

US 421 Slope Stabilization on Pine Mountain Using a Tieback Wall

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Kentucky Transportation Cabinet
Division of Structural Design, Geotechnical Branch



STGEC 2022

Presentation Rev. 08/03/2022

Photo 03/01/2022

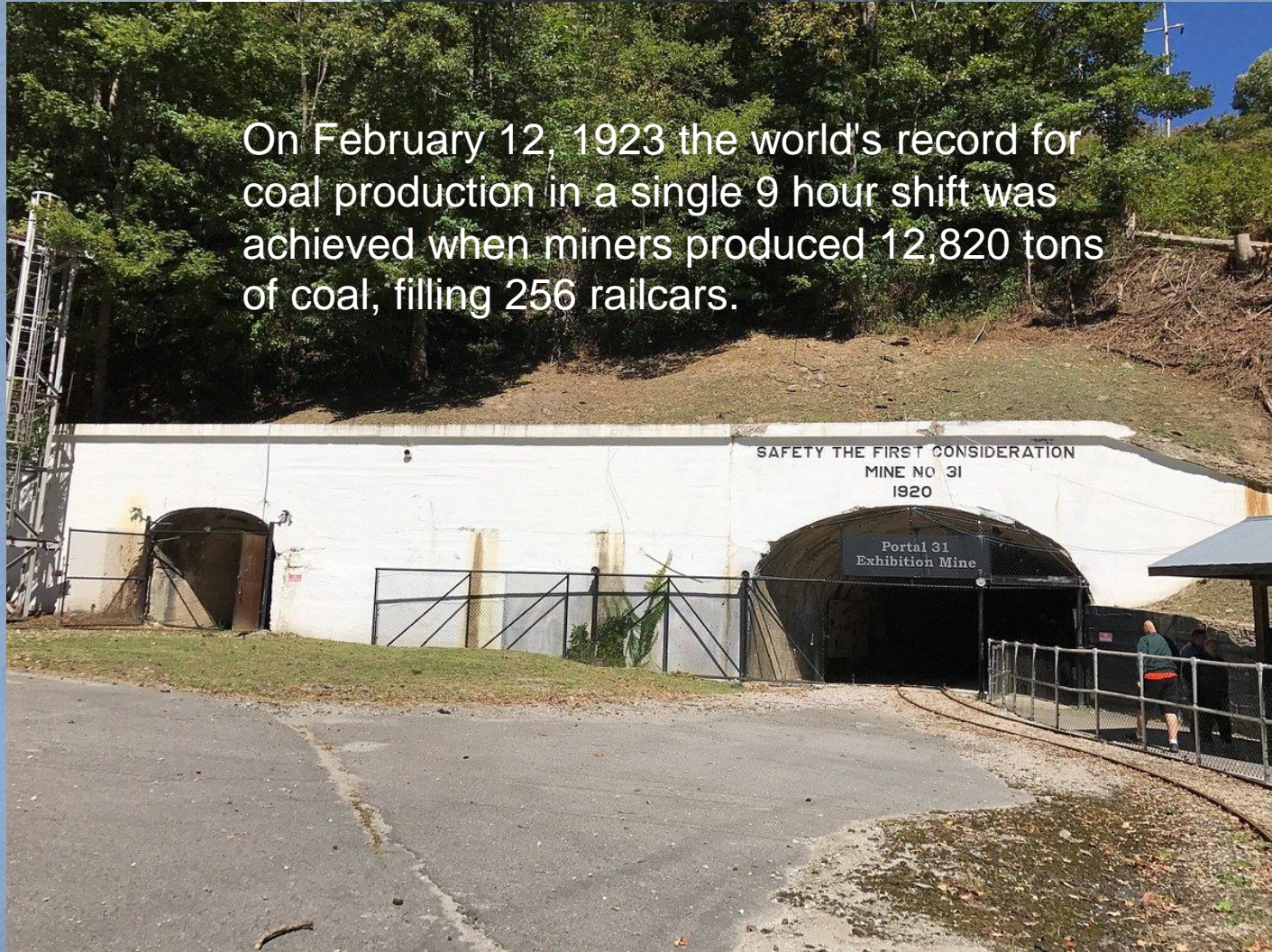
Project Location

Southeastern Kentucky
Approximately 8 miles
North of Harlan, KY
on US 421



Harlan County KY

On February 12, 1923 the world's record for coal production in a single 9 hour shift was achieved when miners produced 12,820 tons of coal, filling 256 railcars.



Project History

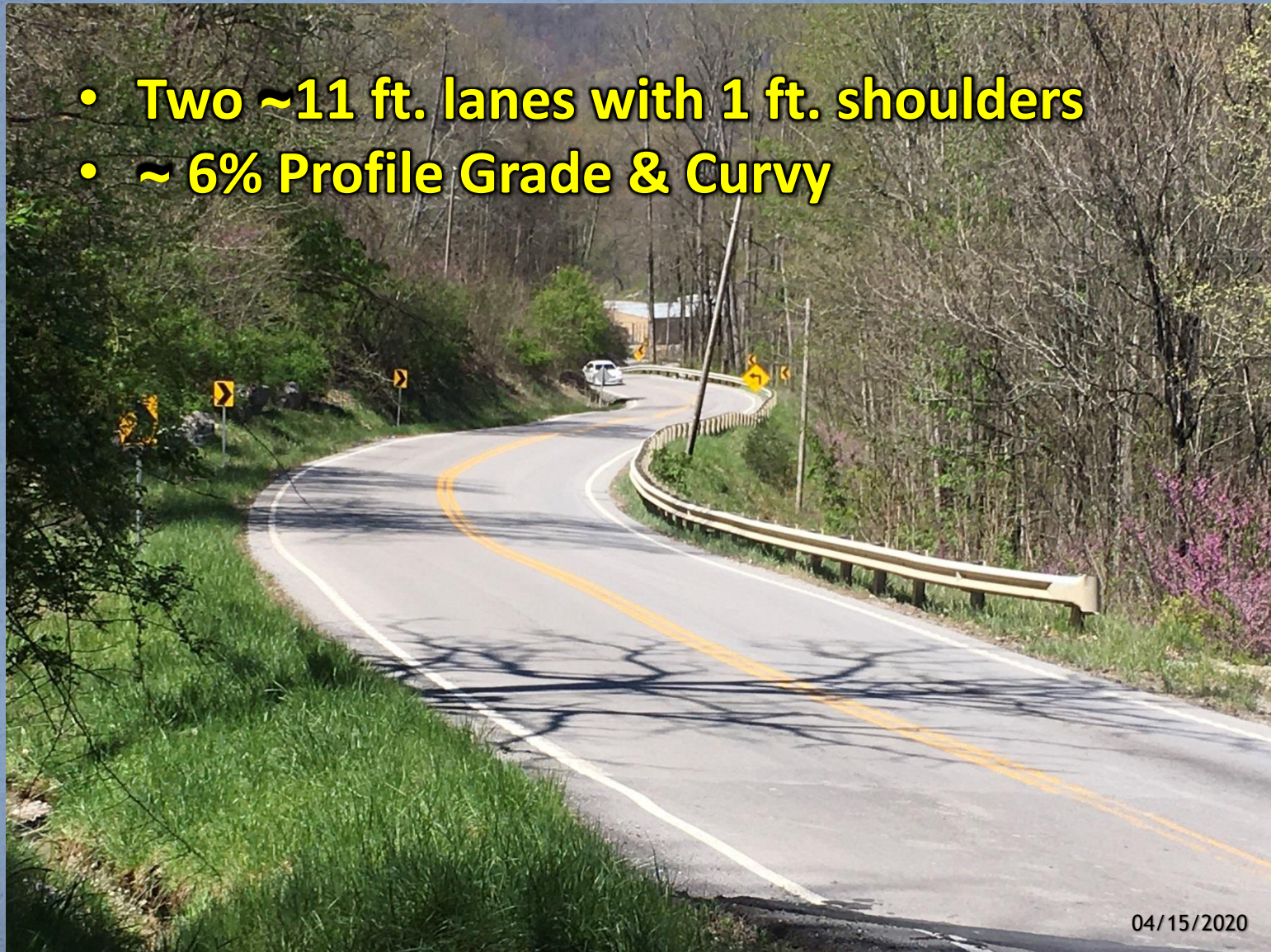
Date & Time: Tue May 19 16:25:47 EDT 2020
Position: 036°53'59.3"N / 083°20'27.3"W
Altitude: 2028ft
Datum: WGS-84
Azimuth/Bearing: 261° S81W 4640mils (True)
Zoom: 1X
US 421 MP 22.88
Slide Repair

