



# Pilot Tests of Arsenic Removal Technologies in the Arsenic Water Technology Partnership



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# Sandia Team Members

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# Outline

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- **The Arsenic Water Technology Partnership**
- **Site selection & Concepts for Pilot Demonstration Tests**
- **Adsorptive Media Tests**
  - Socorro, Anthony, Rio Rancho, Oklahoma
  - Over 20 different media
- **Coagulation-Assisted Filtration Tests**
  - Jemez Pueblo
  - 4 different systems
- **Cost Impacts**
- **Summary**

# Arsenic Water Technology Partnership Background

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- **Congressional Appropriation - \$13M FY03 – FY06**
- **DOE- funded peer-reviewed, cost-shared research program to develop and demonstrate innovative technologies for removal and disposal of arsenic from drinking water**
- **Partner Roles**
  - **Bench-Scale Studies (AwwaRF)**
  - **Demonstration Studies (Sandia)**
  - **Economic Analysis/Outreach (WERC)**
- **Focus on small systems**
  - **40% of resources directed to rural and Native American utility needs**
  - **Minimize costs - capital, operating, maintenance**
  - **Minimize residual quantities & disposal costs**





# Sandia Pilot Test Concepts

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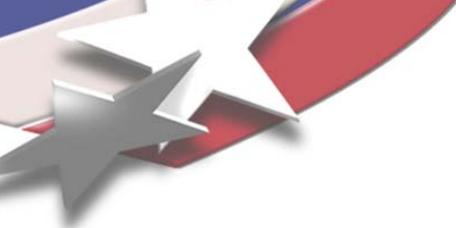
- **Side-by-side demonstrations of technologies tested by AwwaRF bench-scale program, WERC design contest, University programs, or commercial technologies vetted through Vendor Forums**
  - Test duration: 3 – 9 months; longer, if multiple pilots at same site
  - Test size: 0.3 – 10 gpm
  - Different technology classes: adsorptive media, Coagulation/Filtration, *membranes, electrochemical*
- **Cooperative effort between Sandia, Technology Owner and Site Owner**
- **Test Protocols developed with help from NSF International, academia, industry during 2004-2005**



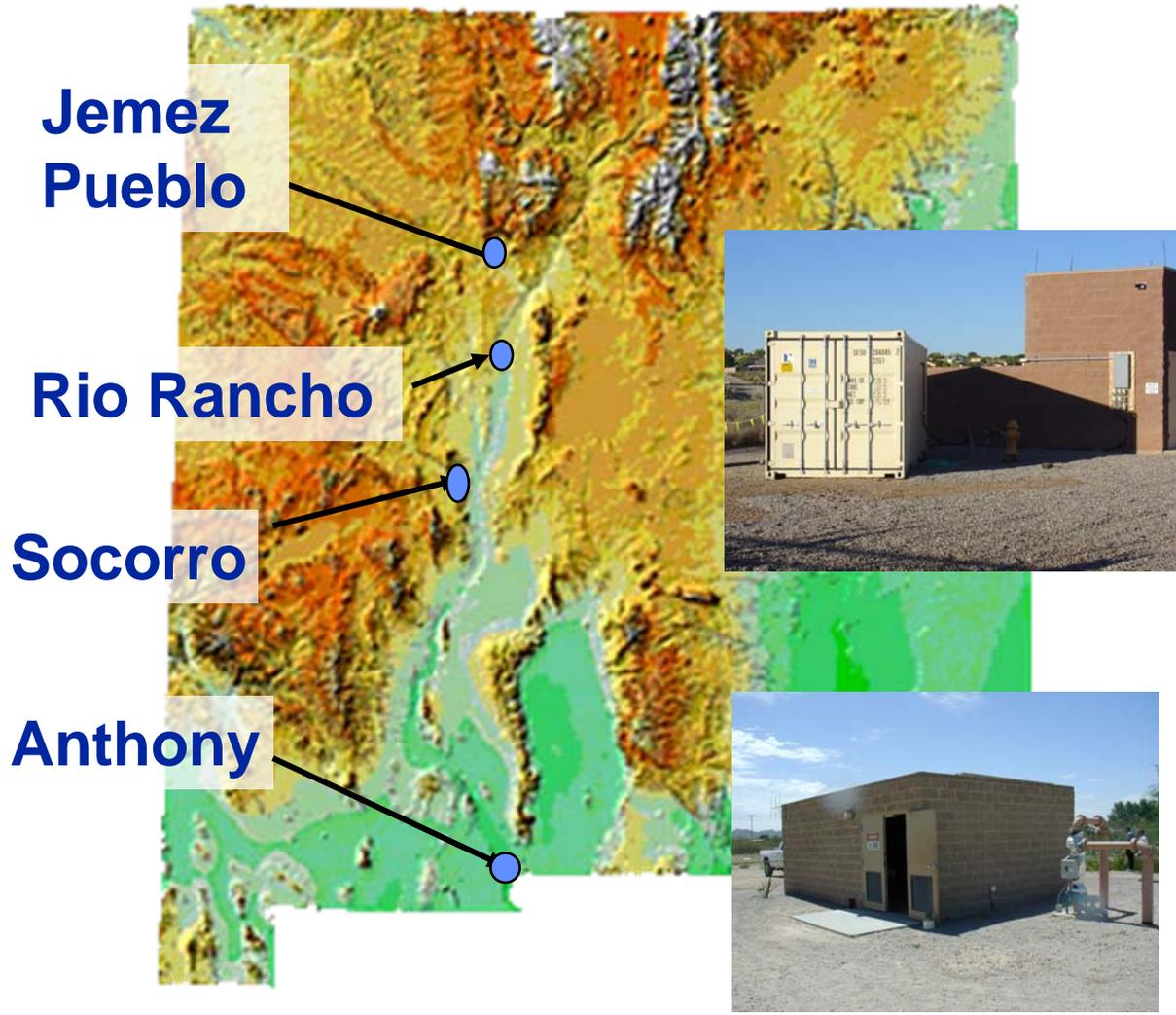
# Things we look for in a pilot site

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- **As concentration (>10 ppb)**
- **Example ground water composition that will help other communities**
  - pH, TDS, foulants such as Fe, Mn, silica, and organics
  - As(III)/As(V)
  - Competing ions (V, SO<sub>4</sub>, etc.)
  - Other contaminants of concern/benefit (e.g, Ra, U, ClO<sub>4</sub>, F)
- **Small size of system to be treated (< 10,000 users)**
- **Community support facilitates rapid deployment**
  - Water utility
  - Municipal government
- **Ability to deal with residuals/treated effluent**
- **Rural and Native American communities that would benefit from assistance**



# Sites in New Mexico



# Site in Oklahoma (Weatherford)





# New Mexico Pilot Sites – Water Quality Summary (Average Values)

	Socorro	Anthony	Rio Rancho	Weatherford
Total As (ppb)	42	20	20	30-40
% Arsenite (As(III))	5%	90%	5%	70-80%
V (ppb)	11	<5	15.5	20-30
SiO <sub>2</sub> (ppm)	25	37	25	24
SO <sub>4</sub> (ppm)	30	180	110	140
Ca (ppm as CaCO <sub>3</sub> )	44	70	55	200
Fe (ppm)	0.04	0.2-0.5	0-0.15	0.5-1.0
pH	8.0	7.7	7.5	7
Conductivity (μS/cm)	340	1300	620	560
Alkalinity (ppm as CaCO <sub>3</sub> )	130	180	160	125
TOC (ppm)	0.50	0.80	0.30	No Data
NO <sub>3</sub> (ppm as N)	0.40	0	2	No Data
F (ppm)	0.50	0.50	0.90	0.40



# New Mexico Pilot Sites – Water Quality Summary (Average Values)

	Weatherford, OK	Jemez Pueblo
Total As (ppb)	30-40	20
% Arsenite (As(III))	70-80%	95%
V (ppb)	20-30	<1
SiO <sub>2</sub> (ppm)	24	50
SO <sub>4</sub> (ppm)	140	24
Ca (ppm as CaCO <sub>3</sub> )	200	155
Fe (ppm)	0.5-1.0	1.2
pH	7	7.5
Conductivity (μS/cm)	560	770
Alkalinity (ppm as CaCO <sub>3</sub> )	125	290
TOC (ppm)	No Data	2
NO <sub>3</sub> (ppm as N)	No Data	0
F (ppm)	0.40	1

# First Community Pilot: Socorro, NM

## BACKGROUND INFORMATION

- **Socorro Population:**  
Approximately 9,000
- **100% groundwater source for drinking water**
- **Pilot site (Springs) is at one of several wells for community**
  - **2 warm springs (90°F) provide 500 gpm, 40 – 45 ppb As(V) by gravity flow**
  - **Formerly site of tap for bottled water company**
- **Optimal F for oral health**



