Arsenic Treatment - Lessons From the Past Few Years

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PUBLIC HEALTH
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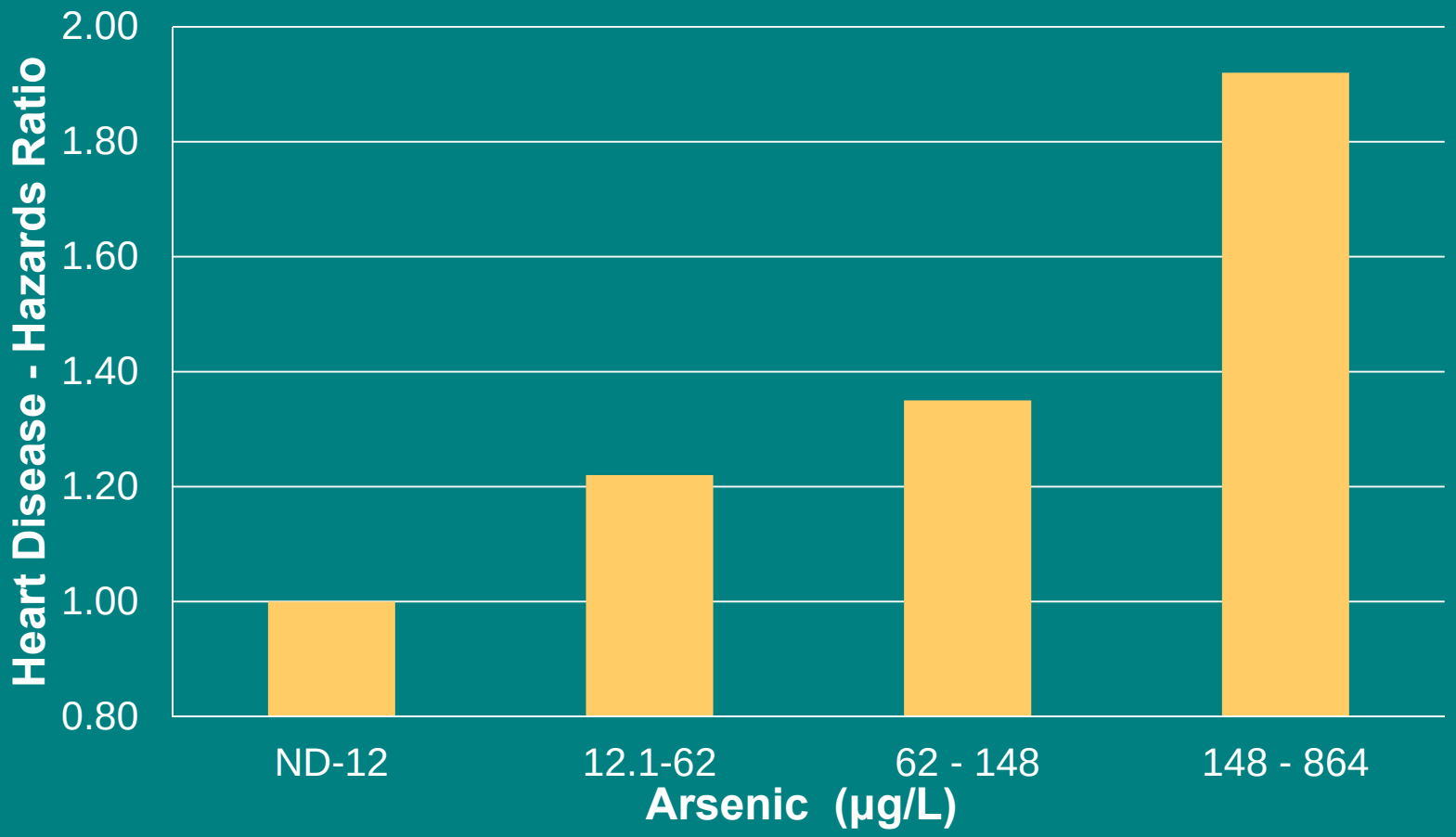
Washington State Department of Health

Office of Drinking Water Mission

To protect the health of the people of Washington State by ensuring safe and reliable drinking water.

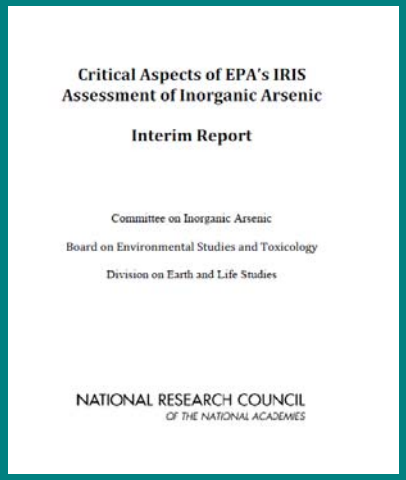
Arsenic and Heart Disease



Ref. British Medical Journal 2/2011

Other Recent Health Findings

- Cancer
  - Current 1/10,000 health risk is at 2 ppb
- Toxicological Reviews
  - EPA IRIS (2010) - Draft
    - More potent carcinogen than previously indicated
  - National Research Council (2013)
    - Review multiple health endpoints – skin, diabetes, neurodevelopmental
    - Sensitive life stages (early childhood)
    - Could lead to lower MCL?? (maybe)



Arsenic Treatment Experiences (USEPA)

- EPA Treatment Demonstration Studies
  - 50 Water Systems
    - 31 Adsorbent (62%)
    - 2 Ion Exchange (4%)
    - 15 Oxid./Coag./Filtration (30%)
    - 2 Reverse Osmosis (4%)
  - Treatment performance varied
    - Sauk Center, MN – 33% > As MCL
    - Pentwater, MI – 45% > As MCL

Arsenic Treatment Experiences (WA)

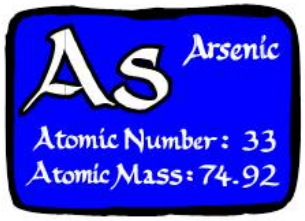
- **Overall Perspective** (as of 12/2013)
  - 116 Affected Water Systems
    - 64 Treating (55%) - Includes blending
    - 36 Non-treatment alternative (31%)
    - 16 Installing treatment/undecided (14%)
  - Physical Treatment (SDWA Regulated)
    - Performance has varied
    - 8 of 52 (15%) - Most recent As sample greater than MCL

Arsenic Treatment Optimization Program – Why/What?

