Optimized Corrosion Control Treatment: Bench-Scale Testing for Portland Water Bureau

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Acknowledgements

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PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

Overview

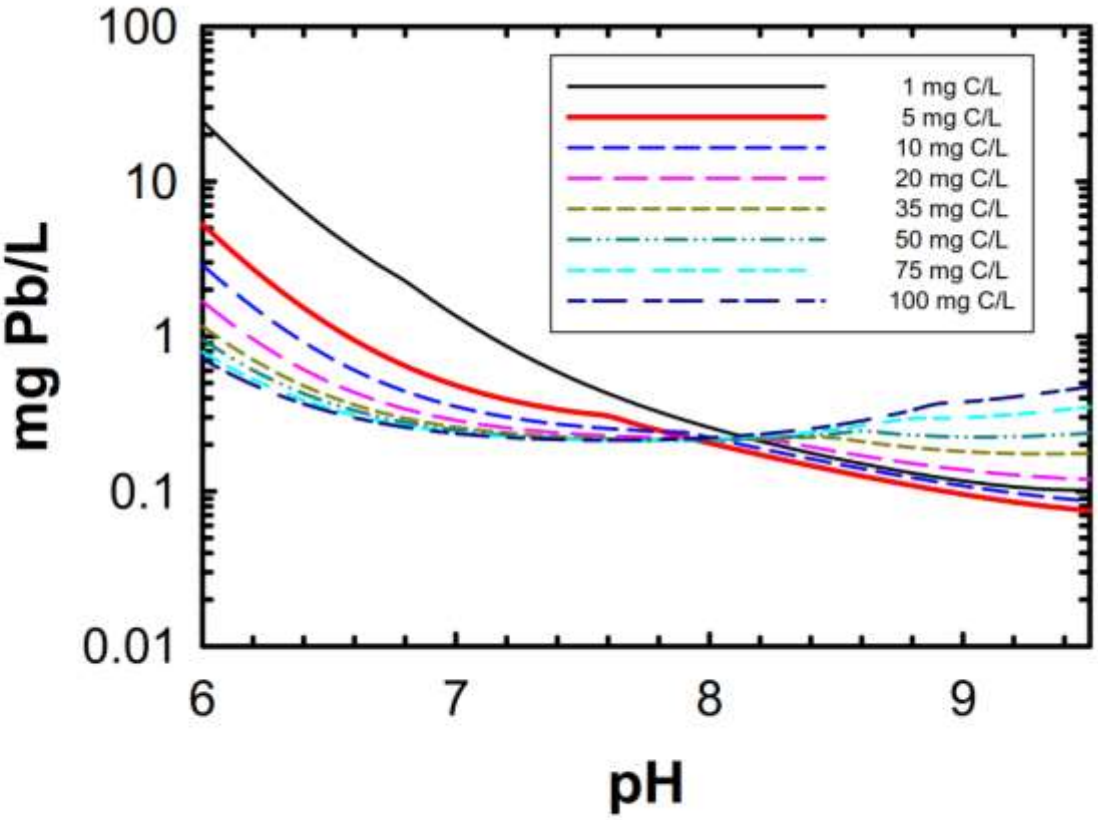
- Why was this study needed?
  - Impact of changing DIC
- How was the study structured?
  - Bench-scale test plan
- What were the results?
  - Pb release:
    - Existing conditions
    - GW – Orthophosphate CCT
    - SW – Orthophosphate CCT
    - SW – pH/alkalinity CCT

WHY WAS THIS STUDY NEEDED?

PWB Source Water

- Surface water (Bull Run)
  pH ~8.0
  Alkalinity ~7 mg/L as $CaCO_3$ (~1.5 mg/L as C)
- Groundwater (CSSWF)
  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

Classic Lead Solubility as a Function of pH



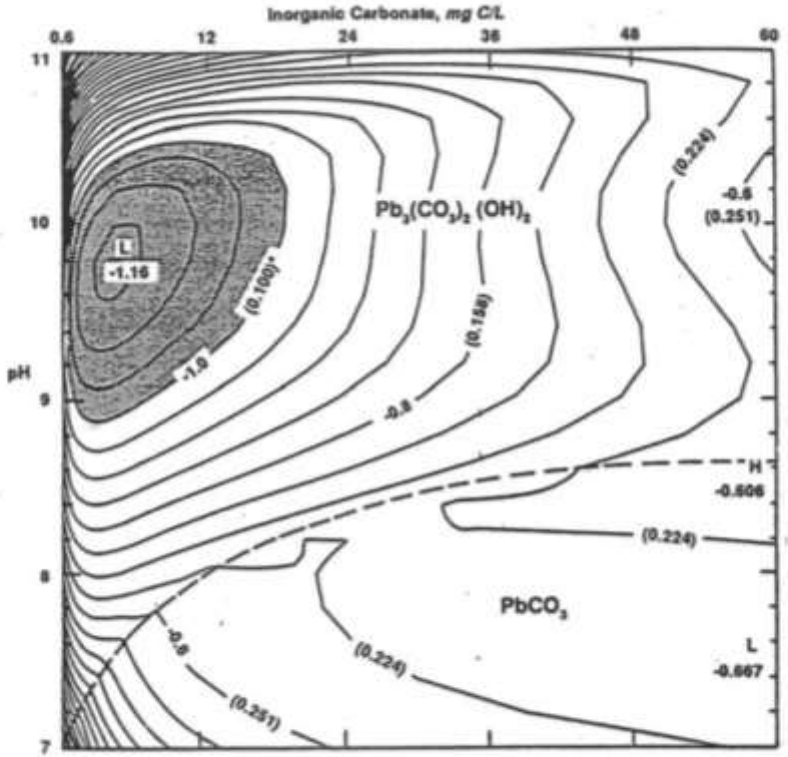
Source: Adapted from Schock and Lytle 2011

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

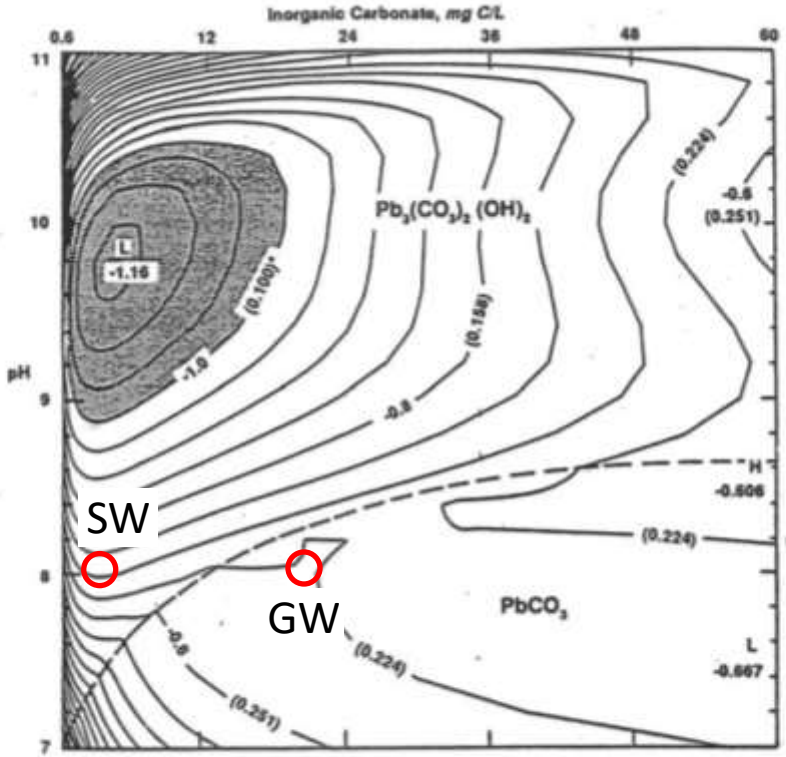
- Hydrocerrusite
  - $Pb(II)_3(CO_3)_2(OH)_2$ (s) anhydrous lead carbonate
  - More stable
  - Dissolves at higher DIC

Potential for Scale Change



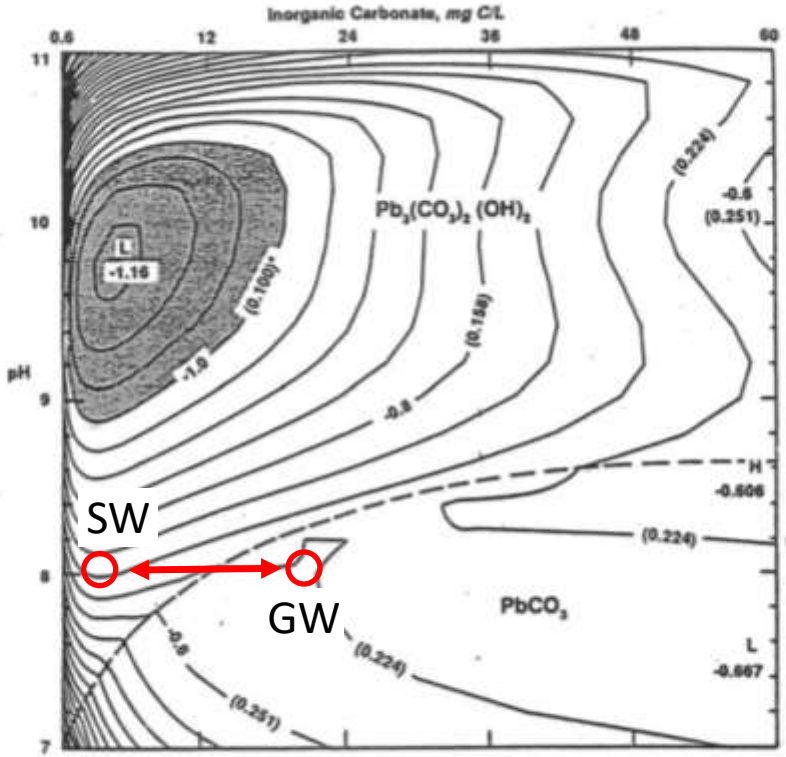
Source: EES 1990

Potential for Scale Change



Source: EES 1990

Potential for Scale Change



Source: EES 1990

Bench-Scale Test Goals

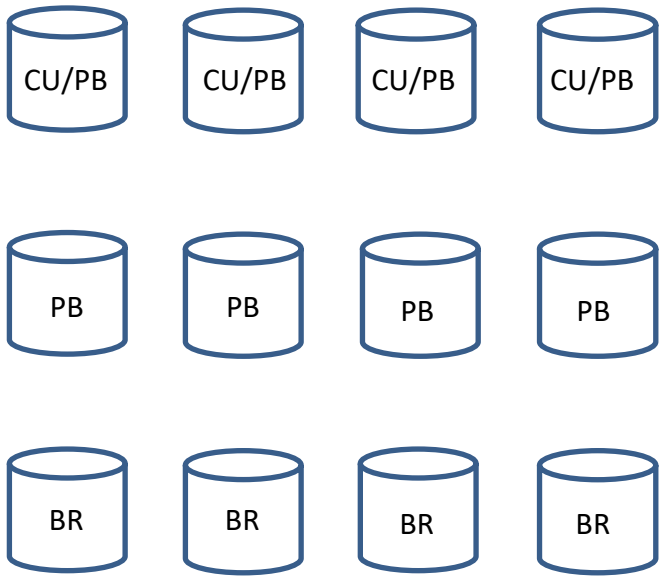
- Compare relative performance of CCT
  - Orthophosphate to pH/alkalinity
  - Orthophosphate doses
  - pH/alkalinity
- Evaluate potential for Pb release under changing water quality conditions
  - 100% SW to SW:GW blend
  - 100% GW to SW:GW blend

HOW WAS THIS STUDY STRUCTURED?

