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Geohazards Impacting Design of the The Ohio River Bridges, East End Crossing, Section 4 Northbound and Southbound Tunnels

Matt Grzelak, PE

Lexington, KY

August 7, 2014

Presentation Outline

- Project overview
- Site geology
- Potential geologic hazards
- Construction methodology
- Support schemes
- Project status

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Project Overview – Location

KEY

LOCATION MAP

VICINITY MAP

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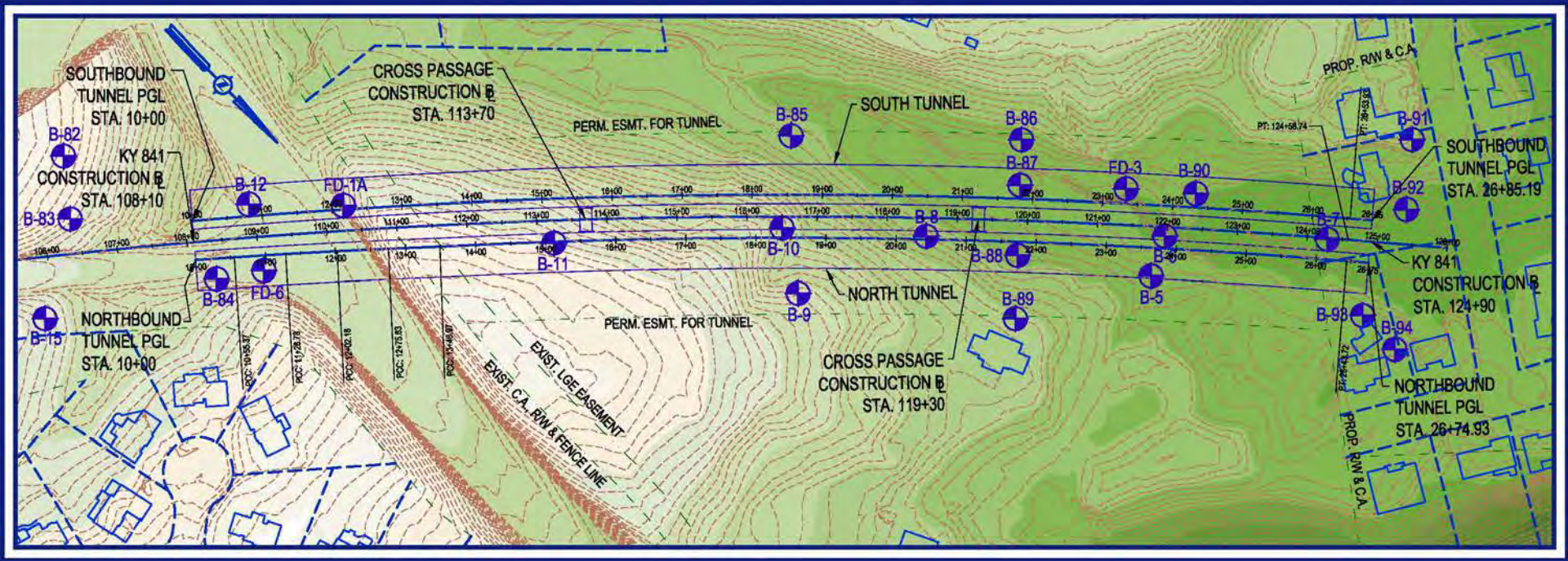
Project Overview – Location



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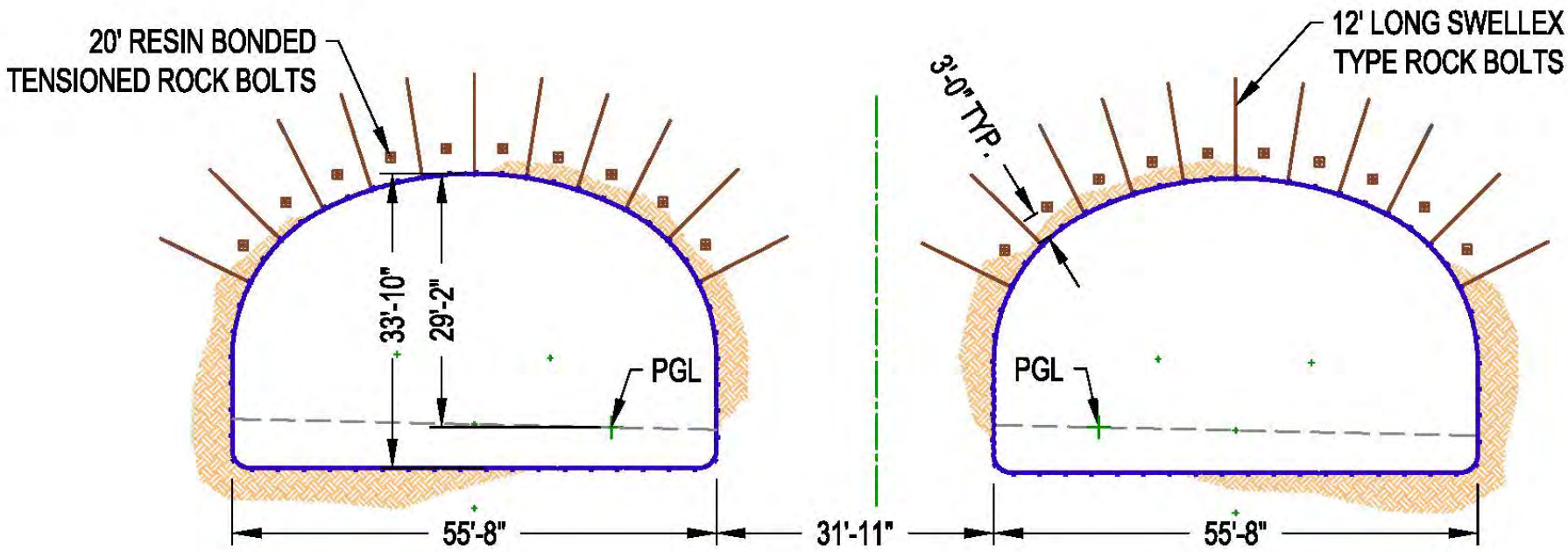
Project Overview – X-Section at Portal



