Comparison of field and laboratory low-pH Fe(II) oxidation rates

Presented by:

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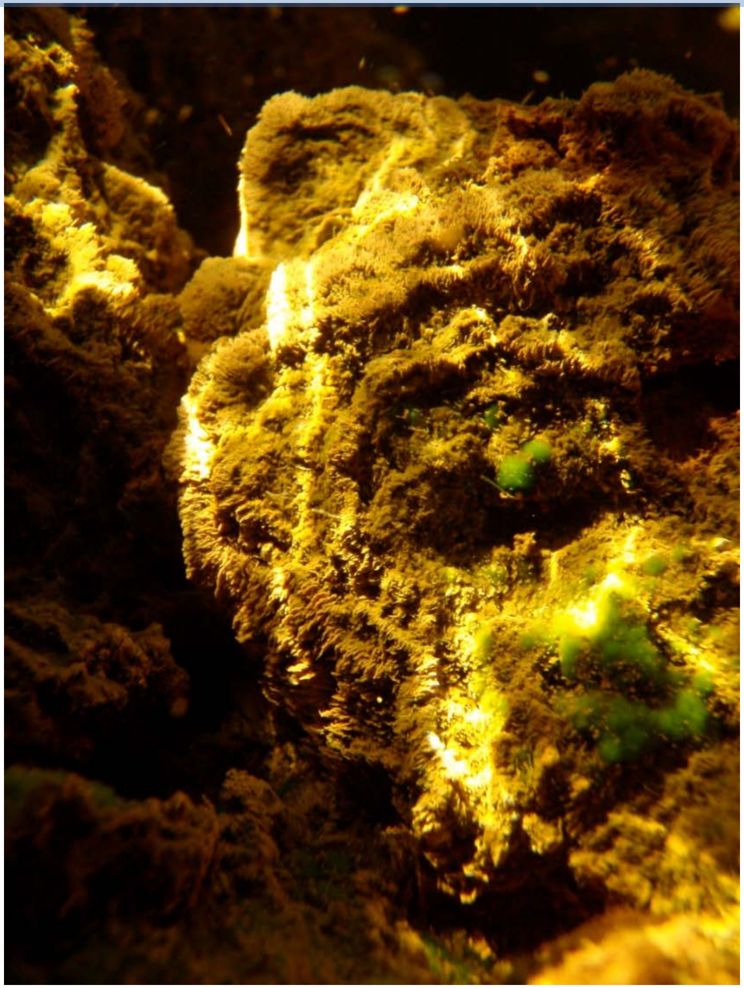
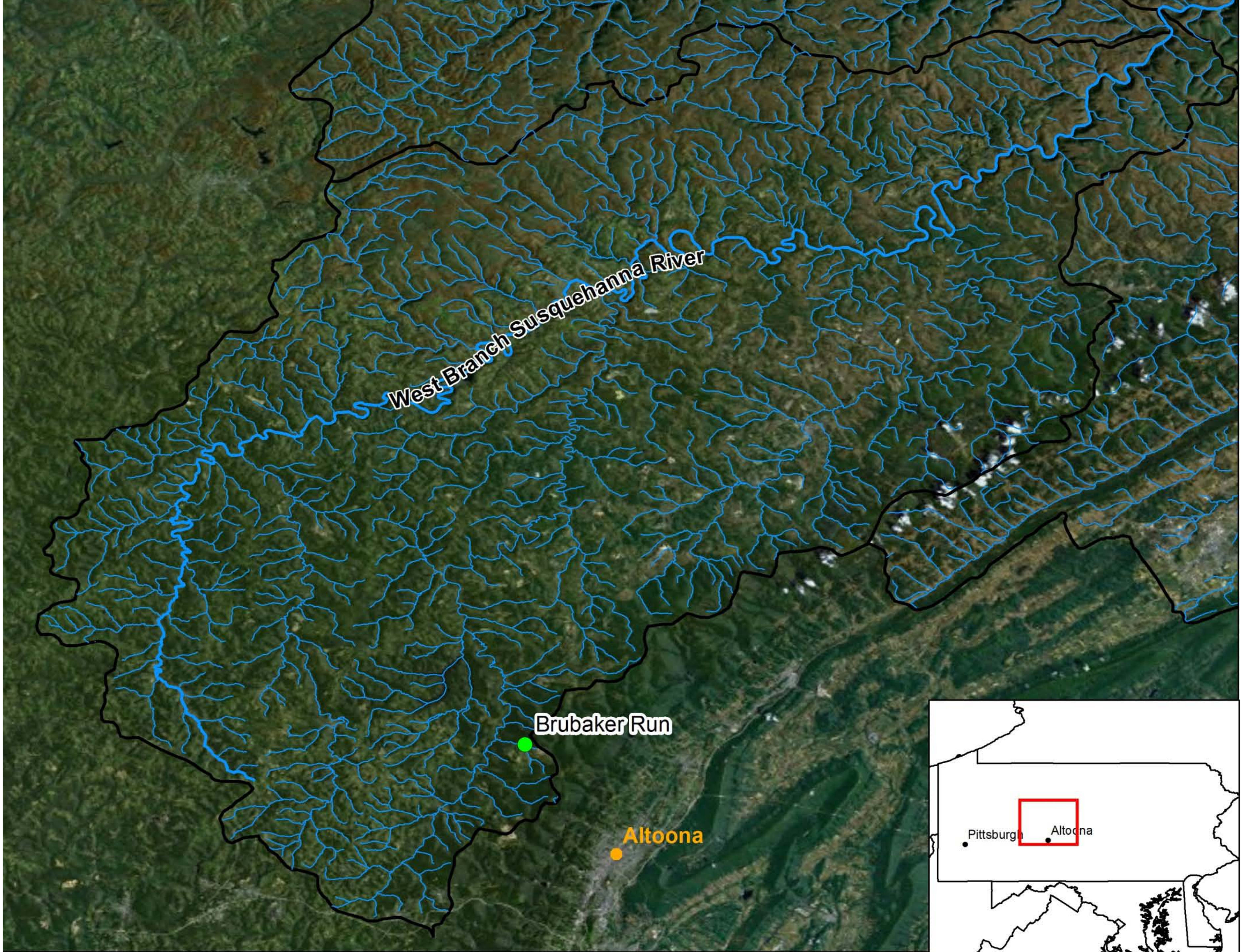


