Lead & Copper Rule When Blending Different Water Sources

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CORNWELL
ENGINEERING GROUP

Overview

- Corrosion Control Theory
  - Corrosion control treatment (CCT) strategies
  - Impact of changing DIC
- Case Study 1
  - Bench-scale test plan
  - Pb release:
    - Existing conditions
    - GW – Orthophosphate CCT
    - SW – Orthophosphate CCT
    - SW – pH/alkalinity CCT
- Case Study 2
  - Pb release

CORROSION CONTROL THEORY

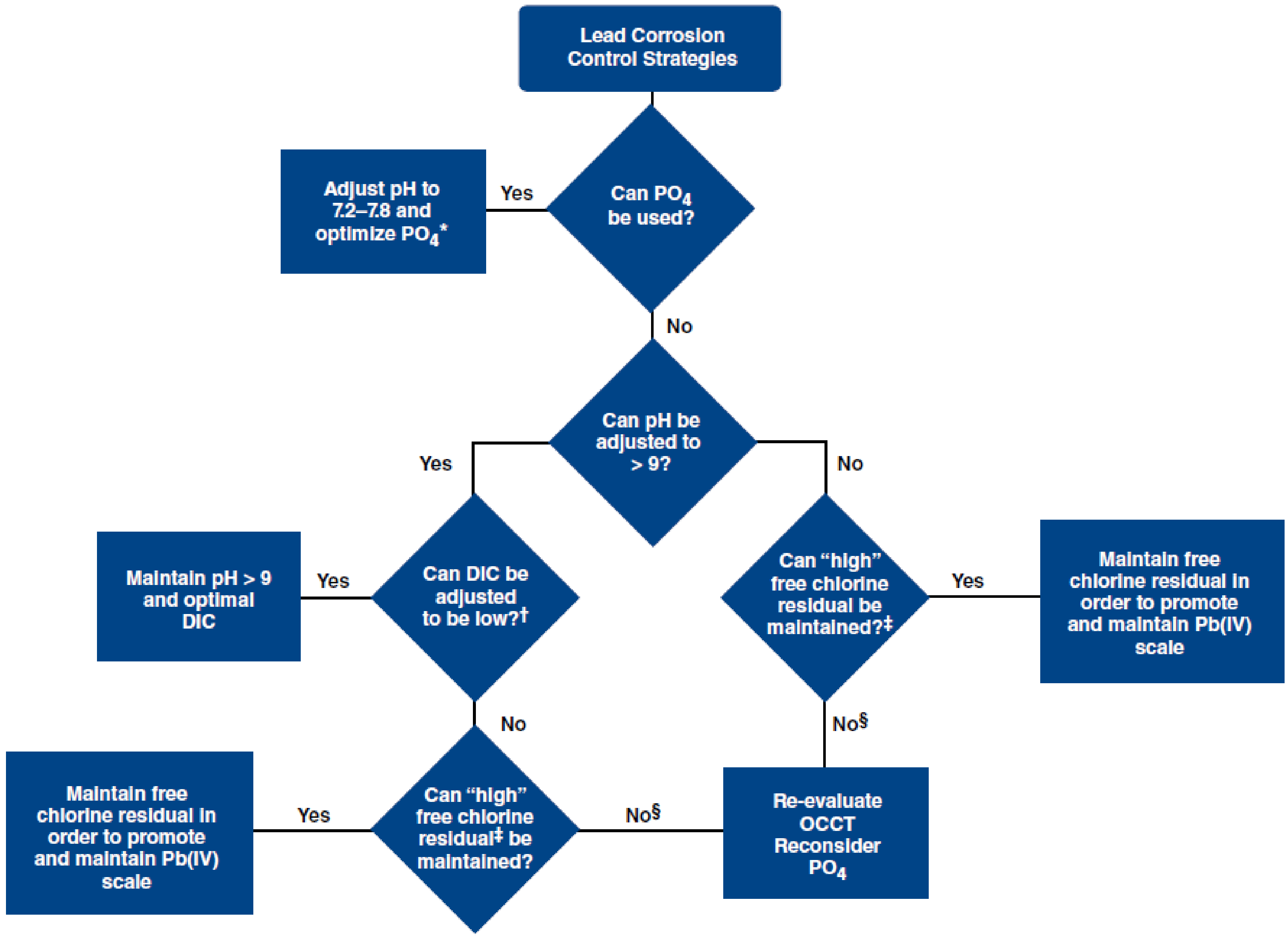
Lead & Copper CCT

- Old Strategies vs. What We Know Now

Old Strategies	What We Know Now
– Passivation (pH / Alkalinity)	– Passivation (pH / Alkalinity)
– Passivation (PO_4, Silicate)	– Passivation (PO_4)
– $CaCO_3$ precipitation	– High Cl_2 resid - Pb(IV) scale

- Decision Tree Approach
  - First consider PO_4 (pH from 7.2 to 7.8)
  - If can't, consider increasing pH>9 units
    - Possibly optimize DIC if adjusting pH
  - If can't, consider increasing Cl_2 residual to form Pb(IV) scale
  - ----- Also see next slide -----

Improved LCR Compliance Understanding

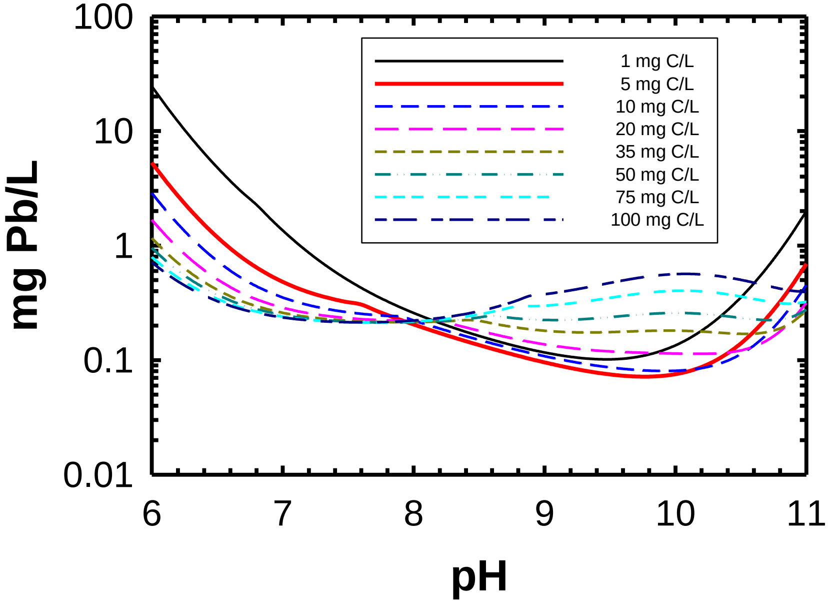


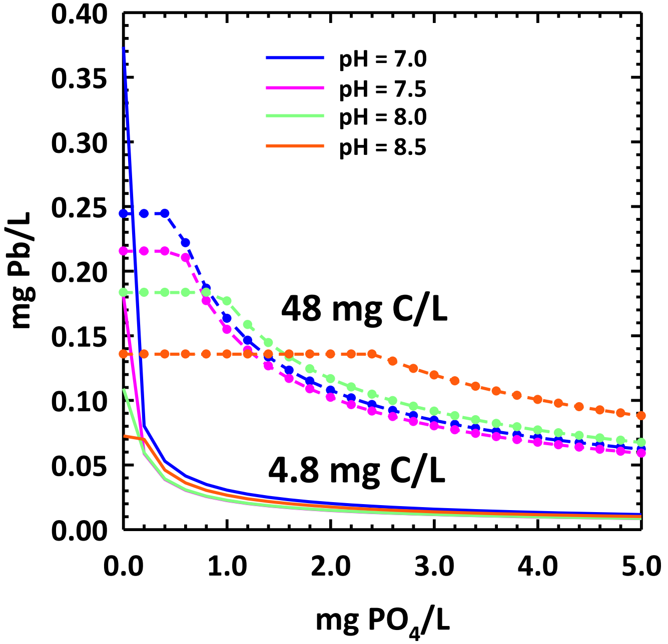
CCT is Source Water Dependent

- CCT can be influenced by multiple water quality parameters
  - pH
  - Dissolved Inorganic Carbon (DIC) / Alkalinity
  - Dissolved Oxygen (DO)
  - Total Dissolved Solids (TDS)
  - Chloride-to-Sulfate Mass Ratio (CSMR)

Classic Pb(II) Solubility

Fresh Surface, Effect of DIC





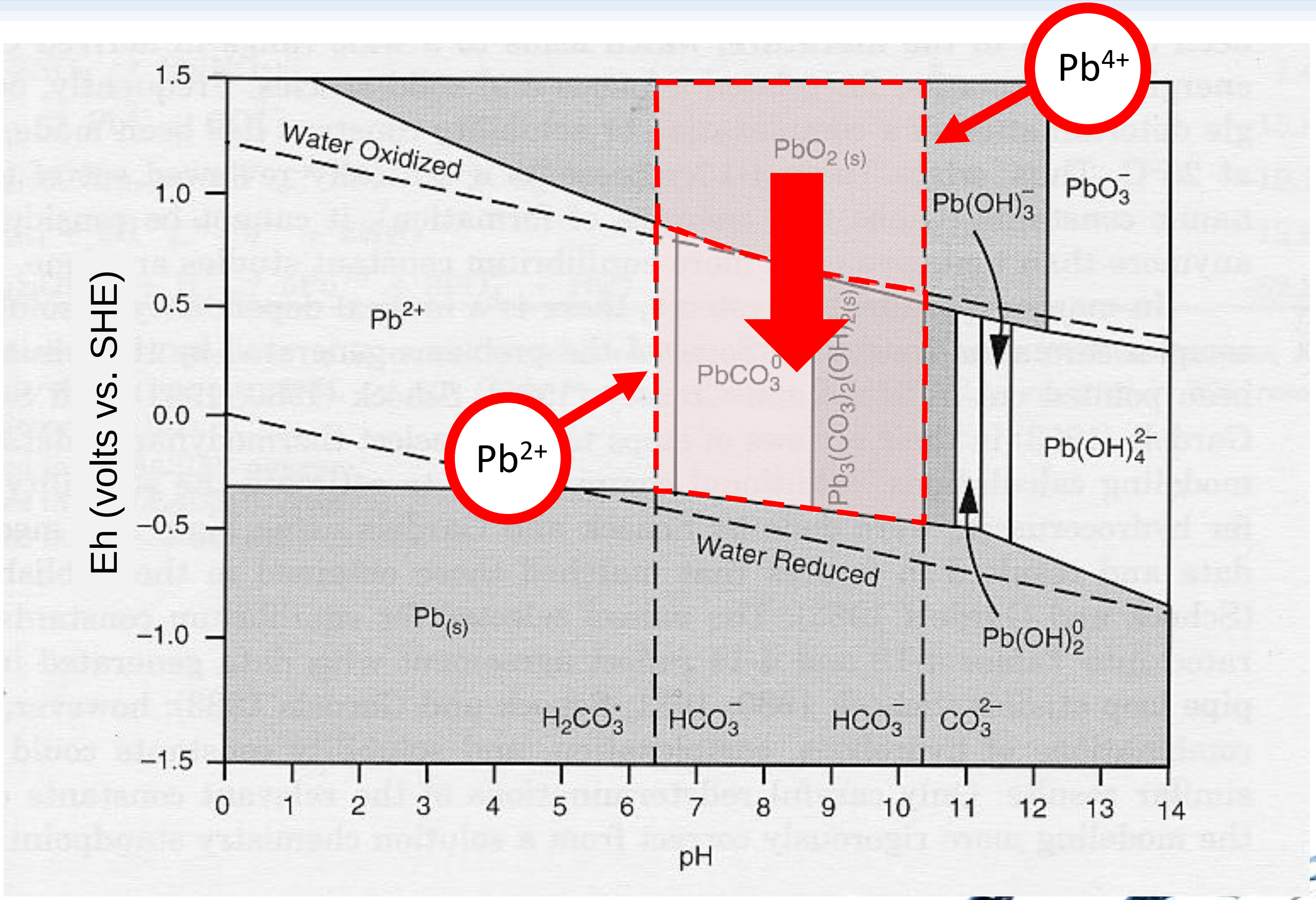
Source: Schock Presentation to NDWAC WG

Improved Understanding of Lead Scales

- Cerrusite
  - $Pb(II)CO_3$ (s) lead carbonate
  - Less stable
  - More prone to sloughing, formation of particulate lead
  - Dissolves easily when WQ not favorable to production

- Hydrocerrusite
  - $Pb(II)_3(CO_3)_2(OH)_2$ (s) anhydrous lead carbonate
  - More stable
  - Dissolves at higher DIC