SOUTH PORTAL SUPPORT
ELEVATION

Project Overview – X-Section at Portal

Site Geology – Field Techniques

- Surficial geologic mapping
- Surface-based geophysical
- Borings (horizontal, vertical, inclined)
  - Observation wells (some nested)
  - Down-hole geophysics
  - In-situ packer tests

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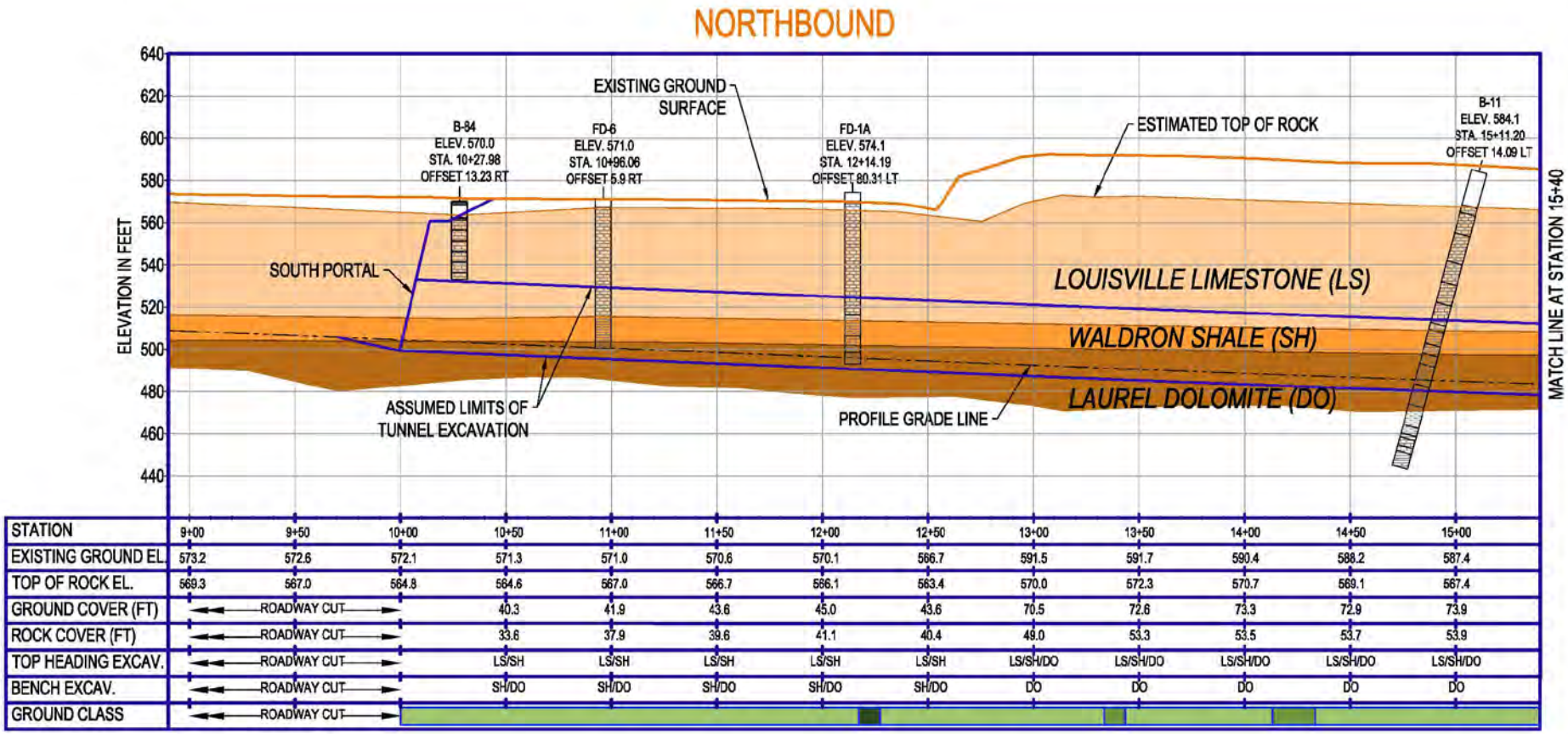
Site Geology – Subsurface Profile