# First Community Pilot: Socorro, NM

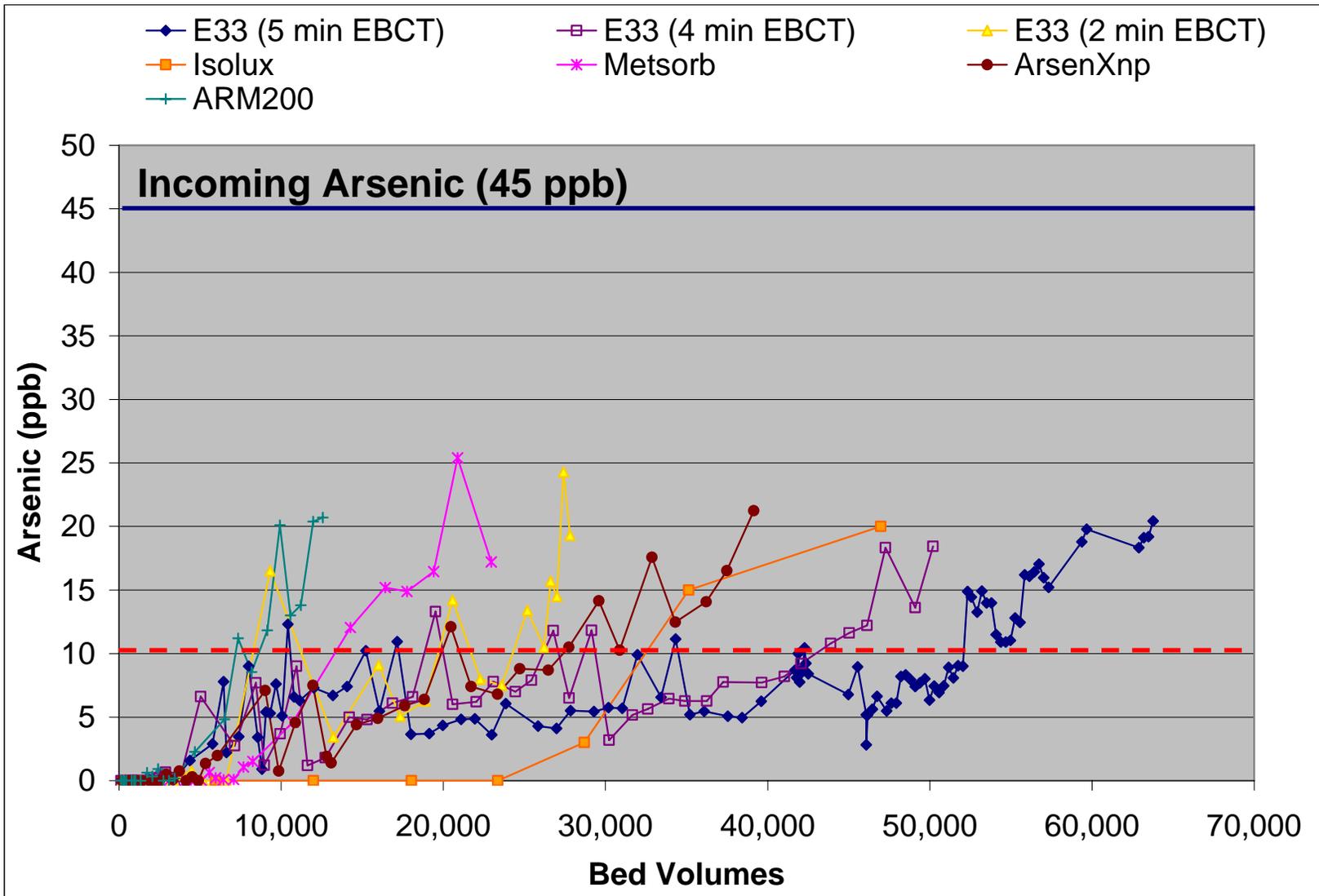
## PHASE 1 Pilot – Ambient pH

- Feb-Oct 2005
- Media Tested
  - Fe oxides: E33, ARM200
  - Resin - ArsenX<sup>np</sup>
  - Ti-oxide - Metsorb
  - Zr-oxide - Isolux
- EBCT study of E33
  - 2, 4, 5 min



# First Community Pilot: Socorro, NM

## Phase 1 Results



# Media Performance in Socorro, NM Phase 1 (Ambient pH)

## • Arsenic Removal Capacity

Parameter	ARM200 (FeOx)*	Metsorb (TiOx)	ArsenX <sup>np</sup> (Resin)**	Isolux (ZrOx)	E33, 5-min (FeOx)
BV to 10 ppb	8,600	13,000	27,000	32,000	52,000
Capacity at 10 ppb, mg/g	0.6	0.7	1.4	1.3	4.2
Capacity at 35K BV, mg/g	1.2	1.4	1.8	1.4	2.9
Depletion - C/Co at 35K BV	0.88	0.60	0.35	0.38	0.12
BV at C/Co = 0.8	33,000	87,000	53,000	63,000	>65,000
Capacity at C/Co = 0.8	1.14	2.24	2.10	1.96	> 5.0

\*ARM200 was a pre-production batch

\*\*ArseneX<sup>np</sup> batch was defective



# Media Performance in Socorro, NM Phase 1 (Ambient pH)

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- Effect of EBCT on Arsenic Removal Capacity

Parameter	E33		
	2 min	4 min	5 min
BV to 10 ppb	24,000	43,000	52,000
Capacity at 10 ppb, mg/g	1.9	3.6	4.2
Capacity at 35K BV, mg/g	2.5	3.01	2.9
Depletion - C/Co at 35K BV	0.50	0.15	0.12
BV at C/Co = 0.8	84,000	> 63,000	> 65,000
Capacity at C/Co = 0.8	4.02	> 4.9	> 5.0



# Media Performance in Socorro, NM Phase 2b (Ambient pH vs. pH 6.8)

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## Phase 2b:

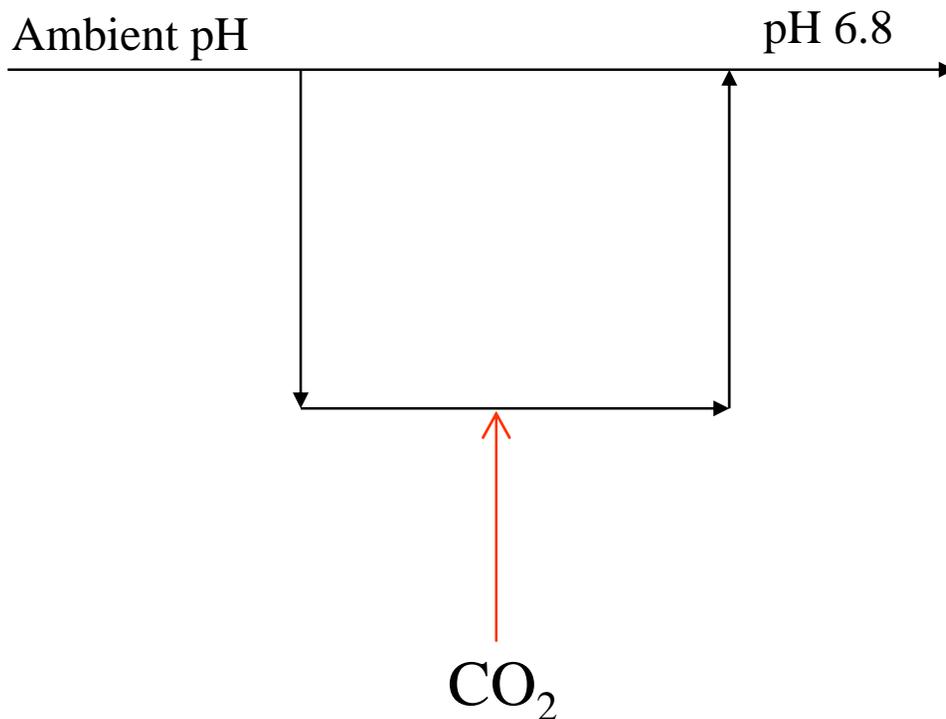
- **Side-by side comparisons of 5 media at 2 pH levels (ambient and pH 6.8)**
  - ArsenX<sup>np</sup> – New, QC'd batches
  - Isolux – larger cartridge
  - Kemiron – FeOx media
  - SANS – Sandia proprietary media
  - Metsorb – TiOx media
- **Evaluate inadvertent effects of treatment**
  - Loss of pH control
  - Loss of flow
- **Evaluate AwwaRF & University media (pH 6.8)**
  - AwwaRF: Auburn University, ASU
  - University Media: NMSU, NMT

