# Permeability of Shrink-Swell Soils:

## Water Movement Using Field Saturated Hydraulic Conductivity Tests (Ksat)

The materials being presented represent my own opinions, and do NOT reflect the opinions of NOWRA or sponsors of the 2023 Mega-Conference.

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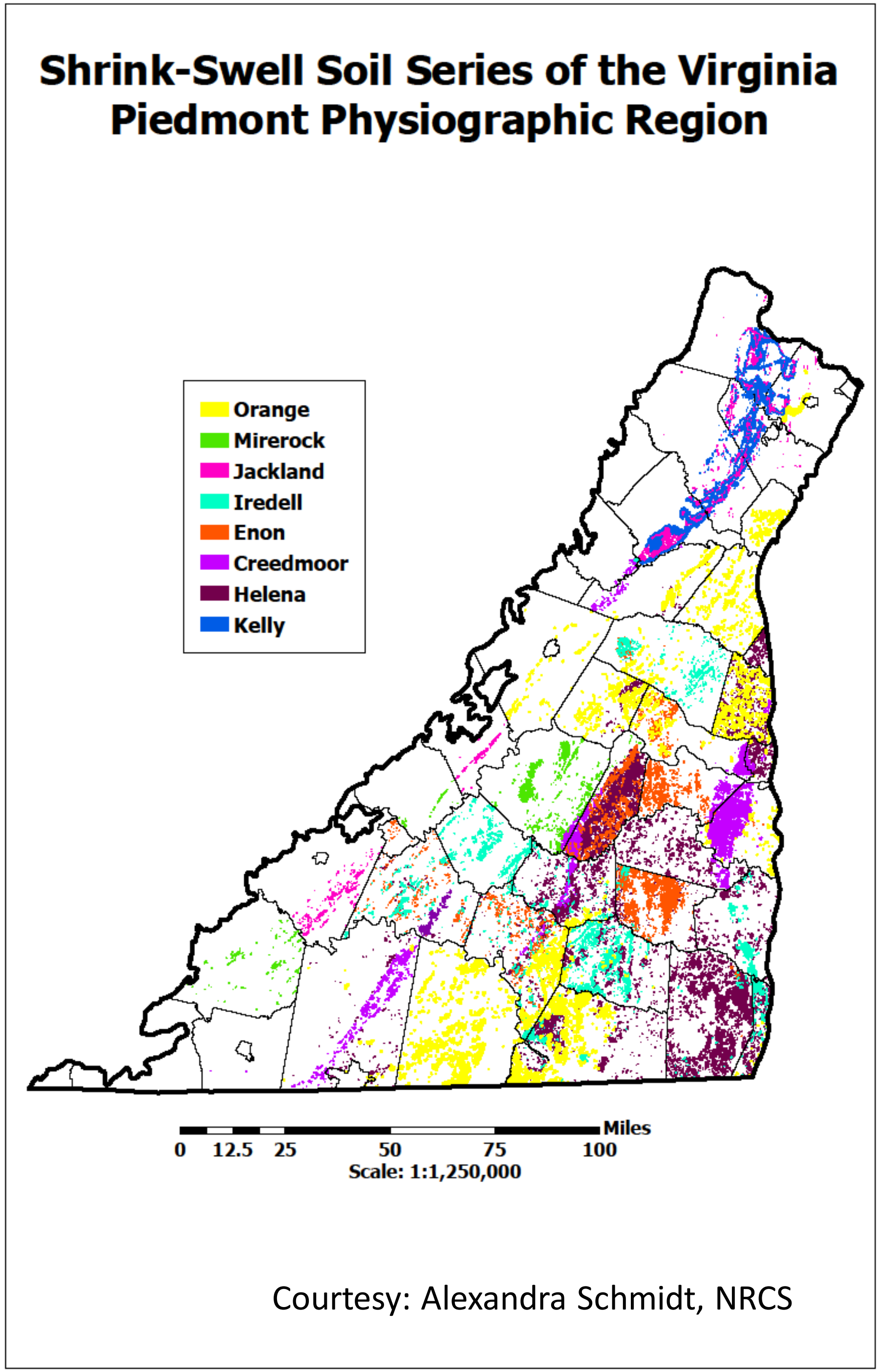
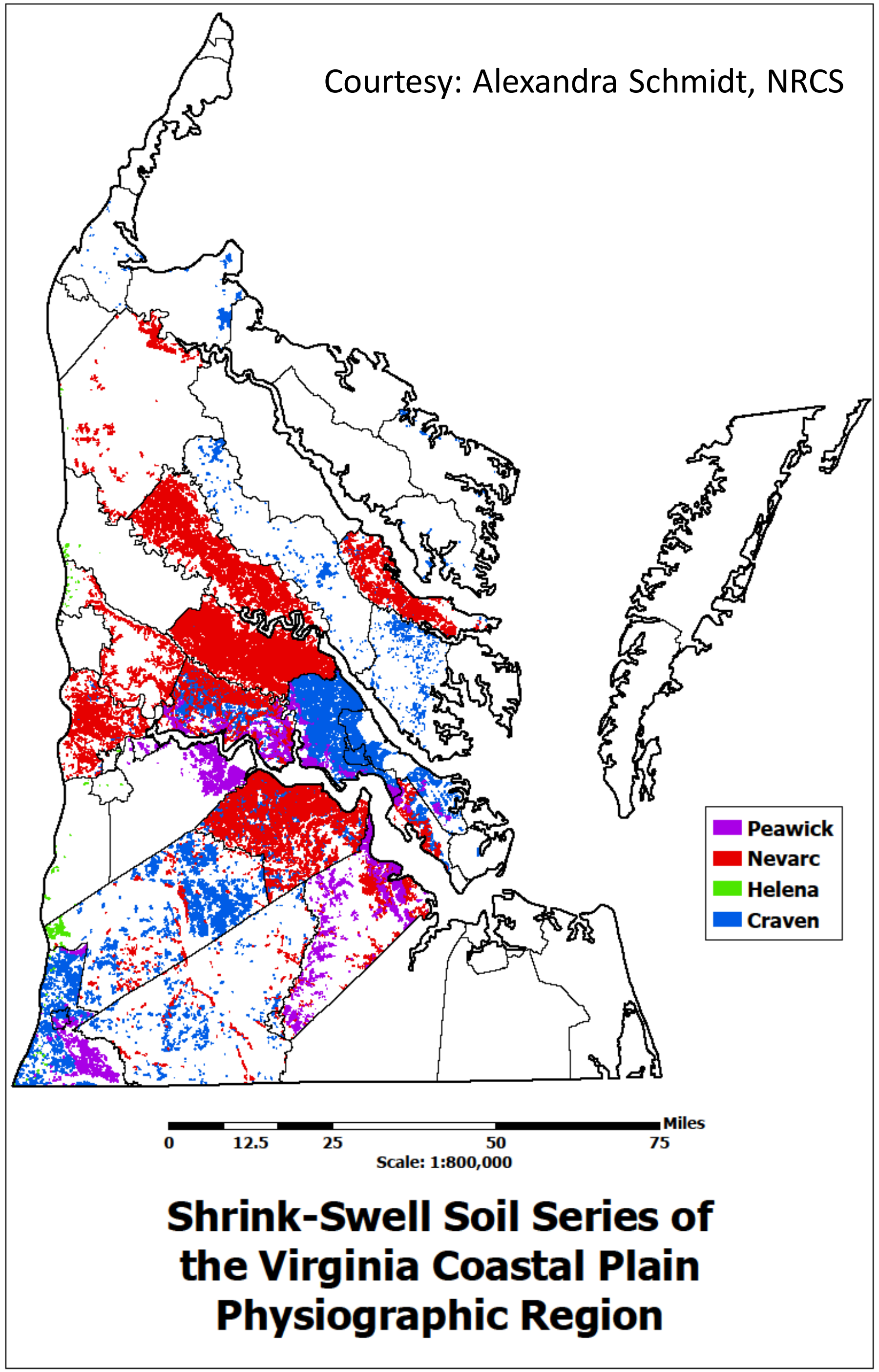
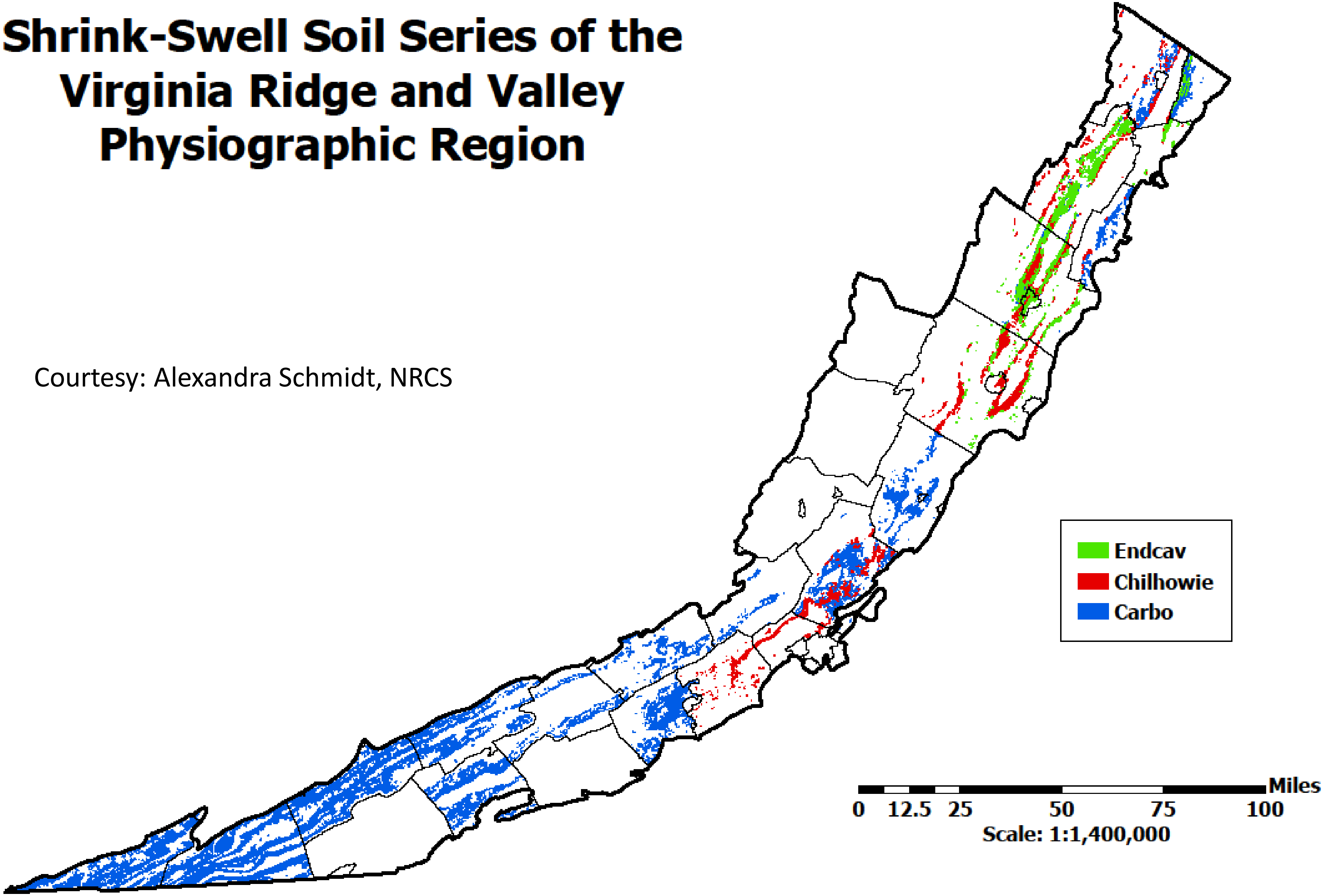
Typical high shrink-swell soil in the Virginia Piedmont


