

Applications of a novel corrosion control treatment from bench top to full scale pilot study

The use of magnesium sulfate to mitigate lead leaching

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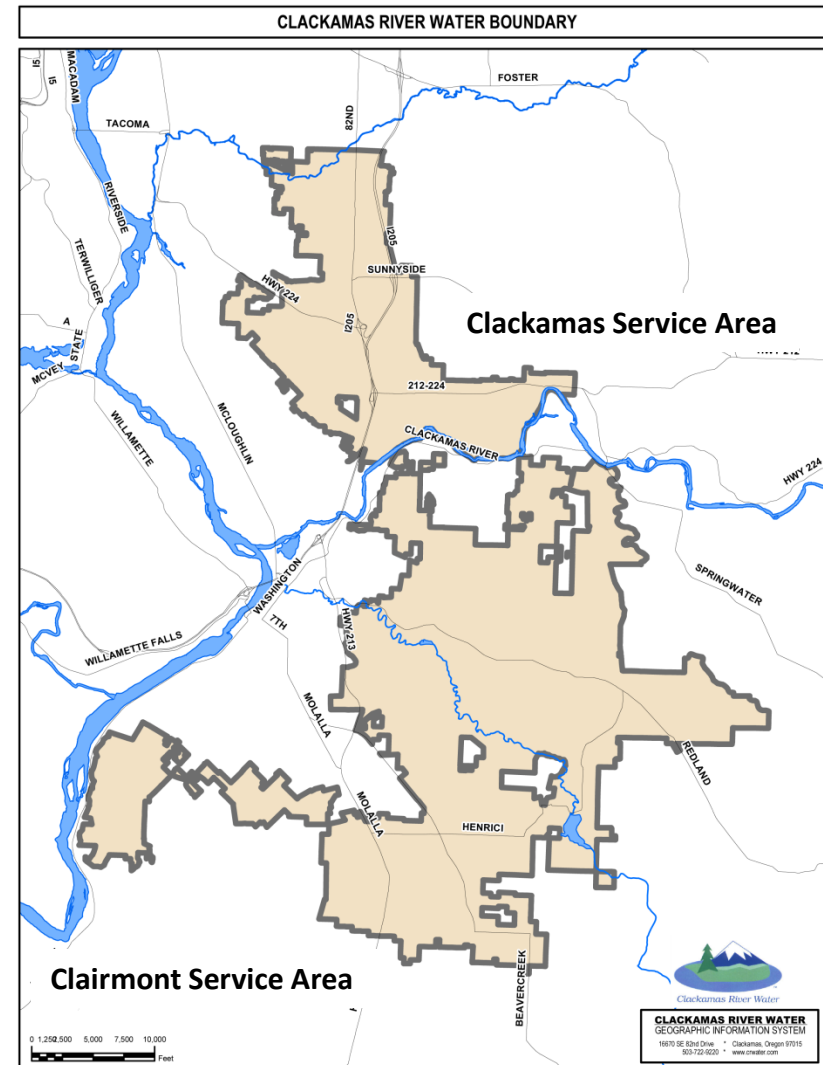
Water Quality Manager
Clackamas River Water

Outline

- Introduction
- Bench Testing
 - Objectives
 - Results
 - Bench Study Conclusions
- Full Scale Pilot Study- CRW Clairmont System
 - Objectives
 - Design/Set-Up
 - Results
 - Pilot Study Conclusions
- Applying Knowledge to CRW Clackamas System
- Conclusions, Implications, and Impact

About Clackamas River Water (CRW)

- Regional water service provider in the Portland metropolitan area
- Sources from the Clackamas River
- Serves a population of approximately 80,000
- Two service areas:
 - The Clackamas service area is serviced by CRW's water treatment plant
 - In the Claimont service area water must be purchased from a neighboring water provider