Pb Solubility and Oxidation Reduction Potential



Courtesy Chris Hill, Arcadis

CASE STUDY:
Blending Surface Water and Ground Water

Case Study Source Water

- Surface water

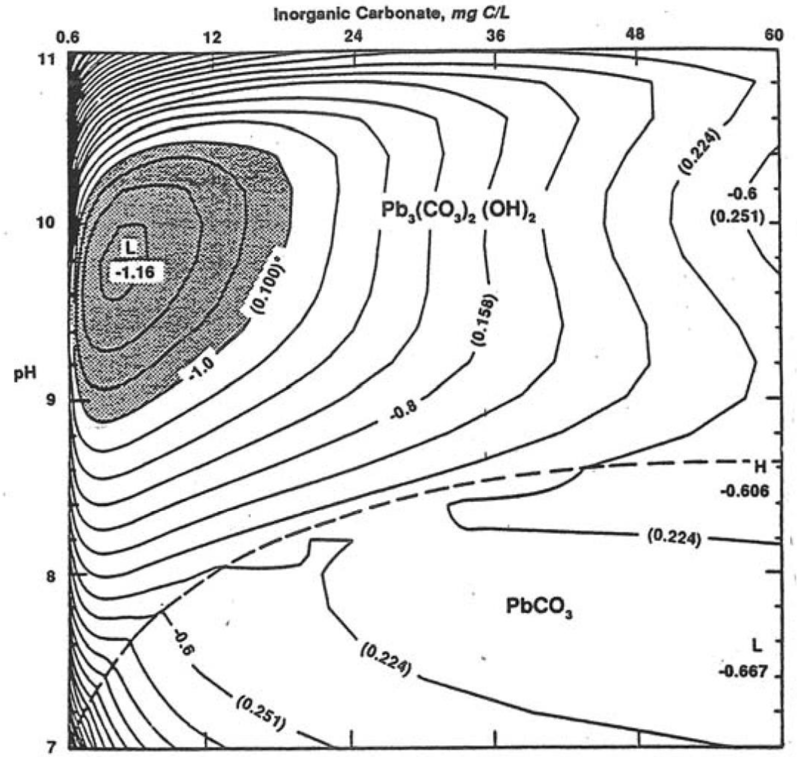
  pH ~8.0

  Alkalinity ~7 mg/L as $CaCO_3$ (~1.5 mg/L as C)
- Groundwater

  pH ~8.0

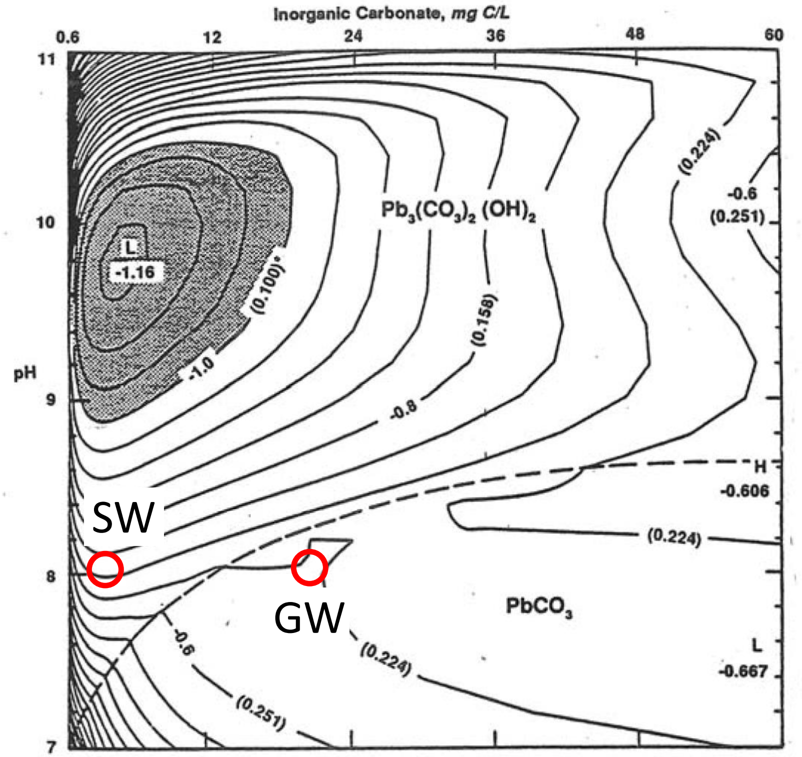
  Alkalinity ~90 mg/L as $CaCO_3$ (~22 mg/L as C)
- System might be supplied with:
  - 100% SW
  - SW supplemented with GW
  - 100% GW

