



Hazard Assessment Study: Westside Subway Extension Project Century City Area, California

Exponent - Failure Analysis Associates

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February 7, 2012





Exponent Assignment

Perform engineering and scientific peer review of Metro reports:

- Subway tunneling and station construction in seismic fault zones,
- Construction and operation of Subway under Beverly Hills High School buildings
- Impact of tunneling construction and operating a Subway under other facilities, infrastructure in the City, both under private property and within the public right-of-way.



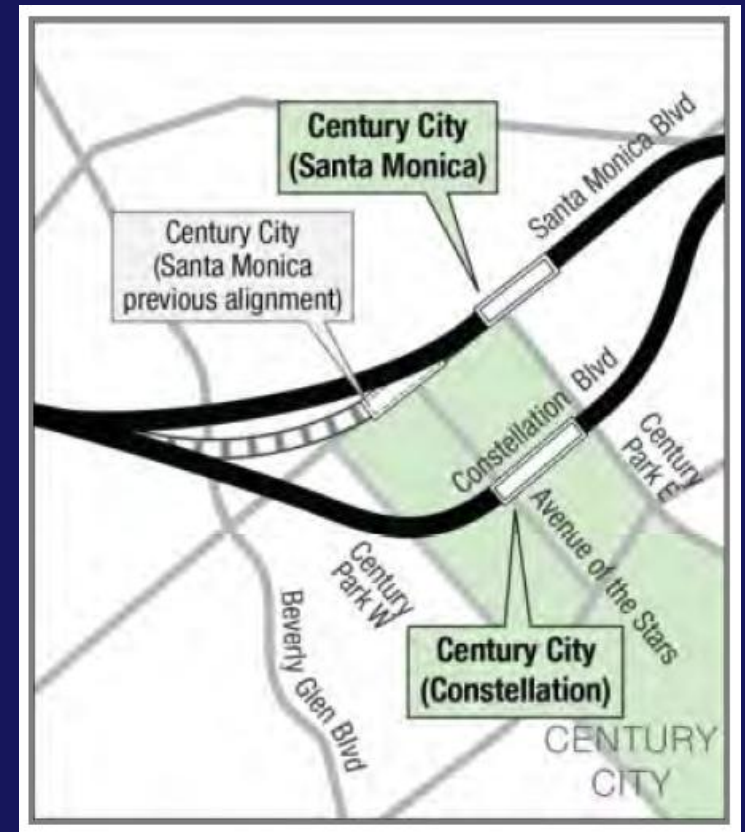
Exponent's Project Team

- **Piotr D. Moncarz, Ph.D., P.E., SCPM**
 - Overall project management
- **Philip J. Shaller, Ph.D., P.G., C.E.G.**
 - Seismological and geological aspects
- **Subodh R. Medhekar, Ph.D., P.E., CRE**
 - Tunneling risk assessment
- **Jeffrey P. Hunt, Ph.D., P.E.**
 - Gas methane and oil well hazards
- **Eric R. Ahlberg, Ph.D., P.E.**
 - Tunneling impact on buildings and infrastructure



Outline

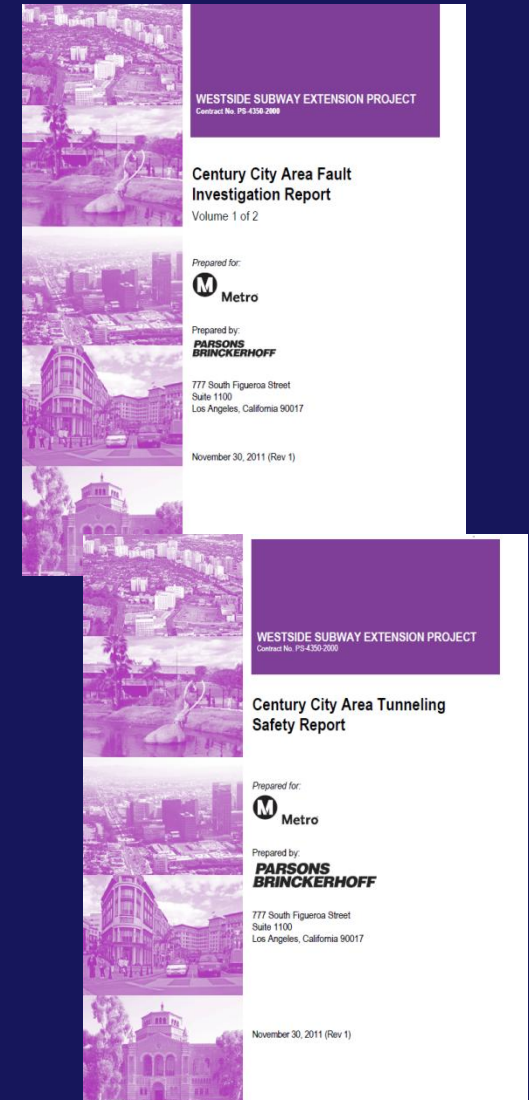
- Risk Assessment Overview
- Santa Monica Station
- Constellation Station
- General Tunneling Hazards
- Potential Future Steps





LA Metro Reports

- “Century City Area Fault Investigation Report”
 - Study of active fault traces near proposed stations and tunnel alignments
- “Century City Area Tunneling Safety Report”
 - Tunnel alignment options
 - General tunneling hazards



