



# The Role of Geotechnical Baseline Reports in Managing Project Risks

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# Topics

Historical Perspective

Assessing Geotechnical Risk

Risk Sharing Philosophy

Geotechnical Data Report

GBR Fundamentals

Lessons Learned

Future Developments

# Historical perspective

**1970s: Construction claims spiraled, industry got a black eye**

**1974: US National Committee on Tunneling Technology**

“Better Contracting for Underground Construction”

**1984: US National Committee on Tunneling Technology**

“Geotechnical Site Investigations for Underground Projects”

*“Should spend at least 1% and up to 3% of the construction value on exploration”*

**1989-1991: Underground Technology Research Council (UTRC)**

1989: Silver book – “Avoiding and Resolving Disputes in Underground Construction”

1991: Maroon book – “Avoiding and Resolving Disputes in Construction”

- *Differing Site Conditions Clause*

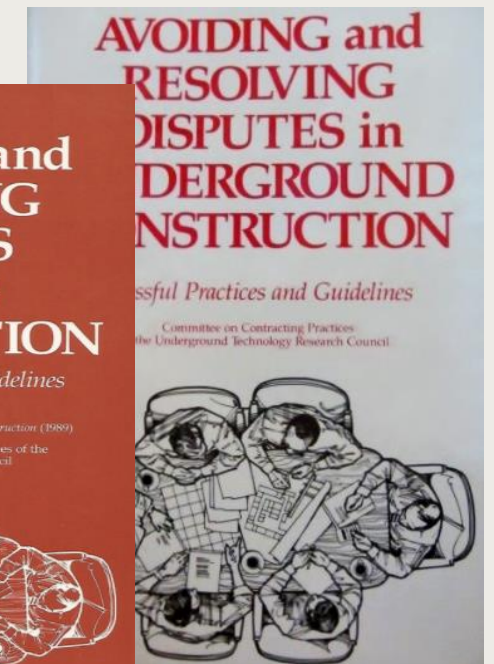
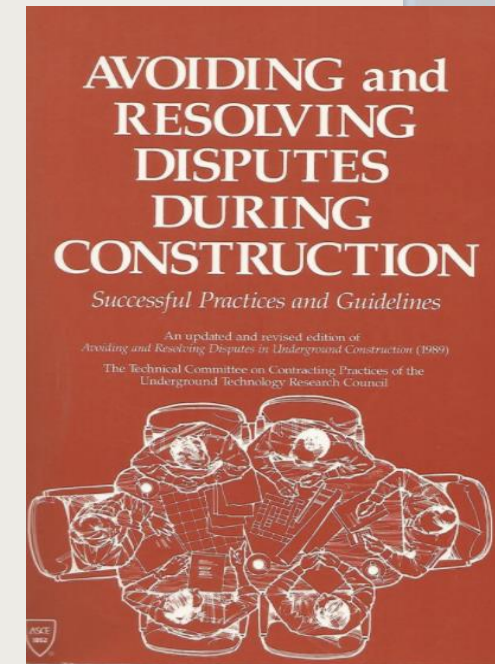
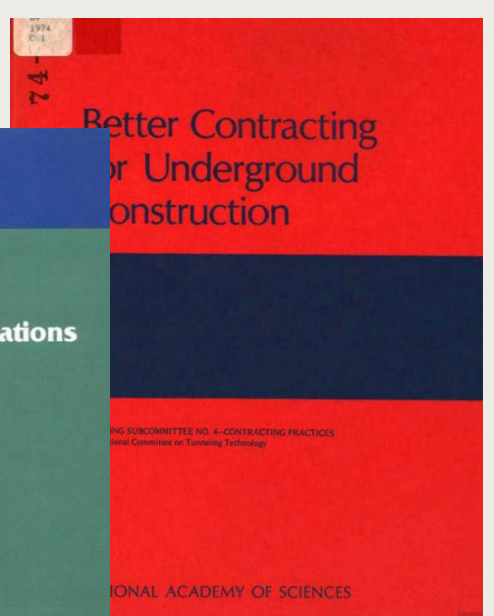
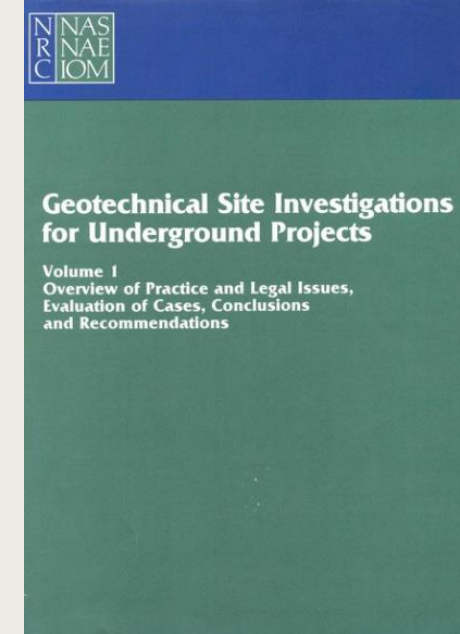


- *Geotechnical Baseline Report*

- *Escrow Bid Documentation*



- *Dispute Review Board*



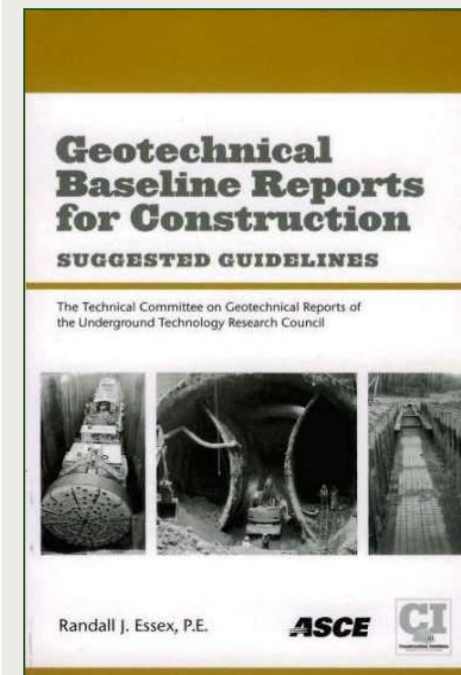
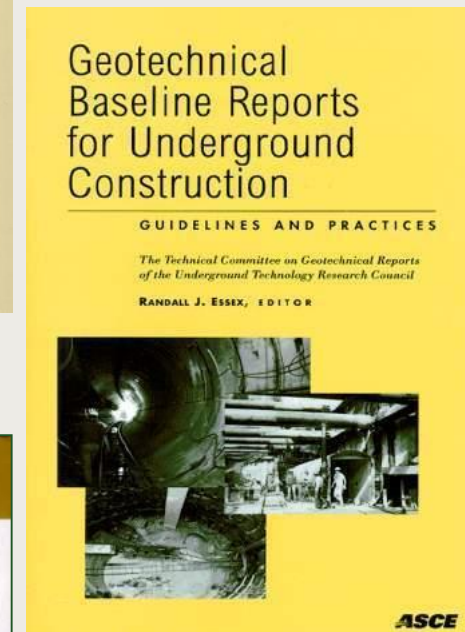
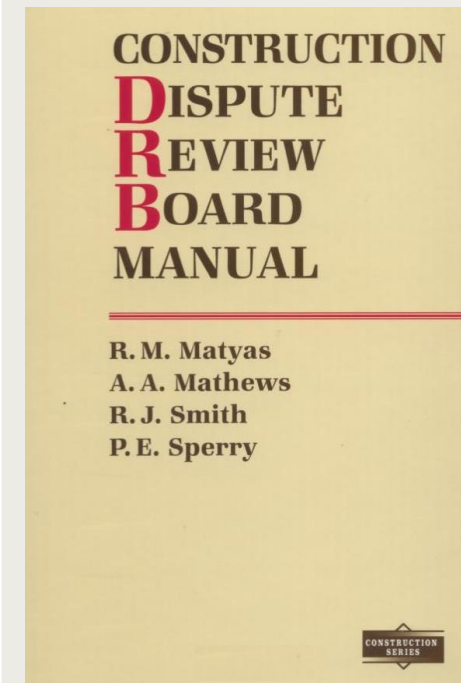
# Historical perspective (cont'd)

**1996: Construction Dispute Review Board Manual**

**1997: GBRs for Underground Construction (Yellow Book)**

**2007: GBRs for Construction (2nd Edition) “Gold Book”**

**201X: GBRs for Construction (3<sup>rd</sup> Edition)**



# Assessing geotechnical risk

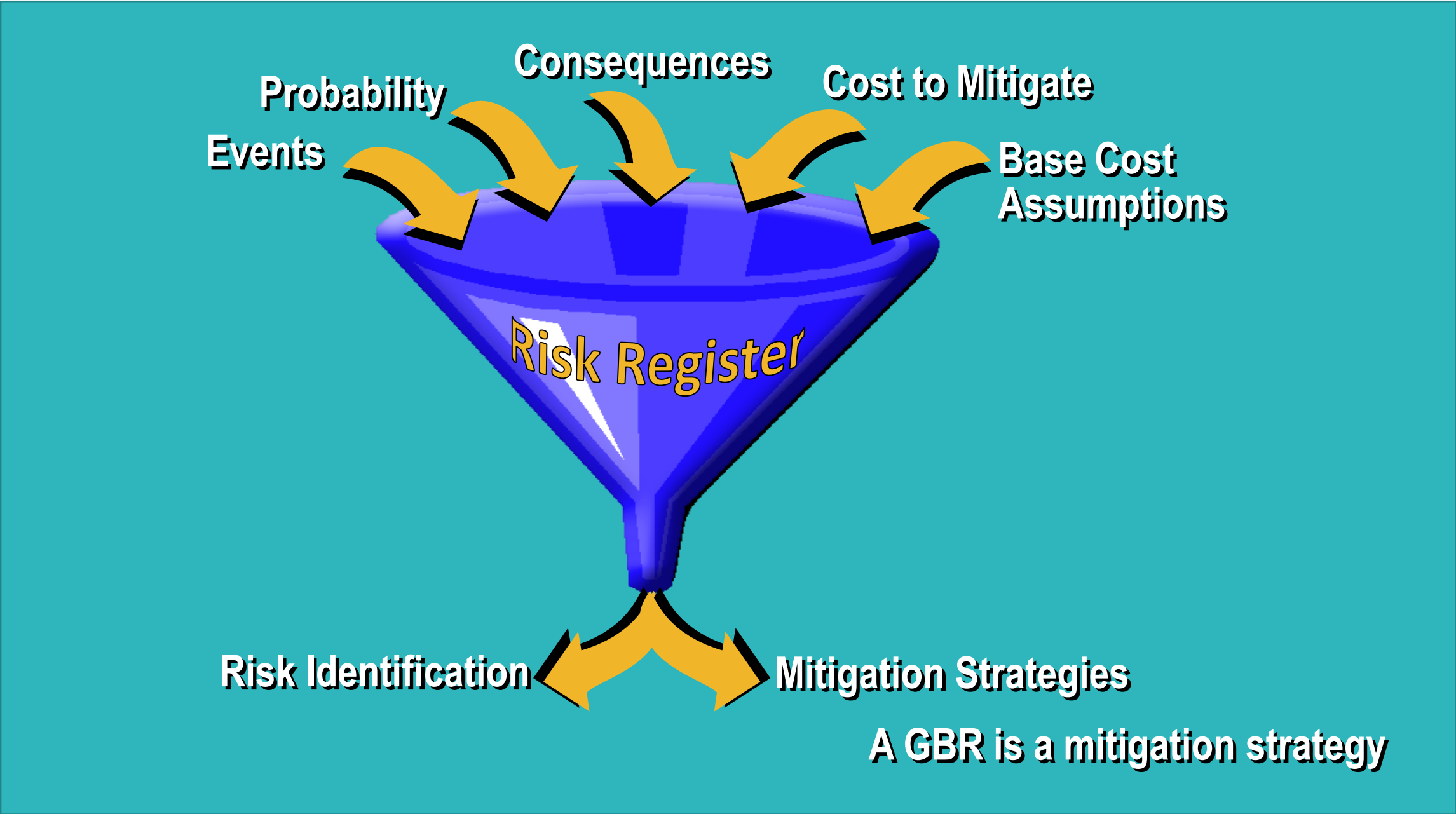


# Types of risk for an underground project

- Regulatory/Permitting
- Design/Operational
- Financial/Commercial/Contractual
- Site Access/Logistics
- Construction
- Environmental
- Health/Safety/Security

*Geotechnical conditions can affect every risk category*

# Risk assessment process



# Risk sharing philosophy

Surface vs subsurface construction  
Risk sharing vs risk shedding





# Surface vs. subsurface construction

## Surface Works

Complicated construction

Simple constraints

Can “work-around” delays

## Underground

Repetitive construction

Complicated constraints

Linear = Limited Critical Path

No “work-arounds”

