# *Constructing in Congested Areas Without Damaging Existing Structures*

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**Mueser Rutledge Consulting Engineers**

***GeoVirginia 2016***
***October 10-12, 2016, Williamsburg, VA***

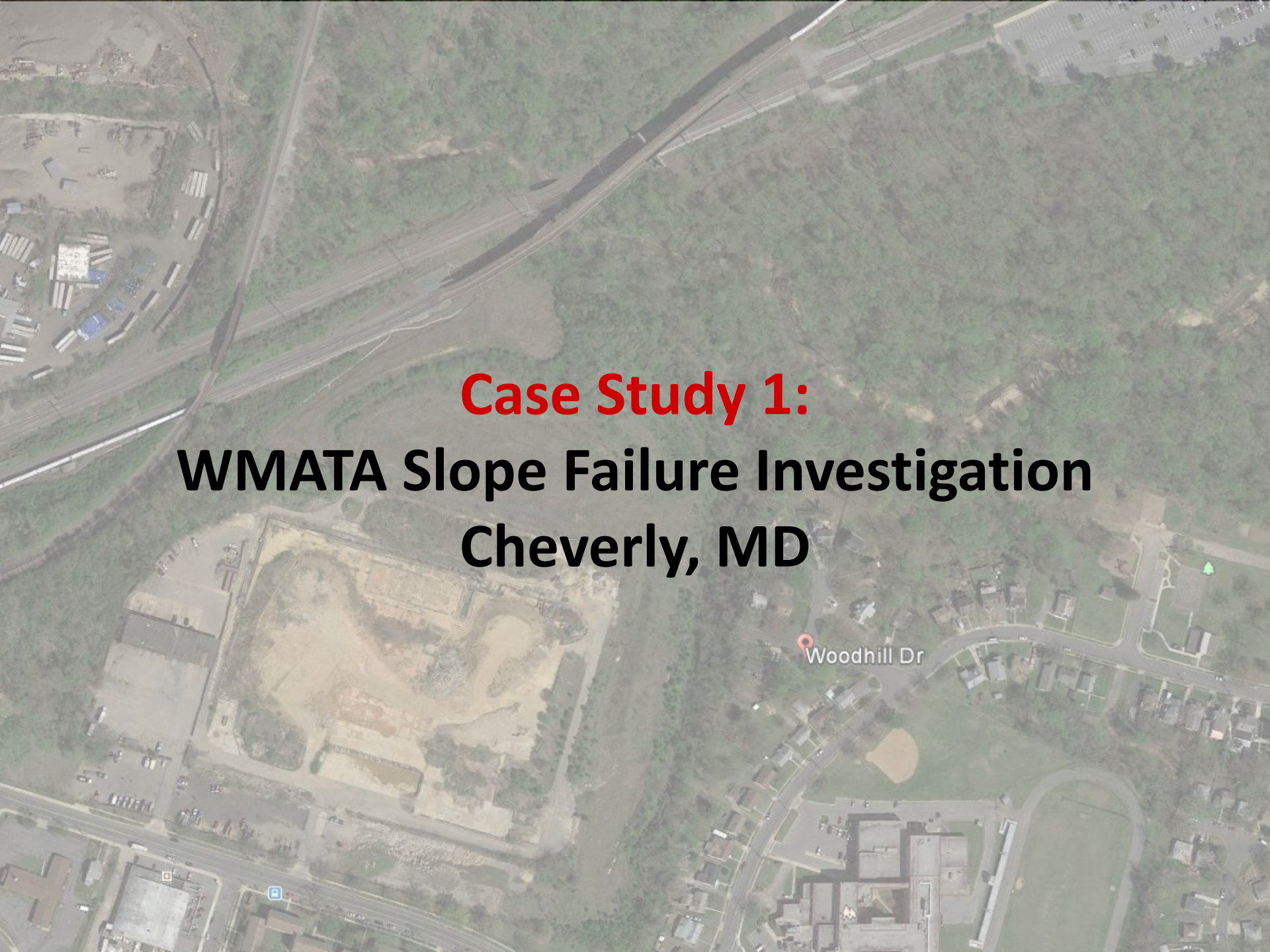
# Case Studies

**WMATA Slope Failure Investigation**
**Cheverly, MD**

**Rosslyn Central Place**
**Arlington, VA**

**Walter E. Washington Convention Center**
**Washington, DC**

**DC Marriott Marquis Convention Center Hotel**
**Washington, DC**



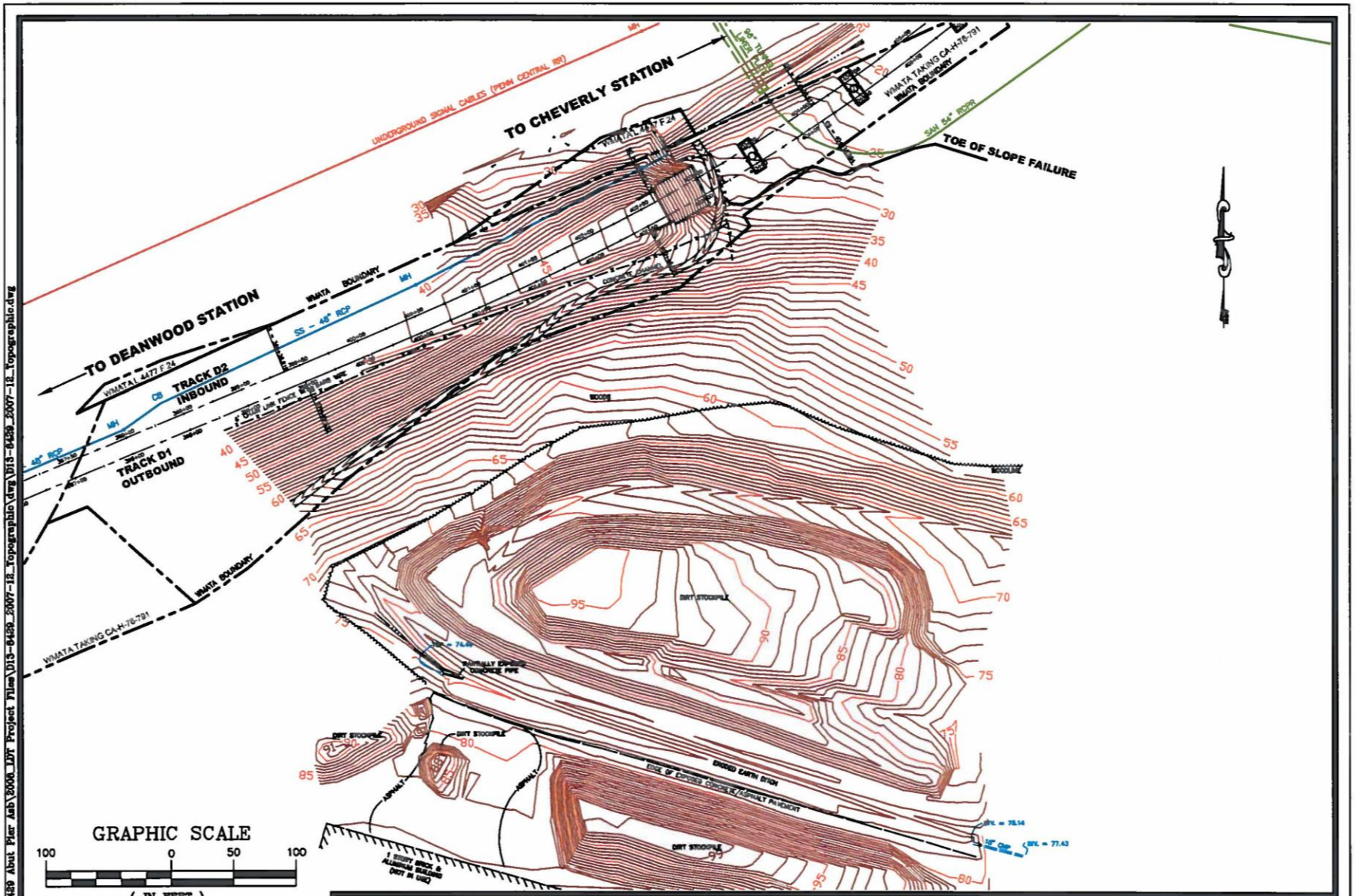

# Case Study 1:

# WMATA Slope Failure Investigation
# Cheverly, MD

# Site Conditions

- Movement in a slope flatter than 1V:3H
- 2.3’ lateral movement of a WMATA bridge pier near the base of slope
- Site was underlain by hard fissured clay
- Stability analyses – marginal stability


Damaged Bridge Abutment
Beaver Heights
18’ fill for parking Lot
North Englewood Playgroun
Woodhill Dr
250 feet
© 2010 NAVTEQ © 2011 Microsoft Corporation Image courtesy




# WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

WMATA SURVEY REQUEST: D13-CMD-8429

FIELD SURVEY DATE: 12/09/2007

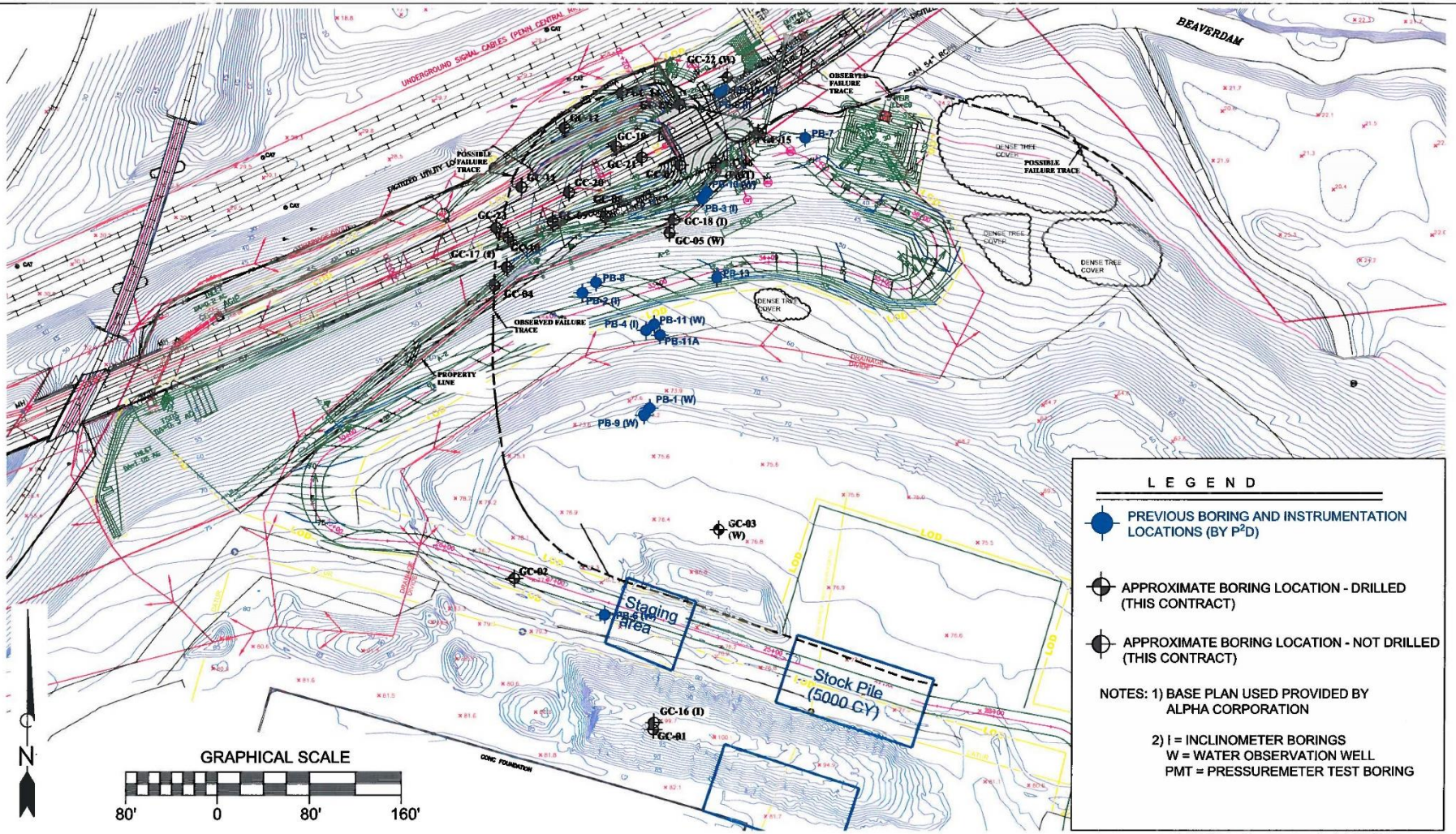
WMATA - OPRS / ENSS - SURVEY

DEPARTMENT OF OPERATIONS SERVICES
ENGINEERING SUPPORT SERVICES

metro

## NEW CARROLLTON ROUTE
## 2007 TOPOGRAPHIC SURVEY
## WITH COMPOSITE UTILITIES AND DEEDS

F:\SURVEY\data\D-13\8429 Abut Pier Adv\2000_IDF Project Files\D13-8429_2007-12_Topographic\dwg\D13-8429_2007-12_Topographic.dwg




RFP No GP 9163 / JAF

| ORIGINATORS | | |
|---|---|---|
| EK DRAWN | 06-23-09 DATE | |
| PKL DESIGNED | 06-23-09 DATE | |
| RSV CHECKED | 06-23-09 DATE | |
| JS APPROVED | 06-23-09 DATE | |

| REFERENCE DRAWINGS | |
|---|---|
| NUMBER | DESCRIPTION |

| REVISIONS | | | | | | |
|---|---|---|---|---|---|---|
| NO | DATE | DESCRIPTION | ORIG | CHK | SUPV | APPR |

WASHINGTON METROPOLITAN AREA TRANSIT AUTHORITY

CLARK DESIGN BUILD

emc², inc.
10110 Molecular Drive, Suite 310, Rockville, MD 20850
Tel.: (301) 424-8696 Fax: (240) 499-8917
Emc2@emc2engineers.com

GeoConcepts Engineering, Inc.
19955 Highland Vista Dr., Suite 170, Ashburn, Virginia 20147
(703) 726-8030 (703) 726-8032 fax

# CHEVERLY ABUTMENT REHABILITATION BORING LOCATION PLAN

| SCALE: | FIGURE: | |
|---|---|---|
| AS SHOWN | 5 | DECEMBER, 2010 |

# Cause of Failure

- 18 ft. of fill recently placed for a parking lot at the top of the slope
- Fill placed on private land

