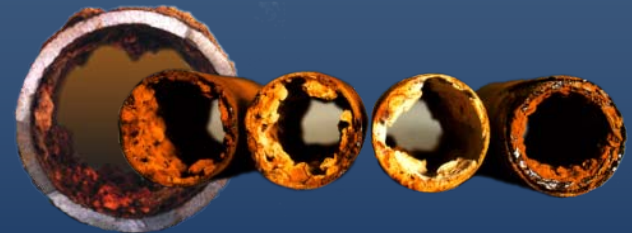




Evaluating Low Profile Bubble Aeration for Carbon Dioxide Removal, Corrosion Control and Radon Reduction

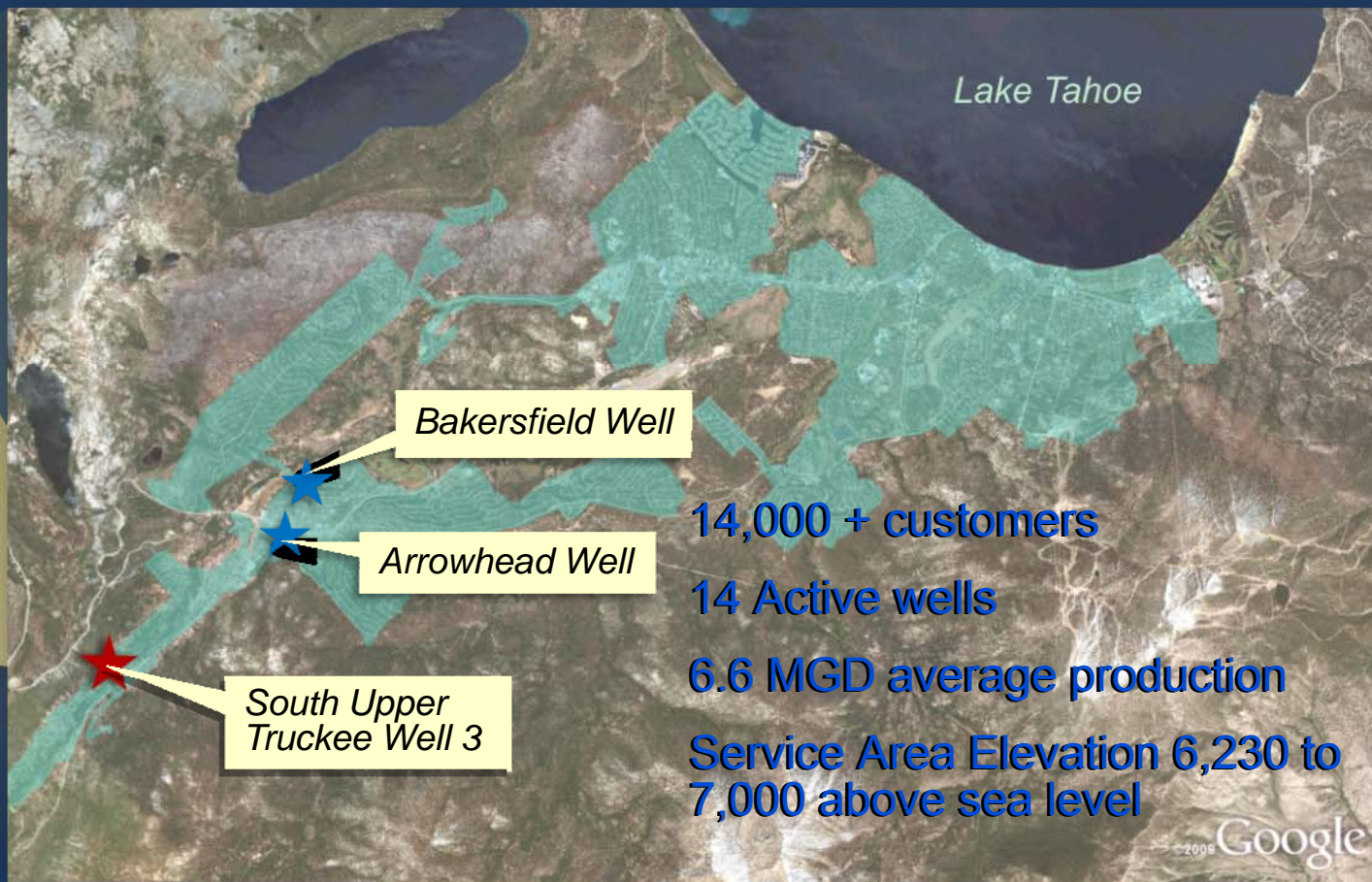


Milt Larsen, Kennedy/Jenks
Bob Ryder, Kennedy/Jenks
Ivo Bergsohn, S Tahoe PUD





Location Map



Arsenic Compliance Plan



- ▼ **Arrowhead & Bakersfield Wells**
 - Reduce their production
 - Provide arsenic treatment

- ▼ **S Upper Truckee Wellfield**
 - Increase production
 - Treat to reduce water's corrosivity