“Beware the velocity of the loss\*”

\*George Fox – Grow Tunneling

Risks and consequences are different



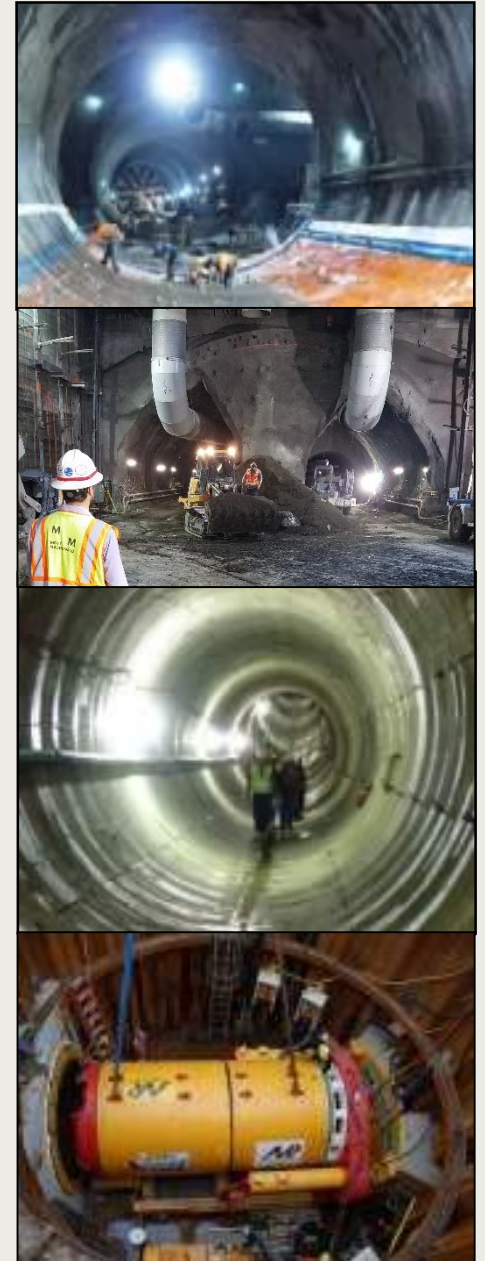
# Risk sharing vs. risk shedding

## Risk Sharing:

Owner ultimately owns the ground but  
Contractor is responsible for anticipated conditions

## Contractor still carries the risk for:

Appropriate means and methods  
Safety / Workmanship  
Cost / Schedule Performance

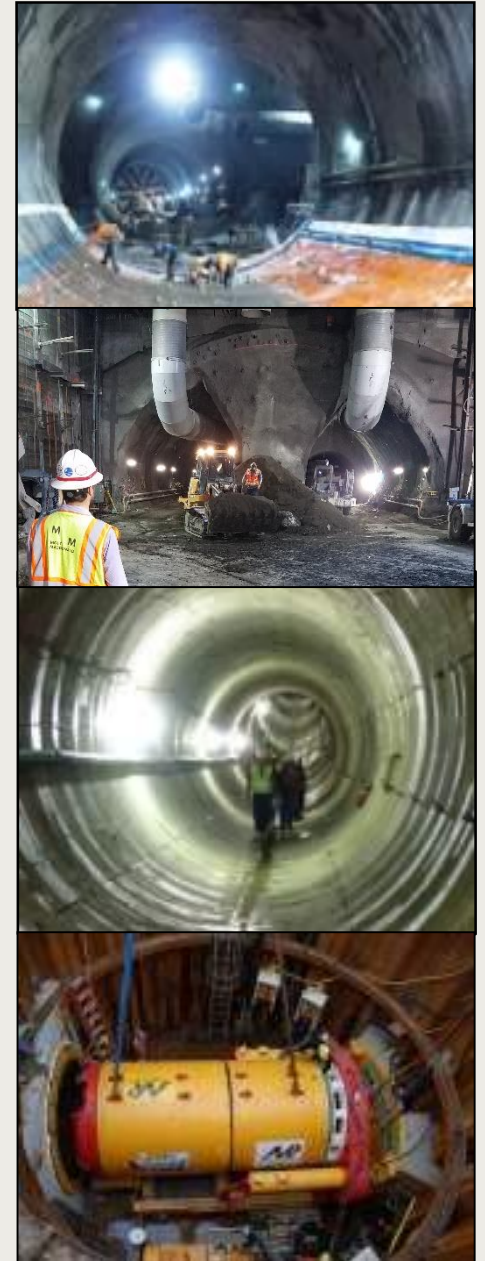


# Risk sharing goals

Provide common basis for all bidders

Avoid disputes / resolve quickly

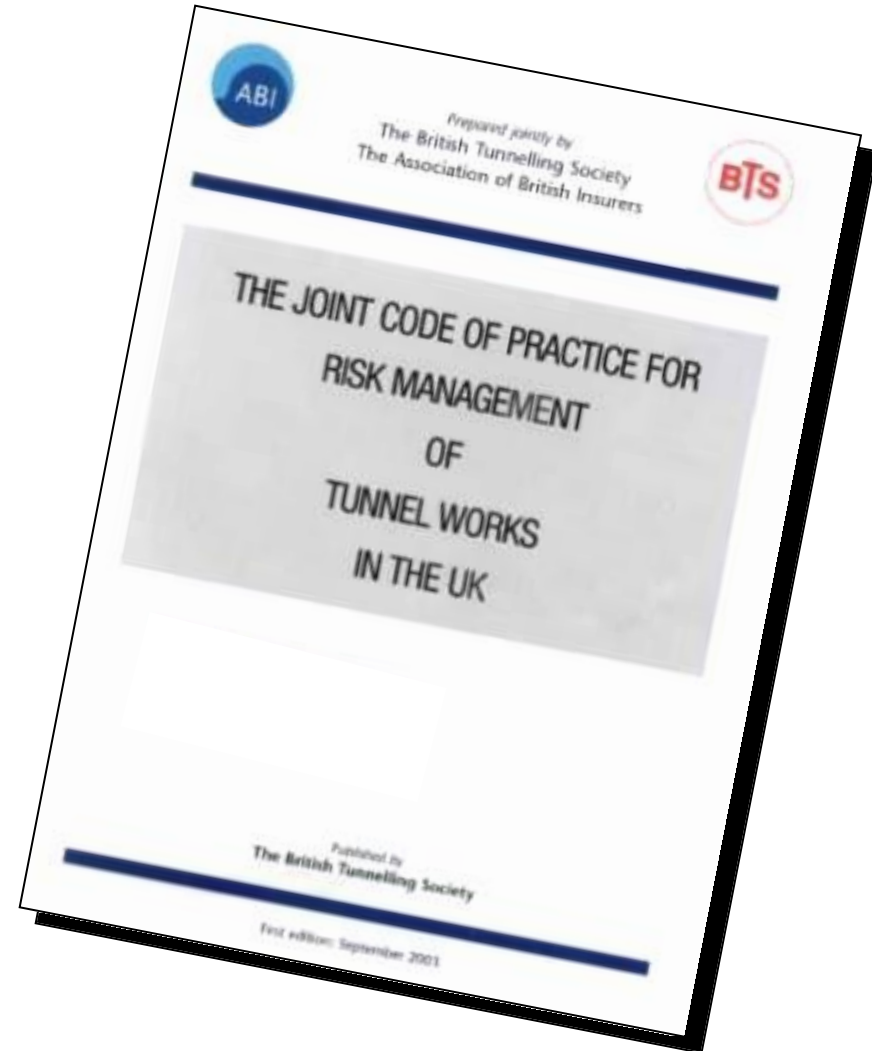
*Keep the lawyers out of our business*



# Joint Code of Practice for Management of Tunnel Works in the UK (2003)

The 1990s – 2000s

- Several spectacular UK tunnel failures
- Insurance losses following 9/11 attack
- Insurers needed to reduce their risk exposure
- Two driving principles
  - Risk Registers
  - Reference Conditions (a.k.a. Baselines)



# Joint Code of Practice for Management of Tunnel Works in the UK (2003)

## Section 7 - Project Development Design Studies

By the end of the *Project Development Stage*, the *Client* shall prepare (or have prepared on his behalf) **ground reference conditions** or **geotechnical baseline conditions**<sup>1</sup>. Such "*Ground Reference Conditions*" or "*Geotechnical Baseline Conditions*" may not necessarily be those that have been assumed and adopted for the development of a preferred project option or options in terms of project outline designs or detailed designs as appropriate. They shall, however, be issued to tenderers as integral and formative information provided at time of tender on which tenders should be based (see Section 8). The *Client* shall take responsibility for the "*Ground Reference Conditions*" or "*Geotechnical Baseline Conditions*" so issued which shall form the basis for comparison with ground conditions encountered. The nature and form of the "*Ground Reference Conditions*" or "*Geotechnical Baseline Conditions*" shall be sufficiently detailed to obviate any argument as to matters of fact on which the tender was to be based and also provide the baseline against which encountered conditions can be reliably assessed.

<sup>1</sup> **See "*Geotechnical Baseline Reports for Underground Construction –Guidelines and Practices*" published by the America Society of Civil Engineers, 1997**

# GBR fundamentals

Tunneling “Facts of Life”

What is a GBR

How is it used?

## 8 Underground “Facts of Life”

Tunnel projects are linear and can extend for miles

Subsurface conditions can vary significantly across the site

Subsurface conditions influence construction methods and cost

Underground “surprises” = commercial risk

Contractors do not accept risk, they price risk

Owners seek the lowest cost of construction

It's cheaper to anticipate risks than be surprised

Contracts that anticipate risks result in fewer claims and lower costs

# We prepare a Geotechnical Baseline Report to

**Describe the anticipated subsurface conditions and how they will influence the construction**

**Describe how they influenced the design**

**Identify the key subsurface risks on the project**

**Describe how those risks are allocated between the contractor and the owner**

**Describe how conditions beyond the baselines will be addressed**



# A GBR is...

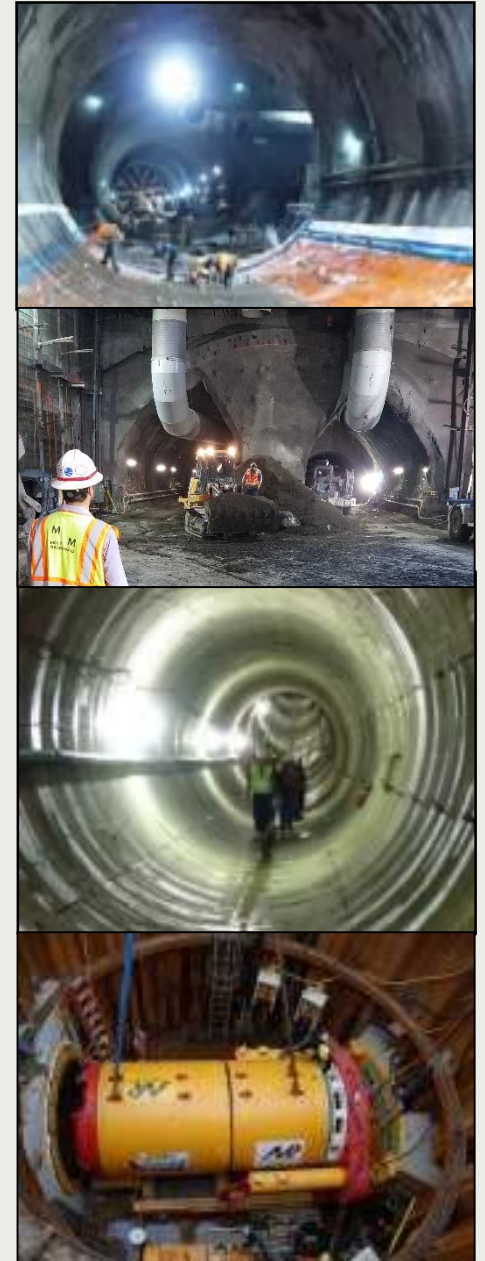
A contract document

A set of realistic contractual assumptions regarding the anticipated subsurface conditions

An aid to administering the DSC clause

A guidance document for bidding the project

A means to help manage the construction

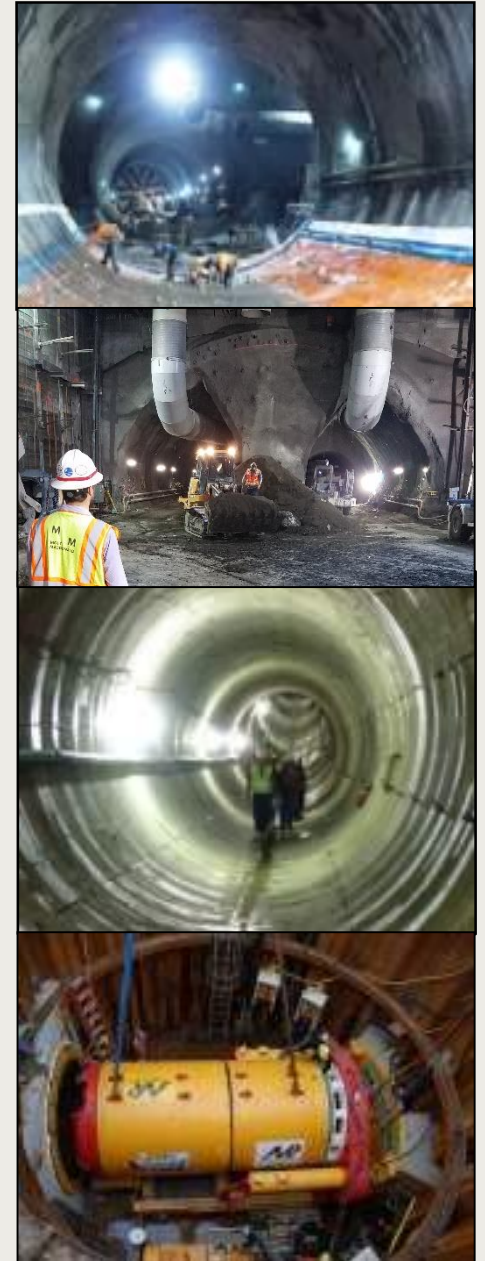


# If there is a claim

If the Contractor submits a claim that different conditions were encountered...