- **Slope failed following a February 2019 storm event for which Kentucky received a Presidential Disaster Declaration.**
- **The Kentucky Transportation Cabinet (KYTC) worked with the Federal Highway Administration (FHWA) to use a repair eligible for FHWA Emergency Relief (ER) Funding.**
- **KYTC and FHWA agreed that a permanent rock-anchored tieback wall with soldier piles embedded into bedrock was acceptable for ER funding.**

05/19/2020

Roadway Geometry

- Two ~11 ft. lanes with 1 ft. shoulders
- ~ 6% Profile Grade & Curvy

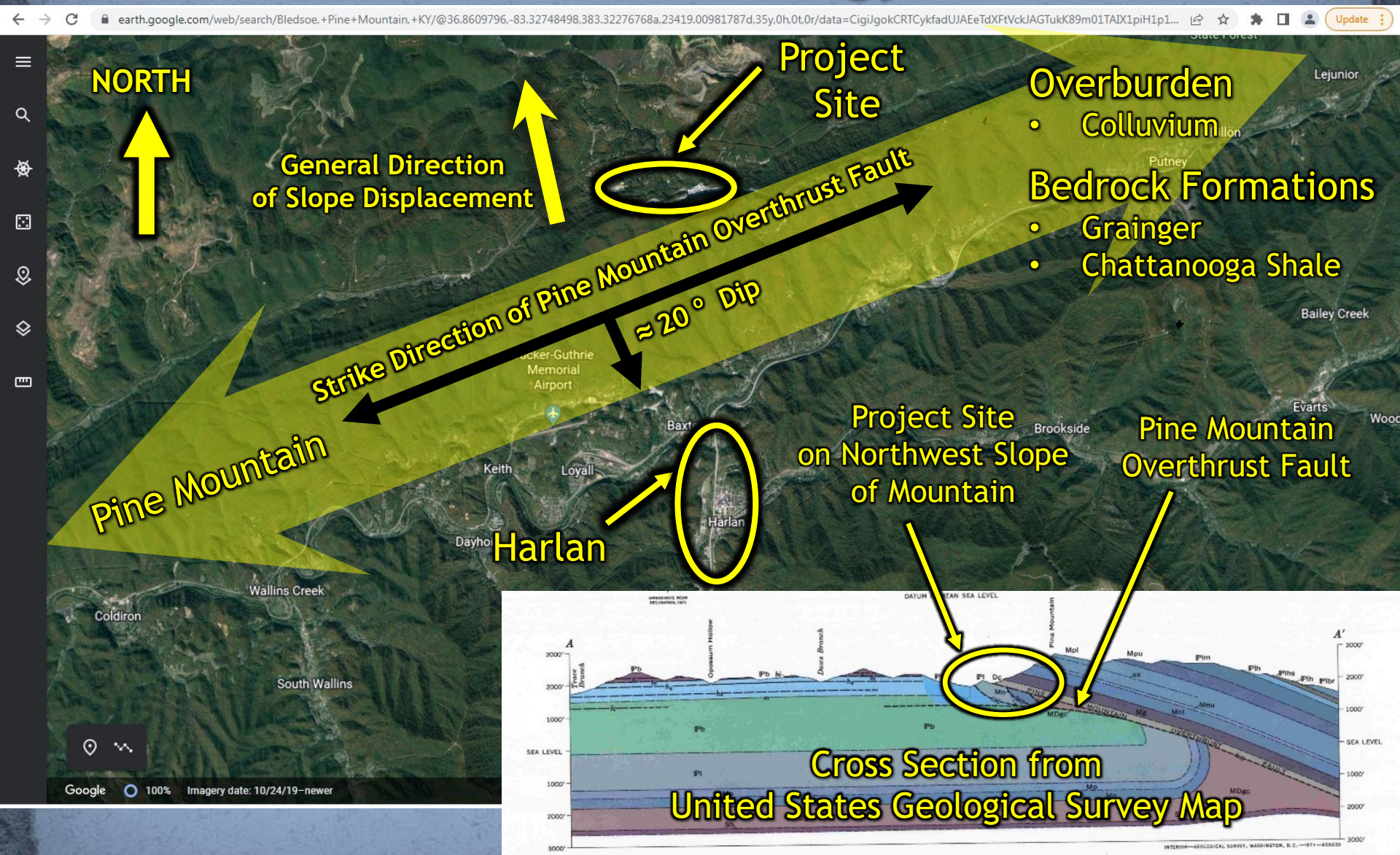


04/15/2020

Maintenance of Traffic Challenges



Site Geology



Subsurface Conditions

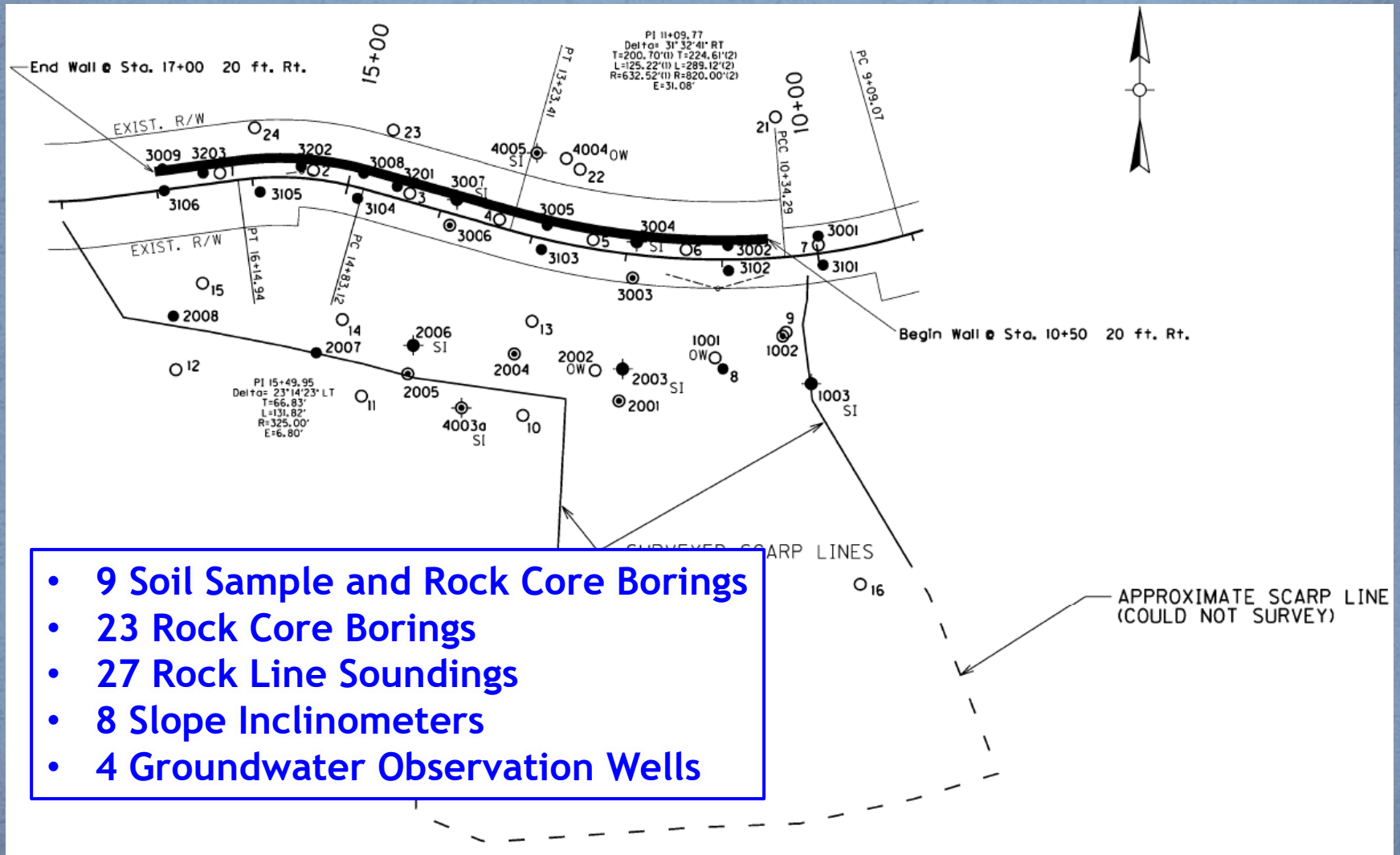
- Overburden generally described as brown and gray moist clay with rock fragments, cobbles, floaters and boulders



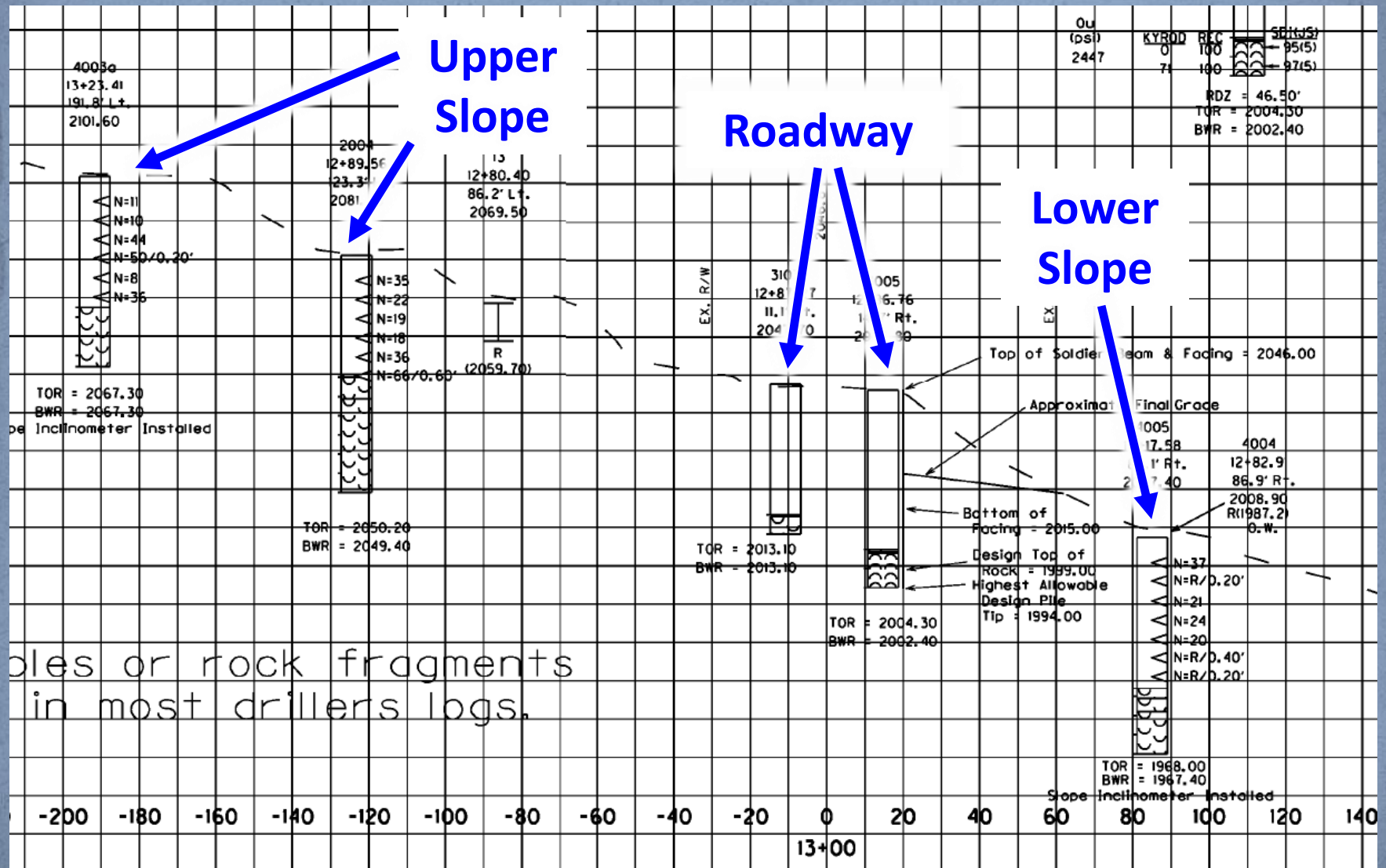
- Bedrock Consists of Chattanooga & Grainger Shale Formations
 - Compressive Strength - 50 to 6000 psi (Avg \approx 2000 psi)
 - KY Modified Rock Quality Designation - 0 to 94 (Avg \approx 12)
 - Slake Durability Index - 7 to 100 (Avg \approx 74)

