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Preventing Acid Rock Drainage
Can Source Control Really Be Successful?

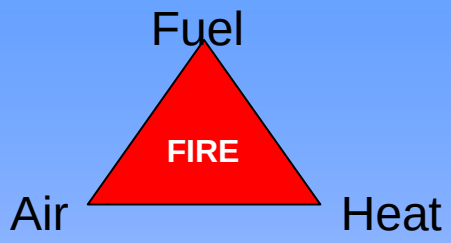
Paul Eger

Sovereign Consulting

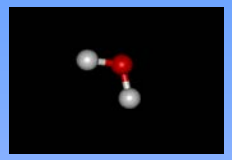
Lakewood, Colorado

Acid Rock Drainage

Acid Rock Drainage Tetrahedron

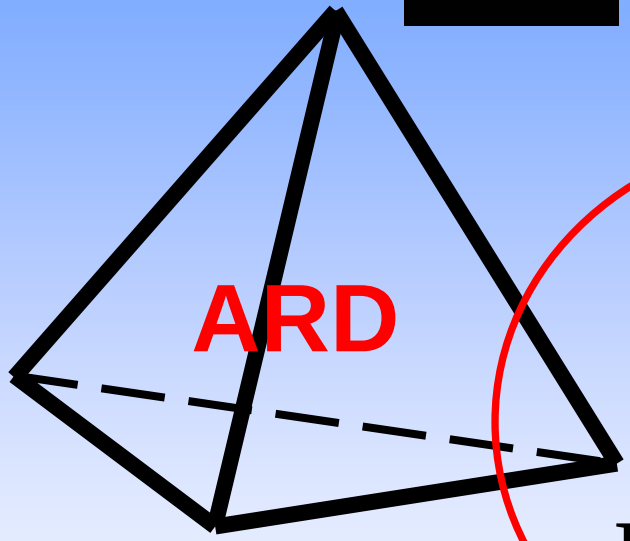


Water



Oxidizer

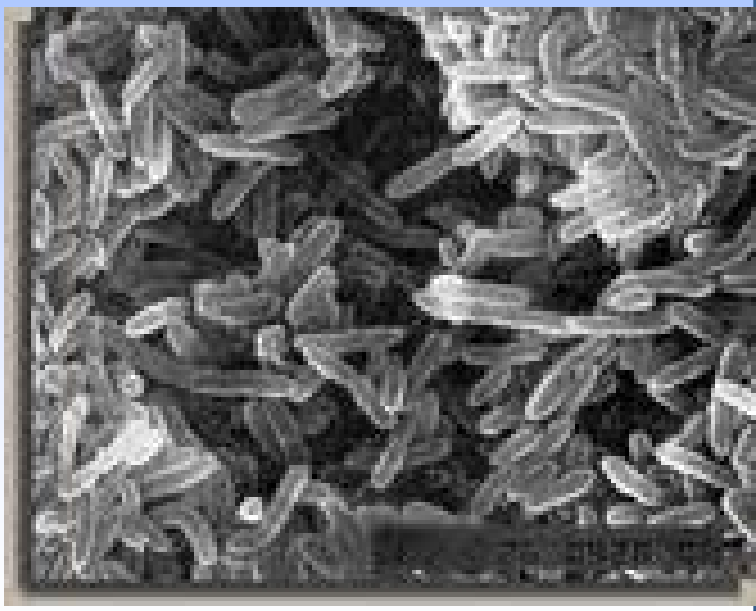
(Air, Fe^{+3})