Potential for Scale Change



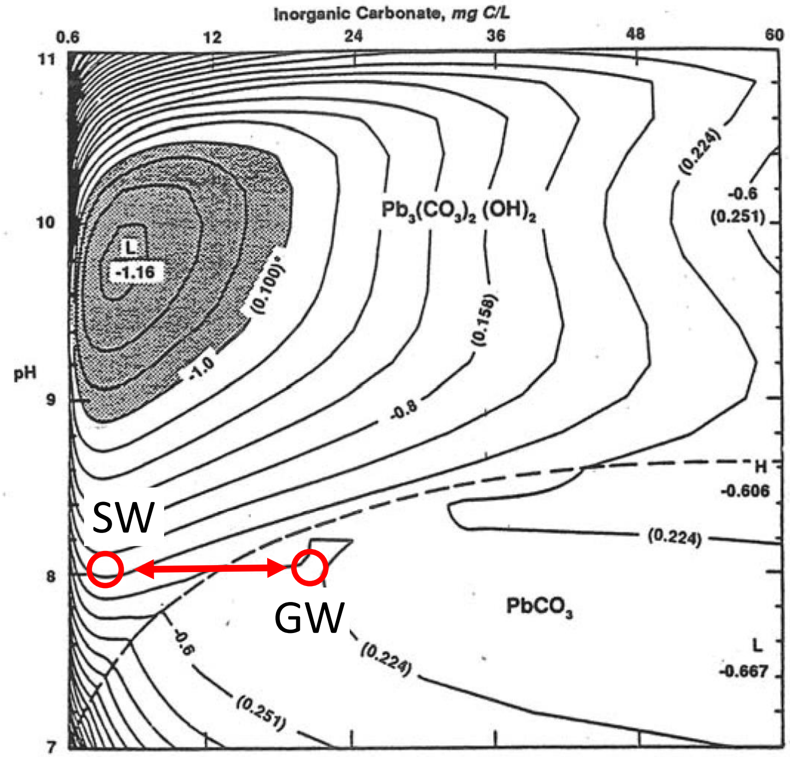
Source: EES 1990

Potential for Scale Change



Source: EES 1990

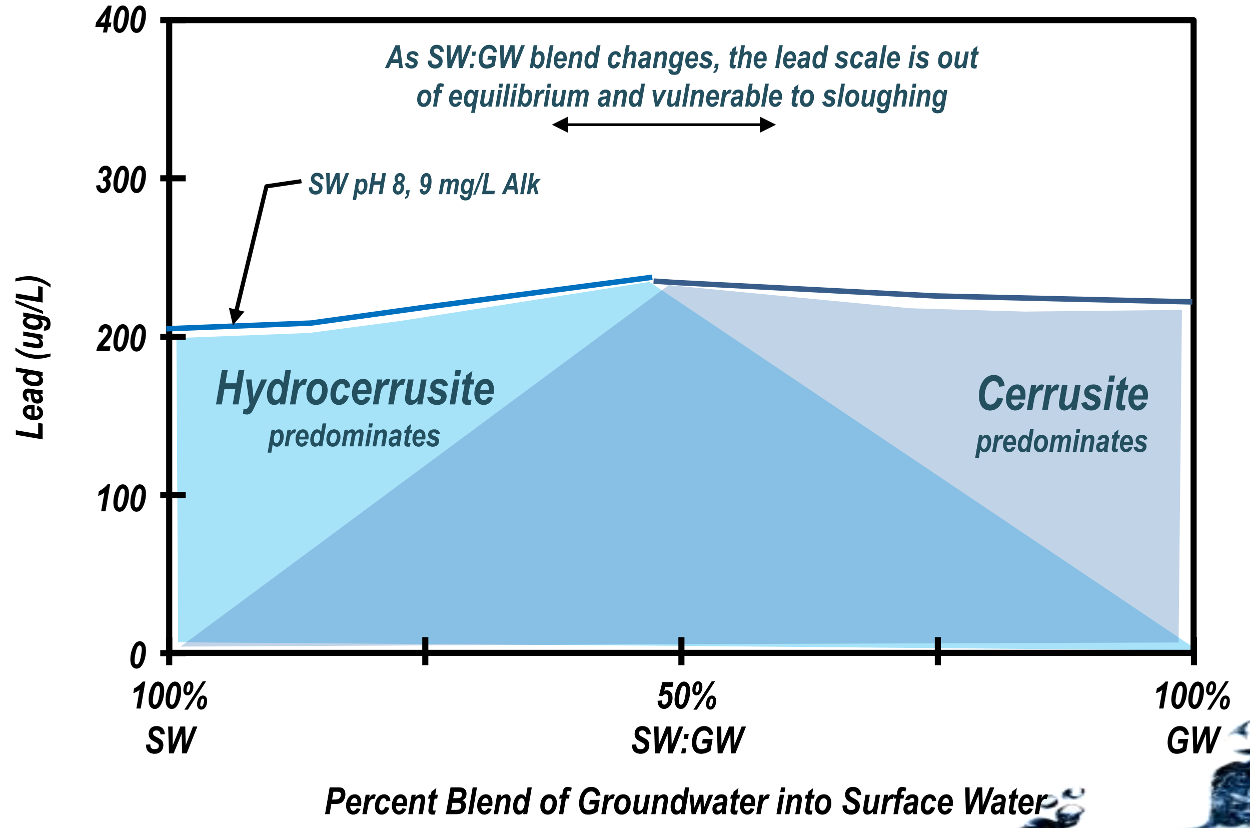
Potential for Scale Change



Source: EES 1990

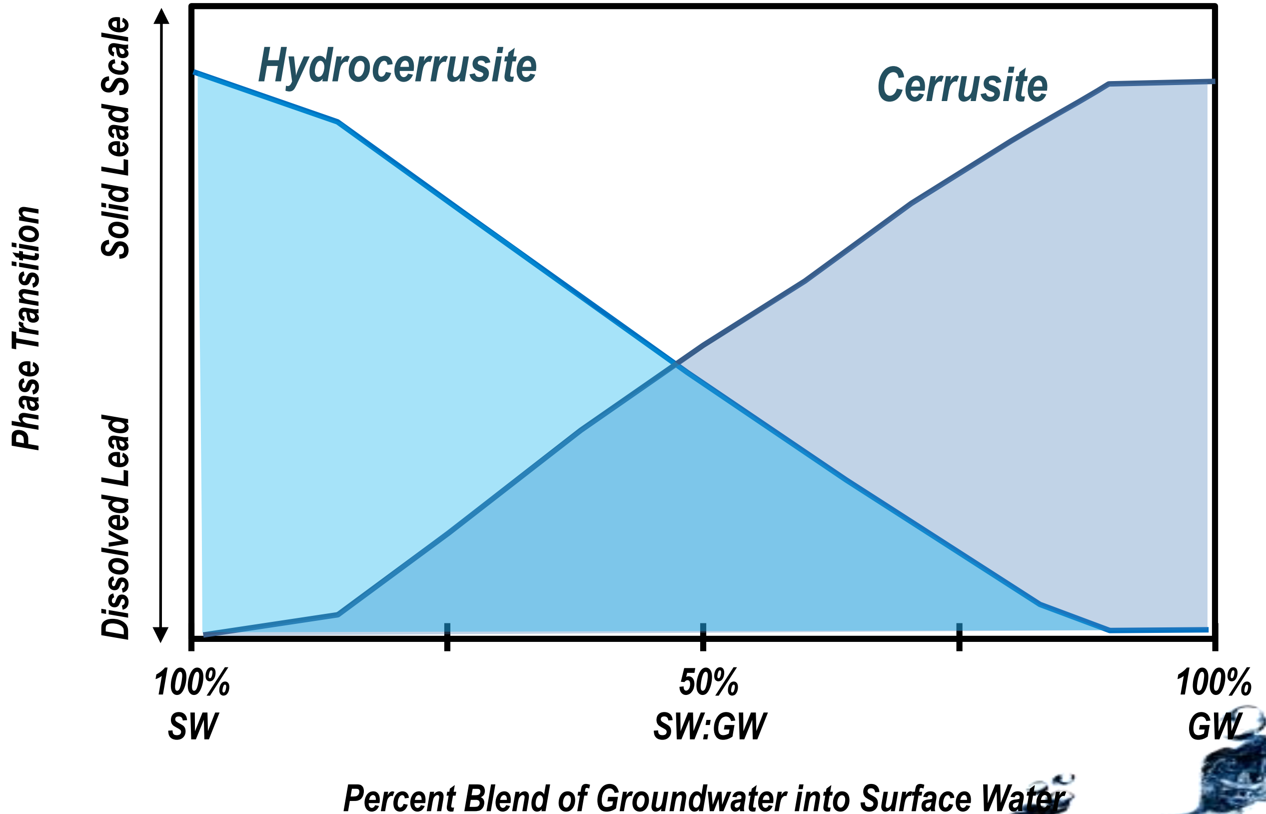
Improved Understanding of Lead Scales

- Modeled Pb scale equilibrium



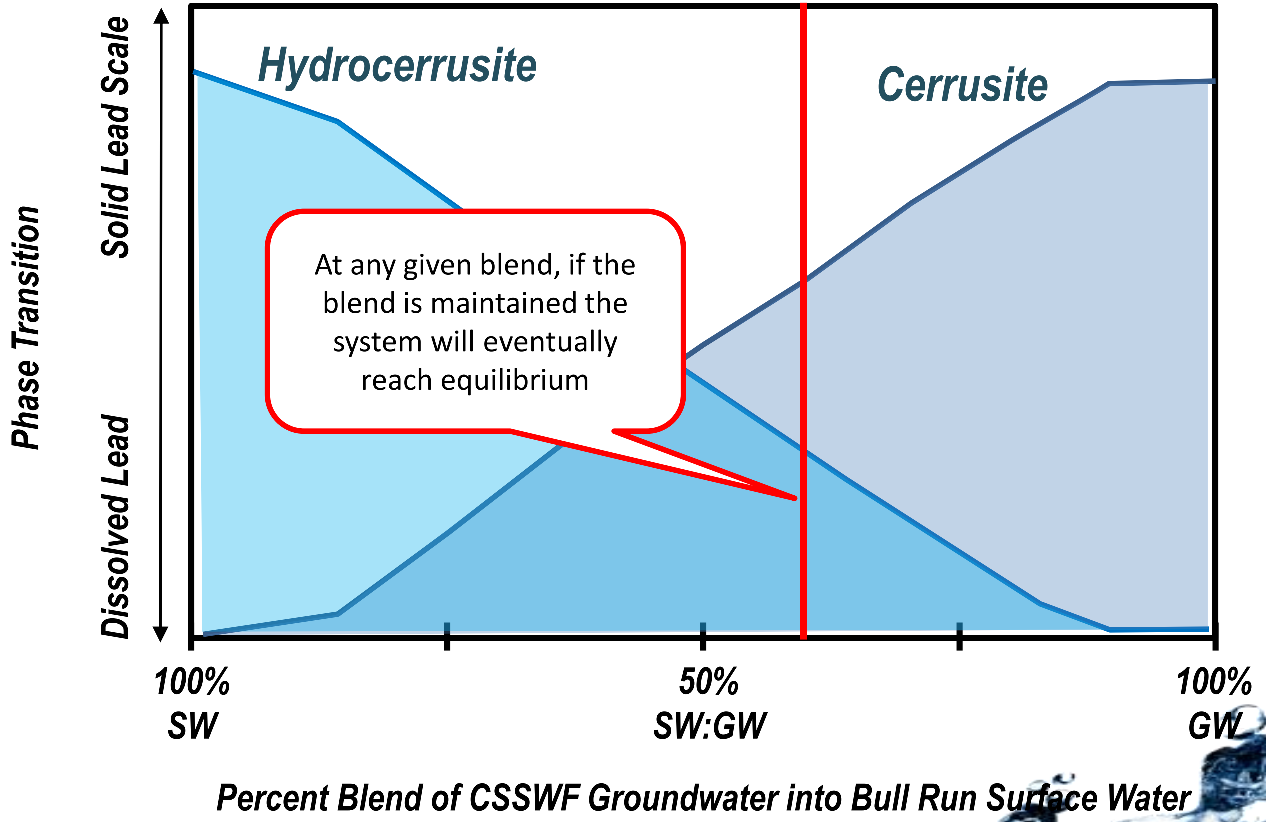
Improved Understanding of Lead Scales

- Modeled scale species change



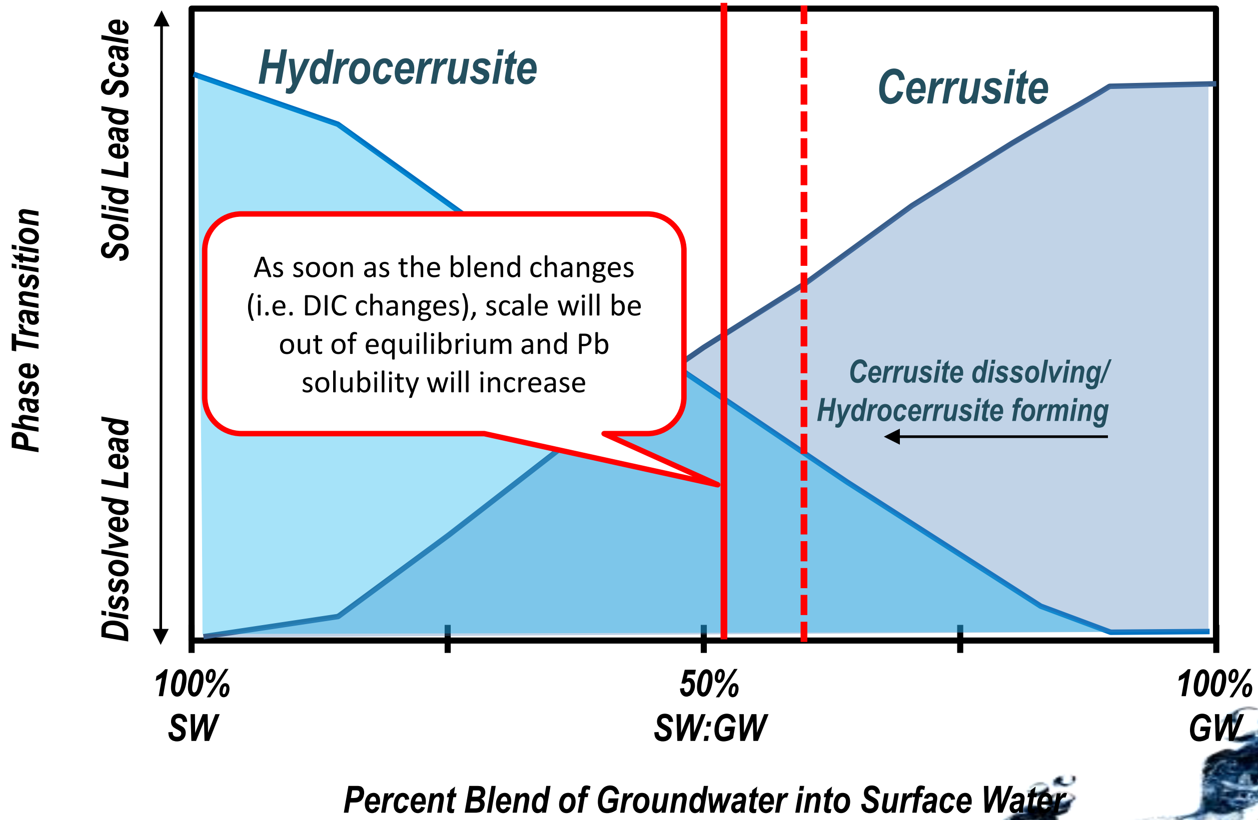
Improved Understanding of Lead Scales

- Change leads to increased lead solubility



Improved Understanding of Lead Scales

- Change leads to increased lead solubility



Bench-Scale Test Goals

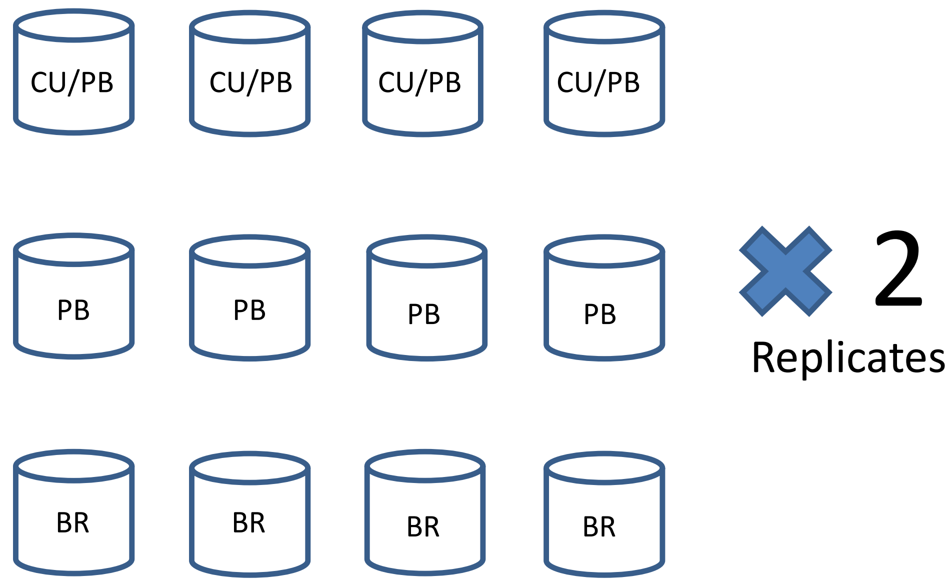
- Compare relative performance of CCT
  - Orthophosphate to pH/alkalinity
  - Orthophosphate doses
  - pH/alkalinity
- Evaluate potential for Pb release under changing water quality conditions
  - 100% SW to SW:GW blend
  - 100% GW to SW:GW blend

CASE STUDY:
Bench-Scale Test Plan

Overview of Study and Methods

Test 1 - pH/Alkalinity Testing (Phase 1)

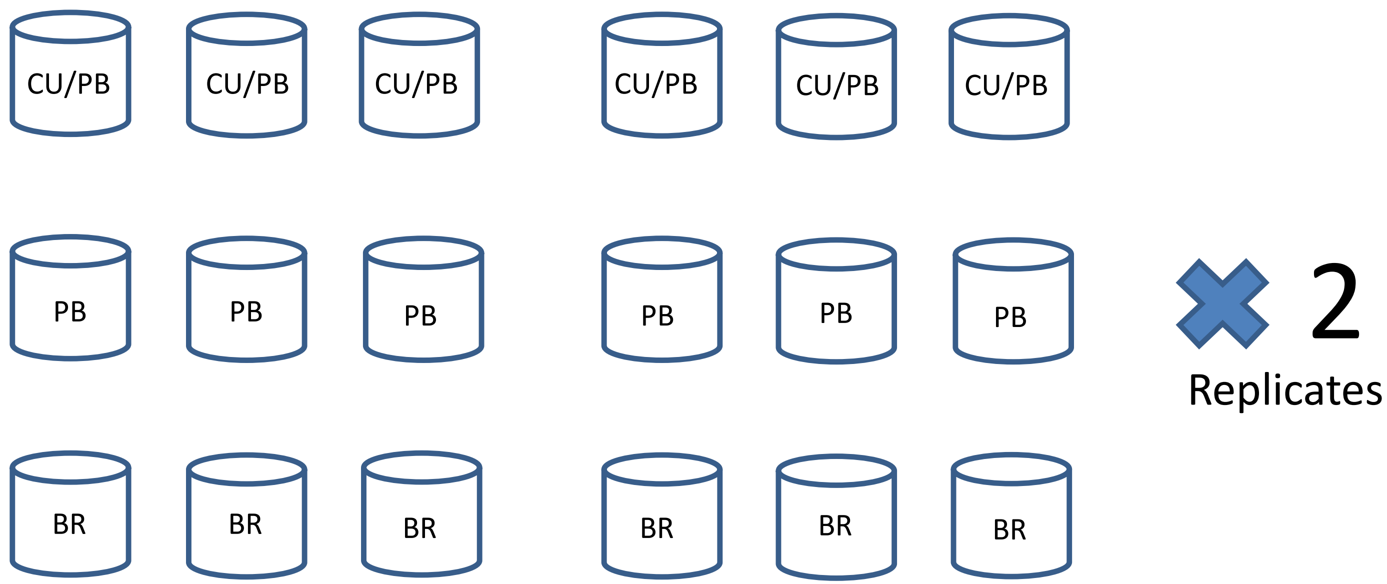
Source	SW	SW	SW	GW	
pH	8.0	8.6	9.3	8.0	
ALK	7	35	25	90	(mg/L as $CaCO_3$)



Overview of Study and Methods

Test 2 – Orthophosphate Testing (Phase 1)

Source	SW	SW	SW	GW	GW	GW	
pH	8.0	8.0	8.0	8.0	8.0	8.0	
Ortho	0.5	0.75	1.0	0.5	0.75	1.0	(mg/L as P)

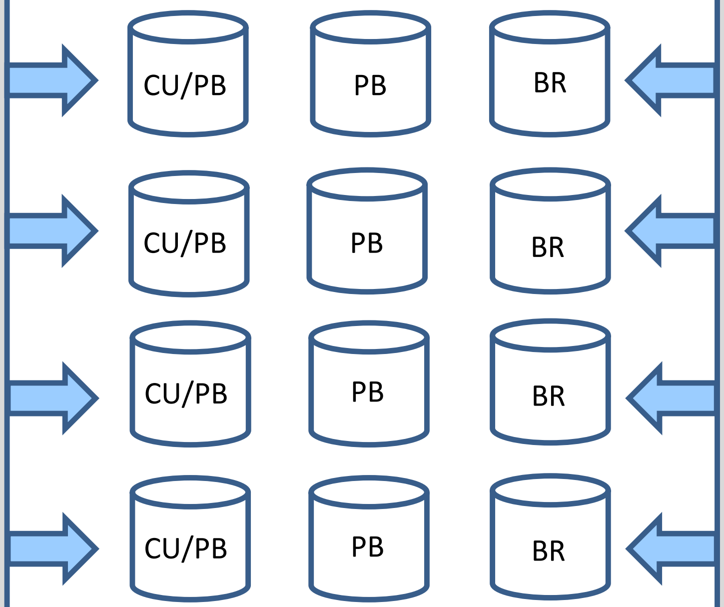


Overview of Study and Methods

Test 1 - pH/Alkalinity Testing (Phase 2)

Equilibrated Coupon Water

	pH	ALK
SW	8.0	7
SW	8.6	35
SW	9.3	25
GW	8.0	90



Blend Water

	pH	ALK
GW	8.0	90
GW	8.0	90
GW	8.0	90
SW	8.0	7

*Alkalinity units- (mg/L as $CaCO_3$)

Two Coupons Per Condition Blended at:

85% SW
15 % GW

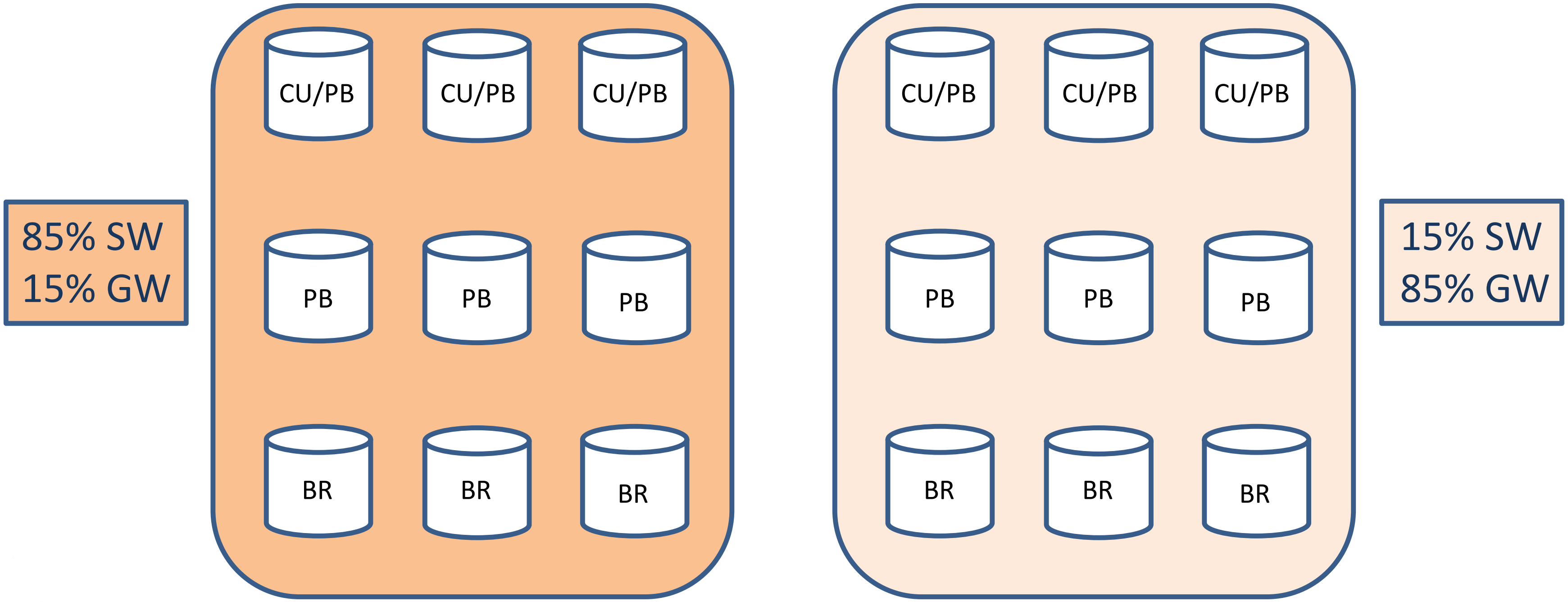
OR

15% SW
85 % GW

Overview of Study and Methods

Test 2 – Orthophosphate Testing (Phase 2)