09/01/2020

Scope of Geotechnical Investigation



General Boring Placements



Summary of Groundwater Observation Well Data

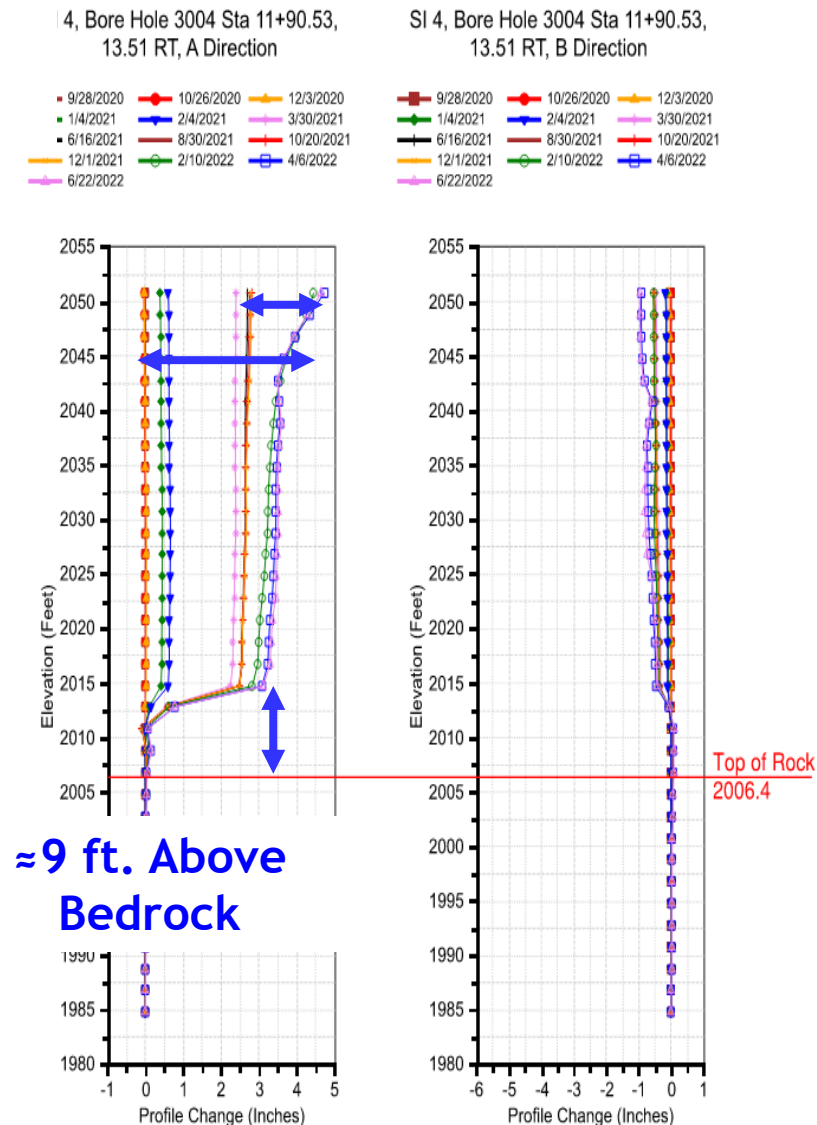
Table 5 – Summary					Groundwater Observation Well Data	
General Location On Slope	Boring No.	Station	Average Groundwater Depth Generally ≈ 7 to 8 ft.		Approx. Average Groundwater Depth (ft.)	Approx. Average Groundwater Elevation (ft.)
Upper Slope	4001a	11+51.8	378.8 L	2180.9	8	2173
Middle Slope	1001	11+06.4	102.2 L	2084.2	7	2078
	2002	12+15.0	124.8 L	2087.4	12	2075
Lower Slope	4004	12+82.9	86.9 R	2008.9	8	2001

Typical Slope Inclinometer Plot

6/16/2021
To
6/22/2022

≈ 2 in. Displacement

≈ 5 in. Displacement
Total

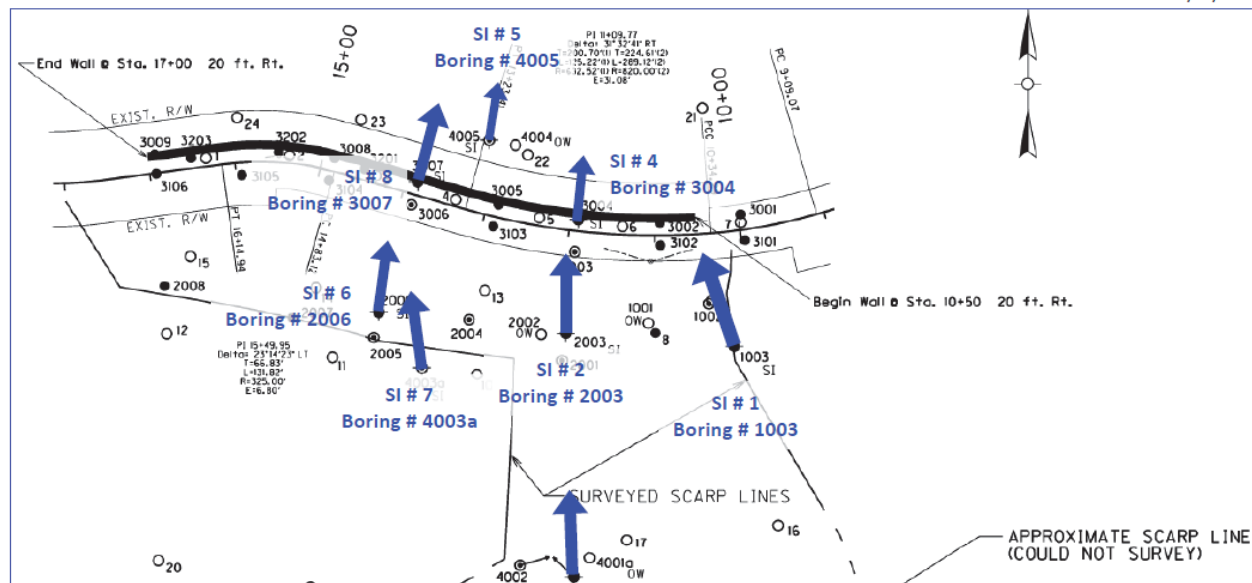


Measured Slope Displacements

Displacements Along Apparent Failure Surface

Arrow Sizes are Approximately Proportional to Displacement Magnitudes
Arrows Indicate Approximate Displacement Directions