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 $CaCO_3$)



2 Replicates

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 $CaCO_3$)
	CU/PB	CU/PB	CU/PB	CU/PB	
	PB	PB	PB	PB	
	BR	BR	BR	BR	

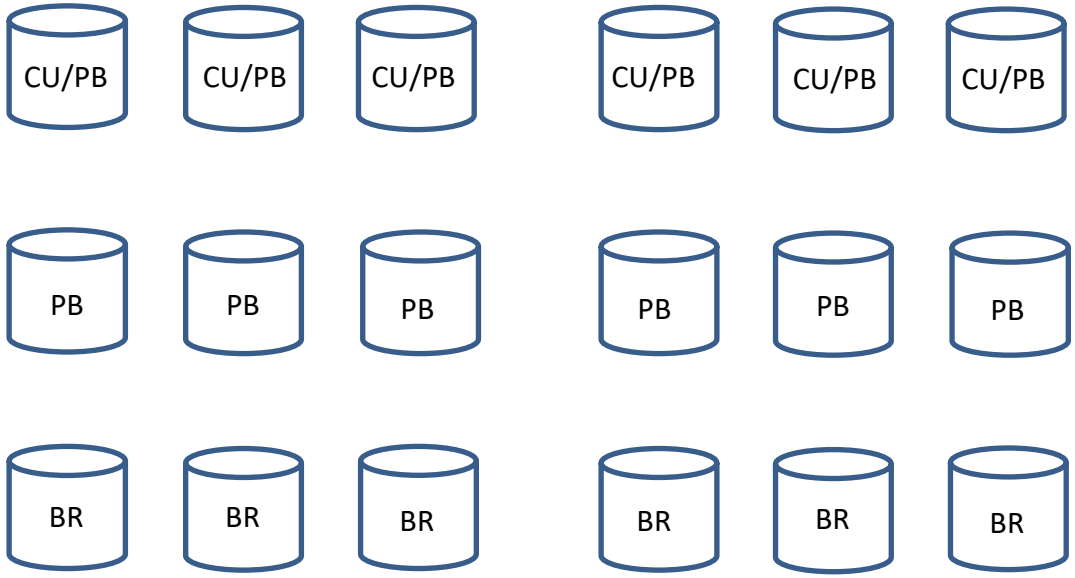
× 2 Replicates

pH did not hold

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)

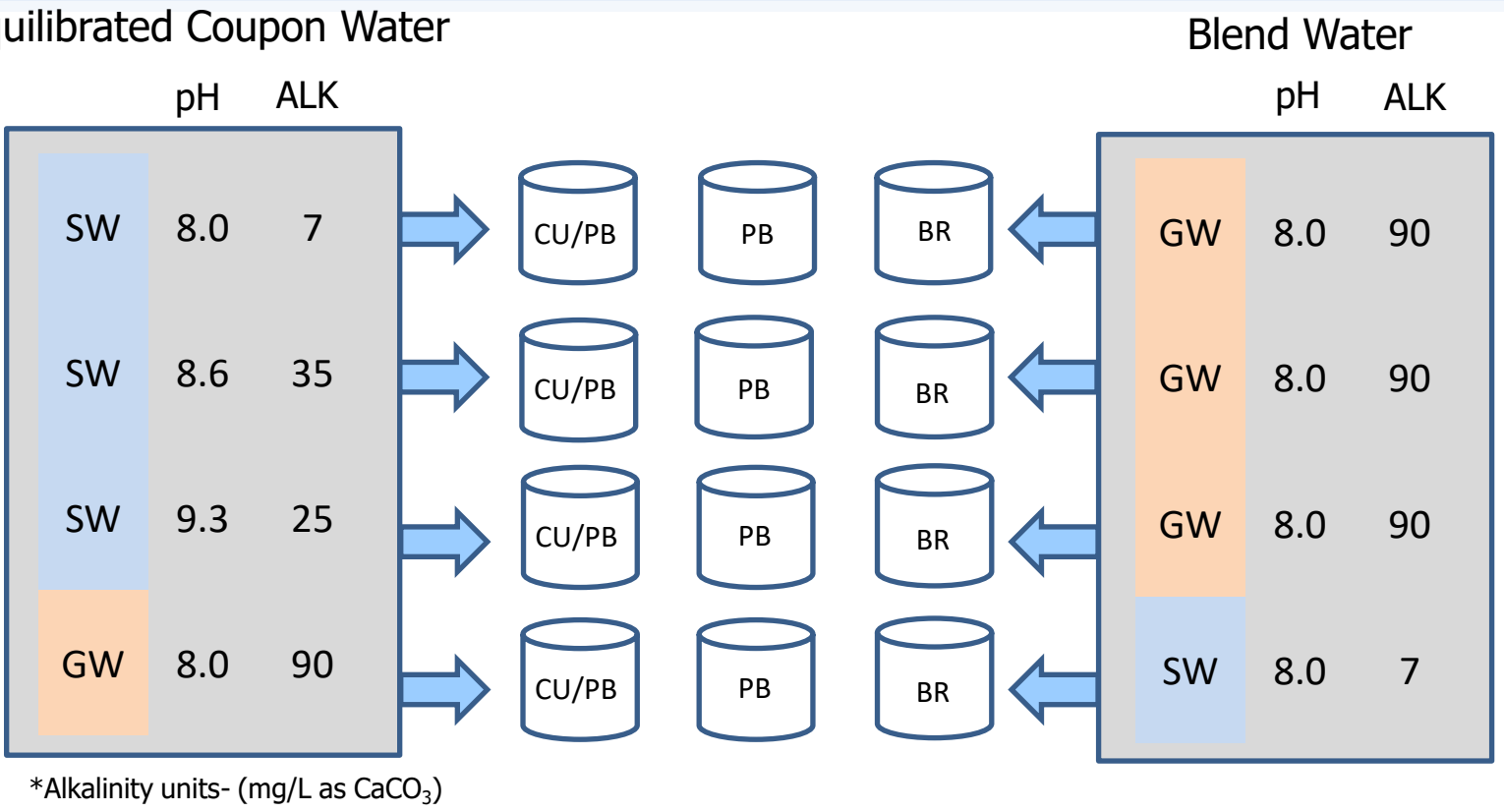


× 2

Replicates

Overview of Study and Methods

Test 1 - pH/Alkalinity Testing (Phase 2)



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

Two Coupons Per Condition Blended at:

85% SW
15 % GW

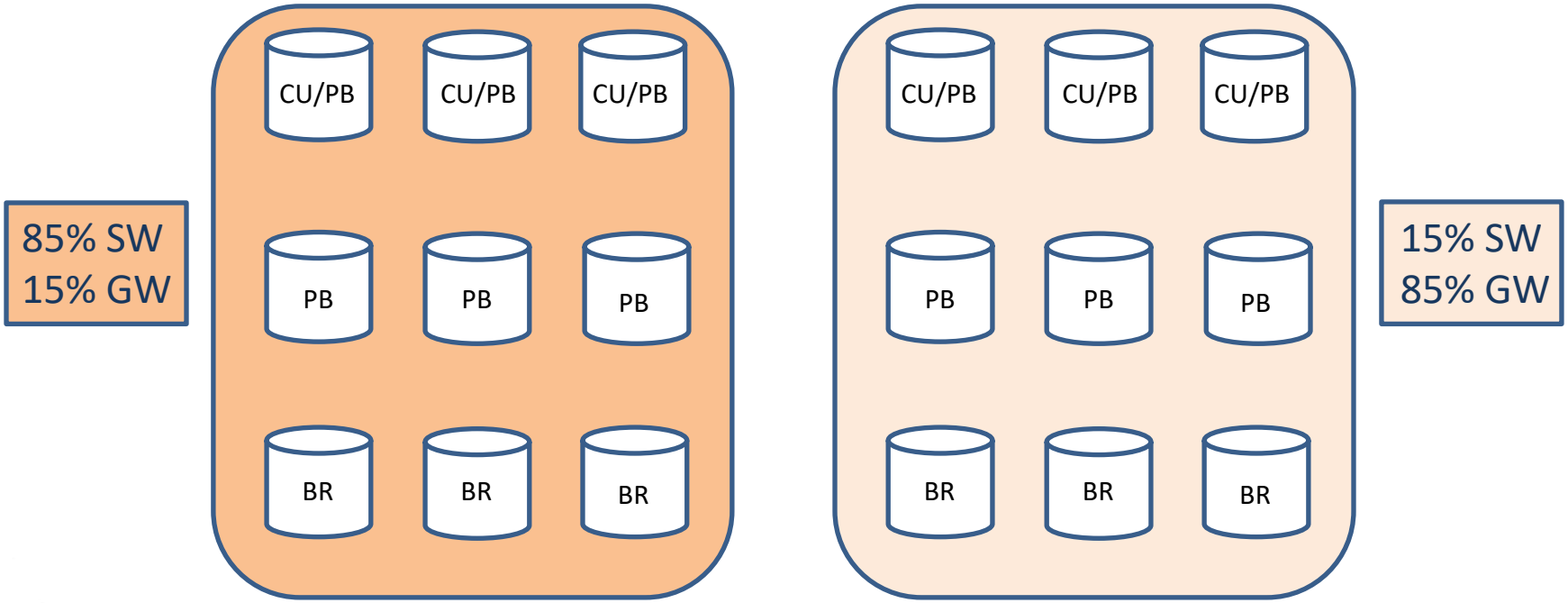
OR

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)