The GBR answers the question “Different from what?”

The GBR is the first document a DRB will refer to when evaluating the claim

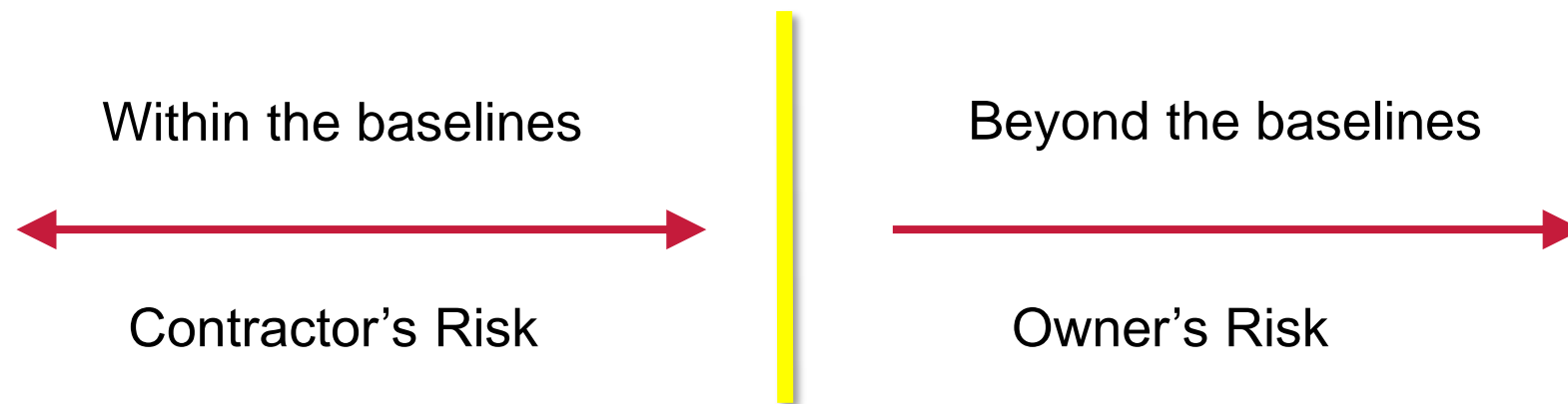


# Baseline philosophy

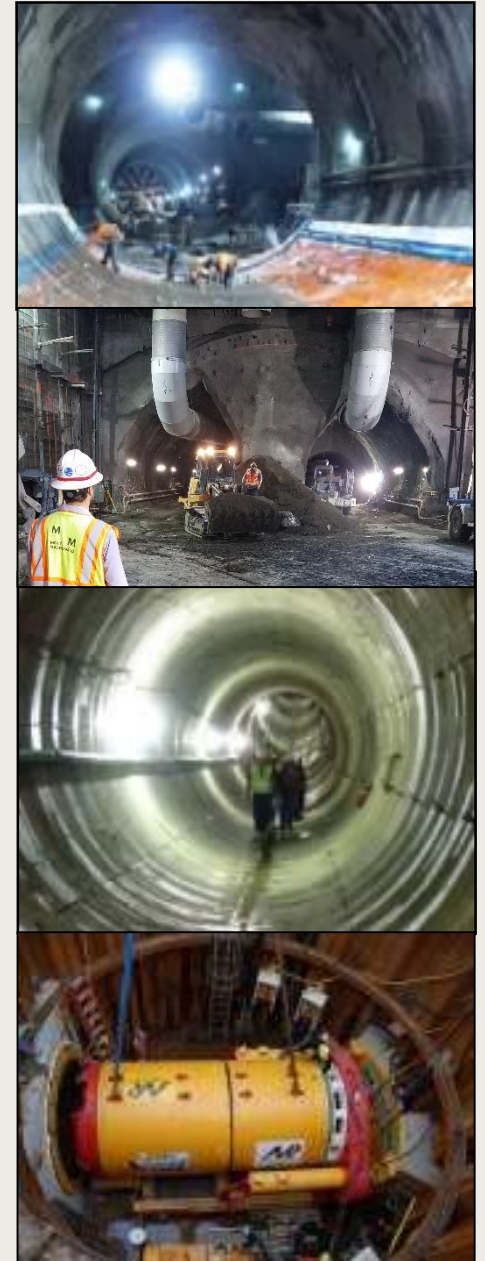
Baselines describe anticipated conditions

Baselines should be a realistic reflection of the available information

Assume the baseline is a “line in the sand”



Can set provisional sums for potential conditions outside the baseline

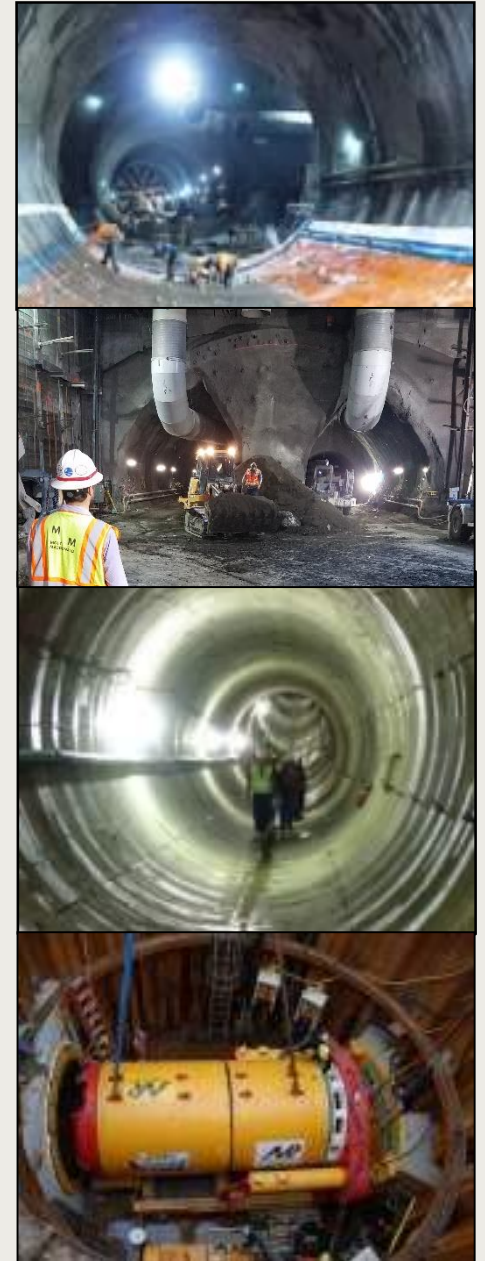


# Baseline philosophy (cont'd)

The GBR should be brief  
30-50 pages max (simple → complex)

Owners should be engaged to understand:

- that where the baselines are set will influence pricing and outturn costs
- that more risk averse baselines will increase the bid prices and overall cost (though they will reduce change orders and claims)
- that more realistic baselines with provisional and contingency sums will result in lower overall cost

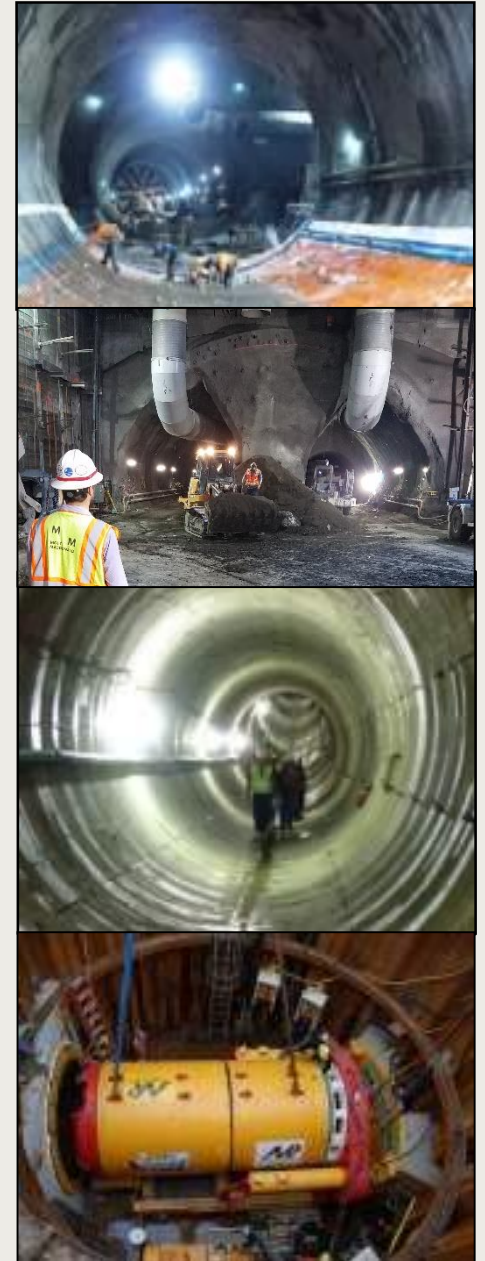


# Provisional Sum Example 1

Groundwater inflows to large TBM excavation

- How much groundwater is expected to flow into the tunnel?
- 50 l/s? 100 l/s? 200 l/s? 400 l/s?
- Large impact to bid costs if GBR says 30 vs 300
- Can set the GBR baseline at lower level (say 50 l/s)
- Then ask the bidders to fill in the following chart:

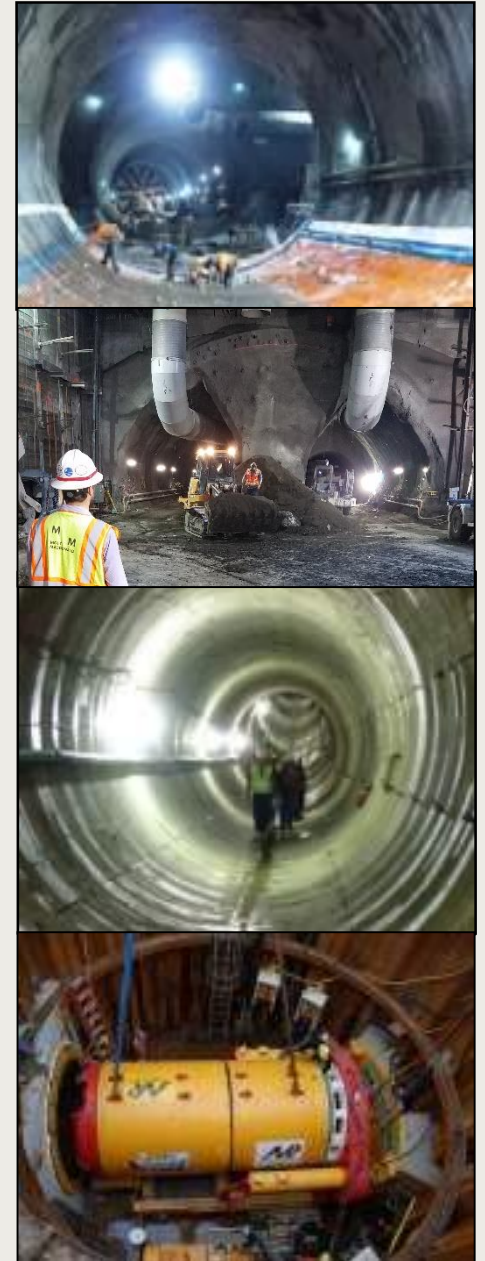
Amount of inflows (at portal)	Additional Cost, \$/shift	Additional Delay, hours/day
51 – 100 l/s		
101 – 200 l/s		
201 – 300 l/s		
301- 400 l/s		