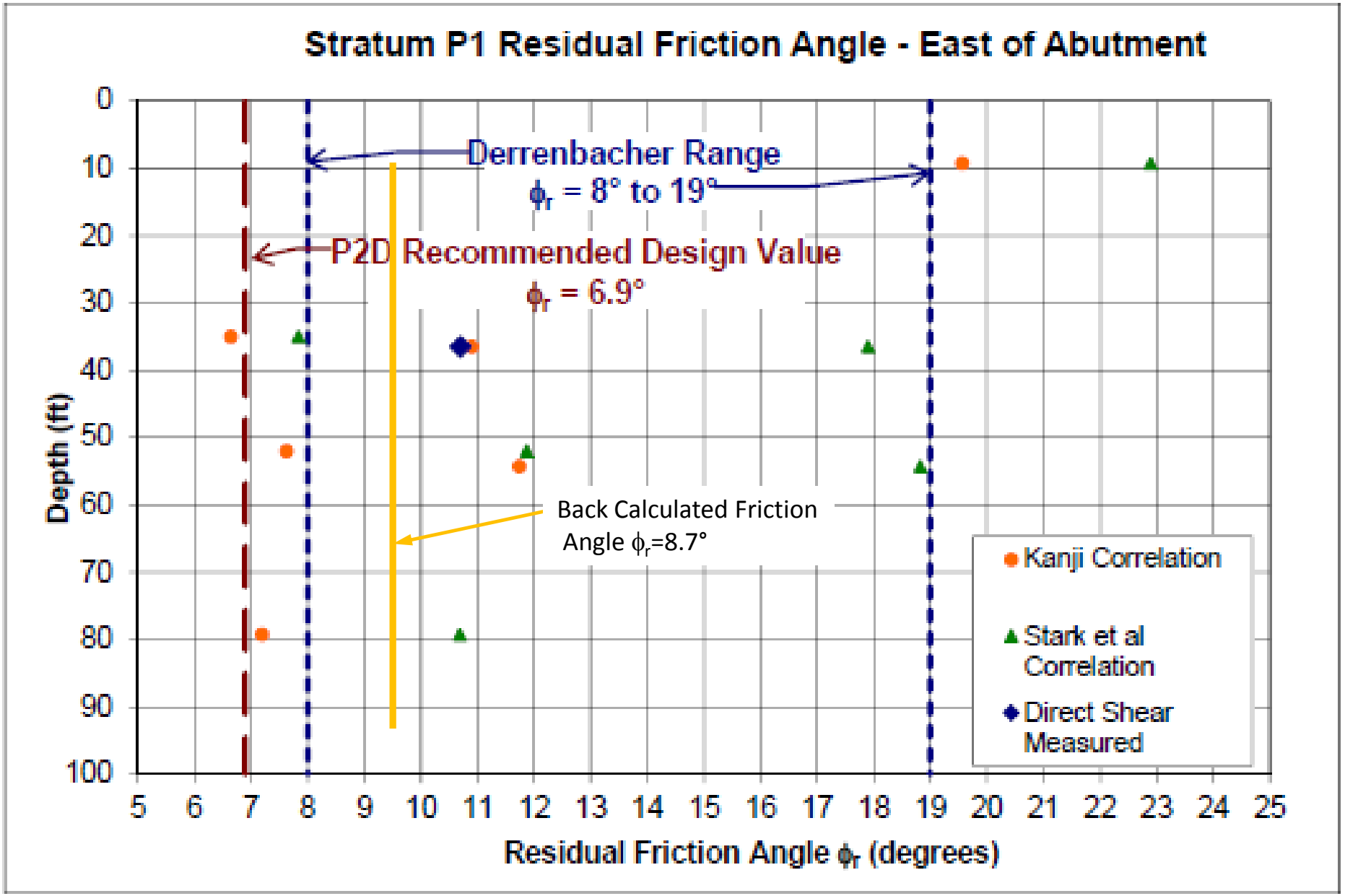
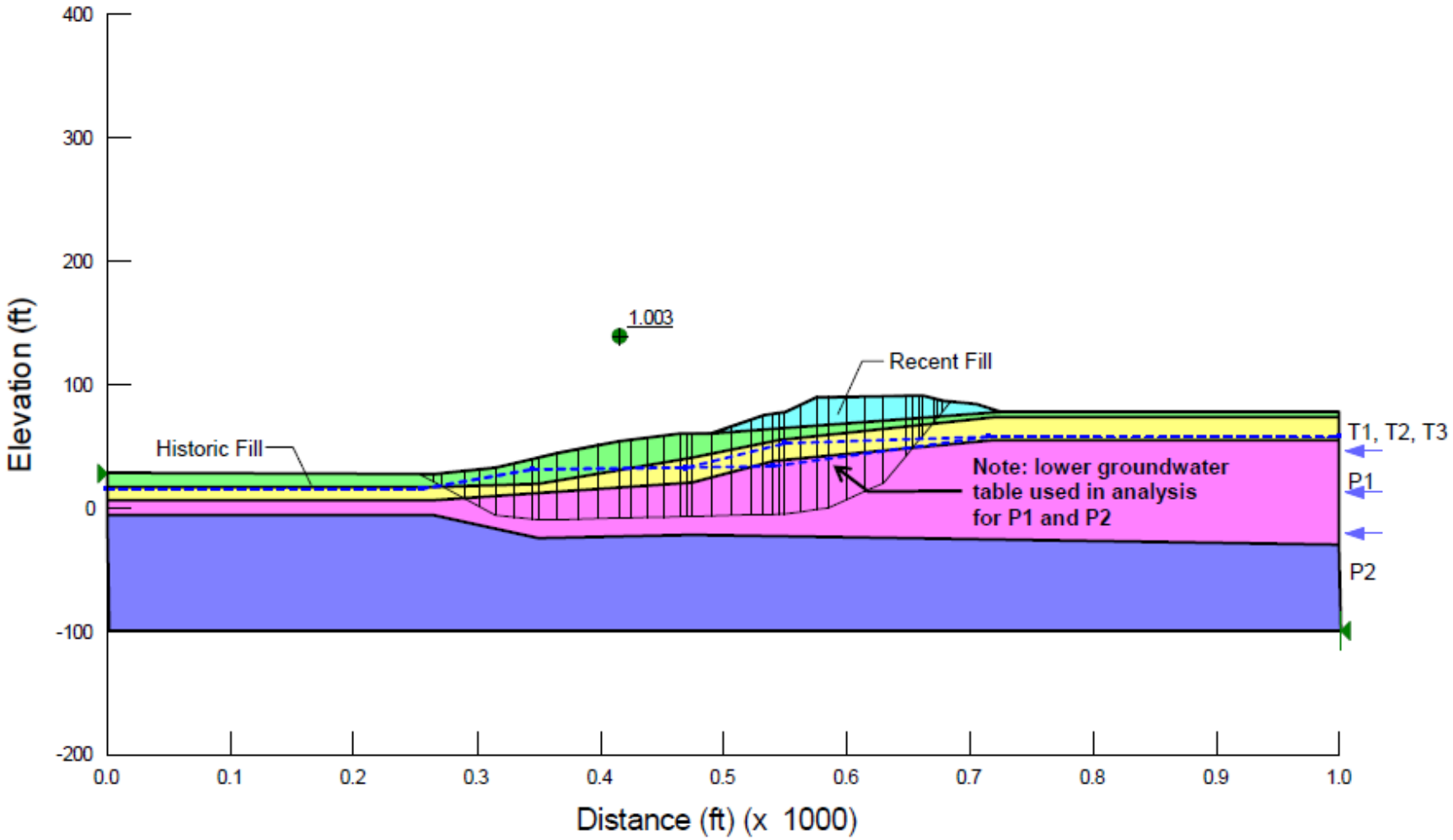



Figure 2 - Residual friction angle vs. depth east of the Abutment




Material Properties:

| Name | Moist Unit Weight* $lb/ft^3$ | Cohesion $lb/ft^2$ | Internal Friction Angle |
|---|---|---|---|
| Recent Fill | 120 | 0 | 28° |
| Historic Fill | 120 | 0 | 28° |
| T1, T2, and T3 | 130 | 0 | 30° |
| P1 | 125 | 0 | 8.7° |
| P2 | 130 | 0 | 36° |

*Note: Saturated unit weight is 5 $lb/ft^3$ more than moist for all soils.

**CHEVERLY SLOPE STABILIZATION REVIEW**

PRINCE GEORGES COUNTY MD

**MUESER RUTLEDGE CONSULTING ENGINEERS**

14 PENN PLAZA – 225 W 34TH STREET, NEW YORK NY 10122

| SCALE | MADE BY: ALS | DATE: 2-18-11 | FILE No. |
|---|---|---|---|
| N/A | CH'KD BY: JMT | DATE: 2-18-11 | 11285 |

P2D 85' OFFSET DIRECTIONAL CROSS-SECTION (B-B)
DEEP FAILURE SURFACE

PLATE 3

PLATE 3

# Solutions Considered

- Several types of ground stabilization
- Remove the fill after negotiation with property owner
- Installation of drilled piers near base of slope to increase F.S.

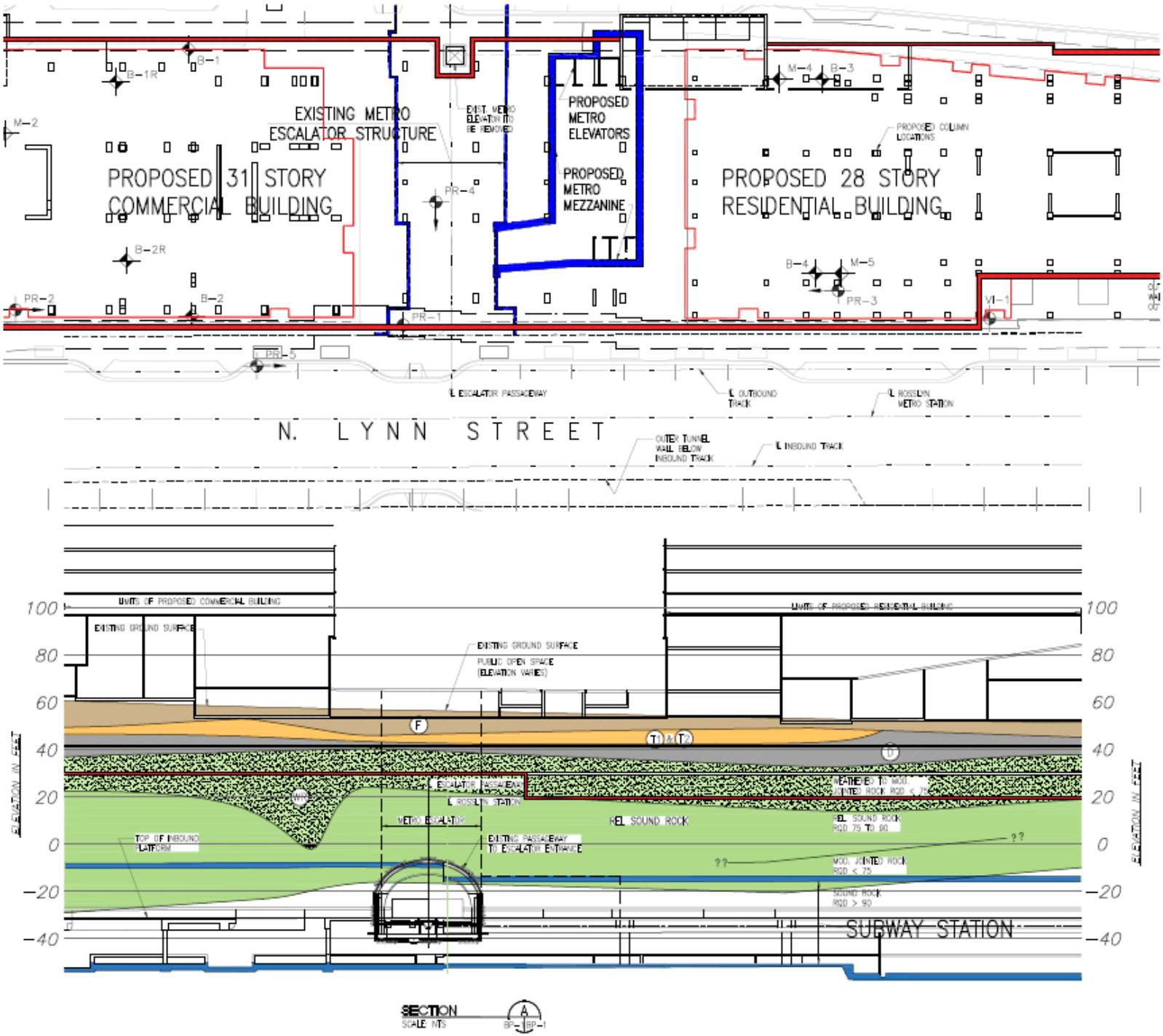
# Lessons Learned

**Solutions need not be expensive stabilization of the ground but slopes can often be stabilized by simple means.**

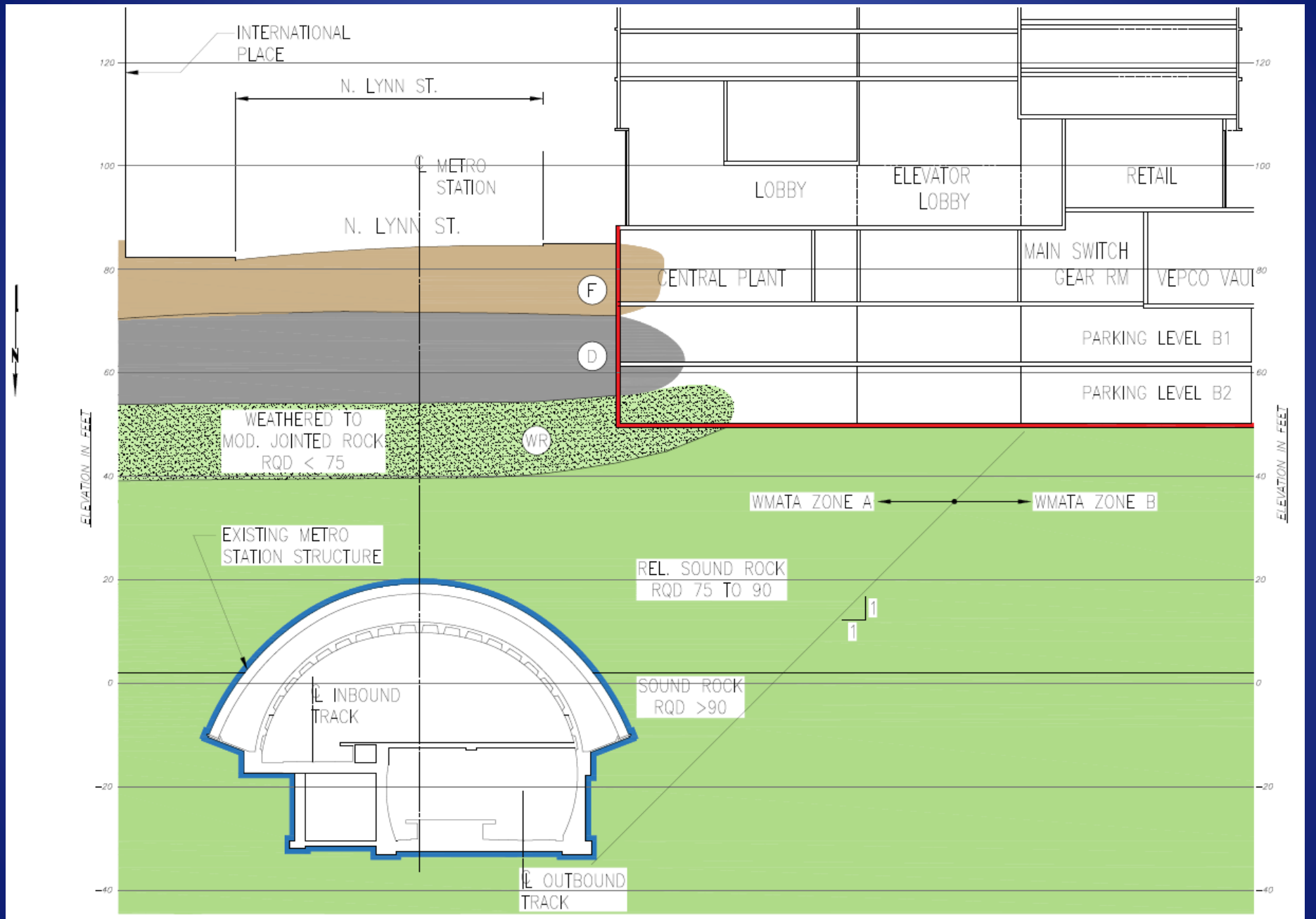
# Case Study 2:
# Rosslyn Central Place at Rosslyn Metro Station
# Arlington, VA

# Site Conditions

- Construction of office and apartment buildings immediately next to a deep rock subway station
- Construction of a new elevator entrance to the station mezzanine between the new structures




SECTION
SCALE: NTS
A
BP-1 BP-1


INTERNATIONAL PLACE
N. LYNN ST.
℄ METRO STATION
N. LYNN ST.
LOBBY
ELEVATOR LOBBY
RETAIL
MAIN SWITCH GEAR RM
VEPCO VAULT
CENTRAL PLANT
PARKING LEVEL B1
PARKING LEVEL B2
F
D
WR
WEATHERED TO MOD. JOINTED ROCK RQD < 75
WMATA ZONE A
WMATA ZONE B
EXISTING METRO STATION STRUCTURE
REL. SOUND ROCK RQD 75 TO 90
SOUND ROCK RQD >90
℄ INBOUND TRACK
℄ OUTBOUND TRACK
ELEVATION IN FEET
120
100
80
60
40
20
0
-20
-40

# How to Minimize Impacts on the Metro Station

- Determine the number of below ground parking levels to minimize stress change around the Metro Station
- Evaluate stresses both during excavation and for the completed structures
- Use construction methods that would not damage the station while constructing the new elevator/stairway shaft and mezzanine approach to the station

