ENGINEERING THE PROCESS OF CCR IMPOUNDMENT CLOSURE

Successful Preparatory Techniques with Construction Examples to Enable Accelerated Mass Filling for Closure-In-Place of CCR Impoundments

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ABSTRACT

The closure of many large coal combustion residuals (CCR) impoundments, be it closure-in-place or closure-by-removal, entails work within and over challenging ground conditions, consisting of hydraulically-deposited, saturated, fine-grained CCR materials with high sensitivity and low shear strength. In some circumstances, a sizeable supernatant pool exists, bordered by exposed deltas and areas surcharged by stockpiled or “dry-stacked” materials. The initial subsurface conditions and corresponding margin of stability can vary significantly over the CCR impoundment. Accordingly, as with any significant construction over soft ground, CCR impoundment closure necessitates some extent of construction engineering.

This paper and companion presentations focus on important geotechnical considerations in constructing CCR impoundment closures, present data representative of more challenging CCR foundation conditions, and describe engineered preparatory techniques that have proven successful in establishing safer and more stable conditions to support conventional, heavy earthwork construction. Drawing from our recent and ongoing CCR impoundment closures, we cover the initial geotechnical investigations and findings, highlight the more problematic ground conditions that were identified, present the major pre-dewatering preparations undertaken in different impoundment areas, and discuss how our engineered process has enhanced safety and led to successful CCR impoundment closures. We close this paper with examples of preparatory techniques that we’ve applied to first enhance ground stability, and subsequently enable an accelerated rate of heavy earthwork construction (mass filling and/or excavation). The need for continued engineering support during construction is emphasized.

In our recent construction of CCR impoundment closures, we have managed continuing discharges and a supernatant pool, addressed less stable areas surcharged by past "dry" disposal activities and stockpiling, and orchestrated construction over submerged and exposed deltas. We've relied on findings from self-performed geotechnical investigation and engineering to establish a construction process that ultimately enables accelerated mass filling (akin to traditional heavy earthwork construction) for closure-in-place of the CCR impoundment. This pairing of engineering and construction has contributed to safer and more efficient closure-in-place construction.

This paper and companion presentations also provide a constructor's perspective on implementing an engineered process to prepare CCR impoundments for accelerated mass filling. We cover the major impoundment subsurface dewatering and unwatering measures, mitigation of potential stability issues presented by existing surcharges and stockpiles, initial preparation of basin areas, safety precautions, and training, inspection and monitoring systems that have contributed to successful in-place closures. Means to manage and improve stability during initial or preparatory earthwork operations are discussed, including passive and active dewatering, geogrid use, strategic fill placement, selective excavation, best practices for upstream construction, and engineered sequencing.

Engineering presented by Don Grahlherr[1] and Preparatory Construction presented by Steven Turner[1] at the 2022 World of Coal Ash Conference, May 16-19, 2022.

INTRODUCTION

The closure of many large CCR Impoundments, be it closure-in-place or closure-by-removal, entails work within and over challenging ground conditions, consisting of hydraulically-deposited, saturated, fine-grained CCR materials with high sensitivity and low shear strength. In some circumstances, a sizeable supernatant pool exists, bordered by exposed deltas and areas surcharged by stockpiled or “dry-stacked” materials. The initial subsurface conditions and corresponding margin of stability can vary significantly over the CCR impoundment. Accordingly, as with any significant construction over soft ground, CCR impoundment closure necessitates some extent of construction engineering.

The available geotechnical information at the time the closure project is advertised for construction bids can be limited, due to investigations being concentrated in more accessible, above-water areas of the CCR impoundment with properties presumed based on past experience. The location, extent, continuity, and behavior of sensitive, fine-grained CCR materials within the impoundment and their implications for closure construction, especially from the standpoint of ground stability and safety, are often not well delineated and characterized. Accordingly, some extent of initial or advance geotechnical investigation by the construction contractor is often warranted to support engineered plans for closure construction.

This paper focuses on important geotechnical considerations in constructing CCR impoundment closures, presents data representative of more challenging CCR foundation conditions, and summarizes engineered preparatory techniques that have proven successful in establishing safer and more stable conditions to support conventional, heavy earthwork construction. Drawing from Tetra Tech’s recent and ongoing CCR impoundment closures, we summarize the initial geotechnical investigations and findings, highlight the more problematic ground conditions that were identified, present the major pre-dewatering preparations undertaken in different impoundment areas, and discuss how our engineered process has enhanced safety and led to successful CCR impoundment closures. Considerations of stability during closure construction are discussed, including pre-planning and impoundment preparation, instrumentation and monitoring, benefits of *Earthwork Construction Plans*, and associated best practices for upstream construction.

For reference in the subsequent discussions, PowerPoint® slide decks from the following WOCA 2022 presentations are attached:

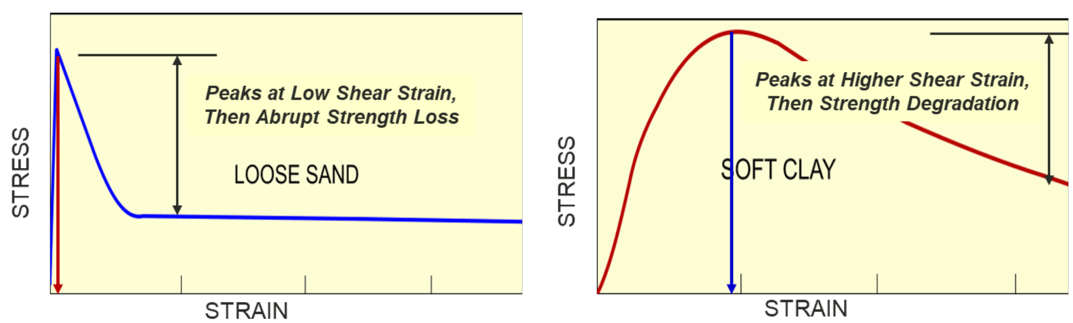
> Attachment 1 - Engineering The Process Of CCR Impoundment Closure: Successful Preparatory Techniques to Support Heavy Earthwork Construction
>
> Attachment 2 - Preparatory Construction To Enable Accelerated Mass Filling For Closure-In-Place Of CCR Impoundments

Tetra Tech is an advocate of in-situ testing for characterizing hydraulically-deposited CCR materials, as complimentary methods are available that can characterize the broadest extent of the CCR deposit. Our emphasis herein is on identification and characterization of “problematic ash,” that being nearly saturated to saturated, very soft to soft (or very loose to loose), highly sensitive, fine-grained CCR material. Where it exists in significant extent (thickness, area, continuity), “problematic ash” typically controls ground stability (bearing capacity, slope stability, propensity to flow slides) as it is susceptible to an abrupt degradation in shear strength as depicted for loose “sand-like” behavior in the following graphic.

WHY WE CARE ABOUT THE GENERAL SOIL BEHAVIOR CLASSIFICATION

“Sand-Like” & “Sensitive, Fine-Grained”: Low Peak Strength, Inordinately Low Residual Strength, and Susceptible to Cyclic Mobility When “Triggered”

“Sand-Like” *vs* “Clay-Like”



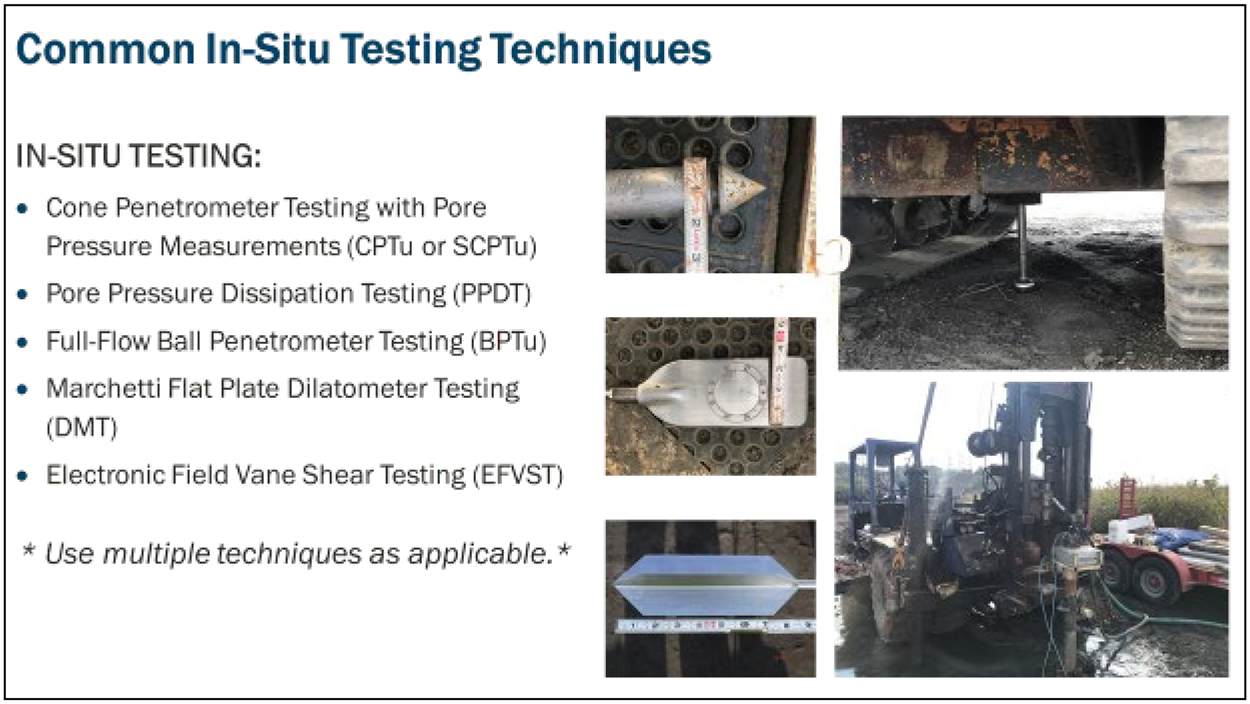
Key Distinctions:

- Strain at Peak <u>Undrained</u> Shear Strength
- Abruptness of Drop in Shearing Resistance
- Degree of Strength Loss, Sensitivity, St = $S_{u\text{-}peak}/S_{u\text{-}remolded} > 4$

Such CCR materials are typically highly sensitive as a result of high void ratio and weak or “metastable” microstructure, and therefore, are not amenable to undisturbed sampling or reconstitution in the laboratory (e.g., via pluviation) for geotechnical testing. Consequently, laboratory testing for geotechnical characterization of shear strengths, cyclic/dynamic behavior, hydraulic properties, and compressibility might not be representative. In contrast, in-situ testing provides greater opportunity to capture the representative range of “mass” geotechnical properties, while enabling improved inference of the extents of problematic ash for closer evaluation of potential hazards.

Common in-situ testing techniques include:

- Cone Penetrometer Testing with Pore Pressure Measurements (CPTu or SCPTu)
- Pore Pressure Dissipation Testing (PPDT)
- Full-Flow Ball Penetrometer Testing (BPTu)
- Dilatometer Testing (e.g., Marchetti Flat Plate Dilatometer, DMT)
- Electronic Field Vane Shear Testing (EFVST)



APPLICATION OF IN-SITU TESTING

As a general summation, CPTu or SCPTu is effective in broadly characterizing the spatial distribution of CCR materials in-situ, assessing sensitivity and generalized soil behavior, and deducing an extensive scope of geotechnical properties. PPDT, although time-consuming in fine-grained materials, helps establish the state of porewater pressures, and estimate hydraulic properties. Fine-grained CCR materials tend to lack plasticity as normally associated with clayey soils, and their behavior under load or in shear is often considered “transitional,” i.e., being neither predominantly drained nor undrained. For comparison purposes, Tetra Tech customarily prescribes some CPTu at a 1 centimeter per second (1 cm/sec) penetration rate in addition to the standard 2 cm/sec rate to evaluate differences in dynamic pore pressure development, interpreted soil response (contractive versus dilative), and characterization of soil behavior type (SBT). In some instances we have found that the longer period allowed for drainage at the slower (1 cm/sec) penetration rate yields different responses and SBT, and enables confirmation and/or refinement of the zones considered highly sensitive.

BPTu, though more common in offshore environments with soft marine deposits, enables estimation of the large strain to minimum undrained shear strength ($S_{u\text{-}Min}$) of saturated, very soft, fine-grained CCR materials, and is a good tool to screen for "problematic ash." Also, the ball penetrometer can be cycled up-and-down through a specific horizon (e.g., 3- to 5-foot thick zone) after initial penetration to assess possible degradation of resistance and readier "flow" around the ball penetrometer. DMT yields an estimate of undrained shear strength (S_u) at low strain, in contrast to the BPTu which involves shear distortion and "material flow" more analogous to a bearing-type failure. The DMT also characterizes compressibility and in-situ stress state (constrained modulus [M], OCR). EFVST is a widely accepted means to determine peak and remolded S_u, from which sensitivity can be quantified as $S_t = S_{u\text{-}Peak} / S_{u\text{-}Remolded\ or\ Min}$.

In applying multiple techniques, site-specific correlations and comparisons can be made for important parameters, including shear strength. For example, EFVST can be paired with CPT to estimate a site-specific range of the dimensionless correlation factor, N_{kt} for use in the relationship $S_{u\text{-}Peak} = (q_t - \sigma_v) / N_{kt}$, rather than relying on a presumptive range for natural soil (e.g., N_{kt} = 6 to 18 in "natural" clay).

Caveats – Soil vs CCR, and Laboratory vs. In-Situ Conditions

It is important to acknowledge that the broader knowledge base in applying these in-situ testing techniques for geotechnical characterization is from testing in silica soils with sensitivity less than 4 ($S_t < 4$), so caution is advisable if extending correlations to more highly sensitive soil and non-soil or atypical deposits. Also, undrained shear strength is not an intrinsic property of saturated soil, ash, or other conglomeration of particles, but rather enables a total stress alternative to modeling shear strength when effective stresses (steady-state analyses) or pore pressure response (dynamic or deformation analyses) cannot be reasonably deduced for effective-stress based models, or the material is not anticipated to adhere closely to Mohr-Coulomb failure criterion as it exists in-situ. Laboratory shear strength testing is performed under controlled volume with limited pore pressure redistribution. In contrast, considerable shear distortion, volume changes, and pore pressure redistribution occur within deposits of higher void ratio, weakly structured CCR materials (i.e., highly sensitive or problematic ash) as seepage gradients and loading conditions change.

GEOTECHNICAL CONSIDERATIONS WITH EMPHASIS ON "PROBLEMATIC ASH"

"Problematic Ash" Defined

As generally described previously, "problematic ash" is nearly saturated to saturated, very soft to soft (or very loose to loose), highly sensitive, fine-grained CCR material. More specifically in relation to natural soils, Tetra Tech considers fine-grained CCR zones with sensitivity greater than 4 ($S_t > 4$) to be potentially problematic, more so where the deposit has been continuously submerged. The extent (thickness, area, continuity) of "problematic ash," state of in-situ pore pressures (hydrostatic or excess), and rate of construction are critically important when assessing influence on ground stability and the presumption of drained versus undrained response, and the appropriateness of peak versus remolded (or minimum) undrained shear strength.

Influence of Earthwork Construction Rate

Usually, a slow to moderate rate of earthwork construction with conventional heavy equipment supported by a low frequency of haul truck traffic (subsequently defined as "*Preparatory Earthwork*") does not pose a significant risk of global instability, unless the work area is already marginally stable. On our larger CCR impoundment closure projects, Tetra Tech has identified areas of marginal stability coinciding with:

- scarps associated with past slides and major sloughs;
- higher and steeper surcharges (stacks and stockpiles) and "high walls" of CCR (exposed and submerged);
- zones of CCR foundation exhibiting significant excess pore pressures; and
- areas where adverse seepage gradients have been induced by pool drawdown and/or active dewatering of "productive" (coarser ash) layers underlying highly sensitive, fine-grained ash.

Even absent these adverse conditions, there still remains a risk of local bearing instability and sloughing where sensitive zones of CCR predominate at shallower depths, as these zones can be degraded by equipment vibrations such as from recurring passes of a bulldozer in spreading stockpiled materials or distributing fill for in-place closure. An additional and often overlooked factor influencing ground stability is ground cracking, which is common when surcharging (via filling) or stress-relieving (via excavation) soft ground. Runoff from precipitation or snowmelt can charge cracks with water and contribute to instability, analogous to the effect of a water-filled tension crack.

Distinctions Between "Preparatory Earthwork" and "Mass Earthwork"

Tetra Tech differentiates the rate of construction in terms of "*Preparatory Earthwork*" and "*Mass Earthwork*," based on earthwork volume per area (e.g., cubic yards/acre [cy/acre]), planned type of equipment to be used, and corresponding equipment activity within a given work area. For example, refer to the following table and graphic pertaining to characterizations of "*Preparatory Earthwork*" and "*Mass Earthwork*."

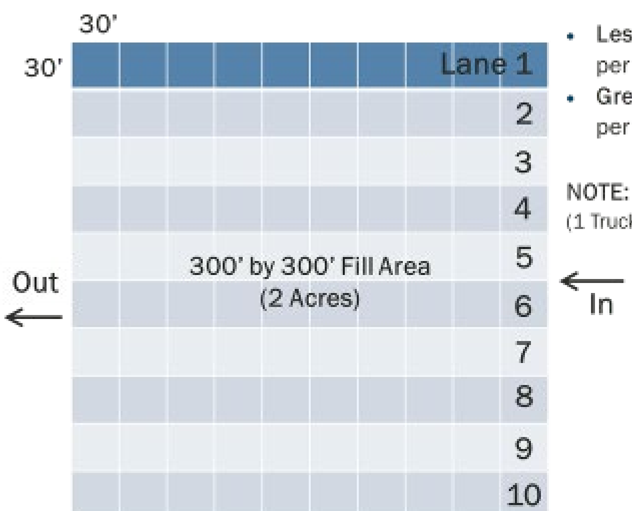
RATE OF CONSTRUCTION: Preparatory Earthwork *or* Mass Fill Construction ??

(Generalized Distinctions from Tetra Tech Experience – Indirectly related to implications of repetitive ground vibrations and extent of induced excess porewater pressures [PWP].*)*

FACTOR	PREPARATORY EARTHWORK	MASS FILL CONSTRUCTION
Sustained Rate of Fill Construction:	Slow: less than 2,500 cy/day	Greater than 2,500 cy/day
Frequency of Equipment Traffic, Especially Haul Trucks & Dozers (i.e., Regularity of Vibrations):	Intermittent Various Work Areas	Regular & Frequent Sustained in a Work Area
Purpose(s):	Reduce Elevation Differentials & Develop Access Corridors (Earthwork to alleviate highwalls & surcharges, develop peripheral & interior access corridors, feed dredges, and grade surfaces for drainage)	Fill Construction to Raise Surfaces to Top-of-Subgrade (Circuit hauling, dumping, spreading & tracking/compaction; and other mass redistribution of materials)
Location(s):	Varied Work Areas Warranting Preparatory Treatment	Focused Work Area, per Mass Fill Construction Phases

Concept of "Repetitive" Traffic in 2-acre Area (Significance of Vibrations & PWP)

Distinction Between "Preparatory Earthwork" vs "Mass Fill Construction"



- Less Than 10 Equipment Passes in 1 HR per lane is *Preparatory Earthwork* (limited vibrations,& PWP)
- Greater Than 1 Dumped Truckload in 1 HR per lane is *Mass Fill Construction* (adverse vibrations & PWP)

NOTE: 1 Dumped Truckload ≈ 9 Equipment Passes
(1 Truck pass + 8 Dozer passes [to spread & compact fill])

The bid documents for CCR impoundment closures invariably include prescribed schedule milestones and the Design Engineer's and/or Owner's estimates of construction quantities, including major earthwork volumes, theoretical liner/cap areas, and cover soil volumes. However, the association of schedule and quantities of work, and the corresponding rates of construction required by the prescribed schedule milestones are often either overlooked or not stated/acknowledged. The closure schedule and sequencing should be dictated by the rates of construction that are engineered to support a safer work environment. Also notable is that the prescribed trigger dates and timelines in the CCR Rule failed to consider what rates of construction can be safely sustained during CCR impoundment closures.

IDENTIFICATION OF "PROBLEMATIC ASH"

Informative Mapping (Bathymetry, Topography, Ortho-Imagery), and History of Construction

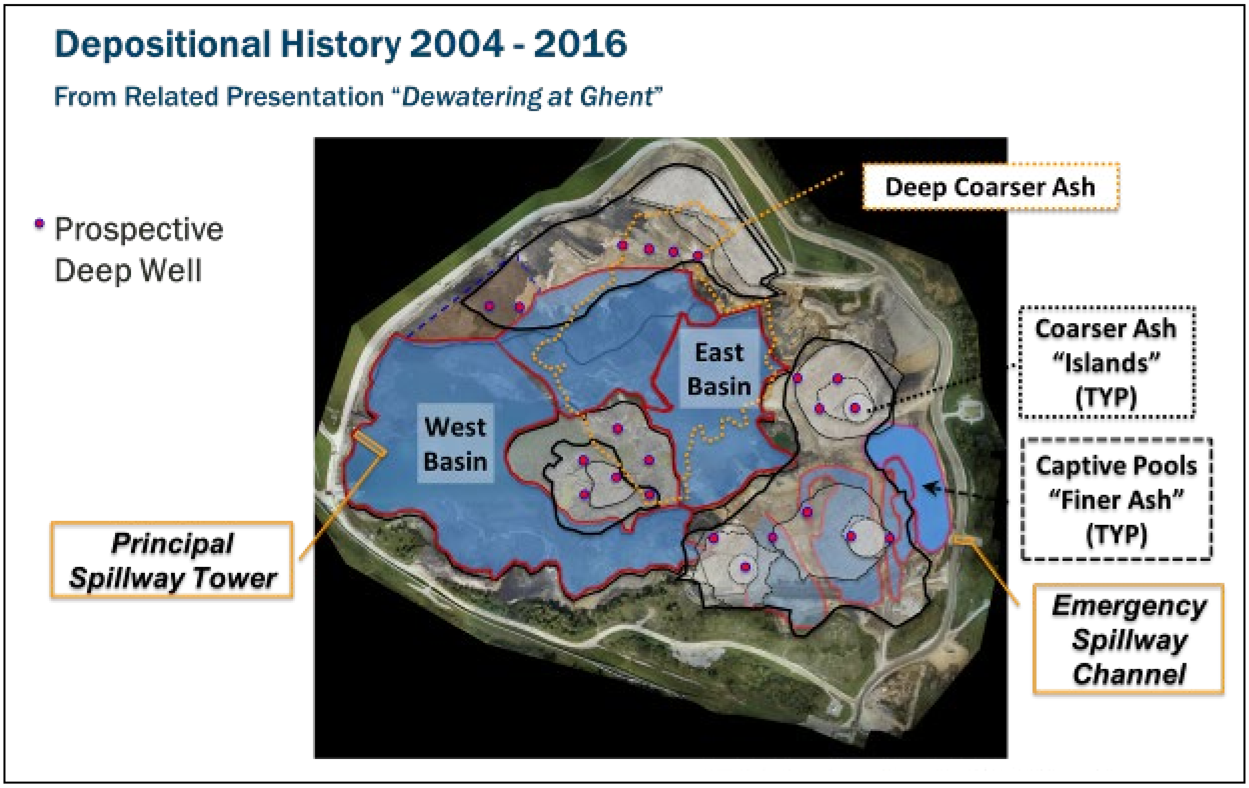
For various reasons, depositional history being one aspect, specific areas of CCR impoundments often pose greater ground control challenges than other areas. Recent mapping of the CCR impoundment and background information on the facility operation are often available for early assessment of potential problem regions of the CCR impoundment, and to support development of a focused geotechnical investigation program. Some of the important geometric parameters and background information that can be ascertained from recent mapping and the history of construction are outlined below.