# Provisional Sum Example 2

## Contaminated ground / groundwater

- Contractor is responsible for full-time safety officer
- Must maintain and be able to implement safety plan if contaminated ground or groundwater is encountered
- Owner sets \$\$ aside as contingency fund
- If and when contamination encountered, Owner pays additional costs for tests, handling, removal, and disposal



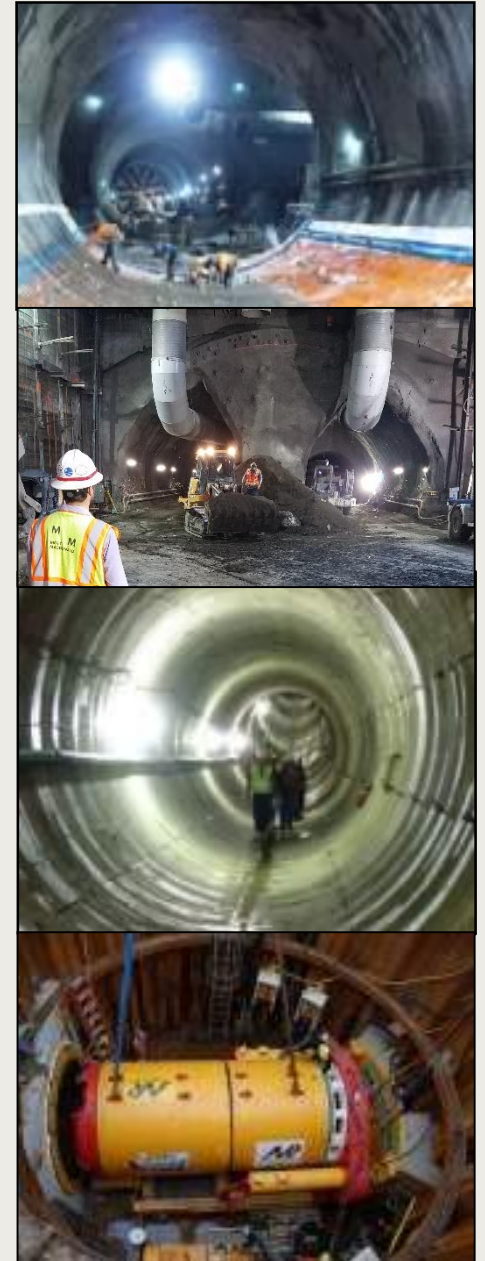
# Physical and behavioral baselines

## Physical baselines

Properties and strength characteristics - independent of construction means and methods

## Behavioral baselines

How the ground reacts to excavation processes



# Physical baselines

## Soils

Clays, silts, sands and gravels

Strength,  $c/\Phi$ ,  $K_A$

Unit weight, water content, grain size

Atterberg limits

SPT (blow count)

Abrasivity, stickiness potential

Permeability (horizontal and vertical)

Cobbles, boulders, obstructions

Groundwater levels, artesian conditions

Contaminated ground / groundwater

## Rocks

Rock types - Sedimentary, Igneous, Metamorphic

Strength - UCS, BTS, Point load, Punch penetration

Mineralogy - Grain size, shape, interlock

Boreability: DRI, CLI, Cerchar Abrasivity

Stickiness potential (claystones – beware of current vs future water contents)

Rock Mass Defects - Joints, fractures, faults, shears, weathering, alteration

Permeability, Gas, Contamination



# Behavioral baselines

How the ground will react to the excavation process

Soil tunnels: Tunnelman's classification (firm, raveling, running, flowing, squeezing)

Rock tunnels: blocky, blocky and seamy, cutterhead plucking, slaking, swelling, stress-related spalling and slabbing

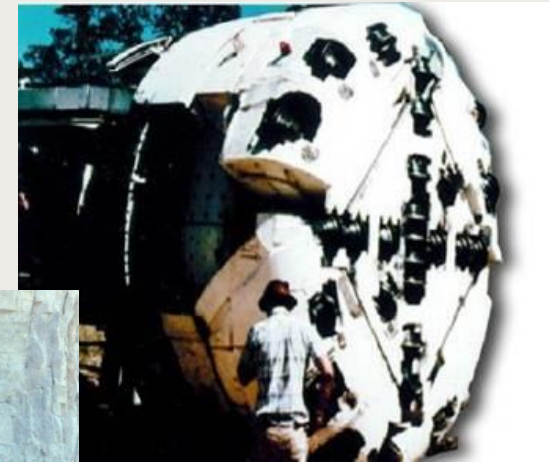
Open/pressurized face shields



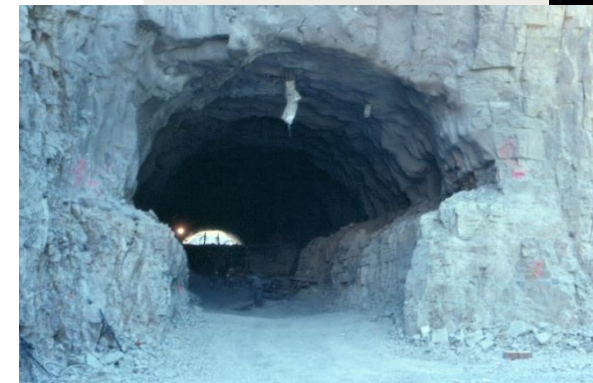
SEM/NATM



Rock TBMs



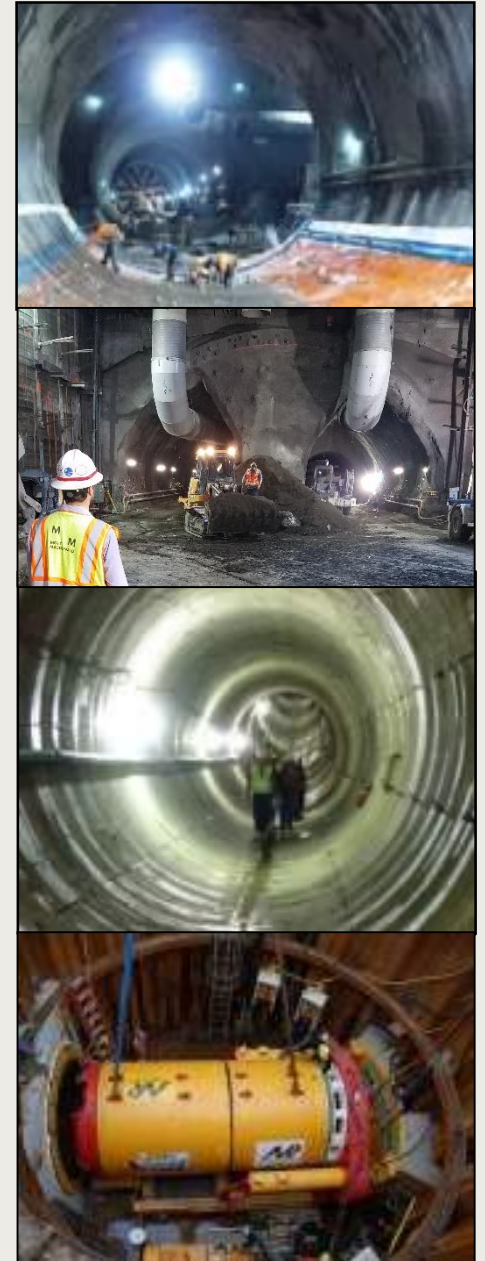
Drill and blast



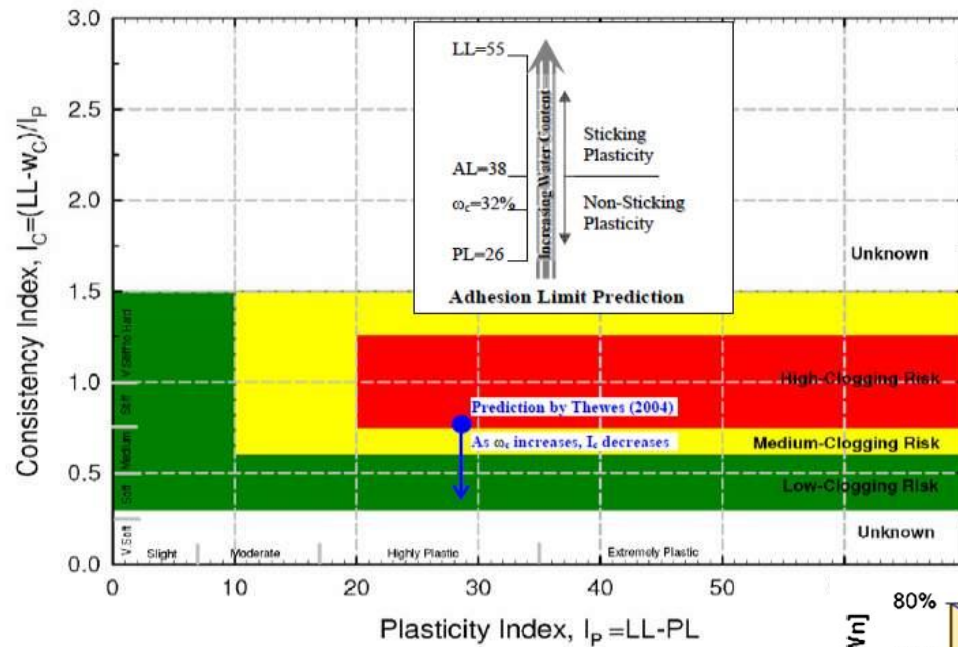
# Pressurized Face Tunneling

Cohesive soils – Consistency Index:  
Function of LL, PL, and WC

Granular soils – response to different foam  
dosage rates

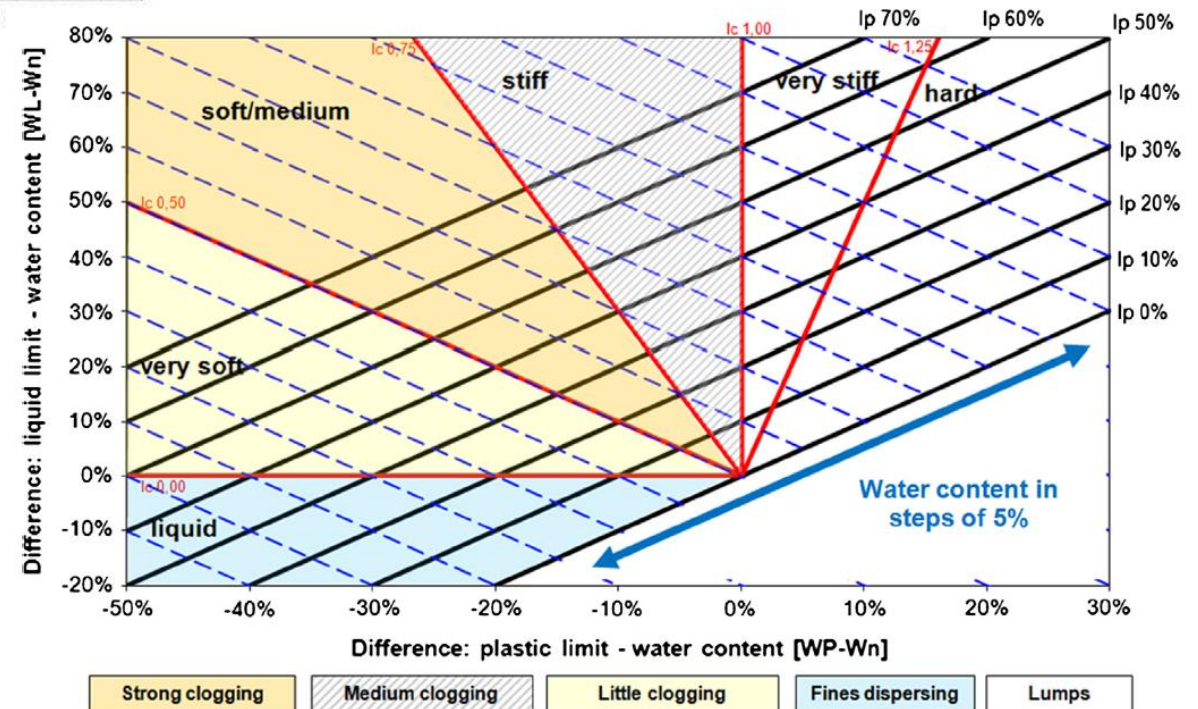


# Cohesive Soils: Consistency Index (Stickiness, Clogging)



Thewes and Burger (2004) *Clogging risks for TBM drives in clay*. *Tunnels & Tunnelling International*, pp.28-31. June.