Shrink-Swell Soil Series of the Virginia Piedmont Physiographic Region
Orange
Mirerock
Jackland
Iredell
Enon
Creedmoor
Helena
Kelly
Miles
0
12.5
25
50
75
100
Scale: 1:1,250,000
Courtesy: Alexandra Schmidt, NRCS

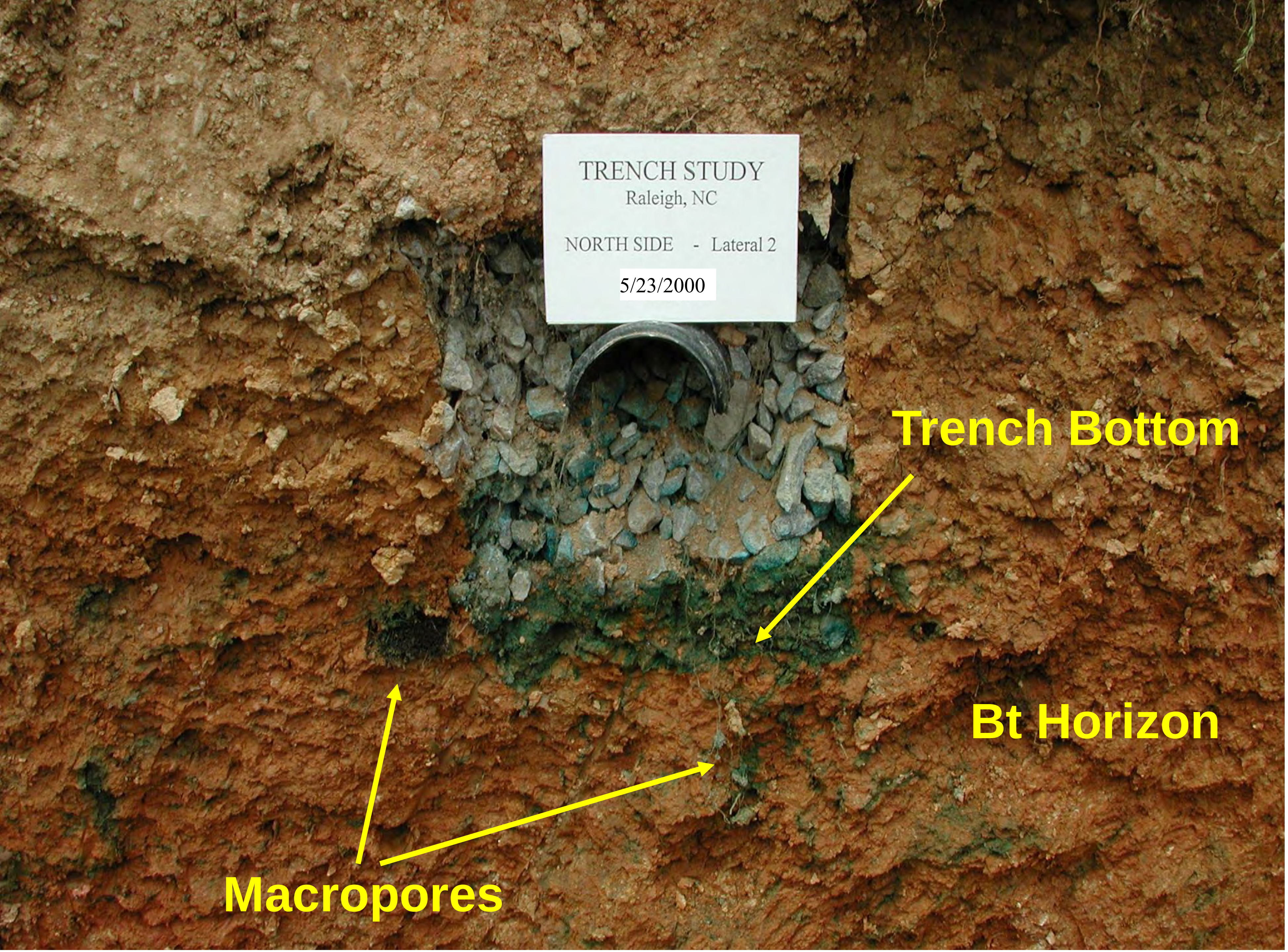

Courtesy: Alexandra Schmidt, NRCS
Peawick
Nevarc
Helena
Craven
Miles
0
12.5
25
50
75
Scale: 1:800,000
Shrink-Swell Soil Series of the Virginia Coastal Plain Physiographic Region