Immediate/Early Considerations and Parameters

- Existing Geometry and Features:
  - Grade Differentials - Surcharges and "High Walls"
  - Slopes of Exposed Deltas and Submerged CCR
  - Depth of Pool/Basin (Area of "Free" Water)
  - Sluicing & Depositional History
  - Historic Elevation Range of Pool Fluctuations (Drawdown Intervals, if applicable)
  - Evidence of Past Slips

From Topographic & Bathymetric Mapping, Ortho-imagery,
Supplied Historic Records, Desktop Research

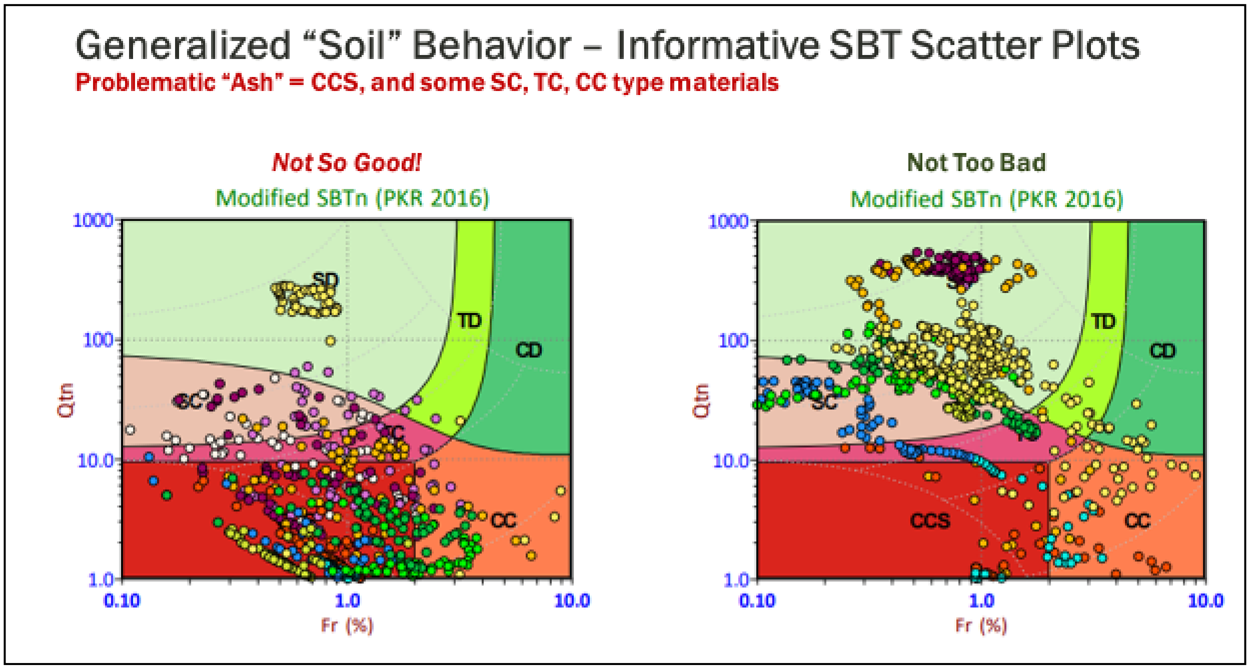
The history of operations and sluicing, and chronology of aerial imagery enable inference of the general distribution of coarser and finer ash within the impoundment, an example of which is presented below.

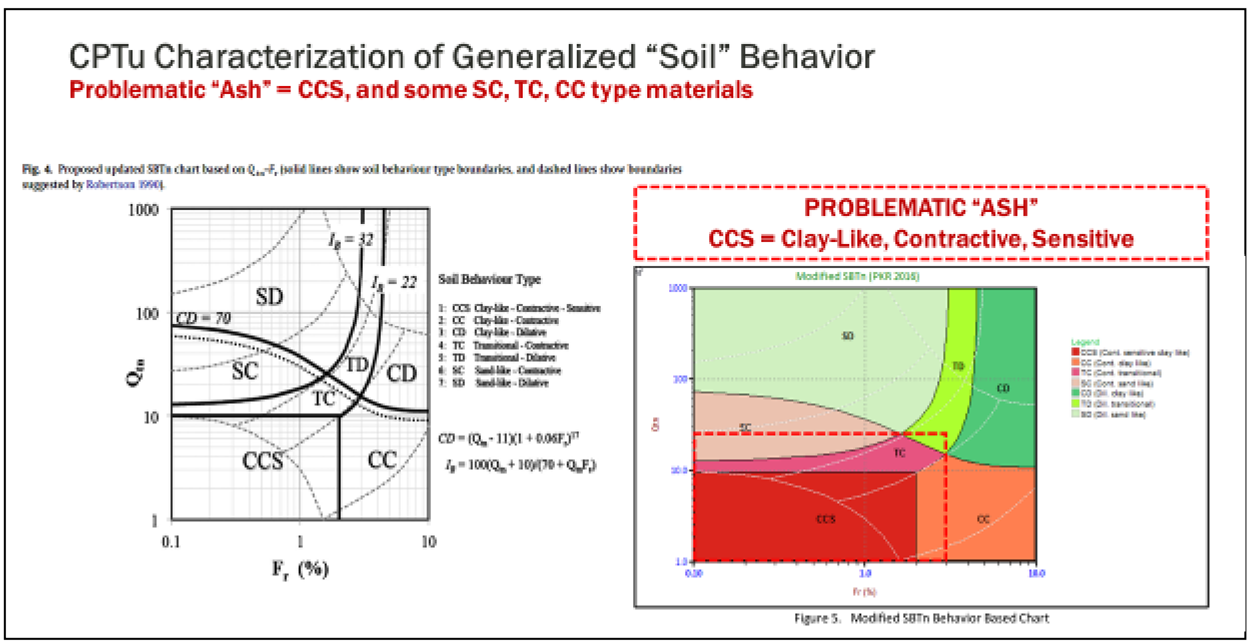


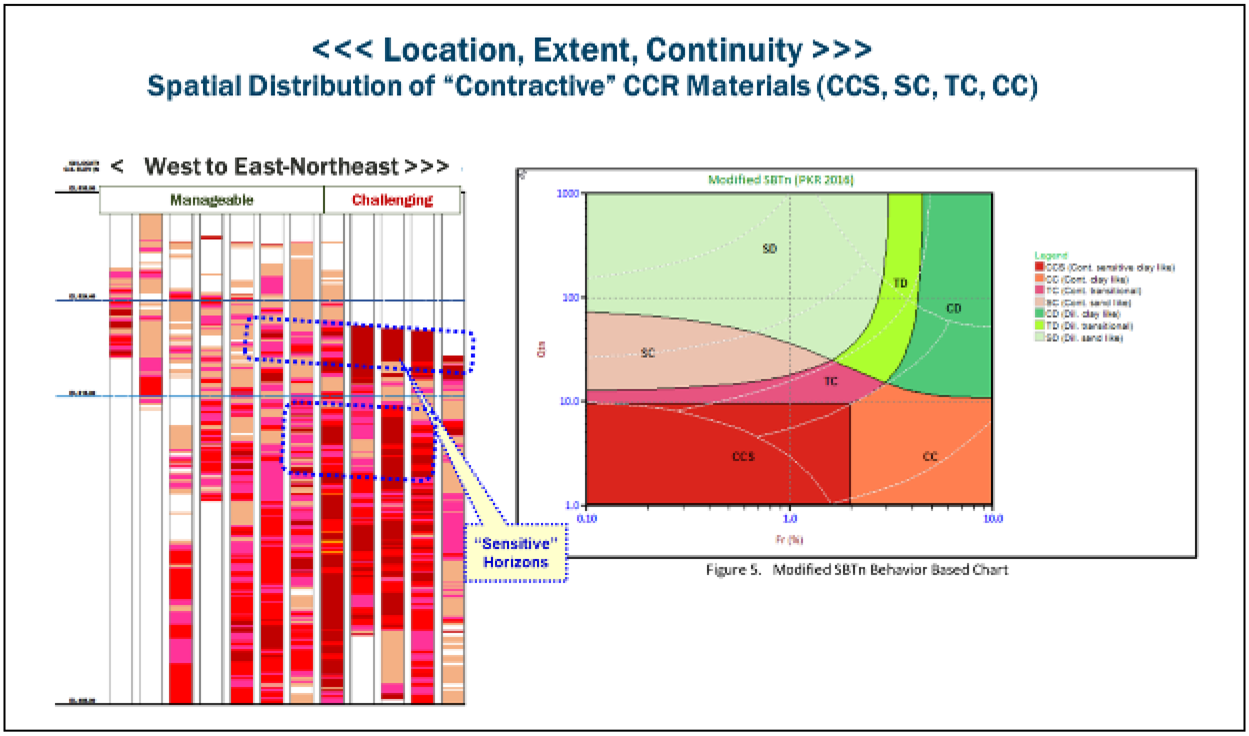
Such information is useful in planning supplemental geotechnical investigation, preliminarily scoping dewatering measures (e.g., finger drains, filtered sumps, deep dewatering wells, wellpoints), differentiating or ranking areas relative to potential ground control challenges, segmenting the impoundment for phased closure, and preparing baseline "*Preparatory Earthwork*" construction plans. Tetra Tech's practice is to prepare the CCR impoundment for closure in a manner that first enhances stability before accelerating the rate of earthwork construction within a subarea or phase of work. The escalation of the type of equipment in use (amphibious to non-amphibious, and LGP and long-reach to normal pressure and normal reach equipment), and rate of earthwork construction are dependent on satisfactory findings from visual inspections of ground performance, intrusive investigation (e.g., equipment probing, observation holes, test pits), and instrumentation data (primarily piezometric data) if available from a nearby location.

General Characterization of Subsurface Conditions via CPTu

The CPTu characterization of soil behavior type (SBT) provides an efficient means to infer the subsurface extent of "problematic ash", while the SBT scatter plots for each CPTu sounding allude to the prevalence of problematic ash through the investigated depth at an individual location. Though rudimentary, the color-coding of potentially problematic ash based on SBT is informative when inferring the extent of such materials, and deciding how best to group or cluster other geotechnical data based on subsurface variations over the CCR impoundment. The following graphics provide an example of how this basic information can be applied.





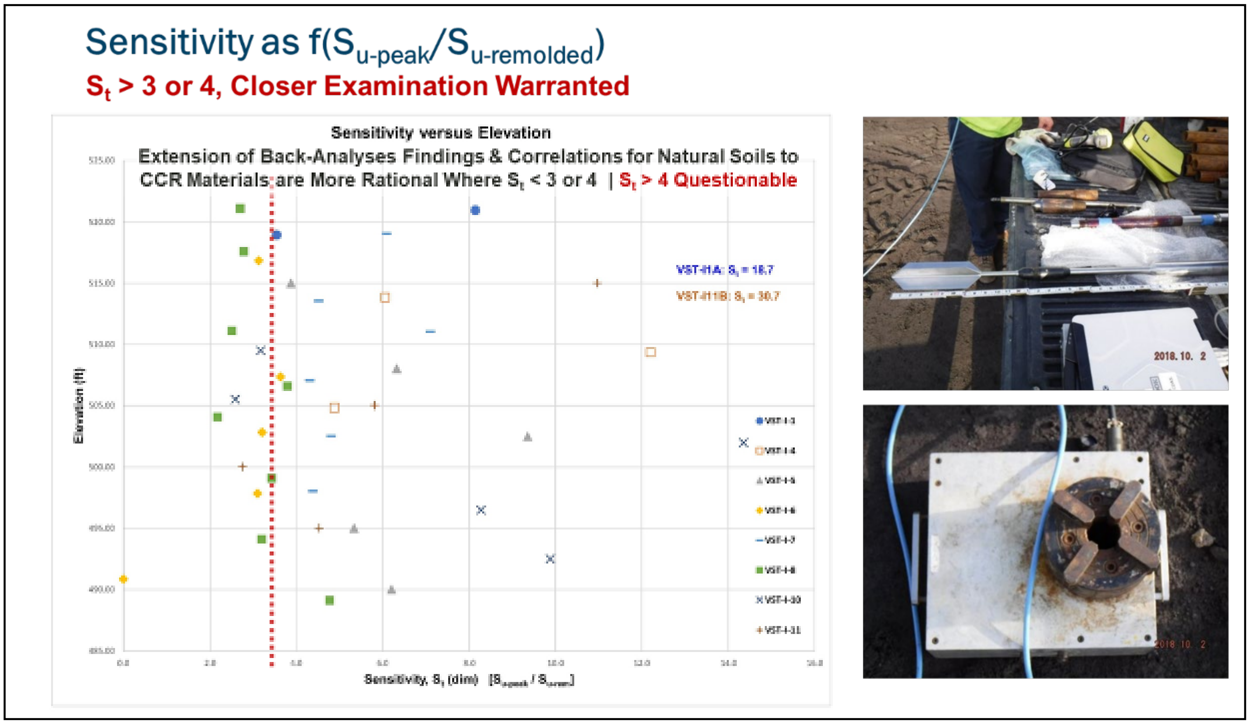


EXAMPLE DATA FROM MORE CHALLENGING CCR FOUNDATIONS

EFVST involves testing discrete zones of the CCR foundation, in contrast to the continuous to short-interval testing associated with CPTu, BPTu and DMT. Accordingly, EFVST should be focused within potentially problematic ash zones inferred from other available subsurface information and preceding in-situ testing. These softer, more sensitive fine-grained ash zones often control stability when conducting earthwork activities, particularly when executed at a high rate of construction ("Mass Earthwork"). Both peak and remolded or minimum undrained shear strengths should be determined with EFVST.

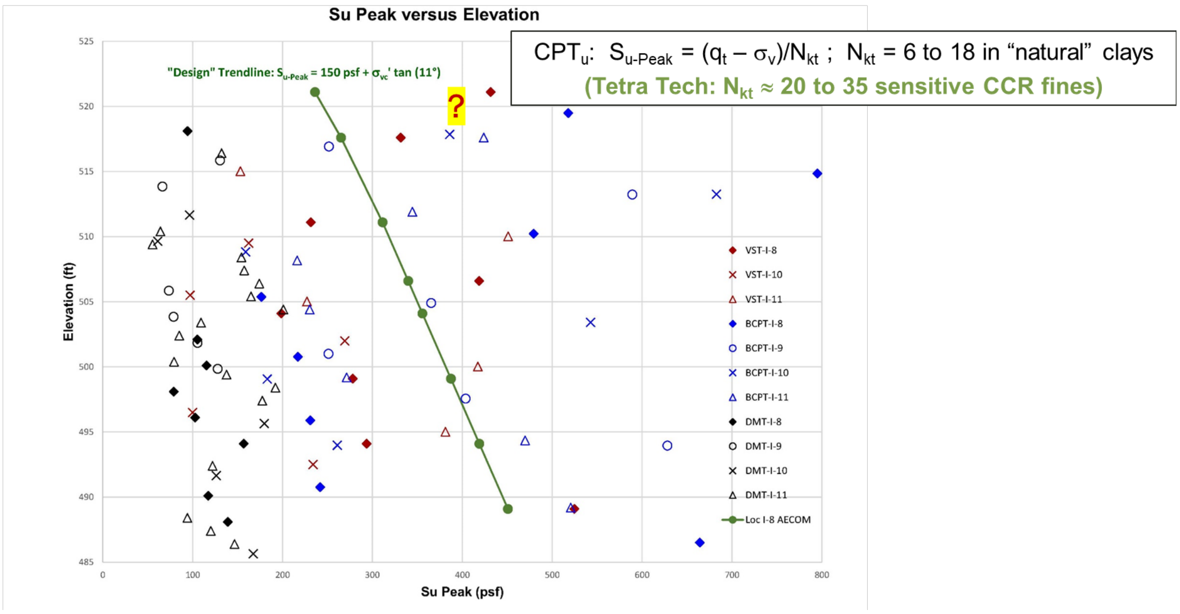
Under a "preparatory earthwork" rate of construction, presuming conditions approximate steady-state, and sufficient data on the phreatic level and foundation pore pressures (e.g., for semi-confined and confined ash horizons) are available, effective stress analyses can be performed. Alternatively, or for comparison, undrained analyses applying peak undrained shear strengths can be performed to evaluate stability under a "preparatory earthwork" rate of construction, or when the "suspect" problematic zones or horizons lie at greater depth where they are more highly confined and have diminished influence on stability. Of course, steady-state limit equilibrium analyses are inadequate if past stacking or stockpiling of CCR materials, early pool drawdown, active subsurface dewatering, or other construction activities have induced adverse seepage gradients, and/or high excess pore pressures.

Under a "mass earthwork" rate of construction, one must consider the implications of a possible degradation of undrained shear strength due to recurring ground vibrations, adversely changing seepage gradients (e.g., from pool drawdown, active subsurface dewatering, or stress relief from broader, deeper excavations), construction-induced excess pore pressures, and attendant deformations working over and in soft ground. The more appropriate shear strength for sensitive, fine-grained ash in such circumstances might be the large strain or remolded undrained shear strength, as the transient pore pressures through the predominant zone or along the predominant plane of movement can't be reliably defined for effective stress analyses, or it is apparent or anticipated that the strength degradation would defy effective-stress modeling. Where the ash exhibits higher sensitivity based on CPTu characterization or EFVST ($S_t > 4$), closer examination of the geotechnical data, subsurface conditions, and stability situation is warranted.



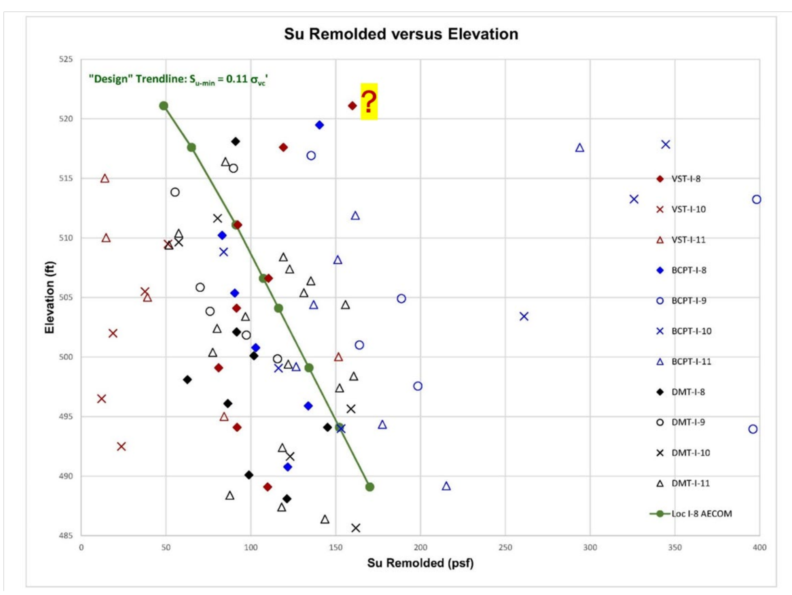
Similar to other hydraulically-deposited “residual” materials (e.g., slurried fine coal refuse, and mine tailings) and high activity soils (e.g., sodic soils and high activity clays), impounded CCR deposits exhibit significant variabilities and often possess unique attributes in fabric/particle structure, chemistry, and/or mineralogy relative to natural silica soils, especially where they've been perpetually submerged. Therefore, a normally-consolidated characterization of shear strength through the deposit, such as by an undrained shear strength ratio (USS: $S_u/\sigma'_{c\text{ or }vo}$ [or] $S_u = c_u + \sigma'_{vo}\tan(\phi)$), is often inadequate or misleading. For example, the grouped smattering of peak undrained shear strengths (“raw”/uncorrected EFVST results) below exemplifies the need for a much more refined assessment of layering, grouping of data, and discretization of shear strengths.

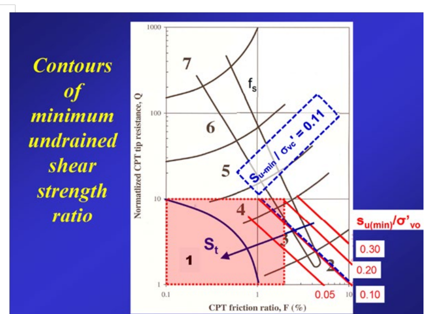
Undrained Shear Strength (USS: $S_{u\text{-}peak}$ or $S_{u\text{-}remolded\ or\ min}$): “PEAK”

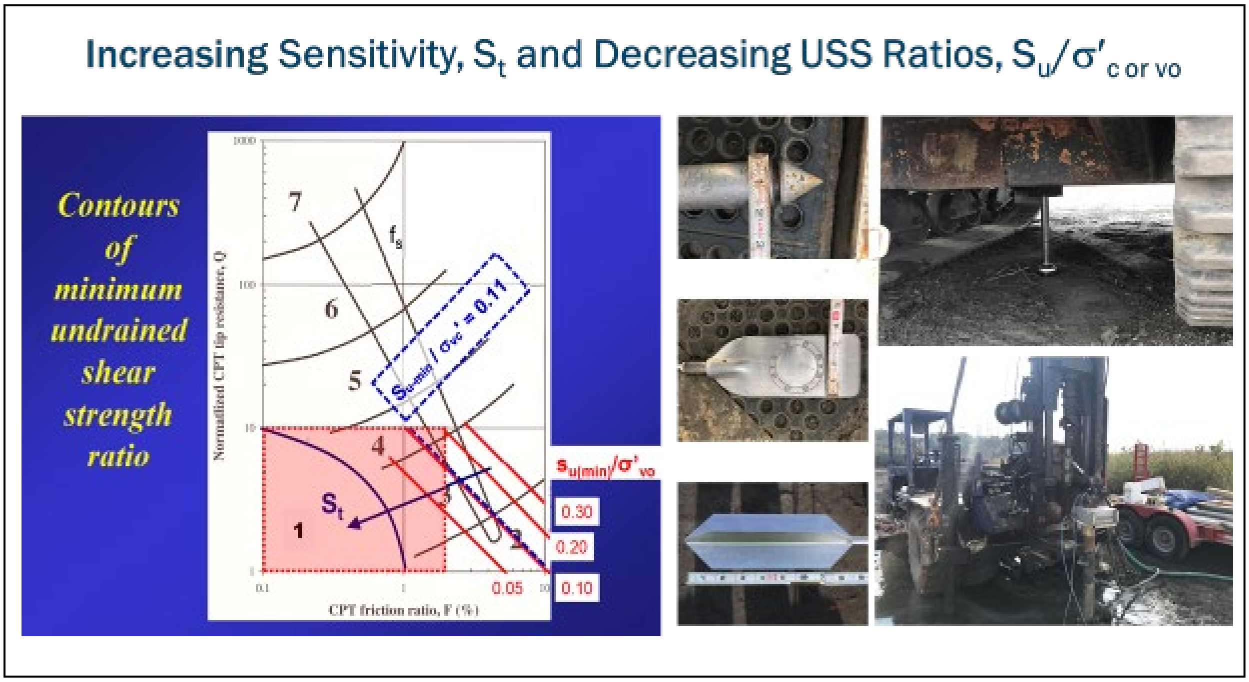


With regard to remolded undrained shear strengths, similar caution should be applied if contemplating shear strength relationships that presume the materials are normally consolidated and will abide by Mohr-Coulomb behavior in the traditional sense of relative homogenous, natural soil deposits. Also, with increasing sensitivity, post-peak shear strength behavior is very difficult to quantify for the in-situ deposit, though a detailed program of laboratory testing might suggest otherwise.