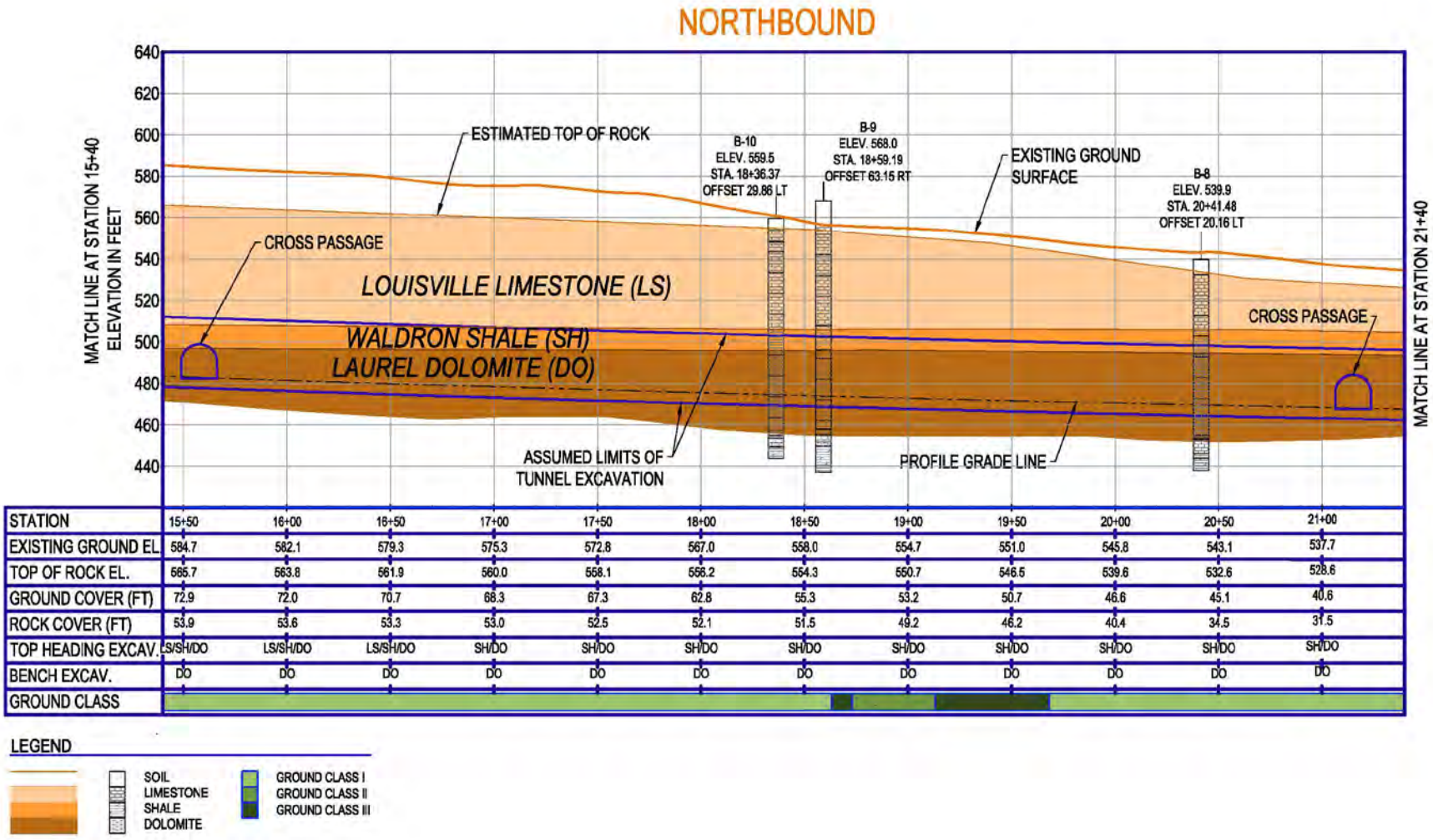
STATION	9+00	9+50	10+00	10+50	11+00	11+50	12+00	12+50	13+00	13+50	14+00	14+50	15+00
EXISTING GROUND EL.	573.2	572.6	572.1	571.3	571.0	570.6	570.1	566.7	591.5	591.7	590.4	588.2	587.4
TOP OF ROCK EL.	569.3	567.0	564.8	564.6	567.0	566.7	566.1	563.4	570.0	572.3	570.7	569.1	567.4
GROUND COVER (FT)	ROADWAY CUT			40.3	41.9	43.6	45.0	43.6	70.5	72.6	73.3	72.9	73.9
ROCK COVER (FT)	ROADWAY CUT			33.6	37.9	39.6	41.1	40.4	49.0	53.3	53.5	53.7	53.9
TOP HEADING EXCAV.	ROADWAY CUT			LS/SH	LS/SH	LS/SH	LS/SH	LS/SH	LS/SH/DO	LS/SH/DO	LS/SH/DO	LS/SH/DO	LS/SH/DO
BENCH EXCAV.	ROADWAY CUT			SH/DO	SH/DO	SH/DO	SH/DO	SH/DO	DO	DO	DO	DO	DO
GROUND CLASS	ROADWAY CUT												

