Blending of Desalinated and Surface Water into a Distribution System: Effects on Lead and Copper Corrosion

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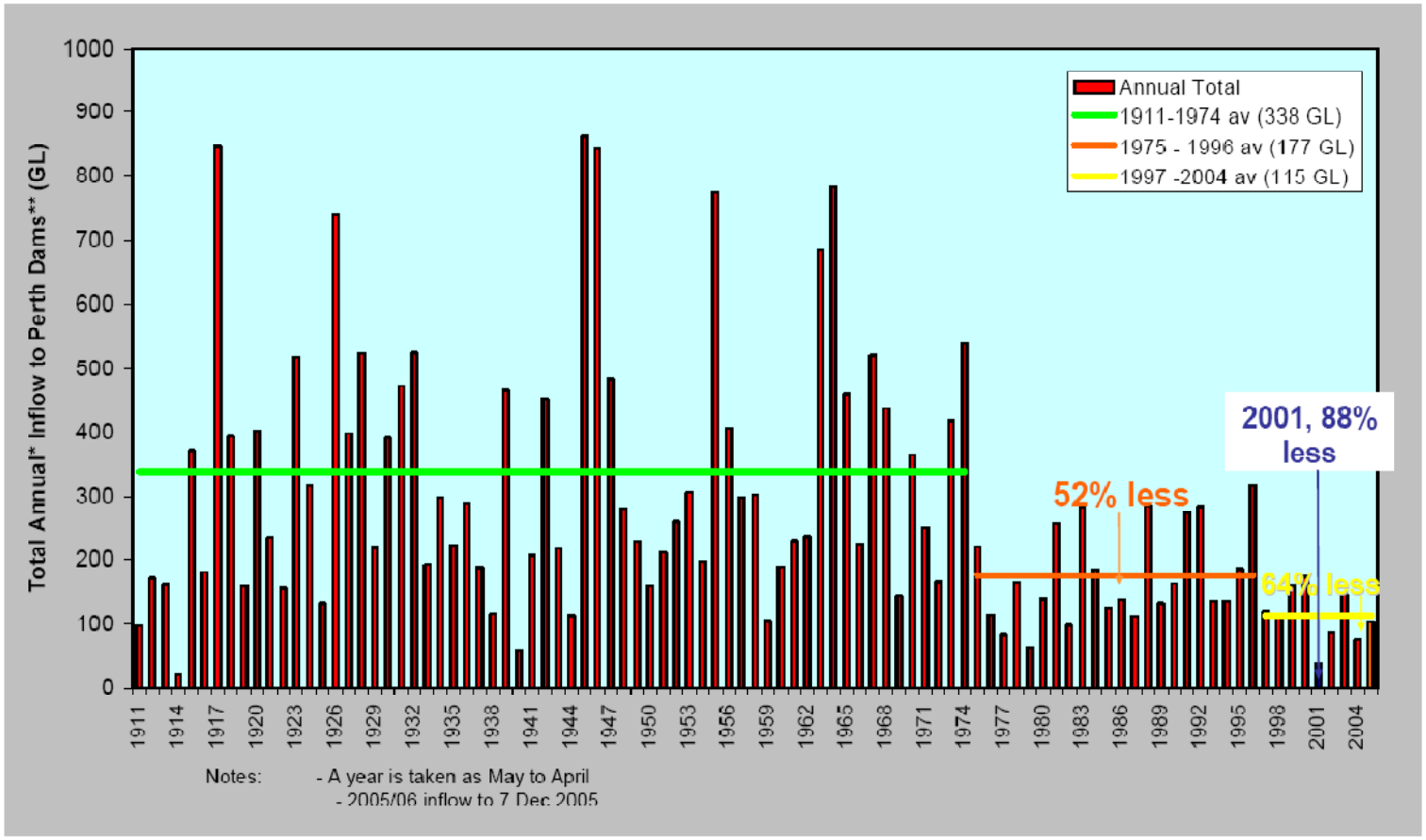
Outline

- Desalination and its local/global role
- Some aspects of desalinated water chemistry
- Santa Cruz seawater reverse osmosis desalination plant
- Concerns concerning water quality and distribution system stability
- Experimental data
- Conclusions

Benefits of seawater desalination

- Unlimited supply
- Coastal location of major population centers
- In come cases, no other currently existing and/or reliable drinking water supplies
  - Middle East
  - West and South Australia droughts

Changes of dam inflows in Western Australia



Water Restrictions imposed

Selected SWRO plants

Plant	City	Capacity (mld)	Commissioning	Comments
Point Paterson SWRO	Port Augusta, SA	15	to be approved	Brine will be used for salt production
Gold Coast SWRO	Gold Coast, QSL	55 (125)	Late 2009	Construction/maintenance problems
Binningup SWRO	Perth, WA	140 (280)	Late 2011	
Kwinana SWRO	Perth, WA	144 (250)	completed 2006	Shutdowns due to hypoxia in Cockburn sound
Kurnell SWRO	Sydney, NSW	250 (500)	Summer 2009	
Port Stanvac SWRO	Adelaide, SA	270	Late 2012	Output doubled during construction
Wonthaggi SWRO	Melbourne, Vic.	410	2011-2012	Subject to litigation
Santa Cruz SWRO	***Santa Cruz, CA***	***9***	***2015***	***Pilot plant operations completed***

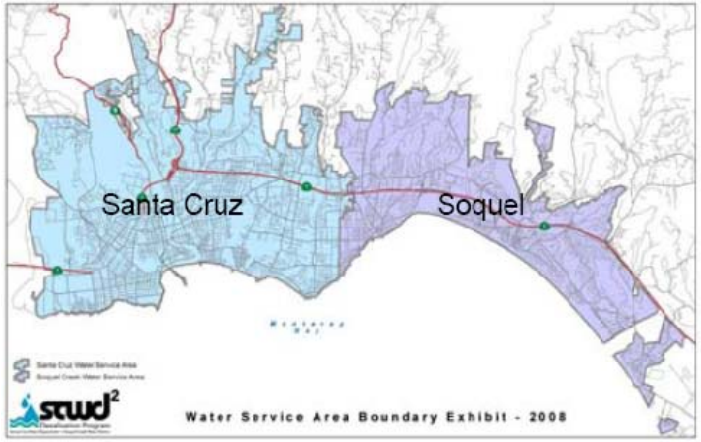
Desalination challenges: drinking water quality

- High concentration of bromide
  - Increased production of brominated disinfection by-products (DBPs)
  - More toxic Br-containing trihalomethanes and haloacetic acids
  - Remove increases desalination costs
- Higher concentrations of iodide
  - Iodinated DBPs?? Effects unknown??
- High concentration of boron
  - May be toxic, difficult to remove
- High concentrations of chloride
  - Effects of corrosion??
- Low concentration of natural organic matter
  - Effects on corrosion??

Santa Cruz SWRO plant

- City of Santa Cruz gets its drinking water supply from surface water and groundwater sources
  - Surface water supply from the North Coast Sources, San Lorenzo River, and Loch Lomond Reservoir
  - Surface water treated at Graham Hill Water Treatment Plant
  - Groundwater supply from Live Oak Wells

- Soquel Creek Water District relies primarily on groundwater for its drinking water supply
  - Aromas Red Sands Aquifer and Purisima Aquifer



Water Needs

- During non-drought conditions water use in the area is 15% greater than that replenished on an annual basis
  - Increases to 40% during water shortages
- Increasing population in the area
- Climate change may decrease precipitation
- Shortage of water during drought conditions
- Aromas Red Sands and Purisima Aquifers are being depleted
  - Decreasing water availability
  - Possible saltwater intrusion into aquifers

Site Description

- Pilot plant testing began in Mach 2008 and ended in April 2009
- Full-scale plant design from 2009 to 2012
- Full-scale plant construction from 2012 to 2015
- Proposed to use old wastewater plant outlet pipe for influent
- Use current wastewater plant outlet pipe for concentrate discharge

Water Quality: Seawater

- Three Periods every year
- Normal condition (March-August)
  - Least challenging water quality
- Red-tide Season (September-December)
  - High TOC
  - Possibly high algal toxins
- Storm Season (November to March)
  - High turbidity
- Related issues (RO fouling/pretreatment)

