Predicting TDS Release from Overburden

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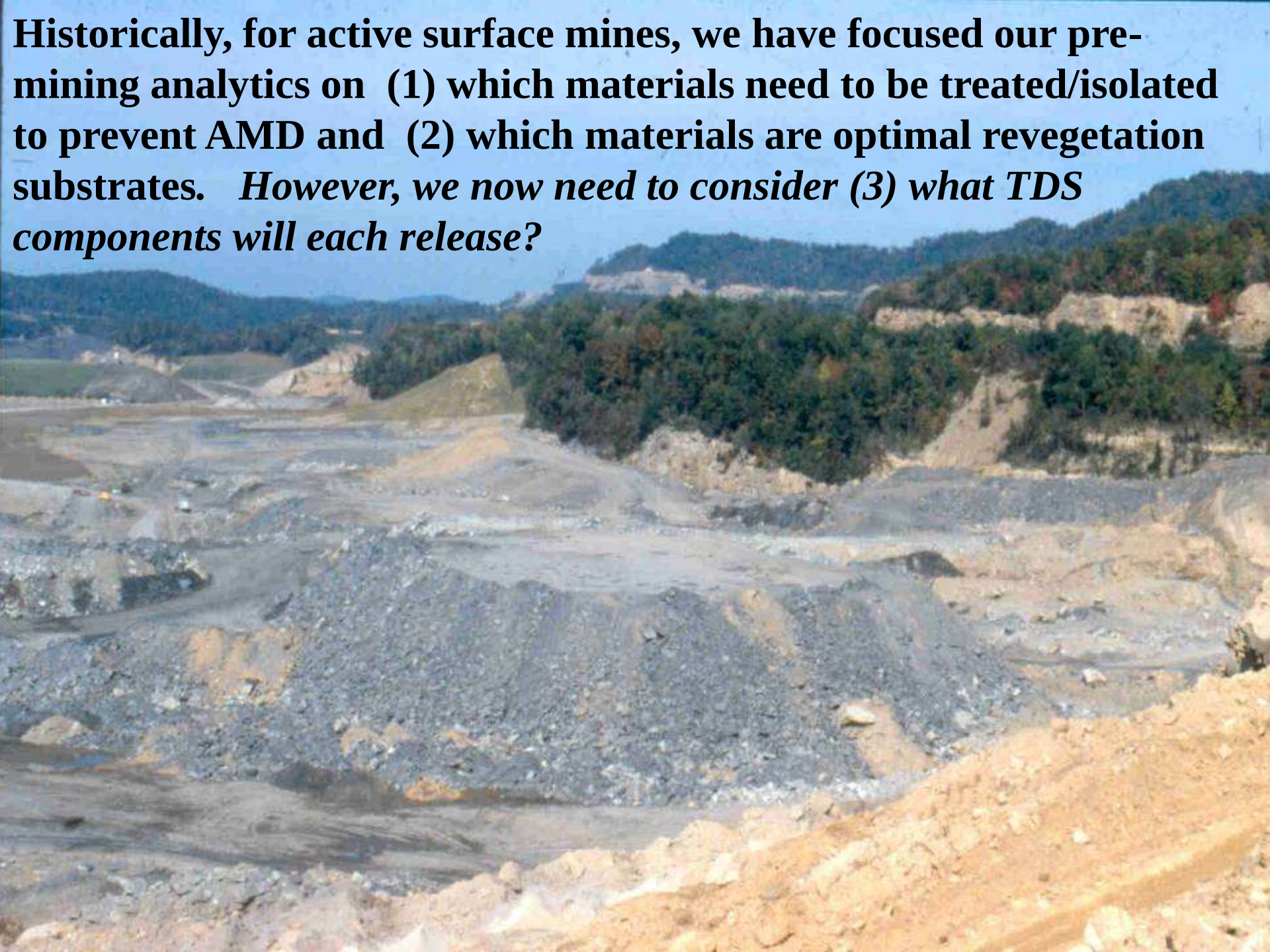


Historically, for active surface mines, we have focused our pre-mining analytics on (1) which materials need to be treated/isolated to prevent AMD and (2) which materials are optimal revegetation substrates. ***However, we now need to consider (3) what TDS components will each release?***

Overall Objective

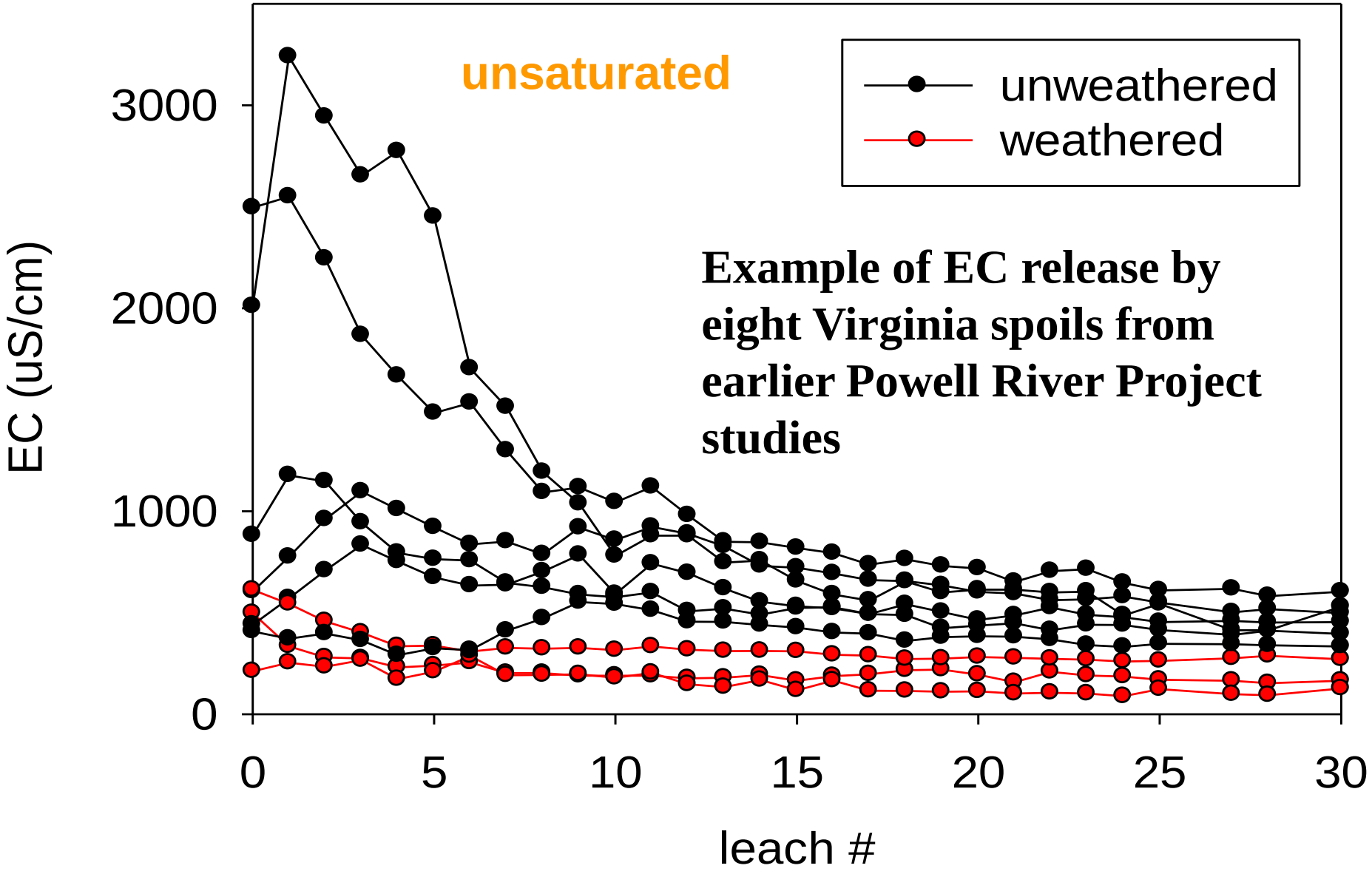
The primary objective of this overall research program is to develop new methods for characterizing and predicting constituent (TDS, Se and other elements of concern) release potentials from coal overburden and refuse materials.

