Constructing and Testing a Low Permeability Barrier Using Weathered Mine Spoil

Sarah Smith[1], Carmen Agouridis[2], Ph.D., P.E. and Richard Warner[2], Ph.D.

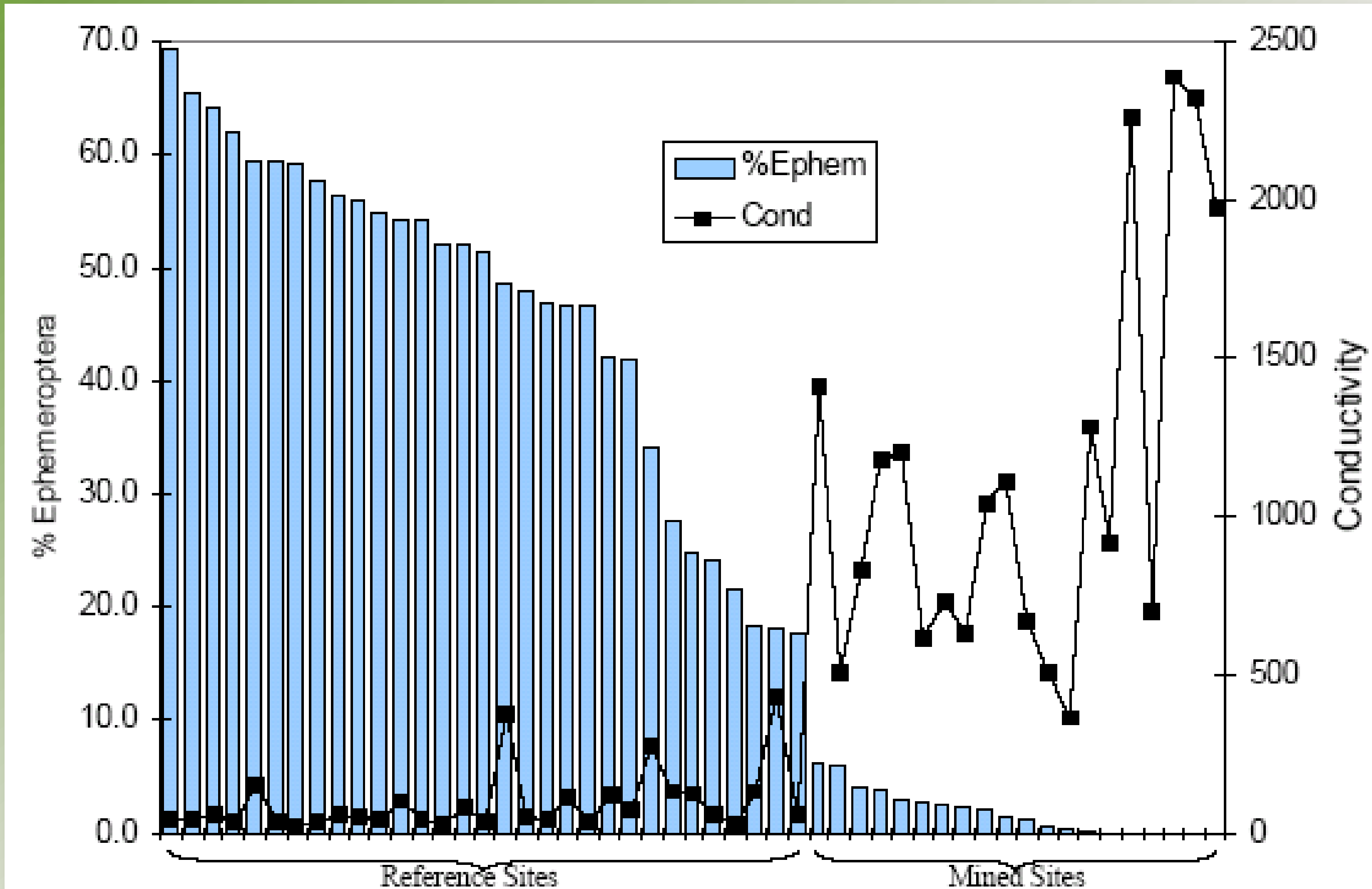
University of Kentucky, [1]Department of Chemical Engineering, [2]Department of Biosystems and Agricultural Engineering

Presentation Outline

- Environmental challenges in Appalachia Coalfields
- Problematic strata identification and isolation
- Project objective
- Methodology
- Results
- Implications

Environmental Challenges

- Mining process breaks apart rocks into smaller fragments creating larger surface areas that can interact with water
- Can lead to water quality impairments