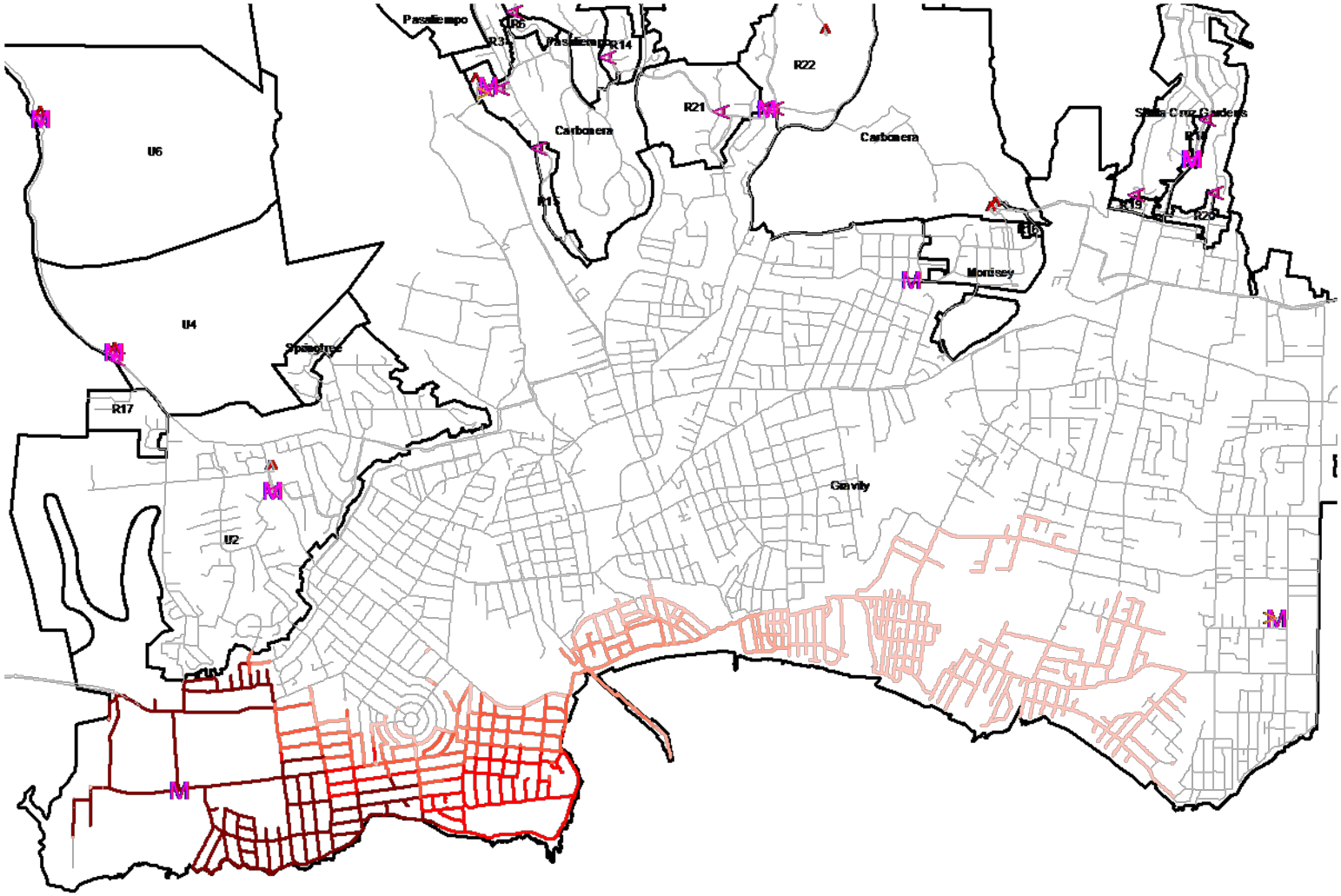
Water Quality: Seawater

Parameter	Average Value	Units	Period
TDS	36000	mg/L	Normal condition
pH	8.1	--	All year around
Temperature	14	°C	Normal condition
Turbidity	3	NTU	Normal conditions
	16	NTU	Red-tide events
	>50	NTU	Storm events
TOC	1.1	mg/L	Normal conditions
	19	mg/L	Red-tide events
DOC	1	mg/L	Normal conditions
	7	mg/L	Red-tide events
Boron	4.4	mg/L	Normal conditions

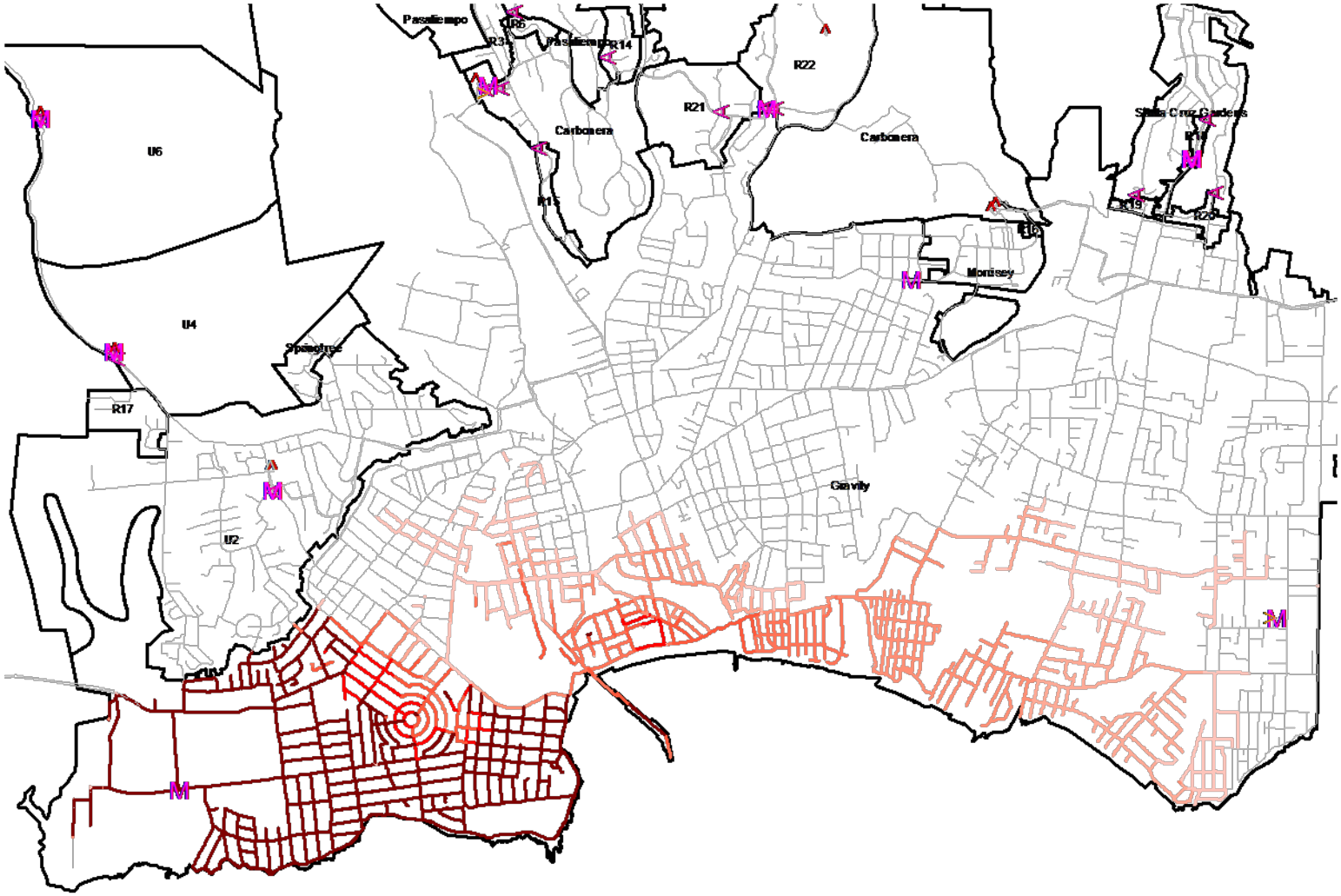
Comparison of basic water chemistries of desalinated and conventionally treated surface water

Items	Desalinated Water (pilot plant product)	Graham Hill WTP Water
pH	6.4	7.7
Ca	0.6	23.4
Mg	3.6	9.9
Cl	157	28
SO_4	5.5	79.2
DOC	0.1	1.4