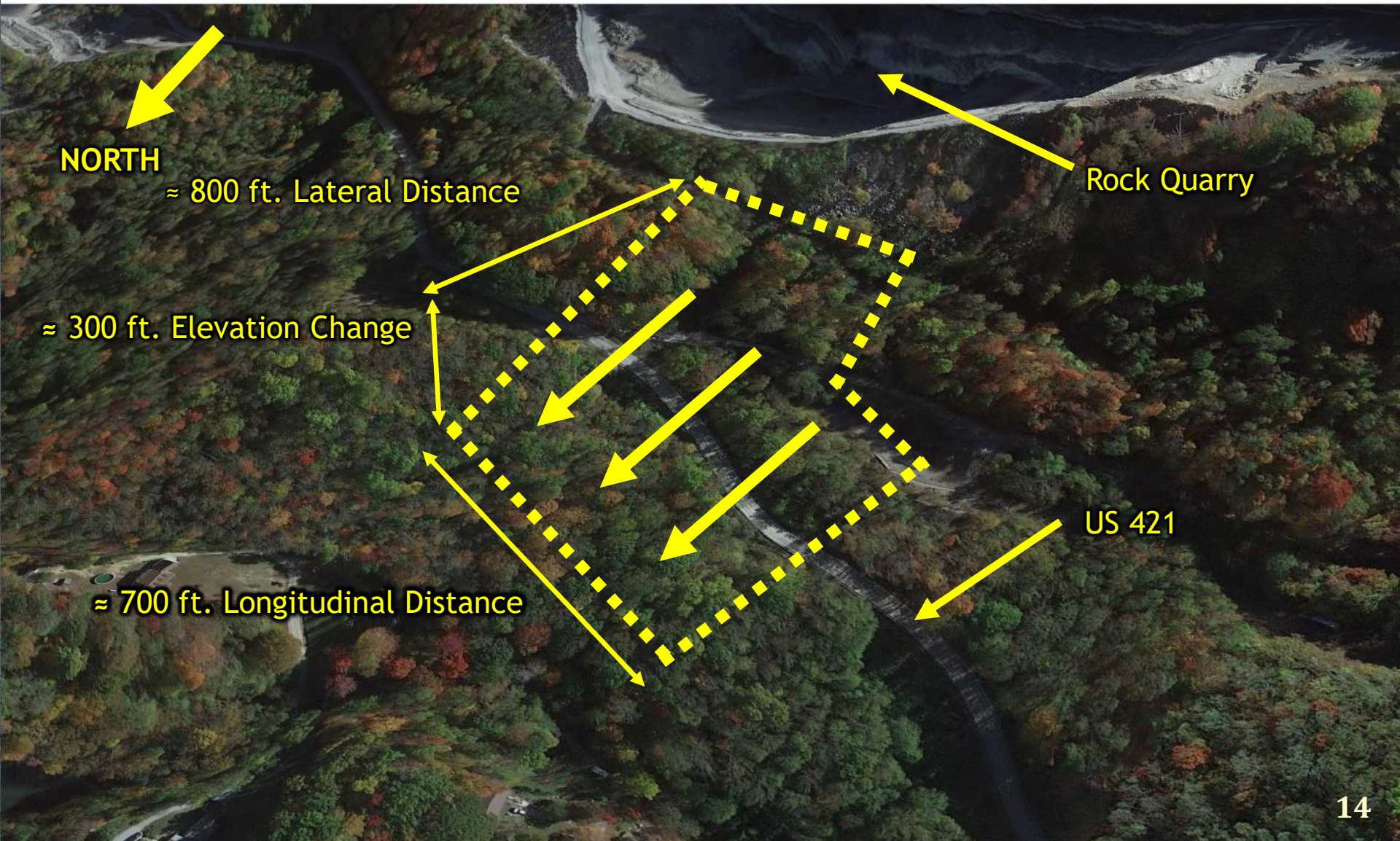
Rev 06/21/2021



- Measured Displacements (before letting)
 - ≈ 2 to 4 inches
 - Varied from ≈ 4 to 15 ft. above bedrock
- Size of arrows approximately proportional to displacement magnitude
- Direction of arrows approximately in resultant direction of movement

Approximate Extents of Sliding Mass

earth.google.com/web/@36.89965918,-83.34068607,627.65378821a,614.42286181d,35y,128.73118552h,60t,0r



Cross Section - Station 12+00

**2-D Limit Equilibrium Analyses
Janbu Method (Force Equilibrium)**

**Back-Calculated Parameters
For Existing Conditions
Factor of Safety = 1.0**

$\gamma = 120 \text{ pcf}$
 $\gamma_{\text{sat}} = 125 \text{ pcf}$
 $\phi' = 22^\circ$
 $c' = 100 \text{ psf}$