Corrosion Concerns Christmas Valley Pressure Zone



- ▼ Lead & Copper Rule Monitoring (system wide)
 - 90th percentile lead – 6.4 µg/l
 - 90th percentile copper – 0.48 mg/l
- ▼ 4 of 7 first draw tap samples exceeded 1.3 mg/l copper when the South Upper Truckee wells were in service
- ▼ Premature corrosion failures
 - Hot water heaters
 - Sand separator



Water Quality Issues Related to Corrosion



- ▼ **Low pH – weak acid** (lead, copper, galvanized steel)
- ▼ High carbon dioxide (copper, steel, cement lining & AC pipe)
- ▼ High dissolved inorganic carbon (lead & copper)
- ▼ Elevated dissolved oxygen (steel, galvanized steel, copper)
- ▼ Negative Langelier & CCPP, low Aggressiveness Index (cement lining & AC pipe)
- ▼ High Larson Index (steel)



Corrosion Control Alternatives



- ▼ Phosphate Inhibitor

- Supplemental pH adjustment needed
 - Runoff concern

- ▼ Silicate Inhibitor

- Supplemental pH adjustment needed

- ▼ pH Adjustment

- Alkaline Chemical Addition

- Very high chemical requirements

- Aeration

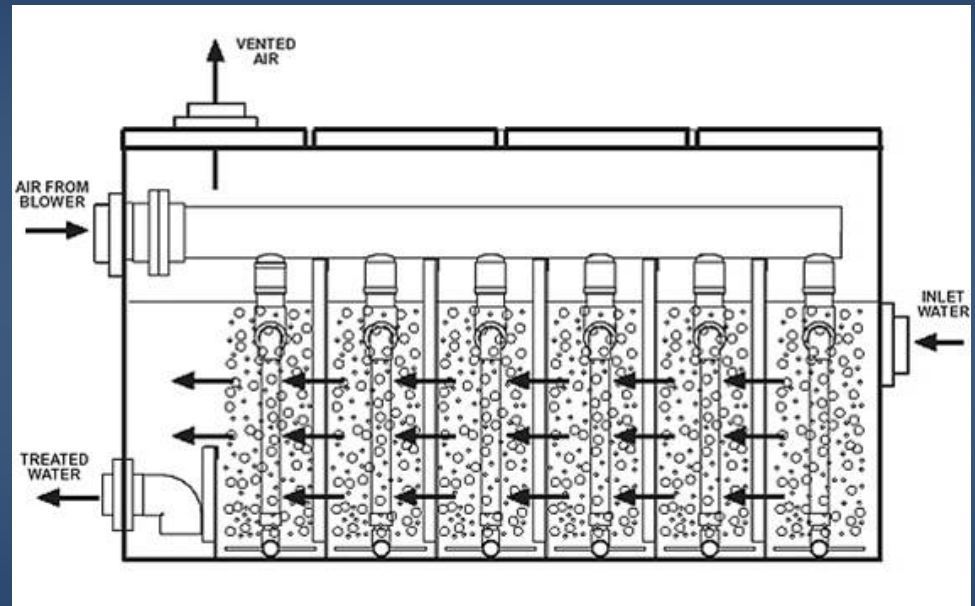
- Economical method of raising the pH



Aeration Alternatives



- ▼ Low Profile Aeration
 - DeepBubble Multi-Stage Aeration
 - Shallow Tray Aeration
- ▼ Packed Tower Aeration
- ▼ Venturi Eductor CO₂ Stripping
- ▼ Multiple Tray Aeration
- ▼ Rotating Packed Bed Stripping