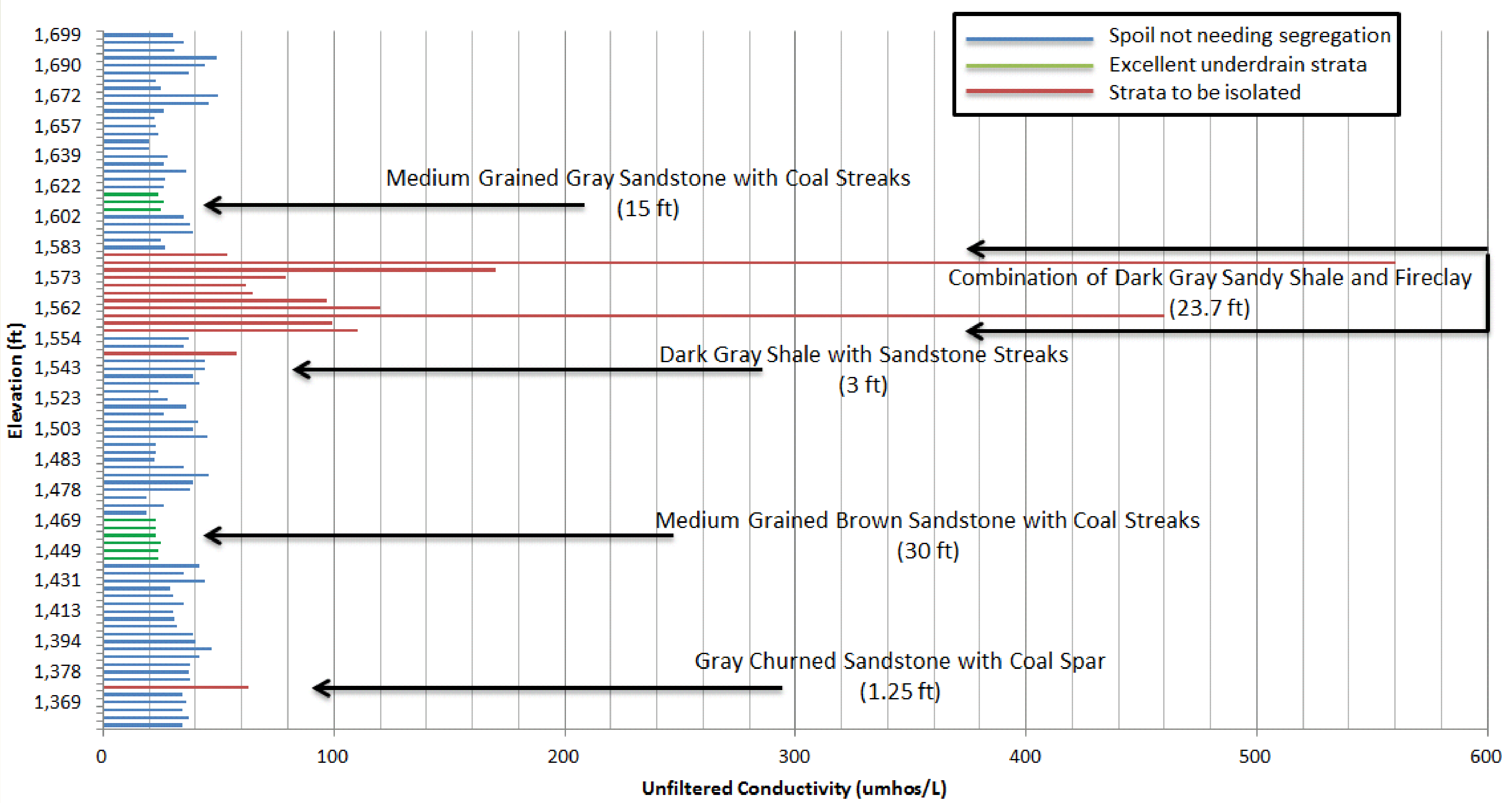


U.S. Environmental Protection Agency (USEPA)