Undrained Shear Strength (USS: $S_{u\text{-}peak}$ or $S_{u\text{-}remolded\ or\ min}$): “REMOLDED”







<u>Cautionary Notes</u>

In the authors' experience, it is inadvisable to account for increases in shear strength of fine-grained CCR materials during incremental vertical construction, until excess pore pressures are shown to be fully dissipated. Even then, increases in undrained shear strength due to additional consolidation deduced from laboratory testing might not be effective until the in-situ material ages and "heals," especially if the material has been sheared undrained to strains nearing those coinciding with the peak undrained shear strength or has been remolded as a result of ground deformations. Notably, when problem ash exists at shallower depths, closure-in-place fill construction can be accompanied by relatively large ground deformations that involve shear distortion, displacement, intermixing, and pore pressure redistribution within the underlying foundation.

Additionally, it should be appreciated that the SHANSEP (*Stress History and Normalized Soil Engineering Property*) procedure and similar models for staged construction evaluations over compressible ground (specifically "clays") are predicated on certain important assumptions:

- Each discretely considered zone must be relatively homogenous.
- Generally, the incremental strains are small, and the strain rates are slow to moderate.
- The materials exhibit low to moderate sensitivity, and characteristic Mohr-Coulomb behavior or compliance with a similarly based model. (Sensitivity is in large part related to the porewater chemistry, void ratio, and material mineralogy, particle shape, and particle structure or fabric.)

- It must be practical to sample and test the material without altering its structure dramatically, so the laboratory-based consolidation and shear strength testing can be extrapolated to the in-situ deposit.
- To be valid, the soil behavior in-situ must conform closely to the model derived from the laboratory testing program.
- You must have reliable knowledge of the stress history and past pre-consolidation pressures through the in-situ deposit.

The SHANSEP procedure was developed for low-sensitivity clays that have been “normally” consolidated and “aged” to some stress state, not “young” hydraulically-deposited low plasticity or non-plastic silts.

For thicker deposits and zones of fine-grained CCR, representative undrained shear strengths (S_u) should be used for discrete zones, unless the use of USS ratios is clearly supported by the in-situ test data. The application of peak or remolded values of S_u should be based on the rate of construction, seepage regime, and the index properties, sensitivity, age, stress history, and in-situ state of the different zones of CCR that are influential on stability.

ENGINEERED PREPARATORY TECHNIQUES

The geotechnical investigations and evaluations for closure construction provide the engineering basis to plan and phase the construction, define the extents and means of “*Preparatory Earthwork*,” establish inspection protocol, and formulate instrumentation programs with data trigger levels. Impoundment areas found to be more marginally stable should be addressed with appropriate preparatory techniques to enhance stability before an accelerated rate of construction is permitted. Such techniques, as previously applied by Tetra Tech, might encompass:

- A slow rate of conventional earthwork (cutting, filling, grading) to mitigate exposed (above-water) “high walls,” which correspond with steep slopes and higher surcharges;
- In-basin redistribution of CCR materials via dredging, sluicing, and/or with amphibious equipment to displace pooled water, alleviate grade differentials, and progress toward “levelizing” the main impoundment basin (i.e., area of the supernatant pool);
- Subgrade improvement with amphibious excavators by mixing drier CCR into very soft, wet foundation CCR, and spreading CCR fill to establish “walkable” subgrade for geogrid deployment;
- “*Preparatory Earthwork*” construction of selective geogrid-reinforced fills for strategic access corridors, to stabilize problem subgrade areas, and to enhance overall stability;
- Passive dewatering (e.g., finger drains and channels) and active subsurface dewatering (filtered sumps, deep dewatering wells, wellpoints);
- Drawdown of the residual supernatant pool, and maintenance of depressed pool and groundwater levels;

- Implementation of passive and active dewatering as necessary during basin/pond grading operations; and
- Development and implementation of a plan for porewater pressure and ground performance monitoring.

CONSTRUCTION EXAMPLES

The following graphics reflect some of these preparatory techniques being applied during actual CCR impoundment closures executed by Tetra Tech.

Preparatory Activities for Mass Fill of CCR Impoundments

1. Mitigate "highwalls"/"surcharges" around impoundment perimeter and within basin.
2. "Levelize" impoundment areas to alleviate surcharges <u>and</u> displace *rather than draw down* supernatant pool.
3. "Preparatory Earthwork" to develop strategic geogrid-reinforced access corridors.

Amphibious Excavator – Highwall Removal

Levelizing via Hydraulic Dredge

Geogrid Reinforced Access Corridors

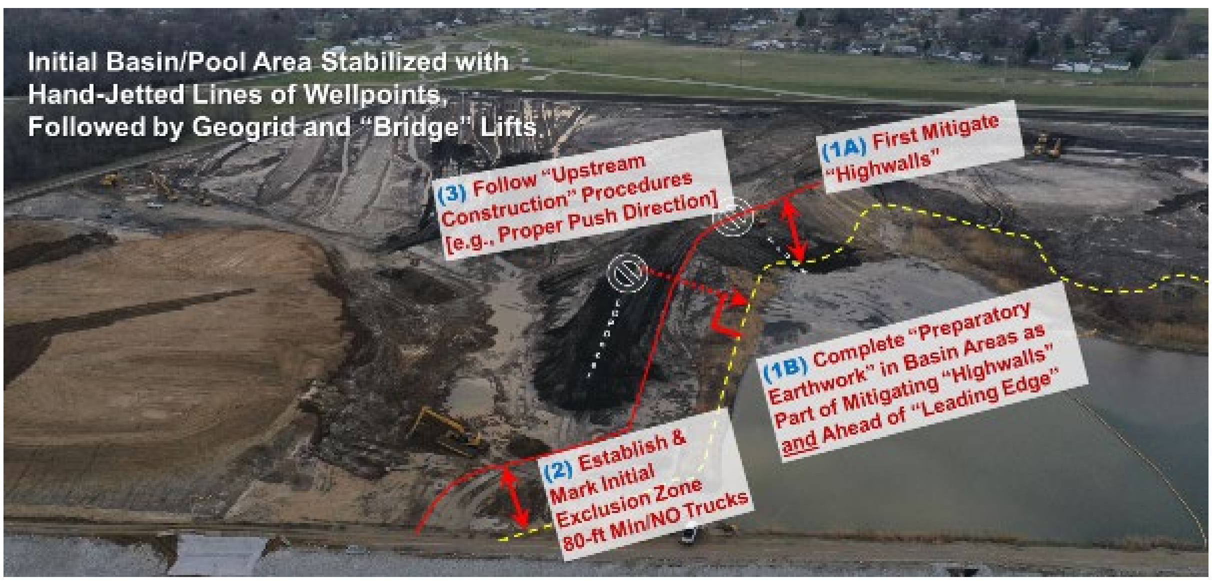
Dredge-Filling to Displace Pool, and Preparation of Working Subgrade with Amphibious Excavators

Preparatory Activities for Mass Fill of CCR Impoundments

4. Perform subsurface working dewatering where necessary.
5. Enhance stabilized base to support planned rate of construction activity.

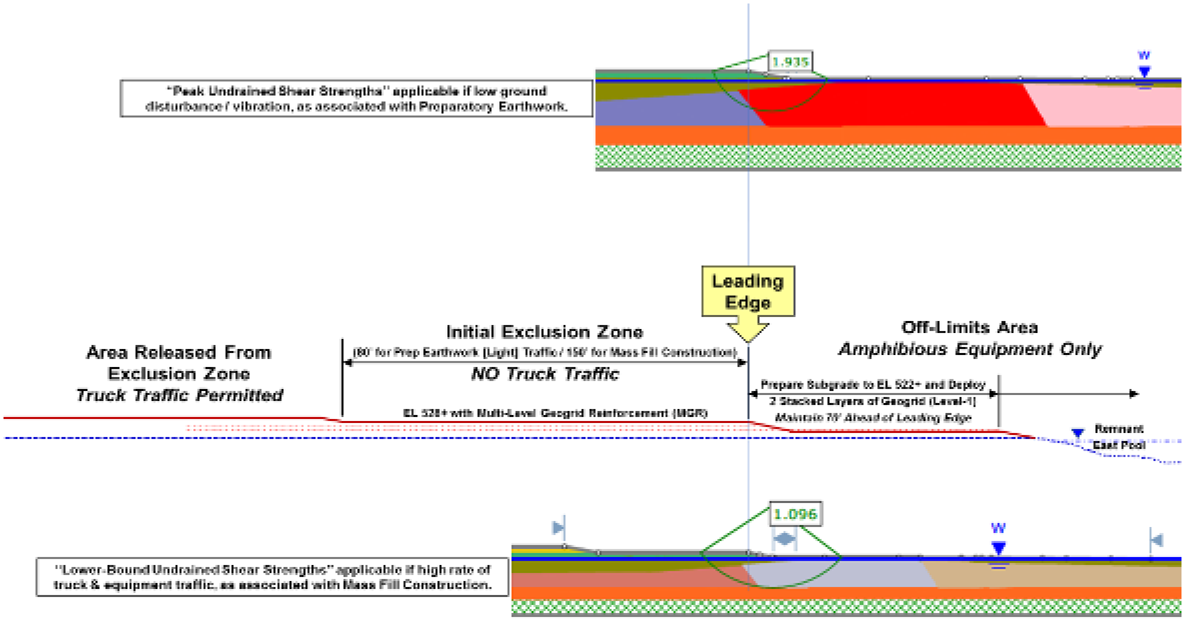
Subsurface Dewatering – Well Point System

Geogrid Reinforcement to Support Mass Fill Operations



Preparatory Activities for Mass Fill of CCR Impoundments

6. Stage & regulate earthwork construction and restrict fill surcharge differentials.

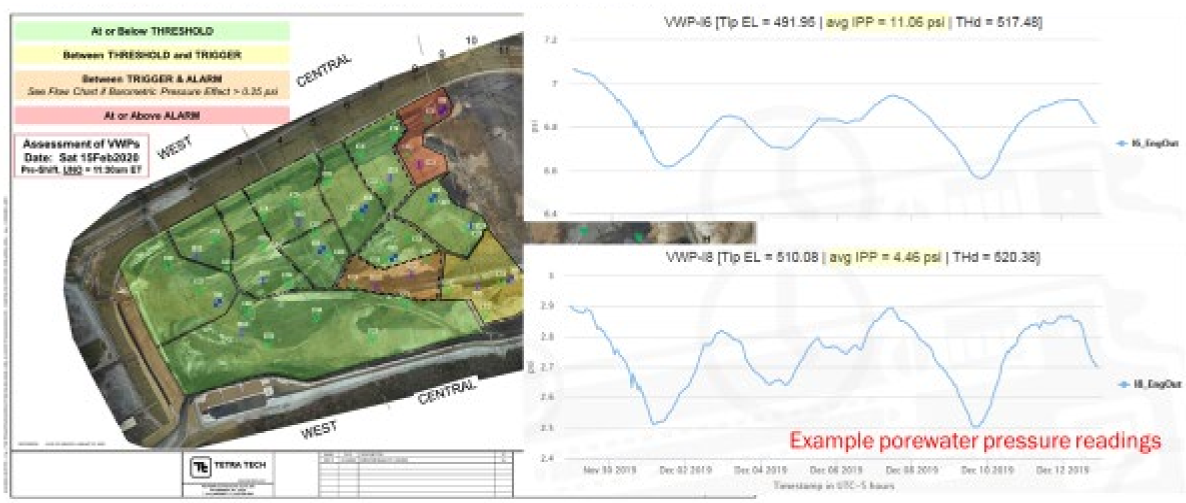


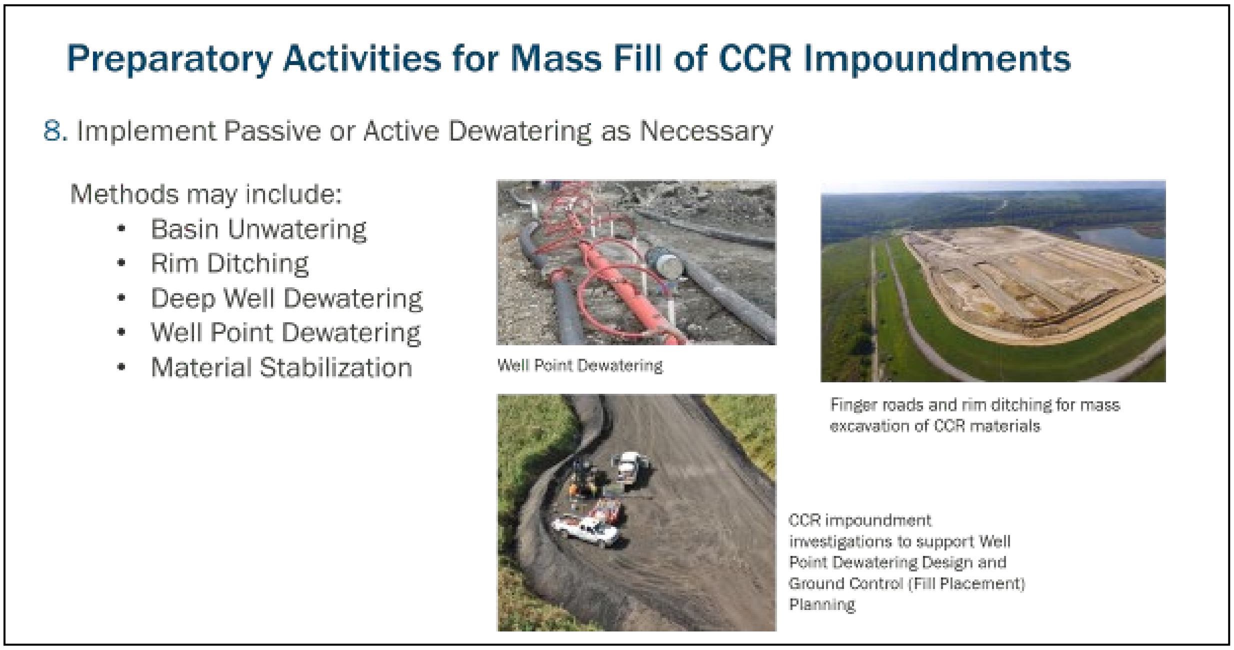
Work Zones established during filling operations to restrict access based upon subsurface conditions. Field conditions monitored and adapted to actual conditions based upon evaluations with Tetra Tech Geotechnical Engineering.

Preparatory Activities for Mass Fill of CCR Impoundments

7. Monitor porewater pressures and ground performance.

Work activities adjusted, if necessary, based upon readings and evaluation against established Trigger and Alarm levels.





ENGINEERING DURING CONSTRUCTION

Heavy earthwork construction (mass filling and/or excavation) within basins/impoundments warrants continued engineering involvement throughout the closure process. Engineering should be integrated with construction on major CCR impoundment closures to provide real-time support of in-basin operations. The integration of engineering and construction teams during closure ensures that work plans, and associated sequencing, construction means and methods, inspection protocol, and task-specific safety measures are properly interpreted and applied and updated as changes in ground behavior and project conditions warrant.

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Attachment 1

Engineering the Process of CCR Impoundment Closure:
Successful Preparatory Techniques to Support Heavy Earthwork Construction

Presenter: Don Grahlherr, PE

Co-Authors: Christopher Lewis, PE
Jeffrey Heun, PE
Steven Turner

SAFETY MOMENT

Safety Moment

Have an evacuation plan:

- At a minimum, do a quick visual of the layout and locate the primary and secondary exits
- If you are going to be in a building for an extended time, locate the emergency evacuation plan posted on the wall which usually includes a mapped location of the exits, as well as fire extinguishers, and first aid kits.

❖ RELATED PRESENTATIONS: (Tetra Tech, LG&E/KU, Keller)

Preparatory Construction to Enable Accelerated Mass Filling for Closure-In-Place of CCR Impoundments [Emphasis on Construction Techniques]

Dewatering at Ghent (ATB-1, ATB-2) [Deep Well & Wellpoint Dewatering]

PRESENTATION TOPICS

Major Topics

1. Geotechnical Investigation
    a) In-Situ vs Laboratory Testing
    b) Common In-Situ Testing Techniques
    c) Porewater Pressures – PPDT & VWPs
2. Geotechnical Considerations – Emphasis on "Problematic Ash"
    a) Rate of Construction
    b) Basic Considerations and Data Needs
    c) Identification of Problematic Ash
    d) Sampling of Data for More Challenging CCR Foundation Conditions
3. Engineered Preparatory Earthwork Techniques
4. General Process for Closure-in-Place of CCR Impoundments

GEOTECHNICAL INVESTIGATION

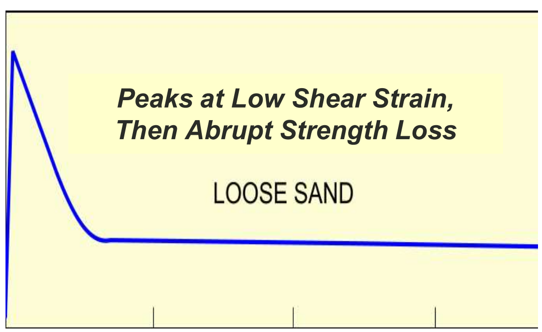
In-Situ Testing *Preferred*/Lab Testing *of Limited Applicability*

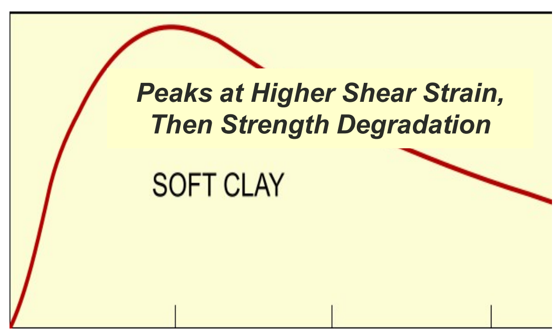
Some Issues Affecting Laboratory Geotechnical Testing of CCR Materials

1. Practical scope of Lab Testing is minimal compared to In-situ Testing.
2. The controlling zones and layers of CCR are very difficult to sample, transport, and prepare for testing without significant disturbance.
3. Difficult to preserve ("undisturbed") or replicate (lab-pluviated samples) the in-situ void ratio and micro-structure/"fabric" (void distribution) of loose/soft CCR materials, especially if Sensitive.
4. For remolded lab samples, differences in lab water vs in-situ porewater chemistry can significantly affect results.
5. Lab shear strength testing is typically controlled-volume. In contrast, behavior during earthwork construction over impounded CCR involves shear distortion, displacements & stress redistribution, pore pressure redistribution, and vibrations and potential strength degradation.

Technical Limitations

1. CCR DEPOSIT: Difficult to Reliably Characterize **Sensitive Fine-Grained CCR Deposits.**
2. LAB SHEAR STRENGTH TESTING: Controlled Volume, Undrained Shear (**Questions:** In-Situ Void Ratio, Influence of Particle Structure, Degree of Consolidation, PWP Redistribution, Volume Change).
3. KNOWLEDGE BASE: Primarily from NC to Slightly OC, Natural Soils with **Sensitivity, S_t < 3 or 4.**
4. LIMIT EQUILIBRIUM ANALYSES: An Informative Tool, **Not a Solution** (Deformation Considerations = Displacement and Shear Distortion to Attain Bearing Equilibrium; Excess PWPs Might Persist).





General Comments on Laboratory Testing

LABORATORY TESTING:

- Index Testing Suites:
  - FGD Byproduct pH & Calcium Content **(pH > 9.5, higher potential of/for weak diagenitic cementation)**
  - Lab Consolidation and S-wave Velocities for Assessment of Diagenesis **(involved procedure)**
  - Moisture Contents/Hydrophilic Behavior **(water content relative to Liquid Limit)**
  - Grain (Particle) Size Distribution **(micro-structure or “fabric” very important for sensitive CCR)**
  - *Effective* Specific Gravity **(Standard ASTM Method overstates Gs)**
  - Atterberg Limits **(5-pnt, w/ LL by Fall Cone Method and reduced # blows via Casagrande Method)**
  - In-Situ Moisture, Density & Void Ratio **(undisturbed tube samples?)**
- Consolidation/Compressibility **(complex in-situ drainage paths)**
- Hydraulic Conductivity/Permeability **(difficult to extrapolate in-situ “mass properties”)**
- Shear Strength **(emphasis & greater reliance on in-situ testing for Impounded CCR)**

Common In-Situ Testing Techniques

IN-SITU TESTING:

- Cone Penetrometer Testing with Pore Pressure Measurements (CPTu or SCPTu)
- Pore Pressure Dissipation Testing (PPDT)
- Full-Flow Ball Penetrometer Testing (BPTu)
- Marchetti Flat Plate Dilatometer Testing (DMT)
- Electronic Field Vane Shear Testing (EFVST)

** Use multiple techniques as applicable.**

In-Situ Testing for Geotechnical Characterization

CPTu or SCPTu: Broadly characterize the spatial distribution of CCR materials in-situ, and deduce an extensive scope of geotechnical properties.

(Standard 2 cm/sec, and some Modified 1 cm/sec penetration rates in "transitional" materials)

PPDT: State of porewater pressures, and hydraulic properties.

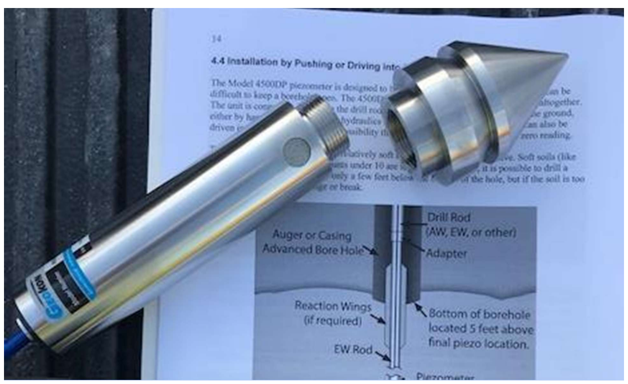
BPTu: $S_{u\text{-}Min}$ of saturated, very soft, fine-grained CCR materials = Good tool to screen for "Problematic Ash" (i.e., full-flow: shear distortion with bearing-type failure)

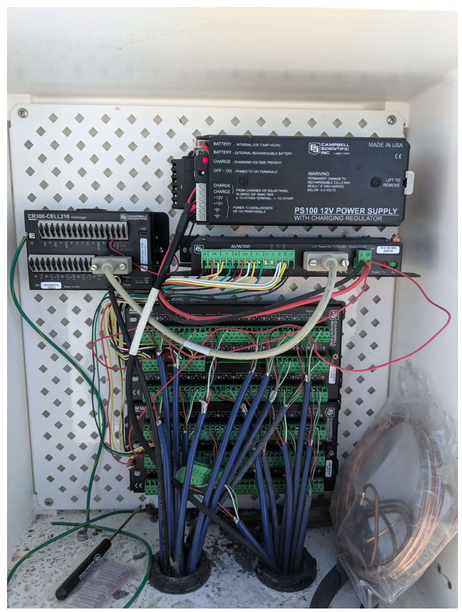
DMT: S_u, Compressibility (OCR, Constrained Modulus [M]), In-situ Stress State

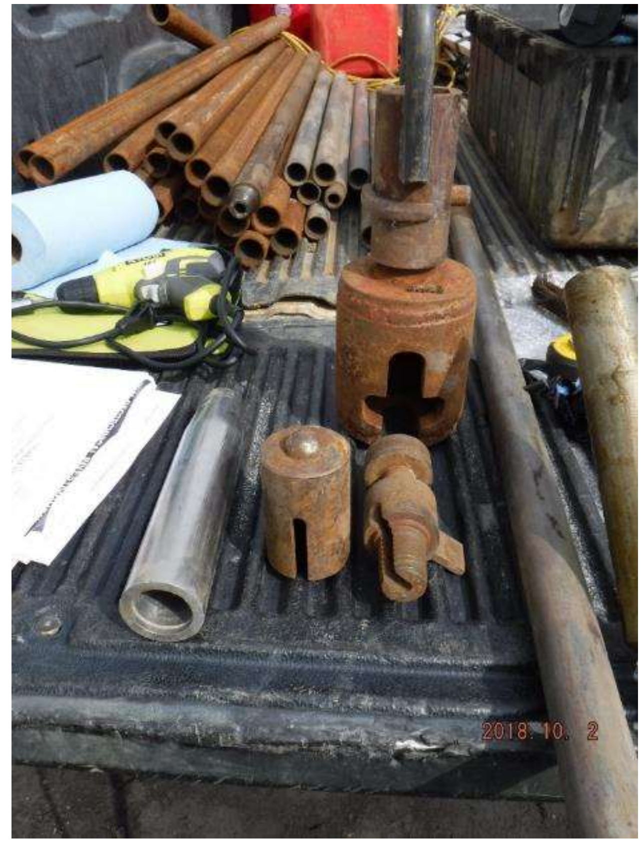
EFVST: Peak & Remolded USS, and Sensitivity ($S_{u\text{-}peak}$, $S_{u\text{-}rem}$, S_t) of fine-grained CCR

Monitoring Porewater Pressures
Baseline, Pre- & Post-Dewatering, and During Construction

- PPDT results and VWP data are valuable for effective stress analysis of existing conditions and staged construction.



