Geotechnical Baseline Reports - Fundamentals

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Risk Management in Underground Construction

Prepared by
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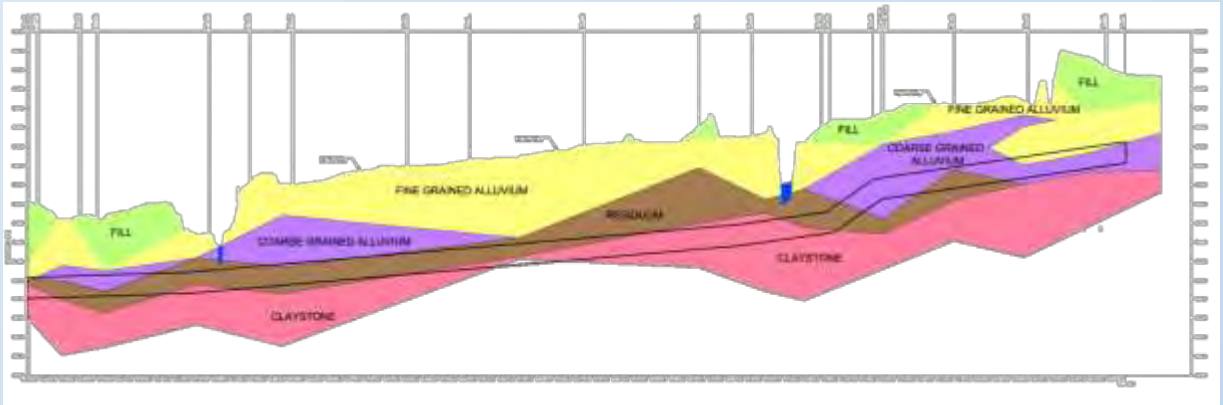
Creating Space Underground

In association with
RISK MANAGEMENT in Underground Construction

Challenges of Underground Construction

Underground Work Axioms – 1

- Tunnel/trenchless projects – linear, if one process stops, everything stops
- Subsurface conditions can vary significantly along alignment
- Means, Methods, and Construction Costs are influenced/impacted by subsurface conditions
- Inherently Risky (Owner, Engineer, Contractor, Third-Parties)
- Buried surprises often translate to commercial risk



Underground Work Axioms - 2

- Contractors **price** risk, they **do not simply accept** it
- Owners desire the lowest cost to construct their projects
- Advantageous to anticipate risks than to be surprised by them
- Contracts that anticipate/allocate risk typically result in lower overall cost and fewer claims
- The Owner ultimately "**Owns The Ground**"

Evolution of GBR is Complicated

- Pre-GBR Era:
  - Risk Shedding
  - **"You Bid It – You Build It"**
  - Persistent Litigation
- Motivations for GBR Development:
  - Better Risk Sharing
  - Provide unambiguous geotechnical interpretations
  - Basis for claims evaluation/resolution within Contract
  - Reduce bidder risk contingencies, disputes, and litigation
- More Detail to Follow

The Geotechnical Baseline Report (GBR)

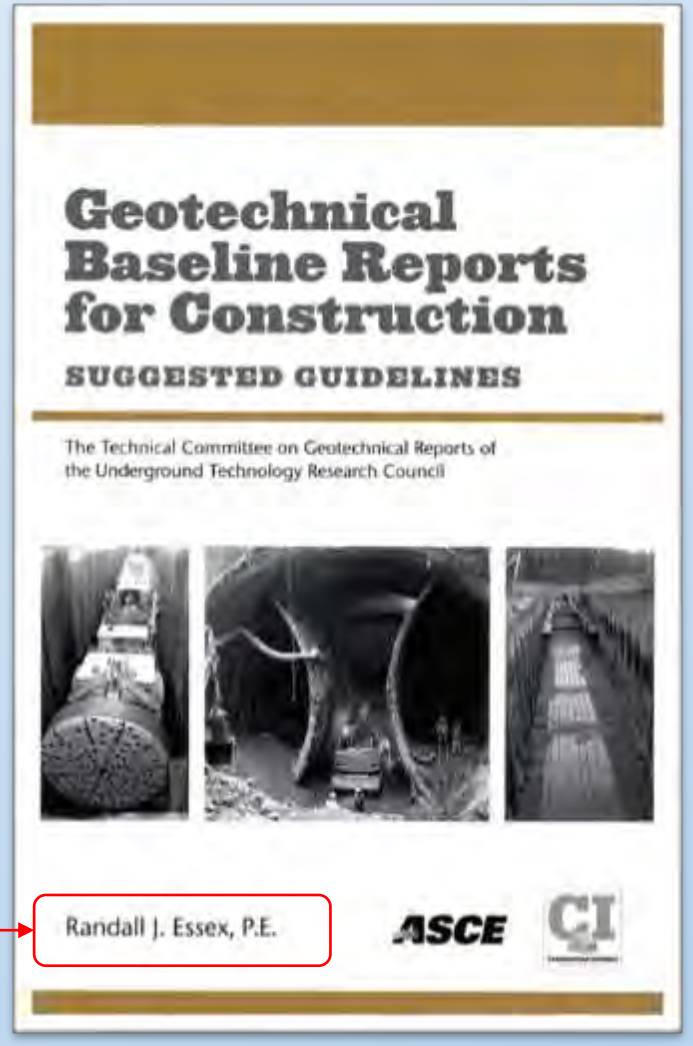
Goal of the GBR

"The Geotechnical Baseline Report is the Contract vehicle to tell the Contractor everything they need to know about the *existing* ground conditions and behaviors to be successful at building the job, for no more cost, and in no more time, than necessary."