These prediction methods must predict short-term peak discharges and long-term release characteristics and component ions.

Initial efforts are focused on spoils that would be disposed of in backfills and valley fills, but refuse materials will be analyzed in a later phase of the program.

MUDSTONE: weathered vs unweathered

8 samples



Additional & Related Objectives

To develop scaling factors to relate laboratory bench and column analyses to actual field leaching conditions.

To determine the field relationships among depth of weathering, soil/spoil colors, rock hardness and other factors related to TDS elution potential to optimize spoil segregation decisions.

Multiple Projects and Sponsors!

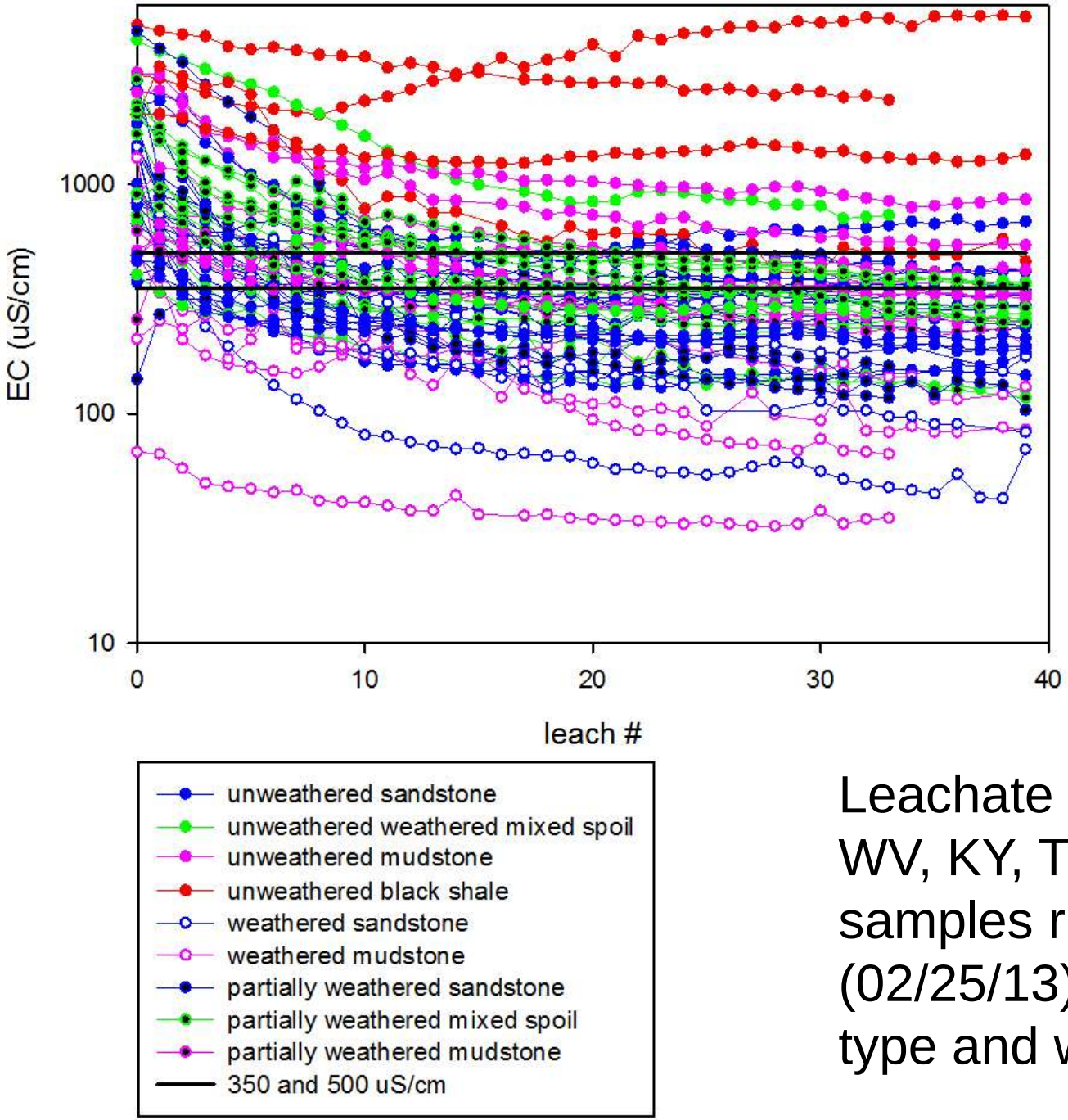
- **ARIES supports integrated TDS prediction studies for a wide suite (40+ spoils) of regional overburden materials. Our project is joint with UK and WVU.**
- **Powell River Project supported original leaching studies (to 2011) and currently supports spoil weathering x depth profiles.**
- **OSM is funding TDS similar prediction studies for TN spoils and refuse materials.**

- Each sample run in triplicate under unsaturated conditions (3 columns per sample) with simulated rain.
- Whole spoil crushed & screened to < 0.5 inch.
- Typically run for minimum of 20 weeks (40 cycles) with 2 x 2.5 cm of rain per week (1 cycle = 2.5 cm)

