Water Quantity and Water Quality Considerations for Cost-Effective Acid Rock Drainage Water Treatment

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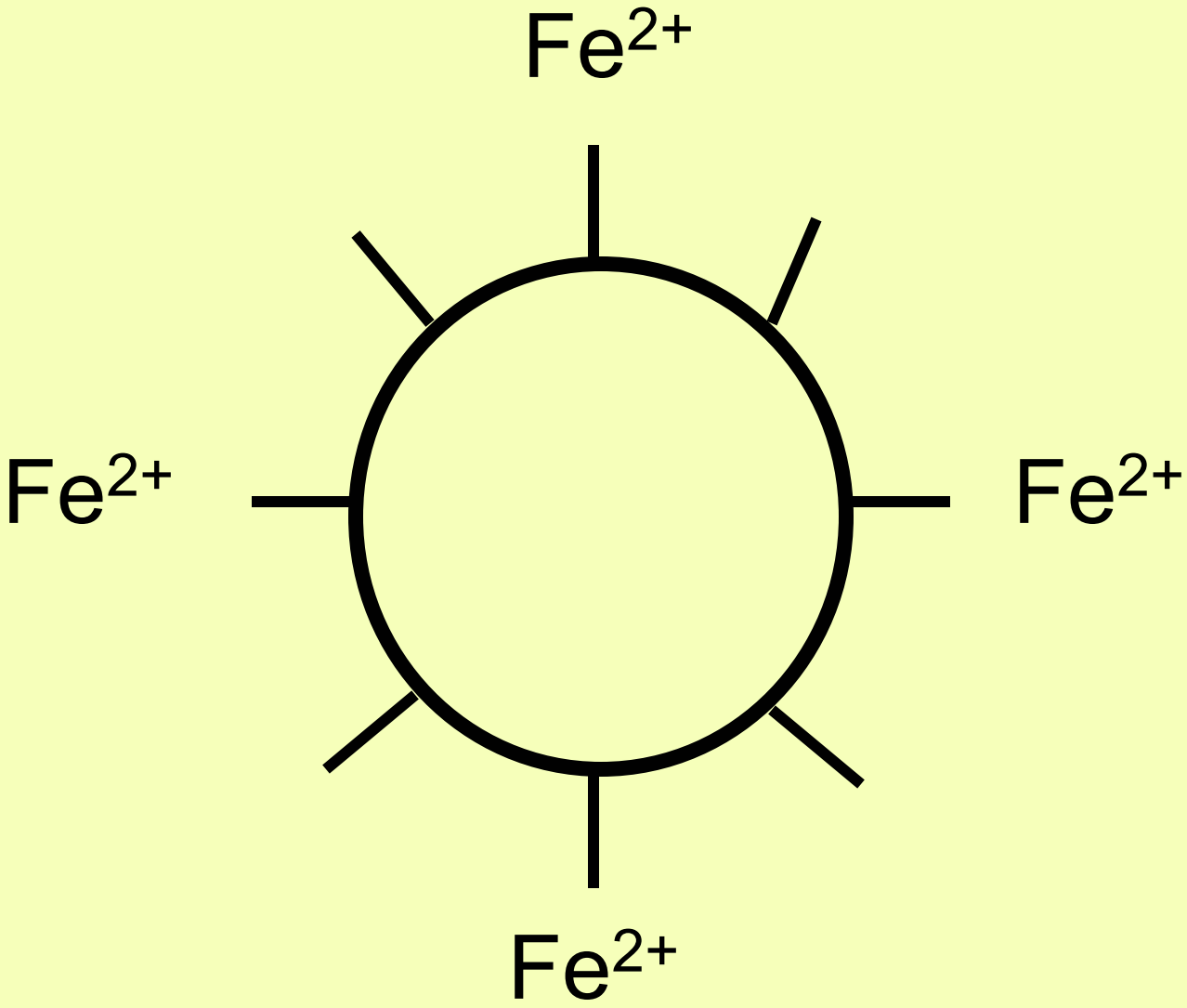
Fe^{2+}
Fe^{2+}
Fe^{2+}
Fe^{2+}

How much ARD stream water needs to be treated?

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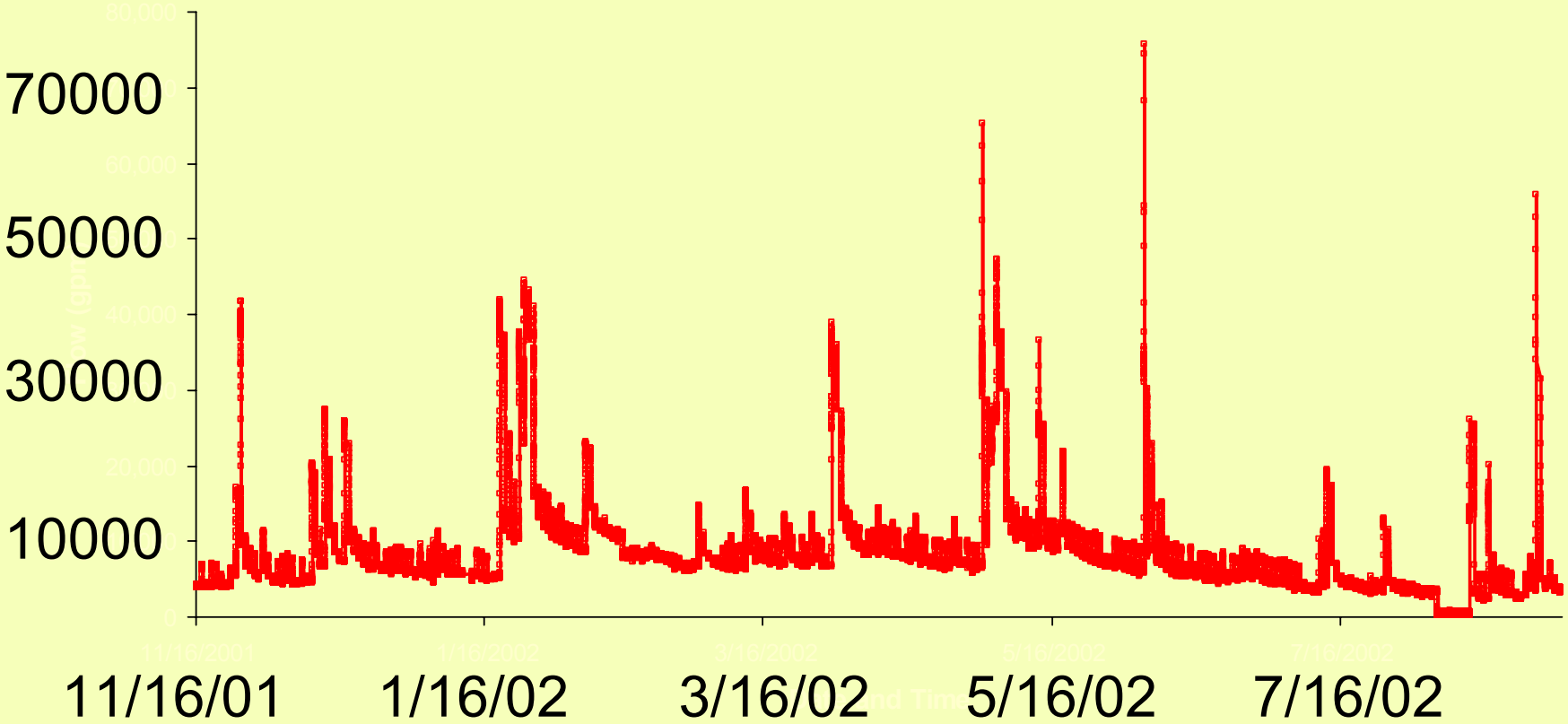
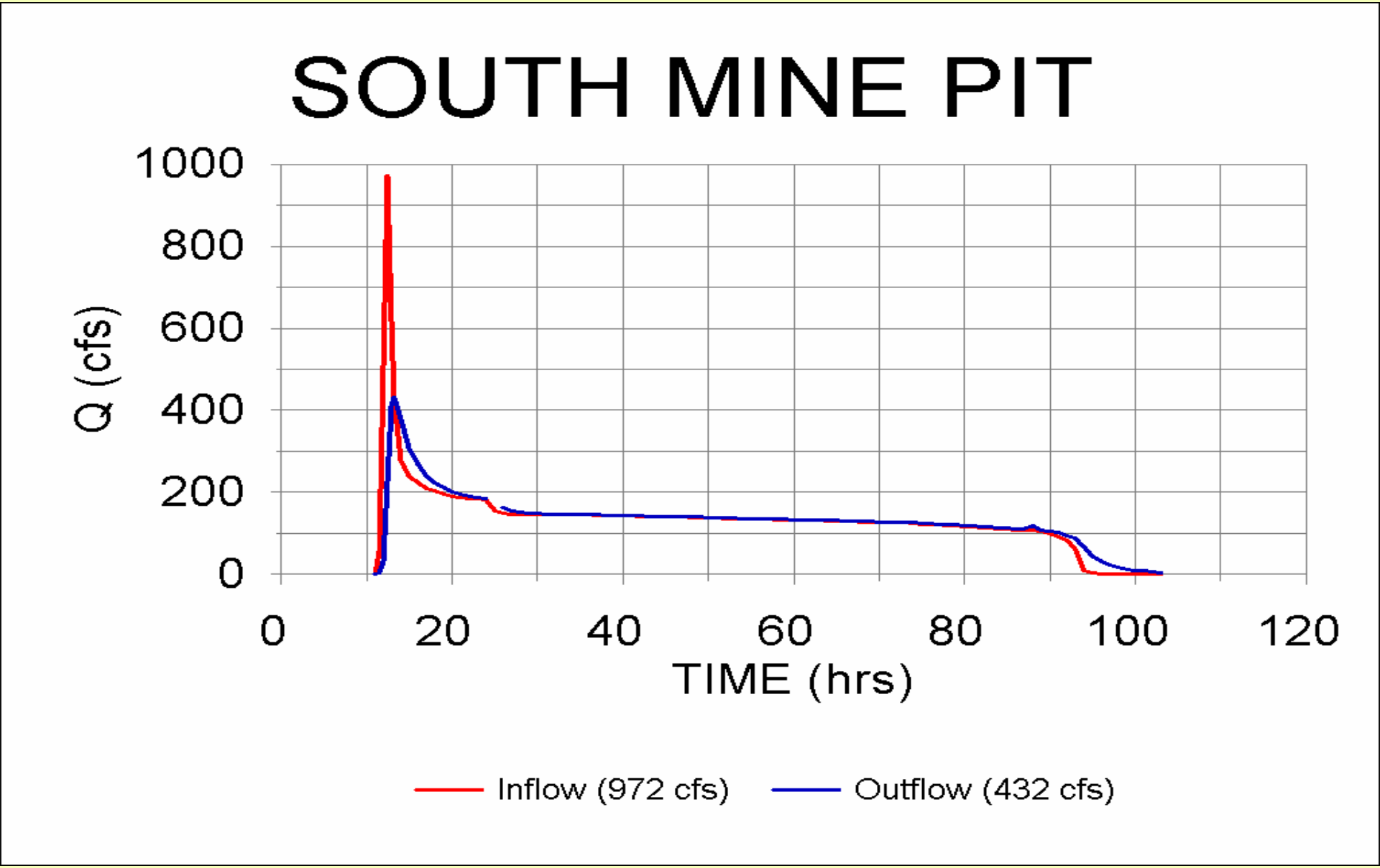
Water quantity?