- Not all treatment is successful
- Encompass concepts from Area Wide Optimization Program (AWOP)
  - Seek first to understand
  - Invest in people (operators/technical capacity)
  - Empower small operational and treatment adjustments
  - Provide a greater level of public health protection

Arsenic Treatment Optimization Program

The Arsenic Treatment Optimization Program (ATOP) is an effort to improve performance of arsenic treatment facilities. ATOP focuses on effective arsenic removal to maximize public health protection.



The Washington Department of Health promotes performance and monitoring goals for water treatment plants treating arsenic-contaminated sources.

Optimization Goals for Treatment

Performance

- Treated water total Arsenic annually averages 5 ppb or less, and never exceeds 8 ppb (prior to blending with another source).

Monitoring

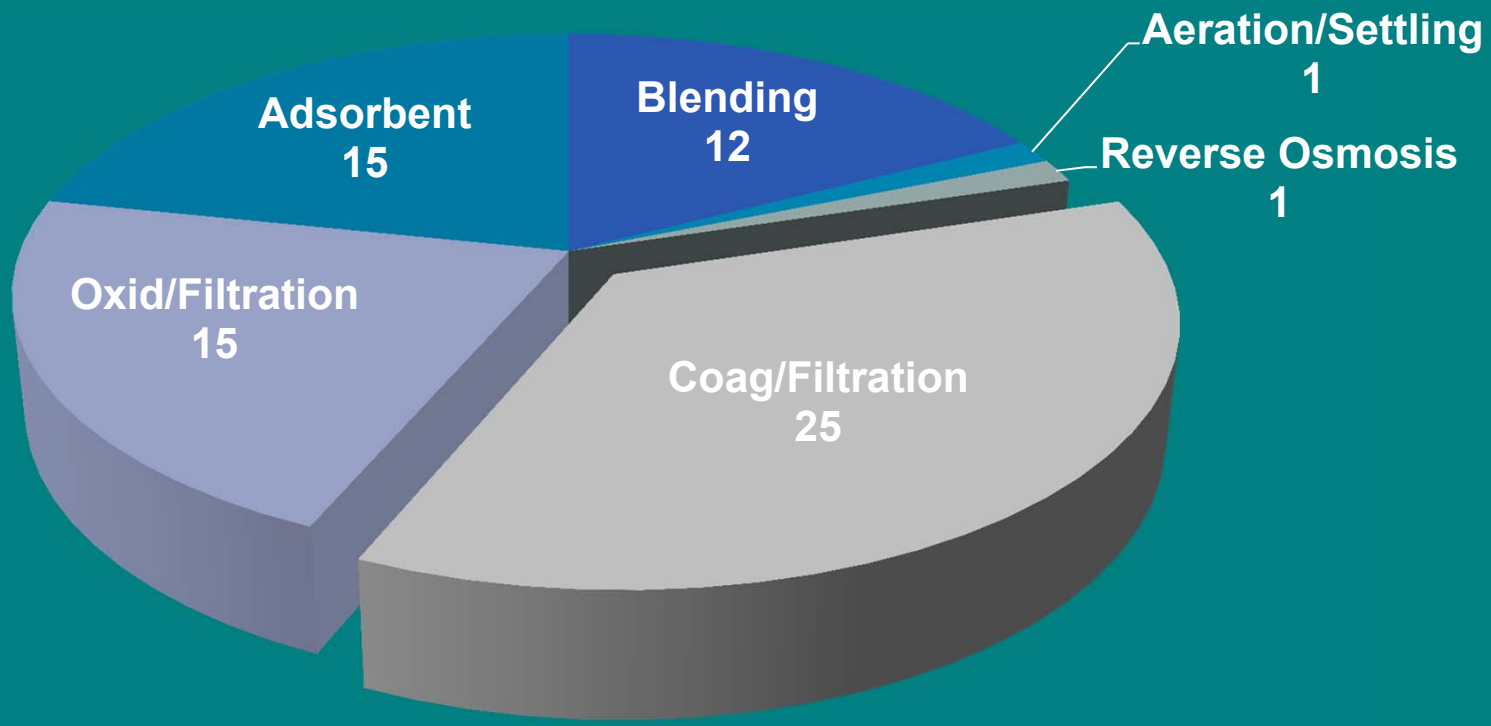
- Treated water Arsenic is monitored at least monthly. Samples are taken prior to blending.
- Systems using oxidation/filtration treatment – monitor raw and finished water Iron levels at least weekly.
- Systems that adjust pH – monitor pH continuously.

Washington State Department of Health
Division of Environmental Health
Office of Drinking Water

For more information about ATOP, please contact Stephen Baker at (360) 236-3138 or stephen.baker@doh.wa.gov

Arsenic Treatment in WA

Number of Systems by Technology Type



Before Reevaluating Design

- It is important to:
  - Be aware of the range of options.
  - Understand your raw water quality.
  - Test your assumptions.
  - Realize that the situation may be "special."
  - Avoid shortcuts.

Design & Operations - Some Considerations

- Adsorbents
  - Raw water quality
  - Oxidant and contact time
  - Type of adsorbent
  - pH adjustment
  - Empty bed contact time (EBCT)
  - Backwash
- Coag/Filt (Ox/Filt)
  - Raw water quality
  - Filter media - type, depth
  - Oxidant dose and contact time
  - Coagulant dose and contact time
  - Filter loading rate, run length, backwash

Test Your Assumptions

- Arsenic treatment can be challenging
- Each application is unique
- Full-scale failure is not uncommon
- Pilot Testing Tools
  - Jar testing (Ox/Coag/Filt)
  - Small-scale pilot tests (Ox/Coag/Filt; IX)
  - Rapid small scale column tests (Adsorbents)

Rapid Small Scale Column Tests (RSSCTs)