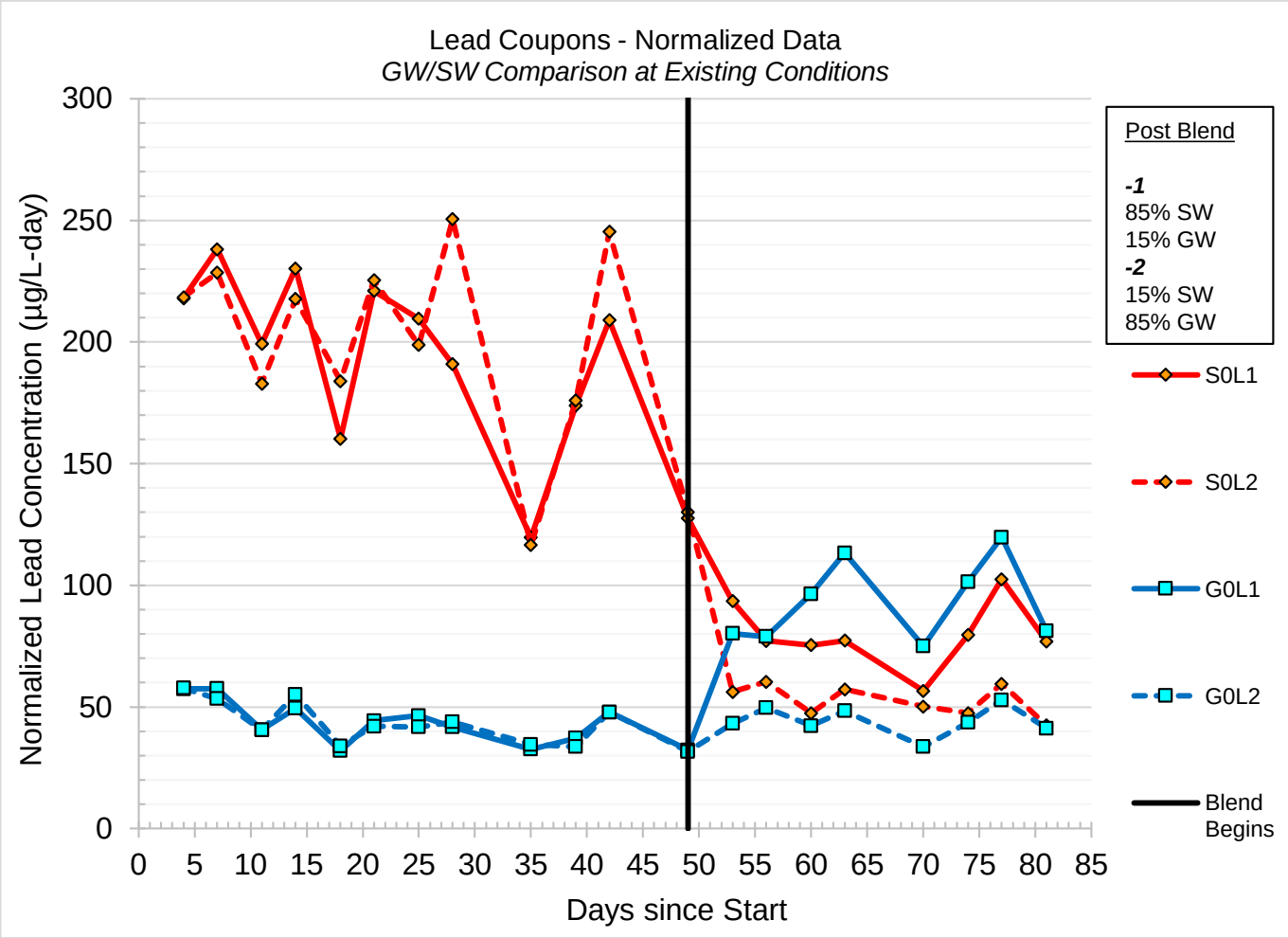


WHAT WERE THE RESULTS?