# Shrink-Swell Soil Series of the Virginia Ridge and Valley Physiographic Region

Courtesy: Alexandra Schmidt, NRCS

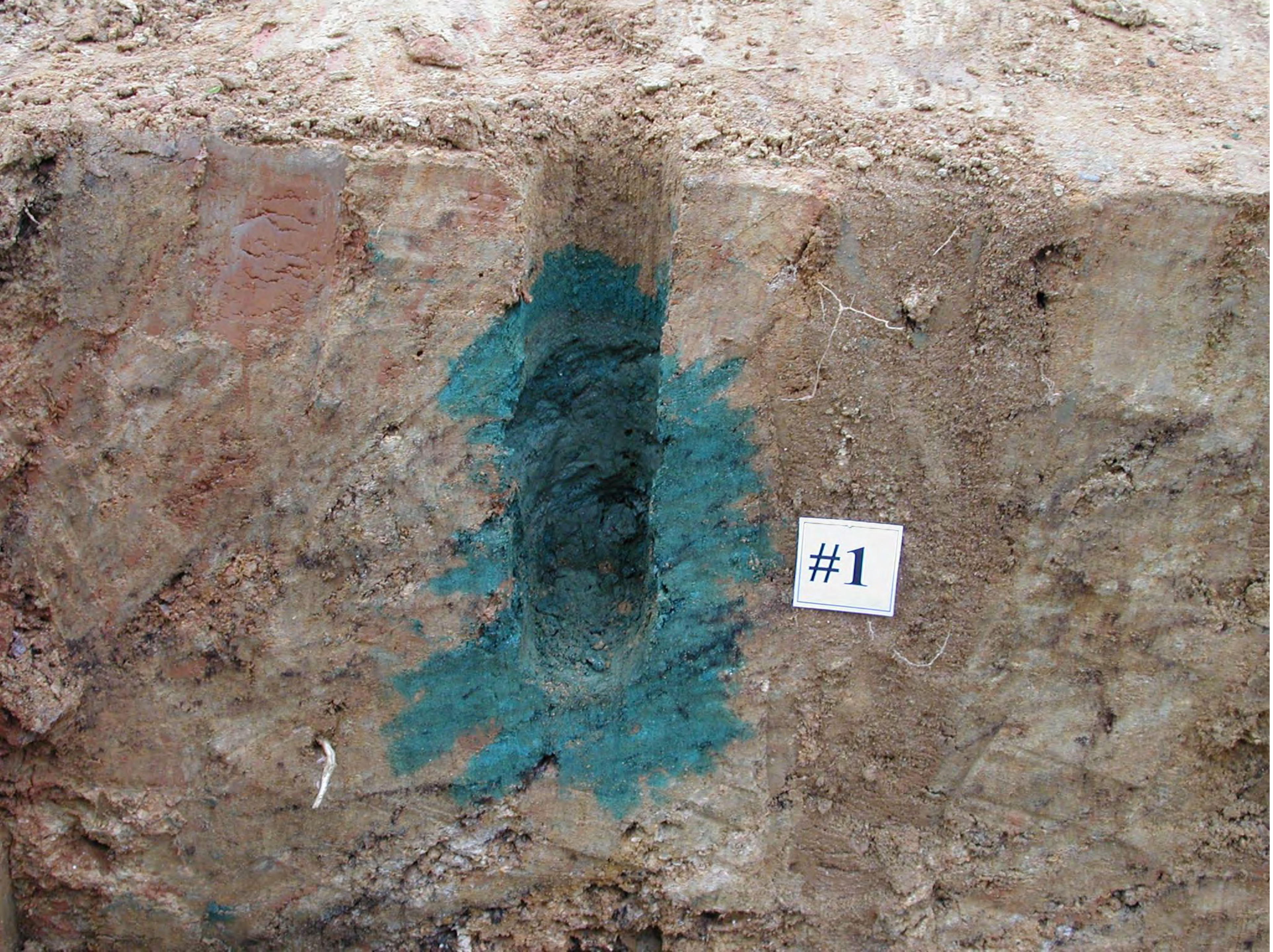


# Effluent movement in soils

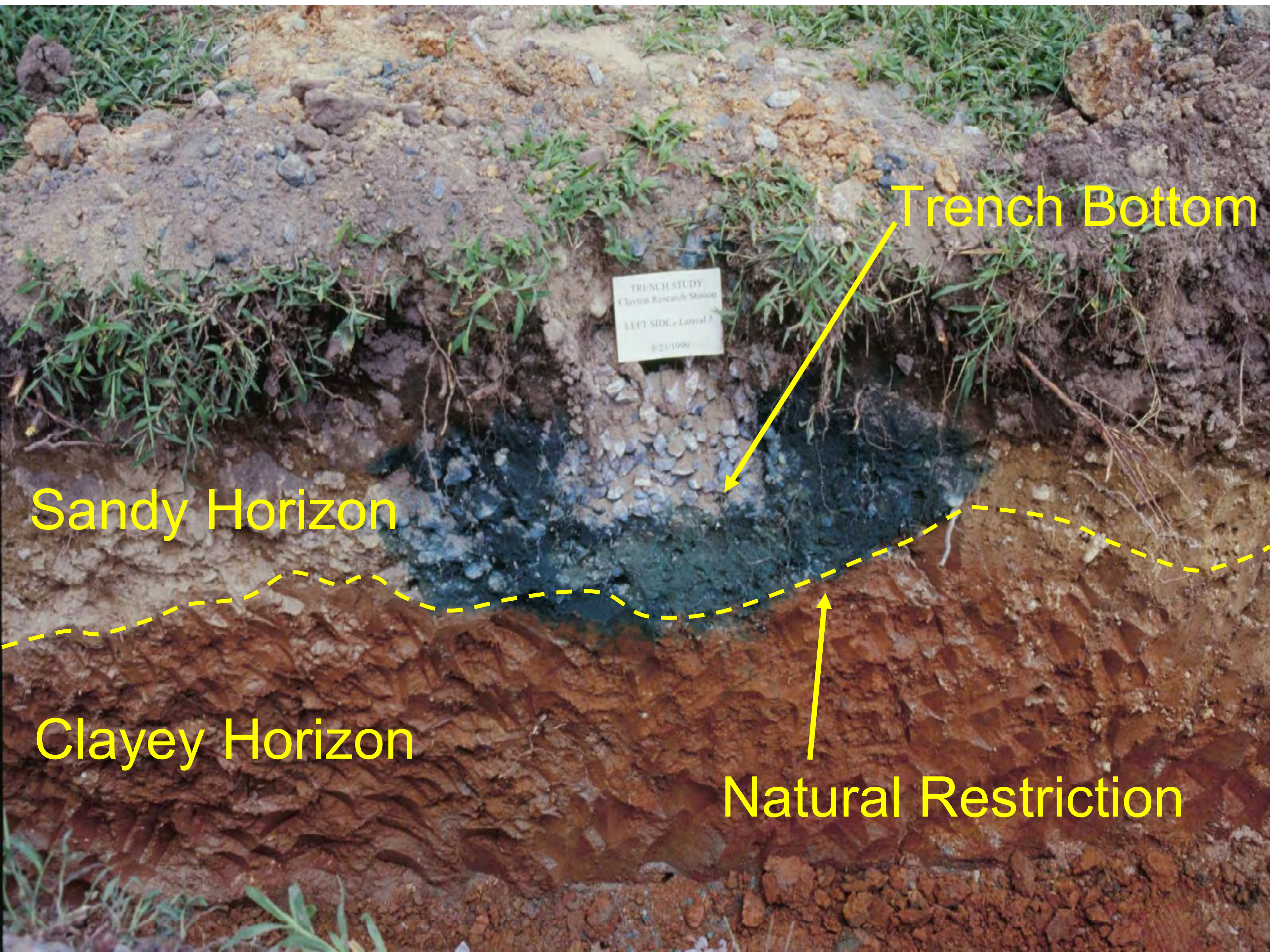



**Water movement concentrated along macropores**


**Water movement concentrated along macropores – ped faces and root channels**




**Water movement along rock controlled structure in saprolite**




**Lateral water flow**

# Identifying Shrink-swell Soils


**What a shrink-swell soil profile looks like from an auger boring**

# “Massive-looking” A or Ap horizons

“Double helix” shape of the Btss out of the auger bucket

**Very Sticky - Soil adhering to the outside of the auger bucket**

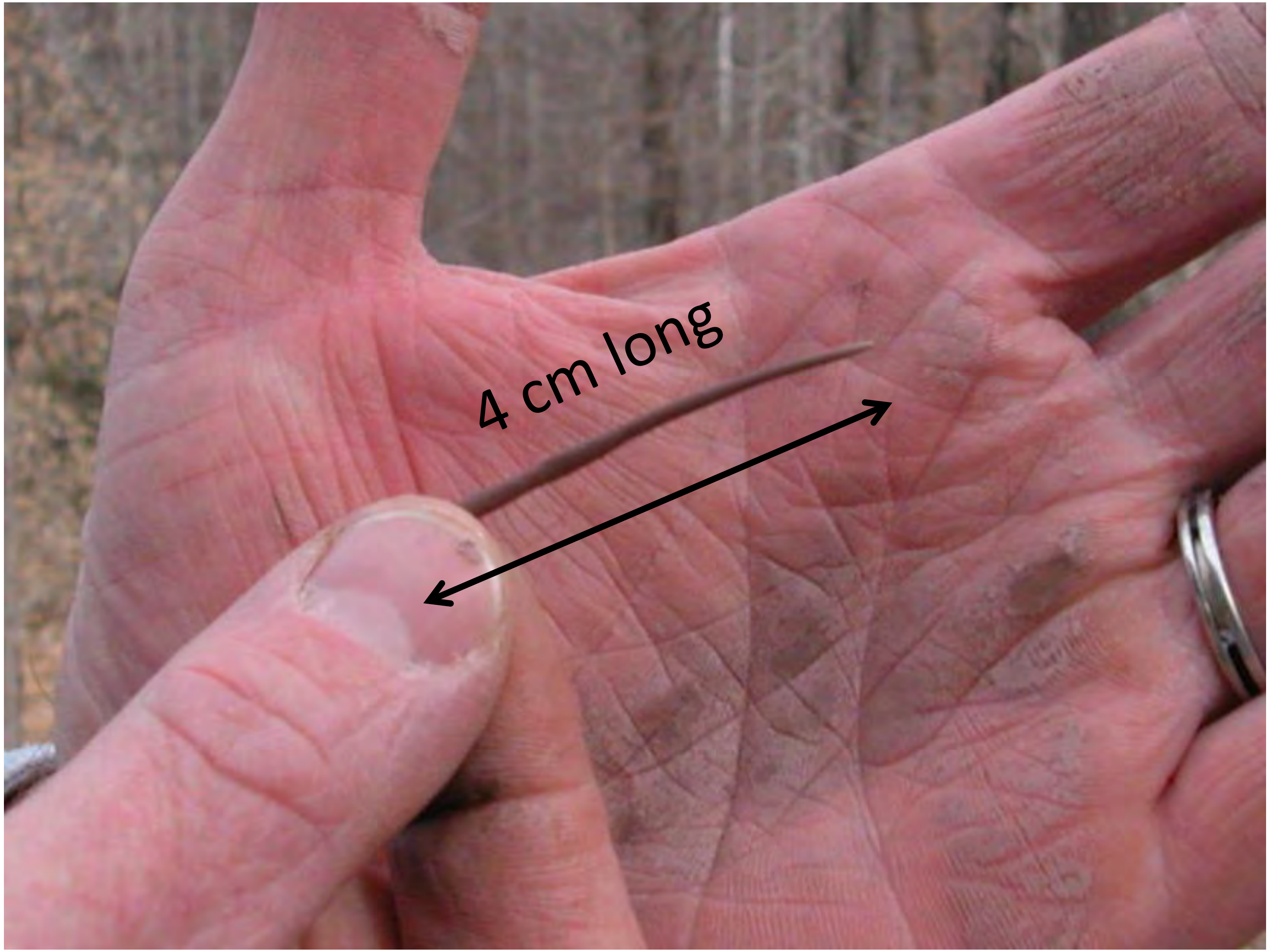
# Excessively long texture “ribbons” can indicate shrink-swell soil properties


# Slickensides of a Btss Horizon

# Pressure Faces


Parent material


Mafic and
Ultra-mafic
rock




# Plasticity

2 mm
diameter
wire

**Very Plastic**

# Plasticity

**Producing a soil "wire" 2 mm in diameter and 4 cm long is <u>very plastic</u>**

USDA NRCS "Field Guide for Describing and Sampling Soils, vs. 3.0"

# Stickiness

The capacity of the soil to adhere to other objects. Stickiness is estimated at the moisture content that displays the greatest adherence when pressed between thumb and forefinger

Soil adheres firmly to both fingers after release of pressure.  Soil stretches greatly upon separation of fingers

**Very Sticky**

# This research was prompted by:

- Development pressure in Northern VA to build on shrink-swell soils where onsite sewage systems are used for treatment and disposal

- Need for Ksat data to assess Btss permeability (soils greater than 120 MPI perc rates)

- Assess impact on septic system design and performance


Jackland silt loam, 0 to 2 percent slopes (62A)

Jackland and Haymarket soils, 2 to 7 percent slopes (63B)

Jackland and Haymarket soils, 7 to 15 percent slopes, very stony (64C)

Hattontown-Jackland complex, 0 to 2 percent slopes (53A)

Elbert silt loam, 0 to 2 percent slopes, frequently flooded (35A)

Urban land-Hattontown complex (99)

# JACKLAND SERIES

Soils of the Jackland series are very deep, moderately well drained and somewhat poorly drained with very slow permeability. They formed in residuum that weathered from diabase, basalt and gabbro of the Northern part of the Piedmont plateau. Slopes range from 0 to 15 percent. Mean annual precipitation is about 40 inches and mean annual temperature is about 55 degrees F.

**TAXONOMIC CLASS:** Fine, smectitic, mesic Aquic Hapludalfs

# HAYMARKET SERIES

Soils of the Haymarket Series are very deep, well drained to moderately well drained with moderately slow permeability. They formed in residuum that weathered from diabase and basalt of the Northern Piedmont uplands. Slopes range from about 0 to 15 percent. Mean annual precipitation is about 36 inches and mean annual temperature is about 57 degrees F.