Dr. Gary S. Brierley

ASCE Guidelines Publication

- Underground Technology Research Council - Published in 1997, updated in 2007
- Developed for underground projects
- Purpose: Balance Risk
- Reflects
  - Decades of experience
  - Industry input and feedback
  - Views on preparation and use
- GBR is not a “warranty”



Essentials for Preparing a Good GBR

- *MUST* be preceded by a Good Geotechnical Data Report
- Not easy to write, not for novices
- Use staff experienced in
  - tunnel/trenchless construction
  - subsurface investigations/ground characterization
  - Writing GBR's
  - bonus if local experience
- Involvement of an Engineering Geologist is *CRUCIAL*
- Ensure some continuity between exploration and GBR staff (else things get lost/forgotten)
- Consider Audience – For bigger projects, contractors will hire their own consultants to review prior to bid, and during construction. They WILL be experienced

Included in Contract Documents

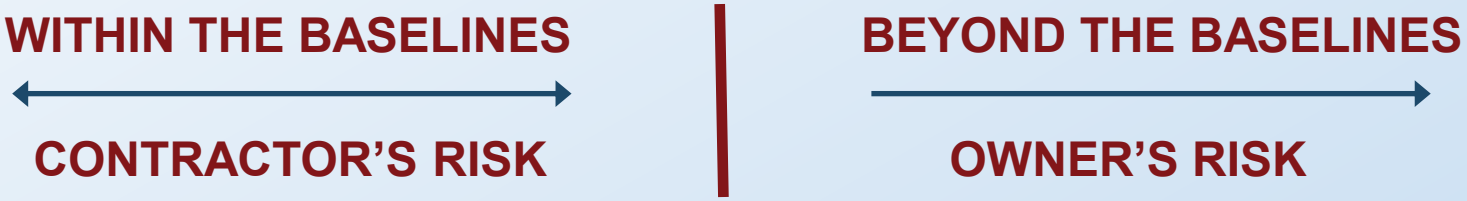
"Dragnet", Jack Webb, 1967

- Traditional DBB Contract Documents
  - General Conditions
  - Project Specifications
  - Project Plans/Drawings
  - GDR – Factual Report of Investigation and Testing Data
  - ➢ **GBR** – Interpretive Report of Subsurface Conditions, Behaviors, Risks, and Construction Considerations

- For Design-Build:
  - ➢ GBR-B – Issued for "Bidding" by the Owner, man focus is physical characteristics and risks
  - ➢ GBR-C – Developed by D/B Team; adds interpreted behavioral baselines specific to team detailed design and means and methods, submitted back to owner for review and acceptance

- GBR has precedence over the GDR within the Contract Structure
- GBR baselines are contractually binding (on both parties), regardless of the presence or absence of specific substantiating geotechnical data.

Using the GBR Baselines



- If conditions are more adverse than baselined
  - The Owner "*owns*" the Ground and the risks beyond the baseline
  - The DSC Clause kicks in to make the Contractor whole
  - Negotiate compensation for additional costs of the DSC
- Owner's preference on risk needs to be understood and considered
  - Excessively conservative baselines = increased bid cost, less potential for DSC
  - Less conservative baselines = more DSC potential, lower bid costs

Geotechnical Baseline Report

- An *INTERPRETIVE* geotechnical report and contract document that generally includes the following:
  - Interpreted Subsurface Profile
  - Description of past underground construction experience nearby
  - Unambiguous descriptions of subsurface *physical properties* and *behaviors* anticipated to be encountered
  - Describes how design was influenced by the conditions and behaviors and any related constraints
  - Descriptions of *key* geotechnical risks identified during design and in the risk register
  - Describes the construction considerations of major project elements with respect to ground conditions/behaviors

Geotechnical Baseline Report

- This *INTERPRETIVE* report establishes a contractual baseline of the subsurface conditions for bidding
  - Contract Document that provides a common "baseline" condition for the prospective bidders – level playing field
  - Baselines are contractual *assumptions* and not necessarily geotechnical *fact*
- Baselines used to allocate/assign subsurface risks
- Establishes "*measurable*" basis for resolution of Differing Site Conditions (DSC) claims during construction
- For a GBR to be effective, a DSC Clause must be included in the Contract Documents
- Often also accompanied by formation of a Disputes Resolution Board

Successful GBR's have Owners That

- Provide appropriate funding for exploration, testing, and design
- Provide appropriate funding to document conditions exposed by construction
- Understand that parties must work as a *team* towards success
- Are on Board with the GBR risk sharing concept
- Maintain an adequate reserve for changes, and pay for valid DSC claims – Contingency Funds
- Understand that if conditions are "better" than baselined they are not entitled to a credit
  - Would remove Contractor's incentive to bid below the baseline (owner cost savings)
- Understand that the baseline *does not* constitute a warranty of conditions to be encountered from the designer