Sliding Mass

**Slope
Inclinometer
Locations**

$\approx 300 \text{ ft.}$

Rock Line

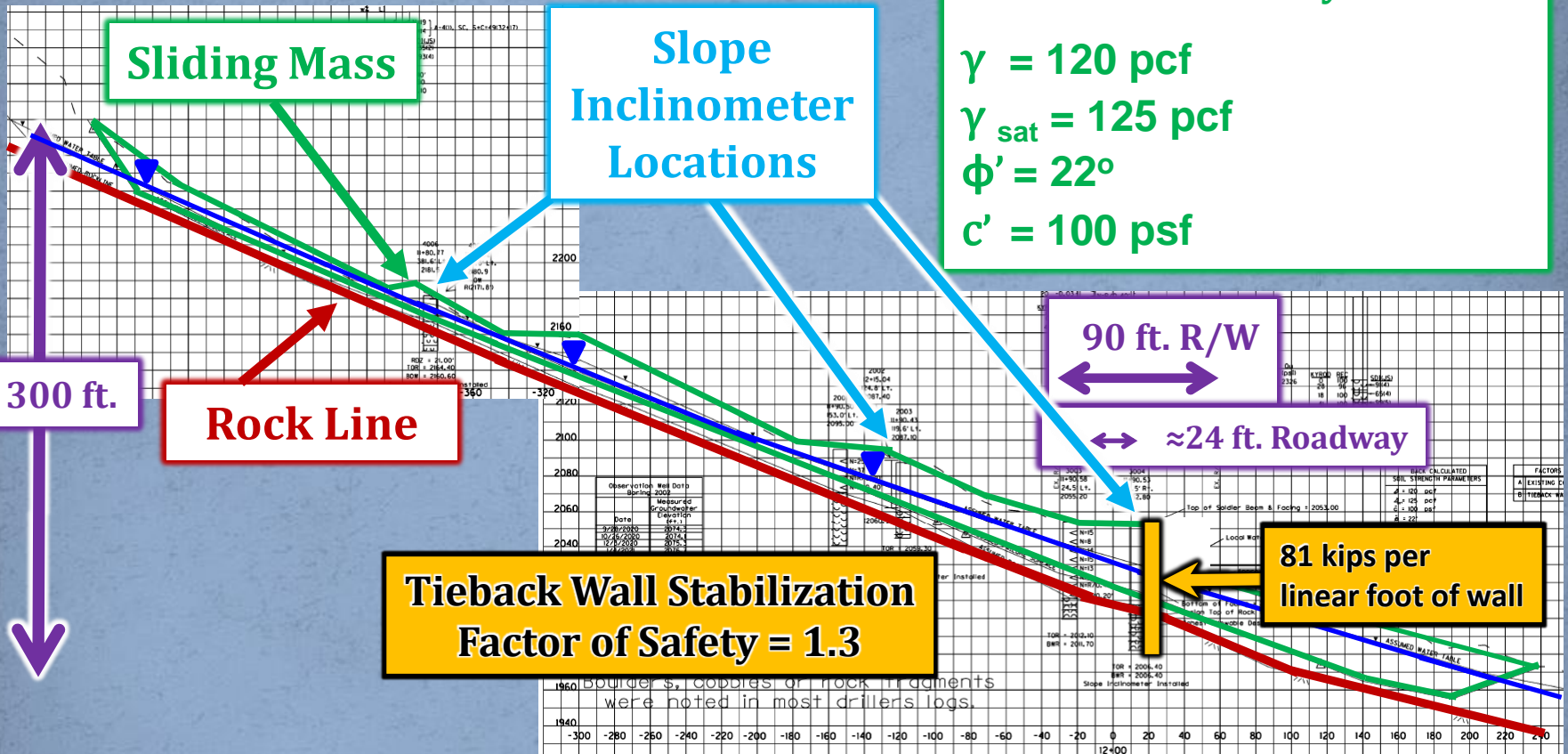
90 ft. R/W

$\approx 24 \text{ ft. Roadway}$

**Tieback Wall Stabilization
Factor of Safety = 1.3**

**81 kips per
linear foot of wall**

$\approx 800 \text{ ft.}$



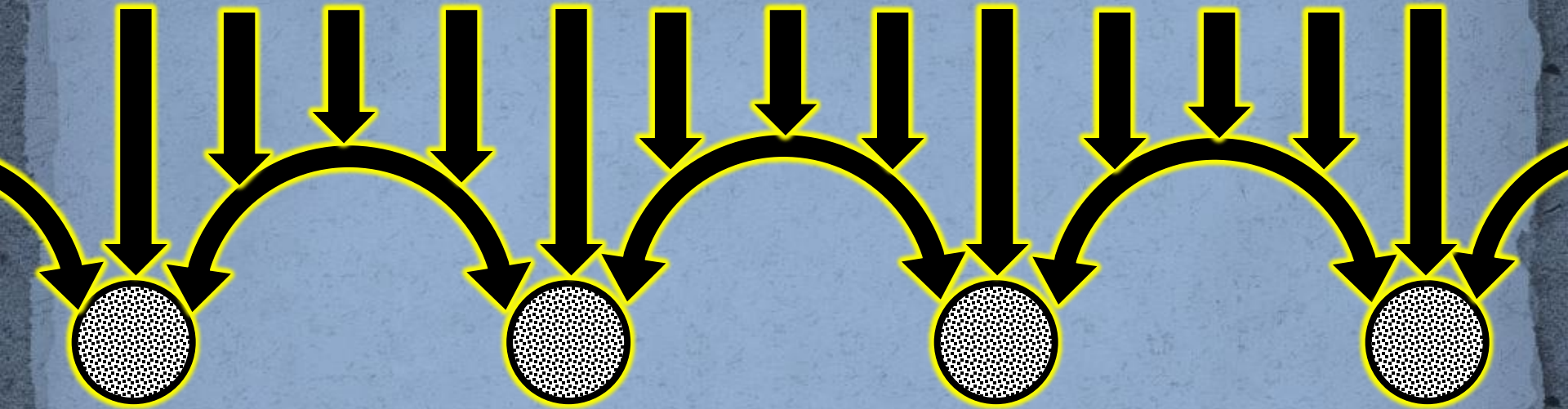
Summary of Limit Equilibrium Slope Stability Analyses

Station	Design Height (H _d) ft	Factored Earth Pressure [Rectangular] (FEP) psf	Factored Earth Load (FEL) kips/ft	Limit Equilibrium Factor of Safety (FOS)
12+00	45.0	1800	81.0	1.3
14+00	26.0	1040	27.0	1.3
15+00	46.0	1840	84.6	1.4

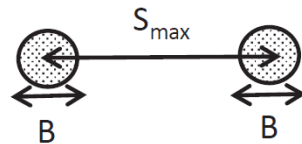
- Varied Design Earth Loads/Pressures to achieve acceptable FOS
- $FEP = 40 H_d \gg FOS \sim 1.3 - 1.4 \gg 40 H_d$ used throughout
- $$FEL = \frac{FEP \times H_d}{1000 \text{ lb/kip}}$$

Soil Arching

below wall facing down to sliding surface



Maximum Soldier Pile Spacing Constraints:



B = diameter of soldier pile concrete backfill
from the bottom of lagging to top of rock (ft.)

S_{max} = maximum center-to-center spacing between
soldier pile concrete backfill (ft.)

Max. Allowable Center-to-Center Spacing:

Station 10+50 to 14+50: $S_{max} = 3.5 B$

Station 14+50 to 16+00: $S_{max} = 3.0 B$

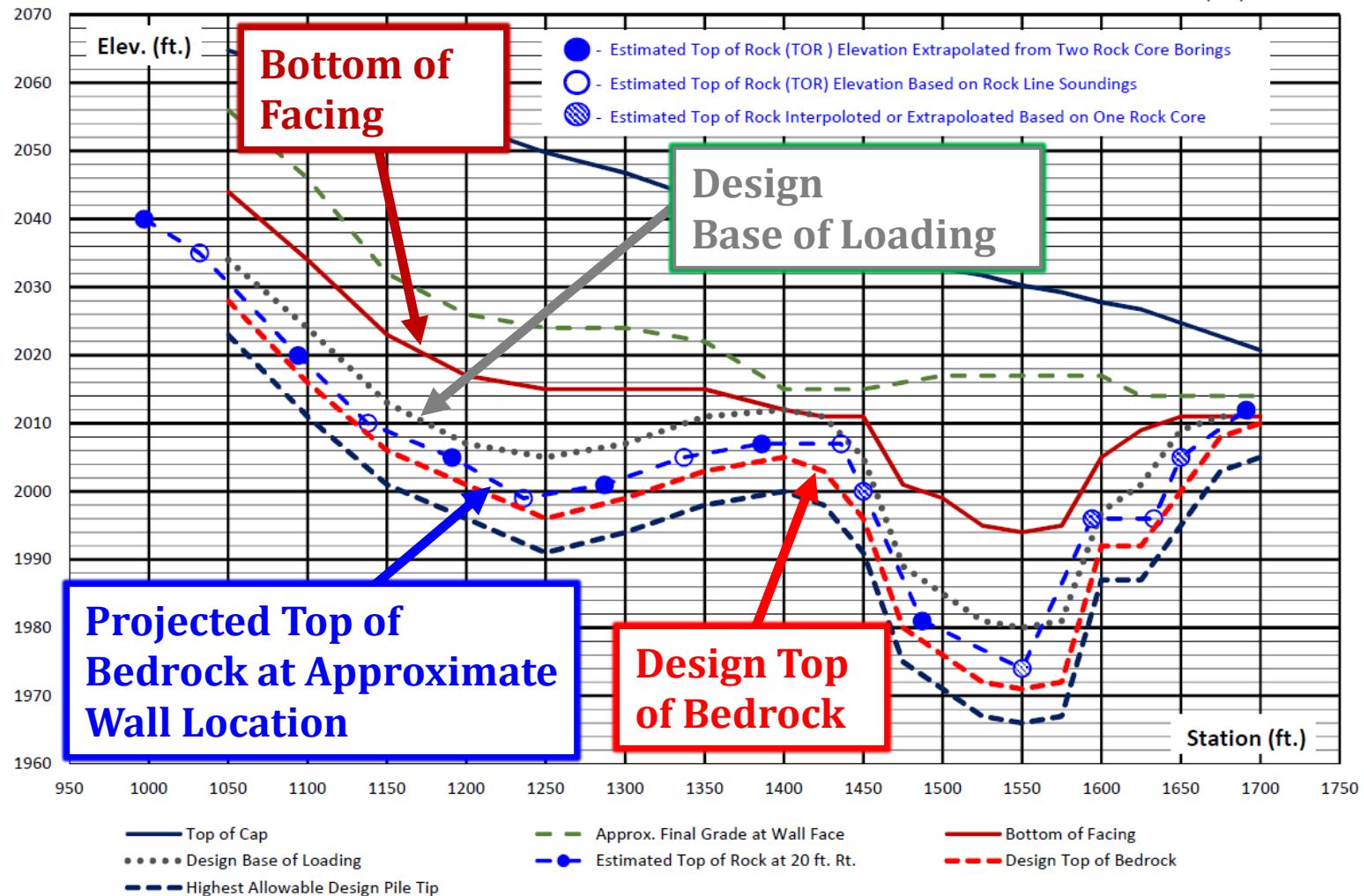
Station 16+00 to 17+00: $S_{max} = 3.5 B$

Wall Profile

(Exaggerated Scale)

Tieback Wall Profile - Harlan Co. US 421 MP 22.8

Rev. 05/12/2021



Construction Contracting Approach

Date & Time: Thu Apr 30 11:24:19 EDT 2020
Position: 036° 53' 59.5" N / 083° 20' 27.6" W
Altitude: 2018ft
Datum: WGS-84
Azimuth/Bearing: 038° N38E 0676mils (True)
Zoom: 1X
US 421 MP 22.85
Slide

Contract procured using conventional Design/Bid/Build method.

Tieback Wall was a "Pseudo Design Build" component.

- **Contract Documents Included:**
 - Geotechnical data
 - Wall geometry, loadings & design criteria
 - Performance-based specifications
- **Specialty Contractor Responsible for:**
 - Performing detailed wall & anchor design
 - Constructing the wall & testing anchors

04/30/2020

Bid Prices

July 23, 2021 Bid Letting Date

Bid Item	Unit	Quantity	Unit Price	Extended Price
Retaining Wall	SF	18,612.5	\$200	\$3,722,500
Horizontal Drains	LF	9,600	\$15	\$144,000
Bridge Chain Link Fence -6 ft.	LF	650	\$99	\$64,350
Foundation Preparation	LS	1	\$325,000	\$325,000
Instrumentation	LS	1	\$50,000	\$50,000
Quality Control	LS	1	\$73,000	\$73,000
Wall & Related Items Total				\$4,378,850
Incidental Items (Paving, Guardrail, MOT etc.) Total				\$1,479,150
Total Contract Bid Price				\$5,858,000
Engineer's Estimate				\$5,957,578

Project Team



U.S. Department of Transportation
Federal Highway Administration

Emergency Relief Funding



KENTUCKY
TRANSPORTATION
CABINET

Pre-Bid Surveying, Engineering, Drilling, Lab Testing & Instrumentation



Construction Contractor

BURNS COOLEY DENNIS, INC.