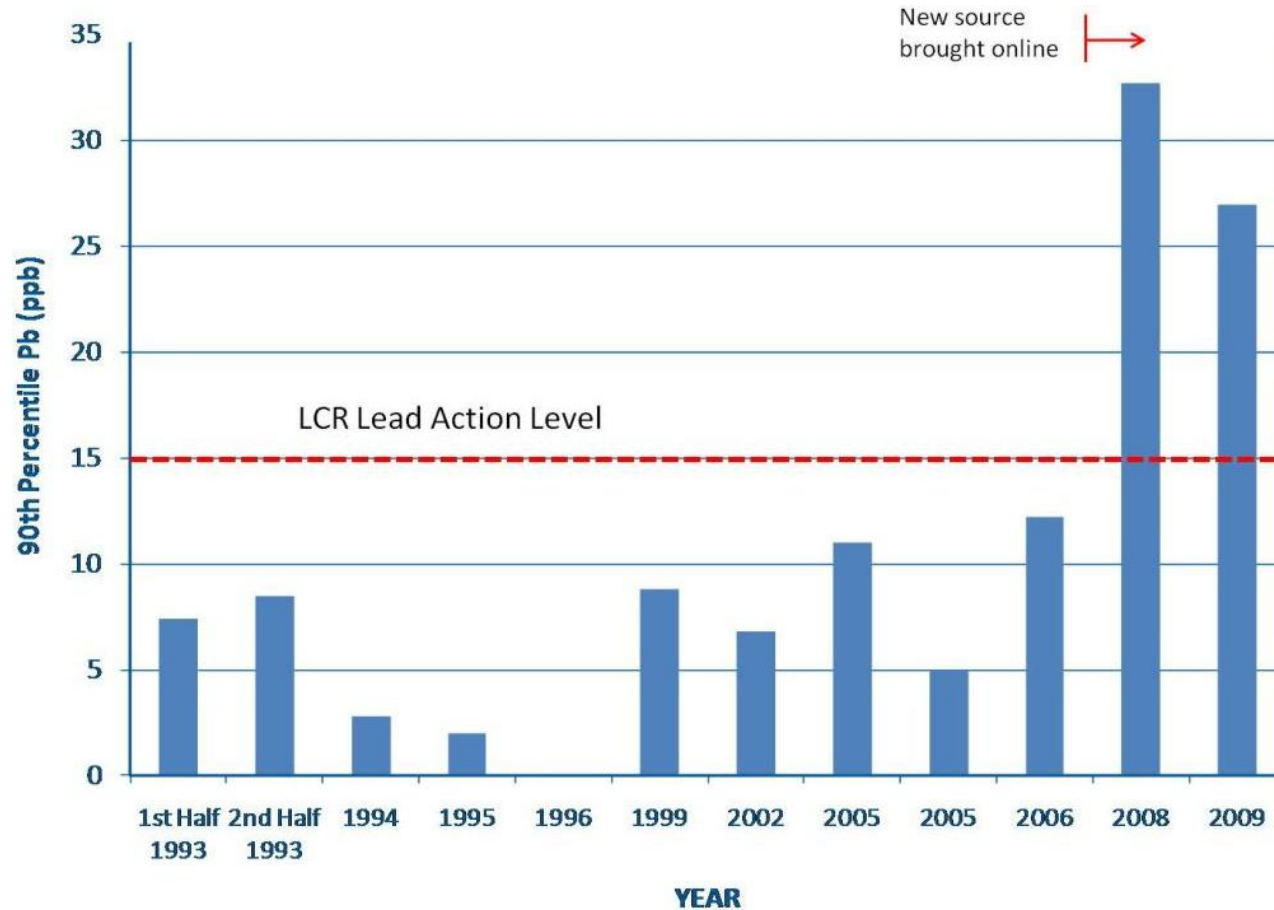
Alternative Source for Clairmont

- Columbia River Basalt Group (CRBG) Aquifer
 - Sheet flow basalts approximately 100ft thick
 - Majority of groundwater located in the interflows between individual basalt flows
 - Faults potentially act as pathways allowing mixing of deeper marine sediment groundwater
 - In 2007 CRW Well #1 was brought online sourcing from the CRBG aquifer
 - Serving a 30% blend of groundwater to 70% surface water for aesthetic purposes.



Columbia River Basalt Group Aquifer

Lead Release Increases in Clairmont Homes Concurrent with New Source



A Review of Water Quality

Average Water Quality for CRW Source Waters			
	Surface Water	CRW Well #1	Blend
pH	7.6	7.9	8.0
Alkalinity	21	125	45
Hardness	16	143	40
Chloride	8.4	187	51
Sulfate	4.4	0.3	1.7
Total Dissolved Solids	64	530	220
Chloride to Sulfate Mass Ratio (CSMR)	1.9	744	30

$$\frac{\frac{mg}{L} Cl^{-}}{\frac{mg}{L} SO_4^{2-}} = CSMR$$

A CSMR <0.6 is suggested to protect against galvanic corrosion of lead solder

At this point...

- Out of compliance with the Lead & Copper Rule
- pH adjustment, orthophosphate addition, and alkalinity additions produce lackluster results in mitigation efforts



Bench Testing

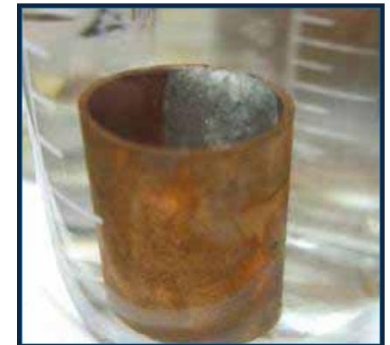
- Determine the maximum percentage of groundwater which can be blended with surface water without adverse impact on lead release
- Determine which, if any, corrosion control treatments allow for higher percentages of groundwater
 - pH
 - alkalinity
 - orthophosphate
 - sulfate addition
- Determine if lowering the CSMR can reduce lead release

