Combined Hydrogen Sulfide & Arsenic Removal Using Aeration, Coagulation & Activated Carbon Filtration

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By

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Introduction

- Background
  - Arsenic in groundwater
  - Arsenic treatment
  - Hydrogen sulfide in groundwater
  - Hydrogen sulfide treatment
- Case Study: North Beach Water District - Wiegardt Wellfield
  - Oxidation
  - Co-precipitaton
  - Catalytic activated carbon filtration

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Arsenic in Groundwater

- Health concerns
  - Cancer causing in transport tissues
- Occurrence is dependent upon the local geology
  - Iron oxides
  - Sulfide mineralization
  - Volcanic deposits
  - High alkalinity
- Occurs in two inorganic oxidation states
  - Arsenite As^{+3}
  - Arsenate As^{+5}

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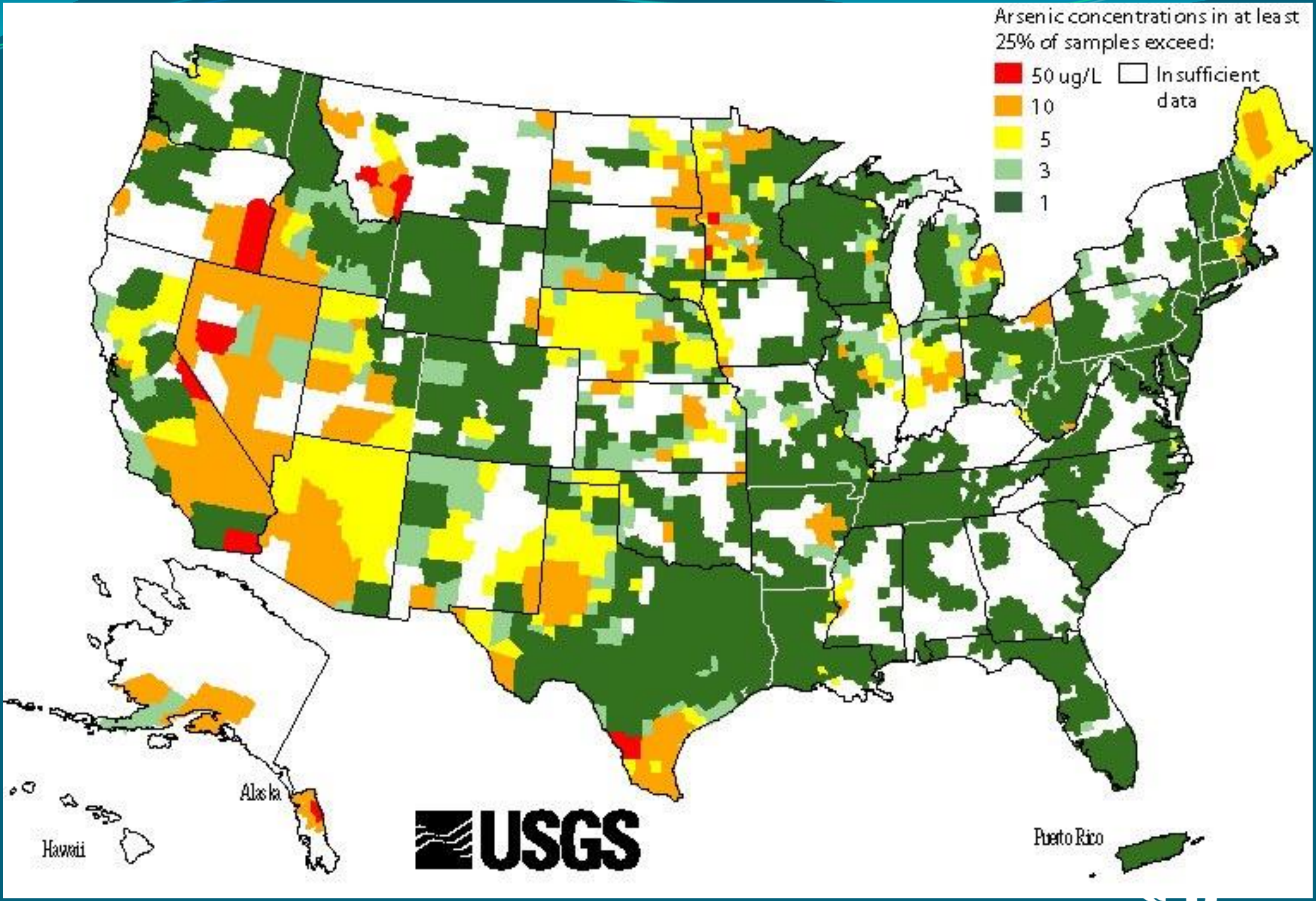

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Arsenic Treatment

- Treatment for Arsenic is required when Arsenic levels exceed 10 ppb
- Traditional arsenic treatment methods:
  - Co-precipitation/Filtration
  - Adsorption
  - Ion Exchange
- Selection of treatment technology is dependent on source water chemistry, particularly the iron concentration.

Hydrogen Sulfide in Groundwater

- Not typically a health concern; contributes to taste and odor.
- Occurrence is in systems with low dissolved oxygen and naturally occurring organic matter.
- Results from the reduction of sulfates in groundwater.