Packed Tower Air Stripper Clement Well



Pilot Testing



▼ Goals

Raise pH ≥ 7.5

CO₂ ≤ 5 mg/l

Rn-222 ≤ 300 pCi/l

▼ Evaluate

Copper - corrosion & leaching

Lead-tin solder - corrosion & leaching

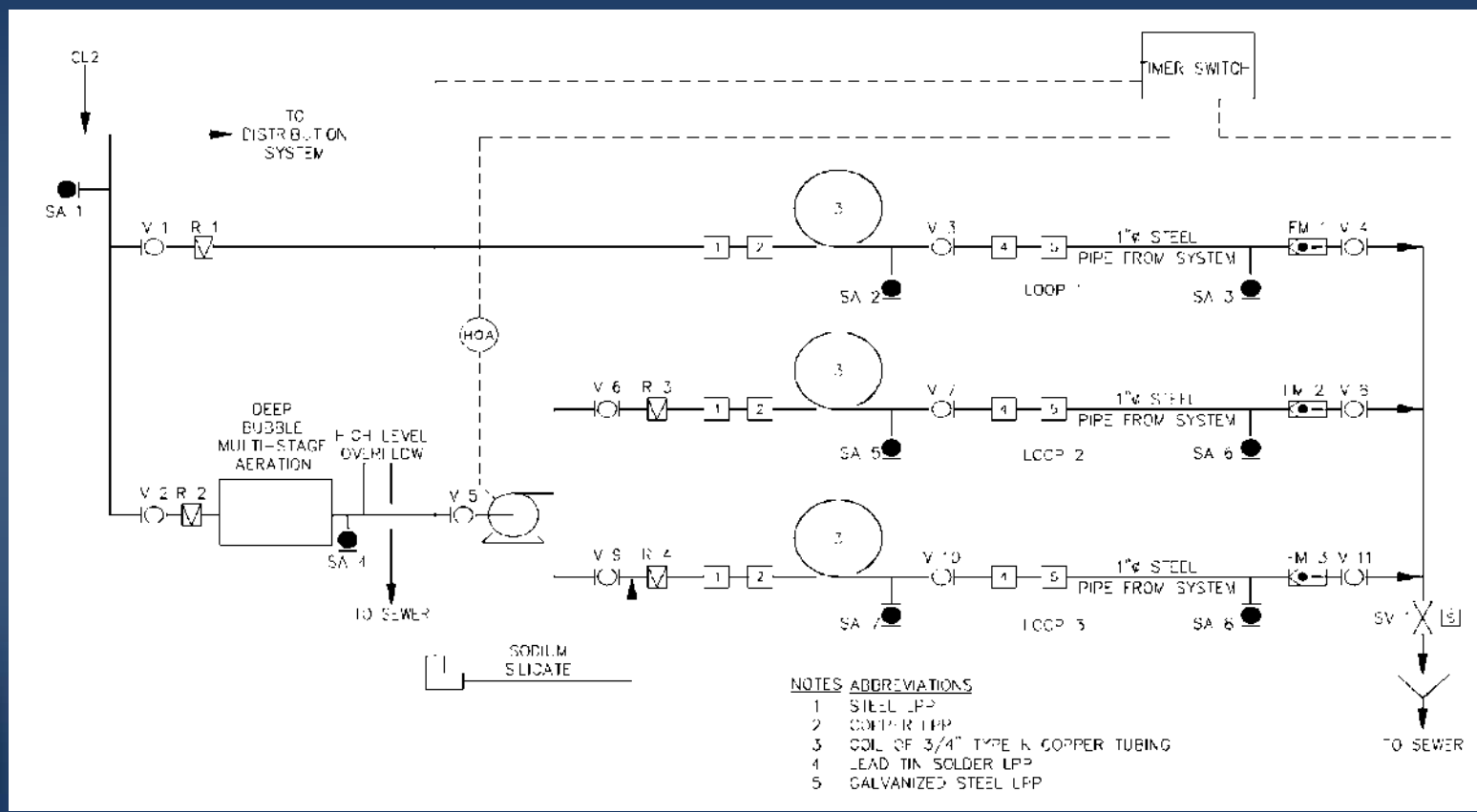
Mild steel - corrosion & scale release

Galvanized steel - corrosion

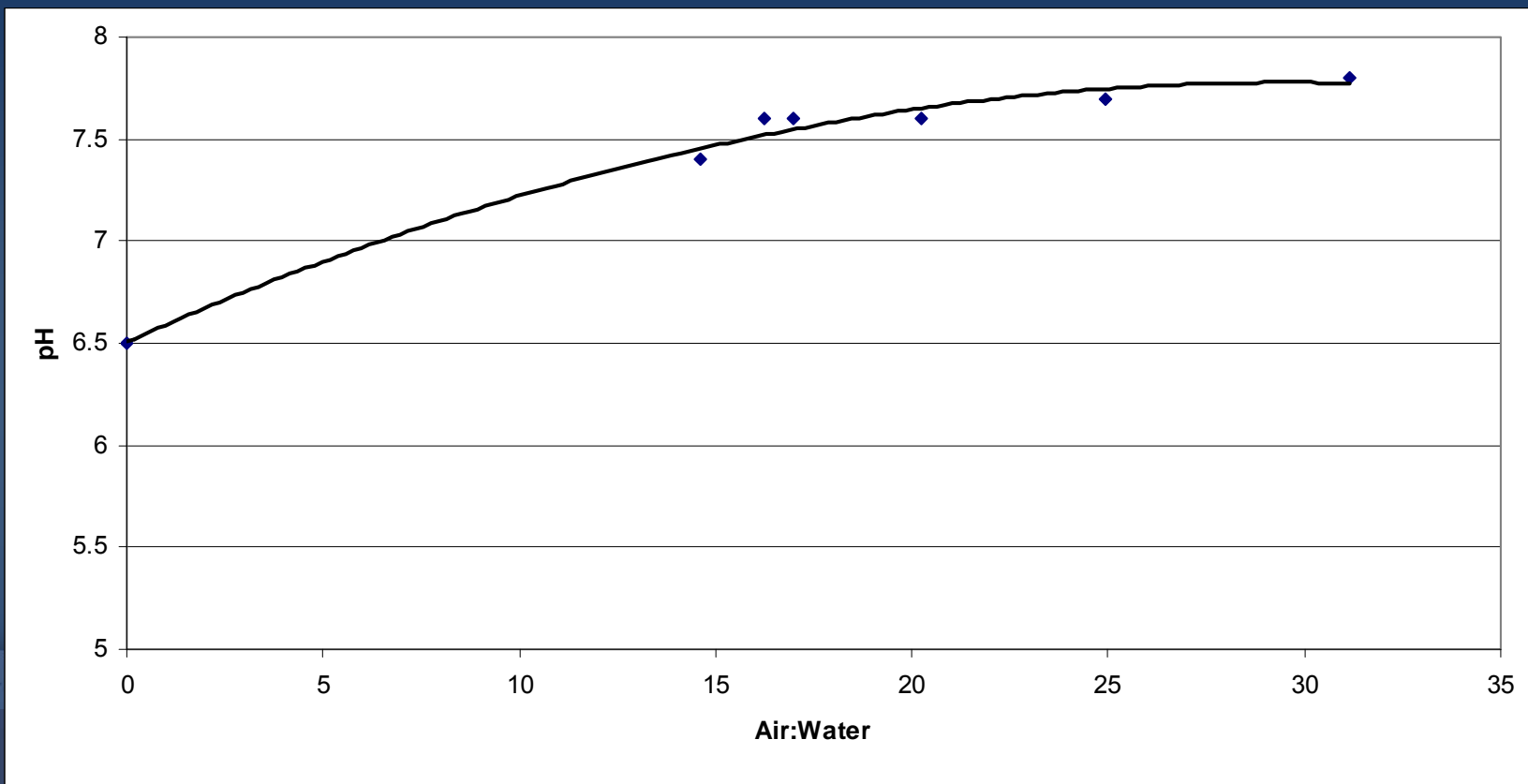