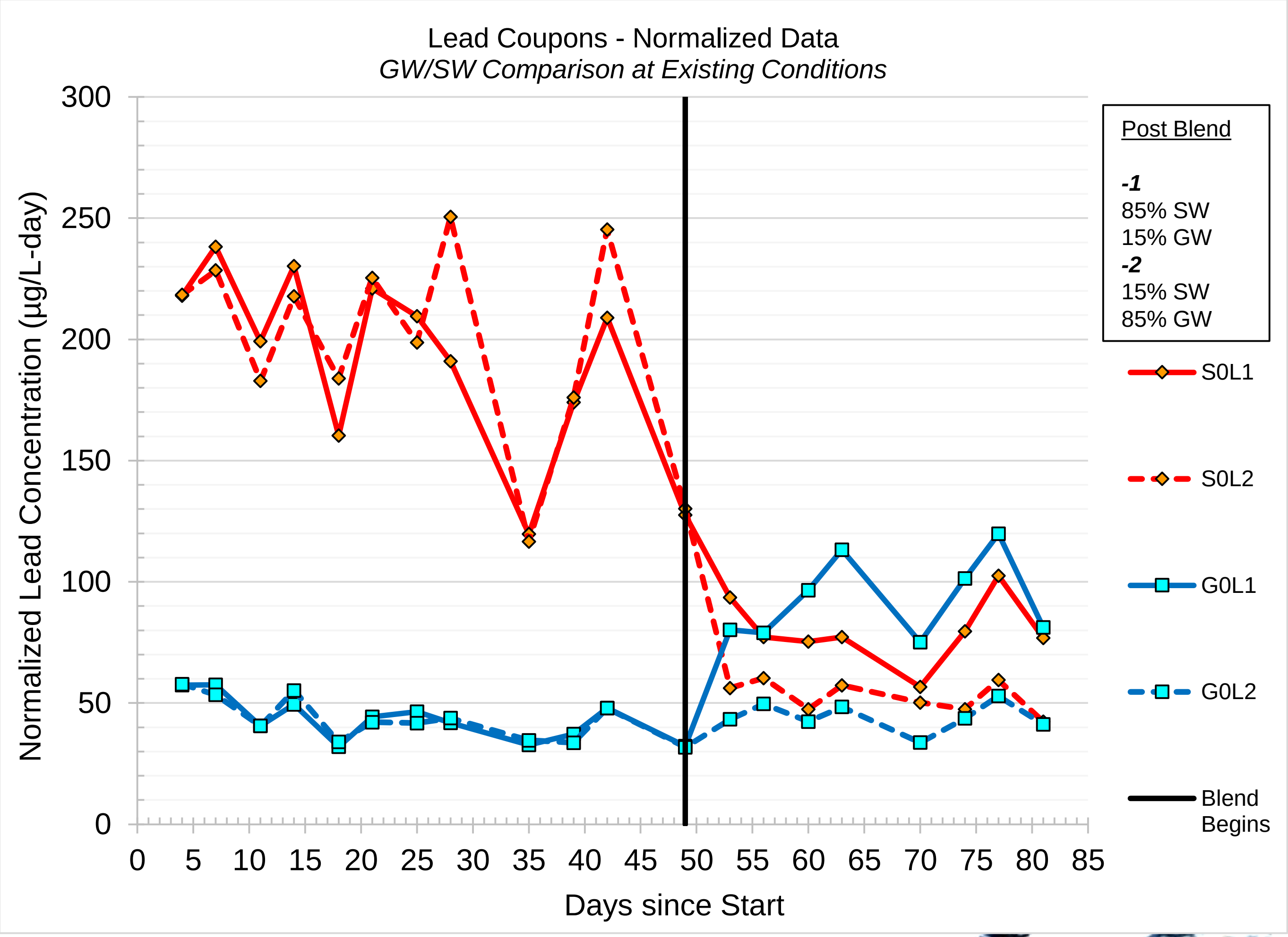
pH	8.0	8.0	8.0	8.0	8.0	8.0	
SW Ortho	0.5	0.75	1.0	0.5	0.75	1.0	
GW Ortho	0.5	0.75	1.0	0.5	0.75	1.0	(mg/L as P)



