Sodium Bicarbonate Injection for Remediation of Acidic Groundwater

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Christina B. Brown, P.E.
AquAeTer, Inc.
Brentwood, Tennessee

AquAeTer

Introduction

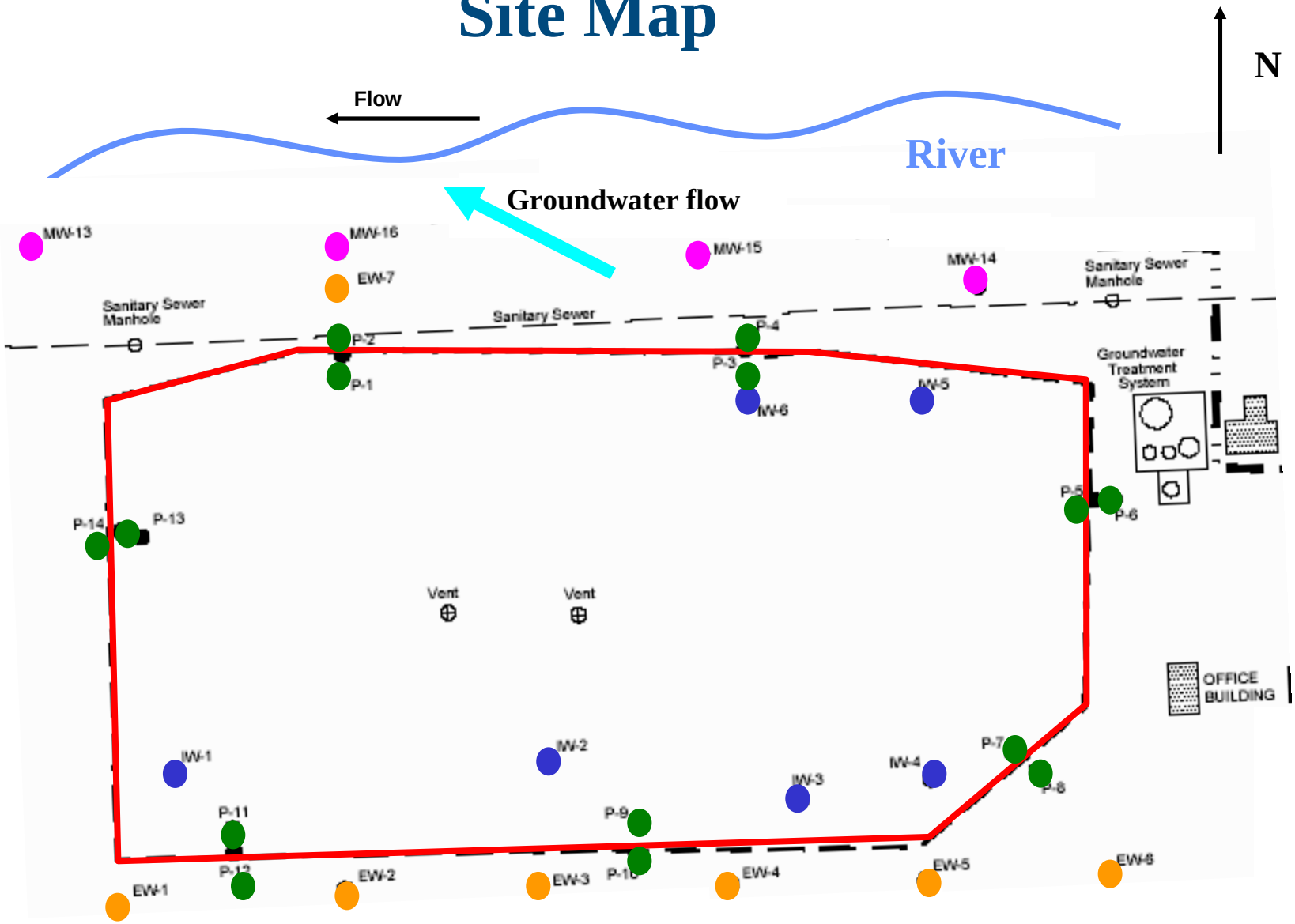
- Problem Background
- Site Overview
- Feasibility Study
  - Field Work
  - Bench Scale Testing
  - Continuous Testing
- Pilot Study
  - Design
  - Results
- Future Plans

Problem Background

- Former chemical manufacturing site
- Natural ravine used for chemical dumping
- Slurry wall and pump and treat system installed in 1980's to remediate groundwater
  - Phenolics
  - BTEX
  - Sulfuric acid
- Treatment successfully reduced phenolic and BTEX concentrations below regulatory limits
  - Groundwater remained highly acidic
- The pH in monitoring wells exterior to the slurry wall began to drop after 2000

