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TVA Kingston Peninsula Disposal Site
Project Challenges Developing Over Karst Formations

Authors: **Mehmet Iscimen, P.E.**; Sarah B. Fick; Cuneyt Gokmen, P.E.; Neil Davies, P.E.; Rachel Burnette-Combs; Scott Turnbow

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TVA

2015 WORLD OF COAL ASH

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KINGSTON FOSSIL PLANT (KIF)
Site Location

PENINSULA SITE
Gypsum Disposal Area (GDA) Phase I

GYPSUM DISPOSAL AREA
Dec. 15, 2010 Drop-out

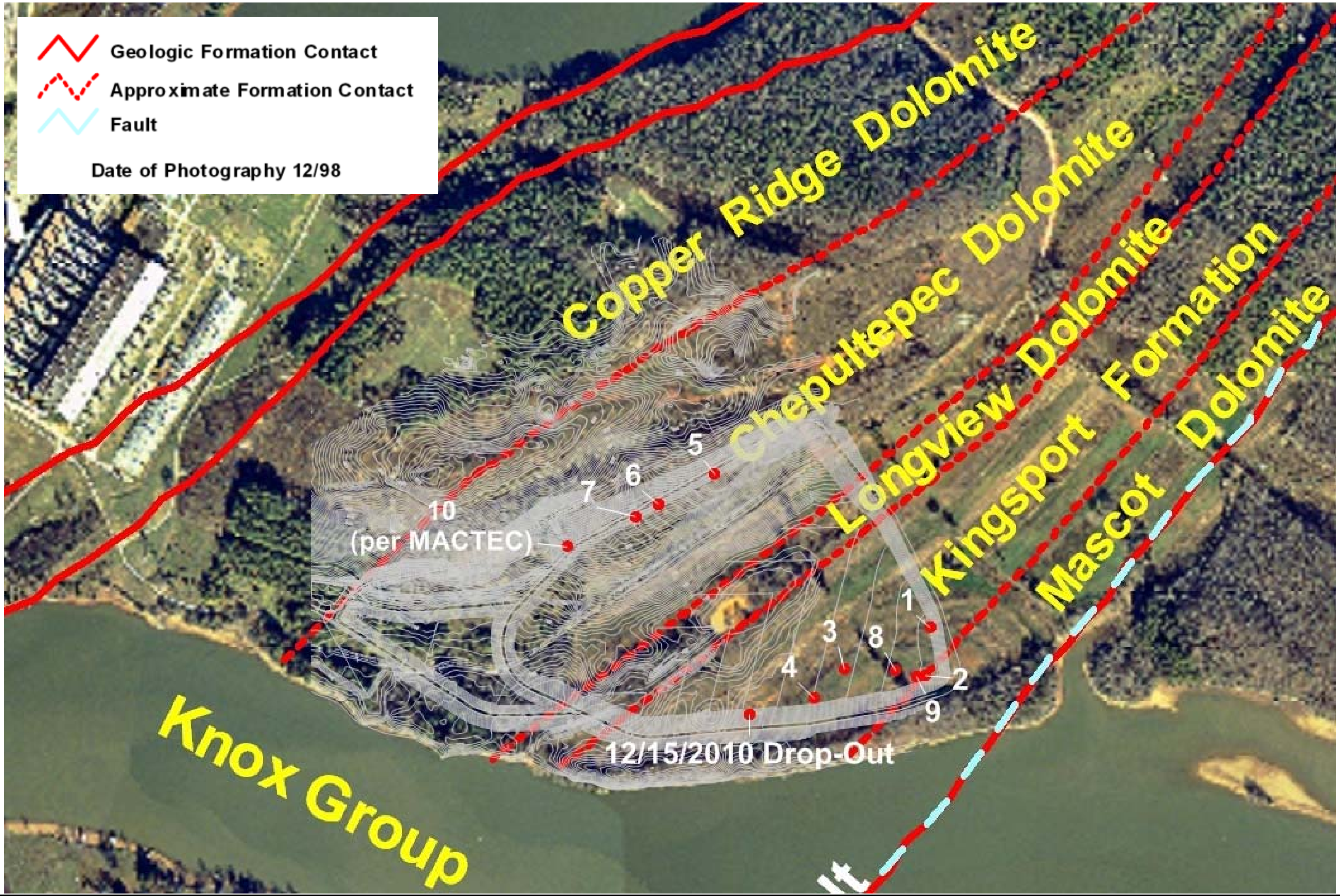
AGENDA

- Project Challenges
- Site Investigation
  - Site Geology
  - Root-Cause Analysis
- Drop-out Investigation & Mitigation
  - Over-excavation and identification
  - Repair effort
- Liner and Drainage Systems
  - Redesigned improved system
  - Ongoing work and research

Project Challenges

- Plant's power generation schedule
  - In <1 year, (I) identify root cause of the subsidence, (ii) develop a corrective action plan, (iii) receive approval of multiple departments within TVA and TDEC, and (iv) implement the construction on a schedule that had no flexibility for delays, due to power demand and operational constraints.
- Complex site geology
  - mainly alluvial residuum soils overlying Knox Group bedrock formation susceptible to the development of karst features and drop-outs.
- Plant operational demands
  - wet to dry transition of CCRs at KIF
  - a dewatering facility for the gypsum was in construction => design and construct a hybrid disposal facility that would meet future dry disposal regulatory requirements, while still being able to operate as a wet disposal facility during the transition.
- Characteristics of CCRs (e.g., wet vs. dry processing, fly ash vs. gypsum, etc.)
  - Particle size compatibility with selected filter media, granular filter thickness, and construction practices => effectiveness of filter and drainage systems / partial or complete clogging.

Geologic Features



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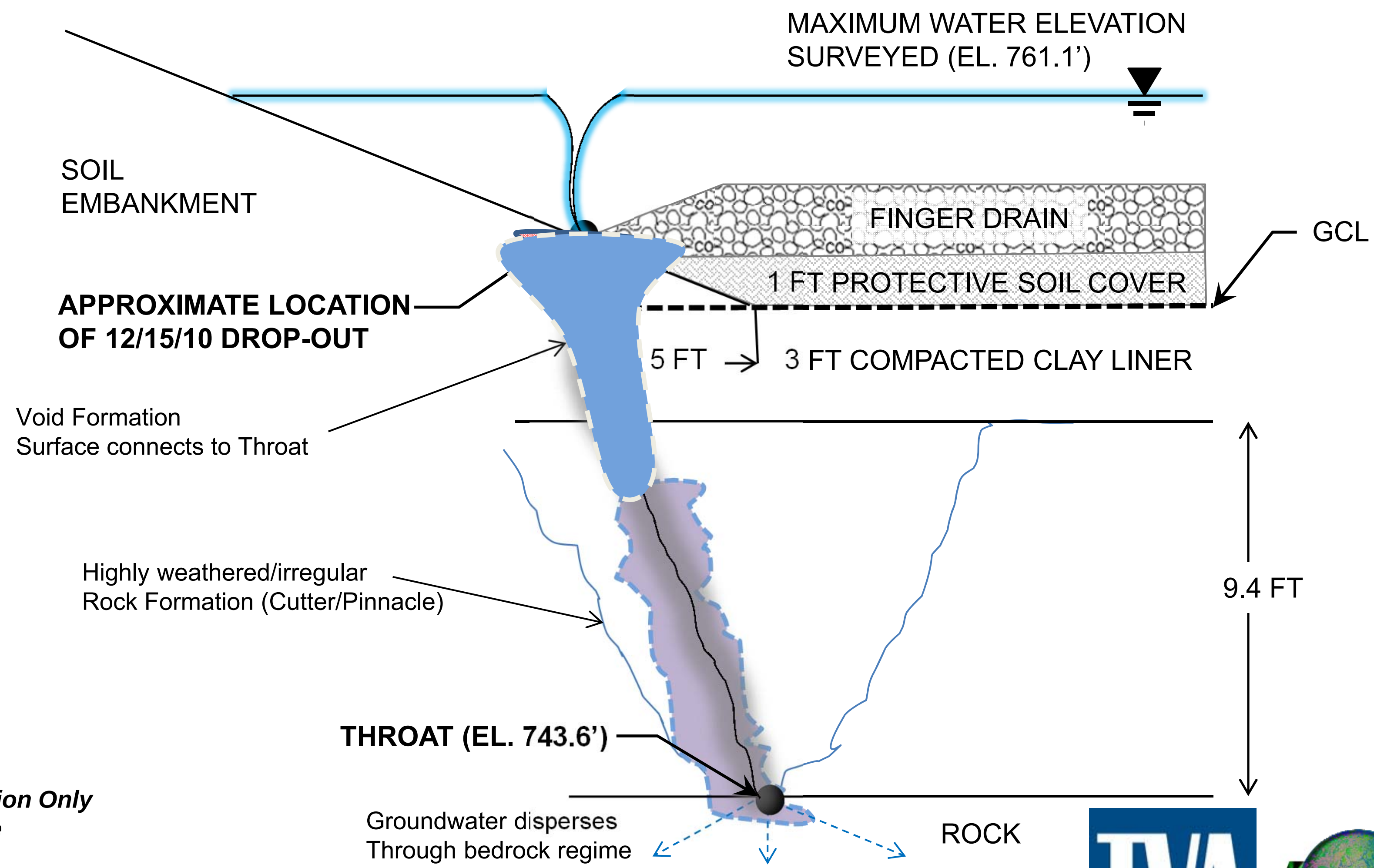
Dec. 15, 2010 Drop-out Suspected Formation Mechanism



For illustration Only
Not to Scale

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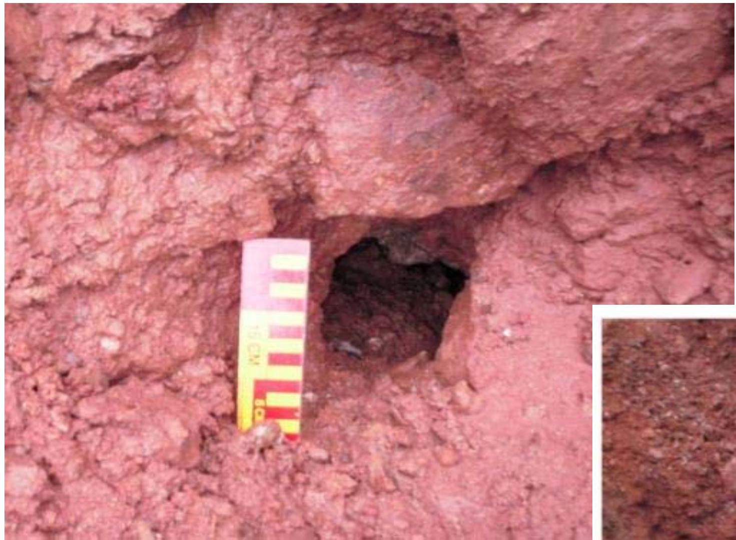
Previous and Post Drop-out Site Investigations