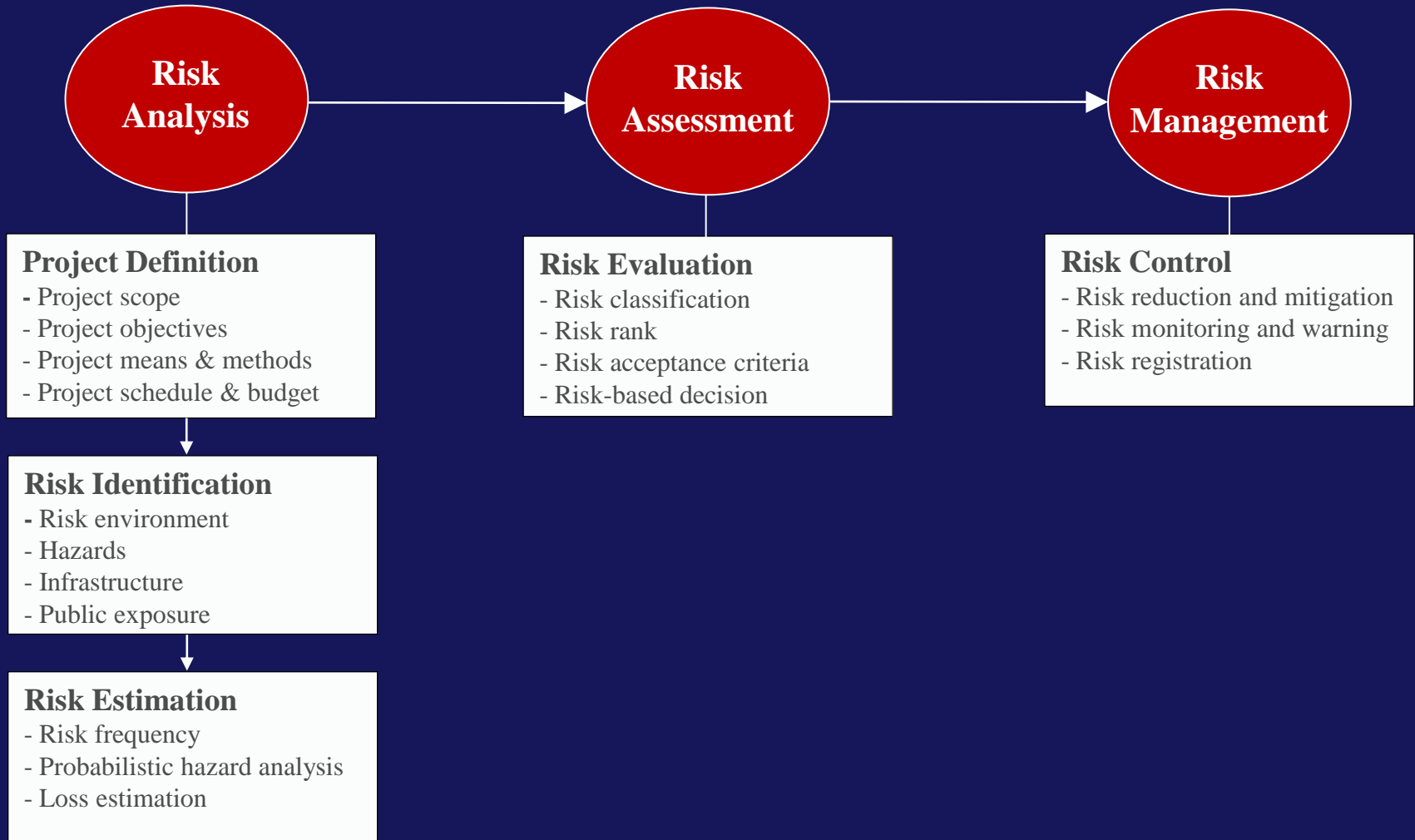


Risk Assessment

- LA Metro reports outline several hazards
- No relevant risk assessment(s) presented to date
- For a project of this magnitude, one would expect:
 - Qualitative Risk Analysis (i.e. Hazard and Operability Study)
 - Quantitative and Probabilistic Risk Analysis with Fault Tree Analysis approach
 - Consequence modeling (fire/explosion, gas seepage, etc.)



Risk Assessment – Flowchart (from Hu *et al.*, 2007)





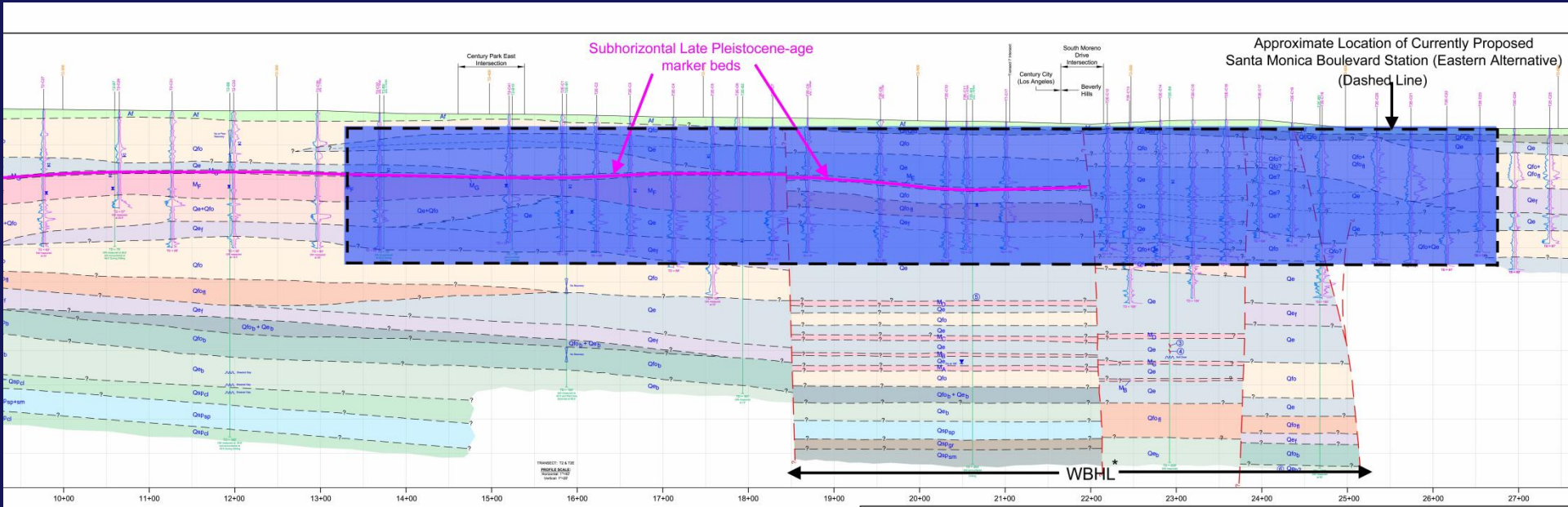
Santa Monica Station

- **Suggested new faults within West Beverly Hills**
Lineament made in the Metro reports are based on inferences from borings rather than direct observation
- **The contention that the faults, if real, are active and would cause excessive deformations in the event of an earthquake is an inference built on an inference**