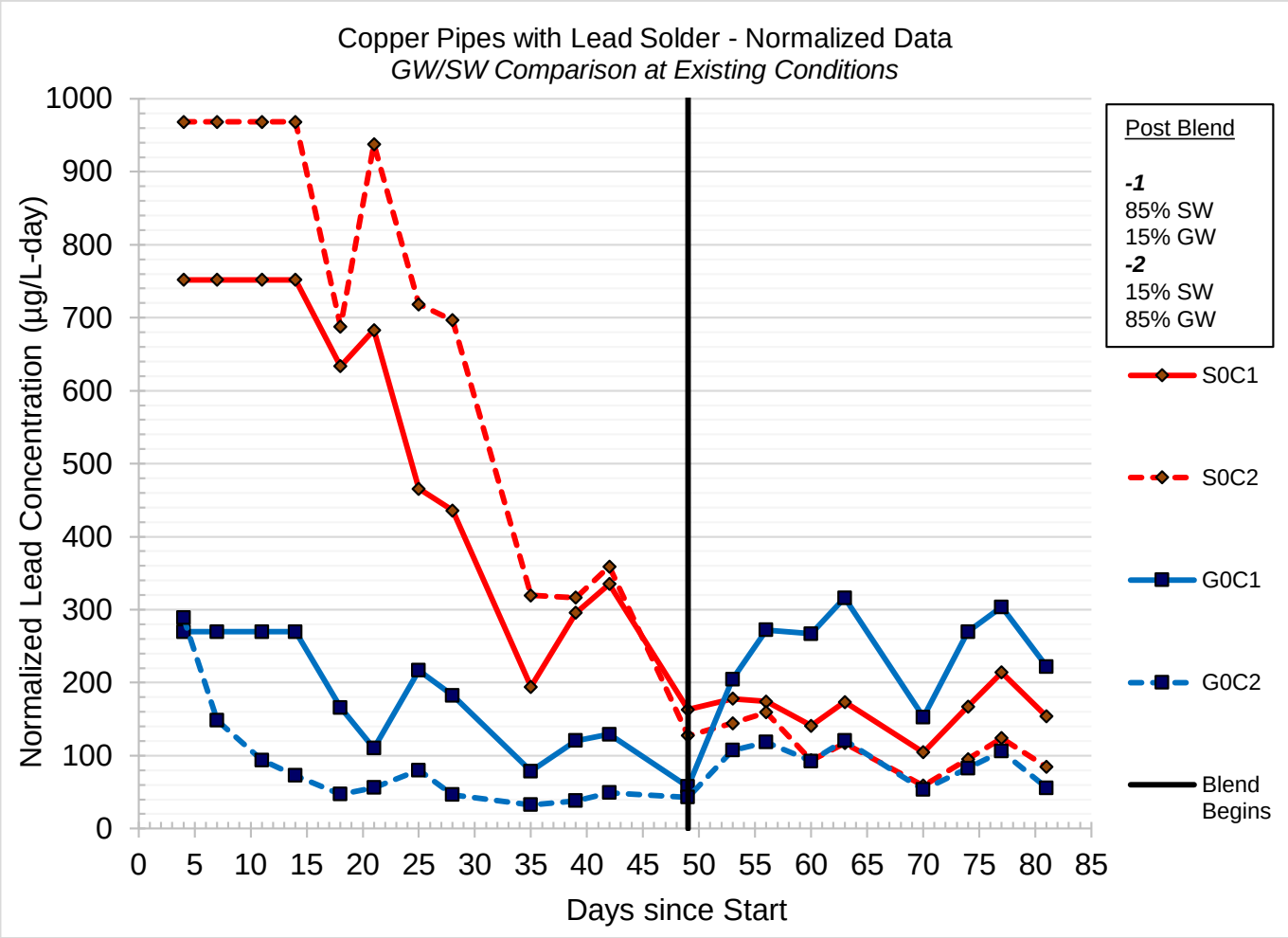
Results

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

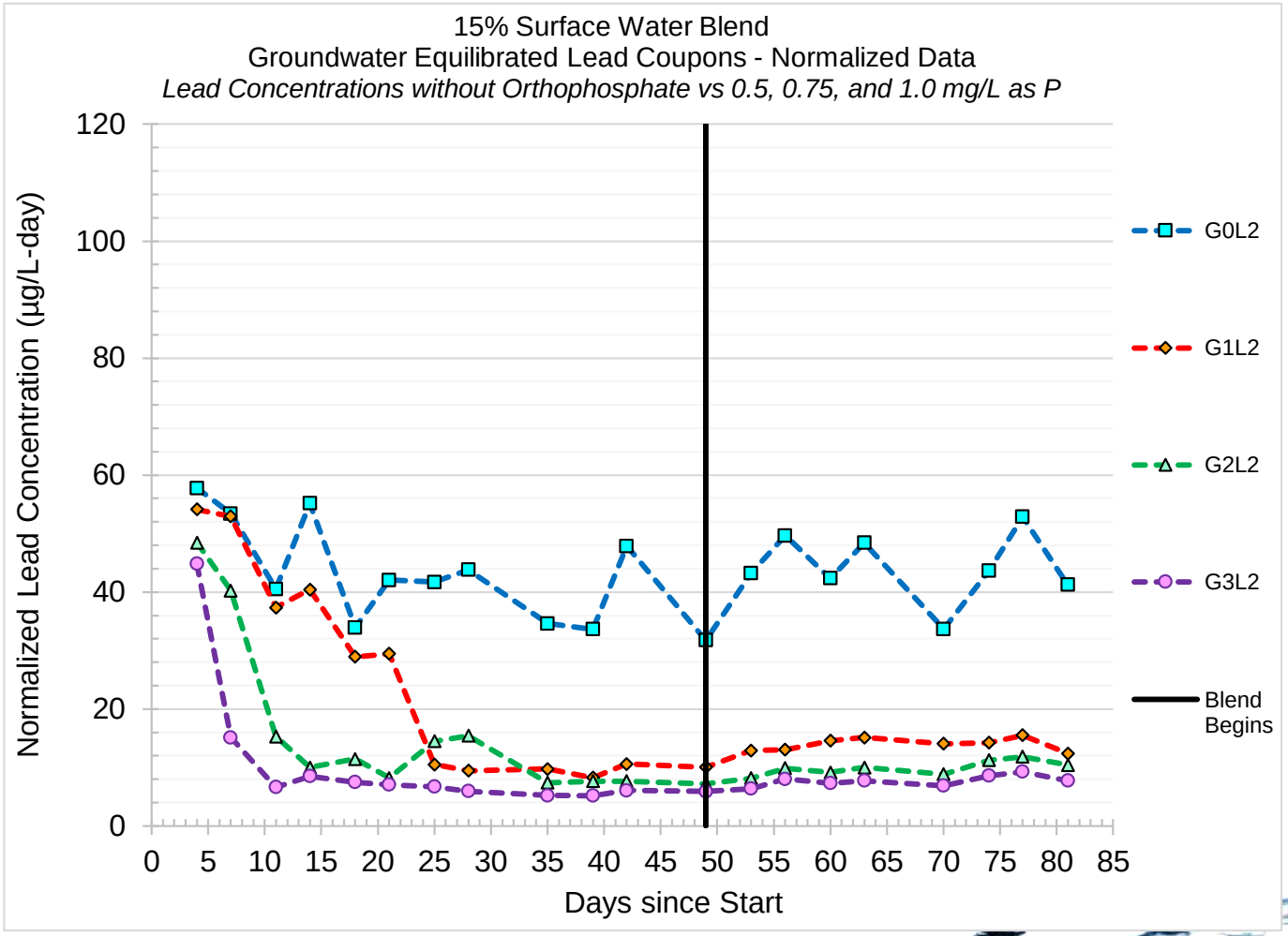


Results

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

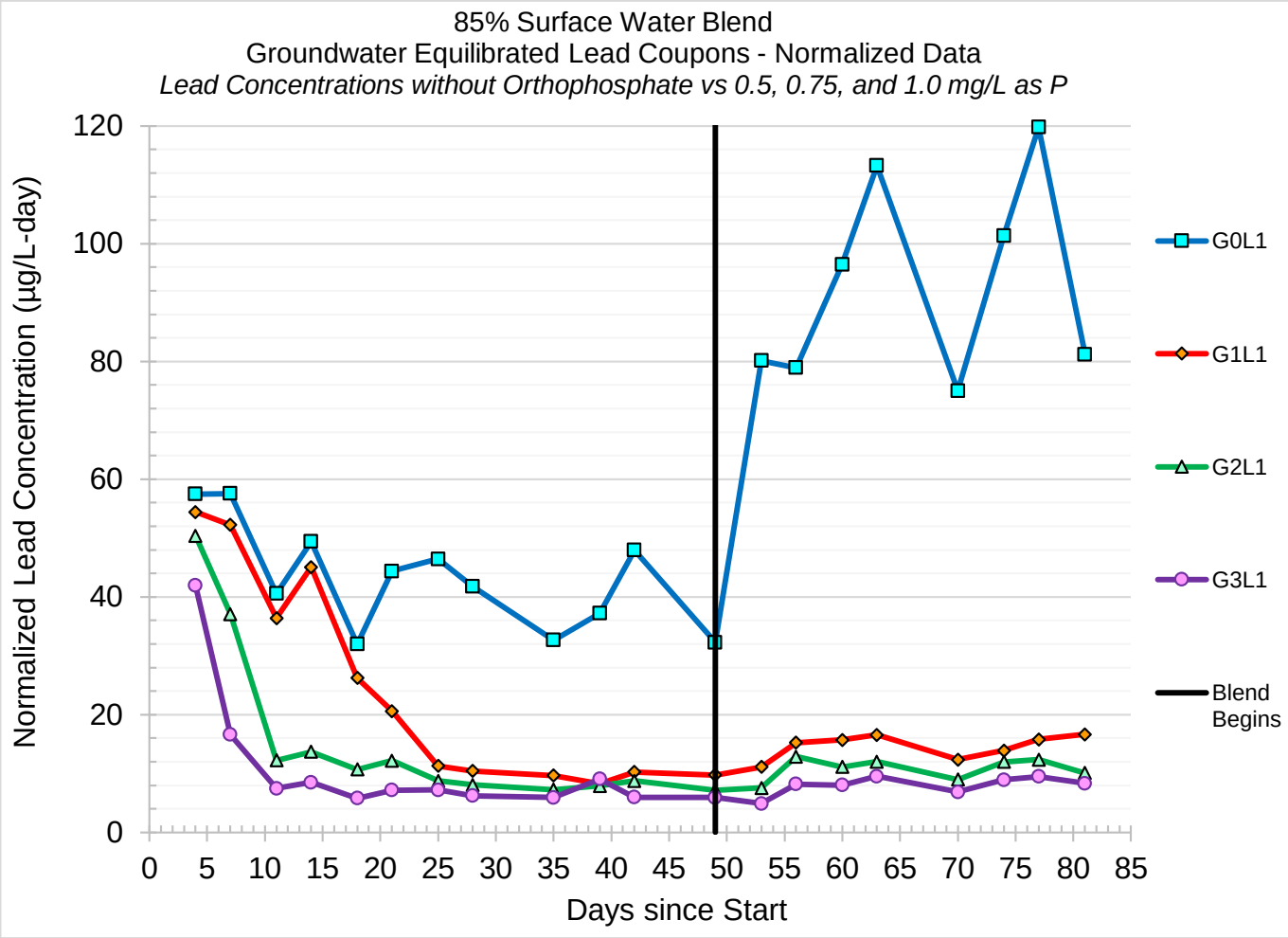
GW Lead Coupons with Orthophosphate

15% Surface Water Blend

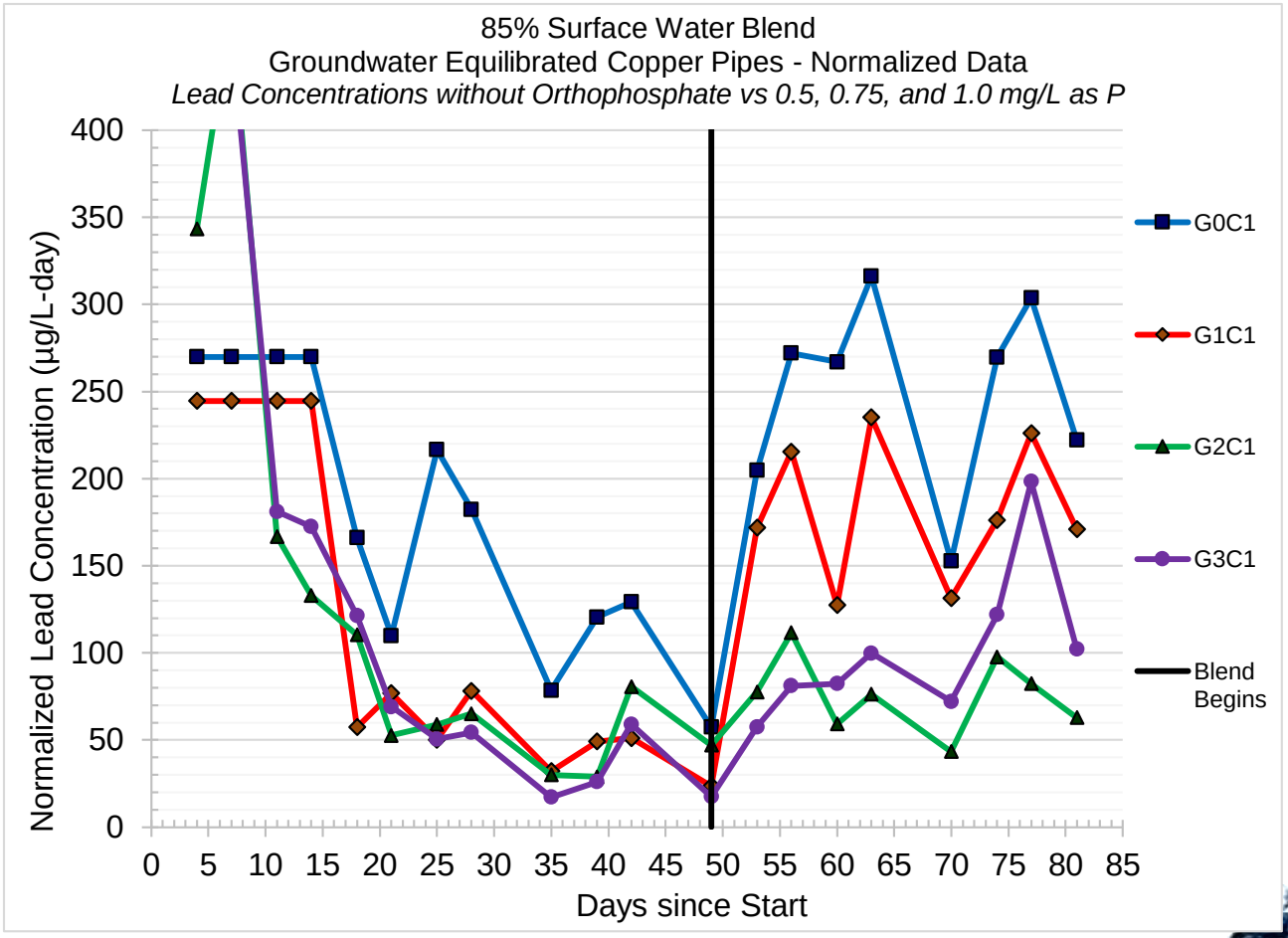