Motivation for Research

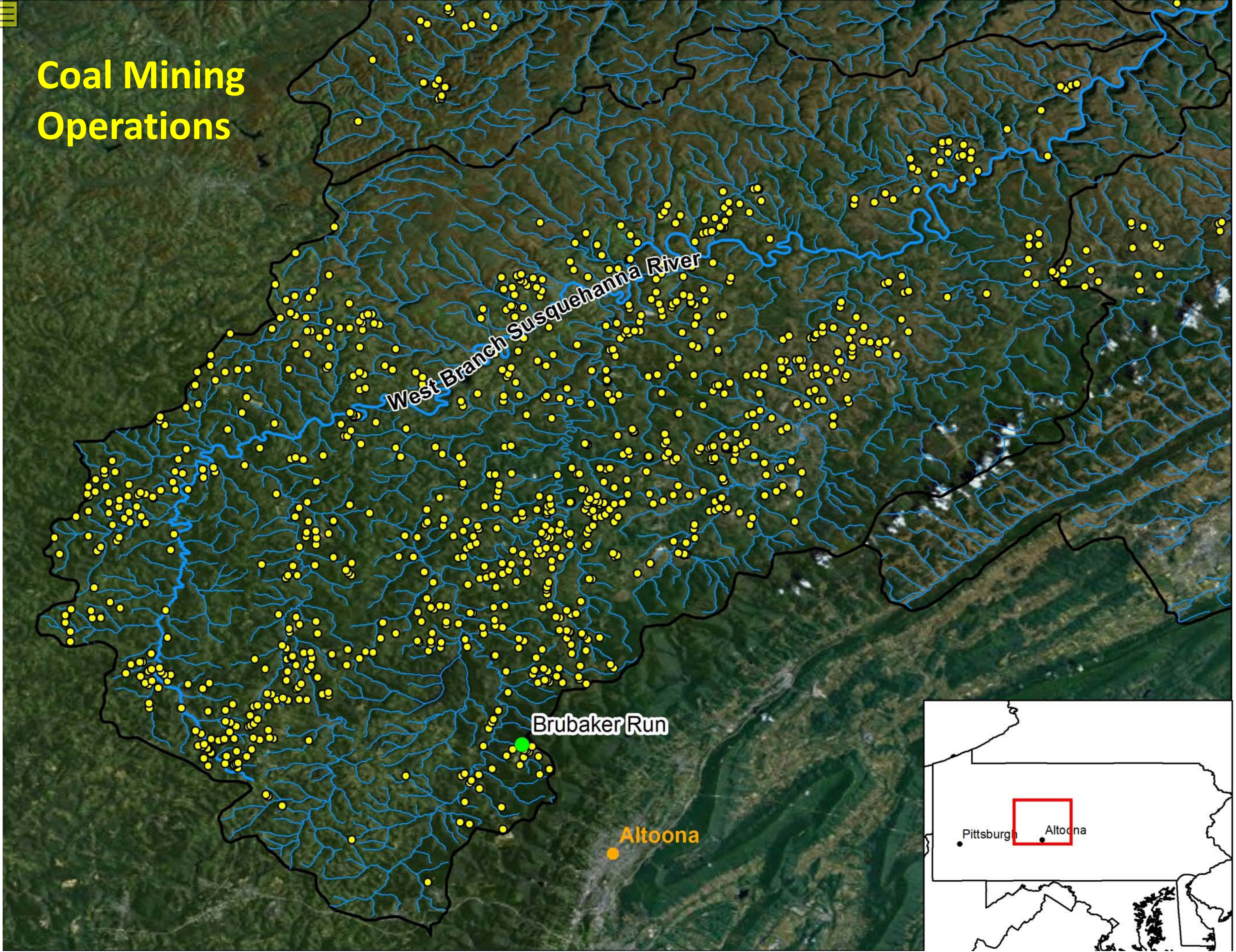
- The estimated worldwide liability costs associated with the current and future remediation of acid drainage are approximately $100 billion (Hudson-Edwards et al. 2012).

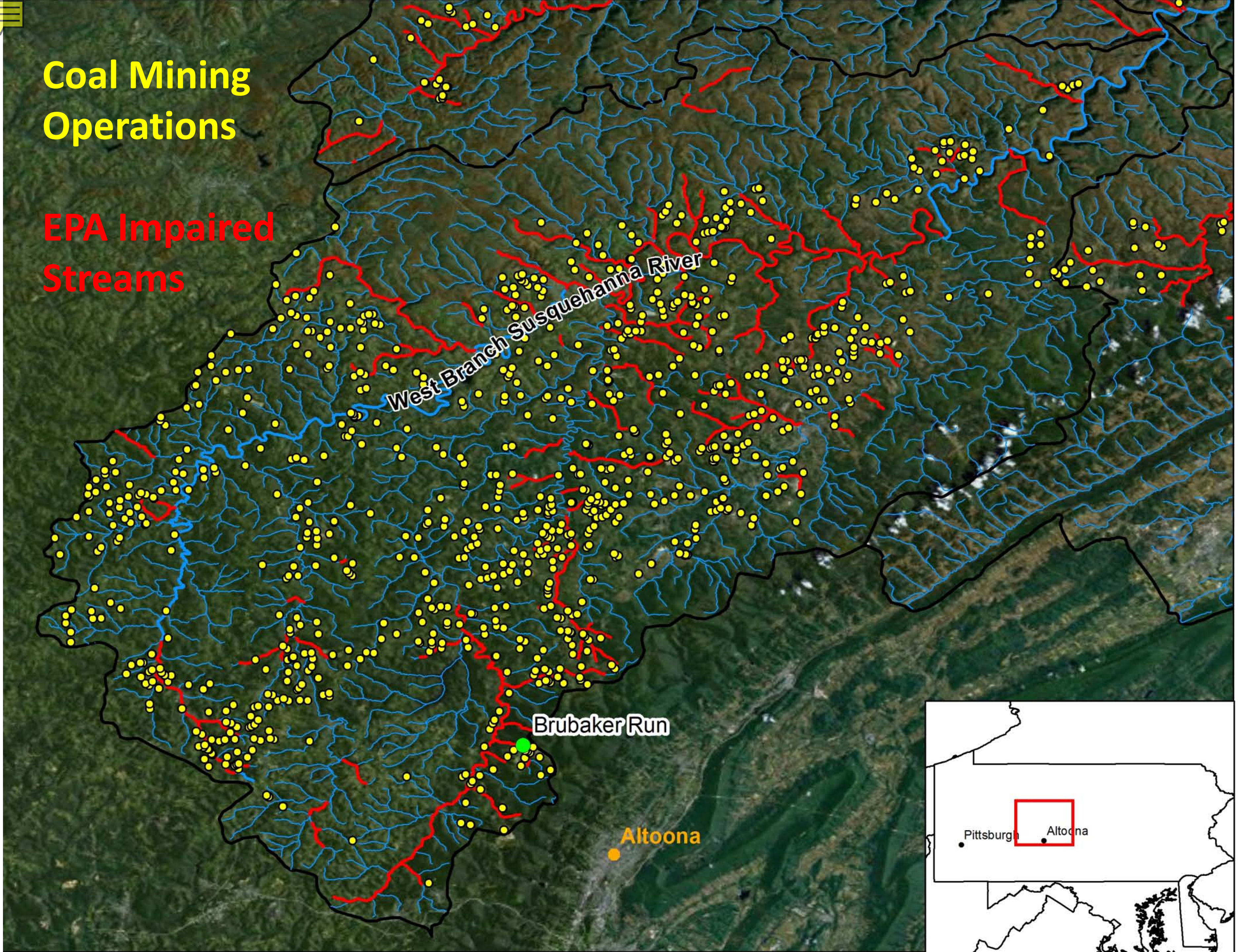
- Estimated between 95 – 99.999% of total mined material for metal mining becomes waste (Nordstrom 2012).

- Coal mine drainage (CMD) is responsible for 10,000 km of streams in the Appalachian region, Northeastern USA (Herlihy et al. 1990).