Flow, gpm





10yr 24hr storm - Peak approx. 200,000 gpm

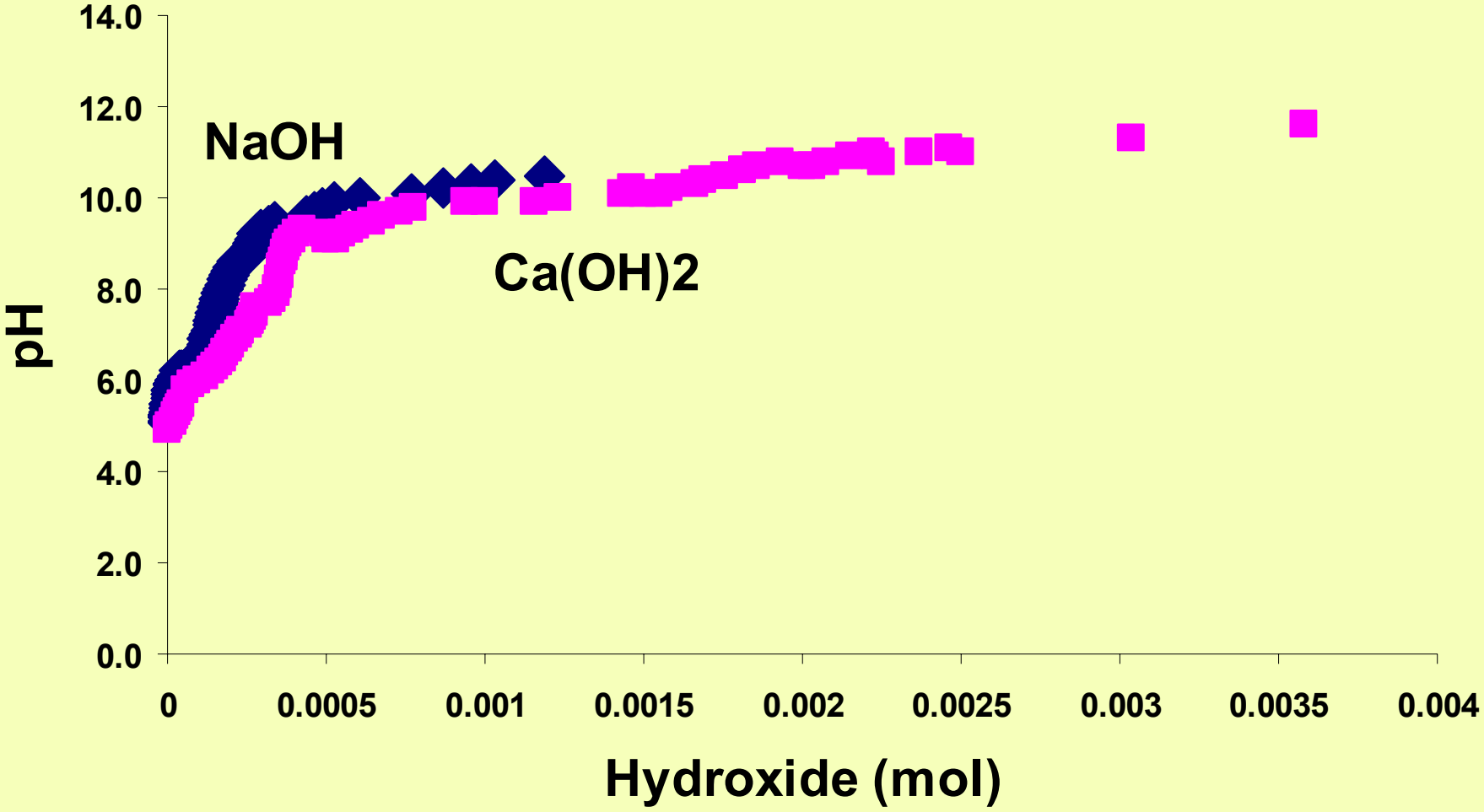
What is the ultimate Water Quality you are trying to achieve?

- Dischargeable pH?
- Remove iron and the majority of the acidity
- Reduce concentrations of “All” metals
- Reduce concentrations of “All” metals below applicable Human and/or Ecological risk-based standards

Typical ARD stream water

- Treatment of large volumes of low iron, low total dissolved solids (TDS) waters
  - pH ranges 3.5 to 6
  - Acidity ranges from 5 to 50 mg/L
  - Oxic surface water

Neutralization of Low Iron, Low TDS Stream Waters



Typical ARD stream water (low TDS)

- **Neutralization reactions limited by**
  - **kinetics of iron oxidation and/or**
  - **nucleation and growth**

ARD Iron Reactions

The oxidation of FeS_2 (Pyrite) by oxygen;