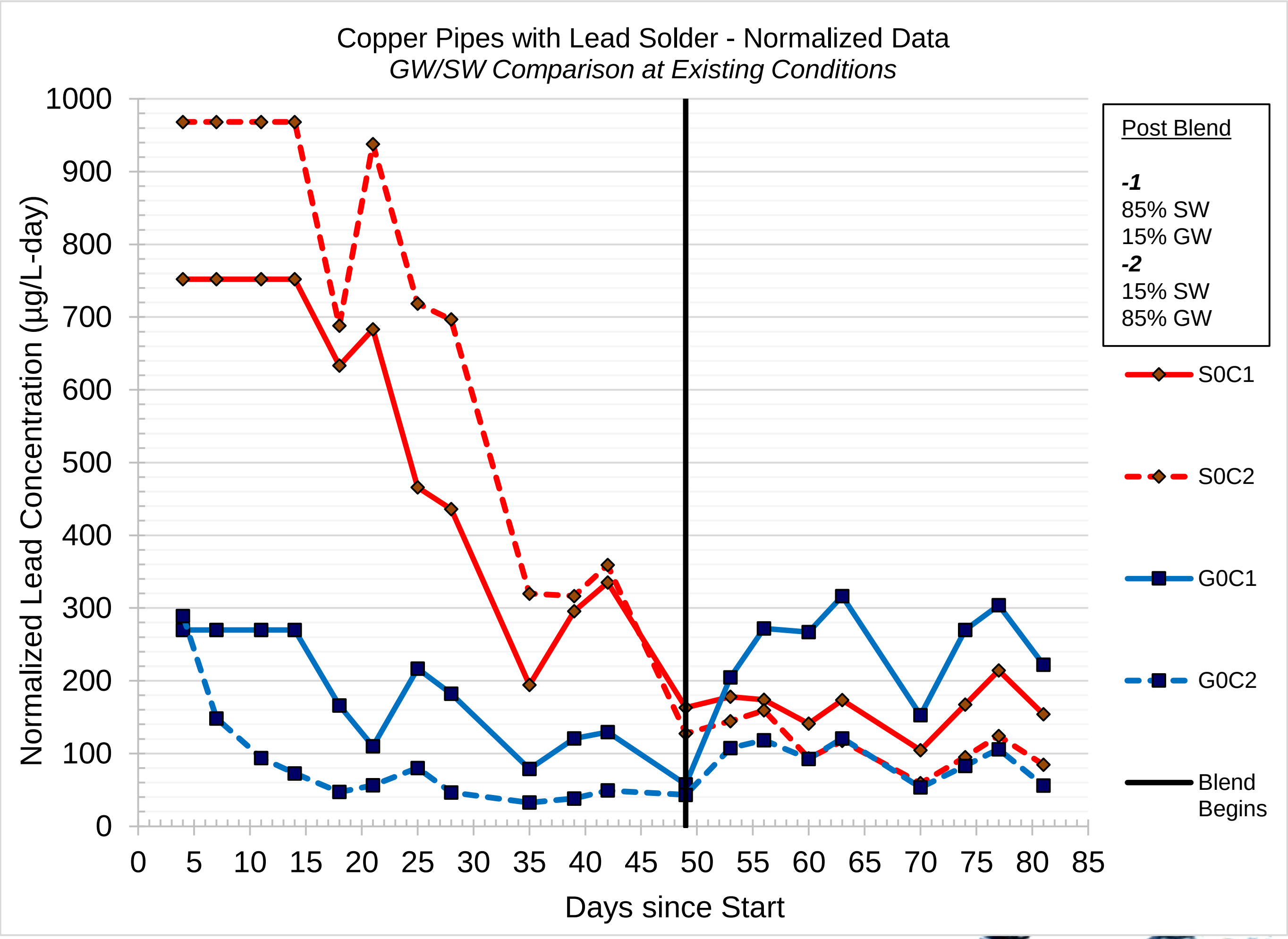
Results

1. EXISTING CONDITIONS
2. GW EQUILIBRATED ORTHOPHOSPHATE
3. SW EQUILIBRATED ORTHOPHOSPHATE
4. SW PH/ALKALINITY ADJUST

Existing Conditions
Lead Coupons – All Blends



Existing Conditions
Copper Pipes (Lead Solder) – All Blends

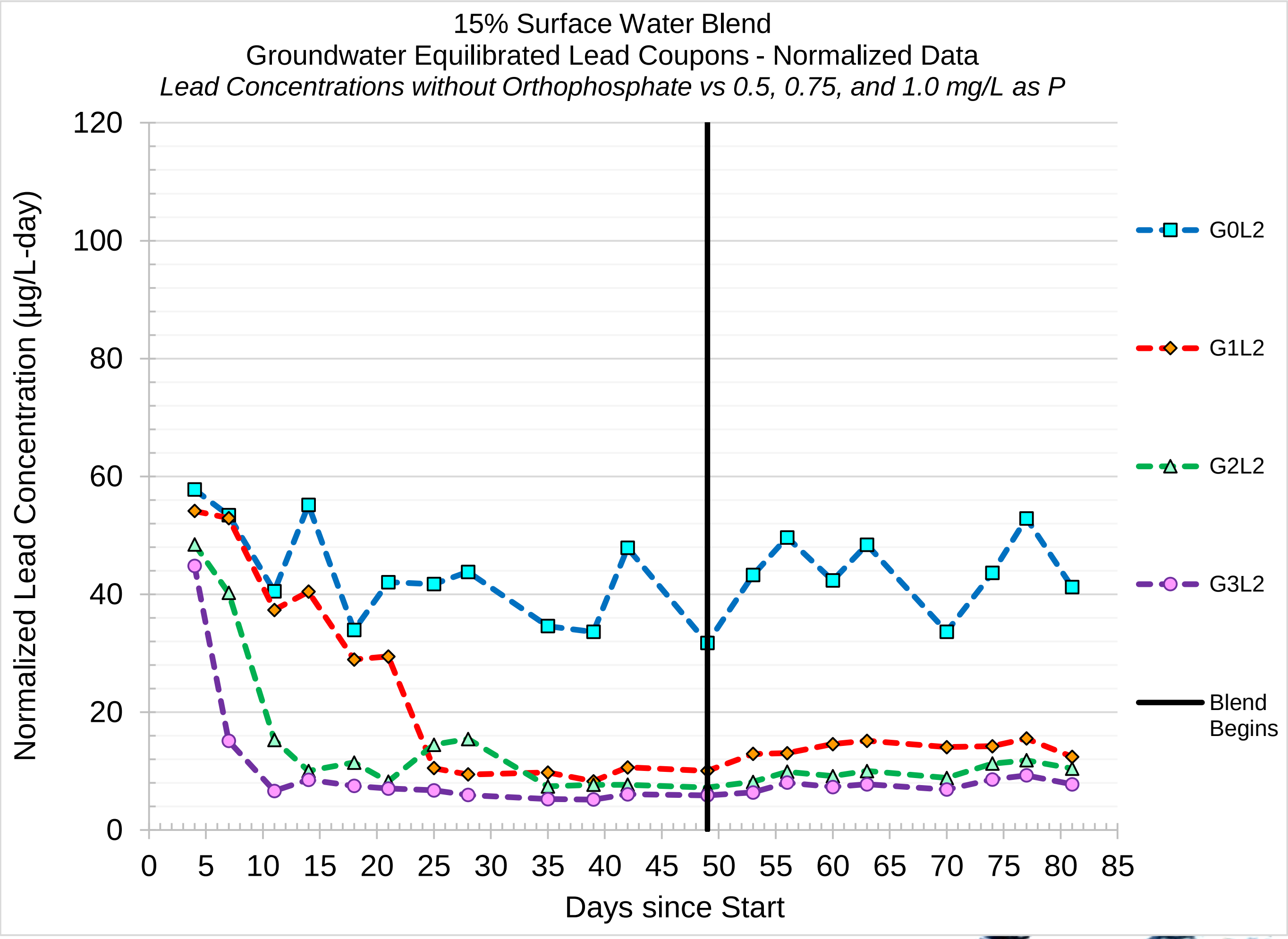


Results

1. EXISTING CONDITIONS
2. GW EQUILIBRATED ORTHOPHOSPHATE
3. SW EQUILIBRATED ORTHOPHOSPHATE
4. SW PH/ALKALINITY ADJUST

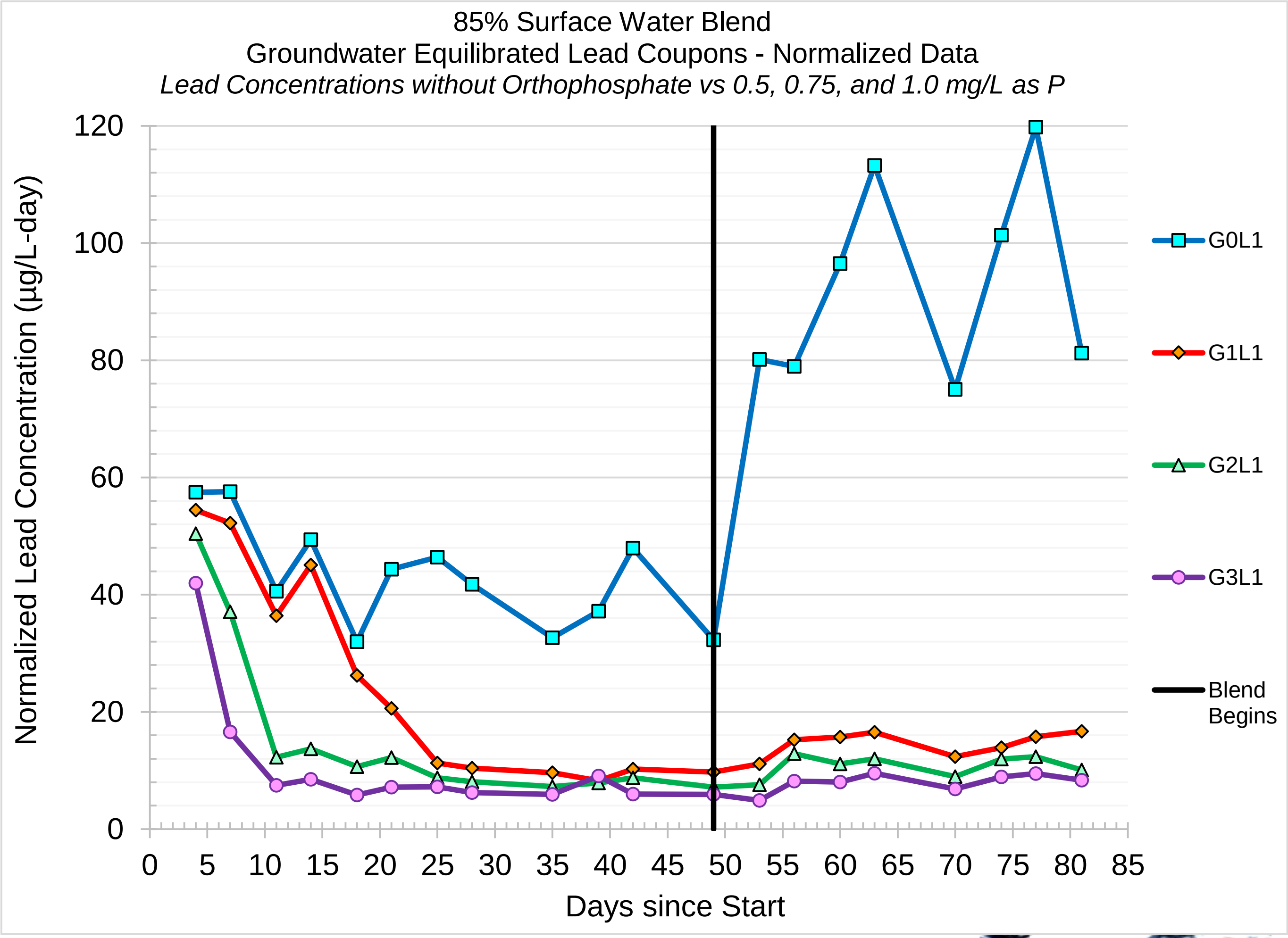
GW Lead Coupons with Orthophosphate

15% Surface Water Blend

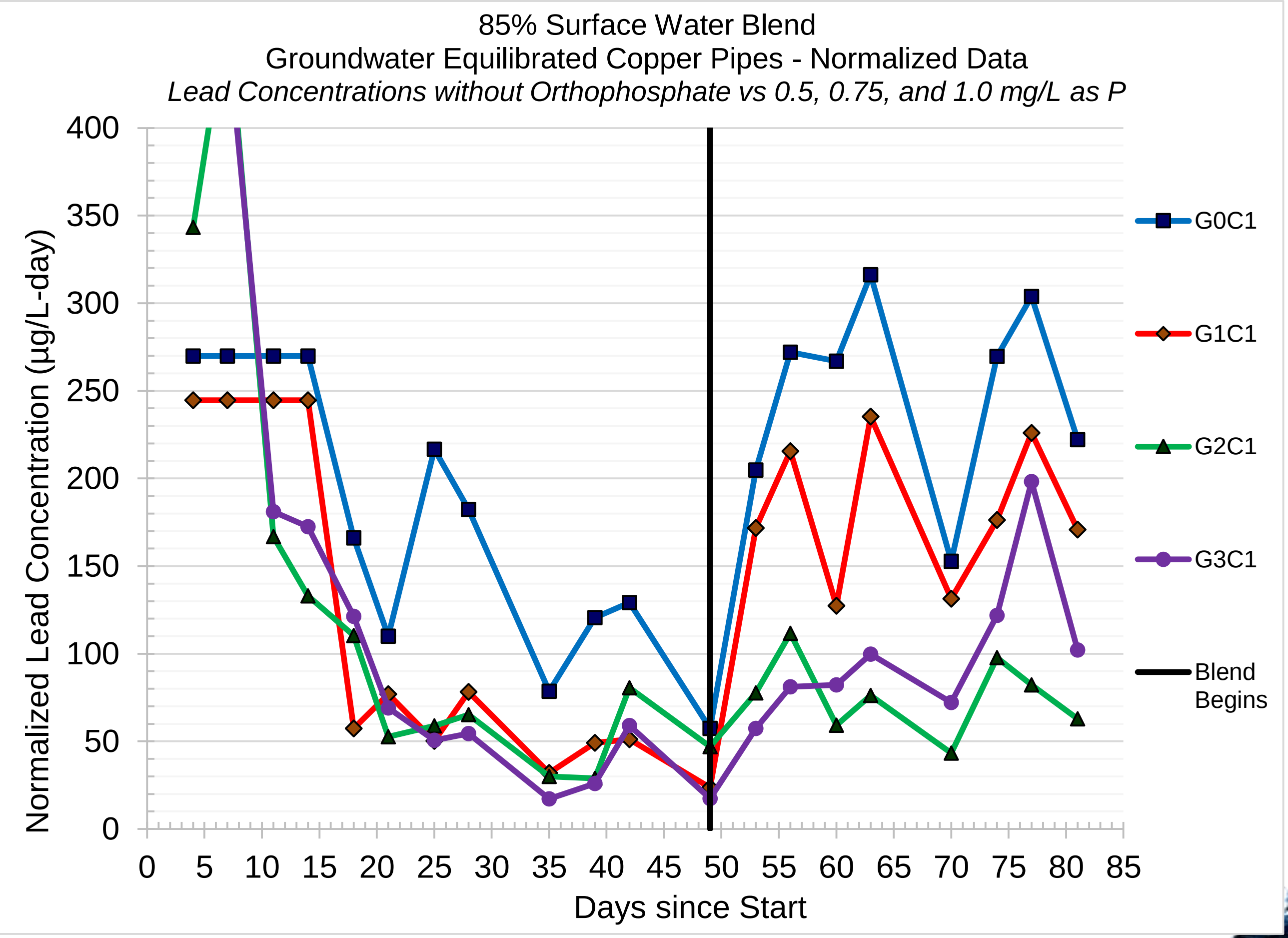


GW Lead Coupons with Orthophosphate

85% Surface Water Blend



GW Copper Pipes (Pb Solder) with Orthophosphate
85% Surface Water Blend

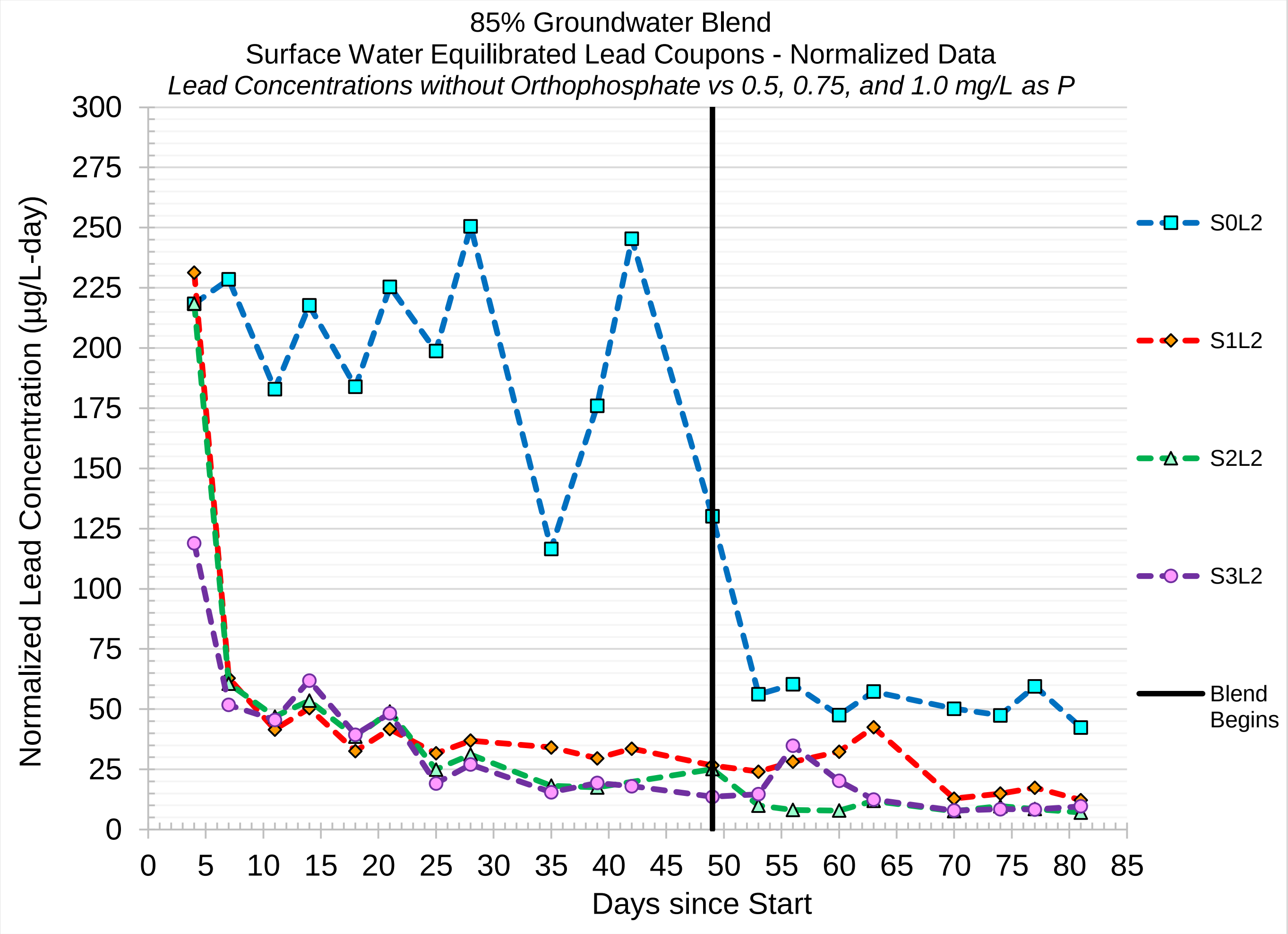


Results

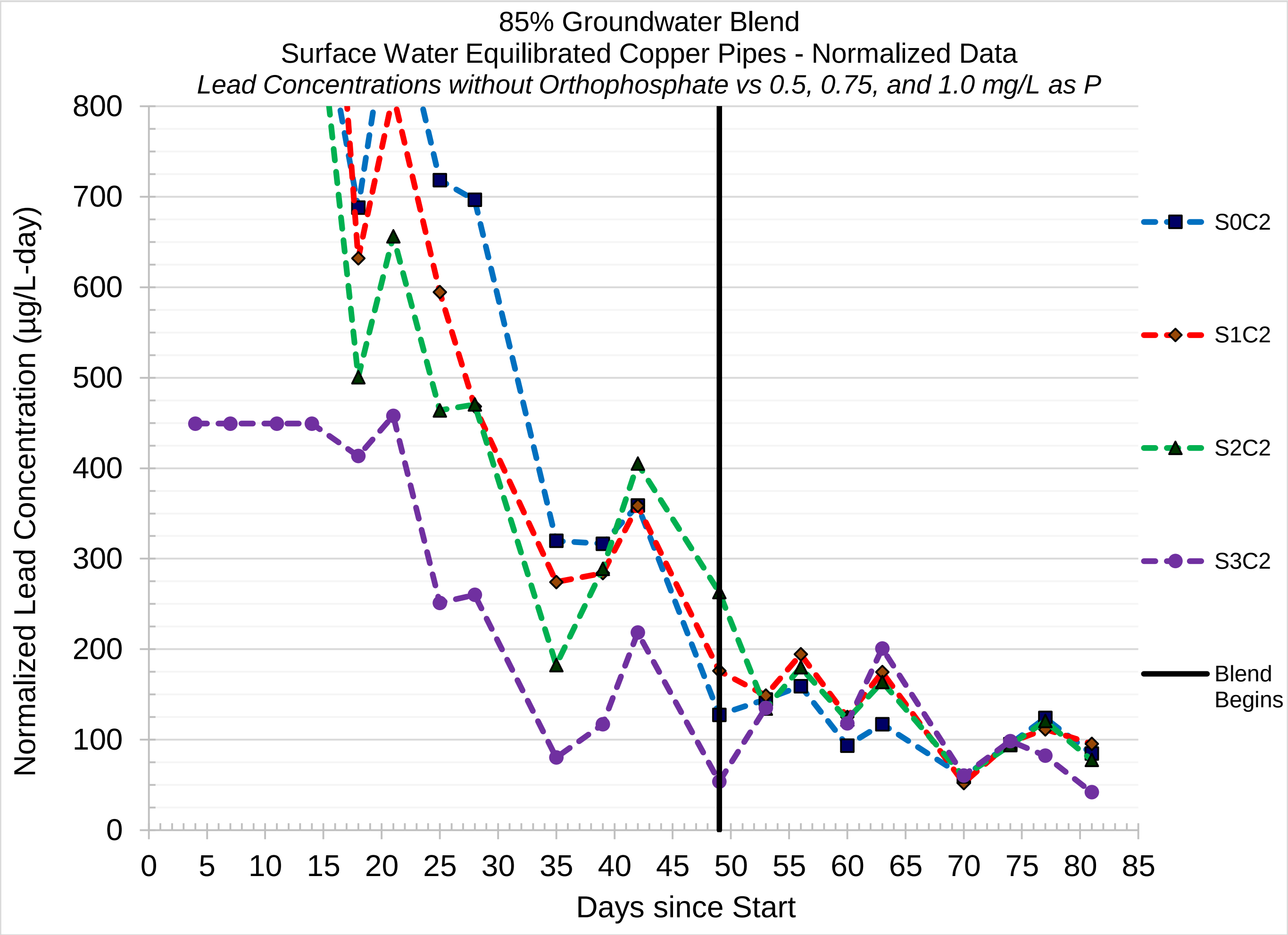
1. EXISTING CONDITIONS
2. GW EQUILIBRATED ORTHOPHOSPHATE
3. SW EQUILIBRATED ORTHOPHOSPHATE
4. SW PH/ALKALINITY ADJUST