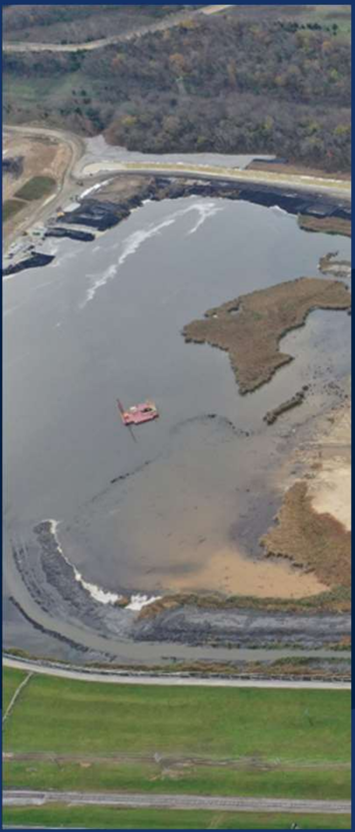




SPT Split-Barrel (Disturbed), Undisturbed Tube, and Bulk Sampling

❖ *Test Pits for "Bulk Sampling" - Very Informative Tool*

Test Pits & Observation Holes afford opportunity to observe sidewall and base stability, horizons of water intrusion, and other shallower subsurface conditions in real time at a controllable scale.



GEOTECHNICAL CONSIDERATIONS
Emphasis on “Problematic Ash”

TETRA TECH
LG&E KU
PPL companies

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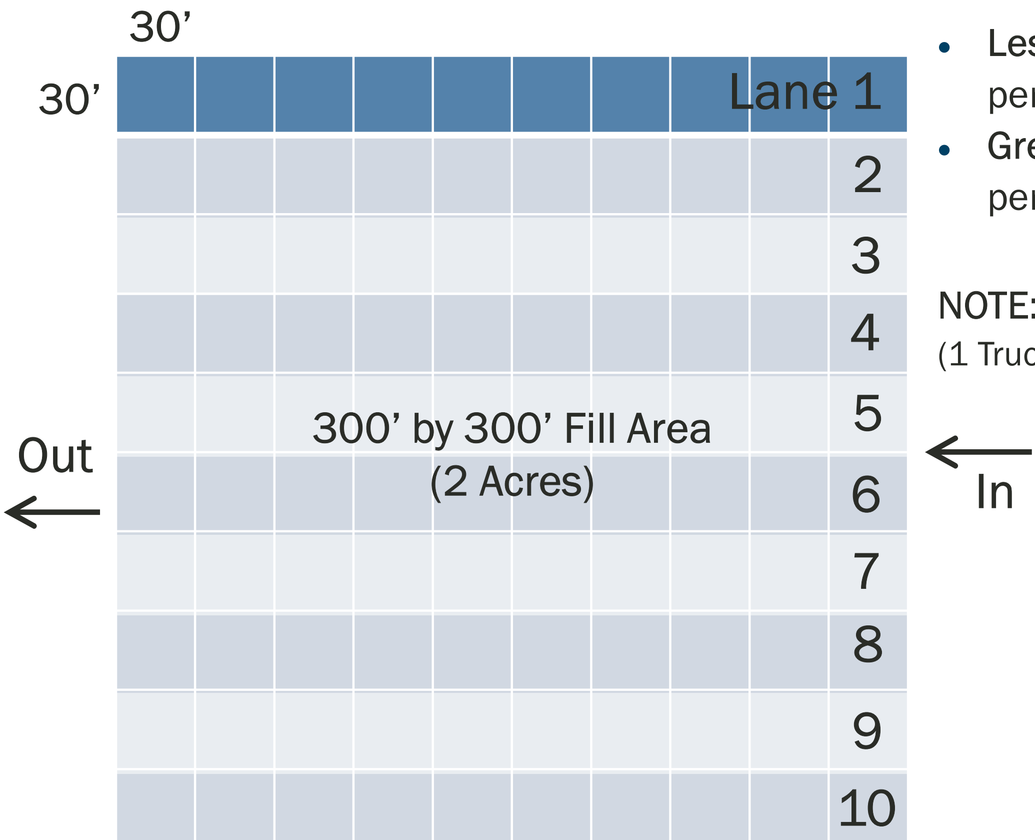
W C A

RATE OF CONSTRUCTION: Preparatory Earthwork *or* Mass Fill Construction ??

(Generalized Distinctions from Tetra Tech Experience – Indirectly related to implications of repetitive ground vibrations and extent of induced excess porewater pressures [PWP].*)*

FACTOR	PREPARATORY EARTHWORK	MASS FILL CONSTRUCTION
Sustained Rate of Fill Construction:	Slow: less than 2,500 cy/day	Greater than 2,500 cy/day
Frequency of Equipment Traffic, Especially Haul Trucks & Dozers (i.e., Regularity of Vibrations):	Intermittent Various Work Areas	Regular & Frequent Sustained in a Work Area
Purpose(s):	Reduce Elevation Differentials & Develop Access Corridors (Earthwork to alleviate highwalls & surcharges, develop peripheral & interior access corridors, feed dredges, and grade surfaces for drainage)	Fill Construction to Raise Surfaces to Top-of-Subgrade (Circuit hauling, dumping, spreading & tracking/compaction; and other mass redistribution of materials)
Location(s):	Varied Work Areas Warranting Preparatory Treatment	Focused Work Area, per Mass Fill Construction Phases

Concept of “Repetitive” Traffic in 2-acre Area (Significance of Vibrations & PWP)
Distinction Between “Preparatory Earthwork” vs “Mass Fill Construction”



- Less Than 10 Equipment Passes in 1 HR per lane is *Preparatory Earthwork* (**limited vibrations,& PWP**)
- Greater Than 1 Dumped Truckload in 1 HR per lane is *Mass Fill Construction* **(adverse vibrations & PWP)**

NOTE: 1 Dumped Truckload ≈ 9 Equipment Passes
(1 Truck pass + 8 Dozer passes [to spread & compact fill])

Immediate/Early Considerations and Parameters

- Existing Geometry and Features:
  - Grade Differentials - Surcharges and "High Walls"
  - Slopes of Exposed Deltas and Submerged CCR
  - Depth of Pool/Basin (Area of "Free" Water)
  - Sluicing & Depositional History
  - Historic Elevation Range of Pool Fluctuations (Drawdown Intervals, if applicable)
  - Evidence of Past Slips

From Topographic & Bathymetric Mapping, Ortho-imagery,

Supplied Historic Records, Desktop Research

Basic Geotechnical Considerations and Data Needs

- Characteristics of Impounded CCR (i.e., CCR Foundation for Closure-in-Place Projects)
  - Subsurface Conditions : “Crust” and Other Layer Types and Thicknesses
  - CCR Sensitivity & Consolidation Rate: Metastable Structure, Settlement, Applicable Shear Strengths, Sustainable Fill Rate…*Susceptibility to Sudden Strength Loss - “Static” Liquefaction*
  - Peak & Residual Shear Strengths (drained & undrained): Stability During Phased Construction, and Upon Closure
  - Hydraulic Properties – In-Situ “Mass” Properties
- Phreatic Surface, and Seepage Gradients
- State of Porewater Pressures

Identification of “Problematic Ash”

Fine-Grained, Low Plasticity to Non-Plastic, Sensitive CCR Materials

(low density & shear strength, susceptible to strength degradation, potentially metastable)

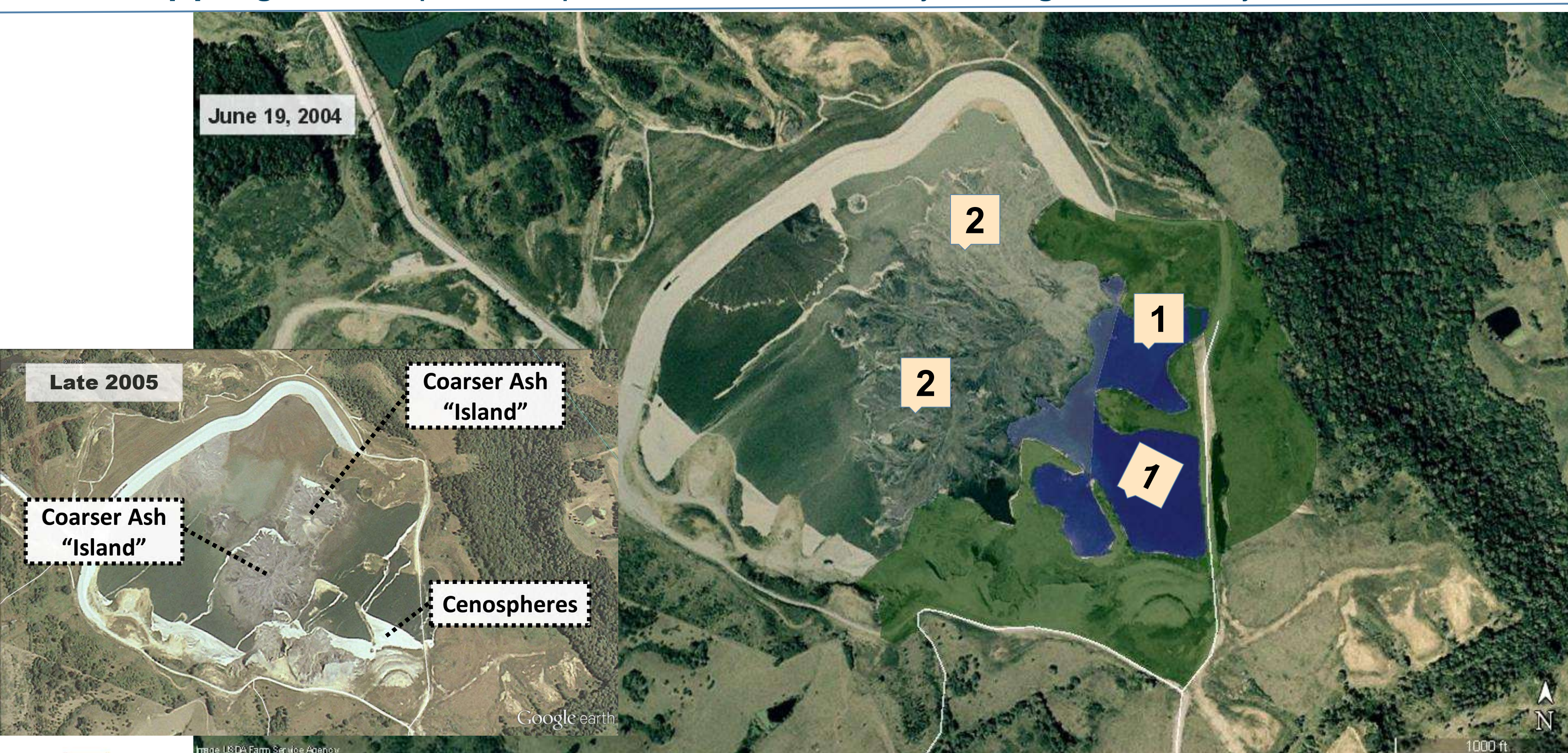
SOME ASPECTS TO REVIEW & EVALUATE:

- Depositional History to Infer General Areas of Finer and Coarser Ash
- CPTu Soil Behavior Type (SBT), Sensitivity = $S_{u\text{-peak}}/S_{u\text{-remolded}}$
- In-Situ Porewater Pressures
- Degree of Saturation, Water Content vs Liquid Limit, Void Ratio
- Particle Shapes & Structure or “Fabric” (Internally Stable, or Weak Particle Structure?)
- Degree of Consolidation (“Normally” Consolidated or Partially Consolidated?)
- Porewater Chemistry, Past Extent of Flocculant Use (Geochemistry vs Metastable Fabric)
- Prevalence & Origin of Cenospheres in Impoundment (inert, hollow spheres composed predominantly of silica and alumina…cenospheres are gray to pearl colored)

Depositional History to Infer General Areas of Finer & Coarser Ash

[1] Sluicing & Grading Create Captive Southeast Pools Where Finer-Grained CCR Accumulates

[2] Large Central Expanse of Exposed Coarser CCR Eventually Submerged & Covered by Sluiced CCR

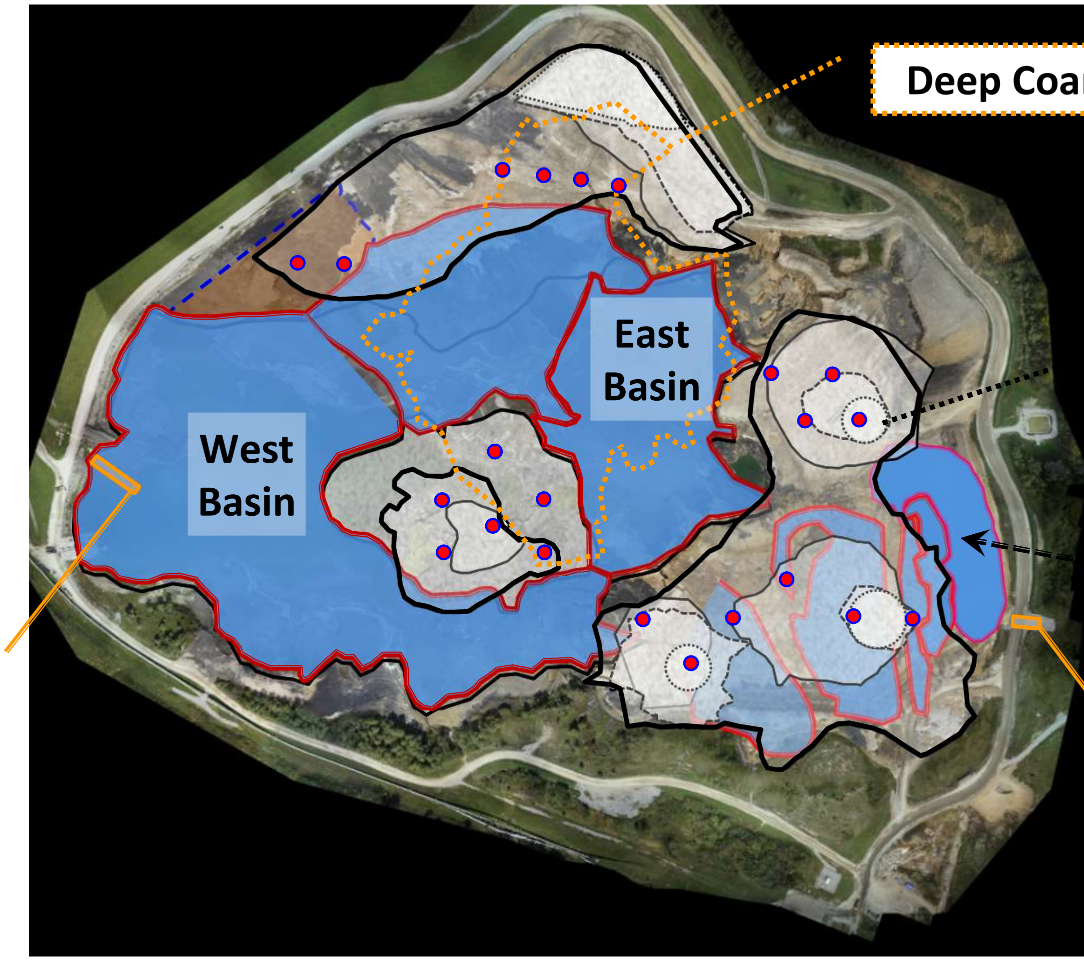


Depositional History 2004 - 2016

From Related Presentation "*Dewatering at Ghent*"

- Prospective Deep Well

Principal Spillway Tower

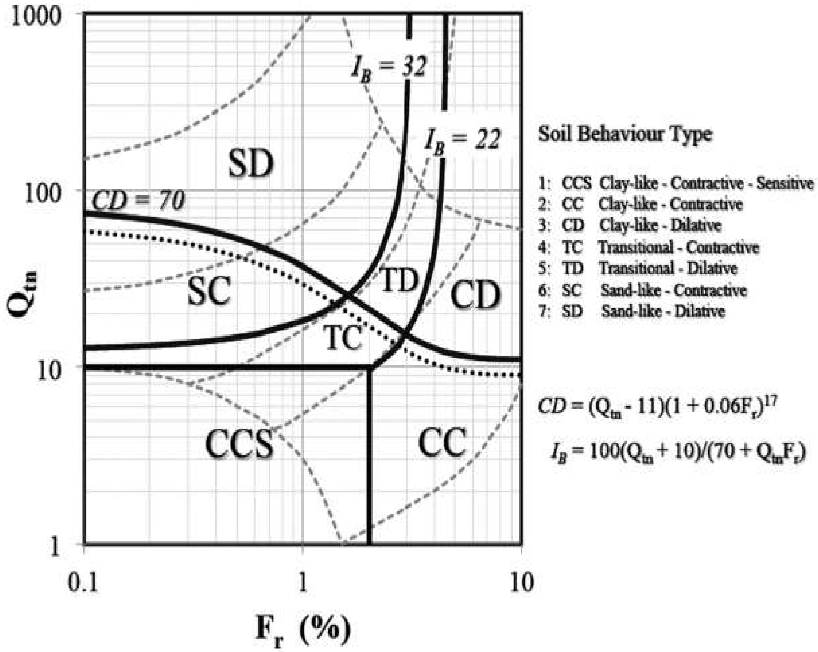


Emergency Spillway Channel

CPTu Characterization of Generalized “Soil” Behavior

Problematic “Ash” = CCS, and some SC, TC, CC type materials

Fig. 4. Proposed updated SBTn chart based on Q_{tn}–F_r (solid lines show soil behaviour type boundaries, and dashed lines show boundaries suggested by Robertson 1990).



PROBLEMATIC “ASH”
CCS = Clay-Like, Contractive, Sensitive

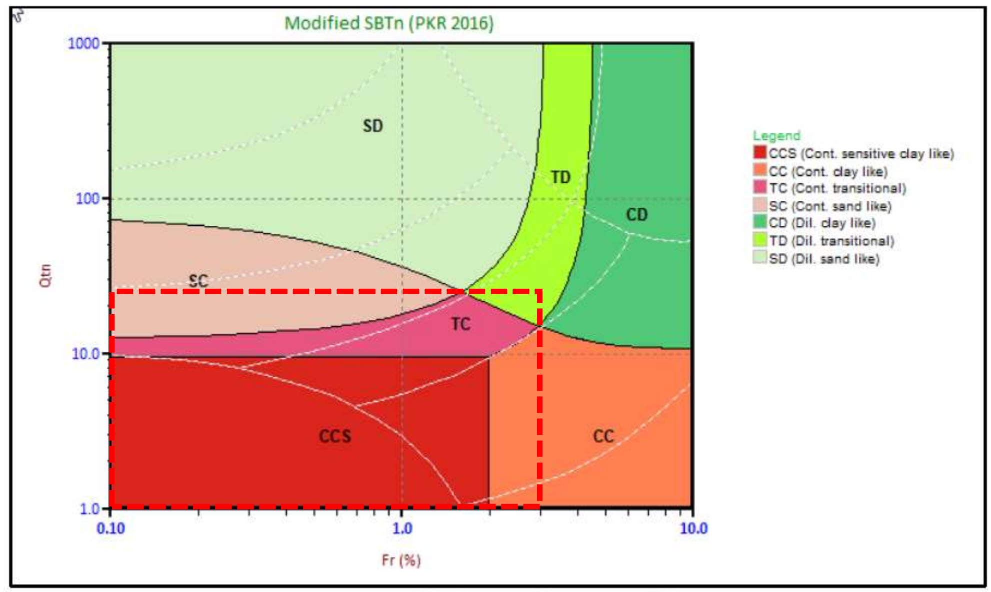
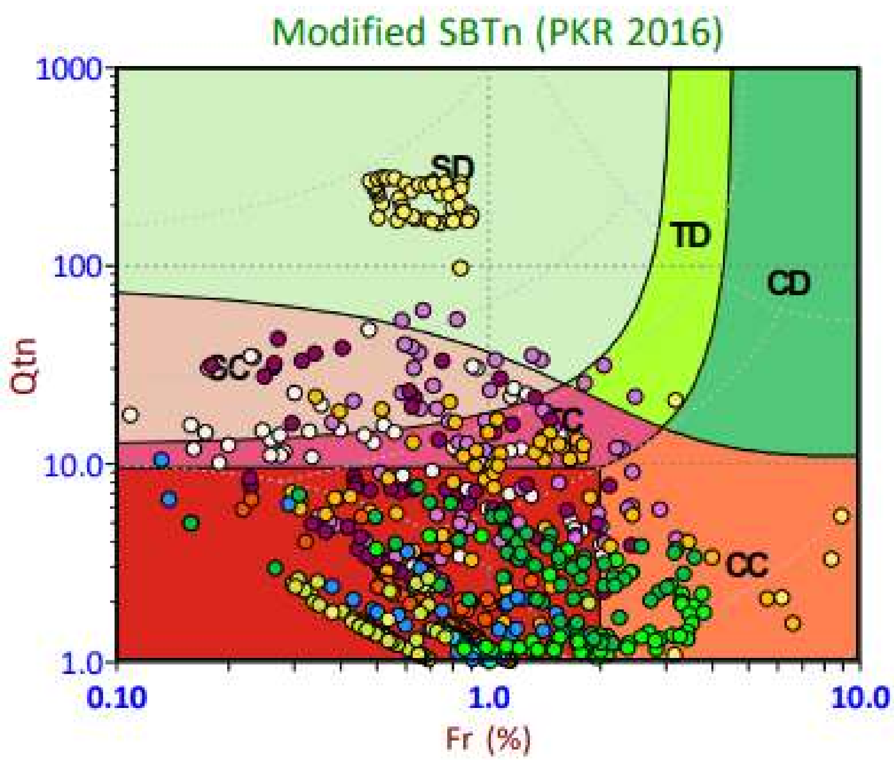


Figure 5. Modified SBTn Behavior Based Chart

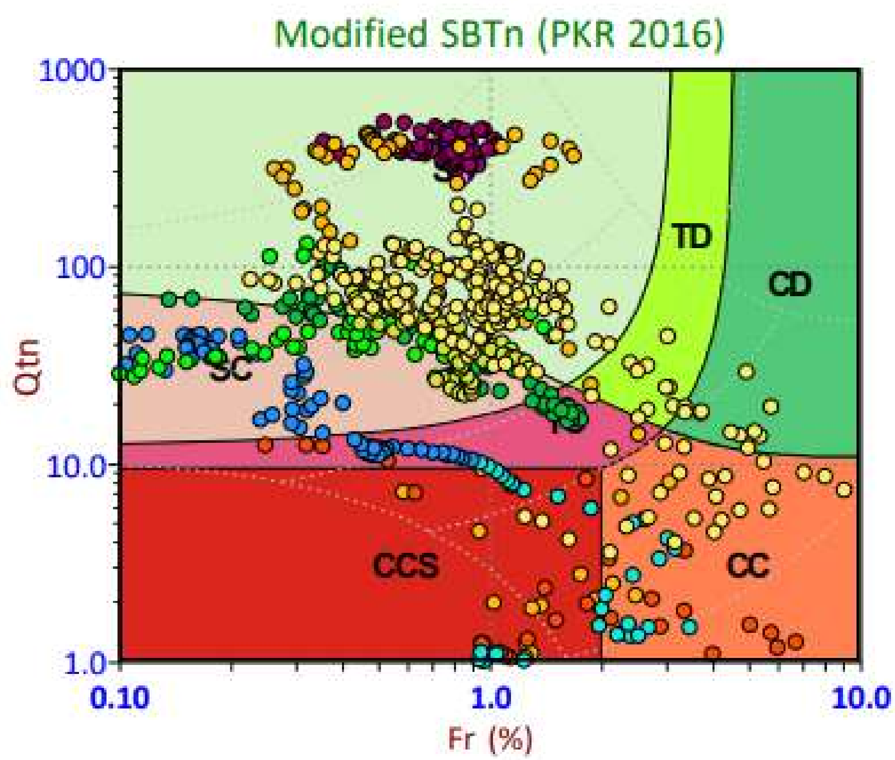
Generalized "Soil" Behavior – Informative SBT Scatter Plots

Problematic "Ash" = CCS, and some SC, TC, CC type materials

Not So Good!