Site Overview

Site Map

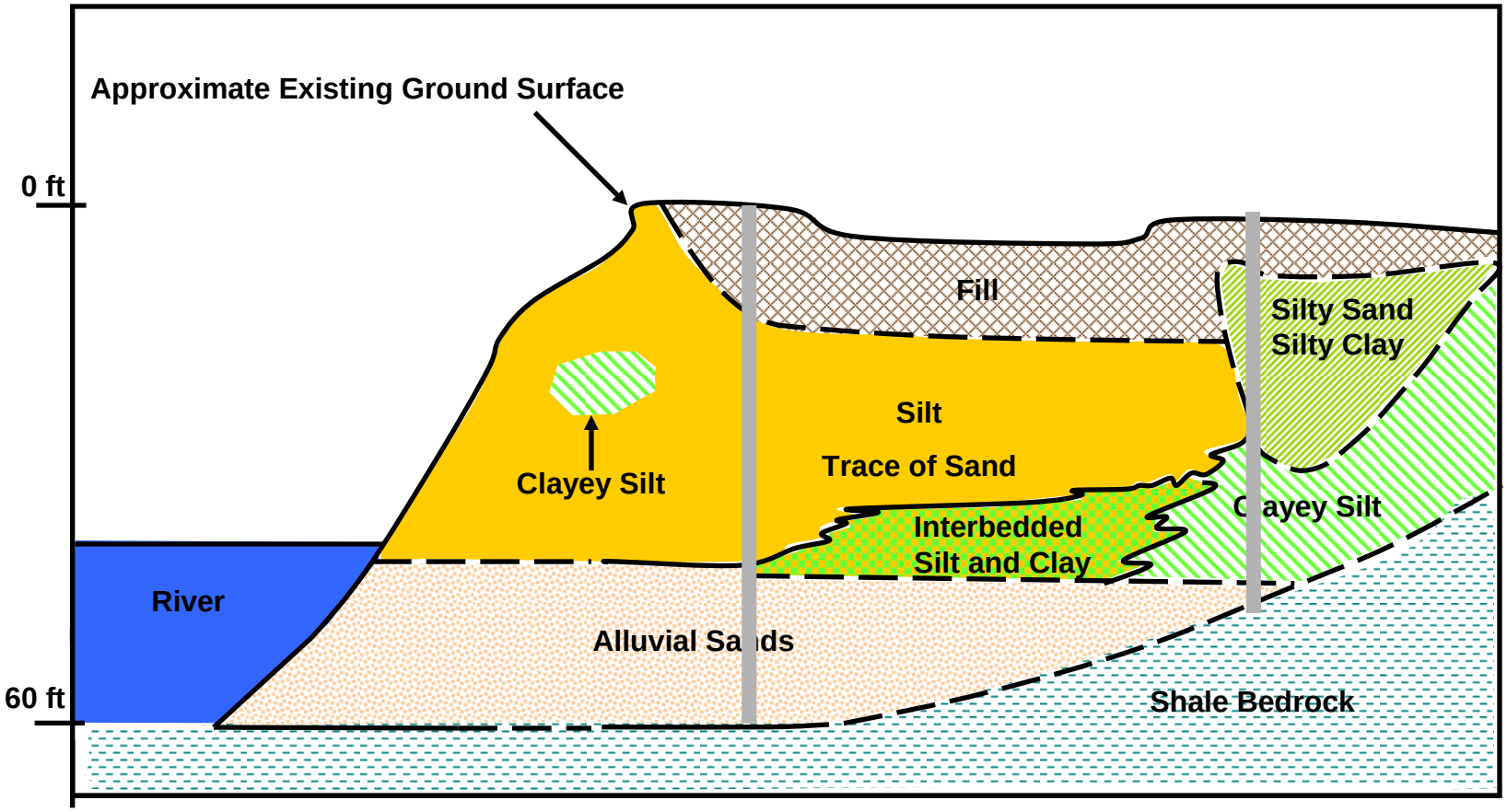

N
Flow
River
Groundwater flow
MW-13
MW-16
EW-7
MW-15
MW-14
Sanitary Sewer Manhole
Sanitary Sewer
Sanitary Sewer Manhole
P-2
P-1
P-4
P-3
IW-6
IW-5
Groundwater Treatment System
P-5
P-6
P-14
P-13
Vent
Vent
OFFICE BUILDING
IW-1
IW-2
IW-3
IW-4
P-7
P-8
P-11
P-9
EW-1
EW-2
EW-3
EW-4
EW-5
EW-6

