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USWAG 2022

Engineering Best Practices for Stable and Safe Construction for Ash Basin Closures

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1: Ash Basin Closures: Learning Cycle

Investigations → **Designs** → **Free Water Removal and "Pond Prep"** → **Construction**

Investigations

- *Mostly in Accessible Areas (which are stronger!)*
- *SPTs and Lab Testing*
- *Limited CPTs*
- *Drained Friction angle > 32 deg narrative*
- *Ash dissipates pore pressures "fast"*
- *Limited Instrumentation*
- *"We know ash behavior" confidence*

Questions:

- *Undrained?*
- *Contractive?*
- *Liquefaction?*
- *CPTs?*

Designs

- ***Closure in Place***
  - *regulatory approval*
  - *"get on the crust and cap"*
  - *solid waste landfill civil-geotechs*
- ***Closure by Removal***
  - *"leave it to Contractor"*
  - *10H:1V slope with seepage-face "safe"*

Questions:

- *Phasing plans and excavation specs?*
- *Tailings Geotechs?*
- *Slope stability?*
- *Instrumentation?*

Free Water Removal and "Pond Prep"

- *Regulatory decanting deadlines*
- *Drawdown rates based on dam safety*
- *Not much instrumentation in ash*
- *Pond prep with rim ditches and bridge lifts*

Lessons:

- *Fatality due to ash slough during prep operations in Midwest*
- *Several major in-pond sloughs during decanting in Southeast*
- *Major in-pond slough of 10H:1V, 30 ft high slope post-decanting*

Construction

Focus on Contractor and Engineer balance for Safe Closures

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2: Ash Basin Closure: *"The Great Balance"*

"Two Extremes", balance may be in the middle

Owner and Contractor Project Needs that may Compete for Priority on a Daily Basis

Contractor Experience and Engineering Best Practices – with *Owner Commitment*

Foundation for Safe and Successful Ash Basin Closure

Play Book A:

- 100% rely on Contractor Experience
- Use best practice means and methods
- Pond evaluation and prep are mainly based on visual inspections and surface feel
- Passive dewatering with rim ditches; monitoring rim ditch water levels – no other instrumentation
- ……

Play Book Z:

- Engineer and Contractor develops Phasing Plan with "50+" excavation sequence sheets
- Basin heavily instrumented: base system + mobile excavation area system
- Slope stability analyses and trigger levels for each step
- Active/mechanical dewatering throughout basin
- ……

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3: Observational Approach always Work?

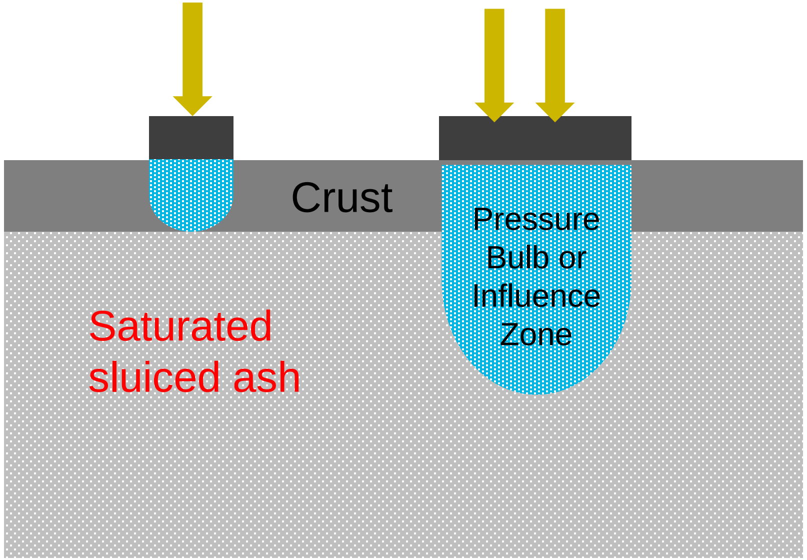
Commonsense Approach?

$$\text{Pressure} = \frac{\text{Weight}}{\text{Contact Area}}$$

Rational Engineering Analysis

$P = F/A$

$P = 2.5F/2.5A = F/A$



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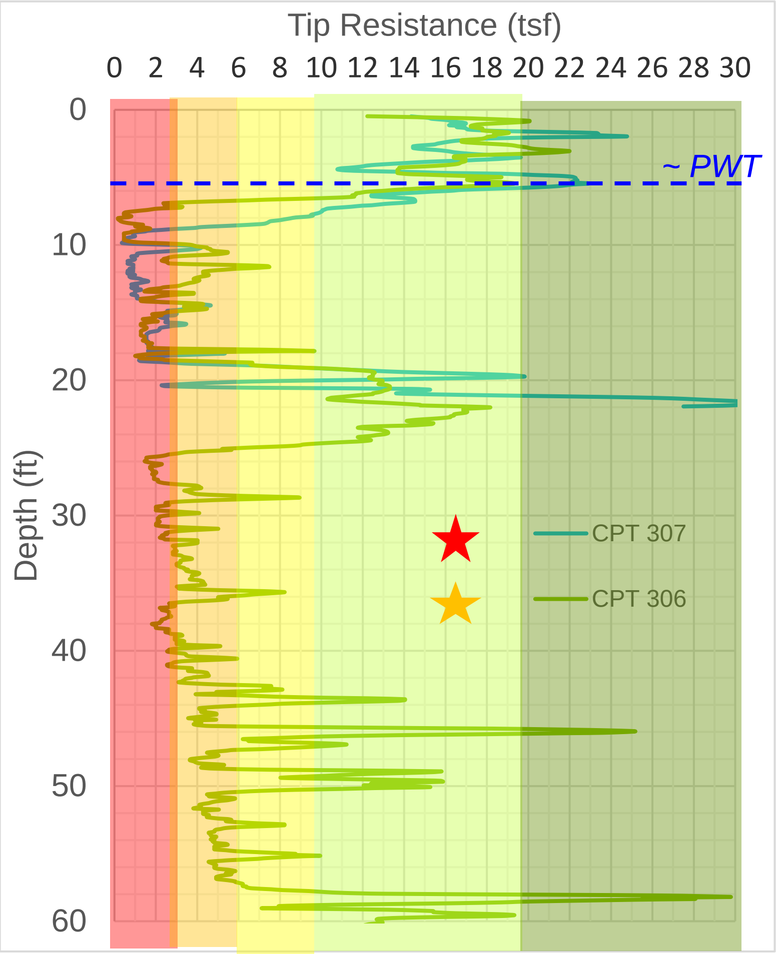
4: CPTs should be Contractors' Ally for Safety



- ★ CPT stopped in the middle and pushed back during field work due to safety concerns
- ★ CPT safely completed to full ash depth

Local (bearing capacity type) instability versus global instability

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5: In-Pond Slide of a 10H:1V slope ~ 2 years following free water removal

~ 30 ft high, 10H:1V ash slope

Free water pool reduced to less than 3 ft about 2 years prior to slide (safely)

Pore water levels inside ash likely remained high though

Once slough triggered, likely resulted in strength loss in loose layer under porewater table

Dam stopped the ash movements proceeding further

Free water *not* involved for major portions of the slide in causing mixing and flow (free water mixing attributed at times for other sloughs by some)