# Analysis to Determine Impact

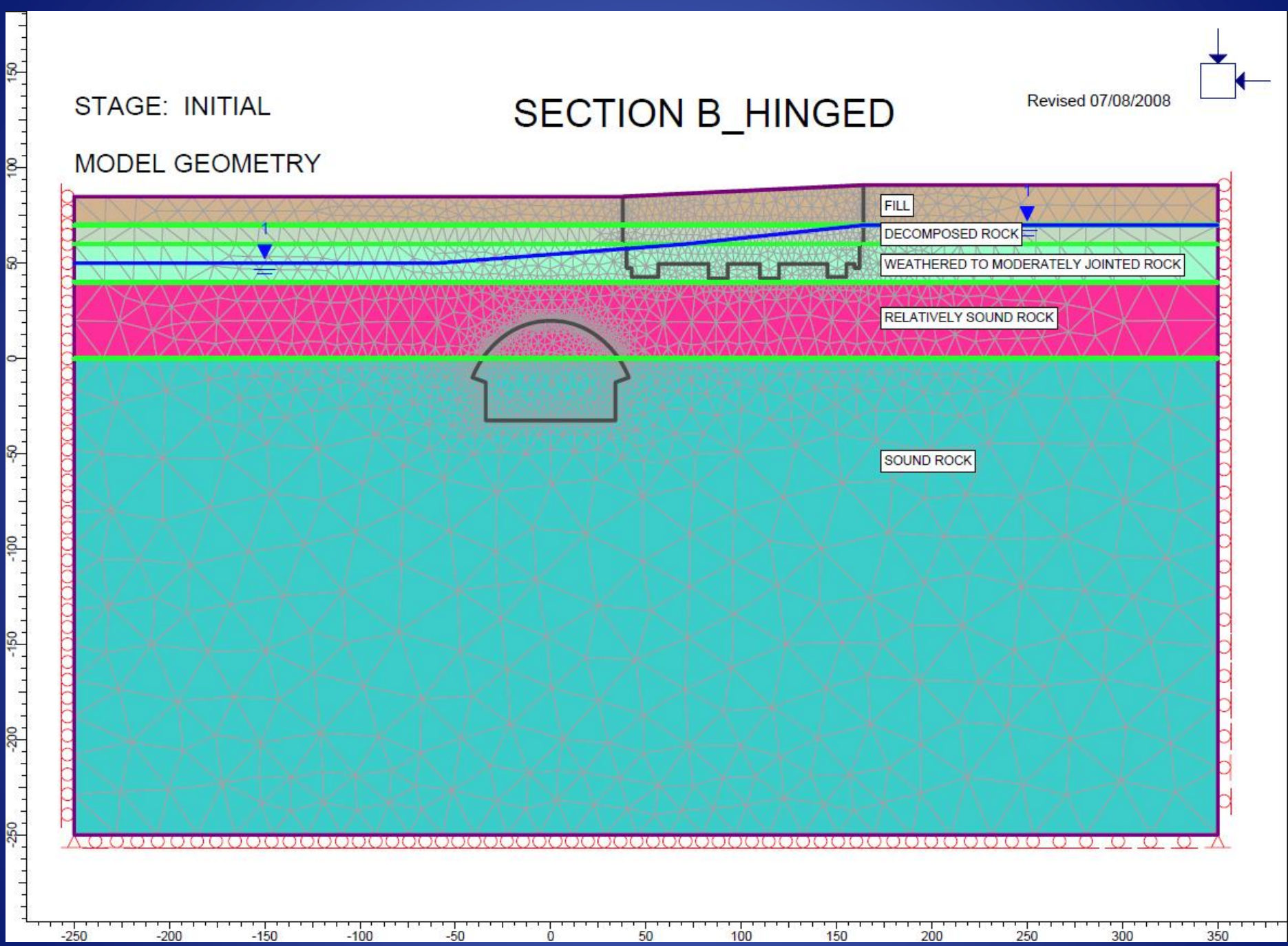
- Analysis Program
- Stress Change in Station Lining

STAGE: INITIAL

# SECTION B_HINGED

Revised 07/08/2008

MODEL GEOMETRY

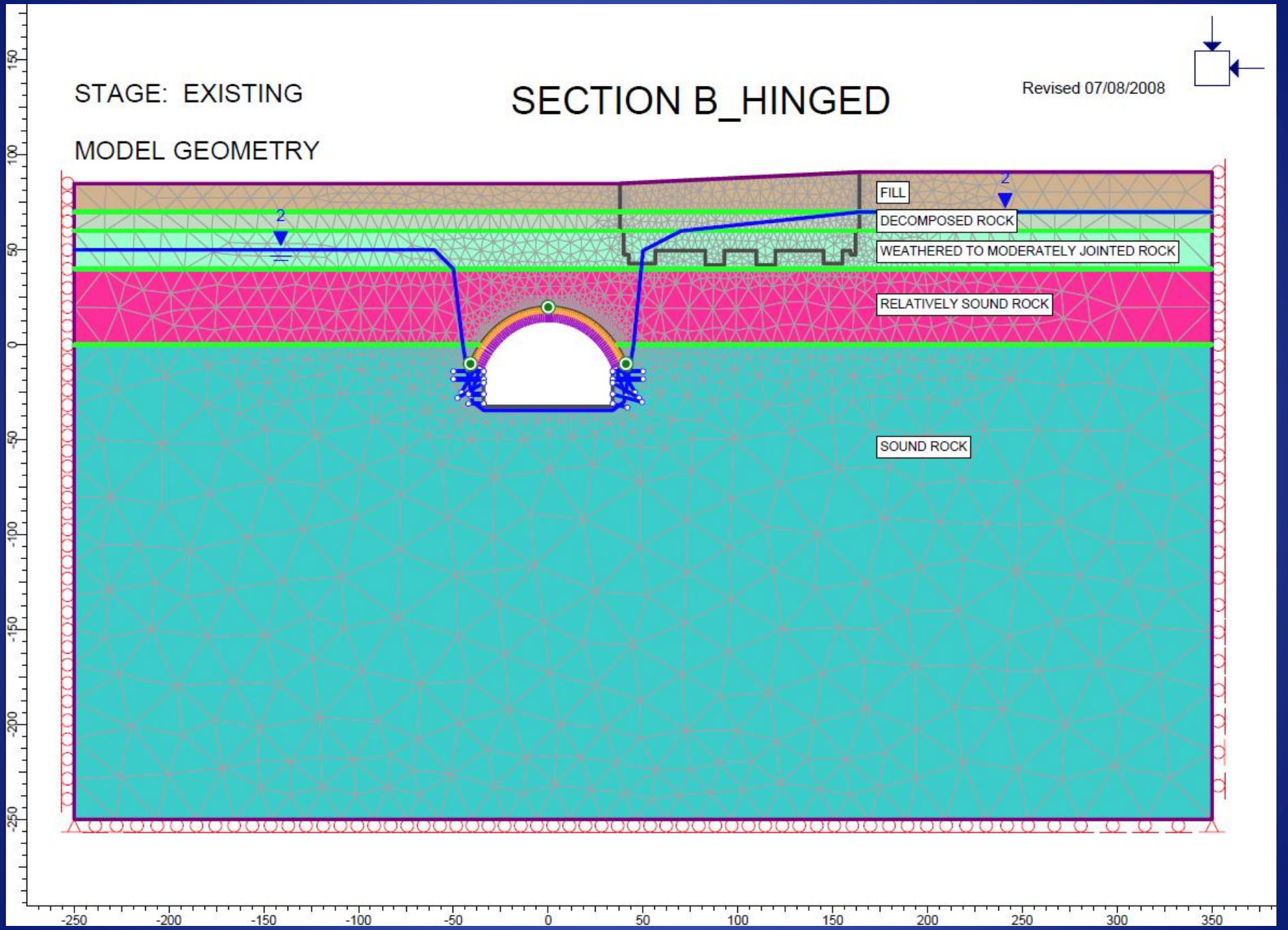


STAGE: EXISTING

# SECTION B_HINGED

Revised 07/08/2008

MODEL GEOMETRY

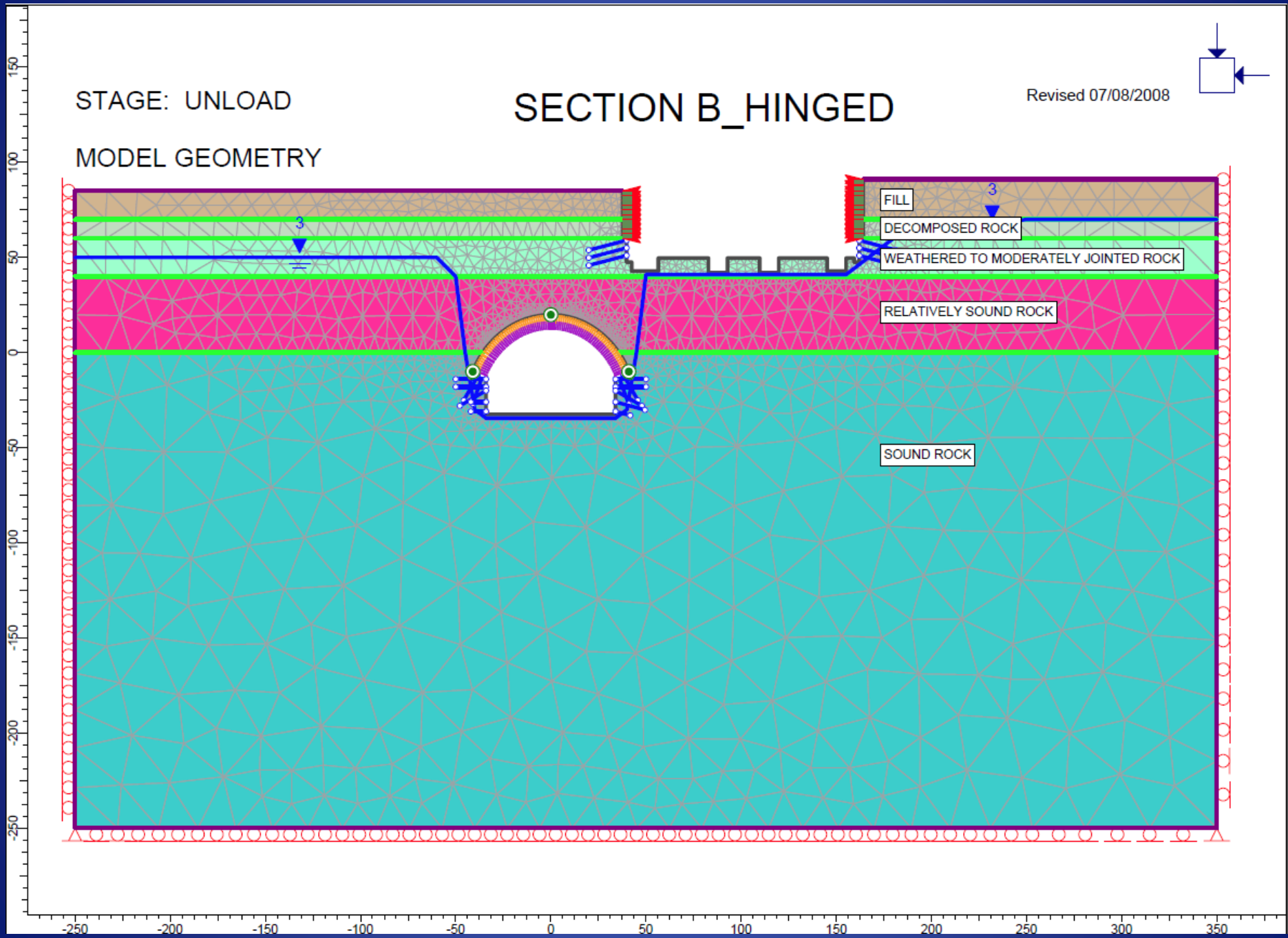


STAGE: UNLOAD

# SECTION B_HINGED

Revised 07/08/2008

MODEL GEOMETRY

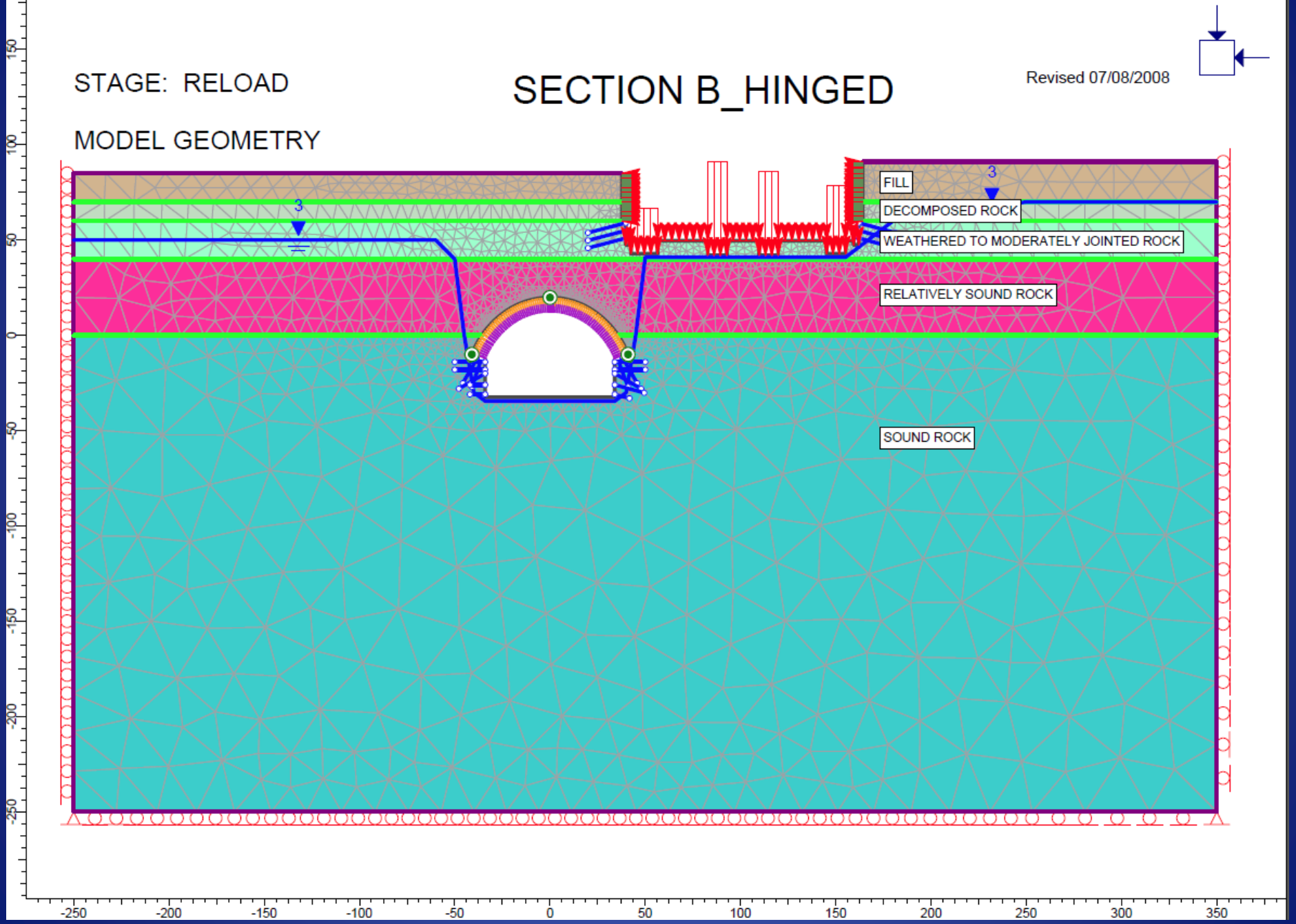


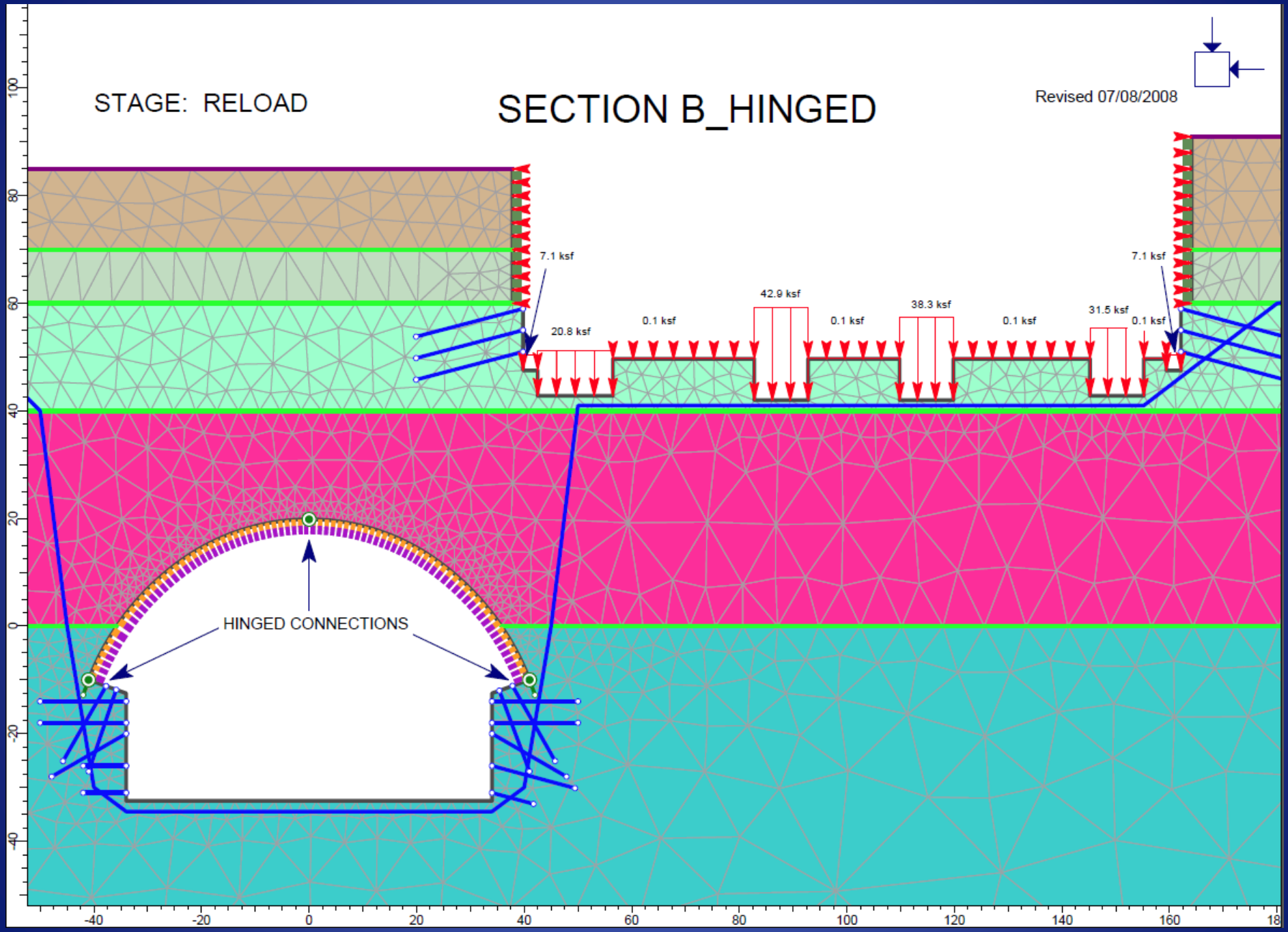
STAGE: RELOAD

# SECTION B_HINGED

Revised 07/08/2008

MODEL GEOMETRY




STAGE: RELOAD
SECTION B_HINGED
Revised 07/08/2008
7.1 ksf
20.8 ksf
0.1 ksf
42.9 ksf
0.1 ksf
38.3 ksf
0.1 ksf
31.5 ksf
0.1 ksf
7.1 ksf
HINGED CONNECTIONS
100
80
60
40
20
0
-20
-40
-40
-20
0
20
40
60
80
100
120
140
160
18