Hollmann, F., Thewes, M. (2013). Assessment method for clay clogging and disintegration of fines in mechanised tunnelling. *Tunneling and Underground Space Technology*, 37, 96-106



# Granular Soils – Slump Tests

## Different conditioners

Foam Injection Ratios

High Density Limestone Slurry

Bentonite

Polymer

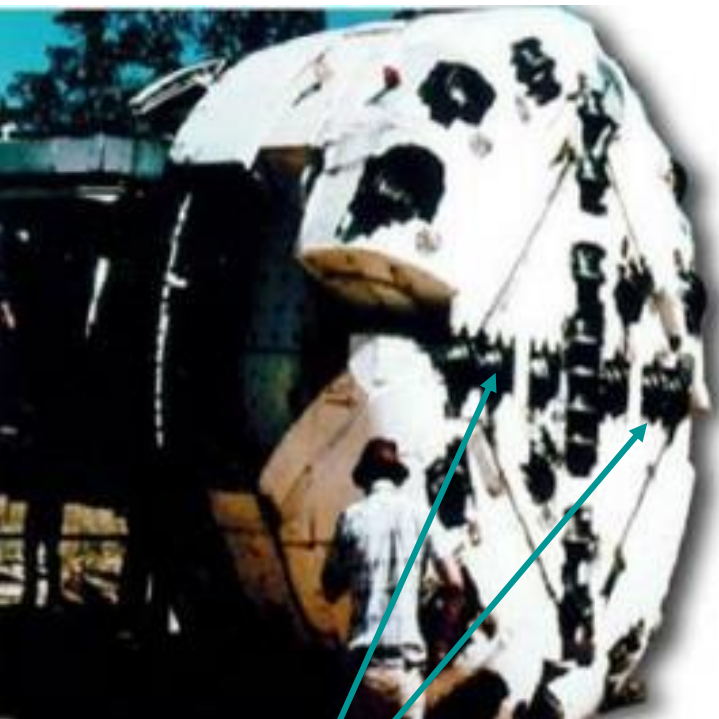


Figure 7 – Photos of soils conditioning on BASF mixture of sand and gravel with low fines

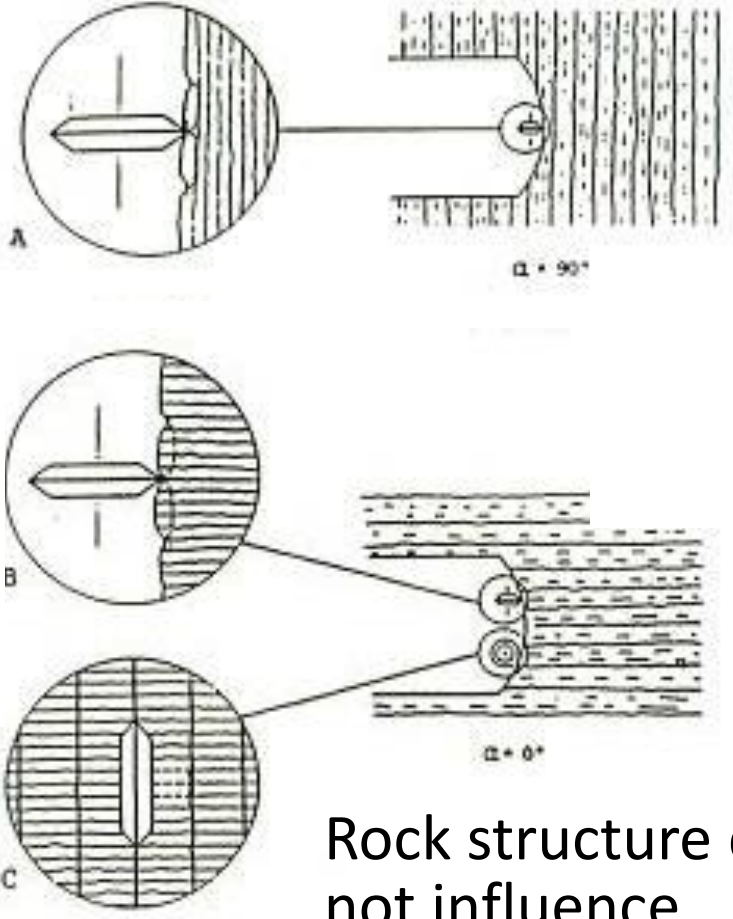
Ball, Young, Isaacson, Champa, Gause (2009). *Research in Soil Conditioning for EPB Tunneling through Difficult Soils*. Rapid Excavation and Tunneling Conference