- **Previous Studies**
  - (1) 15 exploratory borings and 4 seismic refraction surveys by Singleton Materials Engineering Lab (1988); (2) 6 soil borings and 2 bedrock corings by Mactec (2003); (3) 55 geoprobe borings by TVA (2003 and 2005); (4) 26 soil borings, 14 bedrock corings, 13 monitoring wells, and 10 cone penetration tests by Mactec (2005); (5) 26 soil borings and 3 monitoring wells by Mactec (2006).
- **Post Drop-out Studies**
  - Geotechnical Exploration of the Drop-out Area
    - 14 piezocone (CPTu) and 7 seismic cone penetration test (SCPTu) to depths ranging from about 4.4 feet to about 43.8 feet.
    - Shelby tubes
    - Five temporary piezometers were set in five of the CPT sounding holes.
  - Dye-Trace Study
  - Additional Environmental Sampling and Groundwater Level Data Collection
  - Investigation/Repair of the Drop-out
  - Overall Landfill Inspection
  - Overall Subsurface Investigation and Repair Program
    - Over-excavation and Drop-out Mitigation

Dec. 15, 2010 Drop-out

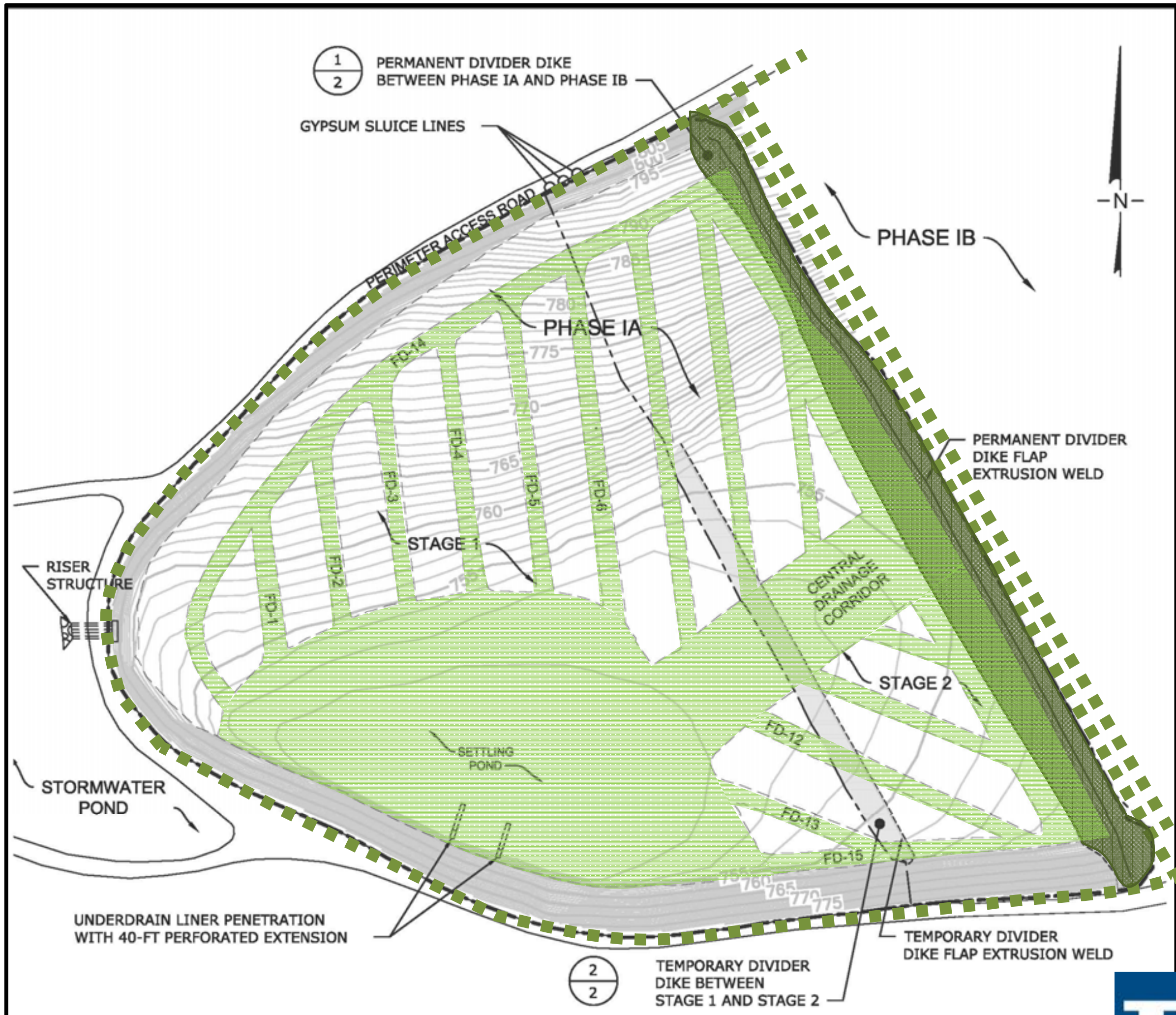


- Incremental excavation to soil/bedrock interface
- Nominal dimension of 3.3 inches

- Dye trace injection piping installed
- Dye injection completed Feb 7, 2011

DROP-OUT INVESTIGATION & MITIGATION
Over-excavation

BACKGROUND
Scope of Work – Phase IA



Remedial Options Considered

- Conventional drilling
- Geophysical methods
- Dynamic compaction
- Over-excavation & proof-rolling

Combined with a robust:

- Liner system
- Drainage system

Highlights of Over-excavation and Proof-Rolling

- Over-excavate seven (7) feet or more below the liner level;
- Proof-roll the bottom of over-excavation with heavy equipment; and
- Back-fill with compacted soil to reach liner grades and establish a "**bridging layer**".

Note that:

- Seventy percent - over-excavation (i.e., in those areas where liner grades are below the predevelopment grades and/or the distance between the liner grades and the predevelopment grades are less than seven (7) feet). In these areas, overburden soil was over-excavated generally 7 feet or more below liner grade, excavation bottom was proof-rolled, and then excavation area was backfilled with compacted soil to reach liner grades; and
- Thirty percent - filling and compaction efforts to establish liner grades (i.e., in those areas where liner grades are 7-ft or more above the predevelopment grades—areas outside the over-excavation zones—received seven (7) feet or more compacted fill material to establish the liner grades and thus they had already been proof-rolled during filling and compaction efforts.

Mine Subsidence Model

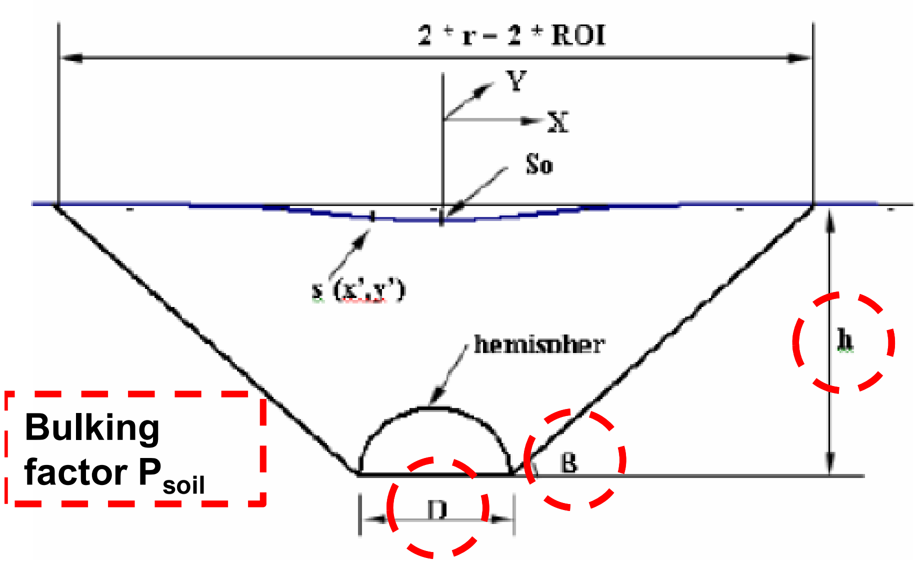


Figure. Mine Subsidence Schematic Model

Void Propagation Spreadsheet

Shallow Void; D=6 ft

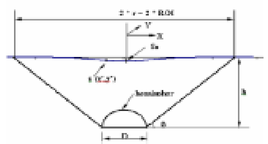
H=	7	ft	(Depth to Top of Void - Bridging Layer Thickness)			
β=	55	deg	(Draw Angle)	β'=	53.58	deg
Psoil=	0.67		(Ground Loss Factor)	D' =	5.25	ft
D=	6	ft	(Diameter of Hemispherical Void)			
d=	3	ft	(Height of the Void - Radius of Hemispherical Void)			
h=	10	ft	(Depth to Bottom of Hemispherical Void)			

Psoil = Ratio of volume of settlement trough to the original void (e.g., Psoil=0.5 for overbuden soil bulks by a factor of 2 to fill void, Psoil=0.67 for overburden soil bulks by a factor of 1.5 to fill void, Psoil=0.80 for overburden soil bulks by a factor of 1.25 to fill void)

s = settlement at the surface at centerline (ft)

x = Horizontal distance at liner from the centerline along x-axis (ft)

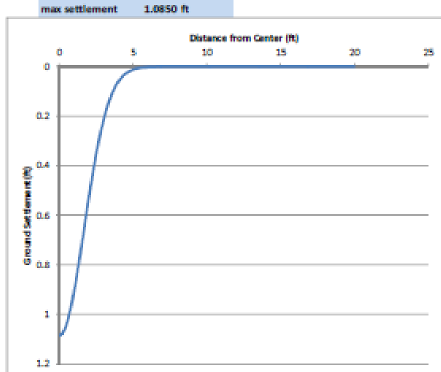
y = Horizontal distance at liner from the centerline along y-axis (ft)

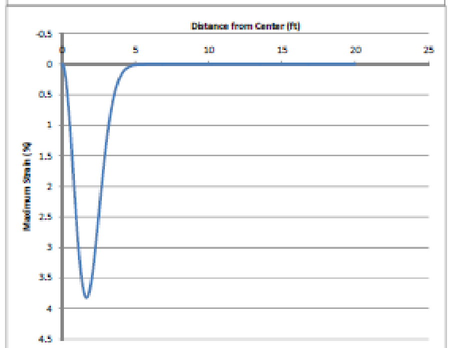


x [ft]	y [ft]	s [ft]	Strain at Liner (%)
0	0	1.084961	
0.005	0.005	1.084956	2.38175E-05
0.01	0.01	1.084941	0.000214353
0.015	0.015	1.084917	0.000595404
0.02	0.02	1.084883	0.001166925
0.025	0.025	1.084839	0.001928852
0.03	0.03	1.084785	0.002881098
0.035	0.035	1.084722	0.004023556
0.04	0.04	1.084649	0.005356095
0.045	0.045	1.084566	0.006878564
0.05	0.05	1.084473	0.008590789
0.055	0.055	1.08437	0.010492578
0.06	0.06	1.084258	0.012583712
0.065	0.065	1.084136	0.014863956
0.07	0.07	1.084005	0.017333049
0.075	0.075	1.083863	0.019990712
0.08	0.08	1.083712	0.022836643
0.085	0.085	1.083551	0.025870519
0.09	0.09	1.083381	0.029091996
0.095	0.095	1.0832	0.032500708
0.1	0.1	1.08301	0.036096269
0.105	0.105	1.082811	0.039878271
0.11	0.11	1.082601	0.043846286
0.115	0.115	1.082382	0.047999863
0.12	0.12	1.082153	0.052338533
0.125	0.125	1.081915	0.056861803
0.13	0.13	1.081667	0.061569163
0.135	0.135	1.081409	0.066460079
0.14	0.14	1.081141	0.071533998
0.145	0.145	1.080864	0.076790346
0.15	0.15	1.080577	0.08222853
0.155	0.155	1.080281	0.087847934
0.16	0.16	1.079975	0.093647924
0.165	0.165	1.079659	0.099627846
0.17	0.17	1.079334	0.105787024
0.175	0.175	1.078999	0.112124763
0.18	0.18	1.078654	0.118640351
0.185	0.185	1.0783	0.125333051
0.19	0.19	1.077936	0.132202111
0.195	0.195	1.077563	0.139246758
0.2	0.2	1.07718	0.146466198
0.205	0.205	1.076788	0.153859621
0.21	0.21	1.076386	0.161426195
0.215	0.215	1.075974	0.16916507
0.22	0.22	1.075554	0.177075378
0.225	0.225	1.075123	0.185156232
0.23	0.23	1.074683	0.193406726