Pilot Testing Schematic



Aeration Performance



Pilot Aeration Unit



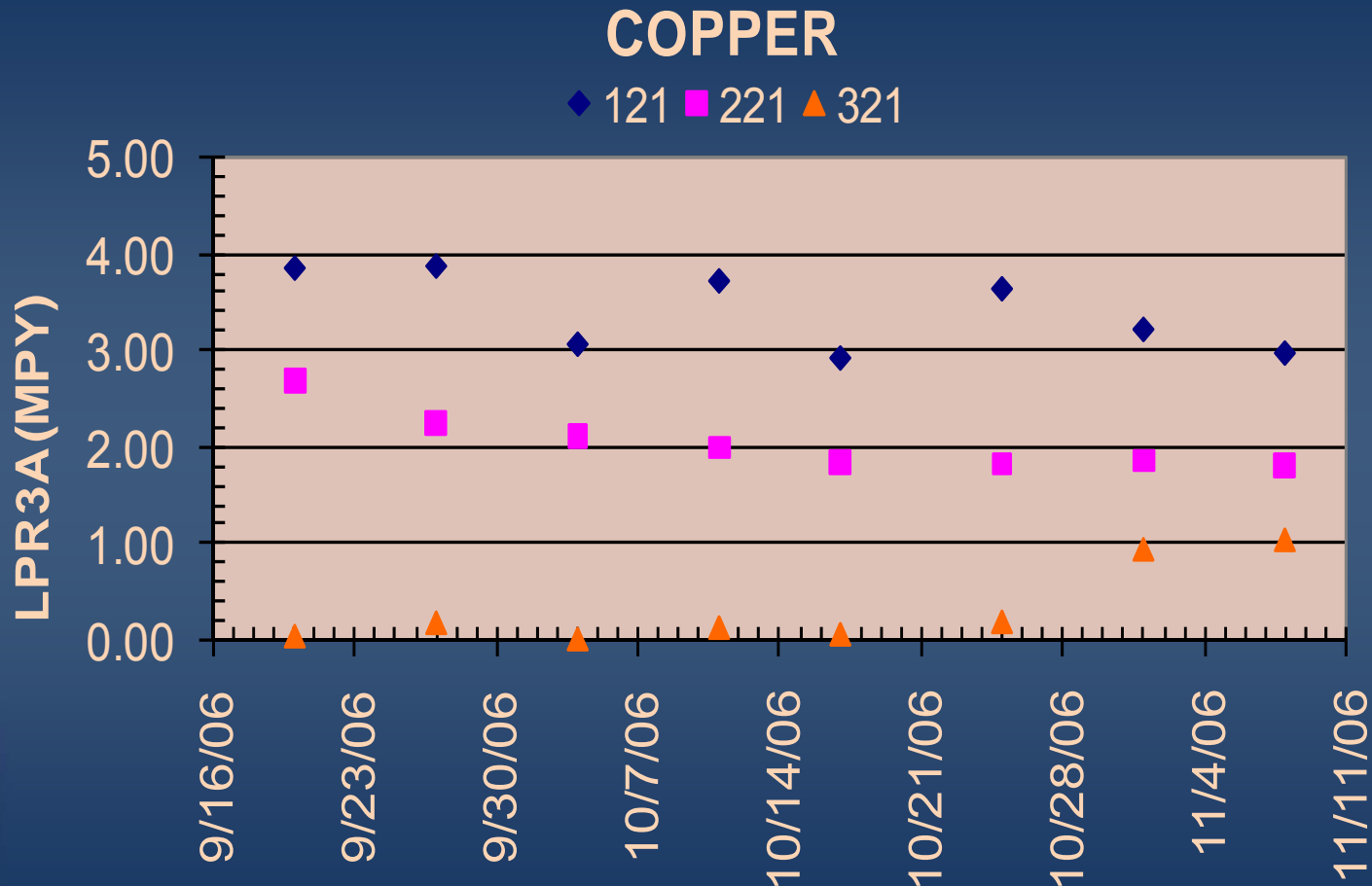
- ▼ Lowered Rn-222
 - Well water 462 pCi/l (median)
 - Aerated water 18 pCi/l (median)
- ▼ Stripped carbon dioxide to less than 5 mg/l
- ▼ Increased pH from 6.2-6.3 to 7.6
- ▼ Moderate increase in dissolved oxygen from 7.4 to 9.5 mg/l