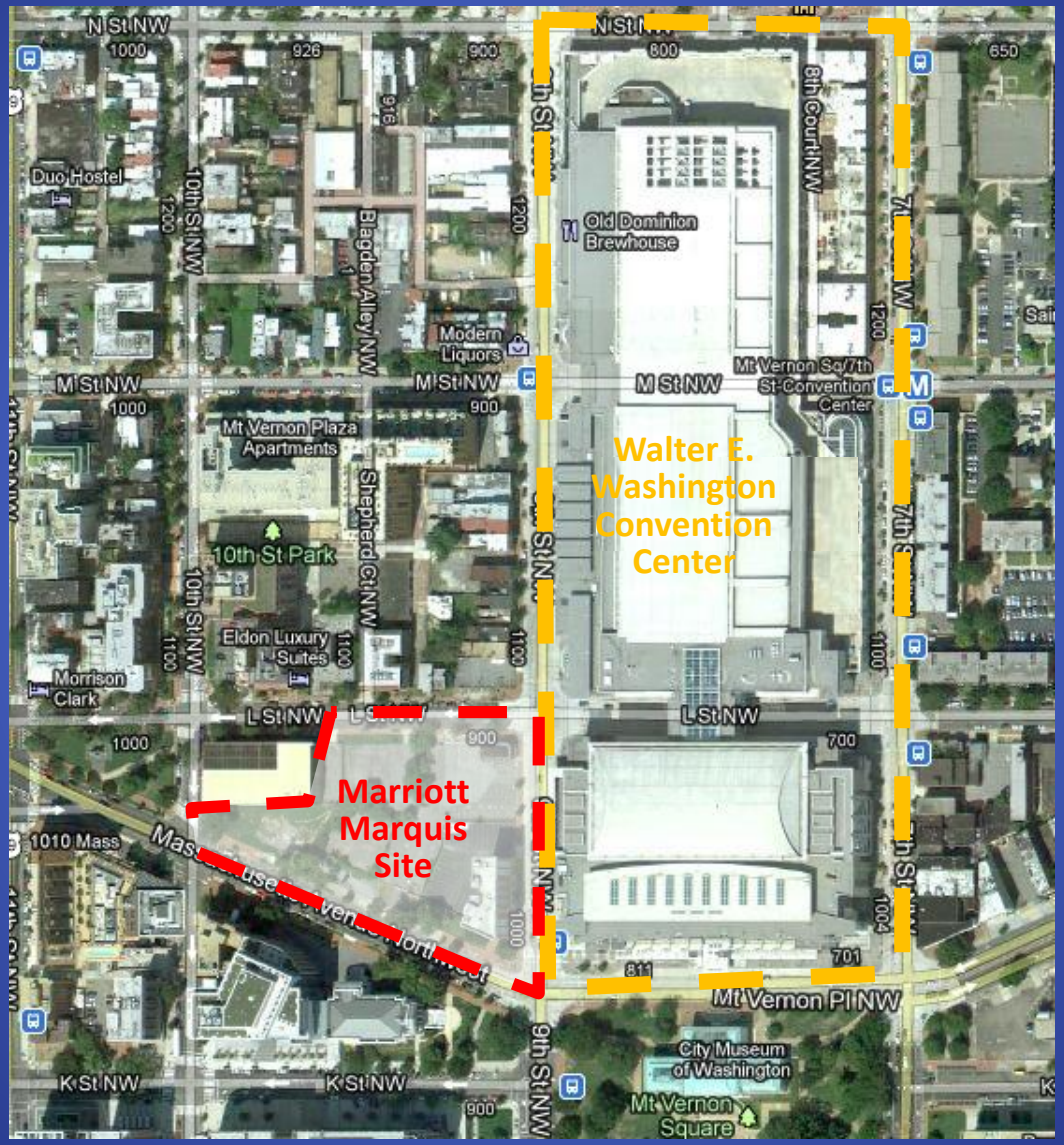
# Lessons Learned

**With the cooperation of the developer, it is possible to build directly next to a subway station by demonstrating successfully to the subway authority that this can be done safely.**

# Case Study 3:
# Walter E. Washington Convention Center
# Washington, DC


September 2002

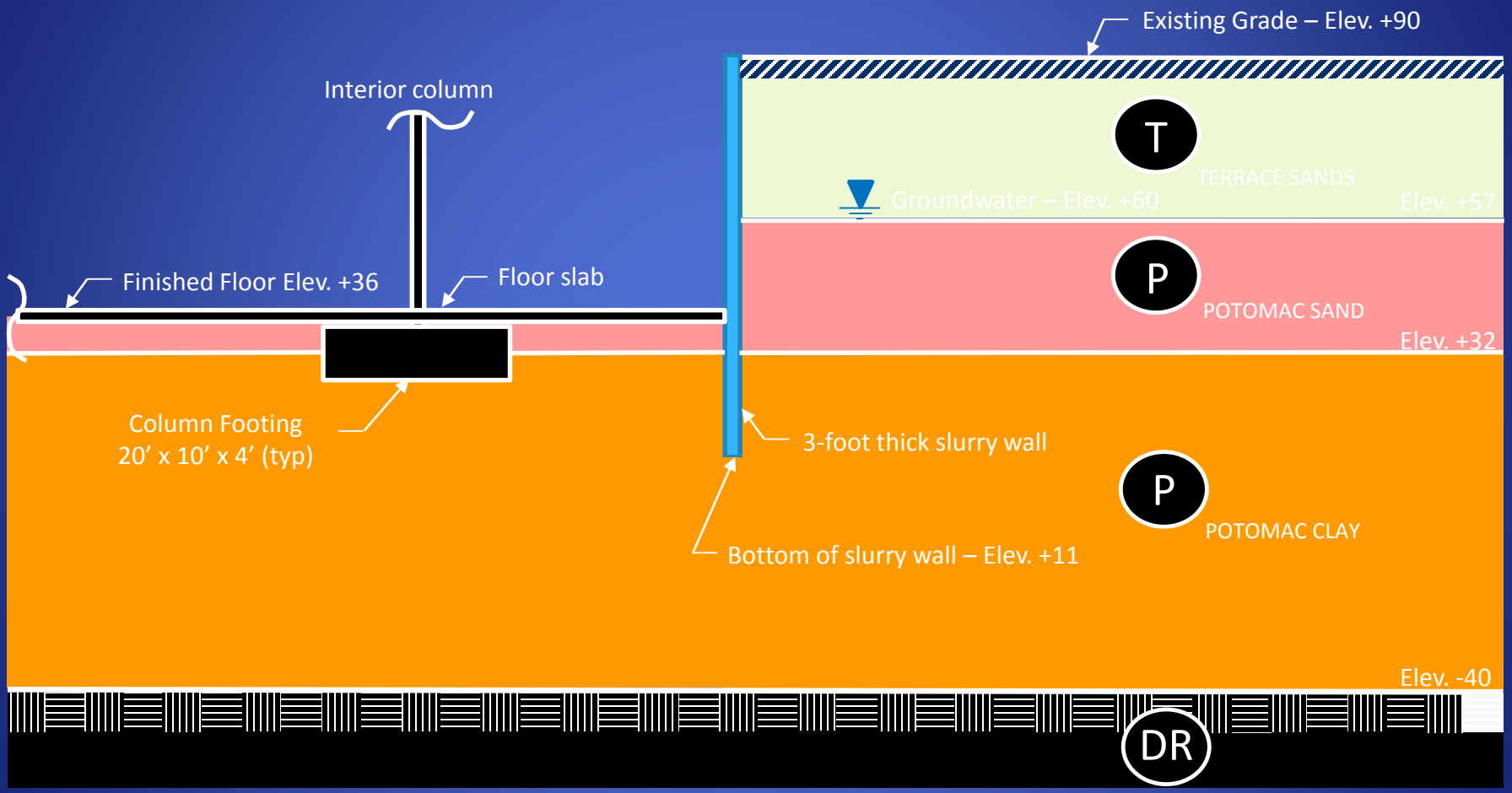
# Location


Walter E. Washington Convention Center
Marriott Marquis Site
N St NW
M St NW
L St NW
K St NW
10th St NW
9th St NW
7th St NW
8th Court NW
Mt Vernon Pl NW
Duo Hostel
Old Dominion Brewhouse
Modern Liquors
Blagden Alley NW
Mt Vernon Plaza Apartments
Shepherd Ct NW
10th St Park
Eldon Luxury Suites
Morrison Clark
1010 Mass
Mt Vernon Sq/7th St-Convention Center
City Museum of Washington
Mt Vernon Square

# Site Conditions

1. Six block Site – 550 x 1450 Feet
2. Basement 40 to 65 Feet Deep
3. Soils – Permeable Sand Over Hard Clay
4. Groundwater up to 40 Ft. Deep
5. Subway/Apartment Bldgs Along East Side
6. Exhibit Hall at Basement Level – High quality Space

# Convention Center Cross Section



# Design Issues

1. Groundwater Cutoff/Underdrainage of Basement
2. Support of High Building Loads on Hard Clay
3. Settlement of Building
4. Column Spacing 90 x 90 Feet
5. Exhibit Hall with 35 Foot Ceilings
6. High Horizontal Loads in Floors

# Design Solutions

1. Permanent Slurry Wall Cutoff Around Perimeter
2. 30 x 30 x 9 Foot Deep Spread Footings
3. Slurry Walls Supported Independently of Interior Walls


1
2
3
4

1) Permanent Buttresses and Temporary Raker Braces

2) Rakers bracing Metro Station


3) Heel Block Test Set Up

4) Spread Footing with Grade Beams

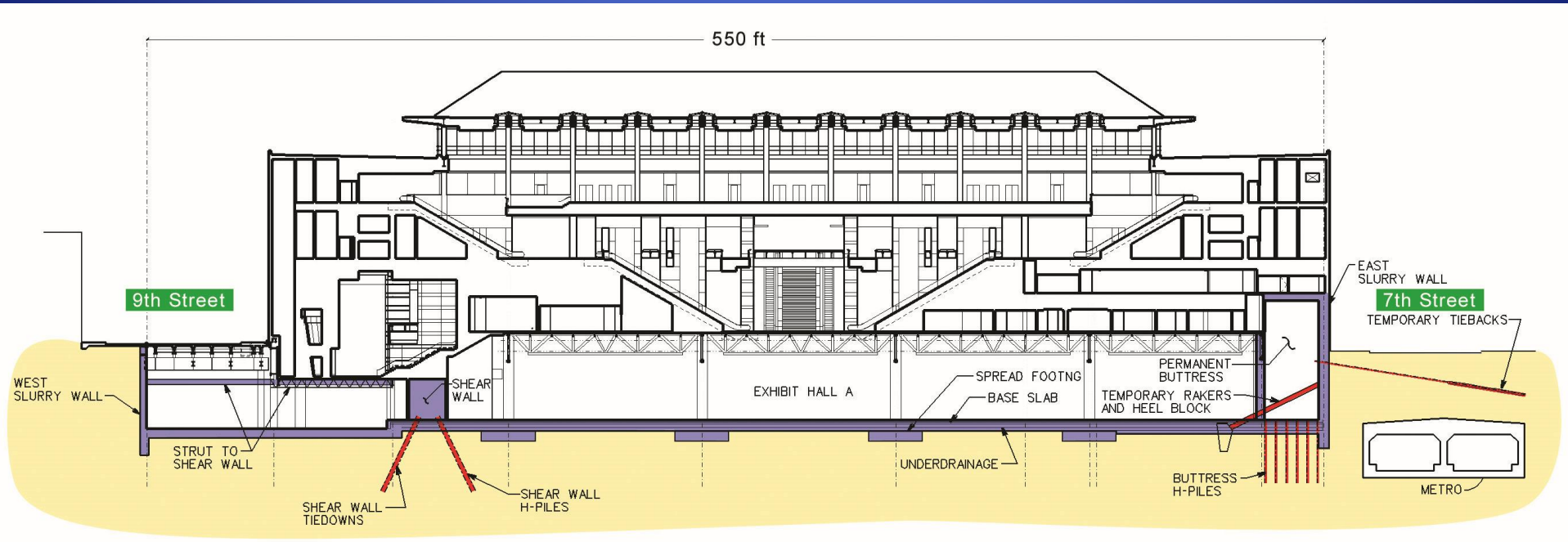
- Innovative dewatering and groundwater cutoff
- Design of the slurry wall for temporary support of excavation and becomes the permanent wall
- Slurry wall relies on a unique combination of tiebacks, rakers, buttresses and shear walls for temporary and permanent lateral earth support
- Design of less costly spread footing founded on the cretaceous clay with steel piles below shear walls and buttresses to reduce wall deflection
- Design of low flow rate underdrainage system

# Lateral Support Methods

1. Staircase Shear Walls Against East Wall Supported on Battered Piles to Minimize Wall Movement
2. Shear Walls Supported on Battered Piles Between Truck Bays With Steel Braces Against the Eastern Slurry Walls
3. Permanent Tie-back Anchors for the Tall North Wall and the Northern Part of the East Wall

# Construction Constraints

1. Western Side of Convention Center extends below 9th Street Leaving Only 25% of the Street for Relocated Utilities. This Provides Space for the Truck Ramp
2. Installation of the Slurry Wall in 9th Street Required
3. The Subway Along the East Side of the Site Restricted Tie-back Anchors to Shallow Depths Above the Subway Resulting in Heavier Reinforcing and Temporary Interior Raker Bracing Using Large Heel Blocks for Reaction


550 ft
9th Street
7th Street
EAST
SLURRY WALL
TEMPORARY TIEBACKS
WEST
SLURRY WALL
SHEAR
WALL
EXHIBIT HALL A
SPREAD FOOTNG
BASE SLAB
PERMANENT
BUTTRESS
TEMPORARY RAKERS
AND HEEL BLOCK
STRUT TO
SHEAR WALL
UNDERDRAINAGE
BUTTRESS
H-PILES
METRO
SHEAR WALL
TIEDOWNS
SHEAR WALL
H-PILES

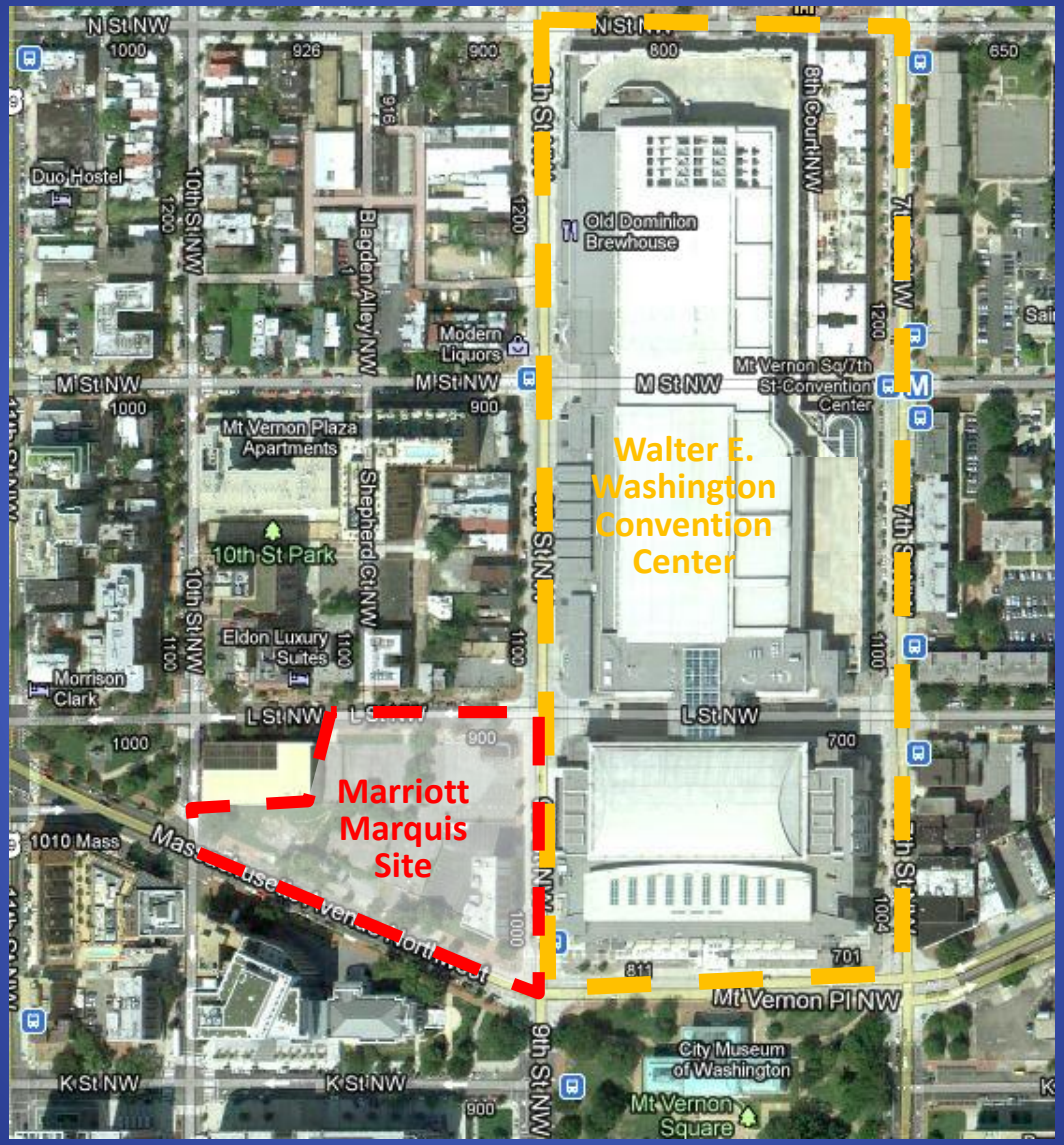
# Lesson Learned

This project demonstrates that, when needed for unusual structures, it is practical support perimeter walls up to 70 feet deep without interior support from floors. This solution required several different methods of support.