# Media Performance in Socorro, NM

## Phase 2b (Ambient pH vs. pH 6.8)

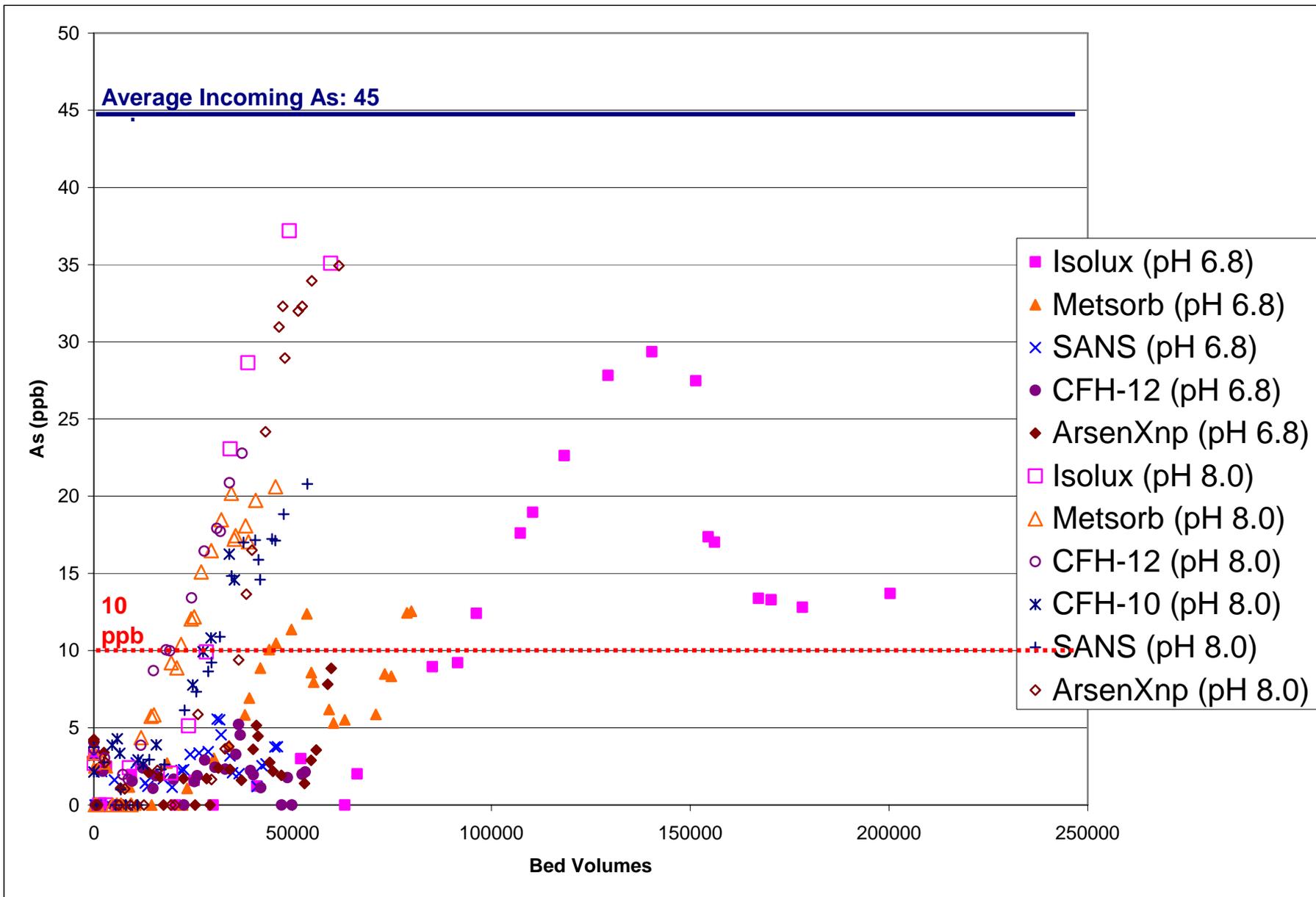
### Phase 2b:

- pH Adjustment using CO<sub>2</sub> gas



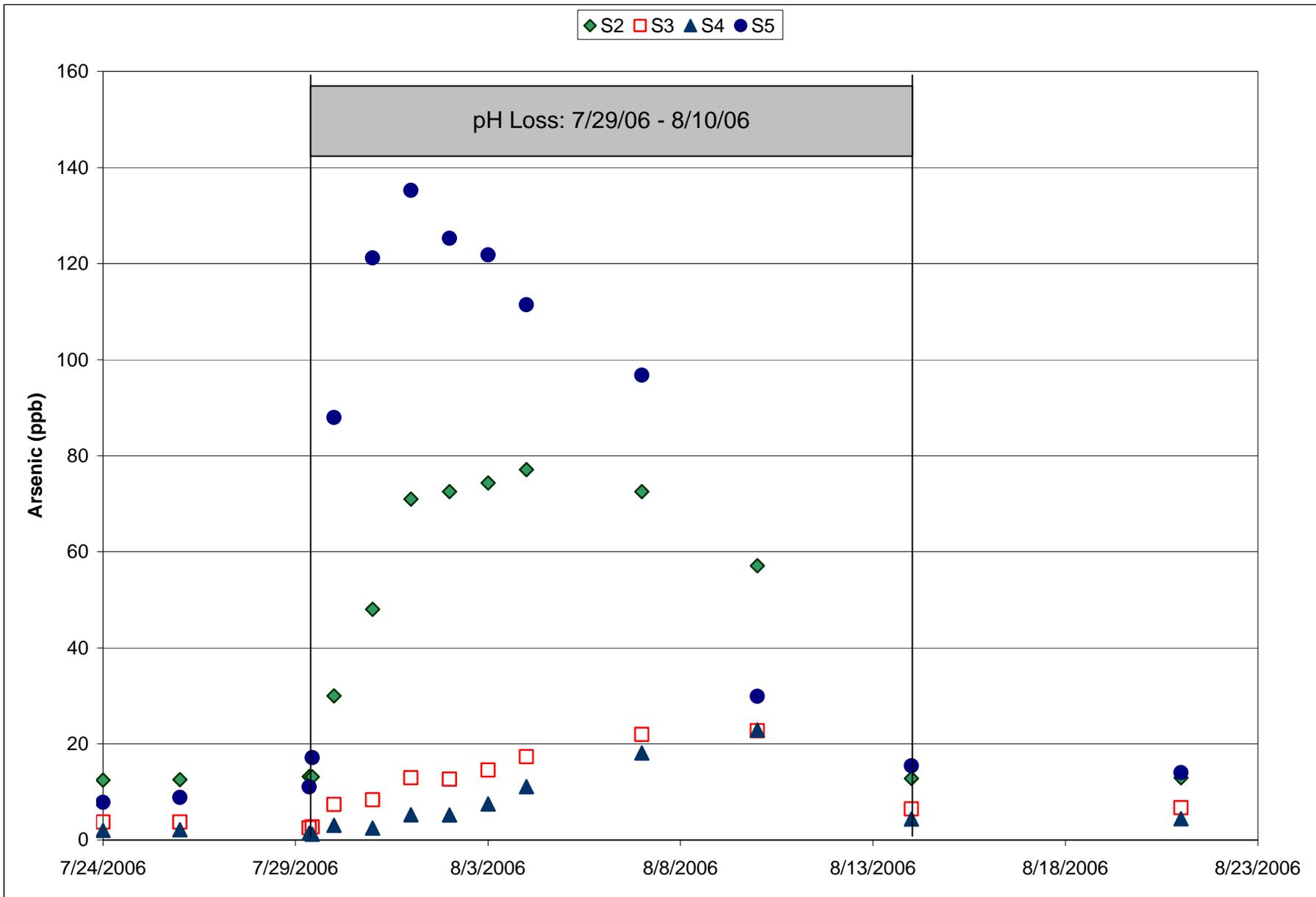
# Media Performance in Socorro, NM

## Phase 2b (Ambient pH vs. pH 6.8)



# Media Performance in Socorro, NM

## Phase 2b (Ambient pH vs. pH 6.8)



# Second Community Pilot: Anthony, NM (Desert Sands MDWCA)

## BACKGROUND INFO.

- Population of Anthony: Approx. 8,000
- 100% groundwater source for drinking water
- Warm springs (~85°F) provide 240-270 gpm, 20 ppb As - mainly As(III).
- High sulfates, TDS
- Intermittent Flow Operation
- Site of Round 1 EPA Pilot Demonstration
- Desert Sands MDWCA has an “exemption”; doesn’t have to comply with As rule for at least 2 years