Linear Polarization Probes & Copper Tubing



Linear Polarization Measurements Copper



Linear Polarization Probes Copper



1-2 Copper



2-2 Copper



3-2 Copper



Copper Corrosion

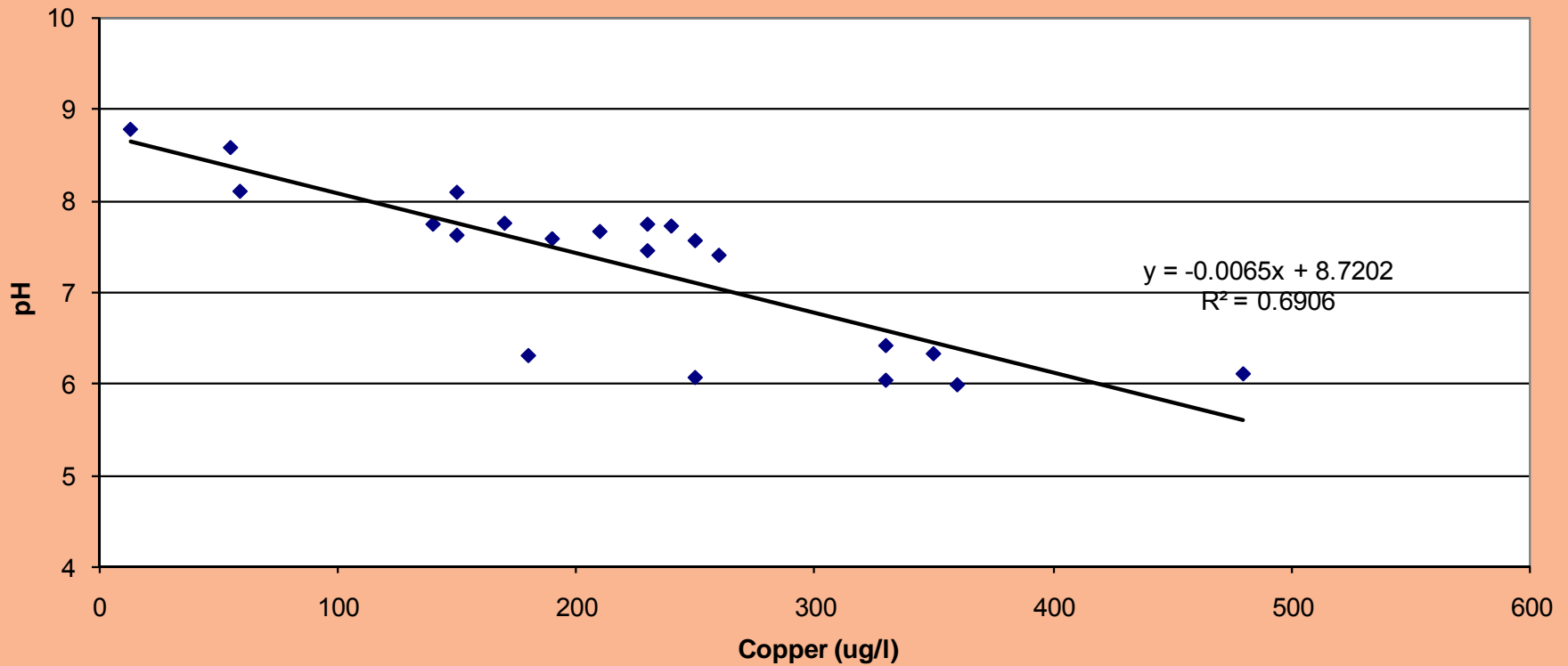


	Uniform Corrosion Rate (mils/yr)	Uniform Corrosion Rate Reduction	Median Pitting Depth (mils)	Maximum Pitting Depth (mils)
Control	5.04	-	Not Apparent	Not Apparent
Aerated	3.34	34%	Not Apparent	Not Apparent
Aerated + Sodium Silicate	0.87	83%	Not Apparent	Not Apparent

