# Sodium Bicarbonate Injection for Remediation of Acidic Groundwater

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

AquAeTer

# Introduction

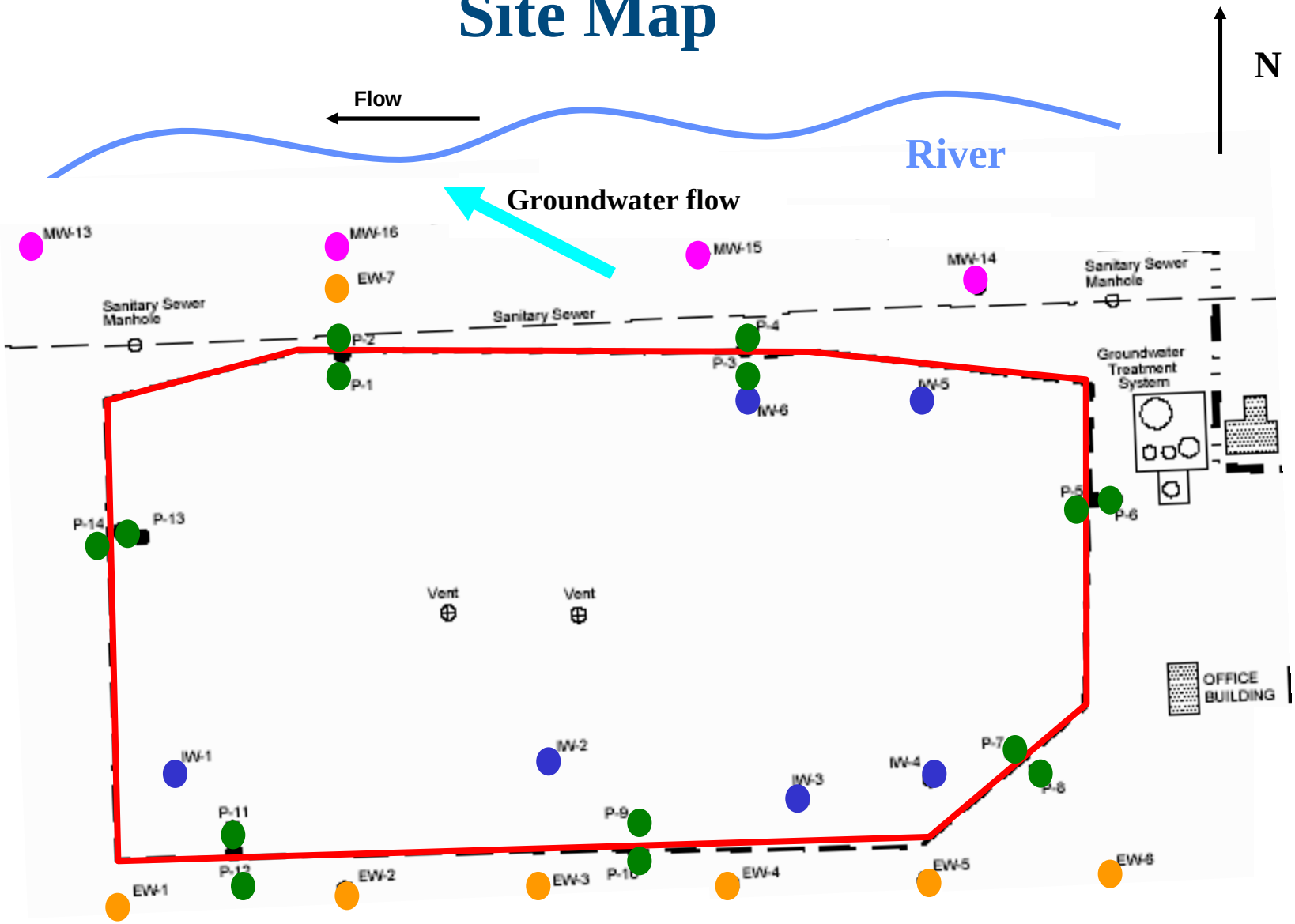
- Problem Background
- Site Overview
- Feasibility Study
  - Field Work
  - Bench Scale Testing
  - Continuous Testing
- Pilot Study
  - Design
  - Results
- Future Plans