Bacteria

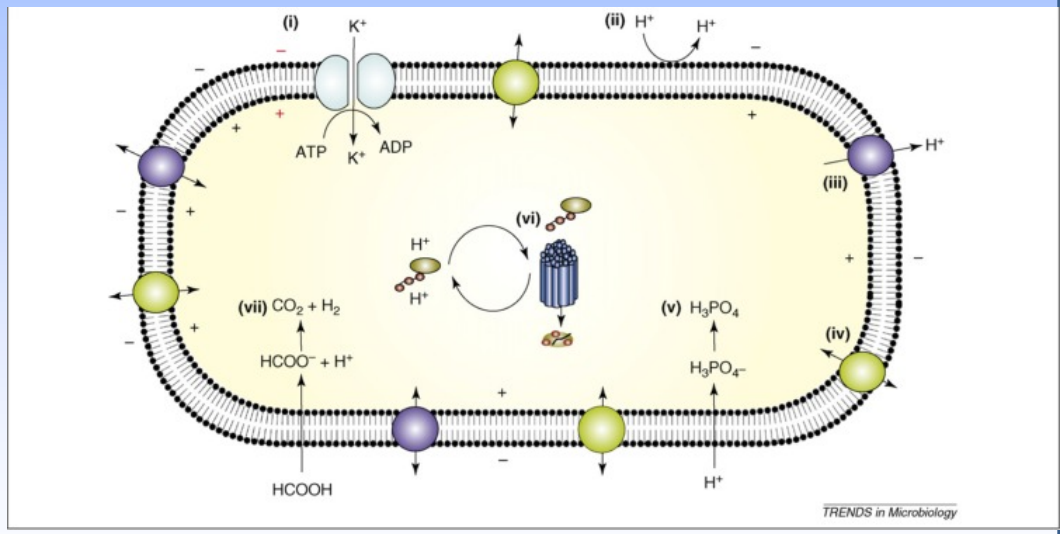
Role of Bacteria

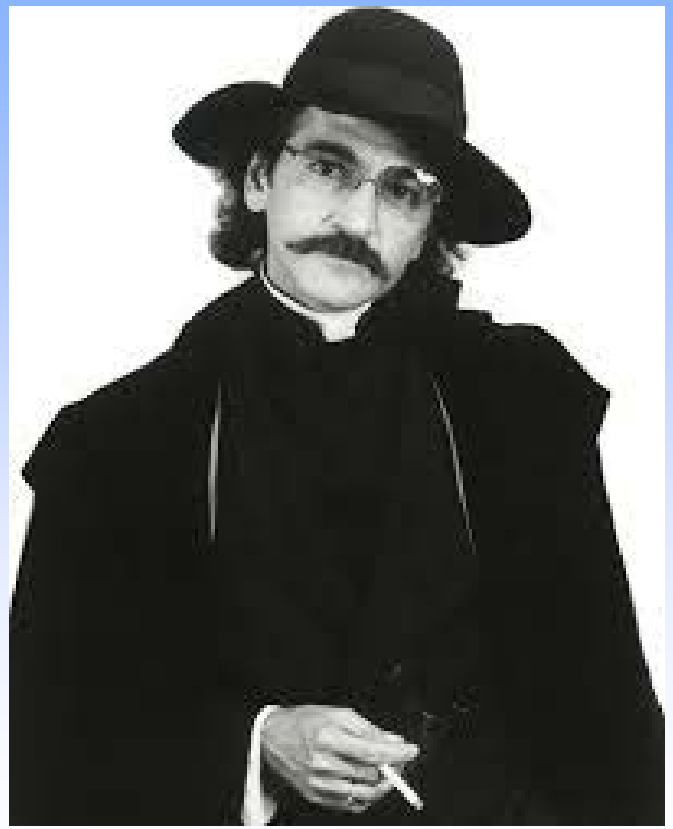
- Thiobacillus Ferrooxidans
- Gain energy through oxidation of iron sulfide minerals
- Thrive at low pH
- Dramatically increase rate of oxidation



Can we stop them?

- Bactericides
  - Jim Gusek
  - A Pathway to Wak-Away? - 30 Year Old Technology to Suppress Acid Rock Drainage Revisited
- Maintain neutral pH





Guido Sarducci's 5 Minute University

Mine Waste Management

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Waste Characterization

- “Know Thy Waste”
- Minnesota reclamation rules require all waste be characterized
- Is your waste reactive?

Reclamation rules

IF THE WASTE IS REACTIVE, THEN….

Do not pass go

Do not collect a permit

Reclamation Rules

If you have reactive mine waste, then..

- Modify material
  - Physical characteristics
  - Chemical characteristics
- Modify environment
- Prevent water from contacting material
  - Collect and treat any residual water

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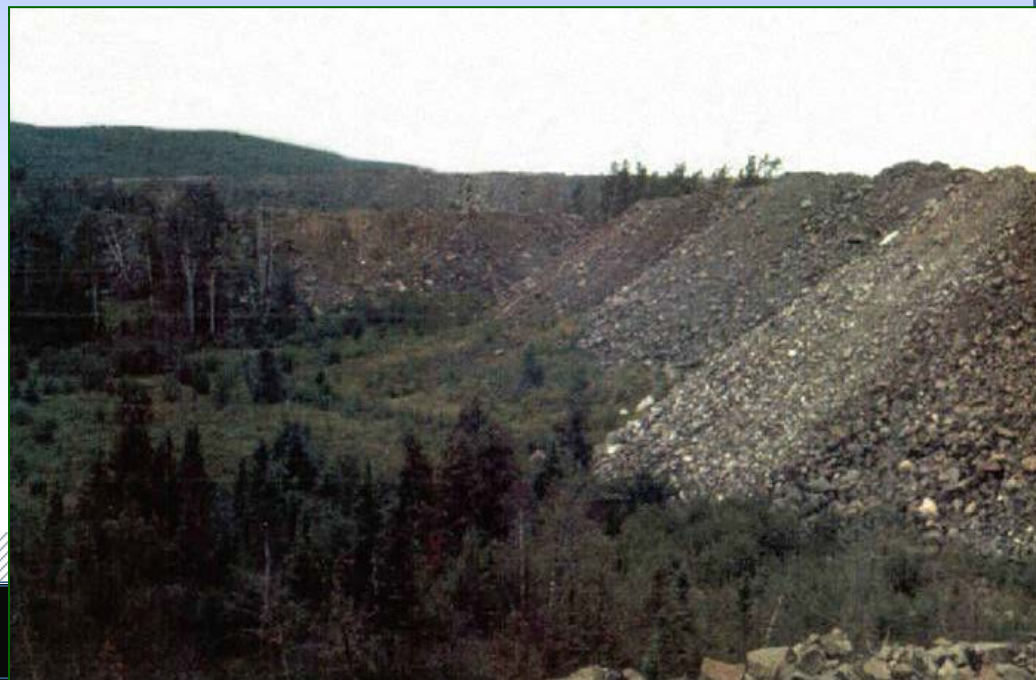
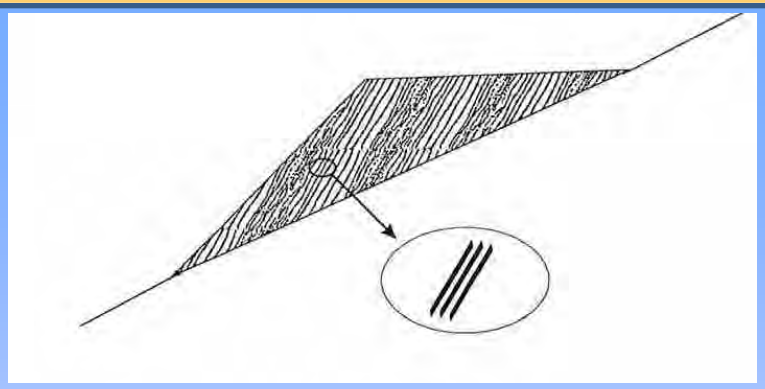
Chemical Modification