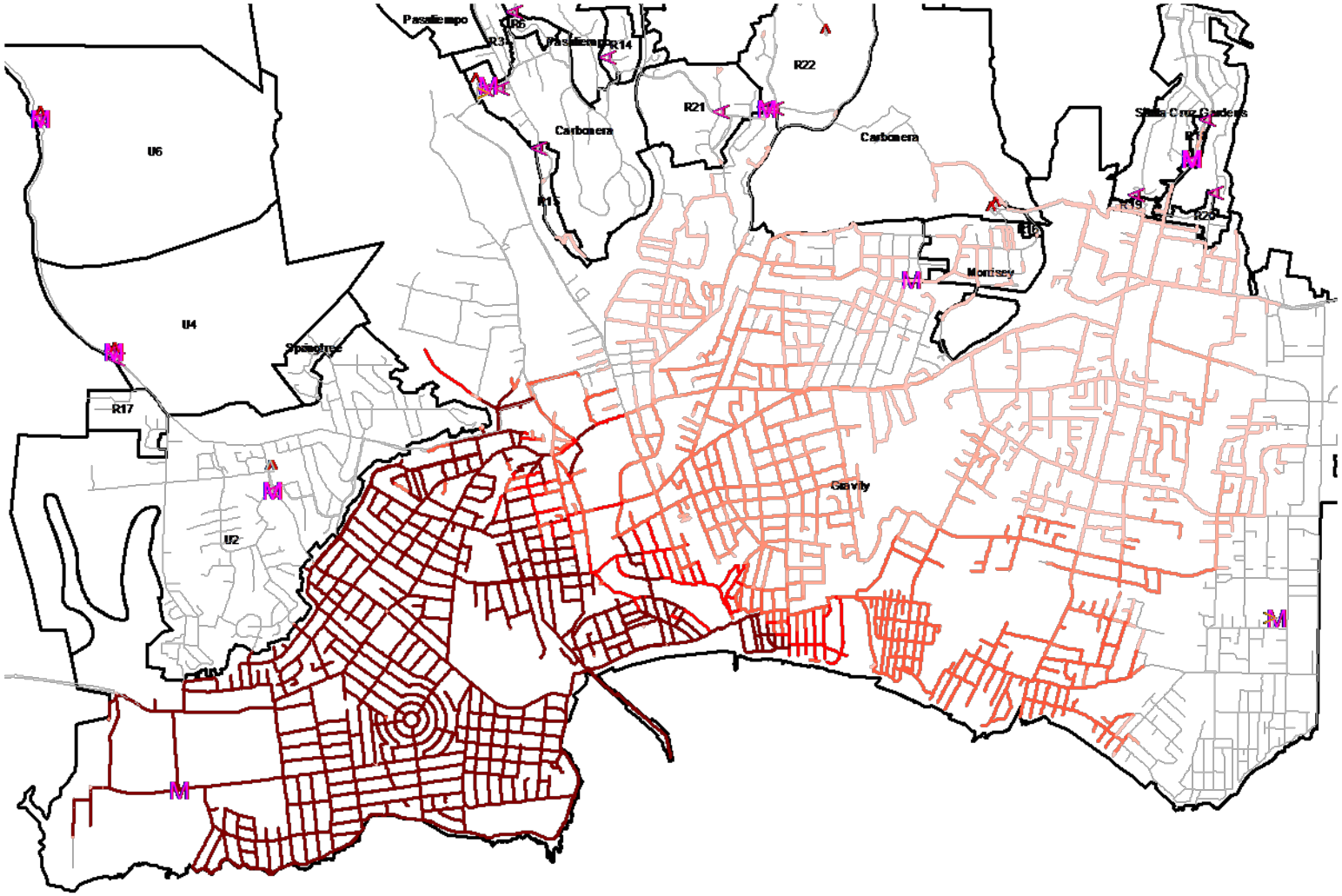
Typical distribution of desalinated/conventional water blends at 1.25 MGD SWRO plant rate



Typical distribution of desalinated/conventional water blends at 2.50 MGD SWRO plant rate



Typical distribution of desalinated/conventional water blends at 4.50 MGD SWRO plant rate



Major research questions

- How does blending of desalinated and conventionally treated water affects metal release and corrosion rates in the Santa Cruz drinking water distribution system?
  - Heavy metals (copper, lead)
  - Iron – total and soluble
- How does desalinated water affect the stability of existing corrosion scales?
- What methods can be used to suppress corrosion and metal release if necessary?
  - Corrosion inhibitors (phosphate)
  - Modifications of pH, alkalinity

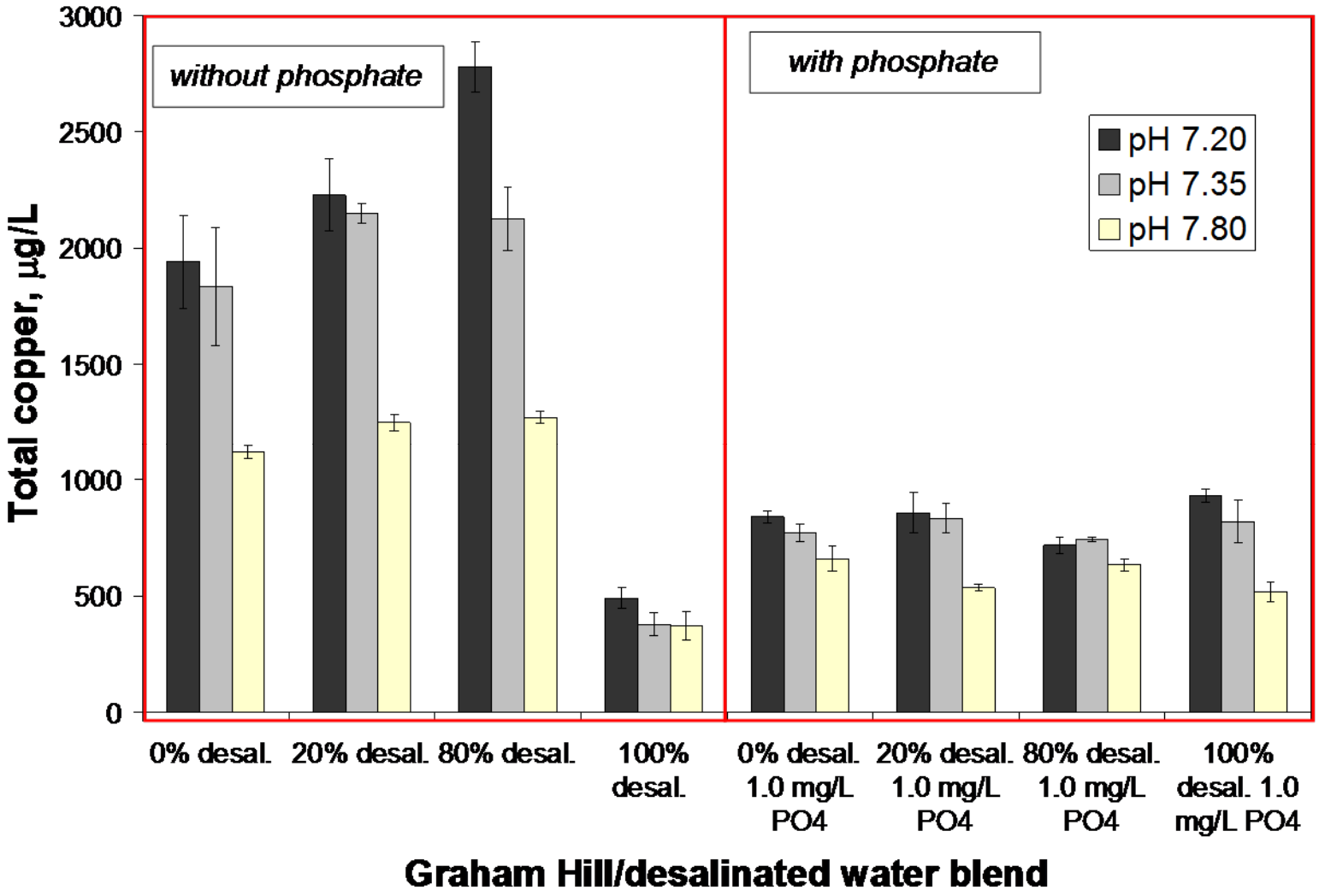
Methodology

- Jar tests
  - Copper and lead/tin solder coupons
  - Water shipped from Santa Cruz
- Relatively short exposure time (8 weeks)
- Two phases of exposures
  - Summer and winter water quality
- Effects of water quality adjustments
  - pH, alkalinity, phosphate
- Measured parameters
  - Metal release (total and soluble)
  - Particle size distributions and ζ-potentials
  - SEM and XRD measurements