Santa Monica Station – Geological Profile

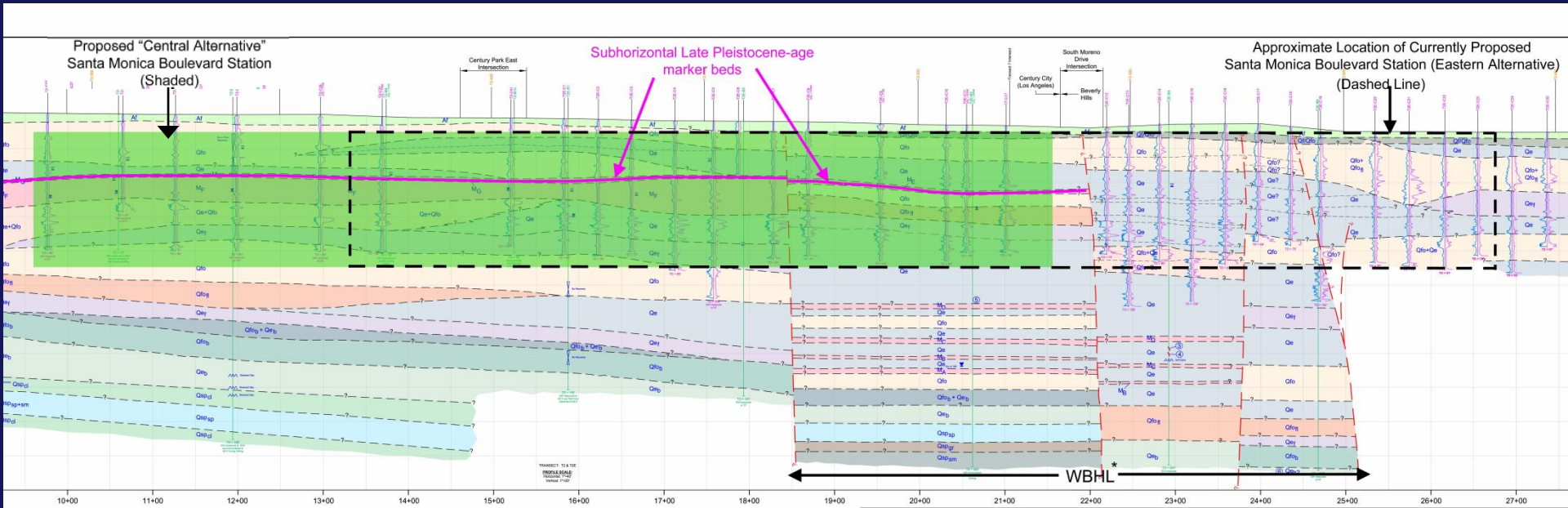
Currently Proposed Station Option





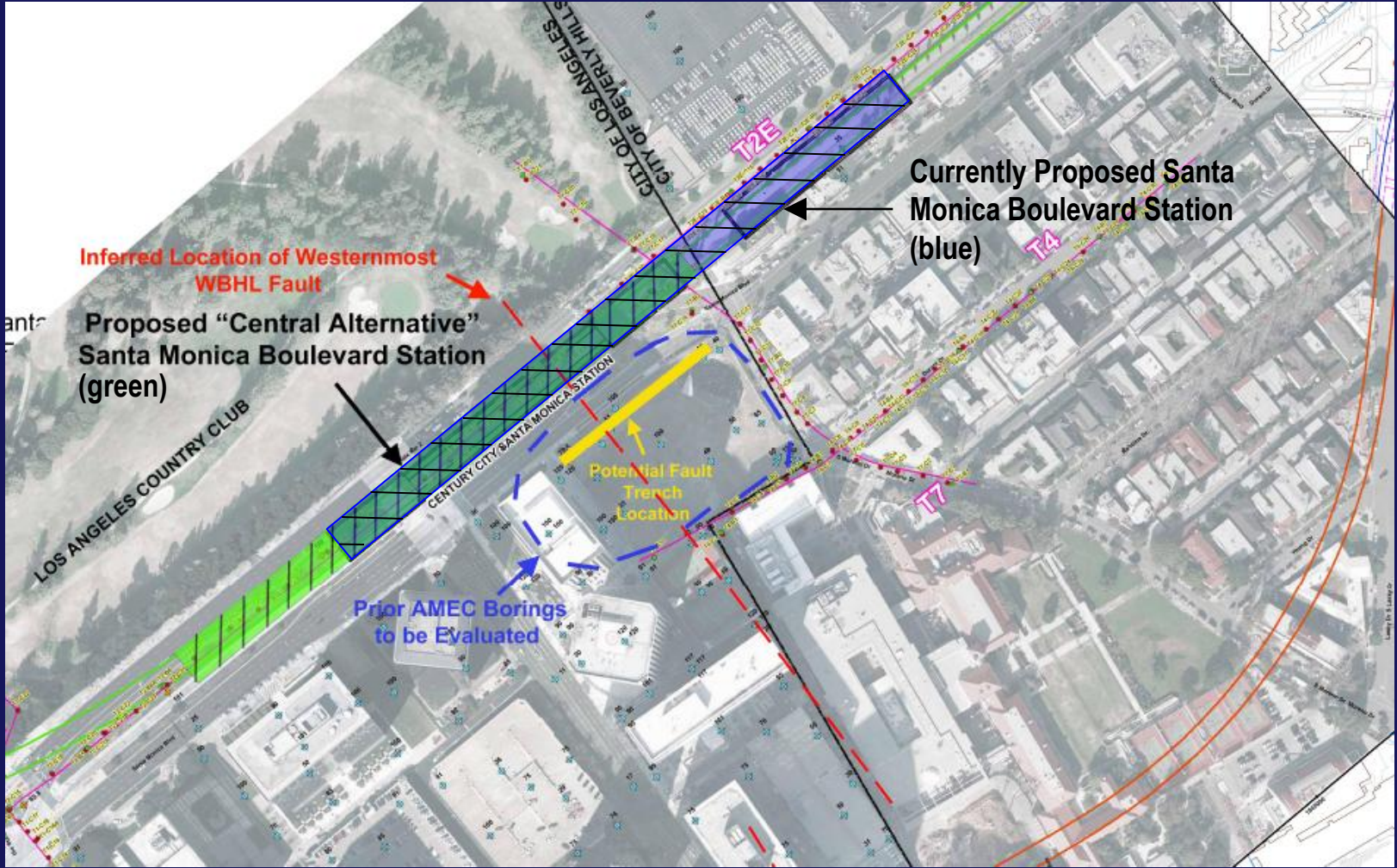
Santa Monica Station – Geological Profile

“Central Alternative” Station Option





Santa Monica Station - Additional Investigations





Constellation Station

- **Nearest inferred fault trace to the Constellation Station is very poorly constrained due to the 450-foot gap between the bracketing borings used to make the fault interpretation**
- **The inferred fault could be located much closer or even beneath the eastern end of the proposed station**