DATA TRUNCATED FOR EASE OF PRESENTATION

max liner strain	3.823	%
max settlement	1.0850	ft

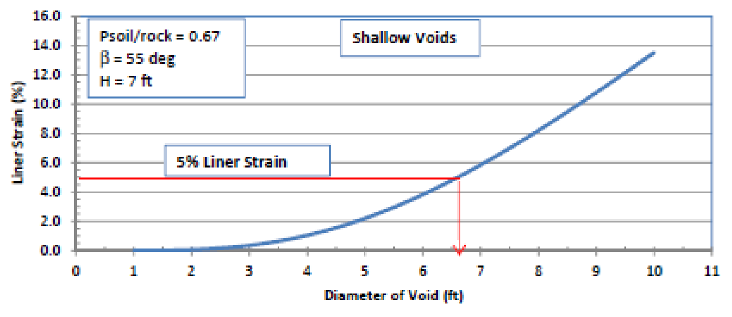


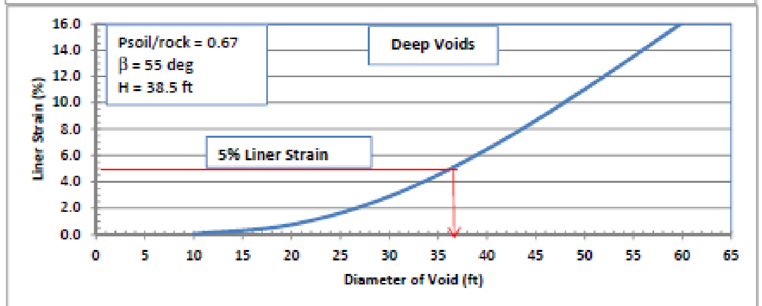


Mine Subsidence Model - II

Table. Maximum Strain vs Void Size

Shallow Voids			Deep Voids		
Psoil/rock = 0.67					
H (Bridging Layer Thickness) = 7 ft			H (Bridging Layer Thickness) = 38.5 ft		
Void Diameter [ft]	Maximum Settlement [ft]	Maximum Strain [%]	Void Diameter [ft]	Maximum Settlement [ft]	Maximum Strain [%]
1	0.0152	0.0023	10	0.3997	0.0421
2	0.0922	0.0646	20	2.0802	0.7387
3	0.2443	0.3553	30	4.9298	2.8822
4	0.4666	1.0406	40	8.6537	6.4628
5	0.7499	2.1989	50	13.0179	11.0212
6	1.0850	3.8227	60	17.8568	16.0765
7	1.4635	5.8505			
8	1.8788	8.1979			
9	2.3250	10.7779			
10	2.7975	13.5122			





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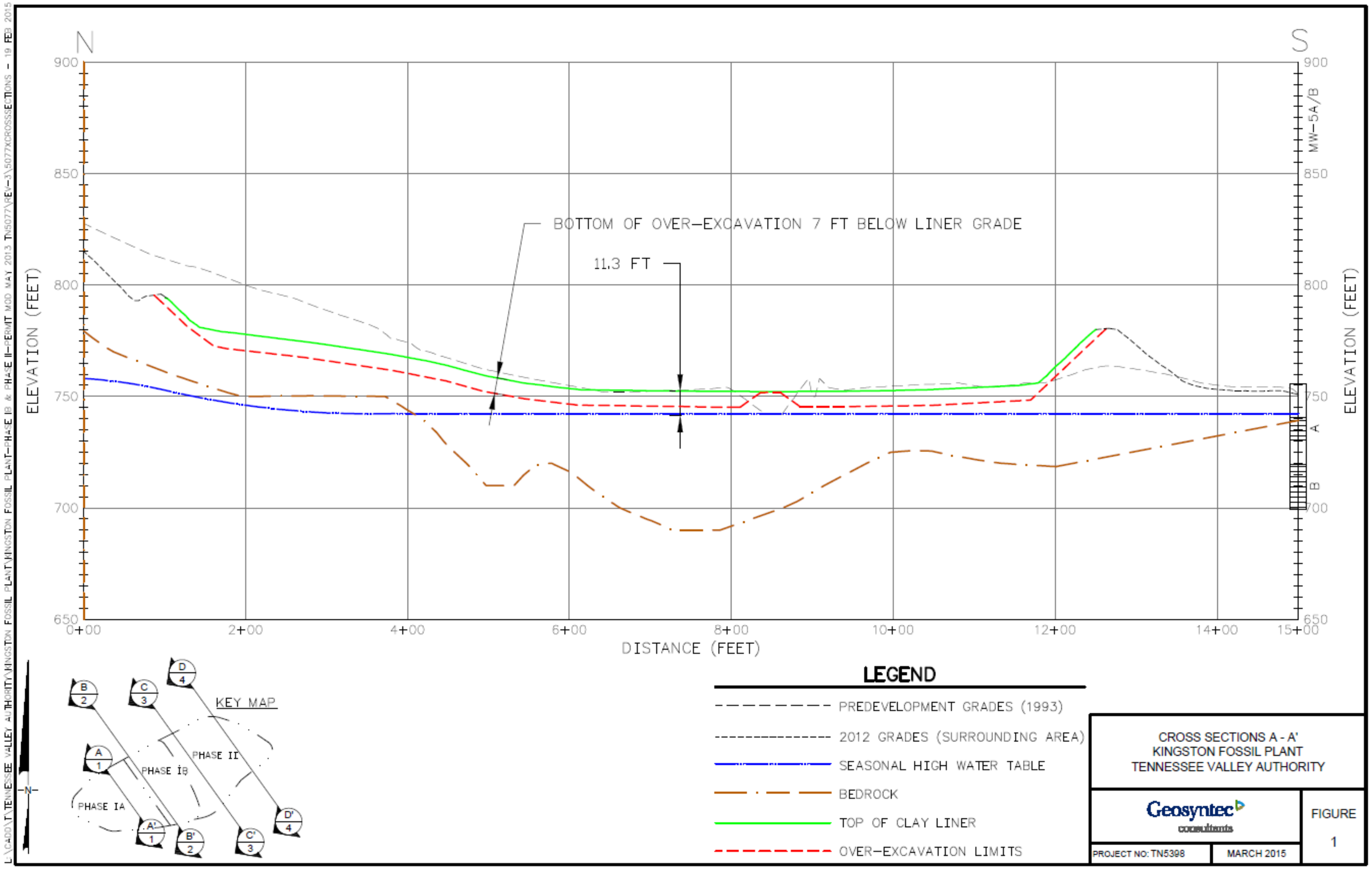
BACKGROUND
Phase IA Typical Cross-Section



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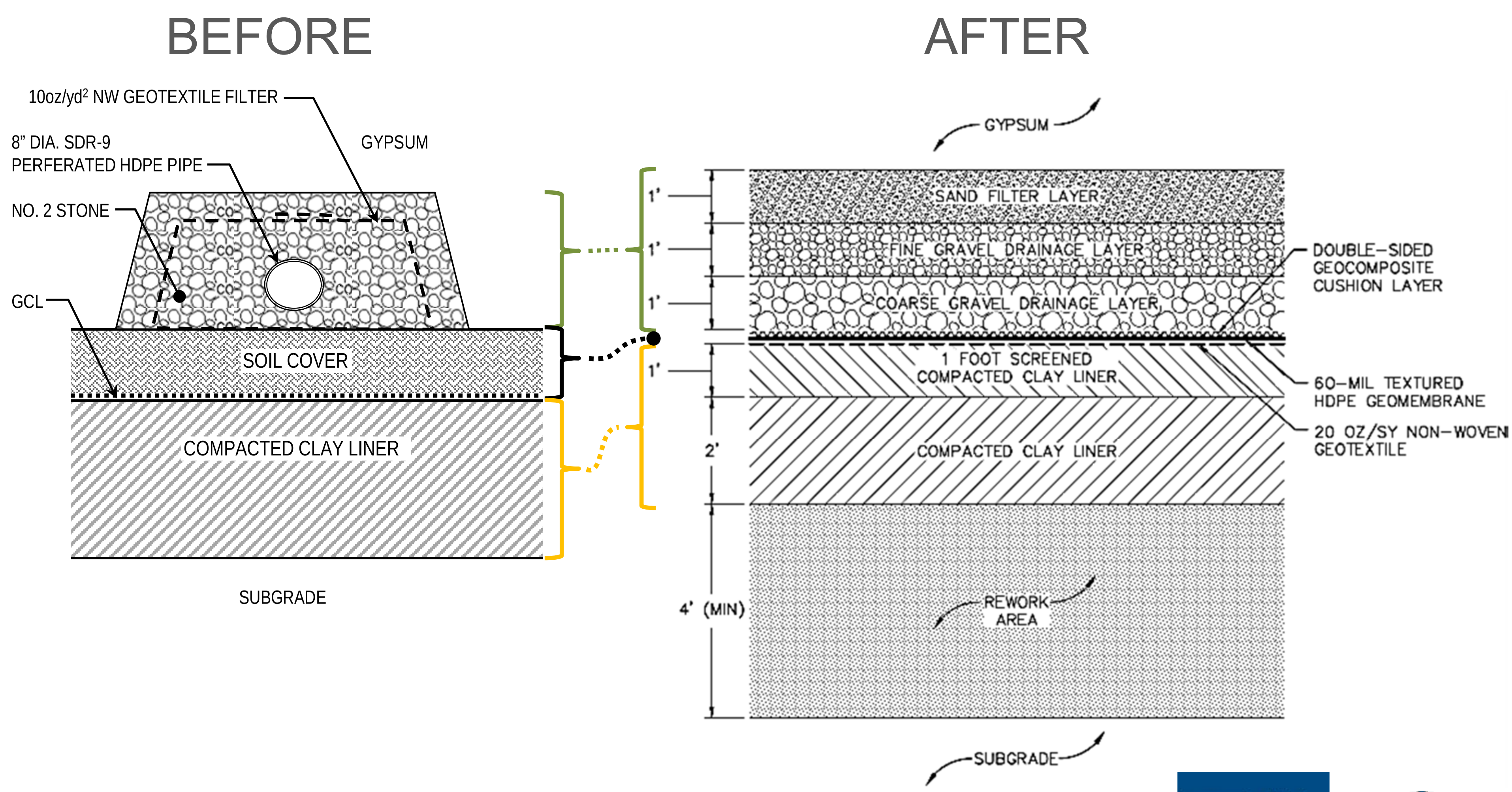
BACKGROUND
Scope of Work