Site Photo

River

Impoundment

Cross Sectional View



Feasibility Study

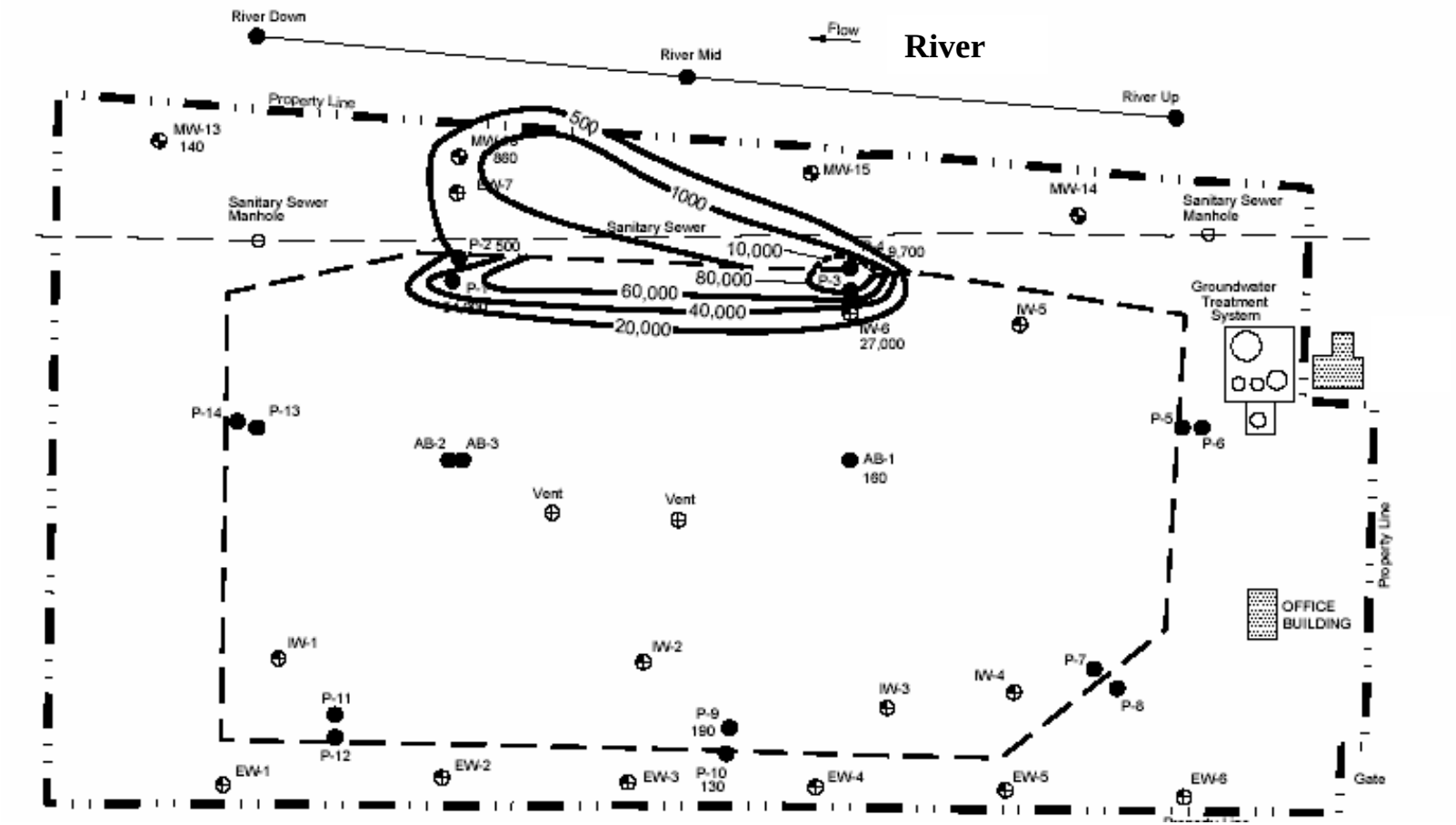
Feasibility Study

- **Goal:** Evaluate remedies to prevent acidic groundwater (pH < 5.5) from reaching river
- Options Considered
  - Passive Neutralization Barrier
    - Limestone
  - Injection of Soluble Alkaline Chemical
    - Sodium Bicarbonate
    - Sodium Hydroxide
- Selection Criteria
  - Technical Feasibility
  - Cost
  - Lifetime

Feasibility Study

- Field Studies
  - Additional sampling (wells and piezometers)
  - Slug testing
  - Collected water for laboratory studies