1) $FeS_2 + 7/2O_2 + H_2O = Fe^{2+} + 2SO_4^{2-} + 2H^+$

2) $\mathbf{4Fe^{2+}} + O_2 + 4H^+ = 4Fe^{3+} + 2H_2O$

3) $Fe^{3+} + 2H_2O = \mathbf{FeO(OH)}_{\mathbf{(solid)}} + 3H^+$

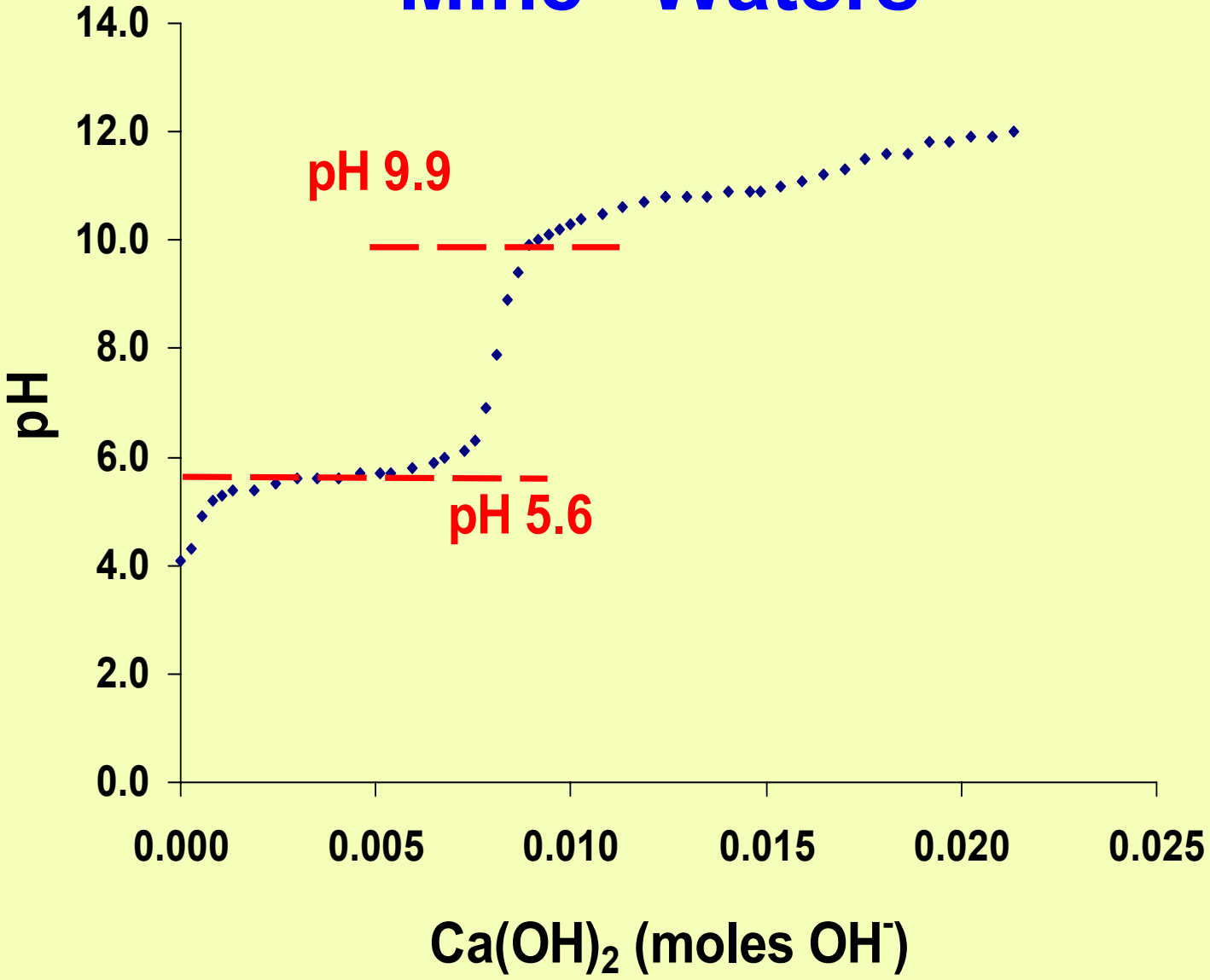
Total Reaction

$FeS_2 + 15/4O_2 + 5/2H_2O = \mathbf{FeO(OH)} + 2SO_4^{2-} + 4H^+$

Typical ARD seep, mine water

Treatment of relatively “small” volumes of high iron, high TDS waters

Neutralization of High Iron, High TDS "Mine" Waters



Typical ARD water

- Neutralization reactions limited by nucleation and growth and/or kinetics of iron oxidation
  - Use high TSS waters as nuclei
  - Use high iron concentration solutions to control geochemical reactions

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Neutralization of typical ARD stream water (low TDS)

- **Potential geochemical solutions**
  - Use high TSS waters as nuclei
  - Use high iron concentration solutions to control geochemical reactions

Ducktown, Tennessee

- Cooperative agreement
  - EPA
  - State of Tennessee
  - Glenn Springs Holdings

- Goal
  - Alleviate contaminant discharge down gradient (Ocoee river), ultimate biological integrity of creek

Ducktown, Tennessee

- Long history of mining in Watershed
- Large watershed (approximately 10,000 acres) with variable flows
- Creek presently runs through a large pit lake

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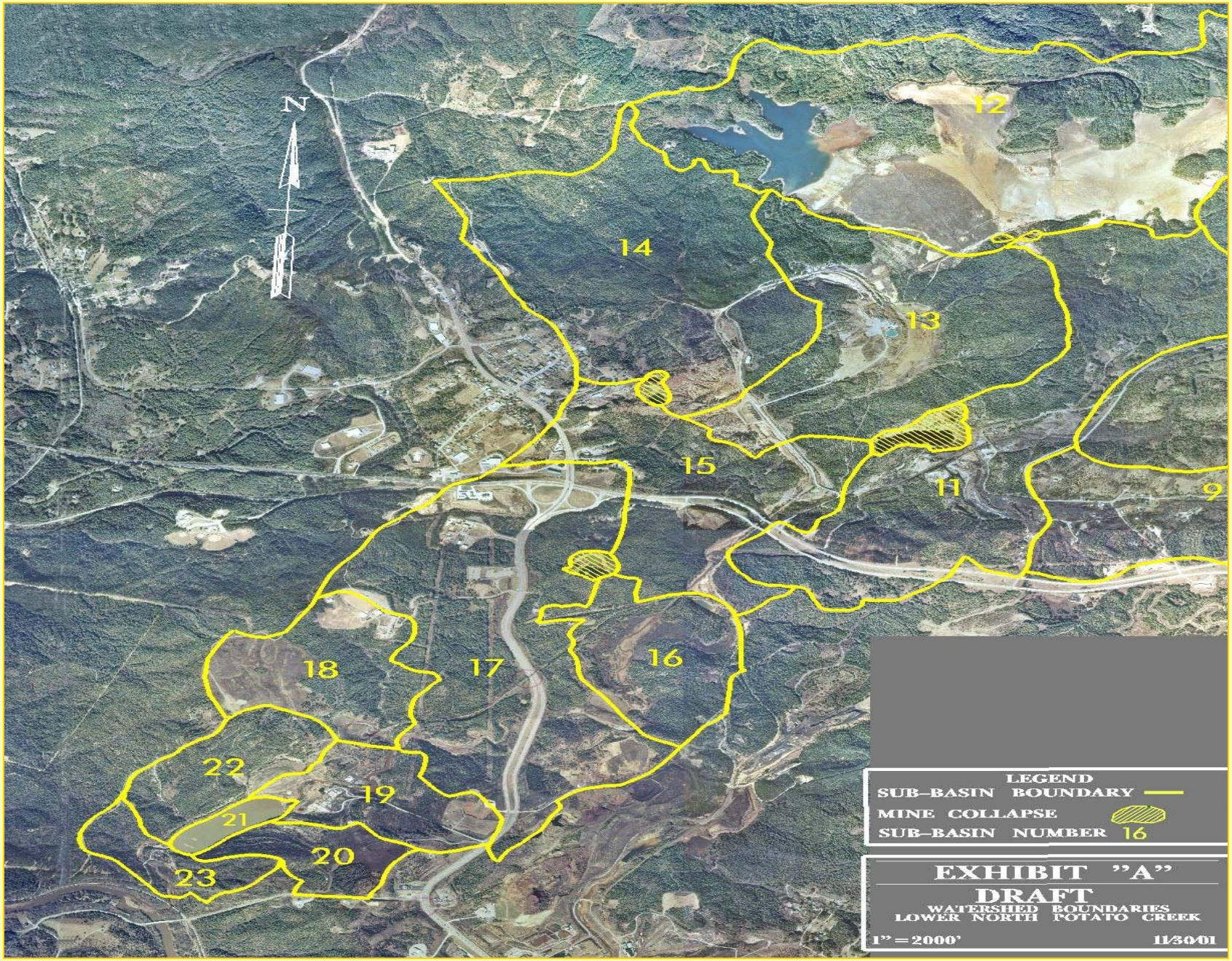
N
12
14
13
15
11
9
18
17
16
22
19
21
20
23
LEGEND
SUB–BASIN BOUNDARY
MINE COLLAPSE
SUB–BASIN NUMBER 16
EXHIBIT "A"
DRAFT
WATERSHED BOUNDARIES
LOWER NORTH POTATO CREEK
1" = 2000'
11/3001