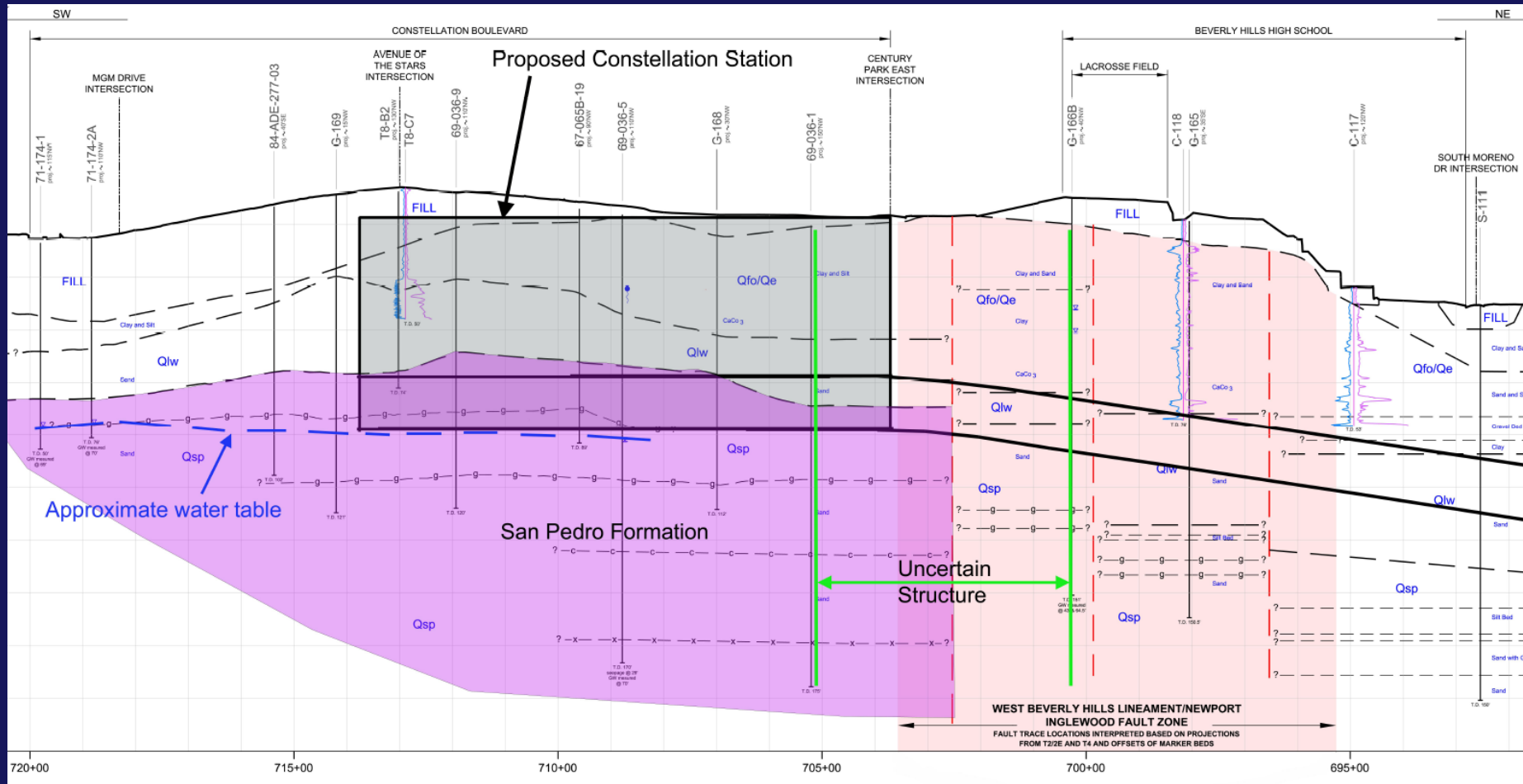
Constellation Station

Westside Extension Transit Corridor Study, Final Alternatives Analysis Report, Chapter 4.0 (January 2009) included the following recommendation:

“Minimize construction in the gas and tar bearing formations as much as possible, particularly the San Pedro Formation’s unsaturated zones. These zones were found to have high methane and hydrogen sulfide (H₂S) concentrations during explorations for Metro’s Mid-City alignments in the 1990’s.”



Constellation Station - Profile





Methane Gas Hazard

California Department of Toxic Substances Control (DTSC) “Advisory on Methane Assessment and Common Remedies at School Sites”

- “Methane sampling spacing generally requires a 100-foot grid system to screen the site.”
- “Reduce or monitor the potential for methane accumulation underneath proposed and/or current structures...”