# Second Community Pilot: Anthony, NM (Desert Sands MDWCA)

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- **Phase 1: Media Tested**

- FeOx: E33, ARM200, CFH12
- ZrOx: Isolux
- TiOx: Metsorb, Adsorbsia GTO™
- Resins: ASM-10HP, ArsenX<sup>np</sup>
- La, Fe, Mg-coated diatomaceous earth: NXT-2

- **Phase 2: December 2005**

- FeOx-Coated GAC
- Fe-coated silicate
- Also: re-loaded ArsenX<sup>np</sup> column

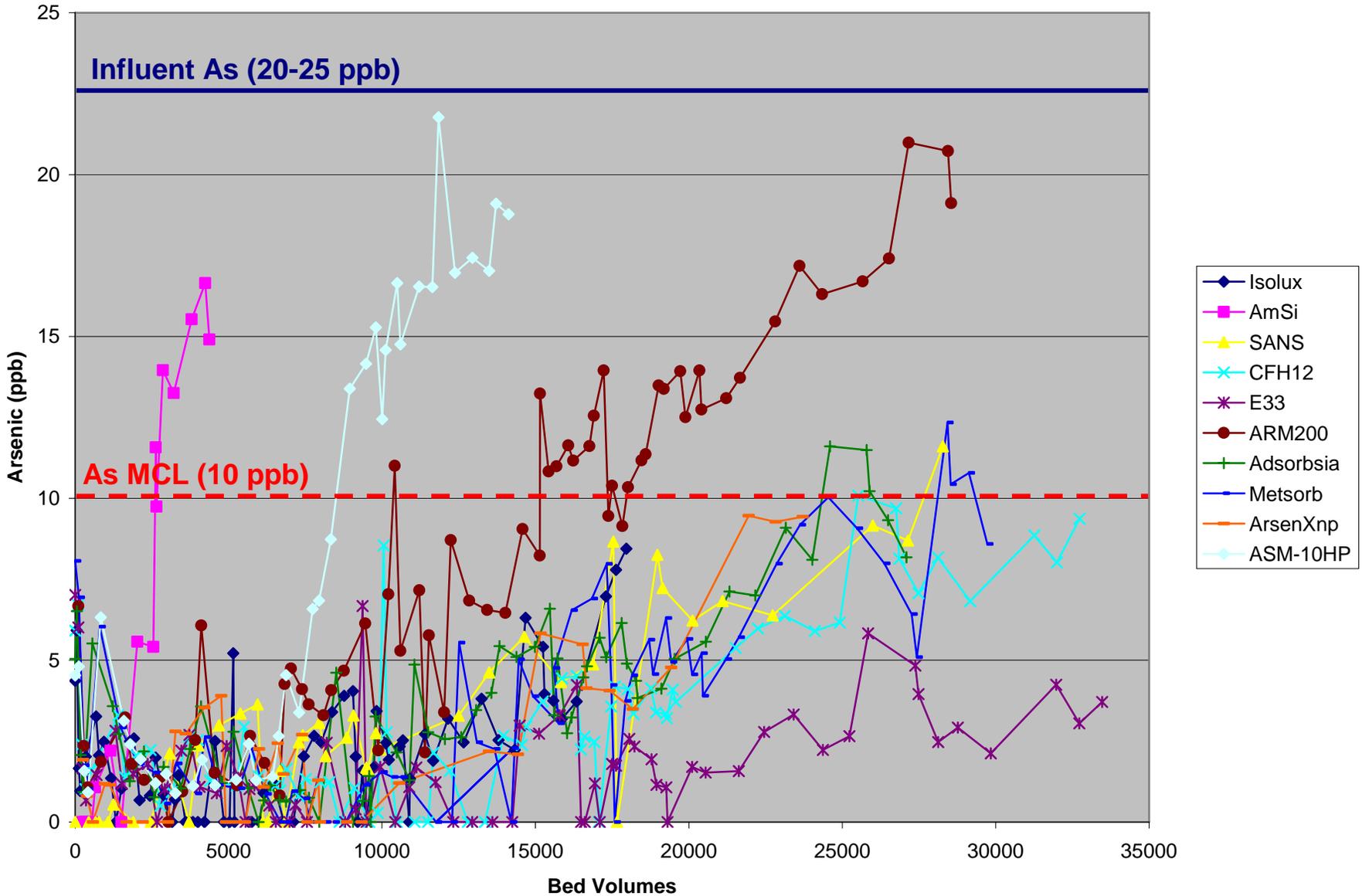
- **Phase 3: June 2006**

- La, Fe, Mg-coated diatomaceous earth: NXT-2
- Modified zeolite: Redisorb
- New batch ARM200

- **Phase 4: October 2006**

- 24/7 flow operation comparing:
  - E33 with 5 μm pre-filter
- vs
- AD26 Fe/Mn/As removal media

# Second Community Pilot: Anthony, NM (Desert Sands MDWCA)

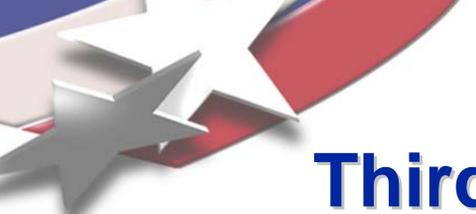


# Third Community Pilot: Rio Rancho, NM

## BACKGROUND INFO:

- Population of Rio Rancho: Approx. 52,000 and growing...
- 100% groundwater source for drinking water
- Deep well (800 ft) provides 2000 gpm, 20 ppb As (mainly As V).
- High sulfates, Vanadium, TDS
- Continuous Flow Operation





# Third Community Pilot: Rio Rancho, NM

## Phase 1

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- **Phase 1: September 2005 Start**

- FeOx: E33, CFH10
- ZrOx: Isolux
- TiOx: Adsorbsia GTO™
- Resins: ASM-10HP, ArsenX<sup>np</sup>
- (2) Under-the-sink Reverse Osmosis Units

- **Continuous Flow Operation**

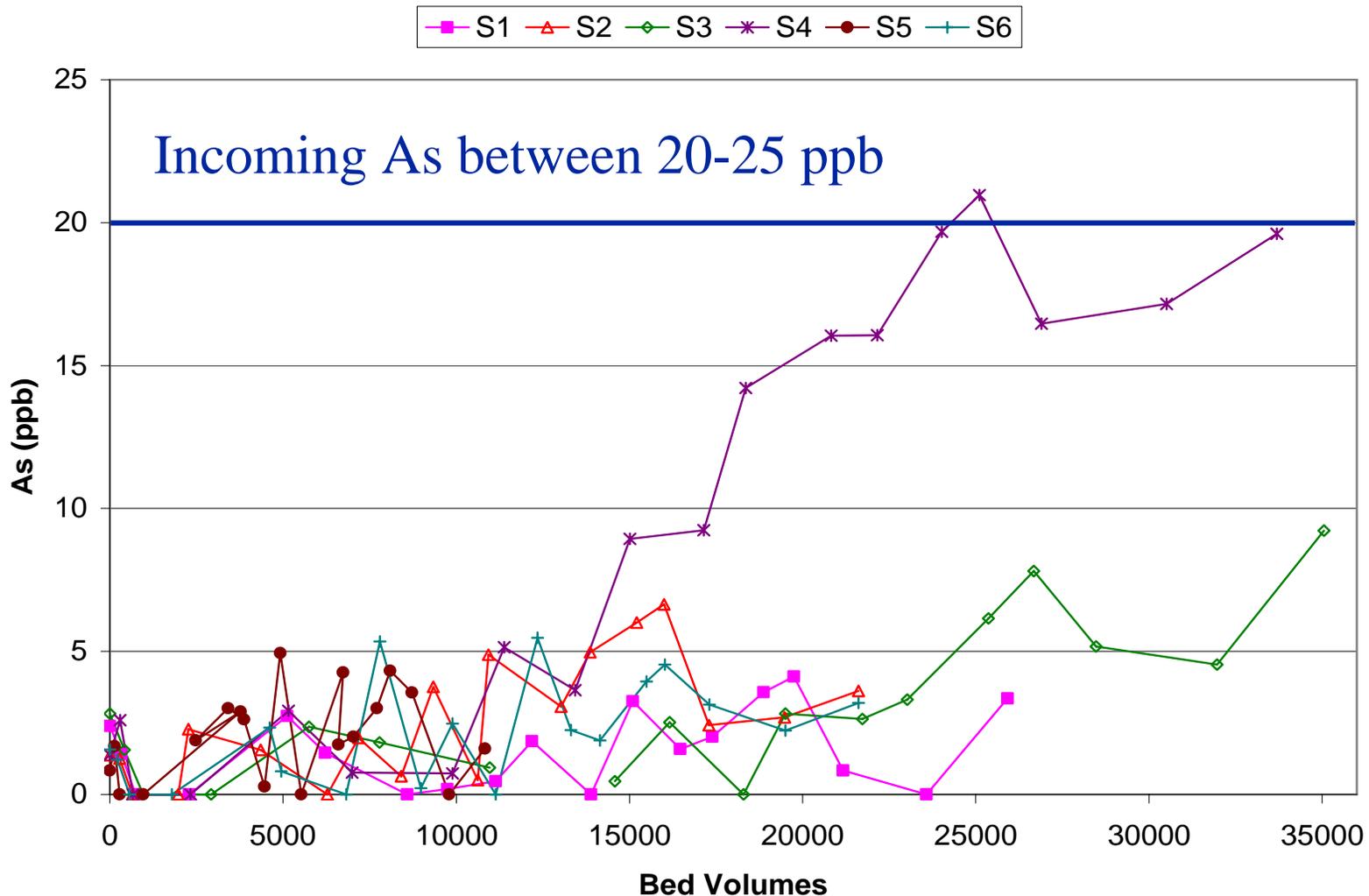
- **Phase 2: September 2005 Start**

- FeOx: E33, CFH12
- ZrOx: Isolux
- TiOx: Adsorbsia GTO™
- Resins: ArsenX<sup>np</sup>; New Batch: ASM-10HP
- Amended Silicate
- Bone Char