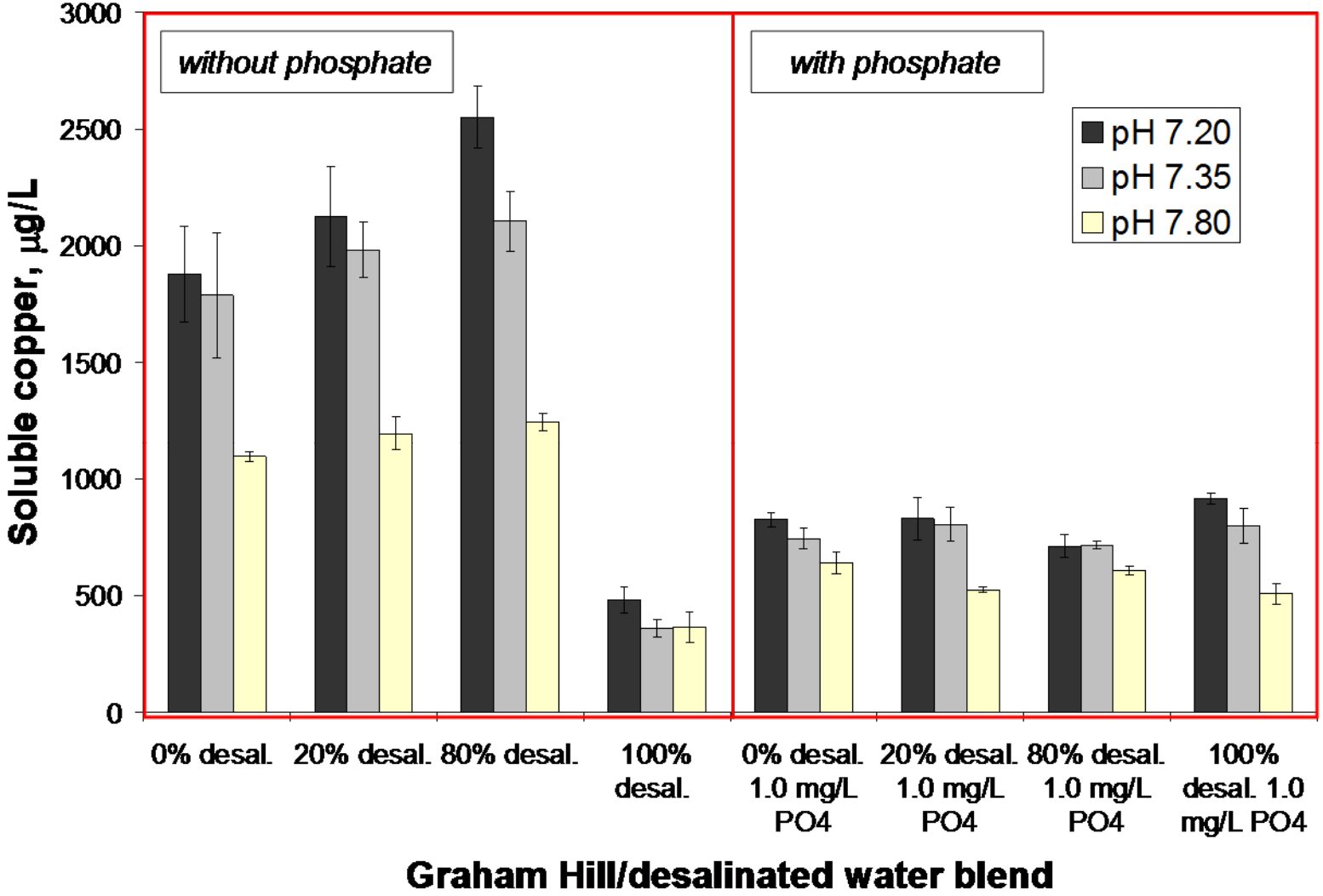
Ranges of explored water qualities

- pH
  - 7.20, 7.35 and 7.80
- Alkalinity of desalinated water
  - 30 to 120 mg/L as $CaCO_3$
- Phosphate concentration
  - 0, 0.5 and 1.0 mg/L as PO_4
- Desalinated water blending ratios
  - 0, 20, 50, 80 and 100%
- Weekly water exchanges

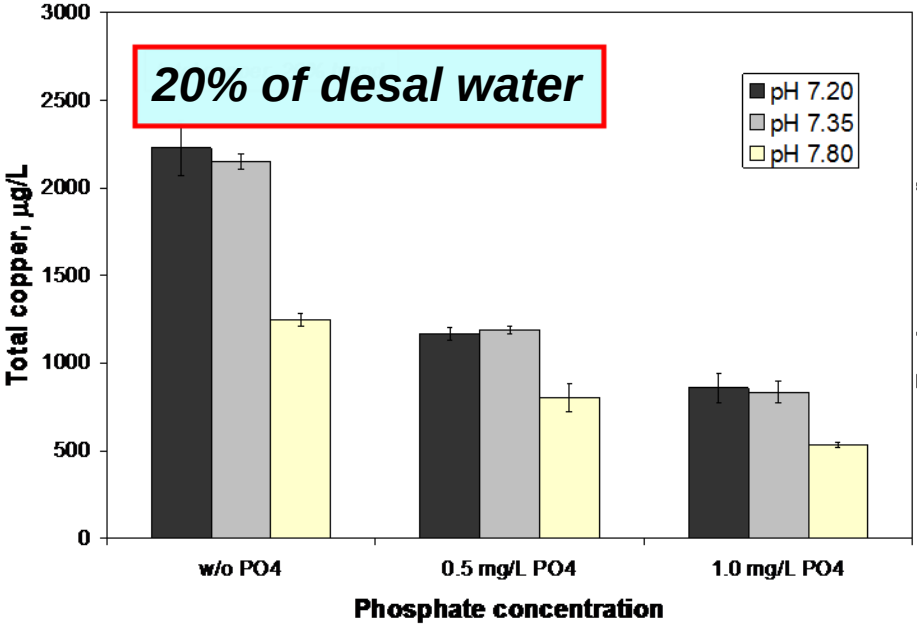
Effects of blending on total copper release