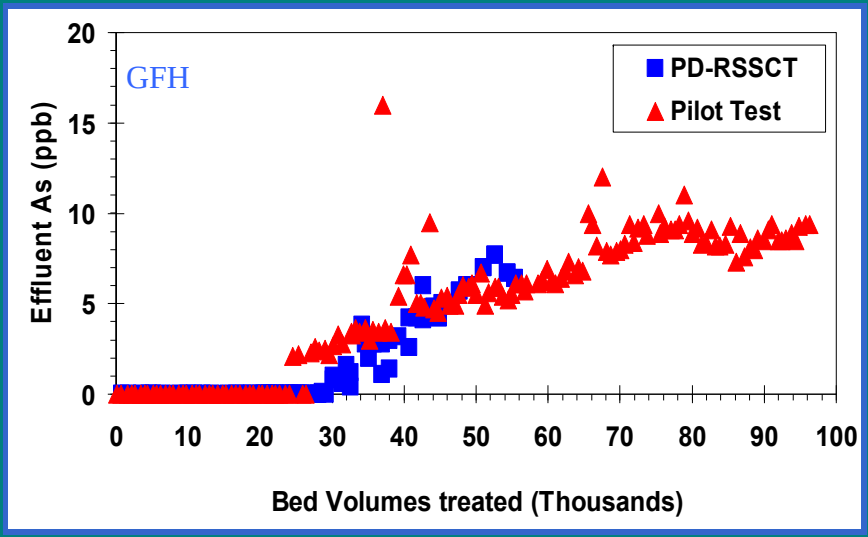
- Used to estimate breakthrough curves for adsorbents
- Rapid (1-3 weeks)
- Small – Bench scale (5-10 gal/day)
- Multiple adsorbents can be compared

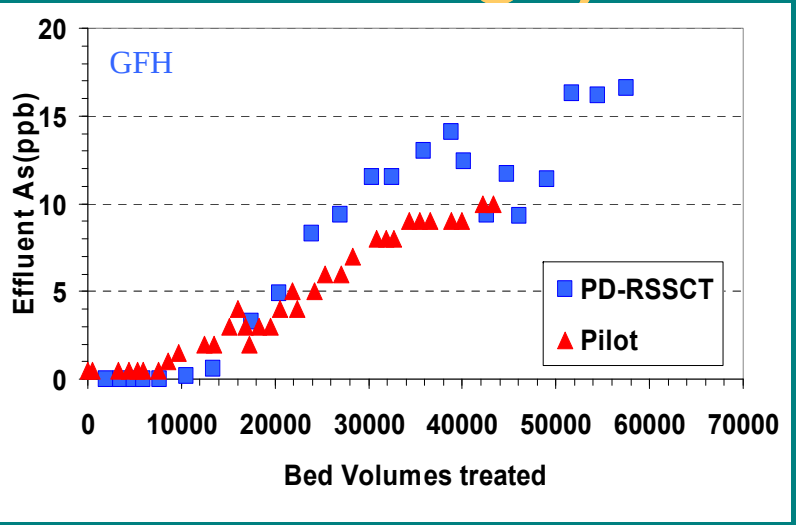
RSSCT Example Valley Vista, AZ

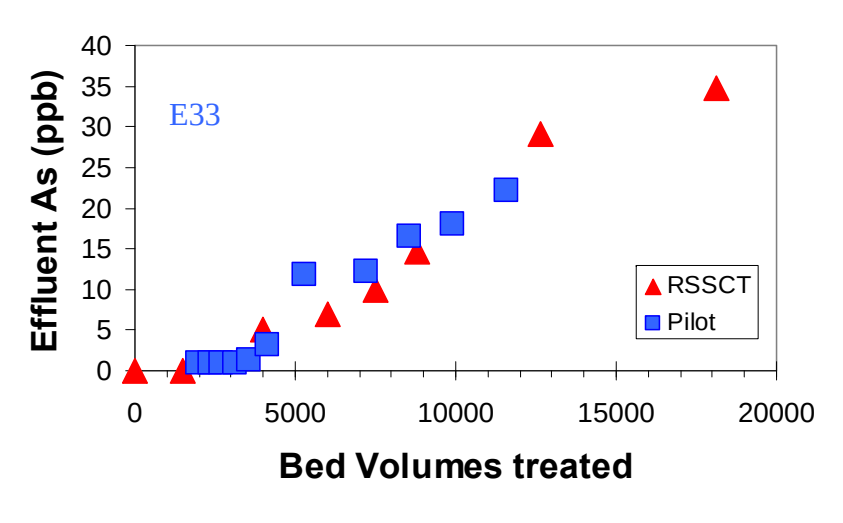
Parameters	AA-FS50	
	Full-scale	RSSCT
Media Radius (mm)	0.425	0.064
Column diameter (cm)	91.4	1.1
Column depth (cm)	183	15.9
EBCT (min)	4.5	0.68
Loading rate (gpm/ft^2)	5.5	5.0
Flowrate (mL/min)	170,100	22.3
Mass of media (g)	--	23
Duration	8 months	3 weeks

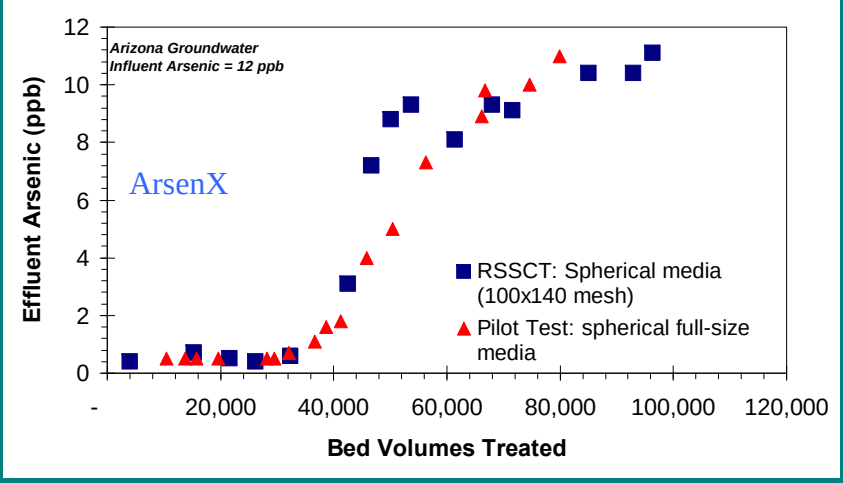
(Ref. Dr. Paul Westerhoff, Ariz. State Univ.)

RSSCT Validation (Pilot vs. RSSCT for As Breakthrough)









(Ref. Dr. Paul Westerhoff, Ariz. State Univ.)