- If waste is predicted to be acid generating one option is to add neutralizing material
- Work began in late 80's early 90's
- Successfully applied in coal industry
- MEND Report (1998) concluded this approach would not be successful in metal mines

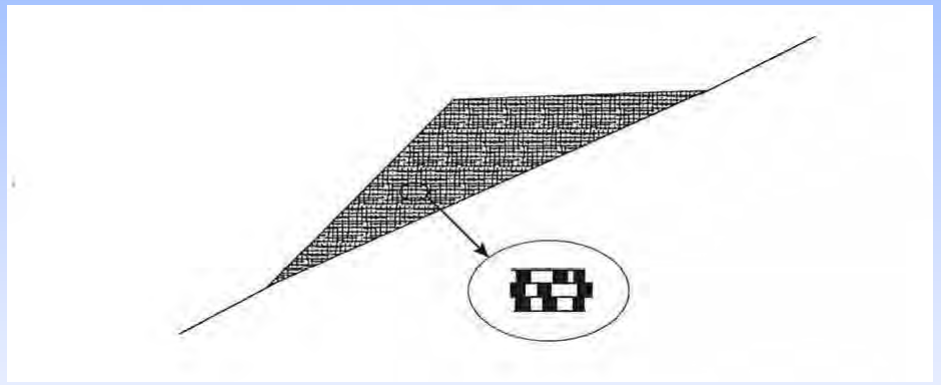


Methods Considered

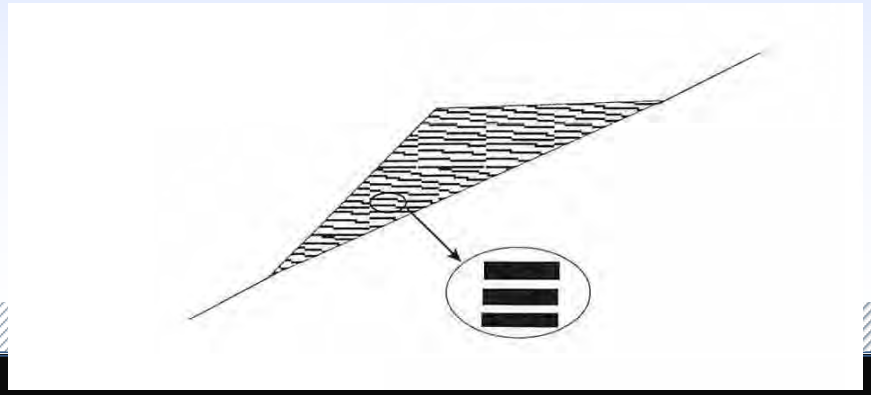
- End Dumping



- Random dumping



- Alternate layers



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Is there a better way?

Practical example of chemical modification

Could it work for mine waste?

Can we simulate this on a pilot scale?

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Could it really work?

- Why should adding fine grained limestone to big rocks be anything but a hare brained scheme?

It's all about reactive surface area

Underground Mine			
Particle size, in	% passing	Sulfur content %	Specific surface area m^2/gm
12	100	0.6% bulk composition	
2			
1	38		
0.0787		0.67%	0.6
0.0035	3	1.65-1.94%	2.6-4.7

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Approach

- Set up pilot experiment at Minnesota Department of Natural Resources Test Facility, Hibbing MN

Rock

- Archean greenstone
- Likely host rock for future metal discoveries in Minnesota
- Soudan Underground Mine
- Characterization
  - Sulfide 0.49%
  - Acid Production Potential= 30.6 lbs $CaCO_3$ equivalent / ton
  - Neutralization Potential = 12.6 lbs $CaCO_3$ equivalent / ton
  - NP/AP = **0.33**

Laboratory tests with 0.39% to 0.50 % S, had produced acid within 4-12 weeks

Approach

- Add fine grained limestone to increase neutralization potential
- "Manufactured Sand"