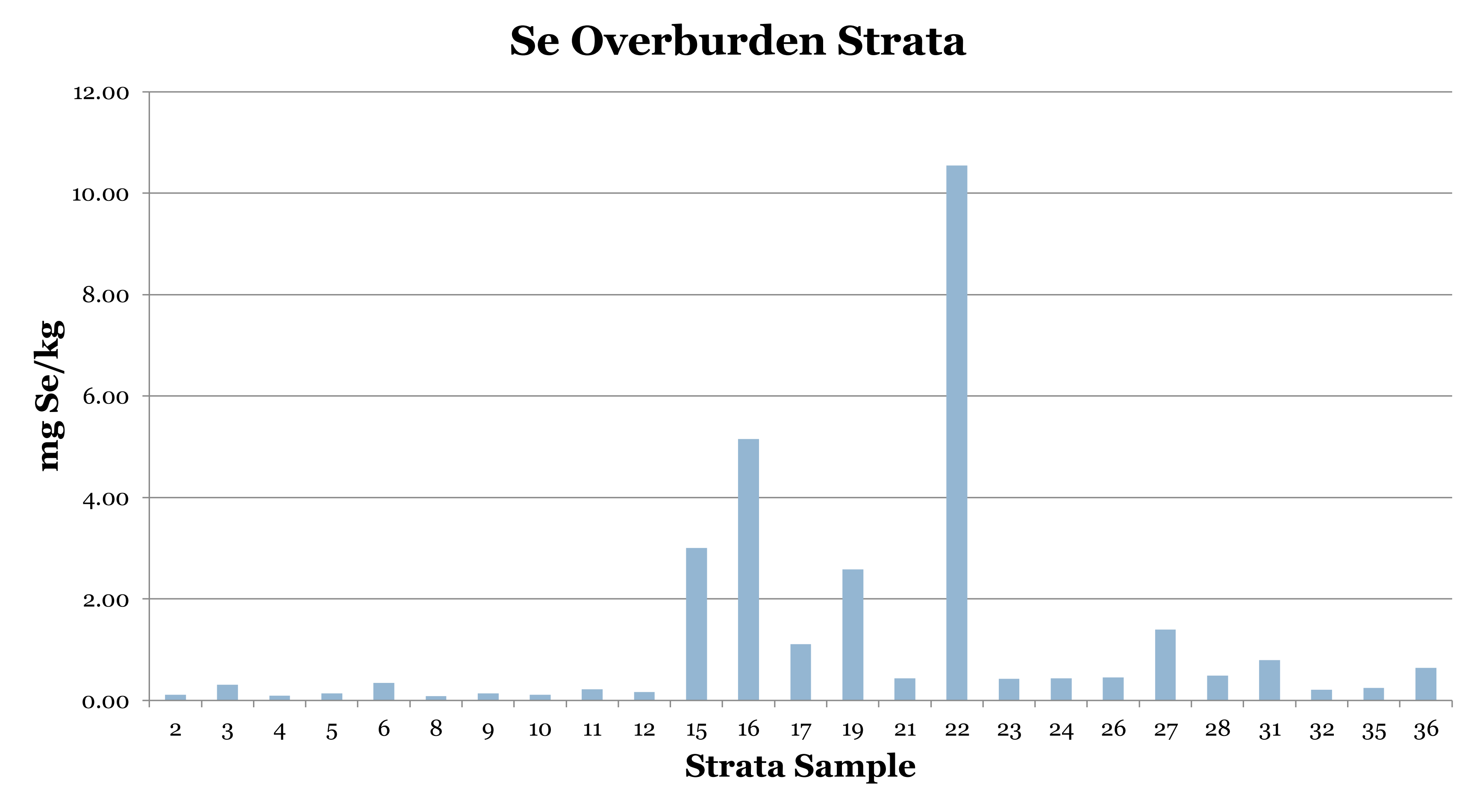
Specific conductance (2011): 300-500 µS cm^{-1}

Problematic Strata (Spoil) Identification

- Not all strata have same potential to generate high specific conductance and selenium levels



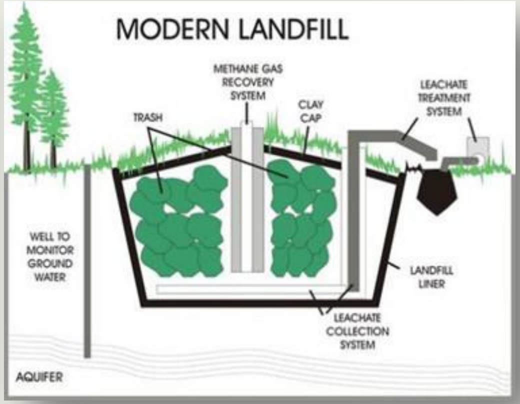
Spoil not needing segregation
Excellent underdrain strata
Strata to be isolated
Medium Grained Gray Sandstone with Coal Streaks
(15 ft)
Combination of Dark Gray Sandy Shale and Fireclay
(23.7 ft)
Dark Gray Shale with Sandstone Streaks
(3 ft)
Medium Grained Brown Sandstone with Coal Streaks
(30 ft)
Gray Churned Sandstone with Coal Spar
(1.25 ft)
Elevation (ft)
1,699
1,690
1,672
1,657
1,639
1,622
1,602
1,583
1,573
1,562
1,554
1,543
1,523
1,503
1,483
1,478
1,469
1,449
1,431
1,413
1,394
1,378
1,369
0
100
200
300
400
500
600
Unfiltered Conductivity (umhos/L)