Study Design

- Water
 - Treated surface water collected from sampling station
 - Groundwater collected from CRW Well #1 after chlorination
- Coupons
 - Brass
 - Lead/copper galvanic couple
- Chemicals
 - Sulfate addition: MgSO_4
 - pH adjustment: NaOH
 - Alkalinity adjustment: NaHCO_3
 - Orthophosphate addition: H_3PO_4
 - DI Water
- Coupons immersed in 50ml of test water
- Water changed 3x's a week
 - Stagnant period of 48 to 72 hours
- Triplicate samples were composited and analyzed for lead at the end of weeks 1, 3, 5, 8, 12 and 15



Brass coupon fixed with epoxy to glass bottom



Lead solder galvanically coupled to a copper pipe section

Testing Conditions

	No Treatment	pH	Alk (mg/L CaCO ₃)		PO ₄ (mg/L as P)	SO ₄ (mg/l to target CSMR)	
			20	40		5	3
Surface Water (Control) (pH=8.3; alk=20; CSMR 3)	Brass/Solder						Solder (CSMR @ 0.5)
Groundwater (pH=7.89; alk=105; CSMR 400)	Brass/Solder	Solder	Solder	Solder	Solder	Solder	Solder
10% Groundwater Blend (pH=8.1; alk=30; CSMR 10)	Brass/Solder						
20% Groundwater Blend (pH= 8.0; alk= 40; CSMR 20)	Brass/Solder	Solder	Solder	Solder	Solder	Solder	Solder
30% Groundwater Blend (pH= 8.0; alk= 45; CSMR 30)	Brass/Solder	Solder	Solder	Solder	Solder	Solder	Solder
50% Groundwater Blend (pH= 7.9; alk= 65; CSMR 50)	Brass/Solder	Solder	Solder	Solder	Solder	Solder	Solder