No injuries – a wake up call for ash basin closures

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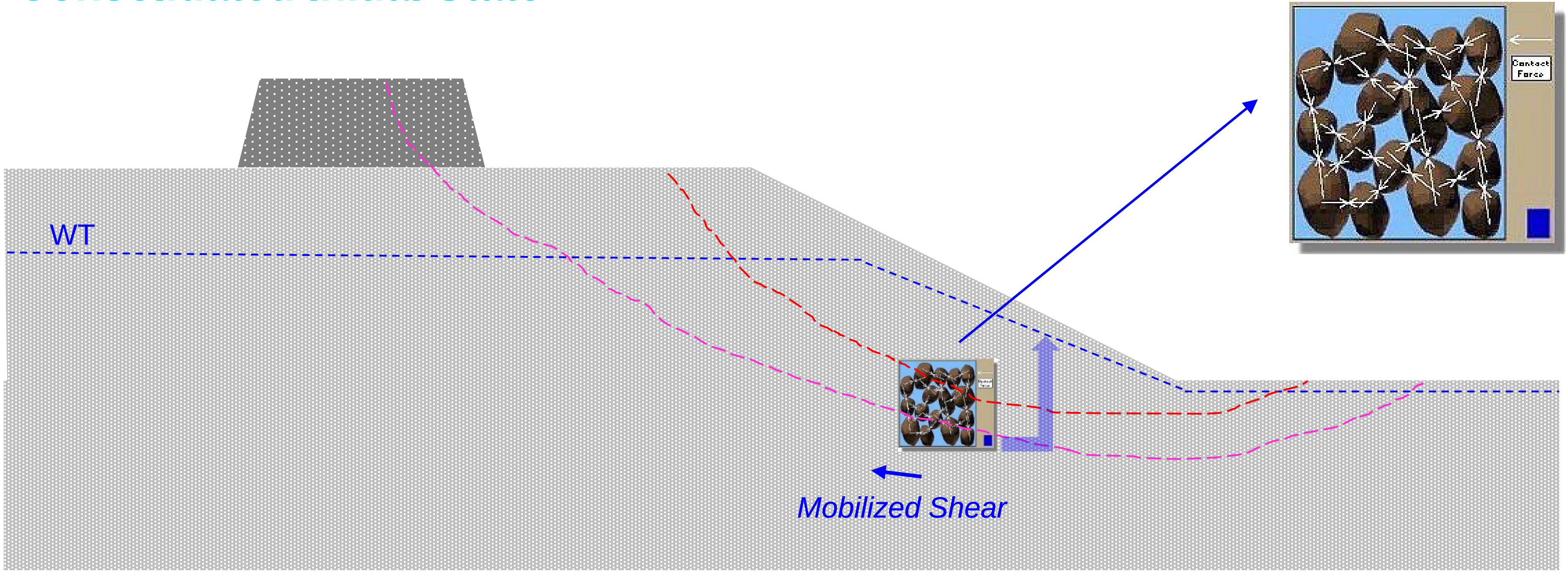
6: Consolidated Initial State

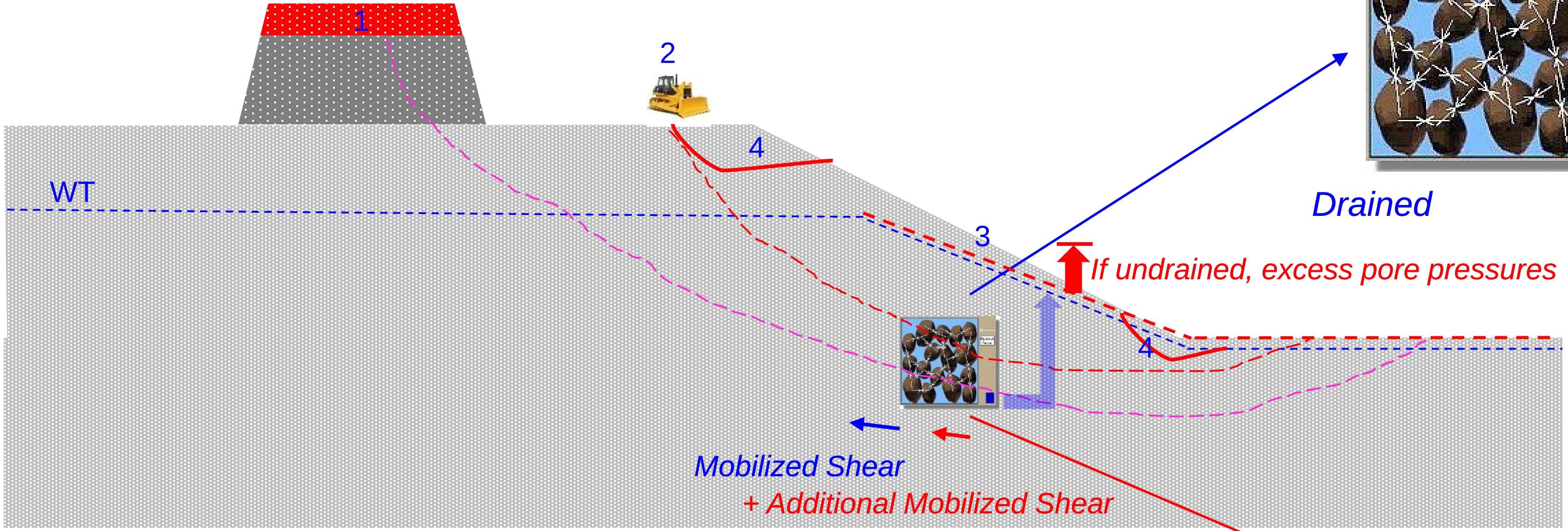


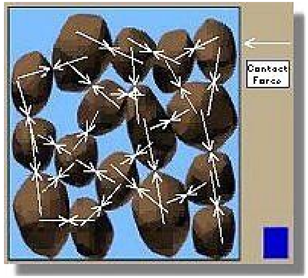
“Static” (or steady state seepage) pore pressures.

Some level of shear strengths mobilized to resist driving forces.

Likely drained shear strengths -> drained factor of safety.

7: Shearing State – Drained or Undrained



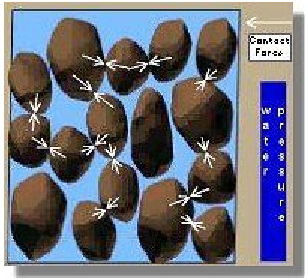


Drained

Additional loads or triggers such as additional fill, construction equipment, increased water table, smaller sloughing in slope, or unknown changes.

Additional shear strengths mobilized to resist driving forces.

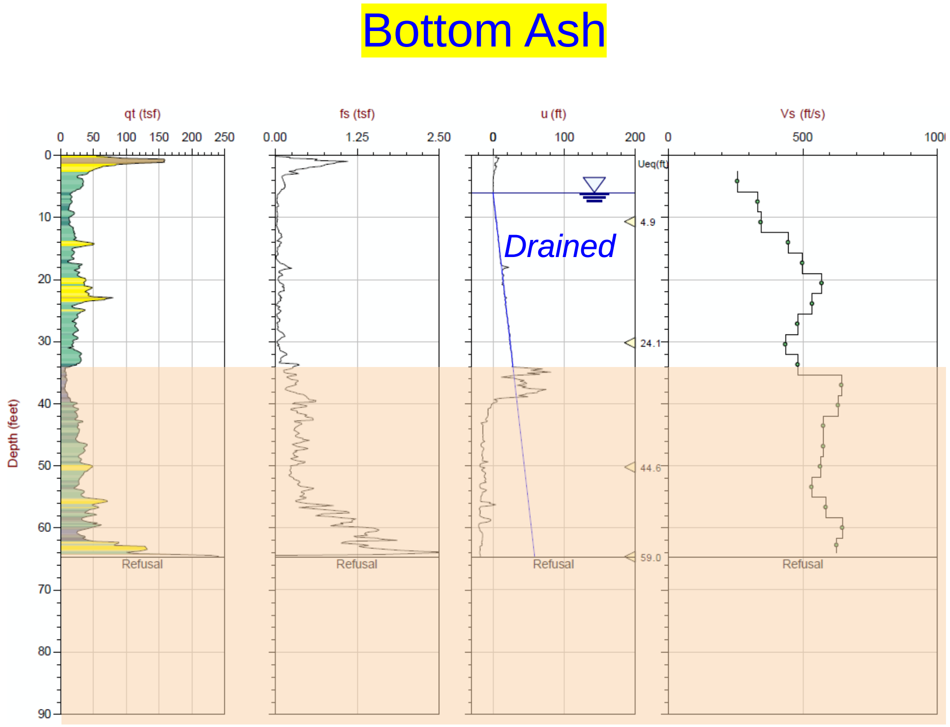
During this additional shear strength mobilization, if no excess pore pressures develop, it is drained. If excess pore pressures develop, it is undrained.