Copper Leaching

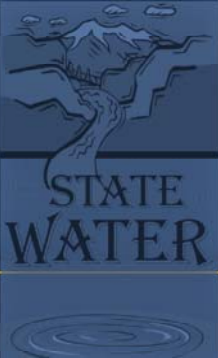
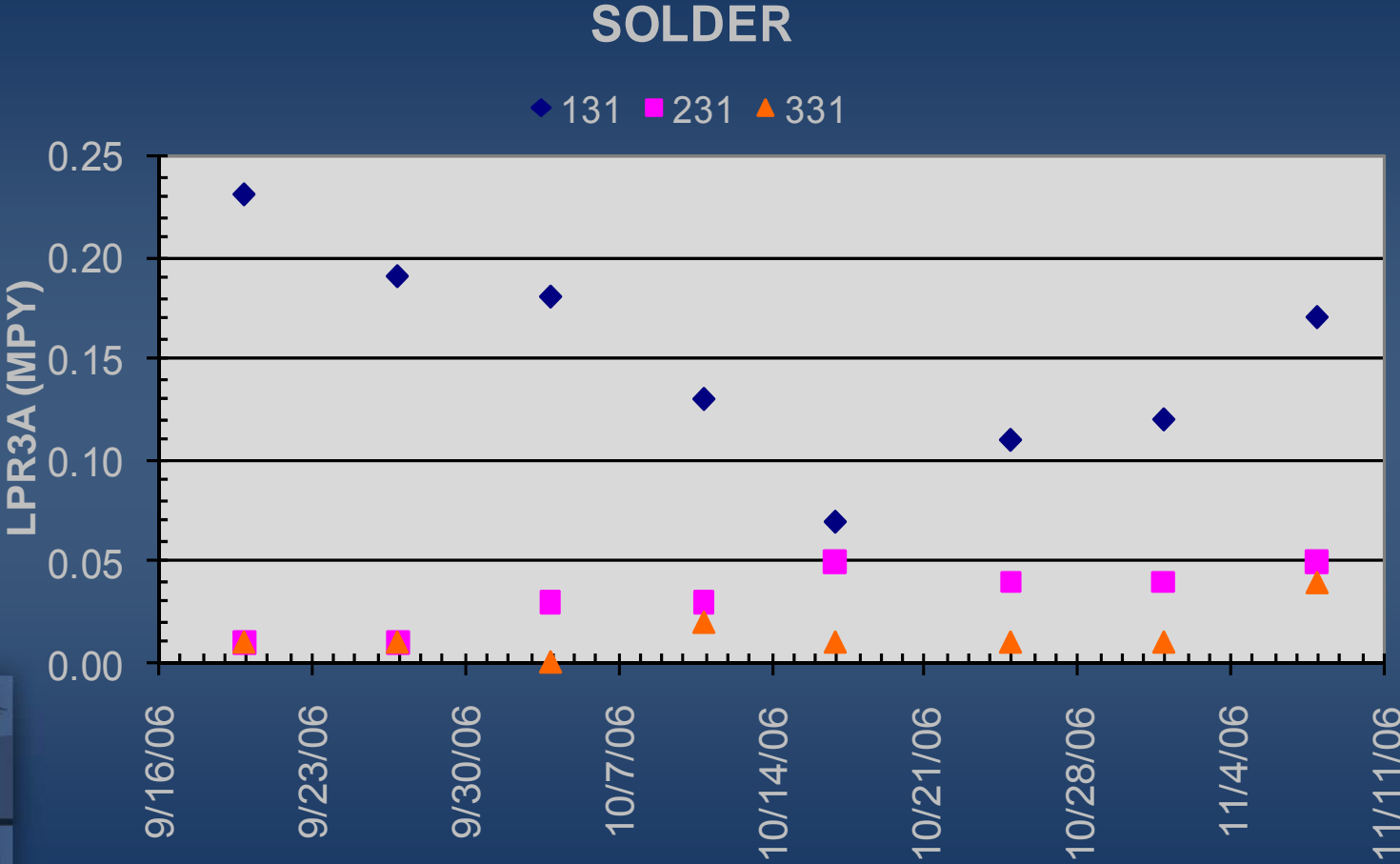


Copper Versus pH (all data)