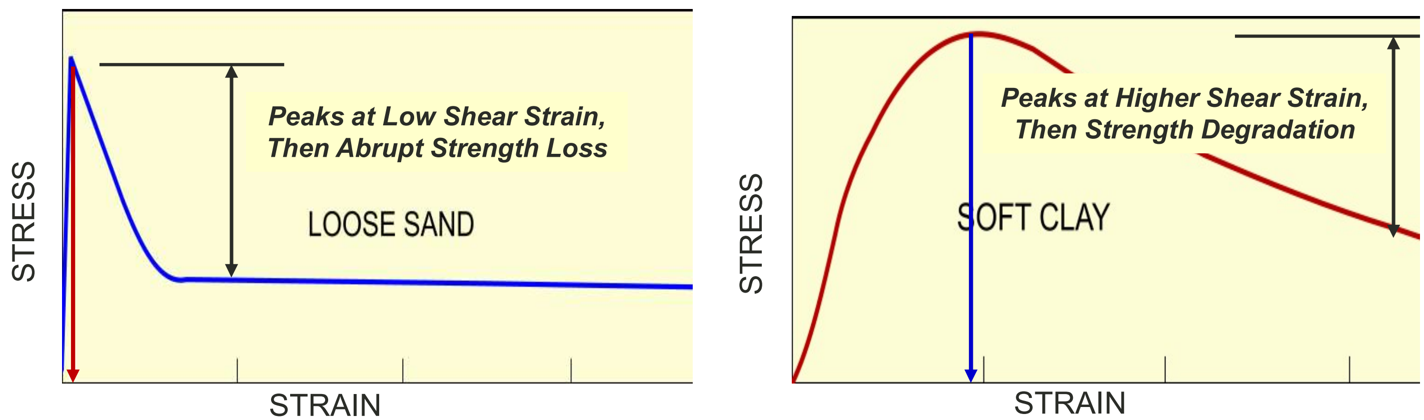
Not Too Bad



WHY WE CARE ABOUT THE GENERAL SOIL BEHAVIOR CLASSIFICATION

“Sand-Like” & “Sensitive, Fine-Grained”: Low Peak Strength, Inordinately Low Residual Strength, and Susceptible to Cyclic Mobility When “Triggered”

“Sand-Like” *vs* “Clay-Like”

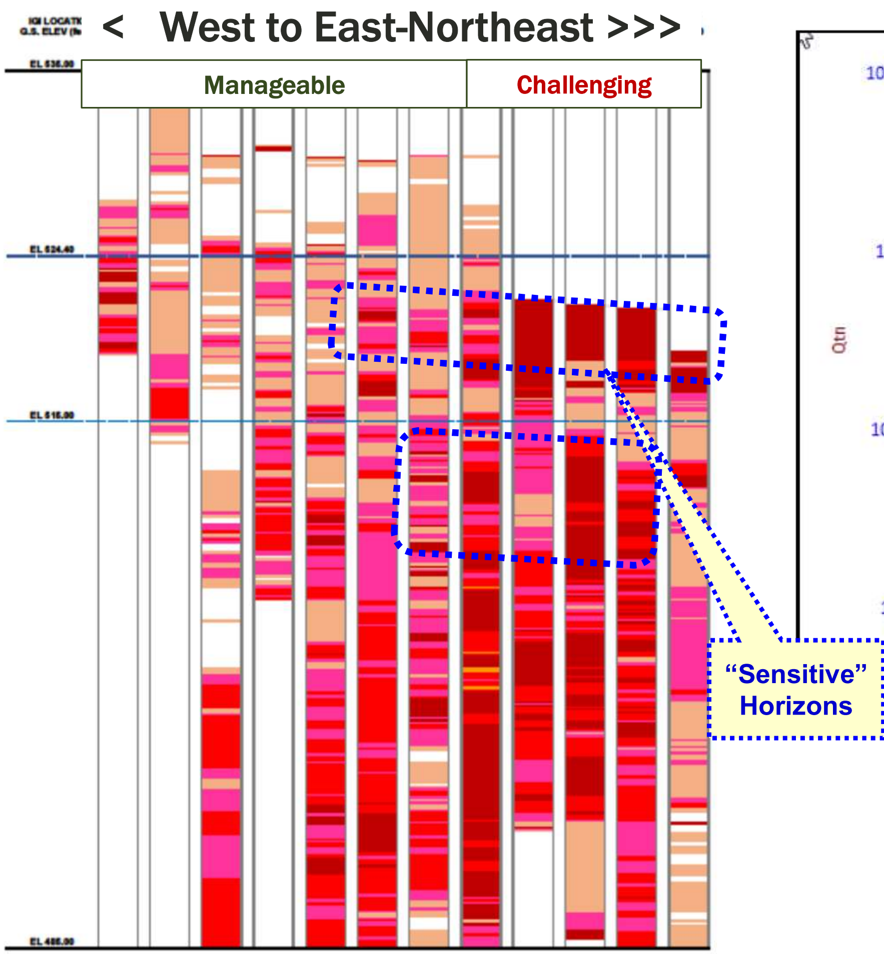


Key Distinctions:

- Strain at Peak Undrained Shear Strength
- Abruptness of Drop in Shearing Resistance
- Degree of Strength Loss, Sensitivity, St = $S_{u\text{-peak}}/S_{u\text{-remolded}} > 4$

<<< Location, Extent, Continuity >>>

Spatial Distribution of “Contractive” CCR Materials (CCS, SC, TC, CC)



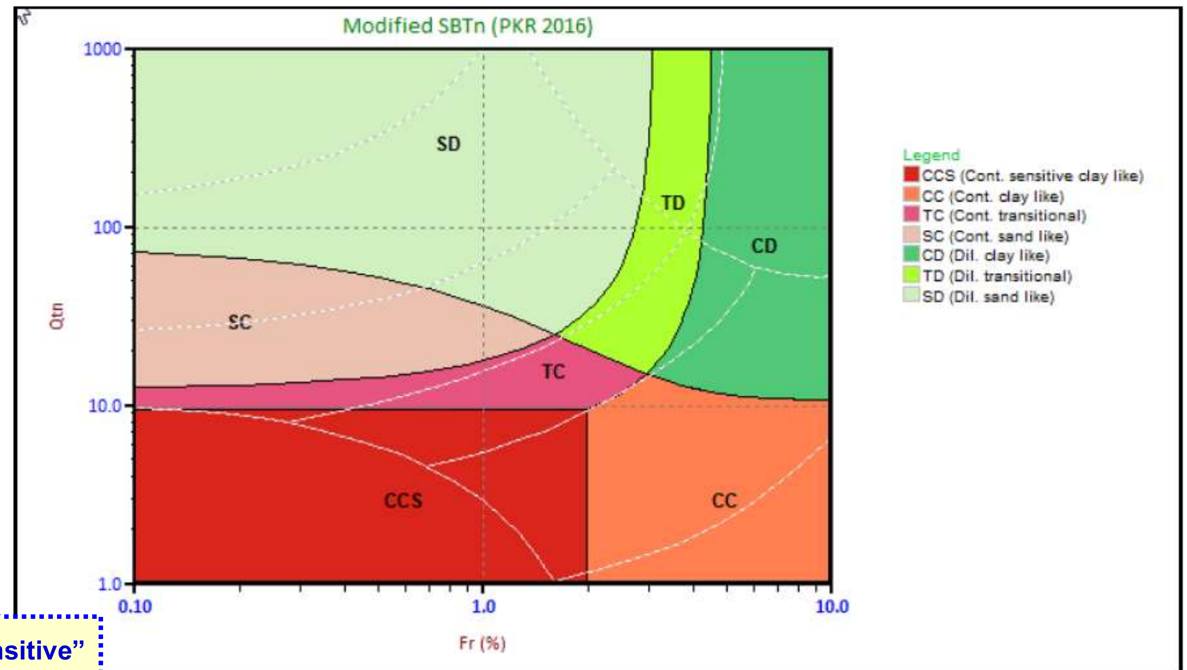
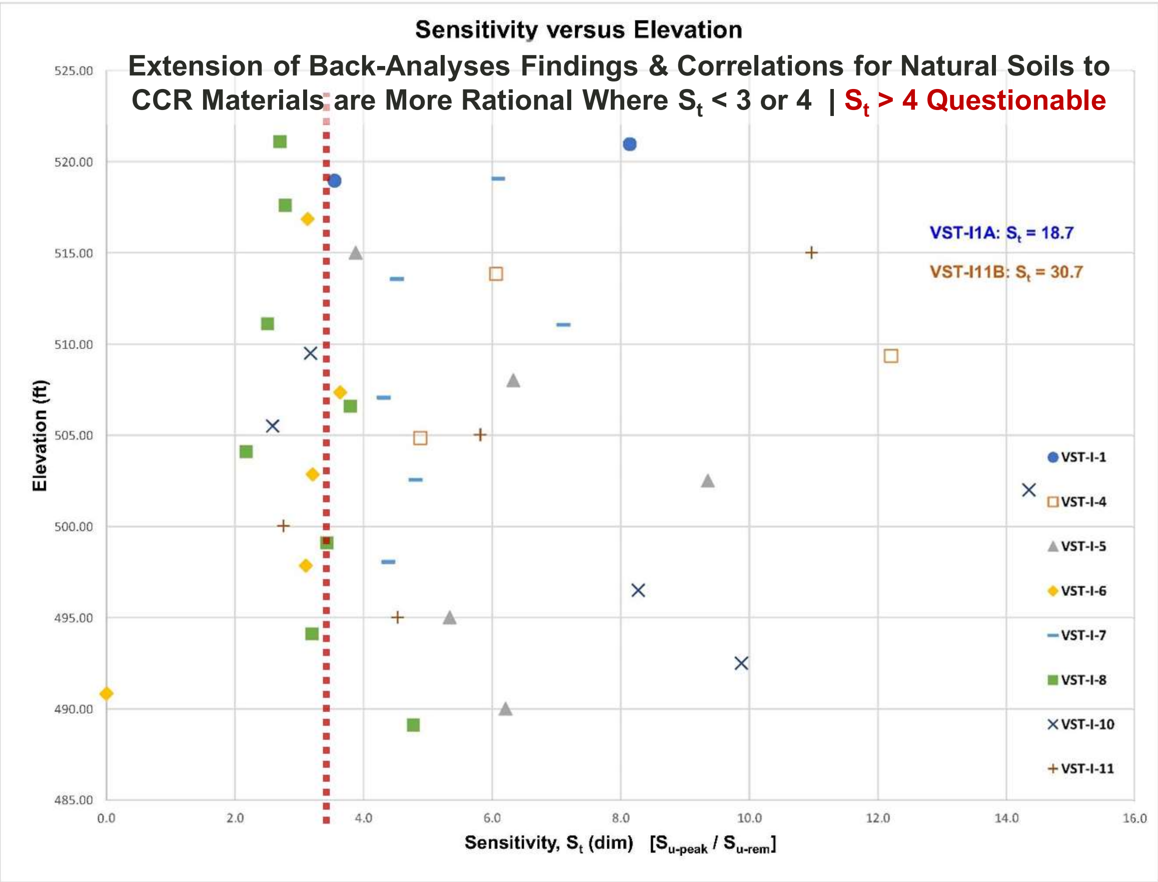
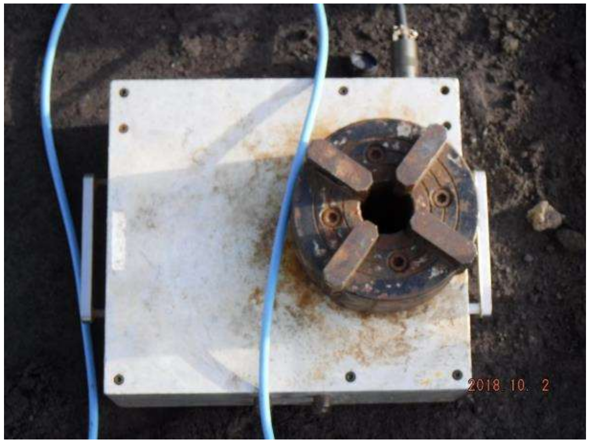


Figure 5. Modified SBTn Behavior Based Chart

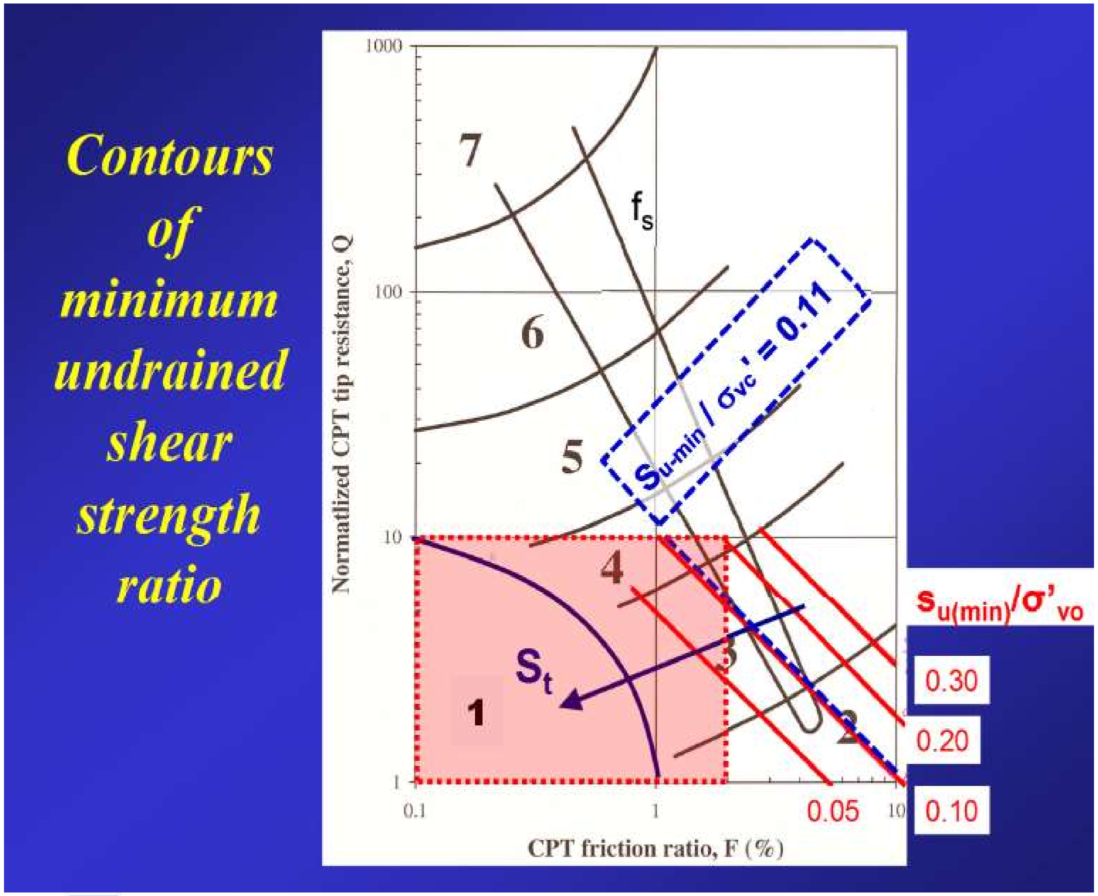
Sensitivity as f($S_{u\text{-peak}}/S_{u\text{-remolded}}$)

S_t > 3 or 4, Closer Examination Warranted





Increasing Sensitivity, S_t and Decreasing USS Ratios, $S_u/\sigma'_{c\ or\ vo}$



DERIVATION OF $S_{u\text{-}min}/\sigma'_{c\ or\ vo}$ CONTOURS

Normalized CPT Parameters ("clays"): *(Lunne, Robertson and Powell, 1997)*

Normalized CPT Tip Resistance, $Q = (q_t - \sigma_v)/\sigma_v'$ [dim]
CPT Friction Ratio, $F = 100\ f_s/(q_t - \sigma_v)$ [%]

$S_{u\text{-}Peak} = (q_t - \sigma_v)/N_{kt}$; N_{kt} = 6 to 18 in "natural" clays **(Tt: $N_{kt} \approx$ 20 to 35 sensitive CCR fines)**

(or)

$S_{u\text{-}Peak} = \Delta u/N_{\Delta u}$; $N_{\Delta u}$ = 4 to 10 in very soft "natural" clays (Adopted Default = 8)

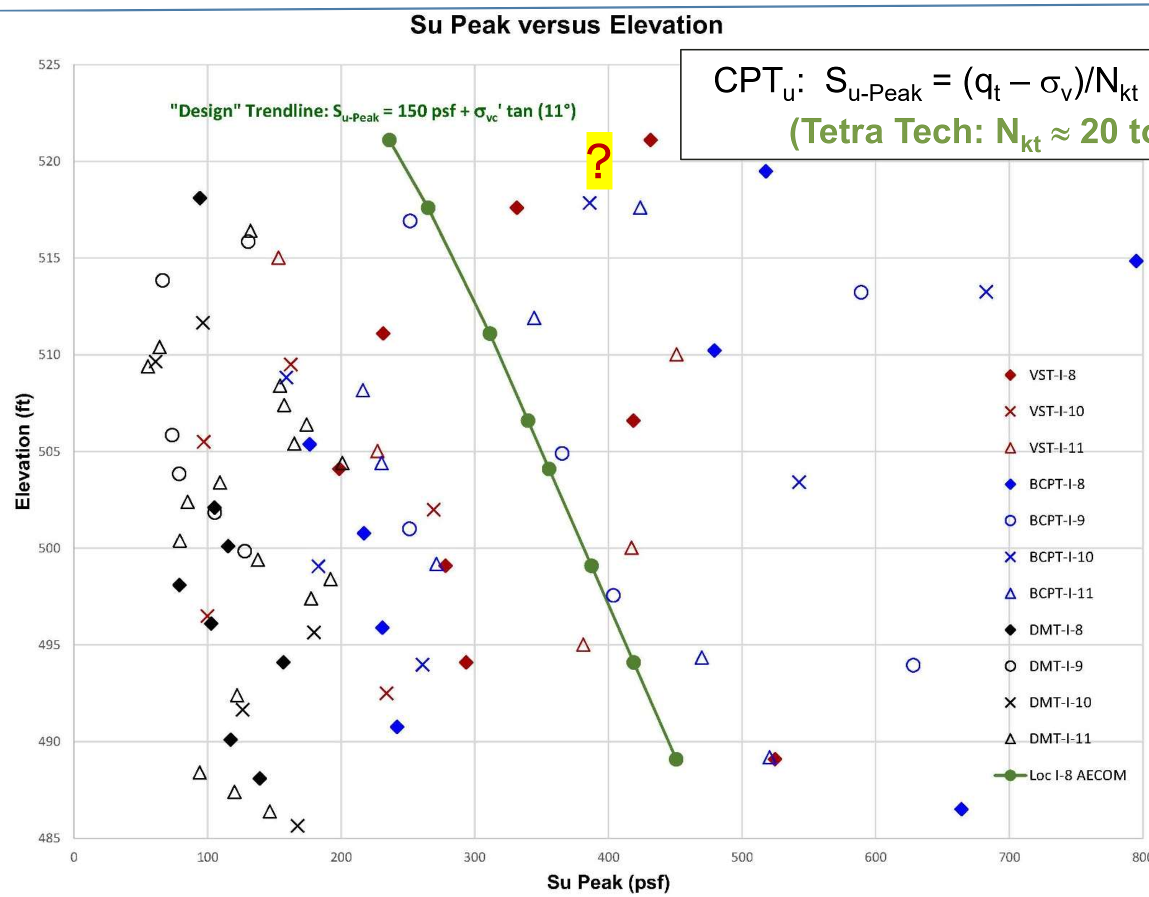
$S_{u\text{-}Min\ or\ Remolded} = f_s$ (i.e., remolded undrained shear strength = CPT sleeve friction, f_s)

Therefore:

$S_{u\text{-}Min}/\sigma_v' = f_s/\sigma_v' = Q \times F/100$ (see Q vs. F Chart for contours)

Assuming average $S_{u\text{-}Peak}/\sigma_v' = 0.25$ for normally consolidated clay,
the $S_{u\text{-}Min}/\sigma_v'$ contours also represent Sensitivity, $S_t = S_{u\text{-}Peak}/S_{u\text{-}Min}$