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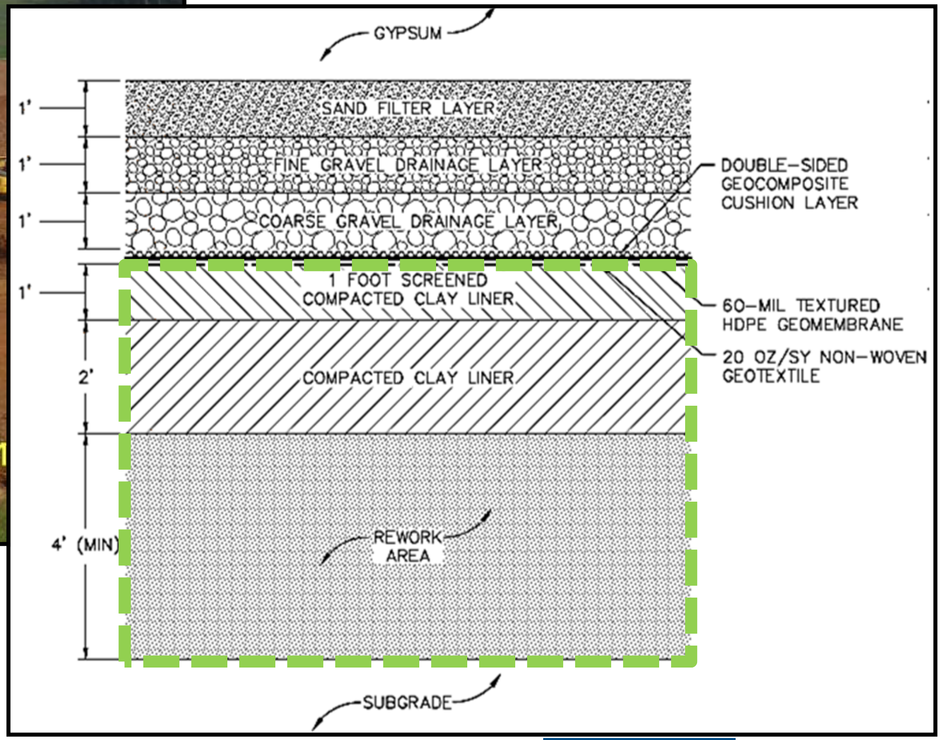
DROP-OUT INVESTIGATION & MITIGATION
Over-excavation



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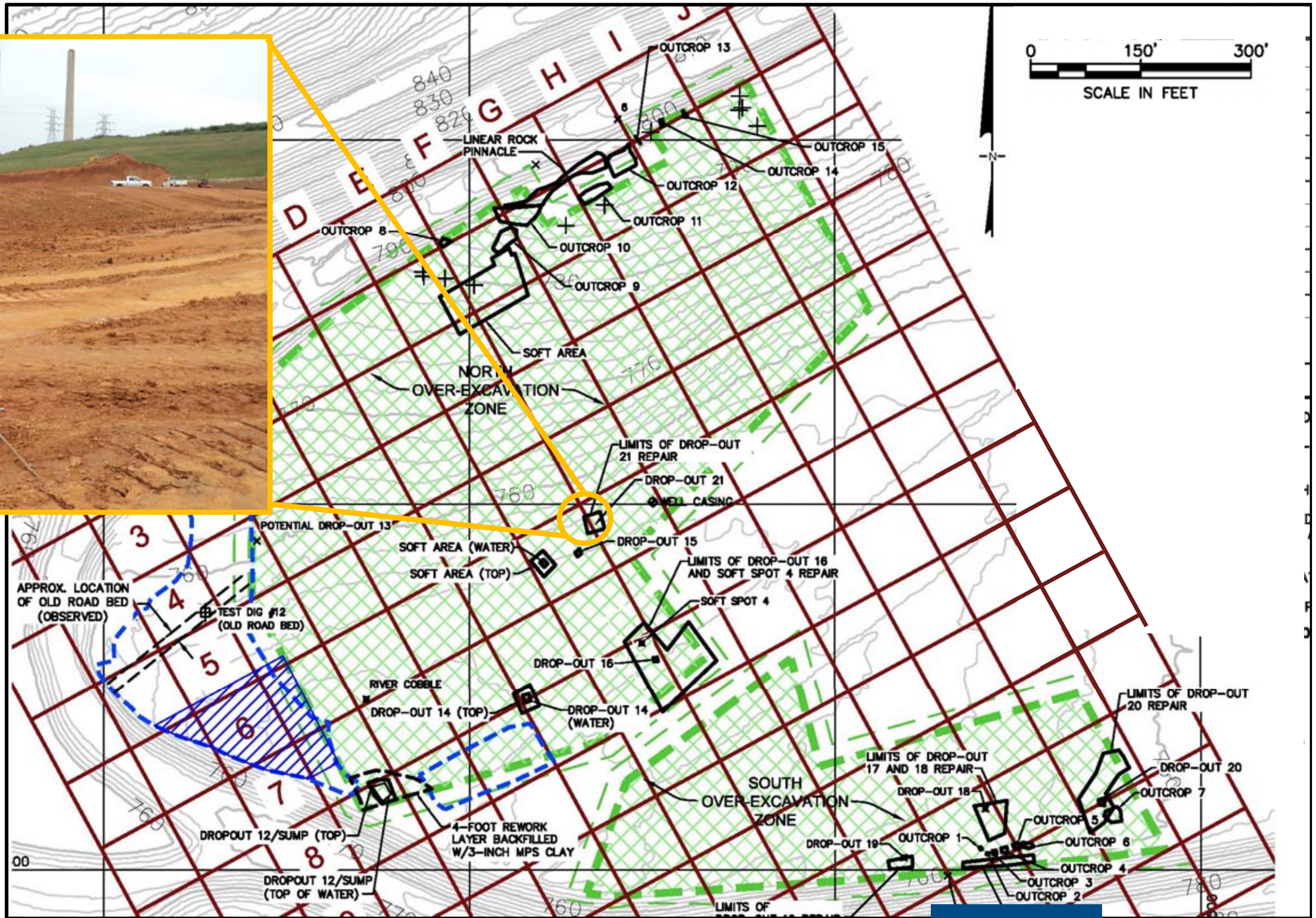
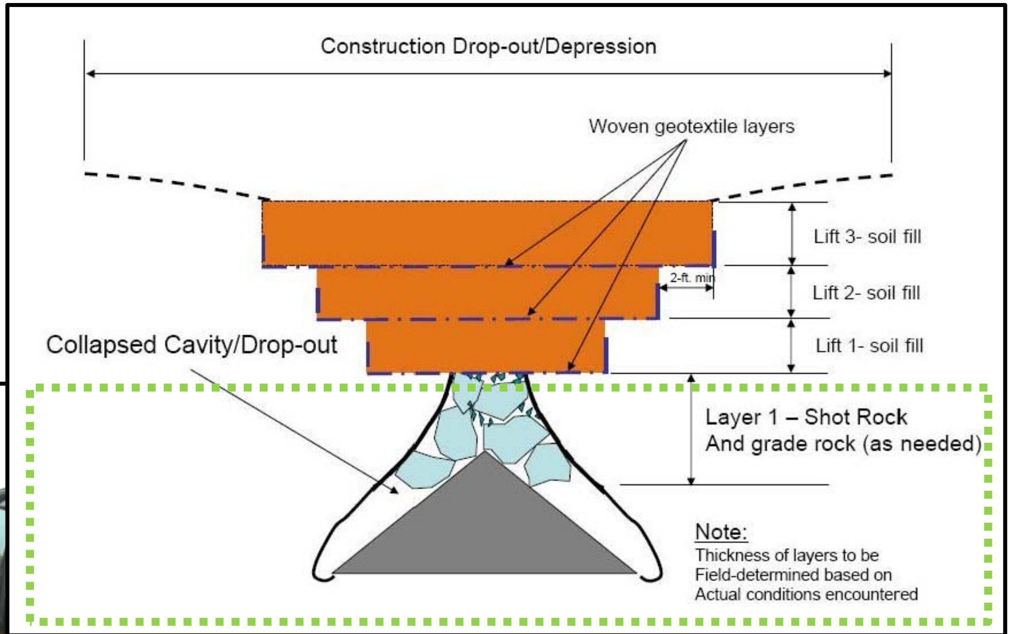
DROP-OUT INVESTIGATION & MITIGATION
Identification



DROP-OUT INVESTIGATION & MITIGATION
Investigation

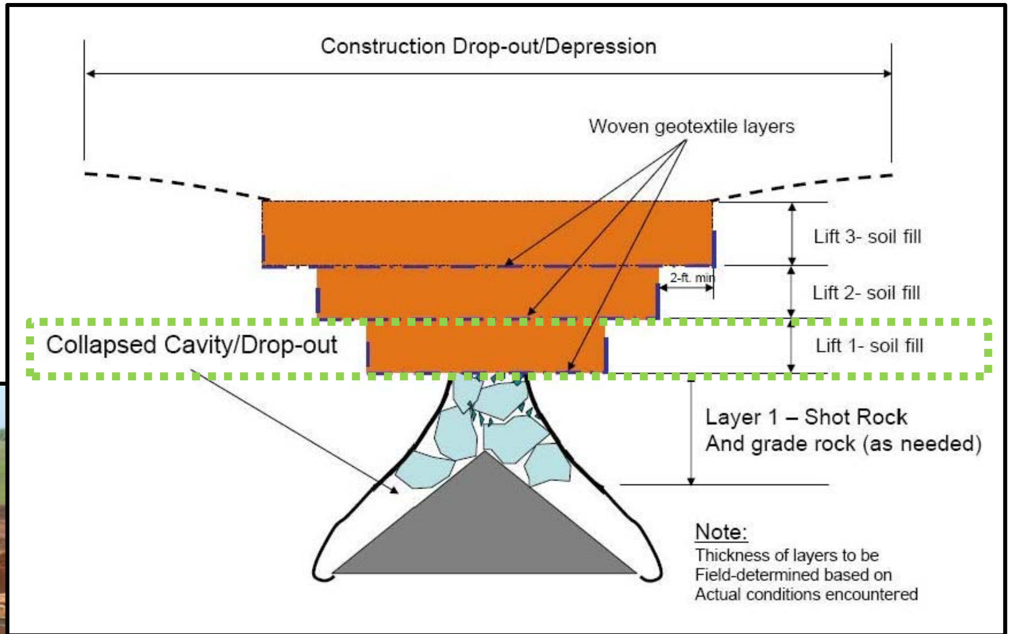
DROP-OUT INVESTIGATION & MITIGATION
Repair Effort



1// Shot Rock

as needed & graded with
No.4 stone (typ.)