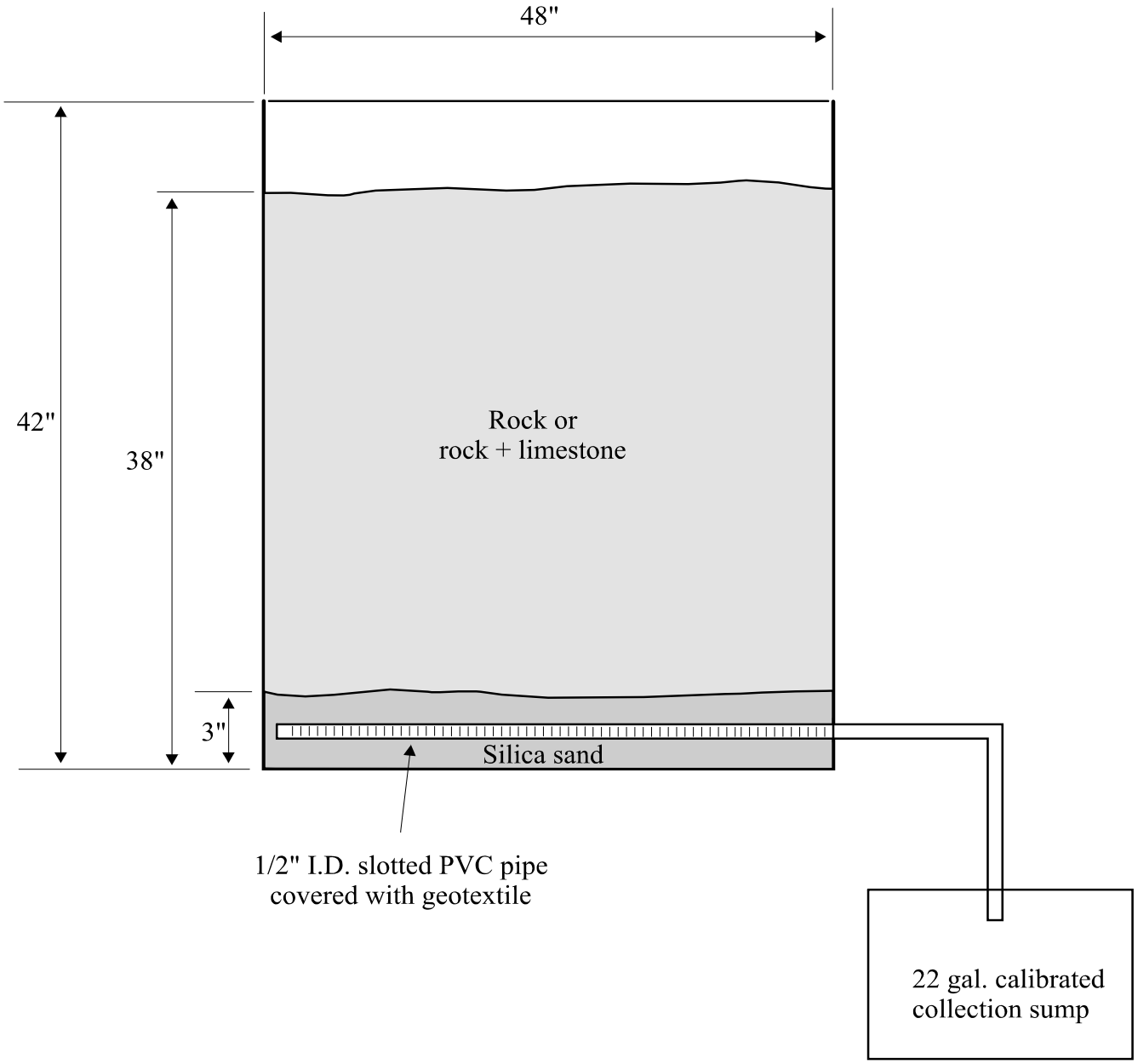
  100 % minus 2 mm

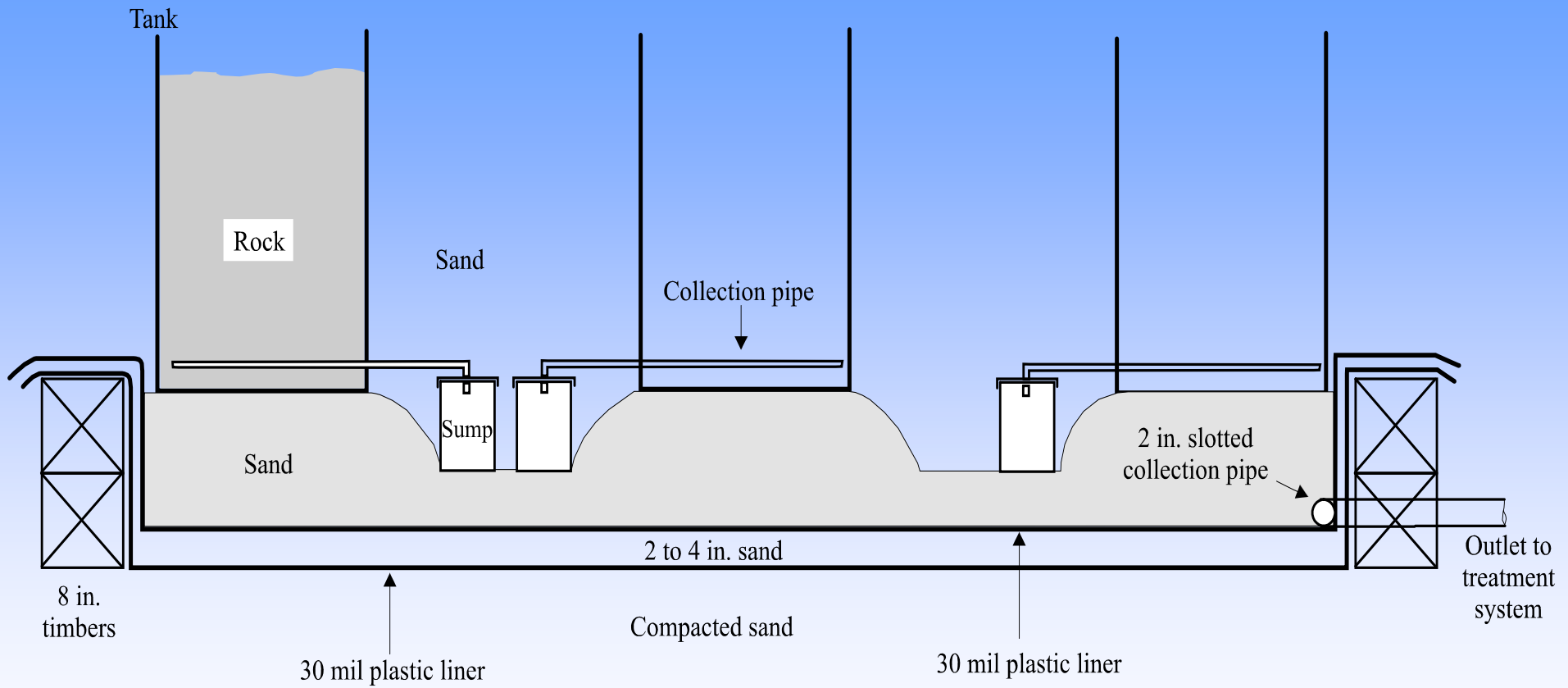
  Magnesium rich, dolostone

- Increase NP/ AP ratio
  - 1:1
  - 3:1

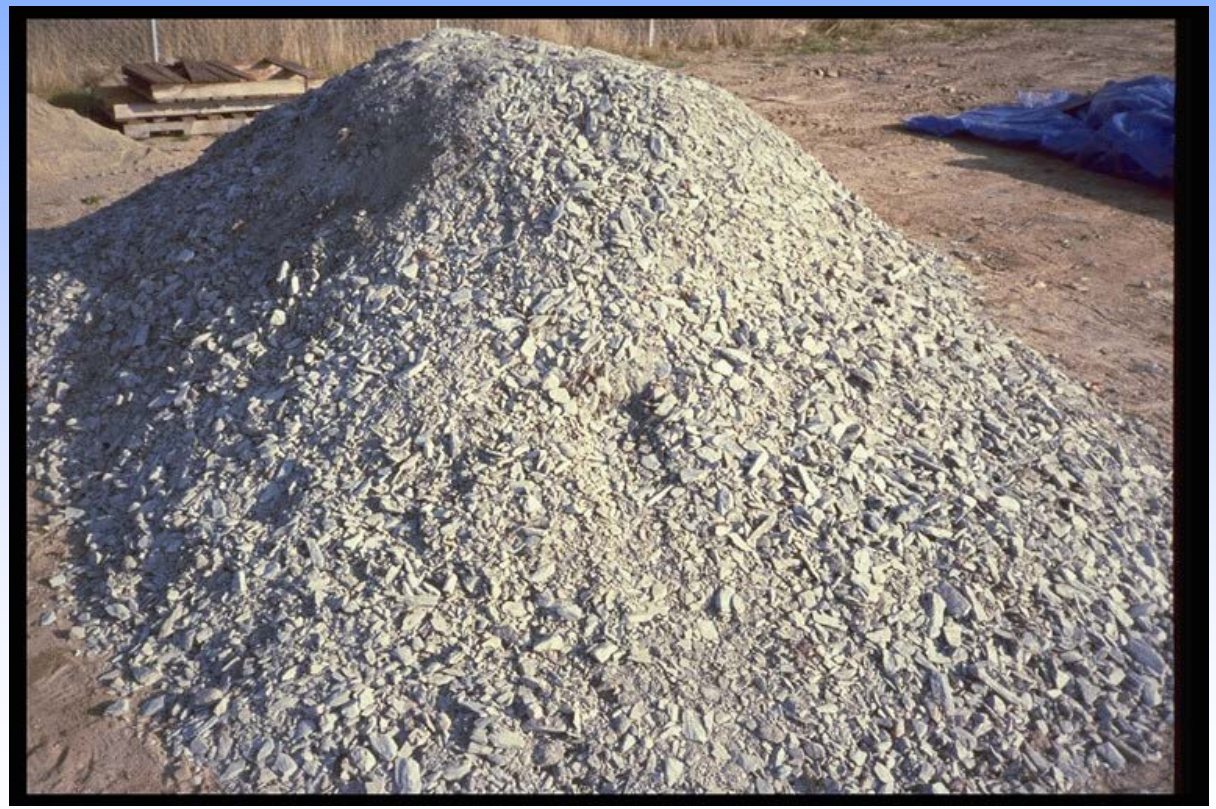
Experimental Design