GW Lead Coupons with Orthophosphate

85% Surface Water Blend



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

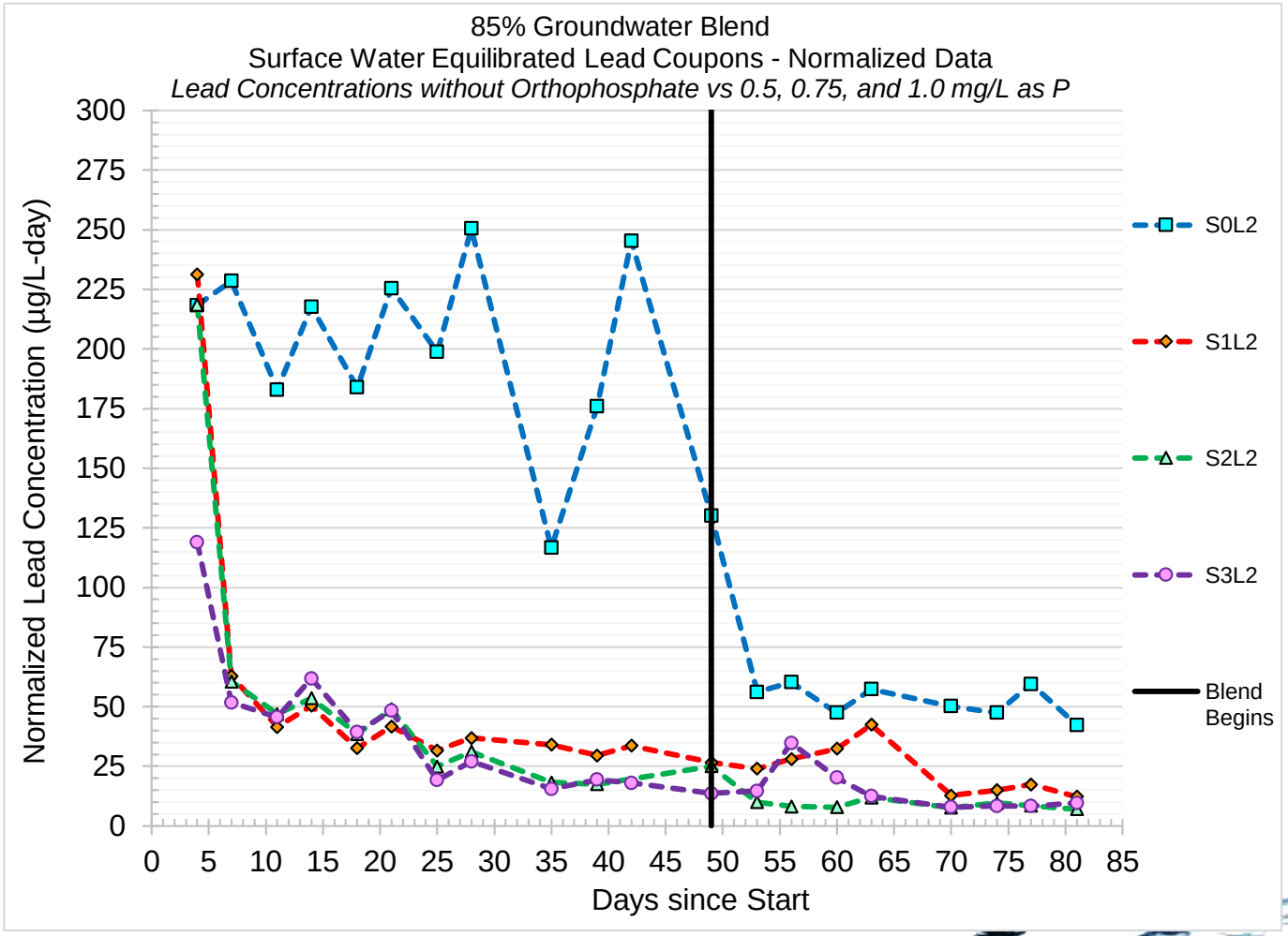


Results

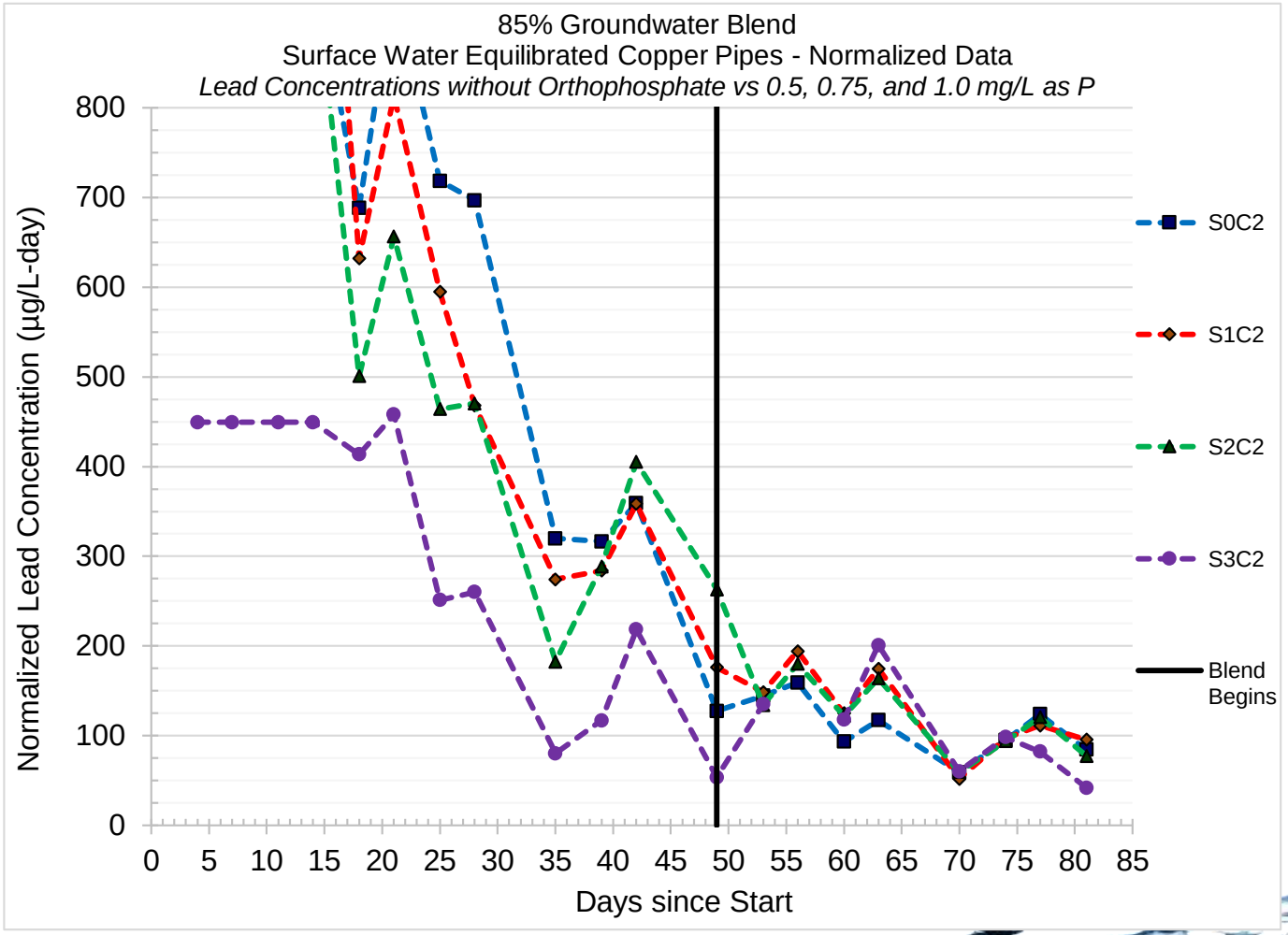
1. EXISTING CONDITIONS
2. GW EQUILIBRATED ORTHOPHOSPHATE
3. SW EQUILIBRATED ORTHOPHOSPHATE
4. SW PH/ALKALINITY ADJUST