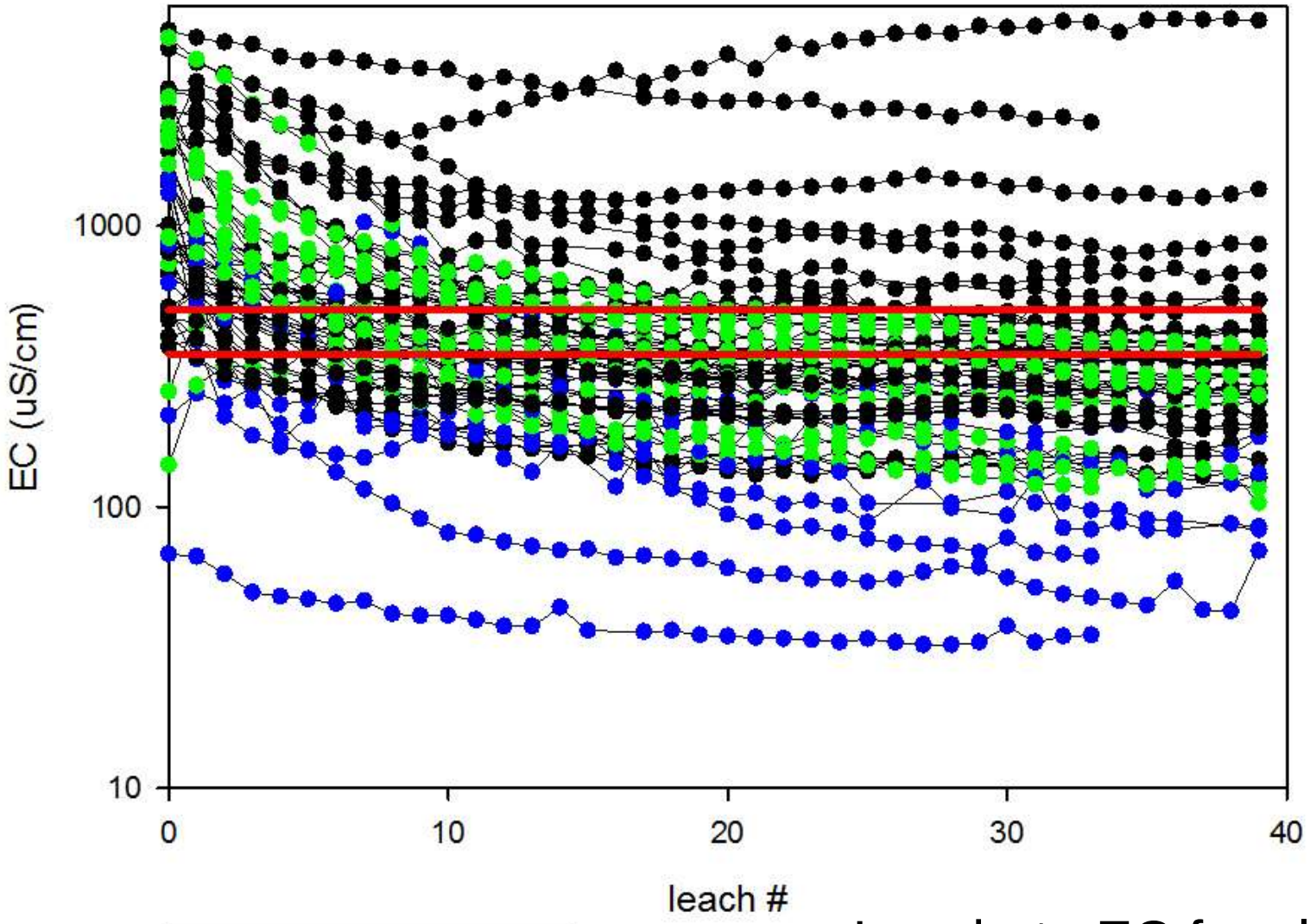
Expanded Column Leaching Work with ARIES

Over the past two years we have collaborated with the Virginia Center for Coal and Energy Research and major regional coal producers (Alpha, Arch, Patriot, TECO and others) in the development of a large multi-state research consortium, as the Appalachian Research Initiative for Environmental Science (ARIES; http://www.energy.vt.edu/ARIES).

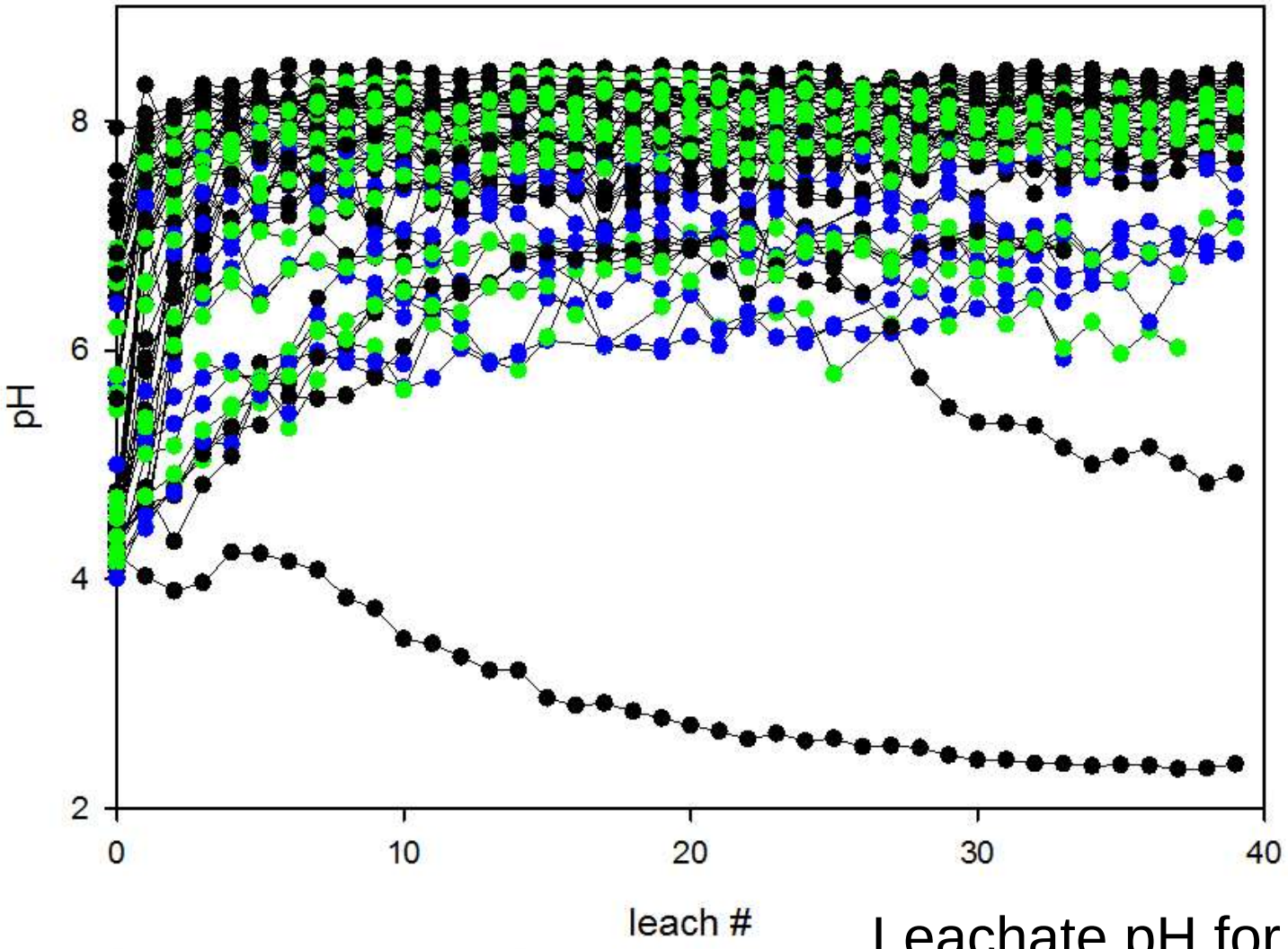
Our TDS prediction research program was expanded greatly (with ARIES funding) to include significant cooperation with the University of Kentucky (UK - Richard Warner and Chris Barton) and West Virginia University (WVU - Jeff Skousen and Louis McDonald). The expanded program involves a *much* larger sample set and much more detailed regional analyses than were capable of addressing with original PRP funding.