SW Lead Coupons with Orthophosphate

85% Groundwater Blend



SW Copper Pipes (Pb Solder) with Orthophosphate
85% Groundwater Blend



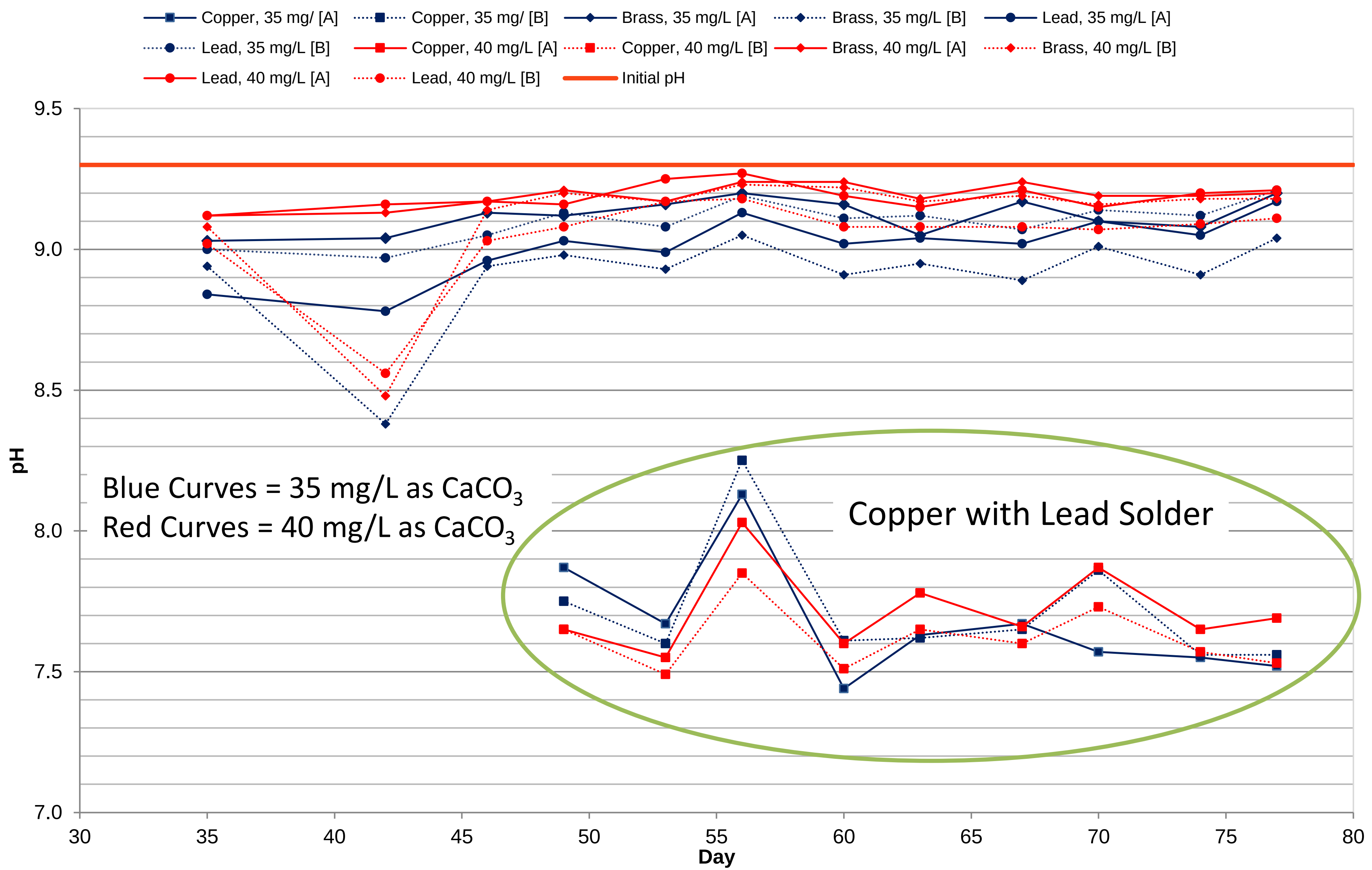
Results

1. EXISTING CONDITIONS
2. GW EQUILIBRATED ORTHOPHOSPHATE
3. SW EQUILIBRATED ORTHOPHOSPHATE
4. SW PH/ALKALINITY ADJUST

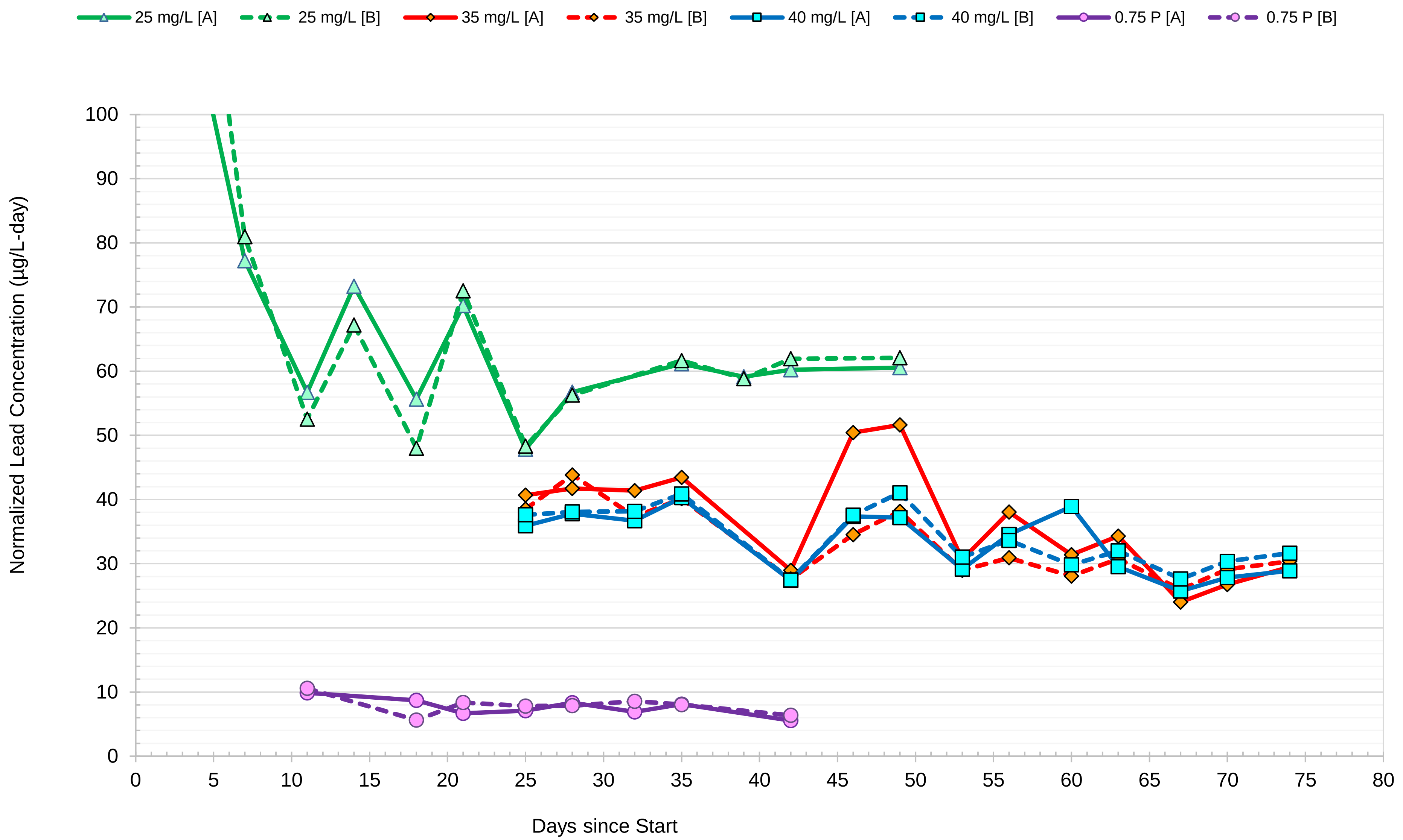
pH Stability Testing

- Phases 1 and 2 indicated pH was not stable in test reactors with alkalinity at 25 mg/L as $CaCO_3$
- New testing evaluated stability of pH 9.3 and pH 9.5 at 30, 34, 40, and 44 mg/L as $CaCO_3$
  - Samples with and without headspace were also evaluated

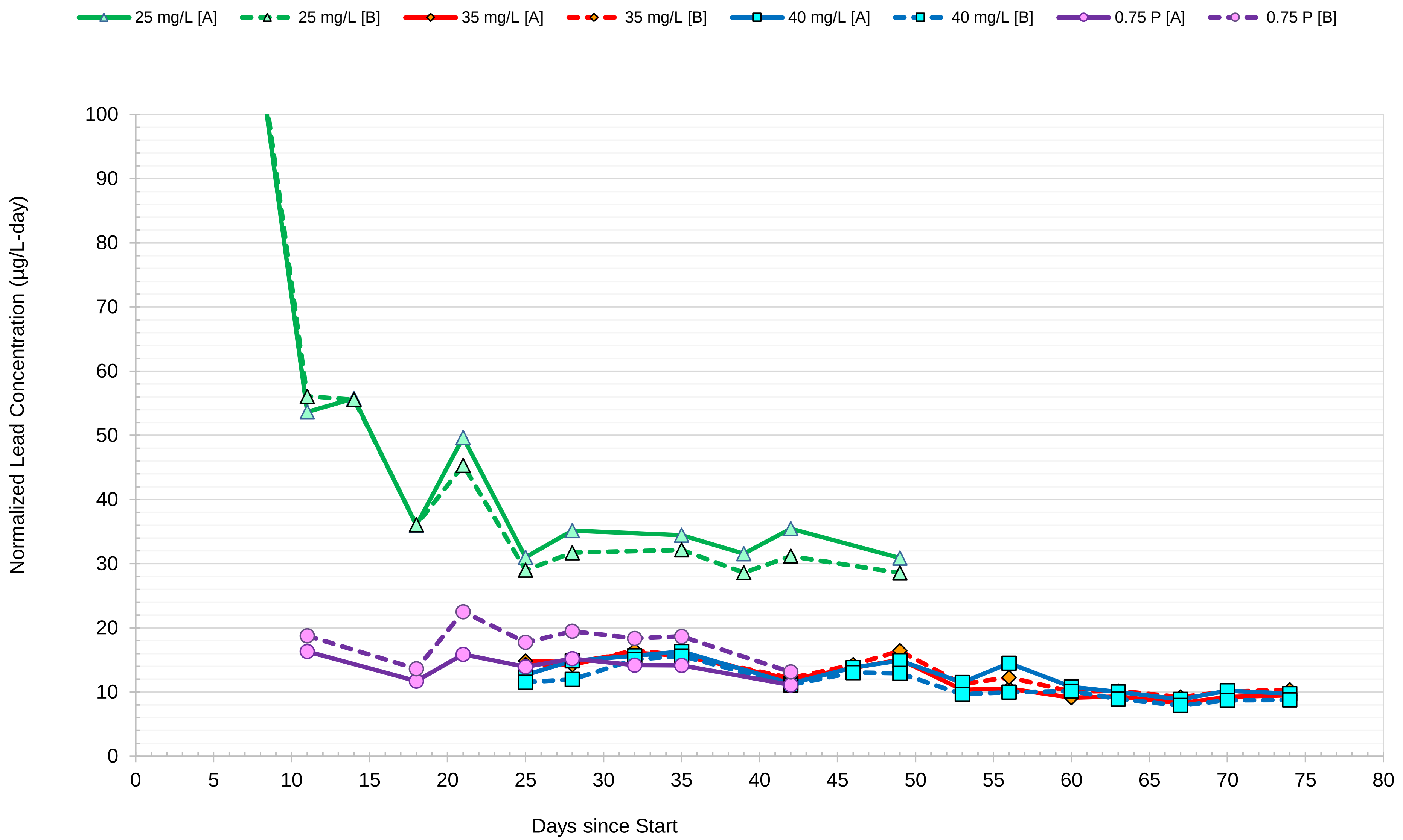
Post-Stagnation pH Values, Without Headspace During Coupon Study