GBR Advantages for Owners

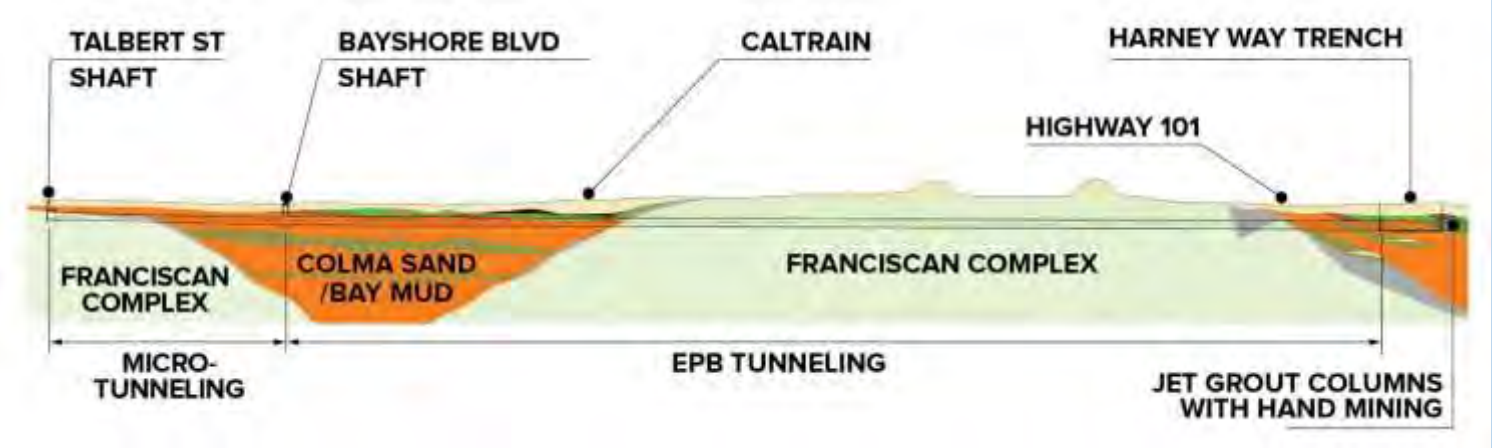
- Higher probability of comparable Contractor bids based on same GBR baselined conditions and behaviors
- Reduced risk-based bid contingencies => lower bids
  - If conditions less adverse than baseline, contractor owns risks.
- Owner does not pay for conditions below/at the baseline
  - Budget contingencies for unrealized DSCs become savings for Owner
- Contractual basis to evaluate and resolve DSC claims
- Attract top tier tunnel/trenchless Contractors, perception of “fair treatment”
- Reduction of potential third-party impacts through risk communication and allocation

GBR Advantages for Contractors

- A ***Good*** GBR describes all the key subsurface details/risks the Contractor needs to know to successfully build the job
- Same subsurface baselines presented to all bidding contractors (helps level playing field)
- Baselines set the thresholds for DSC claims, need only bid to the baseline conditions
- Overly Conservative GBRs
  - Potential additional revenue if conditions encountered are below baselined stemming from unspent risk contingencies in bid
  - Bid advantage for Contractors with local subsurface experience

When GBRs Can Be Beneficial

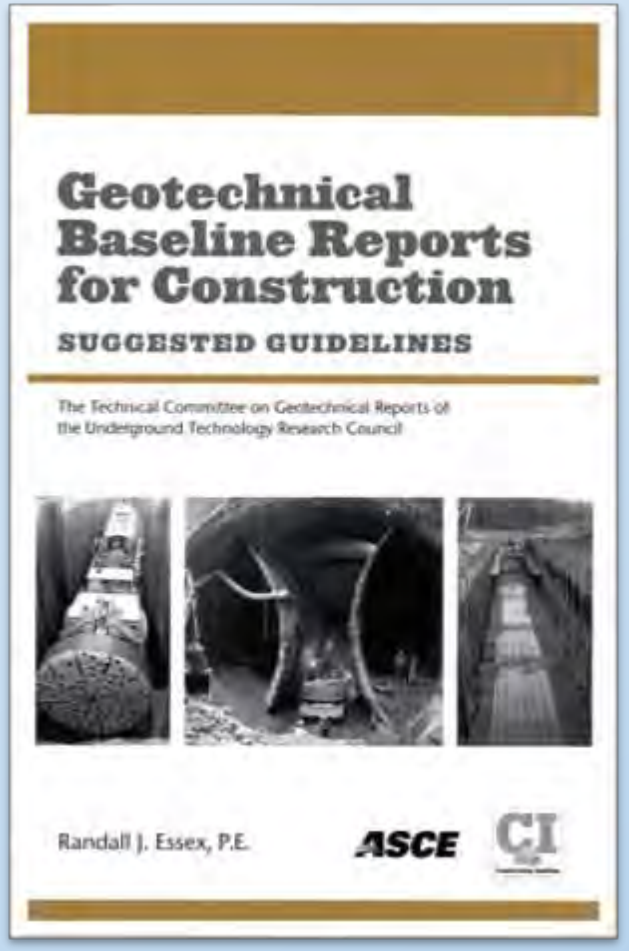
- On Large / Critical Projects with
  - Complex Ground Conditions or Construction Operations
  - Need to limit potential impacts to numerous Third-Parties
  - Non-local bidding Contractors unfamiliar with local subsurface conditions
  - Subsurface conditions that are riskier using certain means and methods
  - Need a means of rapid and objective resolution of DSC claims to keep construction moving