# Hard rock tunneling:

How the rock fabric affects rock cutting action



Disc cutters



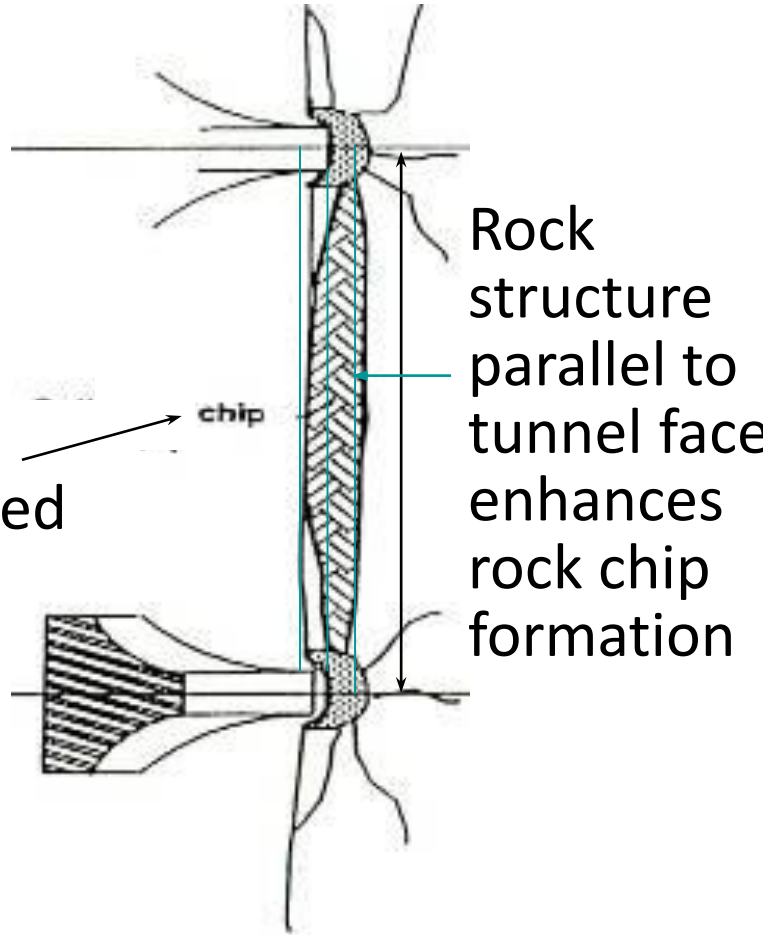
Rock structure enhances boring

Rock structure does not influence boring

Cutter →

Optimum chip formed

Cutter →



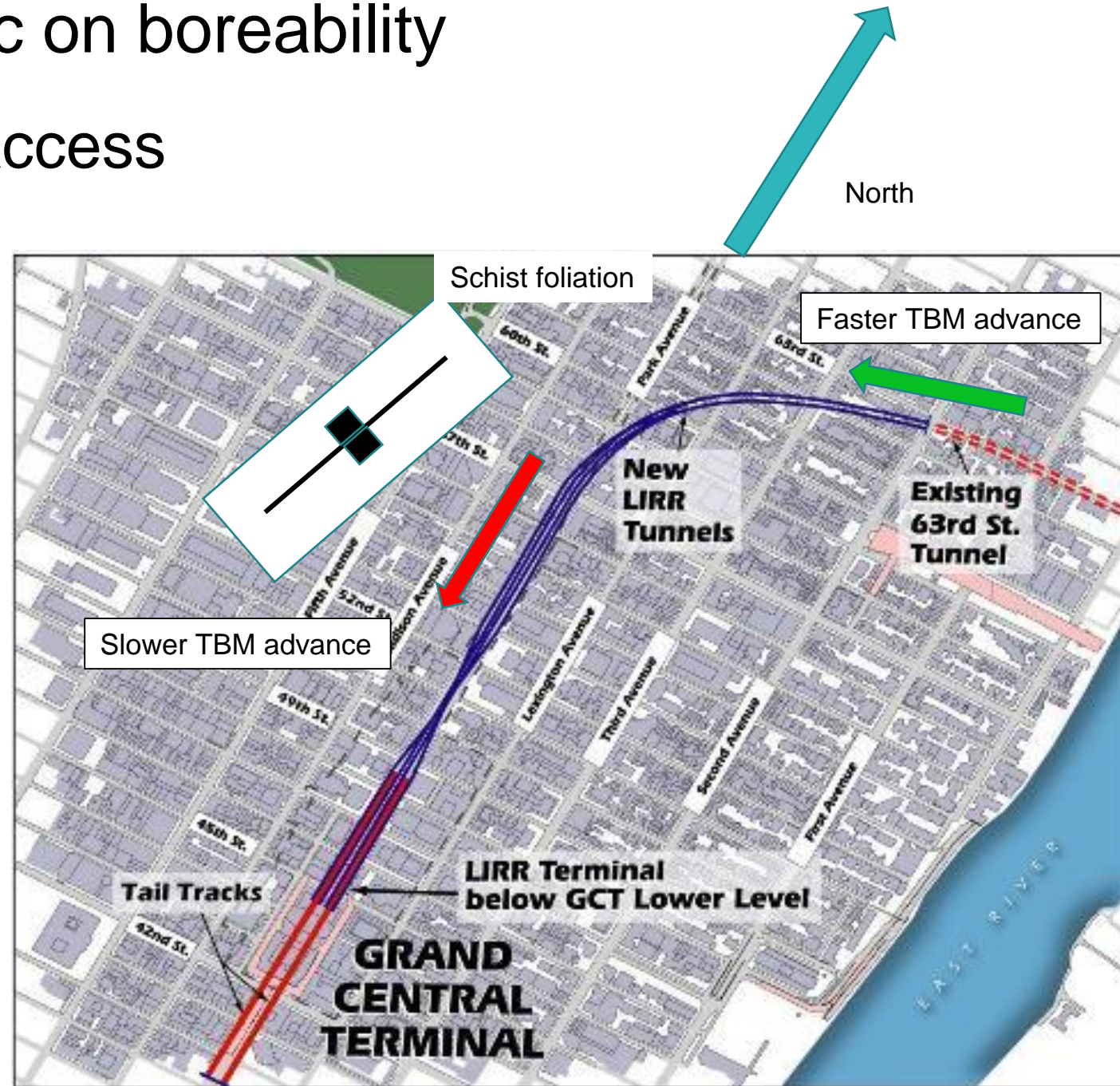
# Impact of rock fabric on boreability

## East Side Access Project, NYC

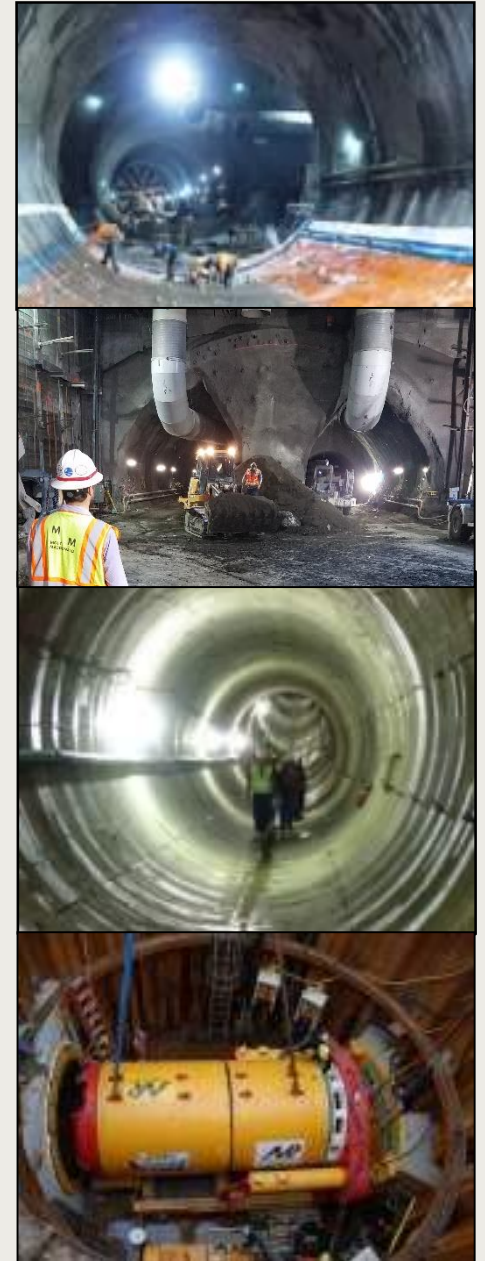
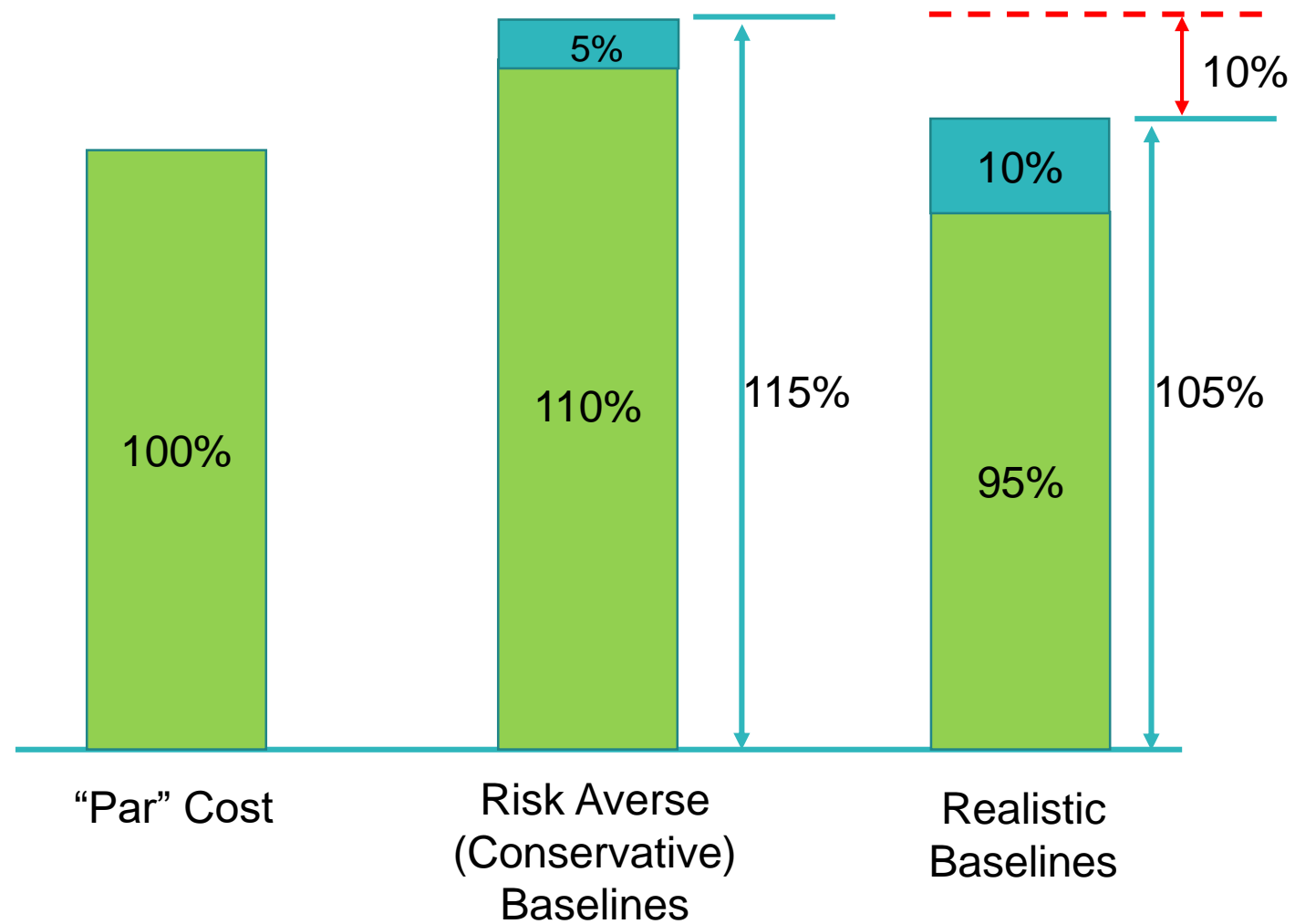


# Impact of rock fabric on boreability

## East Side Access



# Baselines, Claims, and Outturn Costs

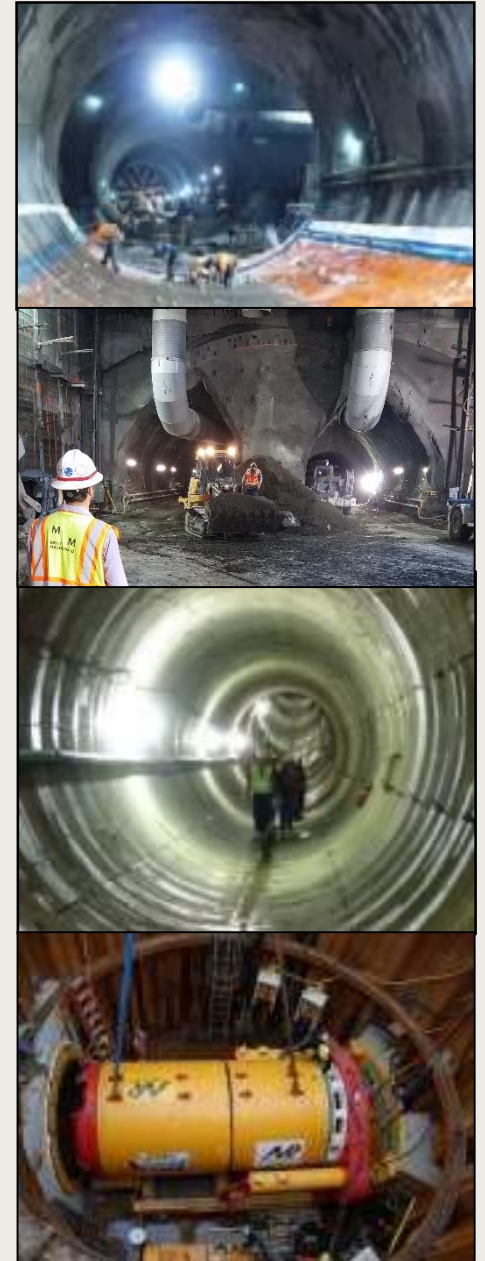




# GBRs were developed for traditional DBB delivery What about DB and P3 delivery?

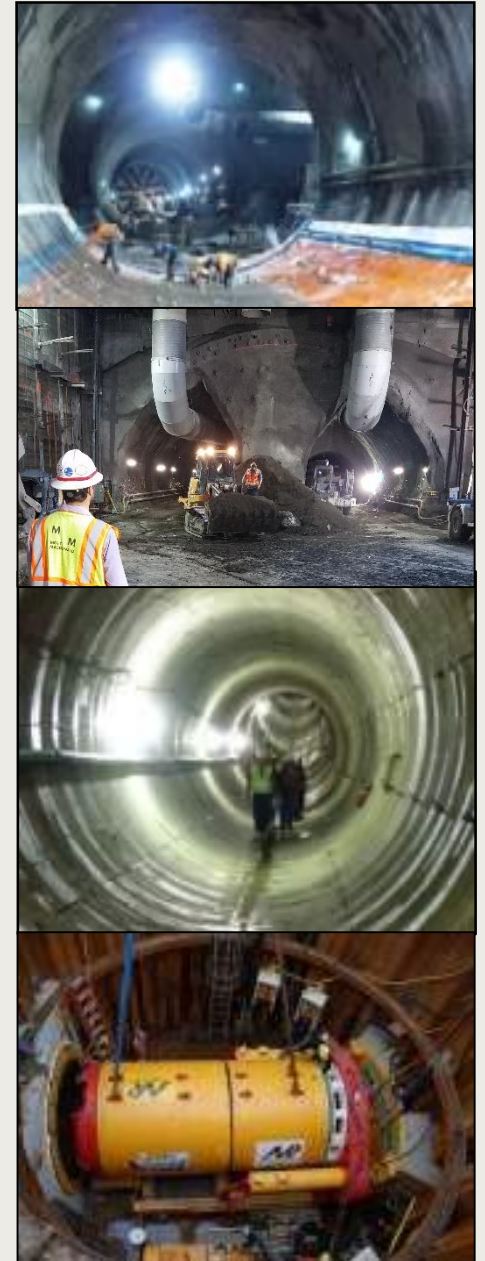
The approach to managing subsurface construction risks should not change

- Follow the same risk sharing philosophy
- Develop and apply a GBR (modified approach)
- Employ a DRB or other alternative dispute resolution method
- Include provisions to address conditions beyond the baselines



# GBRs for DB and P3 delivery

In traditional DBB, the *Owner* is responsible for the design  
In DB and P3, the *Contractor* is responsible for the design



# GBRs for DB and P3 delivery

The Owner carries out site exploration and develops a reference design



Owner initiates the GBR but describes the physical baselines only

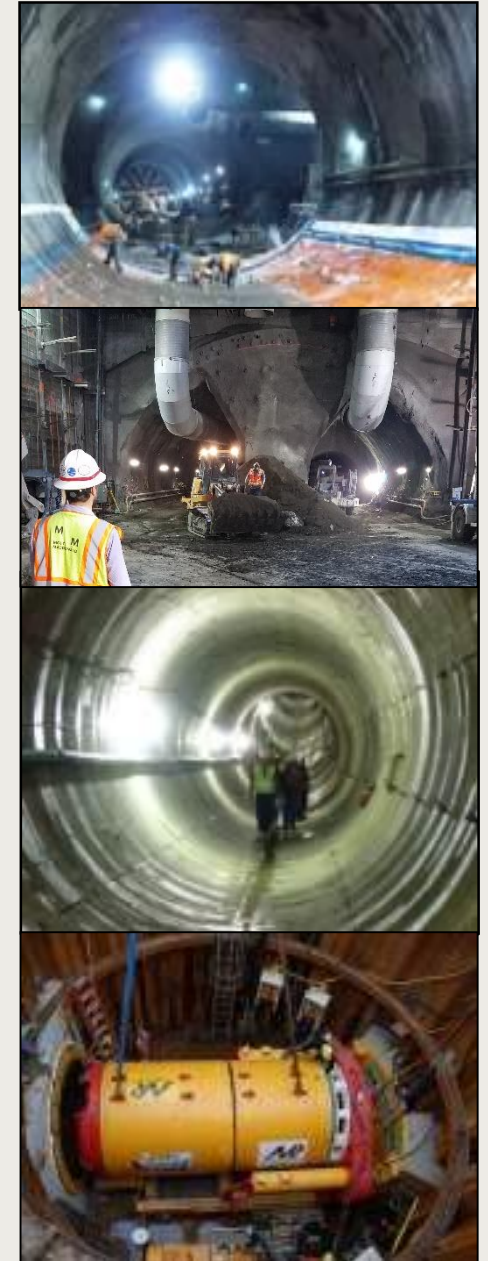
The DB or Concessionaire Team is responsible for the final design and the construction approach, means, and methods



Based on the design and construction approaches, the DB Team adds the anticipated ground behavior to the GBR