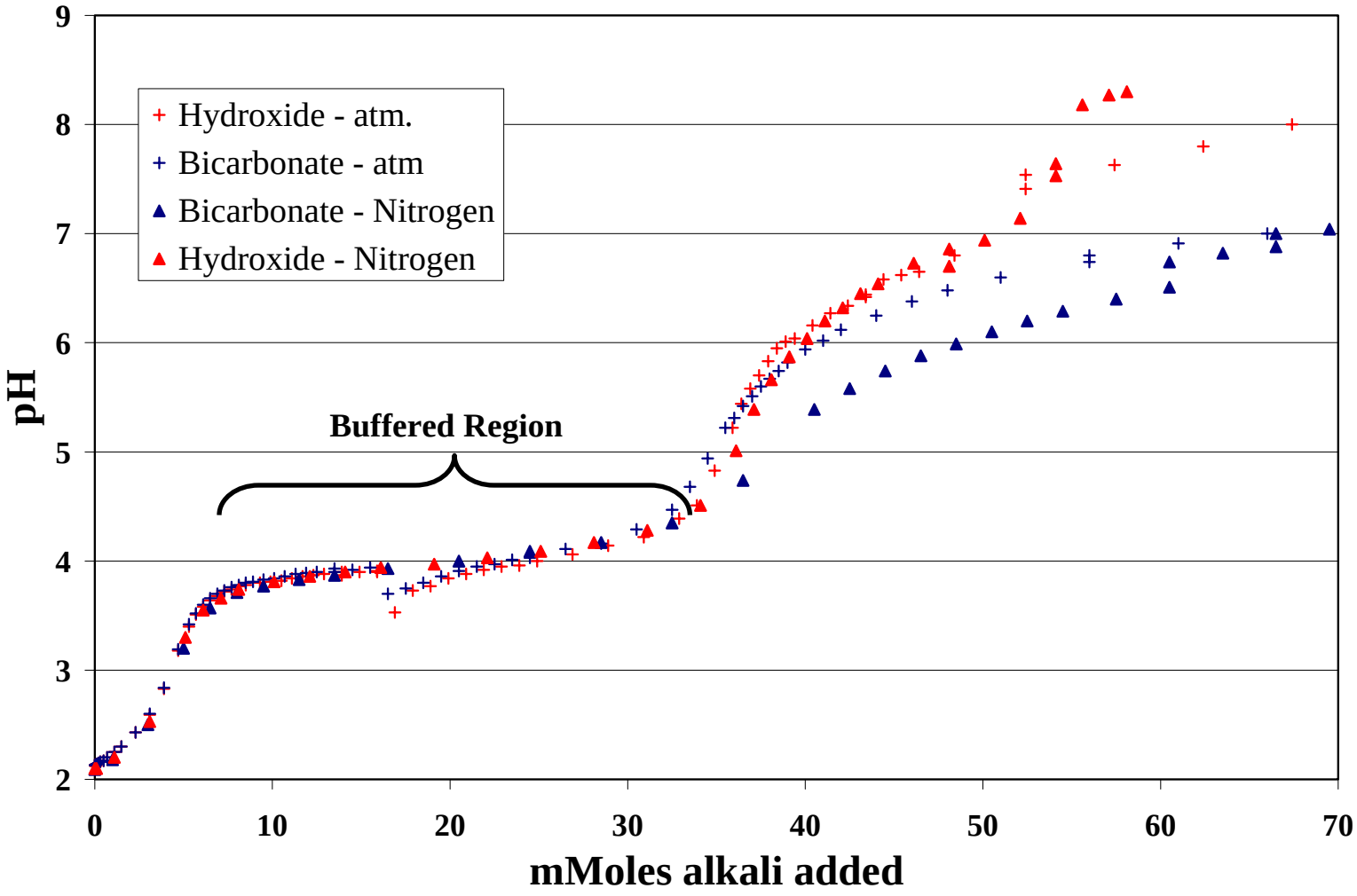
Acidity Contours



Feasibility Study – Bench Scale

- Determine the optimal neutralization agent for field application based on:
  - Precipitate (solids) formation
    - Properties
    - pH range
  - Impact of anoxic environment
  - Off-gassing
  - Heat generation
  - pH endpoint control

Titration Curves



Precipitate Volume Comparison

Bench Scale Summary

- No significant heat or gas generation during any test
- Bicarbonate precipitate was 1/3 the volume of hydroxide and settled much more rapidly
- Anoxic environment has minimal impact on the variables of concern
  - Titration curve is nearly identical in region of concern
  - Precipitate volumes and properties are similar
- Limestone has a very slow reaction rate and armours easily

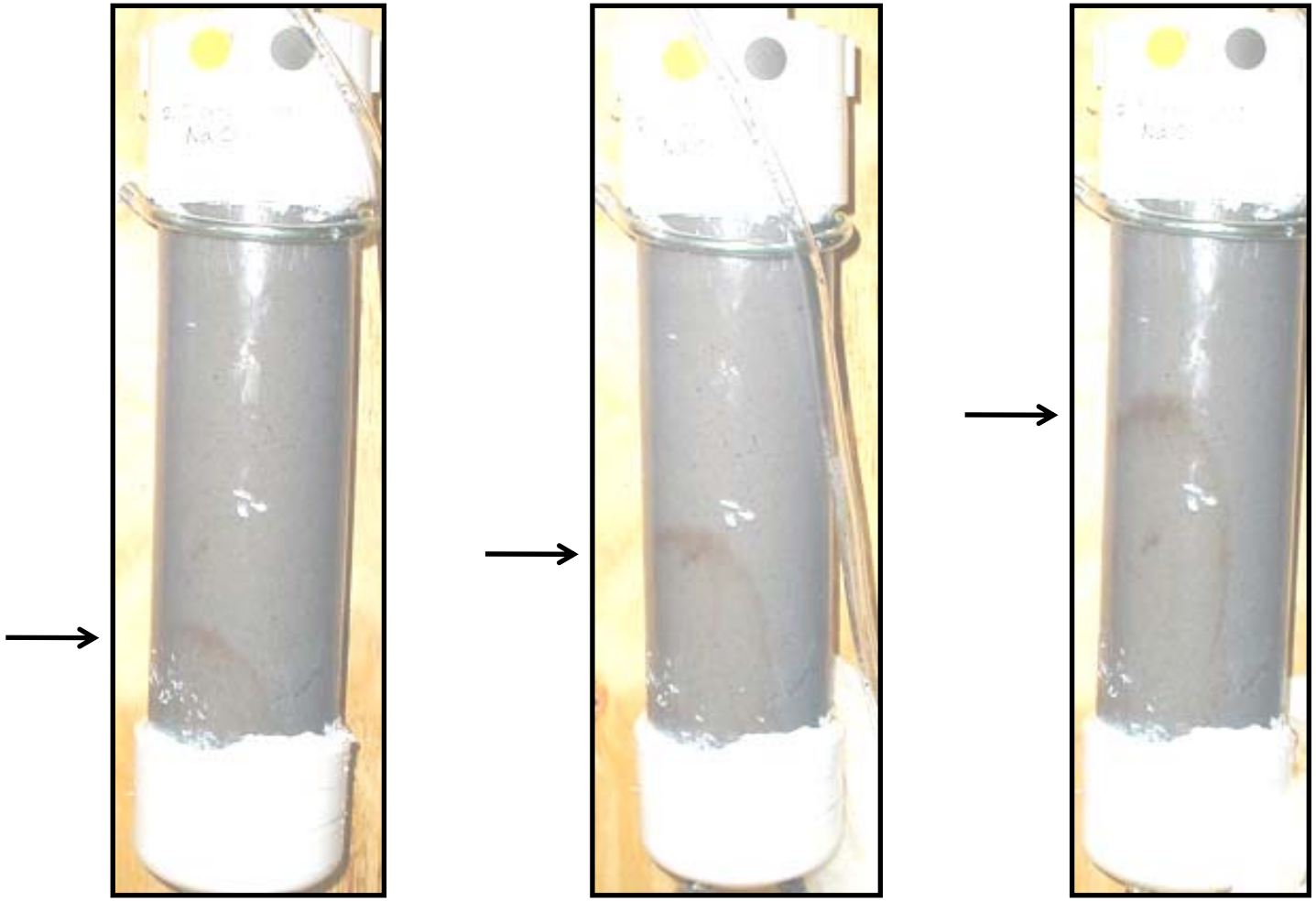
Feasibility Study - Continuous Testing

- Alkaline Injection - Precipitate behavior in porous medium
  - Site water with sodium bicarbonate
  - Site water with sodium hydroxide
- Passive Barrier – Fouling and efficiency
  - Limestone rock with site water
  - Limestone sand with site water