Se Overburden Strata
mg Se/kg
12.00
10.00
8.00
6.00
4.00
2.00
0.00
2
3
4
5
6
8
9
10
11
12
15
16
17
19
21
22
23
24
26
27
28
31
32
35
36
Strata Sample

Problematic Strata (Spoil) Isolation

- Prevent water from infiltrating into problematic spoil
- Spoil isolation one method traditionally used with acid producing materials (not most common)
- Literature plentiful for clay barriers
  - Municipal solid waste, hazardous waste, low-level nuclear waste

Source: asme.org



Source: Bounce Energy


Weathered sandstone for use
as spoil isolation barrier

Project Objectives

- Evaluate field saturated hydraulic conductivity levels on low permeability barrier constructed from weathered sandstones
- Compare field-based saturated hydraulic conductivity values to those obtained in the laboratory

Study Site


West Virginia
Kentucky
MF
Virginia


© 2015 Google
Google earth
1995
Imagery Date: 6/13/2014 37°43'35.50" N 83°09'40.71" W elev 1243 ft eye alt 4511 ft

Low Permeable Barrier Construction

- Spoil dumped with CAT 777 and spread with CAT D9 dozer to nominal depth of 0.7 m
- Water incorporated as needed per da Rosa et al. (2013)
- One pass over entire layer with loaded CAT 777
- Continue layering technique until 3 m lift achieved (~6-7 layers per lift)

Source: cat.com


Source: cat.com


Source: cat.com

Methods: Spoil Characterization

- Spoil collected in 19 L buckets
- UK Regulatory Services
  - Percent sand, silt and clay
  - USDA textural triangle (USDA-NRCS, 2012)
- Liquid limit, plastic limit, and plasticity index
- Shake test

Methods: Laboratory Testing

- Standard proctor test (ASTM D698)
  - Maximum achievable level of compaction (ρ_{max}) for optimum moisture content (MC)
    - MC (gravimetric) ranged between 12-18%
- Saturated hydraulic conductivity (h_{sat})
  - Rigid wall double-ring permeameter

Methods: Field Testing

- Two double-square infiltrometers
  - Outer: 1 m x 1 m
  - Inner: 0.5 m x 0.5 m
- Installed to depth of 0.5 m using Class 200 excavator



Methods: Field Testing

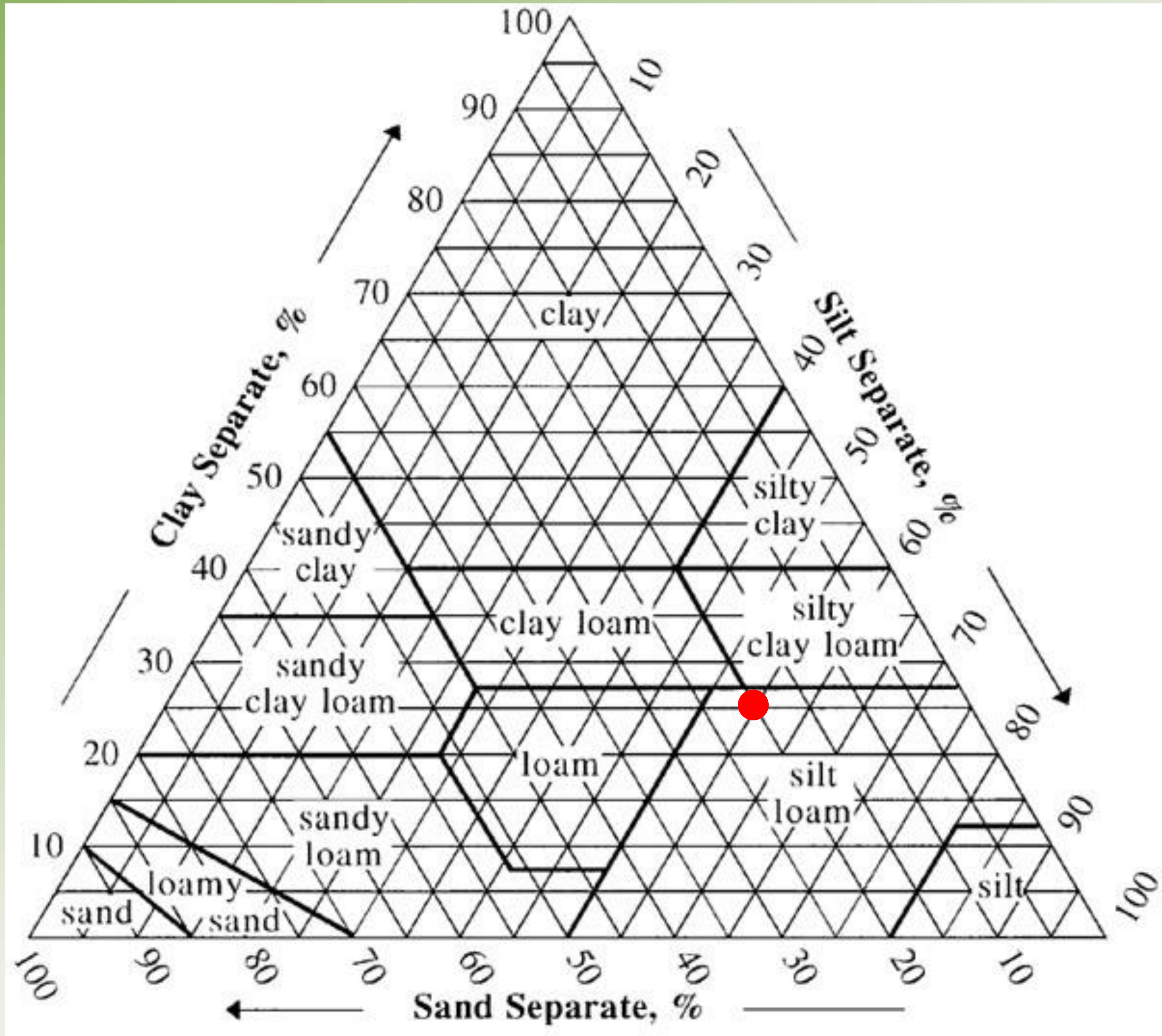
- Filled inner and outer boxes with water
  - Two holes used to fill inner box, later capped
  - 1 m vertical pipe to increase hydraulic head and measure infiltration
- Allowed spoil to saturate for 1 month
- Measured hydraulic gradient for 5-6 hours, 15-min intervals (until steady state achieved)