Testing jars and composite samples



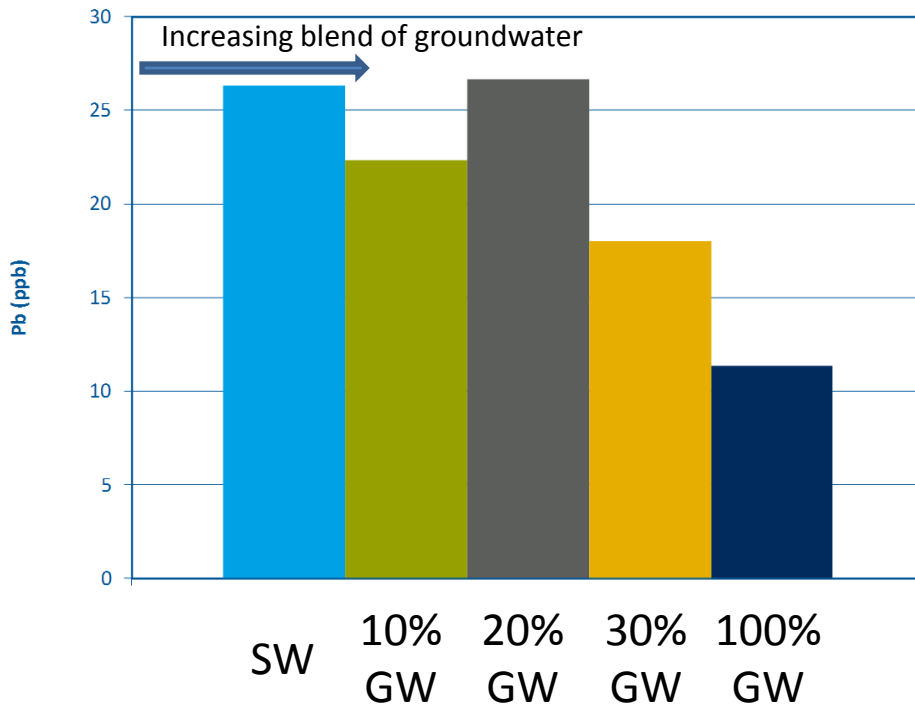
Testing jars under various conditions



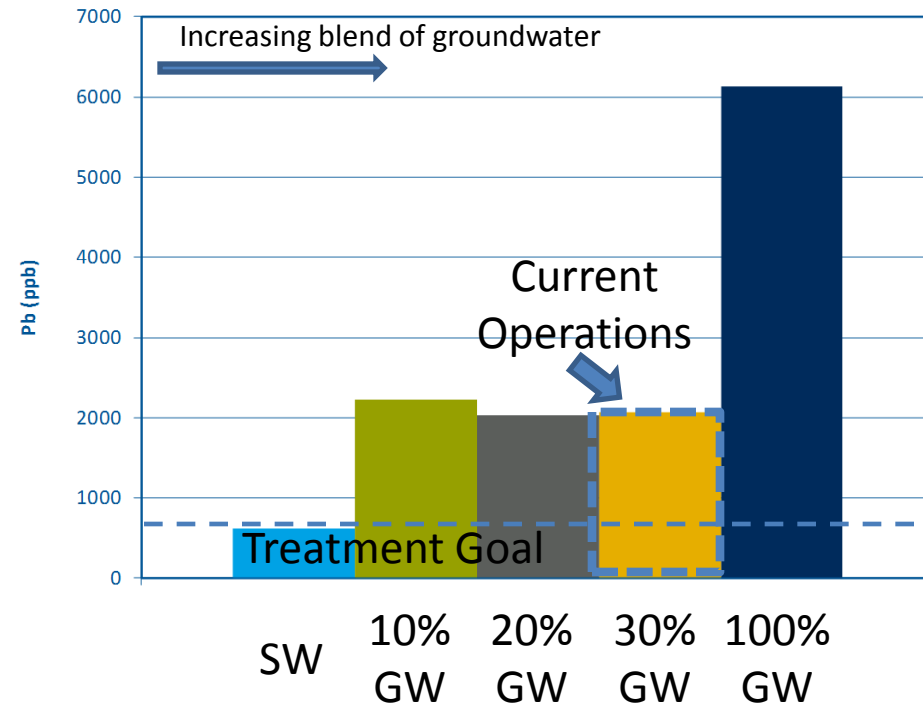
Impact of Water Blends on Lead Release

At the end of 15 weeks

Brass Coupons



Solder Coupons

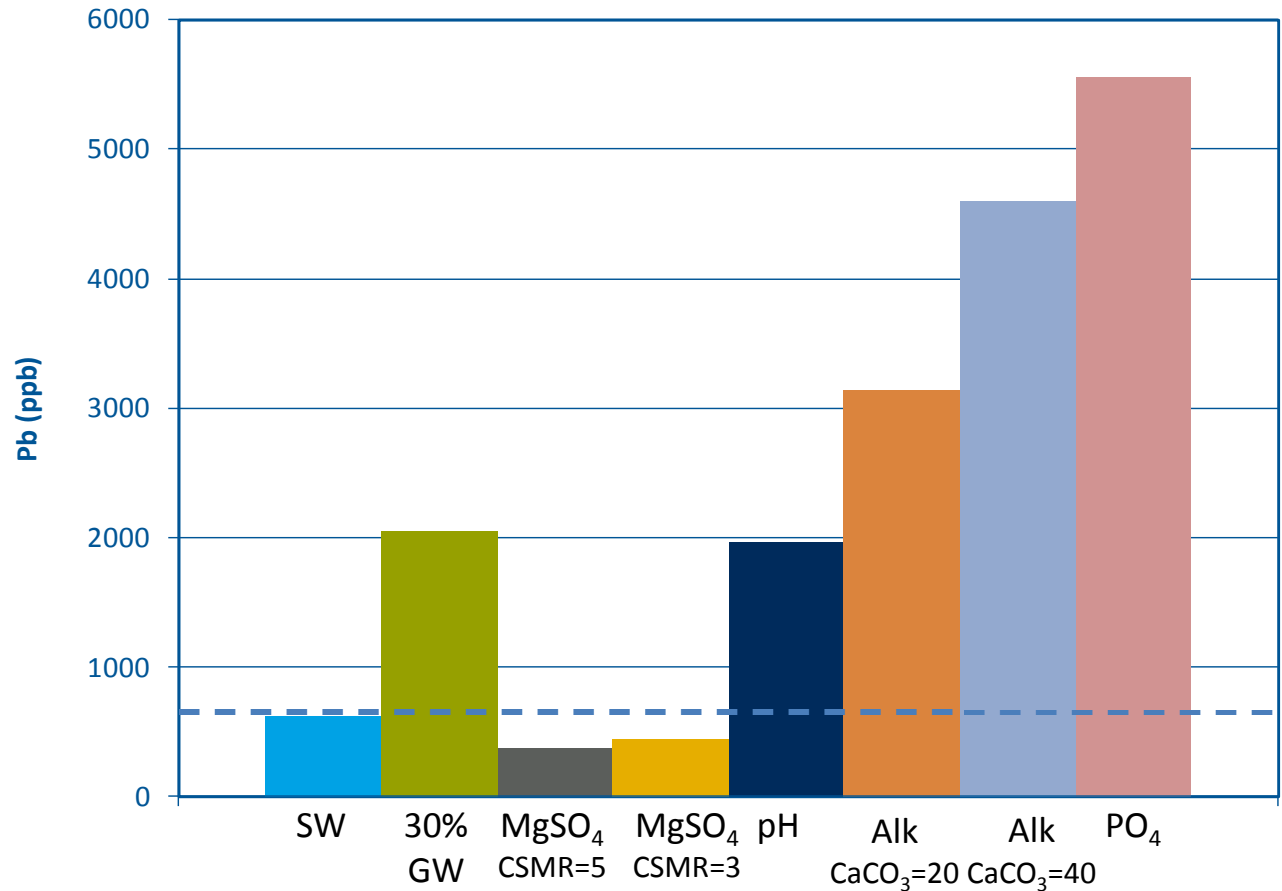


- *Brass*: Lead release **decreased** as the percentage of groundwater increased
- *Solder*: Lead release **increased** as the percentage of groundwater increased
 - A 20 to 30% is the optimal range for our groundwater blend

Effect of Treatment on Lead Release

Pooled results for 20% and 30% blends

Only the addition of sulfate was able to bring the lead release down to the level of the surface water control.