LEGEND

SOIL
LIMESTONE
SHALE
DOLOMITE

GROUND CLASS I
GROUND CLASS II
GROUND CLASS III

Site Geology – Subsurface Profile



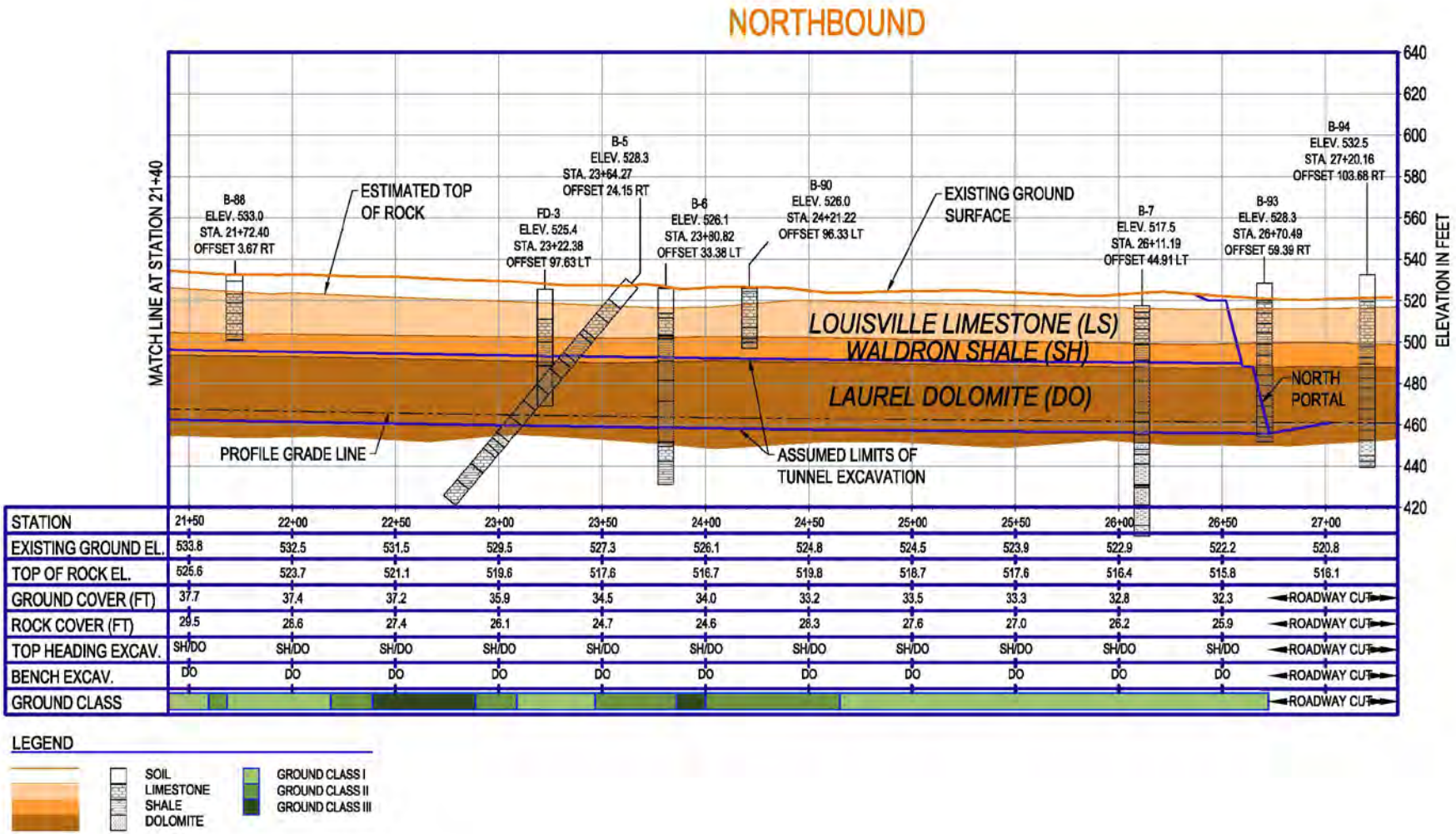
STATION	15+50	16+00	16+50	17+00	17+50	18+00	18+50	19+00	19+50	20+00	20+50	21+00
EXISTING GROUND EL	584.7	582.1	579.3	575.3	572.8	567.0	558.0	554.7	551.0	545.8	543.1	537.7
TOP OF ROCK EL.	665.7	563.8	561.9	560.0	558.1	556.2	554.3	550.7	546.5	539.6	532.6	528.6
GROUND COVER (FT)	72.9	72.0	70.7	68.3	67.3	62.8	55.3	53.2	50.7	46.6	45.1	40.6
ROCK COVER (FT)	53.9	53.6	53.3	53.0	52.5	52.1	51.5	49.2	46.2	40.4	34.5	31.5
TOP HEADING EXCAV.	LS/SH/DO	LS/SH/DO	LS/SH/DO	SH/DO	SH/DO	SH/DO	SH/DO	SH/DO	SH/DO	SH/DO	SH/DO	SH/DO
BENCH EXCAV.	DO	DO	DO	DO	DO	DO	DO	DO	DO	DO	DO	DO
GROUND CLASS												

LEGEND

SOIL
LIMESTONE
SHALE
DOLOMITE

GROUND CLASS I
GROUND CLASS II
GROUND CLASS III

Site Geology – Subsurface Profile



STATION	21+50	22+00	22+50	23+00	23+50	24+00	24+50	25+00	25+50	26+00	26+50	27+00
EXISTING GROUND EL.	533.8	532.5	531.5	529.5	527.3	526.1	524.8	524.5	523.9	522.9	522.2	520.8
TOP OF ROCK EL.	525.6	523.7	521.1	519.6	517.6	516.7	519.8	518.7	517.6	516.4	515.8	516.1
GROUND COVER (FT)	37.7	37.4	37.2	35.9	34.5	34.0	33.2	33.5	33.3	32.8	32.3	ROADWAY CUT
ROCK COVER (FT)	29.5	26.6	27.4	26.1	24.7	24.6	28.3	27.6	27.0	26.2	25.9	ROADWAY CUT
TOP HEADING EXCAV.	SH/DO	SH/DO	SH/DO	SH/DO	SH/DO	SH/DO	SH/DO	SH/DO	SH/DO	SH/DO	SH/DO	ROADWAY CUT
BENCH EXCAV.	DO	DO	DO	DO	DO	DO	DO	DO	DO	DO	DO	ROADWAY CUT
GROUND CLASS												ROADWAY CUT

Potential Geologic Hazards

- Karst features
- Geologic discontinuities
- Groundwater inflow
- Swelling/slaking shale
- High horizontal rock stresses

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Potential Hazards - Karst

- Louisville Limestone and Laurel Dolomite
- Sinkholes and sinking springs
  - Enlarged joints and bedding planes
  - Cavities (air/water/soil/rock)
- Resistivity and refraction surveys
  - “Ground truthing” vs. borings and sinkholes
  - “Hot spot” analogy
- Contingency Plans

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Potential Hazards – Discontinuities

- Sub-horizontal (bedding)
  - Televiewer data
  - Few minor low angle joints (35 to 60 deg)
- Sub-vertical
  - Borings and road cuts
  - Within a few degrees of vertical
- Rock Mass Classification

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Potential Hazards – Groundwater

- Permeability of intact rock (pores) is low
- Groundwater moves through solution joints and channels (transient loads)
- Sinking stream
- Soil/rock interface, LL, LL/WS interface, LD
  - Some perched water at interfaces
  - Regional table probably in LD (or lower)

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Potential Hazards – Swelling/Slaking

- Requires unloading and access to water
- Huder-Amberg Testing
  - 3.3% strain vertical borings (average)
  - Pre-loading = more volume change
- Some of the shale cores slaked severely, majority did not
- Generally, high dolomite content and low clay content; except locally

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Potential Hazards – High Stresses

- Known region where $s_h > s_v$ (typically)
- Close to the Ohio River
- Valley features (tunnel is within a ridge)
- Stress reduction at shallow depths likely
- Modeling at $K_o = 0.5$ more conservative than $K_o = 1$