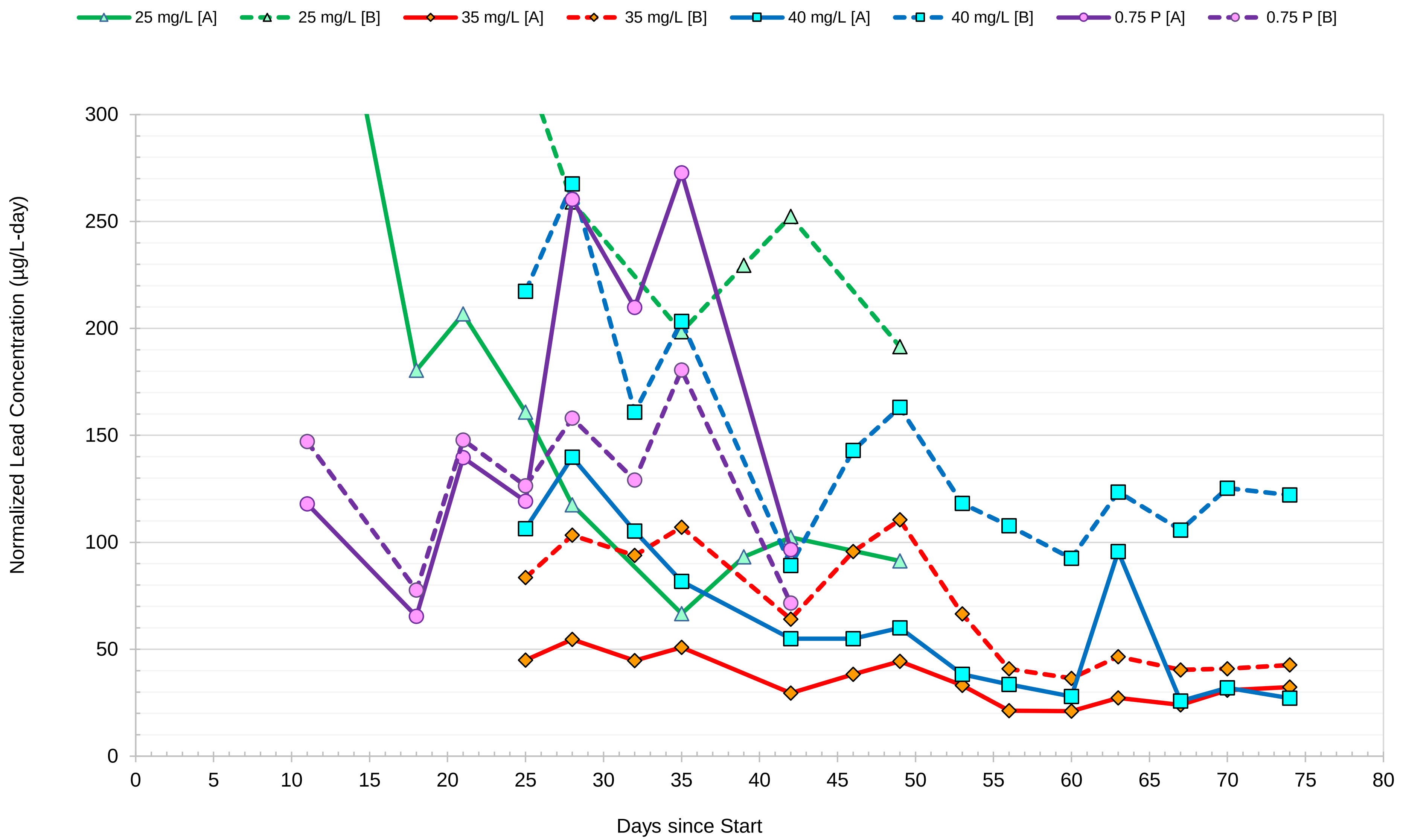
CCT Comparison – Lead Coupons



CCT Comparison – Brass Coupons



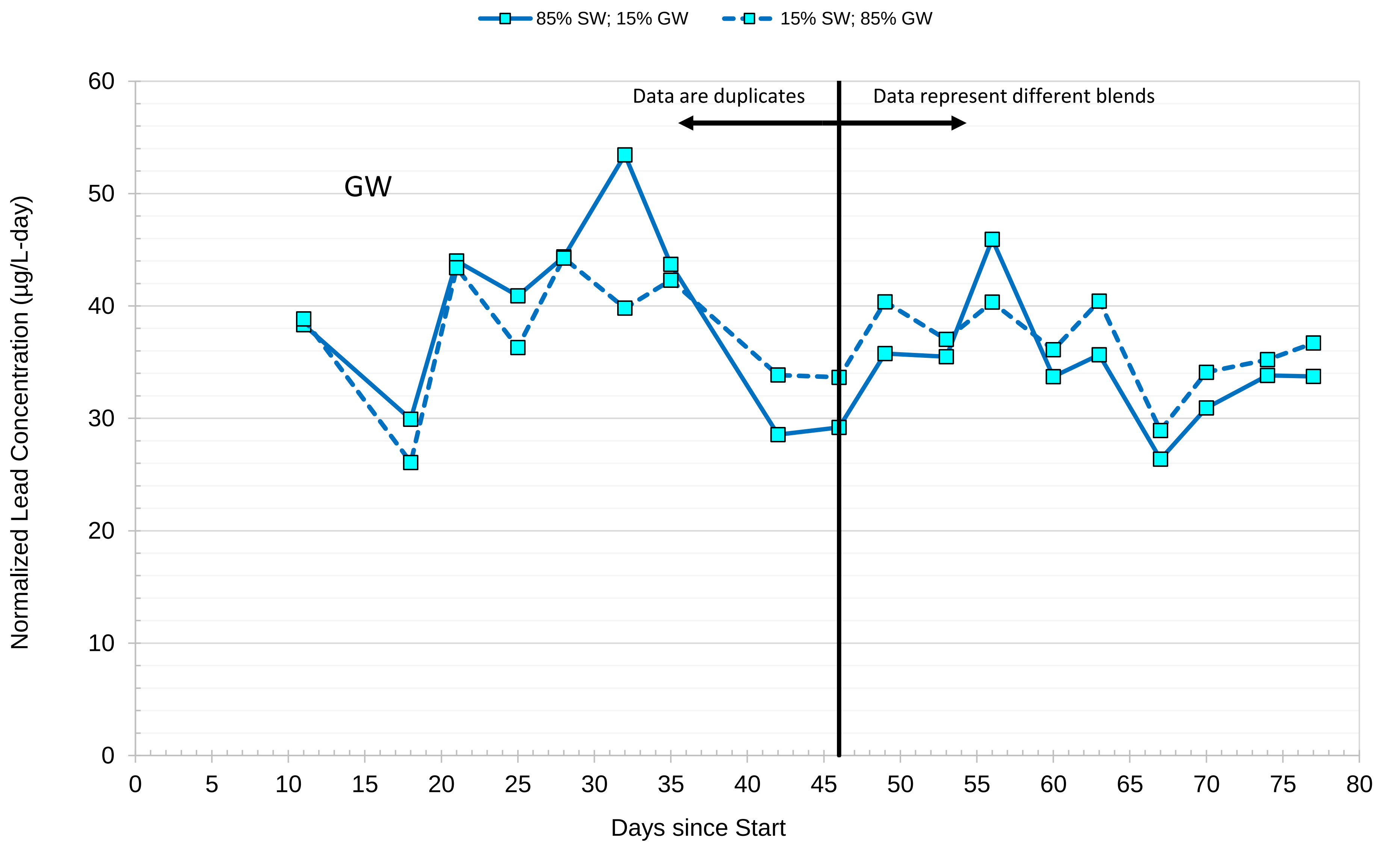
CCT Comparison – Copper with Lead Solder Reactors



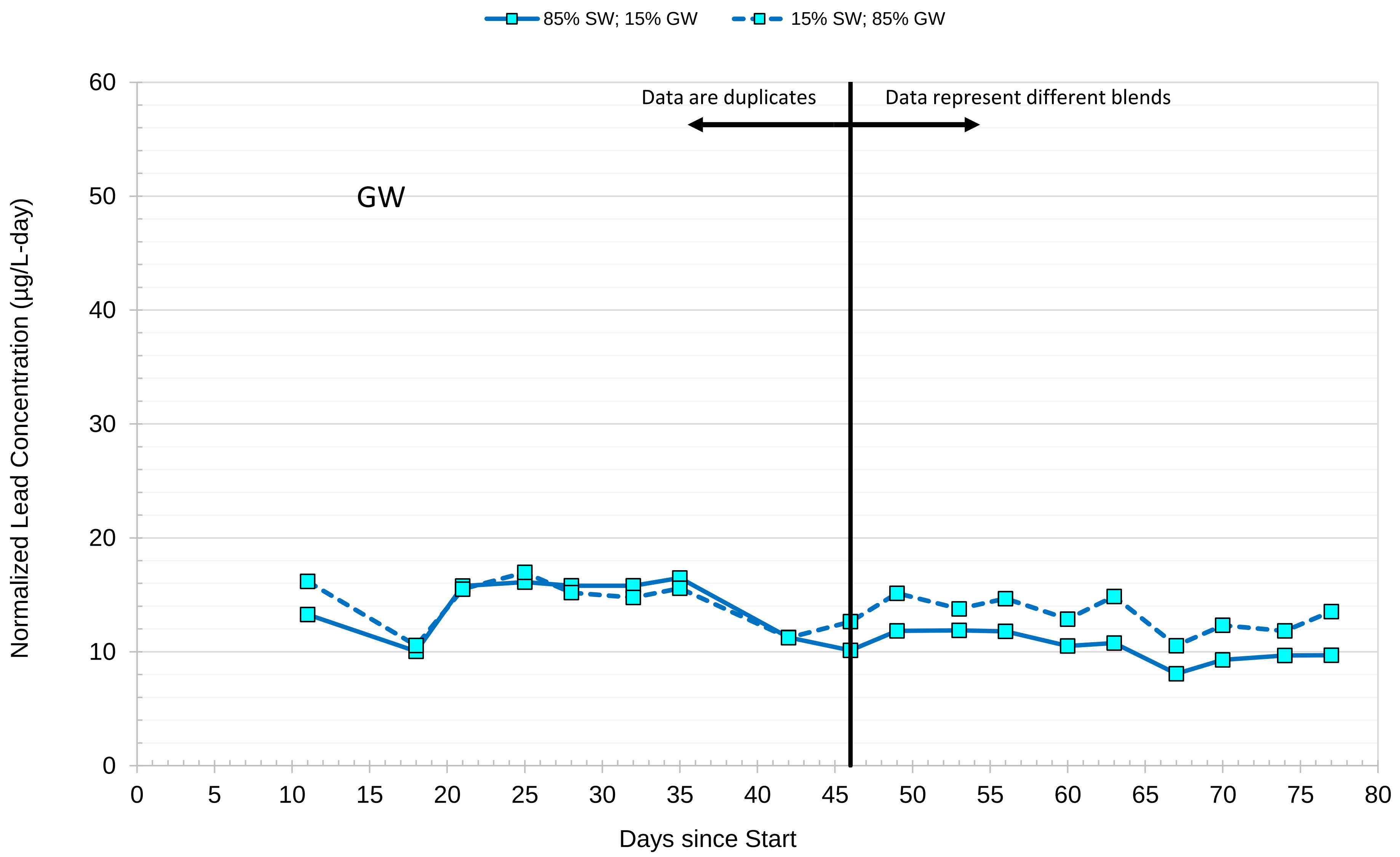
Additional Blending Testing

- Coupons equilibrated with GW were exposed to a blend of GW + SW at pH 9.3
  - Blend ratios were 85:15 and 15:85 SW:GW
- Coupons equilibrated with SW treated with 0.75 mg/L as P were exposed to a blend of SW with 0.75 P + GW without P
  - Blend ratios were 20% and 50% GW