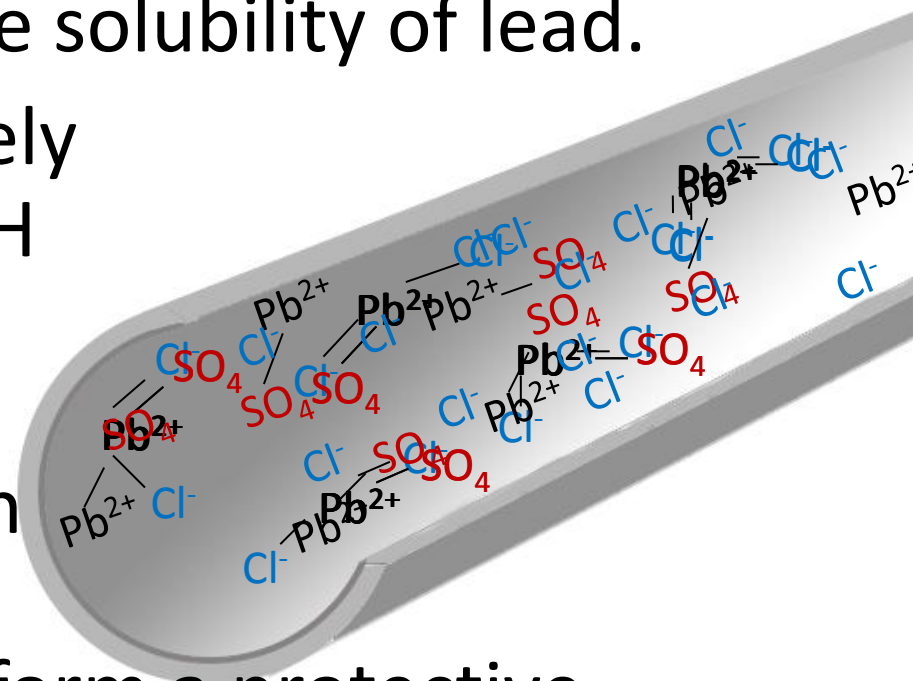
Bench Study Conclusions

- Increased lead release in CRW system is coming from solder, not brass.
- No amount of groundwater can be blended into the surface water supply without treatment.
- MgSO_4 was the only treatment tested able to reduce lead release in the 30% blend to the same level as surface water.
- Alkalinity, orthophosphate, and pH were not effective at mitigating lead release in the blended groundwater.



Solubility as a Potential Mechanism

- Pb^{2+} forms soluble complexes with Cl^- that can significantly increase the solubility of lead.
- PbSO_4 solids are relatively insoluble even at low pH
- By adding MgSO_4 we are adding SO_4 to the System to compete with Cl^- for Pb^{2+}
- Over time the SO_4 may form a protective coating blocking Cl^- from forming soluble PbCl_2 .



Full Scale MgSO_4 Feed System Pilot

- Determine the effect of adding 13 mg/L of MgSO_4 for controlling lead release in the Clairmont distribution system.
- Reduce the 90th percentile lead concentration to below the EPA lead action level of 15 ppb.

Maintain 30% blend of GW to SW

Maintain a CSMR of finished water at 5 or lower

Sample Collection

- Sample pool of fifteen homes that exceeded the lead action level in either of previous two compliance sampling periods (Aug 2008 and Aug 2009).
 - Sampling pool was expanded between later rounds to include more homes receiving surface water only.
- Sampling conducted over five rounds from January 2012 through September 2012.
 - Sulfate feed turned on in March 2012.

	Lead Sampling Round				
	Jan 2012 1	May 2012 2	June 2012 3	Aug 2012 4	Sept 2012 5
Total Homes	13	10	12	20	21
SW Homes	2	2	2	14	12
Blend Homes	11	8	10	6	9