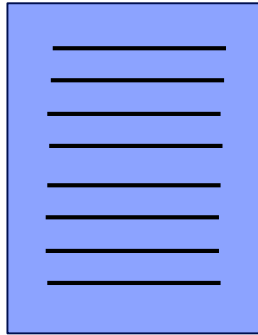


Final GBR document is created through a collaborative effort

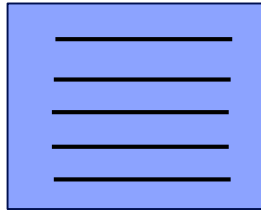


# GBRs for DB and P3 delivery

## GBR-B By Owner



Design Constraints

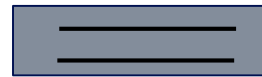


Geologic Conditions

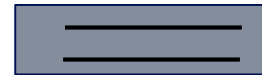


Physical Baselines

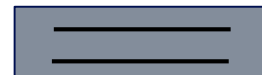
## GBR-C By Contractor



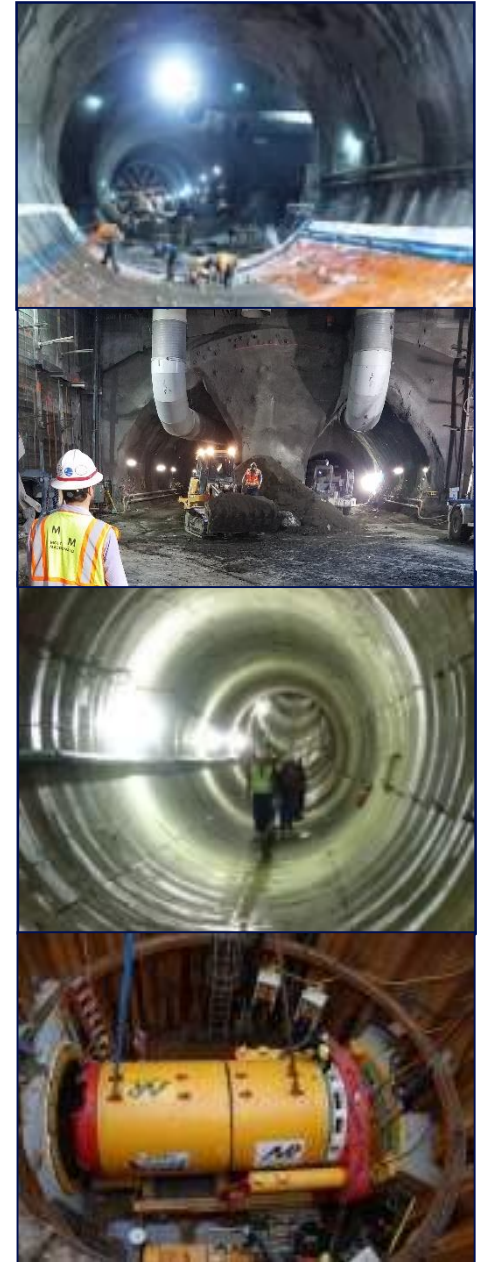
Design Bases



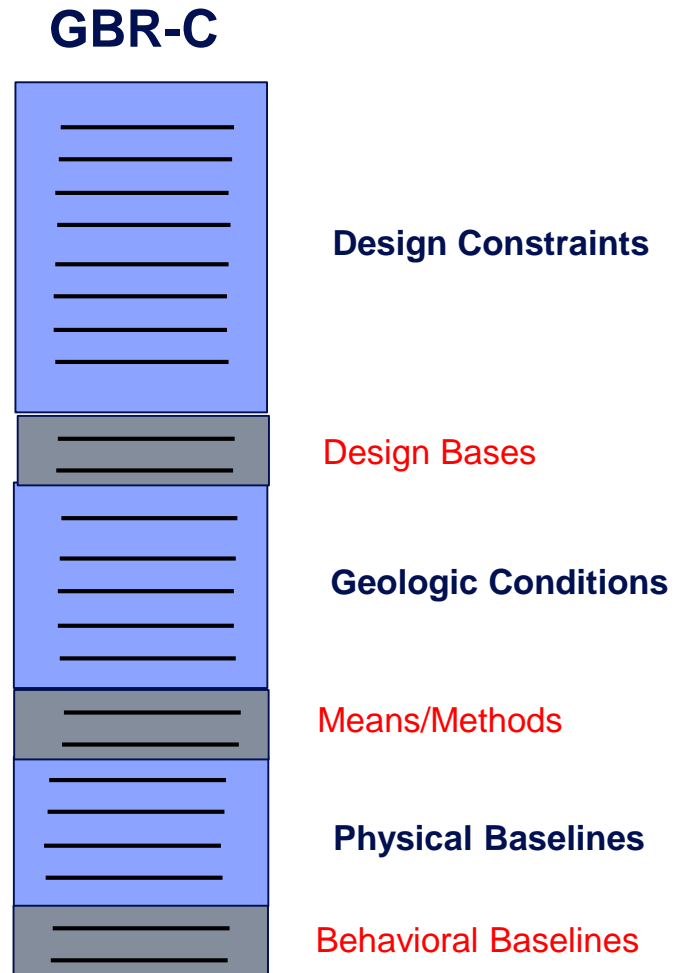
Means/Methods



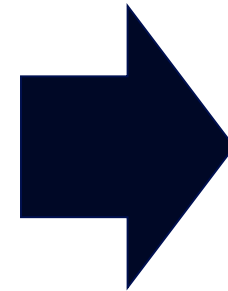
Behavioral Baselines



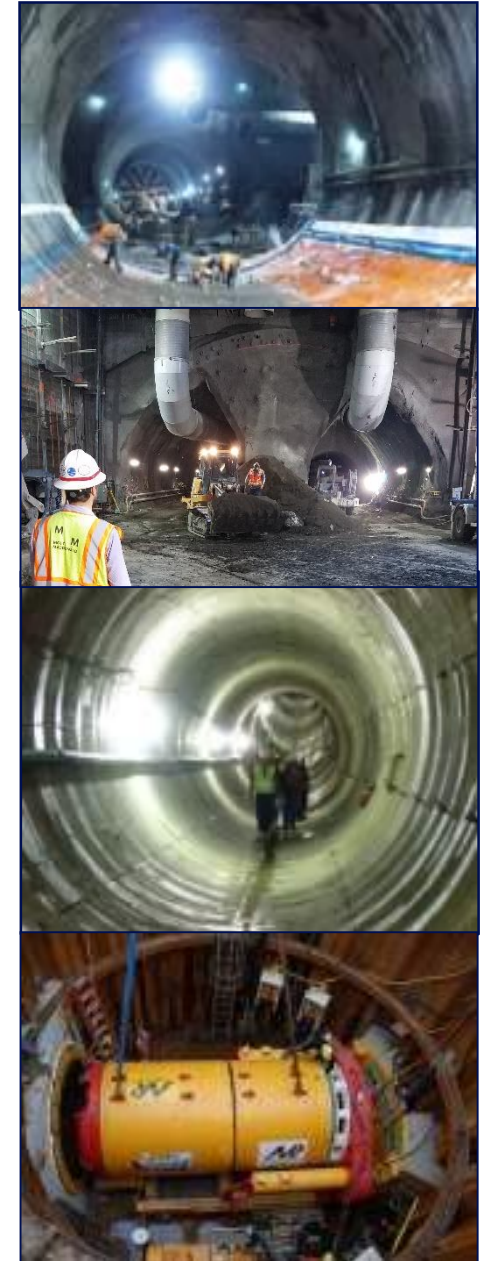
# GBRs for DB and P3 delivery



**Ratified by  
Owner**



**GBR to the  
Contract**





# Lessons learned

Terms

Data vs Baselines

Ground Behavior

Clarify How Baselines Apply

Contractual “Fit”

# Terms

Avoid ambiguous words, such as “could”, “may”, or “might”

if it “might” be encountered, Contractor can assume that it won’t

Avoid qualitative descriptors

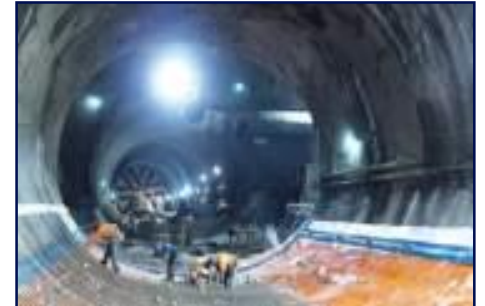
“high” groundwater table

“frequent” occurrence of boulders

“occasional” joints

“short” stand-up time

Use quantitative terms where possible *that can be measured and verified in the field*



# Data vs baselines

What if data is not representative?

- insufficient borings (number, location)

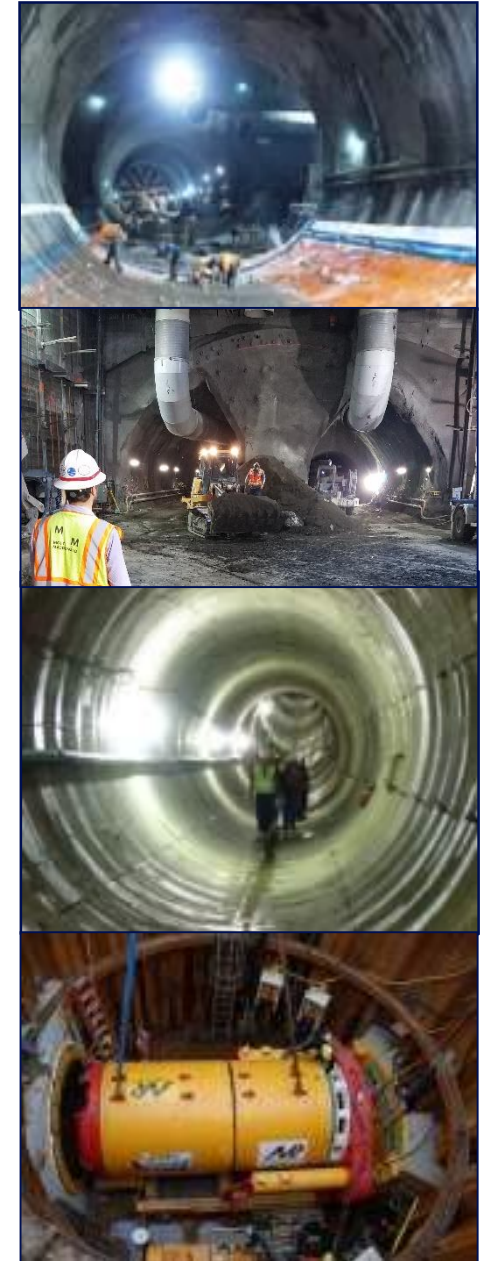
- insufficient testing

- non-representative data distribution

- uncertainty in between the borings

Previous experience is an excellent baseline

Baselines can / should consider more than just the data



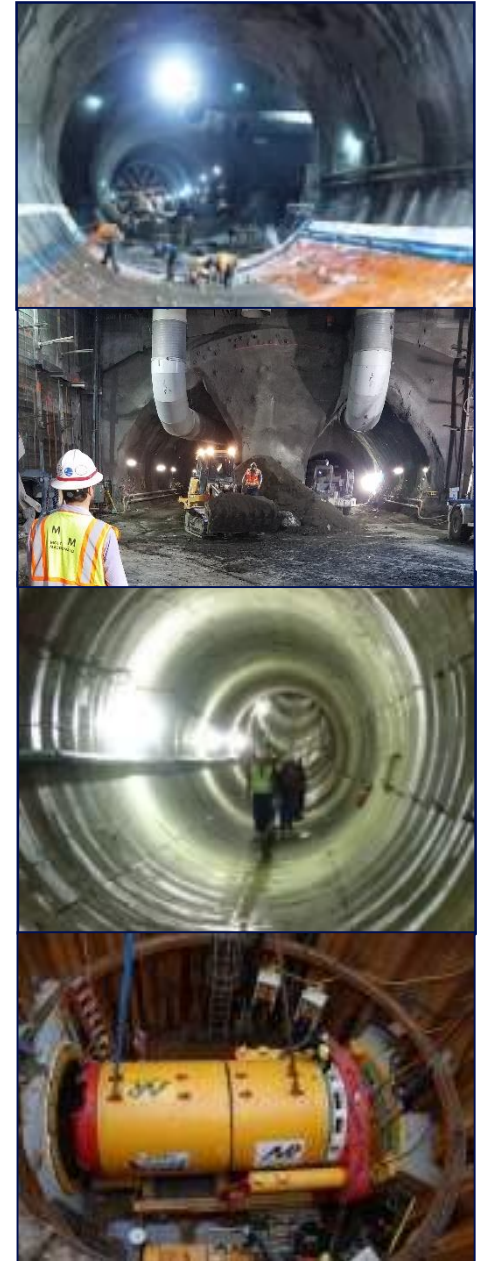


# Clarify how the baselines apply

Are the strength parameters intended for design or for excavation planning?

To what areal extent do the baselines apply – if baselines are written for a 15 m diam shaft, but the Contractor excavates a 25 m shaft or a slot trench, do the baselines apply?