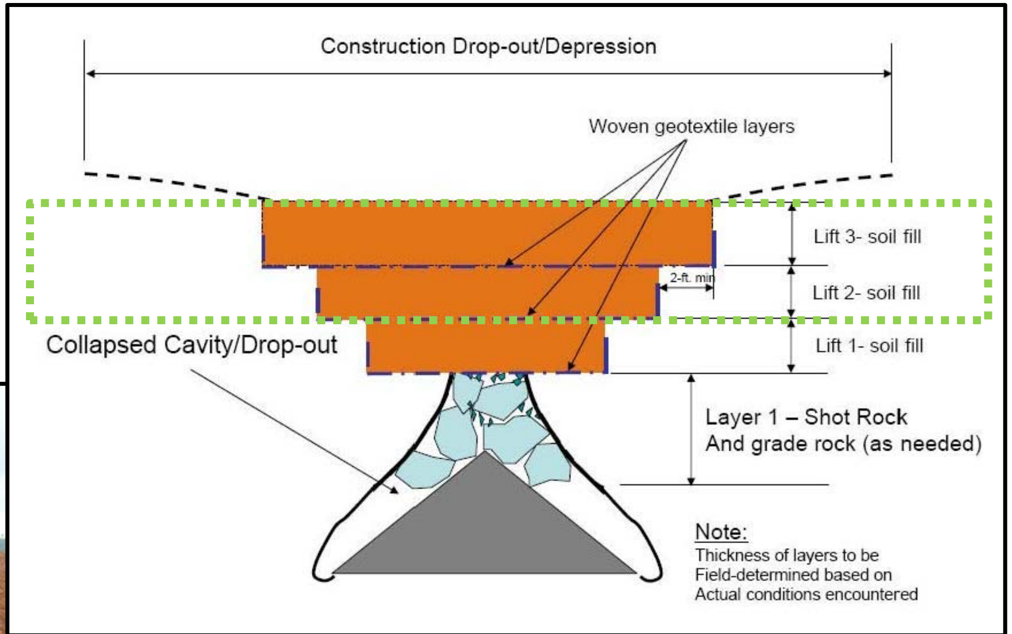
DROP-OUT INVESTIGATION & MITIGATION
Repair Effort



2// Geotextile (GT) & Soil Fill

18 in. loose soil lifts (typ.)

DROP-OUT INVESTIGATION & MITIGATION
Repair Effort

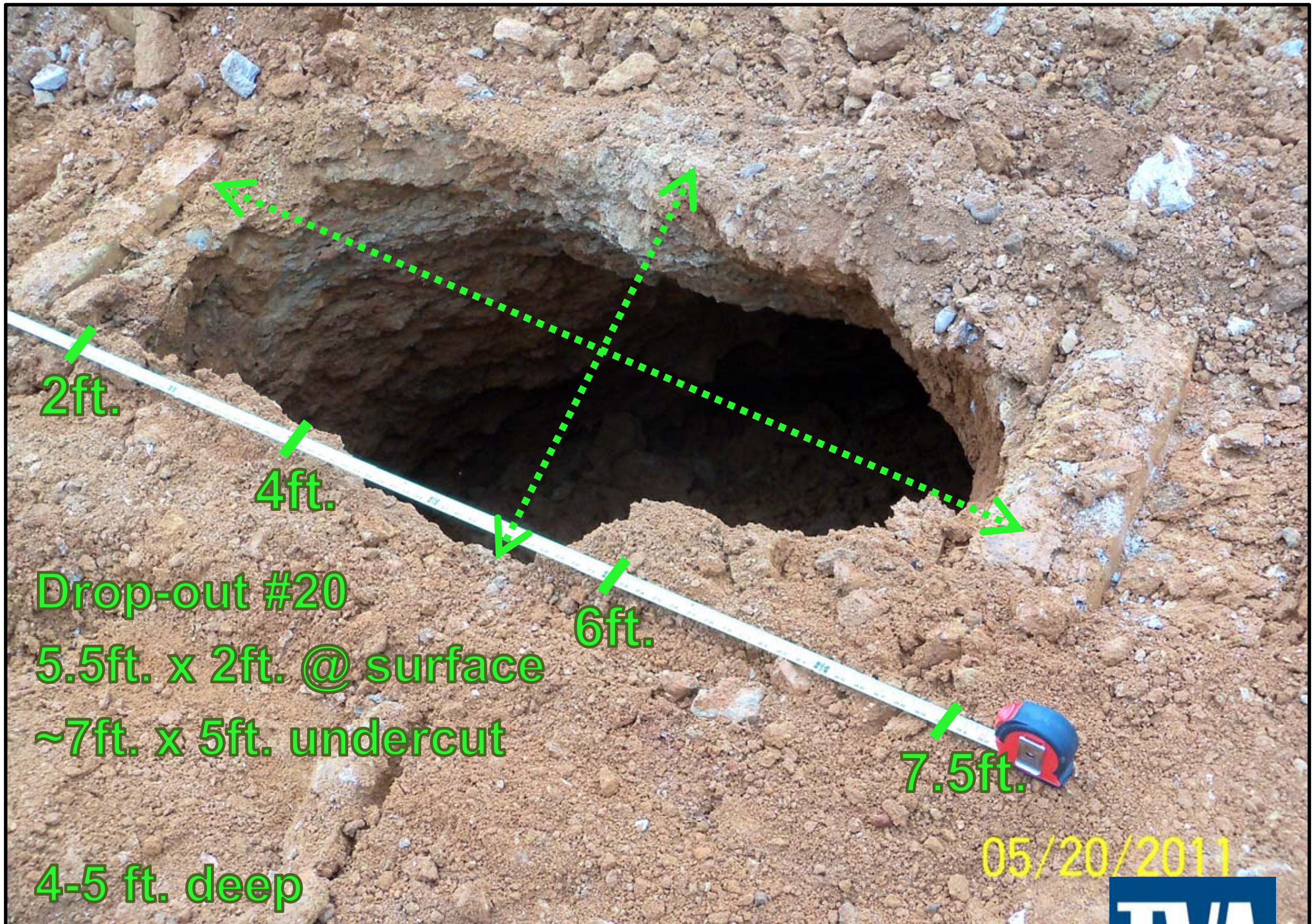


3// Alternating Lifts of Soil Fill & GT

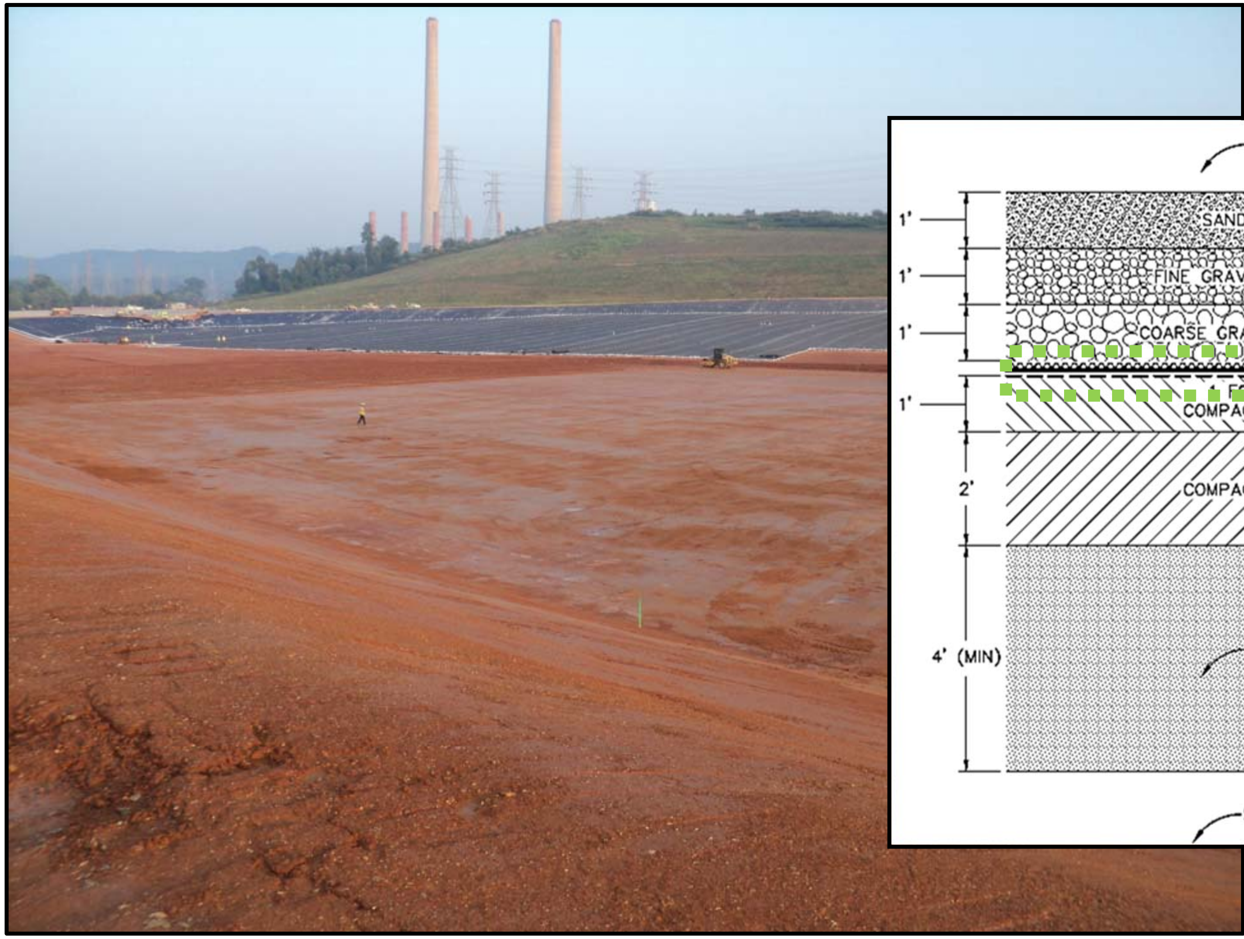
fill to base of excavated area

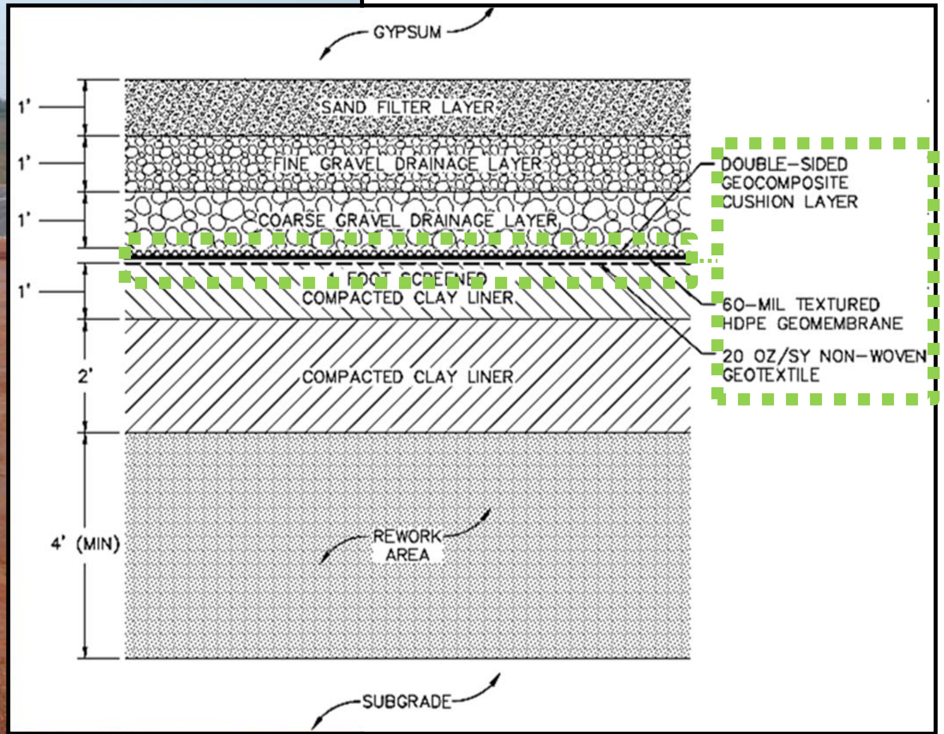
~3-5 lifts (typ)