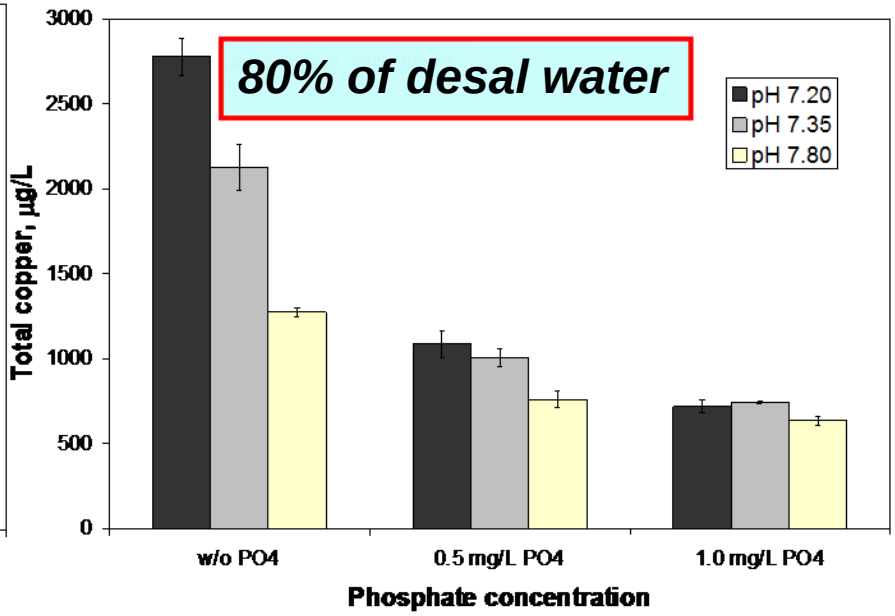


Effects of blending on soluble copper release

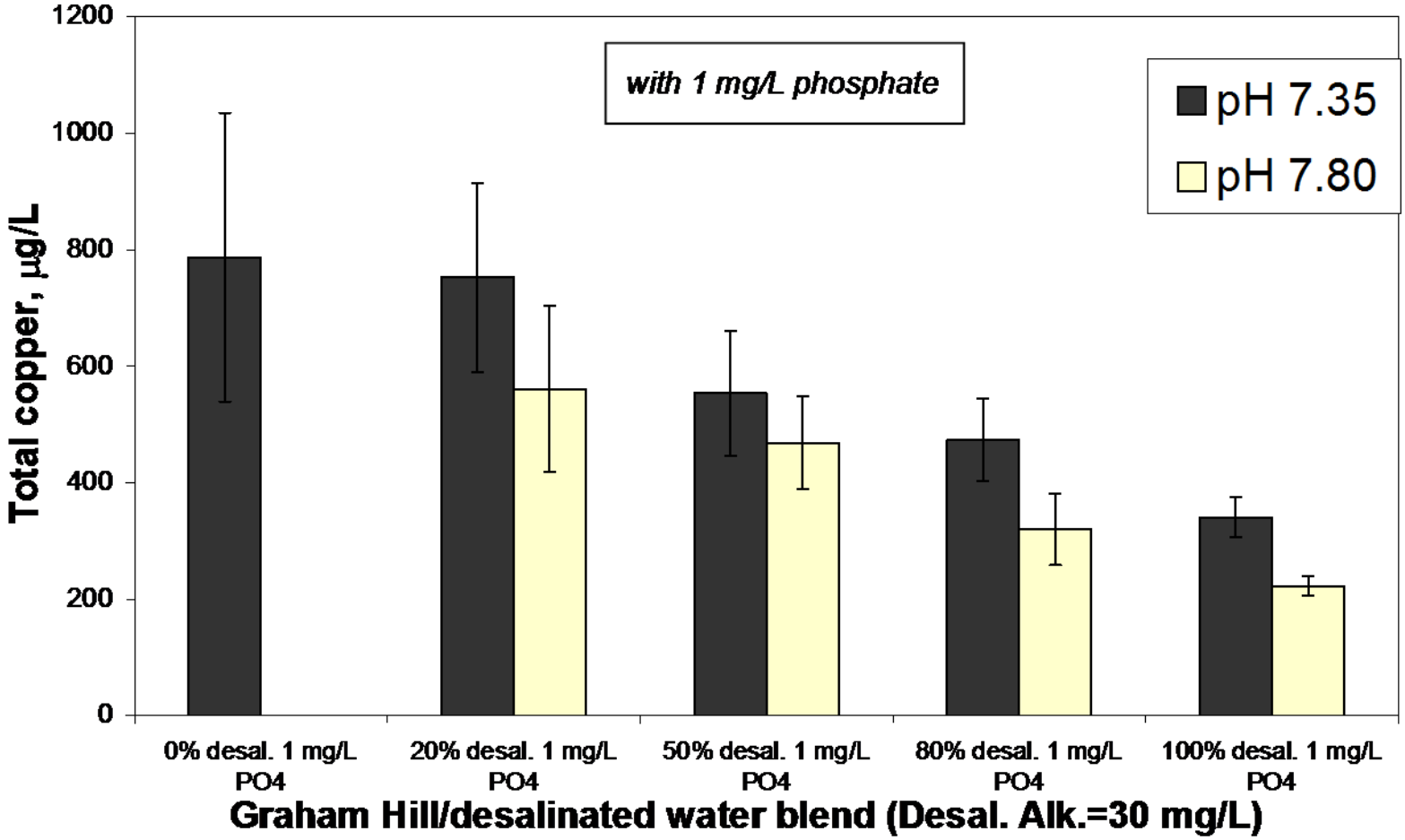


Comparison of total copper for 20% and 80% desalinated blends

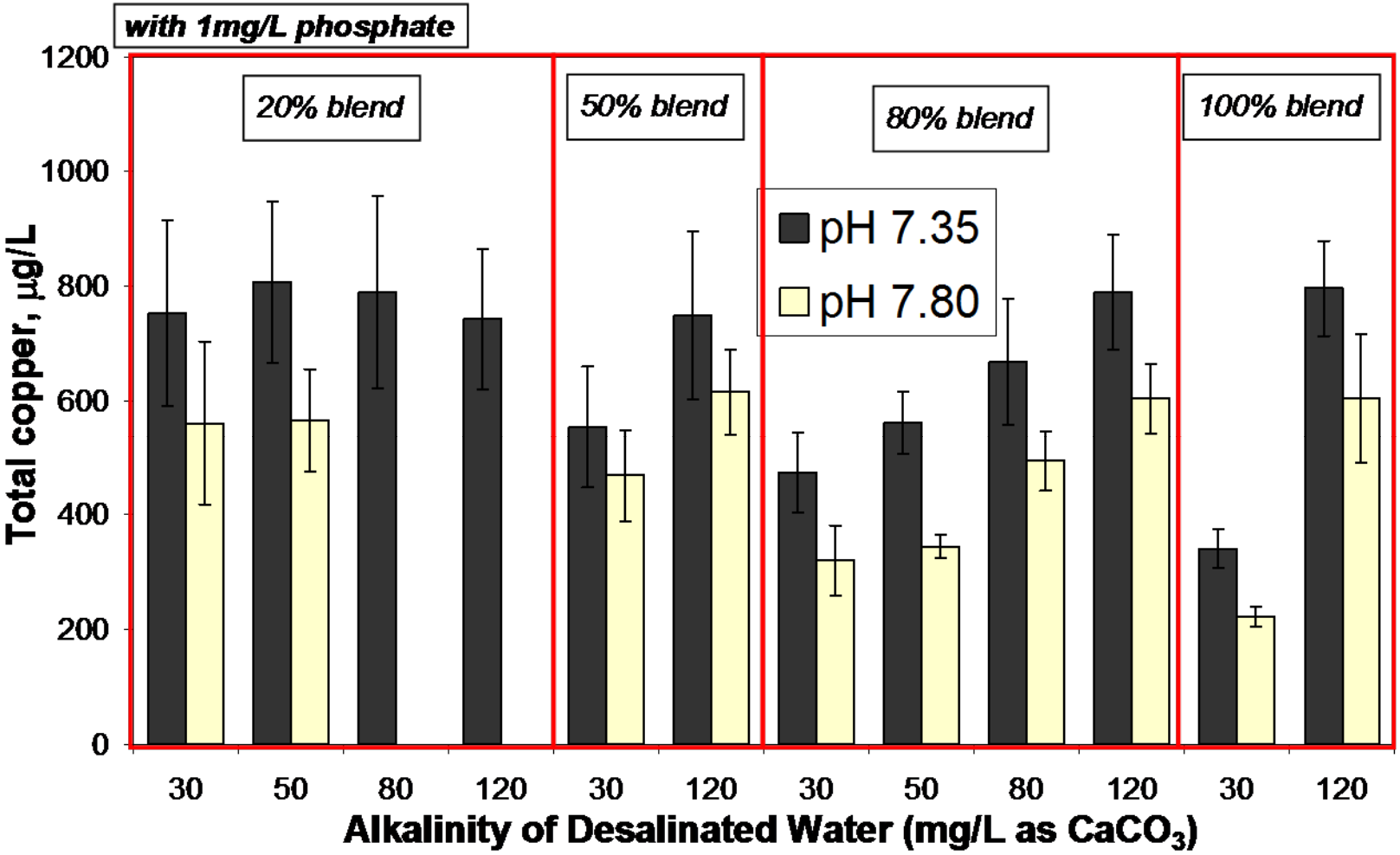




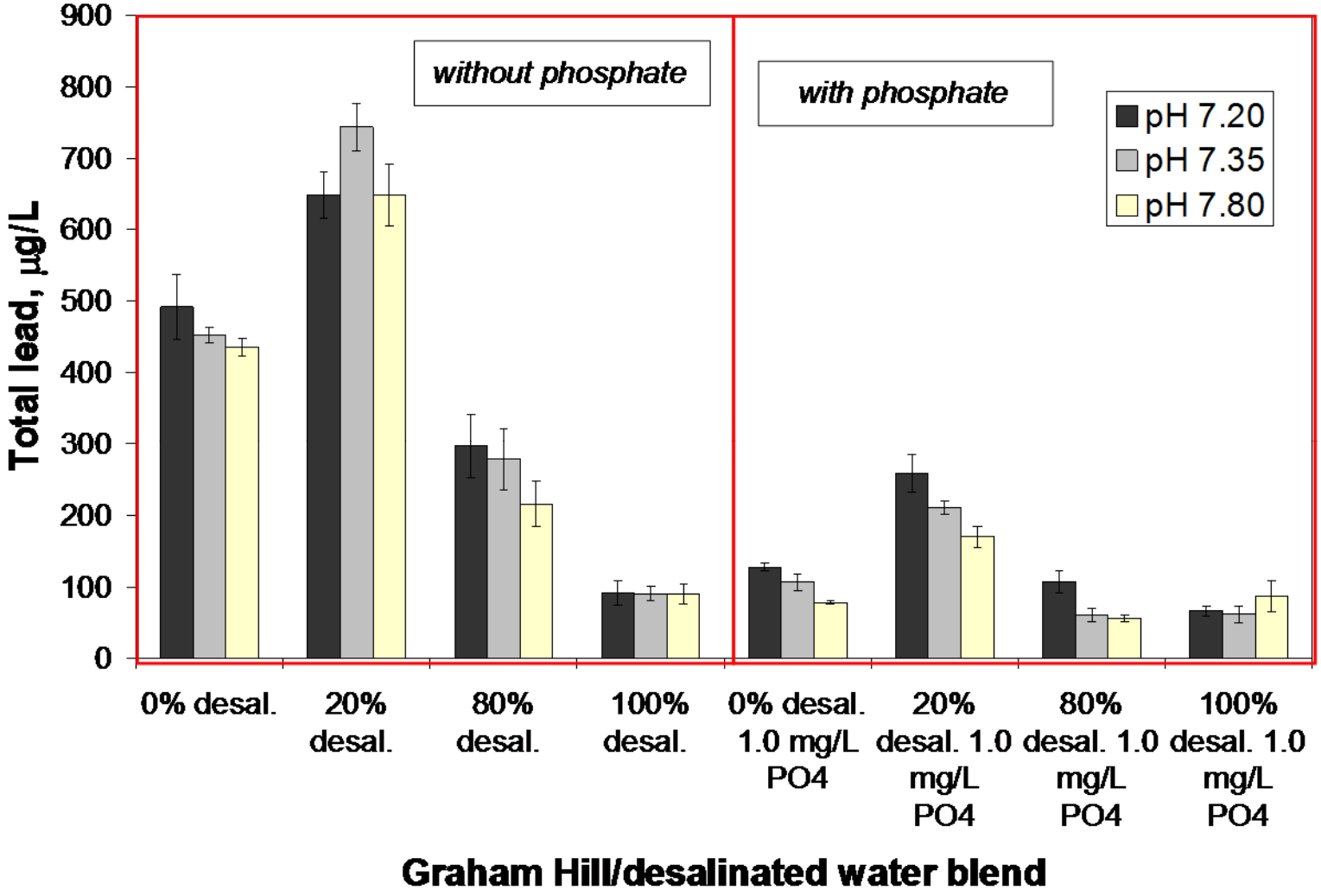