# 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

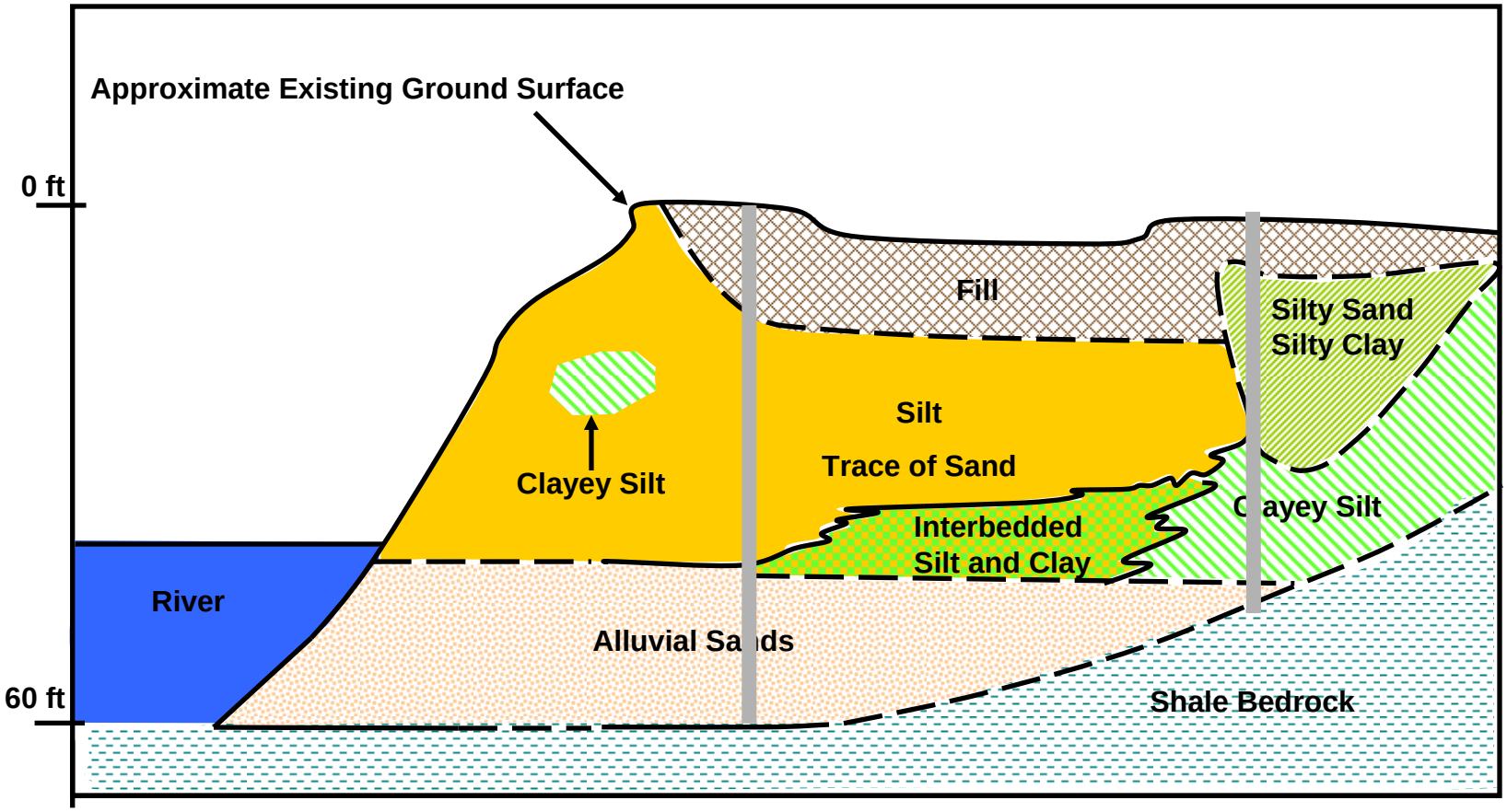

N
Flow
River
Groundwater flow
MW-13
MW-16
EW-7
MW-15
MW-14
Sanitary Sewer Manhole
Sanitary Sewer
Sanitary Sewer Manhole
P-2
P-1
P-4
P-3
IW-6
IW-5
Groundwater Treatment System
P-5
P-6
P-14
P-13
Vent
Vent
OFFICE BUILDING
IW-1
IW-2
IW-3
IW-4
P-7
P-8
P-11
P-9
EW-1
EW-2
EW-3
EW-4
EW-5
EW-6