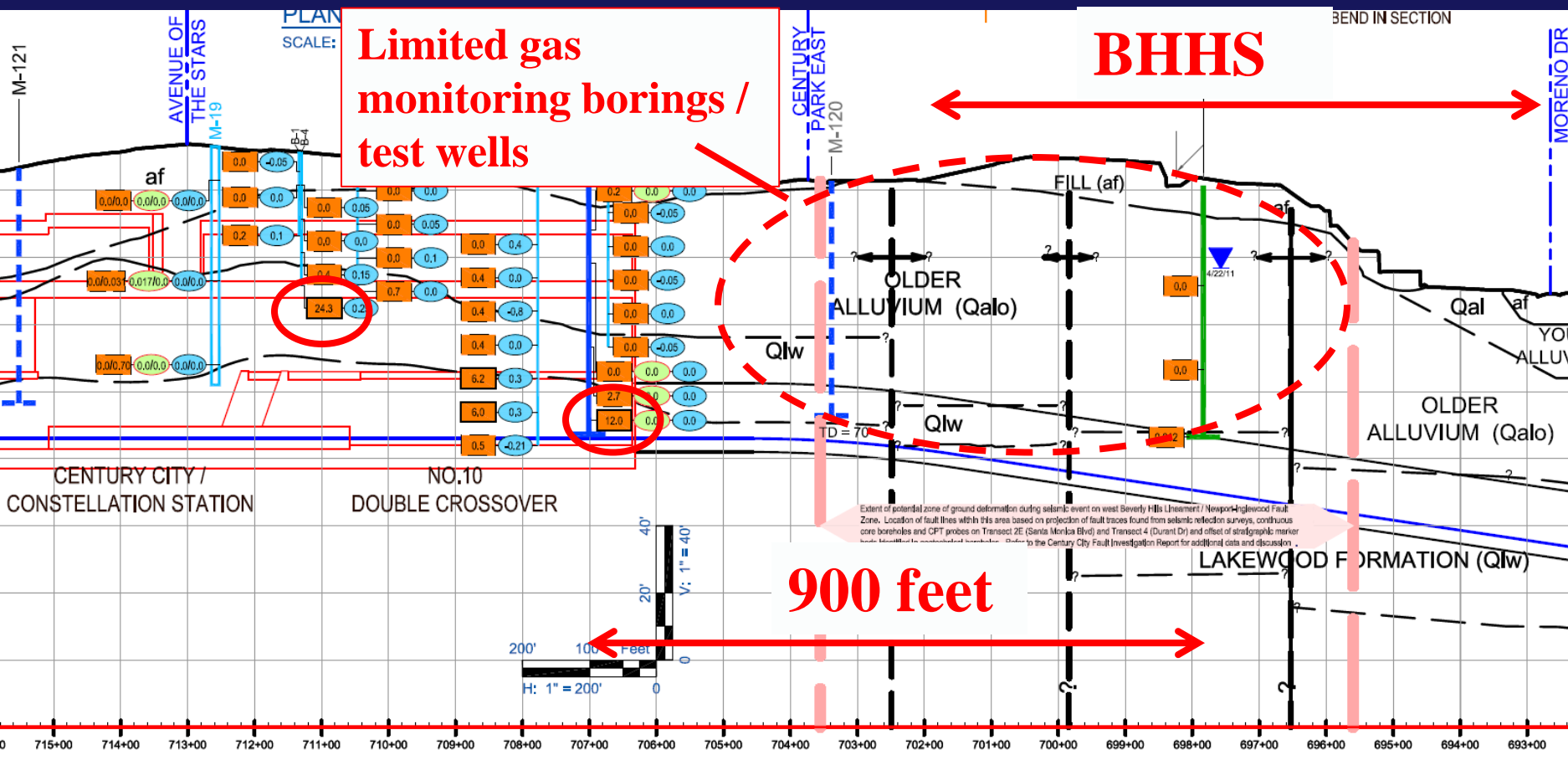
Methane Gas Hazard

California Department of Toxic Substances Control (DTSC) “Advisory on Methane Assessment and Common Remedies at School Sites”

“Any potential changes in site conditions that could have a significant impact on the subsurface methane concentration should be discussed and evaluated. Those areas for which the potential exists for methane to accumulate to the LEL immediately beneath a school building...should require mitigation.”