GBR Timing and Contents

- Outlined at 60% Phase, Written at 90%
- Should not be longer than 50 pages
- Contents

A. Introduction
B. Project Description
C. Sources of Information
D. Geologic Setting
E. Previous Projects
F. Ground Characteristics
G. Design Considerations
H. Construction Considerations



Fundamentals of Preparation

GBR Preparation

- The GBR is intended to *Interpret* the Data
- When data is representative of conditions, baselines should be consistent
- Baselines can over-ride the data
  - Limited borings/lab testing
  - Non-representative data
  - Uncertainty between the borings
  - Previous project/geologic experience in the area
  - Allocate risks for specific conditions
- Understand Owner's Risk Sharing/Tolerance Philosophy
- May not understand the benefits a GBR can bring

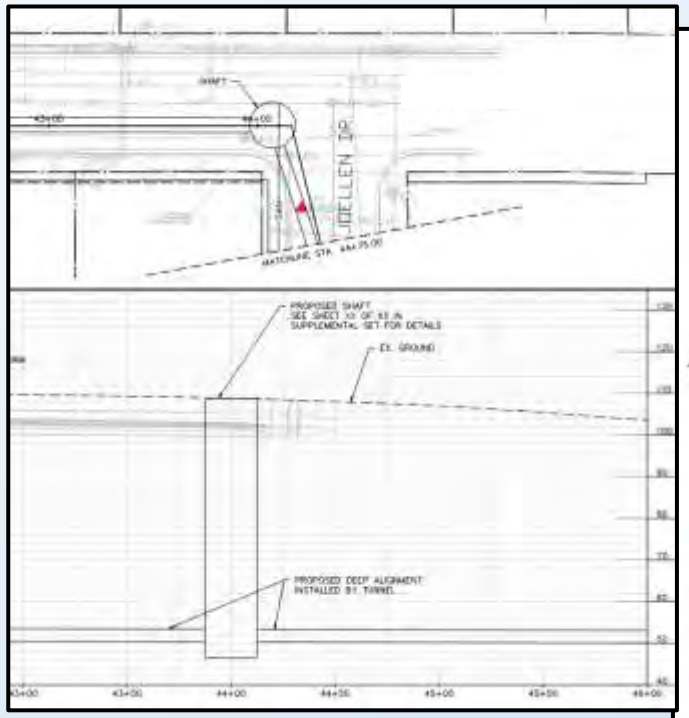
GBR Preparation

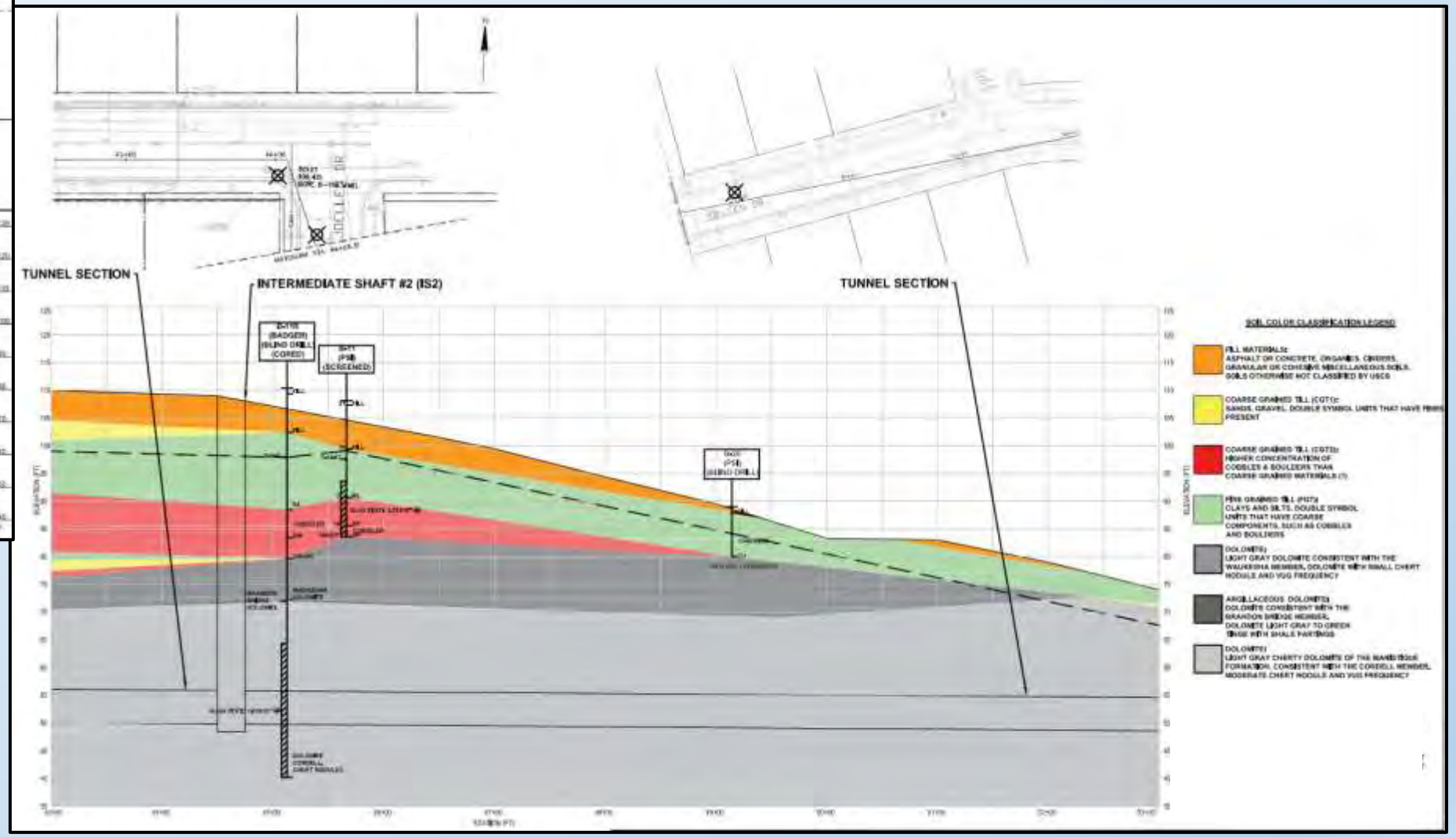
- Provide Contractor with high level background that supports baseline statements
- Describe
  - anticipated subsurface conditions and behaviors
  - the key geotechnical risks identified
  - how these aspects have influenced the design
  - how aspects will influence construction
- Follow URTC "Gold Book" Guidelines
- Simple, concise language
- Unambiguous, and "measurable"
- Careful with terminology:
  - "frequent", "occasional"
  - "thick", "thin"
  - "weathered"