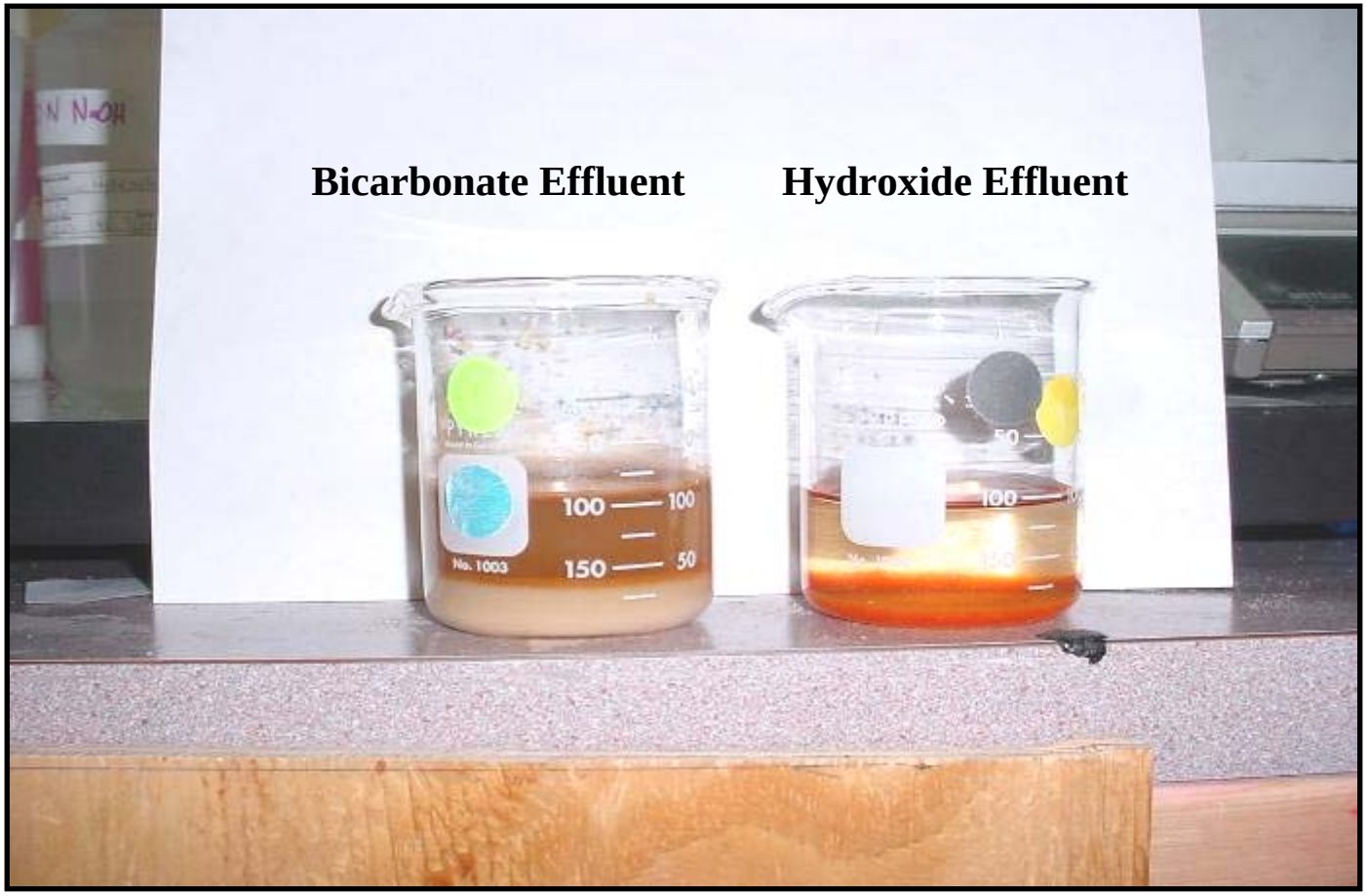
Limestone Columns

Sodium Bicarbonate Column Versus Sodium Hydroxide Column

Progression Of Precipitate Plume In Sodium Hydroxide Column



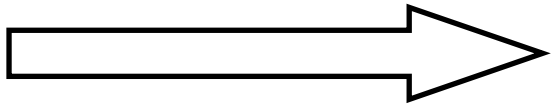
Effluent Precipitate



Continuous Testing Conclusions

- Limestone beds are rendered ineffective very quickly due to precipate
- Precipitate from bicarbonate moves through small pore spaces more easily