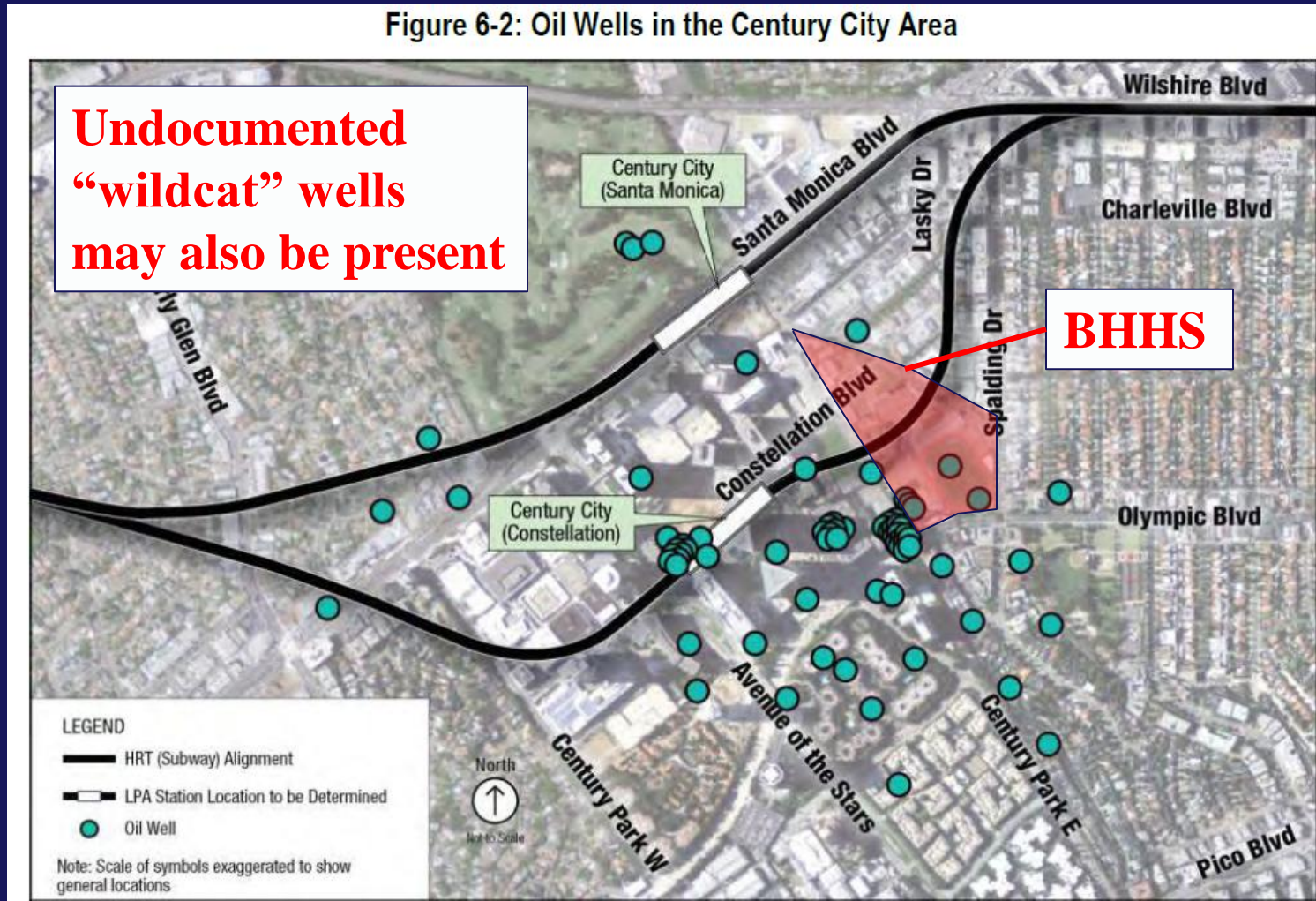
Constellation Station - Profile





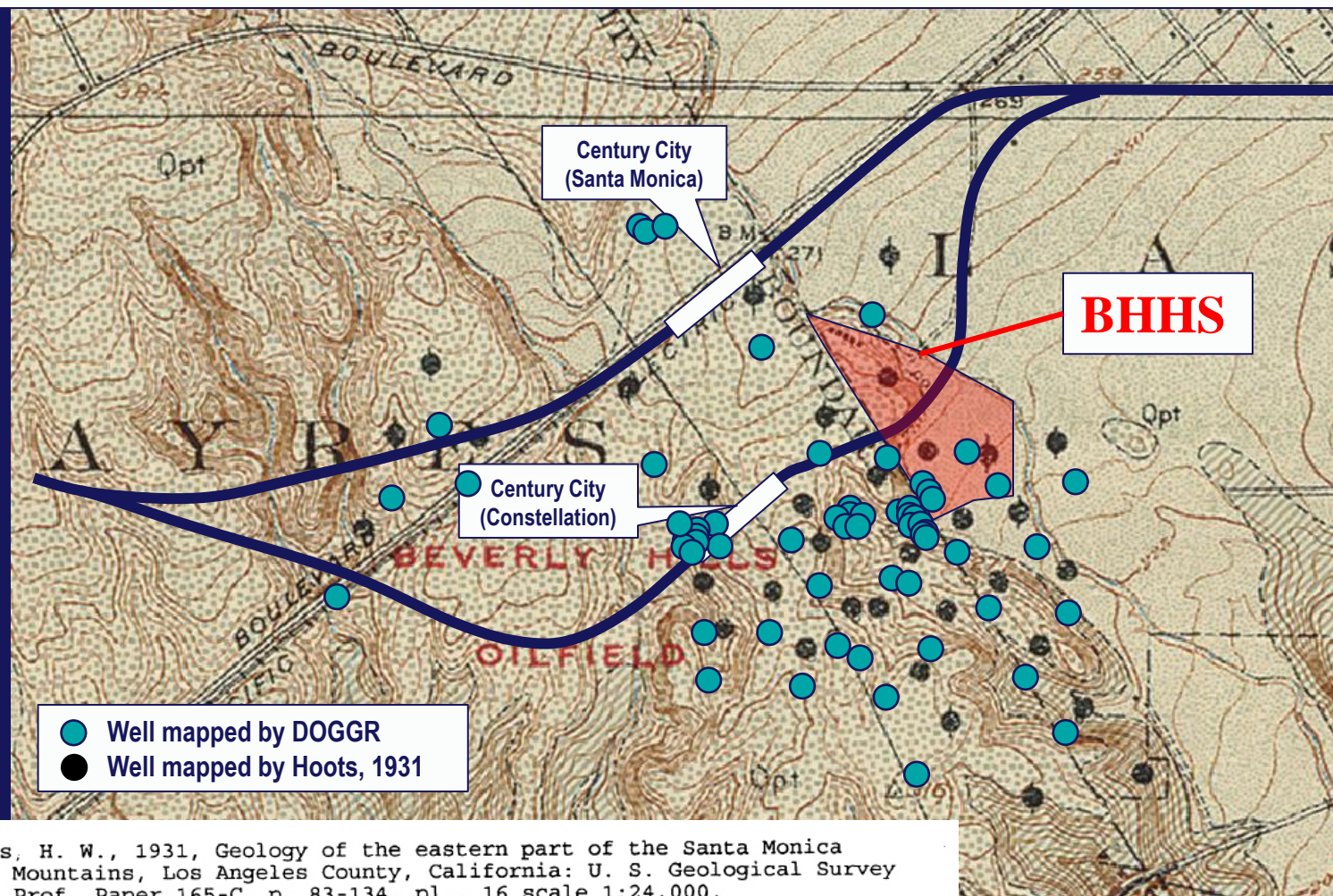
Abandoned Oil Wells (documented on DOGGR maps)

Figure 6-2: Oil Wells in the Century City Area





Abandoned Oil Wells (documented by Hoots, 1931)



Hoots, H. W., 1931, Geology of the eastern part of the Santa Monica Mountains, Los Angeles County, California: U. S. Geological Survey Prof. Paper 165-C, p. 83-134, pl., 16 scale 1:24,000.



Undocumented Oil Wells

- Undocumented oil wells have been encountered on past projects in LA area
- Oil wells can act as conduits for methane gas, allowing pockets of gas to form
- Considerable time and resources are needed to deal with abandoned oil wells when found during tunneling



Undocumented oil well encountered during ECIS project, Los Angeles



Abandoned, cemented oil well in Whitney Canyon, near Los Angeles

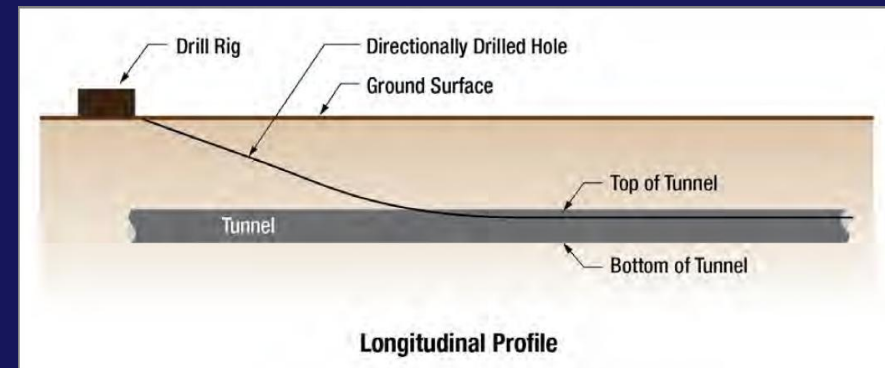


Undocumented Oil Wells

- LA Metro reports describe surface methods for locating undocumented oil wells
 - These methods have limited depth range
- Better methods for locating undocumented oil wells exist, including directional probing along the tunnel alignment