What to Baseline

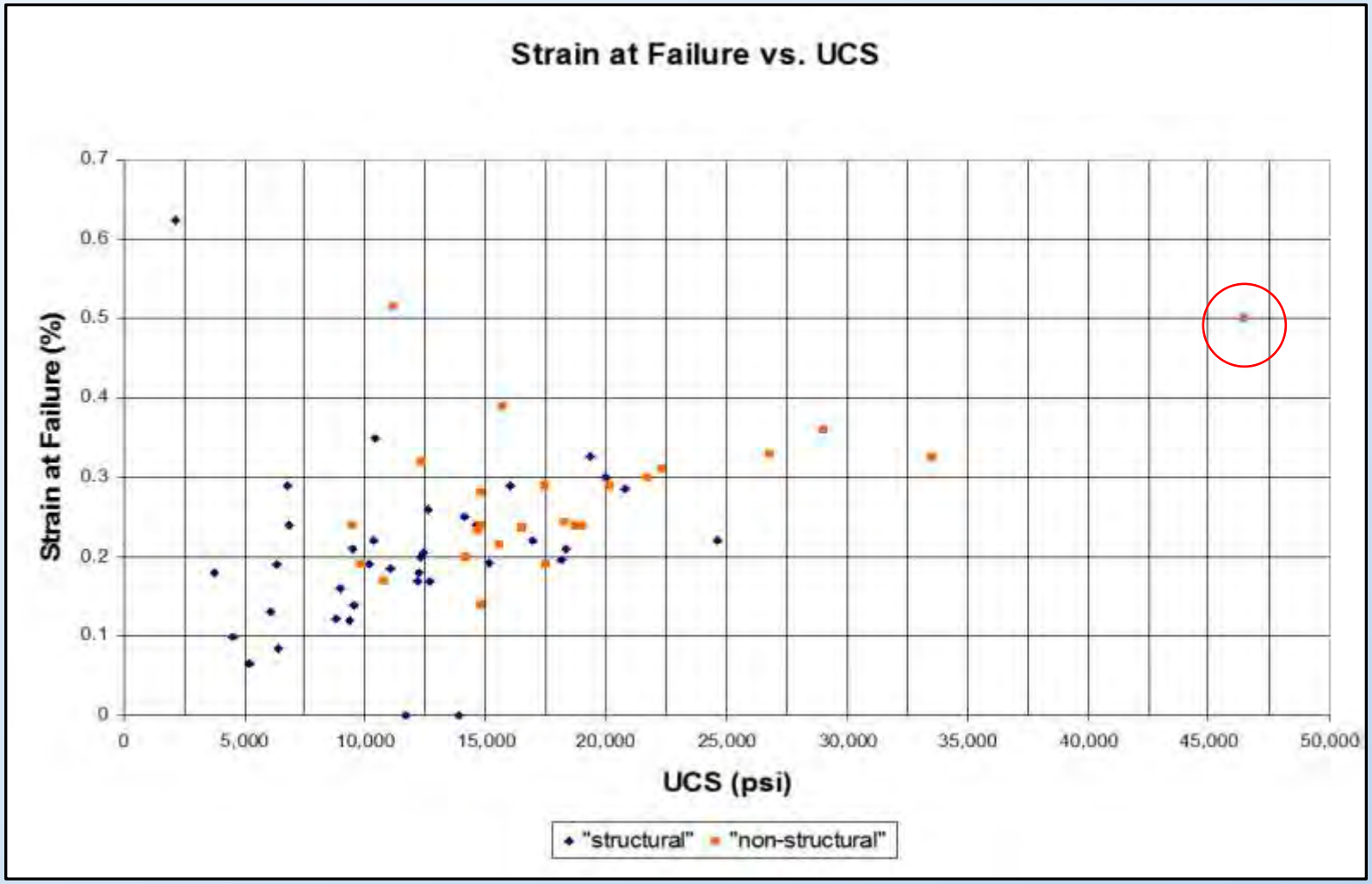
- Baselines should provide the contractor with information needed to *build* the job.
- Baselines
  - Physical – properties, strengths; independent of means & methods
  - Behavioral – how the ground responds to the excavation process
- Provide interpreted subsurface profile with groundwater
  - Profile should delineate units of similar engineering behavior
  - Should depict anticipated units to be encountered by each shaft and along each tunnel/trenchless drive
- Rock – Physical Baselines
  - Intact rock –UCS, BTS, Cerchar, Hardness, PPI, unit weight
  - Rock mass – RQD, bedding, joints, shears, faults, weathering, bedding, foliation, in-situ stress, hydraulic conductivity