- Test Results + Cost Analysis



Bicarbonate Injection

Sodium Bicarbonate Injection Benefits

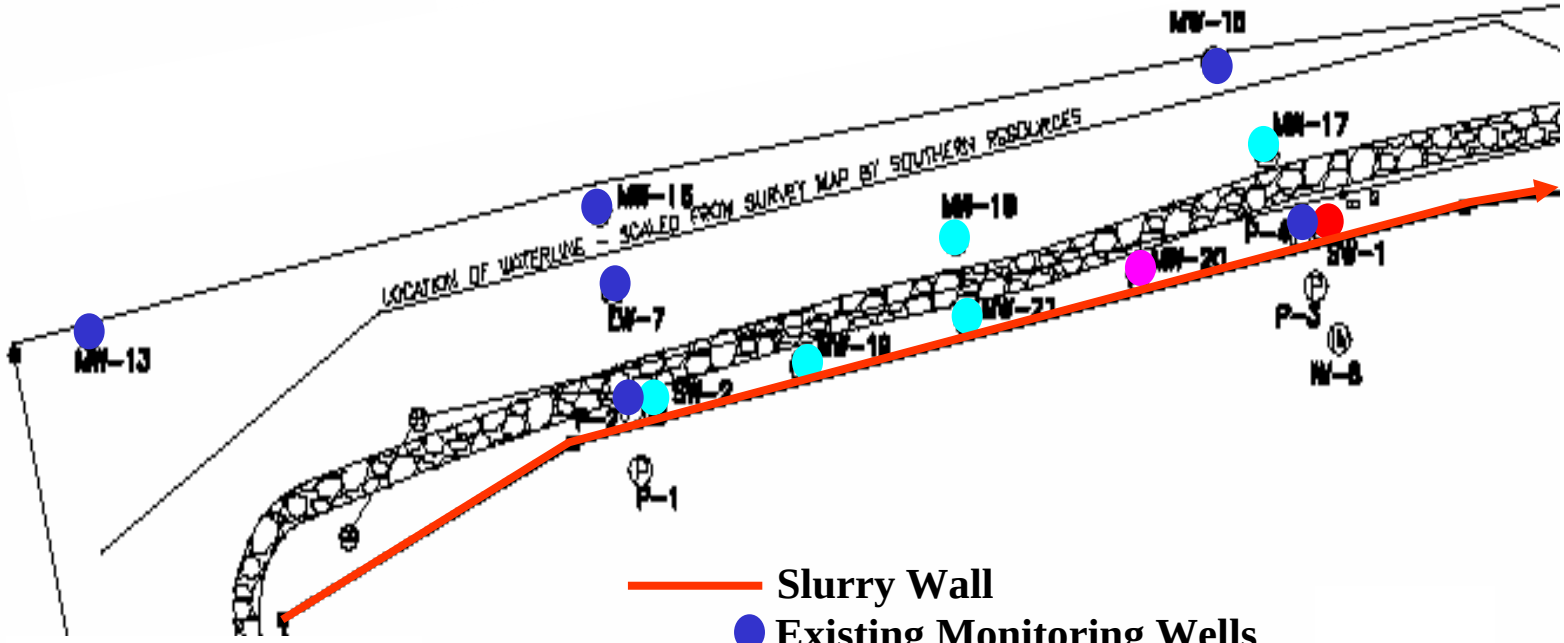
- Soluble chemical will follow groundwater path
- Costs for treatment are significantly less than limestone wall
- Costs for re-treating or moving treatment are minimal
- Maximum pH of 8 – endpoint control
- Smaller volume of precipitate with better properties for aquifer transport
- Remediate soil surface to eliminate rebound issues?
- Plugging of aquifer??