RSSCTs – The 411

- RSSCT service providers:
  - CH2M Hill Laboratory – Corvallis, OR
    - Tim Maloney; 541-768-3124
    - Tim.maloney@ch2m.com
  - University of South Florida
    - Dr. Vinay Gupta; 813-974-0851
    - vkgupta@eng.usf.edu
  - HDR – Denver, CO /CU Boulder
    - Dr. Philip Brandhuber; 303-764-1527
    - Philip.Brandhuber@hdrinc.com
- Cost:
  - Budgetary cost $10K-$20K
  - Ship 55 gal drums ($150 each; 1-2/column)

"Tweaking" the Process - Adsorption

- Re(evaluate) water quality
- Add/Increase preoxidation time [Convert As(III) to As(V)]
  - Free chlorine 1 mg/L, 20 to 60 seconds
  - Other oxidants possible ($KMnO_4$, etc.)
- Increase empty bed contact time
  - Longer bed life at longer EBCT
- Lower pH
- Test other adsorbents - use RSSCTs
- Switch to coagulation/filtration

"Tweaking" the Process – Coagulation/Filtration

- (Re)evaluate water quality
- Increase preoxidation time [Convert As(III) to As(V)]
  - Free chlorine 1 mg/L, 20 to 60 seconds
- Add more coagulant
- Increase coagulant contact time
- Lower filtration rate
- Lower pH

Arsenic Treatment - Field Data Sheet

Washington State Department of Health
Environmental Public Health Programs
Office of Drinking Water

Arsenic Oxid\Coag Filter Plant
Field Data Sheet

System Name	I.D. Number	Date	Evaluation By

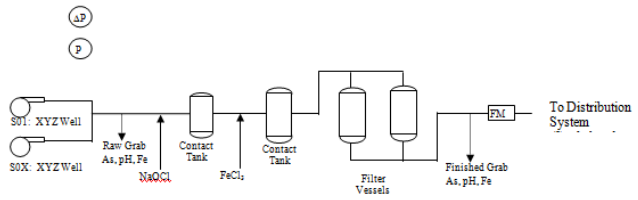
Operator(s) Present:
Others Present:

Raw Water Quality Information:

Source: _____
Production: _____ gpm
[Note: Parameters highlighted in bold text are essential to selecting and troubleshooting treatment].

Date:				
Parameter	**Value**			**Notes**
As (Total) (ug/L)				
As (III)				Speciation between As(III) and As(V) must be done in the field, with samples sent to labs. It is not necessary if adequate pre-oxidation is provided. However, it can be useful in troubleshooting treatment.
As(V)				
Ammonia (mg/L)				An indicator of strong reducing conditions. Interferes with use of Cl_2 as preoxidant.
Ca (mg/L)				High calcium reduces interference from Si lowering the coagulant dose required.
Fe (mg/L)				If there is sufficient iron, a simple iron removal process may work. Sufficient iron usually ranges from 20:1 to 100:1 depending upon pH, and competition Si, PO_4, TOC, etc.
Mn (mg/L)				Mn removal is frequently desired if it is >MCL
pH				The ability of arsenic to bind to iron is strongly affected by pH. Ideal range pH 7.0 or less. At pH >8.0, pH reduction may be beneficial.
PO_4 (mg/L)				Phosphate is chemically analogous to arsenate. Significant interference occurs at >0.040 mg/L.
Si (mg/L as SiO_2)				Silica can cause significant interference at pH>7.5 at 20 mg/L and 50 mg/L regardless of pH.
TOC (mg/L)				TOC exerts an iron demand, so at concentrations >2.0 mg/L it can significantly impact iron dose.
V (mg/L)				Vanadate is similar to arsenate, though concentrations in raw water are typically low (<0.040 mg/L).
Other:				

***Plant Schematic** – Place arrow and letter at chemical addition points and sampling points.*



Chemical Addition – Oxidant(s); Coagulant(s):

Oxidant:
None ☐ Chlorine ☐ Ozone ☐ Permanganate ☐ Other ☐: _____
Dose (mg/L): _____

Coagulant:
None ☐ Alum ☐ Ferric Cl/SO_4 ☐ Polymer ☐ Other ☐: _____
Dose (mg/L): _____

How are dosages determined; how are they controlled?

Contact Time:
Oxidation:
Number of tanks: _____ Total volume of tanks: _____ Volume of pipe: _____
Time (*between oxidant and coagulant addition*): _____ sec
(Note: Usually 20-60 seconds is needed to convert As(III) to As(V) depending upon oxidant and interfering reduced species (ammonia, Fe(II), sulfide)).

Flocculation
Number of tanks: _____ Total volume of tanks: _____ Volume of pipe: _____
Time (*between coagulant addition and filtration vessel*): _____ min
(Note: Usually, 5 minutes of contact time is recommended, though many WTPs get by with less).

Any static or mechanical mixing provided?

Filtration:

Greensand ☐ Greensand Plus ☐ Solid MnO_2 (ATEC) ☐ MnO_2 coated sand (BIRM) ☐
Other ☐: _____

Depth of filter media: _____ in *(Note: Usually 24-36 inches of filter media is required to get a decent filter run)*

Effective size: _____ mm *(Note: 20 mesh = 0.84 mm; 40 mesh = 0.42 mm)*

Number of Filter Vessels: _____ Filter Area/Vessel: _____ sq. ft Total filter area: _____ sq ft.

Filtration Rate: _____ gpm/sq ft

Backwash:
Criteria: Headloss: _____ ft or psi Time: _____ hrs or days Volume: _____ gal
Other: _____