# Site Photo

**River**

**Impoundment**

# Cross Sectional View



# Feasibility Study

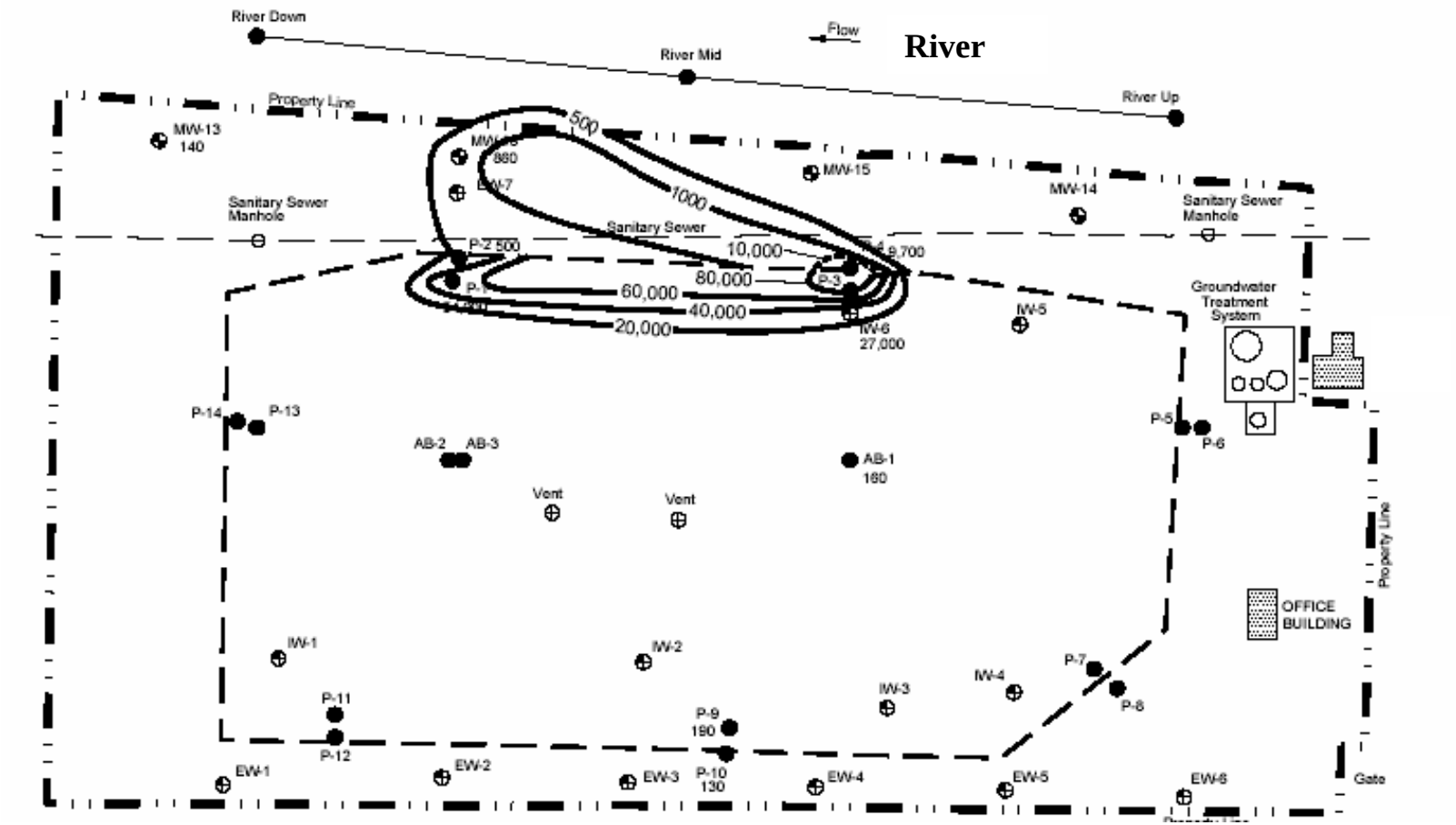
# Feasibility Study

- **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