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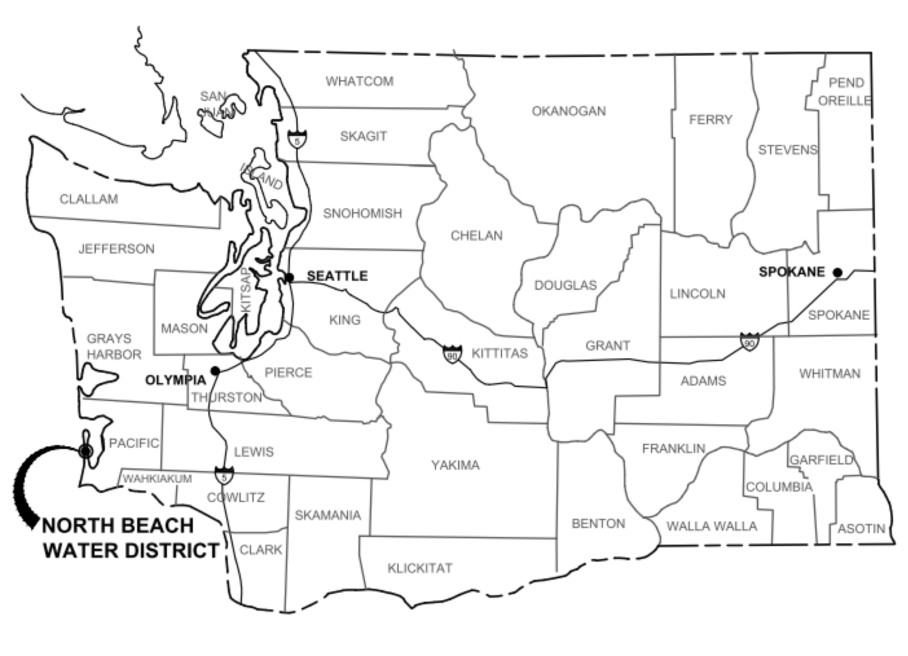
Hydrogen Sulfide Treatment

- No primary or secondary MCL for hydrogen sulfide.
- Removal from groundwater by transformation and physical removal.
  - Oxidation (aeration, chemical, and catalytic)
  - Air stripping (better removal at low pH)

Case Study: North Beach Water District Wiegardt Wellfield

- Provides additional source capacity for the District
- 3 new wells providing 450 gpm of source capacity
- Arsenic at 15 to 16 ppb
- pH > 7
- Noticeable H_2S odor
- Treatment required to reduce arsenic to <10 ppb and H_2S to below noticeable levels.
- The District does not chlorinate, nor do they desire to chlorinate.



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Raw Water Quality

•Parameter	•Well 1	•Well 2	•Well 3	•MCL
•Iron (mg/L)	•<0.1	•<0.02	•<0.02	•0.30
•Manganese (mg/L)	•<0.01	•<0.005	•<0.01	•0.05
•Arsenic (mg/L)	•0.016[1]	•0.016[1]	•0.015[1]	•0.01
•pH (Laboratory)	•7.4	•8.41	•8.48	•—
•Alkalinity (mg/L as $CaCO_3$)	•NA[2]	•56.3	•58.7	•—
•Hardness (mg/L as $CaCO_3$)	•52	•41.8	•49.5	•—
•Conductivity	•178	•189	•197	•700
•TDS (mg/L)	•122	•129	•129	•500
•Nitrate (mg/L)	•<0.2	•<0.1	•ND[2]	•10
•Chloride (mg/L)	•28	•20.1	•19.2	•250
•Sulfate (mg/L)	•5	•3.99	•4.39	•250
•Sulfide (mg/L)	•.024	•NA	•NA	•—
•Calcium (mg/L)	•22	•NA[2]	•NA[2]	•—
•Turbidity	•0.8	•ND[2]	•ND[2]	•—
•Silica	•34	•34.0	•36.1	•—
•Total Organic Carbon (TOC)	•NA	•ND	•ND	•—

Treatment Alternatives Analysis

- Four treatment alternatives were evaluated:
  1. Ozone oxidation, ferric chloride co-precipitation, and MTM filtration.
  2. CO_2 addition, aeration, iron oxide media adsorption.
  3. Aeration, ferric chloride co-precipitation, catalytic carbon filtration.
  4. CO_2 addition, aeration, ferric chloride co-precipitation, sand filtration
- Alternative 3 was selected as it eliminates pumping after aeration; this alternative was piloted.

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Pilot Testing Objectives

- Determine the feasibility of combined aeration, ferric chloride co-precipitation, and catalytic carbon filtration to remove arsenic and hydrogen sulfide.
- Determine the design parameters for a full-scale installation:
  - Hydraulic loading rate
  - Ferric chloride dosage
  - Contact time
  - Effect of potassium permanganate addition
  - Carbon mesh size

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Treatment Mechanics

- Aeration by venturi (DO > 4 mg/L is required for catalytic oxidation).
  - While sorbed to the carbon surface, in the presence of DO, H_2S is oxidized to SO_4 and released back into the water.
- Ferric Chloride Co-precipitation
  - $FeCl_3 + 3H_2O \Leftrightarrow Fe(OH)_3 + 3H^+ + 3Cl^-$
- Catalytic Carbon Filtration
  - $Fe(OH)_3$ precipitates, As sorbs to precipitate and is removed across the carbon bed by physical filtration.

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Pilot System Design Parameters

•Parameter	•Value
•Flow Rate	•4 gph to 24 gph
•Minimum Target Dissolved Oxygen	•4.0 mg/L
•Target Finished Water Arsenic Level	•5 µg/L
•Ferric Test Dosing	•1.5 to 5.0 mg/L as Fe
•Contact Tanks	•2
•Contact Tank Diameter	•2 inches
•Contact Tank Length	•4 feet
•Contact Tank Volume (per tank)	•0.65 gallons
•Contact Time per Tank (4 gph)	•10 minutes
•Contact Time per Tank (24 gph)	•1.6 minutes
•Carbon Filter Diameter	•4 inches
•Carbon Filter Length	•48 inches
•Carbon Type	•Calgon Centaur 20x50 or 12x40
•Carbon Depth	•28 inches
•Target Backwash Rate	•8 gpm/sf
•Total Backwash Flow	•0.7 gpm (42 gph)