West Branch Susquehanna River
Brubaker Run
Altoona
Pittsburgh
Altoona

Coal Mining Operations

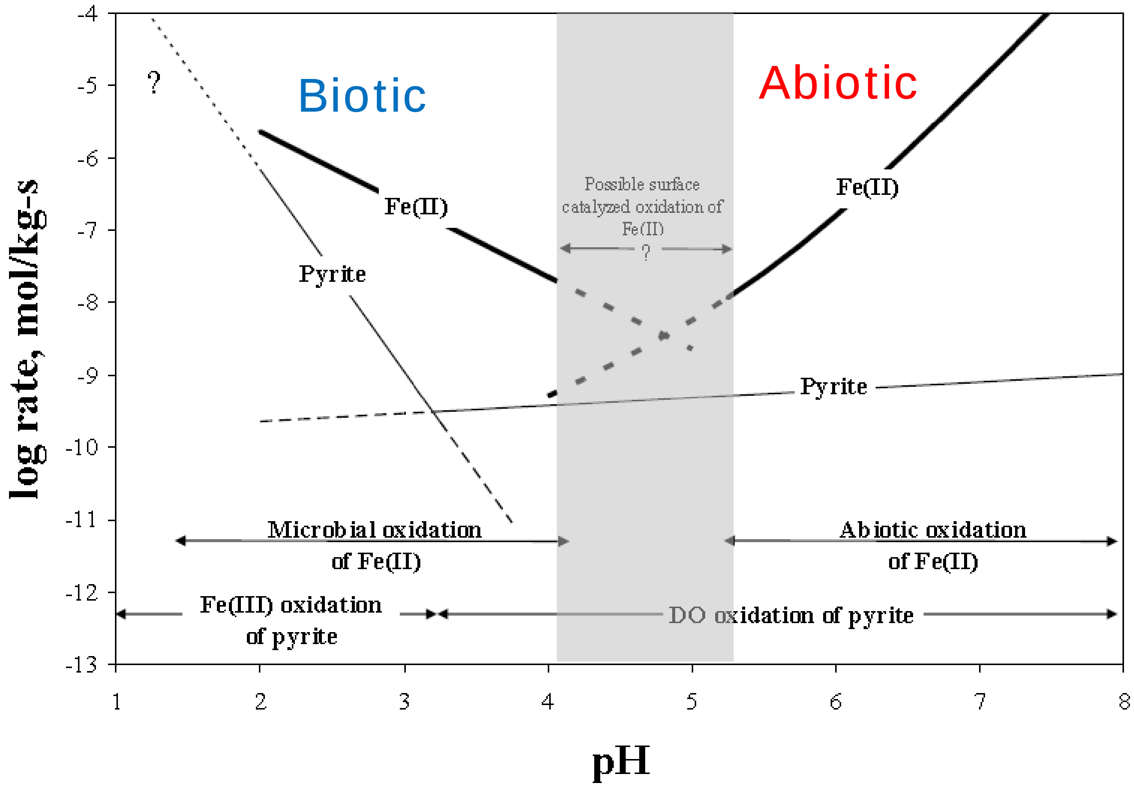



Coal Mining Operations
EPA Impaired Streams
West Branch Susquehanna River
Brubaker Run
Altoona
Pittsburgh
Altoona

Fe(II) Oxidation Kinetics – Brief Overview

Fe(II) – Soluble,
dissolved in solution

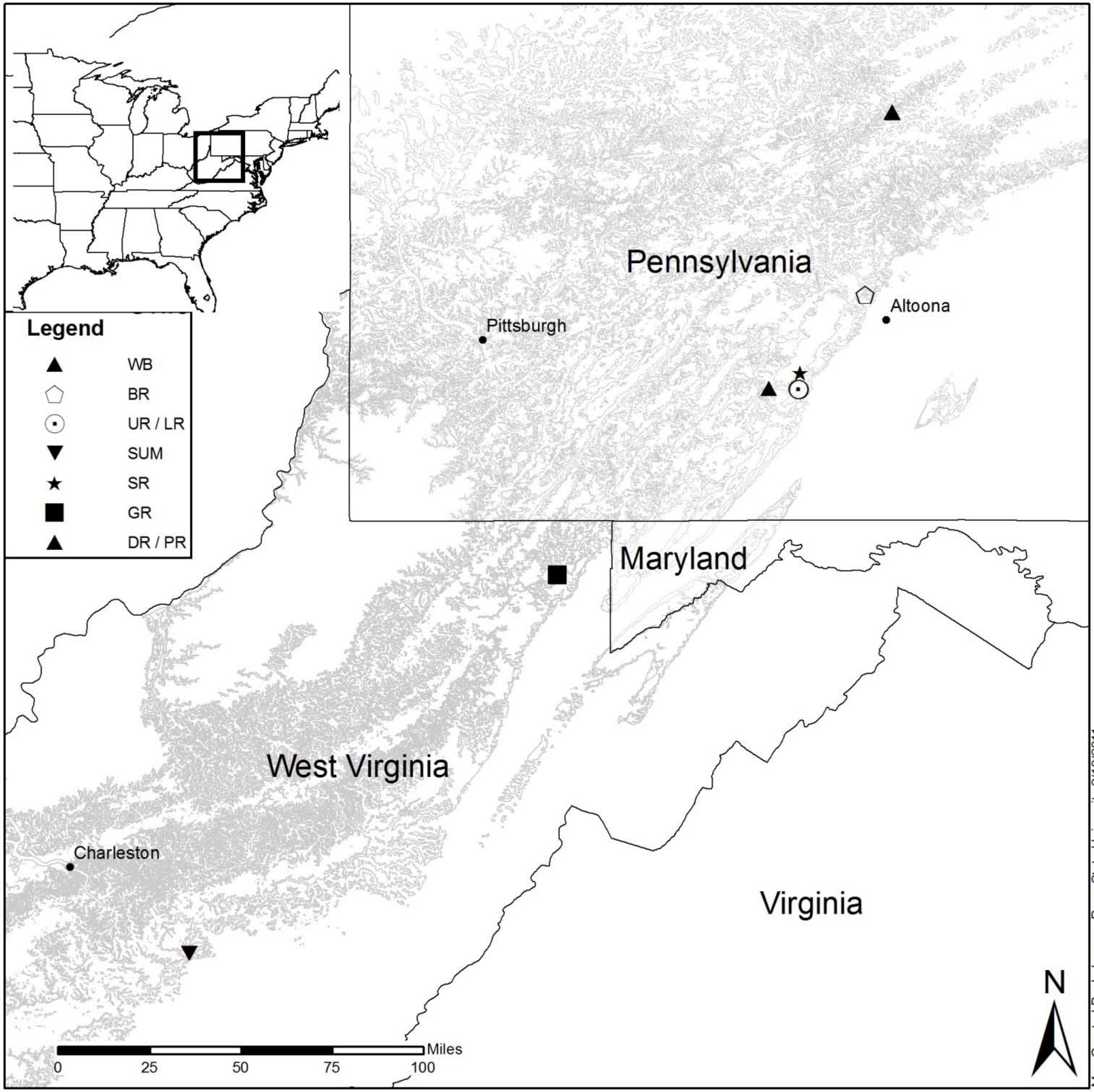
Fe(III) – **Insoluble**,
precipitates out of solution