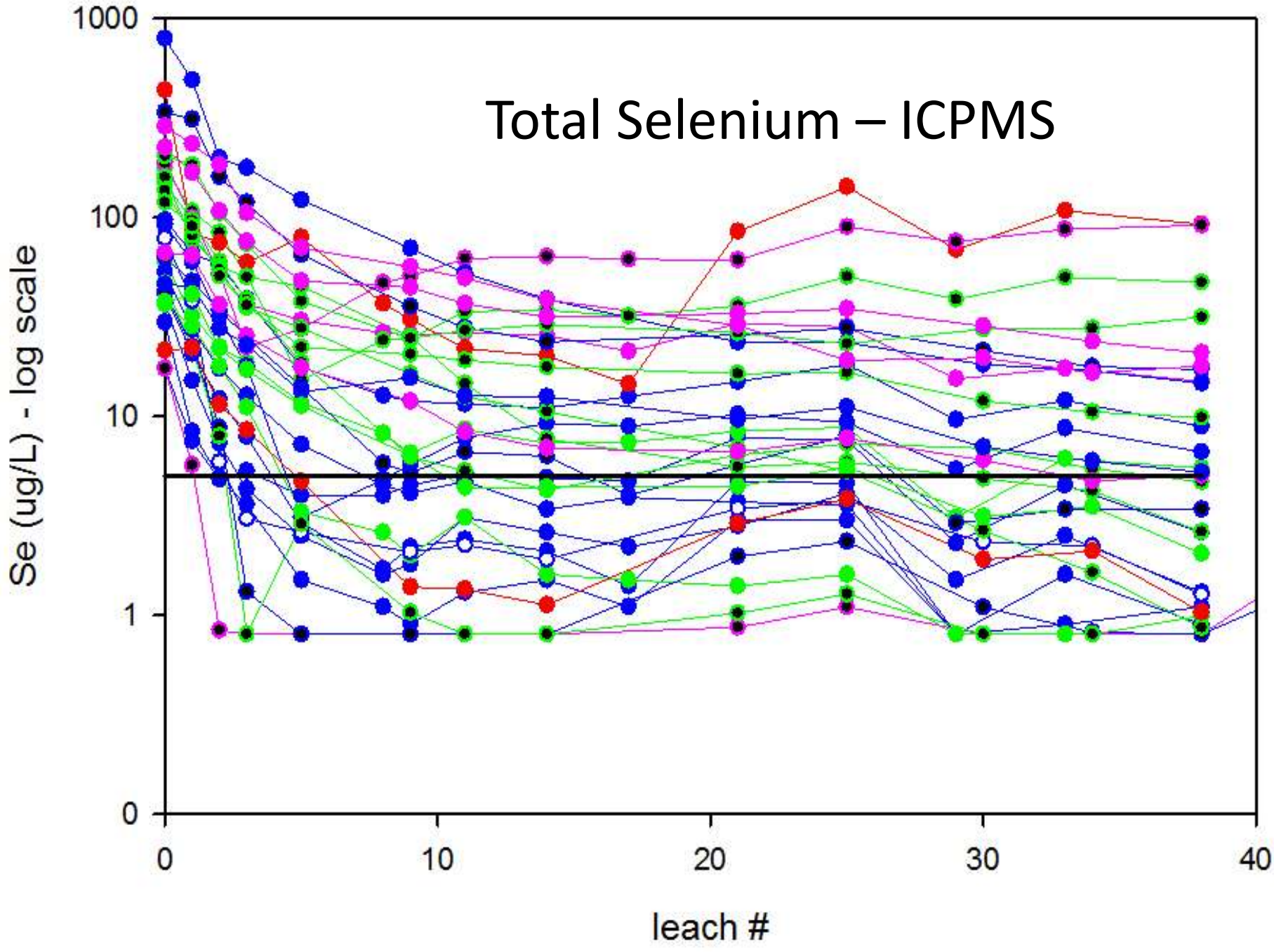
Leachate EC for all VA, WV, KY, TN, and T2 samples run to date (02/25/13); coded by rock type and weathering.