- **Continuous Flow Operation**

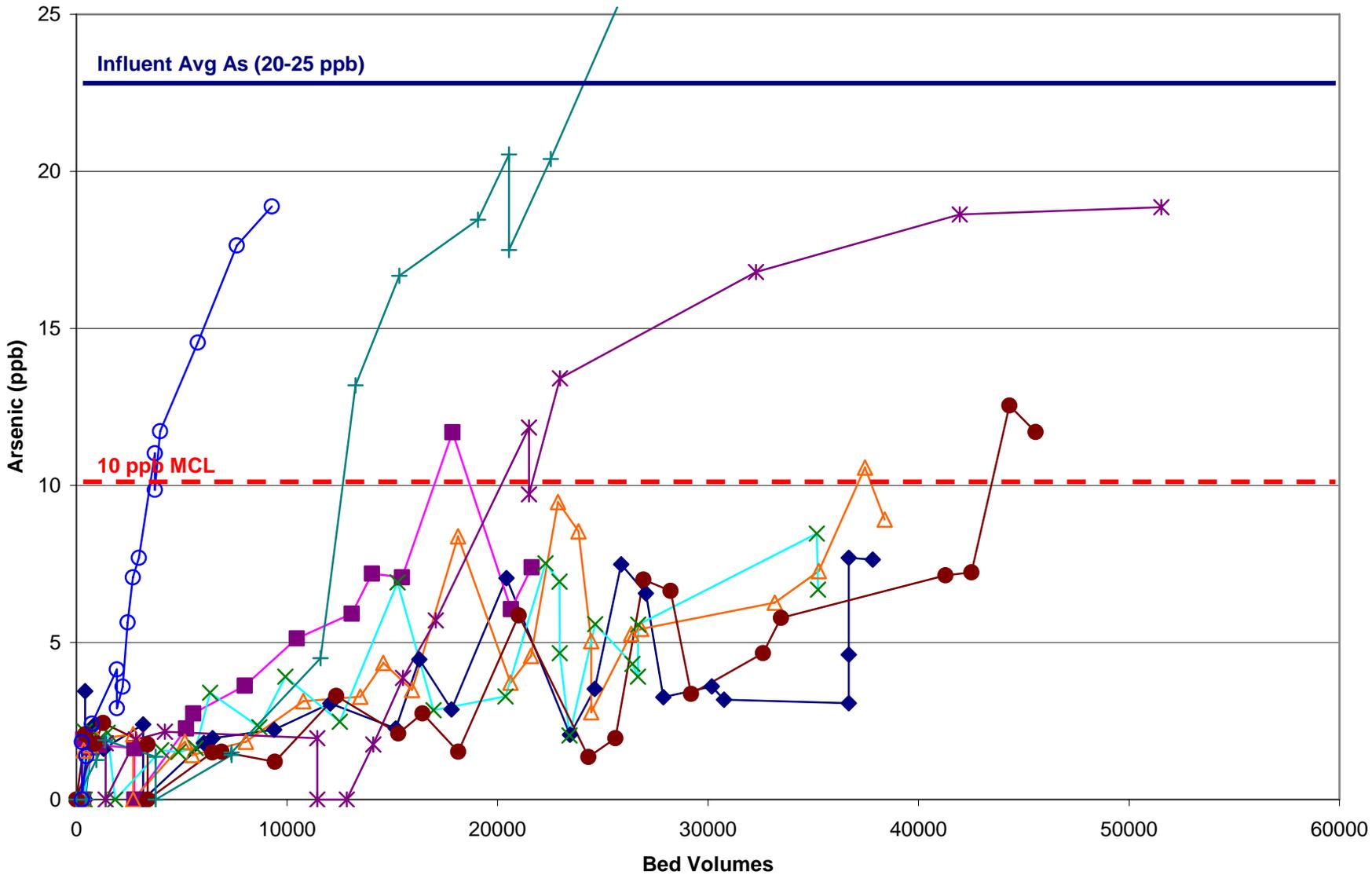
# Media Performance: Rio Rancho, NM Phase 1

S1=E33; S2 = CFH10; S3 =ArsenX<sup>np</sup>; S4 = ASM-10HP; S5=Adsorbsia GTO; S6=Isolux



# Media Performance: Rio Rancho, NM Phase 2

◆ E33   ■ CFH12   ▲ SANS   × Adsorbisia GTO   \* Isolux   ● ArsenXnp   + ASM-10HP   ○ ADA



# Summary: Bed Volume Results

Mfr	Media	SS Phase 1	SS Phase 2b (pH 6.8/ pH 8)	RR Phase 1	RR Phase 2	DS (Ph 1/2)
MEI	<b>Isolux</b>	32,000	92,000/ 28,000	>11,000	20,000	>18,000
Sandia	<b>SANS</b>	N/A	>53,000/ 31,000	N/A	>40,000	>30,000
Kemiron	<b>CFH10</b>	N/A	28,000 (pH 8) <sup>1</sup>	>22,000	N/A	N/A
Kemiron	<b>CFH12</b>	N/A	>46,000/ 18,000	N/A	>22,000	>32,000
AdEdge/ STS	<b>E33</b>	26,000/44,000/ 42,000 (2/4/5 min EBCT)	N/A	>25,000	>40,000	>33,000
Engelhard	<b>ARM200</b>	9,000 <sup>2</sup>	N/A	N/A	N/A	18,000 (Ph1) <sup>2</sup>

<sup>1</sup>The Kemiron media installed in Socorro Phase 2b was CFH12, a larger diameter particle, which may not have been conducive to the 3" column size & pilot flow rates. The smaller diameter particle (CFH10) was installed for comparison in the ambient stream only.

<sup>2</sup>The media installed in Socorro Phase 1 from Engelhard was a pre-production media, as stated by the vendor, Engelhard. Newer media is currently being tested at the Desert Sands site.

# Summary: Bed Volume Results

Mfr	Media	SS Ph 1	SS Phase 2b (pH 6.8/ pH 8)	RR Ph 1	RR Ph 2	DS (Ph 1/2)
Dow	<b>Adsorbsia™ GTO™</b>	N/A	N/A	>22,000	>40,000	25,000 <sup>3</sup>
Hydroglobe	<b>Metsorb</b>	19,000 <sup>3</sup>	45,000/ 22,000	N/A	N/A	28,000 <sup>3</sup>
Purolite	<b>ArsenX<sup>np</sup></b>	28,000 <sup>4</sup>	>60,000/ 37,000	>35,000	36,000	>10,000 <sup>4</sup> / >24,000
Resin Tech	<b>ASM-10HP (1st batch)</b>	N/A	N/A	18,000	N/A	8,500
Resin Tech	<b>ASM-10HP (2nd batch)</b>	N/A	N/A	N/A	13,000	N/A
EP Minerals	<b>NXT-2</b>	N/A	N/A	N/A	N/A	2,400 <sup>5</sup>

<sup>3</sup>These media had clogged and flow was stopped. Both had reached As>10 ppb for at least one data point.

<sup>4</sup>Purolite indicated a Quality Control problem with the first supplied batch of ArsenXnp media. A new batch was installed at Socorro Phase 2, Rio Rancho (both phases), and Desert Sands Phase 2.

<sup>5</sup>This media broke down physically, causing total clogging of the column. The vendor has provided an improved media that is currently being tested at the Desert Sands site.