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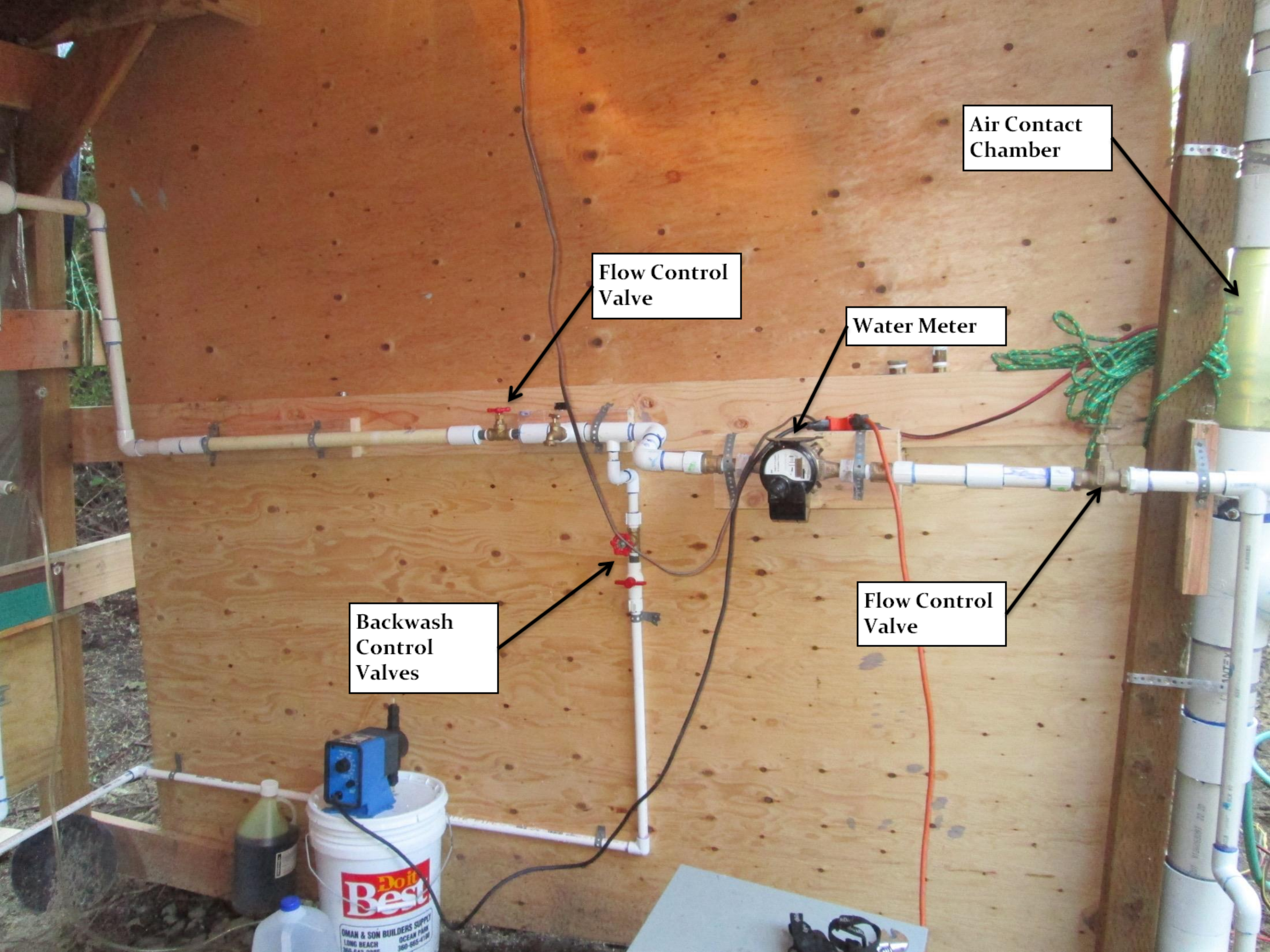
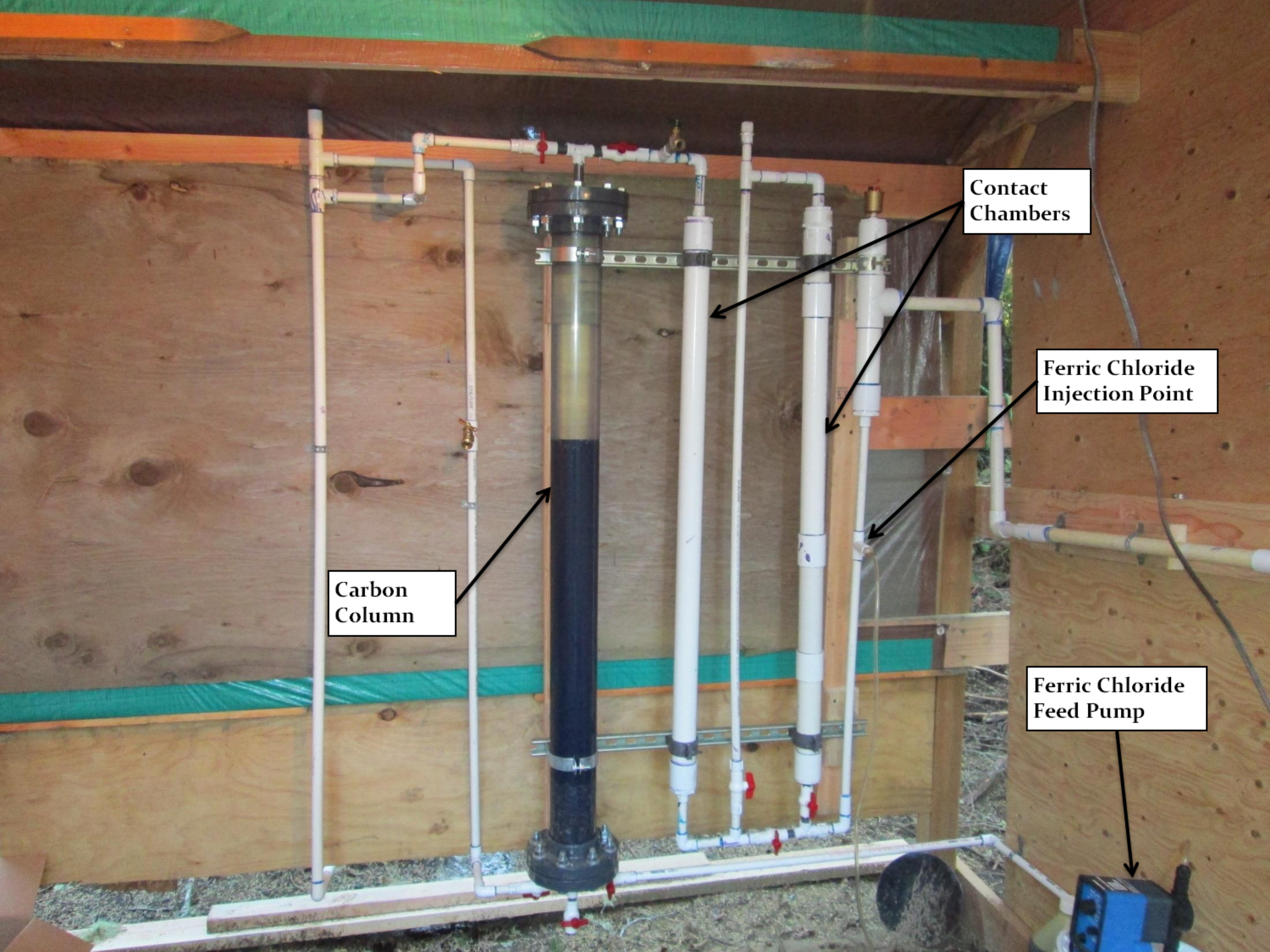
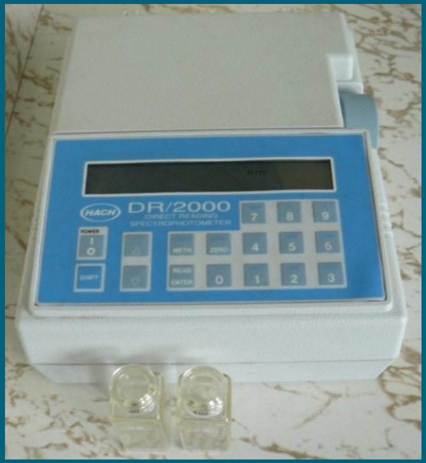
Air Venturi
Wellhead