Williamson et al., 2006

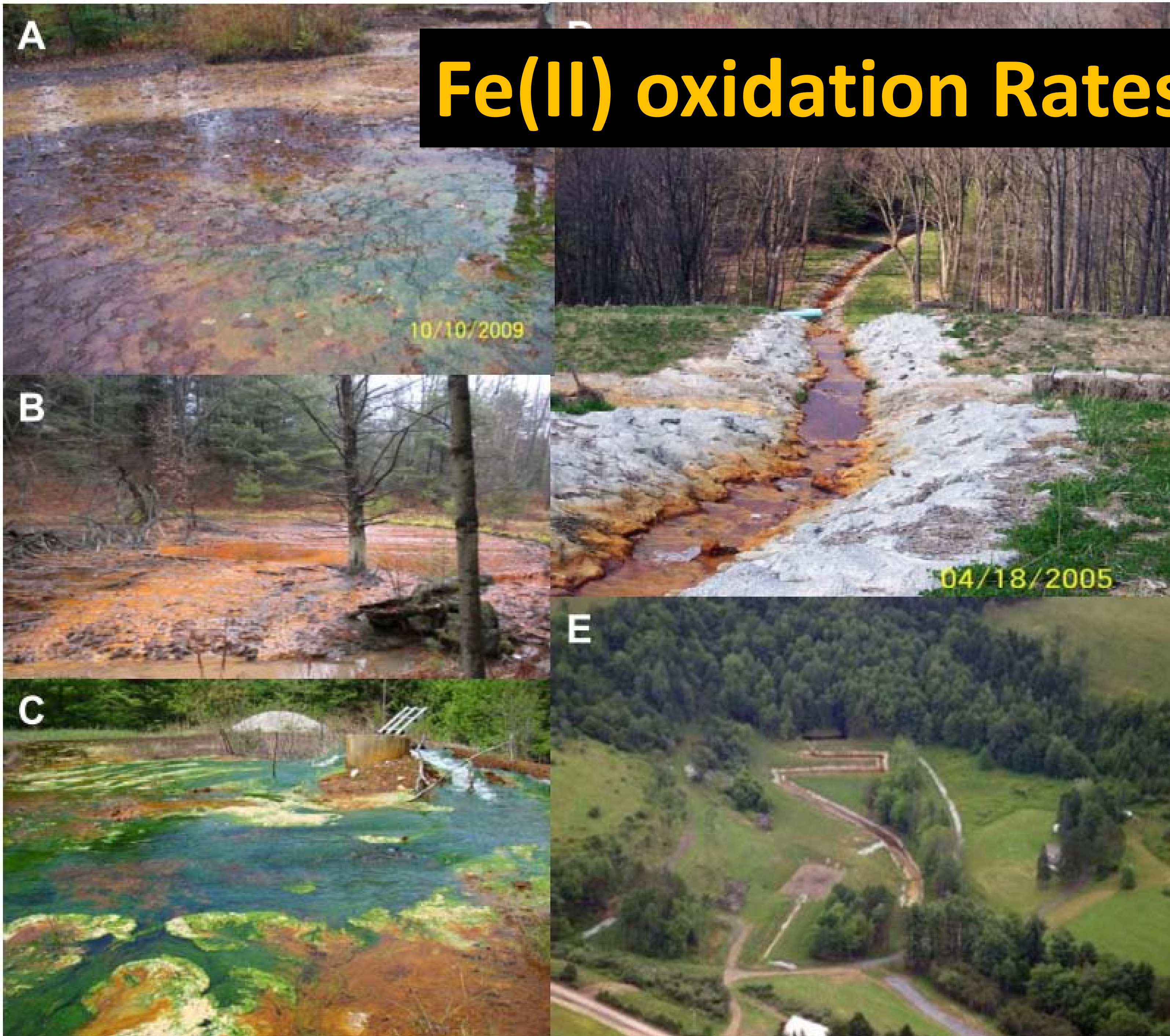
Goal – Oxidize and precipitate

Fe(II) → **Fe(III)**



Legend
WB
BR
UR / LR
SUM
SR
GR
DR / PR
Pennsylvania
Pittsburgh
Altoona
Maryland
West Virginia
Charleston
Virginia
Miles
0
25
50
75
100
N
Map Created By: L. Larson, Penn State University 2/10/2011

Fe(II) oxidation Rates?



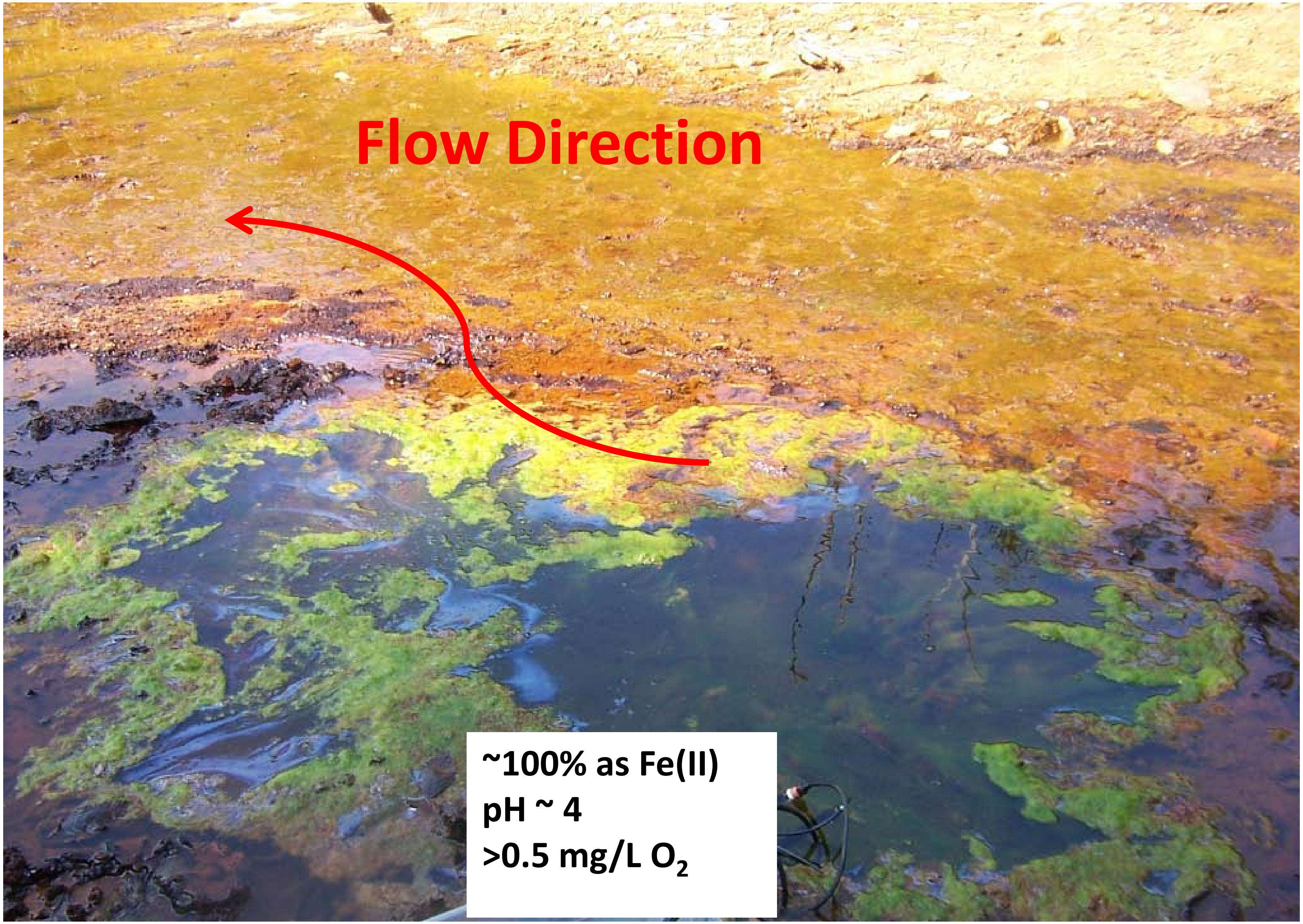
Research Approach

- Establish Fe(II) oxidation rates in the field
- Measure laboratory Fe(II) oxidation rates via constant flow reactors
- Establish specific properties of Fe sediments – ie: active microbial biomass and community structure

Goal:

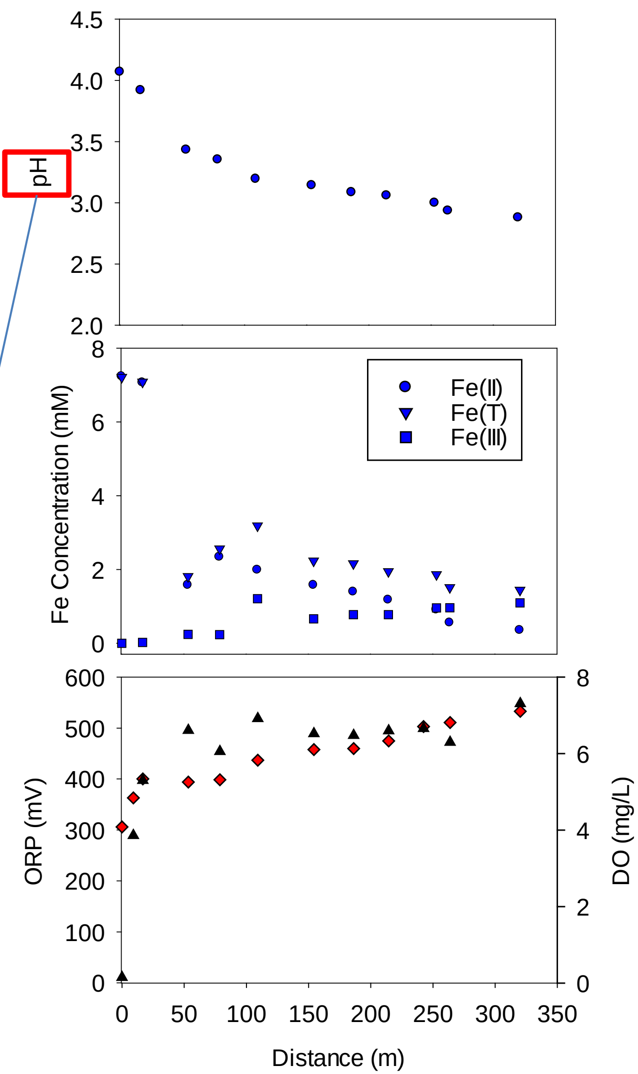
Develop a Fe(II) oxidation design process to optimize land use for passive treatment, prior to alkaline generating processes

Emergence Source Chemistry



Downstream Source Chemistry

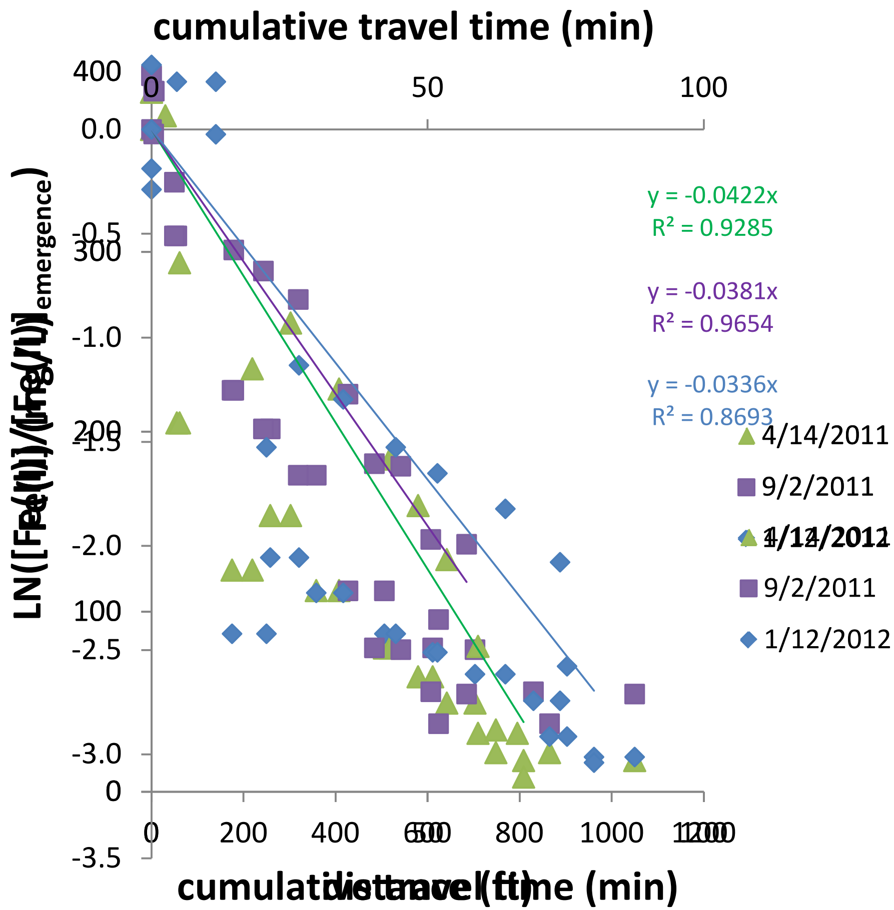
$$Fe^{2+} + \frac{1}{4}O_2 + \frac{5}{2}H_2O = Fe(OH)_3(s) + \boxed{2H^+}$$



Measurement of Field Fe(II) Oxidation Rates

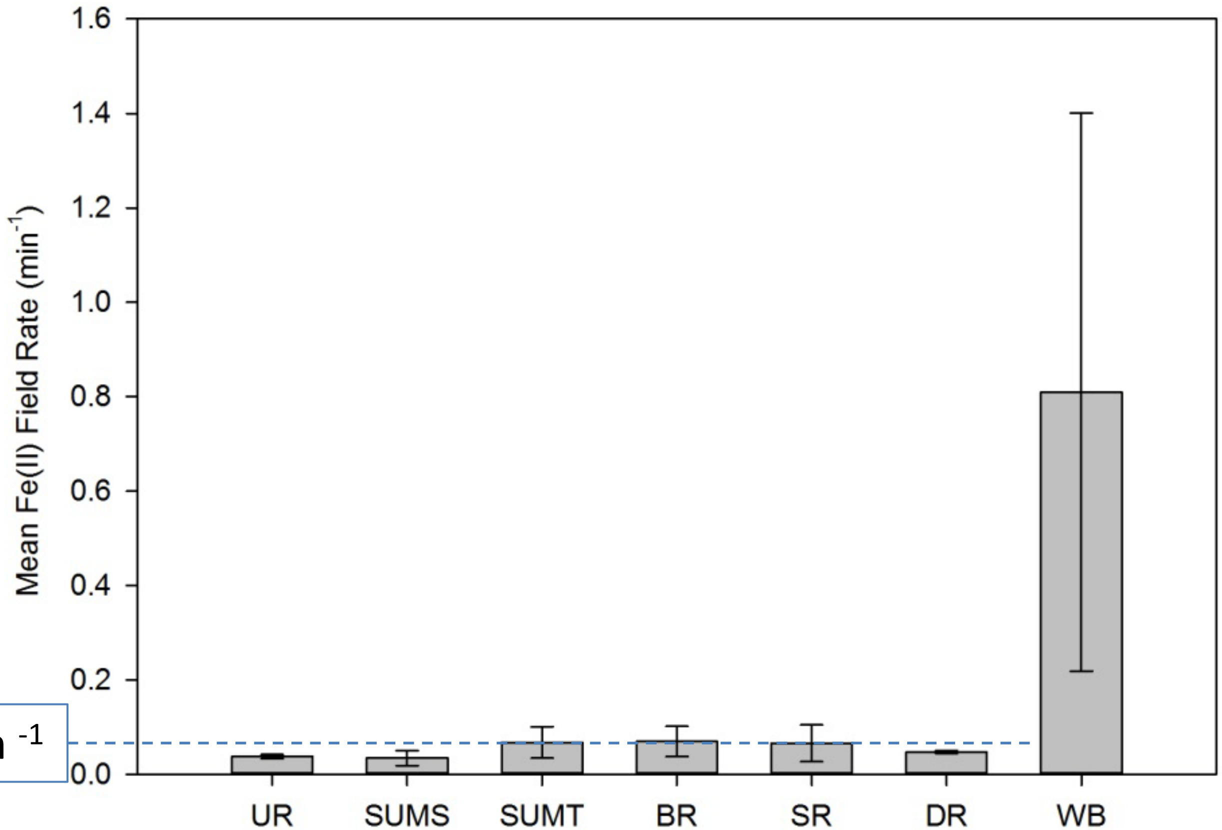
- Geochemical Parameters measured as a function of distance – pH, ORP, Fe(II), Fe(T), DO
- Concurrent measurements of velocity where made to establish a hydraulic residence time.