Methods: Field Extracted Cores

- Four cores (0.7 m tall, 6.5 cm diameter)
- Compaction of spoil in core or below core
- Spoil could not be removed from core
  - Hydraulic conductivity measured in core tube in lab
  - Connected 5 m pipes to cores to expedite the process

Results

- Spoil was silt loam (80.2% fines); ML in USCS classification; low $EC_{25°C}$.
- Achieved average ρ_{max} of 2,100 kg m^{-3} at MC of 15% and average h_{sat} of 5.5 x 10^{-8} at MC of 16%
- Results similar to those from da Rosa et al. (2013) for brown weathered sandstone
- Lab core results showed average h_{sat} of 3.1 x 10^{-9} for all cores (additional compaction occurred with sample collection)
- Achieved comparable h_{sat} in field with loaded truck as compared to lab with proctor



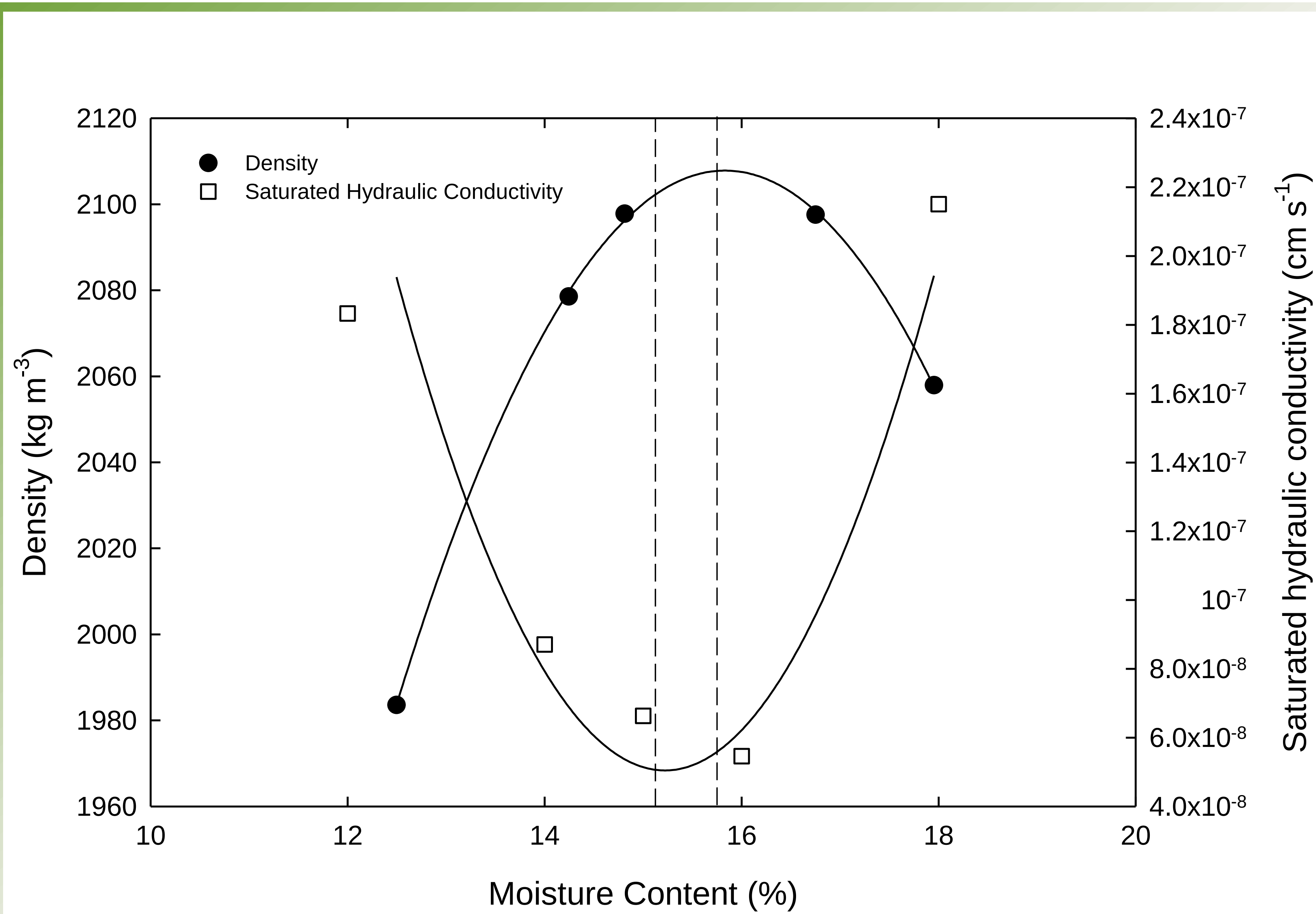
Sand: 19.8±0.7 Silt: 54.1±0.3 Clay: 26.1±0.4

Spoil Subsample	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
1	26	25	1
2	25	25	0
3	25	25	0