Magnetic scanning for oil well casings on lacrosse field of BHHS



Directional magnetometer probing for oil wells along tunnel alignment



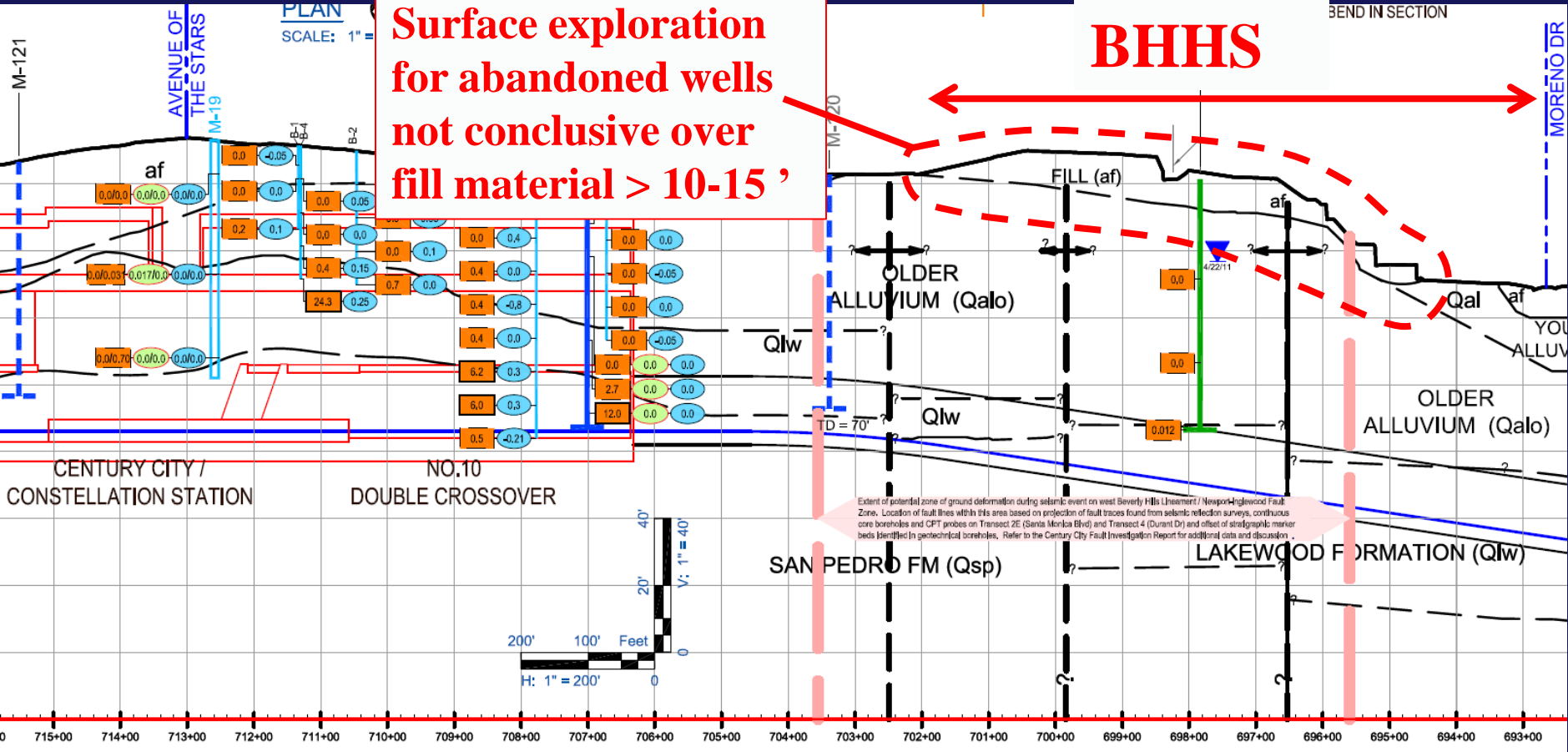
Constellation Station - Profile

Surface exploration for abandoned wells not conclusive over fill material > 10-15'

BHHS

BEND IN SECTION

MORENO DR

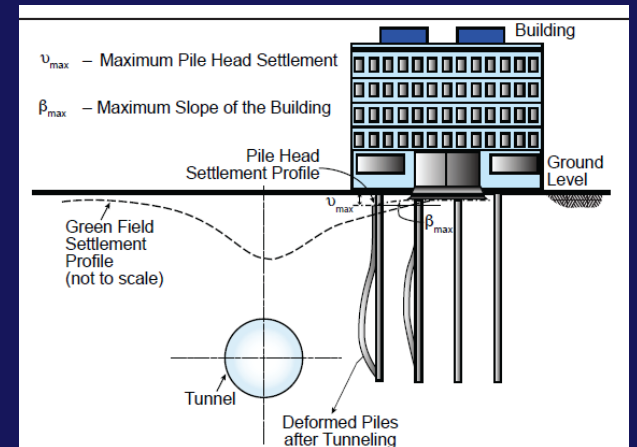


Extent of potential zone of ground deformation during seismic event on west Beverly Hills Lineament / Newport-Inglewood Fault Zone. Location of fault lines within this area based on projection of fault traces found from seismic reflection surveys, continuous core boreholes and CPT probes on Transect 2E (Santa Monica Blvd) and Transect 4 (Durant Dr) and offset of stratigraphic marker beds identified in geotechnical boreholes. Refer to the Century City Fault Investigation Report for additional data and discussion.



Damage from Soil Settlement

- Potential damage to overlying buildings
- Potential damage to underground utilities





BHHS Campus Restrictions

- Due to the hazards, campus buildings would need to be evacuated during tunneling
- Accommodations would need to be made for BHHS students and staff
- Potential impact of tunnels on future BHHS construction

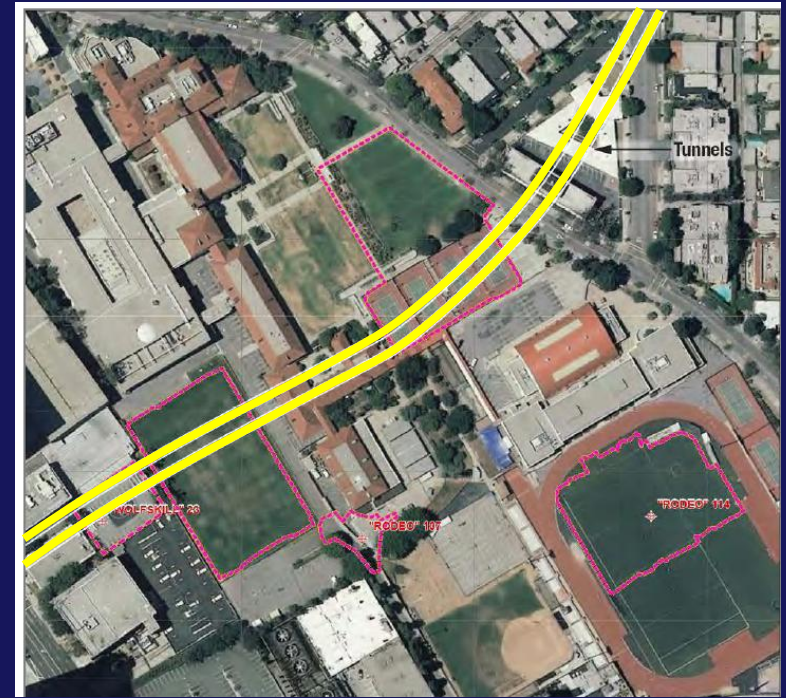
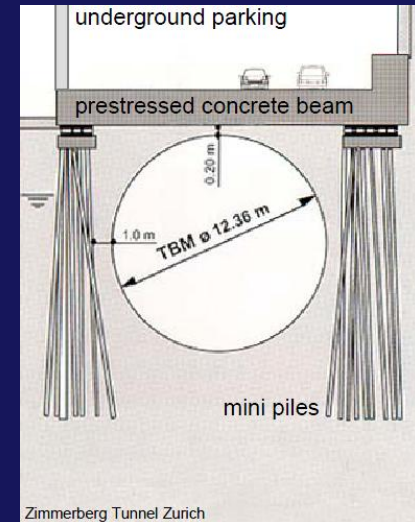
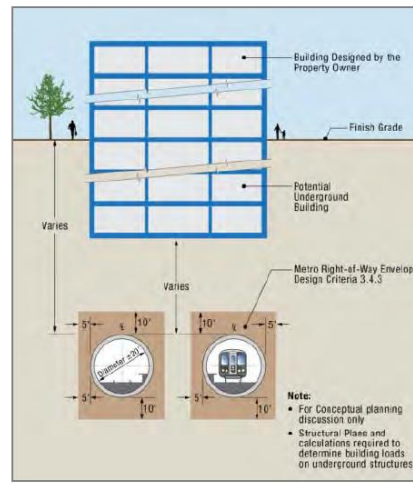