Subsurface Profiles





Example – UCS Baseline



Example – UCS Baseline

4.2.1 Engineering Rock Unit

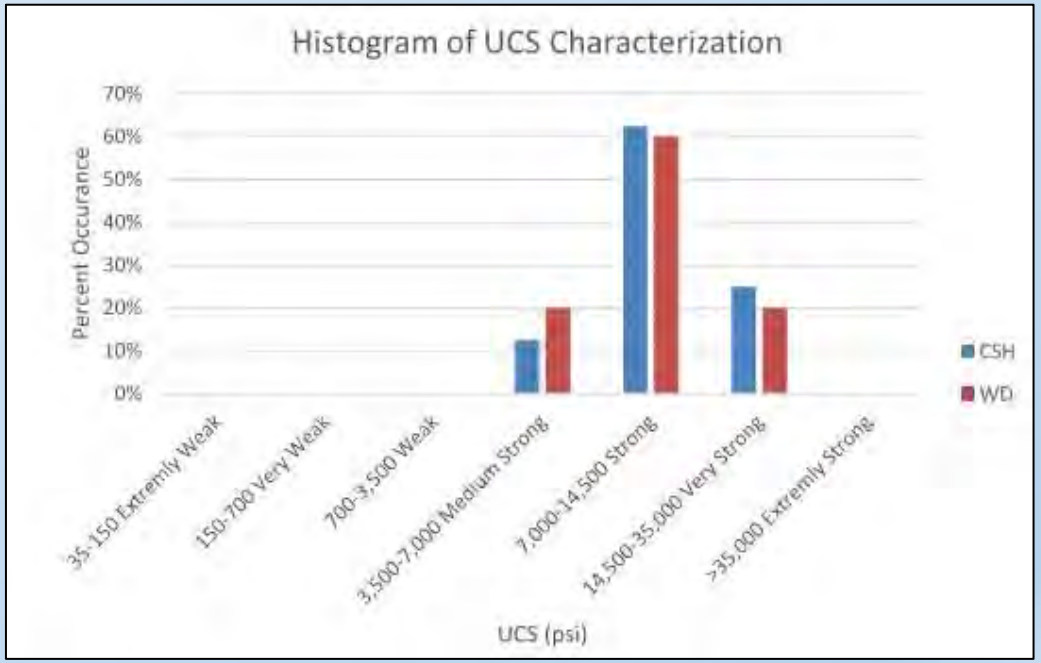
The baseline intact rock properties are presented in Table 4-2. Rock material baselines are presented using arithmetic average, and a value that 90% of the rock does not exceed. It should be noted that the unconfined compressive strength (UCS) baseline value determination included direct UCS tests as well as a correlation factor based upon linear

TABLE 4-1
Summary of Engineering Rock Unit Intact Rock Properties

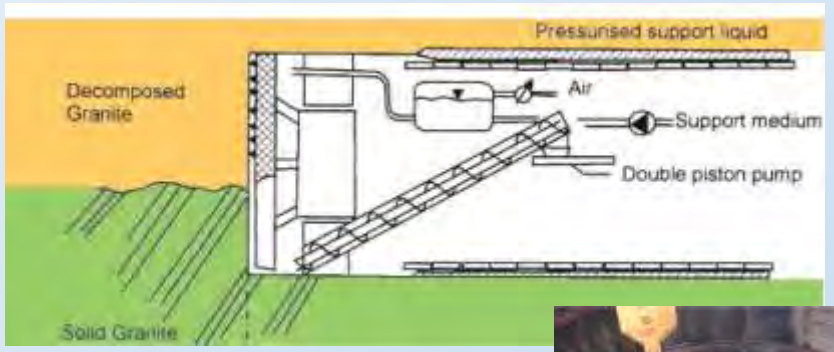
Parameter	Unit	Engineering Unit	
		Average	90 %
Unconfined compressive Strength (UCS)	psi	22,000	< 30,000
Brazilian Tensile Strength (BTS)	psi	2,000	< 2,500
Cerchar Abrasivity Index (CAI)	-	5	< 6
Drilling Rate Index (DRI)*	-	42.5	-
Cutter Life Index (CLI)*	-	14	-

* insufficient test results to reliably estimate ninetieth percentile value.