Ducktown, Tennessee

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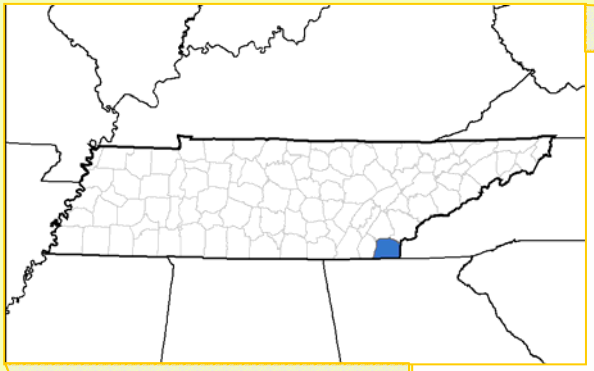
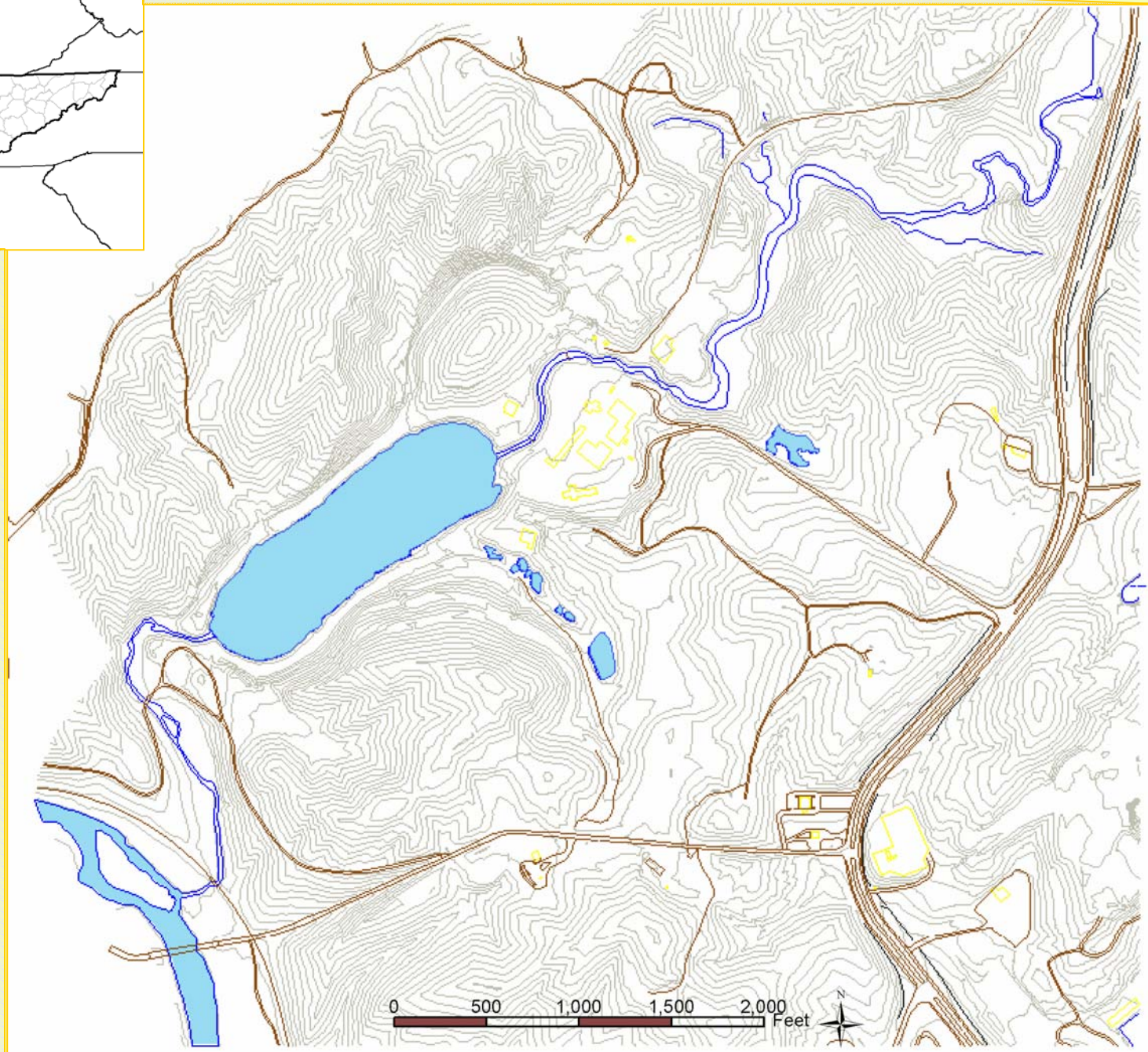
- Creek presently runs through a large pit lake