DROP-OUT INVESTIGATION & MITIGATION
Special Drop-outs



LINER SYSTEM





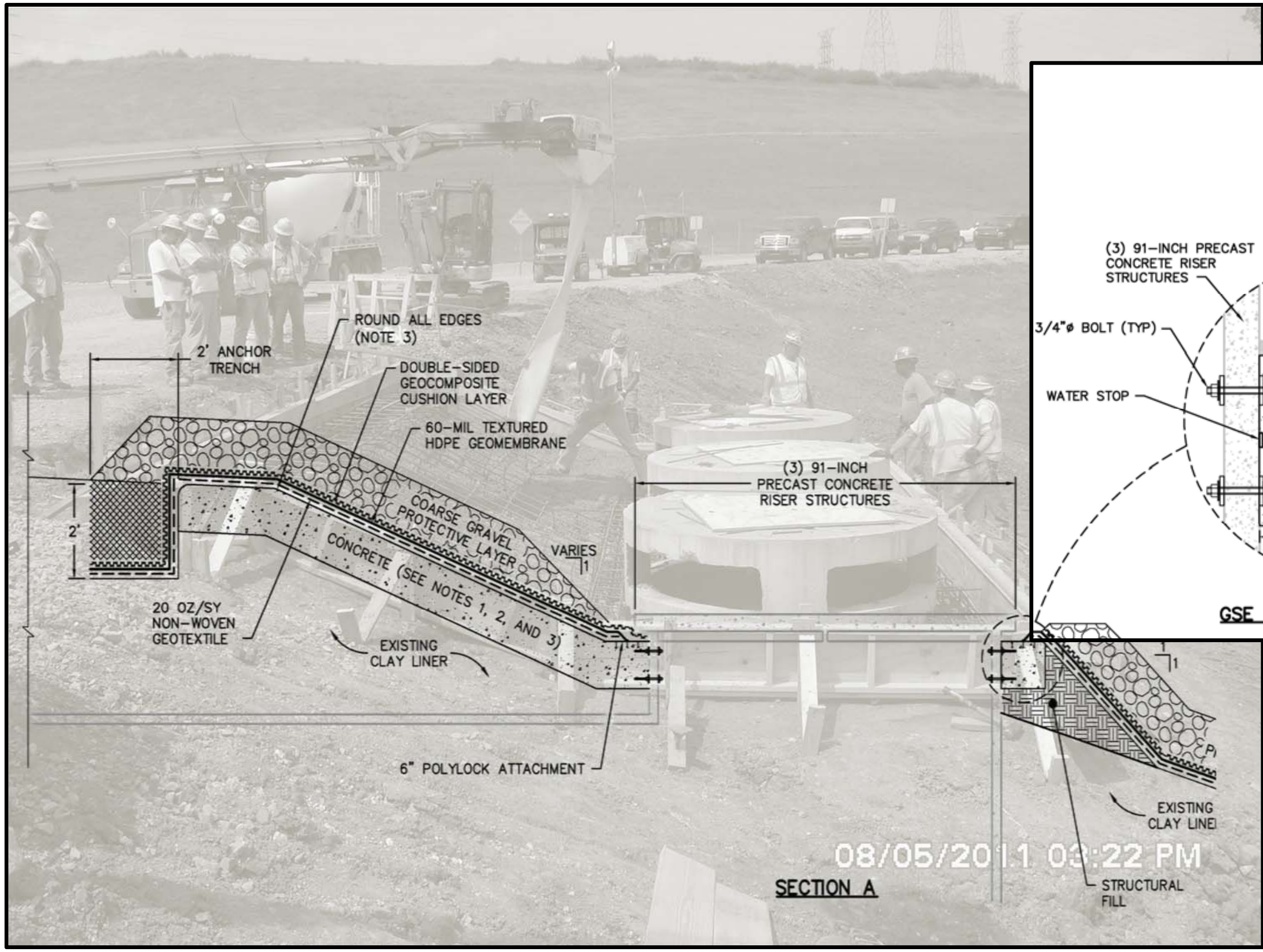
LINER SYSTEM
Concrete Risers Design Solution

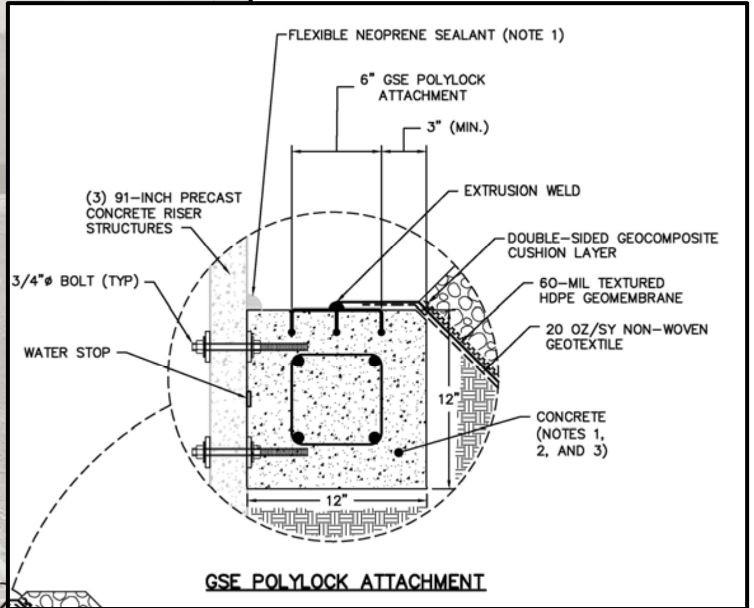
Before

PolyLock™

After

LINER SYSTEM
Concrete Risers Design Solution





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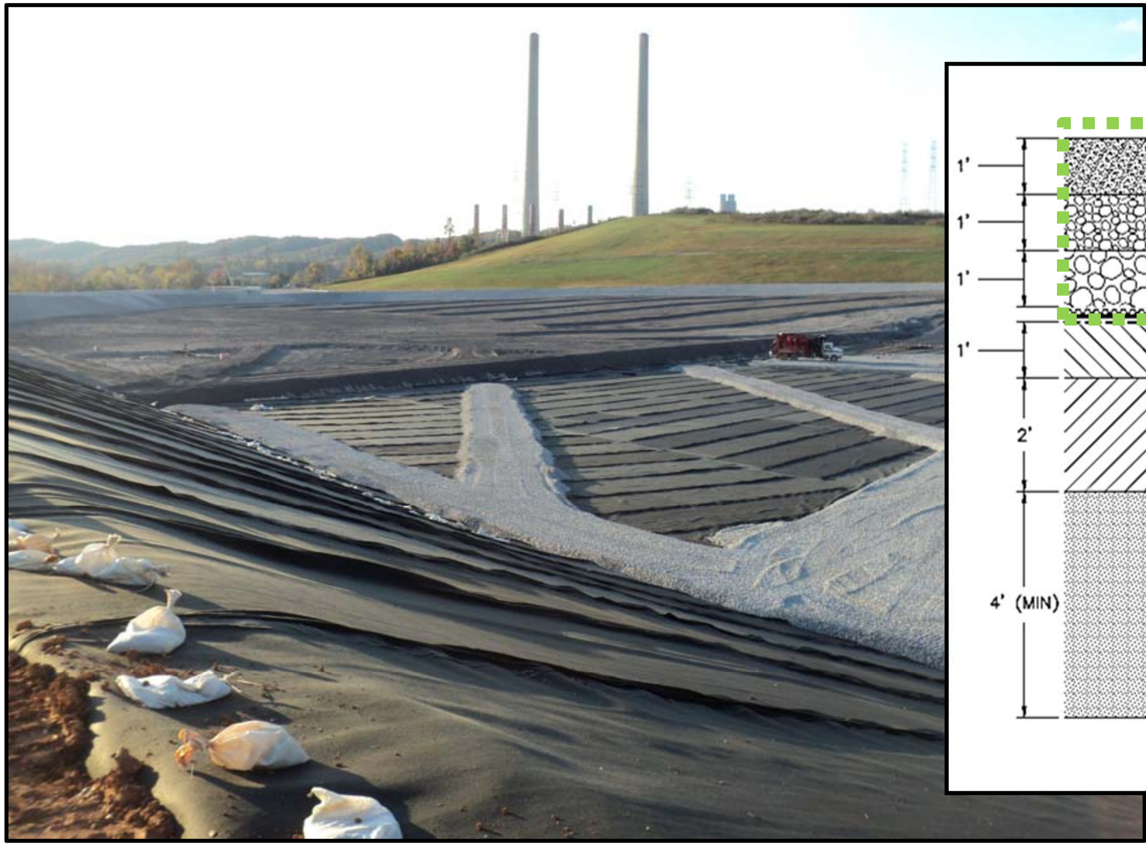
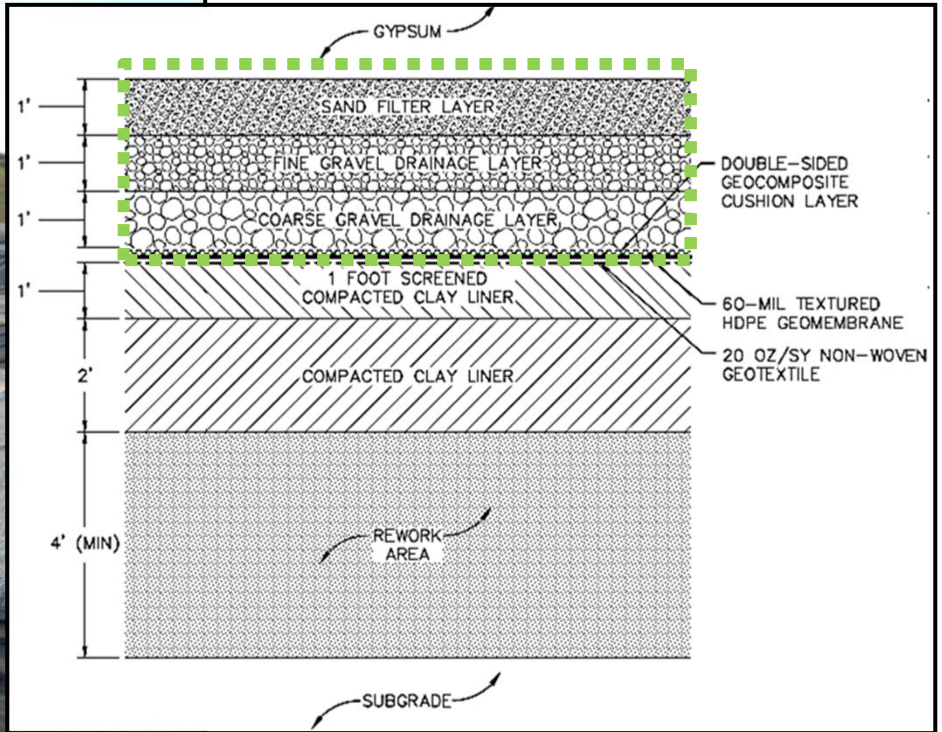
DRAINAGE SYSTEM
Designing for CCRs