Spoil Subsample	Specific Conductance (µS cm^{-1})
1	42
2	41
3	38

Results

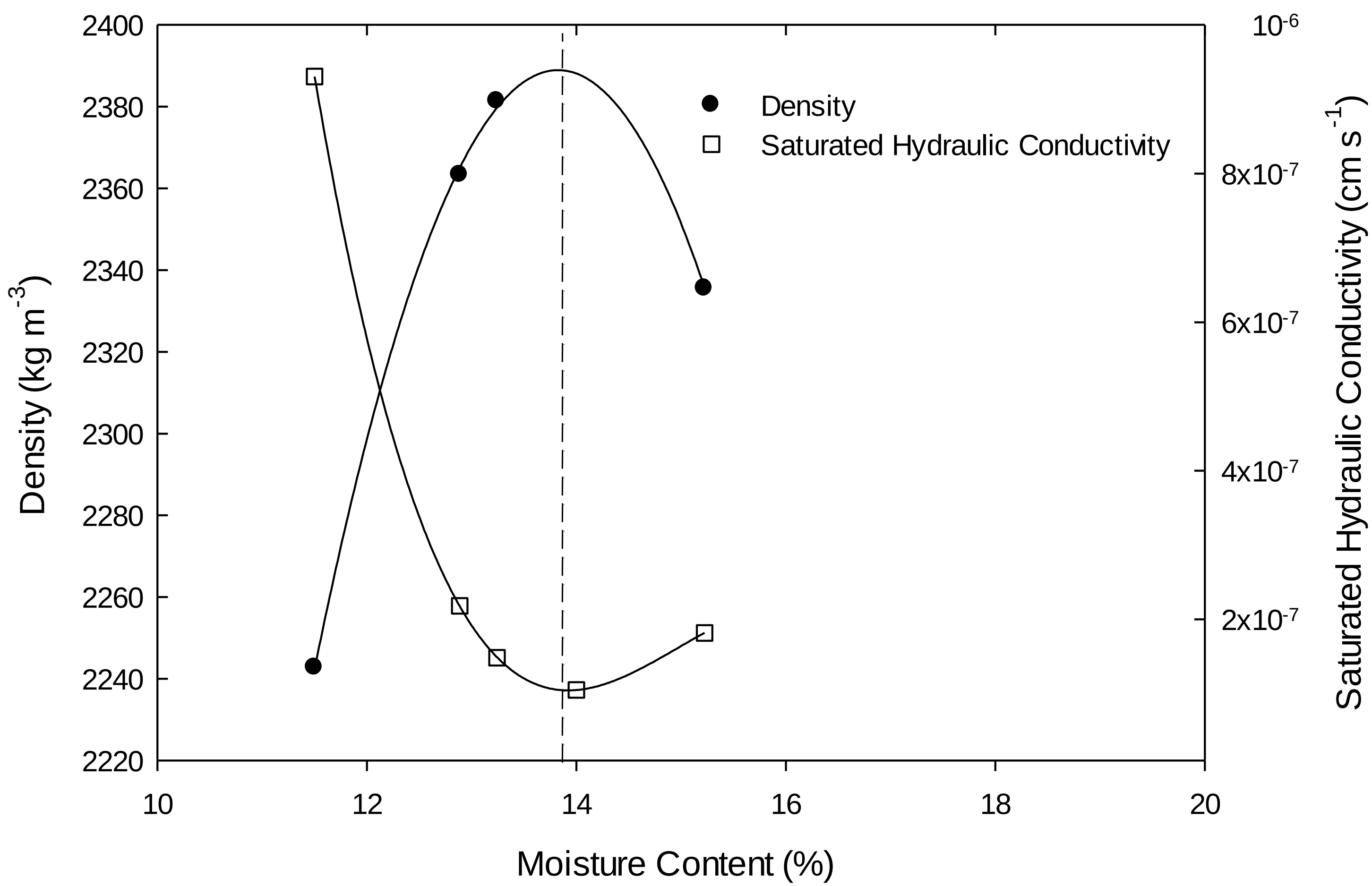
- Spoil was silt loam (80.2% fines); ML in USCS classification; low $EC_{25°C}$.
- Achieved average ρ_{max} of 2,100 kg m^{-3} at MC of 15% and average h_{sat} of 5.5×10^{-8} at MC of 16%
- Results similar to those from da Rosa et al. (2013) for brown weathered sandstone
- Lab core results showed average h_{sat} of 3.1×10^{-9} for all cores (additional compaction occurred with sample collection)
- Achieved comparable h_{sat} in field with loaded truck as compared to lab with proctor



ρ_{max} = 2,100 kg m^{-3} (MC=15%) h_{sat} = 5.5 x 10^{-8} (MC=16%)

Results

- Spoil was silt loam (80.2% fines); ML in USCS classification; low $EC_{25^\circ C}$.
- Achieved average ρ_{max} of 2,100 kg m^{-3} at MC of 15% and average h_{sat} of 5.5×10^{-8} at MC of 16%
- Results similar to those from da Rosa et al. (2013) for brown weathered sandstone