0
500
1,000
1,500
2,000
Feet
N

Ducktown, Tennessee

Deep Pit Water

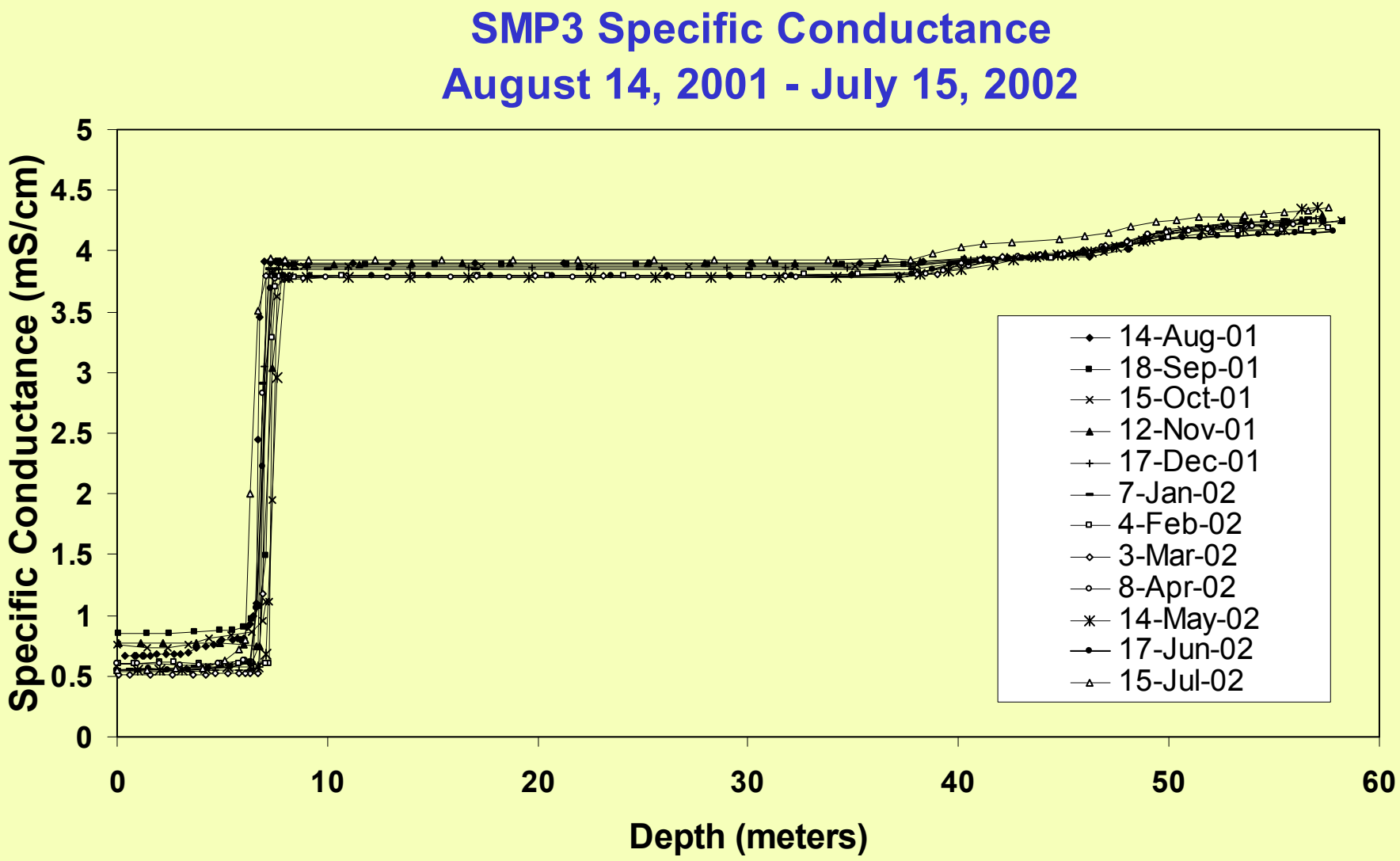
- High Iron, TDS

Surface Water

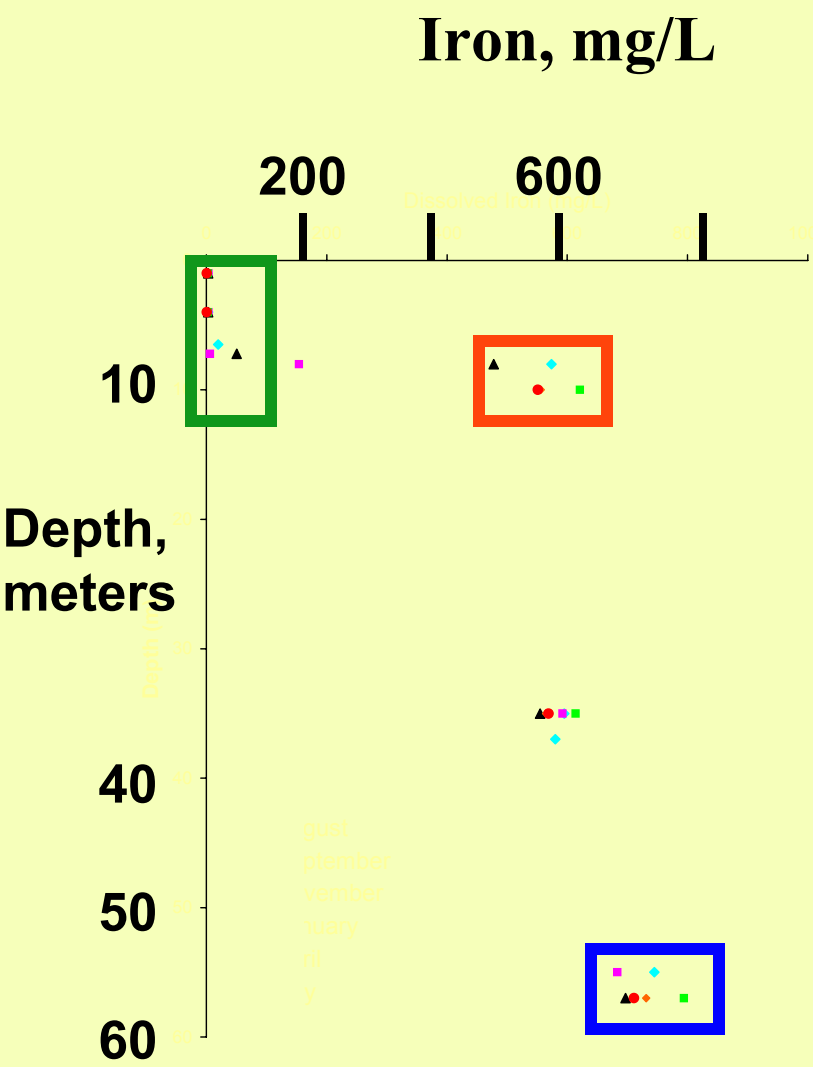
- Low Iron, TDS

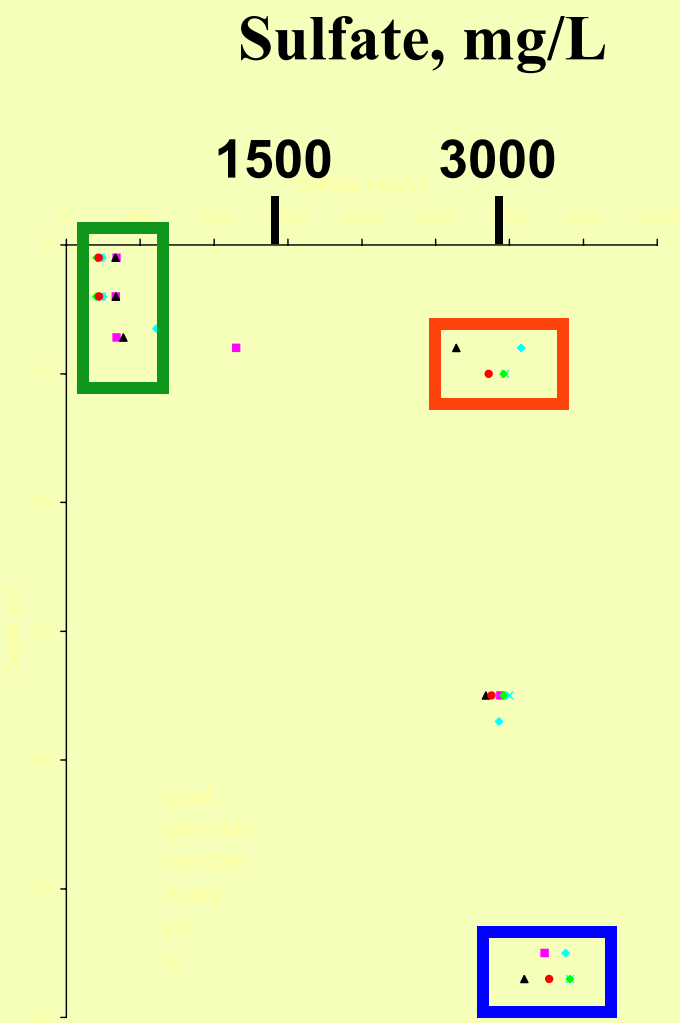
Pit Water

	pH	s.c.	Acidity mg/L	Al mg/L	Cu mg/L	Fe mg/L	Mn mg/L	Zn mg/L	SO_4 mg/L
shallow	**3.37**	**660**	**30**	**1.15**	**0.11**	**3.6**	**2.5**	**0.60**	**262**
deep	**4.64**	**3860**	**1140**	**0.99**	**0.018**	**551**	**37**	**0.88**	**2895**


SMP3 Specific Conductance
August 14, 2001 - July 15, 2002
Specific Conductance (mS/cm)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
10
20
30
40
50
60
Depth (meters)
14-Aug-01
18-Sep-01
15-Oct-01
12-Nov-01
17-Dec-01
7-Jan-02
4-Feb-02
3-Mar-02
8-Apr-02
14-May-02
17-Jun-02
15-Jul-02

Pit Lake Chemistry





Ducktown, Tennessee

Deep Pit Water

- High Iron, TDS
- Low Dissolved Oxygen

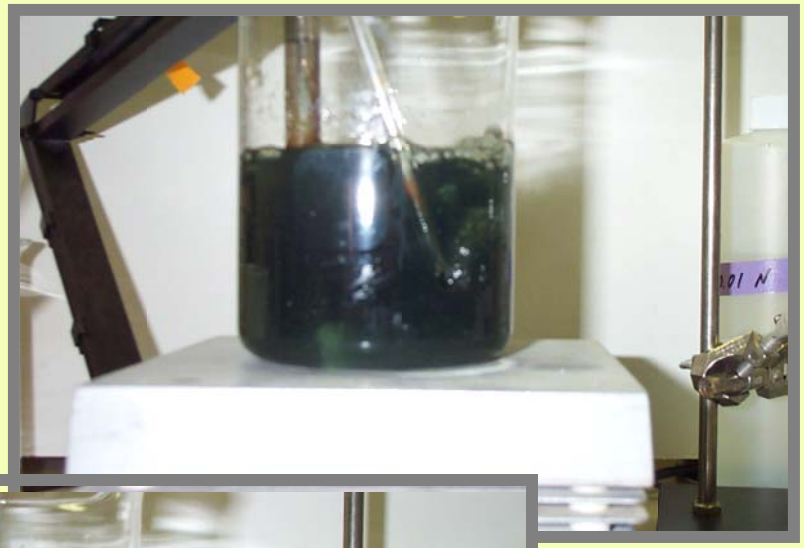
Surface Water

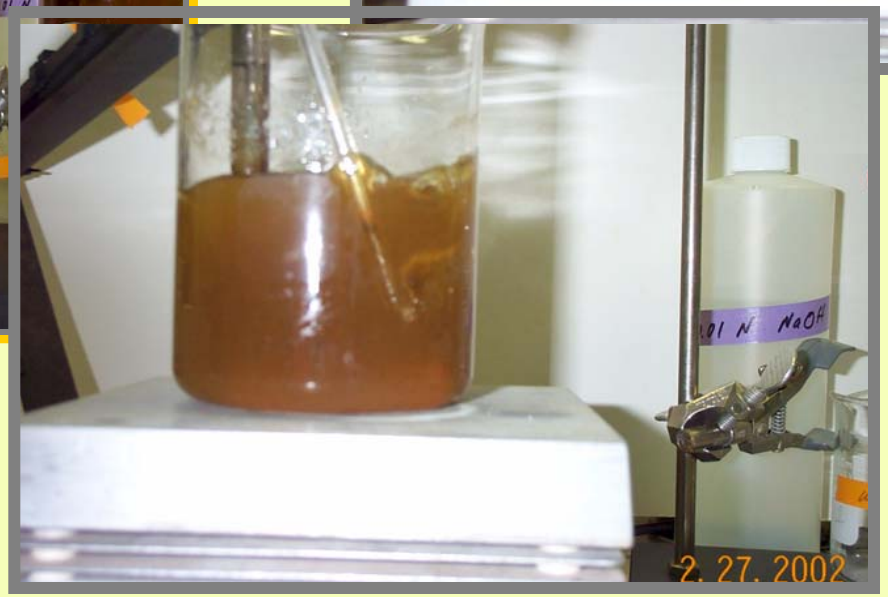
- Low Iron, TDS
- Saturated Dissolved Oxygen

ARD Stream Quality

pH	spec. cond.	Acidity mg/L	Fe mg/L	Mn mg/L	Zn mg/L	SO_4 mg/L
3.5 – 5.6	160-950	3 - 100	2.0 - 25	0.9 - 3.3	0.30 – 1.1	65 - 600