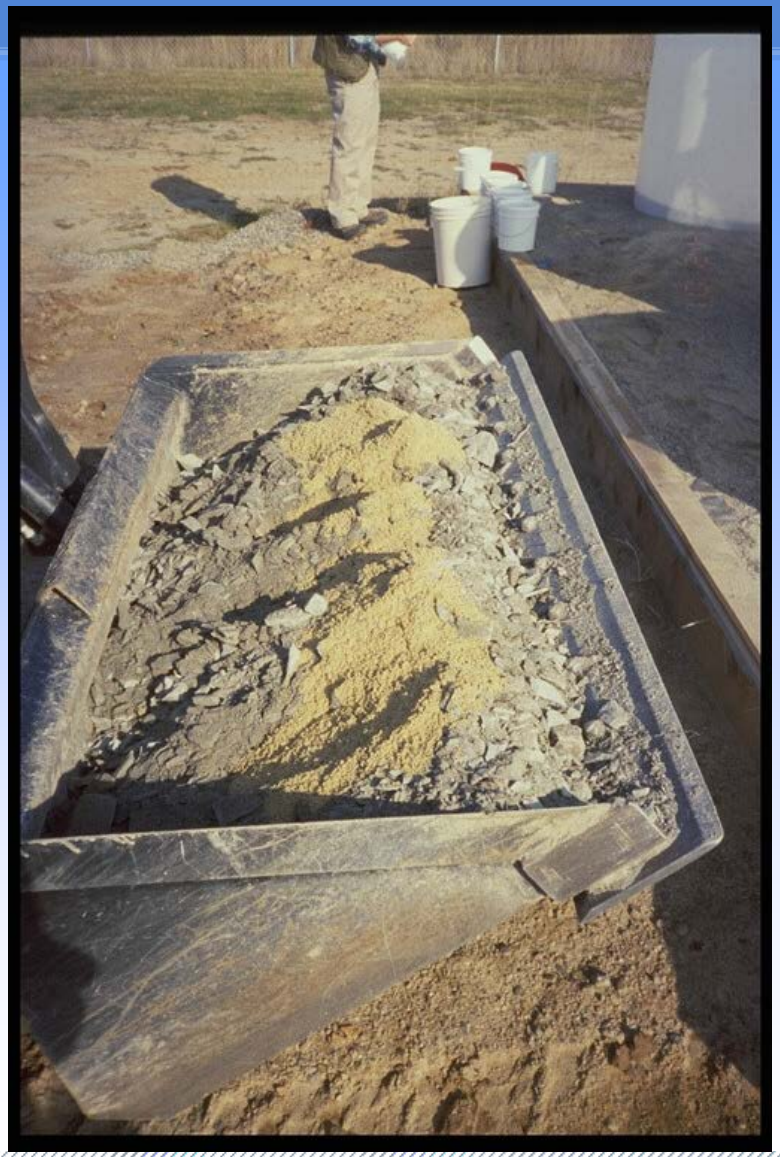
- Three treatments
- Each in duplicate


48"
42"
38"
3"
Rock or
rock + limestone
Silica sand
1/2" I.D. slotted PVC pipe
covered with geotextile
22 gal. calibrated
collection sump