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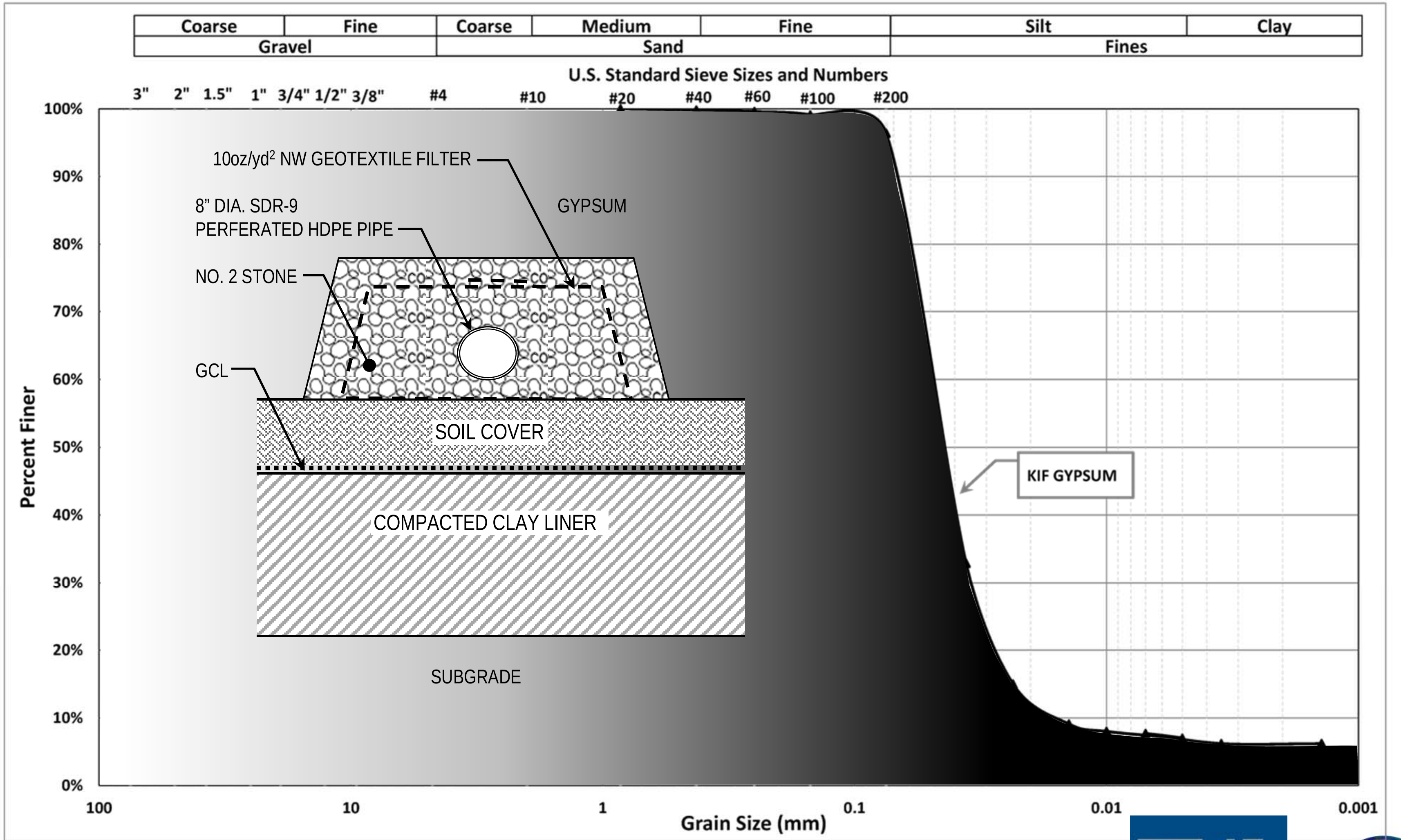
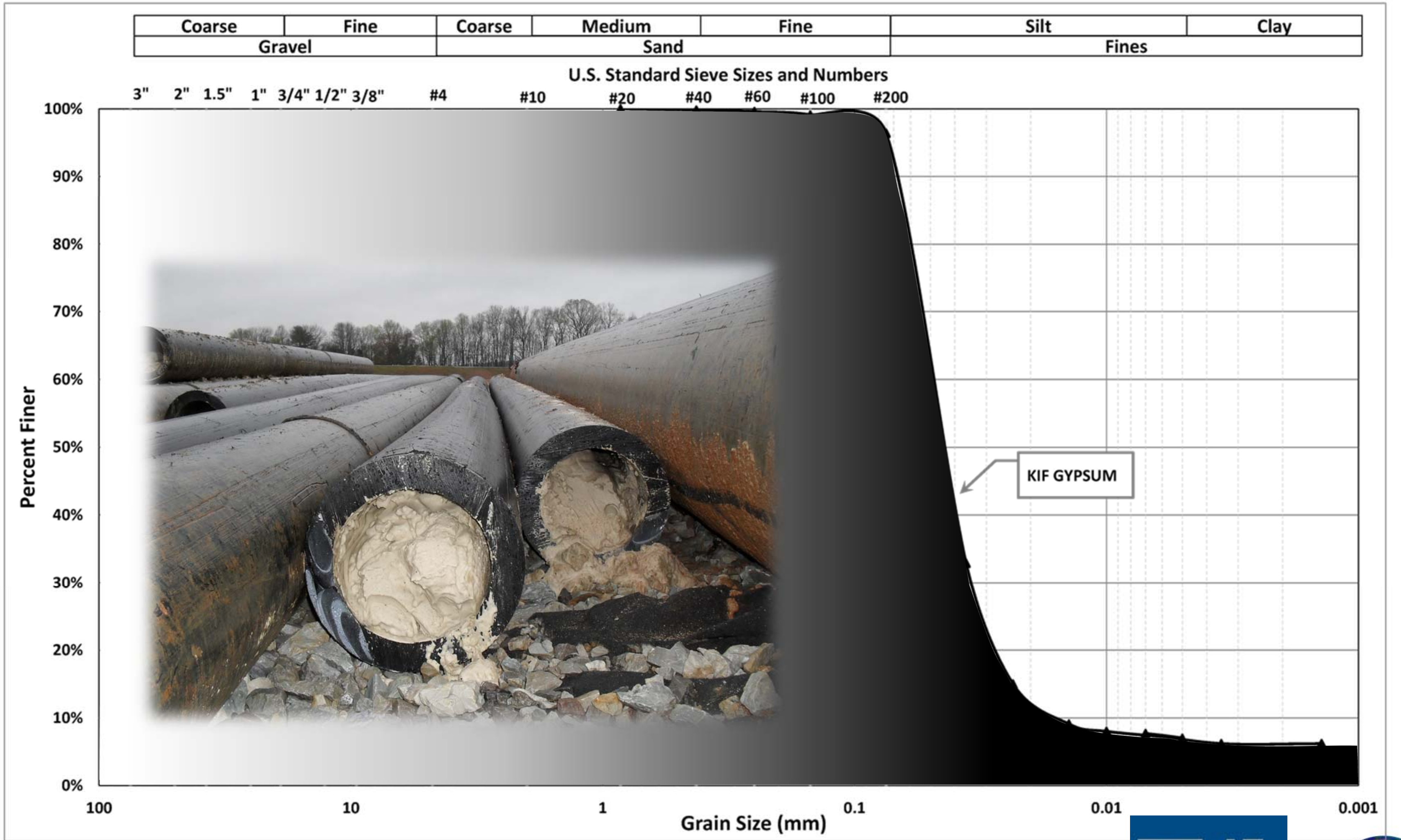
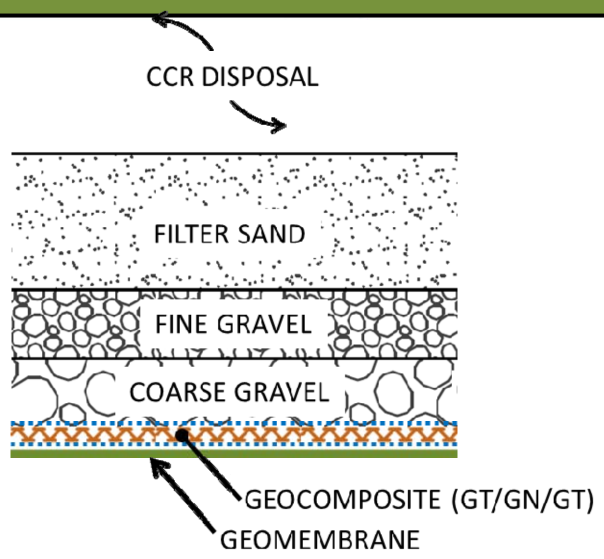
DRAINAGE SYSTEM
Designing for CCRs