Figure 8-1: Right-of-Way Envelope for Metro Tunnels





Life Cycle Analysis

- **LA Metro Ad Hoc Sustainability Committee, September 14, 2011. Motion called for a review of:**
 - “Life-cycle financial considerations including cost (i.e., initial capital as well as maintenance and replacement costs and life-cycle cost analysis)”
 - “Inclusion of life-cycle cost analyses for renewable energy use in awarding construction contracts for new lines”
- **LA Metro reports present no life-cycle analyses of station location or tunnel alignment options**

**Whole-life asset management:
Decision-making process**

(from Hooper *et al.*, 2009)

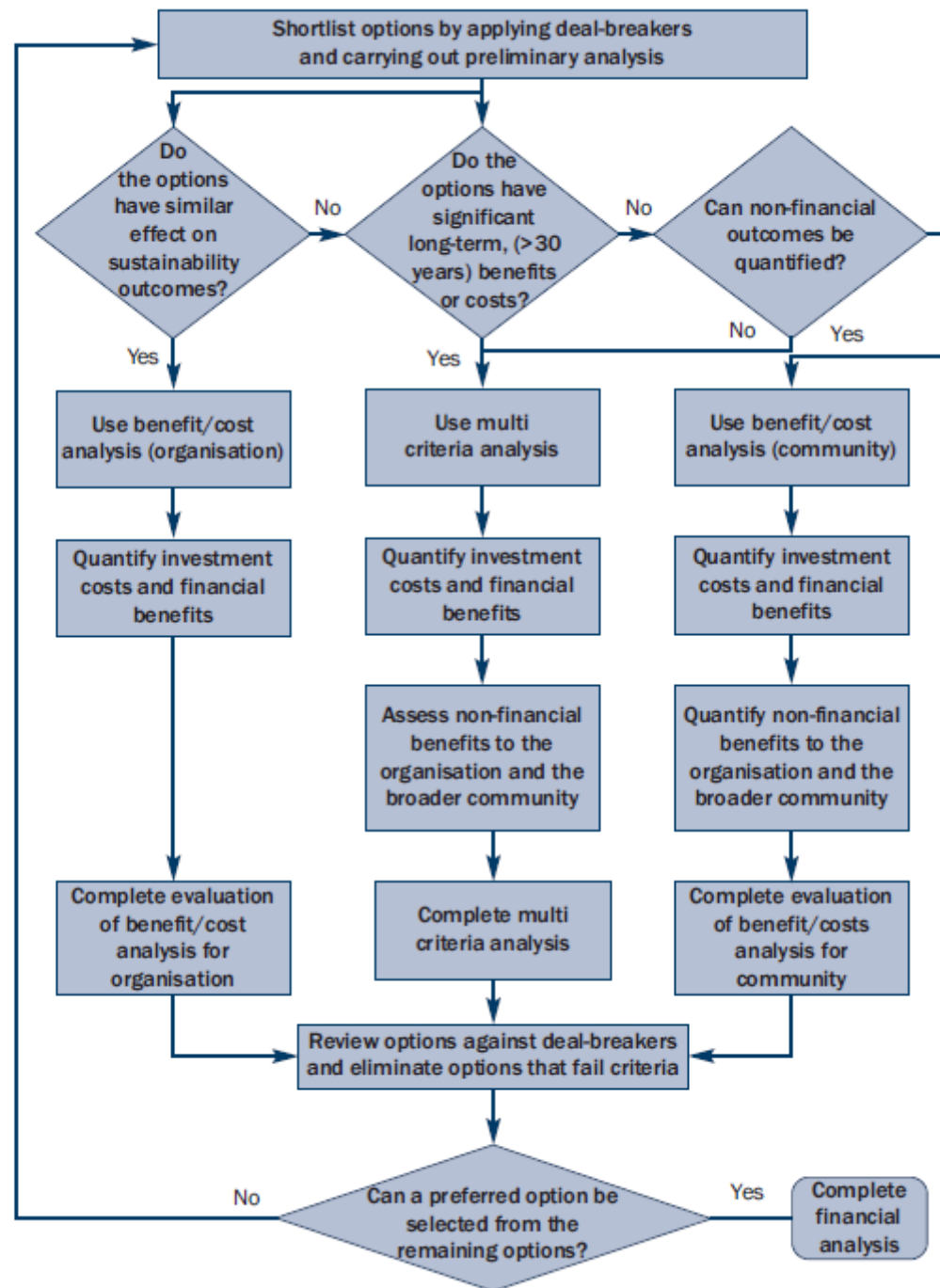


Figure 7.2
Optimised decision making process



Potential Future Steps

- **More studies are needed to justify selection of station location and tunnel alignment**
 - Fault locations and activity not well constrained
 - Limited borings for measurement of methane under BHHS
 - Undocumented oil well casings → directional probing?
 - Limited consideration of soil settlement → pre-construction survey?
- **Then, a quantifiable measure of risk should be made using a risk-based methodology for each station option**



Thank you for your attention

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