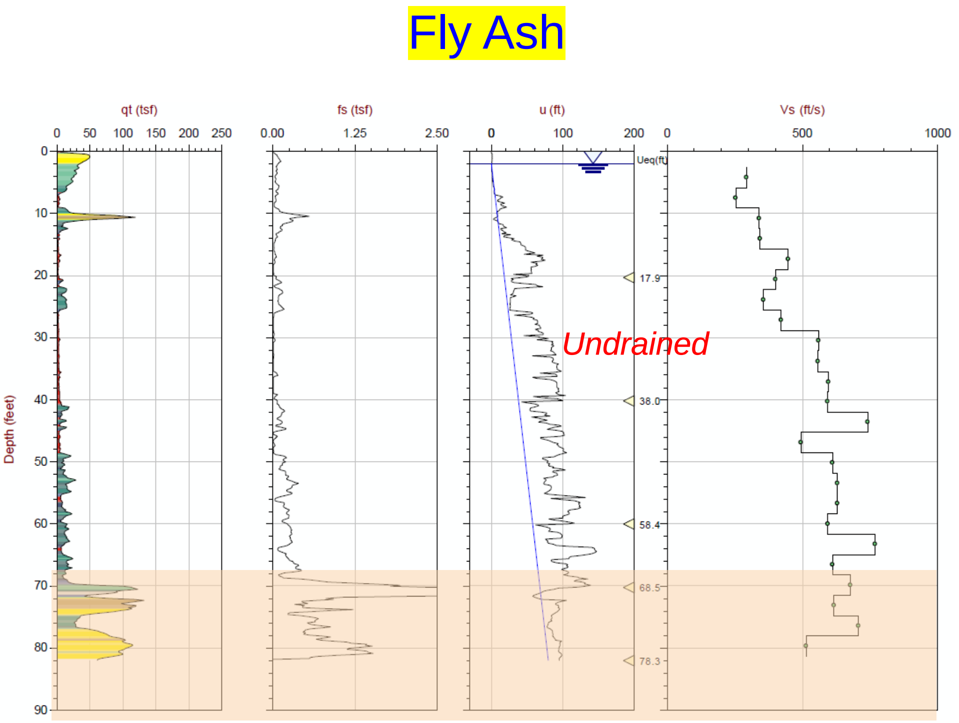
Undrained

Both drained and undrained factor of safety values need to be evaluated.

8: Pore Pressure Response during CPTs



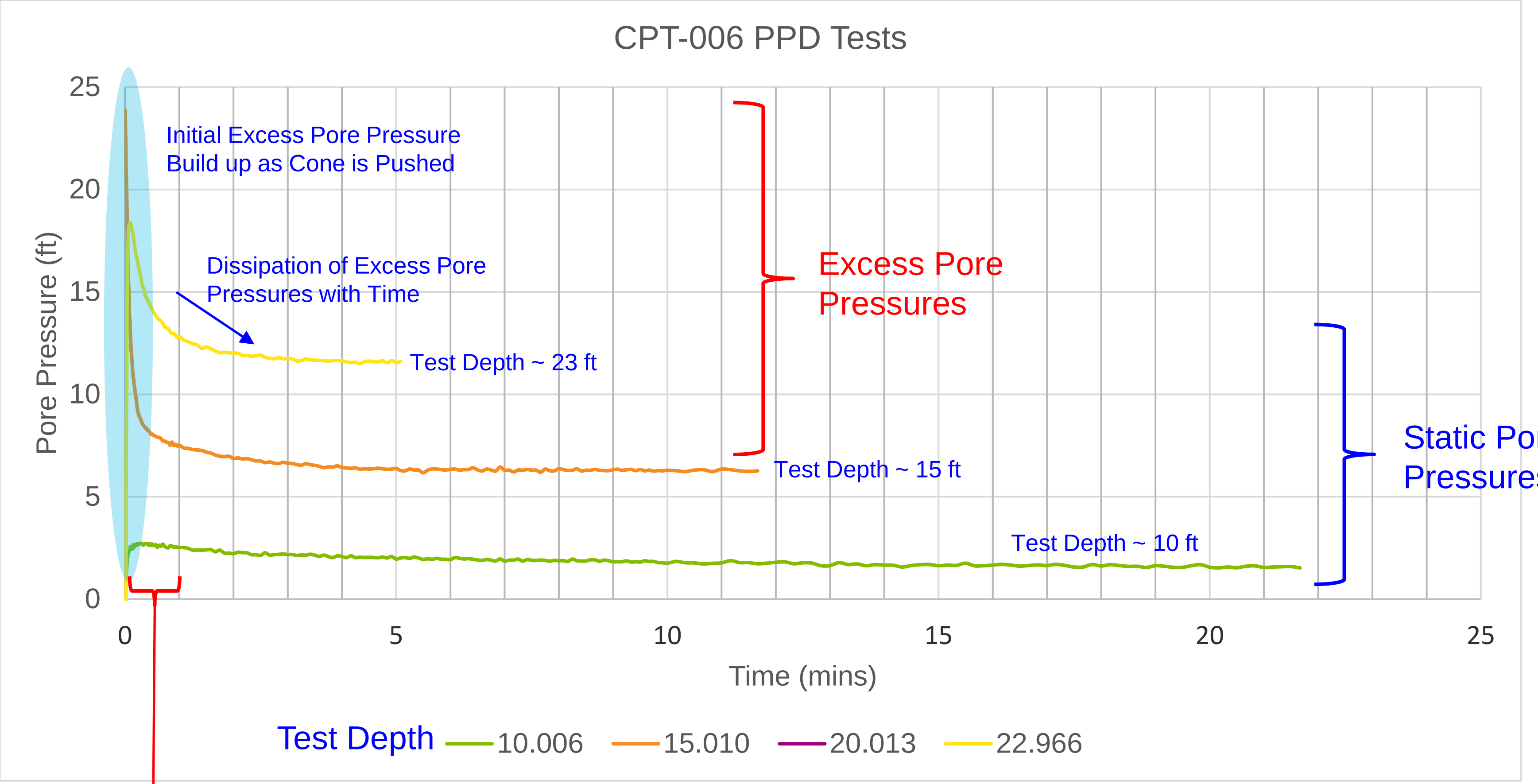
AB 104



AB 101

CPTs by ConeTec for AECOM

9: CPT Pore Pressure Dissipation Tests



Undrained failures can take place within seconds to few minutes

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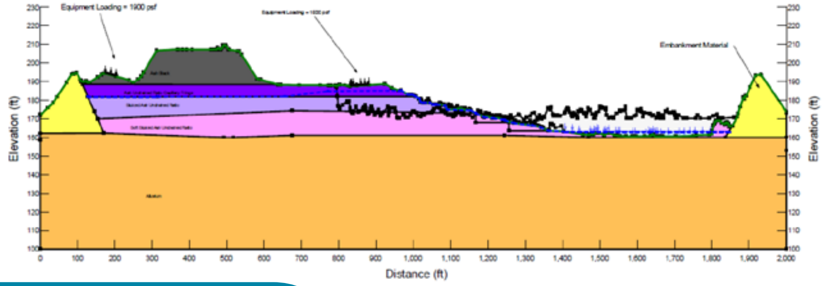
10: Stages of a Slide and Mitigation Approaches