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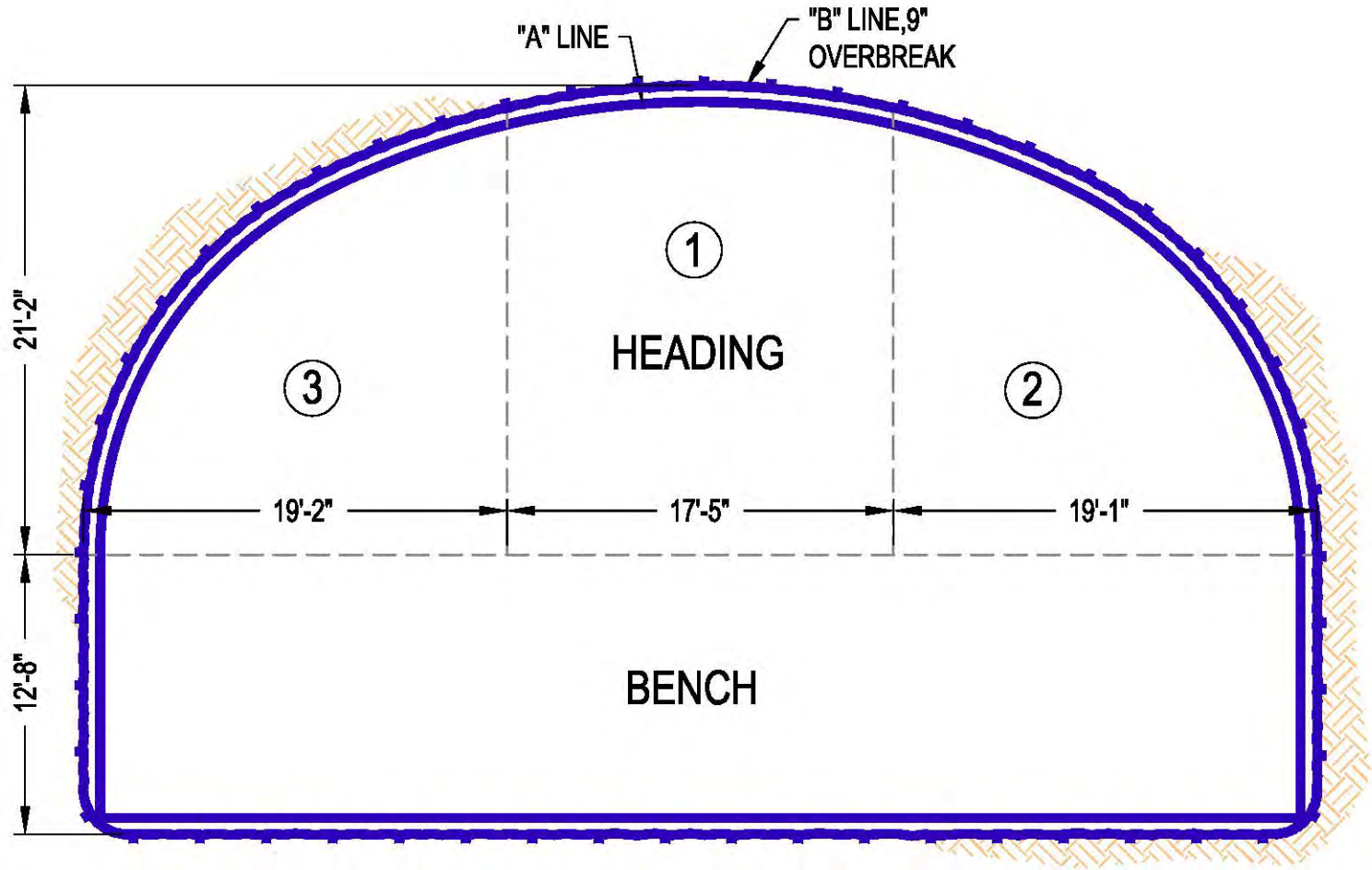
Construction Methodology