Backwash Process:
Flowrate: _____ gpm/sf Duration: _____ min

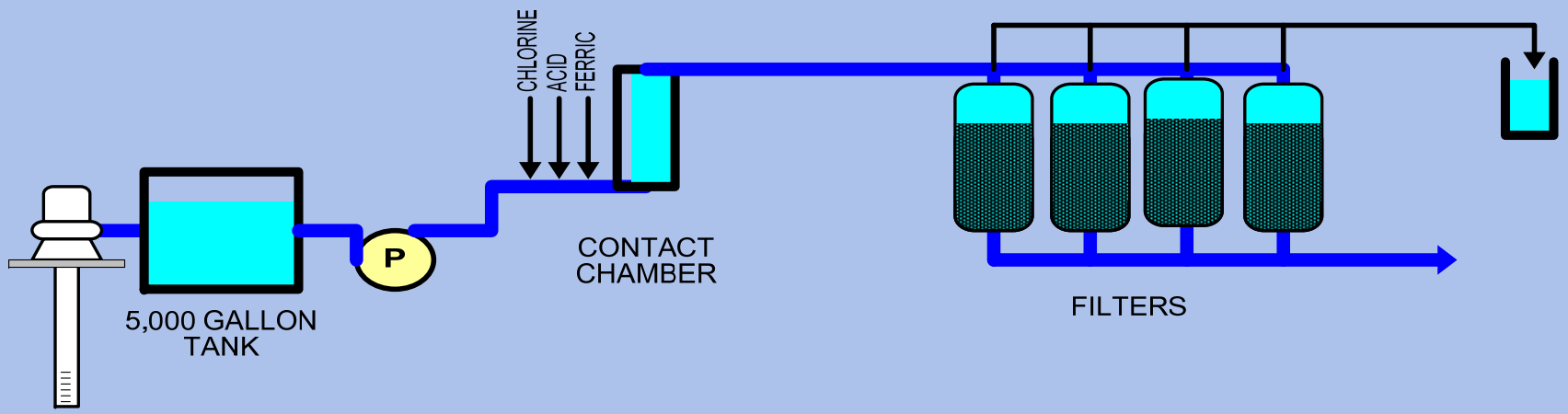
Percent Recovery: _____ %
[Note: Recovery = (Production Vol. - Backwash Vol.)/Production Vol. x 100% – Usually around 92 to 98%]

Disposal: Infiltration Pond ☐ Other ☐: _____

What is the basis for adjustment backwash? Any disposal issues?

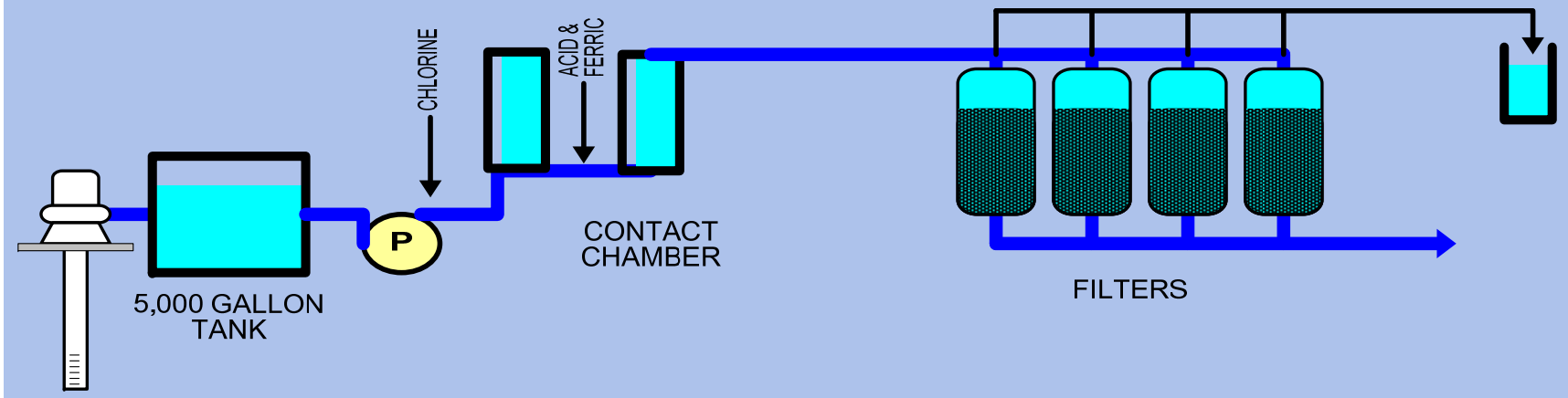
Process Adjustment – Increase Oxidation Time