Bench-Scale Treatability





Bench-Scale Iron Hydroxide Settling Experiments

1 minute

3 minutes

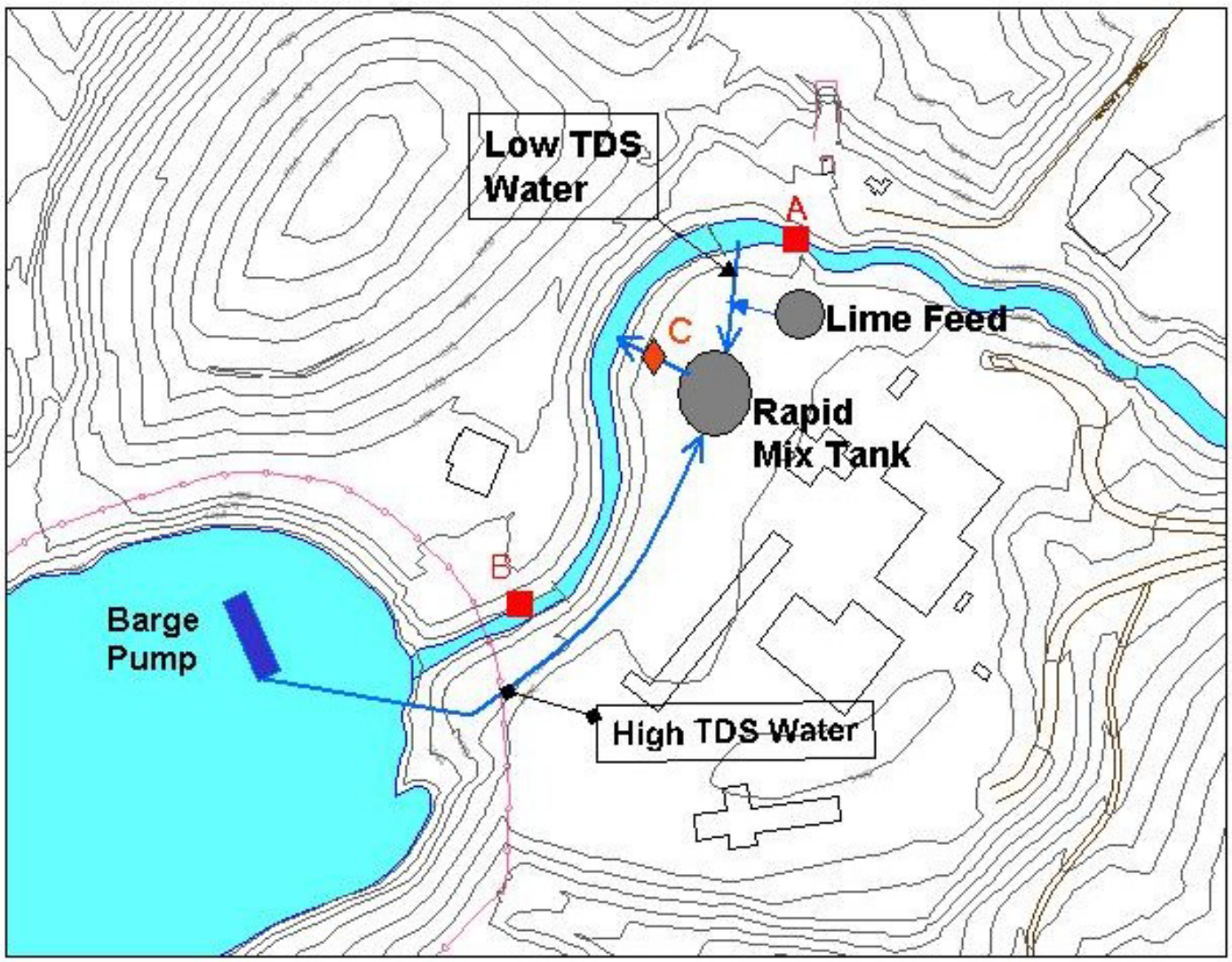
7 minutes

STREAMLINED ECOLOGICAL RISK EVALUATION OF WATER QUALITY IN CREEK

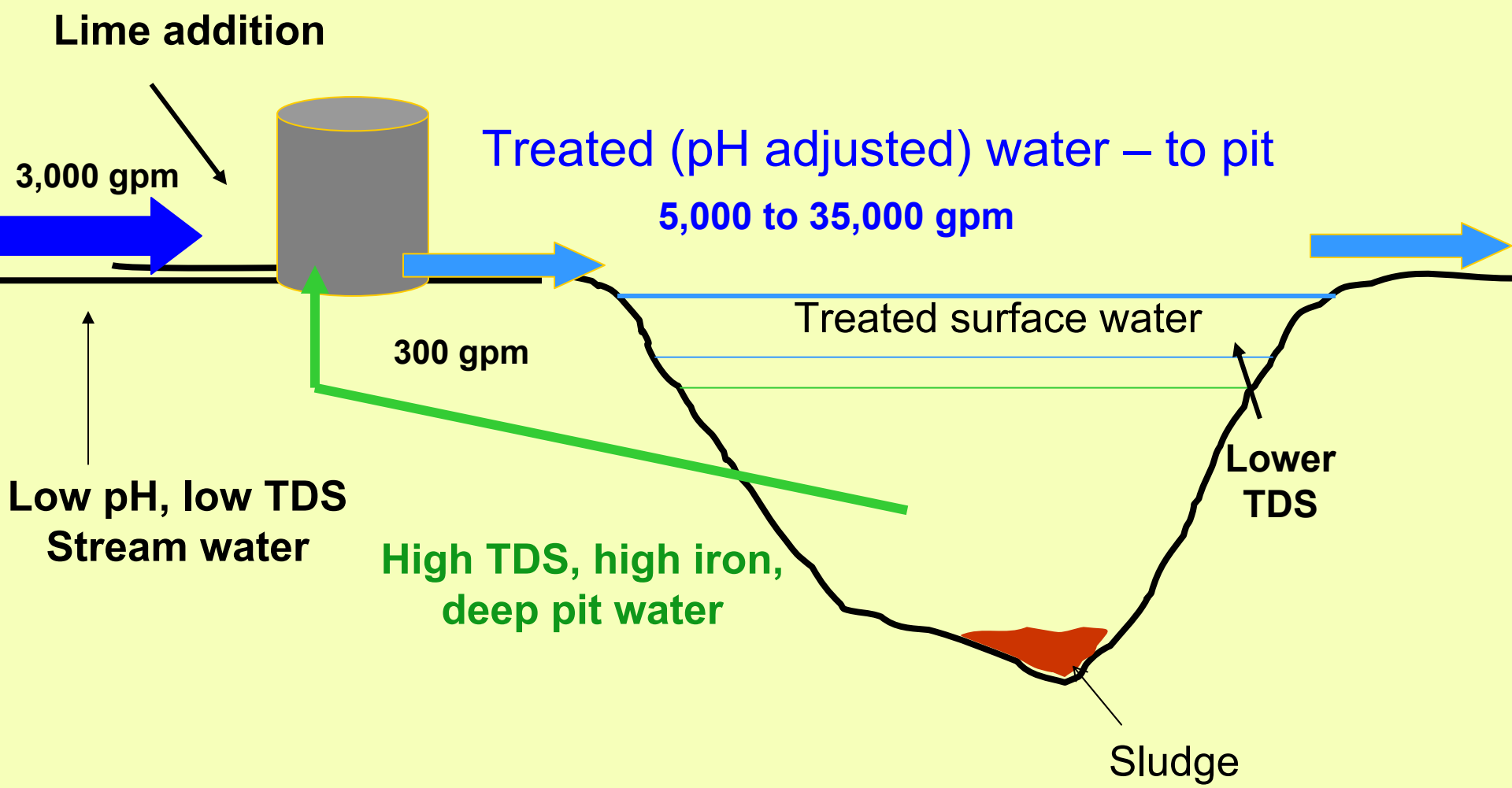
COPECs – EcoHQs

1. Aluminum – 13.3
2. Copper –6.6
3. Iron -3.5
4. Zinc –2.7
5. Cadmium - 1.6
6. Manganese – 1.2
7. Lead – 1.1
8. Cobalt – 1.1

Field Demonstration of Proposed Technology Uncertainties?



Field Treatability Demonstration



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EXTENT OF IRON SLUDGE PLUME AFTER 3.5 HOURS