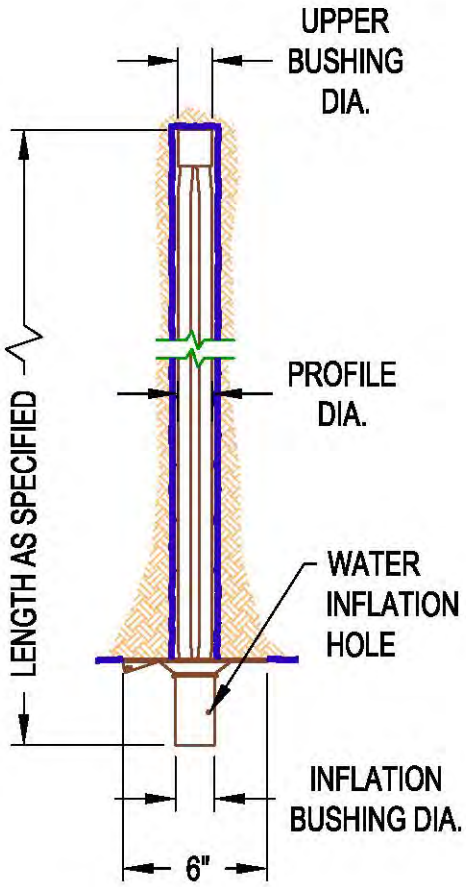


ELEVATION

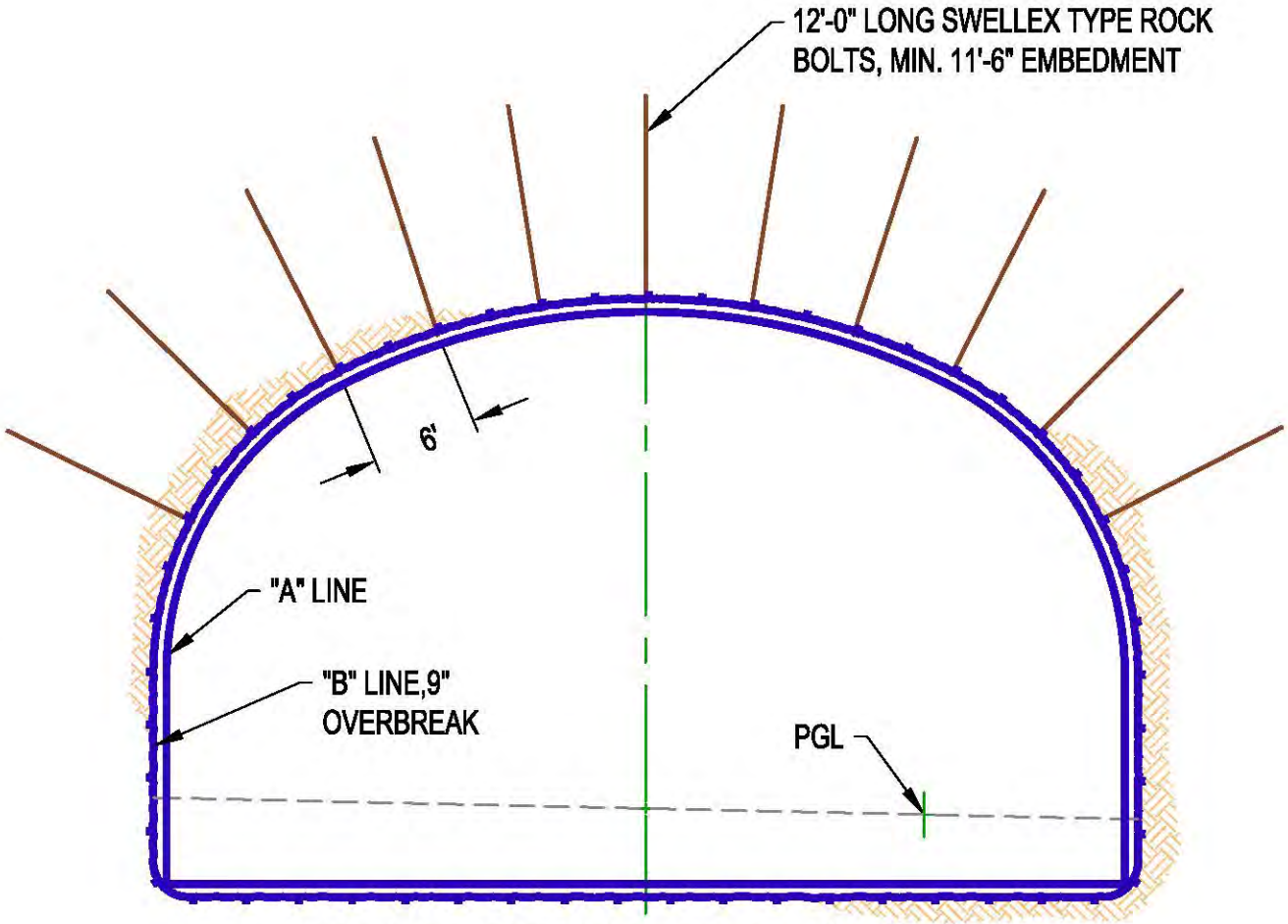
Construction Methodology

PLAN

Support Schemes – Class A



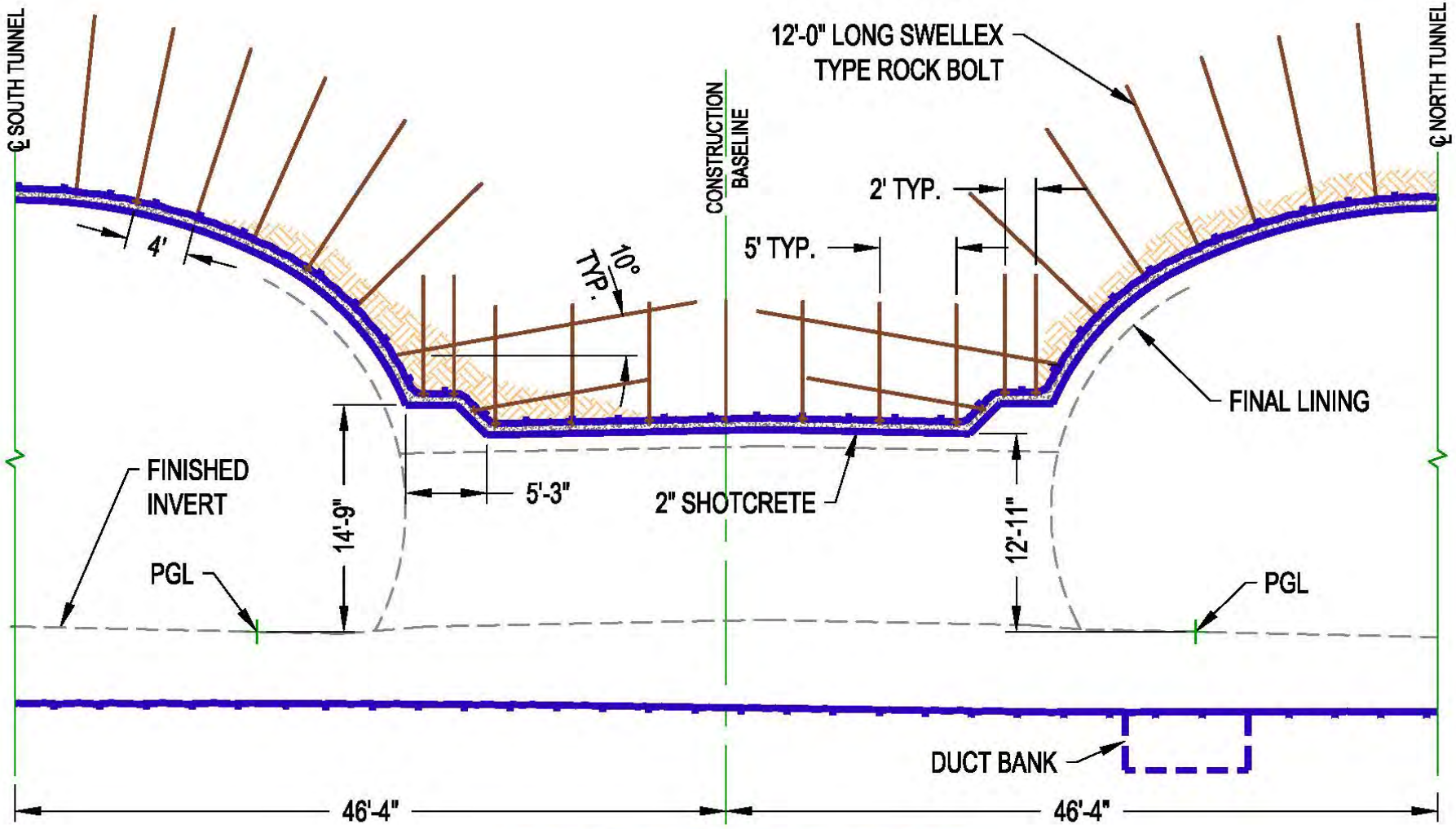
ROCK BOLT



TUNNEL EXCAVATION IS EXPECTED TO BE A MINIMUM OF LINE "A" WITH NO ROCK PROTRUDING INSIDE LINE "A". "B" LINE DEFINES OUTER EXTENT OF EXPECTED OVERBREAK

CLASS A SUPPORT

Support Schemes – Class CP



