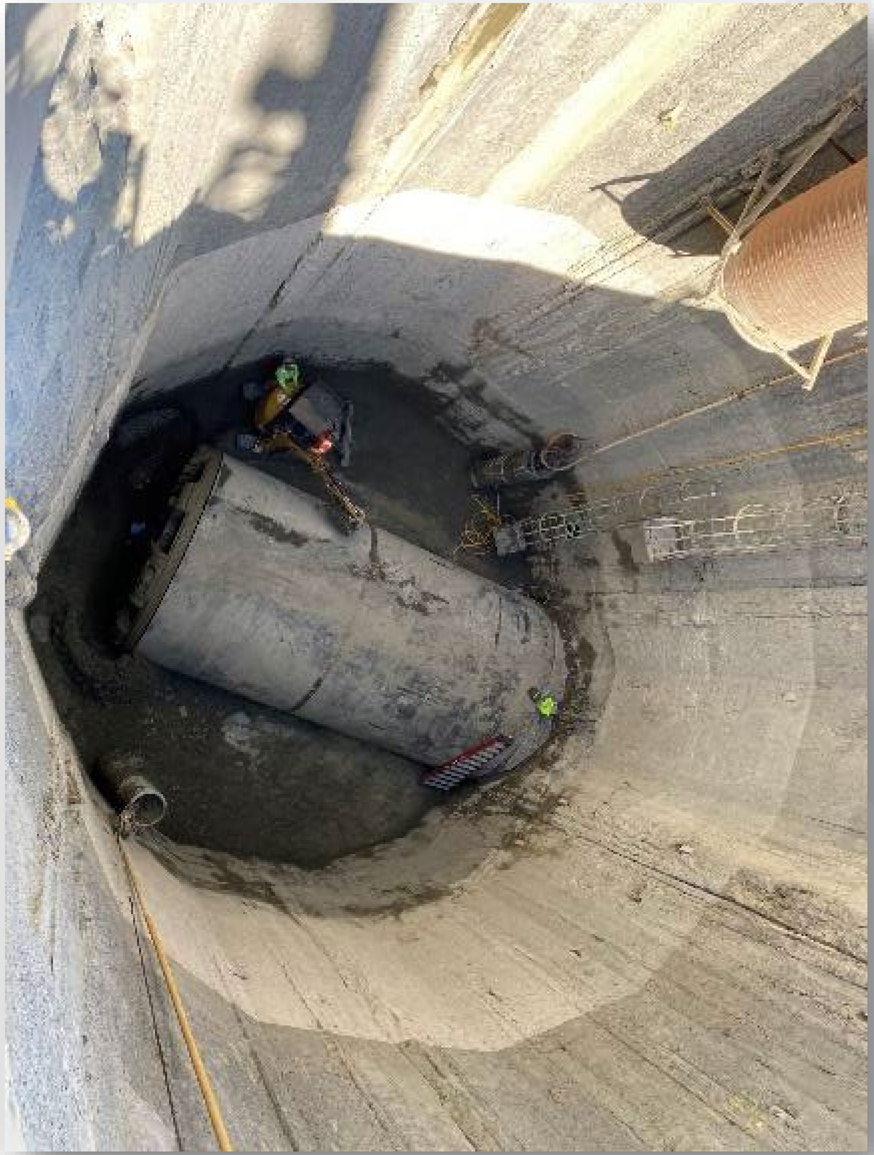
4. TUNNELING WORKS – BREAKOUT (SFS)



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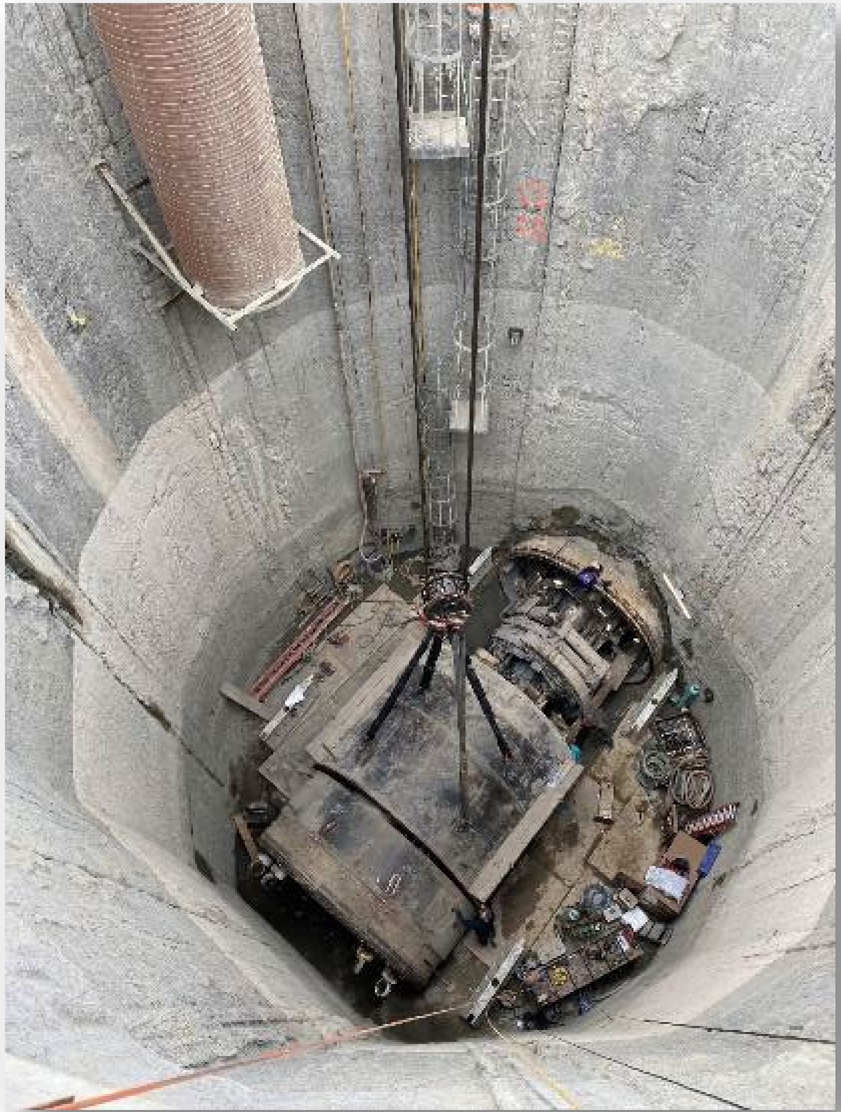

4. TUNNELING WORKS – BREAKOUT (SFS)

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4. TUNNELING WORKS – BREAKOUT (SFS)

4. FRP PIPES – GROUTING – DROP STRUCTURES

Up to 34 pipes per day (2 x 10h) = 680ft/207m

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THANK YOU !
ANY QUESTIONS?

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AFAQ ISO 45001 Santé Sécurité au Travail AFNOR CERTIFICATION
AFAQ ISO 14001 Environnement AFNOR CERTIFICATION

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