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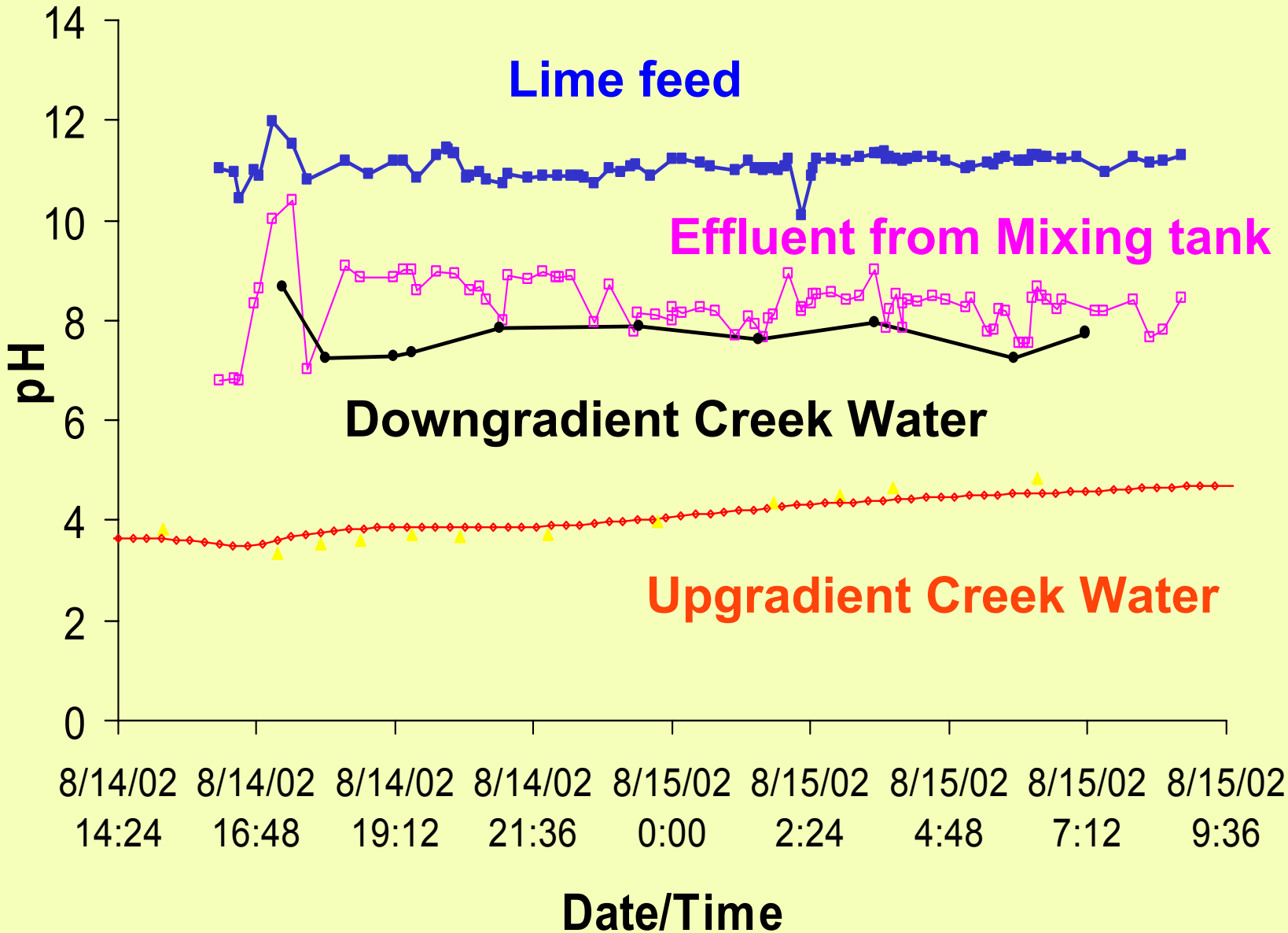
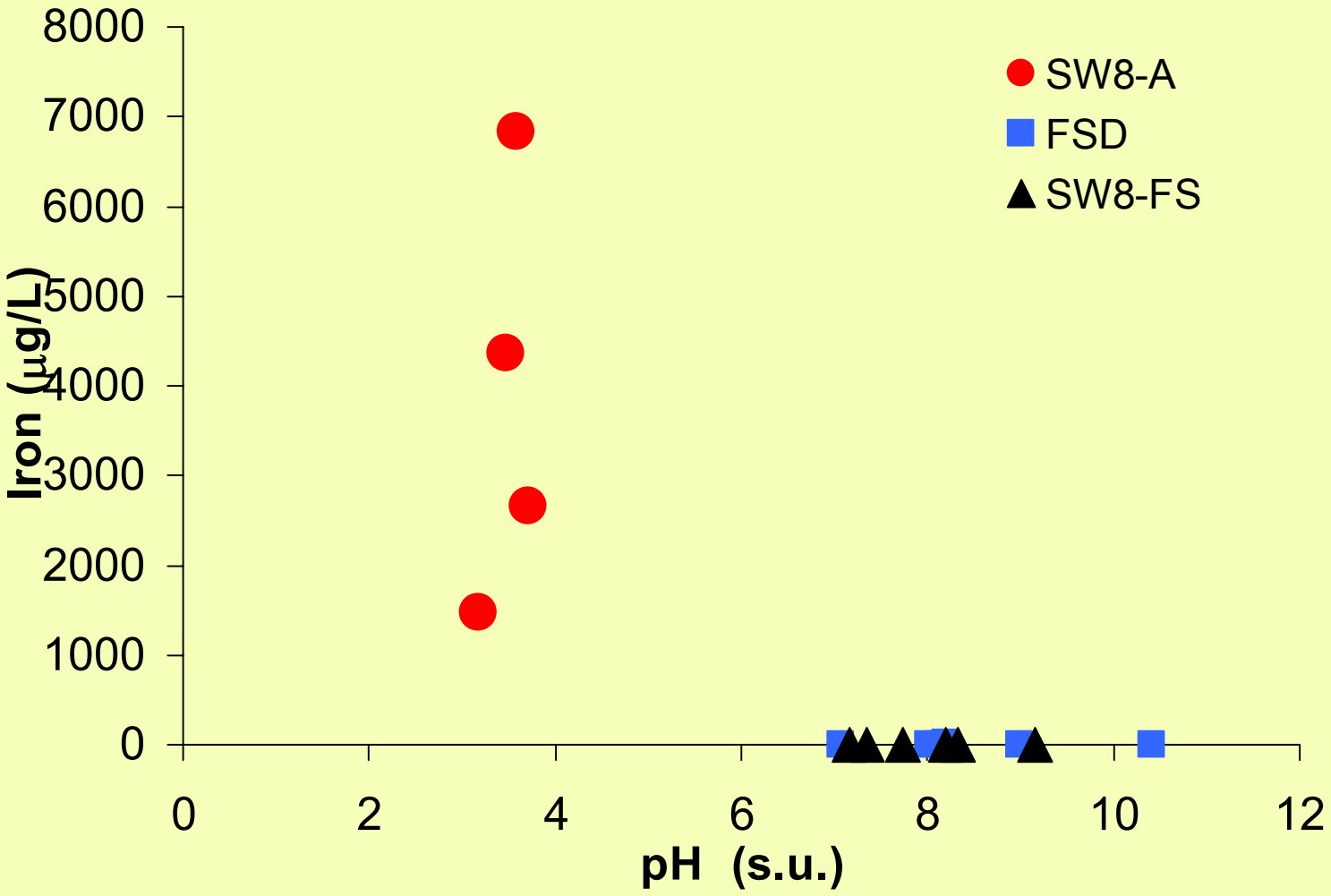
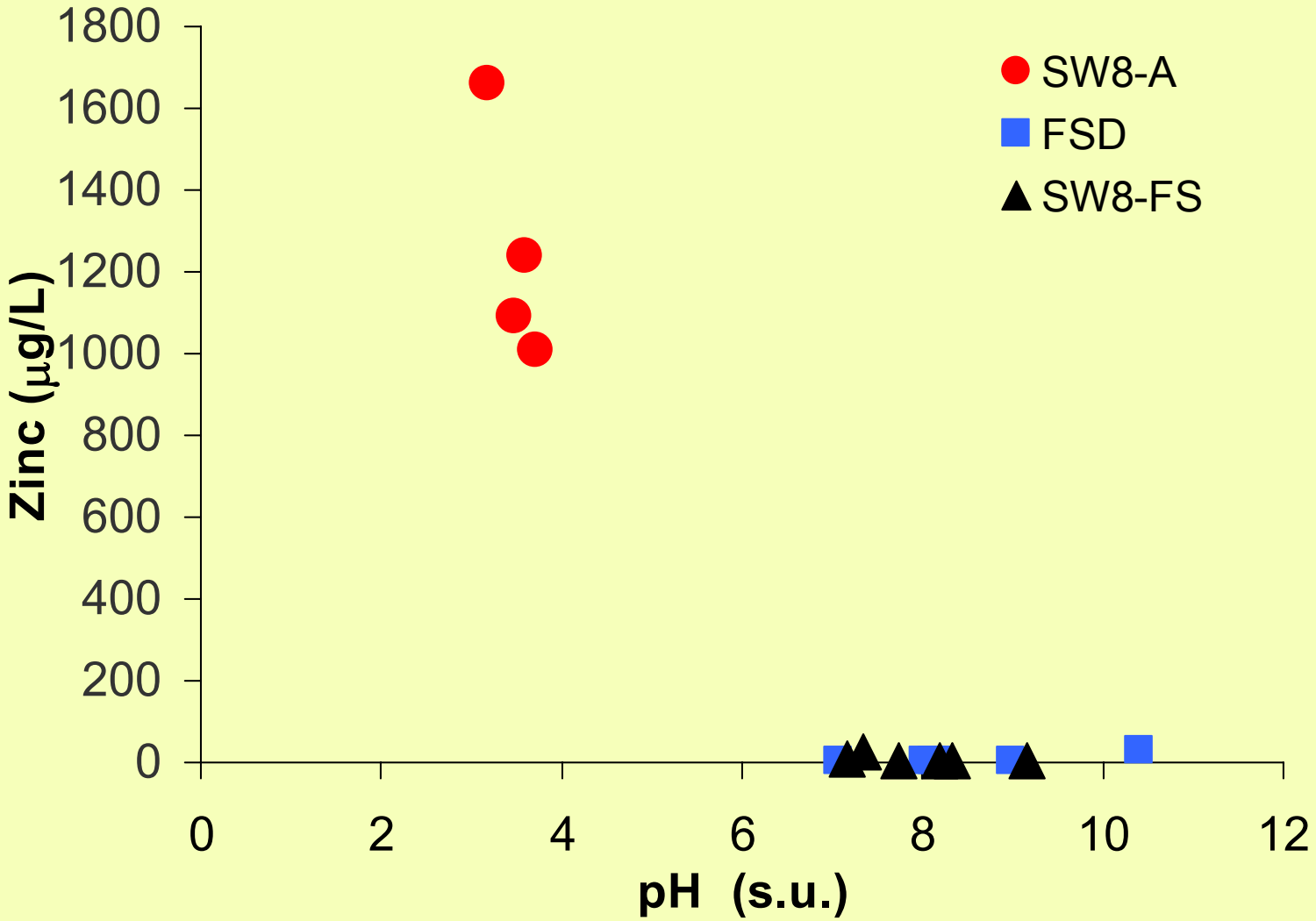
Field Study Results