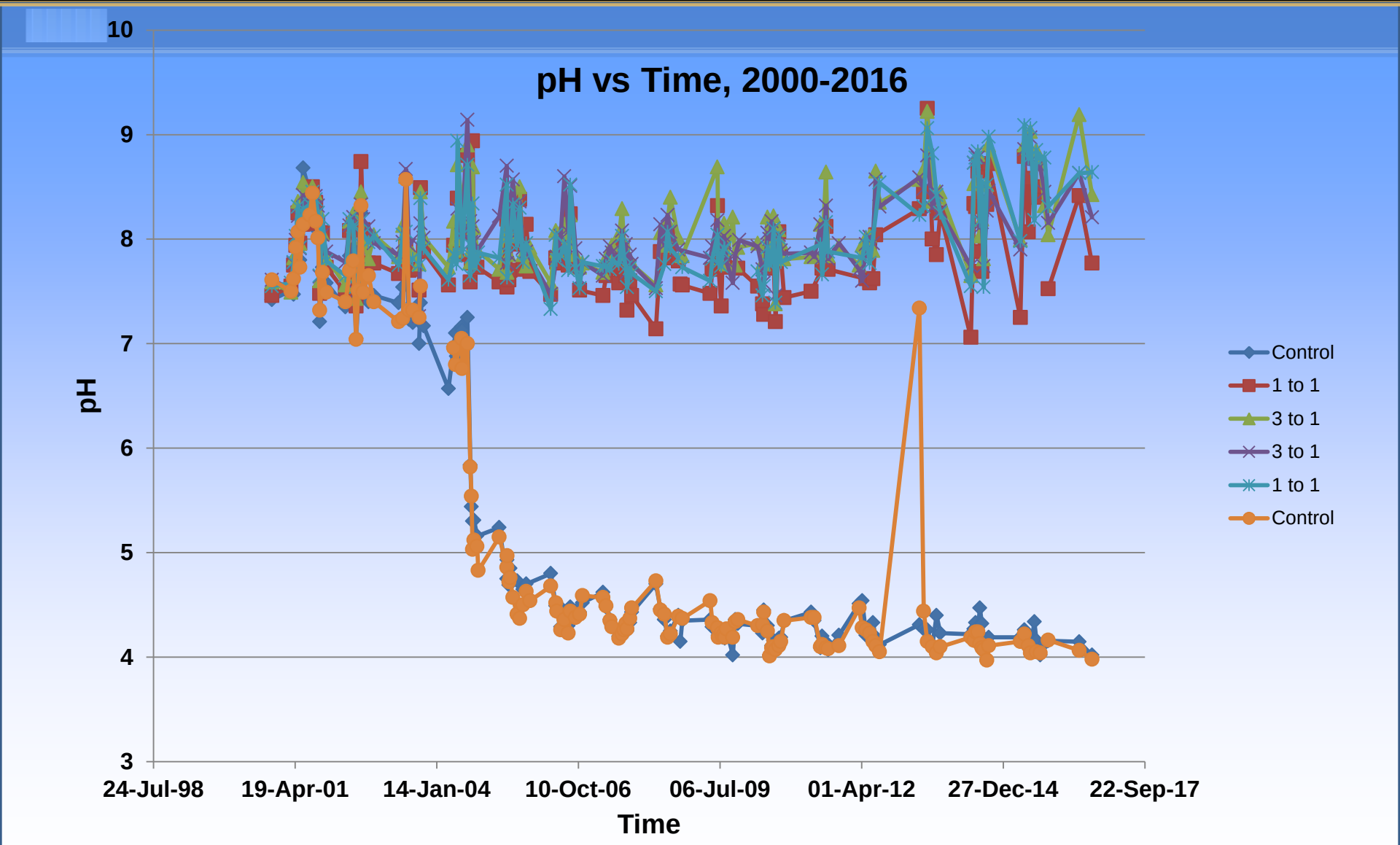

Tank
Rock
Sand
Collection pipe
Sump
Sand
2 in. slotted
collection pipe
2 to 4 in. sand
Outlet to
treatment
system
8 in.
timbers
30 mil plastic liner
Compacted sand
30 mil plastic liner