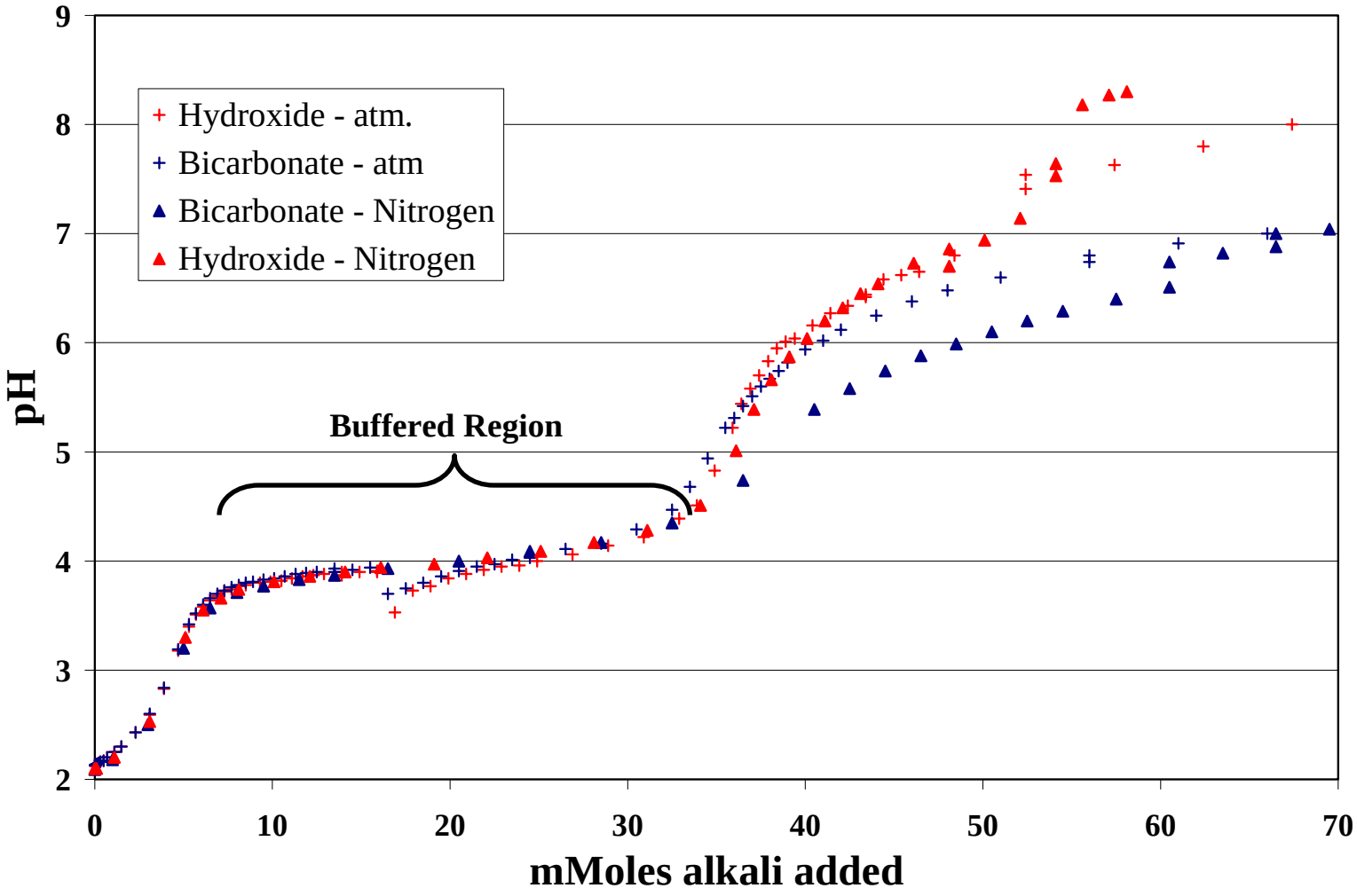
# Acidity Contours



# 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

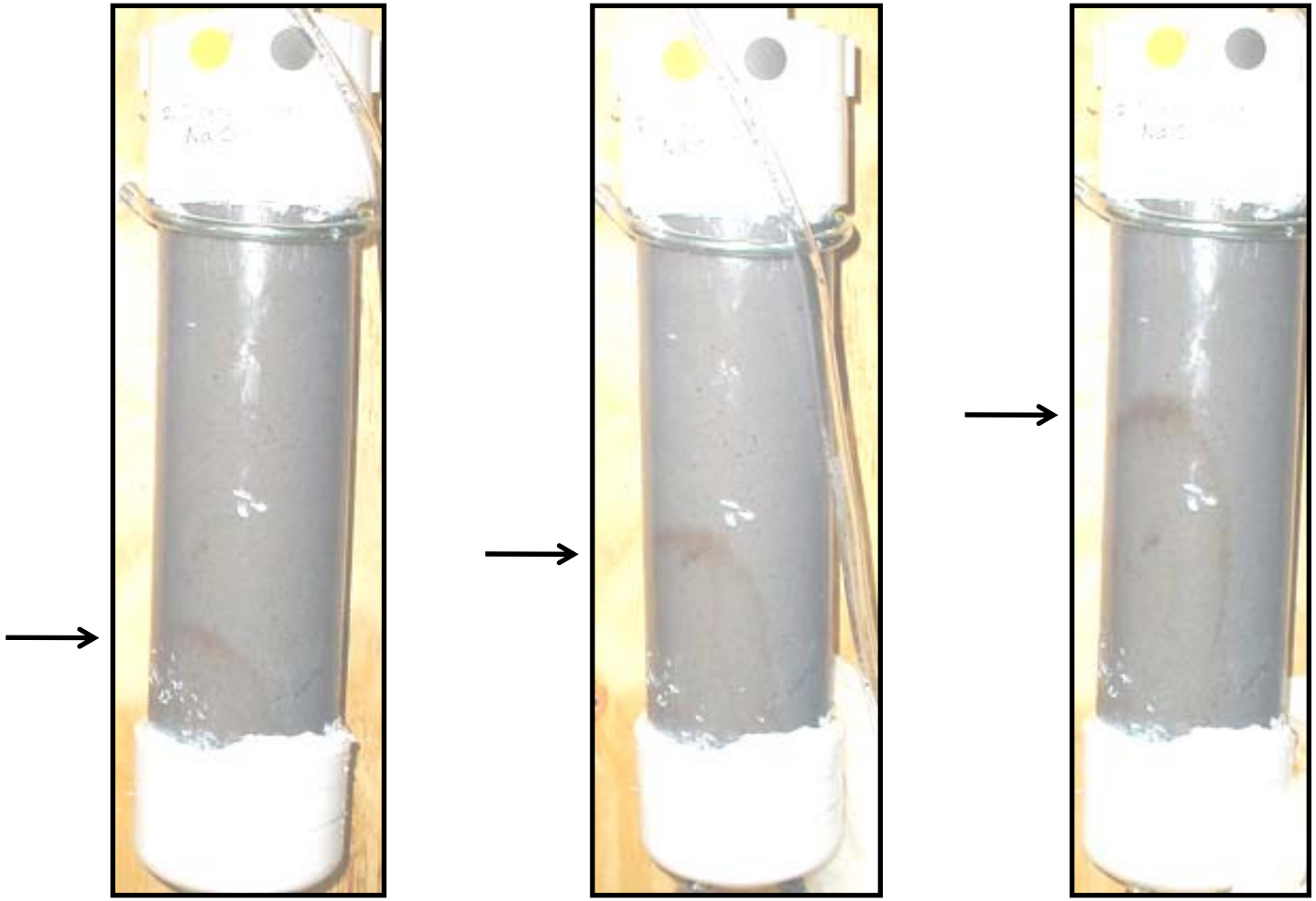
# Feasibility Study - Continuous Testing