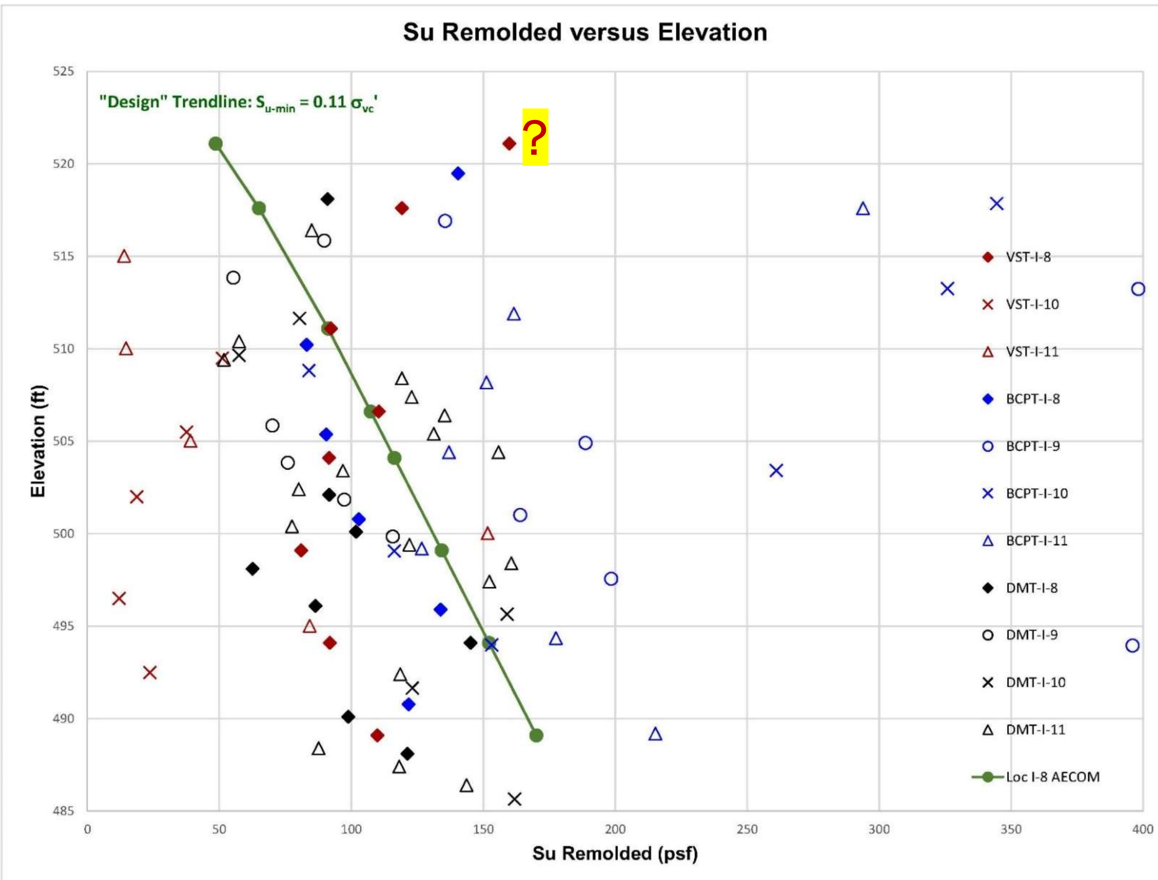
Undrained Shear Strength (USS: $S_{u\text{-peak}}$ or $S_{u\text{-remolded or min}}$): "PEAK"

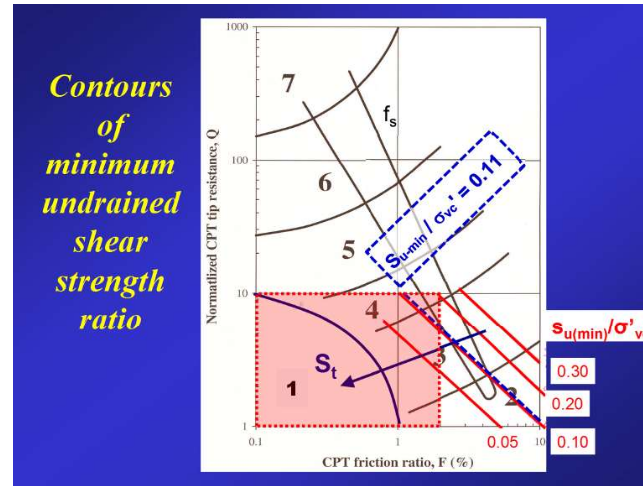


CPT_u: $S_{u\text{-Peak}} = (q_t - \sigma_v)/N_{kt}$; N_{kt} = 6 to 18 in "natural" clays

(Tetra Tech: $N_{kt} \approx$ 20 to 35 sensitive CCR fines)

Undrained Shear Strength (USS: $S_{u\text{-peak}}$ or $S_{u\text{-remolded or min}}$): "REMOLDED"





Water Content (w_c) vs Liquid Limit (LL), Liquidity Index (LI), Void Ratio (e)

In-situ water content (w_c) approaches or exceeds Liquid Limit (LL)

- LL by Cone Penetration or Fall Cone Method, rather than Mechanical (Casagrande) Method

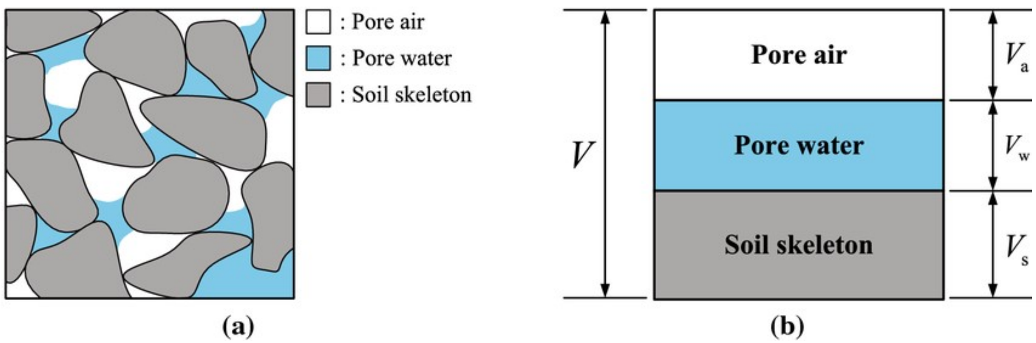
Liquidity Index (LI) approaches or exceeds 1.0

- $LI = (w_c - PL)/(LL - PL)$

Void Ratio (e) is quite high

- $e = V_v/V_s$

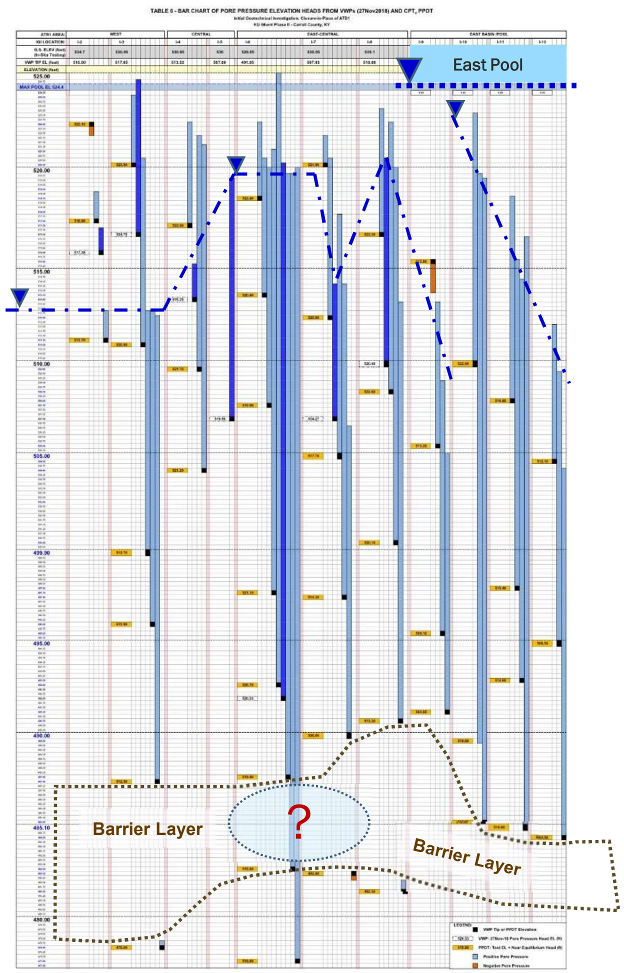
High Degree of Sensitivity, $S_t > 4$



Conclusion: Weak Micro-Structure or "Fabric" of CCR Zone = Metastable

"Metastable" = *stable so long as it is only subjected to minor disturbances*

In-Situ Porewater Pressures: CPTu Dissipation Tests (PPDT), VWPs
(Hydrostatic, Excess Positive Pressures, Semi-Confined to Confined Horizons)



ENGINEERED PREPARATORY TECHNIQUES

TETRA TECH LG&E KU PPL companies

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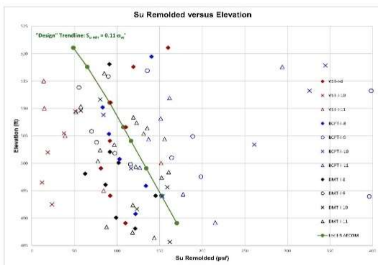
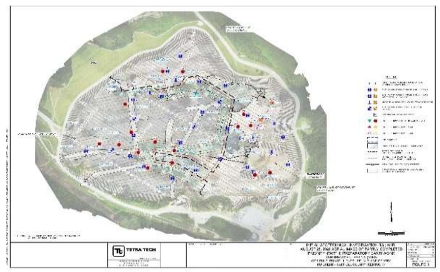
ENGINEERED PREPARATORY TECHNIQUES

INVESTIGATE

EVALUATE



PLAN & PHASE



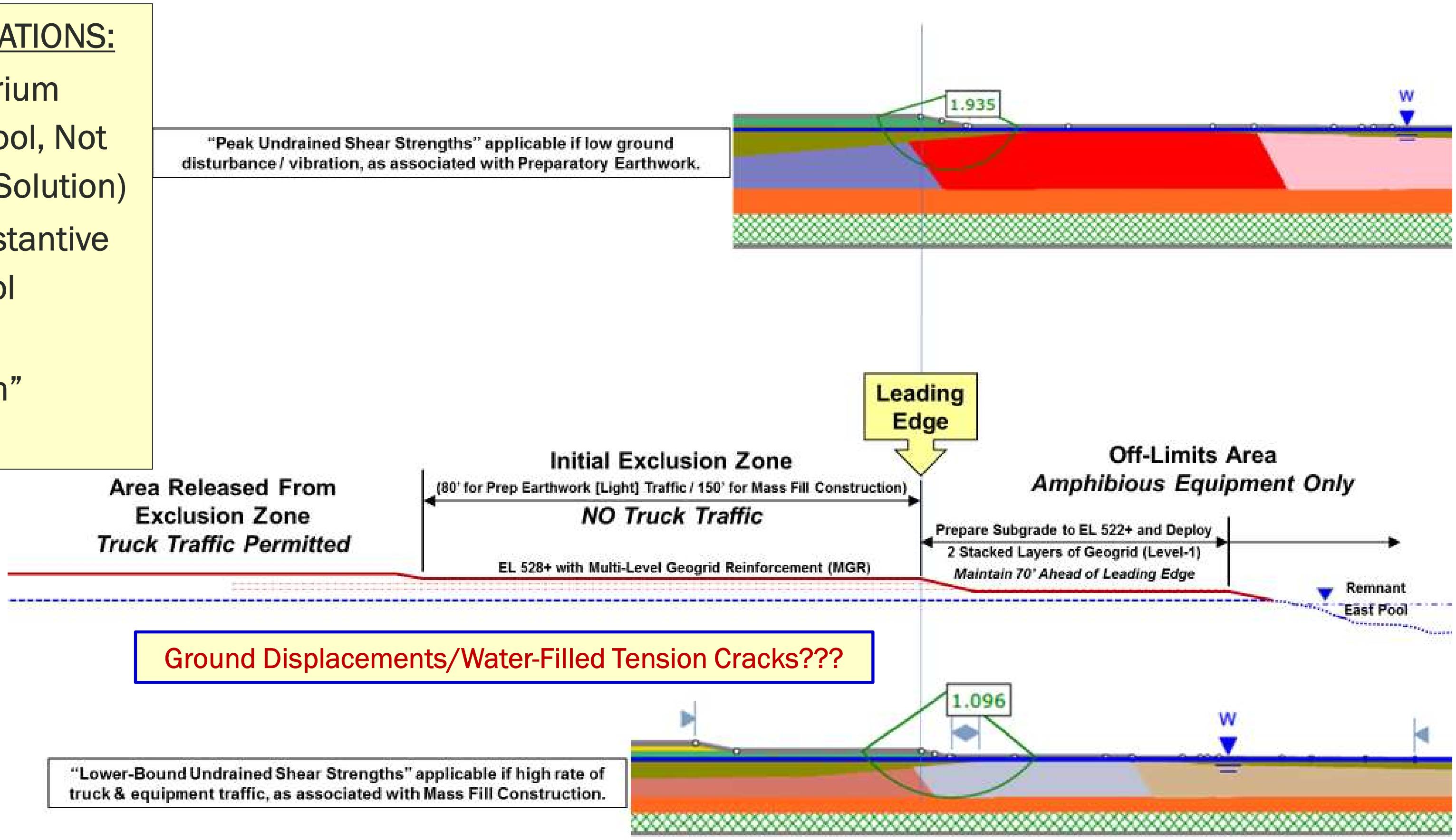
INSPECT/MONITOR

CONSTRUCT

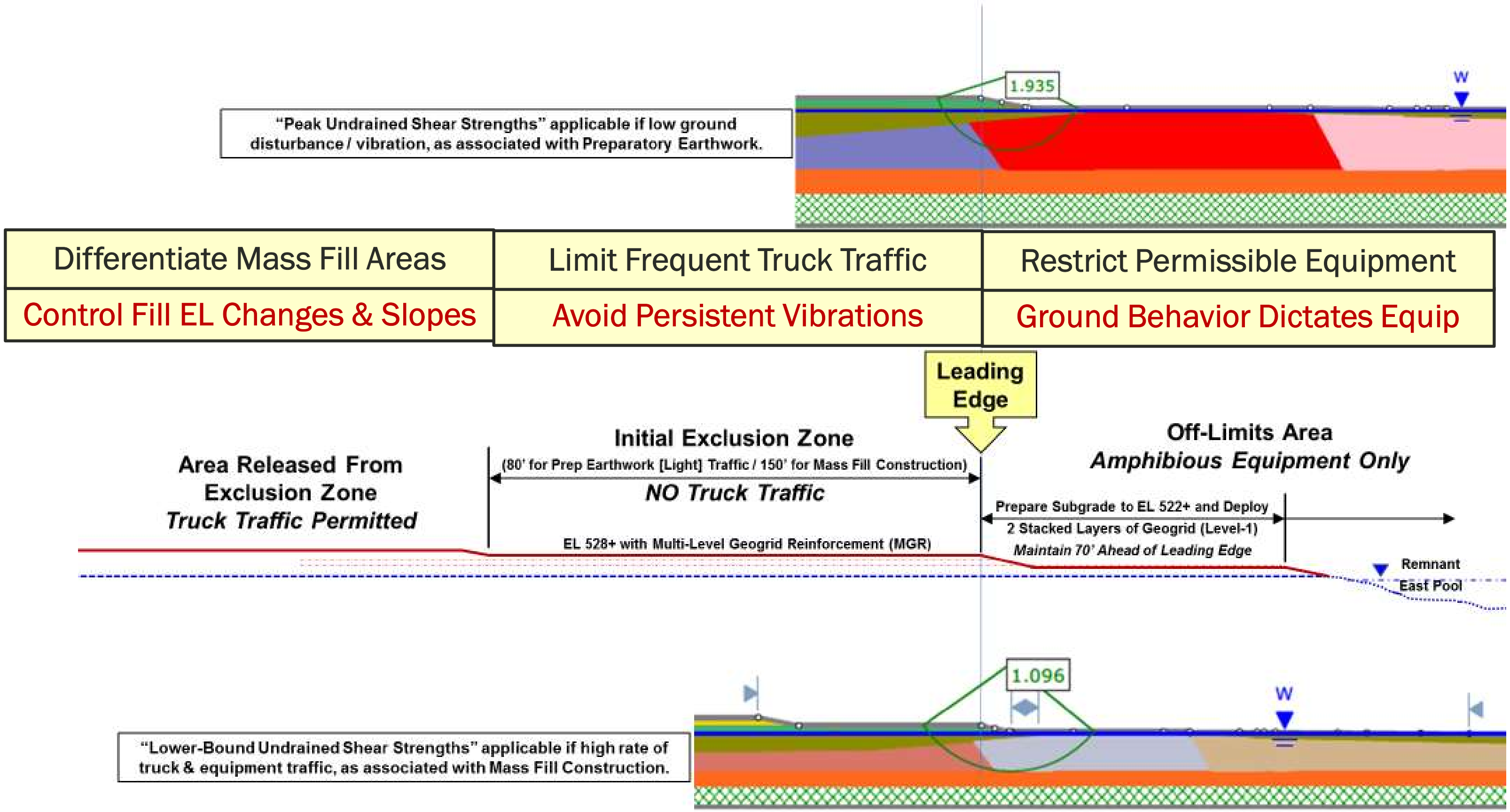
Evaluate and Maintain Overall Stability

<u>RECOGNIZE LIMITATIONS:</u>

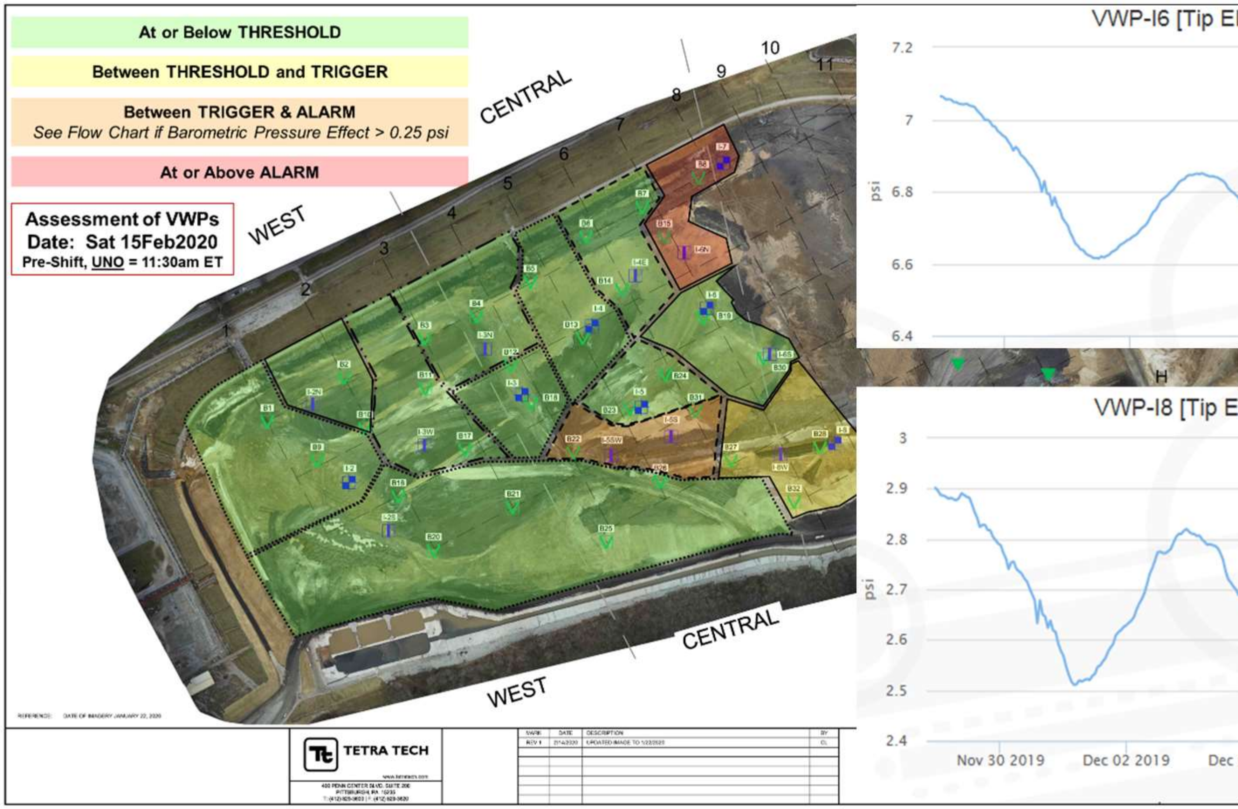
- ❑ Limit Equilibrium Analysis (A Tool, Not an absolute Solution)
- ❑ "Worst" Substantive Zones Control
- ❑ Moreso a "Deformation" Problem



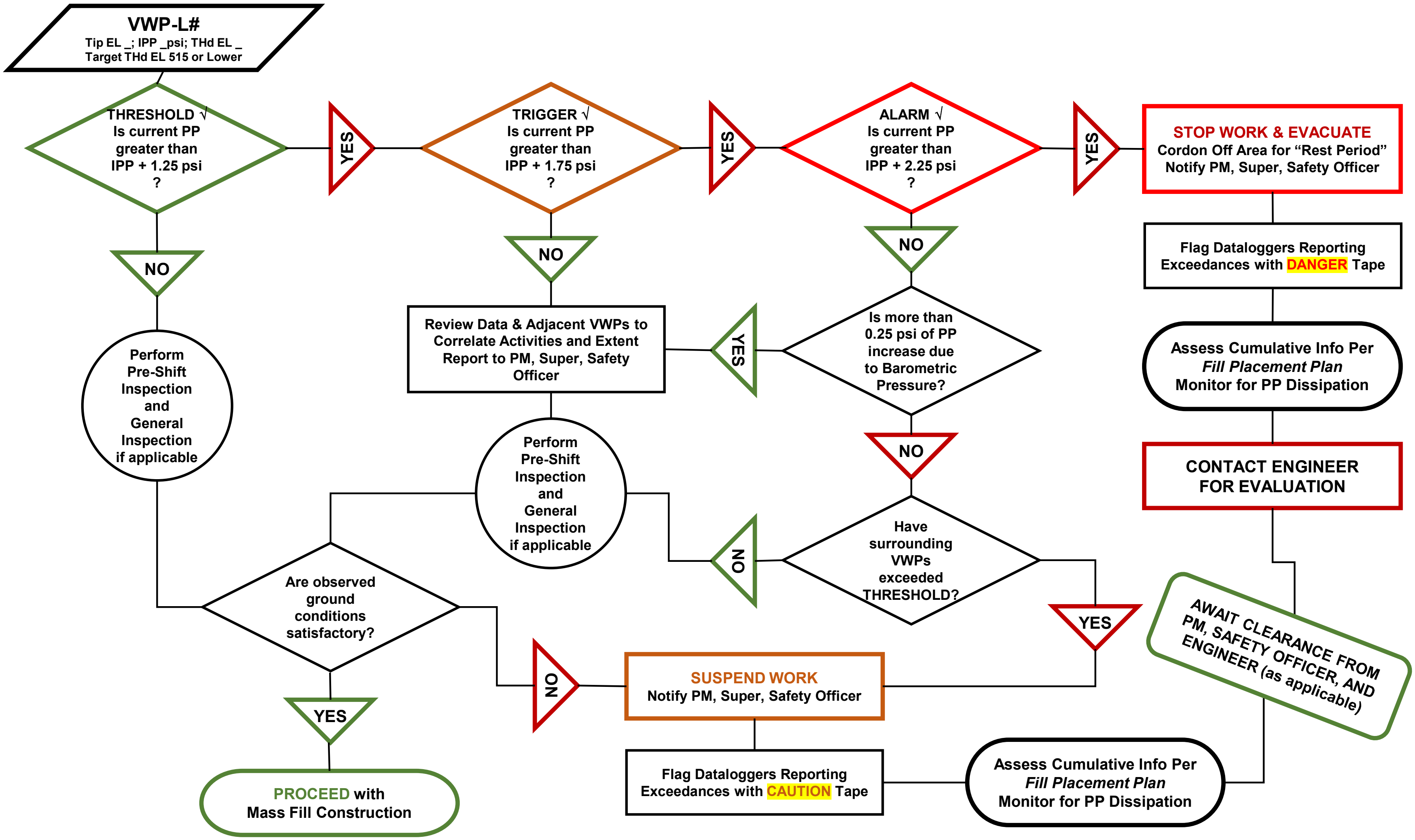
Regulate Construction Process:
Start Slow, Then Escalate/Accelerate as Supported by Inspections & Monitoring