**TAXONOMIC CLASS:** Fine, smectitic, mesic Typic Hapludalfs

# ELBERT SERIES

Soils of the Elbert series are deep and poorly drained with slow to very slow permeability. They formed in local alluvium over residuum of greenstone, diorite, hornblende, gneiss, and other basic dark colored rocks. These soils are on upland flats, in depressions, and along drainageways. Slopes range from 0 to 5 percent. Mean annual temperature is about 55 degrees F and mean annual precipitation is about 42 inches.

**TAXONOMIC CLASS:** Fine, smectitic, mesic Typic Endoaqualfs

# HATTONTOWN SERIES

Depth Class: Very deep
Drainage Class (Agricultural): Well drained to moderately well
Landscape: Piedmont Plateau
Parent Material: residuum weathered from diabase and basalt
Slope: 0 to 25 percent slopes
Mean Annual Air Temperature (type location): 12.4 degrees C. (54 degrees F.)
Mean Annual Precipitation (type location): 1062 mm (42 inches)

**TAXONOMIC CLASS:** Fine-loamy, mixed, active, nonacid, mesic Typic Udorthents

# Regulatory References to Shrink-Swell Soils

- SHDR 610-120: Definitions

"soils with horizons that contain montmorillonite and other clays that excessively shrink upon drying and swell upon wetting"

- SHDR 610-490.F: Characteristics of Soil Suitability

"Shrink-swell soils may exhibit satisfactory percolation rates when dry and therefore must be thoroughly wetted before a percolation test is performed"

- SHDR 610-593.9: Shrink-Swell Soils

"When soils containing horizons with shrink-swell characteristics have been identified, they shall be rejected for use of subsurface soil absorption systems"

# Regulatory References

- AOSS 613-80.12.: Whenever depth to a permeability limiting feature on the naturally occurring site is <18 inches from ground surface, whenever the treatment works does not provide at least 18 inches of vertical separation to a permeability limiting feature, or whenever the design is for a large AOSS, then the following shall apply:

  The designer shall demonstrate that
  - (i) – The site is not flooded during the wet season
  - (ii) -- There is a hydraulic gradient to move the applied effluent off the site
  - (iii) -- Water mounding will not adversely affect the functioning of the soil treatment area or create ponding on the surface

# Research Parameters

- About ½ of the Ksat tests were performed with the Amoozemeter and ½ with the Johnsonmeter
- Tests run to Steady State (3 to 4 consecutive readings that were uniform)
- Tests were temperature corrected to 68˚ F
- Tests performed by J. Conta, E. Severson, and S. Thomas

# Research Parameters

- Majority of tests run in Iredell soils as mapped in Soil Survey of Campbell County, VA, 1977 (NRCS re-correlated to Jackland soil due to shift in mesic-thermic temperature regimes)
- Depth of Ksat tests varied, depending on the soil profile
- Tests run in open, grassy field
- Ksat tests run March 2016 and September 2016

# Research Parameters

- Texture of Btss horizons: clay or clay-silty clay with only 1 outlier (silt loam)

- Duration of Ksat tests varied and was influenced by prior moisture status of the soil (but all run to steady state)
  - Shortest: 78 minutes
  - Longest: 360 minutes (6 hrs.)