$$travel\ time\ (min) = \frac{\overline{d}}{\left(\frac{v_n + v_{n+1}}{2}\right)}$$



$$C(t) = C_o e^{-kt}$$

Field Fe(II) Oxidation Rates Summary

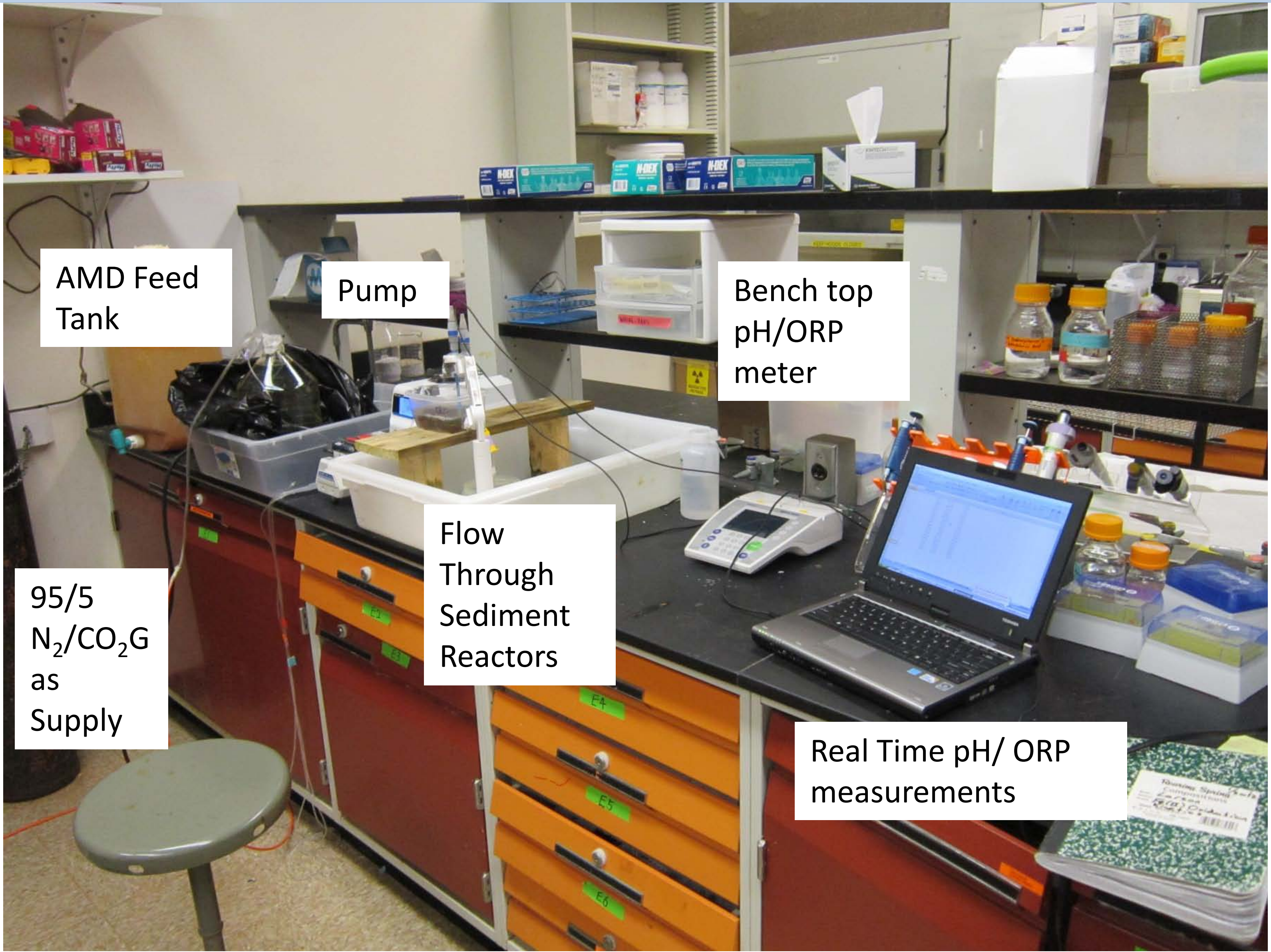


$k_{Fe(II)} = 0.054\ min^{-1}$

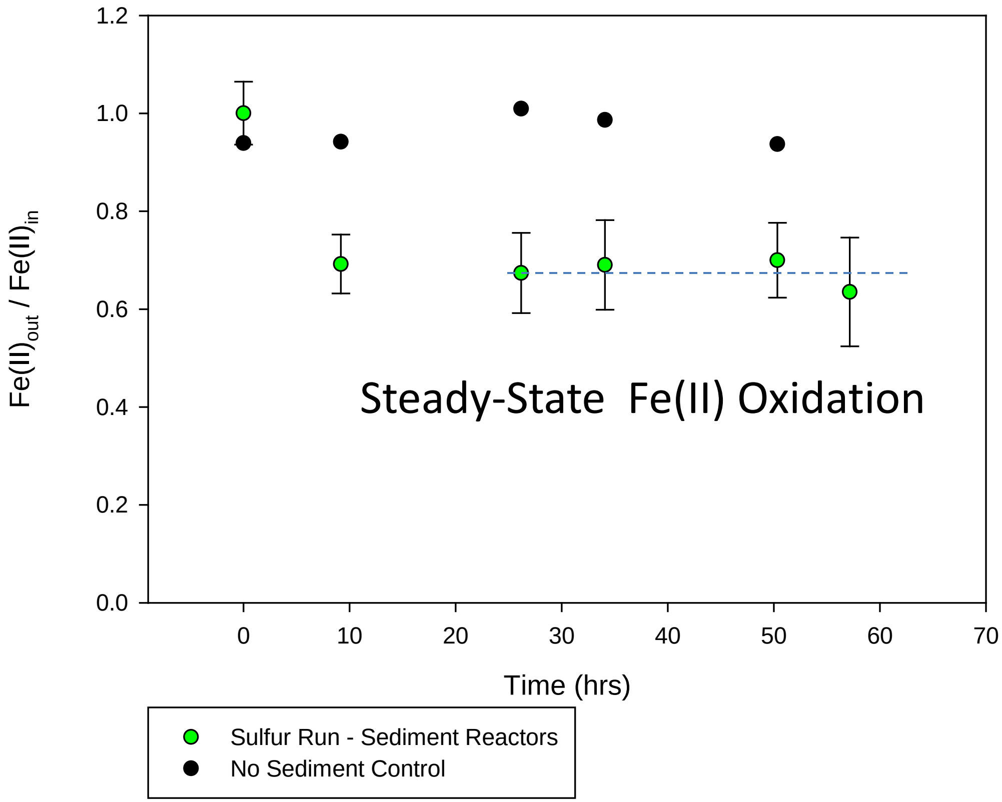
Laboratory Fe(II) Oxidation Reactors

- Sediments reactors run in triplicate (3)
- Simultaneous ‘no sediment’ control reactors (2)
- 8 hour residence time
- Constant flow rate confirmed gravimetrically
- Experiment duration ~60 hours