- 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

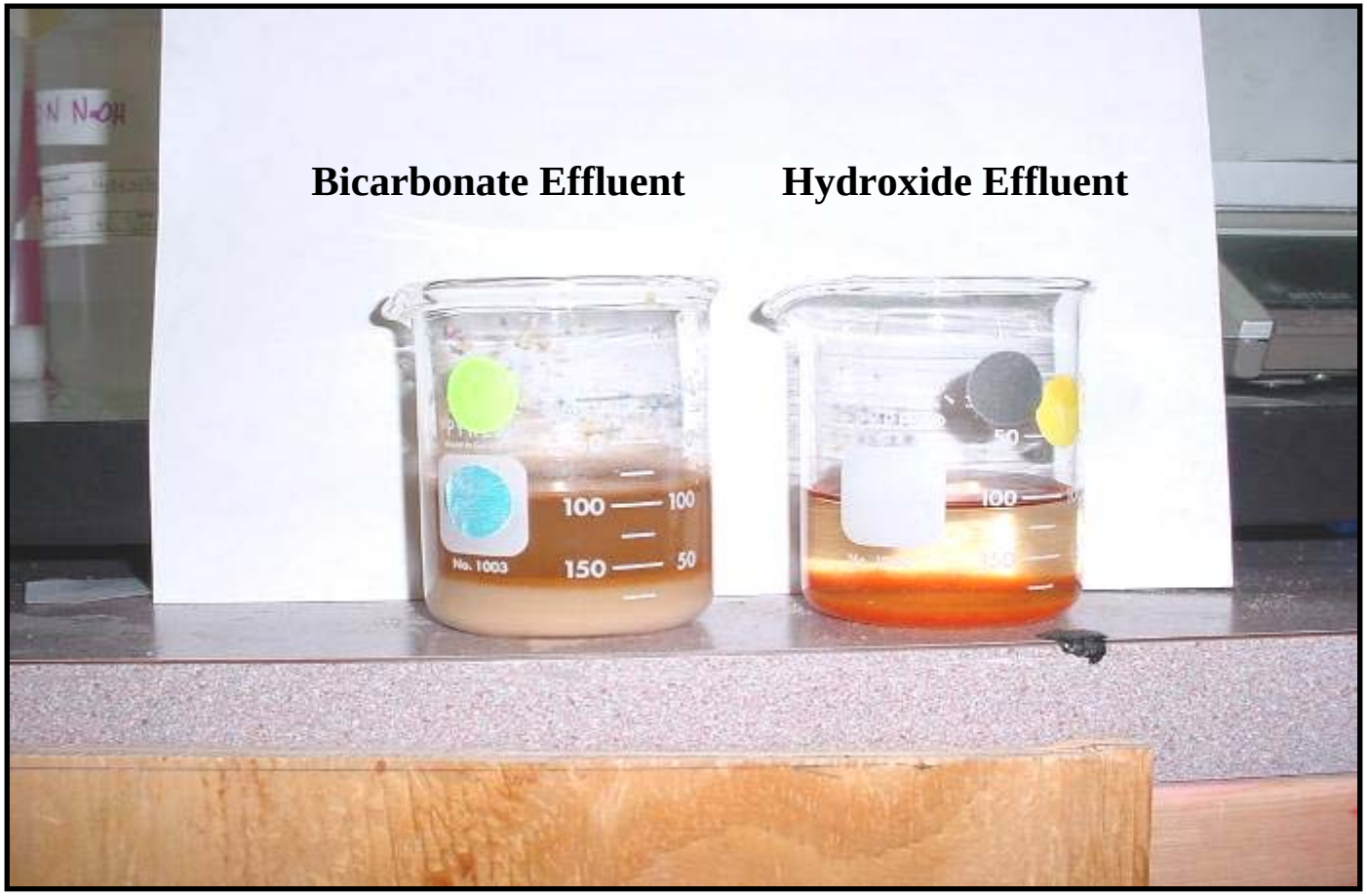
# Limestone Columns

# Sodium Bicarbonate Column Versus Sodium Hydroxide Column

# Progression Of Precipitate Plume In Sodium Hydroxide Column



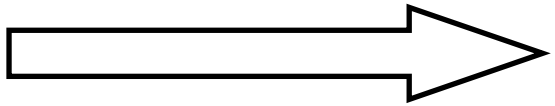
# Effluent Precipitate



# 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

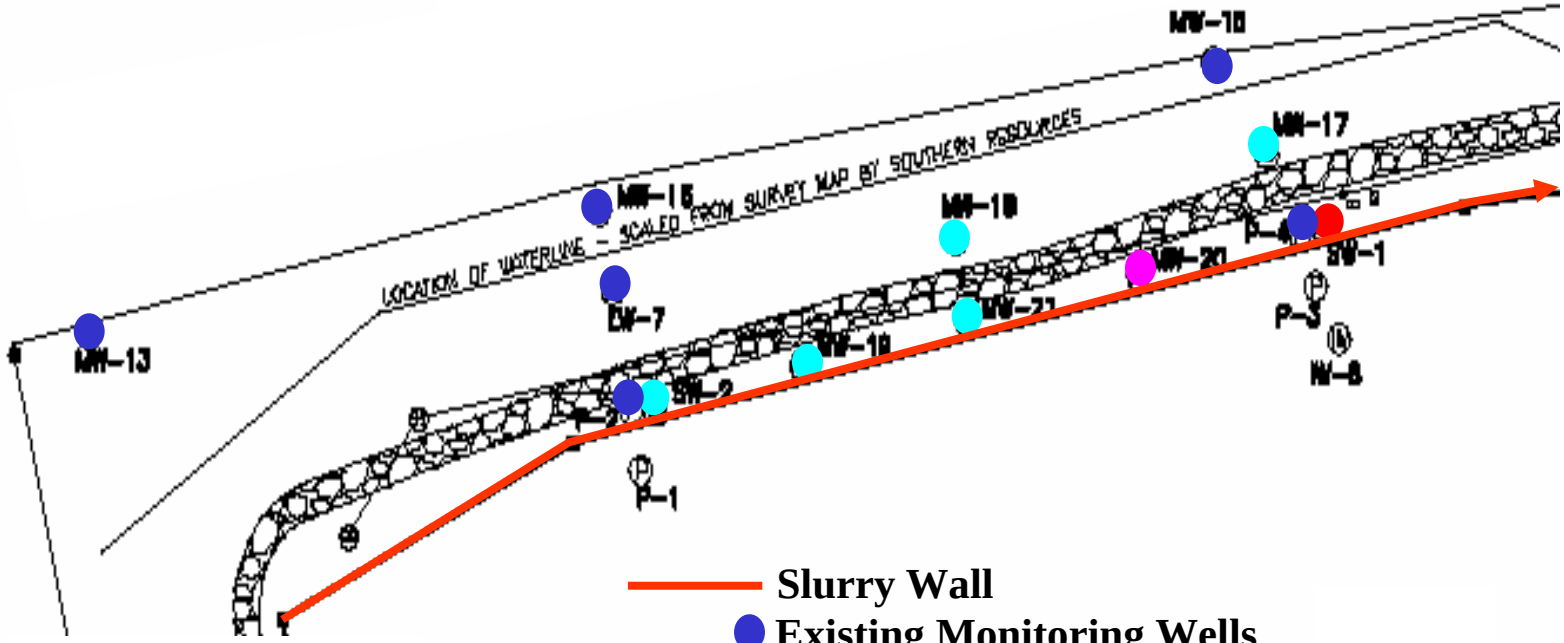
- Soluble chemical will follow groundwater path
- Costs for treatment are significantly less than limestone wall
- Costs for re-treating or moving treatment are minimal
- Maximum pH of 8 – endpoint control
- Smaller volume of precipitate with better properties for aquifer transport
- Remediate soil surface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