Air Contact Chamber
Flow Control Valve
Water Meter
Backwash Control Valves
Flow Control Valve
Do it Best


Contact Chambers
Ferric Chloride Injection Point
Carbon Column
Ferric Chloride Feed Pump

Pilot Testing Protocol

•Parameter	•Method
•Instantaneous Flow Rate	•Flow Meter
•Backwash Flow Rate	•Flow Test (time to fill given volume)
•Hydrogen Sulfide	•Portable Spectrophotometer (Hach DR/2010)
•Total Iron	•Portable Spectrophotometer (Hach DR/2010)
•Arsenic	•Arsenic Test Kit (Industrial Test Systems), and Commercial Laboratory (EPA Method 200.8)
•pH	•Hanna pH Meter
•Temperature	•Hanna Meter
•Dissolved Oxygen	•Portable Spectrophotometer (Hach DR/2010)



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Operational Parameters: Contact Time and Hydraulic Loading

- Little variation in treatment efficacy (iron removal) was seen with hydraulic loadings ranging from 1 gpm/sf to 4.5 gpm/sf. Subsequent evaluation was performed at a loading rate of 4.5 gpm/sf.
- 2 minutes of ferric chloride contact time was adequate for iron/arsenic removal.

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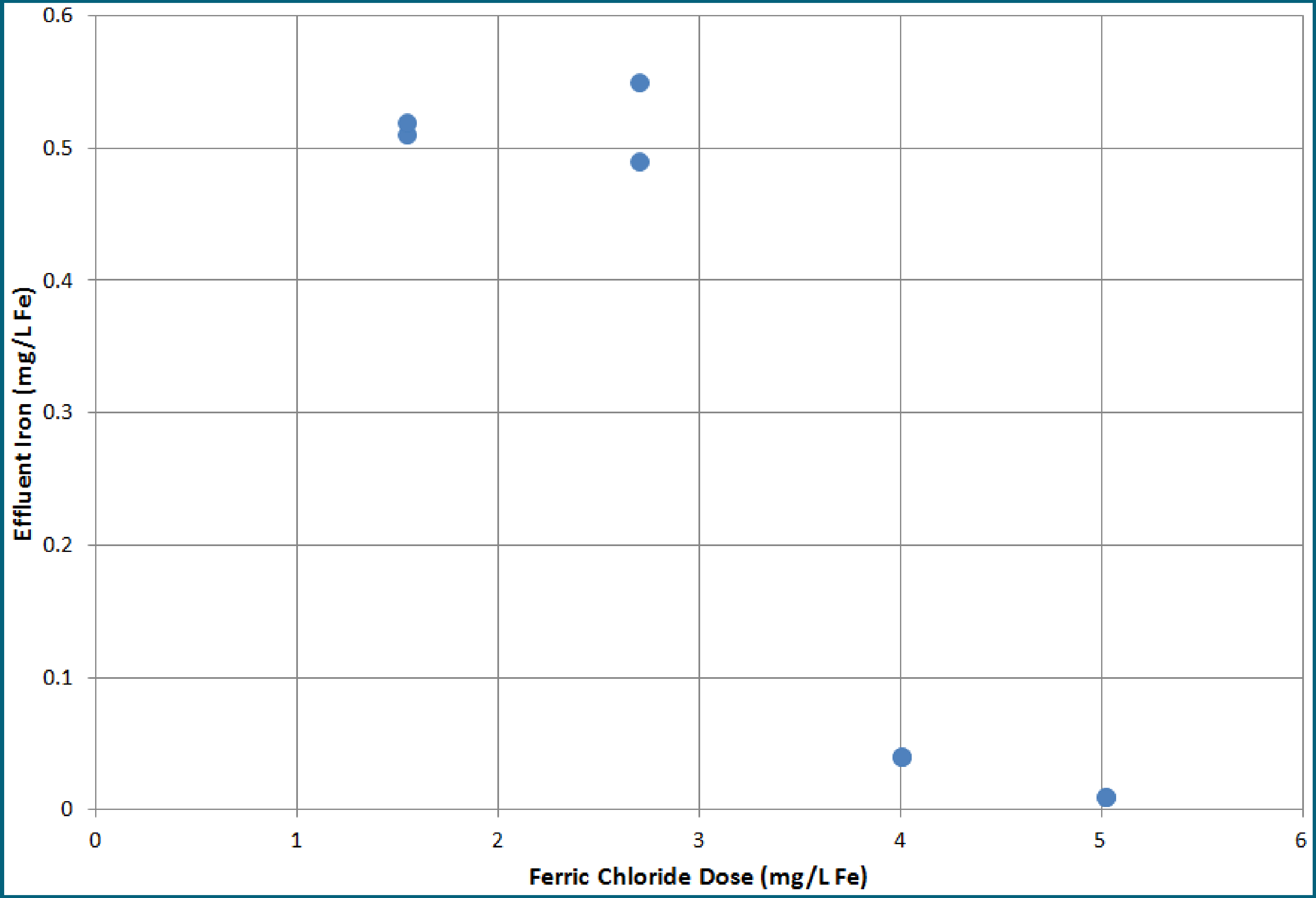
Operational Parameters: Carbon Type