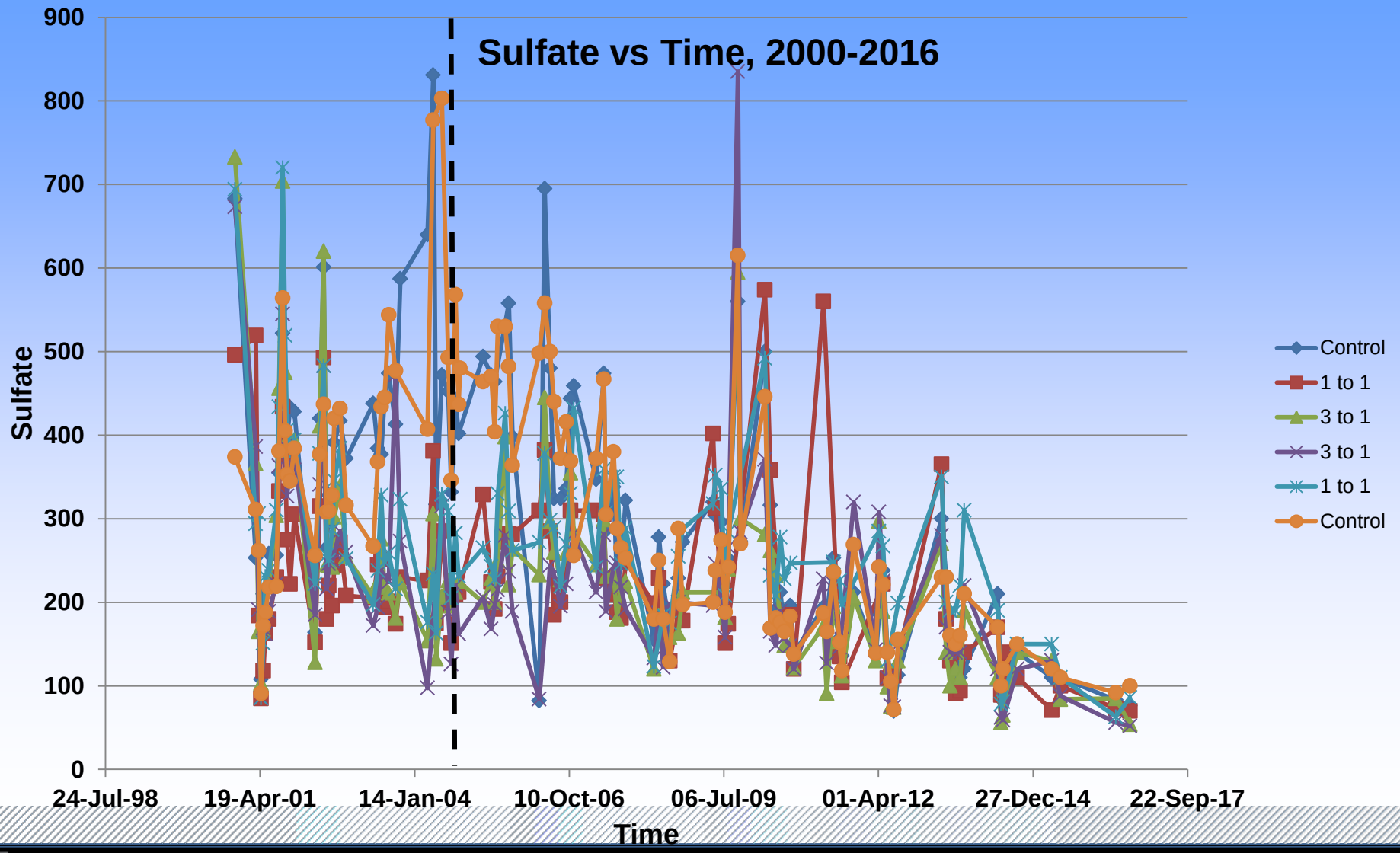
Rock screened to minus 2 inch





Results


pH vs Time, 2000-2016
pH
10
9
8
7
6
5
4
3
24-Jul-98
19-Apr-01
14-Jan-04
10-Oct-06
06-Jul-09
01-Apr-12
27-Dec-14
22-Sep-17
Time
Control
1 to 1
3 to 1
3 to 1
1 to 1
Control


Sulfate vs Time, 2000-2016
Sulfate
900
800
700
600
500
400
300
200
100
0
24-Jul-98
19-Apr-01
14-Jan-04
10-Oct-06
06-Jul-09
01-Apr-12
27-Dec-14
22-Sep-17
Time
Control
1 to 1
3 to 1
3 to 1
1 to 1
Control

Results

Treatment	Average Sulfate Concentration, mg/L
Control	306
1:1	250
3:1	226

Conclusions

Another hare brained scheme vindicated!

- Adding fine grained alkaline material prevented acid drainage
- Both ratios worked (1:1,3:1)
  - Maintained neutral pH
  - Reduced sulfate

Successful treatment for 16 years!

Currently being used at an active gold mine for waste management

Future Work

- Determine effect of treatment on trace metal release
- Mass release calculations
- Estimate lifetimes