Geotechnical and Materials Engineering Consultants

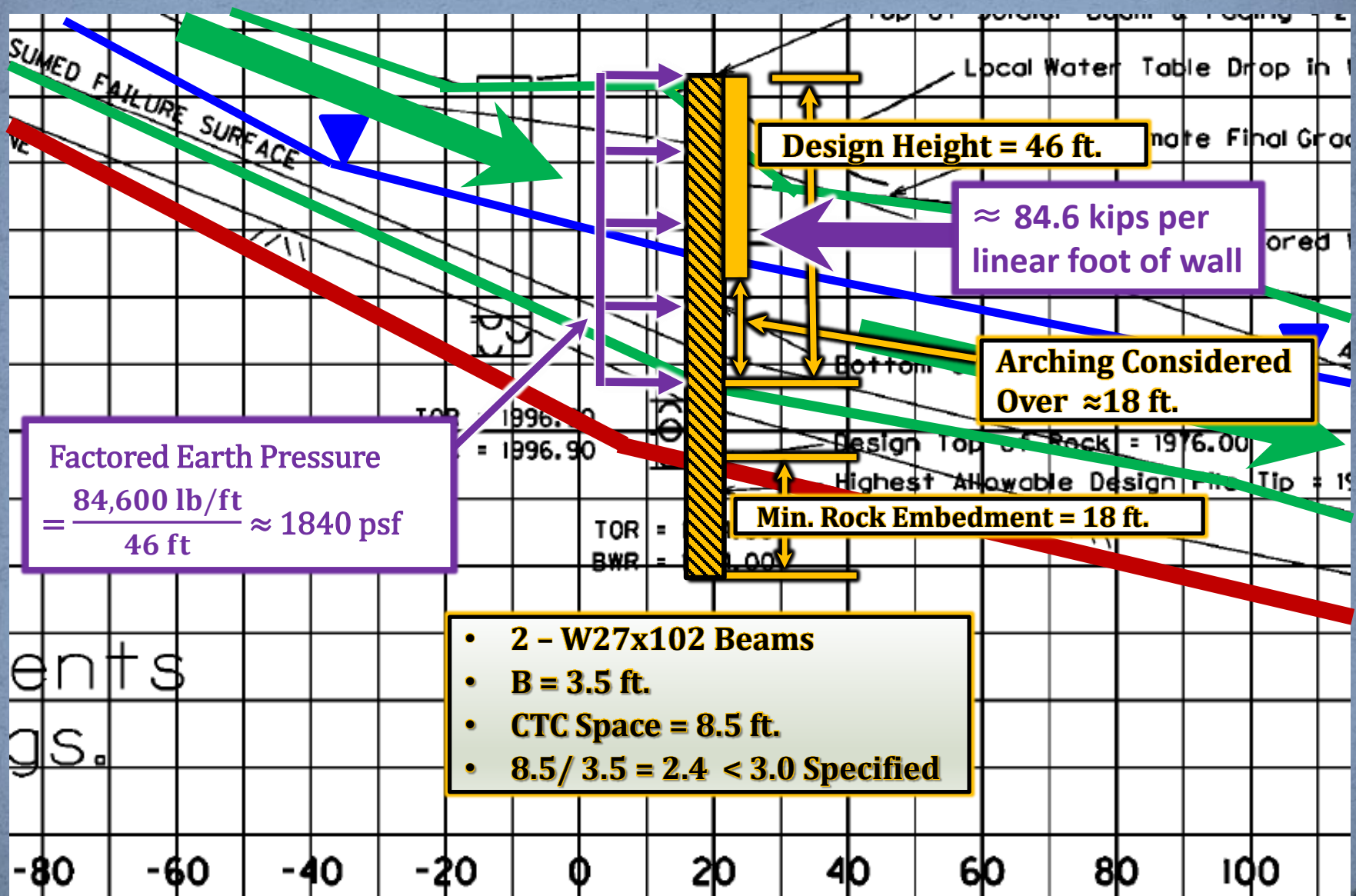
**Contractor's Tieback Wall
Design Consultant**



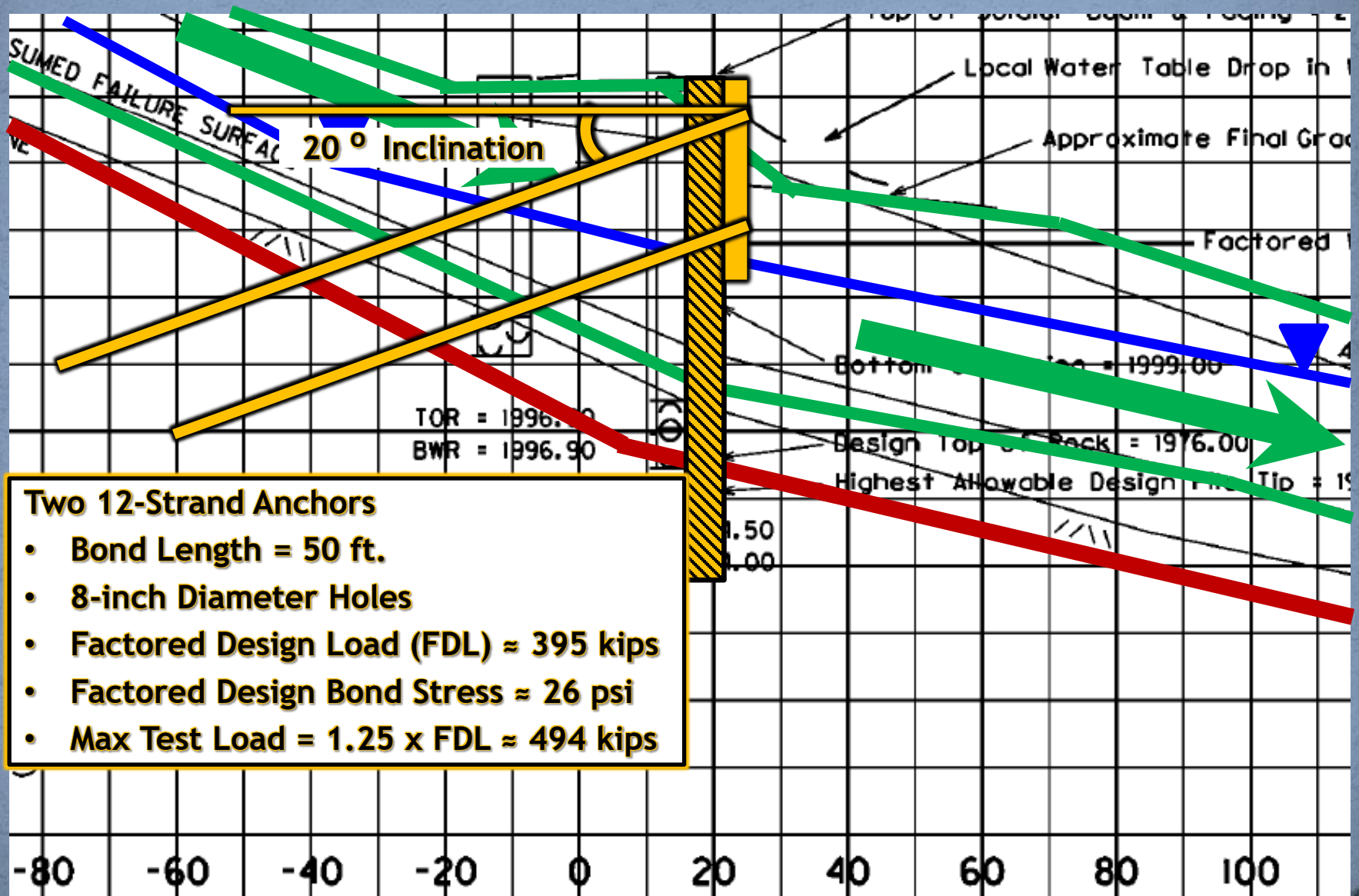
**Contractor's Quality Control Consultant
for Anchor Installation & Testing**

03/29/2022

Wall Design Schematic - Station 15+00



Anchor Design Schematic - Station 15+00



Construction Totals

- Total of 78 piles installed
- Pile spacing stayed consistent (8.5' CTC), used 6 different pile sizes throughout wall
- Maximum pile length 76'
- Average pile length 56'
- Maximum rock socket length 42'
- Average rock socket length 18'
- 78 upper row anchors installed
- 65 lower row anchors installed
- Total of 143 anchors installed



08/22/2022

Thank You for Listening!



KENTUCKY
TRANSPORTATION
CABINET

09/09/2022