- 10 x 40 and 20 x 50 mesh Calgon Centaur activated carbon were prepared.
- 20 x 50 mesh carbon showed greater arsenic removal than 10 x 40 mesh carbon

•Carbon Mesh Size	•Hydraulic Loading (gpm/sf)	•Ferric Chloride Dose (mg/L)	•Post-Column Iron (mg/L)	•Post Column As (µg/L)
•12 x 40	•4.5	•4.0	•0.09	•8
•12 x 40	•4.5	•5.56	•0.02	•8
•20 x 50	•4.5	•4.0	•ND	•4
•20 x 50	•4.5	•5.0	•0.2 (1)	•1

(1) This sample was taken near filter breakthrough during a period of rapid variation in iron concentration. The value listed is a typical value. Values ranged between approximately 0.1 mg/L and 0.35 mg/L.

Operational Parameters: $FeCl_3$ Dose



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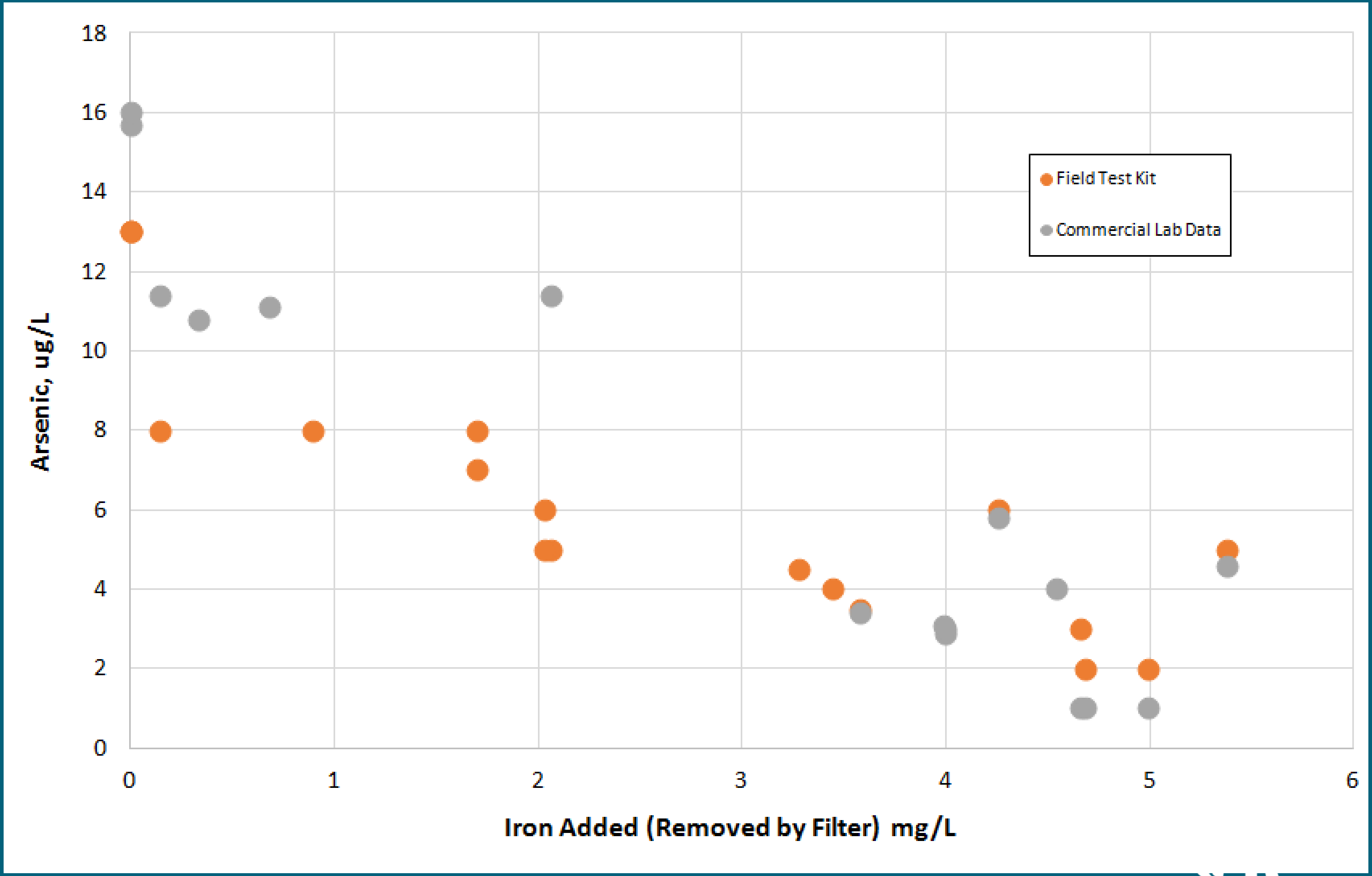
Arsenic Removal with $FeCl_3$ Dose