# Case Study 4:

# DC Marriott Marquis Convention Center Hotel
# Washington, DC

# Location

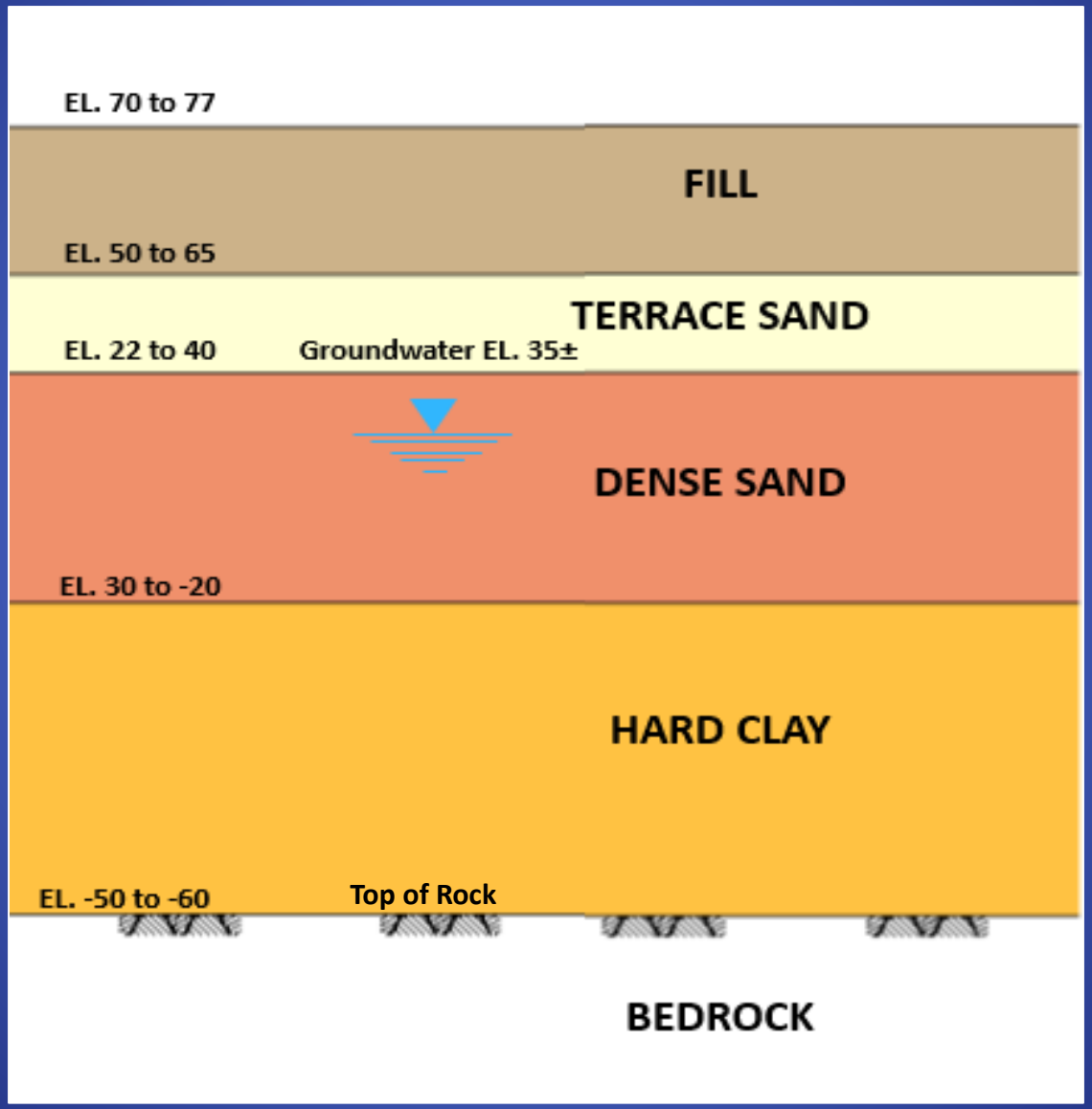

N St NW
Duo Hostel
10th St NW
Blagden Alley NW
Modern Liquors
M St NW
Mt Vernon Plaza Apartments
Shepherd Ct NW
10th St Park
Eldon Luxury Suites
Morrison Clark
L St NW
1010 Mass
K St NW
9th St NW
Old Dominion Brewhouse
8th Court NW
7th St NW
Mt Vernon Sq/7th St-Convention Center
Walter E. Washington Convention Center
Marriott Marquis Site
Mt Vernon Pl NW
City Museum of Washington
Mt Vernon Square

# DC Marriott Marquis

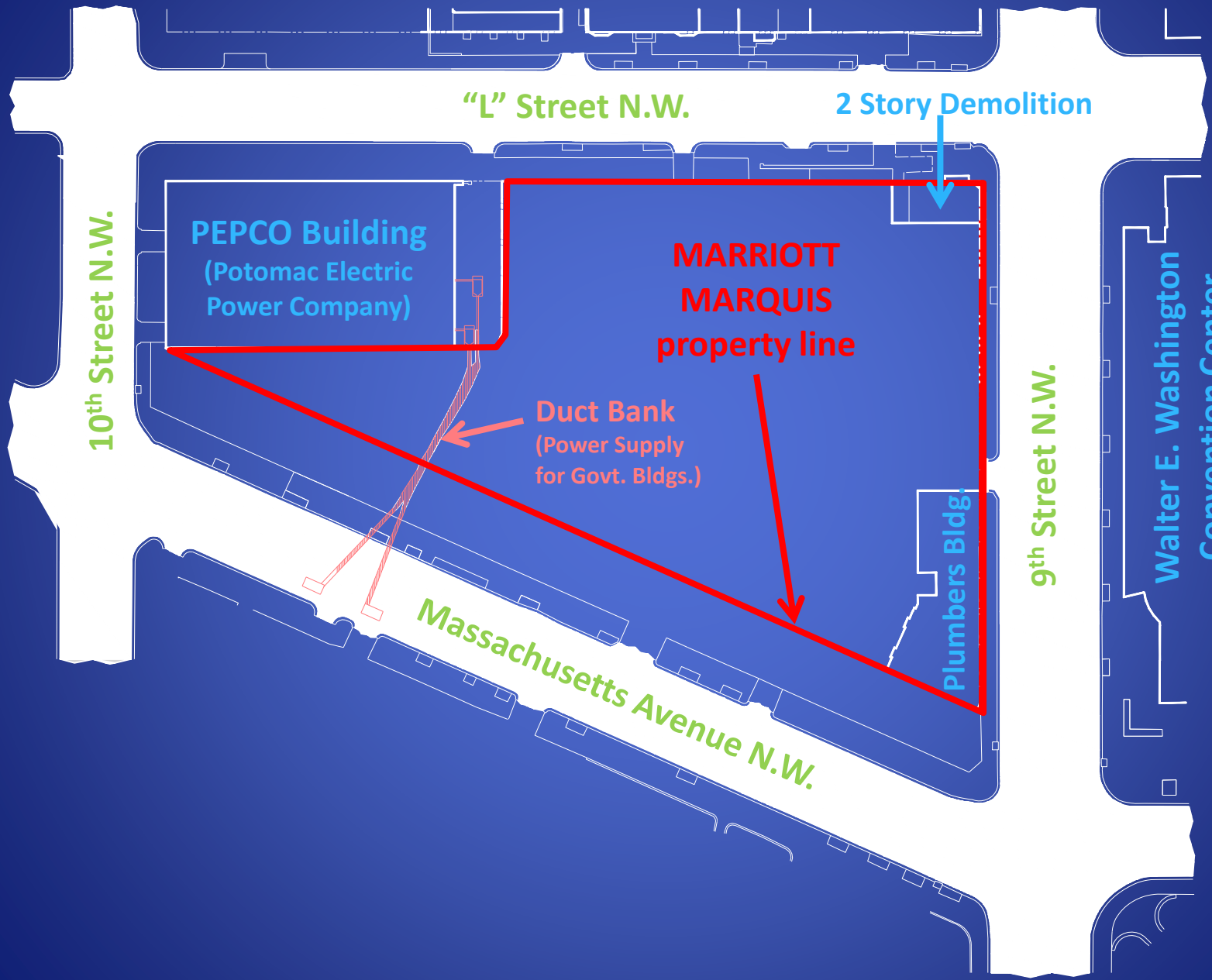
***Opened September 2014***

Photos courtesy of Thornton Tomasetti

# Soil Profile



# Site Plan


"L" Street N.W.
2 Story Demolition
10th Street N.W.
PEPCO Building
(Potomac Electric
Power Company)
MARRIOTT
MARQUIS
property line
Duct Bank
(Power Supply
for Govt. Bldgs.)
Plumbers Bldg.
9th Street N.W.
Walter E. Washington
Convention Center
Massachusetts Avenue N.W.

# Plumbers Building at South East End of Site


July 9, 2008

# Looking North at West End of Site


September 15, 2011

# Alternative Methods of Bracing and Protection Considered

- ✓ Underpinning Adjacent Structures
- ✓ Cross Lot Bracing
- ✓ Tie-Back Soil Anchors
- ✓ Raker Braces
- ✓ Top-Down Construction

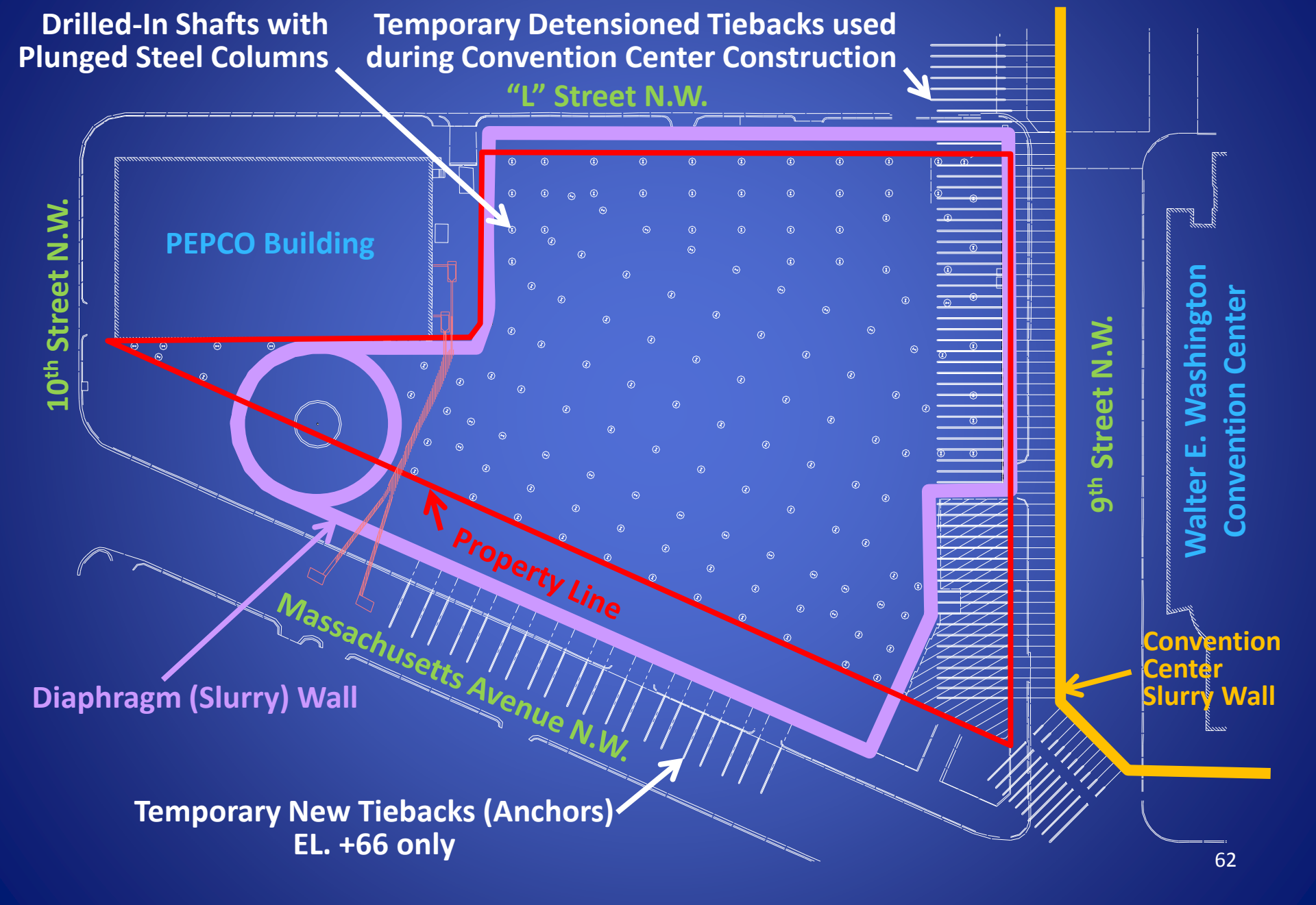
# Top-Down Method of Construction: *Sequence*

- ✓ Install slurry wall & drilled shafts / basement plunge columns
- ✓ Excavate to 1st basement level & construct basement floor as brace
- ✓ Excavate below floor; install 2nd basement floor
- ✓ Install plate girders above ballrooms
- ✓ Begin superstructure construction
- ✓ Continue to progressively excavate & construct permanent underground floors as bracing

# Top-Down Method of Construction: *Benefits*

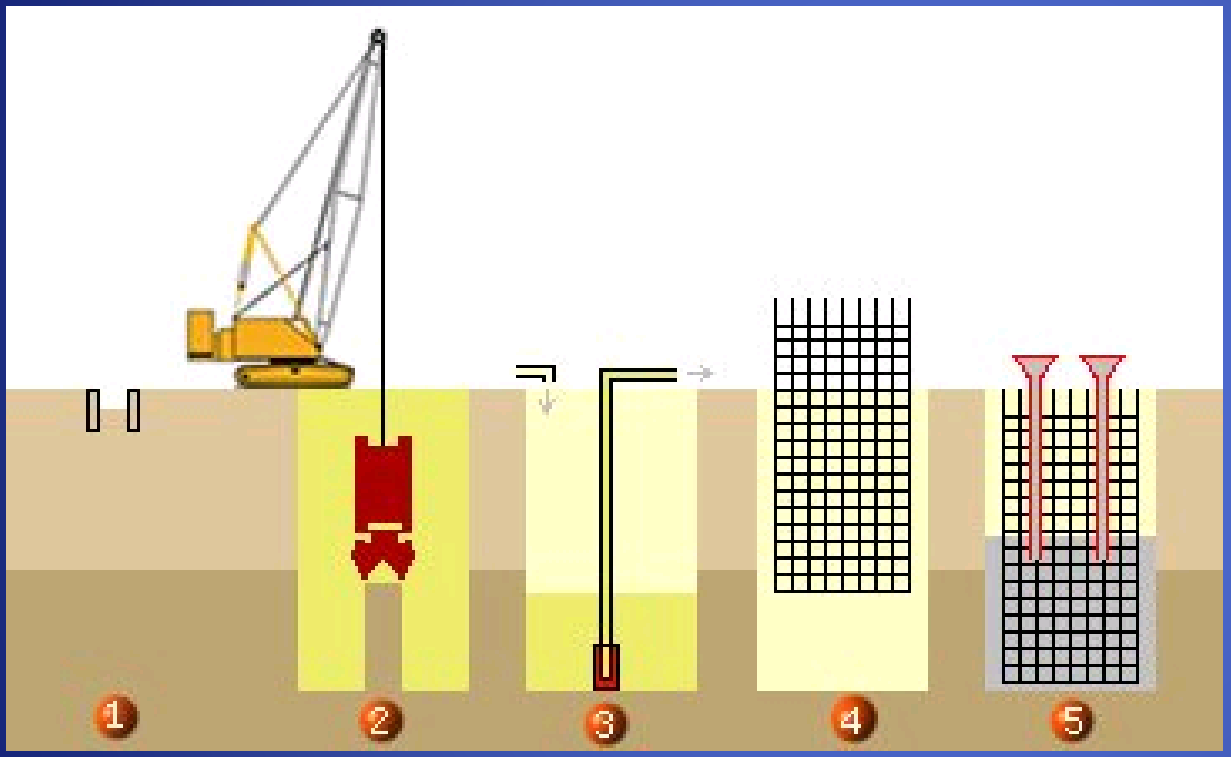
- ✓ Ideal for urban sites, deep excavations & wide construction sites
- ✓ Stiff bracing system minimizes impact on adjacent structures
- ✓ Avoids costly underpinning of adjacent structures
- ✓ Speeds up project completion as superstructure starts before excavation is completed
- ✓ Reduces project financing costs