# Information gathered during the Ksat testing

Date
Location
Horizon
Texture of tested horizon
Apparatus - Permeameter
"Peacock Chart" correlated MPI
Tester's initials
Brief soil profile description

County
Test #
Depth of test (in.)
Test duration (min.)
Water volume/time interval
Ksat (cm/day) @ steady state
Comments

# Compact Constant Head Permeameter (Amoozemeter)

**Johnson Precision Permeameter (Johnsonmeter)**

**Table 4.6**

# Area Requirements for Absorption Trenches

| Saturated Hydraulic Conductivity Rate (centimeters/day) | ** | (Ft2/100 Gals) Gravity | (Ft2/100 Gals) LPD* | (Ft2/Bedroom) Gravity | (Ft2/Bedroom) LPD* |
|---|---|---|---|---|---|
| > 50.0 | (005) | 110 | 110 | 165 | 165 |
| 25.0 – 50.0 | (010) | 120 | 120 | 180 | 180 |
| 17.4 – 25.0 | (015) | 132 | 132 | 198 | 198 |
| 15.9 – 17.4 | (020) | 146 | 146 | 218 | 218 |
| 14.6 – 15.9 | (025) | 158 | 158 | 237 | 237 |
| 13.3 – 14.6 | (030) | 174 | 164 | 260 | 255 |
| 12.0 – 13.3 | (035) | 191 | 170 | 286 | 260 |
| 11.0 – 12.0 | (040) | 209 | 176 | 314 | 264 |
| 10.0 – 11.0 | (045) | 229 | 185 | 344 | 279 |
| 9.1 – 10.0 | (050) | 251 | 193 | 376 | 293 |
| 8.3 -- 9.1 | (055) | 275 | 206 | 412 | 309 |
| 7.6 -- 8.3 | (060) | 302 | 217 | 452 | 325 |
| 6.9 -- 7.6 | (065) | 331 | 228 | 496 | 342 |
| 6.4 -- 6.9 | (070) | 363 | 240 | 544 | 359 |
| 5.8 -- 6.4 | (075) | 398 | 251 | 596 | 375 |
| 5.2 -- 5.8 | (080) | 437 | 262 | 656 | 394 |
| 4.8 -- 5.2 | (085) | 479 | 273 | 718 | 409 |
| 4.4 -- 4.8 | (090) | 525 | 284 | 786 | 424 |
| 4.0 -- 4.4 | (095) | 575 | 288 | 862 | 431 |
| 3.6 -- 4.0 | (100) | 631 | 316 | 946 | 473 |
| 3.3 -- 3.6 | (105) | 692 | 346 | 1038 | 519 |
| 3.0 -- 3.3 | (110) | 759 | 379 | 1138 | 569 |
| 2.6 -- 3.0 | (115) | 832 | 416 | 1248 | 624 |
| 2.2 -- 2.6 | (120) | 912 | 456 | 1368 | 684 |

* Low Pressure Distribution ** Figures in parenthesis are for Standard Perk Test (min/in) from regulations

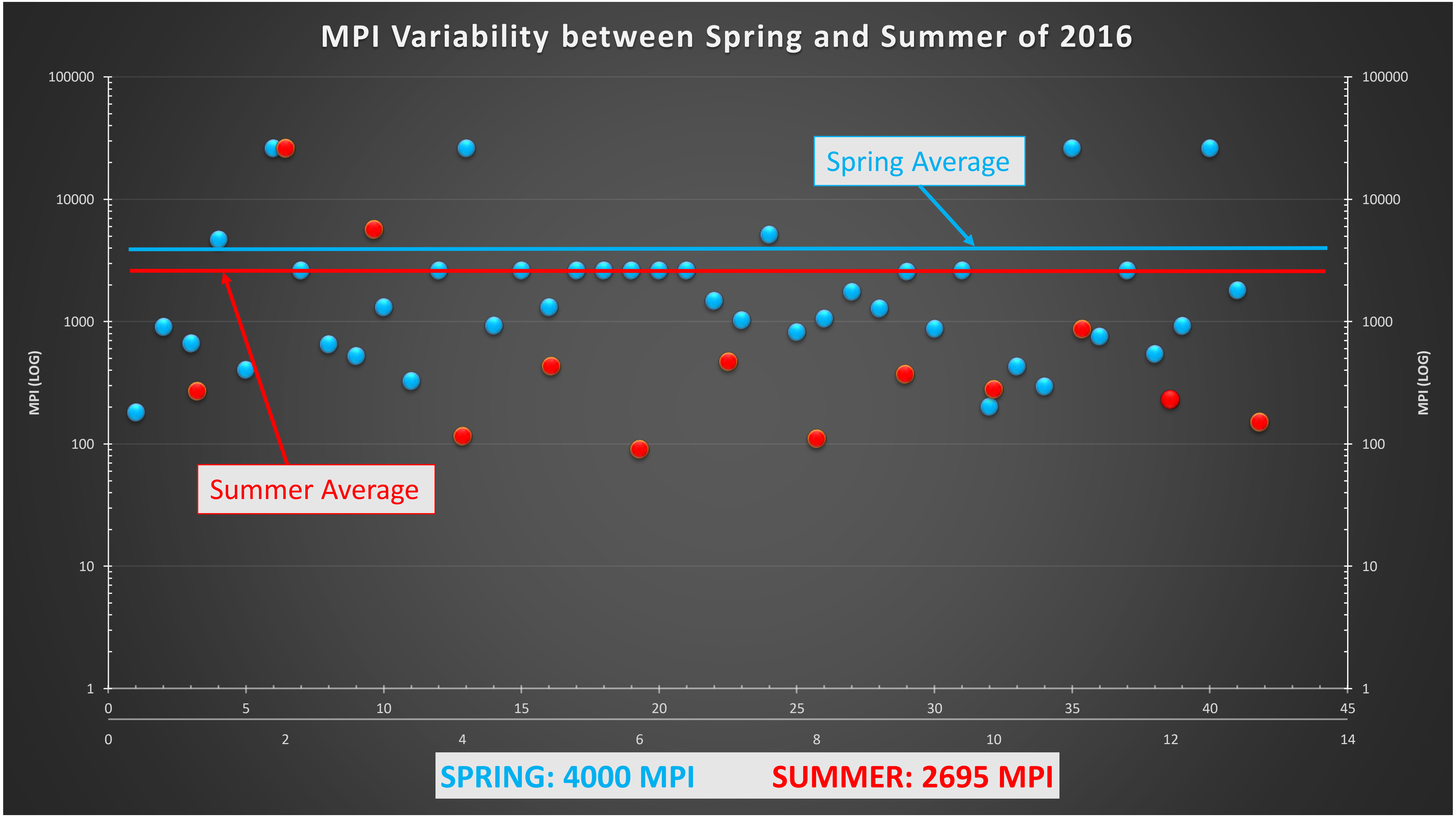
Proposed Changes to the Sewage Handling and Disposal Regulations, May 1989, page 64
**(DRAFT PROPOSAL – MAY 2, 1997)**

Developed from field test and observations over a 5 year period by Carl D. Peacock, Jr., Research Associate and Eastern Virginia Interpretative Soil Scientist