FIGURE 1: CHLORINE/ACID/FERRIC/CONTACT TANK



Moving the Chlorine injection Location and adding Contact time optimized removal

FIGURE 2: CHLORINE/CONTACT TANK/ACID/FERRIC/CONTACT TANK



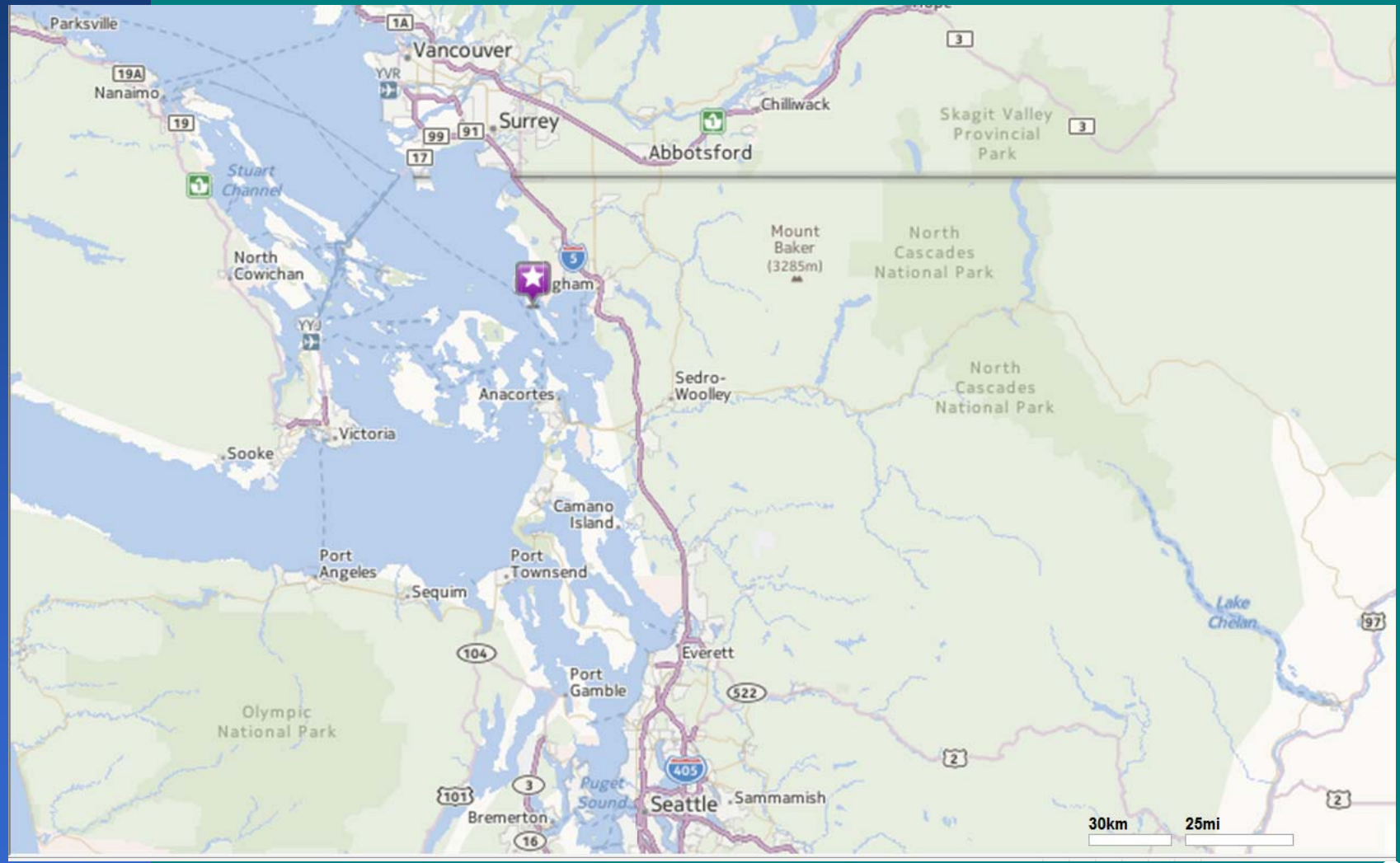
Effect of Increased Oxidation Time

TMWA, Sparks, NV

	Before	After
Preoxidation	Chlorine added with Ferric	Pre-Chlorination 30 Seconds
Raw Water Arsenic, ug/L	158	158
Finished Water Arsenic, ug/L	9.02	1.24
Percent Removal	94.3%	99.2%
Number of Samples	23	19
Raw Water pH	7.7	7.7
Ferric Chloride Dose, mg/L	26	21
Treated Water pH	6.7	6.72
Filter Loading Rate, gpm/sq ft	6.0	6.0
Media Type	Manganese Dioxide	Manganese Dioxide
Media Depth, In	42"	42"

Courtesy CH2M HILL, 2010

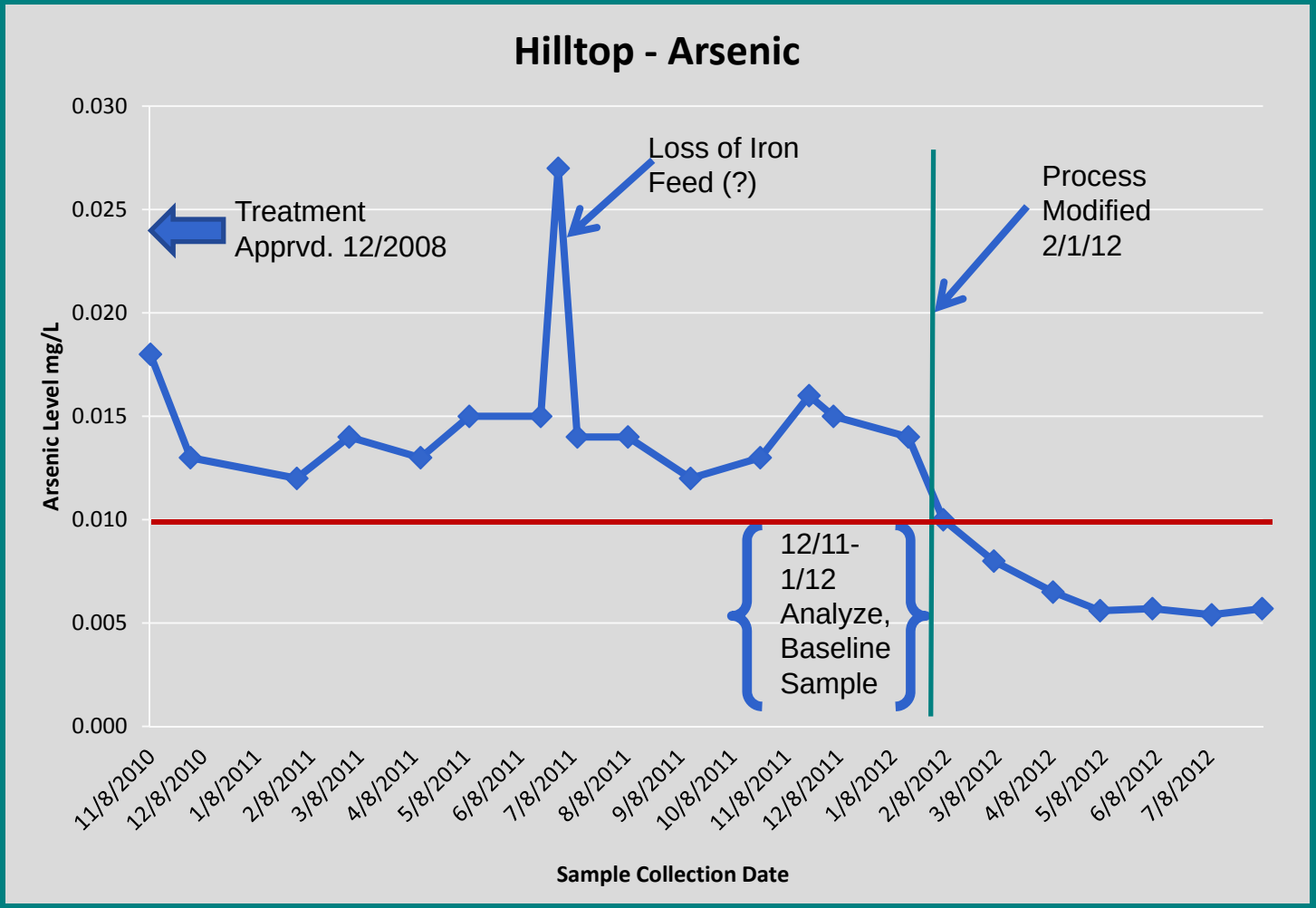
Case Study – Lummi Island, WA



Hilltop Water Owners Assoc.