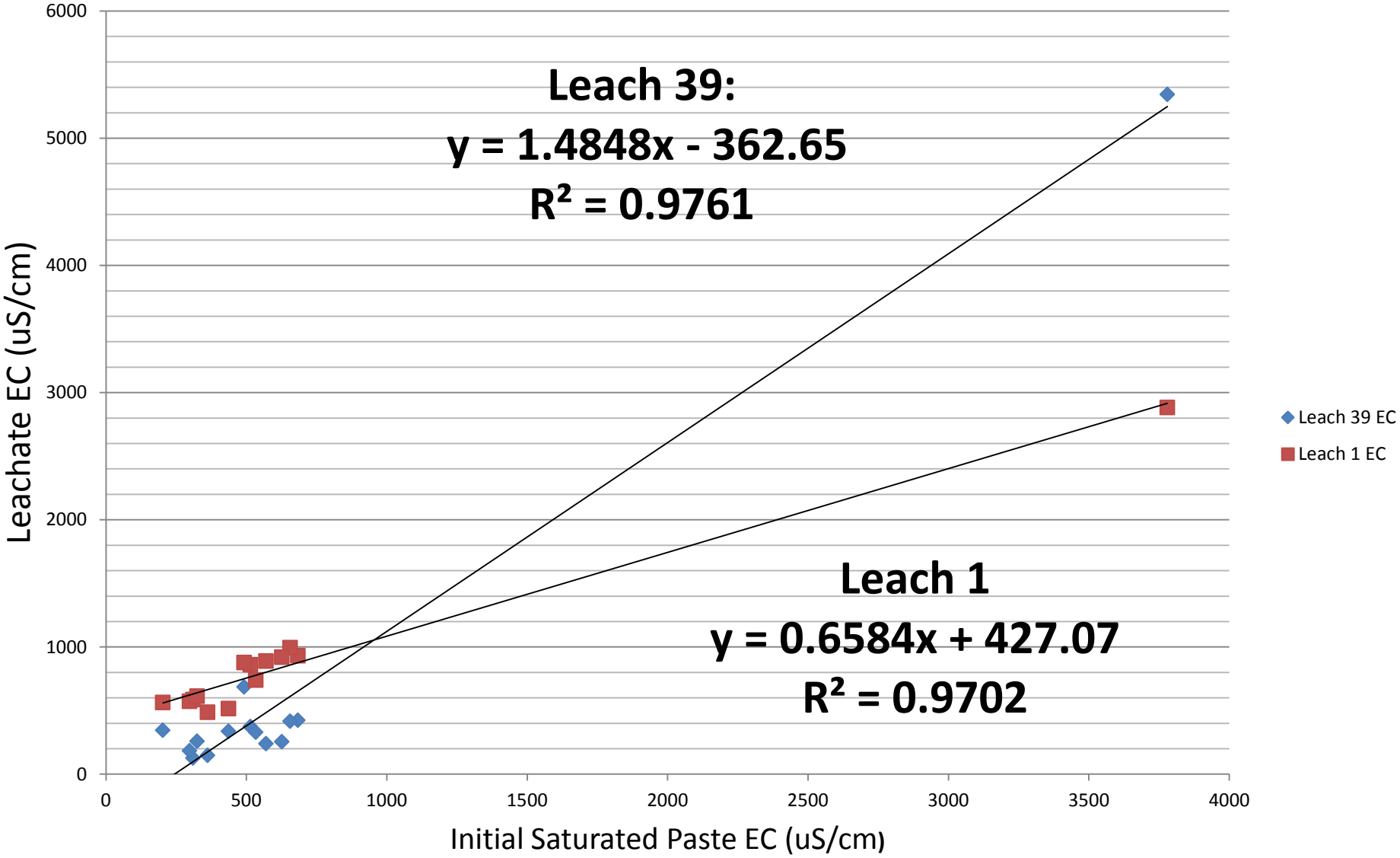


Leachate EC for all VA, WV, KY, TN, and T2 samples run to date (02/12/13): coded by weathering.

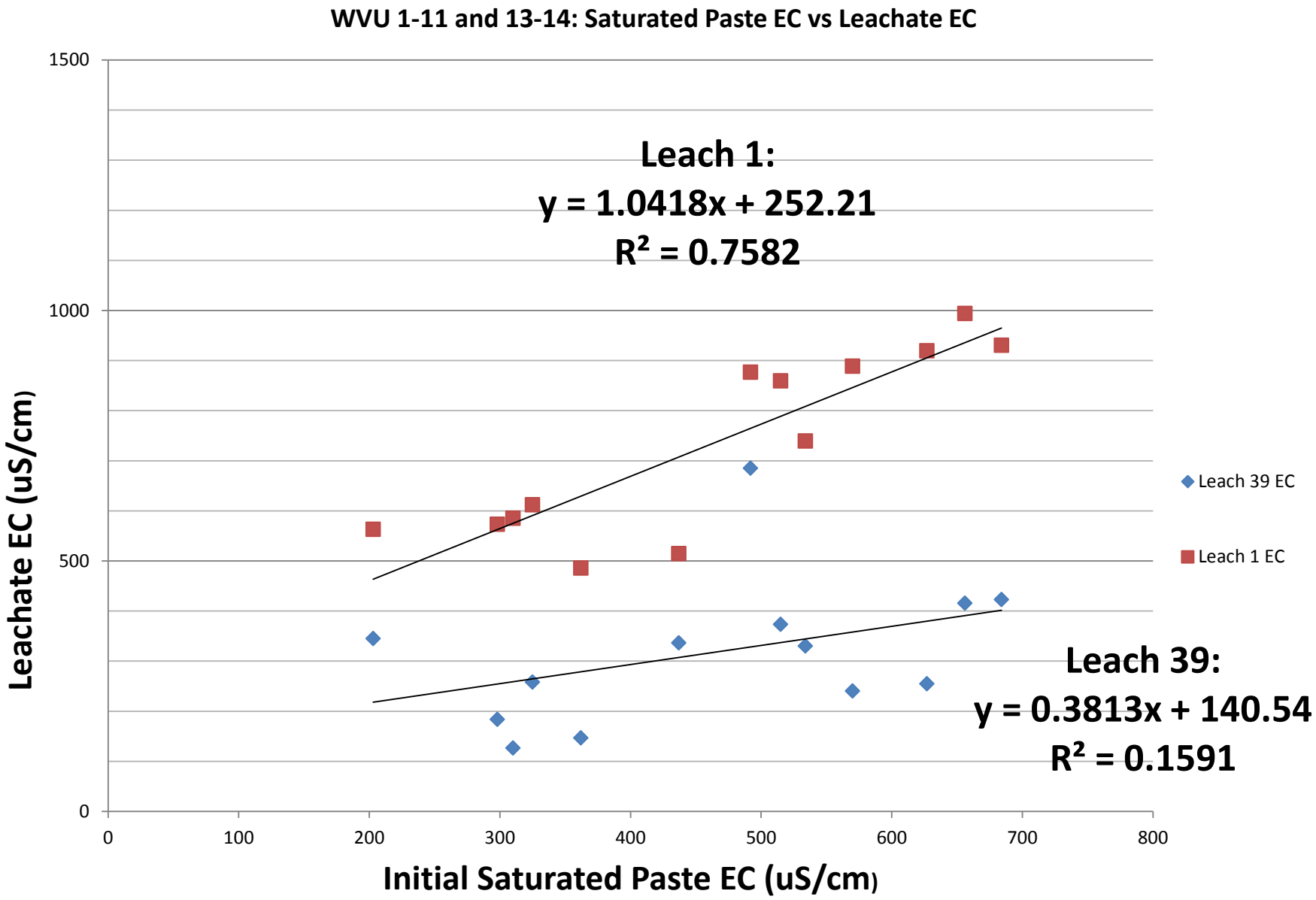


Leachate pH for all VA, WV, KY, TN, and T2 samples run to date (02/12/13): coded by weathering.


Total Selenium – ICPMS
1000
100
10
1
0
Se (ug/L) - log scale
0
10
20
30
40
leach #



Question: can we use initial water:spoil EC to predict initial (Leach 1) and/or long term (Leach 39) EC? Looks good here?



Same regressions with high concentration outliers removed!
Still looks good for initial; but not for long term?

Field Weathering x Depth Study – Powell River Project 2011 to 2014

A range of weathering x depth samples is being collected from the dominant coal bearing formations of the Pottsville Group throughout SW Virginia and Kentucky.

Sampling locations are chosen where a clear association between the surface weathered soil horizons and underlying partially weathered rock horizons can be confirmed and the materials are accessible.

Ideally, we will sample 3 to 4 replicate sequences from each of the 10 primary locations to offer some level of replication and to allow for study of variance within local strata. For the purpose of this study, a "location" is comprised of similar soil to overburden weathering sequences within several hundred meters of one another.

To date, we have sampled over 14 different sequences at five different mine locations.

Figure 1 – An example profile illustrating the sampling scheme. Each distinct layer (red arrows) is collected and described. Special notice of the boundary between brown and gray materials (yellow box) is also taken, in an effort to better characterize the transition between these materials. Of the 14 samples to date, this boundary is tight shale layer ~ 50% of the time.