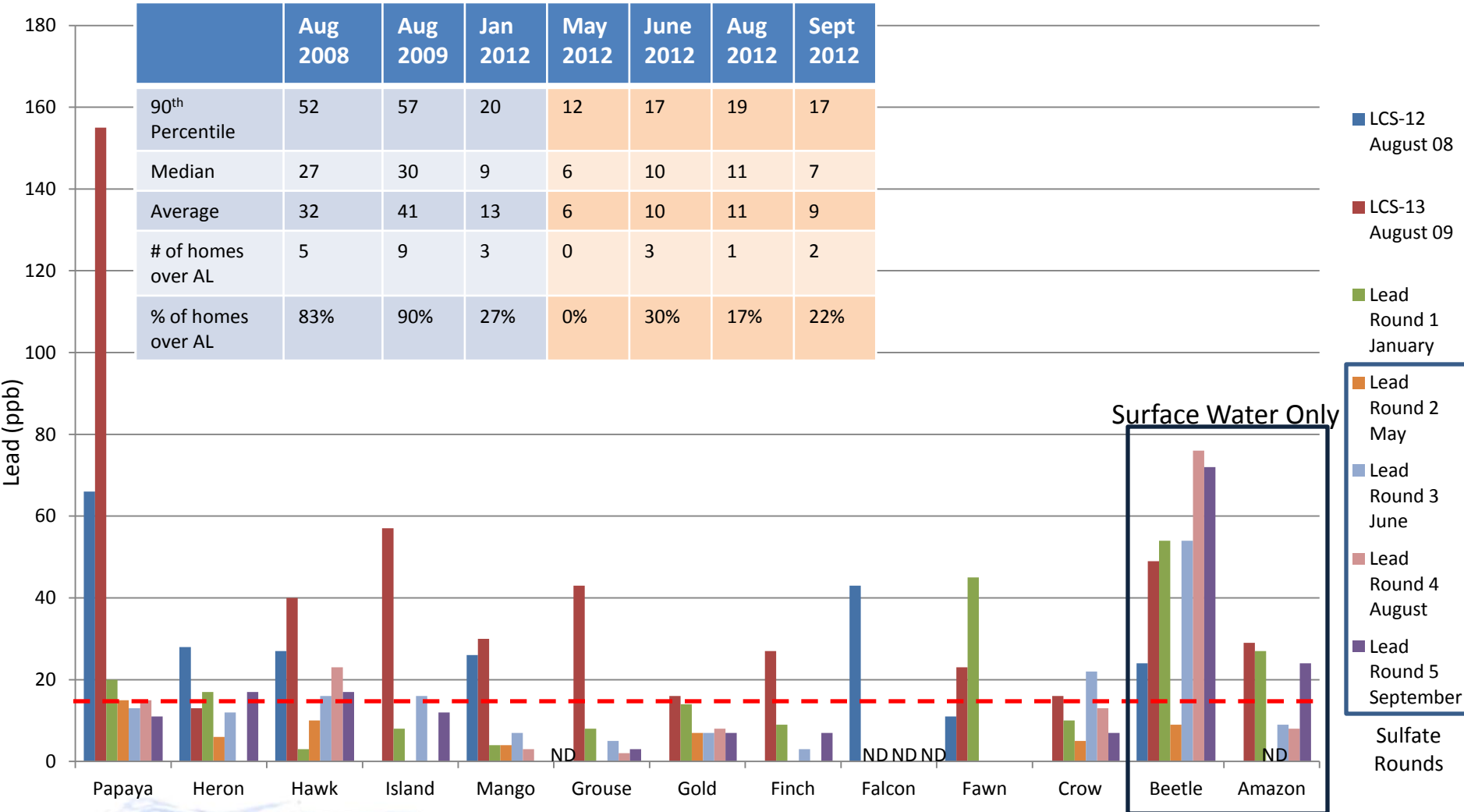
● Pre-Sulfate ● ————— Post-Sulfate ————— ●