Pilot Injection

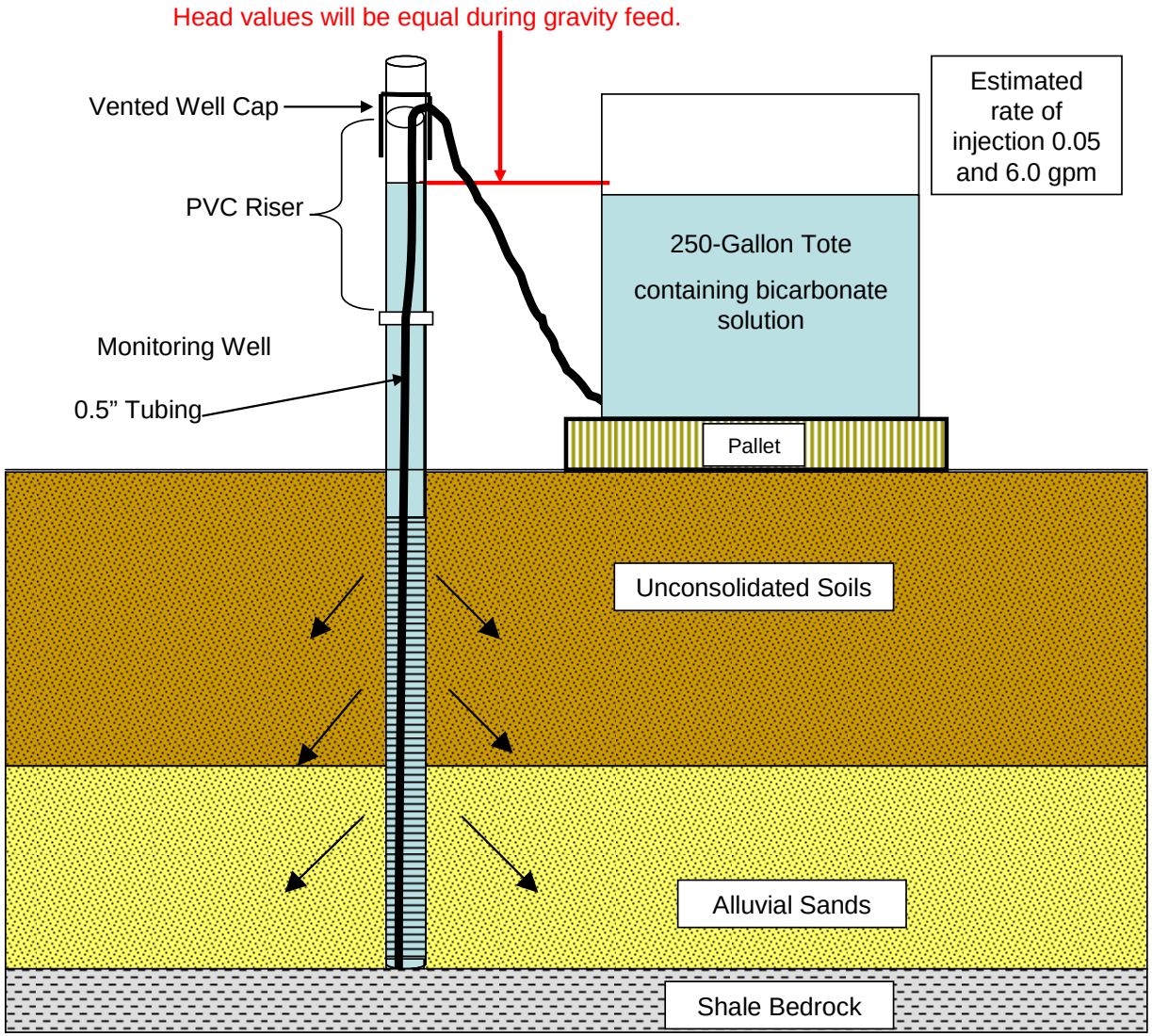
Pilot Injection

- Install additional injection and monitoring wells to north of slurry wall
- Perform titrations with soil and groundwater from borings
- Develop cost effective injection system
- Begin Injection
- Monitor