Linear Polarization Measurements Lead-Tin Solder



Linear Polarization Probes Lead-Tin Solder



1-3 Lead-Tin Solder



2-3 Lead-Tin Solder



3-3 Lead-Tin Solder

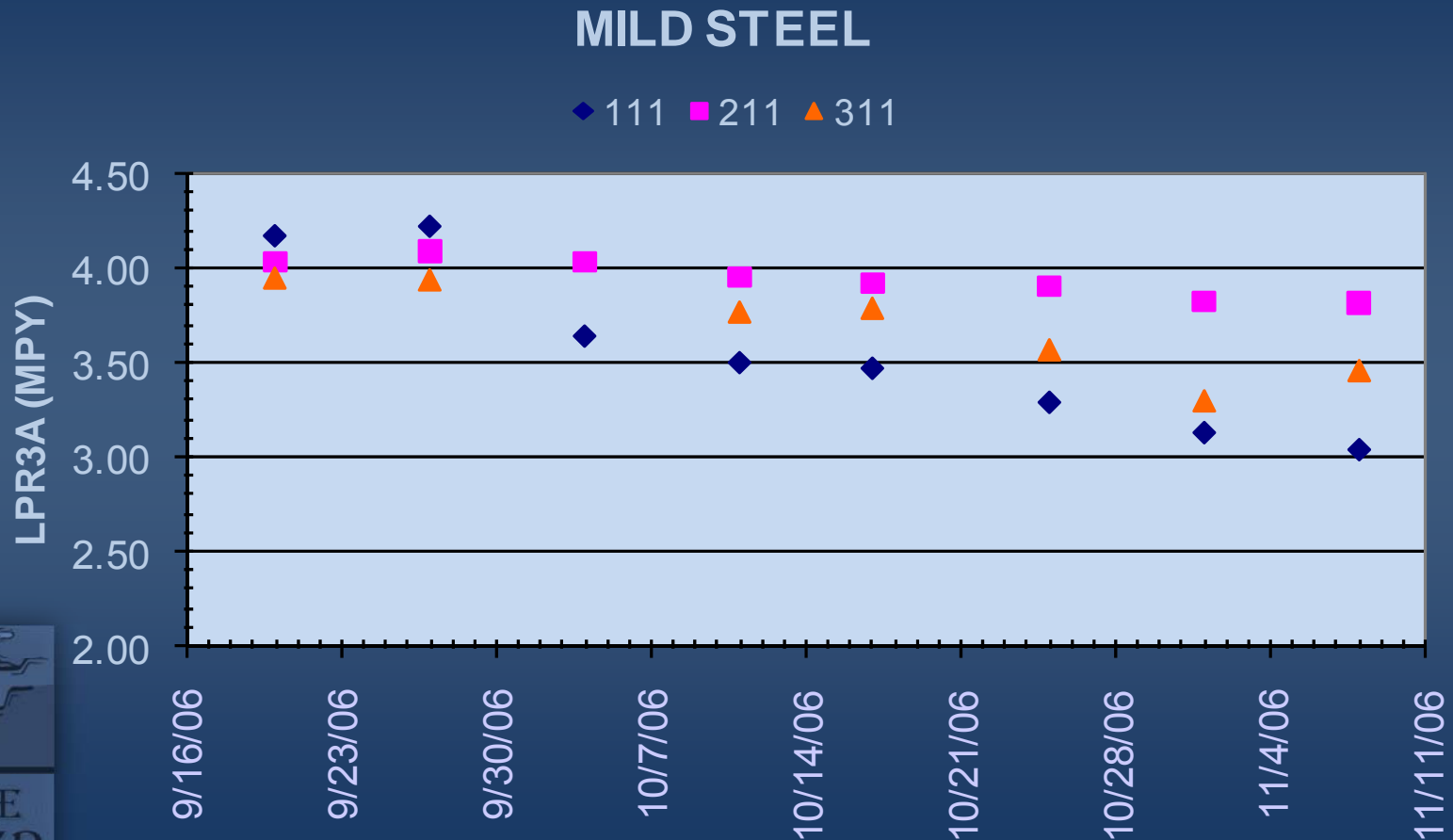


Lead-Tin Solder Corrosion



	Uniform Corrosion Rate (mils/yr)	Uniform Corrosion Rate Reduction	Pitting Density (pits/in²)	Median Pitting Depth (mils)	Maximum Pitting Depth (mils)
Control	0.38	-	20	2	8
Aerated	0.04	90%	10	1	5
Aerated + Sodium Silicate	0.18	52%	5	1.5	5

Linear Polarization Measurements Mild Steel



Linear Polarization Probes Mild Steel



1-1 Mild Steel



2-1 Mild Steel



3-1 Mild Steel



Mild Steel Corrosion

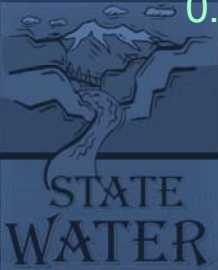
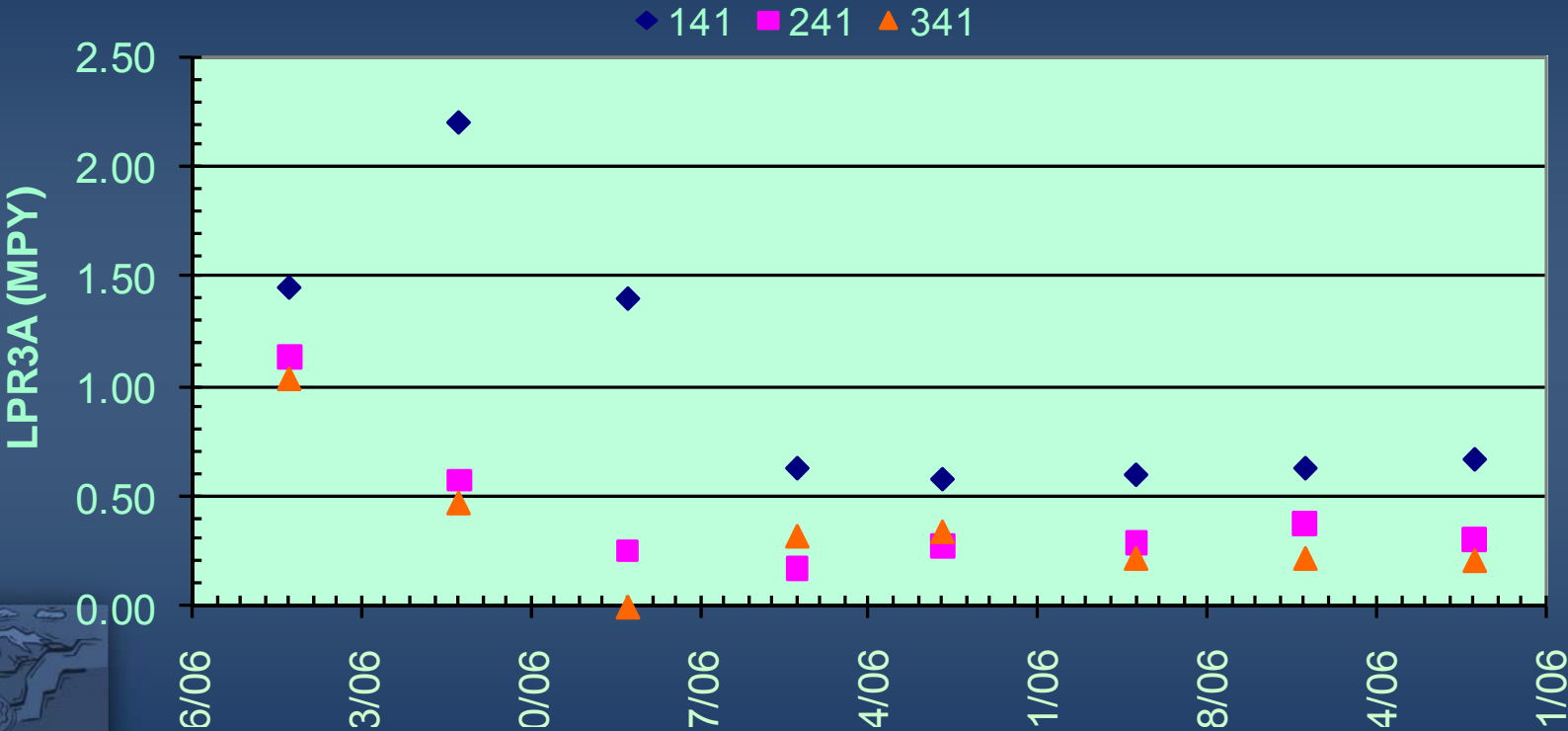