Effects of blending on total copper release in the presence of phosphate (Phase II)



Effects of alkalinity on total copper release in blended water with phosphate (Phase II)



Effects of blending on total lead release (Phase I)



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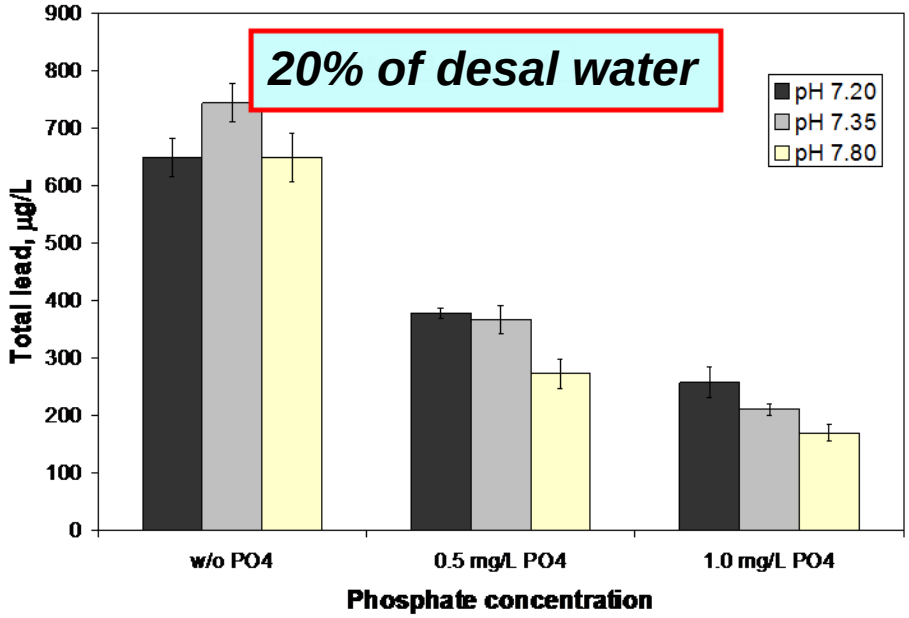