- Lab core results showed average h_{sat} of 3.1×10^{-9} for all cores (additional compaction occurred with sample collection)
- Achieved comparable h_{sat} in field with loaded truck as compared to lab with proctor



Brown weathered sandstone from same mine

ρ_{max} = 2,400 kg m^{-3} (MC=14%) h_{sat} = 1 x 10^{-7} (MC=14%)

52% sand, 34% silt, and 14% clay (48% fines)

Results

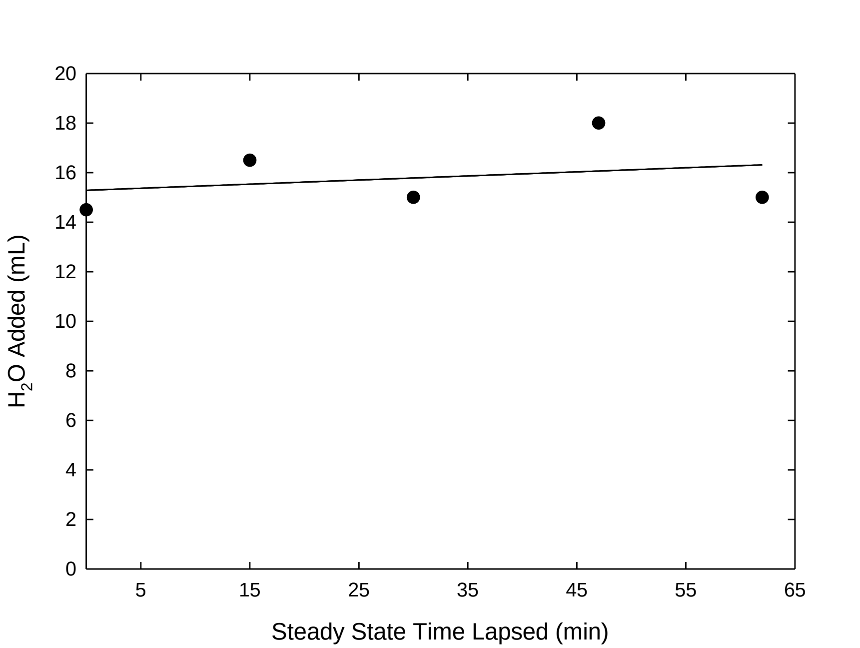
- Spoil was silt loam (80.2% fines); ML in USCS classification; low $EC_{25°C}$.
- Achieved average ρ_{max} of 2,100 kg m^{-3} at MC of 15% and average h_{sat} of 5.5 x 10^{-8} at MC of 16%
- Results similar to those from da Rosa et al. (2013) for brown weathered sandstone
- Lab core results showed average h_{sat} of 3.1 x 10^{-9} for all cores (additional compaction occurred with sample collection)
- Achieved comparable h_{sat} in field with loaded truck as compared to lab with proctor