Stage 1 - a triggering event that starts a small or large slide

Examples:
- Rapid drawdown of water pool
- Equipment load
- Sudden excavation at toe of slope
- Addition of bridge lift at crest of slope
- Scour
- Pore water table increase

Stage 2 - an underlying condition that aggravates the slide and prevents it from being confined locally

Examples:
- Steep and high slopes
- Proximity to free face
- Loose layer



Stage 3 - sliding mass movements building up acceleration and momentum with changing properties of the slide mass

Examples:
- Mass slide
- Flow slide (static liquefaction)
- Mixed with free water and flow

Stage 4 - slide movements coming to a rest due to geometry

Examples:
- a barrier such as dam stopping movements
- at-rest conditions reached on its own due to changing geometry

- 100% reliance on “means and methods” or “observational method” approach may not have full appreciation of underlying conditions beyond what is visible or “basin is telling” when equipment is put on it. [CPTs can help, along with other data]

- Controlling/preventing triggers is not always possible. Assume reasonably likely triggers will occur and evaluate what will happen – and then try and prevent/mitigate it. [(undrained) Slope Stability Analyses can help]

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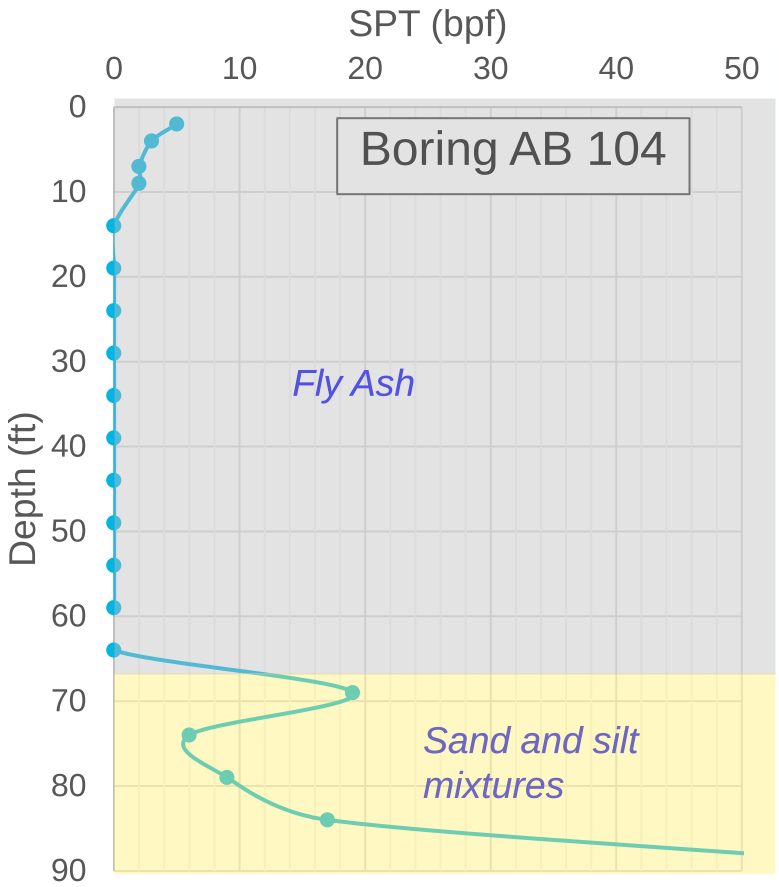
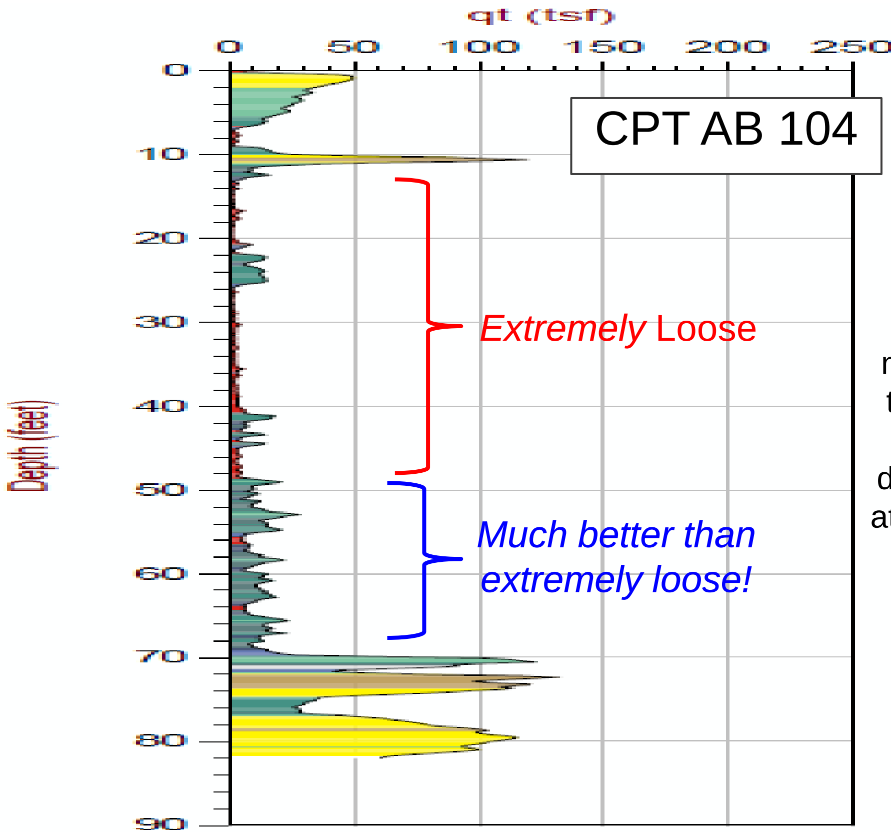
11: Why CPTs are better than Traditional SPTs to Characterize Ash?