# Ksat testing of the Btss horizons of Jackland soil

Spring 2016 testing

Summer 2016 testing

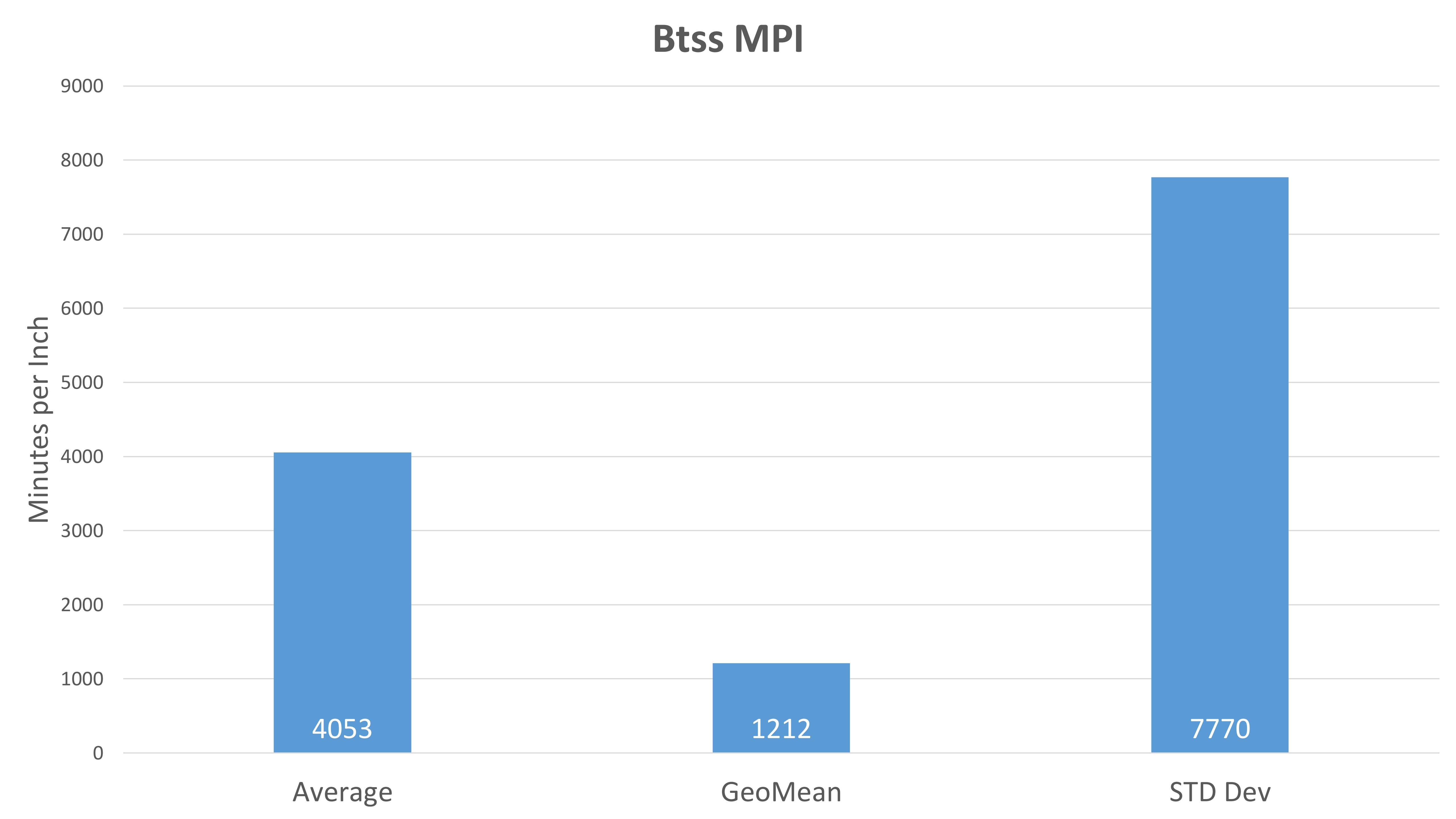

MPI Variability between Spring and Summer of 2016
Spring Average
Summer Average
MPI (LOG)
100000
10000
1000
100
10
1
0
5
10
15
20
25
30
35
40
45
0
2
4
6
8
10
12
14
SPRING: 4000 MPI
SUMMER: 2695 MPI