Monitor Porewater Pressures and Ground Performance

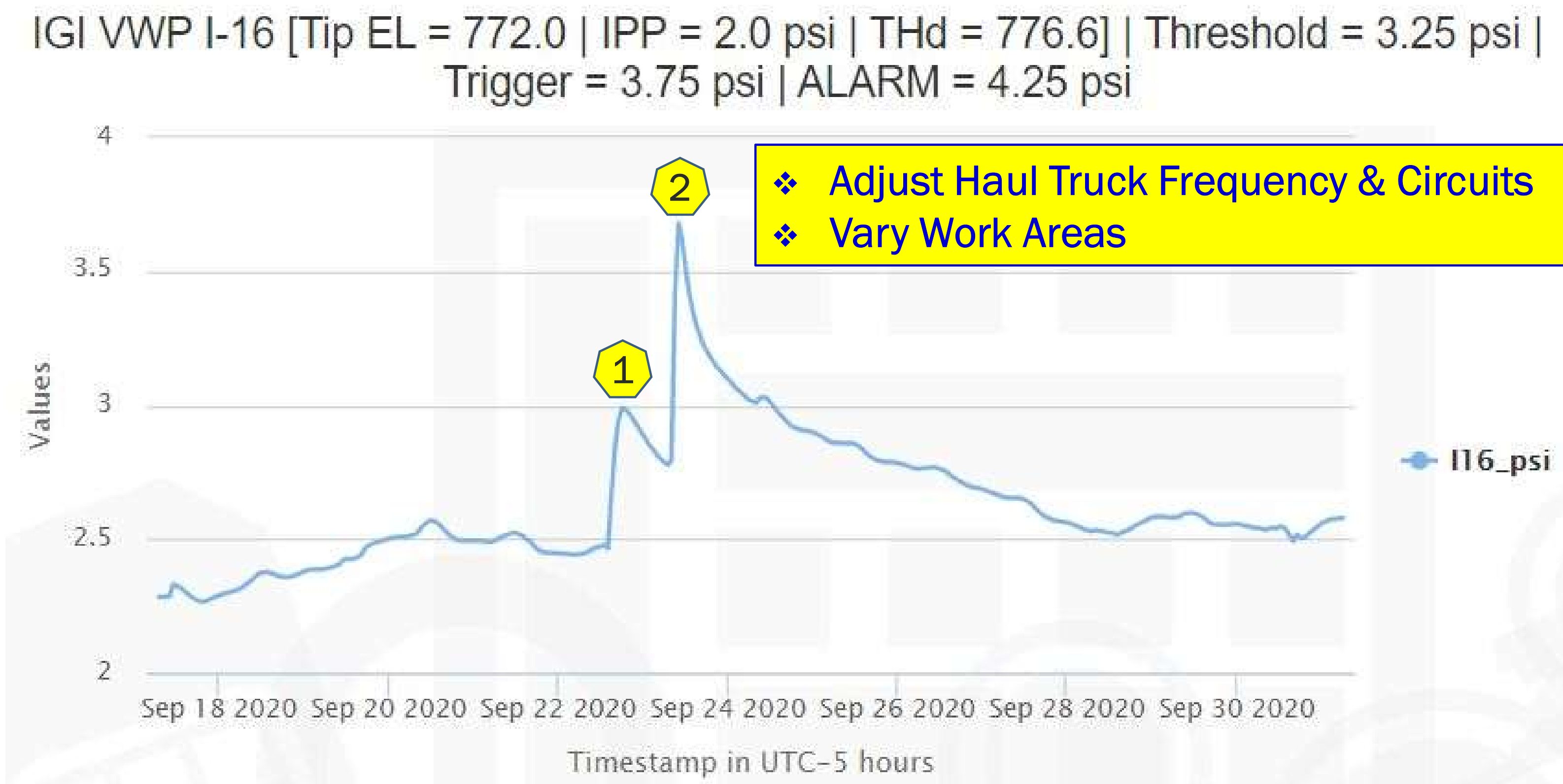


FLOW CHART – GUIDELINES FOR EVALUATING CM VWPs



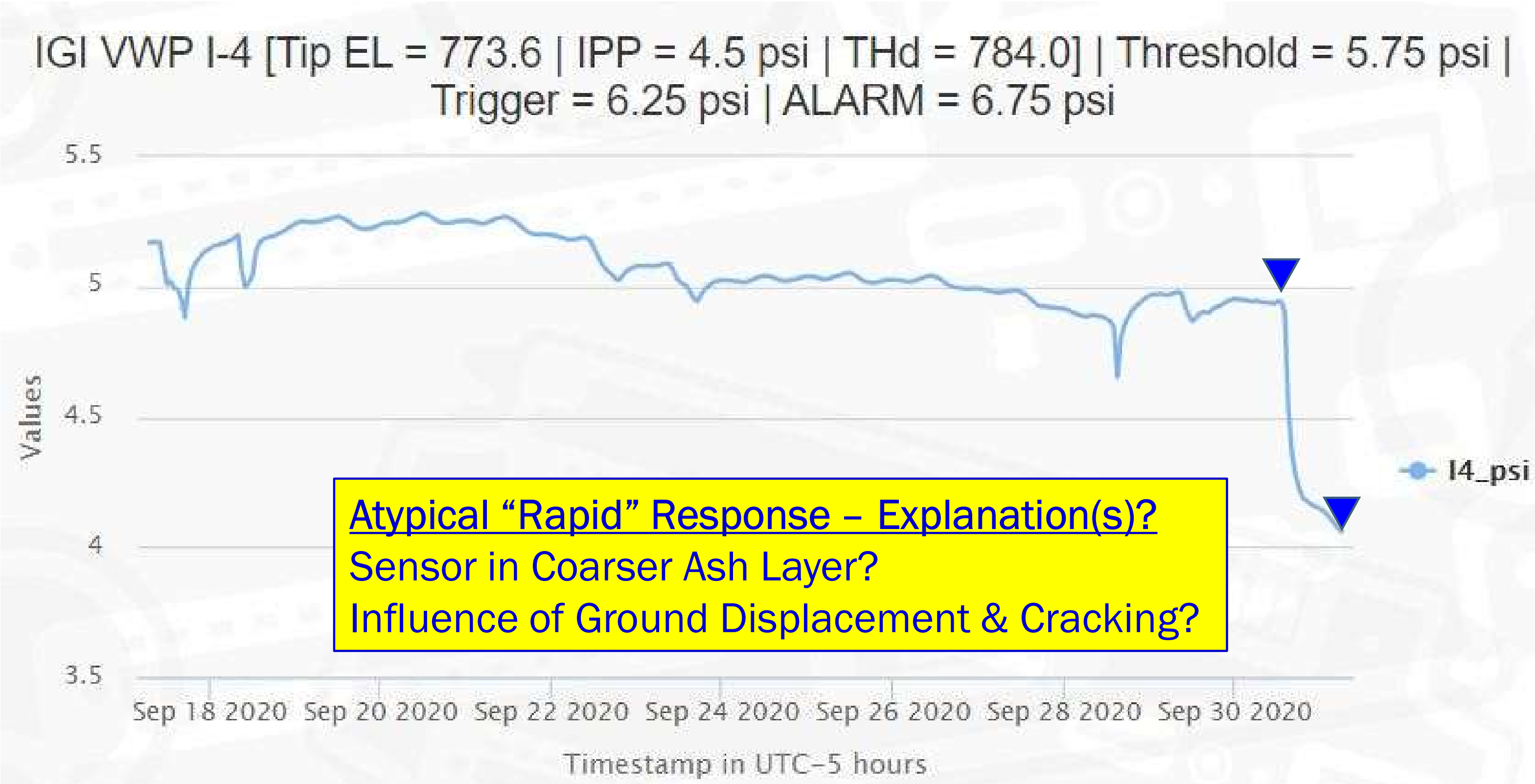
EXAMPLE: Monitoring PMPs During Closure “Mass Earthwork”

Two-Tier “Spike” From Frequent Rate of Haul Truck Traffic:



EXAMPLE - Monitoring PWPs During Closure “Mass Earthwork”

Rapid Response Upon Activating Nearby Deep Well:



GENERAL PROCESS FOR CLOSURE-IN-PLACE OF CCR IMPOUNDMENTS

TETRA TECH

LG&E KU
PPL companies

WORLD of COAL ASH 2022

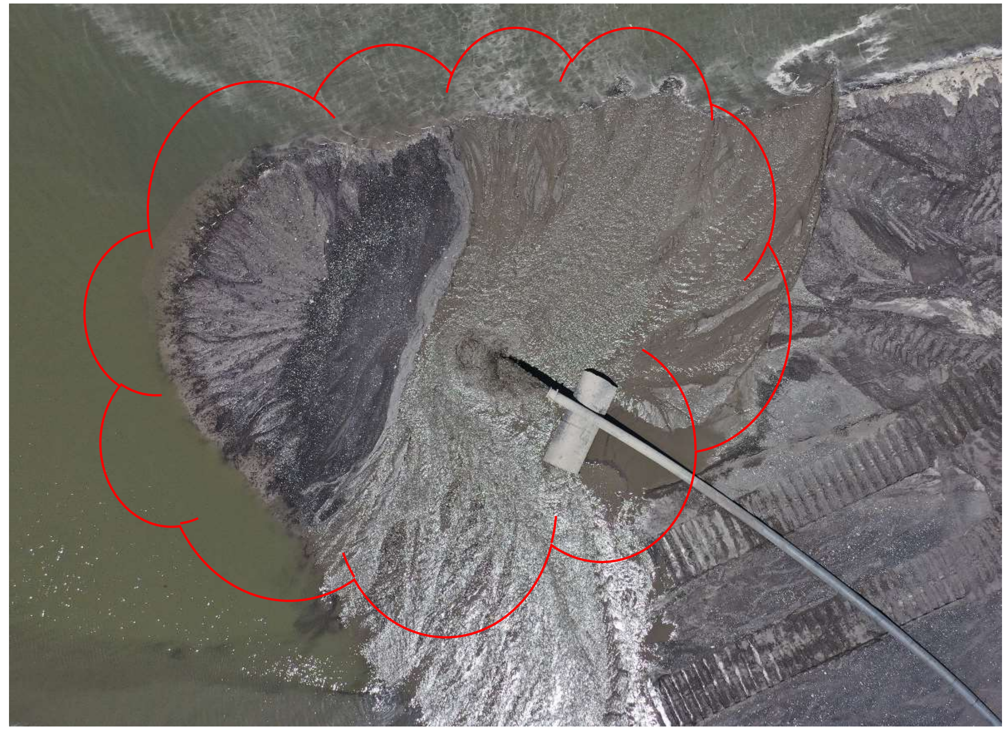
W C A

Process for Closure-in-Place of CCR Impoundments

1. Mitigate “highwalls”/“surcharges” around impoundment perimeter and within basin.
2. “Levelize” impoundment areas to alleviate surcharges <u>and</u> ***displace rather than draw down the supernatant pool.***
3. “Preparatory Earthwork” to develop strategic geogrid-reinforced access corridors.

TETRA TECH LG&E KU PPL companies

Dredge-Filling to Displace Pool, and Preparation of Working Subgrade with Amphibious Excavators

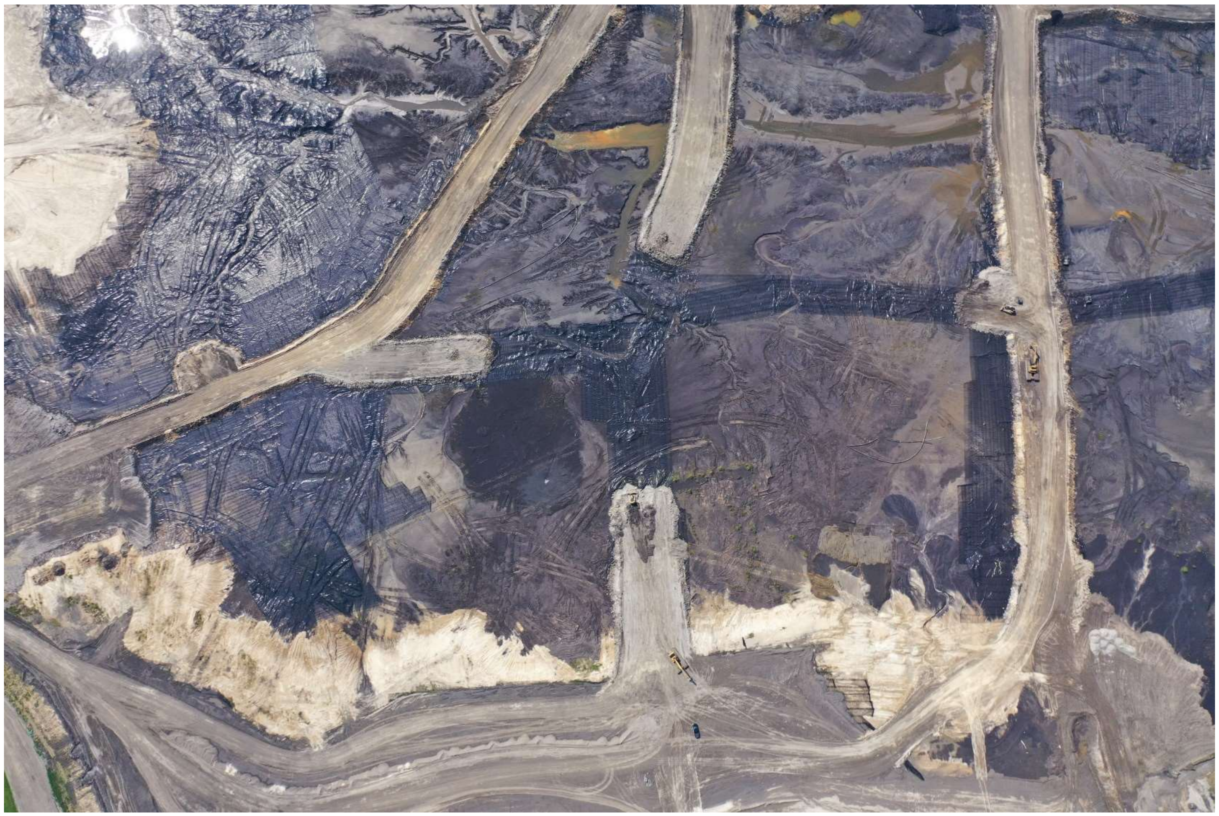


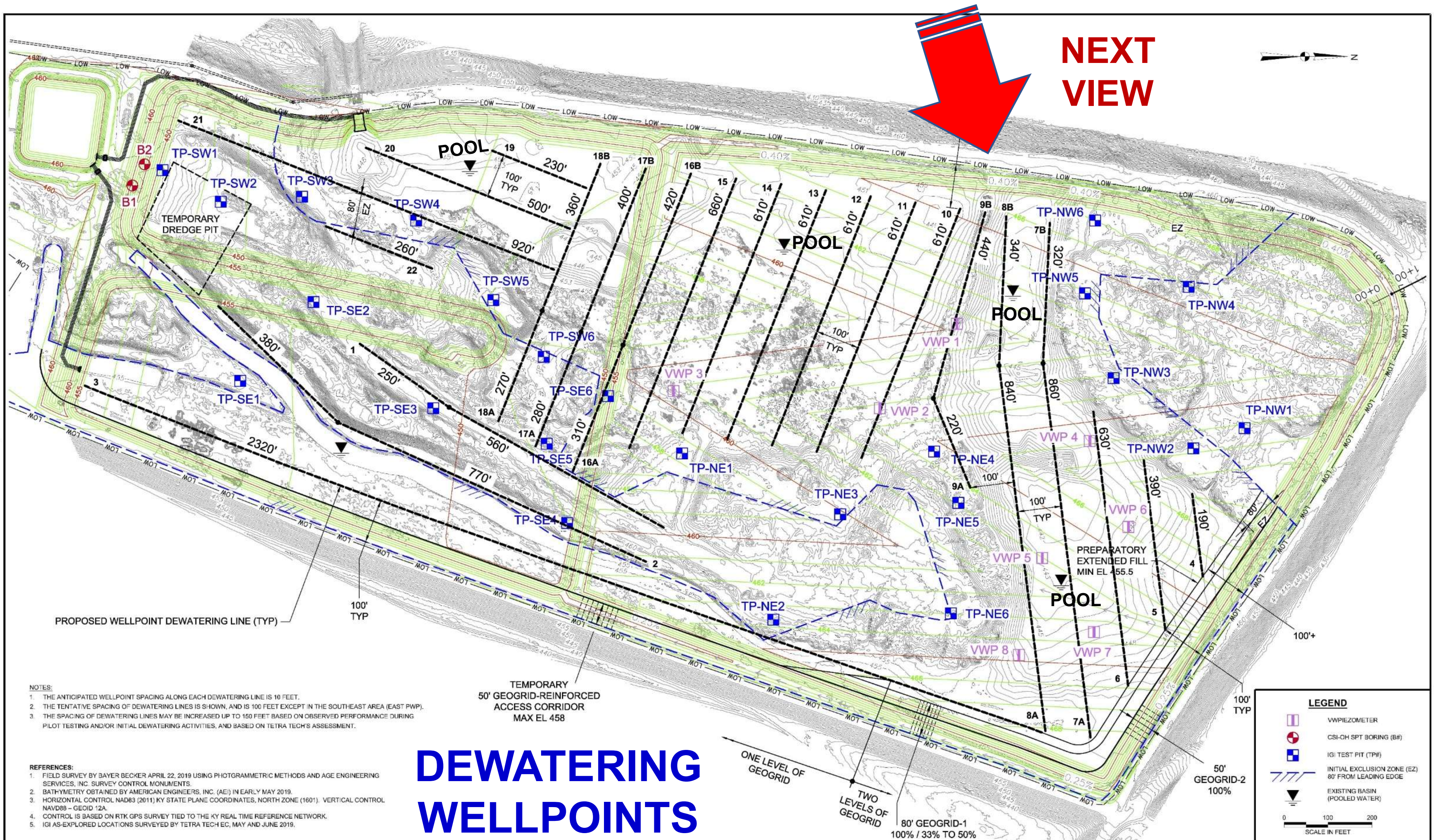
Tetra Tech’s Process for Closure-in-Place of CCR Impoundments

4. Perform subsurface dewatering where necessary.
5. Enhance stabilized working base to support planned rate of “Mass Earthwork” activity.

Strategic Geogrid-Reinforced Access Corridors

Subgrade Probed & Prepared with Amphibious Equipment, Then Strategic Access Corridors Developed with Geogrid-Reinforced Fill





NOTES:

1. THE ANTICIPATED WELLPOINT SPACING ALONG EACH DEWATERING LINE IS 10 FEET.
2. THE TENTATIVE SPACING OF DEWATERING LINES IS SHOWN, AND IS 100 FEET EXCEPT IN THE SOUTHEAST AREA (EAST PWP).
3. THE SPACING OF DEWATERING LINES MAY BE INCREASED UP TO 150 FEET BASED ON OBSERVED PERFORMANCE DURING PILOT TESTING AND/OR INITIAL DEWATERING ACTIVITIES, AND BASED ON TETRA TECH'S ASSESSMENT.

REFERENCES:

1. FIELD SURVEY BY BAYER BECKER APRIL 22, 2019 USING PHOTGRAMMETRIC METHODS AND AGE ENGINEERING SERVICES, INC. SURVEY CONTROL MONUMENTS.
2. BATHYMETRY OBTAINED BY AMERICAN ENGINEERS, INC. (AEI) IN EARLY MAY 2019.
3. HORIZONTAL CONTROL NAD83 (2011) KY STATE PLANE COORDINATES, NORTH ZONE (1601). VERTICAL CONTROL NAVD88 – GEOID 12A.
4. CONTROL IS BASED ON RTK GPS SURVEY TIED TO THE KY REAL TIME REFERENCE NETWORK.
5. IGI AS-EXPLORED LOCATIONS SURVEYED BY TETRA TECH EC, MAY AND JUNE 2019.

DEWATERING WELLPOINTS

TETRA TECH
www.tetratech.com
400 PENN CENTER BLVD. SUITE 200
PITTSBURGH, PA 15235
T: (412) 829-3600 | F: (412) 829-3620

MARK	DATE	DESCRIPTION	BY
REV 1	23JAN2020	UPDATES TO VWP ANNOTATION, VWP-3 TO VWP-1 AND VWP-1 TO VWP-3	CL
REV 2	07FEB2020	AS-INSTALLED / SURVEYED LOCATIONS OF VWP-1_8	CL

INITIAL VIBRATING WIRE PIEZOMETERS
ASH TREATMENT BASIN

ASH TREATMENT BASIN CLOSURE-IN-PLACE (ATB CIP) AND
PROCESS WATER POND (PWP) CONSTRUCTION
LG&E/KU MILL CREEK ATB CCR RULE CLOSURE-JEFFERSON COUNTY, KY

DATE:	07FEB2020
PROJECT NO.:	212IC-SW-002/9
DESIGNED BY:	CL
DRAWN BY:	JL
CHECKED BY:	CL
SHEET:	1 OF x

MC CM VWPs


Initial Basin/Pool Area Stabilized with
Hand-Jetted Lines of Wellpoints,
Followed by Geogrid and "Bridge" Lifts
(3) Follow "Upstream Construction" Procedures [e.g., Proper Push Direction]
(1A) First Mitigate "Highwalls"
Truck
LGP Dozer
(1B) Complete "Preparatory Earthwork" in Basin Areas as Part of Mitigating "Highwalls" and Ahead of "Leading Edge"
(2) Establish & Mark Initial Exclusion Zone 80-ft Min/NO Trucks


VWP-3
VWP-2
VWP-1
VWP-4
VWP-5
VWP-6
VWP-8
VWP-7

Ash Treatment Basin (ATB)

Geogrid Installation Over Prepared "Very Soft" Subgrade, with Expanding Areas of "Mass Fill" Construction

Thank You!

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Chris Lewis Chris.Lewis2@TetraTech.com

RELATED PRESENTATIONS: (Tetra Tech, LG&E/KU, Keller)

Preparatory Construction to Enable Accelerated Mass Filling for Closure-In-Place of CCR Impoundments [Emphasis on Construction Techniques]

Dewatering at Ghent (ATB-1, ATB-2) [Deep Well & Wellpoint Dewatering]

Attachment 2

TETRA TECH

Preparatory Construction to Enable Accelerated Mass Filling for Closure-In-Place of CCR Impoundments

Presenter: Steven Turner

Author: Steven Turner, Christopher Lewis, Jeffrey Heun

Date: May 18, 2022

Implementing an Engineered Process to Prepare CCR Impoundments for Accelerated Mass Filling

TETRA TECH

Safety Moment

1. Laughing 100 times is equivalent to 15 minutes of exercise on a stationary bike.
2. There are more bacteria in your mouth than there are people in the world.
3. You burn more calories sleeping than you do watching television.
4. Right-handed people live, on average, nine years longer than left-handed people.
5. You are about 1cm taller in the morning than in the evening.
6. During your lifetime, you will eat about 66,000lbs of food – that's the weight of about six African elephants.
7. In some parts of the world (one being Malaysia), parents protect their babies from disease by bathing them in beer.
8. Extreme music – such as heavy metal – can positively influence those experiencing anger.
9. It's not just coughs and sneezes that spread diseases. One single bacteria cell can multiply to become more than eight million cells in less than 24 hours.
10. Joining clubs after retirement could extend your life.