# Fourth Community Pilot: Pueblo of Jemez

## BACKGROUND INFORMATION:

- Interesting Facts:
  - Population is near 2,000
  - Tribal Enrollment is near 3,500
  - 90,000 acres
  - Spanish Land Grant (1689) & granted by US Congress (1858)
  - Current Governor (James Madalena) is also a NM State Representative (District 65)
- Culture & History
  - Only remaining village of the Towa-speaking pueblos in NM
  - Most tribal members live in the village known as Walatowa (Towa word meaning “*this is THE place*”)



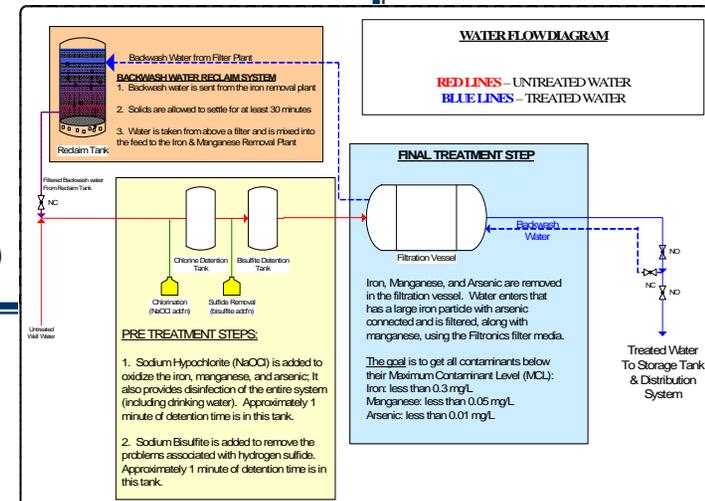
# Fourth Community Pilot: Pueblo of Jemez Full Scale Information

<u>Item</u>	<u>Cost</u>	<u>Funding Source</u>
Filter House & Equipment:	\$550,000	IHS Sanitation Facilities Construction Program
Well & Electric Controls:	\$160,000	IHS Sanitation Facilities Construction Program
365,000 gal Storage Tank:	\$293,000	EPA SDWA Indian Set-Aside Program
Pipelines:	<u>\$216,000</u>	EPA SDWA Indian Set-Aside Program
<b>TOTAL COST:</b>	<b>\$1,219,000</b>	
<b>Annual O&amp;M COST:</b>	<b>\$43,200</b>	Jemez Pueblo

**Includes:**

*Chemicals  
Electrical Cost  
Operators Salaries  
Vehicles/Gas  
Equipment repair/replacement  
Insurance  
Future Expenses (filter media replacement)*

**Source:** Stefanie Pecos-Duarte, IHS





# Fourth Community Pilot: Pueblo of Jemez

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## PILOT INFORMATION:

- Gather information on Full Scale System:
  - As, Fe, Mn Removal Capabilities
  - Other System Performance
- Test four different coagulation-assisted filtration systems (Blue Water Technology, Hungerford & Terry, Kinetico, Orca)
  - Determine optimal Chlorine,  $\text{FeCl}_3$  dosages
  - Determine operational ranges
- Jar Studies & Other Laboratory Tests



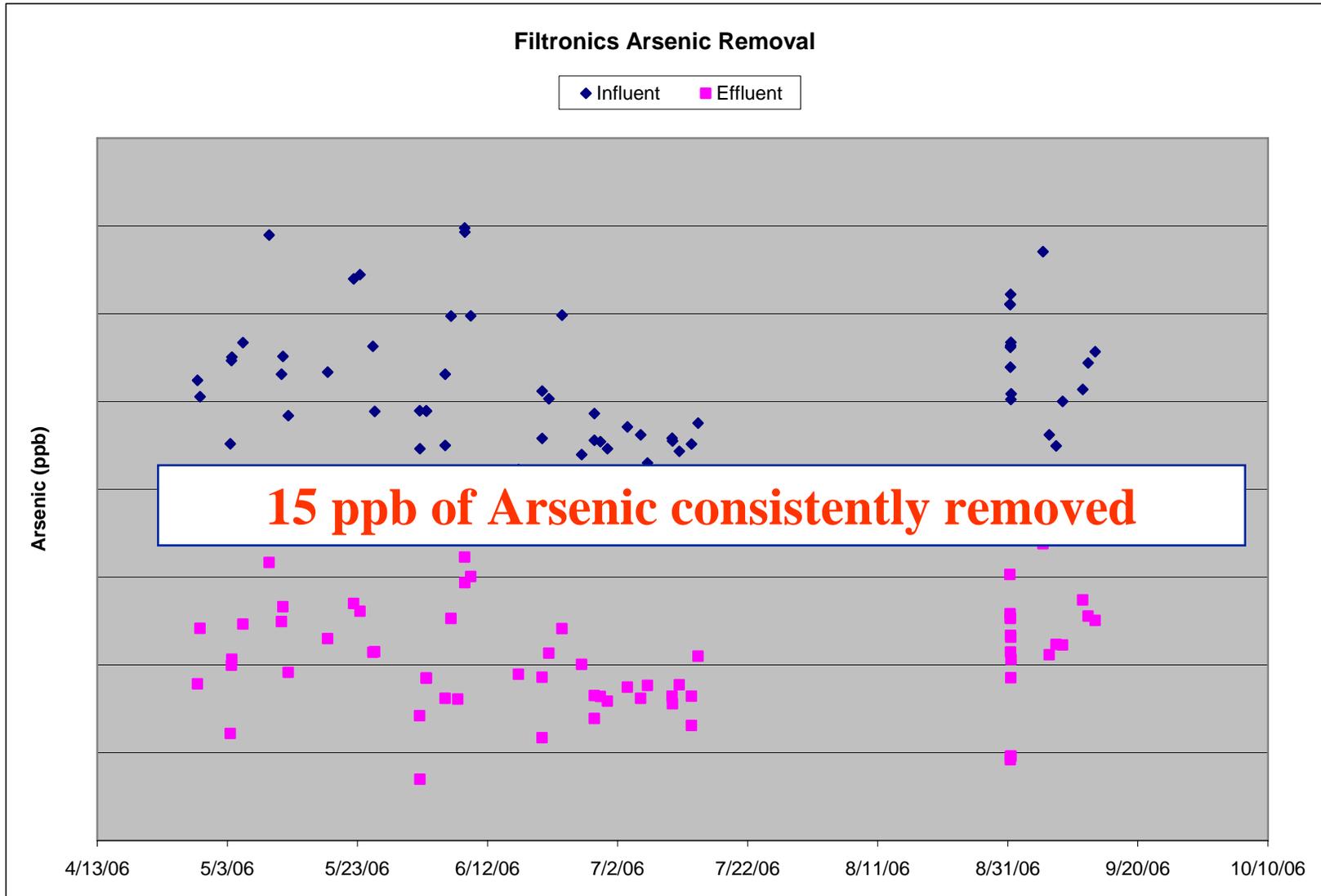
# Fourth Community Pilot: Pueblo of Jemez

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## PILOT INFORMATION:

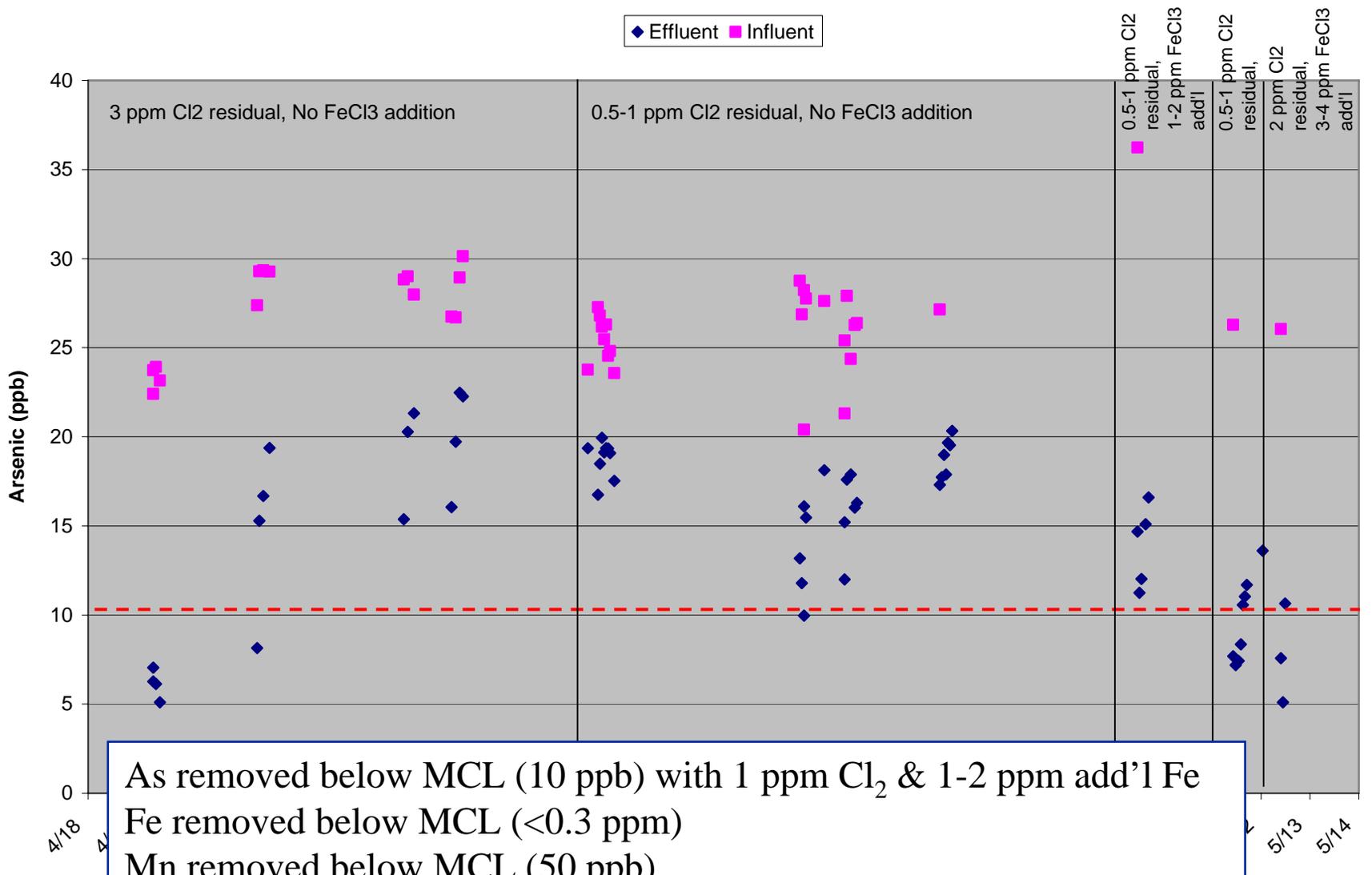
- Kineticico
  - Macrolite ceramic filtration media
  - Pilot unit had capabilities of up to 15 minutes extra contact time
- Hungerford & Terry
  - Greensand Plus filtration media
- Orca (tested two separate media)
  - Sand/Anthracite Mixture
  - Quantum As, Fe, Mn removal media
- Blue Water Technologies
  - Up-flow sand filter; similar design used for PO<sub>4</sub> removal in waste water

# Fourth Community Pilot: Pueblo of Jemez Full Scale Information



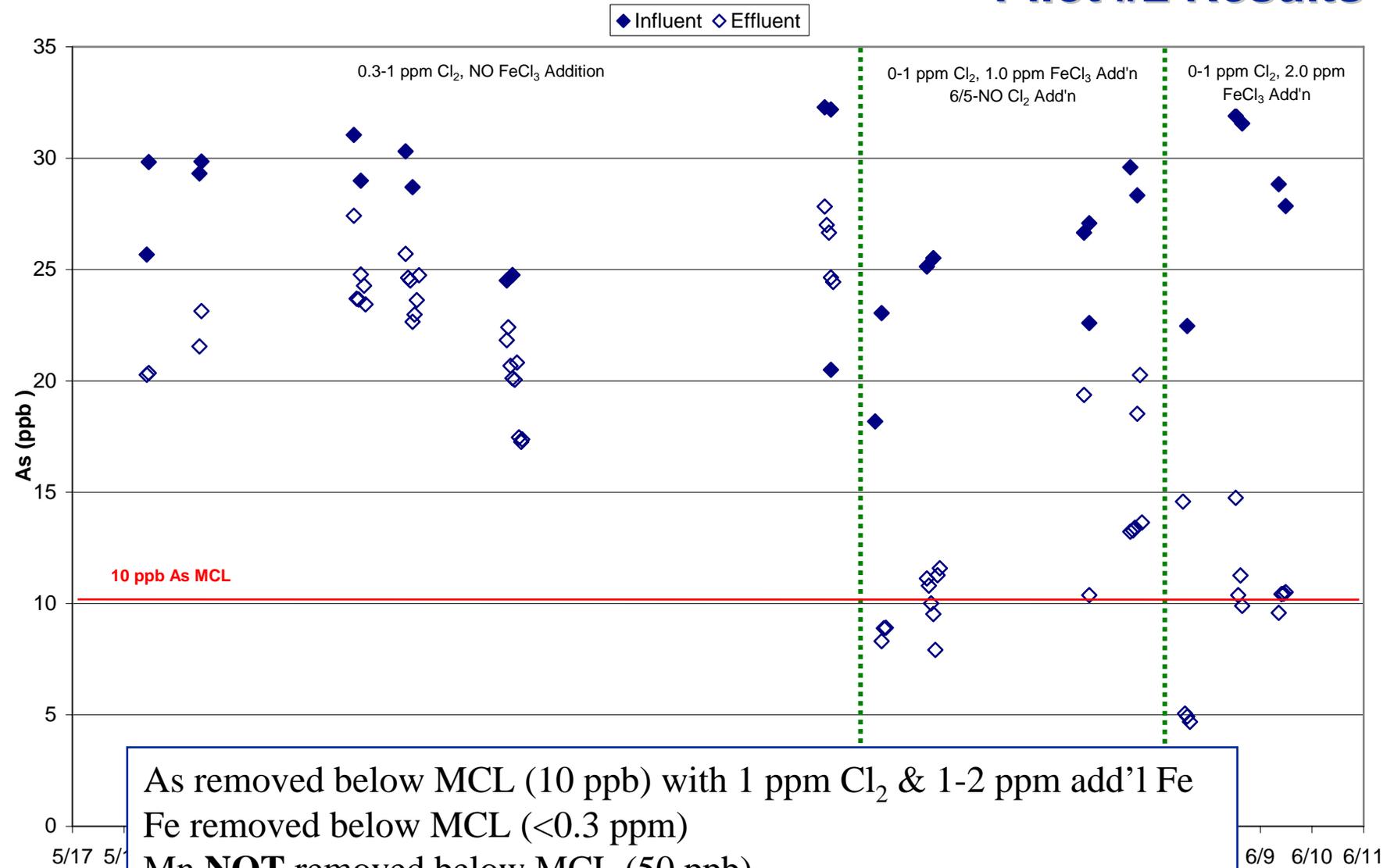
# Fourth Community Pilot: Pueblo of Jemez

## Pilot #1 Results



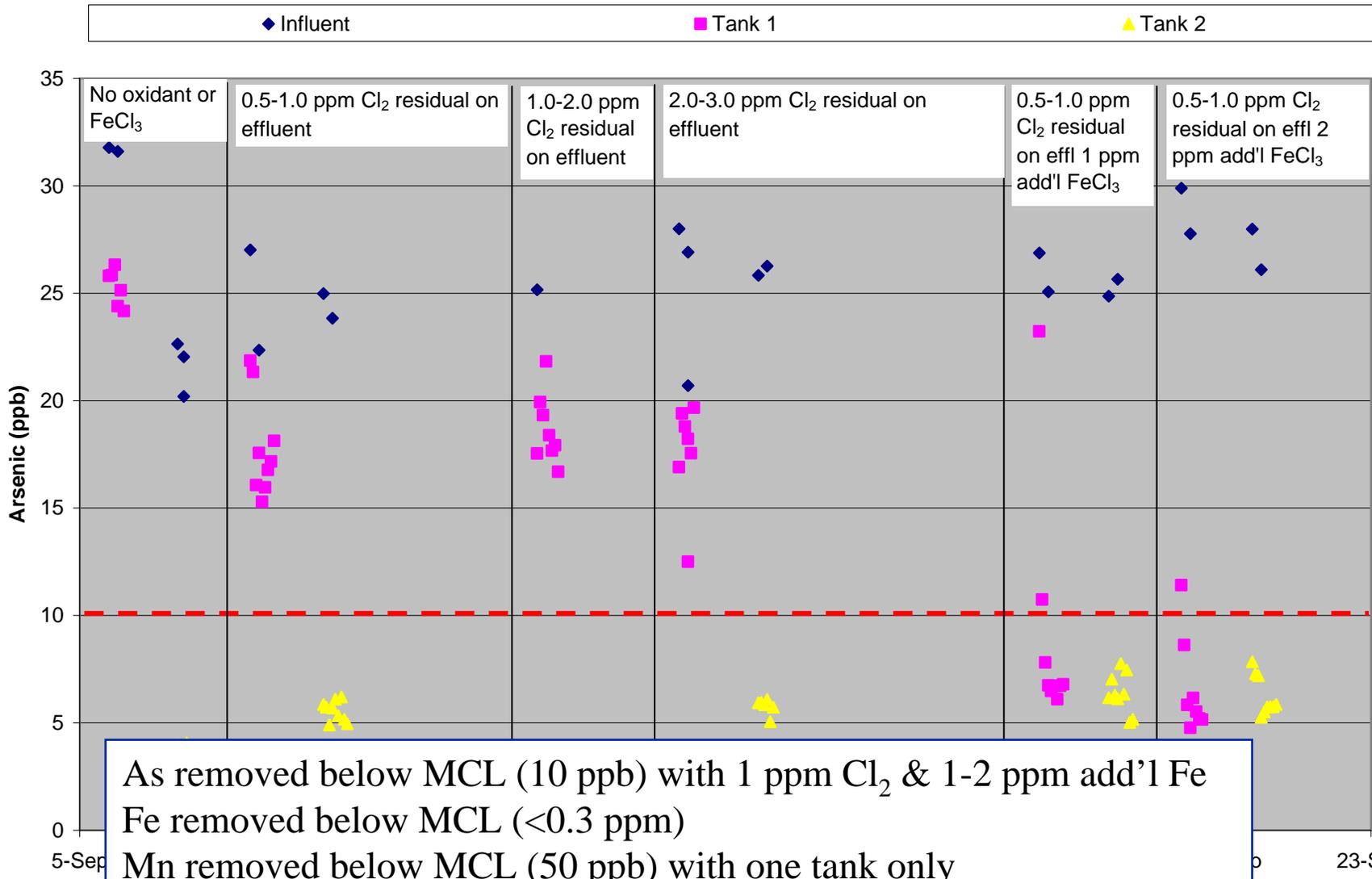
# Fourth Community Pilot: Pueblo of Jemez