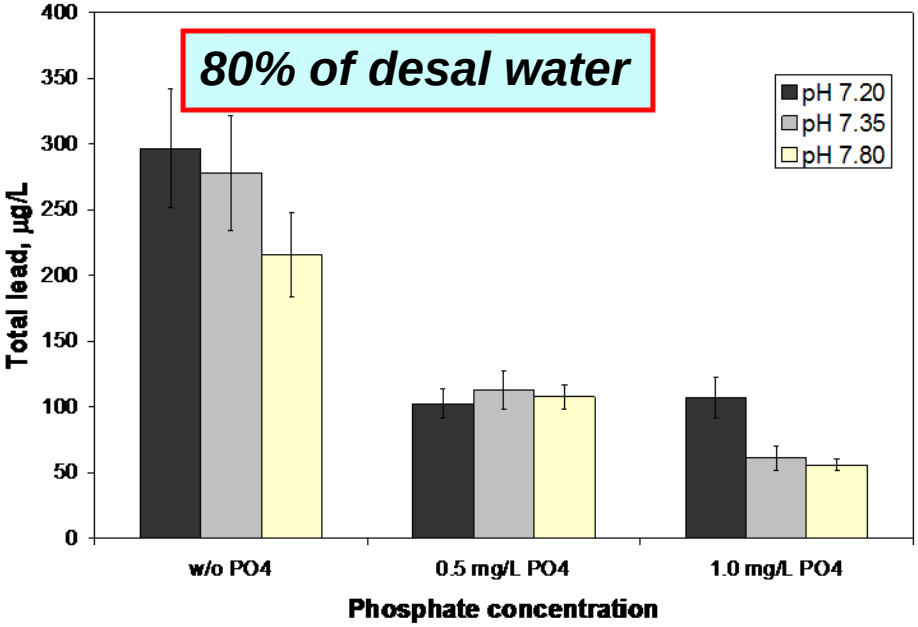

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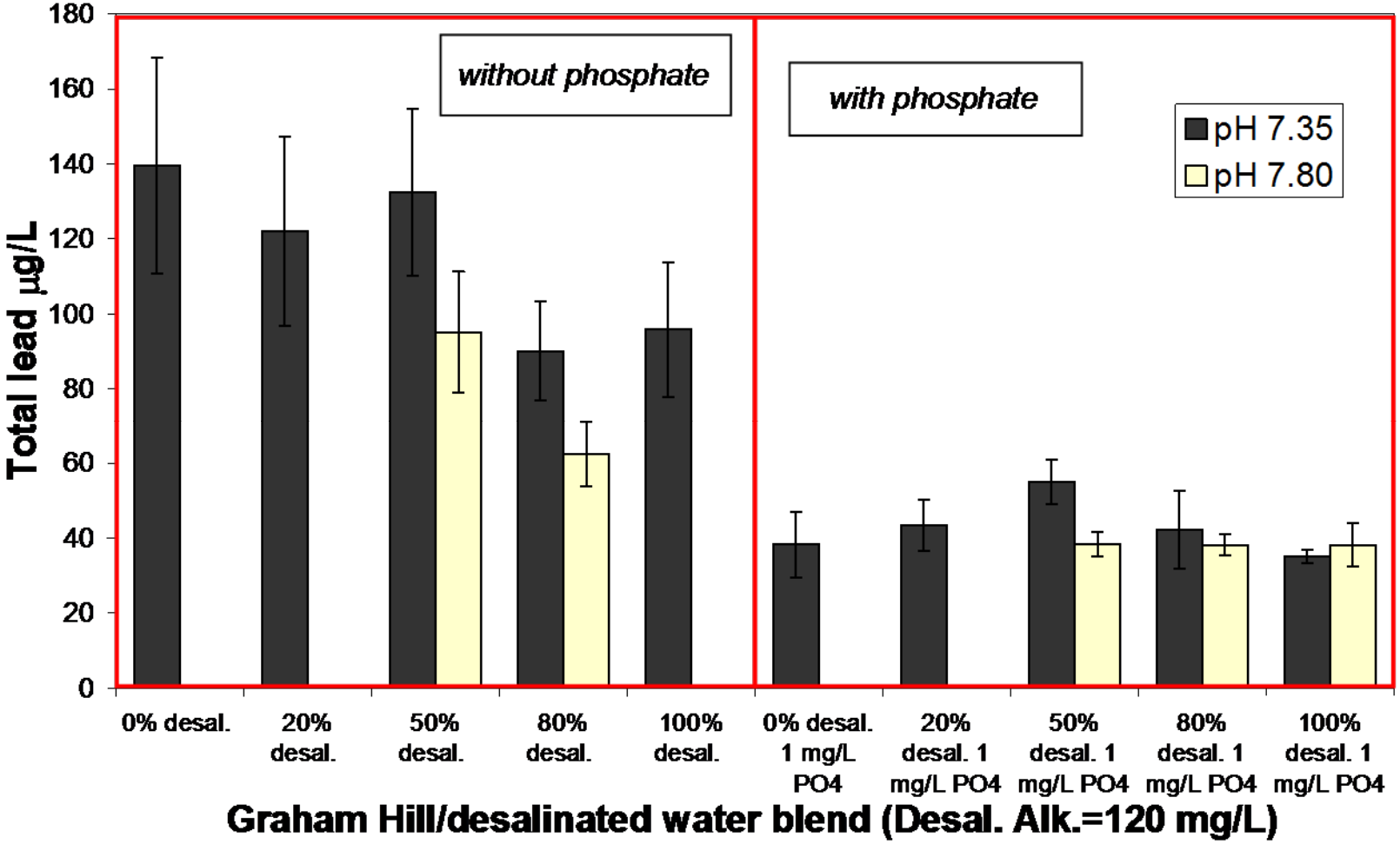
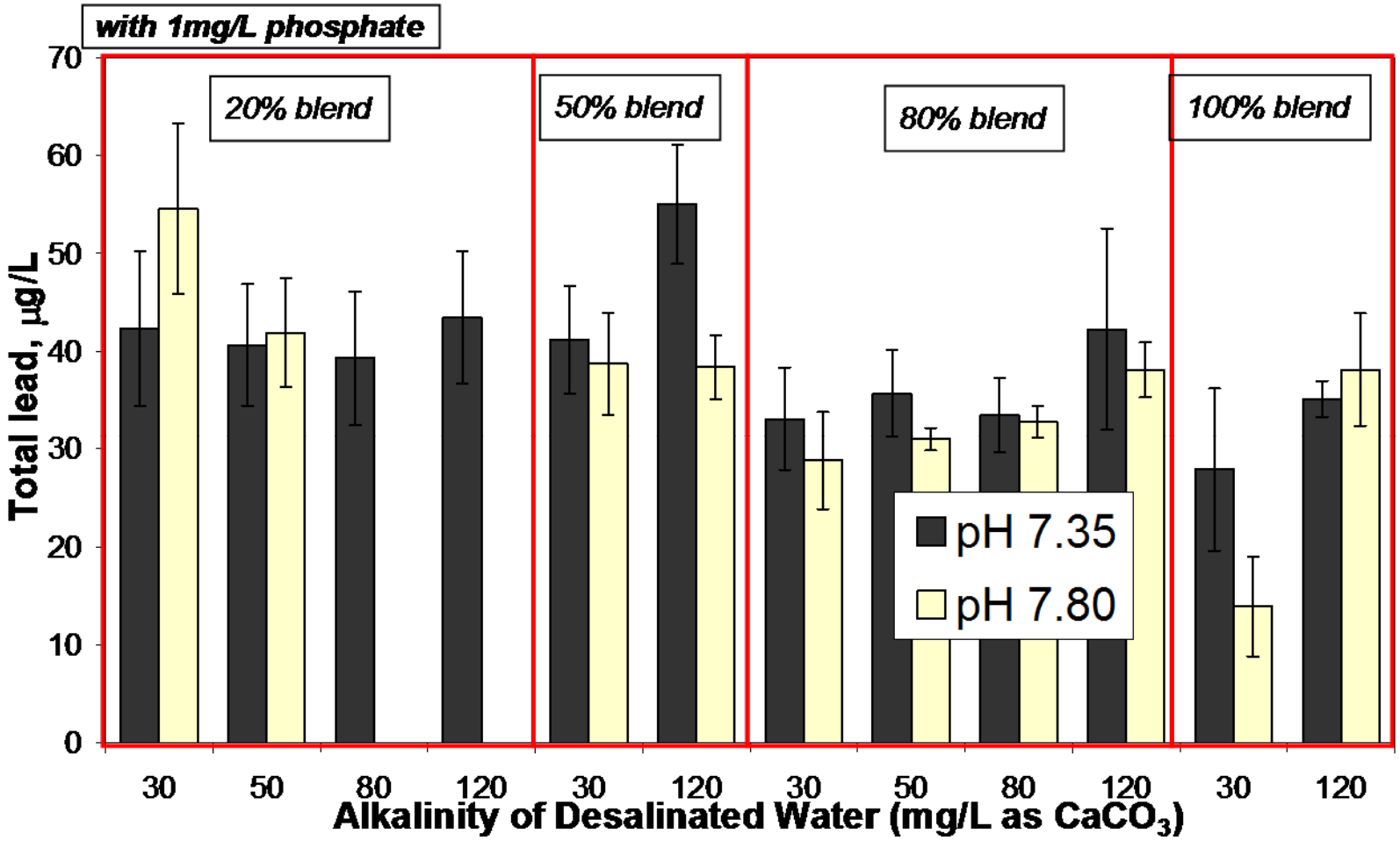
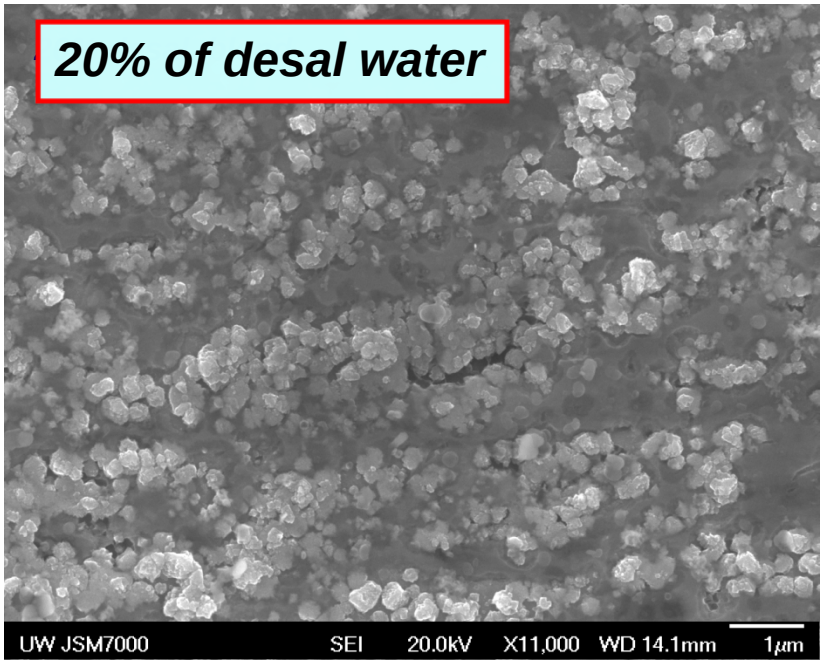
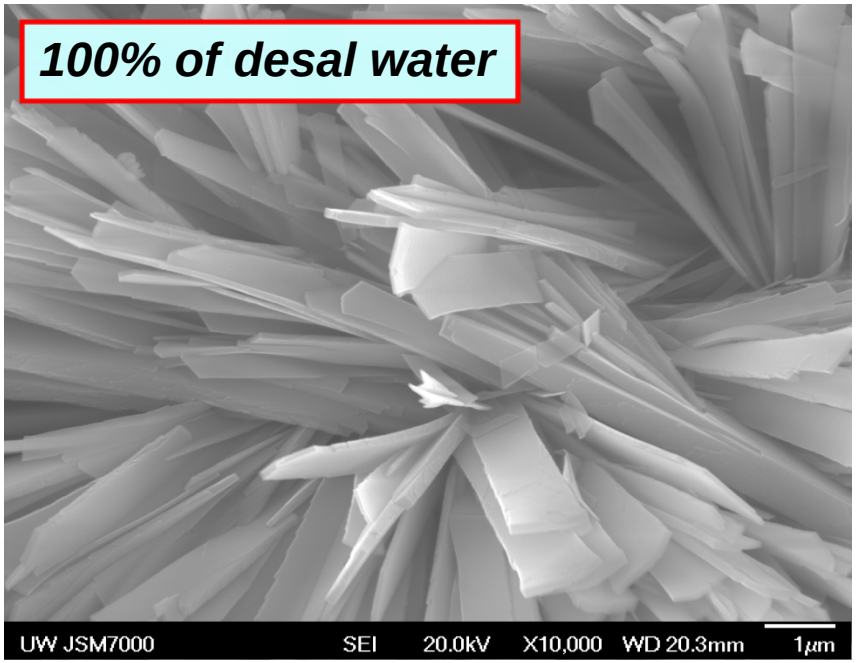