Laboratory Fe(II) Oxidation Rates : Experimental Set-up

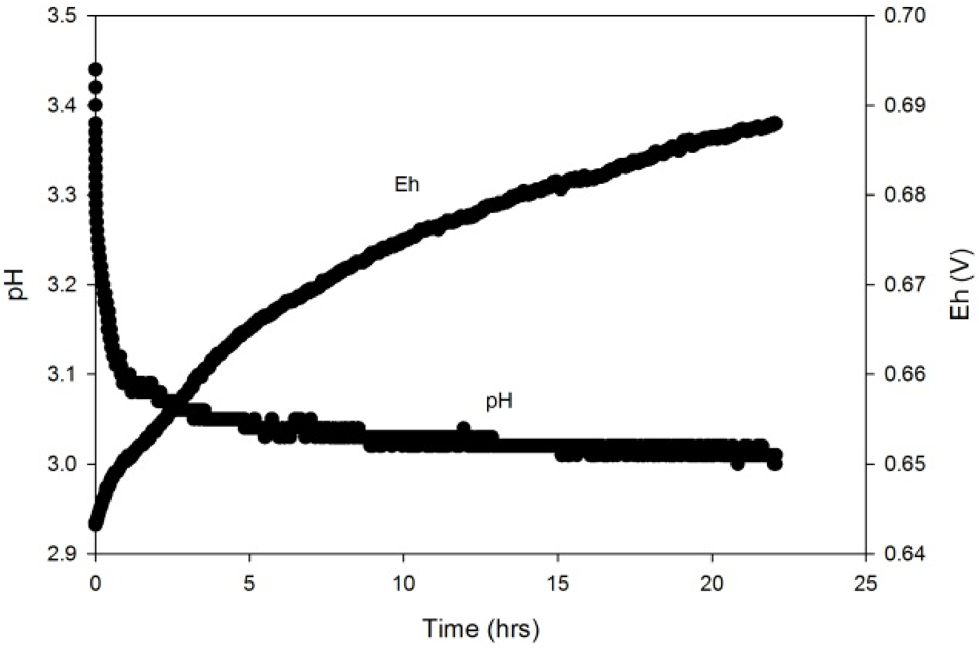


Laboratory Fe(II) Oxidation Rates



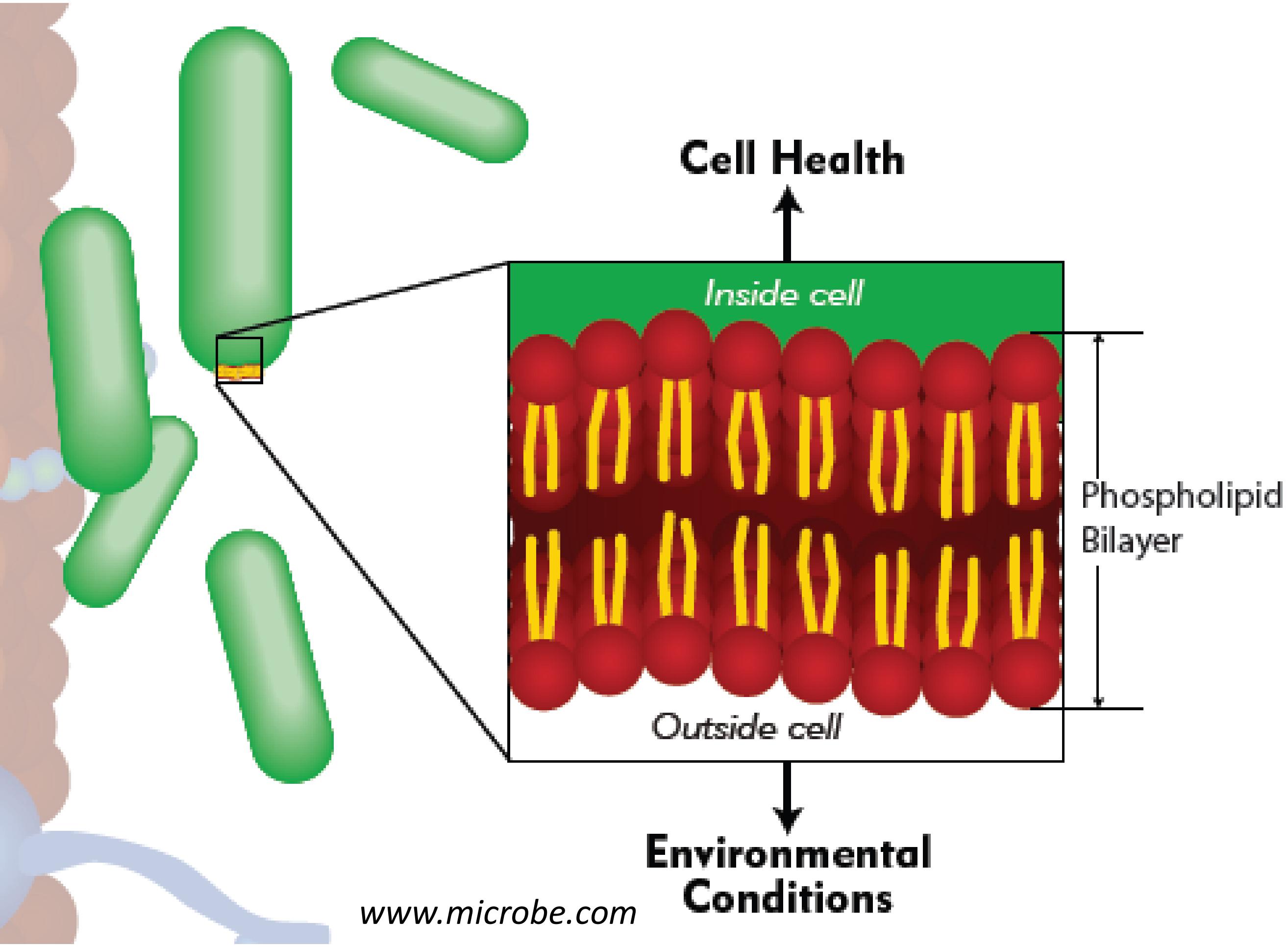
Rate constants were normalized to sediment mass and subsequent active biomass

Laboratory Fe(II) Oxidation Rates - Real Time pH/ORP



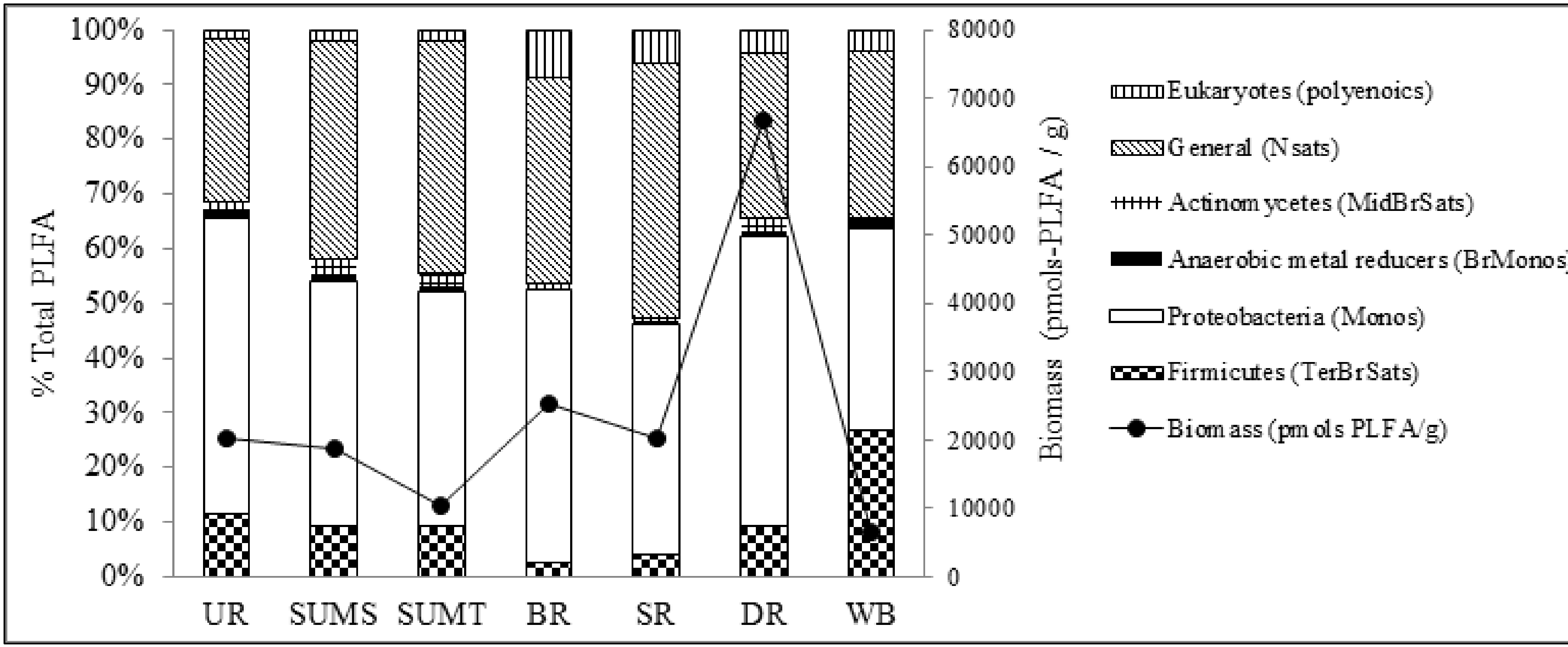
Geochemical parameters
pH/ORP recorded in real-time
every 30 seconds for ~23 hours