Water Quality Analysis

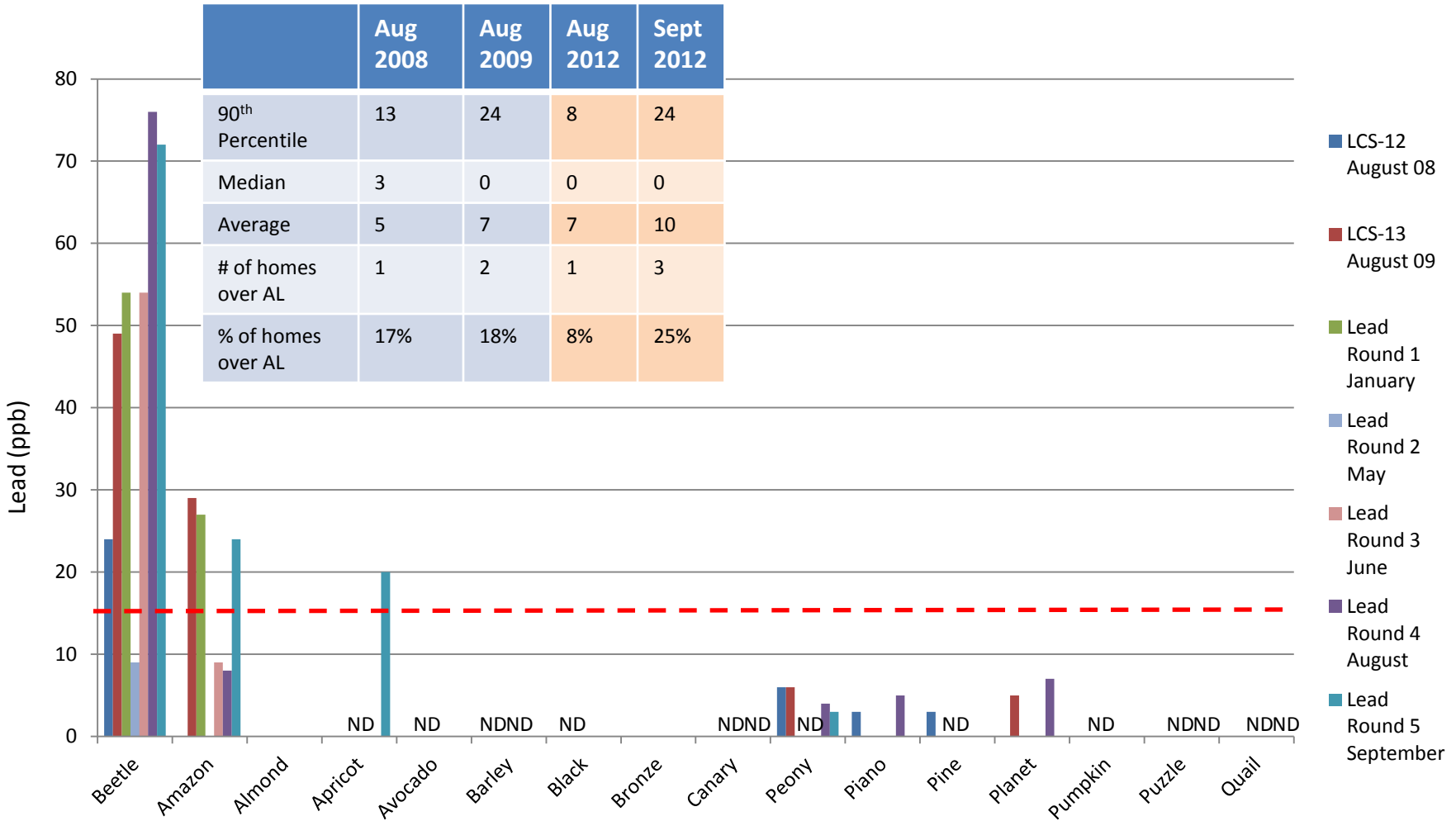
- Monitored by CRW daily at point of entry (POE)
 - pH
 - Water Temperature
 - Sulfate
- Monitored weekly at POE and surface water only POE, sent to analytical lab
 - Chloride
 - Sulfate

} CMSR calculations

Results



SW Only Results



Full Compliance Round Results

- 65 home compliance round conducted in September and October 2012

	# Homes	# Homes Over Action Level	% Over Action Level	Average	90 th Percentile
Overall	65	7	11%	6	15
Blended	51	4	8%	5	12
SW Only	14	3*	21%	9	23

*For compliance purposes, as per State of Oregon guidelines, one sample was disqualified due to an excessive hold time of several days as opposed to the recommended 8 hours.

- The CRW Clairmont system is currently in compliance with the Lead and Copper Rule

Room for Improvement

- 90 percentile of 15 ppb could be improved
- Variables identified that CRW needs to adjust

We can
adjust for—
this →

Maintaining 30% blend of GW to SW

- Blend percentage sometimes peaked at nearly 50% during periods of high demand (July through October)