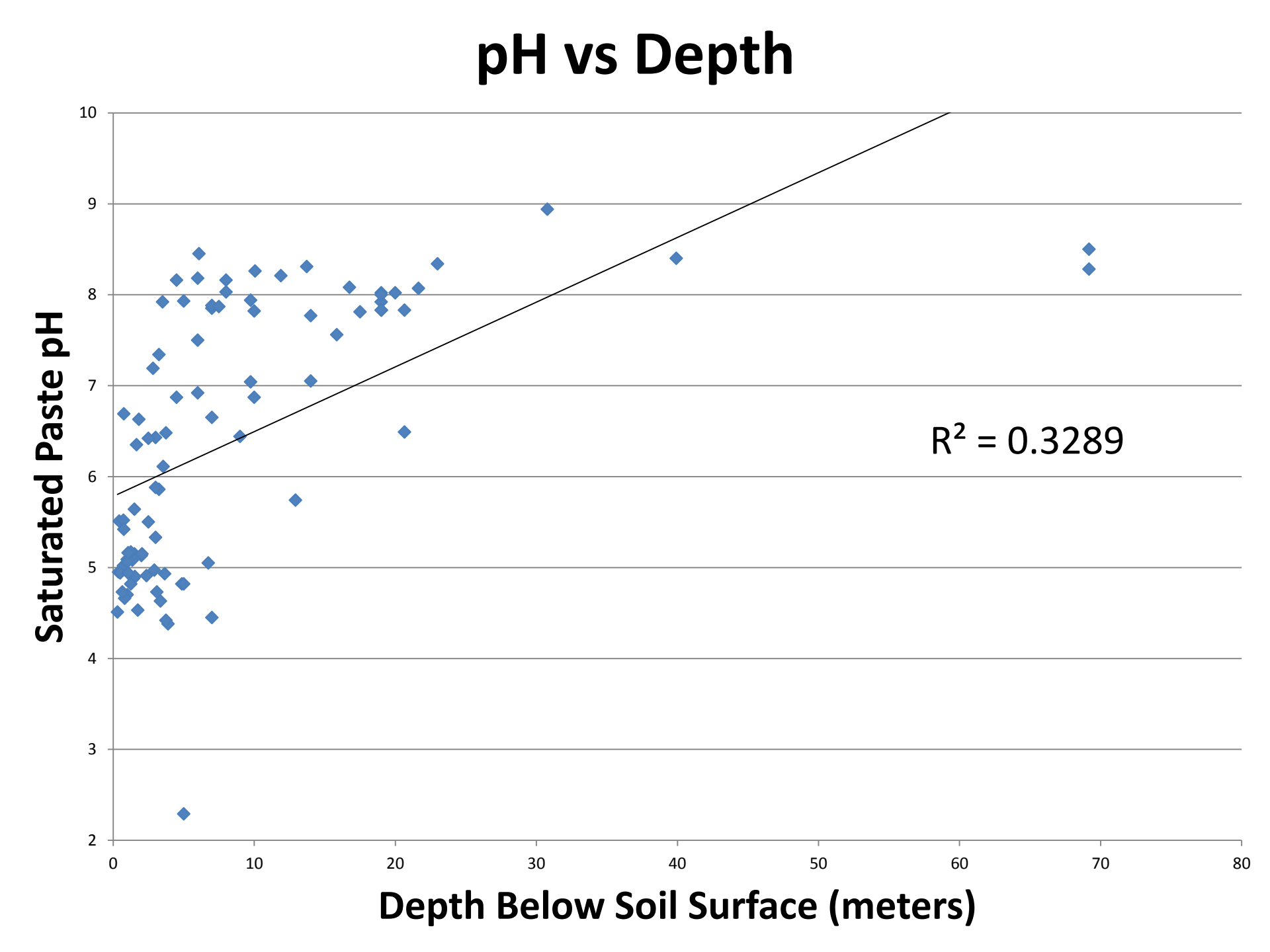
Field Weathering x Depth Study

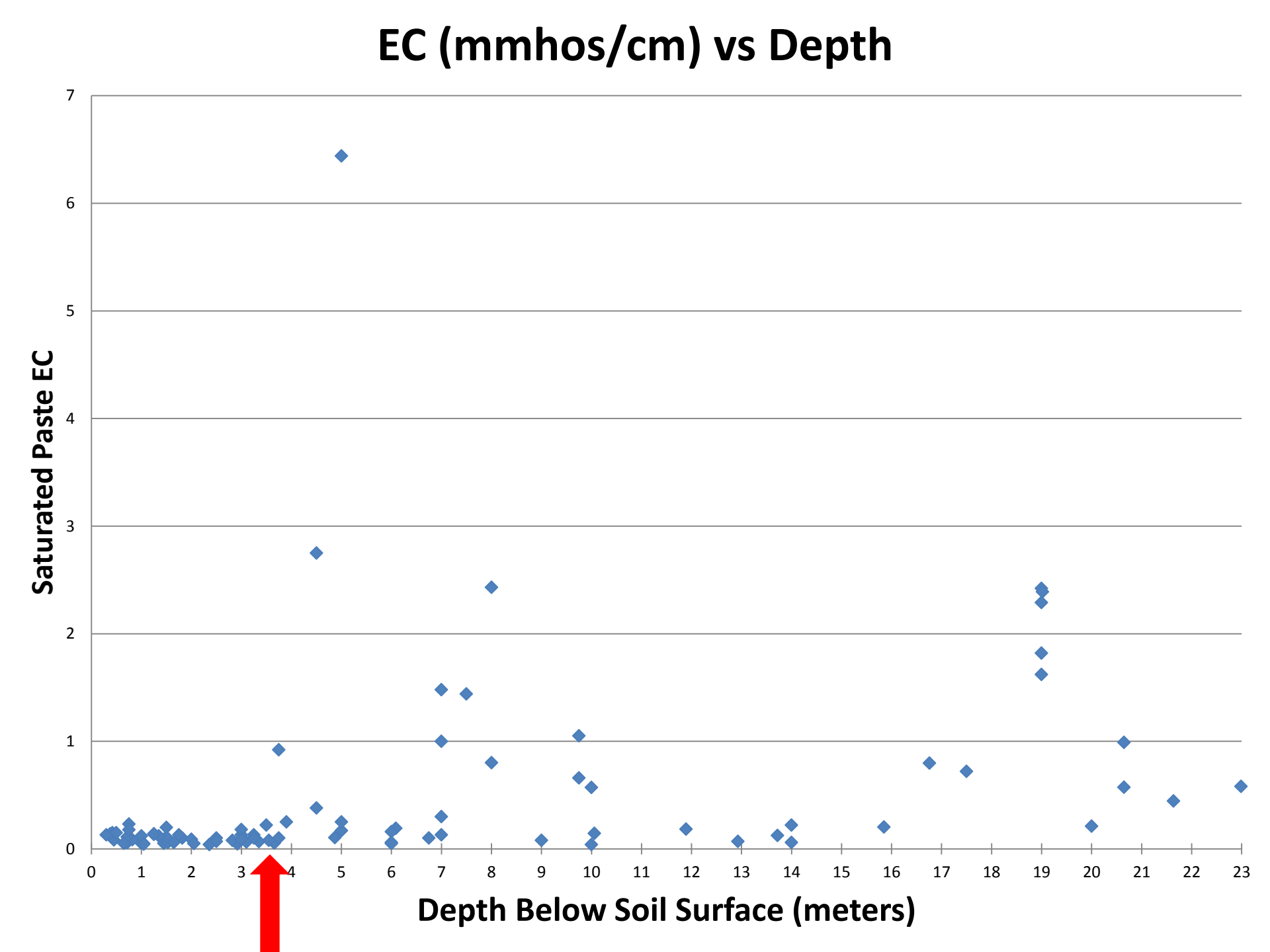
All samples are being be analyzed for the following parameters:

- **Saturated paste electrical conductance (EC) and pH**
- **Saturated paste EC and pH following hydrogen peroxide oxidation**
- **Exchangeable cations**
- **Dilute acid extractable nutrients and metals**
- **Extractable Fe and Mn oxides**
- **Total-S and S-forms if S $\geq$ 0.2%**
- **Calcium carbonate equivalence**
- **% Rock fragments**
- **Particle size analysis**

Note: *EC unit used here is mmhos/cm = 1000 µs/cm*

Depth (m)	Name	Rock Type	Hue	Value	Chroma	pH	EC
.25	A	None	7.5YR	2.5	1	4.10	0.279
1.00	Bt	Sandstone	7.5YR	5	6	4.70	0.062
1.45	Bt	Siltstone	5YR	5	6	4.88	0 .051
2.36	Bt	None	5YR	5	8	4.91	0 .040
2.92	Bt	None	7.5YR	7	1	4.97	0 .045
3.10	C	Soft Coal	7.5YR	2	1	4.73	0 .063
3.35	C	Soft Coal	10YR	2	1	4.63	0 .068
3.66	Cr	Siltstone	10YR	5	4	4.93	0.053
4.87	Cr	Siltstone	10YR	5	6	4.82	0.104
6.09	R	Sandstone	10YR	4	6	8.45	0.192
10.06	R	Sandstone	10YR	4	3	8.26	0.144
11.89	R	Sandstone	10YR	5	1	8.21	0.183
13.72	R	Sandstone	10YR	5	6	8.31	0.124
15.85	R	Sandstone	10YR	4	2	7.56	0.204
16.76	R	Shale	10YR	3	1	8.08	0.796
21.64	R	Sandstone	10YR	4	1	8.07	0.445
30.78	R	Sandstone	10YR	3	1	8.94	0.643
39.93	R	SS w Shale	10YR	4	1	8.40	0.483
69.19	R	Shale	10YR	3	1	8.28	0.640

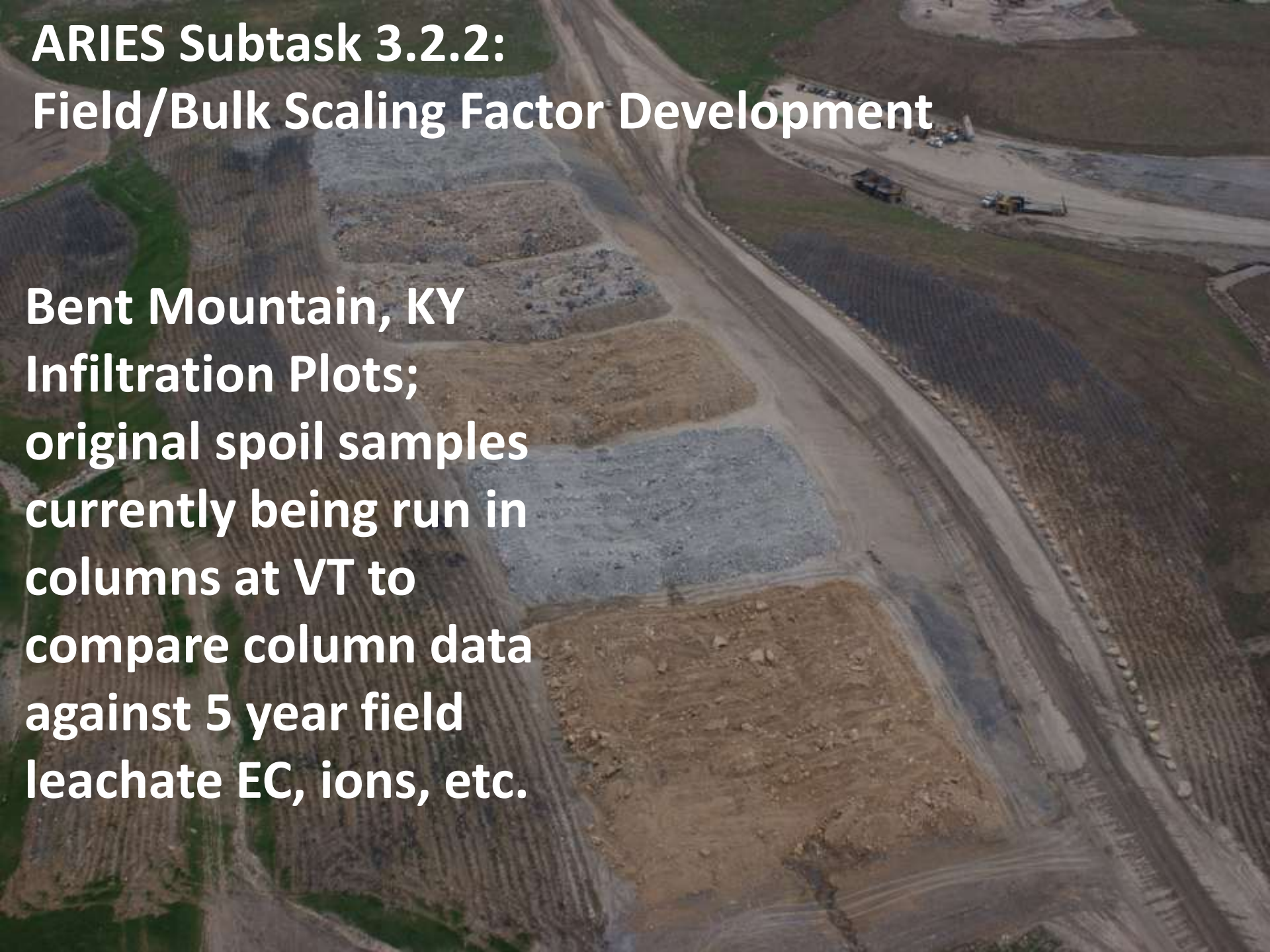

pH vs Depth
Saturated Paste pH
Depth Below Soil Surface (meters)
R² = 0.3289
10
9
8
7
6
5
4
3
2
0
10
20
30
40
50
60
70
80


EC (mmhos/cm) vs Depth
Saturated Paste EC
0
1
2
3
4
5
6
7
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
Depth Below Soil Surface (meters)

Scaling Issues and Studies

- **Leaching columns *may* generate reliable predictor of TDS leaching potentials over time, but do they accurately estimate maximum short term and equilibrium long-term concentrations?**

- **In general, we assume that column data are worse-case and need to be "scaled" to better resemble and predict field data.**



ARIES Subtask 3.2.2: Field/Bulk Scaling Factor Development

Bent Mountain, KY Infiltration Plots; original spoil samples currently being run in columns at VT to compare column data against 5 year field leachate EC, ions, etc.