Phospholipid Fatty Acids (PLFA)

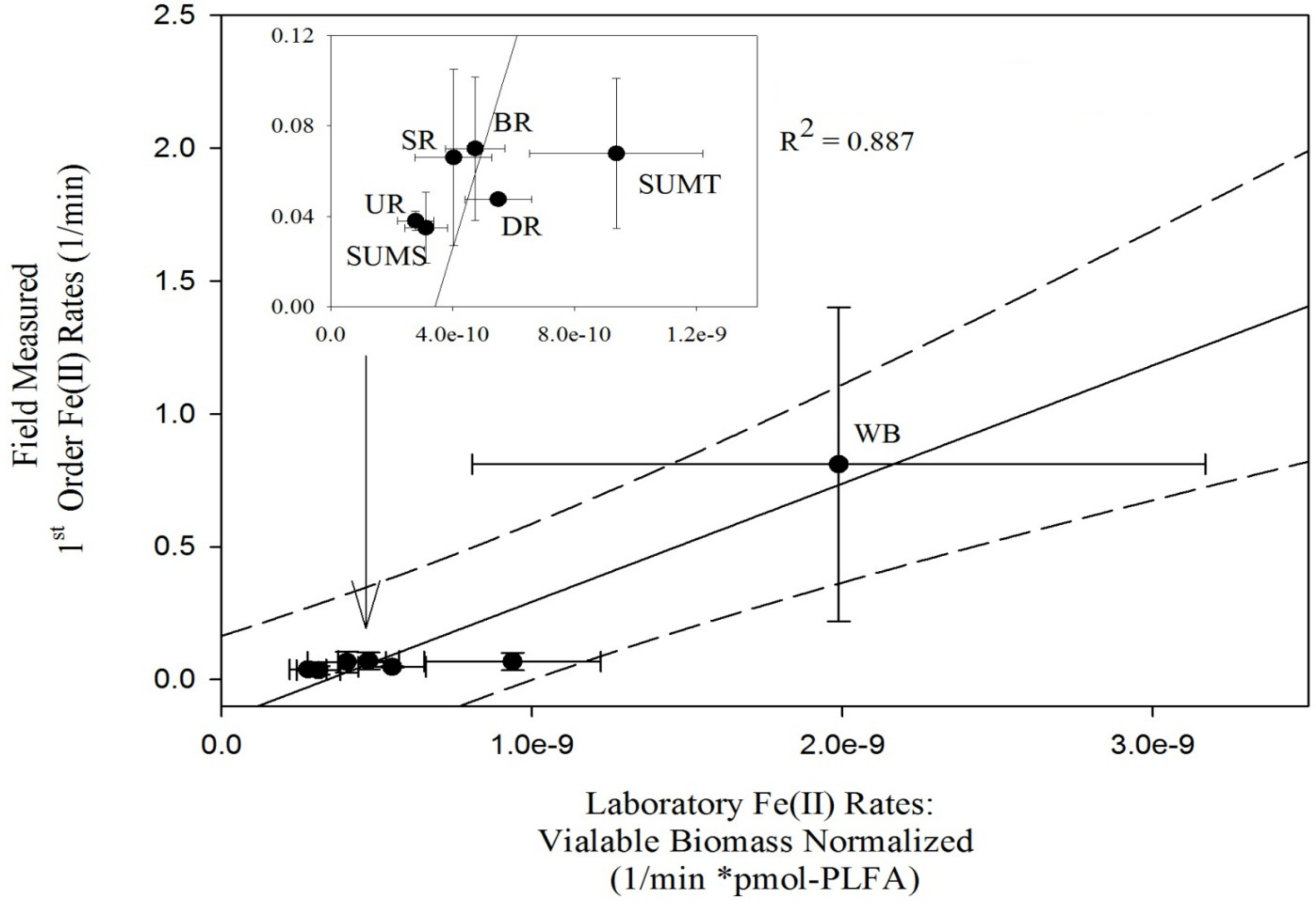


- 'Active' <u>biomass concentration</u>, cell membranes decay rapidly upon death
- Microbial communities have specific PLFA profiles (ie; Proteobacteria, Anaerobic metal reducers, eukaryotes)

Phospholipid Fatty Acids (PLFA)



Comparison of field and laboratory Fe(II) oxidation rates



Bioremediation Project – Summerlee, WV

*Courtesy of Levi Rose, Plateau Action Network

Bioremediation Project – Summerlee, WV

Baffles increase hydraulic residence time

*Courtesy of Levi Rose, Plateau Action Network

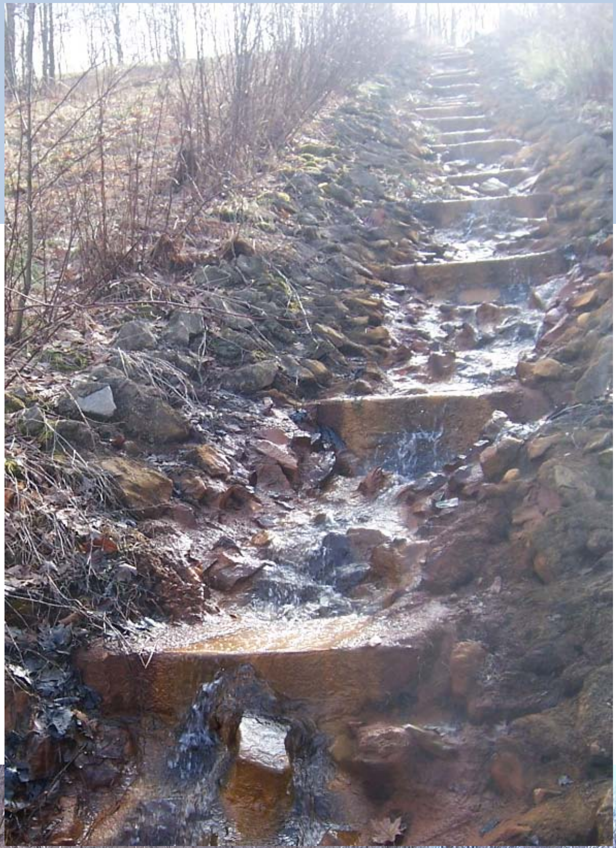
Bioremediation Project – Summerlee, WV

Pollutant	Pre-Construction Loading (lbs/yr)	Post-Construction Loading (lbs/yr)	Reduction
Acid	323,701	214,254	34%
Iron	75,385	48,145	36%

*Data Courtesy of Levi Rose, Plateau Action Network

Conclusions

- We can <u>exploit</u> natural biological low-pH oxidation processes as a pre-treatment strategy
- Fe removal enhances the ability of alkalinity generating processes
- Design parameters, such as hydraulic residence time and surface area, can be optimized
- Variations in biotic diversity and seasonal variations are poorly understood
- Bioremediation projects are currently being explored as long-term passive treatment options




Thanks for your attention