SW Lead Coupons with Orthophosphate

85% Groundwater Blend



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



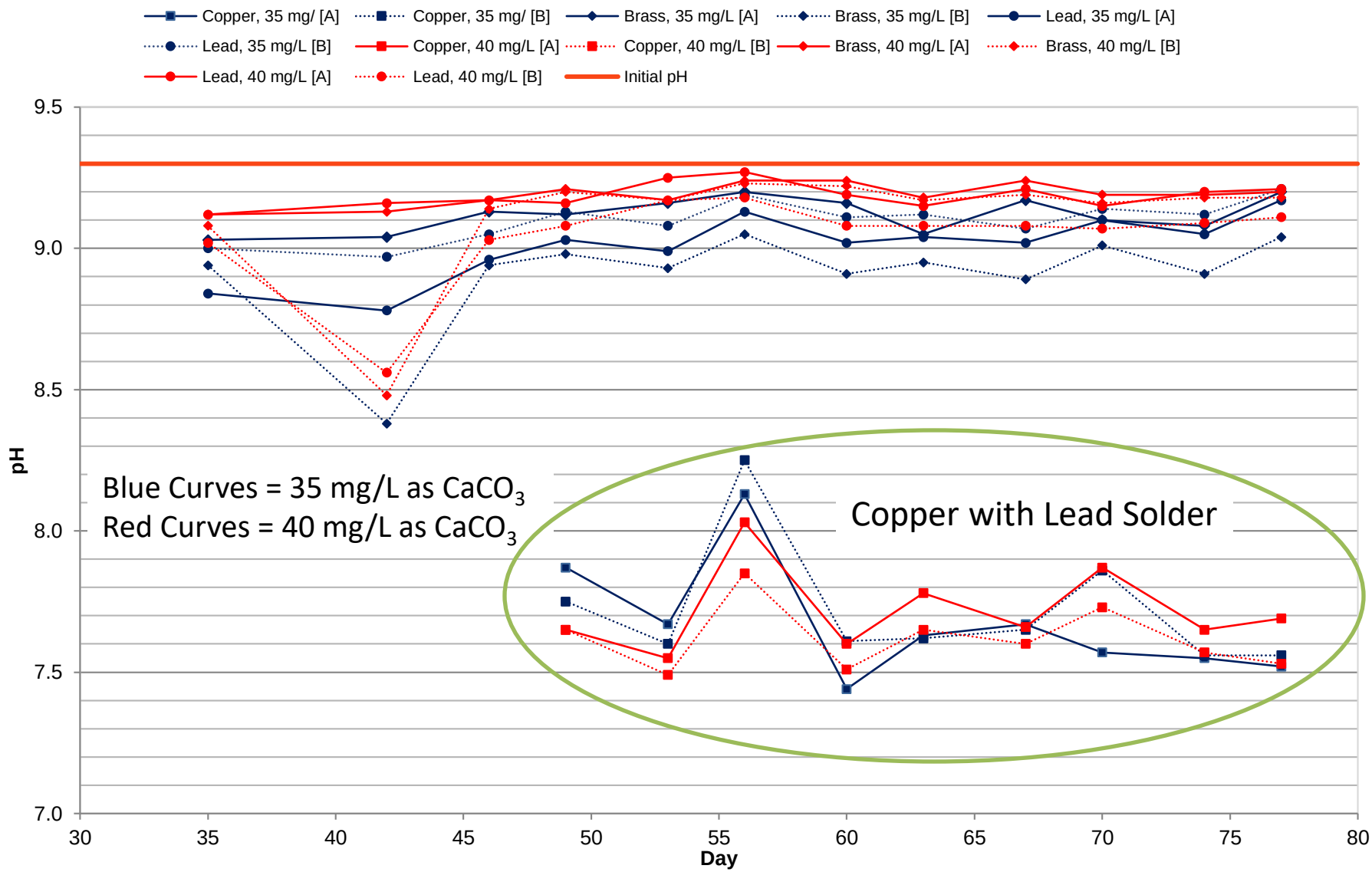
Results

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

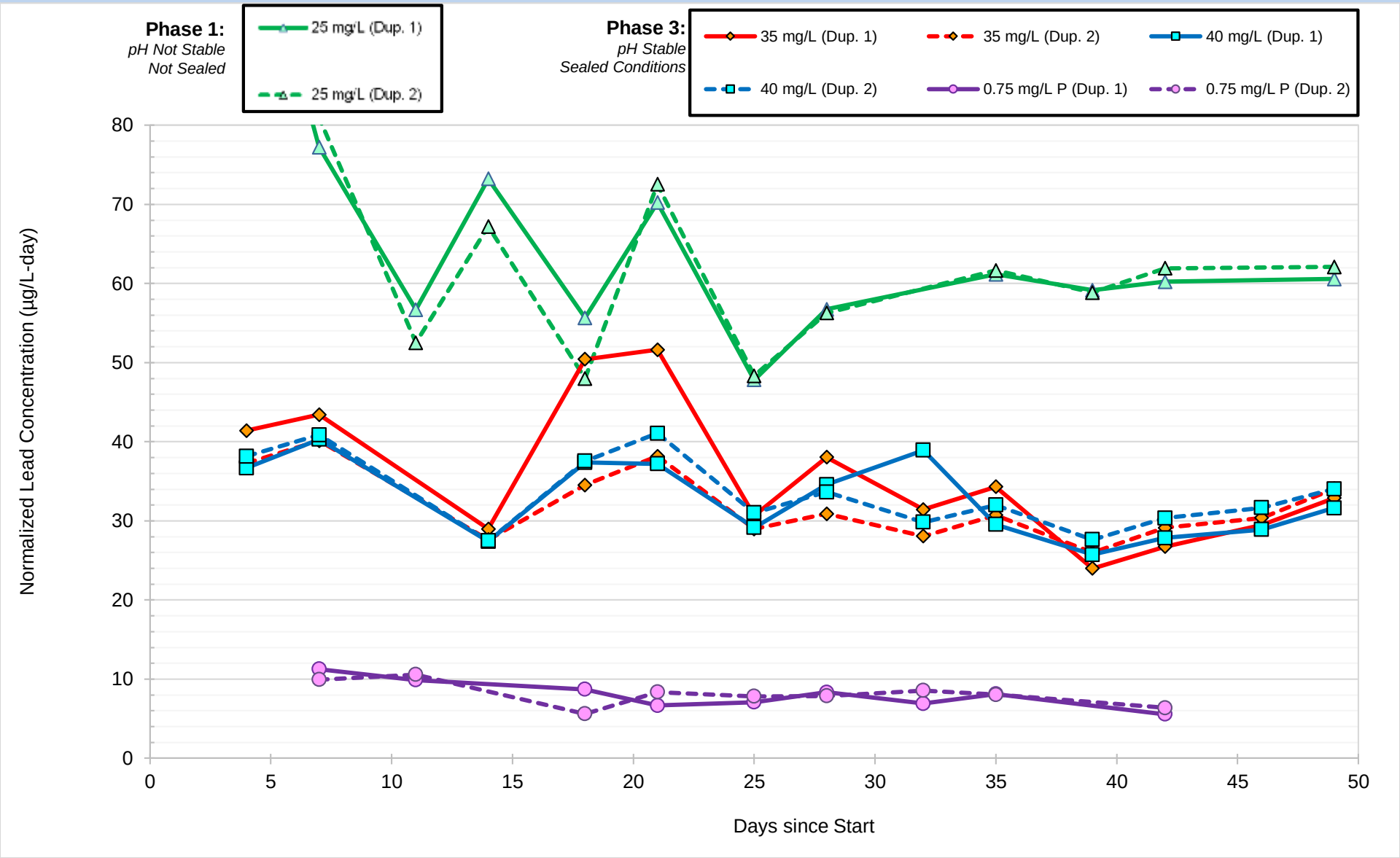
pH Stability Testing

- 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

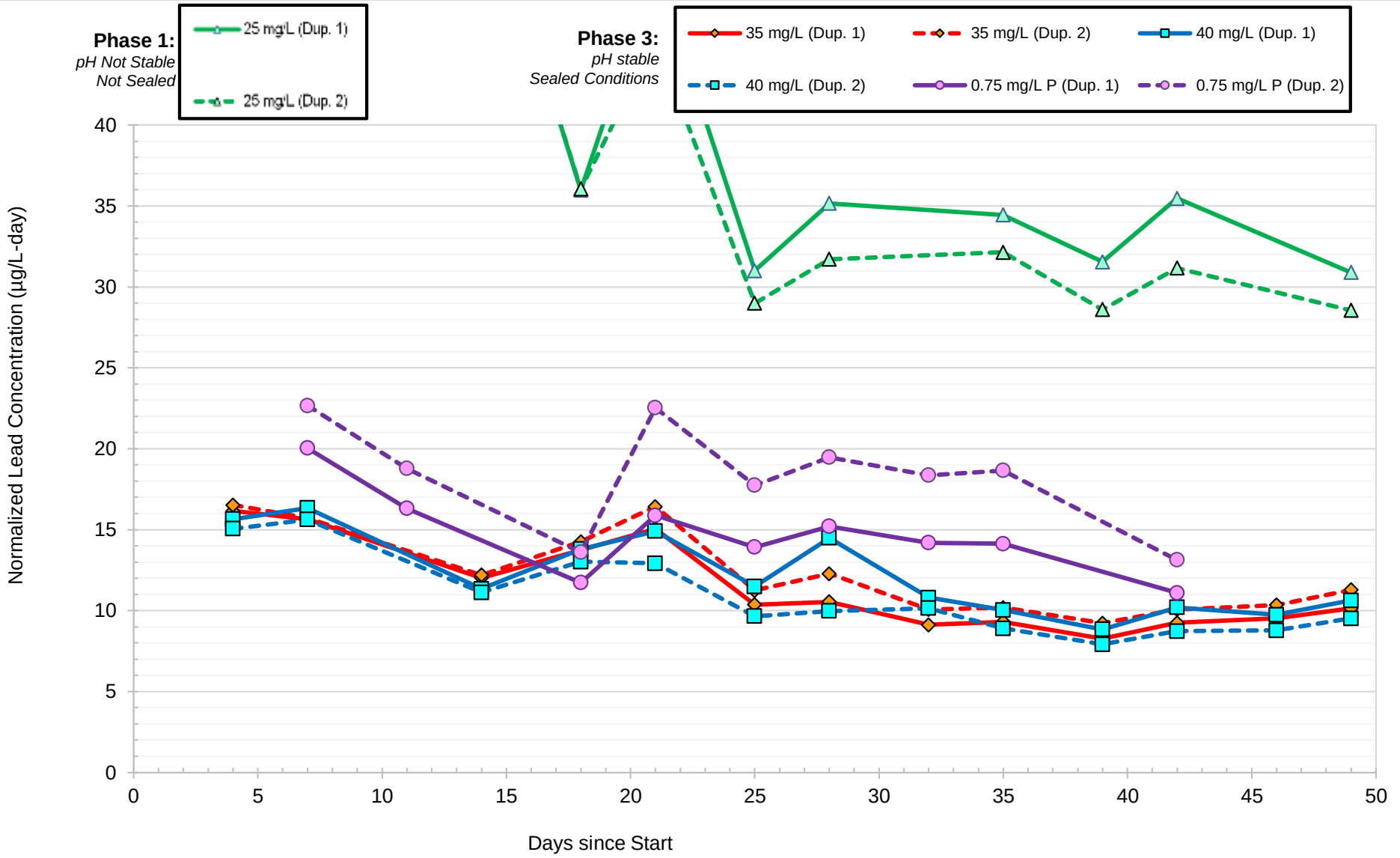
Post-Stagnation pH Values, Without Headspace During Coupon Study