SPTs are not helpful to identify strength differences at adequate level

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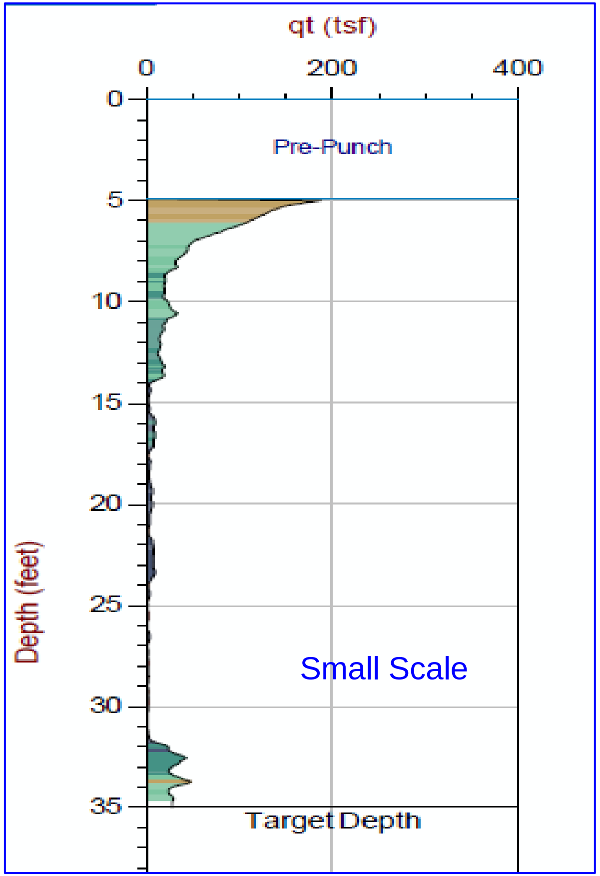
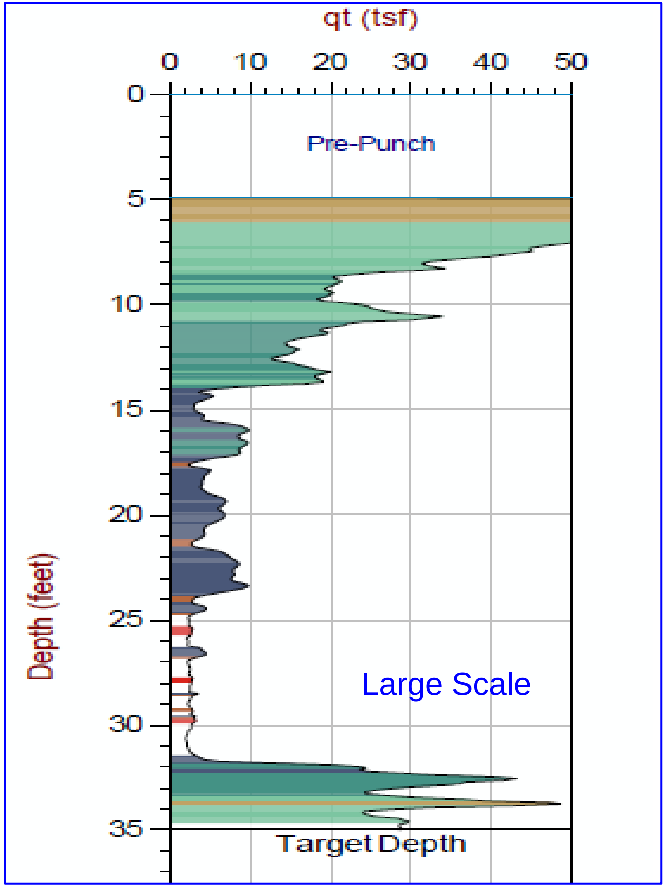
12: High level look versus detailed review of CPT tip resistance





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13: CPT Tip Resistance and Undrained Shear Strength

"60 mins CPT Expert Slide"

CPT Tip Resistance of Ash	Comment	Potential Critical Behavior
q_t < 3 tsf	**Extremely loose. Sample recovery very difficult and will be disturbed.**	Undrained critical – ash may even be at liquefied shear strength condition insitu.
3 tsf < q_t < 6 tsf	**Very loose. Sample recovery challenging.**	Undrained more critical, in general.
6 tsf < q_t < 10 tsf	**Medium.**	Depending on conditions, undrained or drained may be critical.
10 tsf < q_t < 20 tsf	**This is getting to be reasonably "good" for ash!**	Drained friction angles may start being critical.
q_t > 20 tsf	**Good.**	Drained friction angles critical, in general.

This is a general illustrative guidance only. Case-specific interpretation will be needed.

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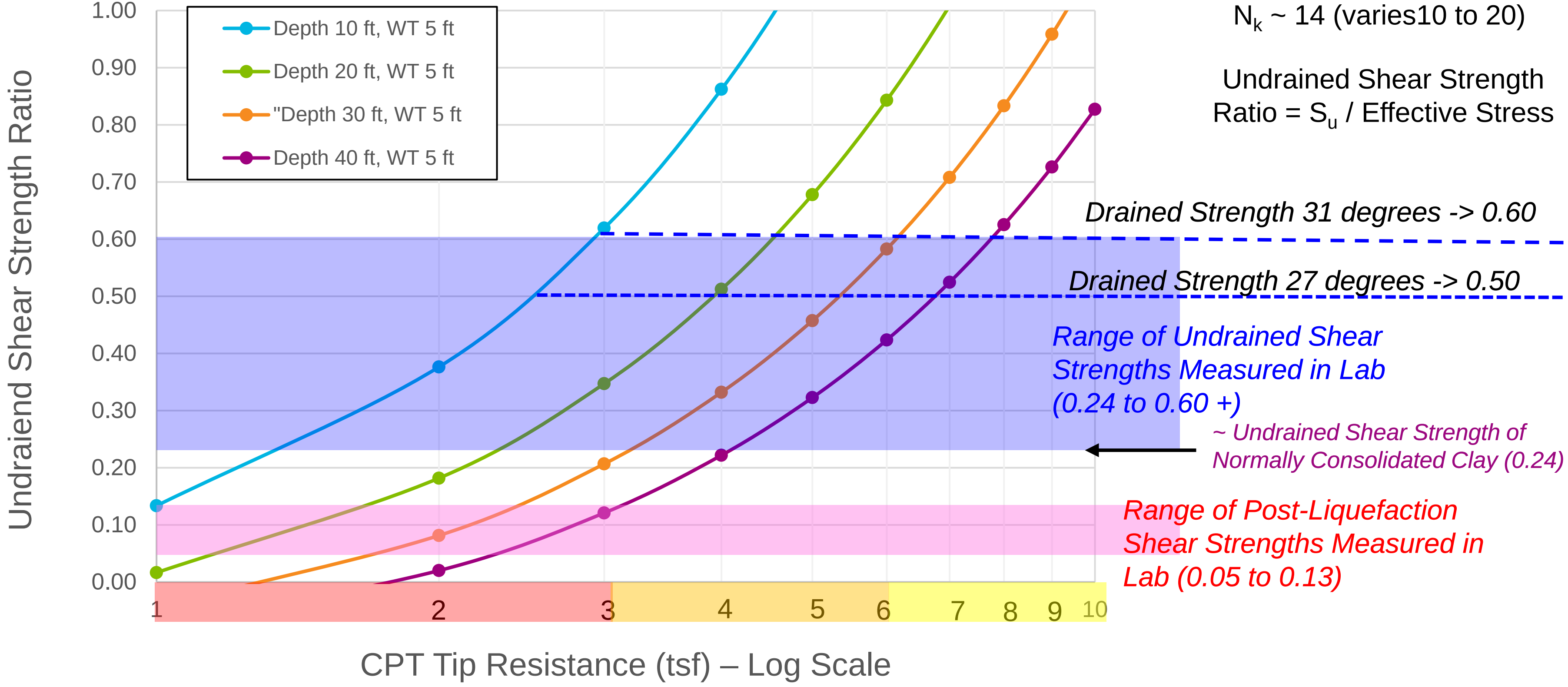
14: CPT Tip Resistance and Undrained Shear Strength

$$s_u = \frac{q_t - \sigma_{v0}}{N_k}$$

N_k ~ 14 (varies10 to 20)

Undrained Shear Strength Ratio = S_u / Effective Stress



This is a general illustrative guidance only. Case-specific interpretation will be needed. Vane shear data and failure back analyses support CPT based strengths.