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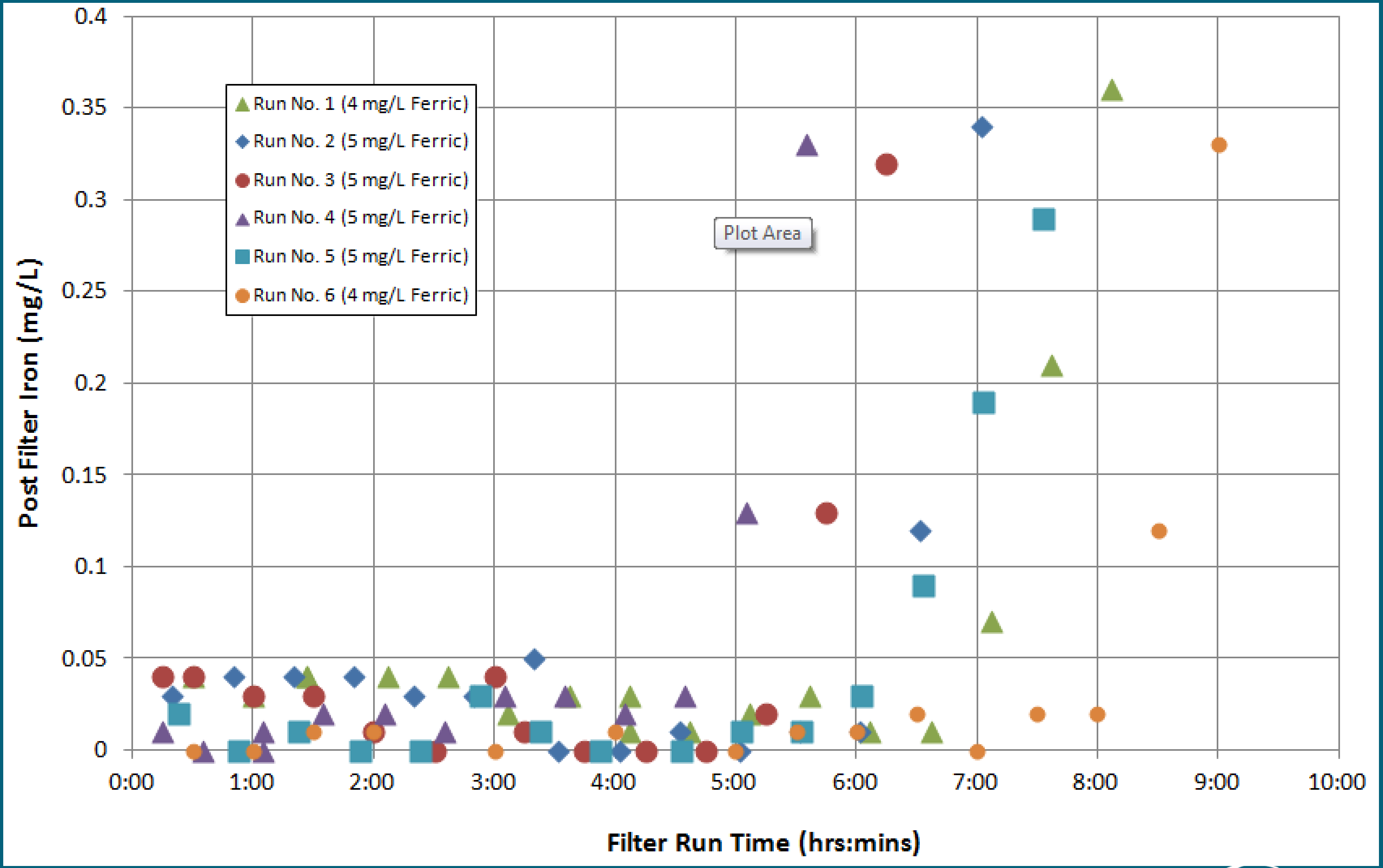
Filter Run Time