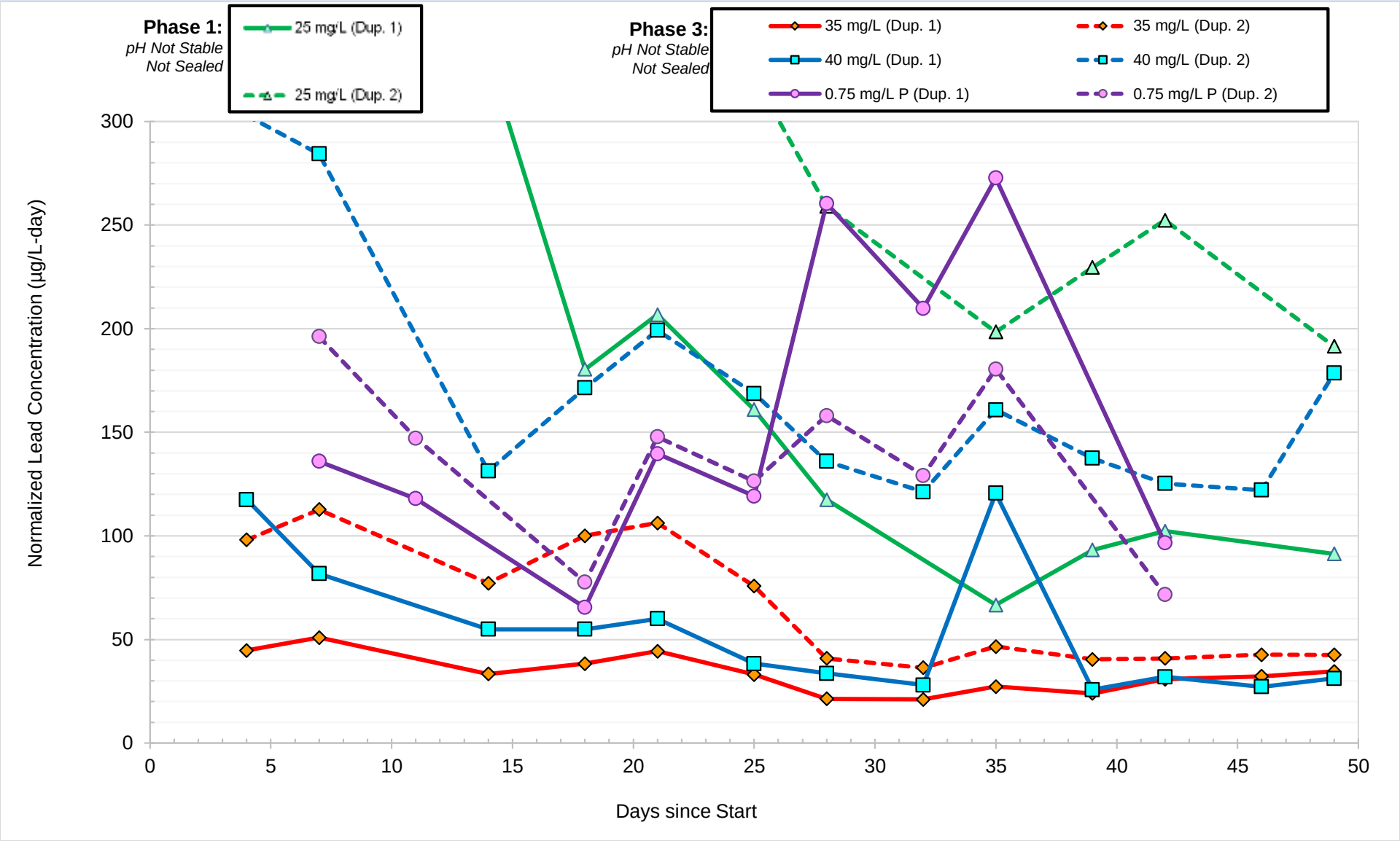
CCT Comparison – Lead Coupons



CCT Comparison – Brass Coupons



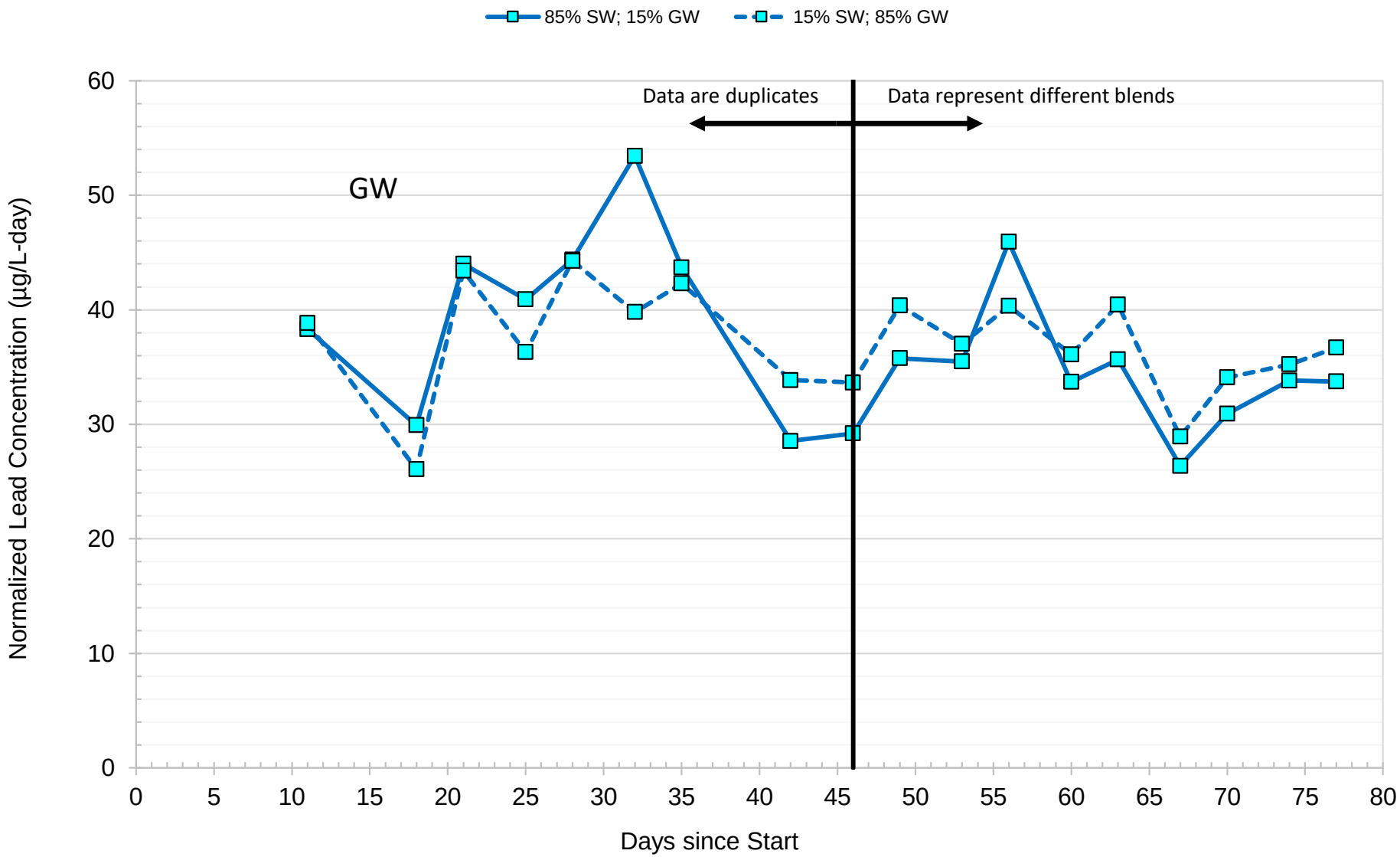
CCT Comparison – Copper with Lead Solder Reactors