CROSS-PASSAGE SUPPORT

Support Schemes – ‘SEM’ Toolbox

- Mine straps
- Rolled “U” channels
- Welded wire fabric
- Additional Shotcrete
- Resin bonded rock bolts
- Split set rock dowels
- Polymer fiber shotcrete
- Grouted rock bolts
- Lattice girders

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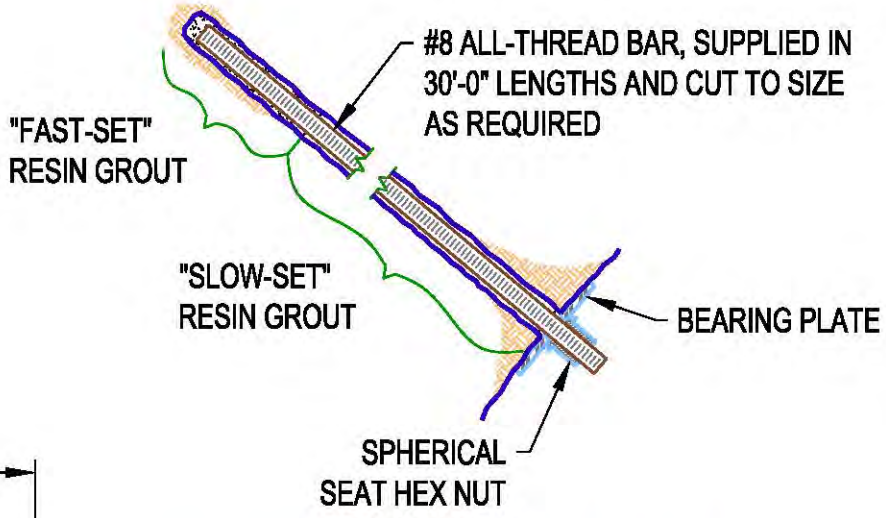
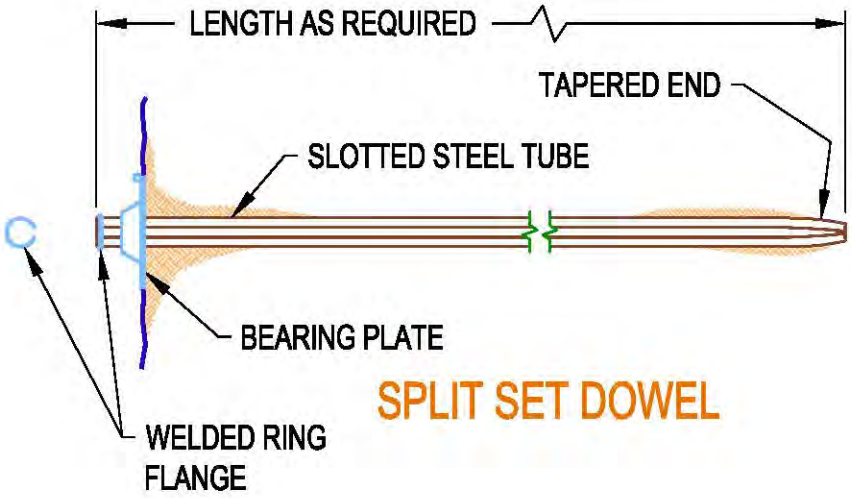
Support Schemes – ‘SEM’ Toolbox