Scaling Issues and Studies

- **For one scaling study, we are testing one common spoil (Harlan fm; raw saturated paste EC ~ 850) in columns, barrels and larger field scale mesocosms.**

- **In a second scaling study, we are comparing our column leaching data for the four UK samples with large field scale lysimeter data from the same spoils at Bent Mountain.**

Harlan fm Spoil Collection –Wise

Large leaching tanks (mesocosms) being placed at VT Turfgrass Research Center


Filter fabric was placed over drainage layer and then spoils placed in tanks.


Buried barrels beyond John's knees receive gravity leachate drainage from the mesocosms.

Raw spoil placed into mesocosms over filter fabric and 10 cm of acid washed gravel. Initiated in October of 2012 and will be continued through 2014?

Large mesocosms (here) supported by ARIES. OSM is also supporting smaller "barrels" on same site with same spoil (Harlan fm) and two coal refuse materials from TN. Mesocosms received spoils up to 18". Barrels received ≤ 5" screened spoils.

First sampling on a very cold day (12/26/12). OSM barrels to right; rainwater collection barrels for potential summer needs in back. Clay Ross and Sara Koropchak stand between ARIES mesocosms and buried collection barrels.

Preliminary Mesocosm Results

- **Limited fall precipitation; first leachates conveniently appeared on December 24.**
- **Initial "first flush" EC was ~ 2200 µs/cm; similar to lab columns where leaching rate was 1x (1") per month.**
- **Current EC is < 400 µs/cm ; will it rise again when spoils dry over summer?**
- **Barrels and mesocosms similar in EC.**

Summary Findings

- **TDS evolution will be directly related to the source strata and extent of historic weathering and oxidation. "Brown is *usually* better!"**
- **The vast majority of bulk spoils subjected to leaching column analysis exhibit high initial EC and Se levels which drop very quickly with leaching, but some materials do exhibit long term EC and SE leaching levels that would indicate they should be isolated away from surface and groundwater contact.**

Summary Findings

- **Maximum EC/TDS elution occurs in the first pore volume of leachates and then declines rapidly in almost all samples. Approximately 2/3 of the 45+ spoil samples tested to date equilibrate at < 500 µs/cm.**

- **Preliminary correlation type analyses indicate that saturated paste EC measurements may be reasonably accurate at predicting the initial maximum EC that can be expected from a given material, but do predict longer term equilibrium emissions very well.**

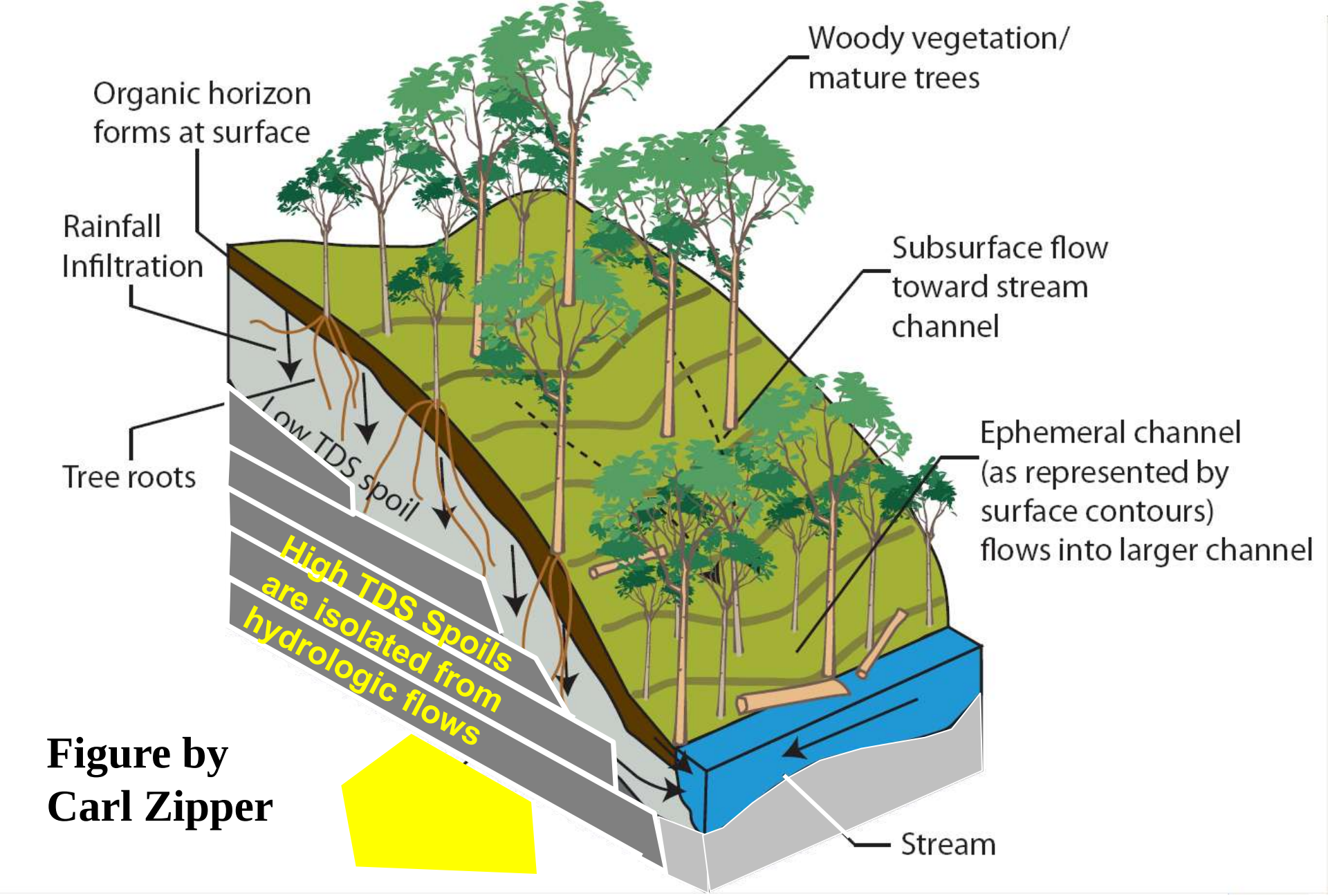


Figure by Carl Zipper

Mined Land, as envisioned: Forest and Hydrologic Restoration, Water Quality Protection. With agency encouragement, we would seek operational prototypes by industry.

Acknowledgments

- **Direct financial support by ARIES, Powell River Project and OSM Applied Research Program-Pittsburgh.**

- **Cooperative work with Jeff Skousen, Louis McDonald and Jessica Odenheimer at WVU and Carmen Agouridis, Chris Barton and Richard Warner at UK.**

- **There are simply way too many individuals and mining industry cooperators to list here. We deeply appreciate them all!**

ARIES Statement

- **A portion of the work reported today was sponsored by the Appalachian Research Initiative for Environmental Science (ARIES). ARIES is an industrial affiliates program at Virginia Tech, supported by members that include companies in the energy sector. The research under ARIES is conducted by independent researchers in accordance with the policies on scientific integrity of their institutions. The views, opinions and recommendations expressed herein are solely those of the authors and do not imply any endorsement by ARIES employees, other ARIES-affiliated researchers or industrial members. Information about ARIES can be found at http://www.energy.vt.edu/ARIES**