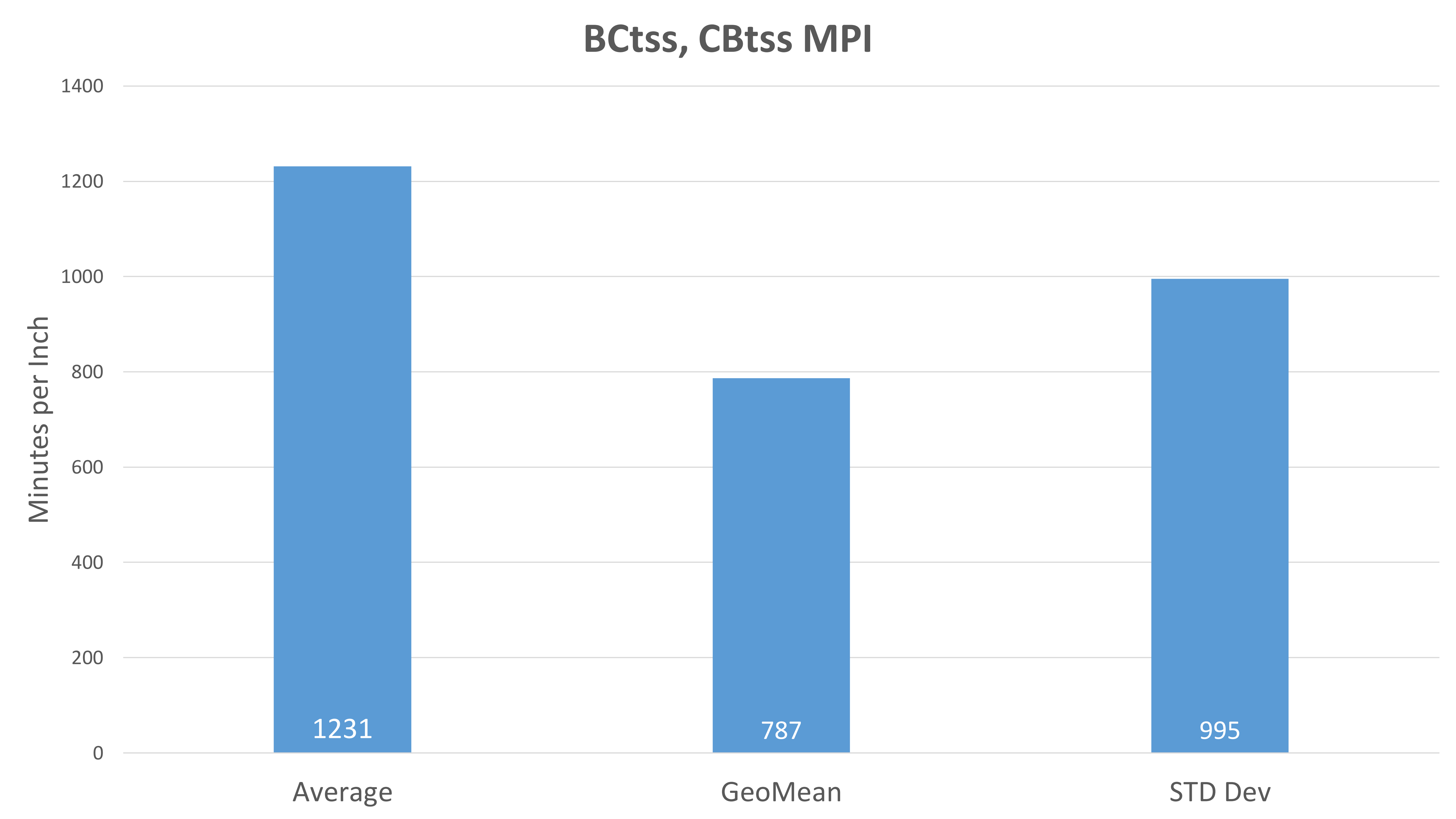
# All “ss” Horizons

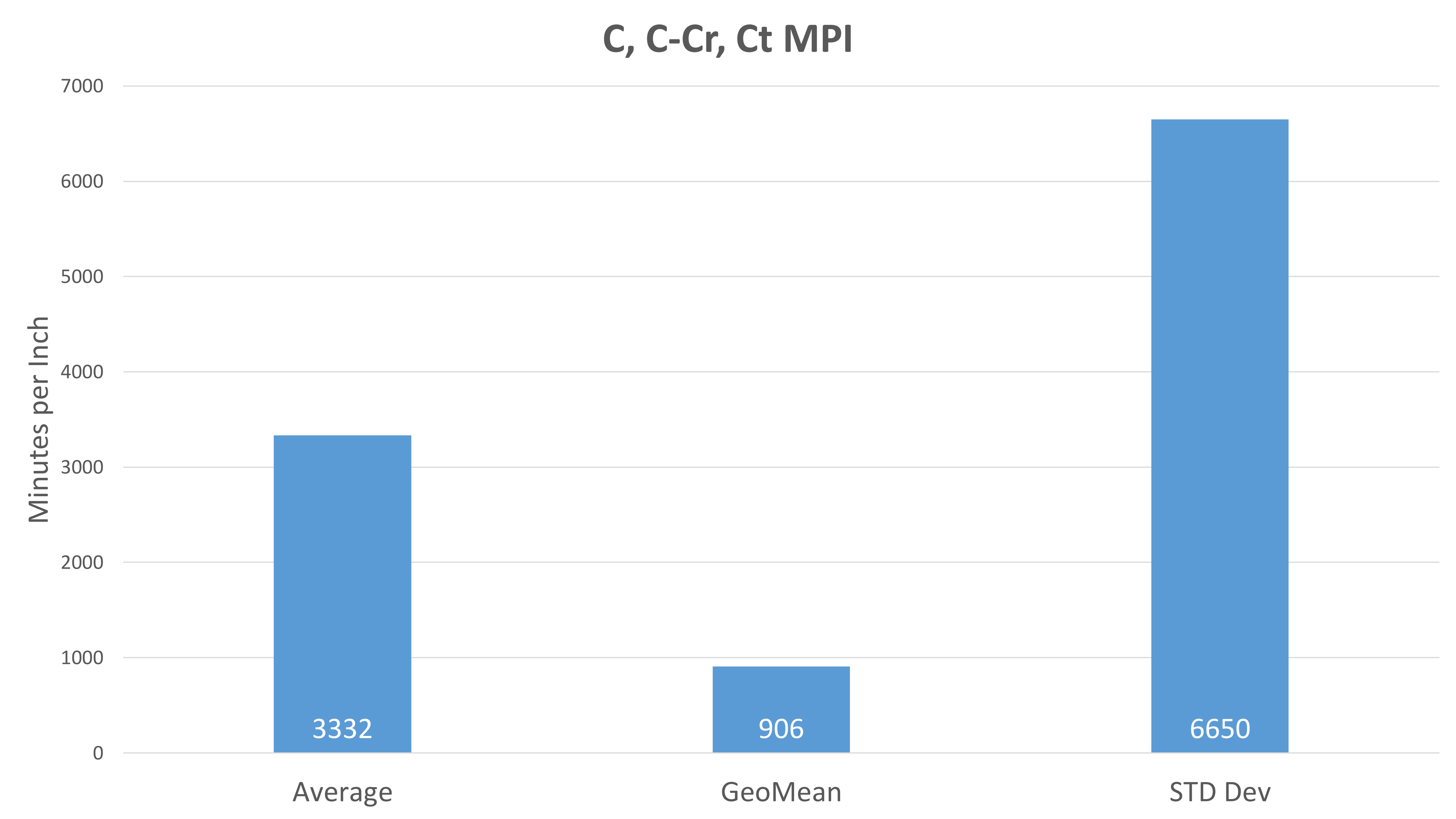
| | MPI | Depth (in.) | Duration (min.) |
|---|---|---|---|
| Average | 3680 | 22.65 | 181 |
| Count | 53 | 53 | 53 |
| GeoMean | 1144.86 | 21.66 | 163.70 |
| Median | 920 | 22 | 165 |

# Btss Horizons

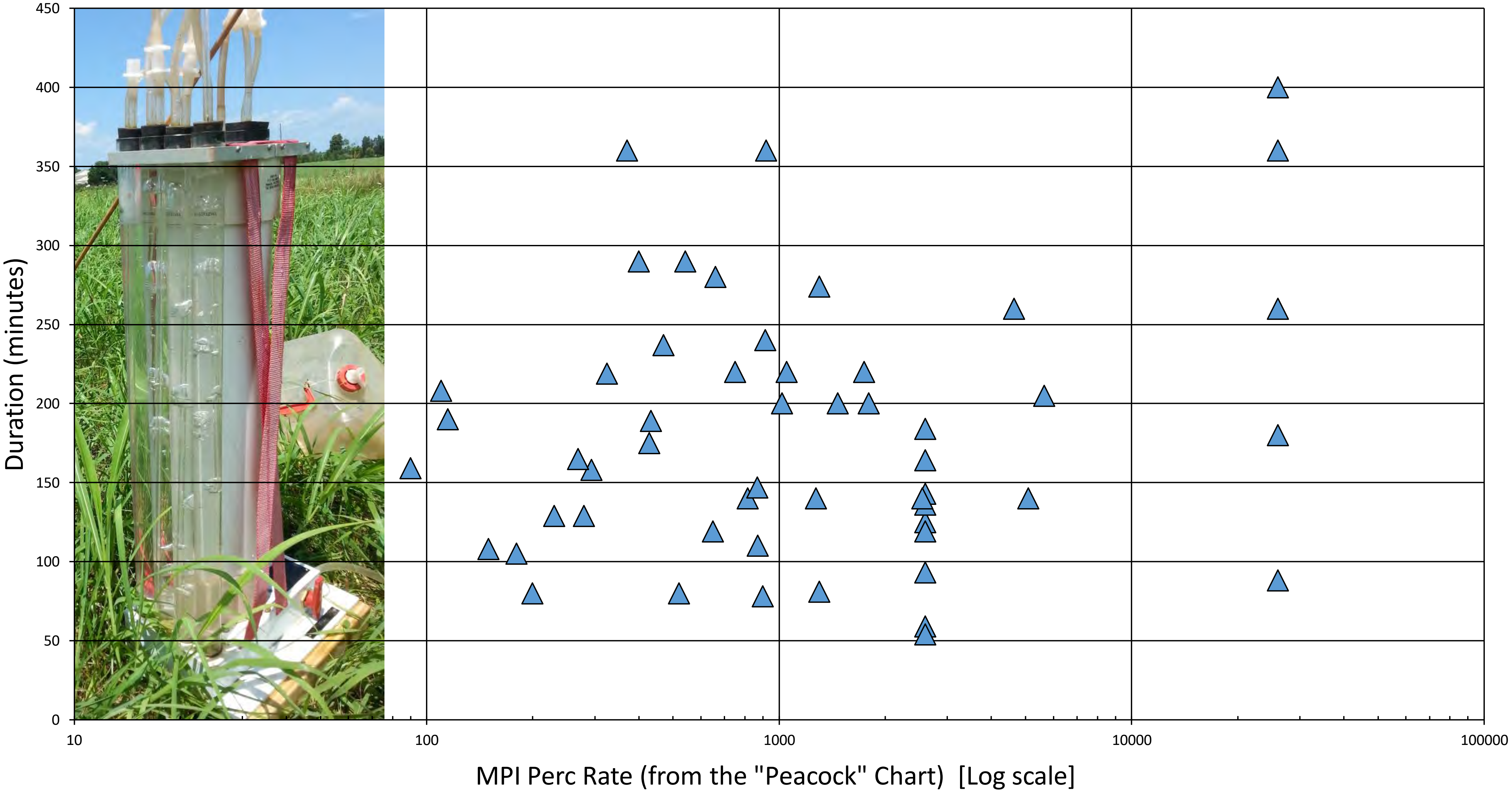
| | MPI | Depth (in.) | Duration (min.) |
|---|---|---|---|
| Average | 4053 | 21.03 | 190 |
| Count | 46 | 46 | 46 |
| GeoMean | 1212 | 20.4 | 174.3 |
| Median | 970 | 20.25 | 177.5 |


Btss MPI
Minutes per Inch
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
4053
1212
7770
Average
GeoMean
STD Dev