# Diaphragm Wall & Drilled Shafts Layout Plan



# Slurry Wall Construction

Washington D.C. Marriott Hotel

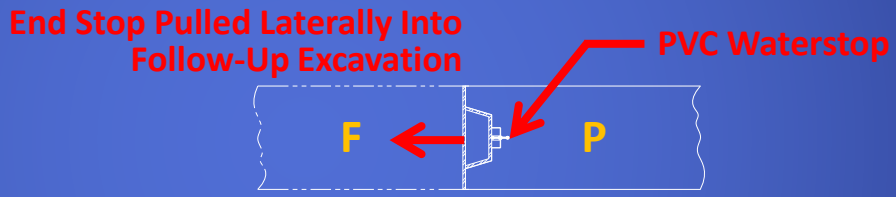



1. Construct guide walls
2. Excavate panel
3. Desand excavated panel
4. Install rebar cage
5. Place concrete

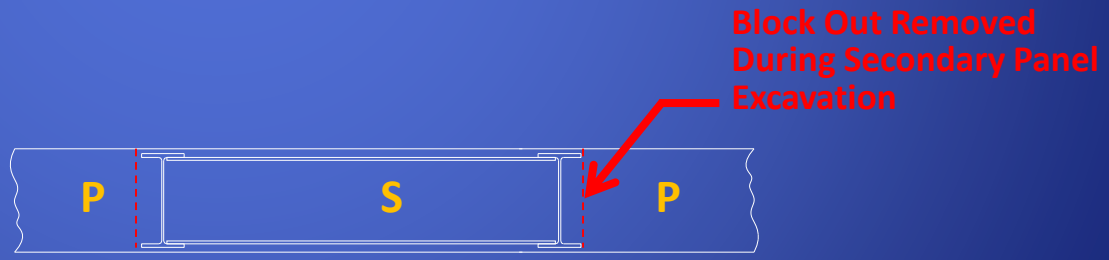
# End Stops Used In Slurry Wall Construction

## Typical Joint
20’ to 24’ Primary
and 9’-3” Secondary


## Water Stop Joint
(Used Along 9th Street)
(20’ to 24’ Panels)



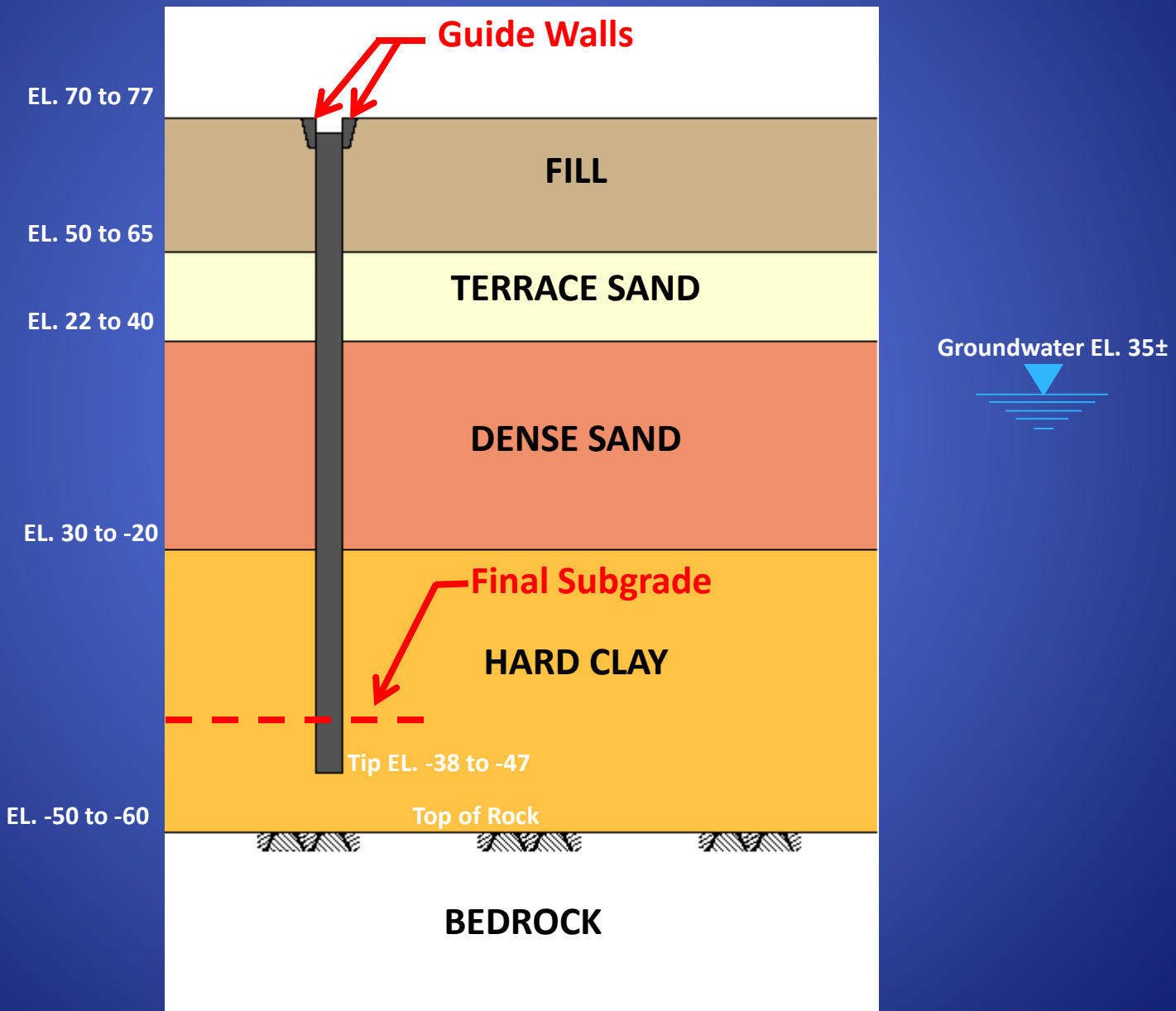

## Steel Beam (w) Joint
(used below shallow utilities)



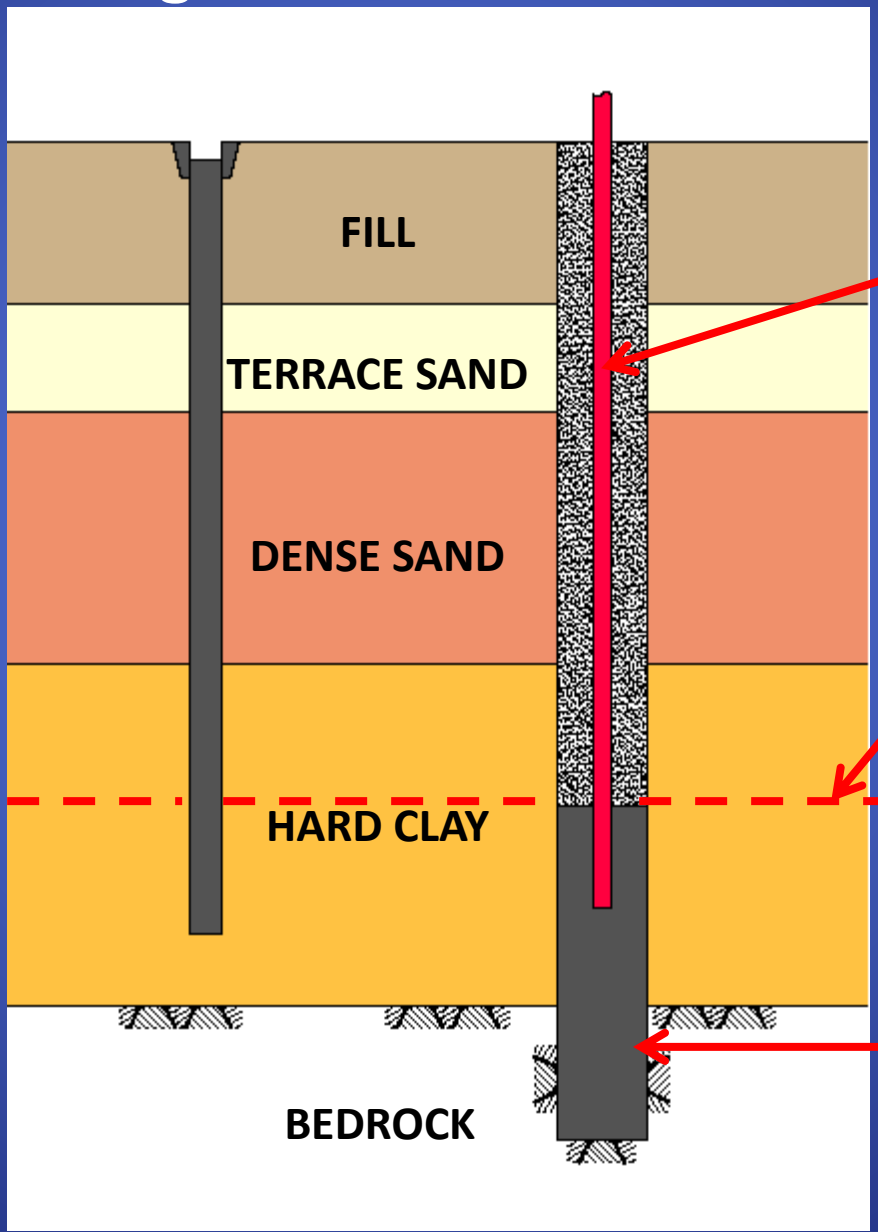

**KEY**
P = Primary Panel
S = Secondary Panel
F = Follow-up Panel

# Diaphragm (Slurry) Wall Construction

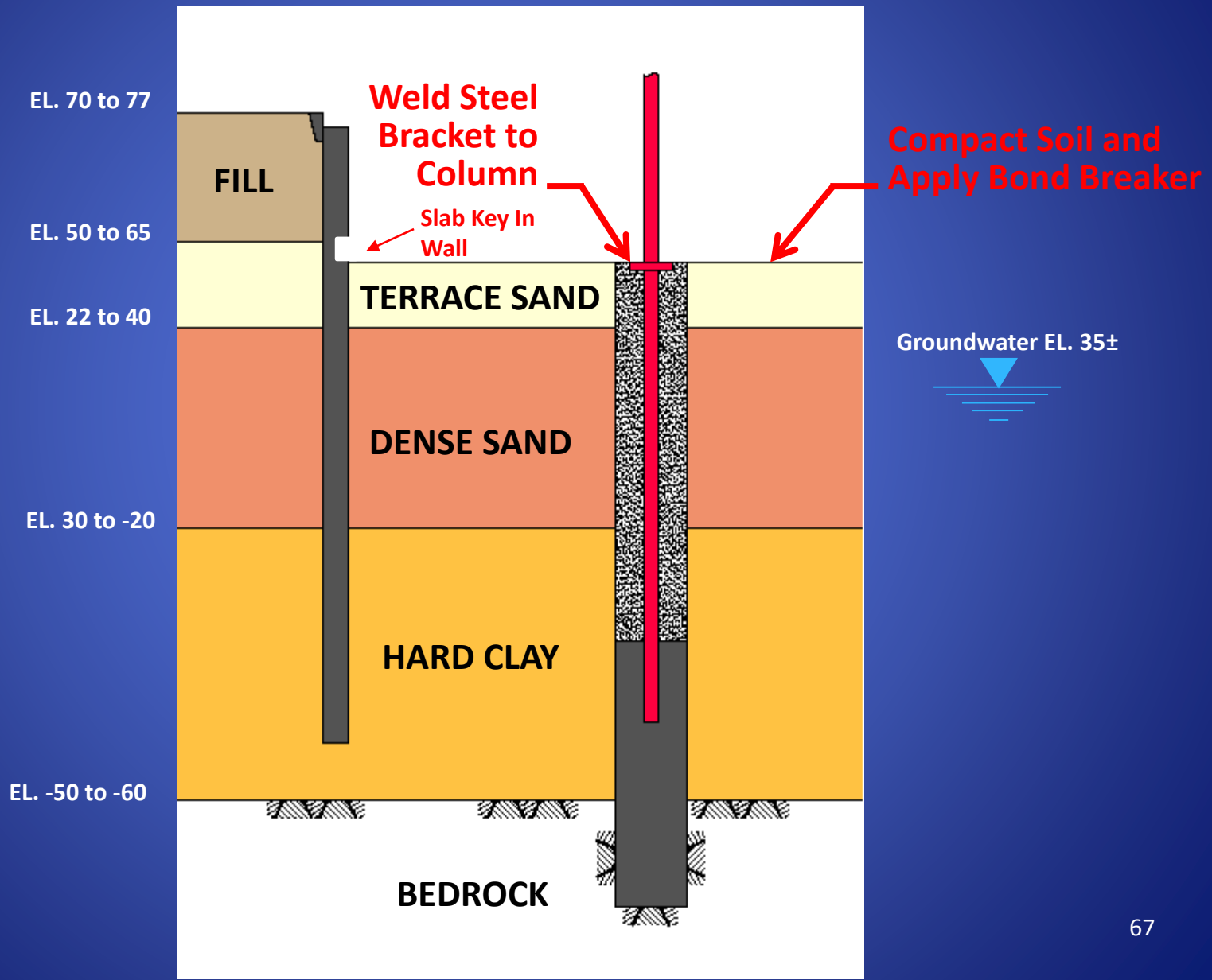
## *(Supports Exterior of Building)*



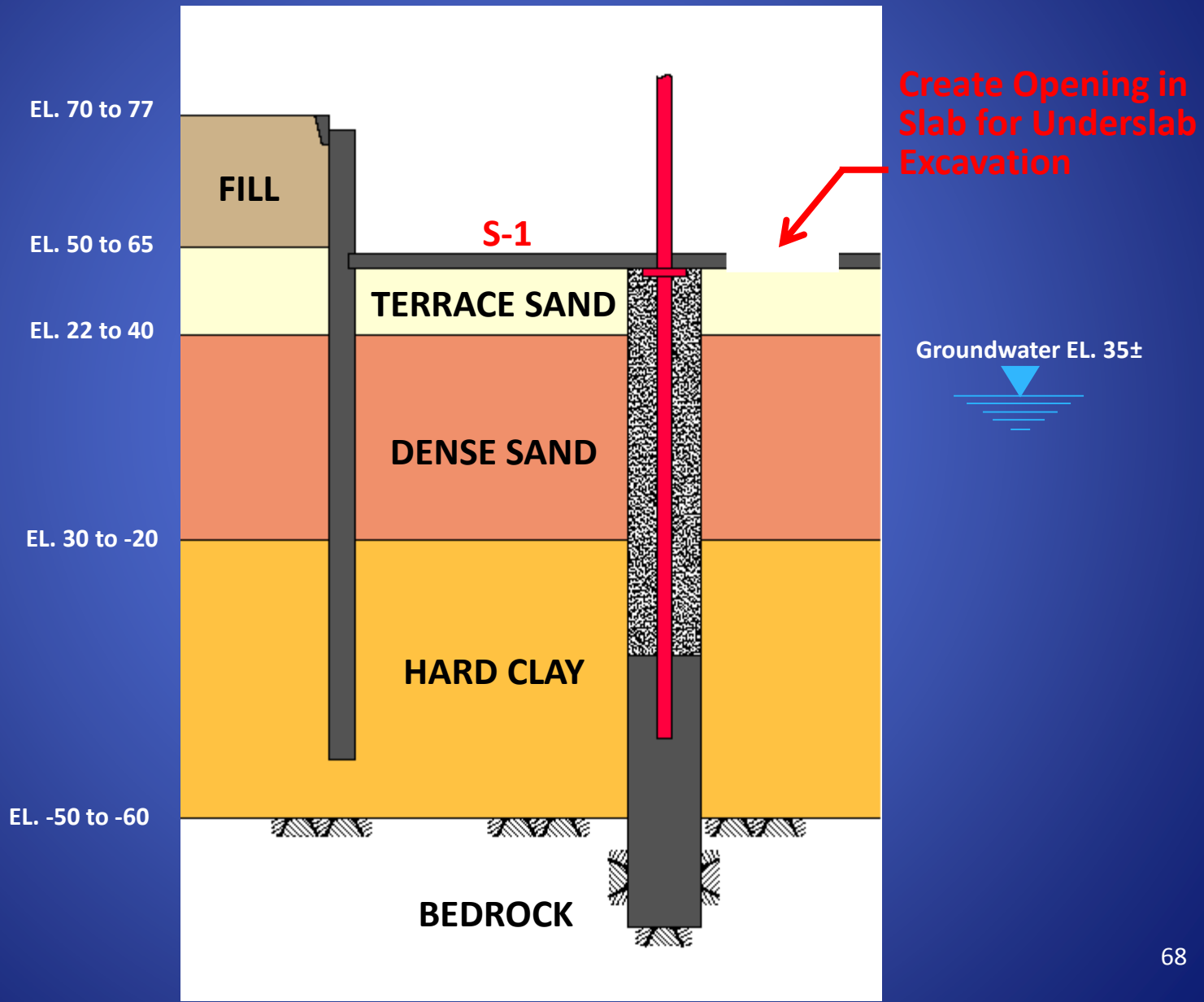
# Drilled Shaft Construction and Plunge Columns Installation