Injection / Monitoring Wells

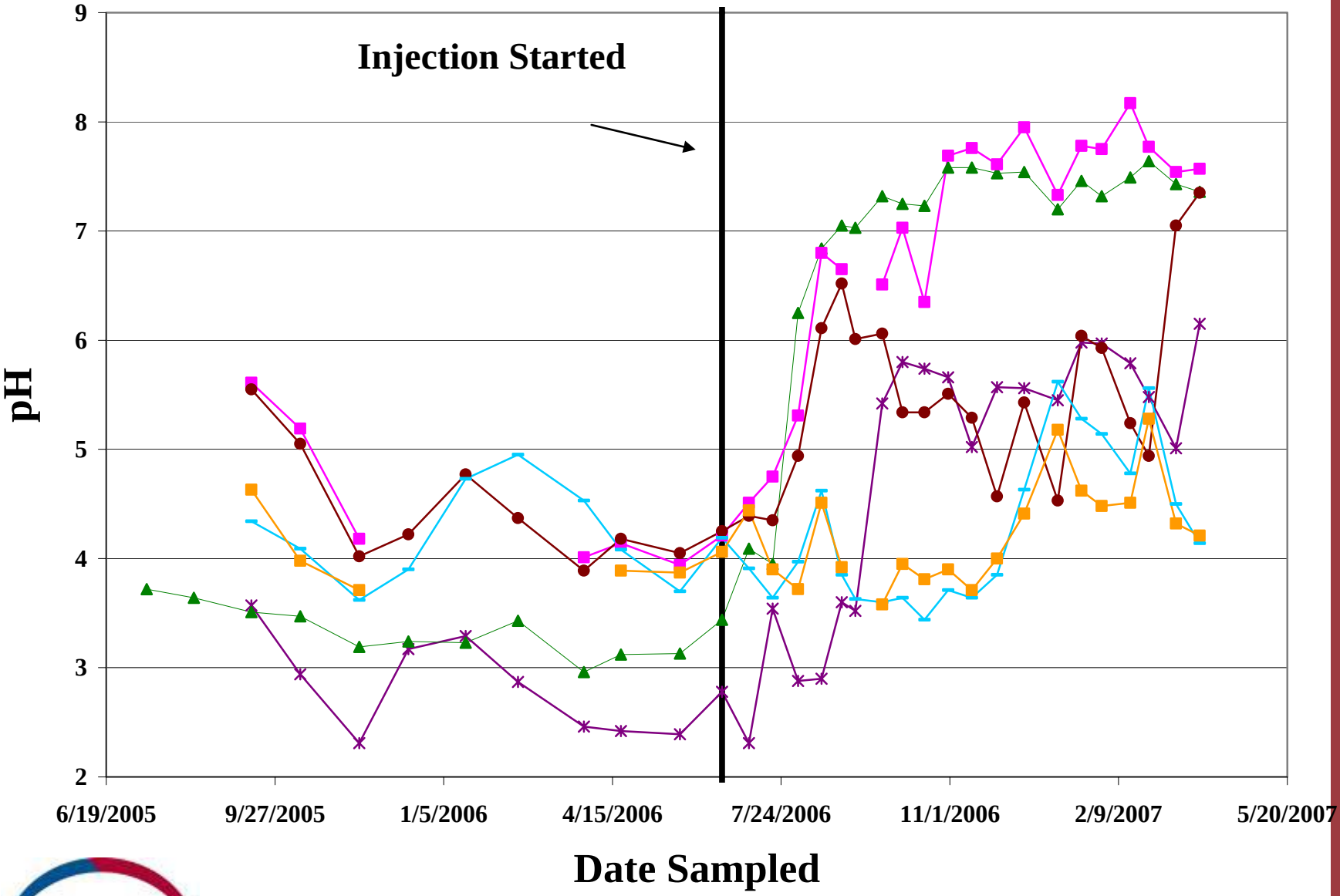


Injection System



Installation

General pH Trends



Specific pH Trends

MW-18 MW-17 Groundwater flow

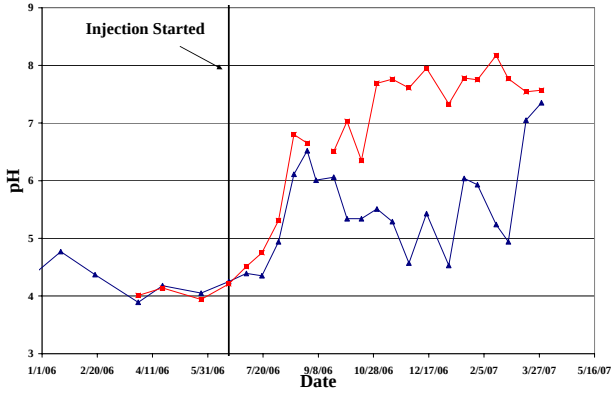
MW-21 Deep IW P-4 Shallow IW

Slurry wall

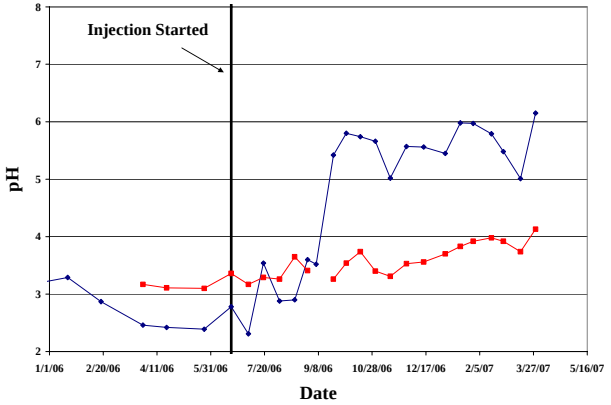
Bottom pH

Top pH

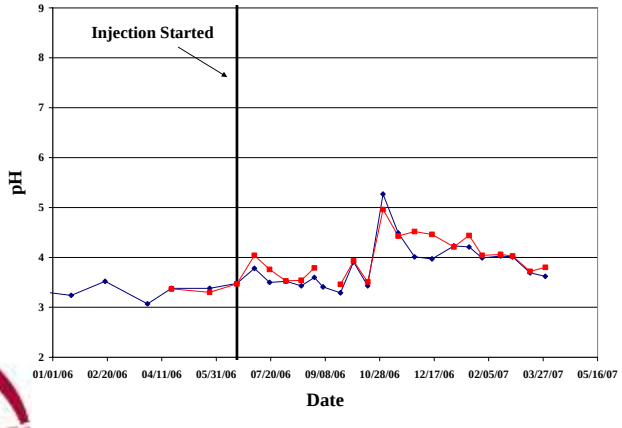
MW-18



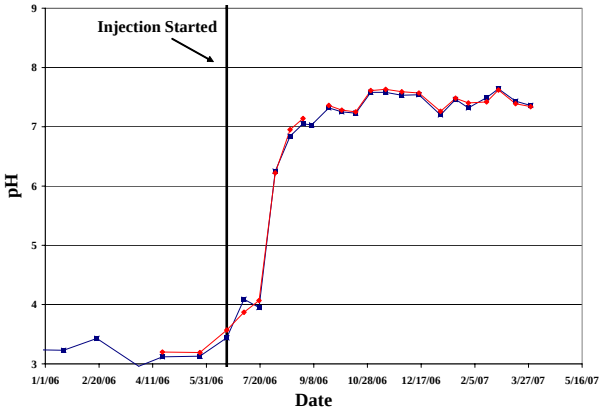
MW-17



MW-21



P-4



Bulk Chemical Delivery System

Slug Testing

Prior to Injection:	**$10^{-3} – 10^{-6}$**
After Injection:	**$10^{-4} – 10^{-6}$**

Material	Hydraulic Conductivity cm/s
Clay	10^{-9} - 10^{-6}
Silt, sand silts, clayey sands, till	10^{-6} - 10^{-4}
Silty sands, fine sands	10^{-5} - 10^{-3}
Well sorted sands, glacial outwash	10^{-3} - 10^{-1}
Well sorted gravel	10^{-2} - 10^{-1}

Future Plans

- Increase the number of injection locations
- Consider interior remediation
- Collect samples from borings in area of remediation to determine impacts to soil properties
- Continue monitoring

Conclusions

- **Sodium bicarbonate injection is showing promising results**
  - **Moving through aquifer and raising pH to acceptable levels within 45 days and up to 100 feet**
  - **Minimal impact on aquifer conductivity**
  - **Simple to implement**
  - **Highly cost-effective**
- **Understanding groundwater chemistry and site hydrogeology are key to success**

AquAeTer, Inc.

optimizing environmental resources – water, air, earth

Chrisie Brown

cbrown@aquaeter.com

(615) 373-8532

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