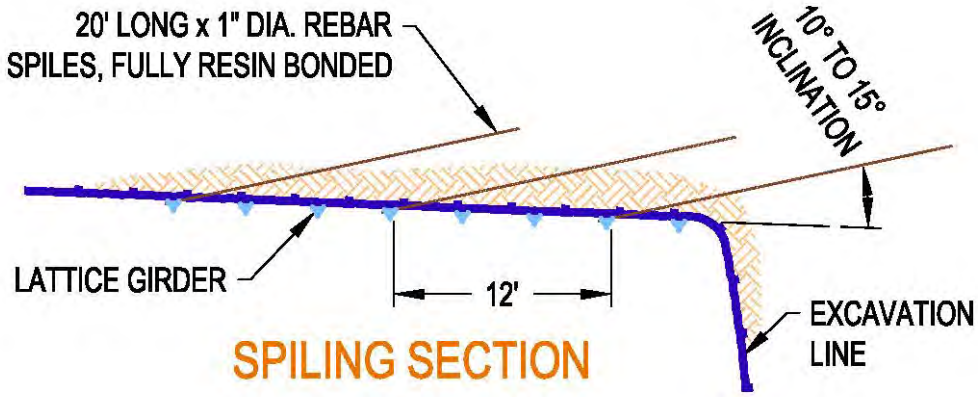


RESIN GROUTED ROCK BOLT

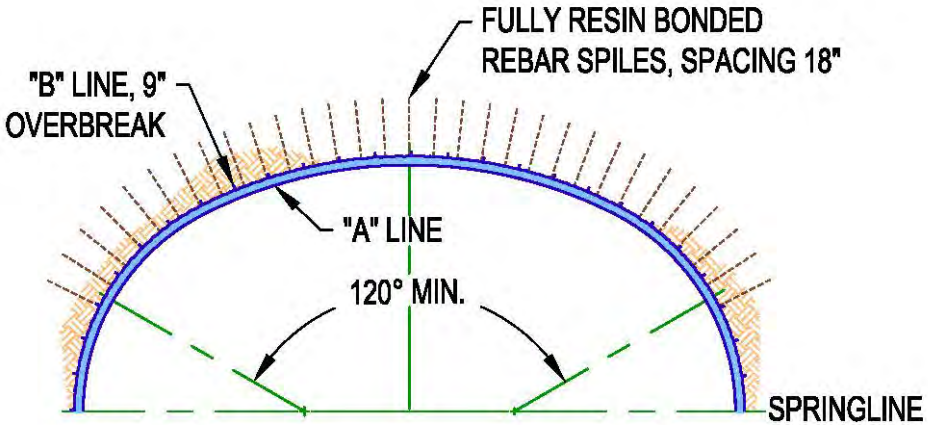


SPLIT SET DOWEL

Support Schemes – 'SEM' Toolbox

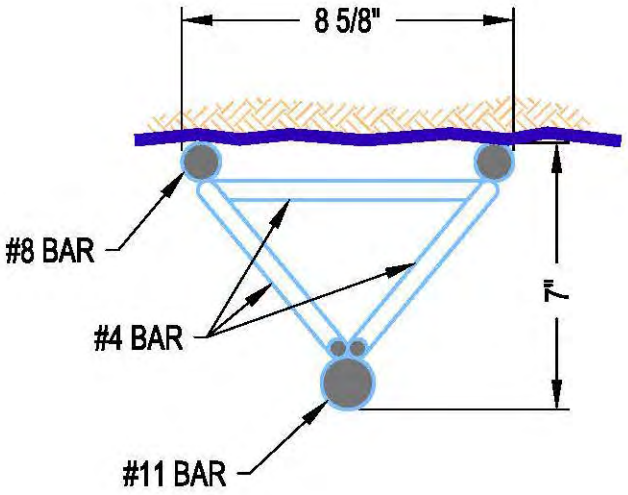


SPILING SECTION

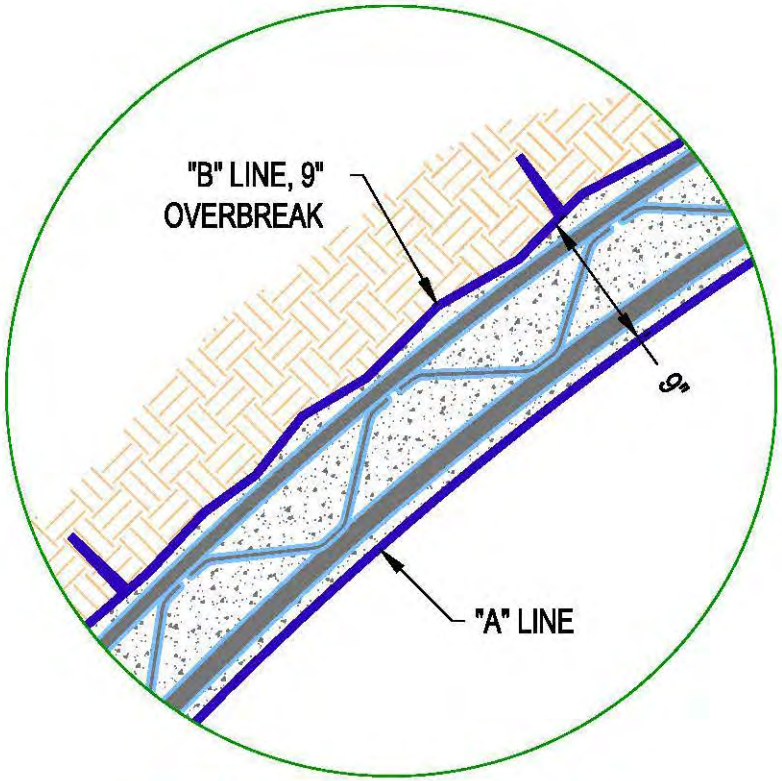


SPILING ELEVATION

Support Schemes – ‘SEM’ Toolbox



LATTICE GIRDER CROSS-SECTION



DETAIL - LATTICE GIRDER

Project Status – Geologic Hazards

- Karst features
  - Portal cuts: limestone solutioned near surface
  - Tunnel depth: no significant features
- Geologic discontinuities
  - Sub-vertical joints observed (dolomite), widely spaced
  - Discontinuous at shale

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Project Status – Geologic Hazards

- Groundwater inflow
  - Few instances < 0.5 gpm, very dry tunnel
- Swelling/slaking shale
  - Effectively mitigated by flashcrete (contract requirement)
- High horizontal rock stresses
  - No observed evidence

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Project Status

- Northbound Tunnel: X,XXX ft / 1,680 ft
- Southbound Tunnel: X,XXX ft / 1,680 ft
- Bench removal and hole through at North Portal (i.e., the tie-in) remaining

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Project Status

Project Status

Project Status

Project Status

Project Status

Questions