We can
adapt to
this →

Variations in GW chloride

- Chloride concentration increased approximately 50% from July through October

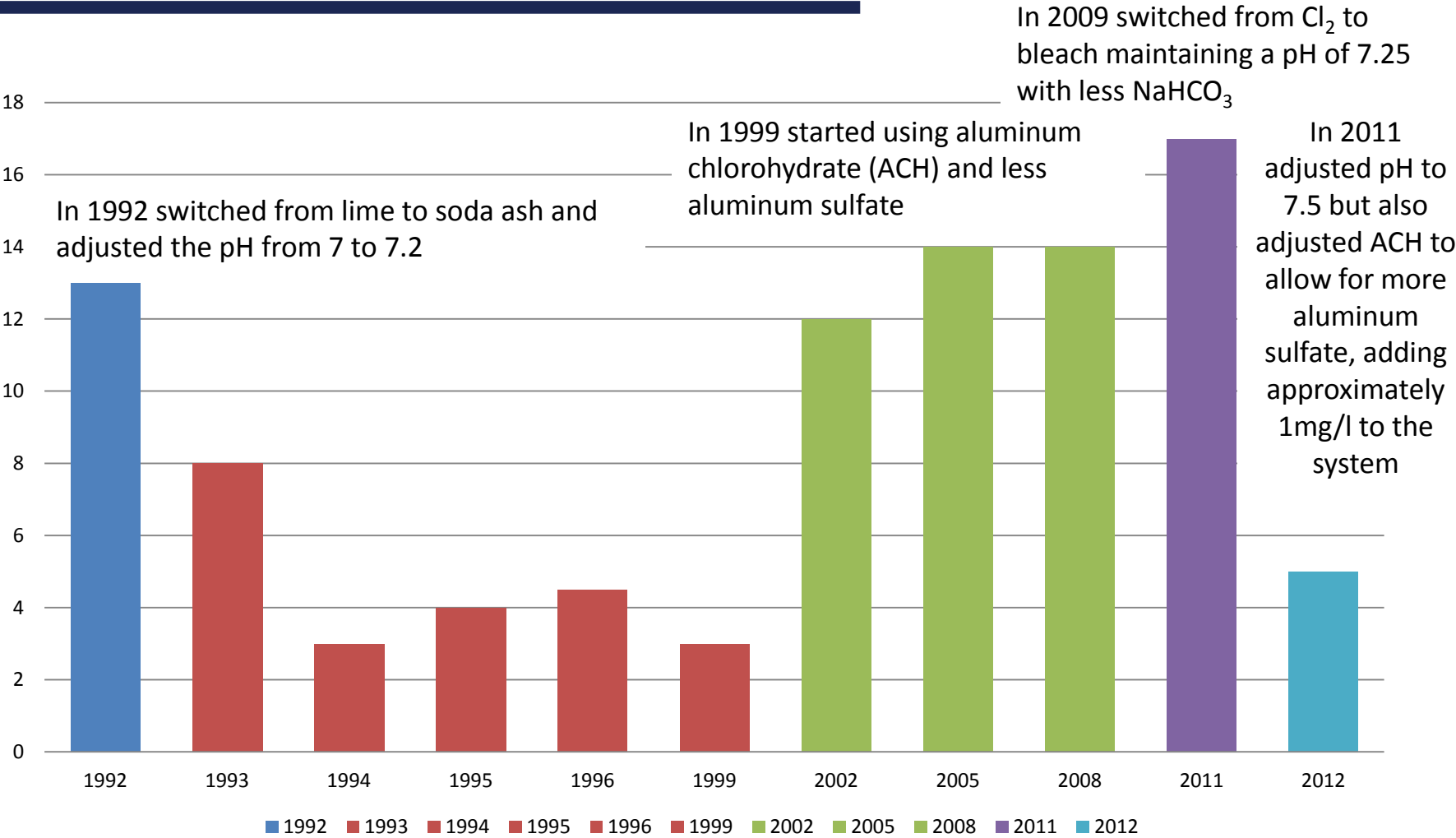
- Need to maintain CSMR ≤ 5 more consistently



Pilot Study Conclusions

- Maximum lead concentration in the distribution system reduced from 155 ppb in 2009 to 17 ppb in 2012
- Overall the results suggest a downward trend
- CRW will adjust processes to better maintain blend percentages and CSMR
- Continue with temporary feed system for 1 more year of sampling

Extrapolation to CRW Clackamas System



Conclusions

- Addition of MgSO_4 for the maintenance of a distribution CSMR of 5 or below may be a viable corrosion control technique for corrosion control of lead
- Overall results are promising and suggest a downward trend in lead release from home plumbing components
- A thorough analysis of water quality properties before choosing a corrosion control method

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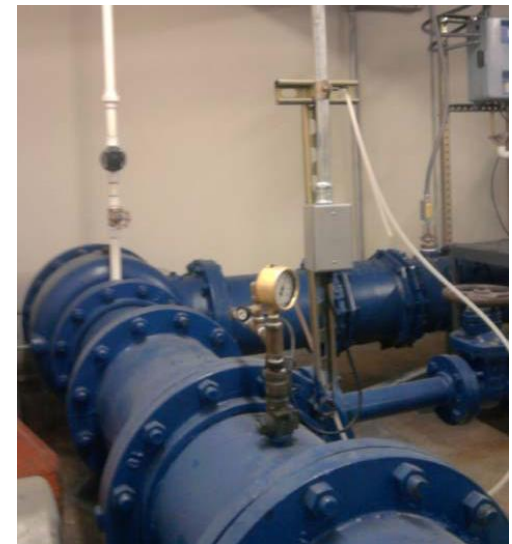
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MgSO₄ Feed System Set up

- 2- 400 gallon open top HDPE tanks with flat bottoms were installed.
- 1 bag of MgSO₄ salt added per inch of water height in the tank to make the feed solution.
- Mixer installed between the two tanks to rotate and mix the contents of either tank.
- The sulfate injection point installed on the 12-inch line immediately following the chlorine injection point.



Well Background

- Drilled in 1973 to a depth of 560ft bgs
- Clay and sand overlie basalt to 299ft bgs
- Casing installed to 302ft bgs so that the well was only open to the CRBG
- Production rates up to 2 cfs
- Water quality issues observed
 - Brackish water
 - Backfilled to a depth of 450ft bgs in 2001