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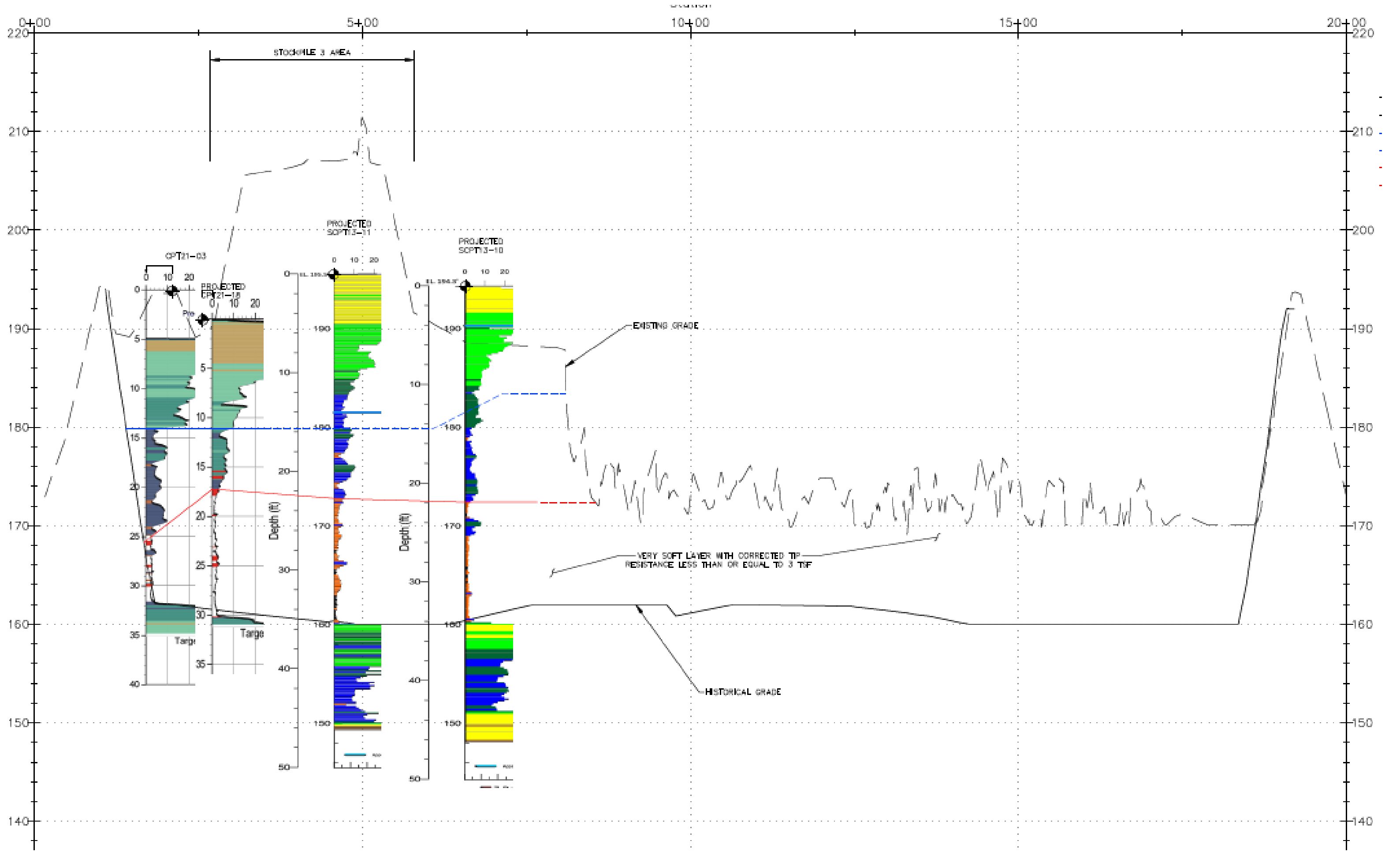
15: CPT Cross Sections



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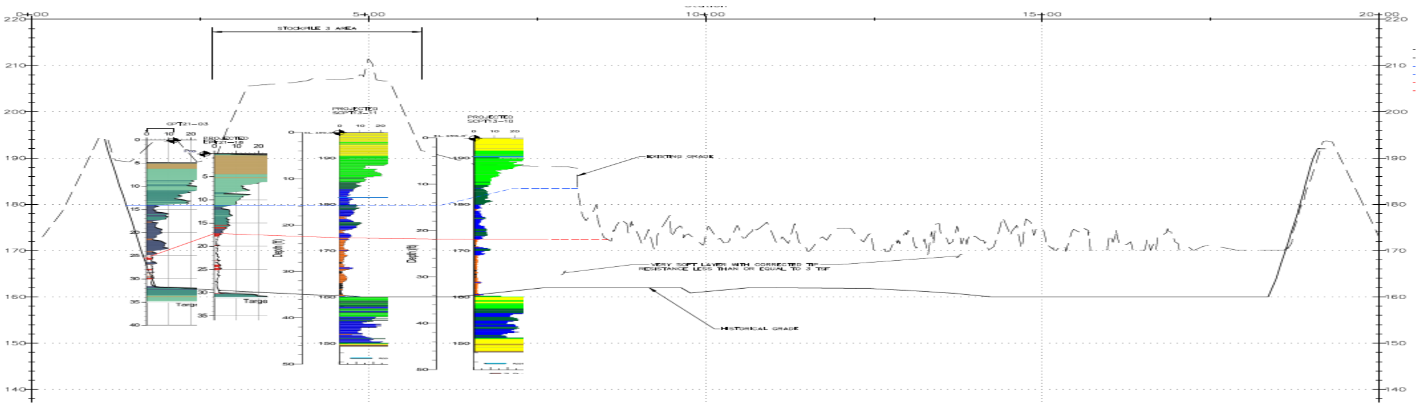
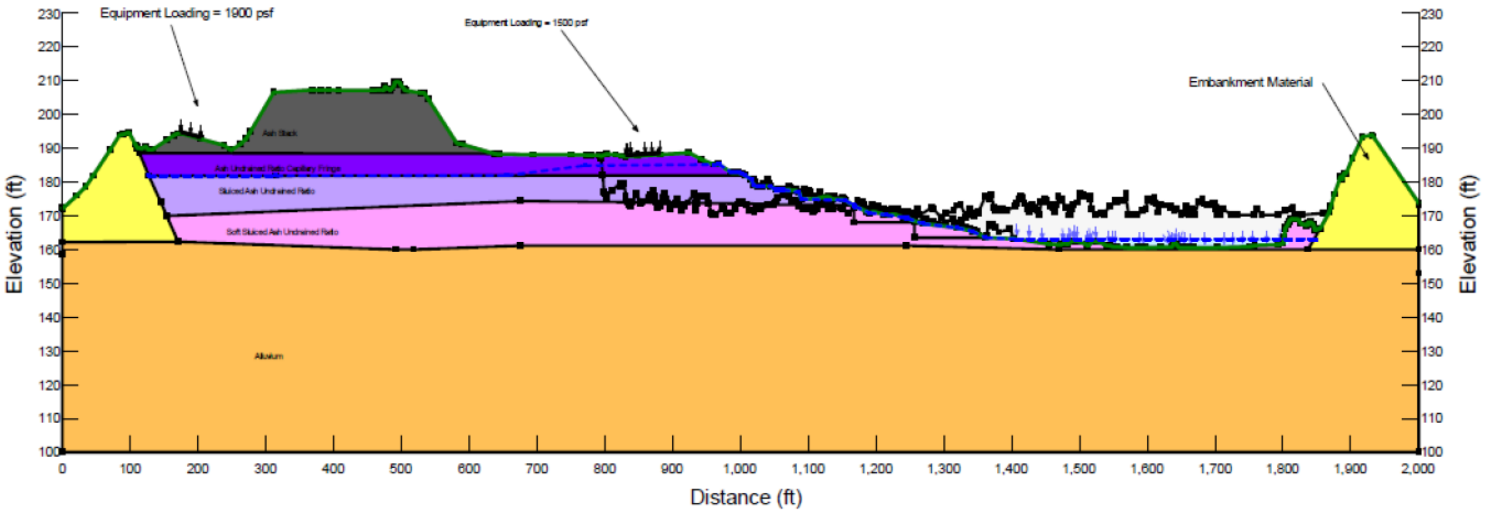
16: CPT Cross Sections used to develop Slope Stability Model with Layers