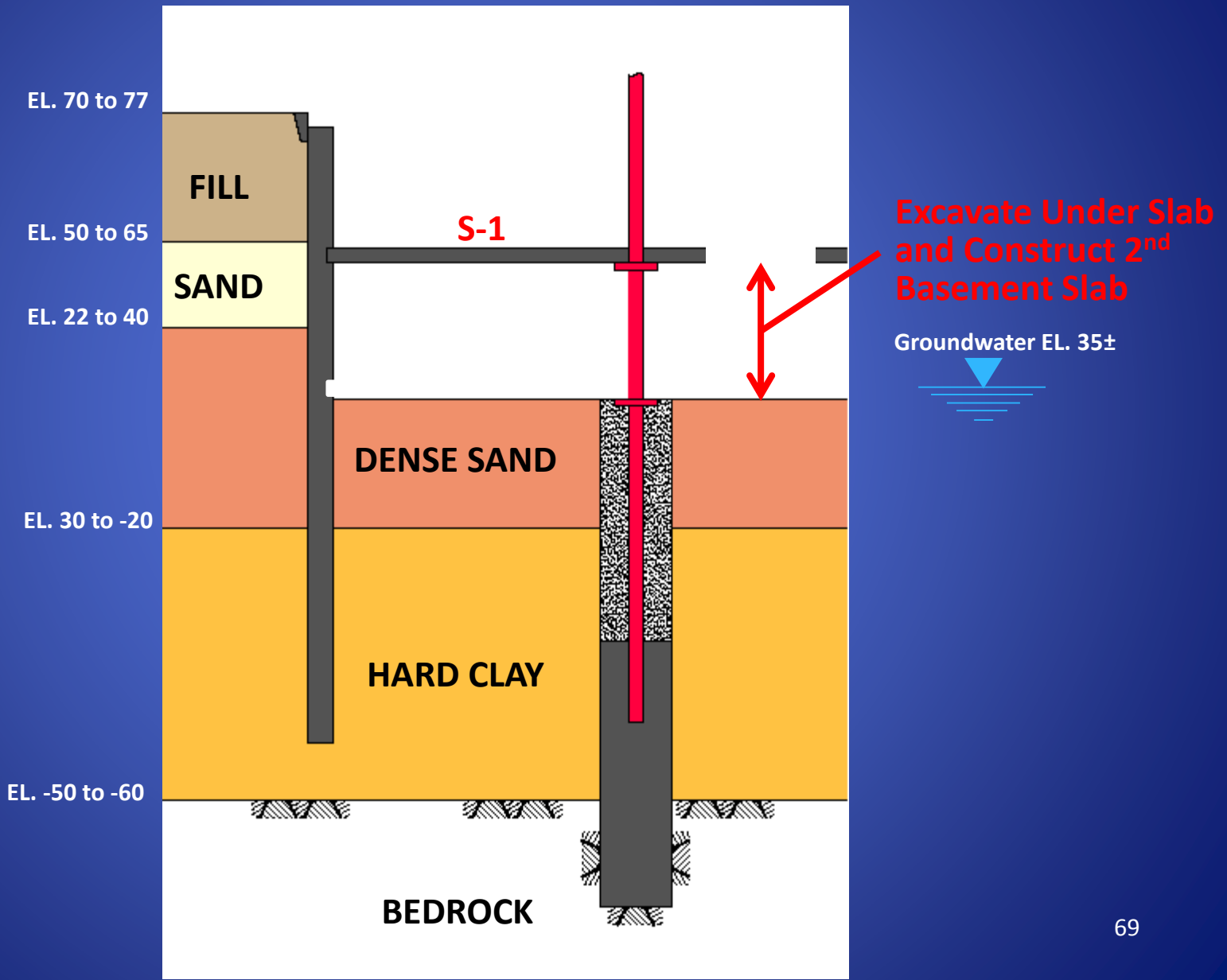
# Excavation for 1st Basement Slab Construction



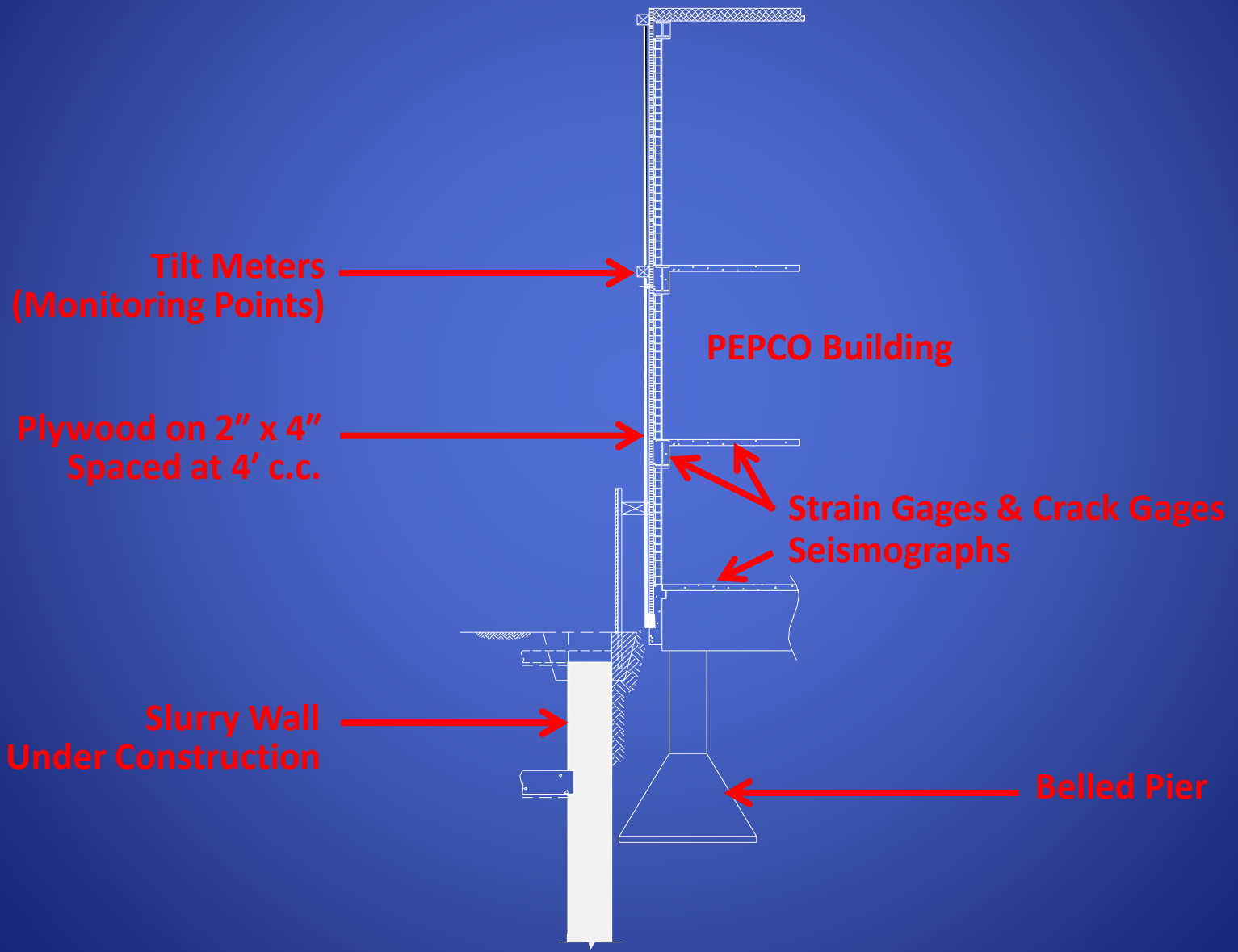
# Construct 1st Basement Slab



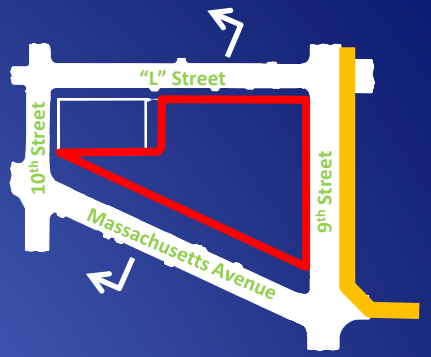
# Excavation for 2nd Basement Slab Construction



# Protection & Monitoring of Existing Building During Slurry Wall Construction



# Section Looking West




Mass. Ave.