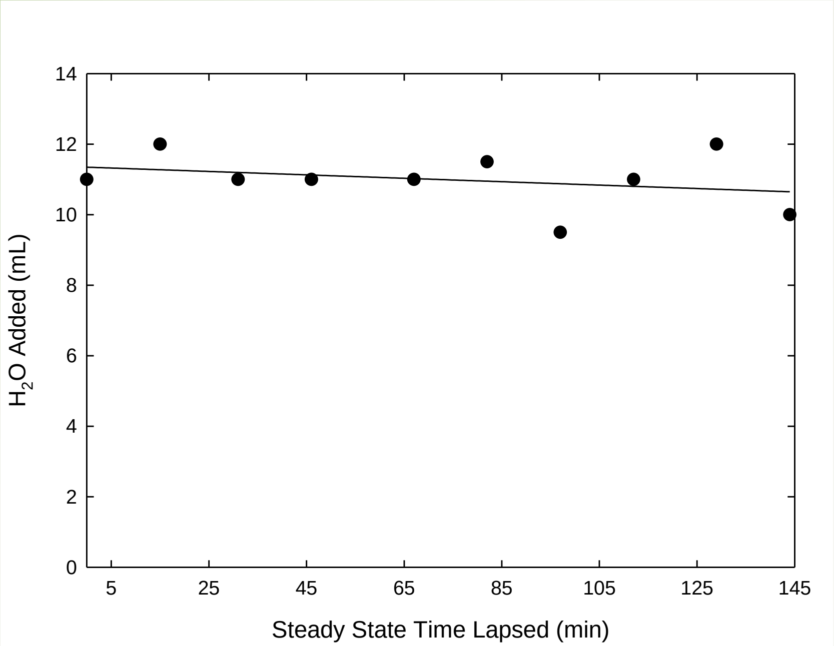
Core ID	Average h_{sat} (cm s-1)	% core filled
A	2.1×10^{-9}	39
B	2.0×10^{-9}	39
C	6.8×10^{-9}	41
D	1.4×10^{-9}	36

Approximately 94 days until cores were saturated

Results

- Spoil was silt loam (80.2% fines); ML in USCS classification; low $EC_{25°C}$.
- Achieved average ρ_{max} of 2,100 kg m^{-3} at MC of 15% and average h_{sat} of 5.5×10^{-8} at MC of 16%
- Results similar to those from da Rosa et al. (2013) for brown weathered sandstone
- Lab core results showed average h_{sat} of 3.1×10^{-9} for all cores (additional compaction occurred with sample collection)
- Achieved comparable h_{sat} in field with loaded truck as compared to lab with proctor





$h_{sat} = 6.7 \times 10^{-8}$

$h_{sat} = 4.0 \times 10^{-8}$

Achieved comparable h_{sat} in field as compared to lab. Higher level of compaction with loaded trucks.

Conclusions

- Lab findings confirmed h_{sat} results from da Rosa et al. (2013)
- Field implementation yielded comparable h_{sat} to that produced in lab
- Can create effective low permeable barrier using brown weathered sandstone

Implications

- Isolating problematic spoil is critical of larger strategy to minimize impacts of mining (new and AML)
- Other necessary components include …
  - Mine operations and planning
  - Construction of weep berms
  - Reforestation
  - Stream network



Acknowledgements

- Greg Higgins at Middle Fork Development
- Otto Hoffmann (UK)
- Alex Fogle (UK)
- Evan Wesley (UK)
- Tyler Sanderson (UK)

Questions?

UNIVERSITY OF KENTUCKY
College of Agriculture, Food and Environment