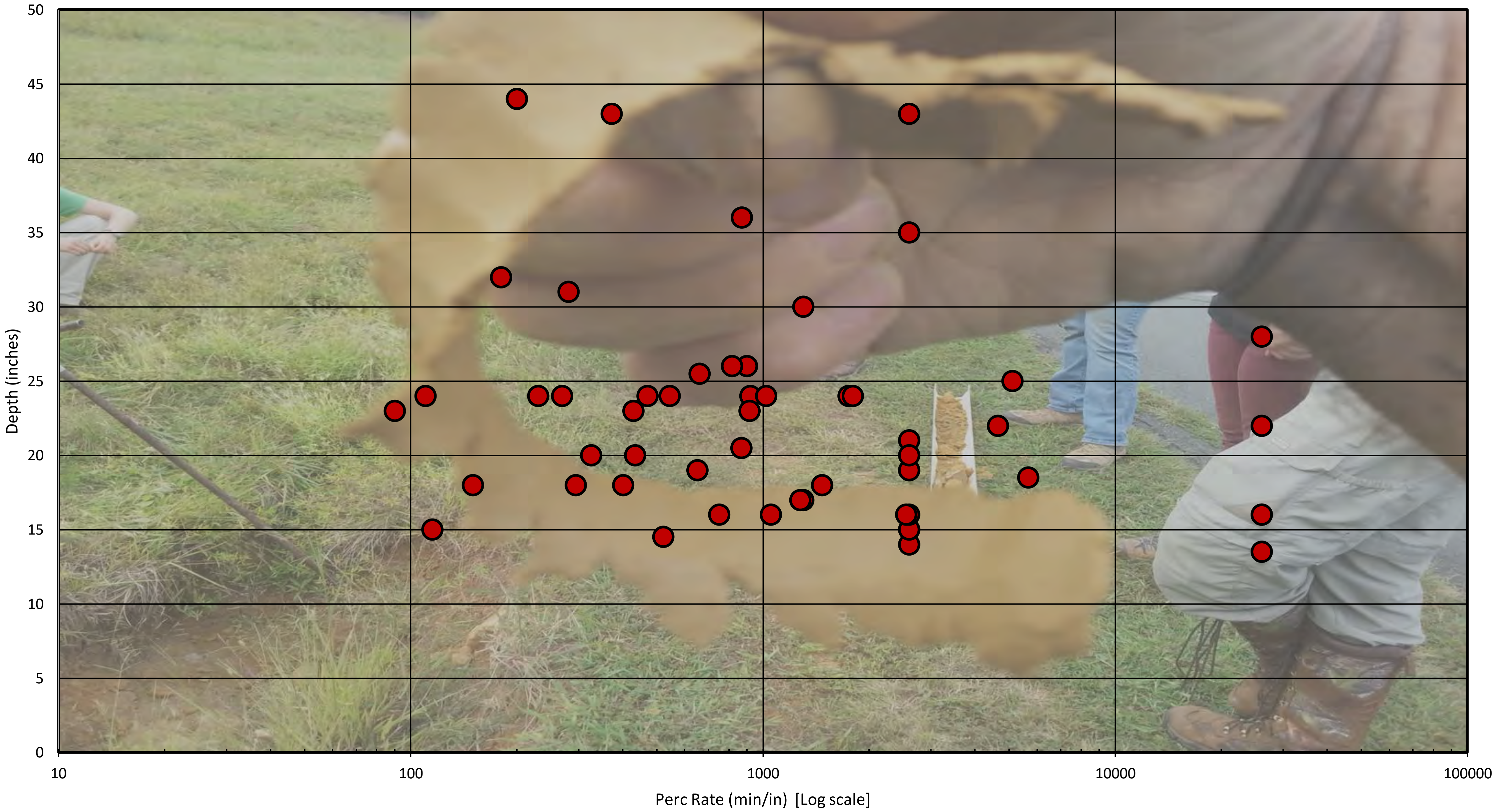

BCtss, CBtss MPI
Minutes per Inch
1400
1200
1000
800
600
400
200
0
1231
787
995
Average
GeoMean
STD Dev


C, C-Cr, Ct MPI
Minutes per Inch
7000
6000
5000
4000
3000
2000
1000
0
3332
906
6650
Average
GeoMean
STD Dev

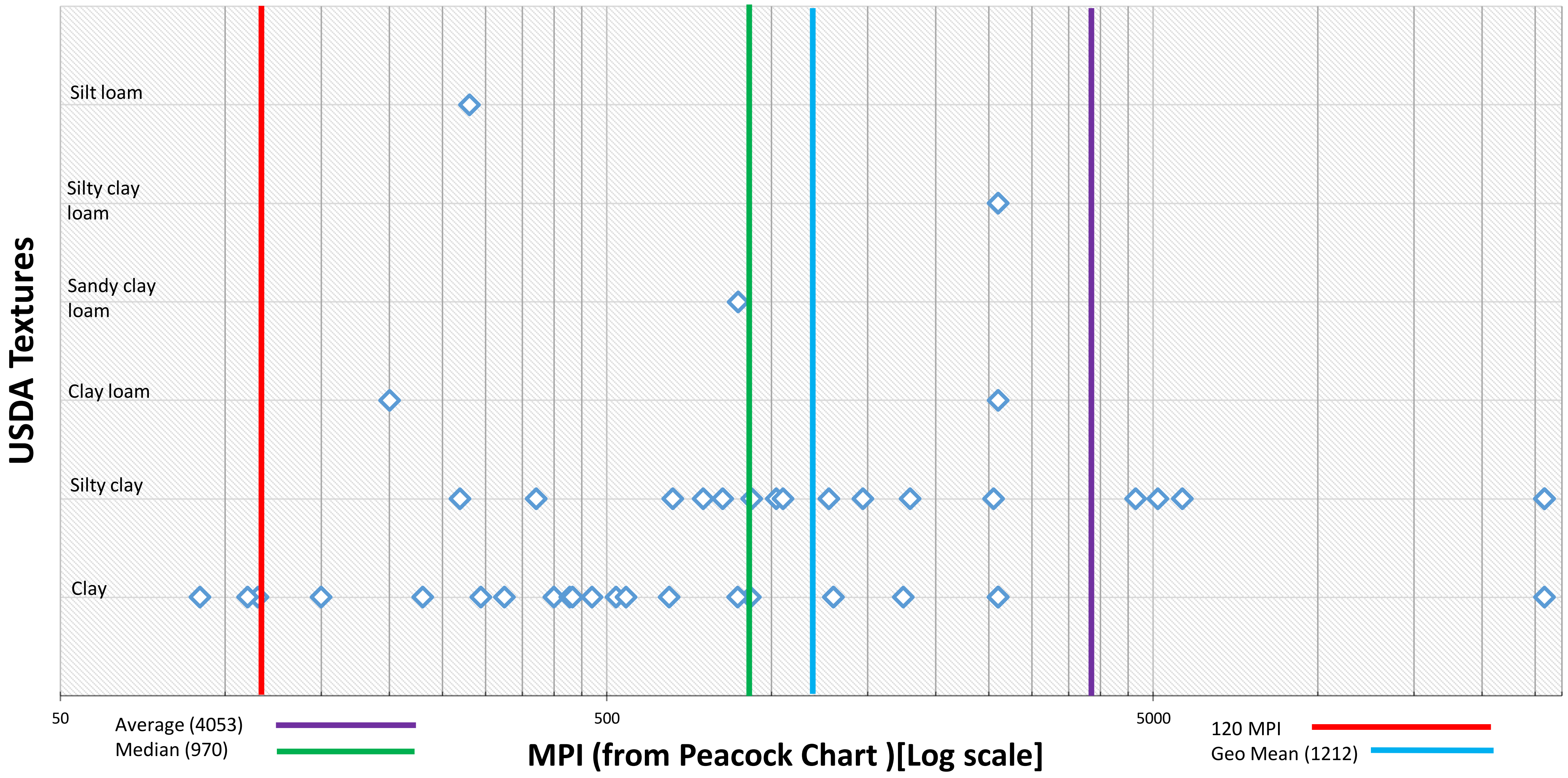
# MPI vs. Duration of Test



# Depth of test vs. Ksat



# “ss” Horizon Textures and Perc Rate (MPI)



# Btss Horizon Research Results

- For the 46 tests run on Btss horizons, results were:
  - Average perc rate was 4053 mpi
  - Geometric mean was 1212 mpi

  - Average Ksat rate was 0.220 cm/day
  - Geometric mean was  0.572 cm/day

  - Standard deviation was very large due to the extremely wide range in Ksat rates

# Research Results

- C and Ct horizon textures included: SL, L, SCL, SiL, SiCL, C
- C horizon perc rates ranged from 90 - 26,000 mpi
- A single test result in a Sandy Loam C Horizon was 90 mpi

(The only passing rate in Saprolite testing)

So…
Based on the results of sandy loam C horizon Ksat testing…

"Jack-sands" are unsuitable for use as onsite system dispersal

# Research Results

- Saprolites were Mafic and contained many black Mn stains and nodules
- Saprolites contained lithochromic colors of Dark Greenish Gray (5G 4/1) and Greenish Gray (10G 5/1) from Hornblende Gneiss
- This study is consistent with prior research indicating minor Mafic influence results in saprolite perc rates much slower than soil texture would predict

# Research Conclusions

- 94% of Btss horizons had a rate >120 mpi
- Geometric mean of Btss horizons was 1212 mpi (0.572 cm/d)
- Of the 13 C-horizons tested, only the SL had a passing perc rate (of 90 mpi)
- The slightest Mafic influence in saprolite results in extremely slow perc rates

# Research Conclusions

- Shrink-swell horizons are considered Permeability Limiting Features
- Nearly level sites with shrink-swell horizons will result in significant water mounding above the dispersal point due to extremely limited permeability
- Only on strongly sloping sites might there be sufficient hydraulic gradient to limit water mounding impacts

# What to do between Ksat readings

References:

VDH Sewage Handling and Disposal Regulations
VDH Regulations for Alternative Onsite Sewage Systems
Unpublished data from Shrink-swell Soil Saturated Hydraulic Conductivity Study
USDA NRCS Field Guide for Describing and Sampling Soils, Version 3.0

# Questions?

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