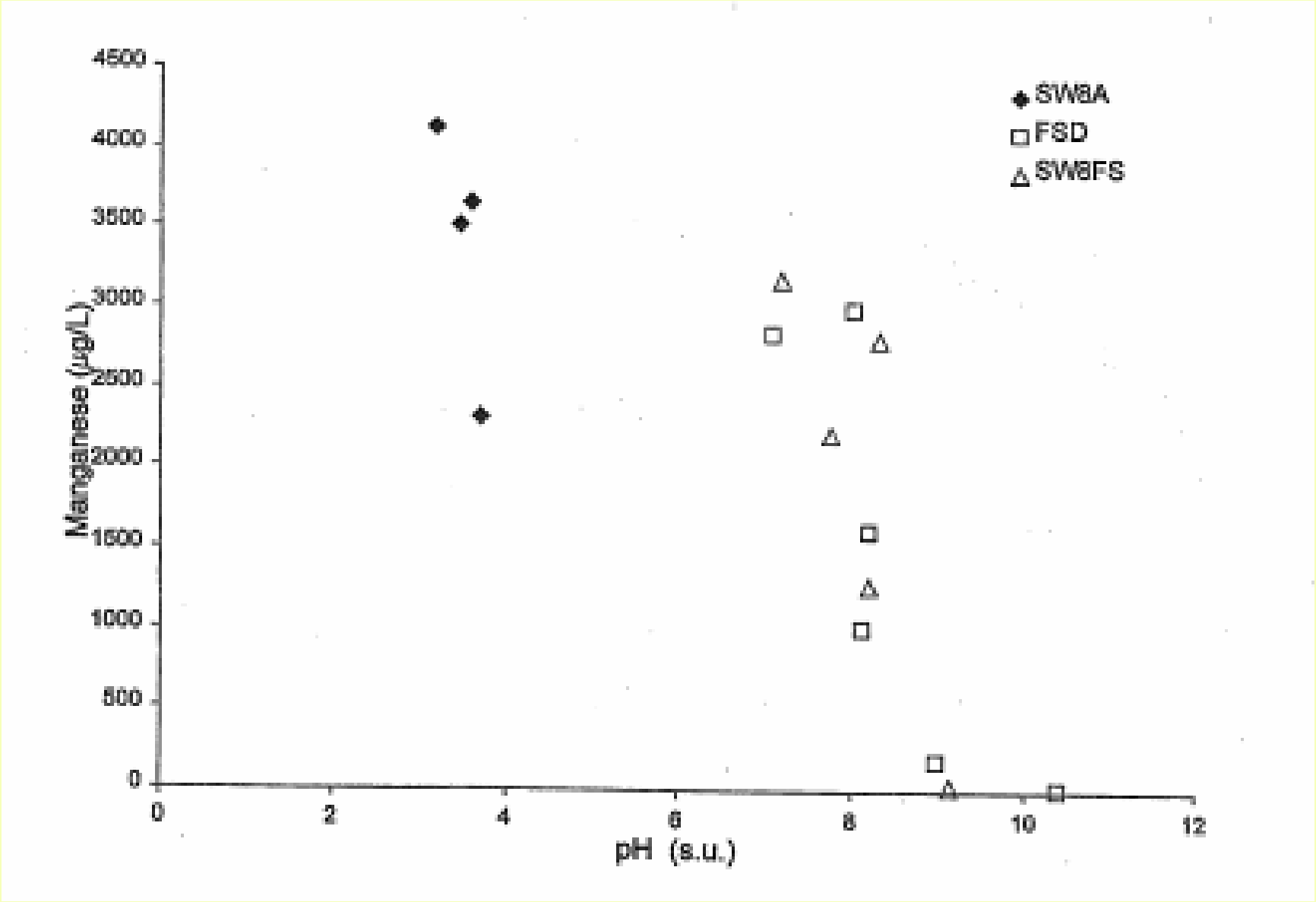
Iron Removal During Pilot Studies



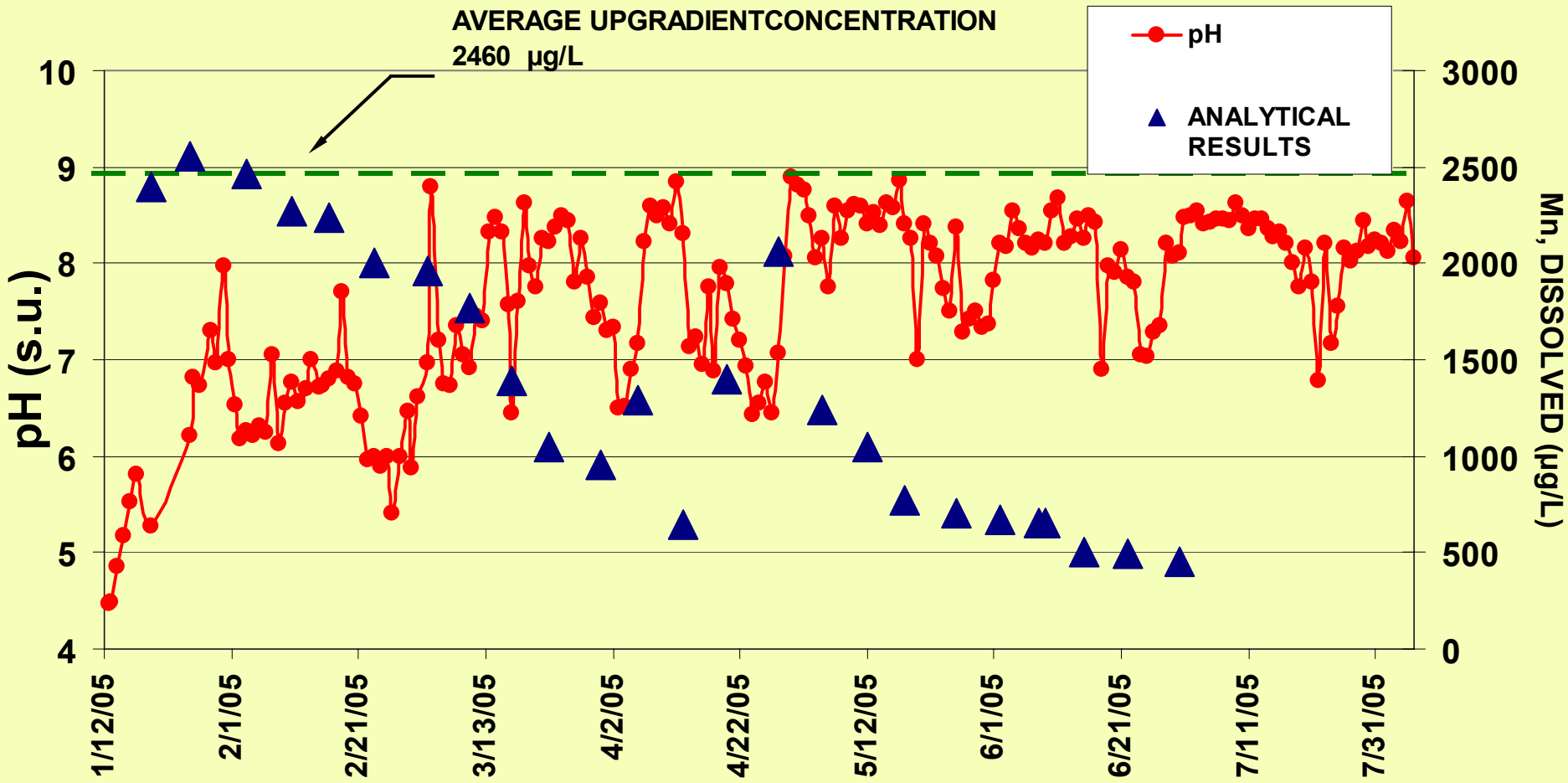
Zinc Removal During Pilot Studies



Manganese Removal During Pilot Studies



Manganese Removal at Pit Discharge



Is it working?