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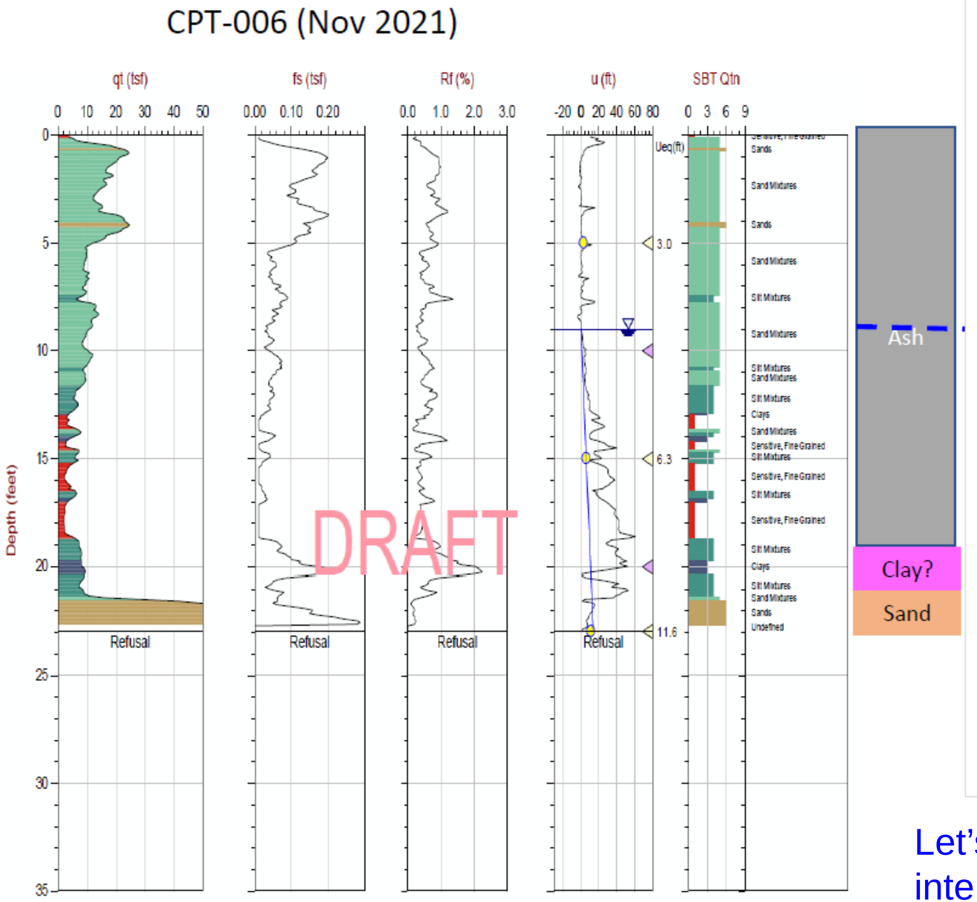
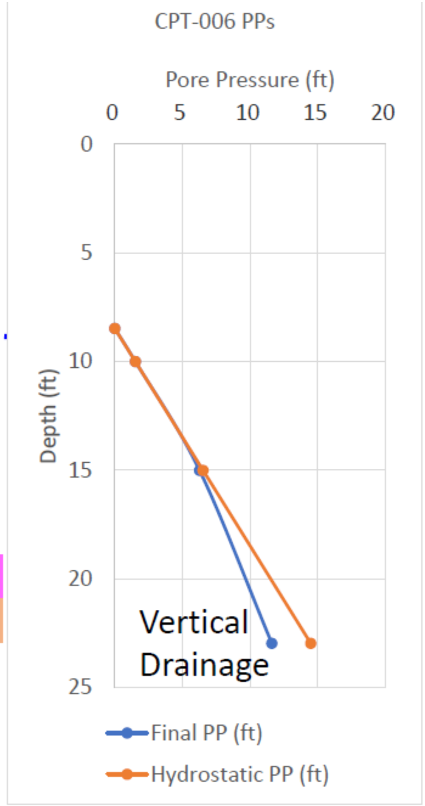
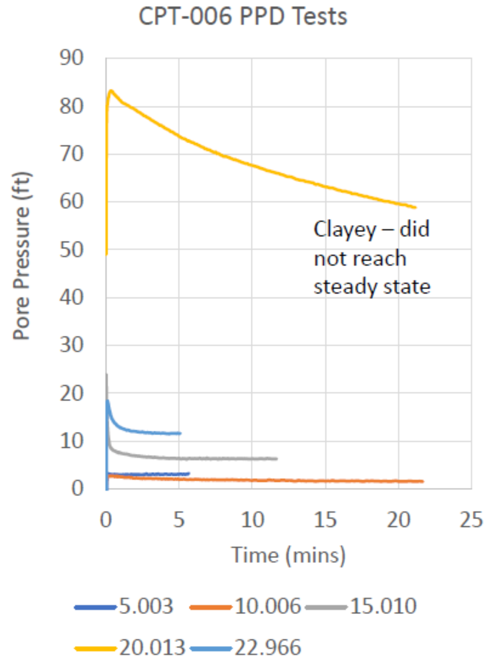
17: Using CPT Dissipation Tests to Evaluate Water Table and Static Pore Pressures







Let's not force a hydrostatic pore water interpretation on draining or seepage condition ash basins when data tells otherwise!

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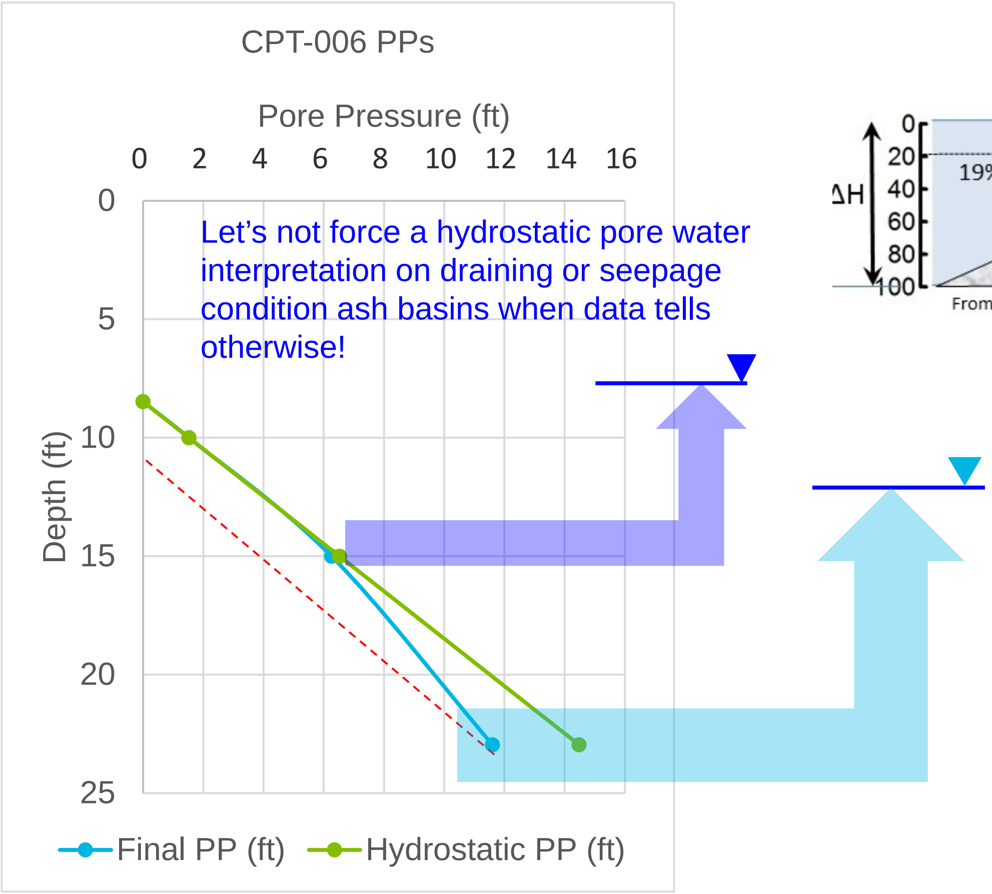
18: Using CPT Dissipation Tests to Evaluate Water Table and Static Pore Pressures