Clogging potential of claystones vs sticky clays



# “Fit” within the Contract

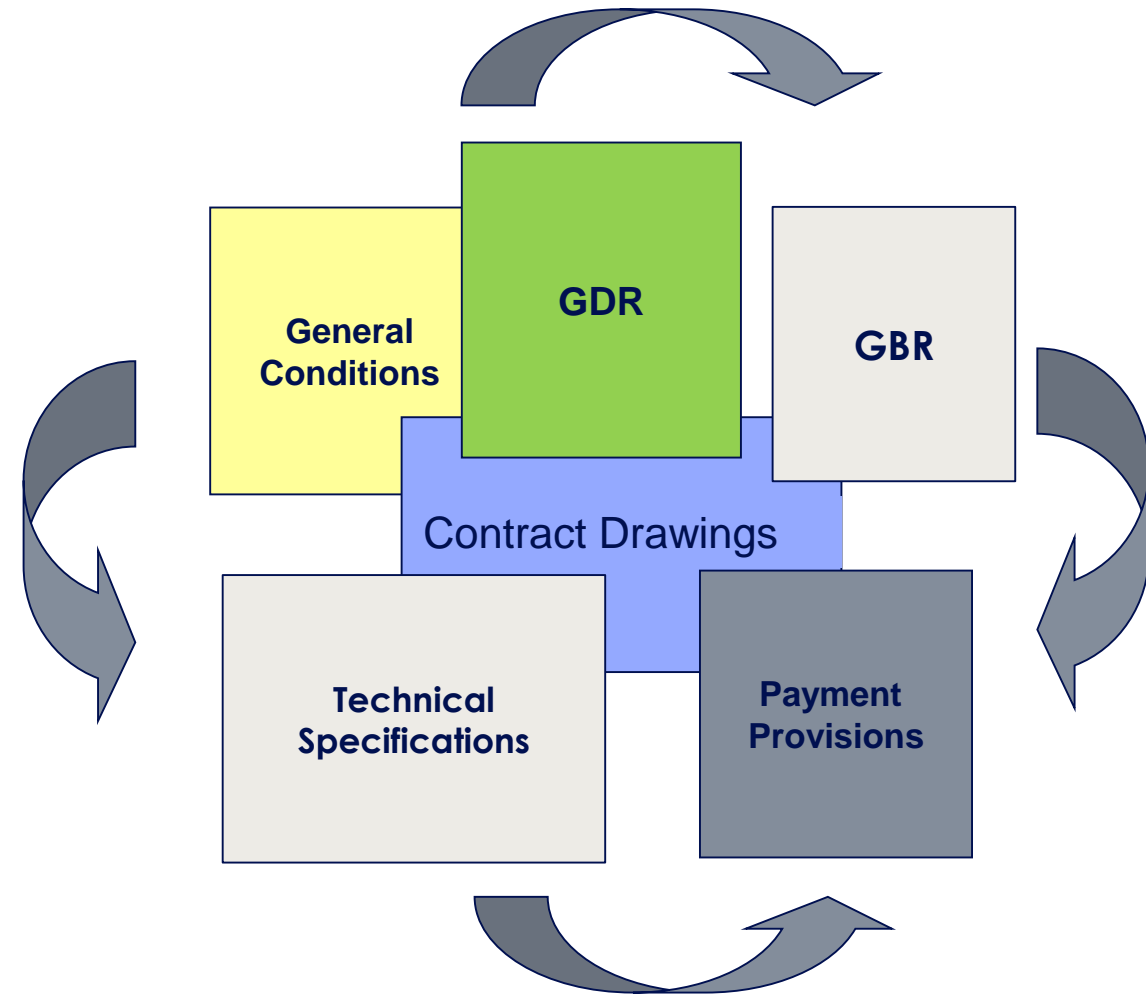
Page-turning consistency check

“3 – C’s”

Clear

Concise

Consistent



# Future developments



# Future developments

GBRs now used in US, Canada, New Zealand, Australia, Switzerland, Chile, Hong Kong, Singapore, UK, India, Abu Dhabi, South Africa

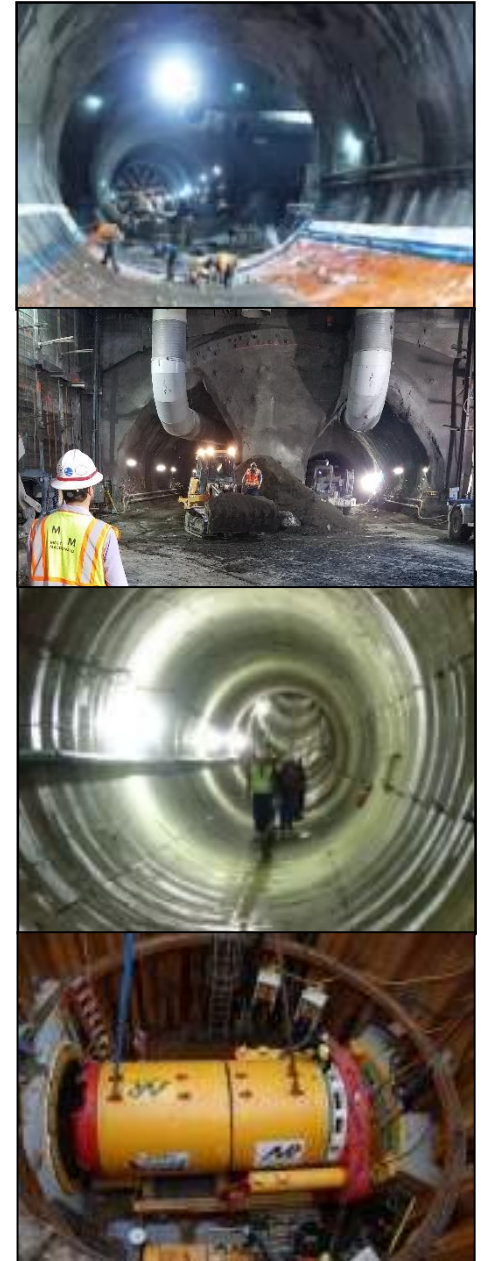
## International Tunnelling Association

Working Group on Contractual Practices

- Joint effort with FIDIC – new “Emerald Book” that will endorse GBRs and DRBs
- Expected by May 2019
- How to adapt GBRs to other international forms of contract (NEC, French, Swiss, HK, Singapore)

## Underground Construction Association of SME

New Committee to create Pamphlet – Alternative procurement approaches for underground construction



# Future Challenges - PPP

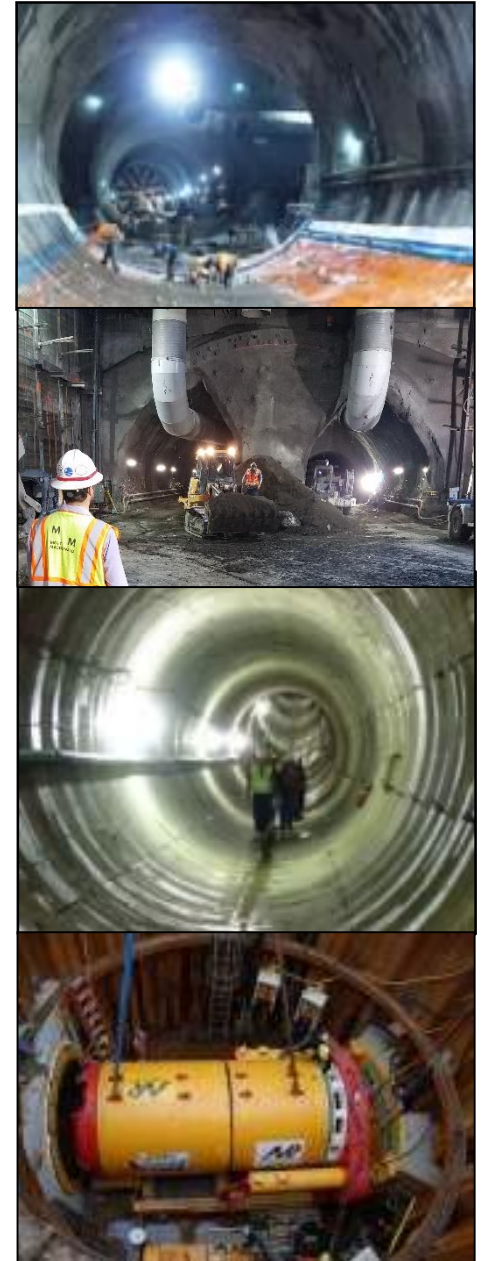
Some PPP advisors believe that they can shed all risk to the developer/concessionaire/contractor

Single price, single completion date

All risks to single party, no risk sharing

Underground industry needs to advance risk sharing solutions, not risk shedding solutions

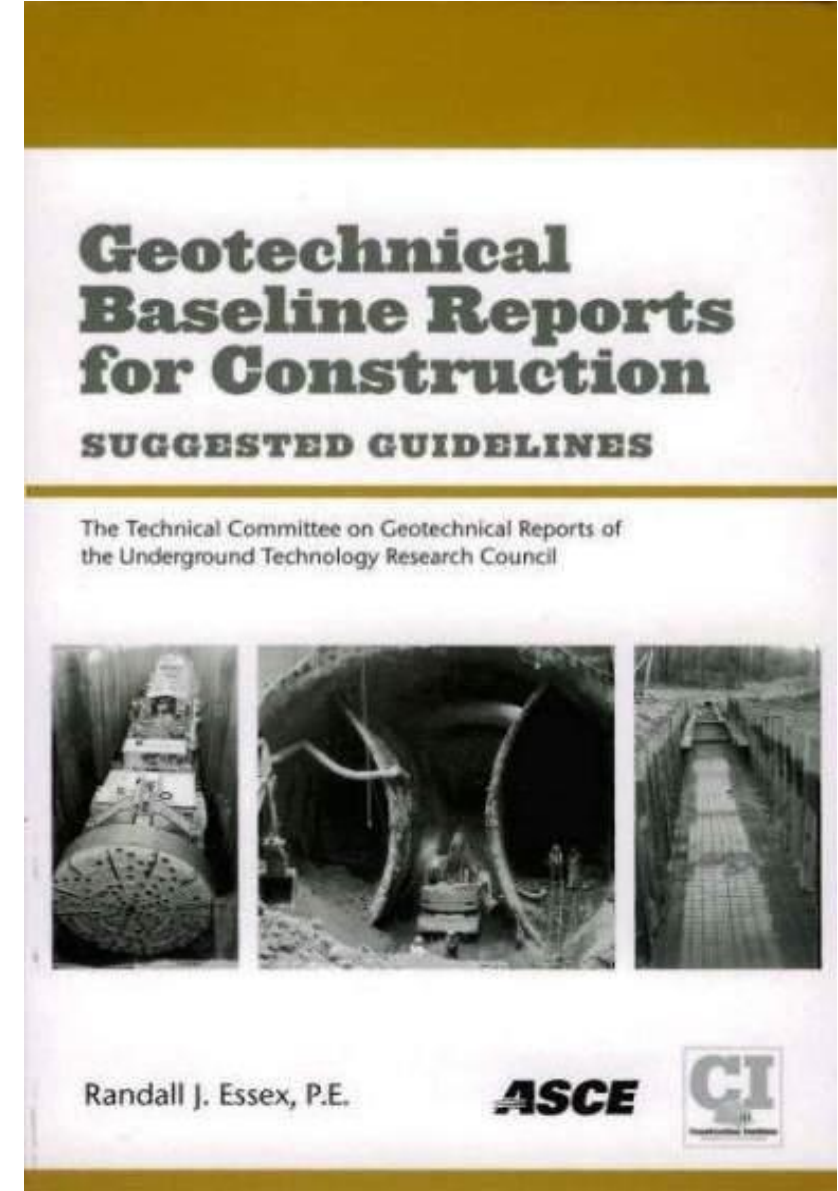
Educational exchanges needed with PPP advisors



# Additional reading

ASCE Book Dept., ISBN 13: 978-0-7844-0930-5

[www.amazon.com](http://www.amazon.com)



# Summary

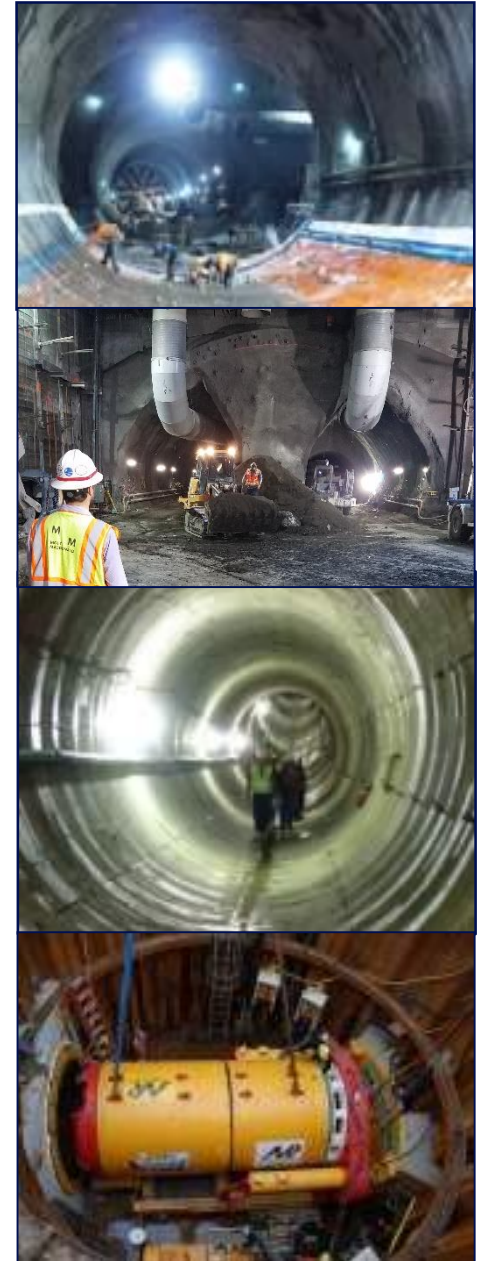
Underground construction is unique

Different contracting strategies are warranted

GBR approach not perfect, but it works

Write reasonable baselines and enforce them

*Benefit from the many lessons learned...*





Thank You!

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