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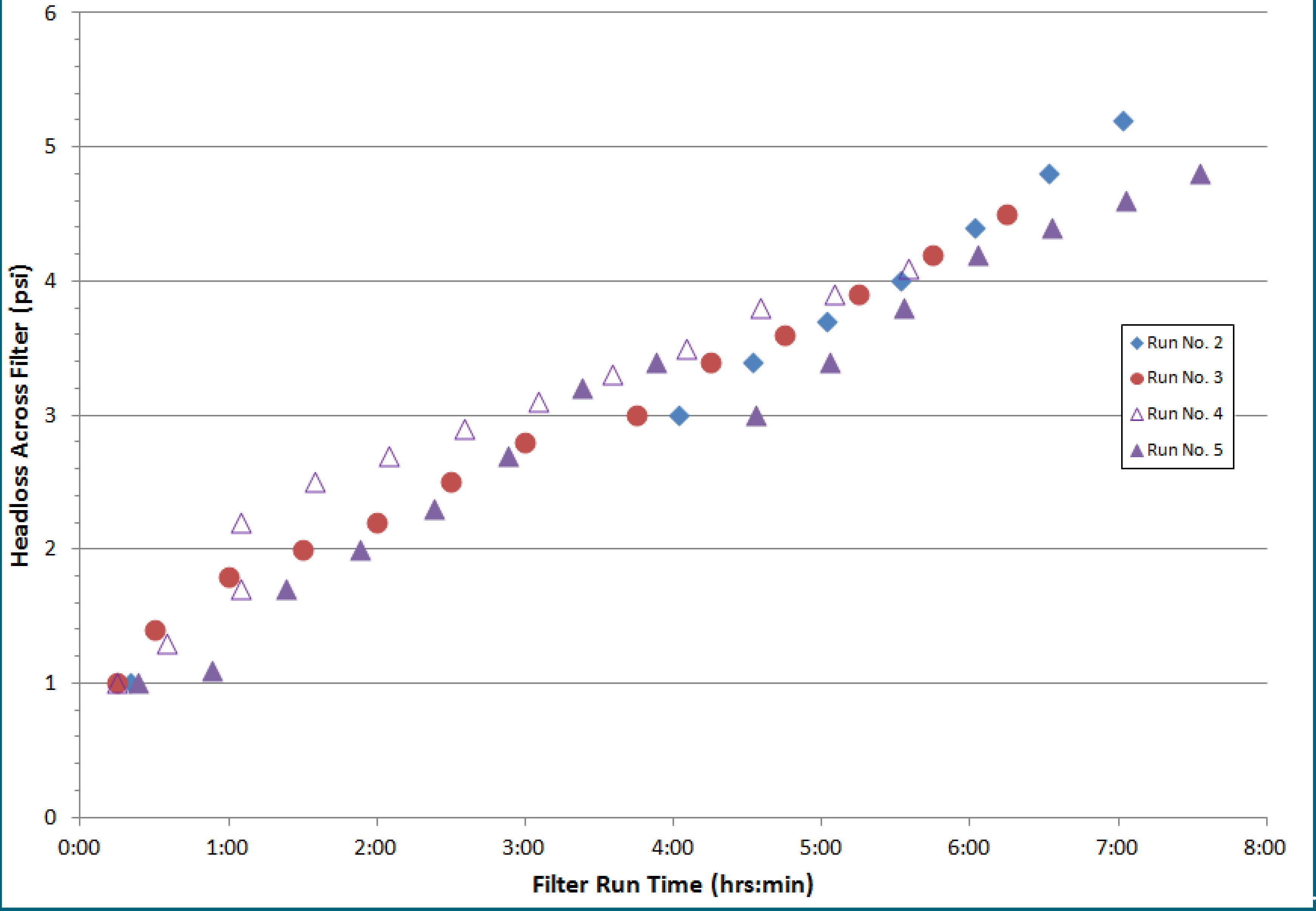
Filter Headlosses



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Operational Parameters: Potassium Permanganate Addition

- The addition of potassium permanganate did appear to increase arsenic removal, likely due to changes in speciation.

•Hydraulic Loading (gpm/sf)	•Ferric Chloride Dose (mg/L)	•Post-Column Iron (mg/L)	•Post Column As (μg/L)(1)
•Without Potassium Permanganate			
•4.5	•4	•0.02	•5.8
•4.5	•4	•ND	•4.6
•4.5	•4	•ND	•4
		•Average	•4.8
•With Potassium Permanganate			
•4.5	•4	•ND	•3.4
•4.5	•4	•0.01	•3.1
•4.5	•4	•— (2)	•2.9
		•Average	•3.1

- Speciation testing indicated 70% in As^{+3} speciation and 30% in the As^{+5} speciation in the raw water.

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Full-Scale Design Parameters

•Parameter	•Value
•Design Flow Rate (gpm)	•450
•Filter Vessel Diameter (ft)	•8
•Number of Filter Vessels	•2
•Hydraulic Loading Rate (gpm/sf)	•4.5
•Ferric Chloride Dose (mg/L)	•4.0[(1)]
•Ferric Chloride Contact Time (min)	•2
•Carbon Bed Depth (inches)	•72
•Carbon Volume (cubic feet)	•603
•Empty Bed Contact Time (min)	•10
•Specific Filtration Capacity (g Fe/cf carbon)	•12.6
•Time to Breakthrough (hrs)	•~18[(2)]
•Approximate Terminal Headloss (psi)	•5 to 13
•Backwash Flow Rate (gpm/sf)	•15

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Conclusions

- Combining aeration/catalytic carbon oxidation and ferric chloride co-precipitation/filtration is effective at removing arsenic to below the MCL.
- Media regeneration is not necessary as the carbon does not act as an adsorbent.
- The entire treatment system is pressurized, eliminating the need for an additional pumping step.