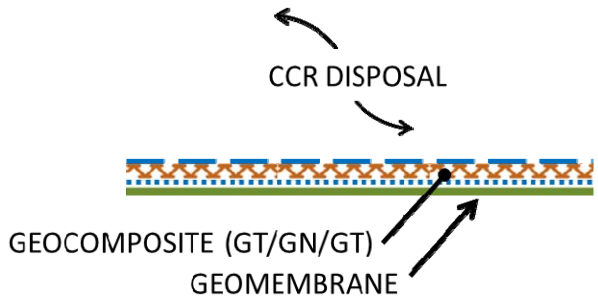


DRAINAGE SYSTEM
Designing for CCRs



STATE OF THE PRACTICE
Filter Design Challenges





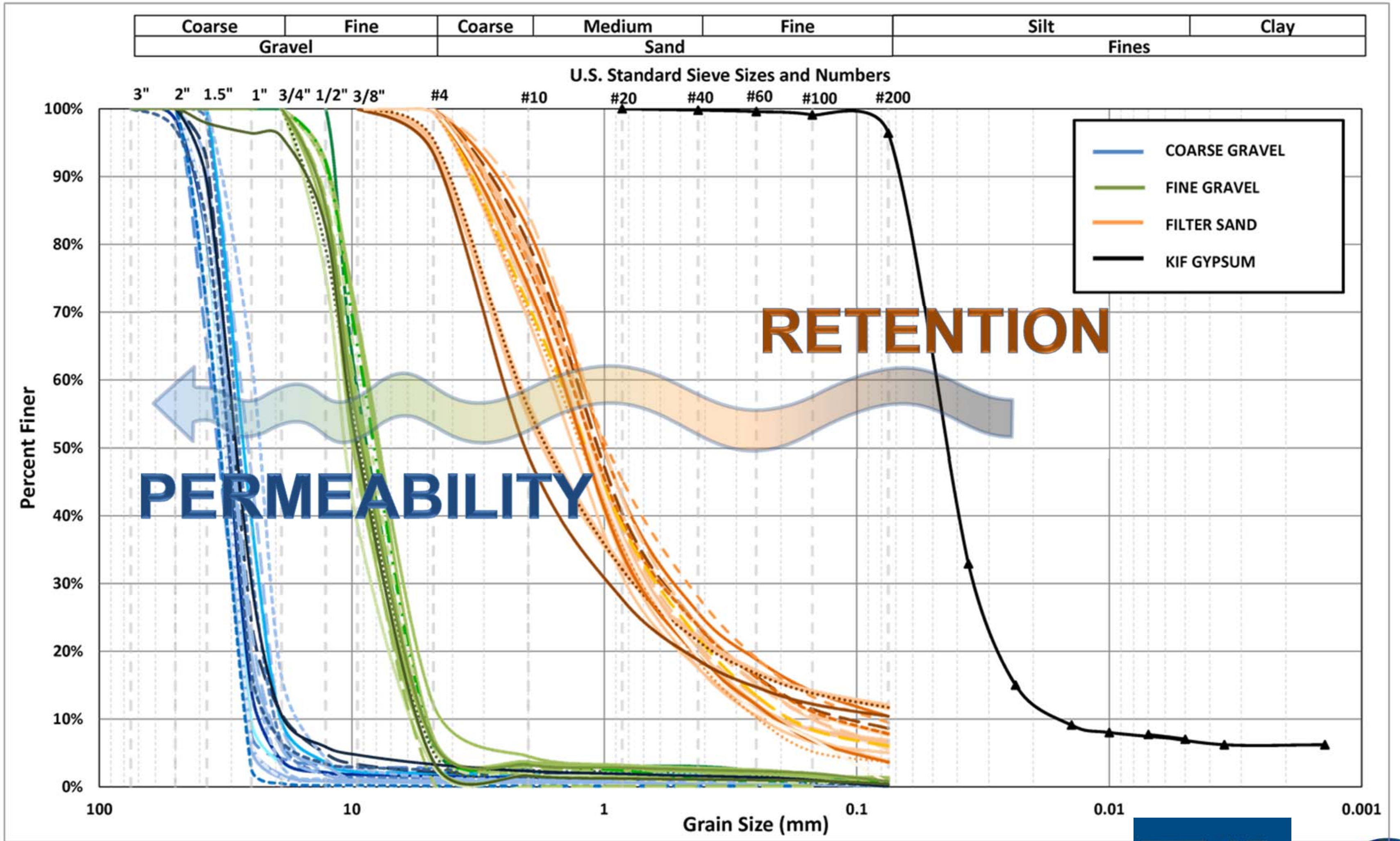
AGGREGATE FILTER

- Capacity
- Redundancy

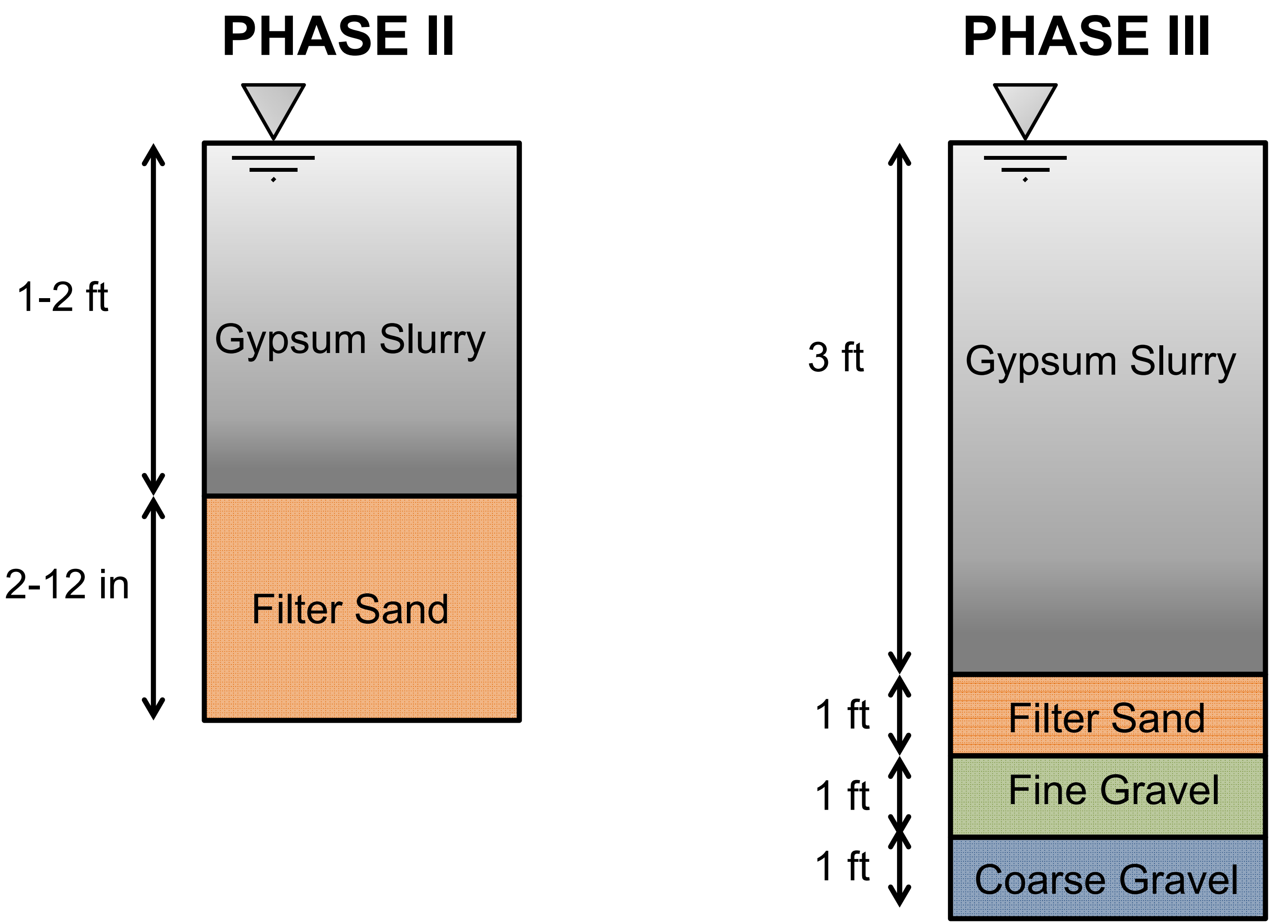
SYNTHETIC FILTER

- Cost
- Airspace / Storage

DRAINAGE SYSTEM
Laboratory Confirmed (Phase I)

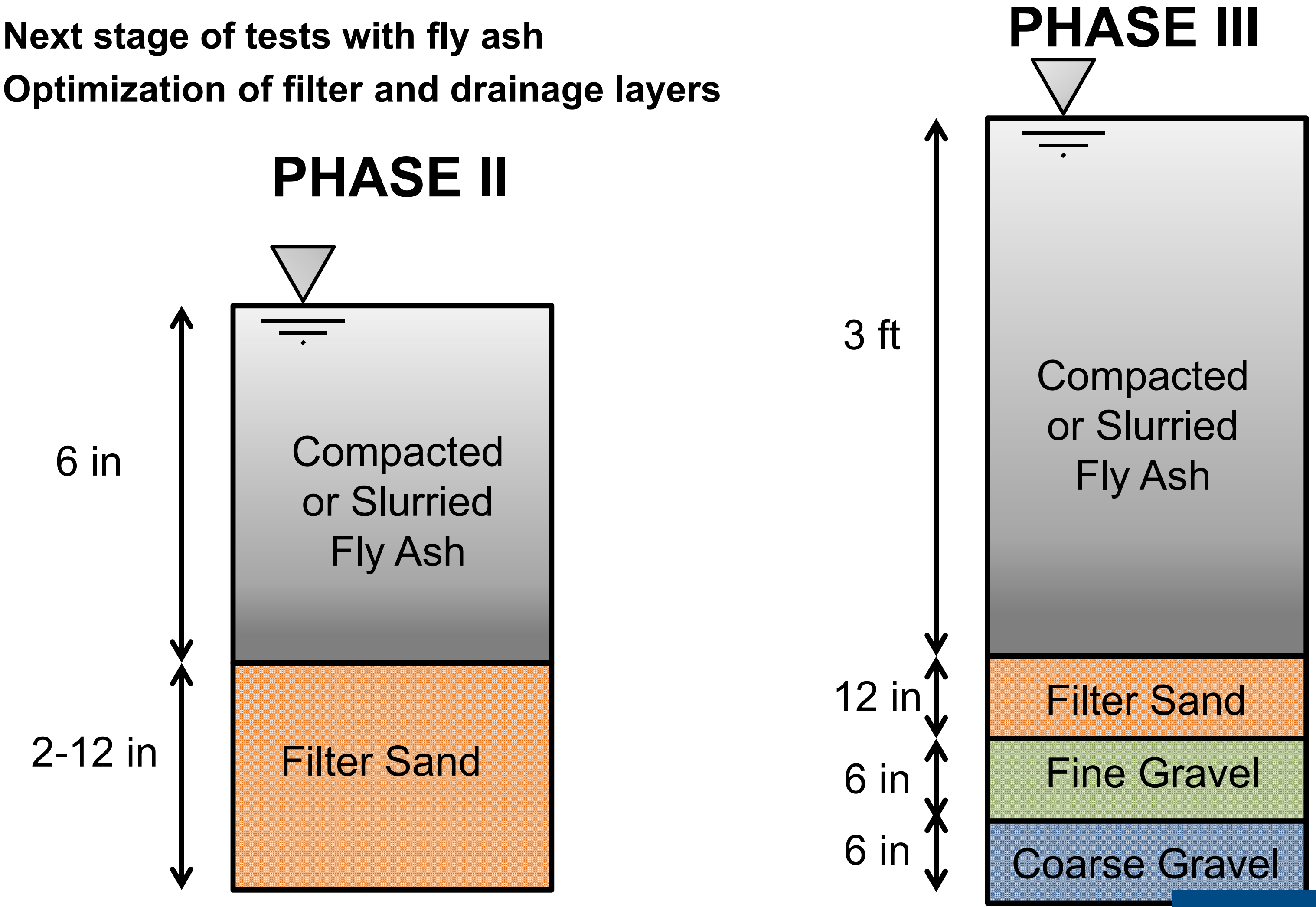


DRAINAGE SYSTEM
Laboratory Confirmation For Gypsum (Phase II & III)



DRAINAGE SYSTEM
Laboratory Confirmation For Fly Ash and Optimization (Phase II & III)

- Next stage of tests with fly ash
- Optimization of filter and drainage layers



DRAINAGE SYSTEM As-Built

EFFECTIVENESS OF LEACHATE COLLECTION SYSTEM

Incoming Gypsum Slurry (during initial wet operation)

Filtered Gypsum Leachate

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PROJECT RECOGNITION

AMERICAN COUNCIL OF ENGINEERING COMPANIES (ACEC) GEORGIA

2014 ENGINEERING EXCELLENCE GRAND AWARD

THANK YOU!

QUESTIONS?