	Uniform Corrosion Rate (mils/yr)	Uniform Corrosion Rate Reduction	Pitting Density (pits/in²)	Median Pitting Depth (mils)	Maximum Pitting Depth (mils)
Control	28.4	-	>100	9	20
Aerated	20.1	29%	50	2	10
Aerated + Sodium Silicate	20.9	27%	30	15	35



Linear Polarization Measurements Galvanized Steel

GALVANIZED STEEL



Linear Polarization Probes Galvanized Steel



1-4 Galvanized



2-4 Galvanized



3-4 Galvanized



Galvanized Steel Corrosion



	Uniform Corrosion Rate (mils/yr)	Uniform Corrosion Rate Reduction	Pitting Density (pits/in²)	Median Pitting Depth (mils)	Maximum Pitting Depth (mils)
Control	19.2	-	10	1.3	10
Aerated	14.5	24%	5	1	5
Aerated + Sodium Silicate	5.1	74%	-	0.3	2

Findings

Copper Corrosion



- ▼ Aeration
 - Reduced copper corrosion 34%
 - Reduced first draw copper 30%
- ▼ Aeration plus sodium silicate
 - Reduced corrosion 83%
 - Reduced first draw copper 58%
 - Silicate addition was beneficial
- ▼ Uniform corrosion
- ▼ No pitting corrosion observed



Findings

Lead-Tin Solder Corrosion



▼ Aeration

- Reduced lead-tin corrosion 90%
- Reduced first draw lead >77%
- Uniform corrosion with very slight pitting

▼ Aeration plus sodium silicate

- Reduced lead-tin corrosion 52%
- Reduced first draw lead >77%
- Uniform corrosion with very slight pitting
- Silicate addition not beneficial



Findings

Mild Steel Corrosion



▼ Control

- High corrosion rate
- Extremely high pitting

▼ Aeration

- Reduced steel corrosion 29% (rate still high)
- Significant reduction in the number and depth of pits (extremely high pitting)
- Slight reduction in 1st draw iron & turbidity downstream of existing pipe

▼ Aeration plus sodium silicate

- Reduced steel corrosion 27% (rate still high)
- Reduced the number of pits
- Increased the depth of pits (compared to control & aeration)
- Increased iron downstream of the existing pipe
- Silicate provided an adverse benefit compared to aeration



Findings

Galvanized Steel Corrosion



- ▼ Control
 - High corrosion rate
 - Moderate pitting
- ▼ Aeration
 - Reduced galvanized steel corrosion 24%
 - Reduced pitting corrosion
- ▼ Aeration plus sodium silicate
 - Reduced galvanized steel corrosion 74%
 - Reduced pitting corrosion
 - Silicate addition beneficial



Treatment Recommendations



- ▼ Provide low profile aeration for South Upper Truckee Well No. 3
- ▼ Do not install sodium silicate at this time
- ▼ Provide room for 3 mg/l NaOH feed or sodium silicate
- ▼ Collect lead & copper tap samples after the facility has been on line 4-6 months



South Upper Truckee Well 3 Aeration Facility



- ▼ 2 DeepBubble Multi-Stage Aeration Units
- ▼ Began operation June 2008
- ▼ Results
 - Raised pH from 6.35 to 7.75
 - Reduced CO₂ from 30 mg/l to <2 mg/l
 - Reduced Rn from 589 pCi/l to 44 pCi/l
 - Christmas Valley tap samples (90th percentile)
 - Pb <2.5 µg/l
 - Cu 0.03 mg/l
 - Supplemental sodium hydroxide is not necessary`



South Upper Truckee Well 3 Aeration Facility