## Pilot #2 Results



# Fourth Community Pilot: Pueblo of Jemez

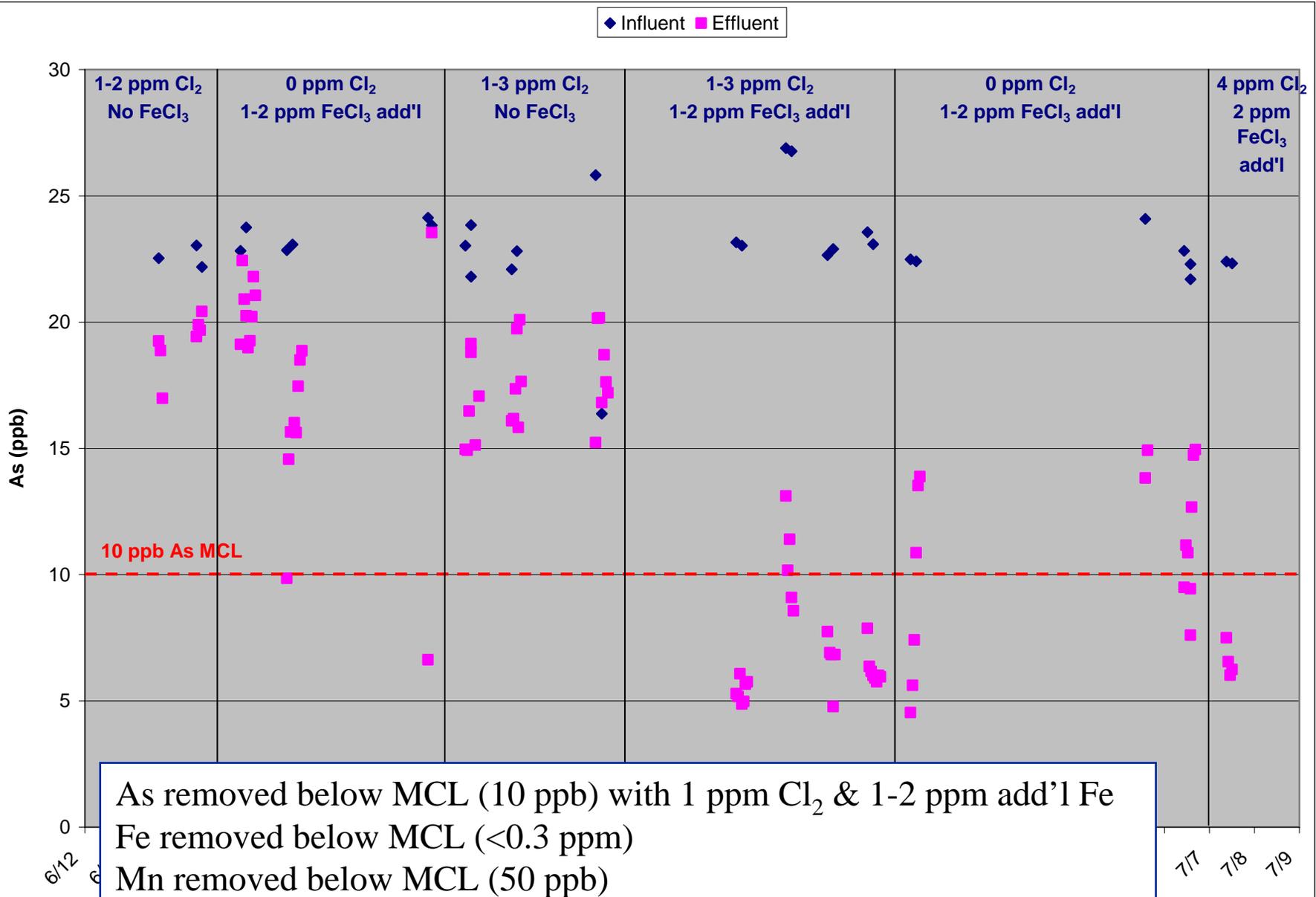
## Pilot #3 Results





# Fourth Community Pilot: Pueblo of Jemez

## Pilot #4 Results





# Fourth Community Pilot: Pueblo of Jemez Pilot Results

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## PILOT RESULTS SUMMARY:

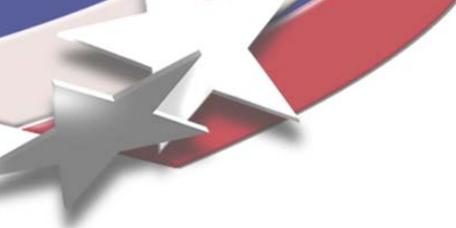
- All Pilot Units removed As below the MCL of 10 ppb
- All Pilot Units removed Fe below the MCL of 0.3 ppm
- Most Pilot Units removed Mn below the MCL of 50 ppb
- Optimal dosage for chemicals:
  - 0.5-1 ppm free chlorine
  - 1-2 ppm additional Fe
- Additional Contact Time may help with floc formation and Arsenic removal

# Fifth Community Pilot: Weatherford, OK

## BACKGROUND INFO:

- Population approximately 10,000
- High TDS, V, hardness, sulfate, iron
- Pilot site is at one of 30+ wells
- Pilot will test:
  - 4 Adsorptive Media (CFH12, E33, Adsorbsia GTO™, ArsenX<sup>np</sup>)
  - Coagulation-Assisted Filtration





# Cost Impacts

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What if...

- I can build a really cheap building?
- Media lasts “forever”?
- Media is free?



# Cost Impacts

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## **BOTTOM LINE:**

- Spend appropriately on the front end – “pay me now, or pay me later”
- Design of arsenic removal system should:
  - Remove As below MCL – Get a guaranteed \$/1000 rate or media capacity from your vendor
  - Allow for minimal maintenance
  - Allow for simple media replacement
    - Do tank(s) have a drain? Large enough access ports?
    - Does your building allow for easy access?
- Plan for annual expenses
  - Labor
  - Media Replacement
  - Chemicals



# Summary: Results

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- **Pilot studies have been completed or are in progress at three sites in New Mexico: Socorro, Anthony, and Rio Rancho, and one site in Oklahoma: Weatherford.**
- **Empty bed contact time (EBCT) does have an affect on the relative performance of the media.**
  - Most media vendors recommend 3-5 minutes EBCT
  - 3 minute EBCT is generally sufficient, in that higher bed volumes to 10 ppb breakthrough are demonstrated regularly.
  - 5 minute EBCT is typical design for most vendors
- **4 separate coagulation-assisted filtration systems have been tested at the Jemez Pueblo**
  - 0.5-1 ppm free Chlorine residual optimal for oxidation
  - 1-2 ppm additional iron ( $\text{FeCl}_3$ ) is optimal for As removal
  - Additional contact time may be needed for floc formation & As/Mn removal



## For More Information:

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### Arsenic Partnership Website

<http://www.arsenicpartners.org/>

### Sandia Website

<http://www.sandia.gov/water/arsenic>

→ Papers, Presentations, Vendor Information, Pilot Results

### WERC CoAsT Website

<http://www.werc.net>

→ Click on Outreach tab, then CoAsT