Effects of alkalinity on total lead release in blended water with phosphate (Phase II)



Comparison of the morphologies of copper surfaces
(pH 7.35, alk. 120 mg/L, w/o orthophosphate)





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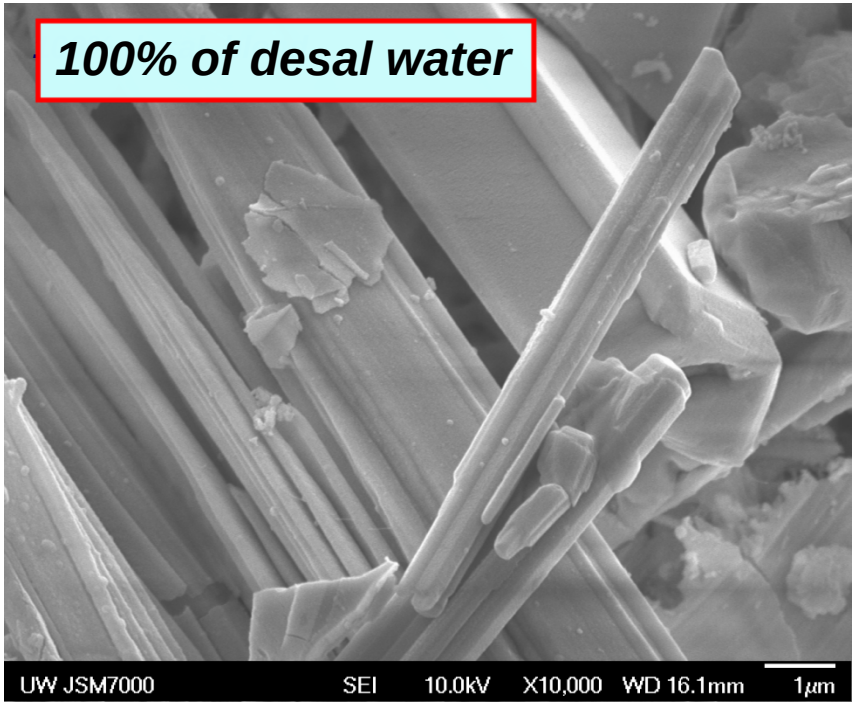
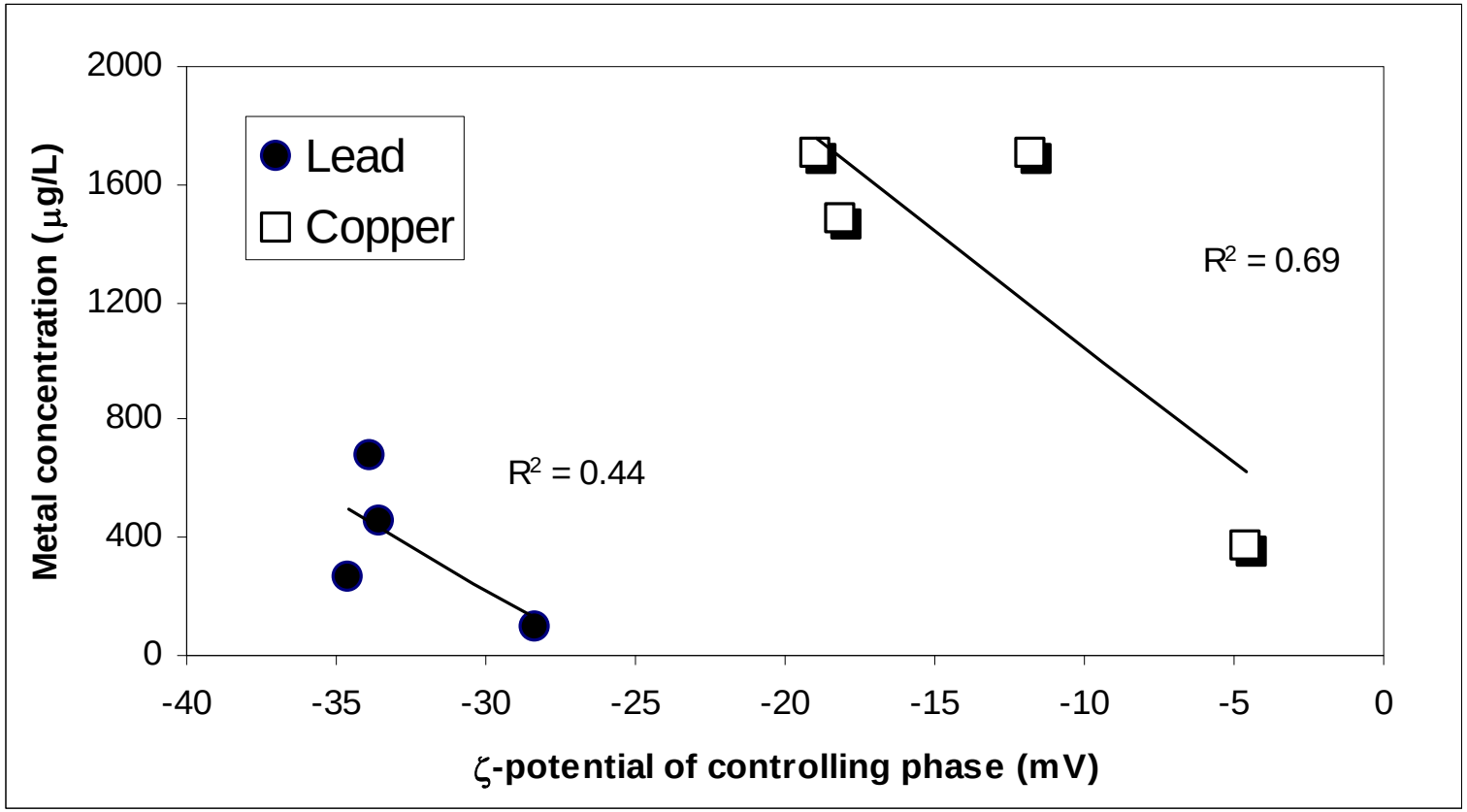


Correlations between changes of ζ-potential of model phases and metal release



Conclusions

- Pronounced effects of desalinated water on copper and lead corrosion
- Lower corrosion rates in 100% desalinated water
  - In the absence of phosphate
- Non-monotonic relationship between the amount of desalinated water and metal release
  - In the absence of phosphate
- Very good performance of phosphate inhibitors
  - Except for copper in 100% desalinated water
- pH and alkalinity modifications still play an important role
- Dramatic changes of surface morphologies and charges
  - Effects of NOM

Items to be explored

- Natural organic matter?
  - Has major effects on the morphology of solids formed in drinking water
    - Disperse, low crystalline solids in the presence of NOM
  - Tends to increases metal release
- The role of chloride and sulfate?
- Behavior of other materials
  - Iron and cementitious surfaces
- Long-term vs. short-term effects

Acknowledgements

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