# Pilot Injection

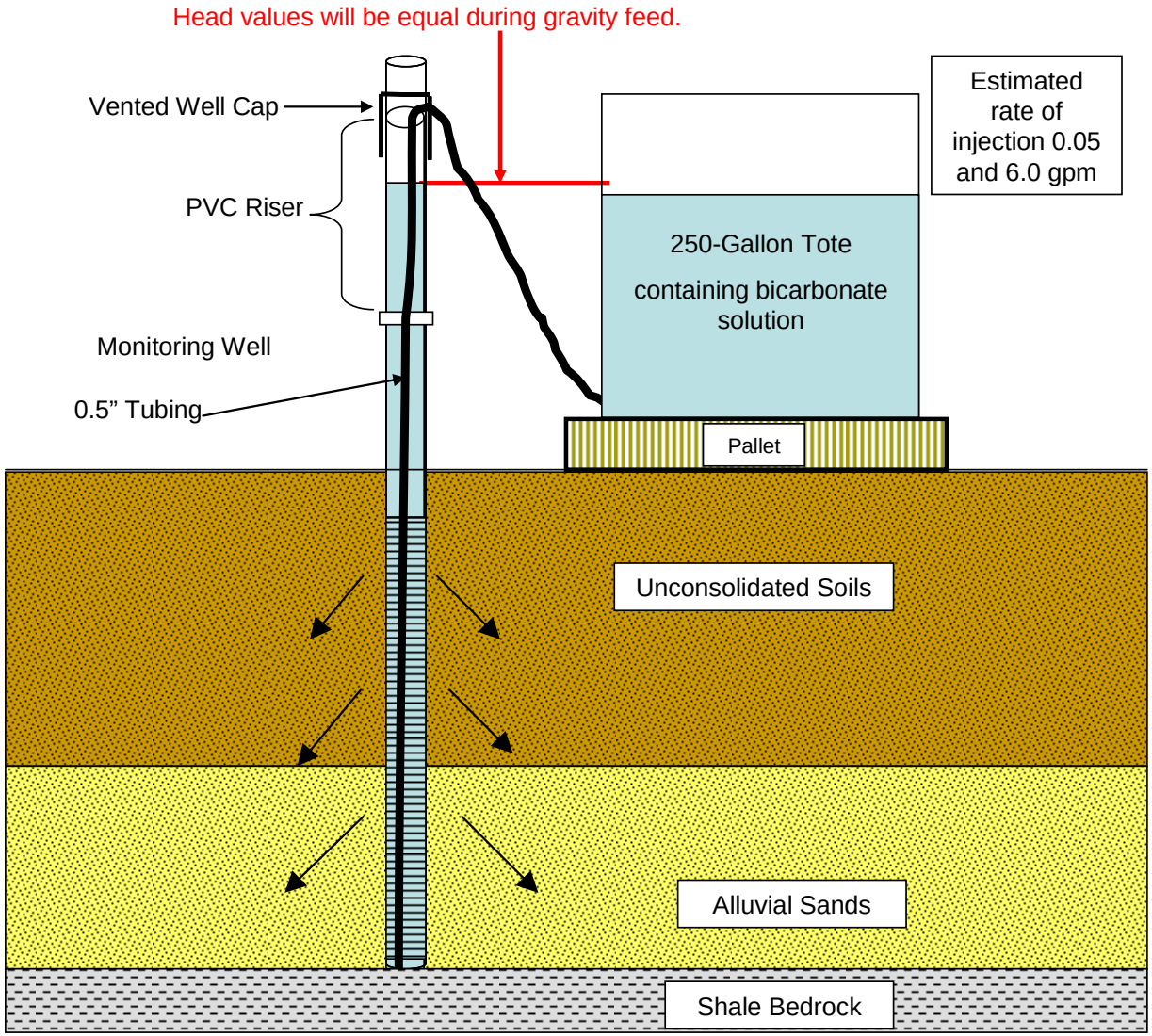
# Pilot Injection

- 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

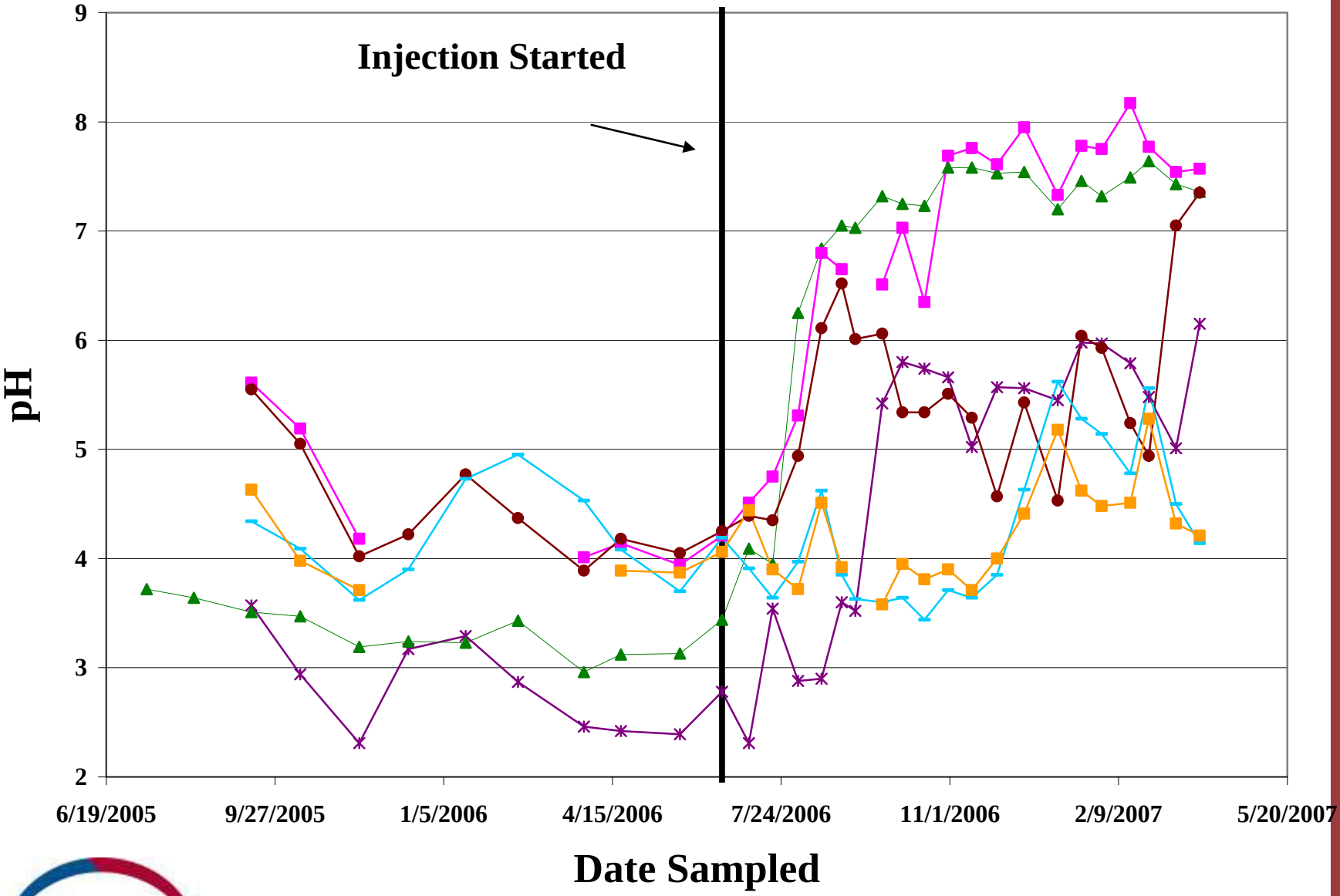


# Injection System



# Installation

# General pH Trends



# Specific pH Trends

MW-18 MW-17 Groundwater flow

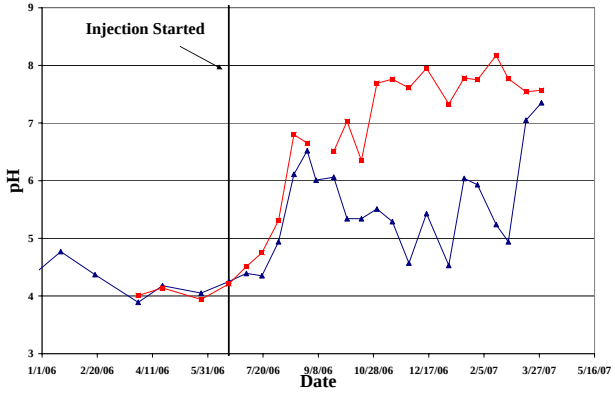