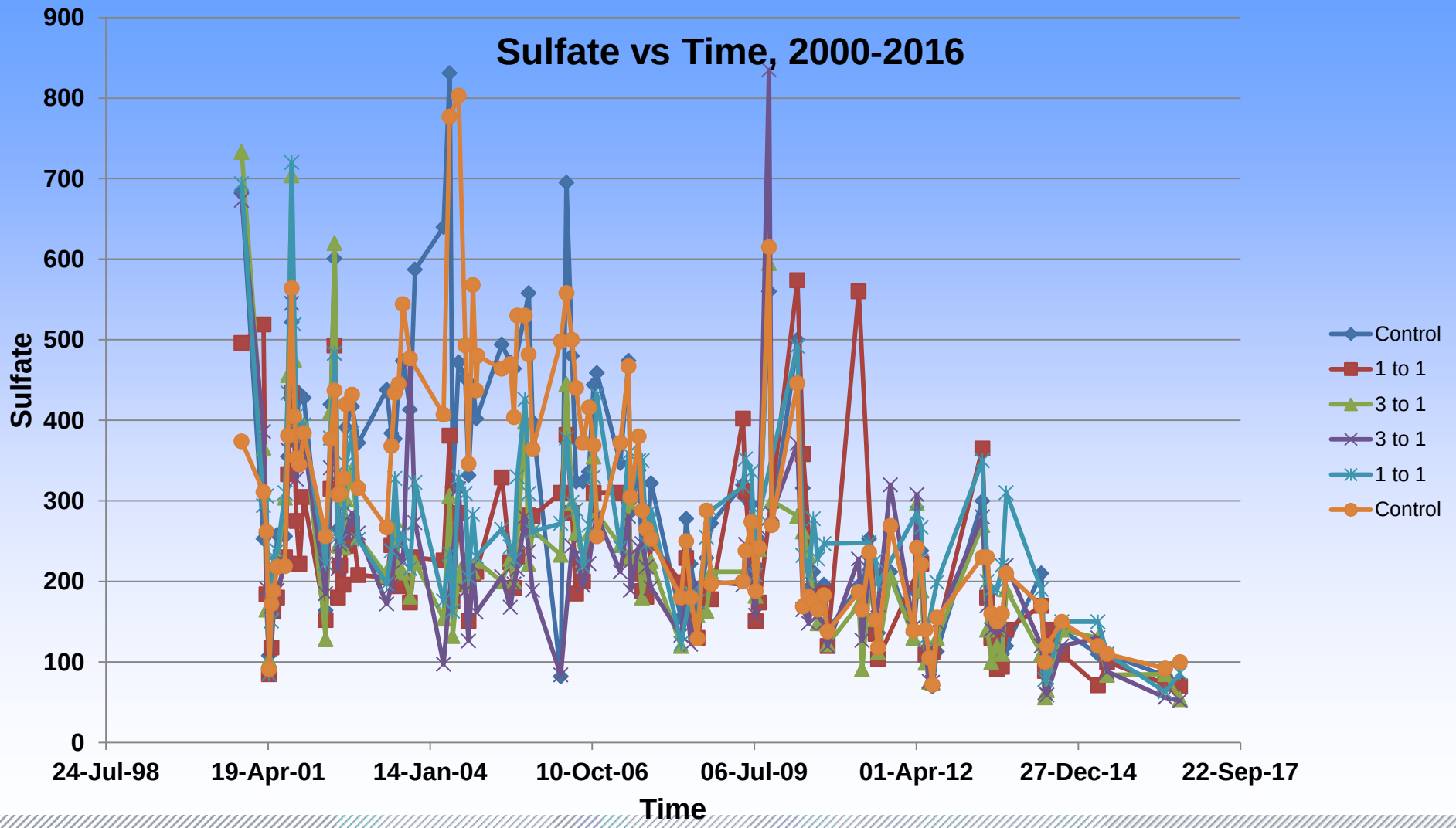
Thank You!

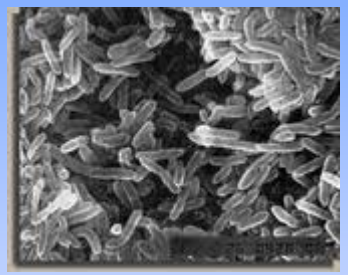
It's all about reactive surface area

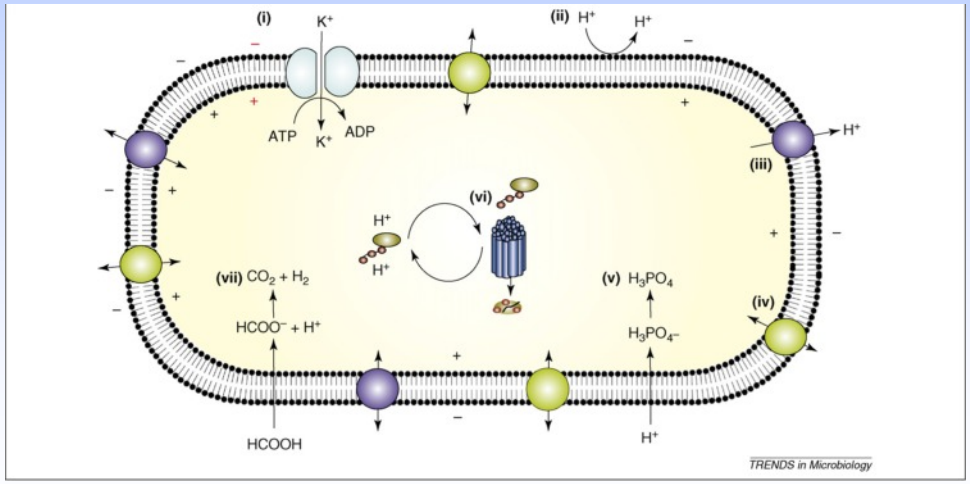
Tank Sample		Underground Mine		
Particle size, in	% passing	% passing	Sulfur content %	Specific surface area m^2/gm
12	100	100		
2	100			
1	76.4	38		
.0787	19.6		0.67%	0.6
0.0035	3.9	3	1.65-1.94%	2.6-4.7

OUTLINE

- Acid Rock Drainage
- Alkaline Addition
  - Theory
  - Applications
    - Coal
    - Metal
- Case Study


Sulfate vs Time, 2000-2016
Sulfate
900
800
700
600
500
400
300
200
100
0
24-Jul-98
19-Apr-01
14-Jan-04
10-Oct-06
06-Jul-09
01-Apr-12
27-Dec-14
22-Sep-17
Time
Control
1 to 1
3 to 1
3 to 1
1 to 1
Control




(i)
K+
ATP
K+
ADP
(ii) H+
H+
H+
(iii)
(iv)
(v) H3PO4
H3PO4–
H+
(vi)
H+
H+
(vii) CO2 + H2
HCOO– + H+
HCOOH
TRENDS in Microbiology