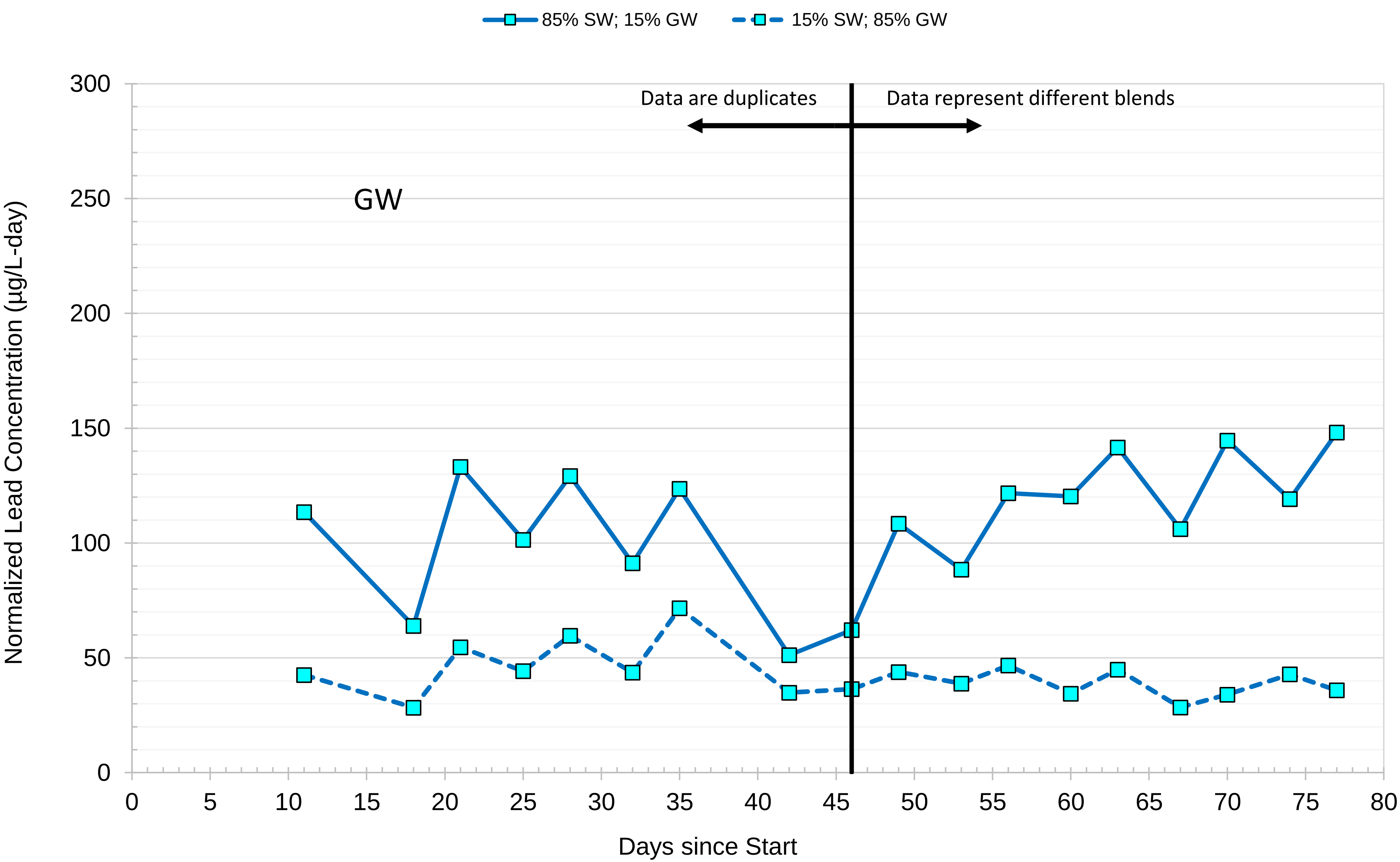
Lead Coupons
GW + SW at pH 9.3



Brass Coupons
GW + SW at pH 9.3

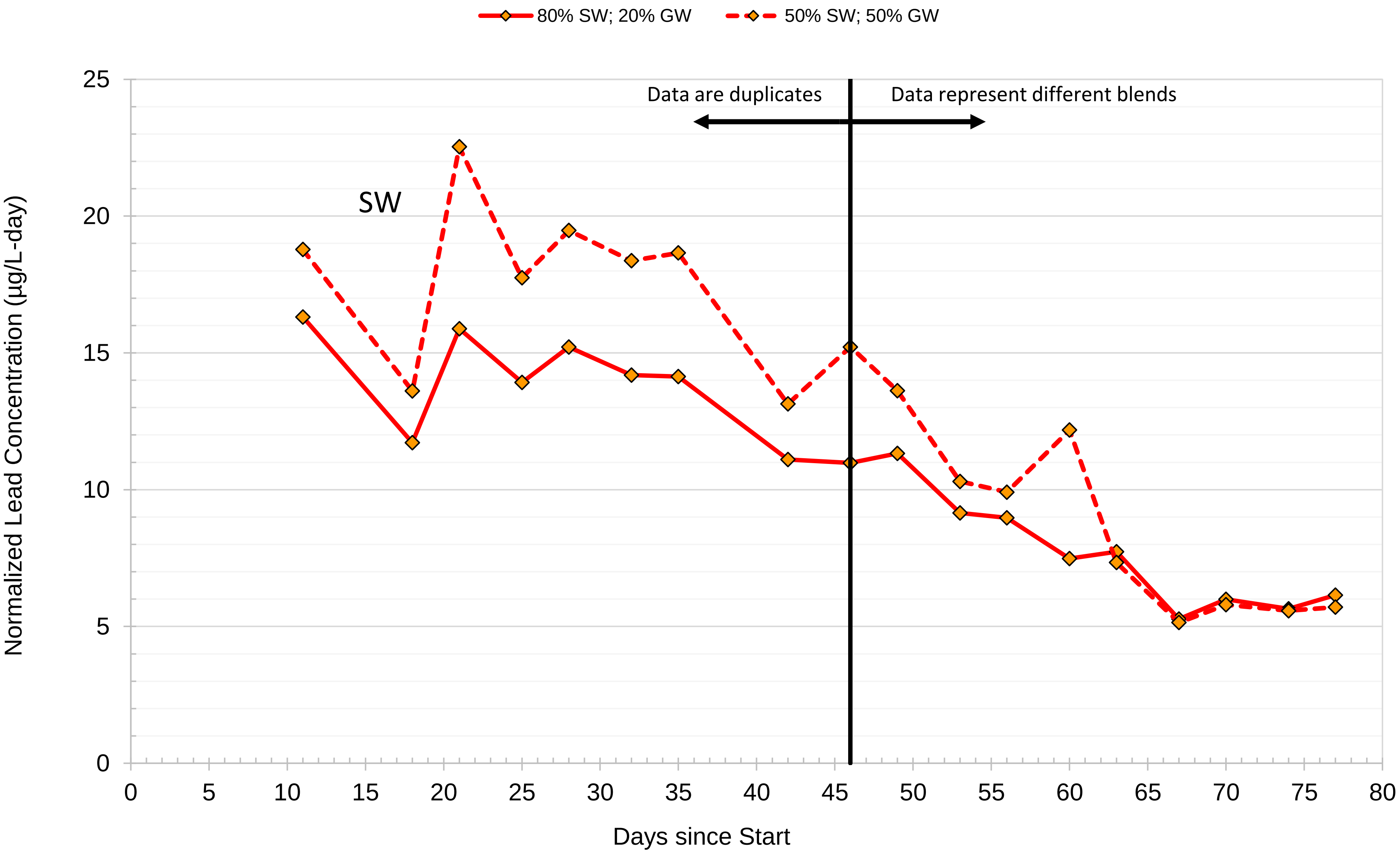


Copper with Lead Solder Reactors GW + SW at pH 9.3

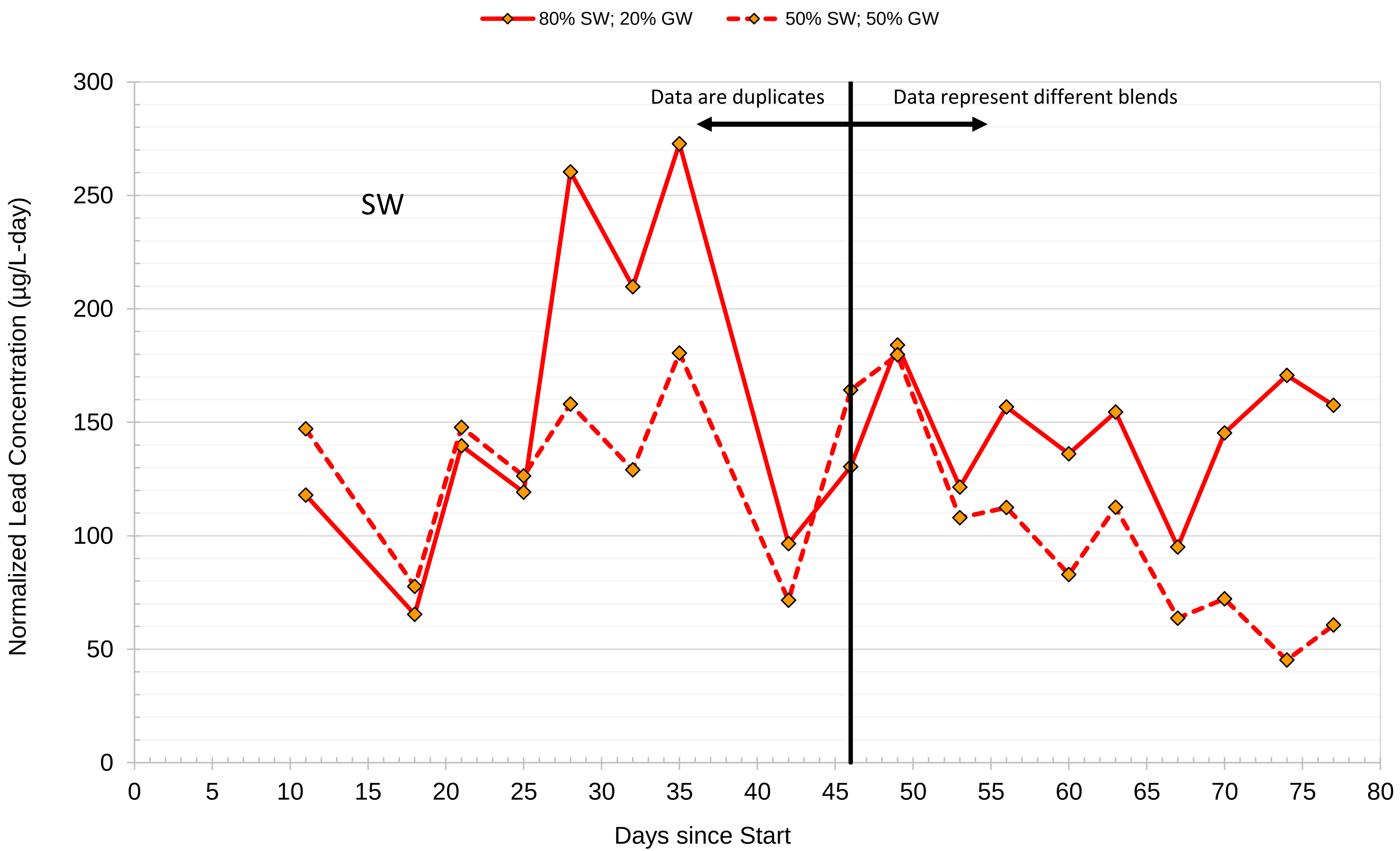


Lead Coupons
SW with 0.75 P + GW with 0.0 P

Brass Coupons
SW with 0.75 P + GW with 0.0 P



Copper with Lead Solder Reactors SW with 0.75 P + GW with 0.0 P

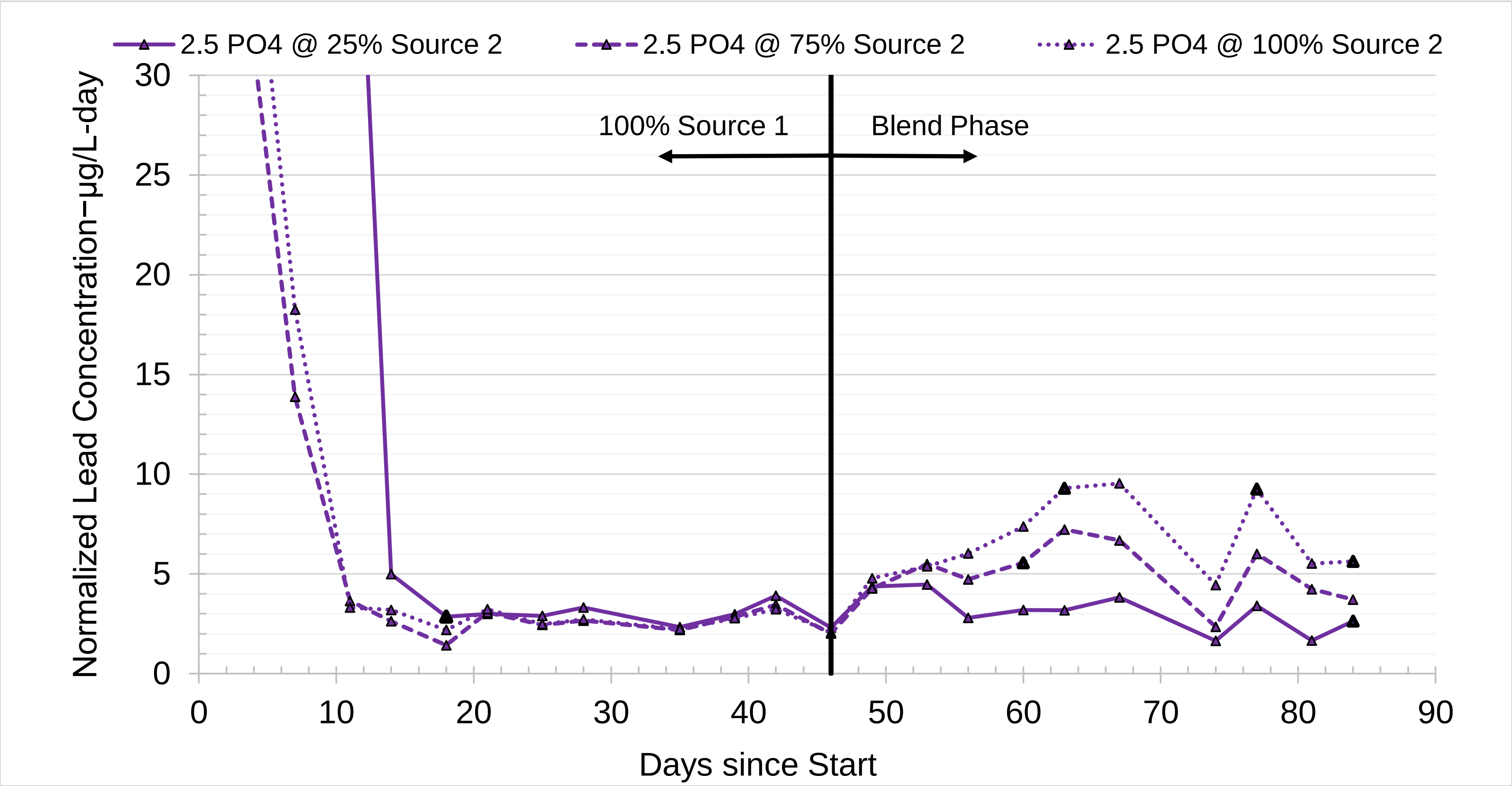


CASE STUDY:
Blending Two Sources with Different PO_4 Doses and Disinfectant Residuals

Case Study Source Water

- Source 1
  PO_4 = 2.5 mg/L
  (neutralized sodium orthophosphate)
  Disinfectant = 1.2 mg/L free Cl_2
- Source 2
  PO_4 = 0.5 mg/L
  (zinc orthophosphate)
  Disinfectant = 3 mg/L total Cl_2 (4.75 Cl_2:NH_4-N)
- Blending is at system intertie
  - Flow is from Source 2 to Source 1's system
  - Blend ratio depends on system demands

Impact of Blending Sources



TAKEAWAYS

Case Study 1

- Both orthophosphate and pH/alkalinity reduced Pb release
  - Ortho CCT had lowest lead levels in lead coupons
  - High pH/alkalinity CCT had lead levels equal to ortho for brass coupons
  - pH could not be maintained in the lab for the copper/lead solder coupons
- If high pH is used for CCT important to maintain pH in system

Case Study 1, continued

- Condition with most potential for Pb release is GW to SW
  - Can be reduced or eliminated with CCT (orthophosphate or pH/alkalinity)
  - This should be monitored in the system if this method is selected
- When GW without ortho was blended into coupons exposed to SW + ortho, the data did not show an increase in lead after blending in GW

Case Study 2

- Blending between Source 1 and Source 2 at intertie can result in increased lead releases
- Lead releases are influenced by proportion of blended water
  - At 25% Source 2 water, lead levels revert to preblend levels within 1 to 3 weeks
  - At higher percentages of Source 2 water, lead may be sustained at higher levels
  - Impact is presumed to be related to diluted PO_4 dosages, although other factors may influence

Questions?

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