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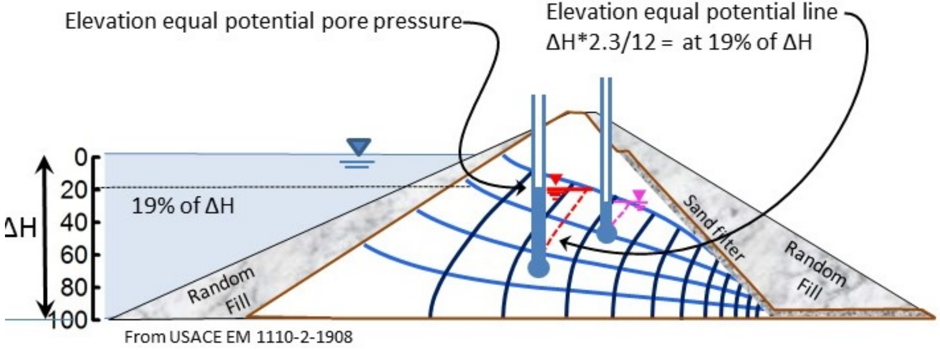

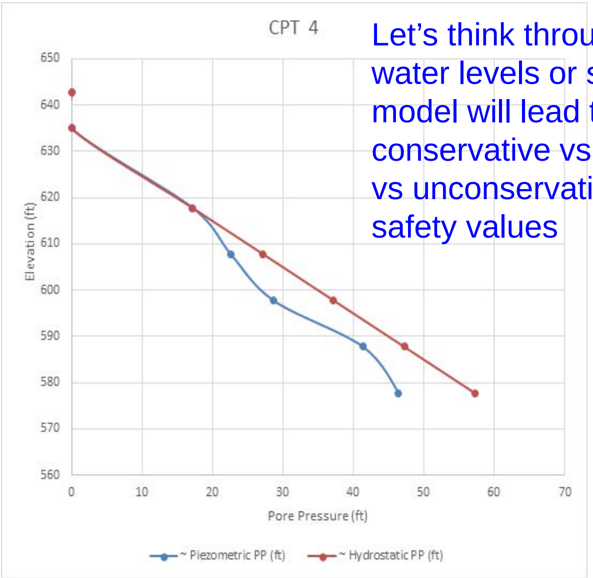

Let's think through which water levels or seepage model will lead to conservative vs reasonable vs unconservative factor of safety values

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19: Pore water pressure/level spatial variation

Reporting options for time trends:

- Long term water level trending focus
- Spikes and excess pore pressure focus
- Good mix of both

Vibrating Wire Piezometers (VWP) can be installed during CPT investigations.

Properly installed (with filter pack) standpipe piezometers screened in ash are ok too (installed by drilling).

This is not the same as GW level contours drawn based on wells outside the ash basin or screened below ash by hydrogeologists!

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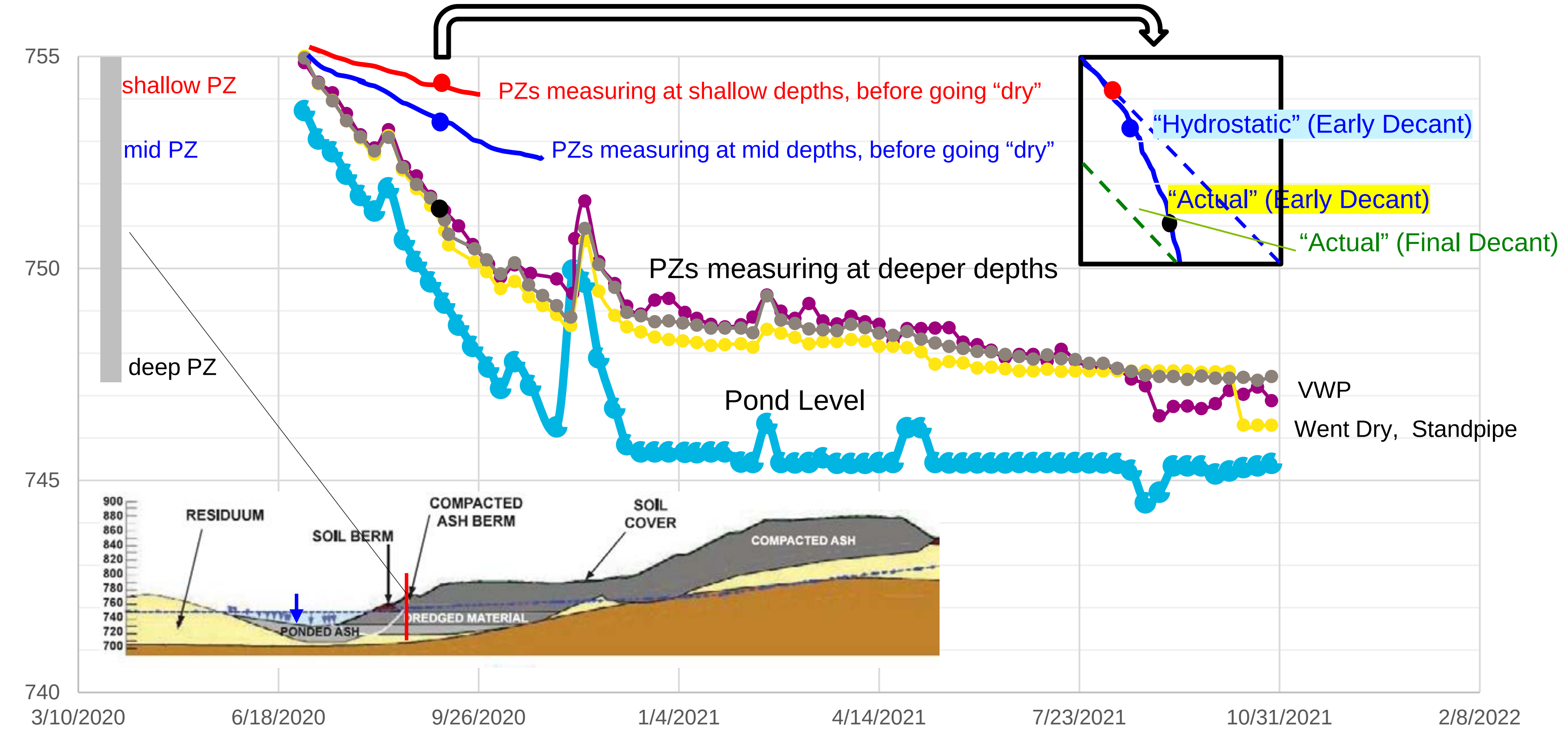
20: Pore water pressure/level time trends



Use of standpipes and VWPs at this site

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21: Summary

1. Based on recent decanting and construction phase ash slides, there is need for more robust use of ***engineering investigation and analyses*** to support construction best practices for safe ash basin closures.

2. ***CPT*** is a great tool to supplement existing SPT boring information for ash basin characterization for ash stability evaluations. CPTs should be used to develop ash layers for slope stability analyses.

3. ***Undrained slope stability analyses*** are generally more critical than drained analyses for loose saturated sluiced fly ash areas. Undrained strengths can be developed using CPTs (lab shear strengths may be impacted by sample disturbance in extremely loose ash areas).

4. ***Instrumentation such as Vibrating Wire Piezometers (VWP)*** can be combined with CPT field work and help to provide data throughout construction and support analyses.

5. ***Dewatering to lower porewater levels*** adequately can lead to mitigation of undrained failure triggers in dewatered ash layers.

6. ***Engineering data evaluation and analyses are a supporting system for construction*** – not a barrier, if used and balanced with "means and methods" approach appropriately.

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Thank you.

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