MW-21 Deep IW P-4 Shallow IW

Slurry wall

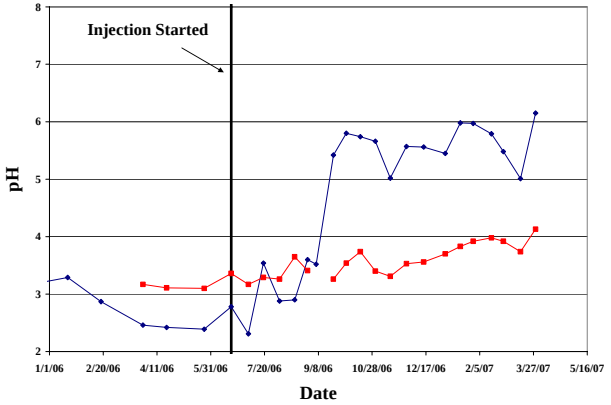
Bottom pH

Top pH

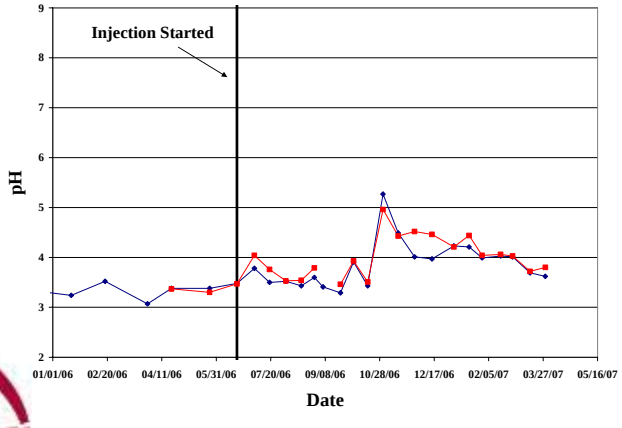
## MW-18



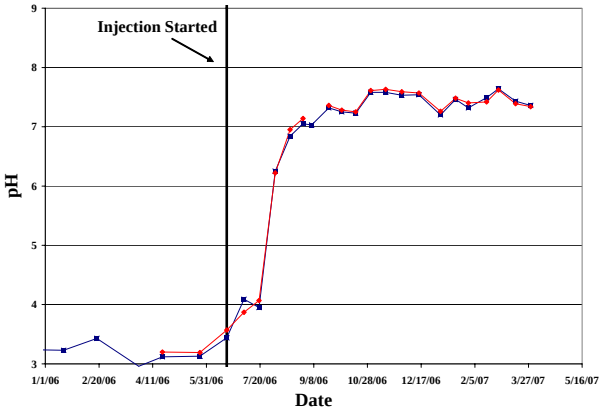

## MW-17




## 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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