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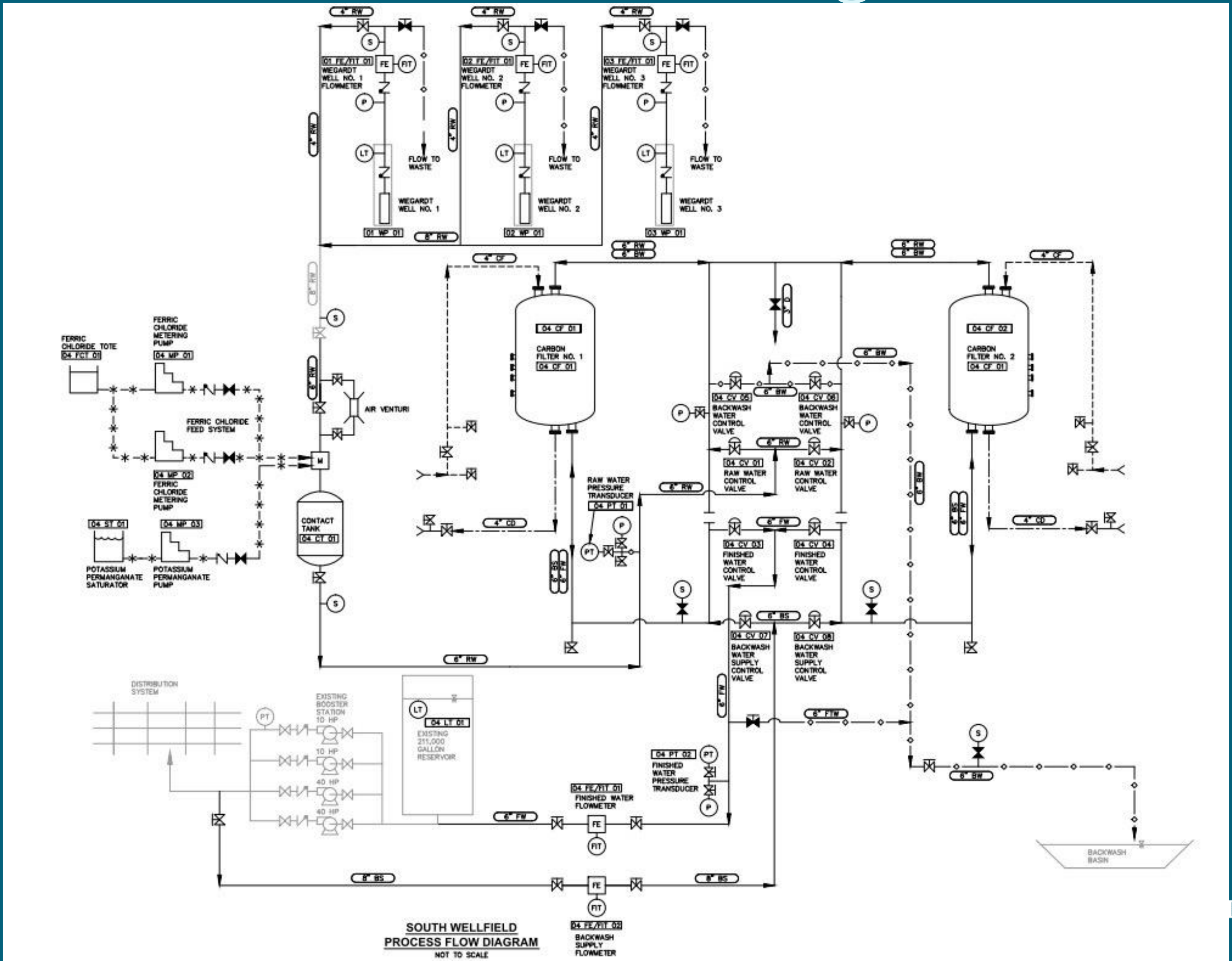
Full-Scale Process flow Diagram



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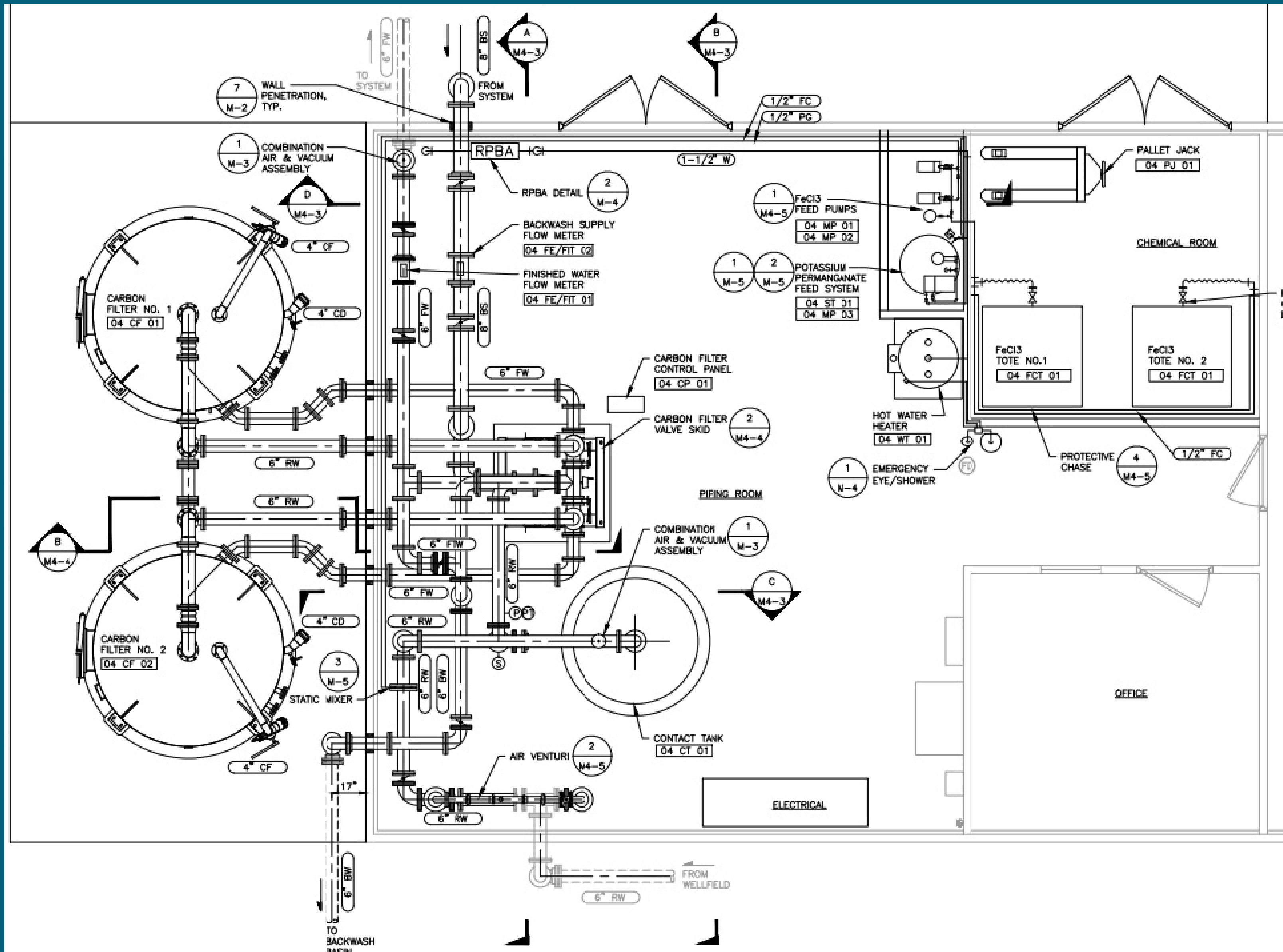
Treatment Building



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Acknowledgements

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Questions?

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