Safety Moment

If you join a club that focuses on laughing while banging your head against a wall and listening to heavy metal music, you will burn over 1,000 calories an hour, not be angry, and live longer ☺

- Major impoundment subsurface dewatering and unwatering measures, mitigation of potential stability issues presented by existing surcharges and stockpiles, initial preparation of basin areas, safety precautions, and training, inspection and monitoring systems
- Means to manage and improve the stability situation during initial or preparatory earthwork operations will be discussed, including passive and active dewatering, geogrid use, strategic fill placement, selective excavation, best practices for upstream construction, and engineered sequencing

It All Begins with the Science.

Engineering Services

Geotechnical Investigation and Preparation of Construction Work Plans

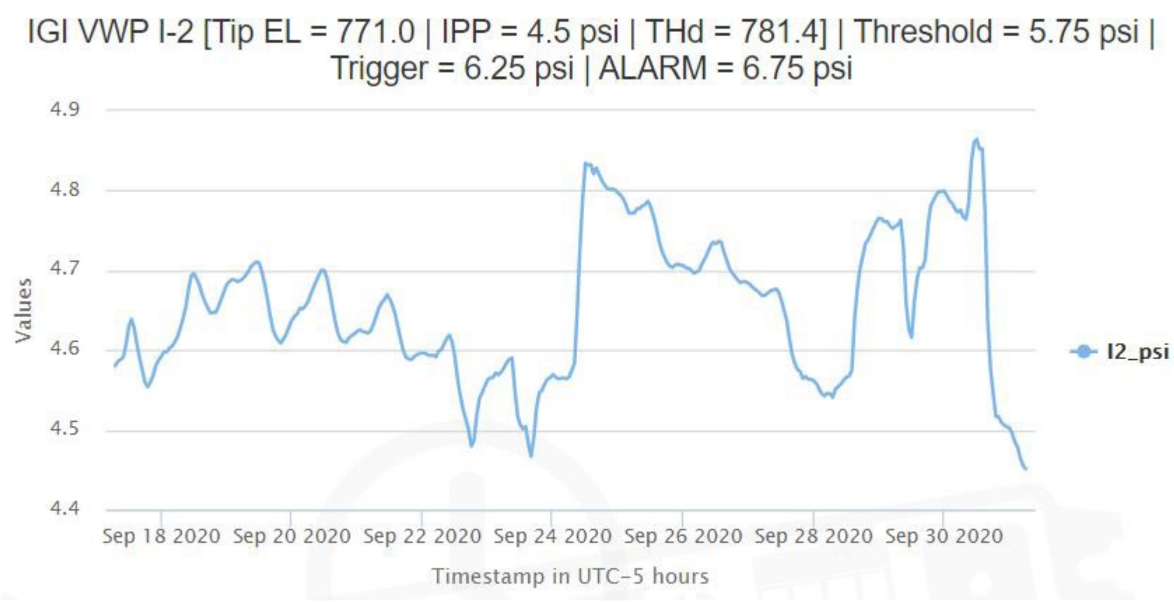
Creation of Safety Training Module for pond Installation of VWP's and mass fill operations (Ground Control Plan)

Construction of Access Corridors for Geotechnical Investigations

Geogrid/Bottom Ash Access Roads to Support Geotechnical Investigations

VWP and Monitoring Module

- Online/On-site real time monitoring of pond stability and pore pressure



Preparatory Construction Activities

Preparatory Activities for Mass Fill of CCR Impoundments

1. Mitigate “highwalls”/“surcharges” around impoundment perimeter and within basin.
2. “Levelize” impoundment areas to alleviate surcharges <u>and</u> displace *rather than draw down* supernatant pool.
3. “Preparatory Earthwork” to develop strategic geogrid-reinforced access corridors.
4. Perform subsurface dewatering where necessary.
5. Enhance stabilized working base to support planned rate of construction activity.
6. Stage & regulate earthwork construction, restrict fill differentials, and accelerate rate only if supported by established *General Inspection* protocol and geotechnical & instrumentation data *(Preparatory Earthwork* accelerated to *Mass Fill Construction* rate).
7. Monitor porewater pressures and ground performance.
8. Implement passive and active dewatering as necessary during basin/pond grading operations

Preparatory Activities for Mass Fill of CCR Impoundments

1. Mitigate “highwalls”/“surcharges” around impoundment perimeter and within basin.
2. “Levelize” impoundment areas to alleviate surcharges <u>and</u> displace *rather than draw down* supernatant pool.
3. “Preparatory Earthwork” to develop strategic geogrid-reinforced access corridors.

Amphibious Excavator – Highwall Removal

Levelizing via Hydraulic Dredge

Geogrid Reinforced Access Corridors

Preparatory Activities for Mass Fill of CCR Impoundments

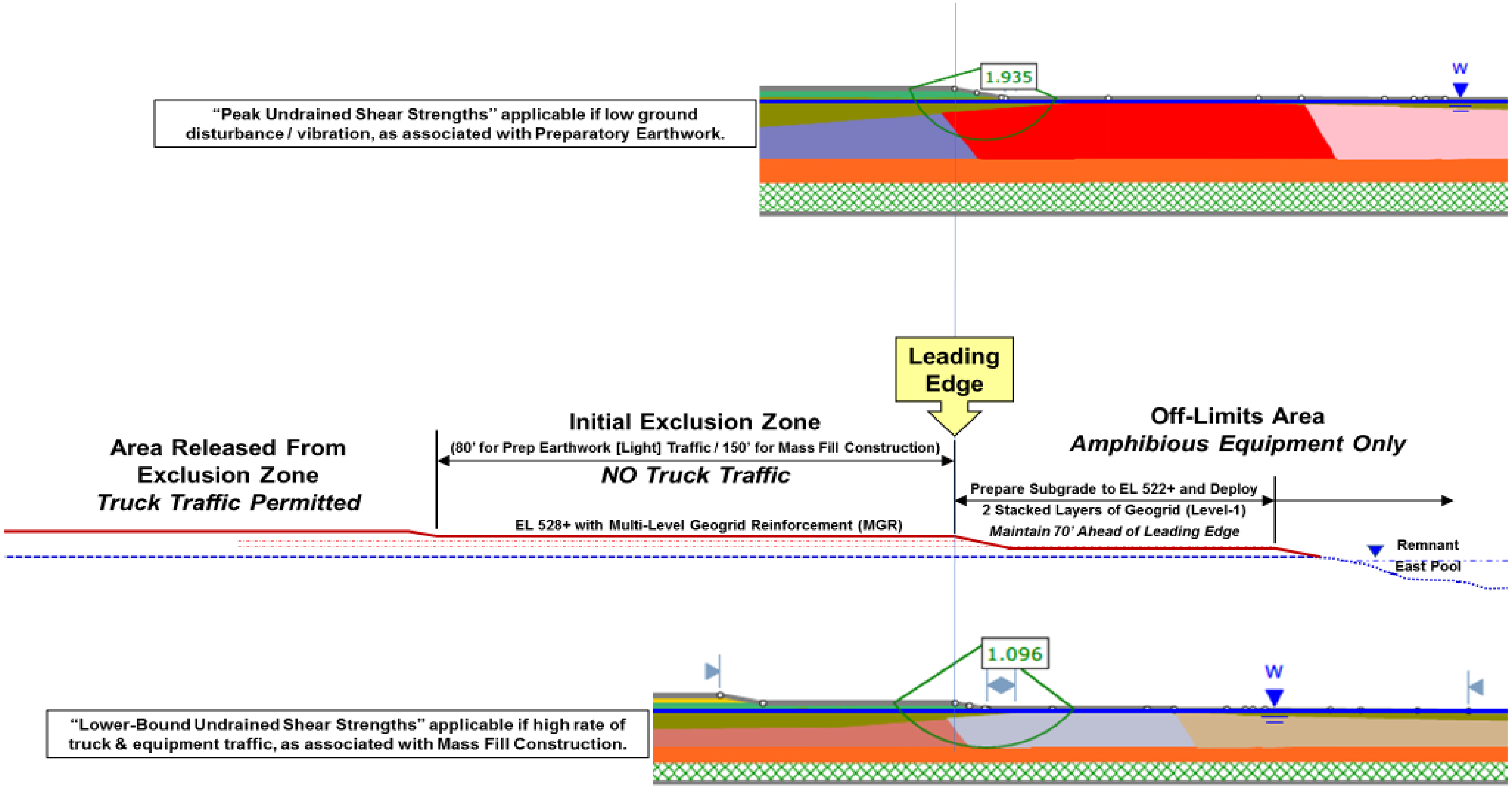
4. Perform subsurface working dewatering where necessary.
5. Enhance stabilized base to support planned rate of construction activity.

Subsurface Dewatering – Well Point System

Geogrid Reinforcement to Support Mass Fill Operations

Preparatory Activities for Mass Fill of CCR Impoundments

6. Stage & regulate earthwork construction and restrict fill surcharge differentials.

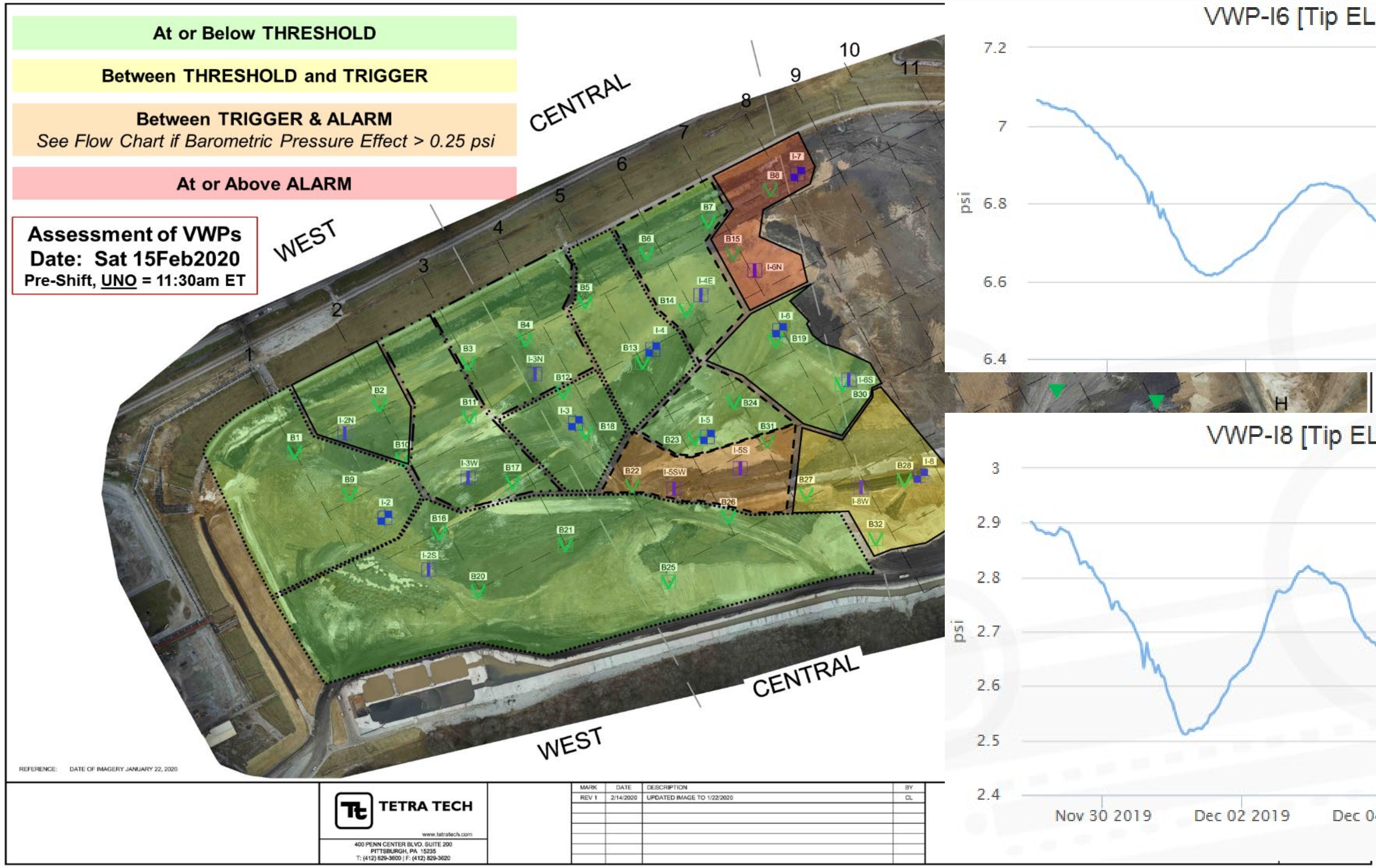


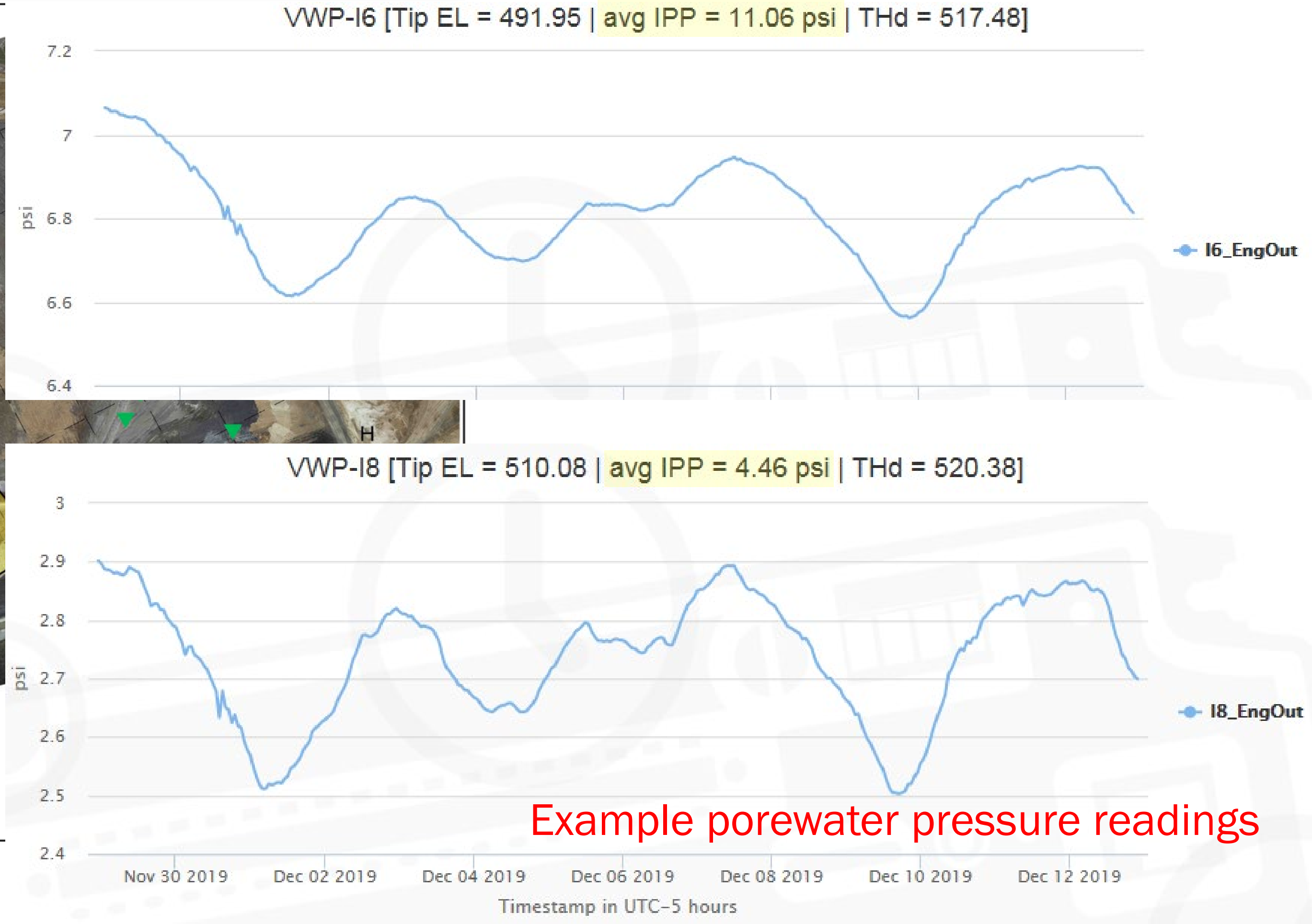
Work Zones established during filling operations to restrict access based upon subsurface conditions.
Field conditions monitored and adapted to actual conditions based upon evaluations with Tetra Tech Geotechnical Engineering.

Preparatory Activities for Mass Fill of CCR Impoundments

7. Monitor porewater pressures and ground performance.

Work activities adjusted, if necessary, based upon readings and evaluation against established Trigger and Alarm levels.





Example porewater pressure readings

Preparatory Activities for Mass Fill of CCR Impoundments

8. Implement Passive or Active Dewatering as Necessary

Methods may include:

- Basin Unwatering
- Rim Ditching
- Deep Well Dewatering
- Well Point Dewatering
- Material Stabilization

Well Point Dewatering

Finger roads and rim ditching for mass excavation of CCR materials

CCR impoundment investigations to support Well Point Dewatering Design and Ground Control (Fill Placement) Planning

Process in Action – Example Project Implementation
Ash Treatment Basin 2 (ATB 2)
Ash Treatment Basin 1 (ATB 1)

Ash Treatment Basin 2 (ATB 2) - 2016 Conditions

Levelizing – Hydraulic Dredging

- Dredge the low areas of the basin full and dewater

Hydraulic Dredges

Amphibious Excavator

Dewatering after Dredging to Levelize Basin

- Remove Stop Logs and Slowly Drain

Develop Channel to Support Dewatering

- Excavated with Amphibious Excavator

Stage Material and Plan for Mass Fill Operations

- Stage Daily Plant Production CCR's around Perimeters and Continue Dewatering

Mass Fill Operations

Continuous involvement of engineers to monitor work progression and update Ground Control Plan/Mass Fill Plan as site conditions change

- Advance Leading Edge in Small Increments (L < or = w/2)
- Leave Remnant Berm at Leading Edge
- Space & Alternate Dozers Pushing Through and Tramming Out of the EZ
- Be Alert to Visible Distress

Mass Fill Operations

Adaptive operations to monitor fill areas and adjust placement sequencing as necessary

- Avoid Areas Warranting a "Rest" Period

September 15th, 2020

June 22, 2021

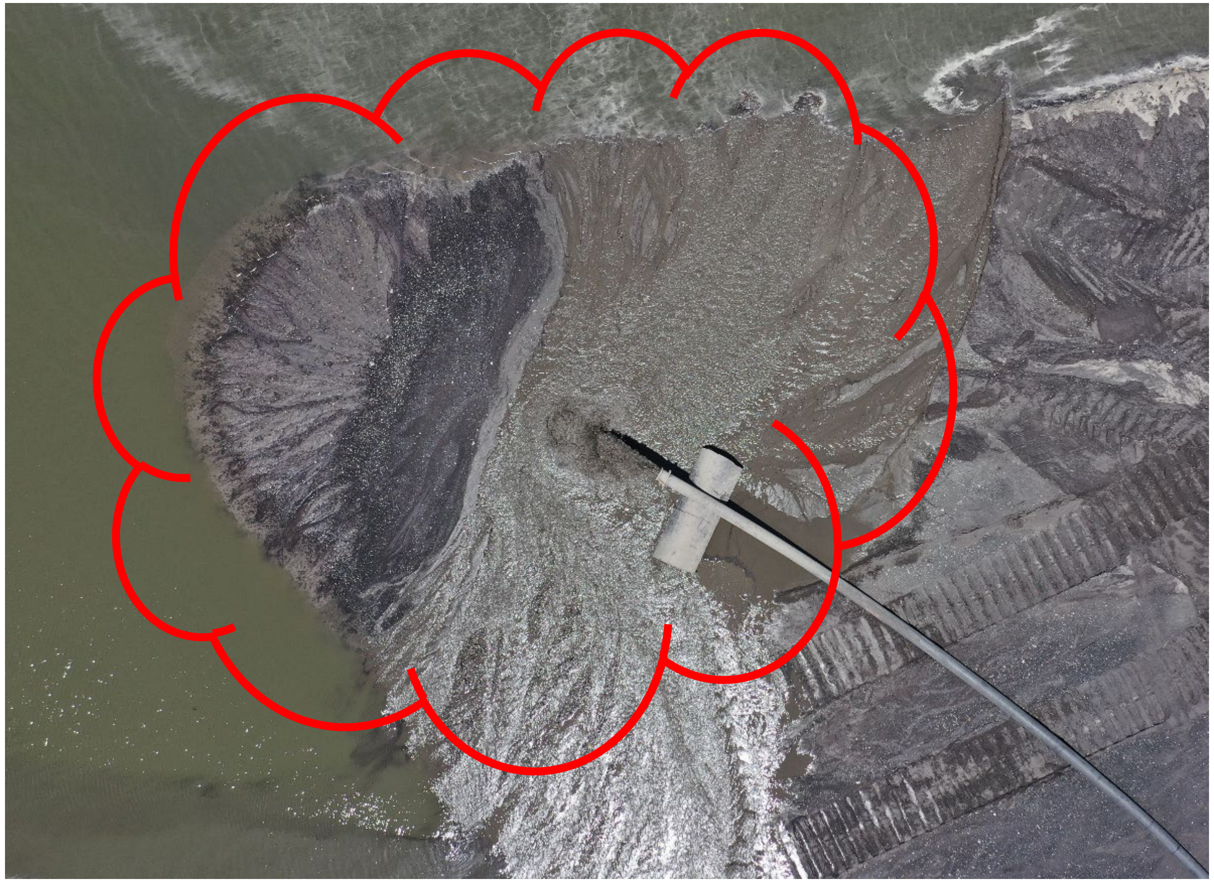
August 18, 2021

January 4, 2022

May 5, 2022

Ash Treatment Basin 1 (ATB 1) - 2016 Conditions

Dredge-Filling to Displace Pool, and Preparation of Working Subgrade with Amphibious Excavators



Geogrid Cover Fill with Amphibious Excavators & LGP Dozers

Geogrid Installation Over Prepared "Very Soft" Subgrade

Geosynthetic Cap System

ATB 1 – January 4, 2022

Continuous Process throughout Impoundment Fill (or Excavation) Operations

Engineering During Construction

- Mass Fill (or Excavation) Operations within ash basins/impoundments warrant continued engineering involvement throughout the construction process
- Integrated construction and engineering to provide real-time support of onsite construction operations and ensure site Plans and Operations are updated as project conditions change

Phased Excavation and Dewatering While Monitoring VWP's

Phased Excavation and Dewatering While Monitoring VWP's

Phased Excavation and Dewatering While Monitoring VWP's

Thank You!

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