- Descriptions of baselines
- Summary Tables
- Histograms – reduced data



Physical Baselines



- Mixed-face locations and conditions
- Top of Rock Variability and nature of Soil/Rock Transition
- Soil Physical Characteristics
  - Classification, strength, water content, unit weight, gradation, Atterberg Limits, abrasivity, consistency, density
  - Swell and collapse potential, sensitivity, stickiness
  - Cementation, gradational or distinct contacts
  - Hydraulic conductivity
- Cobbles and Boulders
  - Strengths, size, distribution, and frequency

Physical Baselines

- Groundwater
  - Levels/elevation – phreatic surface and potential perched, also on profile
  - Presence of artesian conditions
- Water inflow rates
  - Estimate unit hydraulic conductivity and provide a inflow rate
    - Every 100 ft of tunnel will have a water inflow rate of 35 gallons per minute.
    - "Flush Flows"
- Obstructions – what can halt the excavation
  - Rubble/debris, fill, wood, well casings, piles, utilities, foundations, other tunnels
- Hazardous Gases (safety)
- Potentially contaminated ground and groundwater (CAREFUL!)
- Use descriptive terms that can be measured and verified by field observation

What to Baseline - Ground Behavior

- Provide qualitative behavioral baselines
- Industry standards such as Tunnelman's, RMR, GSI, Barton Q
- For Soil, Rock, how groundwater affects Behavior

Tunnelman's for Soil

- Need to convey the soil *BEHAVIOR* to the Contractor to they know how the soils will respond to the planned construction process

TUNNELMAN'S GROUND CLASSIFICATION FOR SOILS (after Heuer, 1974)

DESCRIPTION		BEHAVIOR	TYPICAL SOIL TYPES
Firm		Heading can be advanced without initial support and final lining can be constructed before ground starts to move.	Loess above water table, hard clay, marl, cemented sand, and gravel when not highly overstressed.
Raveling	Slow Raveling Fast Raveling	Chunks or flakes of material begin to drop out of the arch or walls sometime after the ground has been exposed, due to loosening or to overstress and "brittle" fracture (ground separates or breaks along distinct surfaces, opposed to squeezing ground). In fast raveling ground, the process starts within a few minutes, otherwise the ground is slow raveling.	Residual soils or sand with small amounts of binder may be fast raveling below the water table, slow raveling above. Stiff fissured clays may be slow or fast raveling depending upon degree of overstress.
Squeezing		Ground squeezing or extrudes plastically into tunnel, without visible fracturing or loss of continuity, and without perceptible increase in water content. Ductile, plastic yield and flow due to overstress.	Ground with low frictional strength. Rate of squeeze depends on degree of overstress. Occurs at shallow to medium depth in clay of very soft to medium consistency. Stiff to hard clay under high cover may move in combination of raveling at execution surface and squeezing at depth behind surface.
Running	Cohesive Running Running	Granular materials without cohesion are unstable at a slope greater than their angle of repose (± 30-35 degrees). When exposed at steeper slopes they run like granulated sugar or dune sand until the slope flattens to the angle of repose.	Clean, dry granular materials. Apparent cohesion in moist sand or weak cementation in any granular soil may allow the material to stand for a brief period of raveling before it breaks down and runs. Such behavior is cohesive-running.
Flowing		A mixture of soil and water flows into the tunnel like a viscous fluid. The material can enter the tunnel from the invert as well as from the face, crown, and walls, and can flow for great distances completely filling the tunnel in some cases.	Below the water table in silt, sand, or gravel without enough clay content to give significant cohesion and plasticity. May also occur in highly sensitive clay when such material is disturbed.
Swelling		Ground absorbs water, increases in volume, and expands slowly into the tunnel.	Highly preconsolidated clay with plasticity index in excess of about 30, generally containing significant percentages of montmorillonite clay.

(Tunnel Engineering Handbook, Bickel et al, 1996)

Example Baseline Statements

Poor Baseline Statement	Improved Baseline Statement
The Contractor should assume that cobbles exist in the alluvial material at a frequency that may slow production of the tunnel excavation.	As a baseline, the Contractor should assume that cobbles will be encountered at a frequency of 5 cobbles per cubic yard of excavated alluvial material and boulders will not be encountered in the alluvium.
As a baseline, the Denver Formation is likely to have unconfined compressive strengths ranging as high as 100 to 200 psi.	As a baseline, the Contractor should assume that the Denver Formation has a maximum unconfined compressive strength of 150 psi.
The Contractor should assume that the alluvium may behave as running to flowing ground depending on groundwater conditions.	The Contractor should assume that the alluvium will behave as running ground when fully dewatered and flowing ground if saturated.

- Eliminate Ambiguity
- Clear, Specific, Concise, and Measurable

Construction Considerations

- Information and baselines will be different for a drill and blast tunnel than for a EPB tunnel, *EACH GBR IS UNIQUE*
- For each excavation (Shaft/Tunnel), describe what the Contractor should anticipate
  - Relative percentages of each ground unit and locations/depths
  - Groundwater depths and excavation inflows
  - Key risks specific to excavation
  - Potential third-party impacts and associated risks
  - Any restrictions related to geotechnical construction at that location (no dewatering)
  - Baselines specific to each excavation, such as cobbles
  - Geologic/geotechnical hazards specific to each excavation
  - Other relevant geotechnical information needed by the contractor

Construction Considerations

- Consider applicable construction methods when writing the GBR
- Describe anticipated ground behaviors with respect to methodology
- If particular methods create unacceptable risk(s), call them out
- Need to tell the Contractor:
  - Which methods are considered compatible with ground conditions
  - Which methods should not be considered due to heightened risk
    - "Excavation below El. 593 without prior dewatering of the cohesionless silt layer presents significant risk of heave and flowing failure of the shaft excavation base."