- 62 Connections
- Res. Pop. – 72; Total Pop. – 135
- Raw Water Arsenic – 22 to 25 ppb
- Brief History
  - 2004 to 2008 - Try adsorption, other treatment; Make other improvements
  - 12/2008 - Full Scale Pilot of Ox/Coag/Filt
  - 11/2011 - Sanitary Survey

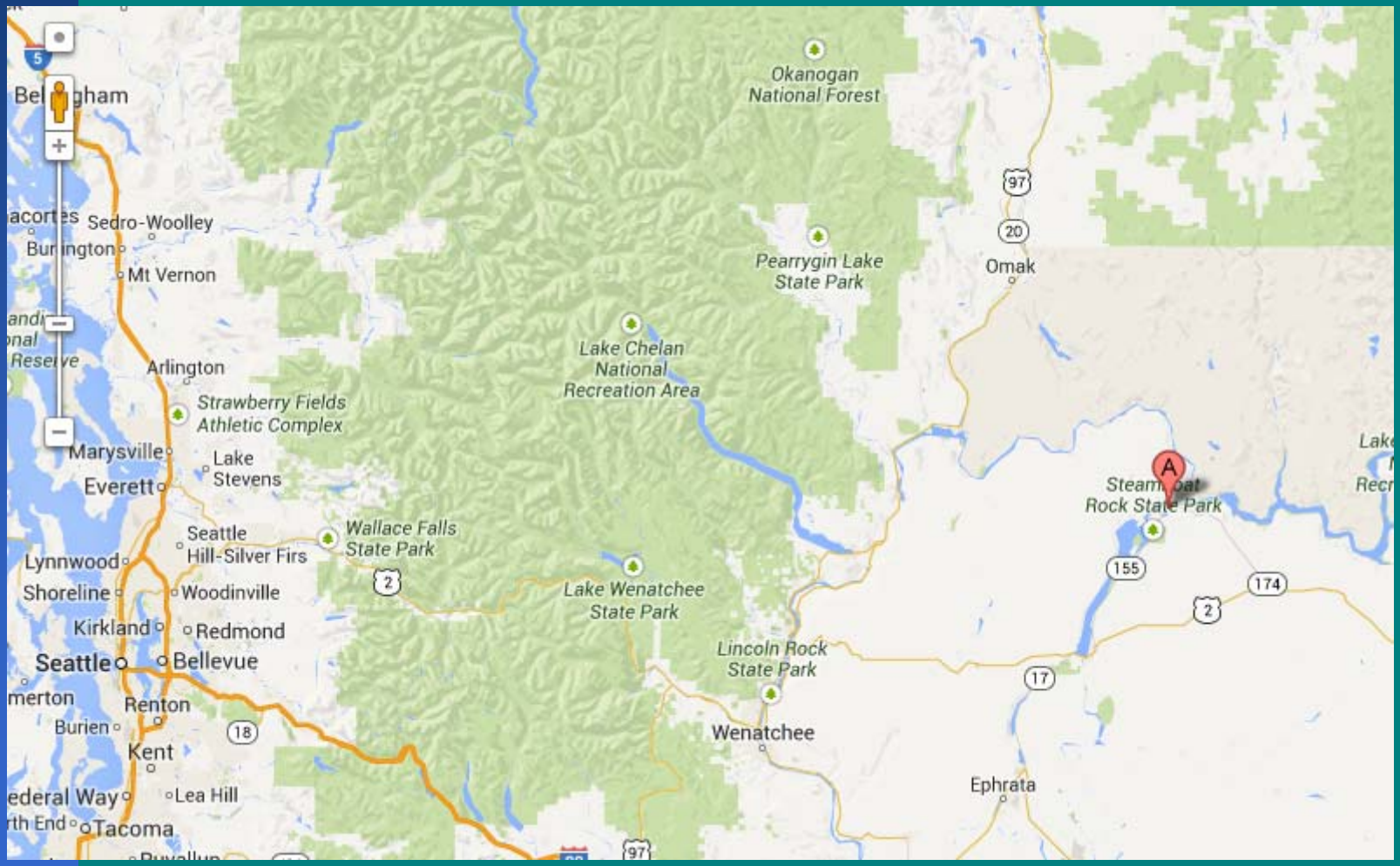
Hilltop – Effect of More Iron



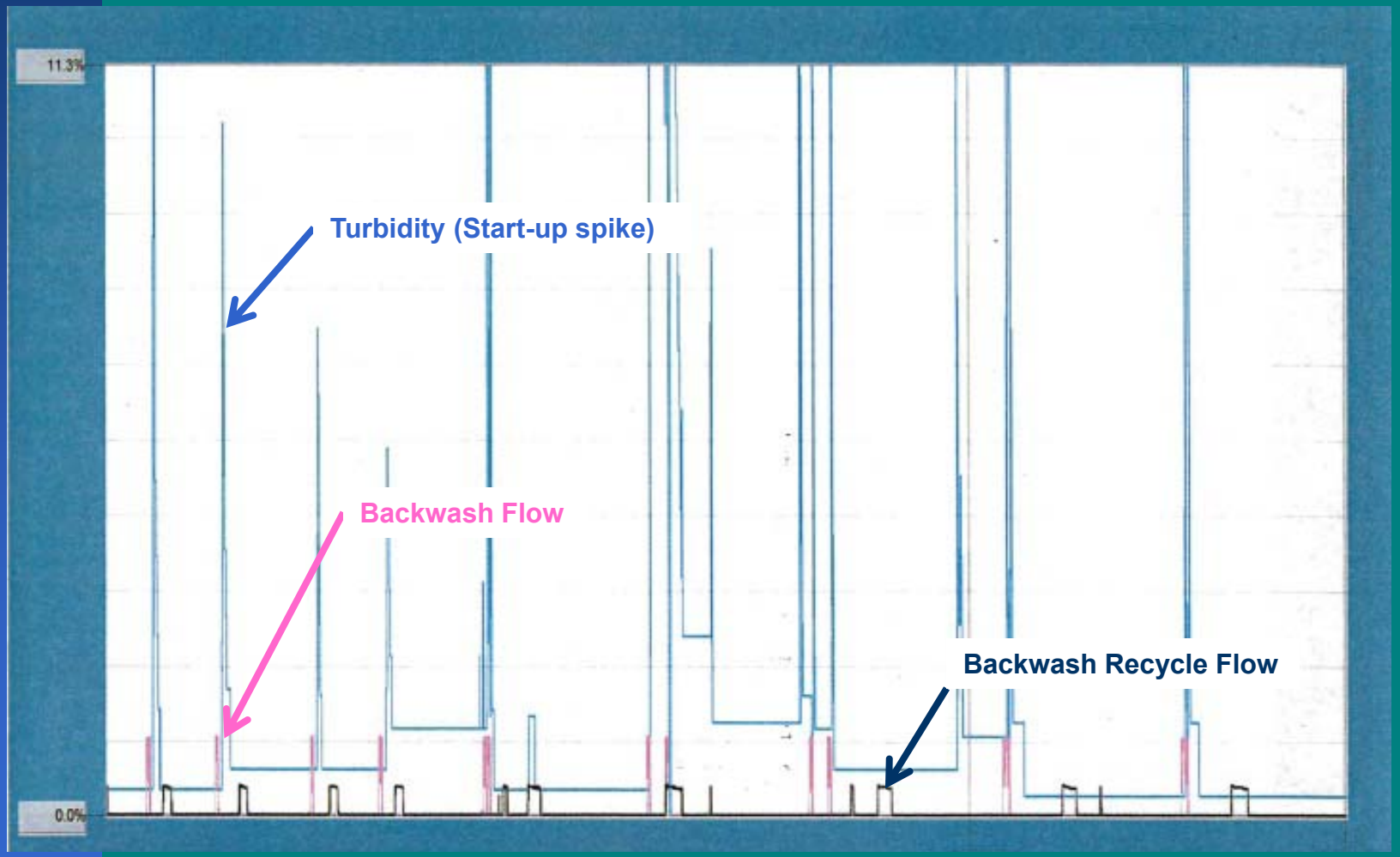
Hilltop - Lessons

- Multiple possible issues
- A curious operator can really help the plant optimize
- Ultimately, Hilltop required only minor operational adjustment
- Success involved cooperation – PWS Owner, Operator, Department of Health Staff

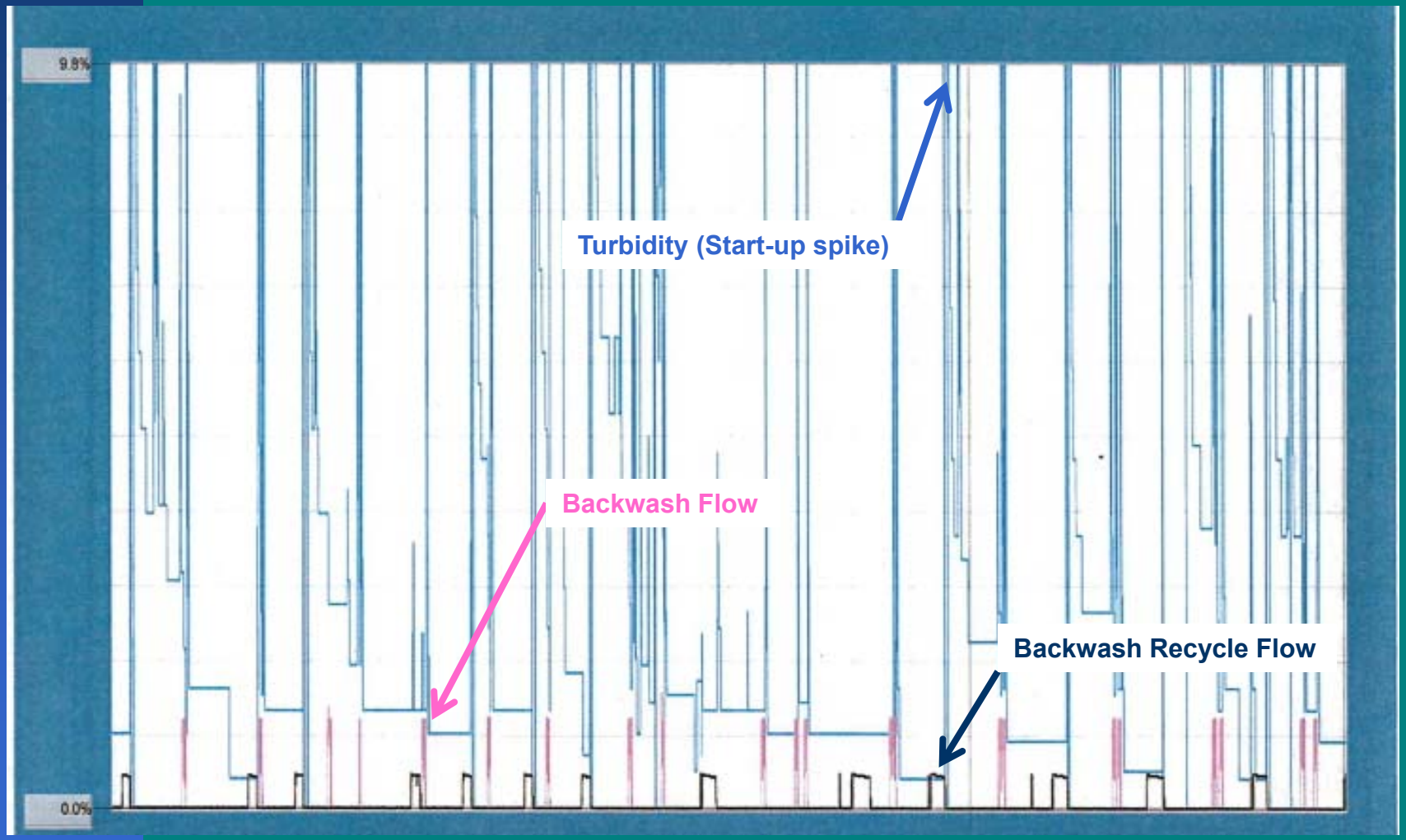
Case Study – Electric City, WA



Electric City – Turbidity and Backwash (Normal)



Electric City – Turbidity and Backwash (Filter Overload)



Monitoring the Process is Key

- Any treatment process, if not adequately designed, operated and maintained, will fail.
  - Arsenic – In WA, one sample/month required
  - Iron – Good surrogate for arsenic removal (ox/coag/filt)
  - Turbidimeters – Provide continuous data (very valuable if recycle backwash)

Summary

- It is possible to meet optimization goals
- Consider plan-do-check-act approach
  1. Collect WQ data – pH, As, Fe, Mn, Si, P, V, TOC
  2. Pilot test – RSSCTs; C/F- Small scale pilot
  3. Monitor the process – Turbidity, Fe, As
  4. Minor “tweaks” - Can improve results

Acknowledgements

- Stephen Baker, Russell Mau, Erika Lindsey, Steve Hulsman - WSDOH
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- Lee Odell – CH2M Hill
- Paul Westerhoff – Arizona State Univ.

Questions / Comments

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