"L" Street

EL. +70

Steel Plate Girders

Upper Ballroom

Steel Girders

Lower Ballroom

Parking Garage

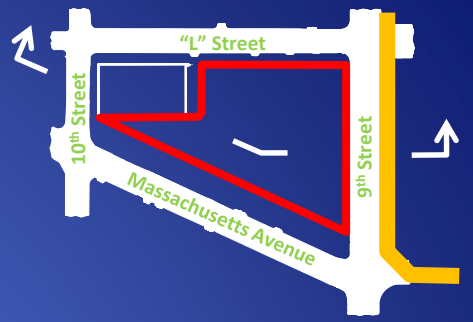
Parking

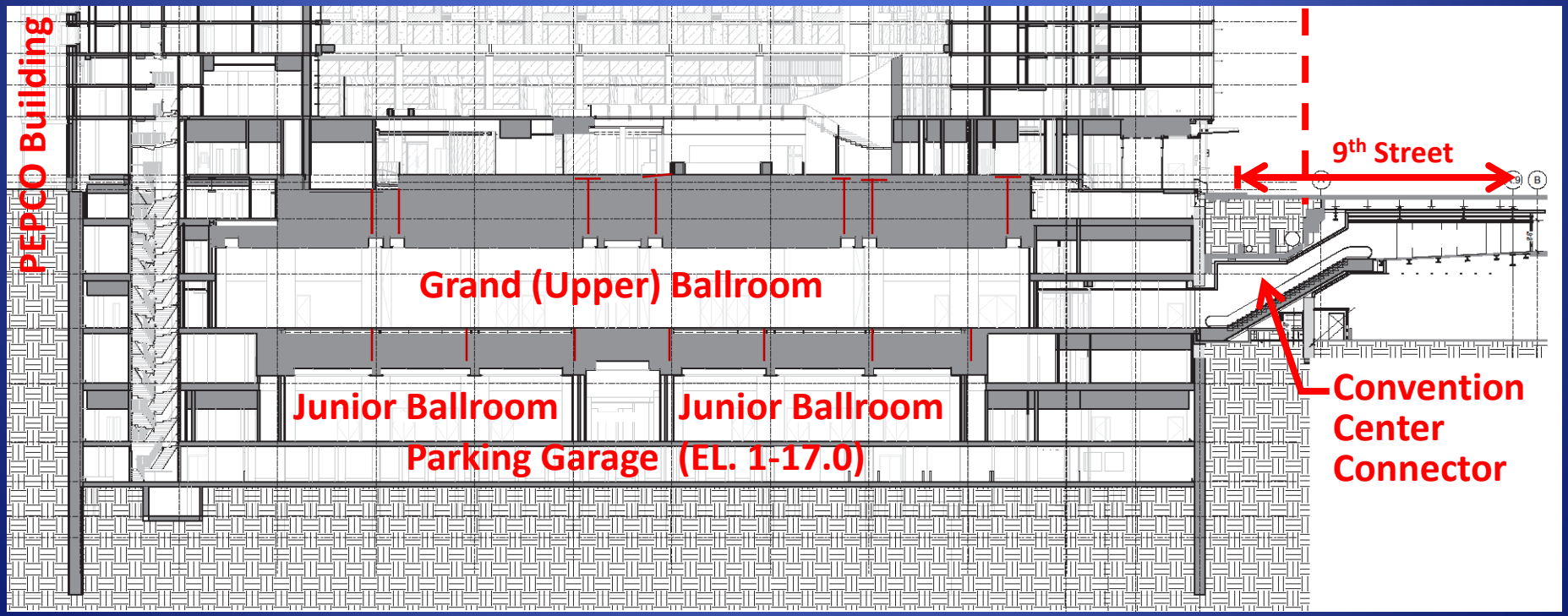
Mechanical

EL. -16

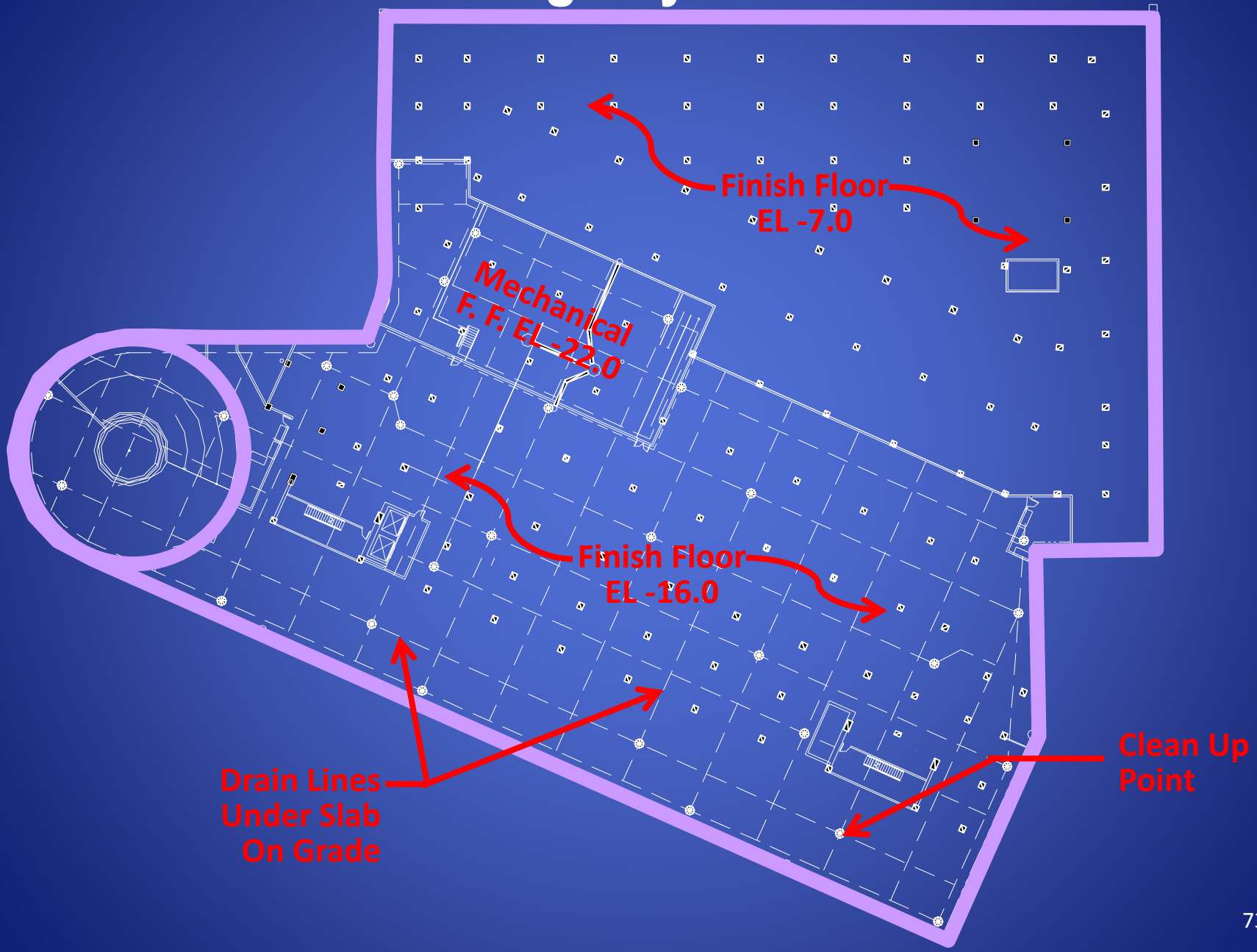
EL. -22

# Section Looking North

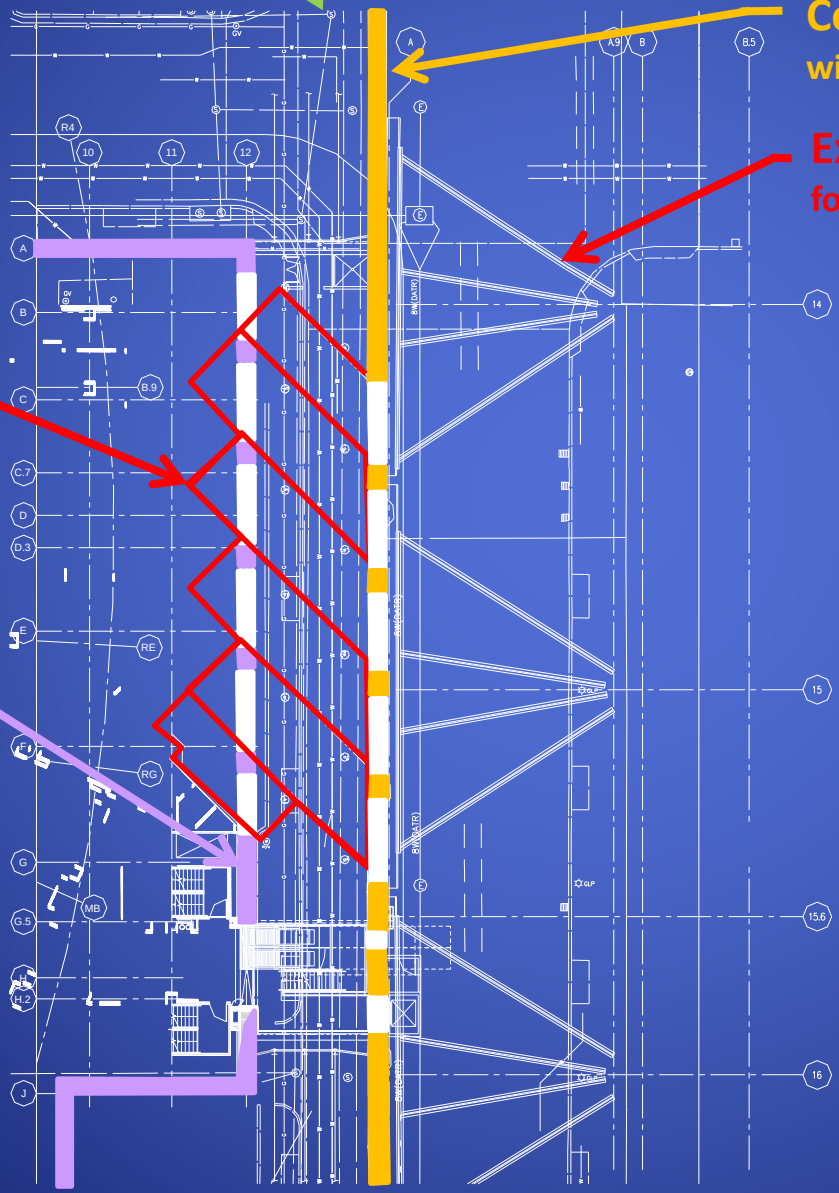


# Underslab Drainage System – Lower Level



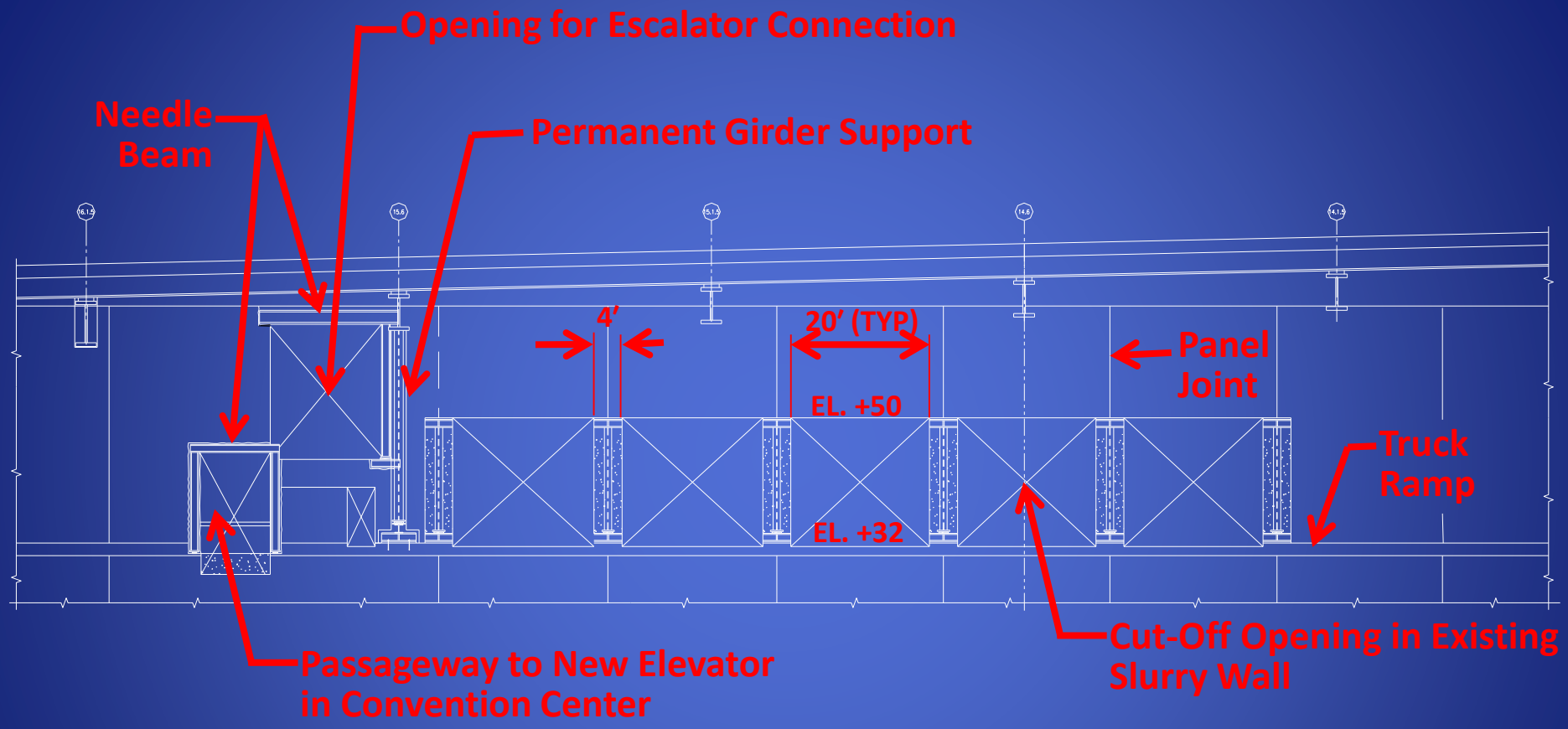
# Truck Loading Dock Cut-Off Openings in Slurry Walls




## Excavation Sequence

1. Install paired hydraulic jacks for each strut
2. Incrementally load jacks to full load
3. Disconnect the bracing system from slurry wall
4. Sequentially excavate in 5 foot lifts. Release jack loads 5 kips for each 5 feet of excavation.
5. After excavation is complete, shim and grout between wall and wales and remove jacks.

# Convention Center Slurry Wall – Looking West




**Construction Procedure**

1. Cut 4'0" Wide Slot at Panel Joints
2. Place Stub Columns in Slots for Panel Support
3. Cut-Off and Form Openings

# Looking North at West End of Site


September 15, 2011

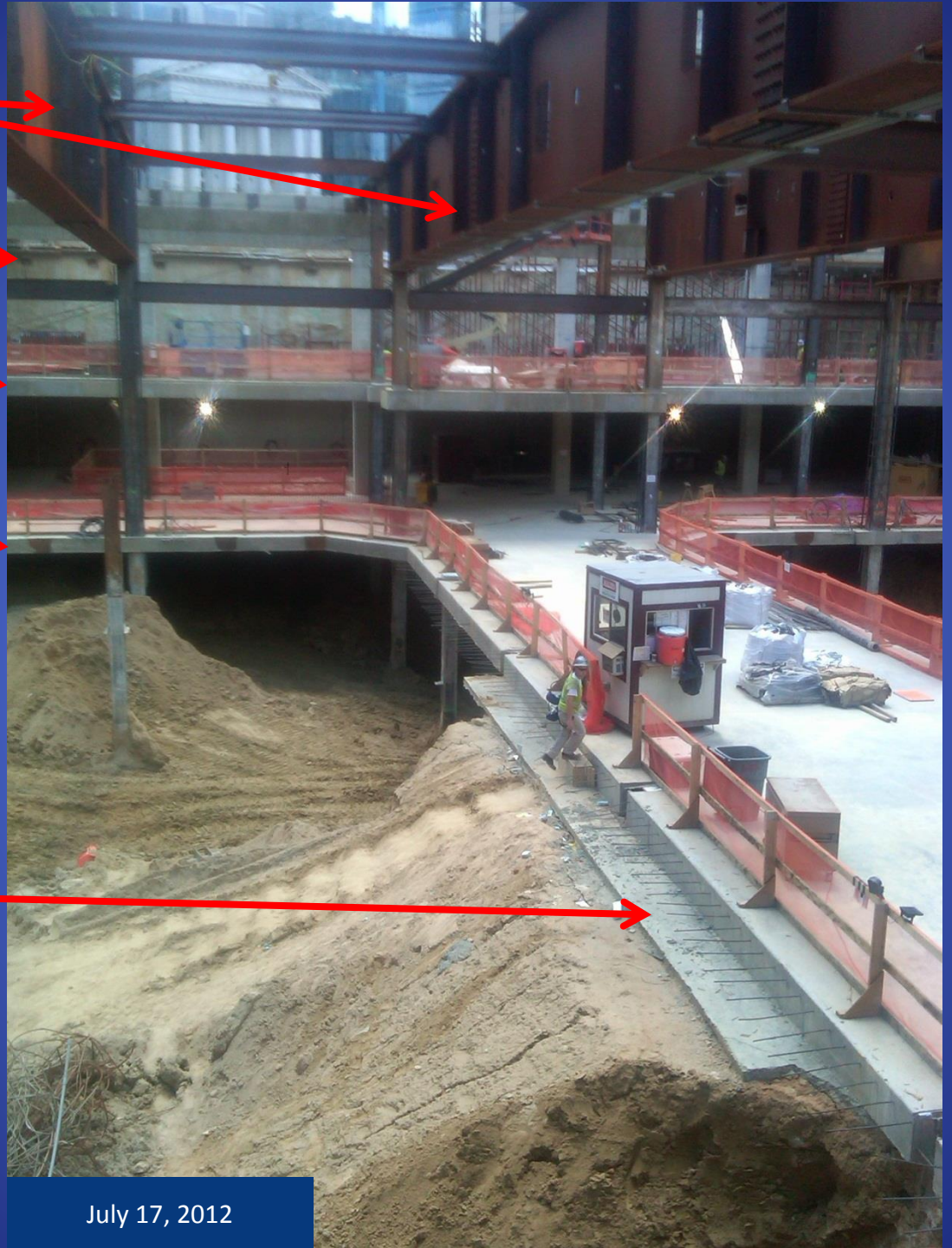
# Helical Ramp Shaft :
## *Shaft Excavation*


September 15, 2011

# Helical Ramp Shaft : *Inner Shaft Constructed*

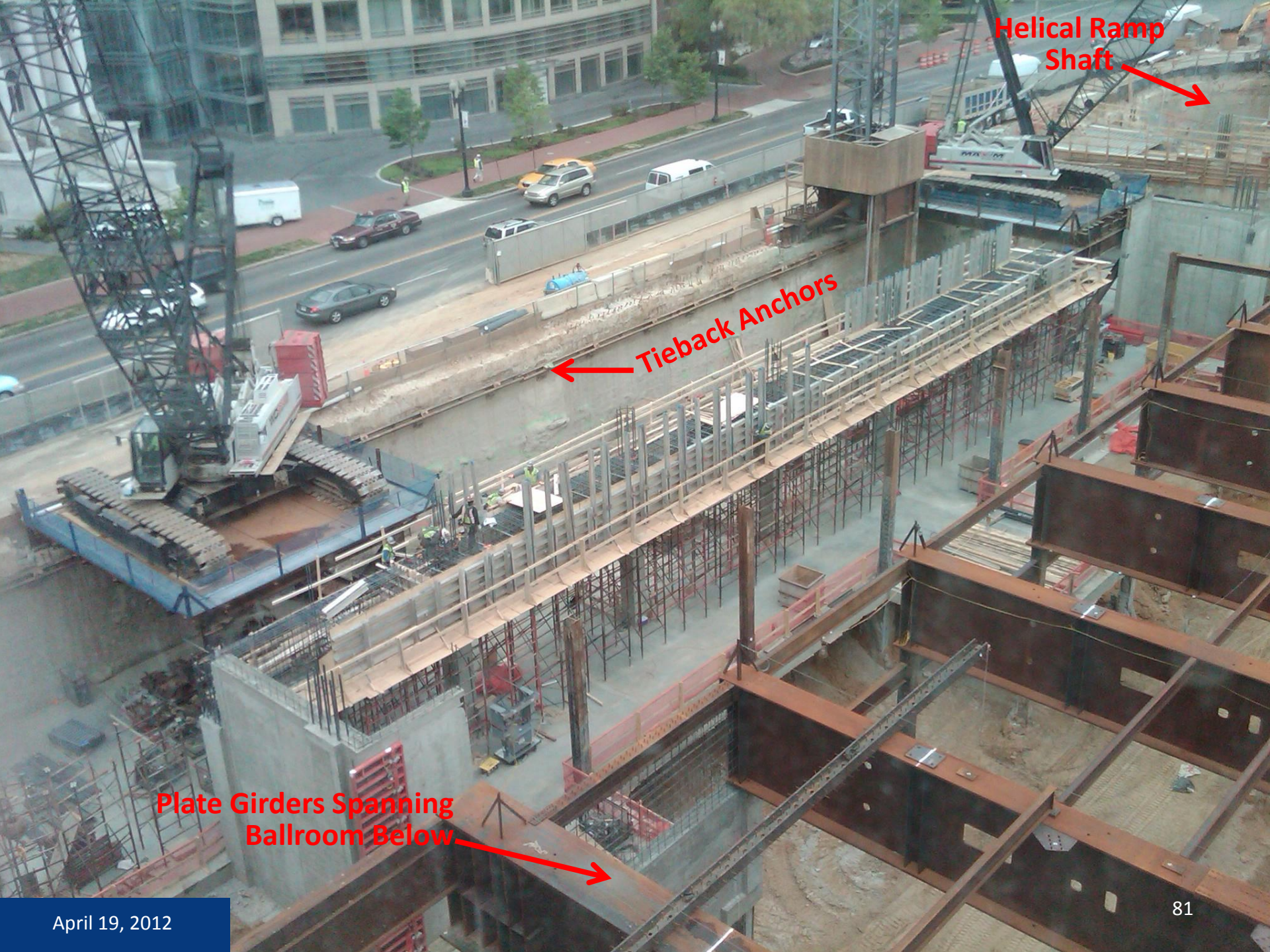
October 19, 2011

February 16, 2012


Ballroom Plate Girders
Tieback Anchors
S-2 Slab
S-3 Slab
Bondbreaker

July 17, 2012


S-1 Slab Completed
Excavation Openings
Preparation for S-2 Slab


Helical Ramp Shaft
Tieback Anchors
Plate Girders Spanning Ballroom Below

# Conclusions

- ✓ Innovative use of Top-Down Construction resulted in the successful 97' deep excavation
- ✓ Use of “hydro-mill” to install “water stop” shear keys simplified slurry wall construction
- ✓ Benefits of Top-Down Construction include:
  - Resulting stiff bracing system eliminating need to underpin adjacent structures
  - Simultaneous construction below and above grade resulting in shorter construction schedule and lower project costs

# DC Marriott Marquis Team

| | |
|---|---|
| *Owner:* | *Marriott International* |
| *Architect:* | *Cooper Carry Architects*<br>*TVS Architects JV* |
| *Construction Manager:* | *Hensel Phelps Construction Co.* |
| *Structural Engineering:* | *Thornton Tomasetti* |
| *Slurry Wall / Tie back anchor Subcontractor:* | *East Coast Slurry Company /*<br>*Trevi Icos JV* |
| *Foundation Engineer:* | *Mueser Rutledge*<br>*Consulting Engineers* |
| *Geotechnical Engineer* | *Schnabel* |

*Thank you!*

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