Example

- Shaft footprint, borings suggest glacial till, but did not encounter oversized materials….
- We know that based on the *nature* of this material, and *local experience*, oversized materials will likely be present
- Still baseline frequency, describe impacts

"The Till is expected to contain up to 30 percent by excavated volume cobbles and boulders, which will hamper excavation in this material.

Steel sheet piles will not be allowed for shaft support, as the predominance of dense soils containing cobbles and boulders is likely to make it difficult to advance sheets to top of bedrock.

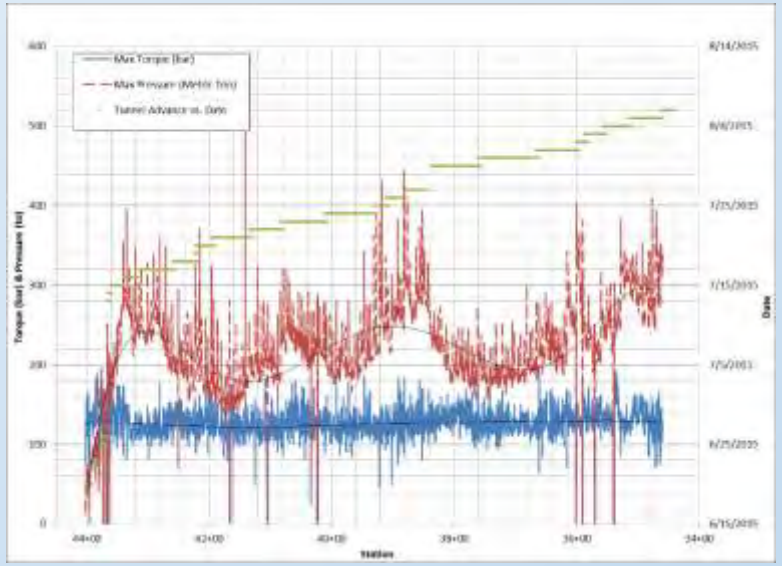
Hole drilling for soldier piles and tiebacks must take into account hole deviations during drilling as a result of encountering boulders or obstructions."

What Not to Baseline

- Don't baseline:
  - irrelevant information
    - The Contractor doesn't care that an electrical line exists 200 ft north of the project.
  - geologic contacts – should only show different behavioral units
  - hard facts – these don't need interpretation
    - "The tunnel will beneath the Harley Davidson Museum."
  - predict performance
    - Cutterhead/tool wear
    - Penetration and advance rates
  - Types or Levels/Concentrations of Contamination or Hazardous Waste
    - If necessary, this belongs within the Environmental Baseline Report (EBR).

Follow-through with Field Verification!

- Physical observations by experienced staff
- Record equipment data
- Field logs
- Photographs
- Samples



- Record actual conditions and quantities
- Critical to verify assumptions and claims
- **"The party with the best records WINS!"**

Evaluating Differing Site Conditions Claims

- For GBR to be effective, a DSC Clause must be included in the Contract Documents
- Two Types of DSC Claims
  - Type 1 – Conditions Differ Materially from Contract
  - Type 2 – Unusual, Unknown, Not normally Encountered
- The GBR defines the ground conditions/behaviors which the Contractor uses as a metric to determine if/when a differing site condition has been encountered
- The GBR is a means for administering the Differing Site Condition Clause (DSC Clause) regarding compensation with added money or time

52.236-2 Differing Site Conditions.

As prescribed in 36.502, insert the following clause:

DIFFERING SITE CONDITIONS (APR 1984)

(a) The Contractor shall promptly, and before the conditions are disturbed, give a written notice to the Contracting Officer of (1) subsurface or latent physical conditions at the site which differ materially from those indicated in this contract, or (2) unknown physical conditions at the site, of an unusual nature, which differ materially from those ordinarily encountered and generally recognized as inhering in work of the character provided for in the contract.

(b) The Contracting Officer shall investigate the site conditions promptly after receiving the notice. If the conditions do materially so differ and cause an increase or decrease in the Contractor's cost of, or the time required for, performing any part of the work under this contract, whether or not changed as a result of the conditions, an equitable adjustment shall be made under this clause and the contract modified in writing accordingly.

Summary

- GBRs are a valid approach to manage and allocate risk for complex underground projects
- GBRs are not easy to write, requires experienced staff
- Must be consistent/compatible with other contract documents
  - Reference other Contract Documents, do not quote or paraphrase them
- Risk sharing between Owner and Contractor can result in reduced project cost, shortened schedule, and ease resolution of DSC claims.
- Adequate subsurface characterization is prerequisite to the preparation of useful/accurate GBR baseline statements.
- Risk sharing facilitates work as a team
- Excessive baselines defeat the objective of the GBR
- No cookie cutter approach, Each project is unique

Thank You!

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