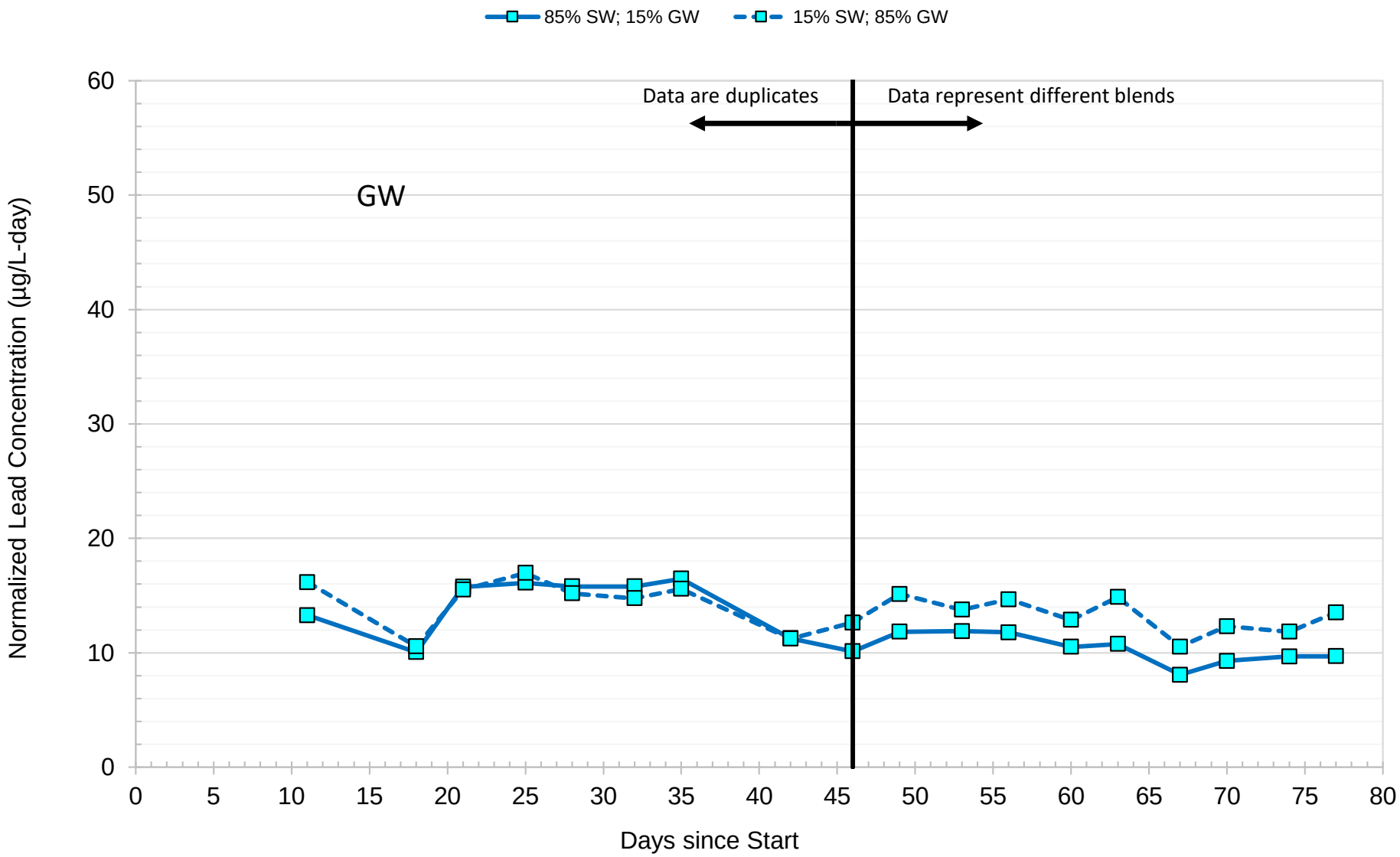
Additional Blending Testing

- 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

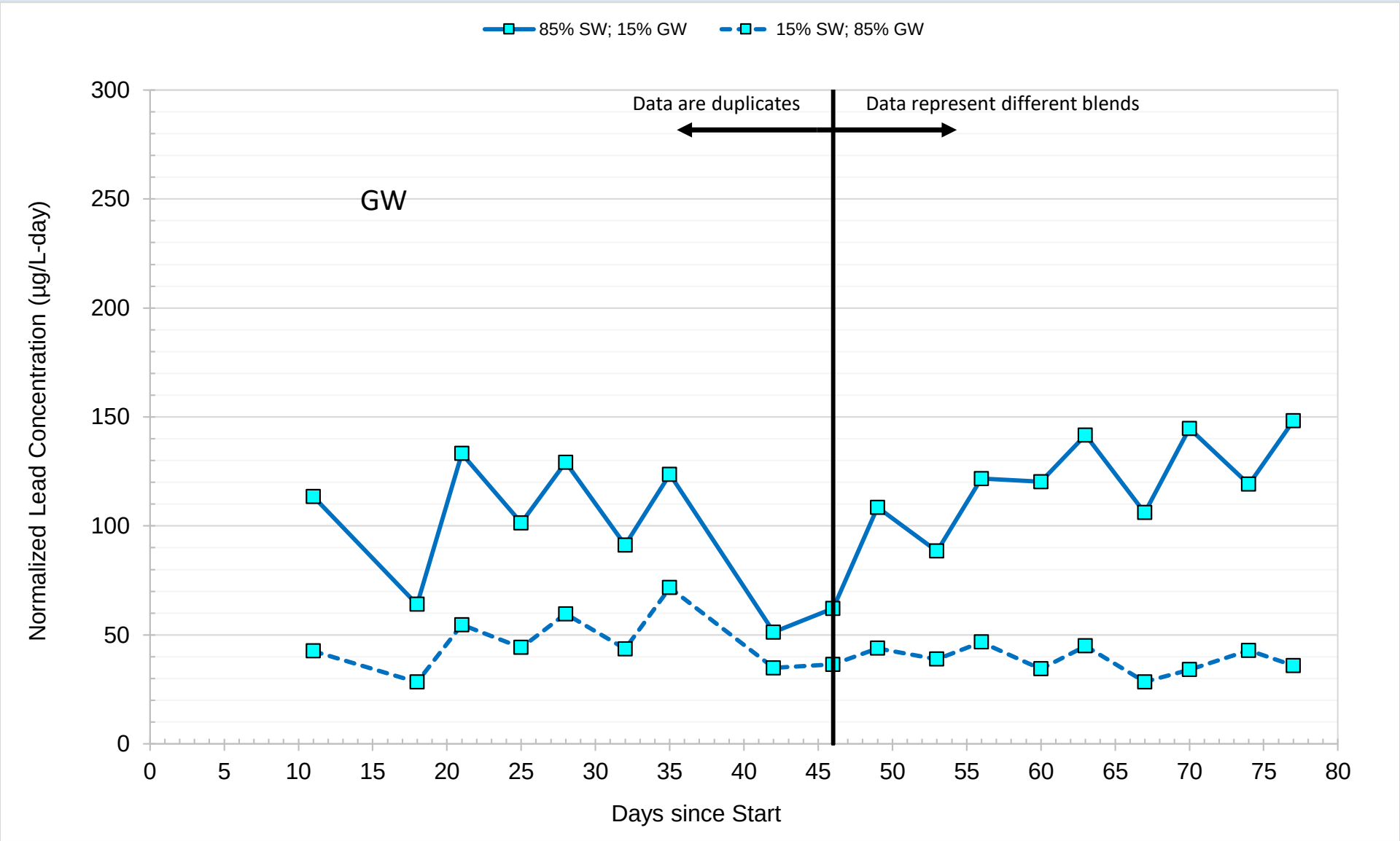
Lead Coupons
GW + SW at pH 9.3



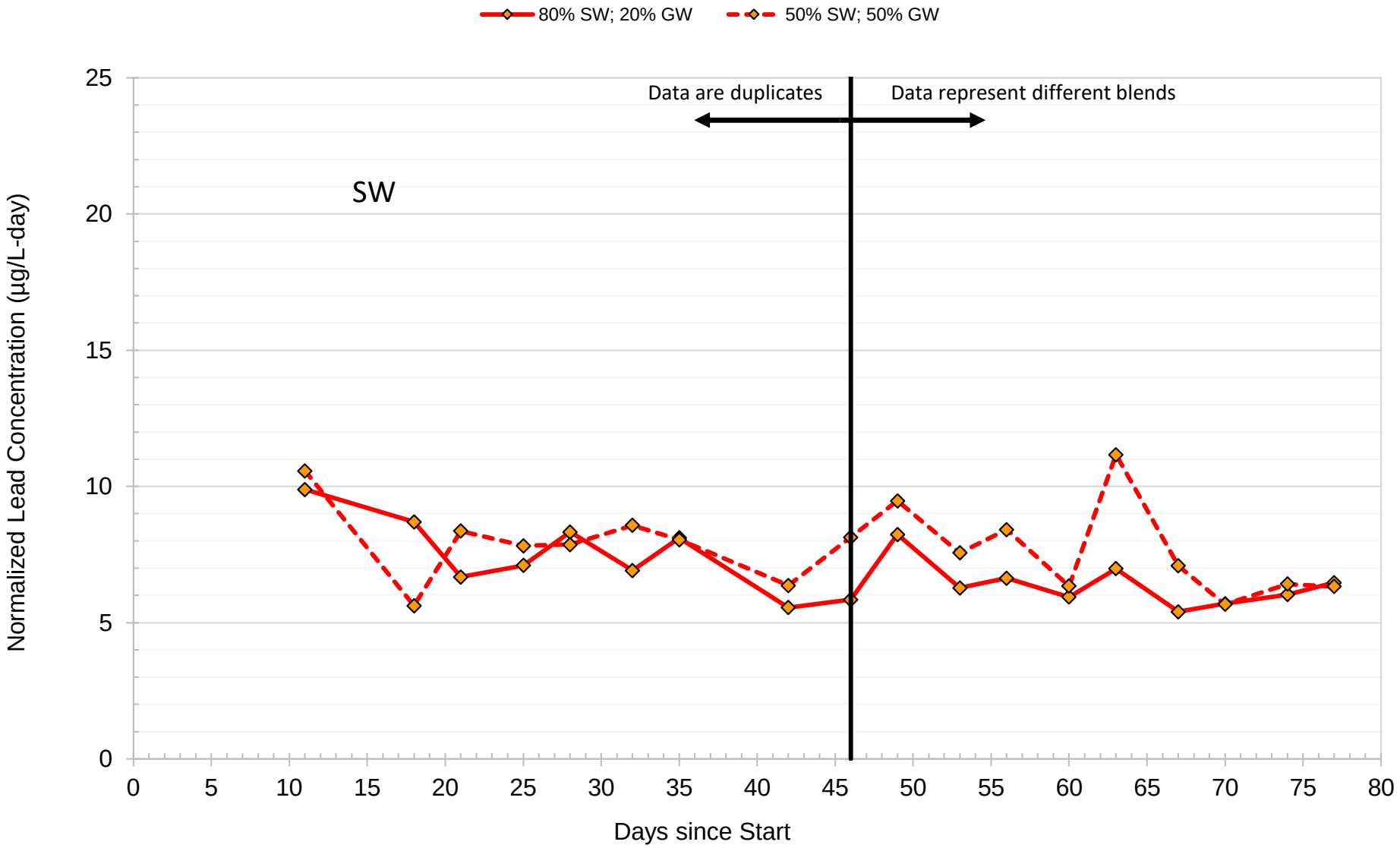
Brass Coupons
GW + SW at pH 9.3



Copper with Lead Solder Reactors
GW + SW at pH 9.3 (target)

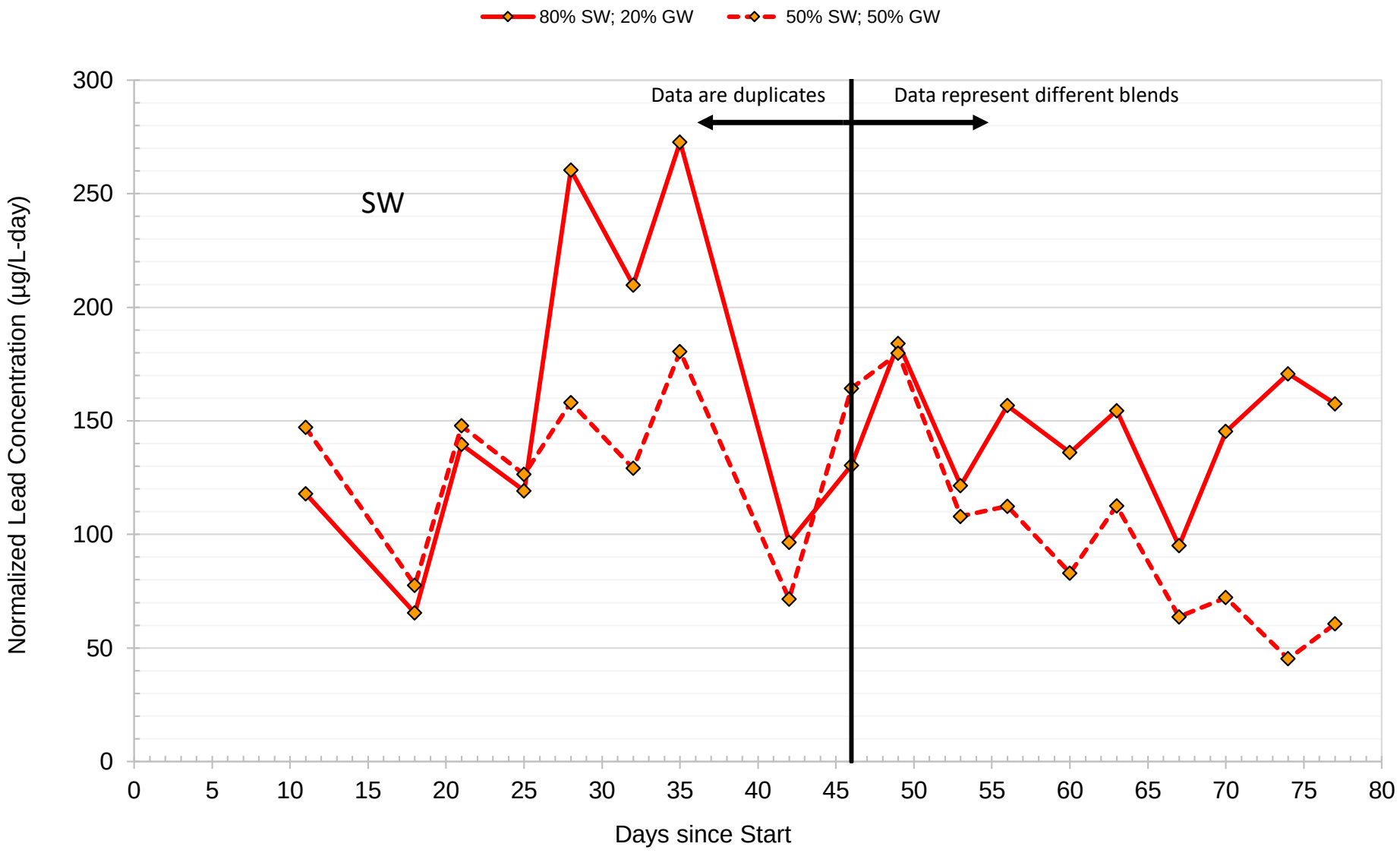


Lead Coupons
SW with 0.75 P + GW with 0.0 P



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



TAKEAWAYS

Summary

- 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

Conclusions

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

Questions?

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